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Sandia SWiFT Wind Turbine Manual

Jonathan White, John Berg, Josh Bryant, Wesley Johnson, Bruce LeBlanc and Josh Paquette

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Sandia SWiFT Wind Turbine Manual

Jonathan White, John Berg, Josh Bryant,
Wesley Johnson, and Josh Paquette
Wind Energy Technologies Department 6121
Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185-MS1124

Abstract

The Scaled Wind Farm Technology (SWiFT) facility, operated by Sandia National Laboratories for the U.S. Department of Energy's Wind and Water Power Program, is a wind energy research site with multiple wind turbines scaled for the experimental study of wake dynamics, advanced rotor development, turbine control, and advanced sensing for production-scale wind farms. The SWiFT site currently includes three variable-speed, pitch-regulated, three-bladed wind turbines. The six volumes of this manual provide a detailed description of the SWiFT wind turbines, including their operation and user interfaces, electrical and mechanical systems, assembly and commissioning procedures, and safety systems.

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Sandia SWiFT Wind Turbine Manual (SAND2016-0746) approved by:

Department Manager		SWiFT Site Lead	
Dave Minster (6121)	Date	Jonathan White (6121)	Date
SWiFT Site Supervisor			
Dave Mitchell (6121)	Date		

Note: Document revision logs are found after the title page of each volume of this manual.

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NOMENCLATURE

CCW	Counterclockwise
CW	Clockwise
DOE	U.S. Department of Energy
FTP	File Transfer Protocol
GPS	Global Positioning System
HSS	High-Speed Shaft
IMU	Inertial Measurement Unit
I/O	Input/Output
LED	Light-Emitting Diode
LSS	Low-Speed Shaft
MAX	Measurement and Automation Explorer
MCOV	Maximum Continuous Operating Voltage
MOC	Management of Change
NI	National Instruments
NWI	National Wind Institute
OSP	Overspeed Protection
PDO	Process Data Objects
PPE	Personal Protective Equipment
RPM	Rotations Per Minute
RTD	Resistance Temperature Detector
SNL	Sandia National Laboratories
SPEC	South Plains Electric Cooperative
SWiFT	Scaled Wind Farm Technology (Sandia facility)
TTU	Texas Tech University
UTC	Universal Time Coordinated
VDC	Volts of Direct Current
Vestas	Vestas Energy Systems
WP&C	Work Planning & Control
WPPO	Wind Power Program Office (DOE program)

ICONOGRAPHY

This manual uses a standard set of iconography to alert readers to critical information, as follows:

 **Safety alert**: Note this critical safety precaution.

 **Ordered step alert**: Performed this step precisely and in specified order.

 **Critical information alert**: Note this critical information.

Volume 1:
Overview

Sandia SWiFT Facility Site Operations Manual (SAND2016-XXXX) approved by:

Department Manager

SWiFT Site Lead

Dave Minster (6121) Date

Jonathan White (6121) Date

SWiFT Site Supervisor

Dave Mitchell (6121) Date

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1. OVERVIEW

1.1. About This Manual

1.1.1. Purpose and Scope

The Scaled Wind Farm Technology (SWiFT) facility, operated by Sandia National Laboratories for the U.S. Department of Energy's Wind Power Program Office (WPPO), is a wind energy research site with multiple wind turbines scaled for the experimental study of wake dynamics, advanced rotor development, turbine control, and advanced sensing at production-scale wind farms.

This manual provides a detailed description of Sandia SWiFT wind turbines, including their operation and user interfaces, electrical and mechanical systems, assembly and commissioning procedures, and safety systems. It is intended for use by workers tasked with operating, servicing, modifying, or assembling Sandia SWiFT wind turbines. This manual should be used in coordination with other SWiFT site supporting manuals and documentation (see Section 1.1.8).

This manual is organized into six volumes, as follows:

Volume 1: Manual Overview – Overview and organization of this manual, its use, and its context in SWiFT site operations and the SWiFT integrated safety program.

Volume 2: Turbine Operation – Operation of a Sandia SWiFT wind turbine, including key features and subsystems, safety systems, operating states of the turbine, and the turbine software user interface.

Volume 3: Electrical System – Detailed descriptions and schematics of the electrical system, subsystems, and components; calibration and maintenance requirements and procedures; troubleshooting procedures; and component and replacement part specifications.

Volume 4: Mechanical Systems – Inspection and maintenance procedures necessary to operate and maintain research wind turbines safely, specifications for the turbine's mechanical subsystems and replacement parts, and drawings of the turbine's mechanical subsystems.

Volume 5: Turbine Assembly – Construction and assembly procedures for erecting a turbine for the first time at the SWiFT site (this volume is under development).

Volume 6: Turbine Commissioning – Startup procedures and calibration tests that must be performed the first time a newly constructed wind turbine is operated (or after major changes are made to the system or safety systems), and "run-in" tests required to verify performance of the turbine systems prior to full turbine operation.

1.1.2. SWiFT Test & Facility Assets

1.1.2.1. Sandia SWiFT Wind Turbines

The SWiFT site currently includes three variable-speed, pitch-regulated, three-bladed wind turbines with active yaw and pitch and high speed rotors. The three research-modified turbines are designated DOE/SNL1 (WTGa1), DOE/SNL2 (WTGa2), and Vestas (WTGb1) corresponding to the two turbines owned and operated by DOE/Sandia and the one turbine owned by Vestas Energy Systems. For the purposes of this manual, all three turbines are referred to as “Sandia SWiFT wind turbines.”

Two turbines, DOE/SNL1 and Vestas, are oriented roughly perpendicular to the prevailing wind direction for comparative rotor tests. DOE/SNL2 is located directly north (downwind) of DOE/SNL1 for turbine-to-turbine interaction and wake studies. The three turbines form a 3-5-6 triangle. Each turbine is 32.5 meters high to the hub and features a rotor diameter of 27 meters. The turbines are specially instrumented with time-synchronized, deterministic data acquisition sensors for turbine state data, such as generator power, rotor speed, yaw angle, and rotor strain.

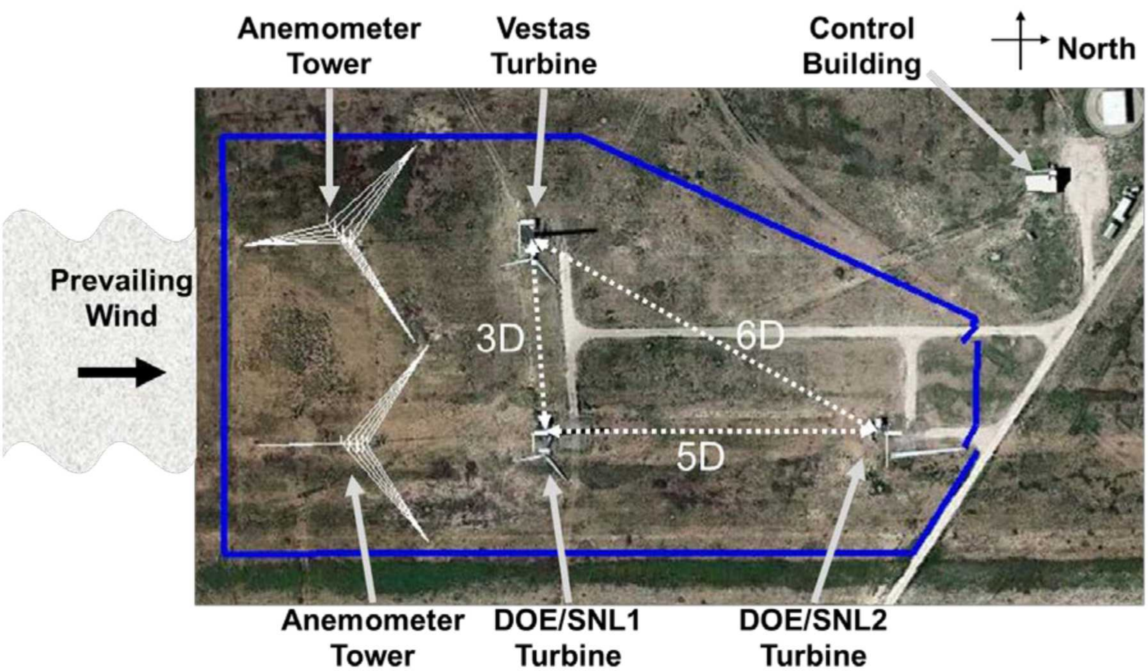

Figure 1. Layout of the SWiFT facility

1.1.2.2. SWiFT Site Assets & Infrastructure

In addition to its three turbines, the SWiFT facility features a **control building** that houses the PCs and software systems for managing the site’s turbines and instrumentation and collecting experimental data. The building includes a main control room, two small offices for proprietary research, and a small electrical troubleshooting lab.

Among the SWiFT site's instrumentation for monitoring weather conditions and gathering data are two **meteorological towers** upwind of the turbine array. The meteorological towers are 2.5 diameters south of the leading row of turbines. Each 58.5-meter-tall tower is instrumented with anemometers and temperature, humidity, and pressure sensors at heights of 10, 18, 31.5, 45, and 58.5 meters.

To support research data transfer, the SWiFT site features a **fiber-optic network** that includes a bundle of 12 single-mode fiber-optic strands between each turbine and meteorological tower and the control building.

Sandia Building 350 at the nearby Reese Technology Center houses SWiFT's Experimental Preparation Lab (a.k.a Assembly Building) and features a 4,500 square foot, environmentally controlled high bay for assembly of experimental rotors as well as a 1,000 square foot machine shop.

Future phased plans for the SWiFT site include the installation of seven more turbines and one more meteorological tower.

1.1.3. Safety

1.1.3.1. Site Safety Philosophy

All work at SWiFT is conducted with human safety as the overriding priority. All decisions will be made with safety as the top priority, and safety is the primary goal of work planning. Every person present at SWiFT has "stop work authority" – the authority and responsibility to halt operations they believe are not safe to themselves, other SWiFT workers, or the public.

Every person present at SWiFT has "stop work authority" – the authority and responsibility to halt operations they believe are not safe.

For detailed information about the SWiFT site's integrated safety program, including hazards, safety controls, and work restrictions, refer to the Sandia SWiFT Facility Site Operations Manual and Sandia SWiFT Site Safe Work Planning Manual.

1.1.3.2. Turbine Safety Systems

Each Sandia SWiFT wind turbine features multiple, redundant failsafe hardware and software systems for safely controlling and stopping turbines. These active engineered safety controls are designed and maintained to minimize, to the greatest degree possible, catastrophic failure or significant damage to turbines and should never be bypassed as part of normal operations.

Turbine safety control systems should never be bypassed without the approval of the Site Supervisor.

Emergency Stop buttons placed at various locations at the SWiFT site and on individual turbines are among the most critical safety controls at SWiFT. All onsite personnel, including visitors, are authorized to press the nearest Emergency Stop button when they witness a serious current or impending safety threat. Note that only the SWiFT Site Supervisor, in consultation with site personnel and Sandia management, has the authority to permit a restart following a turbine Emergency Stop.

Emergency Stop buttons can be found:

- Inside the control building, site-wide (all turbines)
- Inside the control building, each individual turbine
- Outside the control building, site-wide (all turbines)
- Tower base control cabinet, each turbine
- Yaw deck, each turbine
- Top of gearbox, each turbine
- Top control cabinet, each turbine

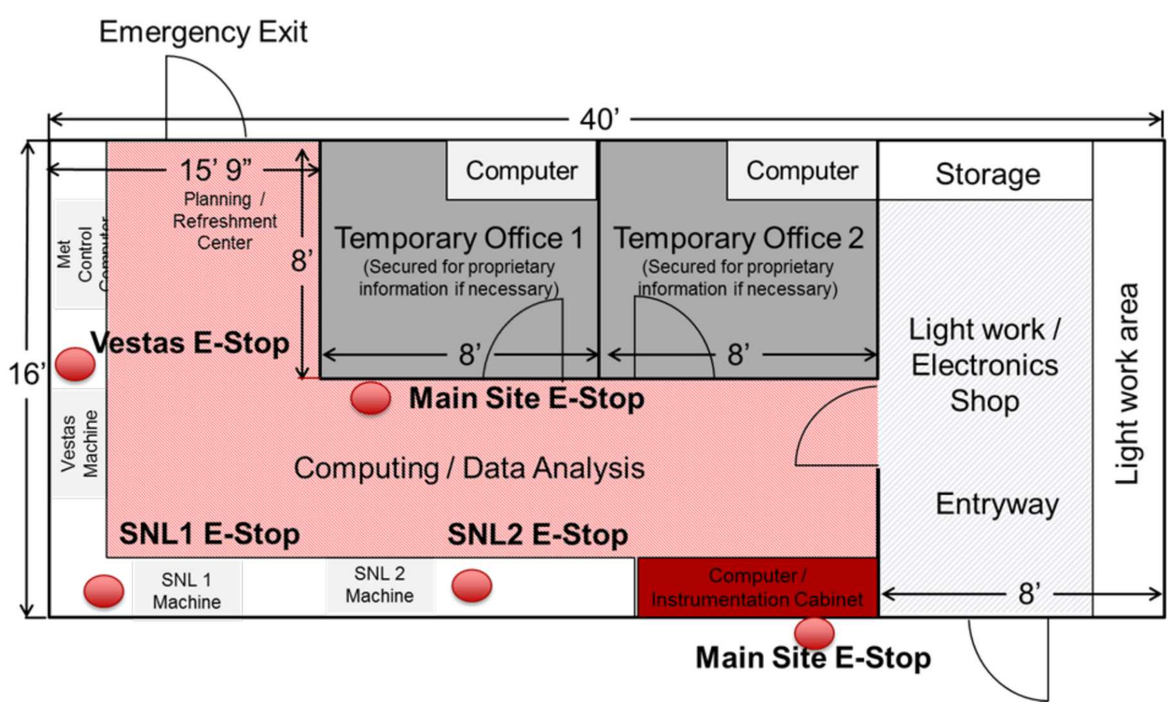

Figure 2. Locations of emergency stop buttons in the SWiFT control building

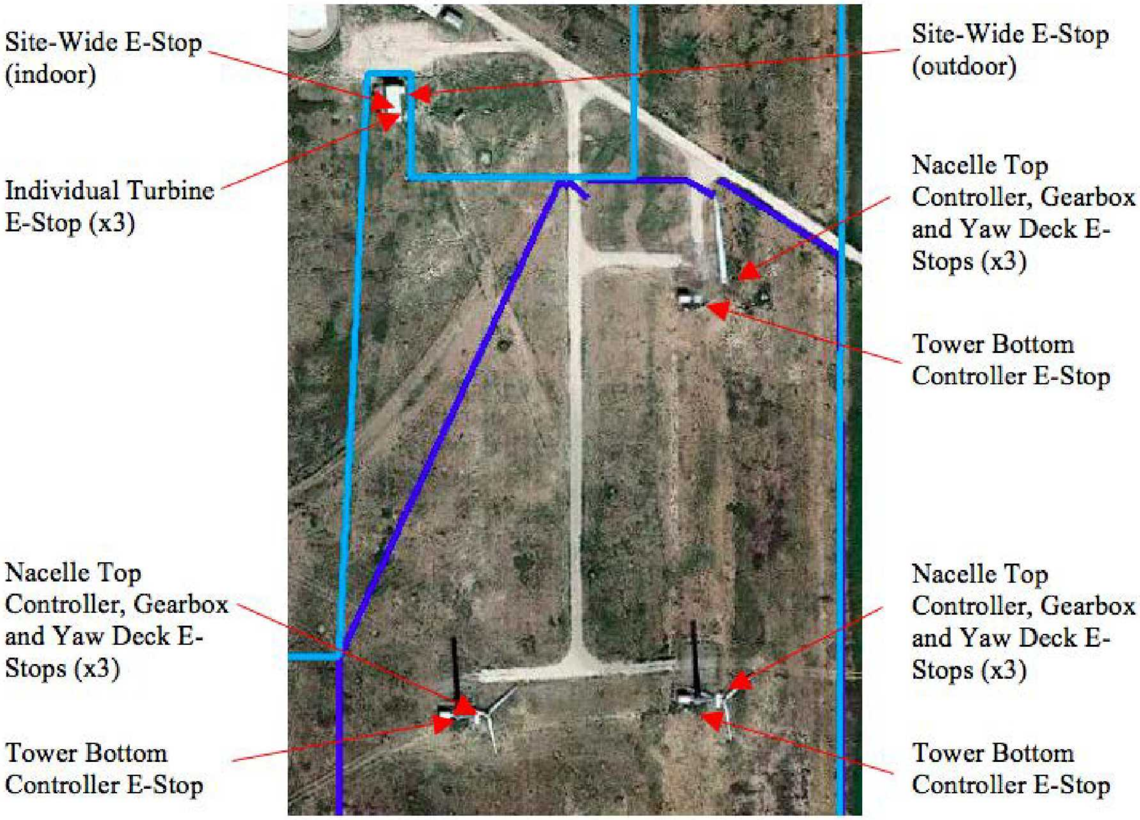

Figure 3. Locations of emergency stop buttons at the SWiFT site

All onsite personnel, including visitors, are authorized to press the nearest Emergency Stop buttons when they witness a serious current or impending safety threat.

Refer to the individual volumes of this manual for detailed information about the hazards and engineered safety controls specific to the turbine subsystems covered in those chapters (e.g., electrical system hazards are a part of Volume 3: Electrical Systems).

1.1.3.3. Site Access & Work Approval

The SWiFT Site Supervisor controls access to the SWiFT field site and approves all work on Sandia SWiFT wind turbines. All staff, workers, and visitors must check in with the Site Supervisor at the SWiFT control building each time they arrive at or depart from the SWiFT field site. No work shall be performed on Sandia SWiFT wind turbines without the written or verbal approval of the SWiFT Site Supervisor.

1.1.3.4. Work Restrictions

Work restrictions that prevent worker exposure to hazards are among the most critical administrative safety controls at SWiFT. Each worker is responsible for restricting their own work in accordance with the SWiFT site's limits, with oversight provided by the Site Supervisor. Restrictions are in place for high wind speeds, hot and cold weather, heavy precipitation, lightning, tornado watches and warnings, icing, and other hazards and apply to climbing, aerial lifting, crane and rigging operations, and other activities at SWiFT. Refer to the Sandia SWiFT Facility Site Operations Manual for details.

1.1.3.5. Emergency Procedures

Emergency procedures are in place for accidents, dangerous situations (including turbine overspeed events), near-miss events, and other safety and turbine structural concerns. Refer to the Sandia SWiFT Facility Site Operations Manual for details. Note that only the SWiFT Site Supervisor, in consultation with site personnel and Sandia management, has the authority to permit a restart following an emergency work stoppage or turbine Emergency Stop.

1.1.4. Modification of Test Assets

All changes to Sandia SWiFT wind turbines – in particular their safety-critical hardware (pitch system, mechanical brakes, and generator braking systems), turbine software, emergency circuits (Stop and E-Stop), and controls-critical sensors required for experimental work or prototype demonstration – shall be managed through the Sandia corporate Engineered Safety Work Planning and Control (WP&C) process and the Management of Change (MOC) process. Additionally, rotor blade changeouts or aerodynamic/structural modifications to rotor blades will be managed by these processes. Refer to the Sandia SWiFT Site Safe Work Planning Manual for details about these processes.

All maintenance and modifications, including minor changes, to any Sandia SWiFT wind turbine must be approved by the SWiFT Site Supervisor.

All changes to Sandia SWiFT wind turbines, including minor changes, must be managed through the Sandia corporate Engineered Work Planning & Control and Management of Change processes and must be approved by the SWiFT Site Supervisor.

1.1.5. Turbine Operational States

To clearly and simply communicate the current state, hazards, and operating protocols, the facility deploys a graded-approach to defining operational states for the site in general, as well as for individual test assets (turbines and meteorological towers). Current operational states can be found on the site operations sign outside the SWiFT control building. Each turbine shall at all times be defined by one of the following states:

- Commissioning
- Normal Operations - Attended
- Normal Operations - Unattended
- Stoppage
- Stowage
- Maintenance
- Construction

Refer to the Sandia SWiFT Facility Site Operations Manual for details.

1.1.6. Roles and Responsibilities

The following SWiFT site officials are responsible for site operations and site safety. Detailed descriptions of roles and responsibilities is provided in the Sandia SWiFT Site Operations Manual.

The SWiFT Site Supervisor is responsible for all on-site, day-to-day safety, operations, and personnel at the SWiFT site.

Department Manager: Responsible for the SWiFT facility including all aspects of safety, operations, and personnel.

Site Lead: Responsible for setting the priorities for SWIFT, interacting with DOE personnel, and overseeing program management and long-term strategic planning.

Site Supervisor: Responsible for on-site, day-to-day safety, operations, and personnel at the SWiFT facility.

Site Technician: Responsible for performing and leading work at SWiFT.

Lead Technologist: Responsible for supporting work activities at SWiFT.

Principal Investigator: Responsible for coordinating all SWiFT work activities with other activities and requirements of Texas Tech University and the National Wind Institute.

SWiFT Staff: Additional staff, collaborators, and contract members of the Sandia Wind Energy Technologies Department.

Table 1. SWiFT site officials (as of 1/4/2016) THIS IS NOT AN EMERGENCY CONTACT LIST OR PRIORITY GO TO LIST			
Department Manager	Dave Minster	dgminst@sandia.gov	O: 505-284-3082 C: 505-933-3481
Site Lead	Jon White	jonwhit@sandia.gov	O: 505-284-5400 C: 505-270-9980
Site Supervisor	Dave Mitchell	dmitche@sandia.gov	C: 806-241-1654
Site Technician	Miguel Hernandez	miguel.l.hernandez@ttu.edu	C: 806-445-6146
Lead Technologist	Wes Johnson	wjohnso@sandia.gov	O: 505-284-1177 C: 505-249-4948
Principal Investigator	John Schroeder	john.schroeder@ttu.edu	O: 806-834-5678 C: 806-239-3927

1.1.7. Training and Reading Requirements

Human safety is best achieved through proper training, documented work plans, and adherence to safety procedures. The Sandia SWiFT Site Operations Manual specifies the minimum training and reading requirements all workers must complete prior to servicing, modifying, or maintaining Sandia SWiFT wind turbines.

1.1.8. Supporting Documentation

This manual should be used in coordination with the Sandia SWiFT Facility Site Operations Manual, which includes details about SWiFT site integrated safety program, and the Sandia SWiFT Site Safe Work Planning Manual, which includes details about formal test planning, construction planning, and management of change procedures.

Other available documentation that may be required for safe mission, site, and turbine operations include:

- SWiFT Software Quality Assurance Process
- SWiFT Facility Test Plan
- Description and Analysis of the Hardware Safety Systems for DOE/SNL SWiFT Wind Turbines
- Management Self Assessment Plan: Scaled Wind Farm Technology (SWiFT) Facility
- SWiFT Facility Plan of Action

In addition, the SWiFT facliity makes use of a variety of ancillary equipment, tools, and devices associated with turbine operations, tests, and maintenance, most supplied by non-Sandia vendors. Consult the appendices of the individual volumes of these manuals for tables of available non-Sandia user manuals and data sheets. These documents are available in the SWiFT control building or from the SWiFT site supervisor.

1.1.9. Manual Change Control

The SWiFT site supervisor, in consultation with other site personnel, has the responsibility and the authority to review proposed changes to this manual and its individual volumes and make determinations about needed revisions. All approved revisions to this manual shall be logged in the appropriate Volume Revision Log found at the beginning of each volume of this manual.

This manual shall be reviewed and revised as needed every 12 months, at a minimum, or when the SWiFT site supervisor determines it is necessary.

Volume 2:
Turbine Operation

Sandia SWiFT Facility Site Operations Manual (SAND2016-XXXX) approved by:

Department Manager

Dave Minster (6121) Date

SWiFT Site Lead

Jonathan White (6121) Date

SWiFT Site Supervisor

Dave Mitchell (6121) Date

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Volume Owner(s): Jonathan Berg, SWiFT Controls Engineer			
Revision	**Date**	**Author(s)/Approval**	**Summary of Change(s)**
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2. TURBINE OPERATION

2.1. Turbine Overview

2.1.1. Sandia SWiFT Wind Turbines

The SWiFT site currently includes three variable-speed, pitch-regulated, three-bladed wind turbines with active yaw and pitch and high speed rotors. The three research-modified turbines are designated DOE/SNL1 (WTGa1), DOE/SNL2 (WTGa2), and Vestas (WTGb1) corresponding to the two turbines owned and operated by DOE/Sandia and the one turbine owned by Vestas Energy Systems. For the purposes of this manual, all three turbines are referred to as "Sandia SWiFT wind turbines."

This volume describes how to safely operate a Sandia SWiFT wind turbine. Section 2.1 provides an overview of a SWiFT wind turbine and its most important features and subsystems. Section 2.2 describes the operating states of the turbine and how errors are handled. Section 2.3 provides a detailed description of the turbine software user interface.

2.1.2. Rotation System

Each Sandia SWiFT wind turbine transforms mechanical energy from the rotating blade-rotor assembly into electrical energy by means of an asynchronous generator located in the turbine's nacelle. The turbine rotation system includes all rotating components, including:

- Three reinforced polyester fiberglass blades
- Rotor assembly including blade bearings
- High-speed shaft that enters the generator
- Sensors and active monitoring systems
- Blade pitch control system

2.1.3. Power Production System

Each turbine is equipped with a three-phase, variable-speed, 60 Hz, 400 HP asynchronous generator located in each turbine's nacelle. Each generator is connected to the electrical grid through a series of power transmission components, including:

- Tower cables
- A full-scale converter (ABB Variable Frequency Drive)
- A pad-mounted transformer
- High voltage underground cables
- A utility-managed grid interconnect

2.1.4. Control System

The turbine control system comprises hardware, software, and predefined control logic. It serves two primary functions:

- It monitors all critical functions of the turbine (e.g. rotor RPM, wind speed, power production, pitch angle, yaw, etc.) to ensure proper operation.
- Based on inputs from this monitoring, it communicates with and automatically drives subsystem actuators (pitch angle solenoid, yaw motor, hydraulic braking, etc.) based on a predefined logic to properly control the turbine in all of its states. These actuators are controllable through the user interface.

All functions of the Sandia SWiFT wind turbine are monitored and controlled via a central microprocessor-based control unit located in the turbine nacelle, distributed control systems connected by an EtherCAT communication protocol, and associated software packages.

2.1.5. Operating System

The National Instruments Veristand operating system provides real-time communication and hardware control for Sandia SWiFT wind turbines. Veristand runs a variety of controls software packages and provides the signal routing between the software modules and the system hardware via the turbine's control processor. The signal processing, controls, and turbine state modules are written in MathWorks Simulink and MathWorks Stateflow. The instrument drivers and logging routines are written in National Instruments LabVIEW.

2.1.6. Software User Interface

Real-time human control of turbines is executed via a Gateway computer in the SWiFT site control building. The turbine user interface is also written in LabVIEW but is not a module in the Veristand operating system. Rather, the user interface runs independently and communicates with a turbine through the Veristand Gateway.

Within certain parts of the user interface, access is restricted to operators with sufficient access permission level, which is validated by a user log-in system.

2.1.7. Site Infrastructure

A site-wide fiber-optic network connects the processor in each turbine with the user interface located in the control building. Data gathered by the processor are stored in the site data storage system.

2.2. Operating Strategy

2.2.1. Turbine Operating States

The turbine controller is always in one of four operating states:

- Run
- Pause
- Stop
- Emergency

Each operating state can be seen as an activity level, where Run is the highest activity level and Emergency is the lowest activity level.

Each operating state is clearly defined so that the turbine's reaction to external conditions is predictable. Predefined logic embedded in the control software for the yaw system, pitch system, generator, and other active systems determines how the turbine responds based on the state.

The following gives a brief description of the four operating states and their characteristics.

2.2.1.1. Run

In the Run operating state:

- The brake is off
- The hydraulic pump maintains working pressure
- Automatic yaw is active
- The turbine is allowed to connect the generator to the grid and produce power
- The pitch control system chooses the optimum blade angle
- The production controller chooses the proper control logic for rotor speed/torque control
- The user interface displays RUN

Once a sufficient rotor speed is reached, the production controller initiates the grid connection and chooses the proper control logic to switch between rotor speed control and torque control. It also chooses the optimal blade angle.

2.2.1.2. Pause

In the Pause operating state:

- The brake is off
- The hydraulic pump maintains working pressure
- Automatic yaw is active
- The pitch control system regulates the blade angle against 90°
- The turbine is idling

- The user interface displays PAUSE

This operating state is useful when testing the turbine because systems are functioning normally but the turbine is not enabled for power production.

2.2.1.3. Stop

In the Stop operating state:

- The brake is off
- The pitch system is bypassed mechanically by opening the full-feather solenoid valves
- The hydraulic pump maintains working pressure
- Automatic yaw is not active
- The user interface displays STOP

2.2.1.4. Emergency

In the Emergency operating state:

- The brake is on
- The pitch system is bypassed mechanically by opening the full-feather solenoid valves
- The emergency circuit is open
- All actuator-controlling outputs from the turbine controller are deactivated
- The control processor is running and measuring all inputs
- The user interface displays EMERGENCY

When the emergency circuit is open, the turbine controller's actuator-controlling outputs are bypassed, making it impossible for the processor to activate any of the actuators.

2.2.2. Changing Operating States

When increasing the turbine's operating state (activity level), the operating state must be increased one level at a time. When decreasing the activity level, it is possible to skip activity levels. Figure 2-1shows the possible pathways for increasing and decreasing the turbine operating state.

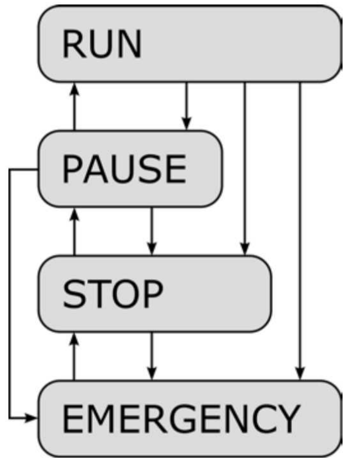


Figure 2-1. Increasing and decreasing operating state

This strategy allows for the safest operation and most efficient error handling. If an error is detected while the activity level is increasing, for example, ascension to the next higher level can be prevented. If a detected error is significant, the operating state can shift from Run to Emergency immediately.

Following are brief descriptions of the actions that take place when changing from one operating state to another.

2.2.2.1. Increasing Operating State

As the turbine steps through increasing operating states, the following changes take place:

Emergency → Stop:

If conditions for being in the Stop operating state are satisfied, then:

- The emergency circuit closes
- The brake is released
- Hydraulic pressure builds to working pressure

Stop → Pause:

If conditions for being in the Pause operating state are satisfied, then:

- Automatic yaw is enabled
- Full-feathering valves are closed, which routes pitch control through the proportional valve

Pause → Run:

If conditions for being in the Run operating state are satisfied, then:

- Processor checks that the rotor is facing the wind direction
- The turbine produces power when sufficient wind is present

2.2.2.2. Decreasing Operating State

As the turbine descends to lower activity levels, the following changes take place:

Stop → Emergency, Pause → Emergency, or Run → Emergency:

- Emergency circuit opens
- Processor outputs are deactivated
- The brake is activated
- All control logic resets
- If coming from Run with generator connected, ABB drive reduces generator speed to zero and disconnects the generator

Pause → Stop:

- Auto yaw is deactivated
- Full-feathering valves open

Run → Stop:

- Auto yaw is deactivated
- Full-feathering valves open
- ABB drive reduces generator speed to zero and disconnects the generator (if previously connected)

Run → Pause:

- Pitch control and torque control gently slow the rotor
- Turbine controller disconnects the generator (if previously connected)

2.2.3. Error Handling

Error handling is a matter of bringing the activity level of the turbine to a lower level. The detection criteria are specified for each error type.

We define the following information for each error.

Log: Name of the error
Detection: Description of how the error is detected
Reaction: The maximum activity level when the error is present or not reset
Restart: The error can be reset automatically, manually at the turbine, or from remote control

If in a given operation state an error occurs for which a lower operating state is specified, the turbine will shift immediately to this lower operating state.

2.2.3.1. Error Detection

The turbine's processor continually scans for inputs indicating errors. Errors are sorted by the error handler so that one error is passed at a time. Only errors that will cause a shift to a lower operating state will pass the error handler.

2.2.3.2. Logging of Errors

Errors are stored in an operating log and in an alarm log.

2.2.3.3. Reaction to Errors

The reaction to errors is always one of the following:

- Decrease to Pause
- Decrease to Stop
- Decrease to Emergency

2.2.3.4. Restart After Errors

The turbine's operating state cannot be increased until the error has been acknowledged. Depending on the type of error, acknowledgment can occur in two ways:

- Some errors can be reset from remote control (Remote ACK). If the operator finds it acceptable to return to normal operations, he or she can reset the error.
- Some errors are critical and cannot be reset from remote control; these errors must be reset after human inspection of the turbine (Local ACK).

2.2.3.5. Log Messages

A complete list of all messages and errors can be found in Appendix A.

2.2.4. Service Modes

The controller features a number of service modes designed to allow for maintenance and testing of turbine subsystems. The following describes each of these service modes and the corresponding states of various subsystems.

Note: Automatic yaw is disabled in all service modes, so yaw errors are expected.

2.2.4.1. Pitch Service Mode

To enter the Pitch Service Mode, the operator must be logged in with sufficient access permission level and the turbine must be in the Pause operating state.

When in the Pitch Service Mode, the operator can manually set the desired pitch angle of the blades and set a desired pitching rate (helpful for tuning the Vickers proportional valve control amplifier).

The following automated pitch tests are available:

- Voltage Test
- Positive/Negative Offset Tests
- Positive/Negative Flow Test
- Sine Test
- Step Test

The generator is not engaged when in Pause, so there is no counteracting torque on the rotor. Manually pitching the blades down to 40 degrees results in a stalled rotation speed of roughly 100 RPM HSS or 3.6 RPM LSS. This is used in the startup sequence of the turbine to determine if there is enough wind to produce power.

2.2.4.2. Hydraulic Service Mode

To enter the Hydraulic Service Mode, the operator must be logged in with sufficient access permission level and the turbine must be in a Run, Pause, or Stop operating state.

When in the Hydraulic Service Mode, the operator can manually set the system to Run, Stop, or Auto.

2.2.4.3. Yaw Service Mode

To enter the Yaw Service Mode, the operator must be logged in with sufficient access permission level and the turbine must be in a Run or Pause operating state.

When in the Yaw Service Mode, automatic yaw can be enabled and disabled. The turbine can also be manually yawed clockwise and counterclockwise. This is typically done for repositioning the machine in service and for testing the behavior of the twist sensors.

2.2.4.4. Brake Service Mode

To enter the Brake Service Mode, the operator must be logged in with sufficient access permission level and the turbine must be in a Run, Pause, or Stop operating state.

When in the Brake Service Mode, an operator can manually activate or release the hydraulic brake fitted to the high speed shaft.

2.2.4.5. Gear Oil Cooler Service Mode

To enter the Gear Oil Cooler Service Mode, the operator must be logged in with sufficient access permission level and the turbine must be in a Run or Pause operating state.

When in the Gear Oil Cooler Service Mode, an operator can set the system to Run, Stop or Auto.

2.2.4.6. Generator Fan Service Mode

To enter the Generator Fan Service Mode, the operator must be logged in with sufficient access permission level and the turbine must be in a Run or Pause operating state.

When in the Generator Fan Service Mode, an operator can set the system to Run, Stop, or Auto.

2.2.4.7. ABB Drive Service Mode

To enter the ABB Drive Service Mode, the operator must be logged in with sufficient access permission level and the turbine must be in a Pause or Stop operating state.

When in the ABB Drive Service Mode, drive state change errors are suppressed, allowing for the drive to be powered off while leaving the turbine in Stop for long periods.

2.2.4.8. Gear Oil Filter Service Mode

To enter the Gear Oil Filter Service Mode, the operator must be logged in with sufficient access permission level and the turbine must be in a Run or Pause operating state.

When in the Gear Oil Filter Service Mode, an operator can set the system to Run or Stop.

2.2.4.9. Generator Service Mode

To enter the Generator Service Mode, the operator must be logged in with sufficient access permission level and the turbine must be in a Pause operating state.

When in the Generator Service Mode, an operator can command the system to execute pre-programmed generator speed tests. These tests include a Sine Test, a Step Test, and a test of the Over-Speed Protection systems.

2.3. Guide to the User Interface

This section contains a description of how to use the LabVIEW user interface to interact with a Sandia SWiFT wind turbine.

2.3.1. User Interface Overview

2.3.1.1. Veristand Operating System

The National Instruments Veristand operating system provides real-time communication and hardware control for Sandia SWiFT wind turbines. The LabVIEW user interface described below communicates with the turbine controller through the Veristand Gateway.

2.3.1.2. Project File

The Veristand Project File defines the structure and software components controlled by the Veristand Real-Time Engine executing on the turbine's central processor, a National Instruments 9082 central processor. The Project File includes Custom Devices, Models, and Channel Mappings to define the overall system structure.

2.3.1.3. Project Deployment

Project deployment is the process of sending the Project File and associated Custom Devices, Models, and Channel Mappings to the turbine processor. The deployment process transfers these files to the processor using FTP (file transfer protocol) and then starts them within the Veristand Engine. Once deployed, the hardware states are actively controlled by the Custom Devices and Models.

2.3.1.4. Veristand Gateway

The Veristand Gateway is an application executing on an operator computer terminal in the SWiFT site control building. The Gateway must be connected to the Veristand Engine executing a Project File. Once connected, the Gateway permits communication between the user interface application and the Custom Devices and Models executing on the turbine processor.

2.3.1.5. Menus

The LabVIEW user interface features a set of menus for communicating with and controlling the turbine's functions. The following sections describe the menus and their use.

2.3.2. Targets Menu Options

The *Targets* menu (Figure 2-2) allows the user to select, connect to, and control a hardware type. When selecting either the *Turbines* options or the *Metrology Towers* option, the Veristand Project must be deployed and the Veristand Gateway must be operational.

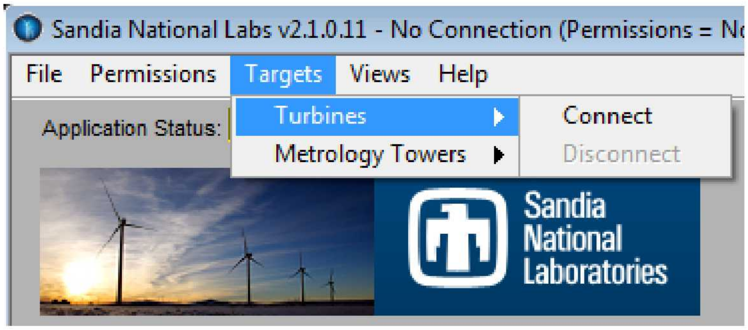


Figure 2-2. Targets menu options

Turbines >> Connect

Selection of the *Turbines>>Connect* menu option results in the display of the *Turbine Selection Interface* (Figure 2-3). The *Turbine Selection Interface* displays an illustration of the SWiFT site.

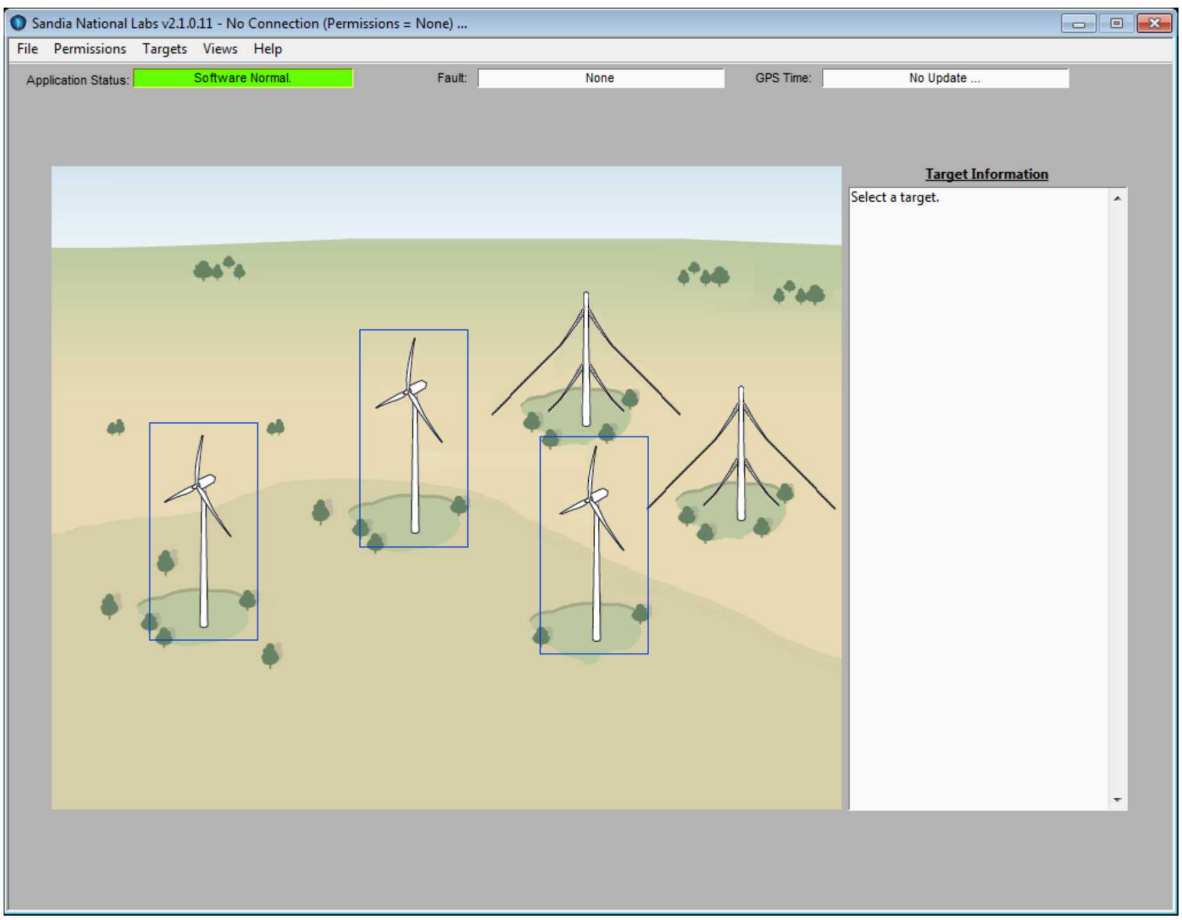


Figure 2-3. Turbine Selection interface

Hovering the mouse within each blue-framed "Hot Spot" region around each turbine updates the *Target Information* box, which provides a description of the turbine hovered over.

Double-clicking within the "Hot Spot" indicates that a connection is desired between the user interface and the Veristand Gateway currently connected to the selected turbine's Veristand Engine and executing Project File. Once the connection process is complete, the user interface displays the screen selectable by *Views>>User Mode* (Section 2.3.3.).

Turbines >> Disconnect

Selection of the *Turbines>>Disconnect* menu option closes the user interface connection to the Veristand Gateway and returns the user to the *Turbine Selection Interface* (Figure 2-3).

2.3.3. Views Menu Options

The following sections describe the interfaces displayed when the user selects one of the *Views* menu options (Figure 2-4). Generally, the *Views* menu options allow the user to interact with specific functionality of the turbine. Brief summaries of the views are given below, which are followed by a more detailed section for each view.

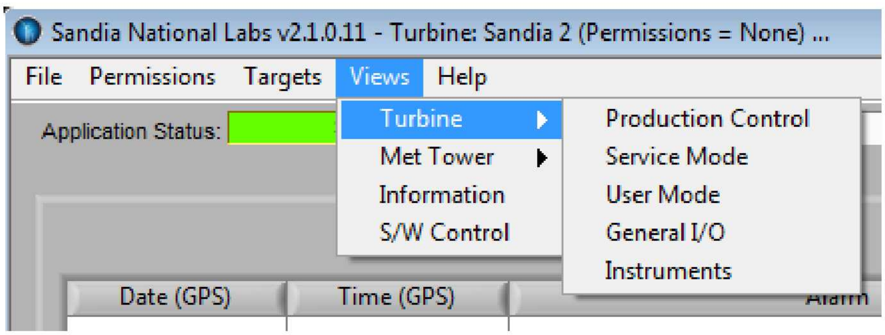


Figure 2-4. Views menu options

Views >> Turbine >> Production Control

Displays the Production Control interface to show the current operating state of the turbine.

Views >> Turbine >> Service Mode

Displays the Service Mode interface to allow the user to control and monitor specific subsystems within the turbine hardware.

Views >> Turbine >> User Mode

Displays the User Mode interface showing the turbine state, active alarms with history, and prompts for any required user interactions.

Views >> Turbine >> General I/O

Displays a listing of all hardware channels and their current statuses.

Views >> Turbine >> Instruments

Displays a set of subpanels. Each subpanel provides data and status information for devices that have special interfaces, such as serial devices and the GPS module.

Views >> Information

This screen provides information regarding the application version, hardware controls, and contact information. It does not provide any means of interacting with the turbine and is intended for application developers.

Views >> S/W Control

Displays an interface used by the programmer to monitor the status of individual application software components. This screen does not provide any means of interacting with the turbine and is intended for programmer debugging purposes only.

Detailed descriptions of the interfaces displayed for each *Views* menu option are provided in Sections 2.3.4.-2.3.19.

2.3.4. General I/O Interface

The *General I/O* interface (Figure 2-5) is displayed when the user selects *Views >> Turbine >> General I/O*. The interface is divided into left and right sides, with the left side showing the status of all digital inputs and outputs and the right showing analog inputs and outputs.

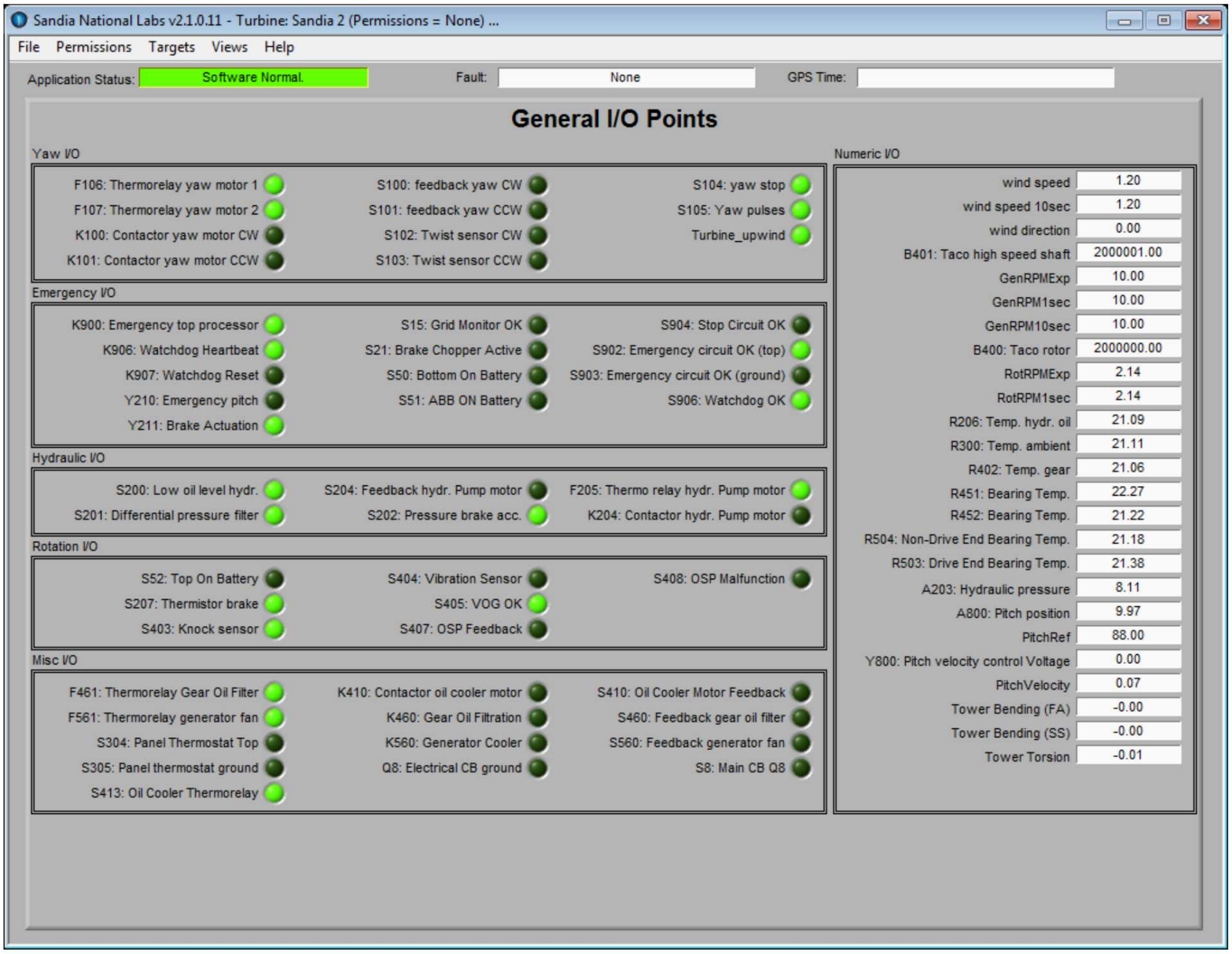


Figure 2-5. General I/O interface

Digital channel status is represented by an indicator light with signifying a low (0 VDC) signal and signifying a high (+24 VDC) signal. Signals are grouped by subsystem. Groupings include *Yaw I/O*, *Emergency I/O*, *Hydraulic I/O*, *Rotation I/O,* and *Miscellaneous I/O*.

Analog signals are grouped into one section, labelled *Numeric I/O*, with wind speed and direction on top, followed by rotational speeds and averages, then temperature measurements in the middle, followed by hydraulic and pitch measurements, and finally tower strain gauges at the bottom. All signals are displayed to two decimal points.

Hardware signals are labeled with the component number and a short text description. Software signals typically lack a component number and have only a description. The text for each channel can be modified by changing the contents of the *General_IO_Captions.csv* file. This file is located in the following folder:

<AppDir>\Config

where <AppDir> is the application installation directory, typically something similar to "C:\Program Files\SWiFT\User Interface."

2.3.5. User Mode Interface

The *User Mode* interfaces (Figure 2-6) are displayed when the user selects *Views >> Turbine >> User Mode*. These interfaces summarize the history of alarms and turbine states as well as current alarms and user interactions required. Three subpanels group the information required for each interface: *Alarm History, Turbine State*, and *User Mode*.

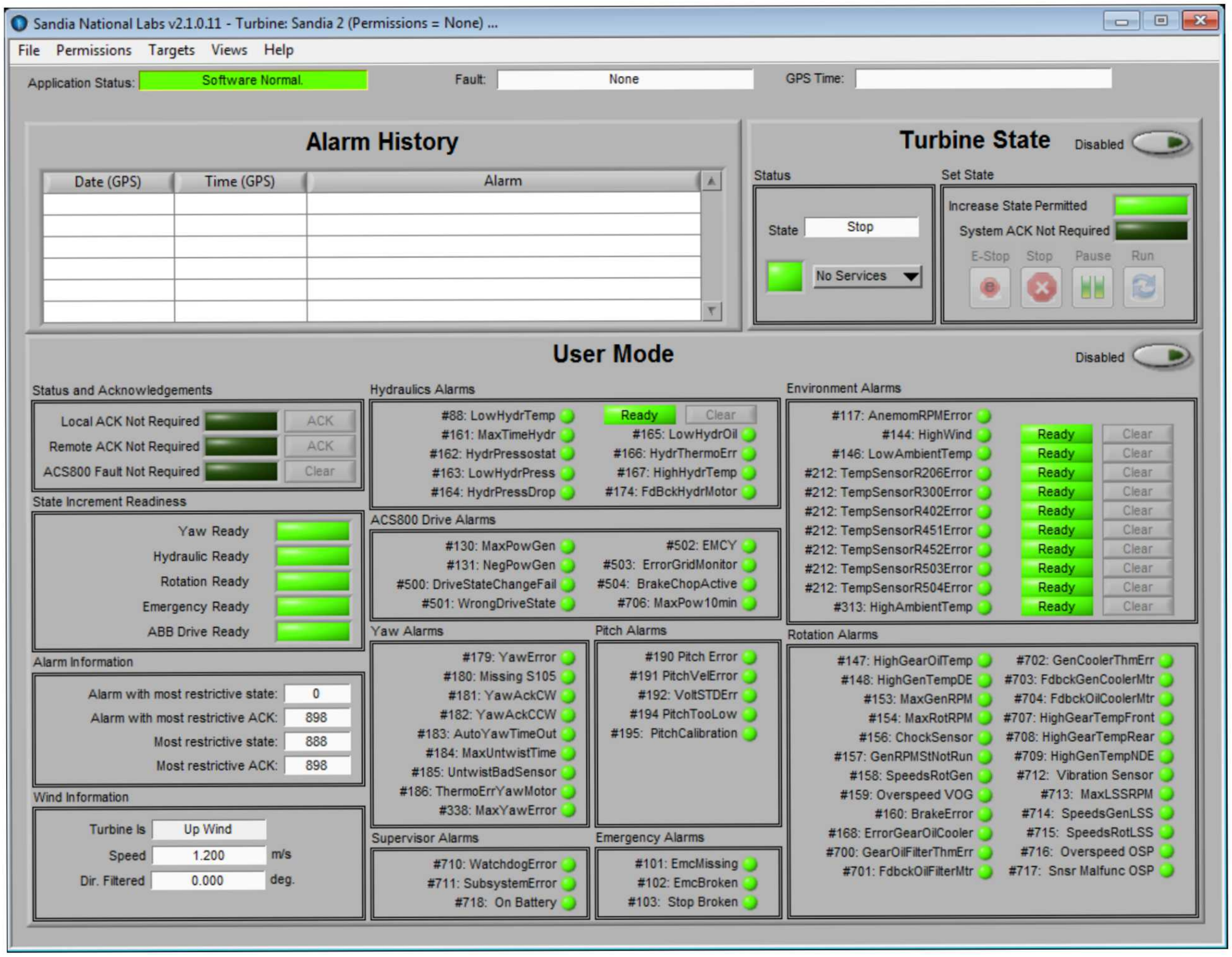


Figure 2-6. User Mode interfaces

Alarm History

The *Alarm History* table (Figure 2-7) lists the last 100 alarms and acknowledgements. Both alarms and acknowledgements are date- and time-stamped.

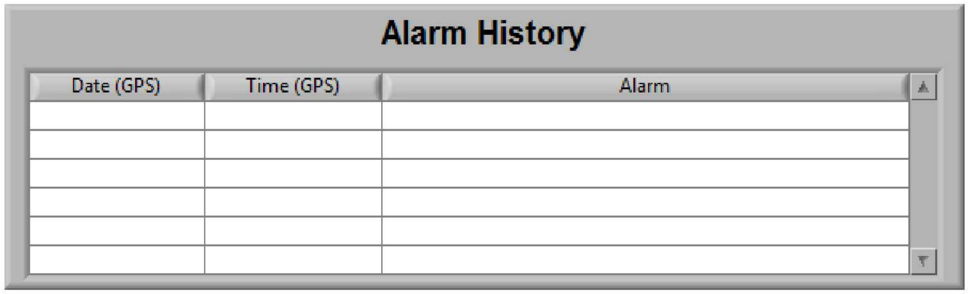


Figure 2-7. Alarm History subpanel

The alarm column is populated with the alarm number and description. For acknowledgements, the alarm column simply states “Acknowledged.” Additionally, all alarms listed in the table are logged to the *Alarm History.log* file located at:

<AppDir>\Logs

where <AppDir> is the application installation directory, typically something similar to “C:\Program Files\SWiFT\User Interface.” Alarm data listed in the log and in the history table are obtained from the *AlarmList.ini* configuration file located at:

<AppDir>\Config

Turbine State

The *Turbine State* subpanel (Figure 2-8) appears on several user interface screens and provides critical information about the current turbine state, as well as names of active service modes, and controls for requesting changes to the turbine state.

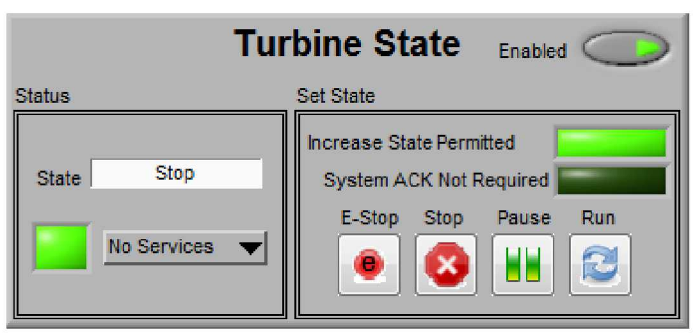


Figure 2-8. Turbine State subpanel

Note: Several subpanels are enabled and disabled by a button in the upper right corner. When pressed, this button requests control of related functionality from the Veristand Project. The operator must be logged in with sufficient access permission level to request for a restricted subpanel to be enabled. Some buttons may be yellow or grayed before enabling as part of the request process; others may simply enable.

The Turbine State subpanel includes two sections: *Status* and *Set State*.

Status: The *Status* section allows the user to review the state of the turbine. It includes three displays:

- **State field**: Indicates the current operational state of the turbine. Values include Unknown, E-Stop (Emergency Stop), Stop, Pause, and Run.
- **Service Mode light:** Indicates whether the turbine can be operated. When service modes are active, the indicator light will change to .
- **State pull-down menu**: Indicates if any, and which, service modes are active. When no service modes are active, the status will be as shown in Figure 2-8. When service modes are active, the pull-down menu will list the active service mode names.

Set State: The *Set State* section indicates when changes to the turbine state are permitted and allows the user to manually change the state of the turbine when permitted. See Section 2.2.1. Turbine Operating States for detailed descriptions of the turbine states and Section 2.2.2. Changing Operating States for explanations of the state transitions.

- **Increase State light**: Indicates if the turbine state can be elevated from the current state to a higher level. Figure 2-8 illustrates the display when a state increase is permitted.
- **System ACK light**: Indicates if the user must acknowledge some type of fault or alarm. Figure 2-8 shows the state when no acknowledgment is required. When acknowledgement is required, the light will display  .
- **E-Stop button**: Allows the user to downgrade the turbine state from any other state to Emergency. This will result in the brake being applied and the blades being forced to full feather.
- **Stop button**: Allows the user to downgrade from turbine states of Pause or Run or elevate from E-Stop to Stop. To elevate to Stop from E-Stop, the *Increase State Light* must display  . Requests when the elevation is not permitted will be ignored.
- **Pause button**: Button allowing the user to downgrade the turbine state from Run or elevate from Stop to Pause. To elevate to Pause from Stop the *Increase State Light* must display  . Requests made when elevation is not permitted will be ignored.
- **Run button**: Allows the user to elevate the turbine state to Run. This puts the controller into production and allows it to produce power. To elevate to Run from Pause, the *Increase State LED* must display  . Requests made when elevation is not permitted will be ignored.

User Mode

The *User Mode* subpanel (Figure 2-9) provides detailed information about currently active alarms, turbine readiness, and wind information. Interaction with the *User Mode* screen functionality is requested with the *Enabled/Disabled* button in the upper right corner.

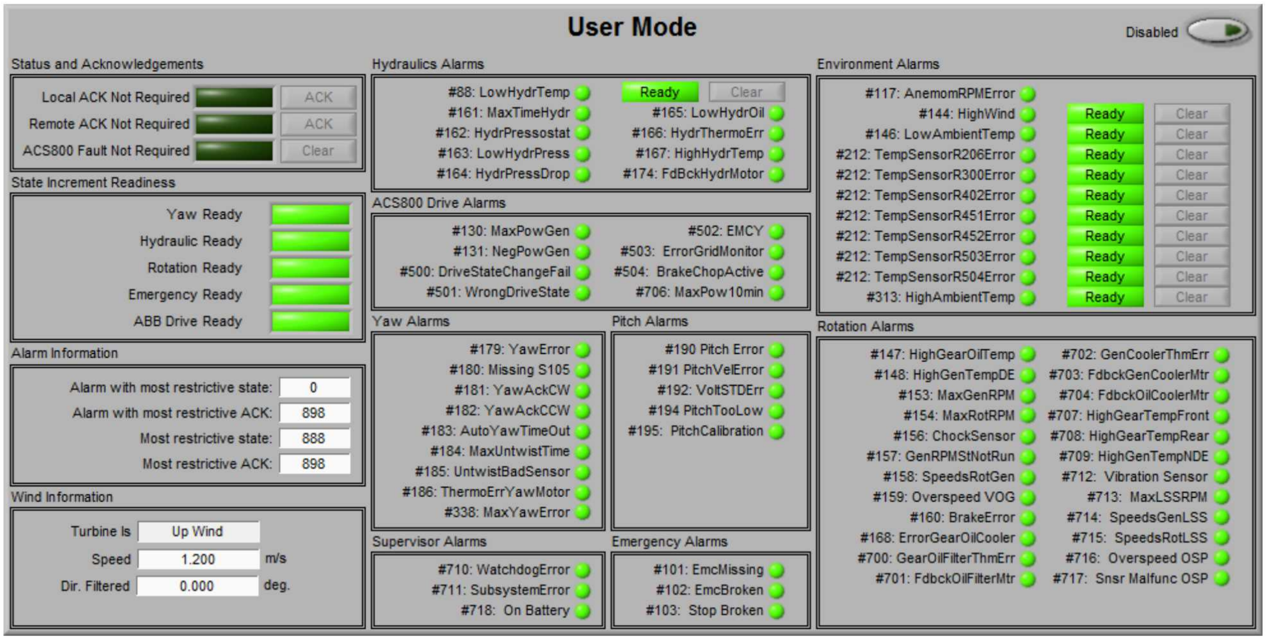


Figure 2-9. User Mode subpanel

Active Alarms Data

Active alarms data occupy the majority of the *User Mode* screen, which groups the data based on the subsystem affected. Alarm information groupings include *Hydraulic Alarms, ACS800 Drive Alarms, Yaw Alarms, Pitch Alarms, Supervisor Alarms, Emergency Alarms, Environment Alarms*, and *Rotation Alarms*. Each alarm state is indicated with a light, where signifies an inactive alarm and signifies an active alarm. Each alarm light is labeled with the alarm number and a short text description. Text descriptions are editable and contained within the *User_Mode_Captions.csv* file located at:

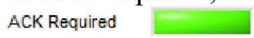
<AppDir>\Config

where <AppDir> is the application installation directory, typically something similar to "C:\Program Files\SWiFT\User Interface."

When investigating turbine alarm status, the user should also refer to the *Alarm History* table (Figure 2-7), as alarms may be active and automatically cleared by the processor. Some alarm states persist for a period of time before being automatically cleared. Alarms of this type include an adjacent countdown status light and override button. Figure 2-9 shows all the override controls in the "no countdown" state (Ready Clear); when in the "automatic reset countdown" state, the control will be displayed as Not Ready Clear.

Turbine Readiness Data

Turbine readiness data is presented on the upper left side of the *User Mode* interface (Figure 2-9).These sections are labeled *Status and Acknowledgements, State Increment Readiness,* and *Alarm Information.*

Status and Acknowledgements: These lights indicate the type of acknowledgement required and allow the user to perform the acknowledgement function. Figure 2-9 displays the indicator state when no user action is required; when the user must acknowledge or clear a fault, the display state will be 

. Faults are acknowledged or cleared by clicking the adjacent button. Should one or more of the three status lights indicate the need for a fault acknowledgement, the *System ACK* light (Figure 2-8) will illuminate.

State Increment Readiness: The *State Increment Readiness* section indicates the state of the five subsystems that determine whether the turbine operating state can be increased. The five subsystems monitored are *Yaw, Hydraulic, Rotation, Emergency,* and *ABB Drive*. A subsystem readiness to increase turbine state is indicated by status 

. All subsystem readiness lights must indicate a "ready" state for the *Increase State* shown in Figure 2-8 to display that a state increase is permitted. The example screen shown in Figure 2-9 indicates that all of the subsystems are ready for an increase in state.

Alarm Information: The *Alarm Information* box displays four numeric value fields. These values are used by the control system to determine the alarm, fault, and readiness state of the turbine control software. They are provided primarily for debugging by advanced users. This information is not required to understand and react to system alarms and faults.

Wind Information: The lower left corner of the *User Mode* screen (Figure 2-9) displays summary wind information. Three numeric values are provided:

- **Turbine Is field**: Displays the "Up Wind" state of the turbine. Values are *Unknown, Not Up Wind*, and *Up Wind*.
- **Speed field**: Displays the current wind speed in meters per second.
- **Direction Filtered field**: Displays the average wind direction in degrees relative to the direction the turbine is facing.

2.3.6. Service Mode Interface

The *Service Mode* interfaces (Figure 2-10) are displayed when the user selects *Views >> Turbine >> Service Mode*. Nine service modes are included in the control software: *ACS800 Service, Brake Service, Gear Oil Cooler Service, Gear Oil Filter Service, Generator Service, Generator Cooler Service, Hydraulic Service, Pitch Service,* and *Yaw Service*. See Section 2.2.4. for information about available service modes.

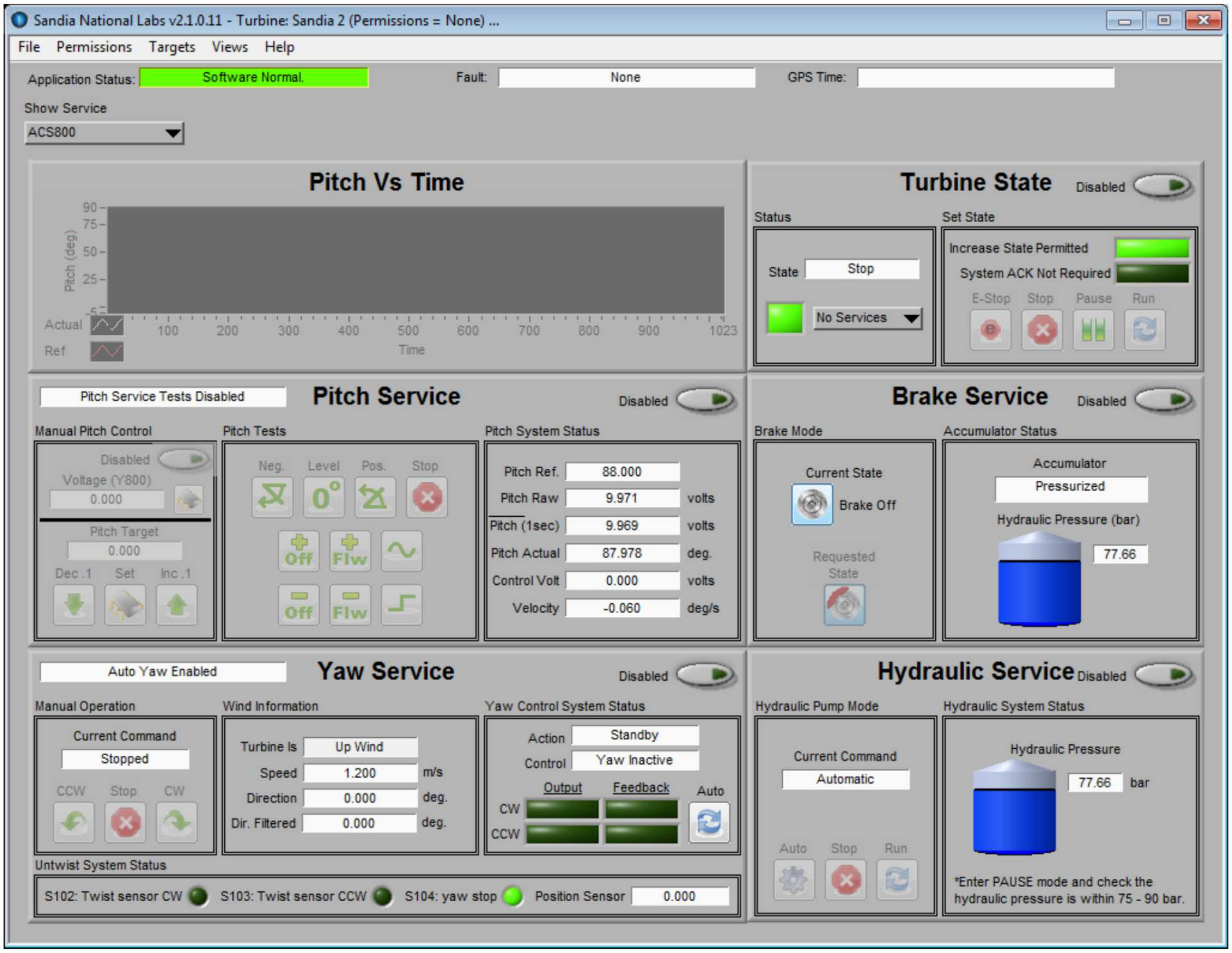


Figure 2-10. Service Mode interfaces

Service modes allow direct user control and testing of processor software subsystems and their respective turbine mechanical systems. Each service mode includes a *Disabled* button for requesting activation of the selected service mode. One or more service modes may be active at any given time; however, the turbine state may be limited to levels Pause, Stop, or Emergency depending on the active service modes. Active service modes are summarized with the square indicator light and pull-down control in the *Status* region of the *Turbine State* subpanel.

Four separate display regions are provided in the *Service Mode* interface. The largest upper left region displays either the *ACS800 Service, Pitch Service*, or *Generator Service* mode interface. The lower left region always displays the *Yaw Service* interface. The middle right region displays either the *Brake Service* or the *Gear Oil Cooler Service* interface. The lower right region displays either the *Gear Oil Filter Service*, *Generator Cooler Service*, or *Hydraulic Service* mode interface.

The Turbine State subpanel is displayed in the upper right region of the *Service Mode* interface.

The *Show Service* pull-down menu (Figure 2-11) allows the user to select which service modes are currently displayed. Note that all nine service modes cannot be simultaneously displayed, and some combinations are not possible.

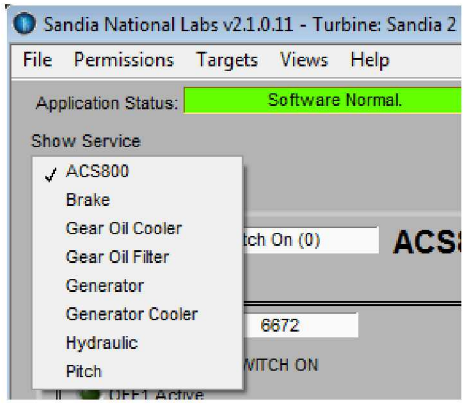


Figure 2-11. Service Mode submenu options

2.3.7. ACS800 Service Interface

Selection of *Show Service>>ACS800* displays the *ACS800 Service* interface (Figure 2-12).

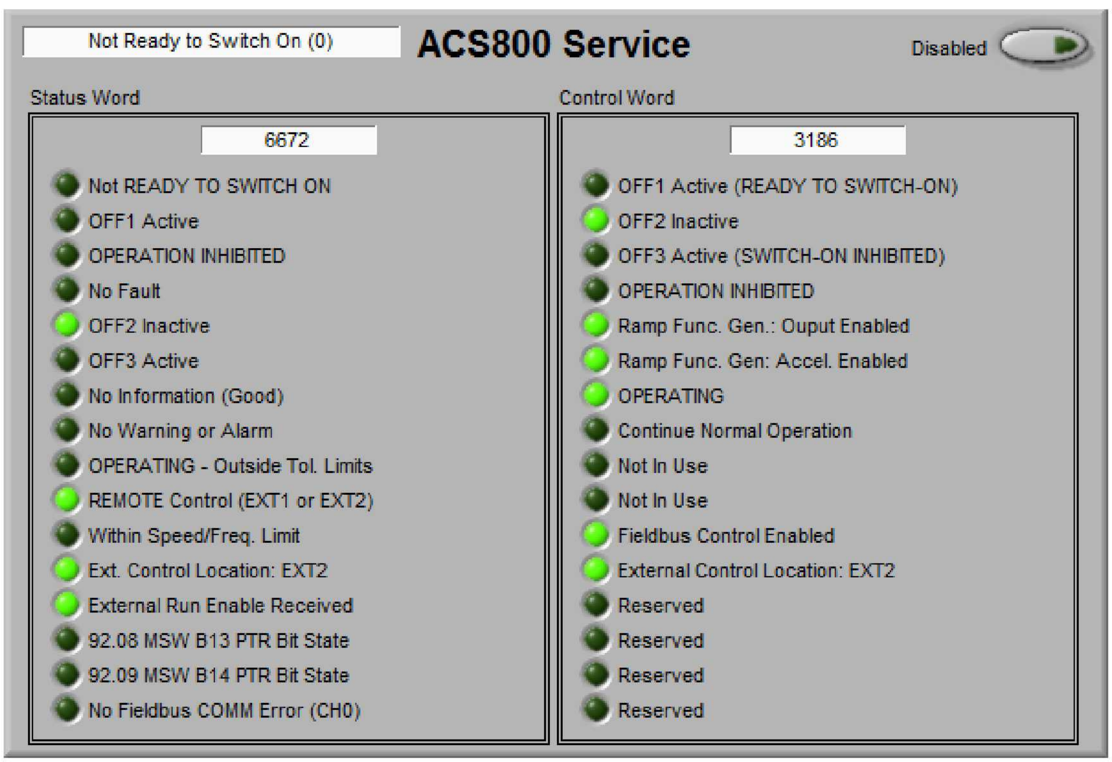


Figure 2-12. ABB (ACS800) Service interface

The *ACS800 Service* interface displays drive summary text in the upper left corner with two detail sections below: *Status Word* and *Control Word*. The *Summary Text*, *Status Word,* and *Control Word* sections provide ASC800 drive state and communications information.

Summary Text: Summary text describes the overall ACS800 drive state. Eight options are possible: *Unknown (-100), Drive Fault (-2), Switch On Inhibited (-1), Not Ready to Switch On (0), Ready to Switch On (1), Ready to Operate (2),* and *Operation Enabled (3)*. The user should refer to the *ACS800 Firmware Manual* to fully understand each drive state.

Status Word: Communications between the turbine processor EtherCAT master and the ACS800 drive includes a number of Process Data Objects (PDOs). One of these is the 16-bit Status Word PDO. Each of the 16 bits of the Status Word indicate the state of a particular setting or function on the ACS800 drive. The *Status Word* section displays the 16-bit word and indicates the state of each Status Word bit. The text labeling each bit changes based on the inactive state, ●, or active state, ●, of that bit. The user should refer to the *ACS800 Firmware Manual* to fully understand the meaning of each.

Control Word: The *Control Word* section displays the value and bit states of the 16-bit PDO used to send requests from the turbine processor to the ACS800 drive. The sent values change the operational state of the drive in the coordinated fashion required by the turbine control system. Each of the 16 bits of the Control Word indicates the needed state of a particular setting or function on the ACS800 drive. The *Control Word* region displays the 16-bit word currently being sent and indicates the state of each Control Word bit. The text labeling each bit changes based on the inactive state, ●, or active state, ●, of that bit. The user should refer to the *ACS800 Firmware Manual* to fully understand the meaning of each.

2.3.8. Brake Service Interface

Selection of *Show Service>>Brake* displays the *Brake Service* interface (Figure 2-13).

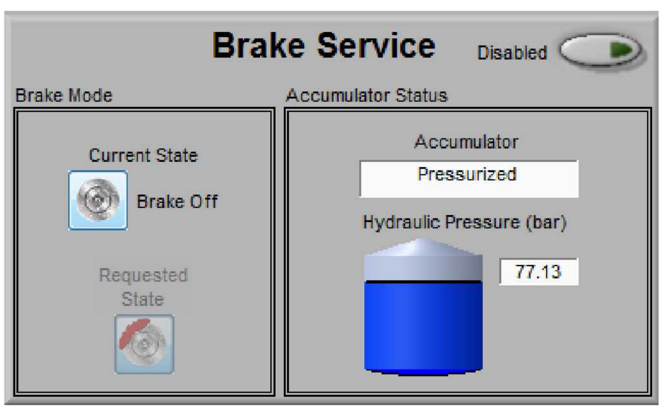
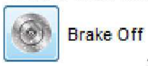


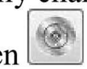
Figure 2-13. Brake Service interface

The *Brake Service* interface allows the user to determine the current status of the brake accumulator, hydraulic pressurization system, and brake activity. Additionally, the user can manually apply the brake. The display is divided into two sections: *Brake Mode* and *Accumulator Status*.

Brake Mode: The *Brake Mode* section has one state display, *Current State*, and one control button, *Requested State*, permitting the user to manual interact with the brake system.

- **Current State indicator**: Displays the current applied, 

, or released, 

, state of the brake.
- **Requested State button**: Allows the user to manually change the state of the brake. When  is selected, the brake is applied, and when  is selected, the brake is released.

Accumulator Status*:* The *Accumulator Status* region indicates the state of the hydraulics related to the brake system, with three displays:

- **Accumulator field**: Indicates the status of the brake accumulator with three possible states: *Unknown, Low Pressure*, and *Pressurized*.
- **Hydraulic Pressure (bar)**: Indicates the current pressure within the hydraulic system in bar.
- **Tank icon**: The dark blue fill level changes based on the current pressure.

2.3.9. Gear Oil Cooler Service Interface

Selection of *Show Service>>Gear Oil Cooler* displays the *Gear Oil Cooler Service* interface (Figure 2-14).

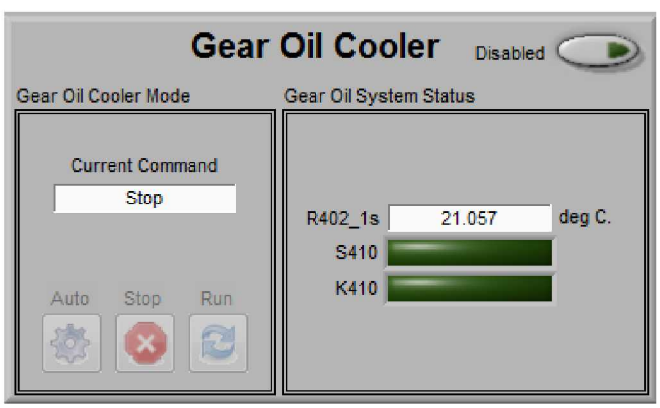


Figure 2-14. Gear Oil Cooler Service interface

The *Gear Oil Cooler Service* interface allows the user to determine the current status of the gear oil cooler motor contactor, oil temperature, and control mode. The user also can manually change the motor control mode. The display is divided into two sections: *Gear Oil Cooler Mode* and *Gear Oil System Status*.

Gear Oil Cooler Mode: The *Gear Oil Cooler Mode* region has one state display, *Current Command*, and three control buttons: *Auto, Stop,* and *Run*, permitting the user to manually interact with the gear oil cooling system.

- **Current Command field**: Indicates the current software control mode of the cooling motor. Modes include: *Unknown, Stop, Run*, and *Automatic*. *Unknown* occurs during startup before communications to the Veristand gateway is established. *Stop* means the control contactor, K410, is de-energized and no cooling is occurring. *Run* means the contactor is energized and the cooling motor is running. *Automatic* means the control software is monitoring the oil temperature via the R402 sensor and turning the cooling motor on and off to maintain an appropriate oil temperature.
- **Auto button**: When pressed, sets the current command to Automatic. Gear oil temperature is monitored by the control software and cooling is activated as necessary.
- **Stop button**: When pressed, sets the current command to Stop, manually turning the gear oil cooling system off.
- **Run button**: When pressed, sets the current command to Run, manually turning the gear oil cooling system on.

Gear Oil System Status: The *Gear Oil System Status* region indicates the state of the cooling motor contactor and current gear oil temperature with three display items:

- **R402_1s field**: Displays the one-second sliding-window average temperature of the gear oil in degrees Celsius.
- **S410 Light**: Indicates the off, , and on, , state of the auxiliary contact on the gear oil cooler motor run/stop contactor, K410. When off, the motor is not running and no cooling is occurring. When on, the motor is running and cooling the oil.
- **K410 Light**: Indicates the off, , and on, , state of the digital output energizing the gear oil cooler motor contactor.

2.3.10. Gear Oil Filter Service Interface

Selection of *Show Service>>Gear Oil Filter* displays the *Gear Oil Filter* interface (Figure 2-15).

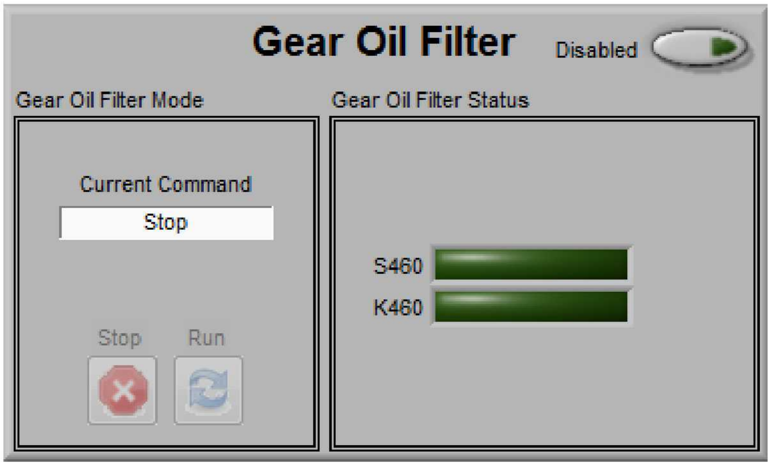


Figure 2-15. Gear Oil Filter interface

The *Gear Oil Filter Service* interface allows the user to determine the current status of the gear oil filter motor contactor and manually change the control mode. The display is divided into two regions: *Gear Oil Filter Mode* and *Gear Oil Filter Status*.

Gear Oil Filter Mode: The *Gear Oil Filter Mode* region has one state display, *Current Command*, and two control buttons, *Stop* and *Run*, permitting the user to manually interact with the gear oil filtration system.

- **Current Command field**: Indicates the current software control mode of the oil filter motor. Modes include: *Unknown, Stop,* and *Run*. *Unknown* occurs during startup before communications to the Veristand gateway is established. *Stop* means the control contactor, K460, is de-energized and no filtration is occurring. *Run* means the contactor is energized and the filter motor is running.
- **Stop button**: When pressed, sets the current command to Stop, manually turning the filtration system off.
- **Run button**: When pressed, sets the current command to Run, manually turning the filtration system on.

Note: Exiting the service mode causes the control mode to return to the default defined for the turbine's current operating state.

Gear Oil Filter Status: The *Gear Oil Filter Status* section indicates the state of the filtration motor contactor with two display items: S460 and K460 LEDs.

- **S460 Light**: Indicates the off, , and on, , state of the auxiliary contact on the gear oil filtration motor run/stop contactor, K460. When off, the motor is not running and no filtration is occurring. When on, the motor is running and filtering the oil.
- **K460 Light**: Indicates the off, , and on, , state of the digital output energizing the gear filtration motor contactor.

2.3.11. Generator Service Interface

Selection of *Show Service>>Generator* displays the *Generator Service* interface (Figure 2-16).

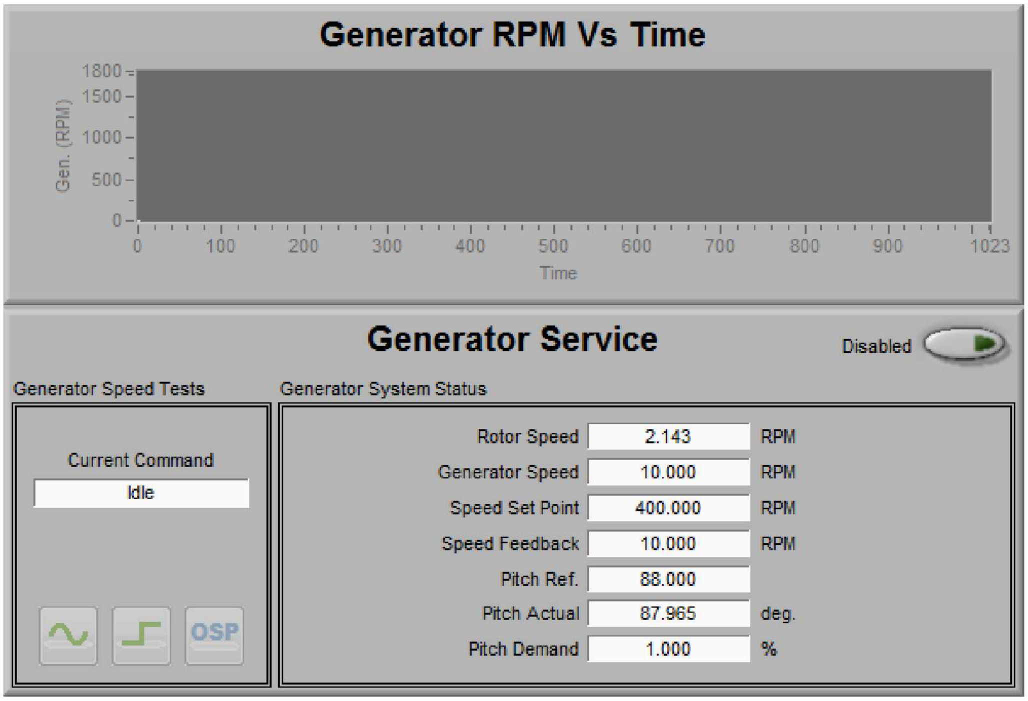


Figure 2-16. Generator Service interface

The *Generator Service* interface is divided into two sections corresponding to status and control interfaces: a *Generator RPM vs. Time* graph and a *Generator Service* section, which is further divided into a *Generator Speed Test* section and a *Generator System Status* section.

Generator RPM vs. Time

Generator RPM vs. Time allows the user to review generator rotational speed over time. This graph is of particular value during execution of the generator Sine, Step, and Over-Speed Protection (OSP) speed tests.

Generator Service

Generator Speed Tests: The *Generator Speed Tests* section has one state display, *Current Command*, and three control buttons, permitting the user to manually execute pre-programmed generator speed tests.

- **Current Command field**: Displays the current testing command state. Options include: *Prepare, Free Wheel, Running Up, Connecting, Power Up, Production, Low Wind Disconnect, Power Down, Disconnect, Running Down*, and *Idle*.

- **Sine Test button**: When  is pressed, the power production controller begins the Sine Test. During the Sine Test, the production controller increments through the various states (see *Current Command*) to determine whether wind conditions permit testing. If wind conditions permit testing, the generator speed will be varied in a sinusoidal manner. The user should review the *Generator RPM vs. Time* graph to ensure that the actual generator RPMs closely track the requested sine function changes from the controller.
- **Step Test button**: When  is pressed, the power production controller begins the Step Test. During the Step Test, the production controller increments through the various states (see *Current Command*) to determine whether wind conditions permit testing. If wind conditions permit testing, the generator speed set point will be varied in step changes. The user should review the *Generator RPM vs. Time* graph to ensure that the actual generator RPM closely tracks the requested step changes from the controller.
- **OSP Test button**: When 

is pressed, the power production controller begins the OSP test. During the OSP test, the production controller increments through the various states (see *Current Command*) to determine whether wind conditions permit testing. If wind conditions permit testing, the generator speed will be slowly increased until the Over-Speed Protection limit is reached. When reached, the OSP systems will trip an Emergency Stop condition causing the turbine blades to stop abruptly. The user should monitor the *Generator RPM vs. Time* graph and the numeric values in the *Generator System Status* region during testing to ensure that the OSP systems activate at the appropriate speed.

Generator System Status: The *Generator System Status* region displays values relevant to the control of the rotational speed of the generator. These seven values are displayed and updated continuously:

- **Rotor Speed field**: Displays the current rotational speed of the turbine blades in RPM. This is the speed of the gearbox low speed shaft.
- **Generator Speed field**: Displays the current rotational speed of the generator in RPM. This is the speed of the gearbox high speed shaft.
- **Speed Set Point field**: Displays the current control system requested rotational speed of the generator in RPM.
- **Speed Feedback field**: Displays the current generator speed feedback signal in RPM, which is used by the production pitch controller. This signal has been processed with a 30-millisecond sliding-window average and two notch filters. The notch filters are intended to avoid drive train feedback resonance at certain frequencies.
- **Pitch Ref. field**: Displays the pitch angle currently requested by the pitch control system, in degrees. The pitch request may come from either the production controller or the pitch service module if Pitch Service is active.
- **Pitch Actual field**: Displays the current blade pitch angle in degrees. The pitch ranges from feather end-stop (88 degrees) to run end-stop (-5 degrees).
- **Pitch Demand field**: Displays the pitch angle currently requested by the production controller, in fraction of full pitch range. Fractional value 0.0 is minimum pitch (-5 degrees) and fractional value 1.0 is maximum pitch (88 degrees).

2.3.12. *Generator Cooler Service Interface*

Selection of *Show Service>>Generator Cooler* displays the *Generator Cooler Service* interface (Figure 2-17).

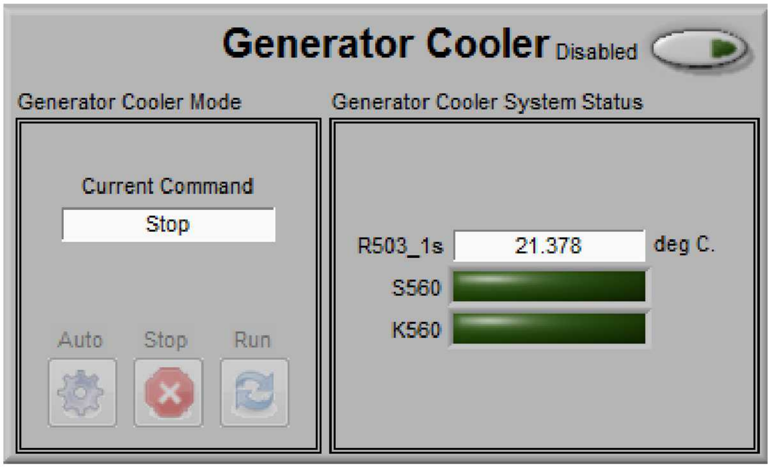


Figure 2-17. Generator Cooler Service interface

The *Generator Cooler Service* interface allows the user to determine the status of the generator cooler motor contactor, generator temperature, and control mode. Additionally, the user can manually change the cooling system control mode. The display is divided into two regions: *Generator Cooler Mode* and *Generator Cooler System Status*.

Generator Cooler Mode: The *Generator Cooler Mode* region has one state display, *Current Command*, and three control buttons: *Auto, Stop,* and *Run*, permitting the user to manually interact with the generator cooling system.

- **Current Command field**: Indicates the current software control mode of the generator cooling motor. Modes include: *Unknown, Stop, Run*, and *Automatic*. *Unknown* occurs during startup before communications to the Veristand gateway is established. *Stop* means the control contactor, K560, is de-energized and no cooling is occurring. *Run* means the contactor is energized and the cooling motor is running. *Automatic* means the control software is monitoring the generator temperature via the R503 sensor and turning the cooling motor on and off to maintain an appropriate generator temperature.
- **Auto button**: When pressed, sets the Current Command to *Automatic*. Generator temperature is monitored by the control software and cooling is activated as necessary.
- **Stop button**: When pressed, sets the current command to *Stop*, manually turning the generator cooling system off.
- **Run button**: When pressed, sets the current command to *Run*, manually turning the generator cooling system on.

Generator Cooler System Status: The *Generator Cooler System Status* region indicates the state of the cooling motor contactor and current generator temperature with three display items: R503_1s, S560, and K560.

- **R503_1s field**: Displays the one-second sliding-window average temperature of the generator in degrees Celsius.
- **S560 Light**: Indicates the off, , and on, , state of the auxiliary contact on the generator cooler motor run/stop contactor, K560. When off, the motor is not running and no cooling is occurring. When on, the motor is running and cooling the generator.
- **K560 Light**: Indicates the off, , and on, , state of the digital output energizing the generator cooler motor contractor.

2.3.13. Hydraulic Service Interface

Selection of *Show Service>>Hydraulic* displays the *Hydraulic Service* interface (Figure 2-18).

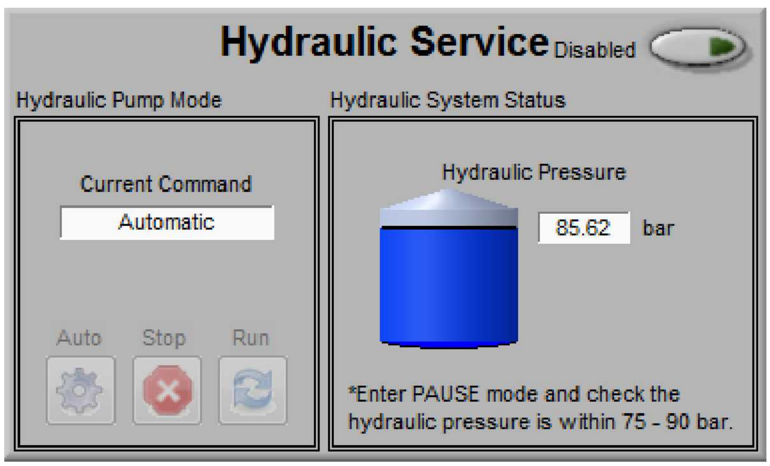


Figure 2-18. Hydraulic Service interface

The *Hydraulic Service* user interface is divided into two sections: *Hydraulic Pump Mode* and *Hydraulic System Status*. This interface allows the user to review the status of the hydraulic system pressurization and change the control mode.

Hydraulic Pump Mode: The *Hydraulic Pump Mode* region has one state display, *Current Command*, and three control buttons: *Auto, Stop,* and *Run*, permitting the user to manually interact with the hydraulic pressurization system.

- **Current Command field**: Indicates the current software control mode of the hydraulic pump motor. Modes include: *Unknown, Stop, Run*, and *Automatic. Unknown* occurs during startup before communications to the Veristand gateway is established. *Stop* means the pump motor is not running and system pressure is not being maintained. *Run* means the pump motor is running and increasing system pressure. *Automatic* means the control software is monitoring the current system pressure and turning the pump motor on and off to maintain an appropriate pressurization.

- **Auto button**: When pressed, sets the current command to *Automatic*. Hydraulic pressure is actively maintained by the control software.
- **Stop button**: When pressed, sets the current command to *Stop*, manually turning the hydraulic pump motor off.
- **Run button**: When pressed, sets the current command to *Run*, manually turning the hydraulic pump motor on.

Hydraulic System Status: The *Hydraulic System Status* section displays the current hydraulic pressure within the system.

- **Hydraulic Pressure field**: Indicates the pressure in the hydraulic system, in bar.
- **Tank pressure icon**: The dark blue "filling" level changes based on the current pressure.

2.3.14. Pitch Service Interface

Selection of *Show Service>>Pitch* displays the *Pitch Service* interface (Figure 2-19).

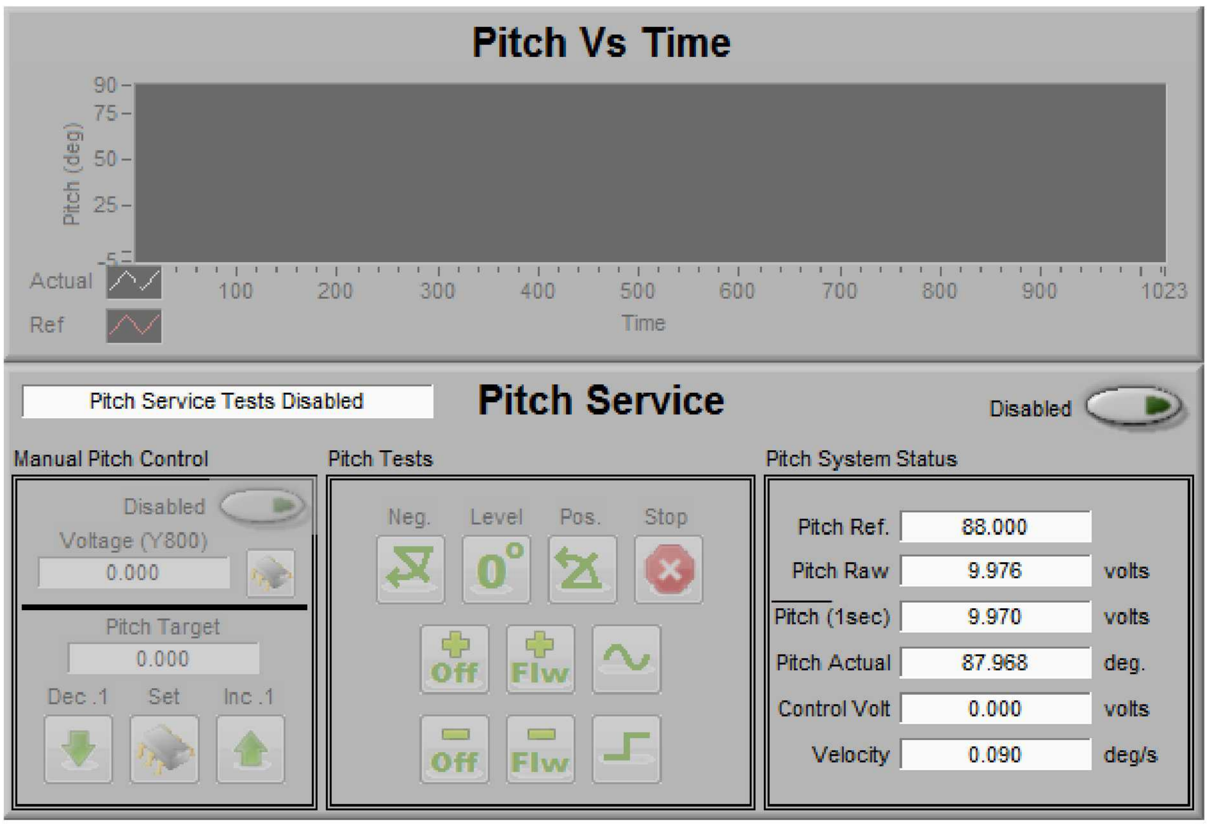


Figure 2-19. Pitch Service interface

The *Pitch Service* interface includes a history display and three pitch service sections: *Manual Pitch Control, Pitch Tests,* and *Pitch System Status*.

Pitch vs. Time

The *Pitch vs. Time* subpanel includes a graph that displays a history of pitch (in degrees) vs. time (in seconds).

Pitch Service

The three sections in the *Pitch Service* subpanel are intended to allow users to monitor and make coordinated changes to the pitch system. Additionally, the *Pitch Service* screen includes a test status text field immediately left of the title. This display indicates the current state of each pitch test being performed; options include: *Unknown, Pitch Service Tests Disabled, Pitch Service Tests Ready, Position Transmitter Voltage Test Running, Position Transmitter Voltage Test Finished, Post Test Running, Preparing Test, Proportional Valve Test Running, Sine Test Running,* and *Step Test Running.*

Manual Pitch Control: The *Manual Pitch Control* area is divided into two separate regions. The upper region allows the user to manually adjust the pitch control voltage, and the lower region allows the user to manually adjust the *Pitch Reference*.

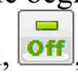
- **Voltage (Y800) field**: Contains a single numeric voltage (Y800) input that allows the user to manually input a value from -10 to 10 representing the control voltage sent to the Vickers proportional valve controller. This subservice should be used when setting the -2 to +2 volt deadband region of the Vickers control system.
- **Set button**: When pressed, the *Set* button, , causes the control software to change the analog output voltage of Y800, the Vickers proportional valve command voltage.
- **Manual Pitch Reference (lower region)**: Allows the user to manually control the pitch reference angle. The *Pitch Target* numeric input allows the user to specify a desired pitch angle to which the control system will move the blades. The pitch angle does not change until the *Set* button is pressed.
- **Dec .1 button**: Selection of the *Dec .1* button, , decreases the current pitch reference angle by 0.1 degrees.
- **Inc .1 button**: Selection of the *Inc .1* button, , increases the current pitch reference angle by 0.1 degrees.
- **Set button**: Selection of the *Set* button, , causes the pitch reference value to be set to the value currently displayed in the *Pitch Target* input.

Pitch Tests: The *Pitch Tests* section contains nine pitch system commissioning test buttons and a single *Stop* button.

- **Negative Pitch Test button**: Selection of the *Negative Pitch Test* button, , pitches the blades to the negative end stop, which is approximately the Run position, at maximum pitch velocity. This is accomplished by setting the Vickers proportional valve control signal to -10 VDC.

- **Zero Pitch Test button**: Selection of the *Zero Pitch Test* button, 

, slowly pitches the blades to zero degrees.
- **Positive Pitch Test button**: Selection of the *Positive Pitch Test* button, , pitches the blades to the positive end stop, which is full feather, at maximum pitch velocity. This is accomplished by setting the Vickers proportional valve control signal to +10 VDC.
- **Positive Offset Test button**: Selection of the *Positive Offset Test* button, 

, slowly pitches the blades to 0 degrees and then continually performs the positive offset test cycle, which is intended for calibrating the Vickers control signal deadband. In the test cycle, for 6 seconds the Vickers proportional valve control signal is held at +2 VDC (parameter PositivOffsetAmpl) and the processor measures the pitch velocity. When the measuring is finished, the pitch moves back to 0 degrees and the calculated pitch velocity is stored in output signal PitchVel_Service. Every 10th second the test cycle begins again.
- **Negative Offset Test button**: Selection of the *Negative Offset Test* button, 

, slowly pitches the blades to 10 degrees and then continually performs the negative offset test cycle, which is intended for calibrating the Vickers control signal deadband. In the test cycle, for 6 seconds the Vickers proportional valve control signal is held at -2 VDC (parameter NegativOffsetAmpl) and the processor measures the pitch velocity. When the measuring is finished, the pitch moves back to 10 degrees and the calculated pitch velocity is stored in output signal PitchVel_Service. Every 10th second the test cycle begins again.
- **Positive Flow Test button**: Selection of the *Positive Flow Test* button, 

, slowly pitches the blades to 0 degrees and then continually performs the positive flow test cycle, which is intended for calibrating the Vickers control signal gain. In the test cycle, for 6 seconds the Vickers proportional valve control signal is held at +9 VDC (parameter ManLimPitchMax) and the processor measures the pitch velocity. When the measuring is finished, the pitch moves back to 0 degrees and the calculated pitch velocity is stored in output signal PitchVel_Service. Every 10th second the test cycle begins again.
- **Negative Flow Test button**: Selection of the *Negative Flow Test* button, 

, slowly pitches the blades to 80 degrees and then continually performs the negative flow test cycle, which is intended for calibrating the Vickers control signal gain. In the test cycle, for 6 seconds the Vickers proportional valve control signal is held at -9 VDC (parameter ManLimPitchMin) and the processor measures the pitch velocity. When the measuring is finished, the pitch moves back to 80 degrees and the calculated pitch velocity is stored in output signal PitchVel_Service. Every 10th second the test cycle begins again.
- **Sine Test button**: Selection of the *Sine Test* button, , causes the pitch system to vary the blade pitch angle in a sinusoidal manner. The user should observe the *Pitch vs. Time* graph to ensure the actual and reference angle closely follow one another.
- **Step Test button**: Selection of the *Step Test* button, , causes the pitch system to vary the blade pitch angle through a series of small step increases and decreases in pitch reference. The user should observe the *Pitch vs. Time* graph to ensure the actual and reference angle closely follow one another.

- **Stop Tests button**: Selection of the *Stop Tests* button, , causes any currently executing test to end.

Note: Only one test can be active at any time. When tests are not being performed, all test buttons will be enabled and the *Stop Tests* button will be disabled and grayed. When the user selects any of the nine test buttons, all other test buttons become disabled and grayed and the *Stop Tests* button will be enabled. Testing will continue until the *Stop Tests* button is pressed.

Pitch System Status: The *Pitch System Status* section allows the user to monitor and manage six numeric, continuously updated values related to the pitch system. These values are the *Pitch Reference, Pitch Raw, Pitch (1 sec), Pitch Actual, Control Voltage,* and *Velocity.*

- **Pitch Reference field**: Displays the pitch angle currently requested by the pitch control system, in degrees.
- **Pitch Raw field**: Displays the voltage, A800, returned from the pitch system feedback sensor, Baluff. This voltage ranges from approximately 0 volts at -5 degrees pitch to approximately 10 volts at 88 degrees pitch.
- **Pitch (1 sec) field**: Displays the one-second sliding-window average of the pitch feedback signal A800, in volts.
- **Pitch Actual field**: Displays the current blade pitch angle in degrees. The pitch varies from feather end stop (88 degrees) to run end stop (-5 degrees).
- **Control Voltage field**: Displays the control voltage, Y800, sent to the turbine's Vickers proportional valve control. This voltage sets the speed at which the blade pitch angle changes. The system is programmed to have a deadband between -2 and 2 voltages. The blades should pitch toward feather (88 degrees) for positive voltages and toward Run (0 degrees) for negative voltages outside the deadband.
- **Velocity field**: Displays the angular rate of change of the blade pitch angle.

2.3.15. Yaw Service Interface

The *Yaw Service* interface (Figure 2-20) is always displayed. The *Yaw Service* functions are enabled and disabled in the same manner as all other service modes.

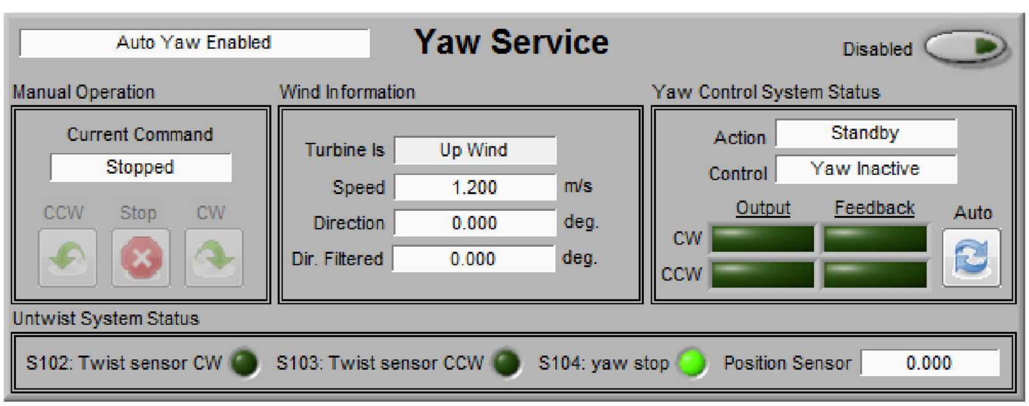


Figure 2-20. Yaw Service interface

The *Yaw Service* panel is divided into four sections: *Manual Operation, Wind Information, Yaw Control System Status,* and *Untwist System Status*. A text field in the upper left corner indicates the current status of the auto yaw function. Display options for the auto yaw function are: *Unknown, Auto Yaw Disabled,* and *Auto Yaw Enabled*.

Manual Operation: The *Manual Operation* section has one state display, *Current Command*, and three control buttons: *CCW*, *Stop*, and *CW*.

- **Current Command field**: Indicates the current control mode of the yaw motors. Displays include: *Unknown, Not Manual, Yawing CW, Yawing CCW,* and *Stopped*. *Unknown* occurs during startup before communications to the Veristand gateway is established. *Not Manual* is displayed when the *Yaw Service* mode is not enabled. *Yawing CW* and *Yawing CCW* indicate the nacelle is being rotated clockwise or counterclockwise. *Stopped* indicates the system is not yawing.
- **CCW button**: When pressed, sets the nacelle to begin rotating counterclockwise.
- **Stop button**: When pressed, stops nacelle yawing.
- **CW button**: When pressed, sets the nacelle to begin rotating clockwise.

Wind Information: The *Wind Information* section displays information obtained from the Sonic Anemometer mounted to the rear of the nacelle. The anemometer communicates with the turbine processor via the onboard RS-485 communication port. The four fields include:

- **Turbine Is field**: Displays the "Up Wind" state of the turbine. Values are *Unknown, Not Up Wind,* and *Up Wind*.
- **Speed field**: Displays the exponential-average wind speed in meters per second.
- **Direction field**: Displays the 1-second average wind direction in degrees relative to the direction the turbine is facing.
- **Dir. Filtered field**: Displays the filtered wind direction used by the yaw control system. This signal's filtering changes when the turbine is yawing versus not yawing. In the 1st order low-pass filter, a long time constant (100 seconds) is used when not yawing, whereas a short time constant (10 seconds) is used when yawing.

Yaw Control System Status: The *Yaw Control System Status* section allows the user to monitor the state of the yaw control system and enable or disable the auto yaw function.

- **Action field**: Indicates the current action being taken by the yaw control system. Display options include: *Unknown, Yawing CW, Yawing CCW, Stopped, Standby,* and *Change Direction*.
- **Control field**: Indicates the current control mode of the yaw system. Modes include: *Yaw Manual, Yaw Automatic, Yaw Untwisting, Yaw Idle,* and *Yaw Inactive*.
- **CW Output & Feedback light**: Indicates the control status of the contactor controlling the clockwise rotation of the nacelle. The *Output* light indicates that the control signal to energize the contactor coil is off, , or on, . The *Feedback* light indicates whether the contactor auxiliary contact is opened, , or closed,

. When both the *Output* and *Feedback* lights are on, the system is yawing clockwise.

- **CCW Output & Feedback light**: Indicates the control status of the contactor controlling the counterclockwise rotation of the nacelle. The *Output* light indicates that the control signal to energize the contactor coil is off, , or on, . The *Feedback* light indicates whether the contactor auxiliary contact is opened, , or closed, . When both the *Output* and *Feedback* lights are on, the system is yawing counterclockwise.
- **Auto button**: Controls the state of the auto yaw function. When pressed, the auto yaw function is toggled from On to Off or from Off to On. The current state of auto yaw control is displayed immediately left of the "Yaw Service" text. The *Auto* button is always enabled regardless of the enabled/disabled state of the *Yaw Service*.

TIP: If you do not want the turbine to start yawing after you change the turbine state from Stop to Pause, use the *Auto* button to disable auto yaw before going to Pause.

Untwist System Status: The *Untwist System Status* displays the digital state of the three mechanical switches in the yaw monitor hardware, often referred to as the "Turtle." Additionally, the value of the *Position Sensor* is displayed.

- **S102: Twist Sensor CW light**: In the off, , state of the switch, no action is required by the yaw control system. When the active state, , is displayed, the yaw control system will untwist in the counterclockwise direction when wind conditions safely permit.
- **S103: Twist Sensor CCW light**: In the off, , state of the switch, no action is required by the yaw control system. When the active state, , is displayed, the yaw control system will untwist in the clockwise direction when wind conditions safely permit.
- **S104: Yaw Stop light**: Indicates whether the yaw system twist is within operating range, , or has reached the maximum permitted twist, . If maximum twist has occurred, one of the other switches, S102 or S103, will also be active and indicate the direction of mandatory automatic untwist.
- **Position Sensor field**: This value is the yaw angle in degrees given by the yaw encoder.

2.3.16. Instruments Interface

Selection of *Views>>Turbine>>Instruments* displays the *Instruments* interface (Figure 2-21).

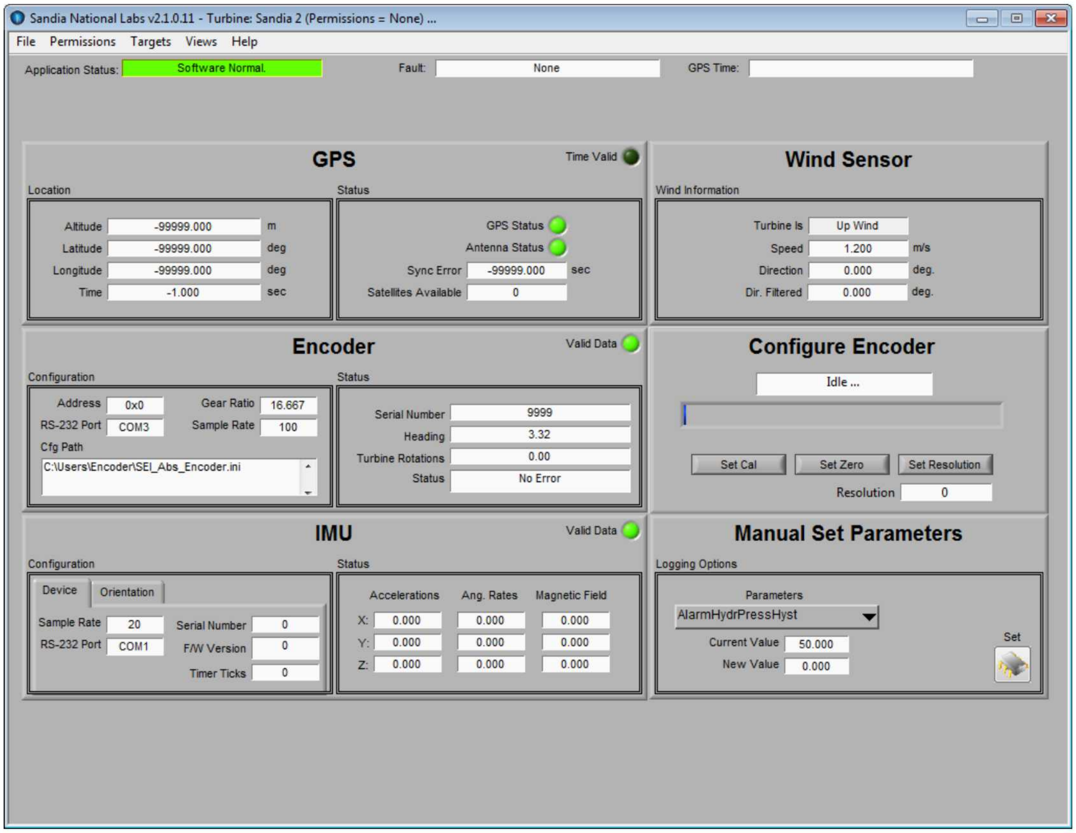


Figure 2-21. Instruments User interface

The *Instruments* interface allows the user to review and interact with devices that have special interfaces. These devices include a Global Positioning System (GPS) receiver module, an encoder, an Inertial Measurement Unit (IMU), an anemometer, and Veristand parameter modification controls.

GPS Module

The *GPS* subpanel (Figure 2-22) provides GPS location and time information as well as status of the National Instruments NI 9467 C-Series GPS device. When the GPS device powers on, it must find available satellites and complete a survey to compute its location and time.

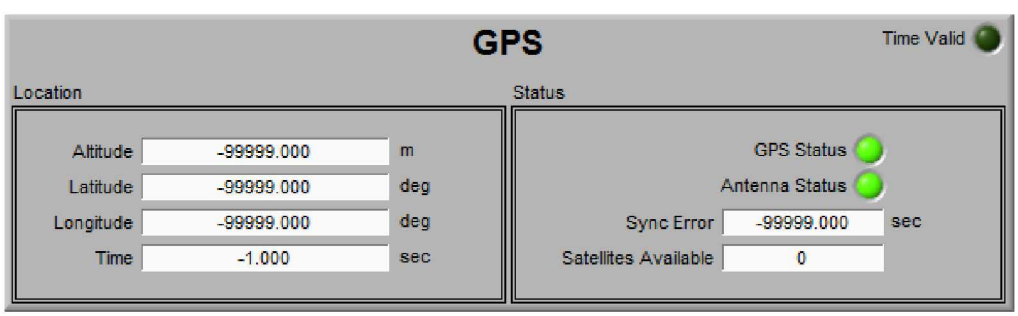


Figure 2-22. GPS instrument subpanel

The subpanel is divided into *Location* and *Status* sections. Additionally, the upper right corner provides the *Time Valid* light, which indicates whether the GPS survey is complete and the data in the *Location* and *Status* sections is valid, , or not, .

Location: Displays data obtained from the GPS device, including:

- **Altitude field**: The elevation of the GPS antenna in meters above sea level
- **Latitude field**: The north-south location of the GPS antenna in degrees
- **Longitude field**: The east-west location of the GPS antenna in degrees
- **Time field**: Current time in seconds from January 6, 1980, at midnight (0 hours 0 minutes 0 seconds), Universal Time Coordinated (UTC).

Status: Allows the user to evaluate the functionality of the GPS device. Displays include:

- **GPS Status light**: Indicates whether the GPS device is functioning properly, , or not, .
- **Antenna Status light**: Indicates whether the GPS and associated antenna are properly connected and communicating, , or not, .
- **Sync Error field**: Indicates the time difference between the GPS clock and the turbine processor clock the last time the two clocks were synchronized. This value is a measure of the turbine processor's clock drift.
- **Satellites Available field**: Indicates the number of satellite signals being used to determine the values in the *Location* region.

Wind Sensor

The *Wind Sensor* subpanel (Figure 2-23) displays information obtained from the Sonic Anemometer mounted to the rear of the turbine nacelle. The anemometer communicates with the turbine processor via the onboard RS-485 communication port.

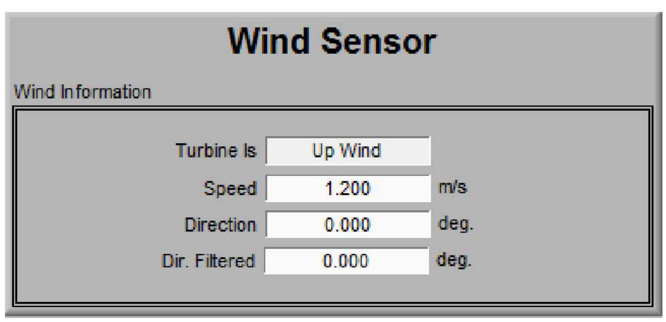


Figure 2-23. Anemometer instrument subpanel

Wind Information: The four display items in the *Wind Information* section include:

- **Turbine Is field**: Displays the "Up Wind" state of the turbine. Values are *Unknown, Not Up Wind,* and *Up Wind*.

- **Speed field**: Displays the exponential-average wind speed in meters per second.
- **Direction field**: Displays the 1-second average wind direction in degrees relative to the direction the turbine is facing.
- **Direction Filtered field**: Displays the filtered wind direction used by the yaw control system. This signal's filtering changes when the turbine is yawing versus not yawing. In the 1st order low pass filter, a long time constant (100 seconds) is used when not yawing whereas a short time constant (10 seconds) is used when yawing.

Encoder

The *Encoder* subpanel (Figure 2-24) allows the user to evaluate the functionality of the encoder. It is divided into two sections: *Encoder* and *Configure Encoder*. The *Encoder* section is further divided into two subsections: *Configuration* and *Status*. The upper right corner provides the *Valid Data* light, which indicates whether the data in the *Configuration* and *Status* regions is valid, , or not, .

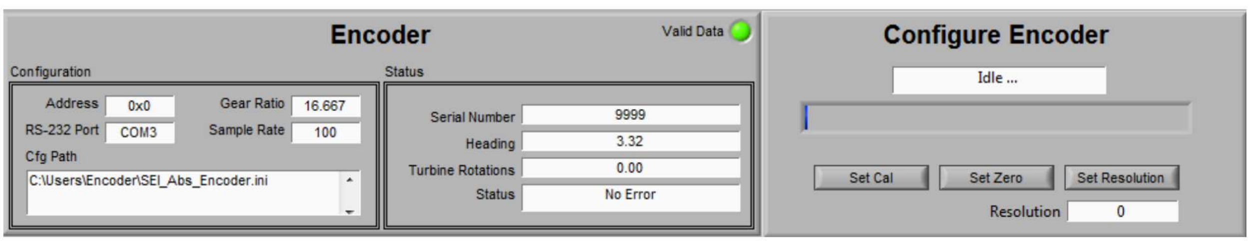


Figure 2-24. Absolute Yaw Encoder instrument subpanel

Configuration: Details the encoder hardware configuration and Veristand Custom Device setup, including:

- **Address field**: The device address used to identify RS-232 messages sent to the device.
- **RS-232 Port field**: The serial communication port alias provided in the National Instrument Measurement and Automation Explorer (MAX) application through which the Veristand encoder Custom Device communicates to the encoder.
- **Gear Ratio field**: The ratio of encoder rotations to turbine rotation.
- **Sampling Rate field**: The number of milliseconds the RS-232 protocol waits between requesting updates of the information displayed in the *Status Region*.
- **Cfg Path field**: Displays the path to a configuration file on the turbine processor hard drive. The configuration file contains settings for the *Address, RS-232 Port, Gear Ratio,* and *Sampling Rate* values.

Status: Information obtained from the encoder, including:

- **Serial Number field**: The manufacturer serial number of the encoder.
- **Heading field**: The turbine heading as determined by the encoder data, gear ratio, and encoder Custom Device programming.
- **Turbine Rotations field**: The number of turbine rotations as determined by the encoder data, gear ratio, and encoder Custom Device programming.

- **Status field**: The error status of the encoder embedded software.

Configure Encoder: Allows the user to perform three calibration tasks via the three buttons. The text display and status bar above the buttons displays the progress of tasks as they are executing on the turbine processor hardware. Input options include:

- **Set Cal button**: Sets the number of nacelle rotations to zero and sets the current turbine/encoder position to South.
- **Set Zero button**: Sets the number of encoder counts and number of nacelle rotations to zero.
- **Set Resolution button**: Sets the number of encoder counts per encoder rotation to the values entered by the user into the Resolution numeric input field.
- **Resolution field**: Numeric input field allowing the user to enter the desired encoder resolution, counts per rotation.

IMU

The Microstrain Inertial Measurement Unit (IMU) uses accelerometers and magnetometers to provide acceleration and orientation information measured within the turbine nacelle. The IMU subpanel (Figure 2-25) allows the user to evaluate the functionality of the IMU hardware and to review data obtained from it.

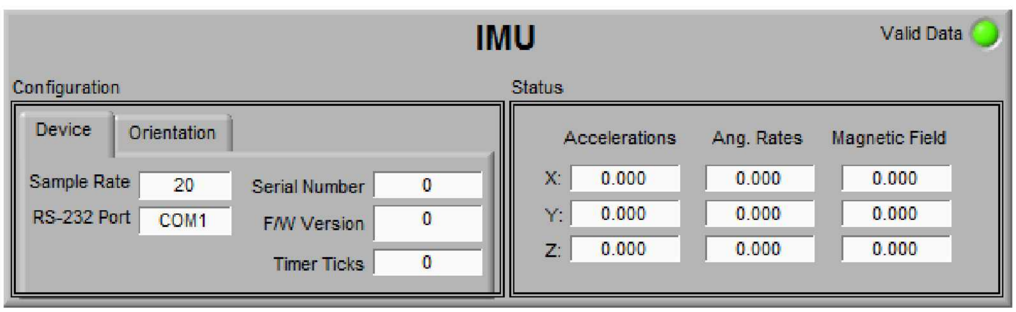


Figure 2-25. Inertial Measurement Unit instrument subpanel

This subpanel is divided into *Configuration* and *Status* sections. Additionally, the upper right corner provides the *Valid Data* light, which indicates whether the data in the *Configuration* and *Status* regions is valid, , or not, .

Configuration: The Veristand project includes an IMU Custom Device that communicates with the IMU via an RS-232 protocol. The *Configuration* section displays information related to this protocol as well as general IMU hardware data embedded in the device microcontroller by the manufacturer.

- **Sampling Rate field**: Milliseconds between updates of the data displayed in the *Status* region.
- **RS-232 Port field**: The serial communication port alias provided in the MAX application through which the Veristand IMU Custom Device communicates to the IMU hardware.

- **Serial Number field**: The IMU's manufacturer serial number.
- **F/W Version field**: The manufacturer version of the embedded software in the IMU microcontroller.
- **Timer Ticks field**: The IMU internal clock count. If this value is not changing every sampling (according to the *Sampling Rate*), the data in the *Status* region cannot be trusted.
- **Orientation tab (control page not shown)**: A 3x3 matrix of values that adjust the XYZ orientation of the IMU relative to the XYZ orientation of the turbine nacelle.

Status: Displays three vectors of interest obtained from the IMU:

- **Acceleration fields**: The XYZ acceleration component experienced by the IMU, in "G"s. 1 = 9.81 meters/second/second.
- **Angular Rate field**: The rotational rates about the XYZ axes of the IMU, in degrees/second.
- **Magnetic Field fields**: The XYZ components of the magnetic field measured by the IMU.

Manual Set Parameters

The Veristand *Manual Set Parameters* subpanel (Figure 2-26) allows the user to modify the parameters used by the control modules.

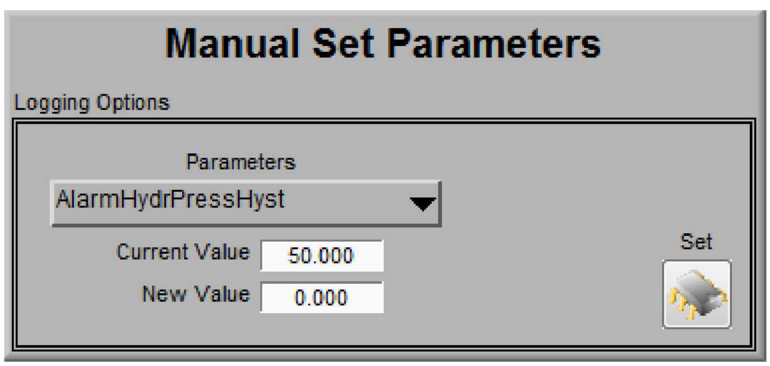


Figure 2-26. Model Set Parameters subpanel

Caution: Changes to parameter values can have significant effect on the operation of the turbine and its control. All changes **must** be made by knowledgeable Sandia staff members.

Logging Options: *Manual Set* fields in the *Logging Options* section include:

- **Parameters menu**: A pull-down menu listing all parameters within the control system. Selection of a parameter will automatically update the *Current Value* numeric display.
- **Current Value field**: Value of the parameter selected in the *Parameters* pull-down menu to three decimal places. Units depend on the parameter selected.

- **New Value field**: User-desired value to which the parameter selected by the *Parameters* pull-down menu is to be set. All parameters can be specified to three decimal places. Units depend on the selected parameter.
- **Set button**: Causes the parameter selected by the *Parameters* pull-down menu to be set to the value in the *New Value* numeric input. (The *Current Value* display will be updated with the new value after the update is complete.)

2.3.17. *Production Control Interface*

Selection of *Views>>Turbine>>Production Control* displays the *Production Control* interface (Figure 2-27).

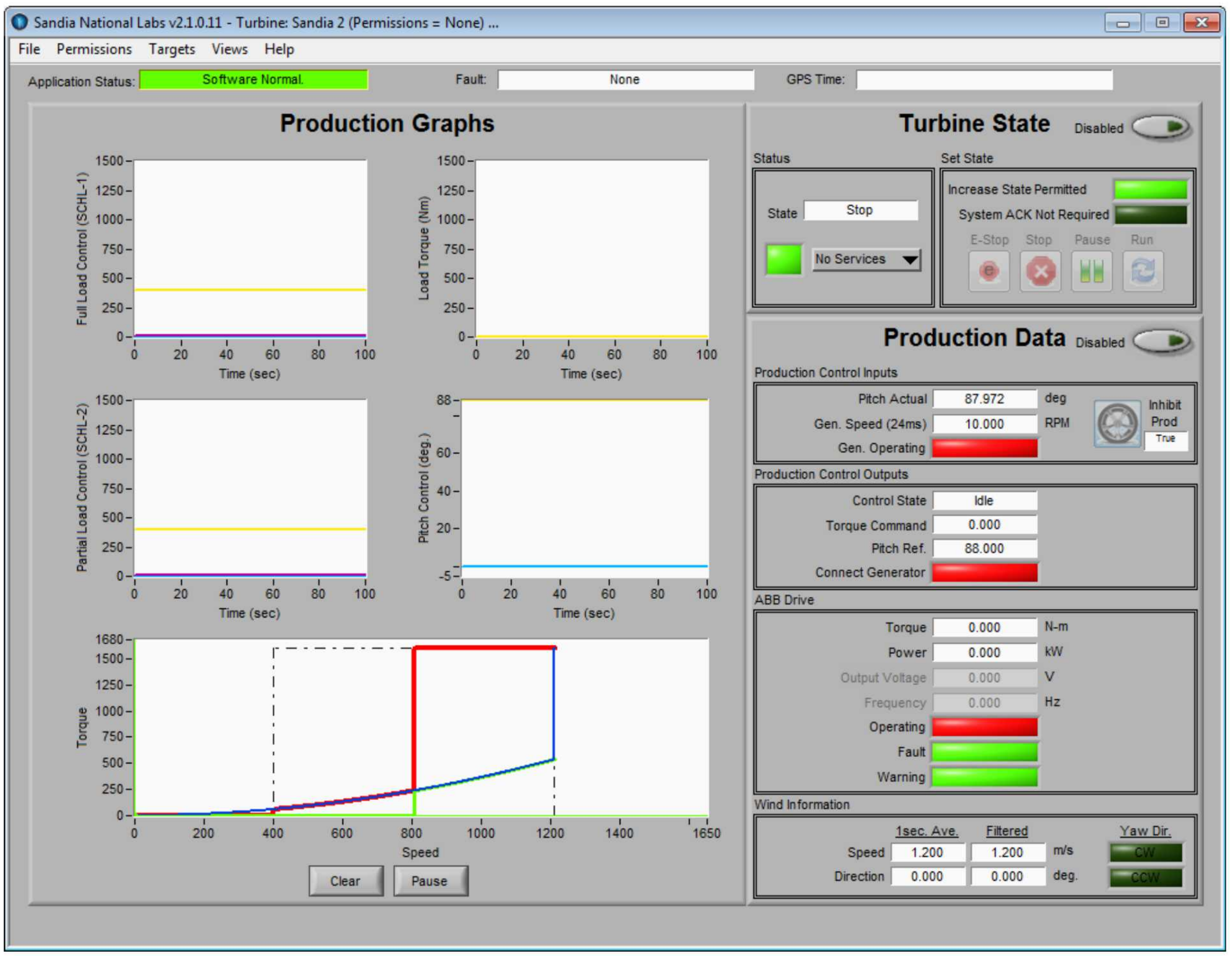


Figure 2-27. Production Control interface

The *Production Control* interface allows the user to monitor and manage parameters related to the turbine's power production and the production controller's management of power production subsystems.

Turbine State

The *Turbine State* subpanel provides information about the current turbine state and active services and provides controls for requesting changes to the turbine state. See Section 2.3.5 (Figure 2-8) for a detailed description of this subpanel and its functions.

Production Data

The *Production Data* subpanel (Figure 2-28) allows the user to evaluate the production status of the turbine. The controls are organized in four groups: *Production Control Inputs, Production Control Outputs, ABB Drive,* and *Wind Information.*

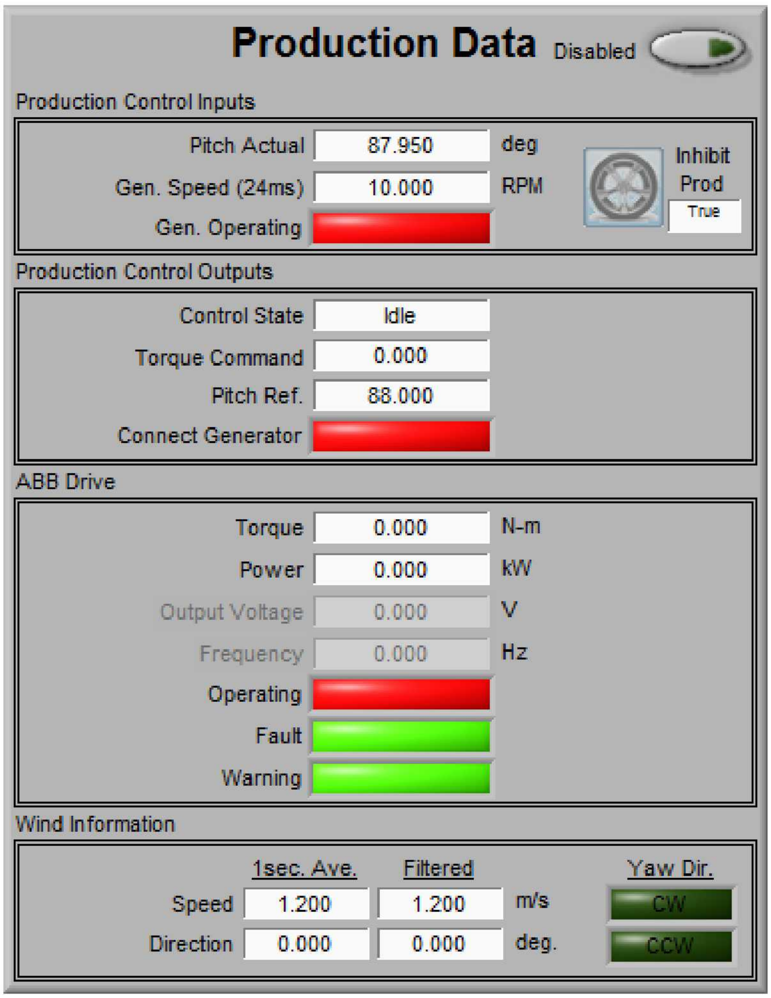


Figure 2-28. Production Data subpanel

Production Control Inputs: Power production occurs only when the turbine is in Run mode and adequate wind conditions exist. The turbine processor software includes a Production Control module that controls the pitch system and communicates with the ABB drive to produce power. The *Production Control Inputs* section displays these inputs to the Production Control module:

- **Pitch Actual field**: Displays the current blade pitch angle in degrees. The pitch ranges from feather end stop (88 degrees) to run end stop (-5 degrees).
- **Gen. Speed (24ms) field**: Displays the 24-millisecond sliding window average of the generator rotational speed at the high speed shaft sensor.
- **Gen. Operating light**: Indicates whether the generator is not producing power, , or is producing power, .
- **Release to Free Wheel button & status**: Status indicates whether Production Control State can increase from Prepare to Free Wheel. Selecting the button changes the status from True to False or from False to True.

Production Control Outputs: Power production occurs only when the turbine is in Run mode and adequate wind conditions exist. The turbine processor software includes a Production Control module that controls the pitch system and communicates with the ABB drive to produce power. The *Production Control Outputs* section displays these outputs from the Production Control module.

- **Control State field**: When the Turbine state is Run, the production controller will go through various modes while attempting to generate power. These modes are: *Unknown, Prepare, Free Wheel, Running Up, Connecting, Power Up, Production, Low Wind Disconnect, Power Down, Disconnect, Running Down,* and *Idle*.
- **Torque Command field**: The torque currently requested by the Production Control module of the generator and ABB variable frequency drive.
- **Pitch Ref. field**: The pitch angle currently requested by the pitch control system.
- **Connect Generator light**: Indicates whether the generator is connected/producing power, , or not connected/not producing power, .

ABB Drive: The *ABB Drive* section reports the operational statuses of the ACS800 drive system. The following statuses are provided:

- **Torque field**: Provides the present torque of the generator as reported by the ABB variable frequency drive.
- **Power field**: Provides the present power output of the generator as reported by the ABB variable frequency drive.
- **Output Voltage field**: Provides the RMS voltage of the AC power from the generator.
- **Frequency field**: Provides the frequency of AC power from the generator.
- **Operating light**: Indicates whether the ACS800 drive is operational, , or not operational, .
- **Fault light**: Indicates whether an ACS800 drive fault exists, , or does not exist, . Drive faults will need to be acknowledged by the user on the *User Mode* panel (Figure 2-9).
- **Warning light**: Indicates whether an ACS800 drive warning exists, , or does not exist, .

Wind Information: The *Wind Information* section displays data obtained from the sonic anemometer mounted to the rear of the nacelle. The anemometer communicates to the turbine processor via the onboard RS-485 communication port. The display items include:

- **Direction 1-Sec Average field**: The one-second sliding window average of anemometer wind direction values, in degrees.
- **Direction Filtered field**: The first-order-filtered, exponentially averaged wind direction values, in degrees.
- **Speed 1-Sec Average field**: The one-second sliding window average of anemometer wind speed values, in meters per second.
- **Speed Filtered field**: The first-order-filtered, exponentially averaged wind speed values, in meters per second.
- **Yaw Dir (CW) light**: When illuminated, light indicates the nacelle is yawing clockwise.
- **Yaw Dir (CCW) light**: When illuminated, light indicates the nacelle is yawing counterclockwise.

Production Graphs

The *Production Graphs* subpanel (Figure 2-29) allows the user to review the history of turbine electrical power production. The following five graphs are provided:

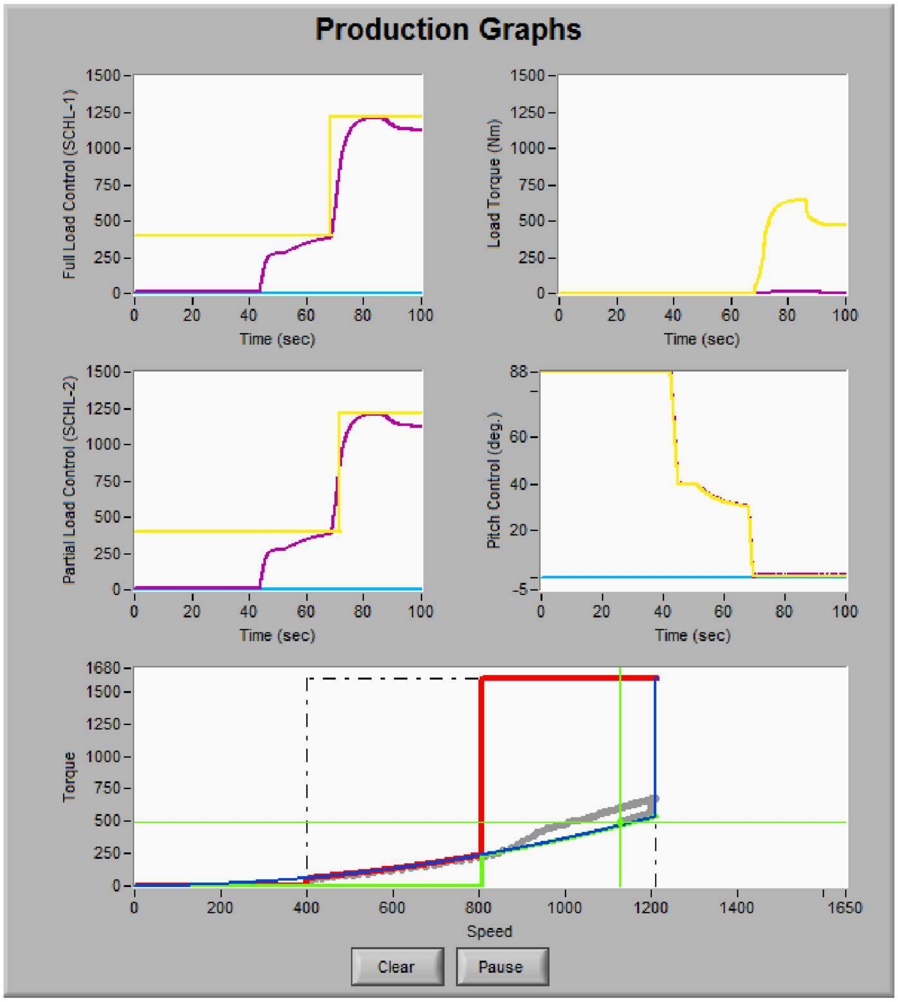


Figure 2-29. Production Graphs subpanel

- **Full Load Control vs. Time graph:** Displays the generator speed RPM time history (purple) in relation to the speed control set point of the pitch controller (yellow).
- **Load Torque vs. Time graph:** Displays the generator torque time history.
- **Partial Load Control vs. Time graph:** Displays the generator speed RPM time history (purple) in relation to the speed control set point of the torque controller (yellow).
- **Pitch Control vs. Time graph:** Displays the blade pitch angle time history.
- **Torque vs. Speed graph:** Each gray dot is a simultaneous reading of generator torque and speed signals. The dots will follow the blue line if wind speed is changing slowly. The production controller will attempt to keep the operating point dots between the lower green curve and the upper red curve. (Note: the red curve overlays the blue curve between 400 rpm and 800 rpm, and the green curve overlays the blue curve between 800 rpm and 1210 rpm.)

2.3.18. Information Interface

Selection of *Views>>Information* displays the *Information* interface (Figure 2-30).

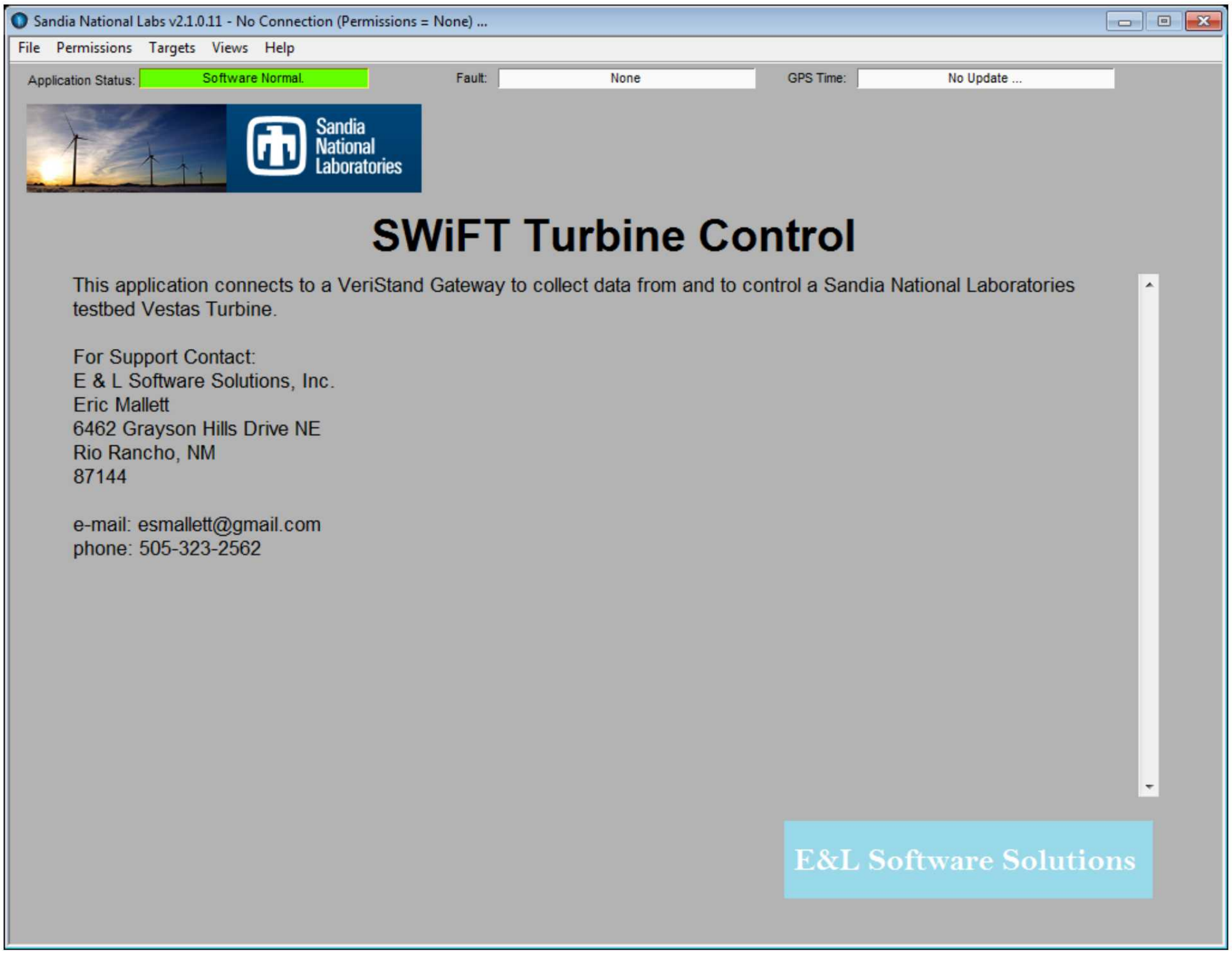


Figure 2-30. Application Information interface

The *Information* user interface displays a brief description of the application along with the programmer contact information. The displayed information is obtained from the *Splash_Dialog.txt* file located at:

<AppDir>\Support Files,

where <AppDir> is the application installation directory, typically something similar to “C:\Program Files\SWiFT\User Interface.”

This file is provided to permit users to add notes that might assist in working with the turbine software applications in the future.

2.3.19. S/W Control Interface

Selection of *Views>>S/W Control* displays the *S/W Control* interface (Figure 2-31).

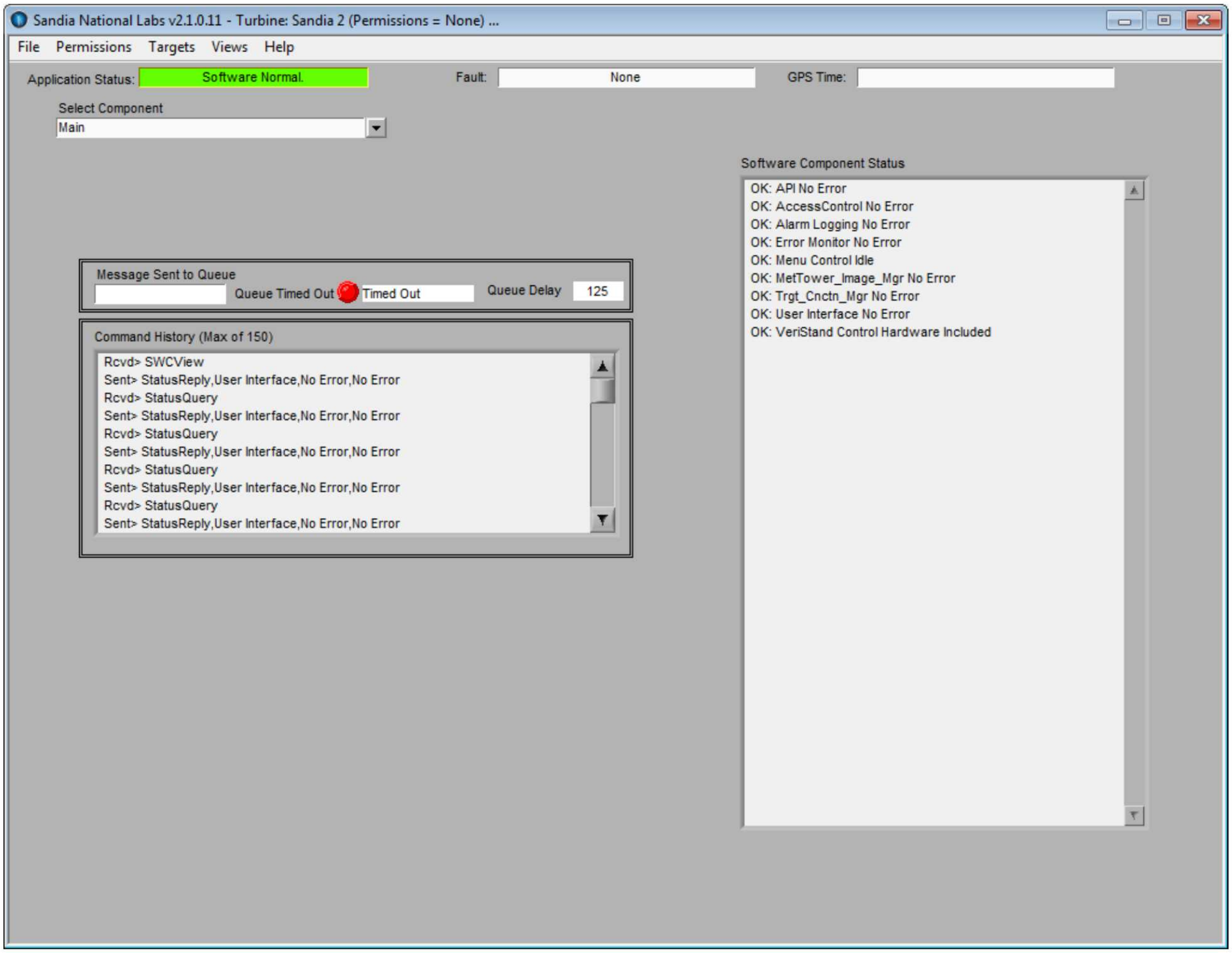


Figure 2-31. Programmer debug interface

The *S/W Control* user interface is included for use by an advanced programmer for application debugging purposes. No turbine control capabilities are included. The interface allows the programmer to investigate issues reported in the *Application Status* display at the upper left of all application screens.

APPENDIX A. ALARM LIST

No.	Log Label	Detection	Reaction	Restart
88	LowHydrTemp	Prevent going to RUN state while hydraulic fluid is cold	Pause	AutoShort
101	EmcMissing	Safety (Emergency) Circuit did not close after turbine state increased to STOP	Emergency	Local
102	EmcBroken	Safety (Emergency) Circuit has opened	Emergency	Local
103	StopCircuitBroken	Stop Circuit has opened	Stop	Local
117	AnemomRPMError	Wind sensor reading near zero while generator speed near nominal	Pause	Remote
130	MaxPowGen	Generator power has exceeded limit	Stop	Remote
131	NegPowGen	Generator power has exceeded negative limit	Stop	Remote
144	HighWind	Average wind speed has exceeded limit HighWindLimit	Pause	AutoNoCntSht
145	HighWindGust	Wind gust has exceeded limit HighWindGustLimit	Pause	AutoNoCntSht
146	LowAmbientTemp	Ambient temperature is below freezing	Pause	AutoNoCntSht
147	HighGearOilTemp	Gear oil temperature is greater than HighGearTempLimit. Mandatory cooldown.	Pause	AutoLong
148	HighGenTempDE	Generator drive-end bearing temperature has exceeded limit	Pause	Remote
152	RPMLimitEmergToStop	Prevent leaving EMERGENCY state while speed is above limit	n/a	n/a
153	MaxGenRPM	Generator speed exceeded limit (default 110% of nominal)	Stop	Remote
154	MaxRotRPM	Rotor speed exceeded limit (default 115% of nominal)	Emergency	Remote
156	ChockSensor	Vibration knock sensor triggered	Stop	Local
157	GenRPMOpStNotRun	Generator still turning after not it RUN for 30 seconds	Emergency	Local
158	SpeedsDisagreeRotGen	Rotor and generator speed sensors disagree	Stop	Local
159	OverspeedOSPR	OSPR has initiated emergency stop	Emergency	Local
160	BrakeError	High brake pad temperature. Prevents releasing brake until cooled.	Emergency	Local
161	MaxTimeHydr	Pressurizing the hydraulic system has taken too much time	Emergency	Remote
162	HydrPressostat	Brake accumulator pressure is low	Emergency	Remote
163	LowHydrPress	Significant loss of pressure from pitch accumulator	Emergency	Local
164	HydrPressDrop	Hydraulic fluid filter may be clogged	Stop	Remote
165	LowHydrOil	Hydraulic oil level is low	Emergency	Local
166	HydrThermoErr	Hydraulic pump motor has drawn too much current	Emergency	Remote
167	HighHydrTemp	Hydraulic oil temperature is greater than MaxHydrTempLimit	Emergency	Remote
168	ErrorGearOilCooler	Gear oil cooler has drawn too much current	Stop	Local
174	FeedBackHydrMotor	Contactor feedback error, hydraulic pump motor	Emergency	Remote
179	YawError	Turbine has yawed too far or yaw sensor has failed	Stop	Remote
180	MissingS105	S105 not changing during yawing (expect to change every 162 degrees)	Stop	Remote
181	YawAckCW	Contactor feedback error, CW Yaw	Emergency	Remote
182	YawAckCCW	Contactor feedback error, CCW Yaw	Emergency	Remote
183	AutoYawTimeOut	Auto yawing continuously for longer than MaxAutoYawTime	Stop	Remote
184	MaxUntwistTime	Untwisting for longer than MaxUntwistTime	Emergency	Local
185	UntwistBadSensor	Unexpected yaw sensor signal during yaw untwist operation	Stop	Remote
186	ThermoErrYawMotor	One or both yaw motors have drawn too much current	Stop	Remote
187	YawAngleLimit	YawAngle is offset from yaw turtle zero point by 180 deg	Stop	Remote
188	YawRateError	YawingRate is either too fast or too slow	Stop	Remote
190	PitchError	Difference between actual pitch and pitch reference exceeded limit	Stop	Remote
191	PitchVelError	Difference between actual and expected pitch velocity exceeded limit	Stop	Remote
192	PitchVoltSTDErr	Variation of pitch control voltage Y800 over 10 seconds has exceeded limit	Stop	Remote
193	PowerSTDErr	Variation of generator power over 20 seconds has exceeded limit	Stop	Remote
194	PitchTooLow	After transition to STOP, pitch did not reach required angle within time limit	Emergency	Local
195	PitchCalibration	Pitch feedback sensor voltage is outside calibration tolerance	Stop	Local
196	PitchLimitProduction	Power production is stopped based on a high wind pitch position	Stop	Local
212	TempSensor	Temperature sensor malfunction	Pause	AutoShort
313	HighAmbientTemp	Ambient temperature is above limit	Pause	AutoNoCntSht
338	MaxYawError	Average yaw error in RUN has exceeded MaxYawErrDeg	Pause	NoErr
500	DriveStateChangeFail	ABB drive was not able to change state within the timeout period	Stop	Remote
501	WrongDriveState	ABB drive state does not match expected state	Stop	Remote
502	EMCY	ABB drive indicates emergency	Emergency	Local
503	ErrorGridFeedMonitor	Grid monitoring relay senses a grid error	Emergency	Local
504	BrakeChopperActive	ABB drive external brake chopper was activated	Stop	Remote
505	BrakeChopperFault	ABB drive external brake chopper reported a fault	Stop	Remote
506	ACS800PulseError	Indicates failure of ACS800 EtherCAT Fieldbus communication	Stop	Remote
507	ACS800Temp	ACS800 reported a temperature over this limit ACS800TempLimit	Stop	Remote
700	GearOilFilterThermoErr	CC Jensen gear oil filter motor has drawn too much current	Stop	Remote
701	FeedBackOilFilterMotor	Contactor feedback error, CC Jensen gear oil filter	Stop	Remote
702	GenCoolerThermoErr	Generator fan motor has drawn too much current	Emergency	Remote
703	FeedBackGenCoolMotor	Contactor feedback error, generator fan motor	Emergency	Remote
704	FeedBackOilCoolMotor	Contactor feedback error, gear oil cooler	Stop	Remote
705	DecToPAUSEbeforeUntwist	Yaw untwist requires turbine state to be PAUSE	Pause	NoErr
706	MaxPow10min	Average generator power has exceeded limit	Stop	Remote
707	HighGearTempFront	Gearbox high-speed upwind bearing temperature has exceeded limit	Pause	Local
708	HighGearTempRear	Gearbox high-speed downwind bearing temperature has exceeded limit	Pause	Local
709	HighGenTempNDE	Generator non-drive-end bearing temperature has exceeded limit	Pause	Remote
710	WatchdogError	Watchdog has been triggered	Stop	Remote
711	SubsystemError	A subsystem's heartbeat failed to change within cycle time	Stop	Remote
712	VibrationSensor	Vibration inertial sensor triggered and latched	Stop	Local
713	MaxLSShaftRPM	LSS speed exceeded limit (default 115% of nominal)	Emergency	Remote
714	SpeedsDisagreeGenLSS	Generator and LSS speed sensors disagree	Stop	Local
715	SpeedsDisagreeRotLSS	Rotor and LSS speed sensors disagree	Stop	Local
716	OverspeedOSP	Phoenix Contact Overspeed Protection has initiated emergency stop	Emergency	Local
717	SensorMalfunctionOSPS	Phoenix Contact Overspeed Protection Shaft indicates sensor malfunction	Stop	Local
718	OnBattery	One of the battery back-ups has activated OnBattery alarm	Stop	Remote
719	SensorMalfunctionOSPR	Phoenix Contact Overspeed Protection Rotor indicates sensor malfunction	Stop	Local

APPENDIX B. PARAMETER LIST

Parameter	Value	Usage
ACS800Pulse	0.5	ABB: alarm 506
ACS800PulseLimit	0.6	ABB: alarm 506
ACS800PulseRecover	1	ABB: alarm 506
ACS800TempLimit	80	ABB: alarm 507
AlarmHydrPressHyst	50	Hydraulic: alarm 163
AlarmHydrPressLimit	50	Hydraulic: alarms 163 & 162
AlarmHydrPressTime	0.2	Hydraulic: alarm 163
AutoLng	3	Constant symbol
AutoLngTime	600	CentralLogic: alarm long cooldown
AutoNoCntSht	5	Constant symbol
AutoSht	4	Constant symbol
AutoShtTime	60	CentralLogic: alarm short cooldown
AutoYawTime	5	Yaw: system parameter
BrakeChipperVoltageLimit	775	
ControlVoltageSTDLimit	8	Pitch: alarm 192
CtrPCL_limit	100	Primary Control Loop up-counter max value
CtrWDS_limit	100	Watchdog system up-counter max value
CtrlVolt_NegativeEnd	-10	Pitch: test parameter
CtrlVolt_PositiveEnd	10	Pitch: test parameter
CycleTime	0.1	Shared parameter: heartbeat period
DebncDelay	0.04	Debounce parameter (S105_DeBnc)
DebncFault	0.1	Debounce parameter (S105_DeBnc)
DebncRecover	1	Debounce parameter (S105_DeBnc)
DelayCheckStop	5	Pitch: alarm 194
DelayEmc	3	Emergency: alarms 101 & 102; Hydraulic: pump operation
DirChangeTime	2	Yaw: system parameter
DriveStateChangeTimeout	10	ABB: alarm 500
EMERGENCY	-1	Constant symbol
Error	1	Constant symbol
ErrorExitDelayTime	2	ABB: system parameter
FanHystTemp	15	Rotation: system parameter
FanLowStartTemp	90	Rotation: system parameter
FeedBackErrorTime	2	Contactor feedback alarm parameter
FeedBackRecoverTime	1	Contactor feedback alarm parameter
FeedBackWaitTime	1	Contactor feedback alarm parameter
FreeWheelMinSpeed	100	ProdCtrl: system parameter
FreeWheelPitch	45	ProdCtrl: system parameter
FreeWheelTime	15	ProdCtrl: system parameter
GearConst	27.5647	Rotation: gear ratio
GenRPMAutoYawLimit	75	Yaw: system parameter
GenRPMOpStNotRunLimit	0.5	Rotation: alarm 157
GenRPMOpStNotRunTime	0.2	Rotation: alarm 157
GenRPMOpStNotRunTimerVal	30	Rotation: alarm 157
GenSpeedSPAmp	1	ProdCtrl: system parameter
GenSpeedSPHigh	1210	ProdCtrl: system parameter
GenSpeedSPLow	400	ProdCtrl: system parameter
GenSpeedSPSinT	240	ProdCtrl: system parameter
GenSpeedSPStepT	60	ProdCtrl: system parameter
GenSpeedSPVOG	1500	ProdCtrl: system parameter
GenSpeedScaleMax	1650	ProdCtrl: system parameter
GenSpeedScaleMin	0	ProdCtrl: system parameter
HighGearFrontTempHyst	80	Rotation: alarm 707
HighGearFrontTempLimit	80	Rotation: alarm 707
HighGearFrontTempTime	20	Rotation: alarm 707
HighGearOilTempHyst	80	Rotation: alarm 147
HighGearOilTempLimit	80	Rotation: alarm 147
HighGearOilTempTime	20	Rotation: alarm 147
HighGearRearTempHyst	80	Rotation: alarm 708
HighGearRearTempLimit	80	Rotation: alarm 708
HighGearRearTempTime	20	Rotation: alarm 708

Parameter	Value	Usage
HighGenDETempHyst	155	Rotation: alarm 148
HighGenDETempLimit	155	Rotation: alarm 148
HighGenDETempTime	20	Rotation: alarm 148
HighGenNDETempHyst	155	Rotation: alarm 709
HighGenNDETempLimit	155	Rotation: alarm 709
HighGenNDETempTime	20	Rotation: alarm 709
HighTempAmbientHyst	38	Enviro: alarm 313
HighTempAmbientLimit	40	Enviro: alarm 313
HighWindCnt	1	Enviro: alarm 144
HighWindGustCnt	1	Enviro: alarm 145
HighWindGustHyst	12	Enviro: alarm 145
HighWindGustLimit	18	Enviro: alarm 145
HighWindHyst	12	Enviro: alarm 144
HighWindLimit	15	Enviro: alarm 144
InitStable_time	10	Pitch: test parameter
LowTempAmbientHyst	-20	Enviro: alarm 146
LowTempAmbientLimit	-20	Enviro: alarm 146
ManLimPitchMax	9	Pitch: test parameter
ManLimPitchMin	-9	Pitch: test parameter
MaxAutoYawTime	635	Yaw: alarm 183
MaxGenRPMRatio	0.1	Rotation: alarm 153
MaxGenRPMTime	0.2	Rotation: alarm 153
MaxHydrPressure	90	Hydr: pump operation
MaxHydrTempHyst	65	Hydr: alarm 167
MaxHydrTempLimit	65	Hydr: alarm 167
MaxHydrTempTime	20	Hydr: alarm 167
MaxNoOfPitchVelErrors	50	Pitch: alarm 191
MaxPitch	86	Pitch: test parameter
MaxPitchError	10	Pitch: alarm 190
MaxPitchErrorTime	1	Pitch: alarm 190
MaxPitchForVelError	80	Pitch: alarm 191
MaxPow10min	202	ABB: alarm 706
MaxPowHyst	1.1	ABB: alarm 130
MaxPowLim	1.1	ABB: alarm 130
MaxPowTime	5	ABB: alarm 130
MaxPowerRefVel	22	ABB: alarm 193
MaxRotRPMTime	0.2	Rotation: alarms 154 & 713
MaxRotorRPMRatio	0.15	Rotation: alarms 154 & 713
MaxRotorTolTime	2	Rotation: alarms 158, 714, 715
MaxTimeHydrMotor	60	Hydr: alarm 161
MaxUntwistTime	1800	Yaw: alarm 184
MaxWindSpeedUntwist	3	Yaw: system parameter
MaxYawErrorDeg	25	Yaw: system parameter
MinHydrPressure	75	Hydr: pump operation
MinHydrTempHyst	-20	Hydr: alarm 88
MinHydrTempLimit	-20	Hydr: alarm 88
MinHydrTempS201	20	Hydr: alarm 164
MinHydrTempTime	20	Hydr: alarm 88
MinPitchSpeedCtrl	-1	Pitch: test parameter
MinPitchWhenStop	80	Pitch: alarm 194
MinTimeHydrMotor	1	Hydr: pump operation
MinWindSpeed	3	Yaw: system parameter
MinYawErrWindSpeed	8	Yaw: alarm 338
NacTempNacFanHyst	5	Rotation: system parameter
NegPowGenHyst	-0.1	ABB: alarm 131
NegPowGenLim	-0.1	ABB: alarm 131
NegPowGenTime	1	ABB: alarm 131
NegativOffsetAmpl	-2	Pitch: test parameter
NoError	0	Constant symbol
NominalGenRPM	1210	Shared parameter
NominalPower	192	ABB: alarms 130 & 131
NotYawingMargin	0.1	
OilTempNacFanLow	60	Rotation: system parameter
PAUSE	1	Constant symbol
PitchCalVoltMax	9.99	Pitch: alarm 195
PitchCalVoltMin	0.02	Pitch: alarm 195
PitchGainSchedDivisor	5.23	ProdCtrl: system parameter
PitchGainSchedMax	27.4	ProdCtrl: system parameter
PitchGainSchedMin	5.48	ProdCtrl: system parameter
PitchLimitProduction	2	

Parameter	Value	Usage
PitchRateMax	8	ProdCtrl: system parameter
PitchScaleMax	88	Pitch: test parameter; ProdCtrl: system parameter
PitchScaleMin	-5	ProdCtrl: system parameter
PitchServiceMaxWindSpeed	8	
PitchVelErrorBand	4	Pitch: alarm 191
PitchVoltBase1	690	Pitch: alarm 190
PitchVoltBase2	1640	Pitch: alarm 190
PitchVoltMax	9.972	Pitch & SigProc: pitch signal conversion
PitchVoltMin	0.04	Pitch & SigProc: pitch signal conversion
PitchVoltSlope1	131	Pitch: alarm 190
PitchVoltSlope2	95	Pitch: alarm 190
PositivOffsetAmpl	2	Pitch: test parameter
PowerMeanLimit	150	ABB: alarm 193
PowerSTDLimit	20	ABB: alarm 193
PowerUpTime	8	ProdCtrl: system parameter
Power_100pct	298.3	SigProcPCL: power signal conversion
PrepTest_vel	2	Pitch: test parameter
PressDropTime	2	Hydr: alarm 164
ProductionPitch	1	ProdCtrl: system parameter
ProductionTorqueCpMax	537	ProdCtrl: system parameter
ProductionTorqueMax	1520	ProdCtrl: system parameter
RPMLimitEmergToStop	0.1	Rotation: alarm 152
RUN	2	Constant symbol
RotorTolMinRPM	0.5	Rotation: alarm 152
RotorTolRatio	0.15	Rotation: alarms 158, 714, 715
RunningDownTime	10	ProdCtrl: system parameter
RunningUpTime	10	ProdCtrl: system parameter
S105Time	353	Yaw: alarm 180
S200Time	2	Hydr: alarm 165
SCHL1_FBFilterFreq1	2.2	ProdCtrl: system parameter
SCHL1_FBFilterFreq2	4.4	ProdCtrl: system parameter
SCHL1_Kp	3	ProdCtrl: system parameter
SCHL1_Ti	7	ProdCtrl: system parameter
SCHL2_Kp	9	ProdCtrl: system parameter
SCHL2_Ti	7	ProdCtrl: system parameter
STOP	0	Constant symbol
SubsystemErrorTime	1	Supervisor: alarm 711
TempAmbientCnt	60	Enviro: alarm 146 & 313
TempSensorInvTime	2	Enviro: alarm 212
TempSensorOpen	200	Enviro: alarm 212, 146, 313; Hydr: alarm 167
TempSensorShort	-45	Enviro: alarm 212, 146, 313; Hydr: alarm 88
TestAnemometerRPM	0.9	Enviro: alarm 117
TestAnemometerWind	0.3	Enviro: alarm 117
Torq_100pct	1604.8	SigProcPCL: torque signal conversion
TorqueScaleMax	1680	ProdCtrl: system parameter
TorqueScaleMin	0	ProdCtrl: system parameter
Torque_100pct	1600	ABB: torque scaling
Ts	0.1	Shared parameter: sample time
Ts_ProdCtrl	0.05	ProdCtrl: sample time
Ts_SignalProc	0.01	SignalProcessing: sample time
Ts_Supervisor	0.01	Supervisor: sample time
UnTwistTime	635	Yaw: system parameter
UpWindOKTime	10	Yaw: system parameter
UpWindYawLimit	18	Yaw: system parameter
VC4_FBFilterFreq	2.7	ProdCtrl: system parameter
VC4_Kp	0	ProdCtrl: system parameter
VOGTime	1	Rotation: system parameter
ValveDeadZone	4000	Pitch: alarm 191
ValveDeadZoneGain	0	Pitch: alarm 191
ValveDeadZoneOffset	0	Pitch: alarm 191
ValveNegativGain	10	Pitch: alarm 191
ValvePositivGain	10	Pitch: alarm 191
VibrationControlOn	0	ProdCtrl: system parameter
VoltageErr_EMERGandSTOP	0	Pitch: constant
Watchdog_tickHigh	7	Watchdog: heartbeat Ts counts high
Watchdog_tickLow	7	Watchdog: heartbeat Ts counts low
WindDir_Tau_not_yawing	100	Yaw: system parameter
WindDir_Tau_while_yawing	10	Yaw: system parameter
YawAngleMax	612	Yaw: system parameter
YawAngleMin	-900	Yaw: system parameter

Parameter	Value	Usage
YawRateCompareDelay	3	Yaw: system parameter
YawingMargin	0.1	Yaw: system parameter
YawingRate	0.6	Yaw: system parameter
ZeroPeriodRPM	0	SigProcPCL: speed signal conversion
local	1	Constant symbol
remot	2	Constant symbol

APPENDIX C. SIGNALS TABLE

Master list of software signals in the SWiFT Wind Turbine software.

Name	File	Revision Date	Description

Volume 3:
Electrical System

Sandia SWiFT Facility Site Operations Manual (SAND2016-XXXX) approved by:

Department Manager		SWiFT Site Lead	
Dave Minster (6121)	Date	Jonathan White (6121)	Date
SWiFT Site Supervisor			
Dave Mitchell (6121)	Date		

VOLUME REVISION LOG			
Volume Title: Volume 3: Electrical System, Sandia SWiFT Wind Turbine Manual (SAND2016-XXXX)			
Volume Owner(s): Dave Mitchell, SWiFT Site Supervisor			
Revision	**Date**	**Author(s)/Approval**	**Summary of Change(s)**
0			

CONTENTS

FIGURES

3. ELECTRICAL SYSTEM

3.1. Electrical System Overview

Electrical system components in Sandia SWiFT wind turbines generate power and provide it to the grid, power or drive subsystems and components, or manage and initiate control and monitoring signals. The system includes an Emergency Stop system and a stop system for automatic and manual turbine shutdown, which are described separately.

Section 3.1 provides an overview of the electrical system and its various subsystems and components. Sections 3.2-3.18 provide detailed descriptions of electrical system subsystems and components, their functions, calibration and maintenance requirements and procedures, troubleshooting procedures and frequencies, and component and replacement part specifications.

3.1.1. Main Current Overview & Diagram

3.1.1.1. Power-Producing & Power-Consuming Systems

The main current diagram can be viewed as a power-producing plant and a power-consuming plant. The **power-producing systems** include the generator, the full-scale convertor, circuit breakers, disconnects, and lightning protection systems. The circuit breakers for the main disconnect Q8 and the full-scale convertor are located in the bus bar section and used to connect to the grid. The grid connection is made in the bottom of the bus bar section.

The **power-consuming systems** include subsystems that draw power for their operation, such as the yaw motors, hydraulic motors, processor electrical supply, and electrical lighting and service outlets. The circuit breaker (F30) for the power-consuming system is located in the bus bar section next to the Q8. All the circuit breakers – F31, F32, F33, F34, F35, F36, and F37 – are located in the fuse section.

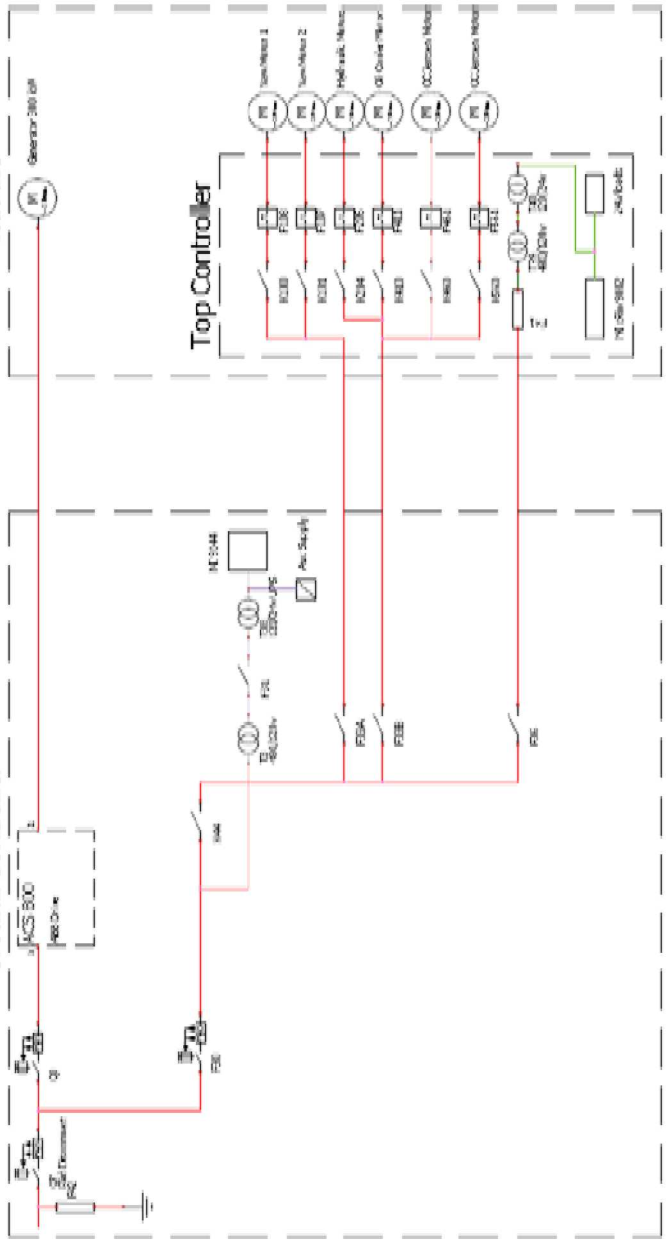


Figure 3-1. One line – Main circuit diagram

3.1.1.2. Turbine Subsystems Diagram

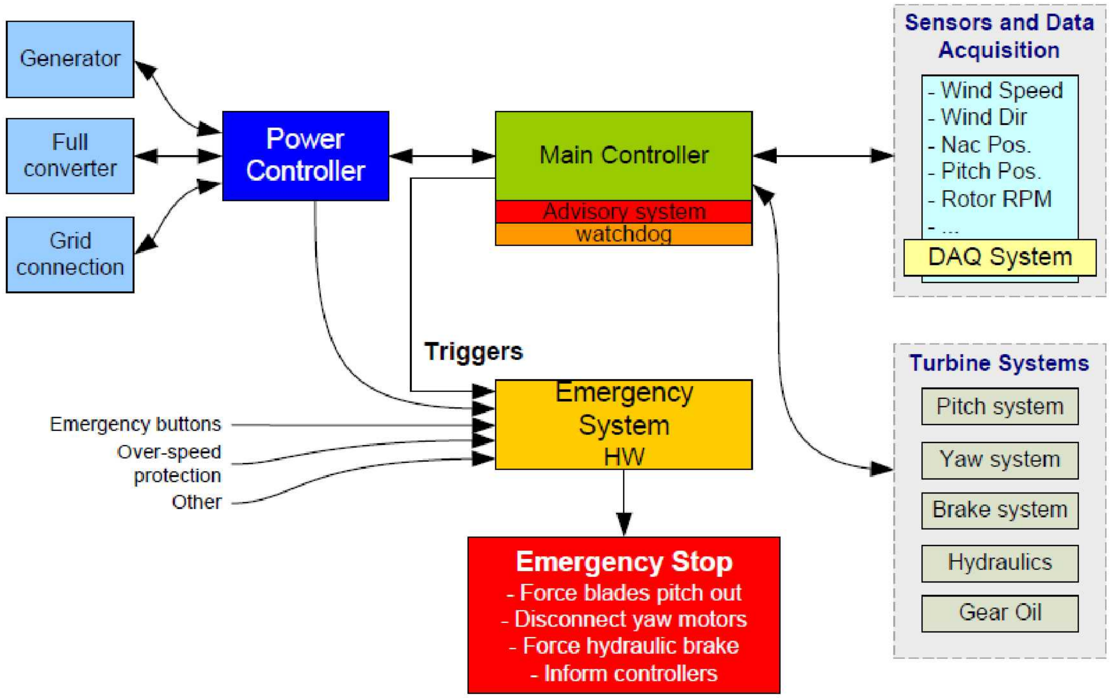


Figure 3-2. Turbine subsystems diagram

3.1.2. Emergency Stop & Stop System

3.1.2.1. Turbine Operating States Overview

The turbine controller is always in one of the following states:

- Run
- Pause
- Stop
- Emergency Stop

Each operating state is an activity level, where Run is the highest activity level and Emergency Stop is the lowest activity level. See Volume 2, Section 2.2 for a detailed description of turbine operating states.

3.1.2.2. Emergency Stop System (E-Stop)

Each Sandia SWiFT wind turbine is equipped with an Emergency Stop circuit that, unless fully closed and complete, breaks voltage to subsystems and causes a full stop of the turbine. In this operating state, the turbine's main processor continues to operate and monitor the state of the system. The Emergency Stop circuit must be closed and cleared before the operating state of the turbine can be elevated to the Stop, Pause, or Run operating states.

The Emergency Stop circuit is opened manually by means of human-operated Emergency Stop buttons distributed in various places on the turbine. A relay (K900) controlled by the main processor can be activated manually through the user interface or triggered automatically by the main controller as a response to predefined operating conditions. The two turbine overspeed systems also automatically open the E-stop circuit, bypassing the main controller. Section 3.2 of this volume describes the Emergency Stop system.

3.1.2.3. Stop System

Each Sandia SWiFT wind turbine is equipped with a stop circuit that when opened breaks voltage to many of the turbine subsystems and causes the turbine to stop. The stop circuit is activated manually by means of a remote stop button, a vibration sensor, or yaw overtwist sensor logic. Section 3.3 of this volume describes the stop system.

3.1.3. Control & Communication System

The turbine control system comprises both hardware, software, and predefined control logic. All functions of the Sandia SWiFT wind turbine are monitored and controlled via a central microprocessor-based control unit located in the turbine nacelle, distributed control systems connected by an EtherCAT communication protocol, and associated software packages.

Controllers are software-based subroutines that serve as the control and monitoring system logic for operation of the turbine's various subsystems. The turbine main controller manages the turbine's highest-level functions. Subsystem controllers are designated by the name of the subsystem they control.

A site-wide fiber-optic network connects the processor in each turbine with the user interface located in the control building. Data gathered from the processor is stored in the site data storage system. Section 3.4 describes the turbine control and communication system.

3.1.4. Grid Power Systems

Each Sandia SWiFT wind turbine transforms the mechanical energy from its rotating blade-rotor assembly into electrical energy by means of an asynchronous generator located in the turbine's nacelle. Each generator is connected to the grid through a series of power transmission components, including (from generator to grid):

- Tower cables
- A full-scale converter (ABB variable frequency drive unit)
- A pad-mounted transformer
- High voltage underground cables, and
- A utility-managed grid interconnect

These subsystems and components are described in Sections 3.5-3.8.

3.1.5. Rotation System

The SWiFT wind turbine rotation system includes all rotating components, from the blade-rotor assembly to the high speed shaft that enters the generator. The rotation system includes sensors and active monitoring systems critical for turbine safety and proper operation. Section 3.10 describes the rotation system.

3.1.6. Pitch Control System

Sandia SWiFT wind turbine blades pivot along their own longitudinal axes to achieve variable blade angles relative to wind direction, called "pitch." This allows for optimum wind energy capture, variable rotor speed control, reduced load on the blades, and the ability to stop the turbine. When the turbine is in the Run operating state, the production controller determines the desired pitch angle of the blades based on the operating conditions. When the turbine is in the Stop or Emergency Stop operating state, the blades will be positioned at a pitch angle of 90° ("full feathered") relative to wind direction, contributing to the corresponding full stop of the rotor system. Section 3.11. describes the pitch control system.

3.1.7. Yaw Control System

Each SWiFT wind turbine's nacelle is mounted on a yaw ring that rotates horizontally 360°. Gear teeth on the yaw ring mesh with two electric motors that control yaw direction. An automatic yaw system keeps the turbine blade-rotor assembly facing into the wind in the Run and Pause operating states; the yaw control system also limits twisting of the tower cables and performs untwisting rotations when needed. Section 3.12 describes the yaw control system.

3.1.8. Hydraulic Control System

The hydraulic control system supplies oil pressure that regulates blade pitch. It also stores oil pressure for braking of the rotor system and full-feathering of the blades (in an emergency stop, for example). Section 3.13 describes the hydraulic control system.

3.1.9. Research Sensors

Sandia SWiFT wind turbines have been modified with a number of sensors for gathering research data. In addition, ambient condition sensors, including a wind vane and an anemometer, provide information to the main controller about environmental conditions. Sections 3.14 and 3.15 describe these sensor systems.

3.1.10. Auxiliary Power Systems

The auxiliary power systems provide power for lighting, controllers, 120v outlets, sensors, communication hardware, and other auxiliary systems. To facilitate service activities, these systems can be activated without turning on the main power to the turbine. Section 3.16 describes the auxiliary power systems.

3.1.11. Power Disconnects

When power is needed for some systems but not others, such as for safe testing and maintenance activities on subsystems, a series of disconnects distributed throughout each turbine's main circuit allows for power disconnection and isolation. Section 3.17 describes the Sandia SWiFT wind turbine power disconnects.

3.1.12. Lightning Protection

Sandia SWiFT wind turbines are equipped with redundant systems designed to protect the turbine's electrical systems from lightning damage. Section 3.18 describes these lightning protection systems.

3.1.13. Electrical System Naming Conventions

This section explains the system for naming the components.

Components (both inputs and outputs) are named with the following letter prefix:

A: Group of components (e.g. controller and controller subroutines)
B: Sensor (e.g. wind vane, thermostat)
D: Auxiliary relay
E: Heating element, fan
F: Thermo relay, circuit breaker
K: Contactor, relay
L: Coil, discharge coil
M: Motor
Q: Circuit breaker for main current circuits
R: Resistance (temperature sensor)
S: Switch function
T: Transformer
U: Rectifier
W: Cable
X: Terminal
Y: Magnetic valve

A signal chain, where a relay activates a contactor that activates a motor, is named after the last component in the chain.

No inputs have the same number, regardless of letter prefix. No outputs have the same number, regardless of letter prefix. Inputs and outputs have the same number when they have a connection with the same component (e.g. control signal and feedback from contactor). The distinction is made by means of the signal's letter prefix.

Two components with a parallel function have the same number, but they can be distinguished by means of a subsequent letter (e.g. K100A, K100B).

An auxiliary relay is defined as a component that exclusively functions as a connecting link (e.g. between a computer output and a contactor coil). The auxiliary relays have the letter prefix D and the same number as the component they serve.

Use of numbers is grouped in the following way:

Signal number	Section
0…99	Electric grid
100…199	Yawing
200…299	Hydraulic
300…399	Weather sensors
400…499	Mechanics of rotation
500…599	Generators
800...899	Pitch system
900...999	Emergency stop and various

3.1.14. How to Use this Volume

Each test section of this volume includes the following subsections:

3.1.14.1. Overview

Overview of the given electrical subsystem and a list of the components in that subsystem.

3.1.14.2. Subsystem Components

Brief descriptions of electrical subsystem components and their functions.

3.1.14.3. Calibration & Maintenance

Recommended calibration or maintenance procedures and durations for the subsystem.

3.1.14.4. Troubleshooting

Tips on resolving common problems relating to the given subsystem.

3.1.14.5. Spare Parts

Lists of components and their related manufacturer part numbers.

3.1.14.6. Drawings

Drawing of the subsystem and its components and their relationships to one another.

3.1.15. Safety Precautions

Working with and near turbine electrical systems presents a number of unique safety hazards. Critical safety precautions specific to electrical systems are called out in the text of this volume.

For a more detailed discussion of turbine and SWiFT site and turbine safety hazards, see the Sandia SWiFT Facility Site Operations Manual, the Sandia SWiFT Test Planning Manual, and the other volumes in this Sandia SWiFT Wind Turbine Manual.

3.2. Emergency Stop System

Each Sandia SWiFT wind turbine is equipped with an Emergency Stop circuit that, unless fully closed and complete, breaks voltage to subsystems and causes a full stop of the turbine. This section describes the turbine Emergency Stop, or E-stop, system.

3.2.1. Emergency Stop System Overview

3.2.1.1. Turbine Operating States Overview

The turbine controller is always in one of the following states:

- Run
- Pause
- Stop
- Emergency Stop

Each operating state is an activity level, where Run is the highest activity level and Emergency Stop is the lowest activity level. See Volume 2, Section 2.2 for a detailed description of turbine operating states.

3.2.1.2. Emergency Stop System Overview

In the turbine Emergency Stop state:

- The hydraulic disk brake (fitted to the high speed shaft of the gearbox) is on
- The pitch system is bypassed mechanically by opening the full-feather solenoid valves, resulting in the turbine blades being fully feathered (turned 90º relative to wind direction)
- The emergency circuit is open
- All outputs from the turbine processor are deactivated
- The processor is running and measuring all inputs
- The turbine's user interface in the control building displays EMERGENCY

The Emergency Stop circuit must be closed before the operating state of the turbine can be elevated to Stop, Pause, or Run.

The Emergency Stop circuit includes:

- Four human-activated Emergency Stop buttons
- Watchdog relay that trips if the processor/software are unresponsive
- Output from the processor
- Output from two Overspeed Protection (OSP) systems

3.2.2. Emergency Stop System Components

3.2.2.1. Emergency Stop Buttons

At the turbine, Emergency Stop can be activated (circuit opened) by pressing any of four buttons. These buttons and their locations are:

- S936 - At the base of tower on the electrical cabinet
- S934 - On the yaw ring/deck near the nacelle ladder
- S935 - At the top of the electrical cabinet in the nacelle
- S933 - At the top of gear box in the nacelle

At the control building, three additional Emergency Stop buttons are available:

- S937a - Site-wide, outside the control building (this button will activate a shutdown of all systems site-wide, including E-stop of all turbines)
- S937b - Site-wide, inside the control building (this button will activate a shutdown of all systems site-wide, including E-stop of all turbines)
- S937c - Individual turbine, inside the control building

3.2.2.2. Emergency Stop Relays

If the Emergency Stop circuit is opened, the following relays will be tripped:

Emergency stop relays	
K902	Informs the processor that the emergency circuit is open
K932A	Breaks the main voltage for all solenoid valves
K932B	Breaks the main voltage for the controller of the proportional valve and breaks the voltage to the yaw and hydraulic motor
K932C	Breaks the voltage for the oil filter and generator fan motors

3.2.2.3. Processor

In case of a serious fault, the turbine's processor automatically opens the Emergency Stop circuit by deactivating K900. An open Emergency Stop circuit deactivates the control voltage to all active components (e.g. pitch, yaw, hydraulics), but allows the processor to run in order to measure system state. A processor input (S902) enables the processor to read the state of the Emergency Stop circuit.

When any of the Emergency Stop buttons is pressed, the Emergency Stop circuit will open. The Emergency Stop circuit cannot be closed until the human operator acknowledges the E-stop event by clearing all faults on the user interface.

3.2.2.4. Overspeed Protection (OSP)

The Over-Speed Protection (OSP) systems automatically activate turbine Emergency Stop when the rotor rotation exceeds the maximum overspeed limit. See Section 3.10 for more information about the OSP systems.

3.2.3. Calibration & Maintenance

3.2.4. Troubleshooting

3.2.5. Spare Parts

SPARE PARTS LIST [NUMBER] – EMERGENCY STOP SYSTEM				
POS	**Item No.**	**Description**	**Type**	**Manufacturer**
K900		Emergency stop relay, computer	RV8H-L-D24, 24VDC	Idec
K902		Relay, emergency stop feedback	RY2S-U-DC24, 24VDC	Idec
K903		Relay, emergency stop feedback base	RY2S-U-DC24, 24VDC	Idec
K904		Relay, stop circuit feedback	RV8H-L-D24, 24VDC	Idec
D906		Aux. relay, watch dog	RY2S-U-DC24, 24VDC	Idec
S906		Feedback, watch dog	CM-WDS	ABB
K906		Aux. relay, watch dog		
K906		Watch dog input, heartbeat		
K907		Watch dog input, reset		
K923A		Emergency stop relay, emergency feat	RH1B-U-DC24, 24VDC	Idec
K932B		Emergency stop yaw, hydraulic, Vickers	RY4S-U-DC24, 24VDC	Idec
K932C		Emergency stop gen. fan, CC Jensen	RY4S-U-DC24, 24VDC	Idec
S933	116361	Emergency stop button, gear	XAL-JI74	Telemecanique
S934	116361	Emergency stop button yaw plane	XAL-J174	Telemecanique
S935	116361	Emergency stop button top panel	XAL-J174	Telemecanique
S936	116361	Emergency stop button base panel	XAL-J174	Telemecanique
S937a		Remote Emergency Stop Site Button – Outside Control Building	6785K31	McMaster Carr
S937b		Remote Emergency Stop Site Button – Inside Control Building	6785K31	McMaster Carr
S937c		Remote Emergency Stop Button – Inside Control Building	6785K23	McMaster Carr
S938		Stop Circuit Remote Button		
E939	194992	Thermal element, base controller	400W 23-1546	Land Sorensen
E940	87915	Thermal control, base controller	PTS 5	Vestas
E941	194992	Thermal element, topcontroller	400w 23-1546	DEVI
E942	87915	Thermal control, top controller	PTS 5	VESTAS
H943	116408	Lamp, aux. supply	SwissTac	Brodersen
H944	116408	Lamp temperature	SwissTac	Brodersen
H945	116408	Lamp, computer	SwissTac	Brodersen
E946A-B	92290	Cooling fan, base control system	842-129	Rudolph Schmidt
B947	93183	Thermostat for cooling fan	Hawn 3150-0045-02-03	Brdr. Beghom
F948	834695	VAS, for top control system	VAS	Vestas
F949	834695	VAS, for base control system	VAS	Vestas
S950	114880	Panel switch, 4 pole		Radio parts
P951A-B	188523	Line equip scada input	Au-Di 212RB	DanDelekron

P956	834583	Lightning protective print		Vestas
F957	834590	Lightning protective print		VESTAS
F958A-B	701285	Varistor box		VESTAS
F960	195009	Varistor, 24V Aux supply	S10V, S14 R25	Siemens
R963	114289	Temperature sensor E940	NTC 4.7Ω –A25	Promax
R964	114289	Temperature sensor E942	NTC 4.7 Ω-A25	Promax
W980		Cable, communication	LI, 10x20, 75mm2	
W981	836764	Cable, emergency stop gear	RHEYFLEX-Y 2x0,75mm2	AEG
W982	836765	Cable, emergency stop yaw plate	REHYFLEX-Y 2x0, 75mm2	AEG
W983	836802	Cable, signals emergency stop/thermostat	REYF, 7x0,75 mm2	AEG
W990	836857	Undergr. Cable, wind-foundation	07RN-F 1x25mm2	AEG
W991A	836859	Undergr. Cable, lower-foundation	07RN-F 1x25mm2	AEG
W991B	836859	Undergr. Cable, tower-foundation	07RN-F 1x25mm2	AEG
W992	836858	Undergr. Cable, top panel-foundation	H07V-K 1x6mm2	AEG
W994A	8366815	Undergr. Cable, l front—foundation	07RN-F 1x25mm2	AEG
W994B	836815	Undergr. Cable, r. front-foundation	07RN-F 1x25mm2	AEG
W996A	836864	Undergr. Cable, 1 rear-foundation	07RN-F 1x25mm2	AEG
W996B	836864	Undergr. Cable, r. rear-foundation	07RN-F 1x25mm2	AEG
W996C	836864	Undergr. Cable, generator-foundation	07RN-F 1x25mm2	AEG
W997	836865	Undergr. Cable, l.hinge-r.inge	07RN-F 1x25mm2	AEG
W998	837466	Undergr. Cable, cylinder foundation	H07V-K 1x6mm2	AEG
W999	837474	Undergr. Cable, hydr. –foundation	H07V-K 1x6mm2	AEG

3.2.6. Drawings

Drawing #	Version # (date)	Description	Filename
	1.0 (9/18/15)	Emergency circuit	
	1.0 (10/30/15)	Site-wide emergency stop	
	1.0 (9/18/15)	Emergency stop circuit top control	
	1.0 (9/18/15)	Emergency stop circuit and aux supply base control	

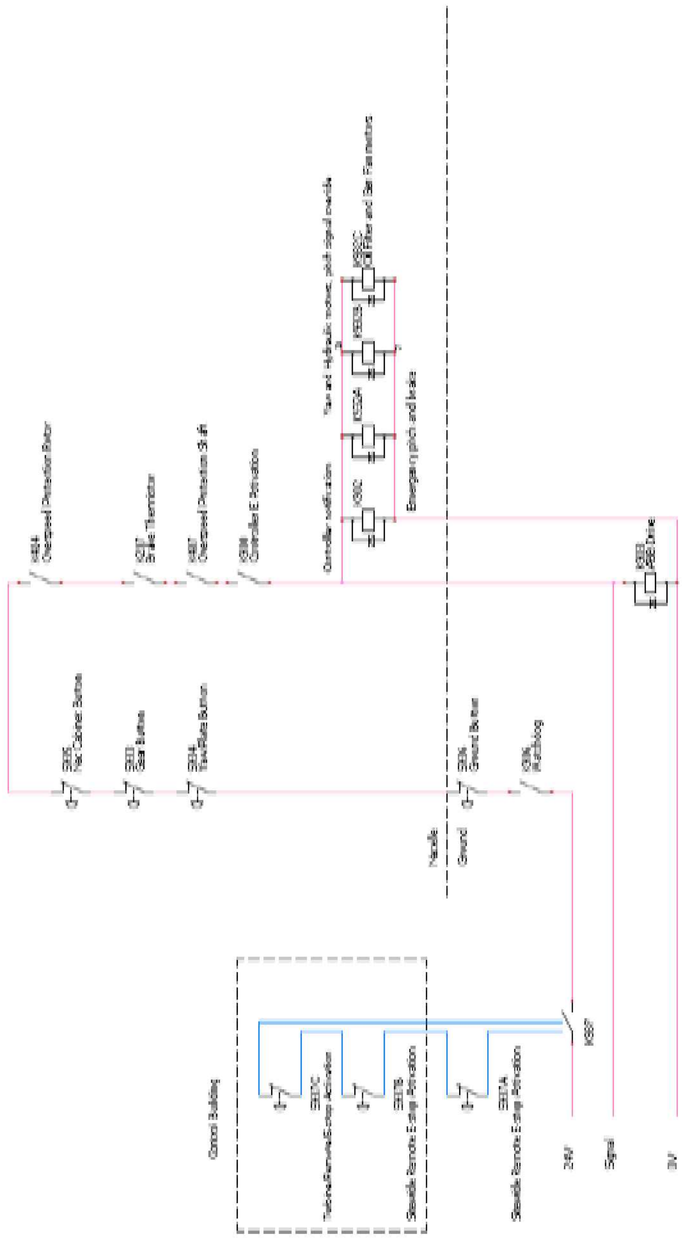


Figure 3-3. Emergency circuit

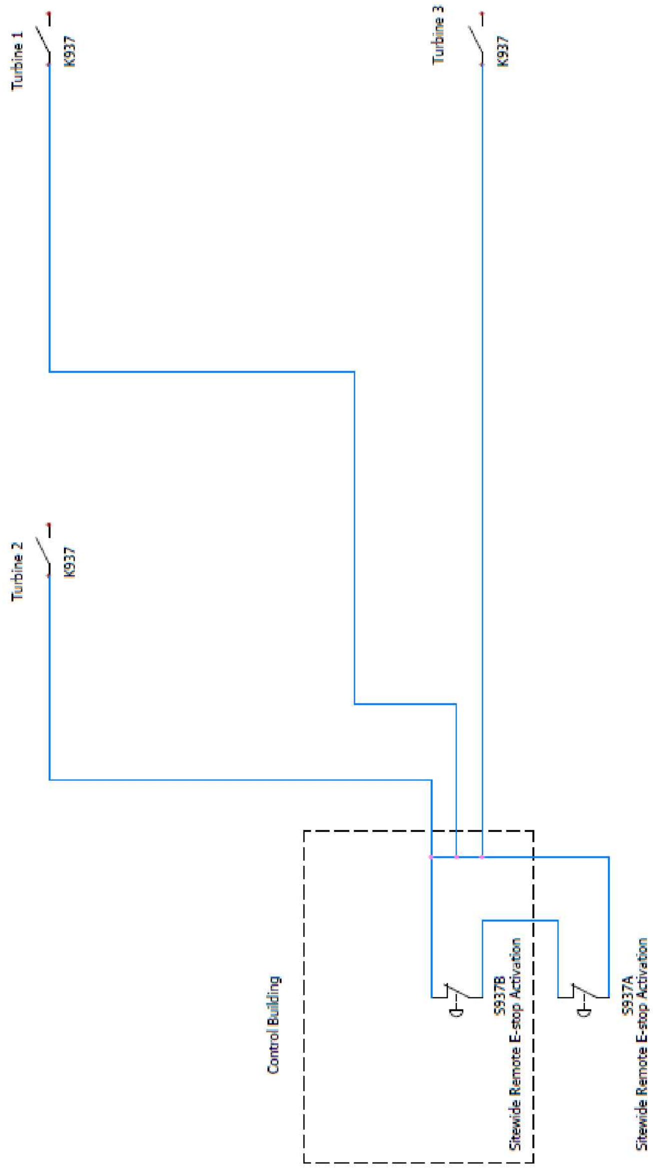


Figure 3-4. Site-wide Emergency Stop

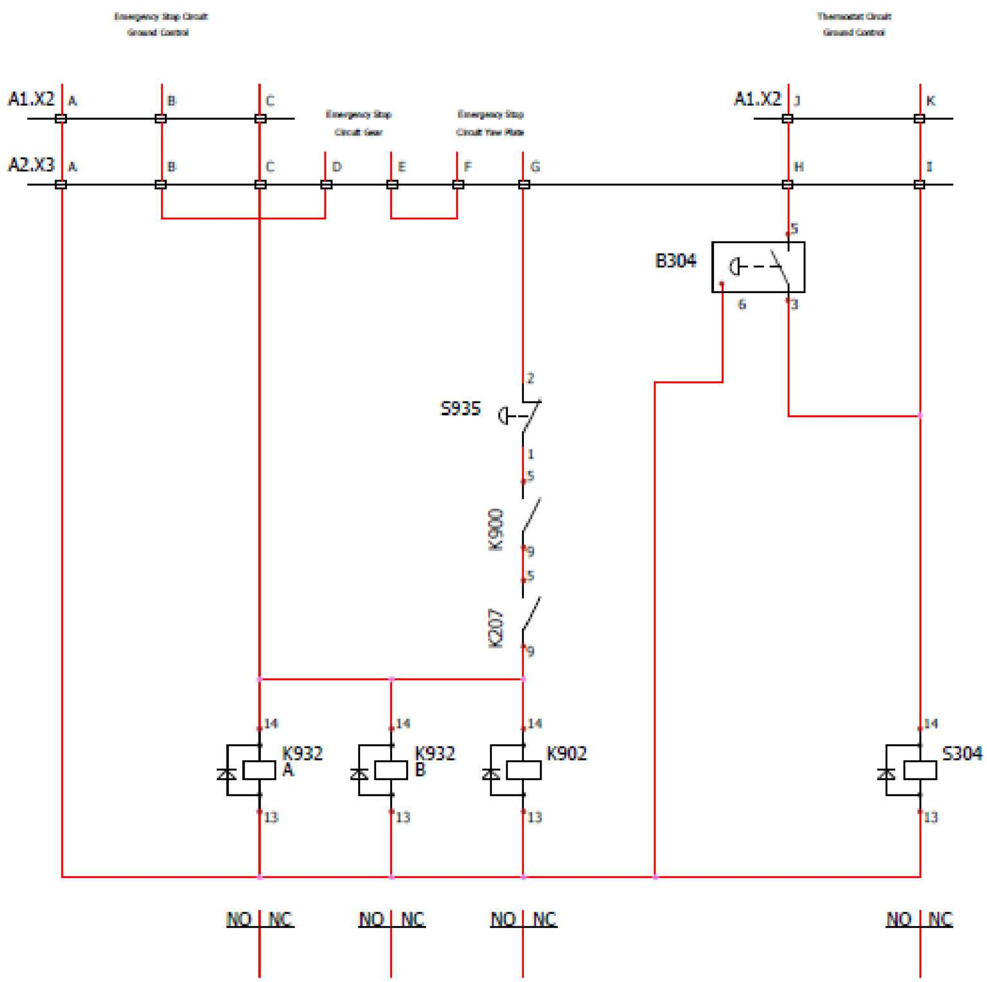


Figure 3-5. Emergency stop circuit top control

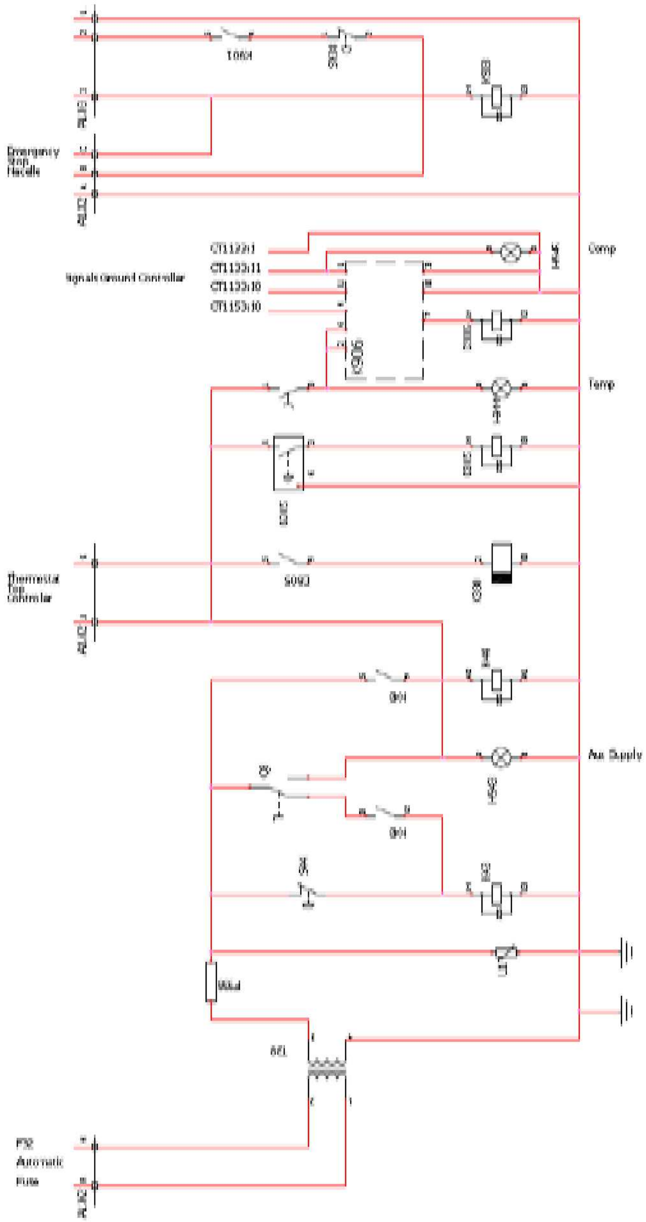


Figure 3-6. Emergency stop circuit and aux supply base control

3.3. Stop System

The Sandia SWiFT wind turbine features redundant hardware-level stop monitoring in the event the controller is not available to catch some critical faults. The stop system provides the capability of the control building, locking out yaw and pitch remotely, regardless of turbine control state. This section describes the turbine stop system.

3.3.1. Stop Systems Overview

3.3.1.1. Turbine Operating States Overview

The turbine controller is always in one of the following states:

- Run
- Pause
- Stop
- Emergency Stop

Each operating state is an activity level, where Run is the highest activity level and Emergency Stop is the lowest activity level. See Section 2.2 or a detailed description of turbine operating states.

3.3.1.2. Stop System Overview

In the turbine Stop state:

- The hydraulic brake is off
- The pitch system is bypassed mechanically by opening the full-feather solenoid valves, resulting in the turbine blades being fully feathered (turned 90º relative to wind direction)
- The hydraulic pump maintains the working pressure of 75-90 bar
- Automatic yaw is not active
- The turbine's user interface in the control building displays STOP

The stop circuit includes:

- S938 – Remote stop button
- S15 and S16 – Grid fault monitoring
- S404 – Three-axis vibration sensor
- S108 – Twist stop sensor

3.3.2. Stop System Components

3.3.2.1. Remote Stop Button (S938)

The remote stop button is located inside the control building, allowing an operator to ensure the turbine has no way of initiating yaw or pitch actions. The remote stop button should be used as a redundant safeguard during climbing and service activities.

3.3.2.2. Grid Fault Monitoring (S15 and S16)

The grid fault monitoring systems are installed in the tower base enclosure and provide independent detection of power grid availability and stability. If grid availability is lost, the grid fault monitoring initiates a turbine stop. This system's detection is independent of the detection provided by the ACS 800 system.

3.3.2.3. Three-axis Vibration Sensor (S404)

The three-axis vibration sensor monitors acceleration forces of the nacelle to detect vibration events that might damage the turbine. In large vibration events, it is best to bring the turbine to a stop state without deploying the brake, as an emergency brake stop could increase the severity of the vibrations and cause damage to the turbine.

3.3.2.4. Twist Stop Sensor (S108)

The twist stop sensor acts as a redundant mechanism for the controller-activated twist stop alarms. Using a combination of signals from the existing twist sensor (see Section 3.12), the twist stop sensor activates based on a set of signals identifying a potential over-twist scenario. The twist stop sensor can activate a turbine stop in the event the controller is not available.

3.3.2.5. Stop Relays

If remote stop is activated, the following relays will be tripped:

Stop circuit relays	
K904	Informs the turbine processor that the stop circuit is open
K922A	Breaks the voltage for the full-feather solenoid valves
K922B	Disables automatic yaw

3.3.3. Calibration & Maintenance

3.3.4. Troubleshooting

3.3.5. Spare Parts

SPARE PARTS LIST [NUMBER] – STOP SYSTEM				
POS	**PCS**	**Item No.**	**Description**	**Notes**

3.3.6. Drawings

Drawing #	Version # (date)	Description	Filename
	1.0 (9/18/15)	Stop circuit	

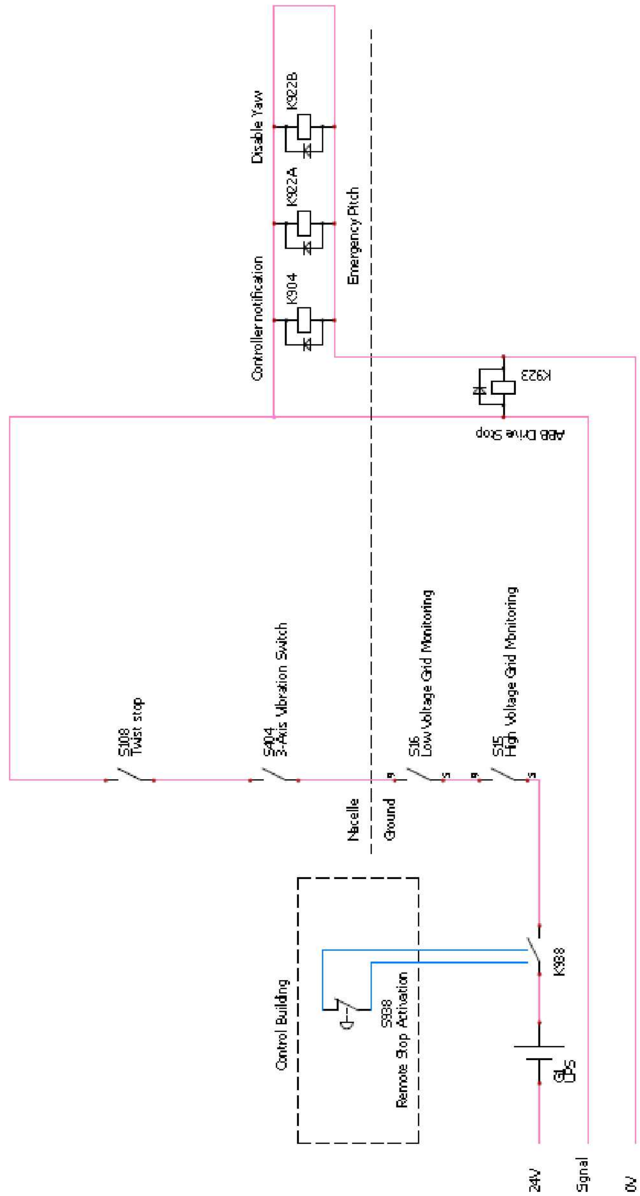


Figure 3-7. Stop circuit

3.4. Control & Communication System

All functions of the Sandia SWiFT wind turbine are monitored and controlled via a central microprocessor-based control unit located in the turbine nacelle, distributed control systems connected by an EtherCAT communication protocol, and associated software packages.

The control system comprises both hardware and software. It serves two primary functions:

- It monitors all critical functions of the turbine (e.g. rotor RPM, wind speed, power production, pitch angle, etc.) to ensure proper operation.
- Based on inputs from this monitoring, it communicates with and automatically drives subsystem actuators (pitch angle solenoid, yaw motor, hydraulic braking, etc.), based on a predefined logic, to properly control the turbine in all of its states. (These actuators are controllable through the user interface, as well.)

3.4.1. Control System Overview

The turbine control system includes the following hardware and software elements:

- A National Instruments (NI) 9082 central processor
- Three National Instruments 9444 EtherCAT expansion chassis
- Nine National Instruments I/O card types
- The National Instruments Veristand Operating System
- National Instruments LabVIEW, MathWorks Simulink, and MathWorks Stateflow software modules
- EtherCAT Scan Engine communication protocol

3.4.2. Control System Hardware Components

3.4.2.1. Processor

The turbine's central processor is a National Instruments 9082 processor based on the Intel I8 core processor. It is physically located in the nacelle electrical cabinet. The processor runs the turbine control software (referred to as "controllers," Section 3.4.3.3.) and initiates the EtherCAT communication protocol (Section 3.4.3.5.).

To execute variable-speed control of the turbine rotor and sync the power production to the grid, the processor is connected to a full-scale convertor from ABB (ACS 800) (Section 3.7).

A site-wide fiber-optic network connects the processor in each turbine with the user interface in the control building. Data gathered from the processor is stored in the site data storage system.

3.4.2.2. Expansion Chassis

In addition to the central processor, the system includes three National Instruments 9144 EtherCAT cxpansion chassis, which provide extra module slots for the processor. (See the

National Instruments 9144 data sheet.) It is necessary to distribute these chassis throughout the turbine near the locations where signals need to be acquired or transmitted. The locations of the expansion chassis are:

- Nacelle electrical cabinet (next to the central processor), to provide additional slots
- Ground electrical cabinet, for signal acquisition at the base of the turbine
- Rotor hub, for signal acquisition in the rotating reference frame

The expansion chassis have eight slots each for connecting hardware modules. Each hardware module provides a specific set of inputs and/or outputs to the turbine systems, as follows. This system of hardware modules provides the ability to easily reconfigure or expand the system, if needed.

Expansion Chassis Slot Assignments	
Nacelle	**Nacelle**
9082 (Nacelle Master)	**9144 (Nacelle Slave)**
Slot 1 – NI 9467 GPS	Slot 1 – NI 9217 RTD Analog Input
Slot 2 – NI 9217 RTD Analog Input	Slot 2 – NI 9476 Digital Output
Slot 3 – NI 9870 RS 232	Slot 3 – NI 9263 Analog Output
Slot 4 – NI 9205 Analog Input	Slot 4 – Empty
Slot 5 – NI 9425 Digital Input	Slot 5 – Empty
Slot 6 – NI 9423 Digital Input	Slot 6 – Empty
Slot 7 – Empty	Slot 7 – Empty
Slot 8 – Empty	Slot 8 – Empty
Ground	**Hub**
9144 (Ground Slave)	**9144 (Hub Slave)**
Slot 1 – NI 9425 – Digital Input	Slot 1 – Empty
Slot 2 – NI 9476 – Digital Output	Slot 2 – Empty
Slot 3 – NI 9237 – Strain	Slot 3 – Empty
Slot 4 – Empty	Slot 4 – Empty
Slot 5 – Empty	Slot 5 – Empty
Slot 6 – Empty	Slot 6 – Empty
Slot 7 – Empty	Slot 7 – Empty
Slot 8 – Empty	Slot 8 – Empty

3.4.3. Control System Software Components

3.4.3.1. Operating System

The National Instruments Veristand operating system provides real-time communication and hardware control for Sandia SWiFT wind turbines. Veristand is optimized for hardware-in-the-loop testing and fast, flexible development and deployment. It also runs a variety of controls software packages, including National Instruments LabVIEW, MathWorks Simulink, and MathWorks Stateflow.

Veristand provides the signal routing between the software modules and the system hardware. In addition, it provides hardware verification, system deployment and undeployment routines, live signal interrogation and manipulation for debugging, and other features. Refer to the National Instruments Veristand page for a full description of its capability: http://www.ni.com/veristand/.

For Sandia SWiFT wind turbines, Veristand provides external communication and control through a Gateway networked computer located in the control building. Real-time controls are being executed on the turbine’s central processor (NI 9082), which is communicating with the Gateway computer over the site-wide fiber-optic communications network.

The user interface communicates with the Gateway computer to pass commands to the turbine control system. The turbine processor continues to operate if the Gateway computer goes offline. A heartbeat signal between the user interface and the turbine processor exists to notify the processor that the user interface is no longer connected when the heartbeat stops.

3.4.3.2. Software Modules

The software modules are blocks of code that are imported into Veristand. Once imported, they act as modular pieces, with their inputs and outputs routed to the correct hardware or software signals. This system allows for subsystems of code to be isolated from each other and organized into logical blocks.

Each software module was written in the language best suited for the application. The controls, turbine state modules, and data processing were written in MathWorks Simulink and MathWorks Stateflow. The logging routines and instrument drivers were written in National Instruments LabVIEW. The turbine user interface was also written in LabVIEW but is not a module in the Veristand system.

3.4.3.3. Main Controller

Controllers are software-based subroutines that serve as the control and monitoring system logic for operation of the turbine’s various subsystems. These subroutines are collectively referred to as “controllers.” The main controller manages the turbine’s highest-level functions. Subsystem controllers are subsidiary to, and initiated by, the turbine’s main controller and are designated by the name of the subsystem they control. The turbine’s “production controller,” for example, makes decisions on whether the turbine is connected to the grid and how it controls the rotor and generator for power production while the turbine is in the Run state.

The following significant subsystem controllers/subroutines and their logic are described in more detail in Section 3.4.3.4.:

- Production Controller
- Pitch Controller
- Yaw Controller
- Hydraulics Controller
- Gear Oil Cooler Controller
- Generator Cooler Controller
- ABB Drive Controller

3.4.3.4. Subsystem Controllers

Production Controller

The turbine's production controller makes decisions on whether the turbine is connected to the grid and how it controls the rotor and generator for power production while the turbine is in the Run state.

To execute these functions, the production controller transitions between many internal states during the Run state. Figure 3-8 (Section 3.4.8.) shows the state chart for transitions of the main controller. The table below describes the various states of the main controller.

States of the Production Controller		
1	Prepare Production	Pitch blades to FreeWheelPitch to allow wind to turn the rotor and warm-up the drive train.
2	Free Wheel	Determine whether there is enough wind to try running up to minimum connection speed.
2	Free-Wheeling Timer	Allow transition to RunningUp if generator speed stays above FreeWheelMinSpeed for long enough.
3	Running Up	Regulate the generator speed, by manipulating pitch, to try to achieve the minimum speed needed, FreeWheelMaxRPM, for transition to electricity production.
4	Connecting Power	Connect to the power grid so that the generator is able to generate load-torque.
5	Powering Up	Transfer control to the production speed controllers.
6	Production	Generate electricity with normal production controls (speed-high/low override controls) operational.
7	Low-Wind Disconnect	Disconnect the generator when wind is too low for power generation.
8	Powering Down	Reduce generator speed by pitching out the blades to reduce driving torque.
9	Disconnect Power	Disconnect the generator.
10	Running Down	Pitch-out the blades to slow the rotor to idling.
11	Idle	Pitch blades to maximum.

Pitch Controller

The pitch controller is responsible for converting desired pitch velocity into voltages for the Vicker's proportional valve control card. The output voltage is between 10V and -10V (maximum positive pitch velocity and maximum negative pitch velocity, respectively).

Yaw Controller

The yaw controller activates the contactors for clockwise and counter-clockwise rotation of the nacelle. The controls are in autoyaw mode in Pause and Run. In autoyaw mode, the controller tracks the wind, keeping the rotor face within 18 degrees of the dominant wind direction. The yaw can also be controlled manually in yaw service mode, giving an operator the ability to rotate the nacelle into desired positions.

Hydraulics Controller

The hydraulics controller activates and deactivates the hydraulic pump based on current pressure in all states above E-stop. The pump is activated on pressures below 75 bar and stopped on pressures above 90 bar.

Gear Oil Cooler Controller

The gear oil cooler controller activates the gear oil cooling motor based on gear oil temperatures. If the temperature is over 60 degrees Celsius, the motor is activated. If the temperature is below 55 degrees Celsius, the motor is deactivated.

Generator Cooler Controller

The generator cooler controller activates the generator. If the max temperature is above 90 degrees Celsius, the generator cooler is activated. If the max temperature is below 75 degrees Celsius, the generator cooler is deactivated.

ABB Drive Controller

The ABB drive controller relays commands to and from the ABB drive. The state of the ABB drive is changed based on the state of the turbine through a control word. The state of the ABB drive is read through a status word. If the state of the ABB drive does not match the desired state, an error is triggered.

The ABB drive controller also relays the desired torque from the production controller as a torque command to the drive. The ABB drive controller also receives the system variables from the drive and relays them as signals in the turbine system and logging systems.

3.4.3.5. Communication Protocol

For communication between the distributed controls hardware in the turbine, an EtherCAT protocol is used. EtherCAT is an Ethernet based field-bus system, providing deterministic communication at speeds up to 1000 Hz running across regular Ethernet cabling. The EtherCAT protocol is run using the EtherCAT Scan Engine custom device in Veristand (https://decibel.ni.com/content/docs/DOC-15510).

EtherCAT communicates through a master/slave chain of nodes. The nodes are wired in series, starting with the master node residing in the turbine's central processor. The master node is in charge of initiating all the slave nodes on deployment. The communication packets are sent outbound down the chain of devices, then returned through the chain back to the master. During the passing of the packet, each node adds a timestamp along with status data. The master node optimizes the communication based on the timestamps to reduce jitter.

Additional information about National Instruments' implementation of EtherCAT for control systems can be found here: http://sine.ni.com/nips/cds/view/p/lang/en/nid/207658.

3.4.4. Error Handling

The turbine controller is always in one of the following states:

- Run
- Pause
- Stop
- Emergency Stop

Each operating state is an activity level, where Run is the highest activity level and Emergency Stop is the lowest activity level. See Volume 2, Section 2.2 for a detailed description of turbine operating states.

Error handling is a matter of lowering the activity level of the turbine depending on the error. If in a given operating state an error occurs that has specified a lower operating state, immediate change to this operating state will occur.

To describe error handling, the following concepts are used:

- Detection of errors
- Logging of errors
- Reaction to errors
- Restarts after errors

3.4.4.1. Detection of Errors

The controller is scanning the sensors to detect errors. The errors are sorted by the error handler so that the most restrictive error is passed to the turbine controller for response. Only errors that will cause a lower operation state than the actual operation state will pass.

3.4.4.2. Logging of Errors

The error handling stores errors in an operating log and in an alarm log.

3.4.4.3. Reaction to Errors

The reaction to errors is always one of the following:

- Decrease to Pause
- Decrease to Stop
- Decrease to Emergency Stop

3.4.4.4. Restart after Errors

Operating states cannot be increased until the error has been acknowledged. Depending on the type of error, acknowledgment can occur in two ways:

- Some errors may be reset from the remote control. If the operator finds it acceptable to start up the turbine, he or she can reset the error.
- Some errors are critical and cannot be reset from remote control; these errors must be reset after human inspection of the turbine.

To describe the operational safety strategy and error handling for each error type that can occur, we define the following information for each error:

- **Log Detection Reaction** - Name of the error
- **Detection** - Description of how the error is detected
- **Reaction** - The maximum activity level when the error is present and not reset
- **Receipt** - The error can be reset through the user interface or manually on the turbine

See Appendix A for the error lookup table, which turbine operators use to determine these responses to errors.

3.4.5. Calibration & Maintenance

3.4.6. Troubleshooting

3.4.7. Spare Parts

SPARE PARTS LIST [NUMBER] – CONTROL & COMMUNICATION SYSTEM				
POS	**PCS**	**Item No.**	**Description**	**Notes**

3.4.8. Drawings

Drawing #	Version # (date)	Description	Filename
	1.0 (9/18/15)	Production state control	
	1.0 (9/18/15)	Communications network	
	1.0 (9/18/15)	Control Master Slot 1	
	1.0 (9/18/15)	Control Master Slot 2	
	1.0 (9/18/15)	Control Master Slot 3	
	1.0 (9/18/15)	Control Master Slot 4	
	1.0 (9/18/15)	Control Master Slot 5	
	1.0 (9/18/15)	Nacelle Slave Slot 2	
	1.0 (9/18/15)	Control Master Slot 6	
	1.0 (9/18/15)	Nacelle Slave Slot 3	

	1.0 (9/18/15)	Nacelle Slave Slot 1	
	1.0 (9/18/15)	Ground Slave Slot 1	
	1.0 (9/18/15)	Ground Slave Slot 2	
	1.0 (9/18/15)	Ground Slave Slot 3	
	1.0 (9/18/15)	Top Controller External Connections 1	
	1.0 (9/18/15)	Top Controller External Connections 2	
	1.0 (9/18/15)	Top Controller External Connections 3	
	1.0 (9/18/15)	Top Controller External Connections 4	

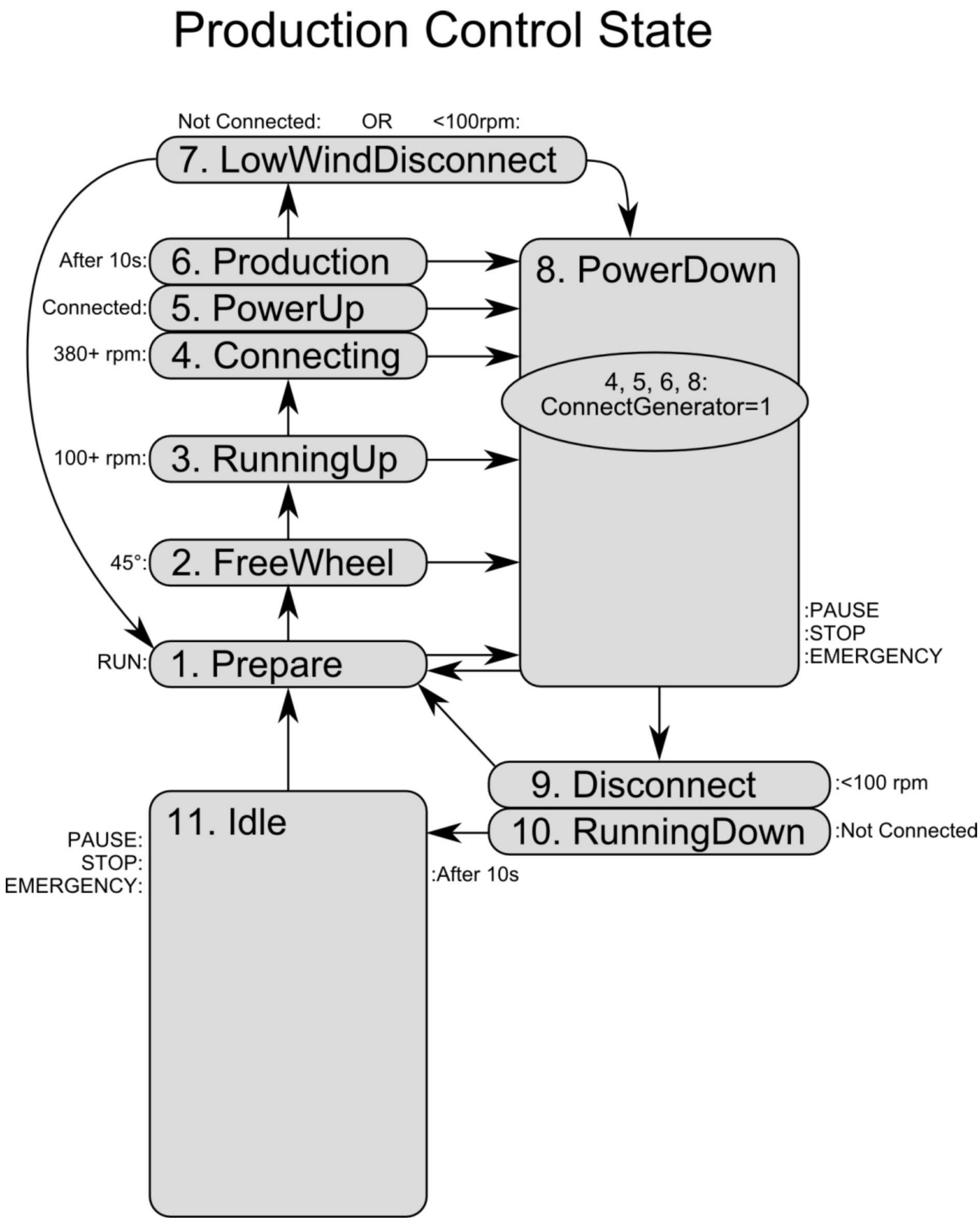


Figure 3-8. State chart showing transitions of the production controller

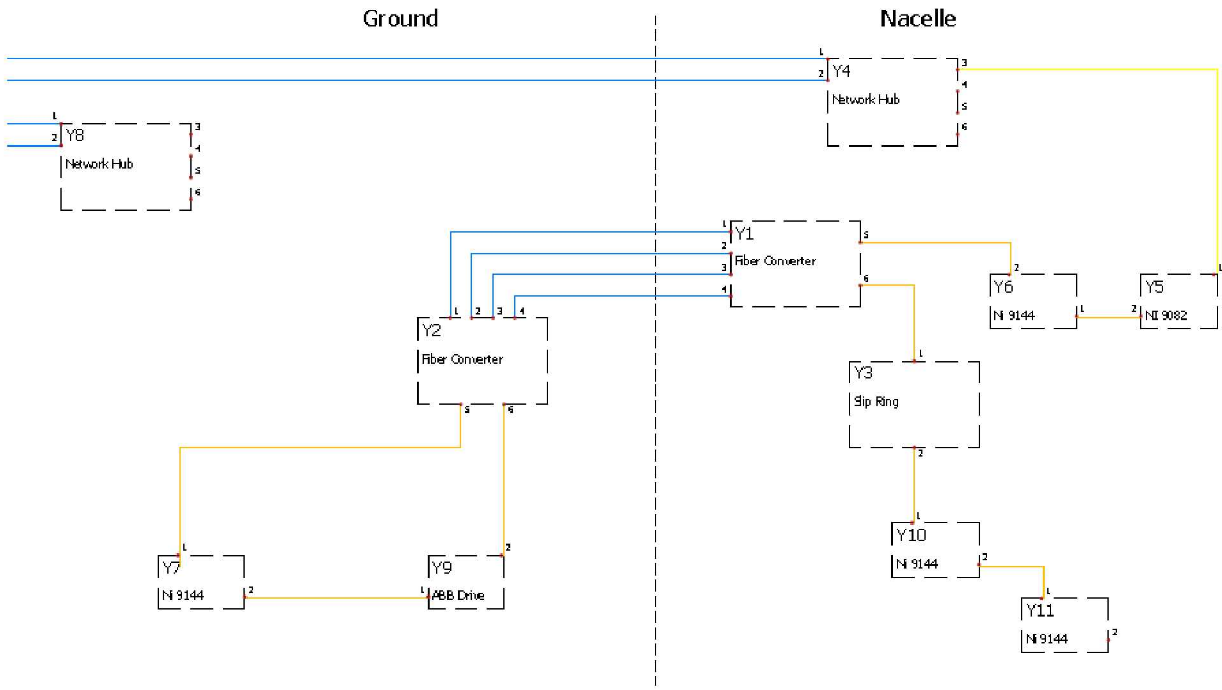


Figure 3-9. Communication Network

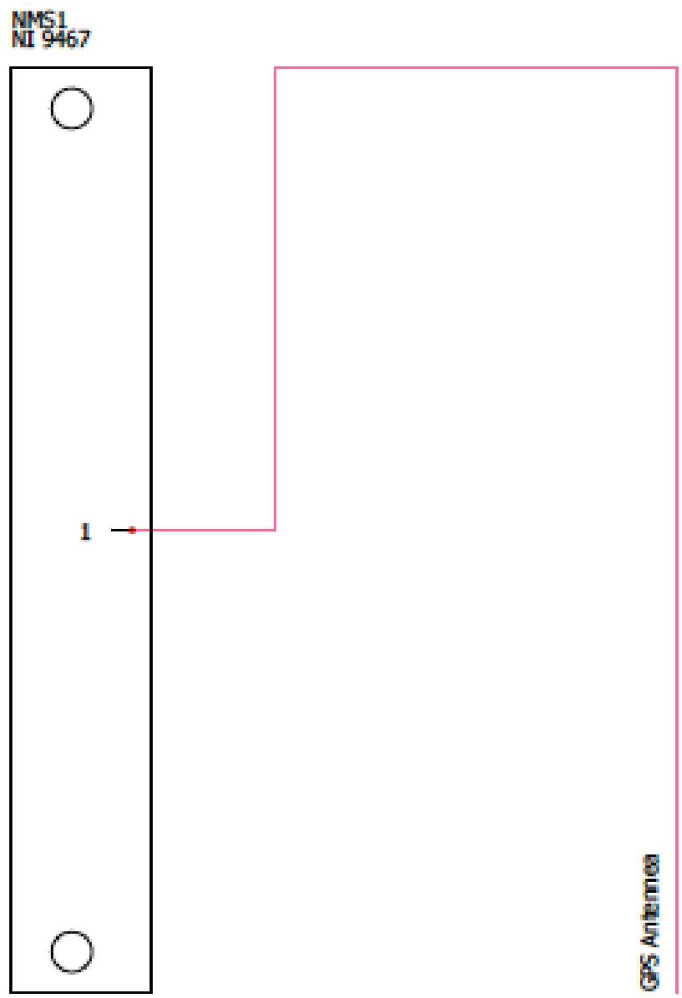


Figure 3-10. Control Master Slot 1

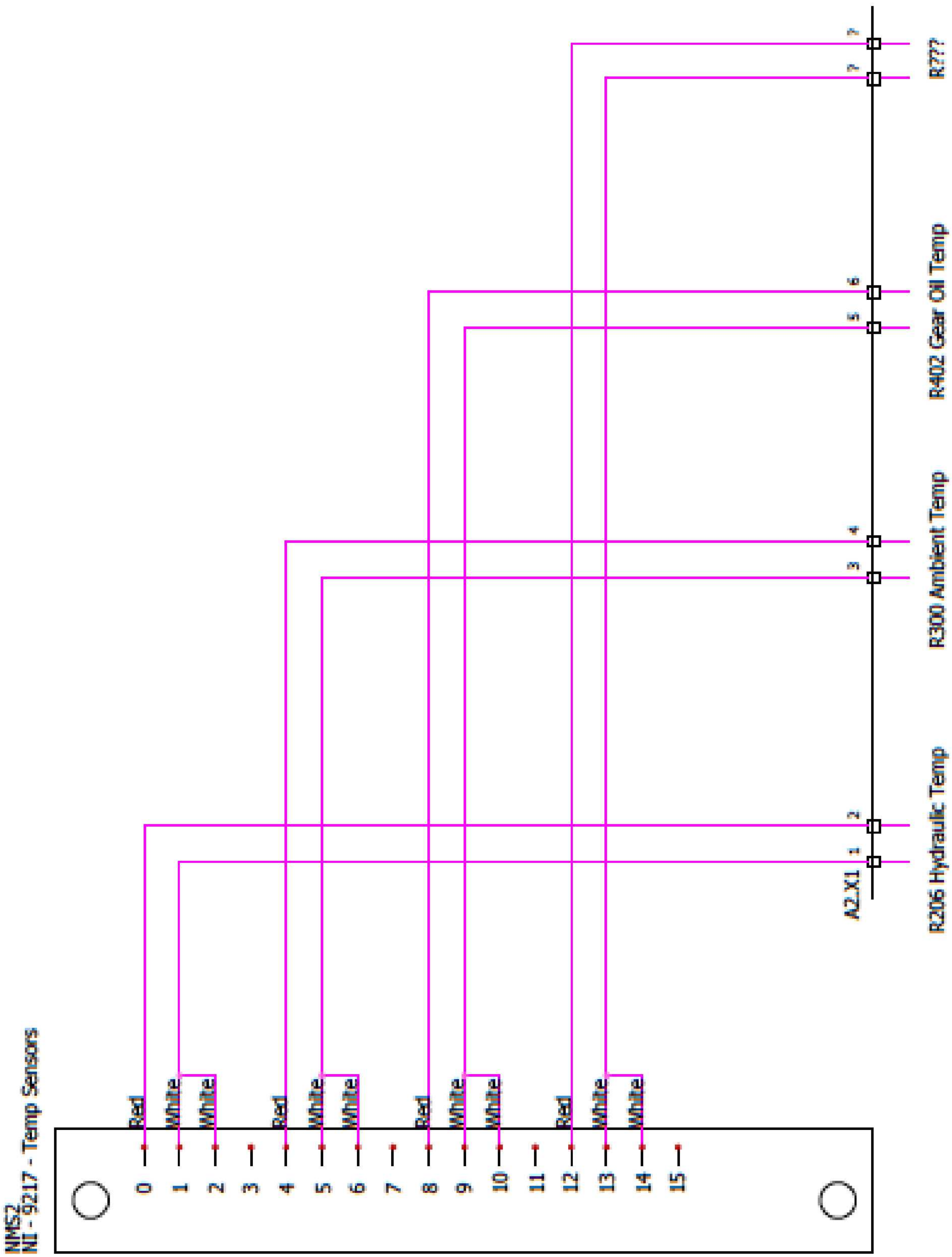


Figure 3-11. Control Master Slot 2

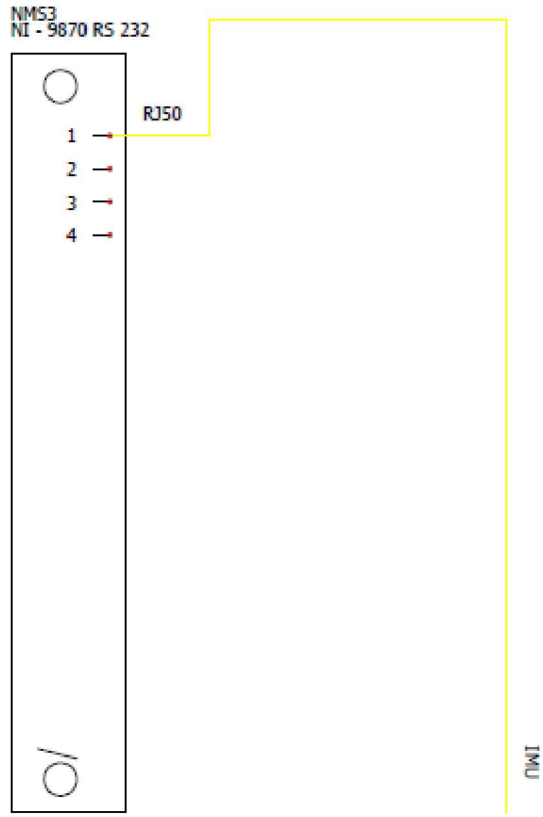


Figure 3-12. Control Master Slot 3

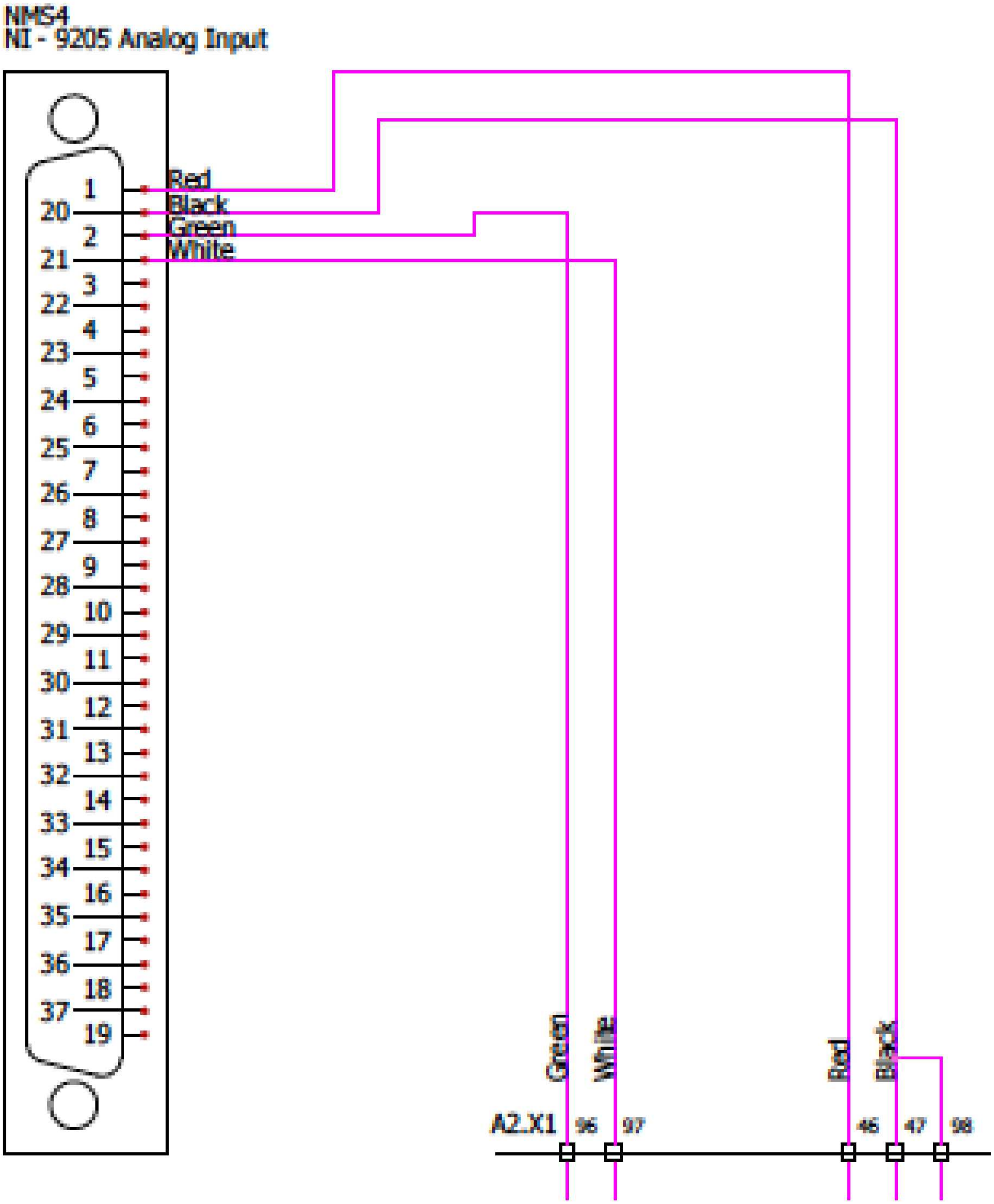


Figure 3-13. Control Master Slot 4

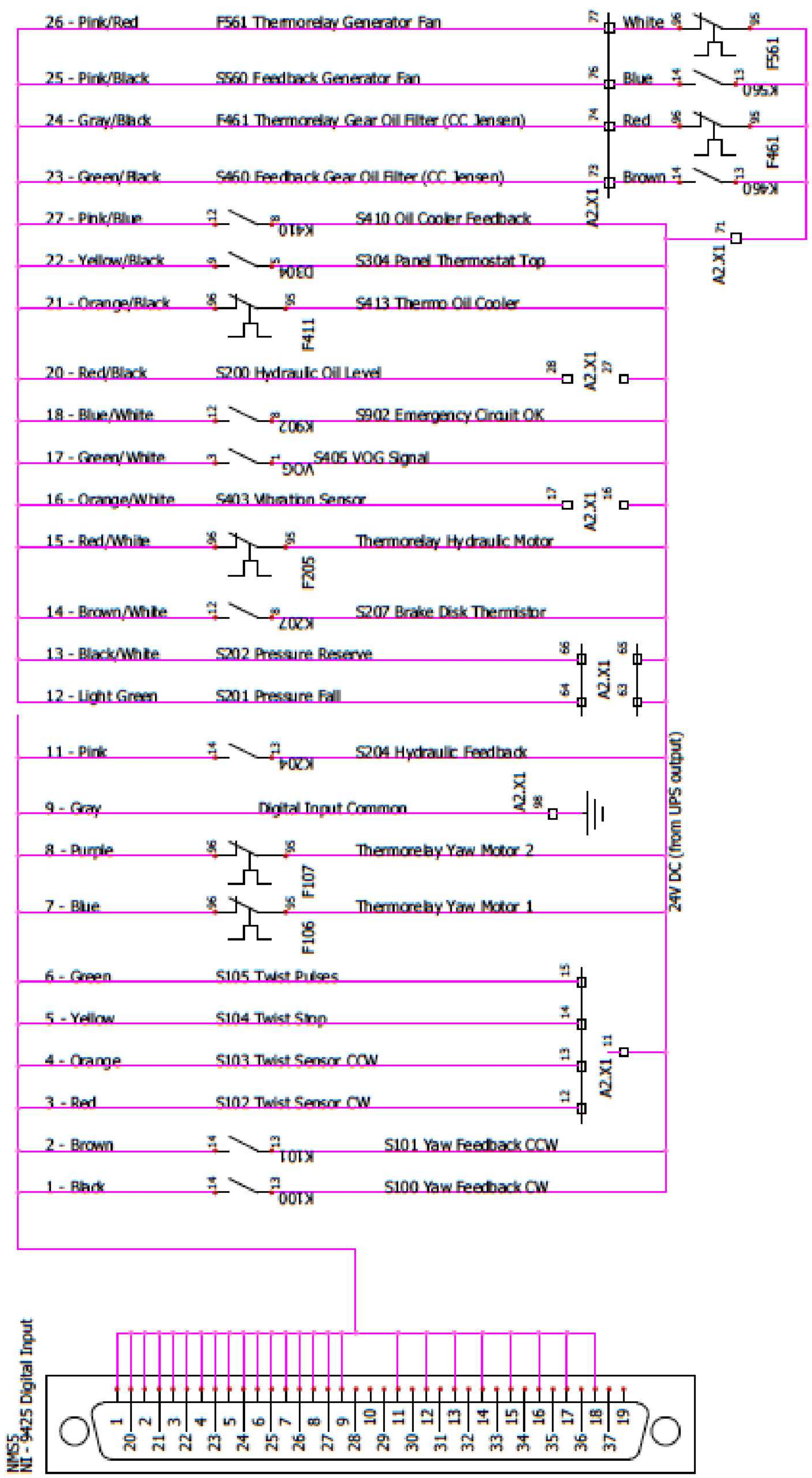


Figure 3-14. Control Master Slot 5

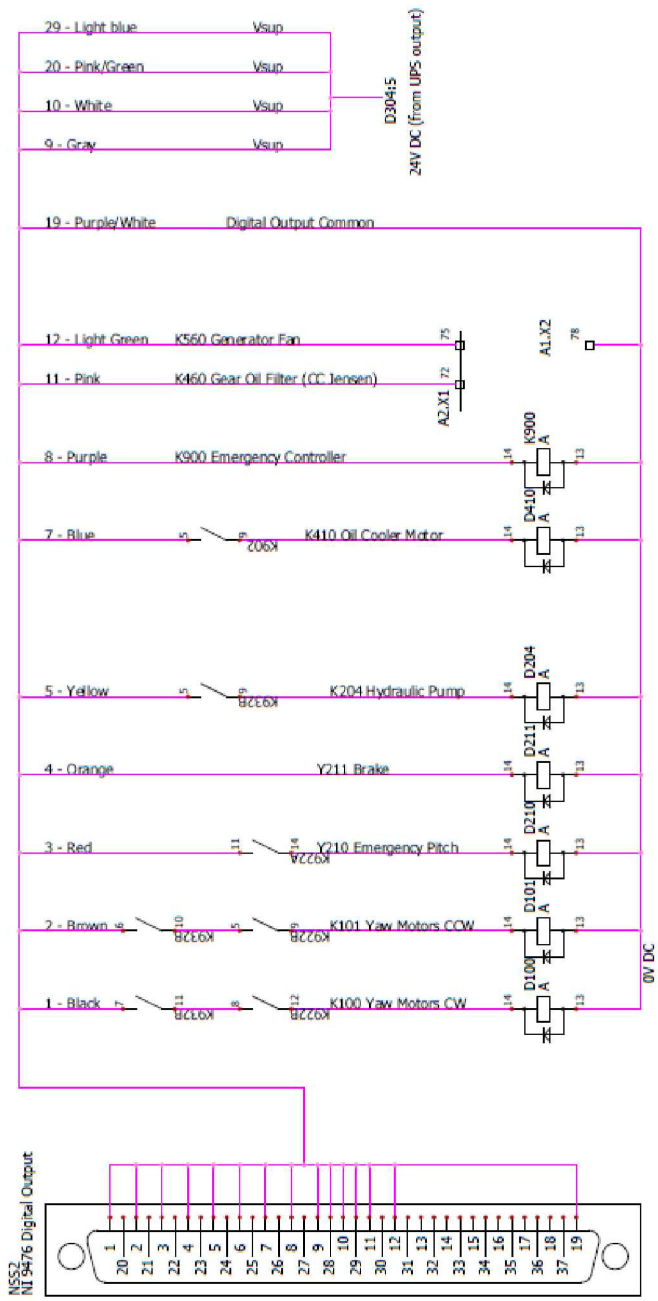


Figure 3-15. Nacelle Slave Slot 2

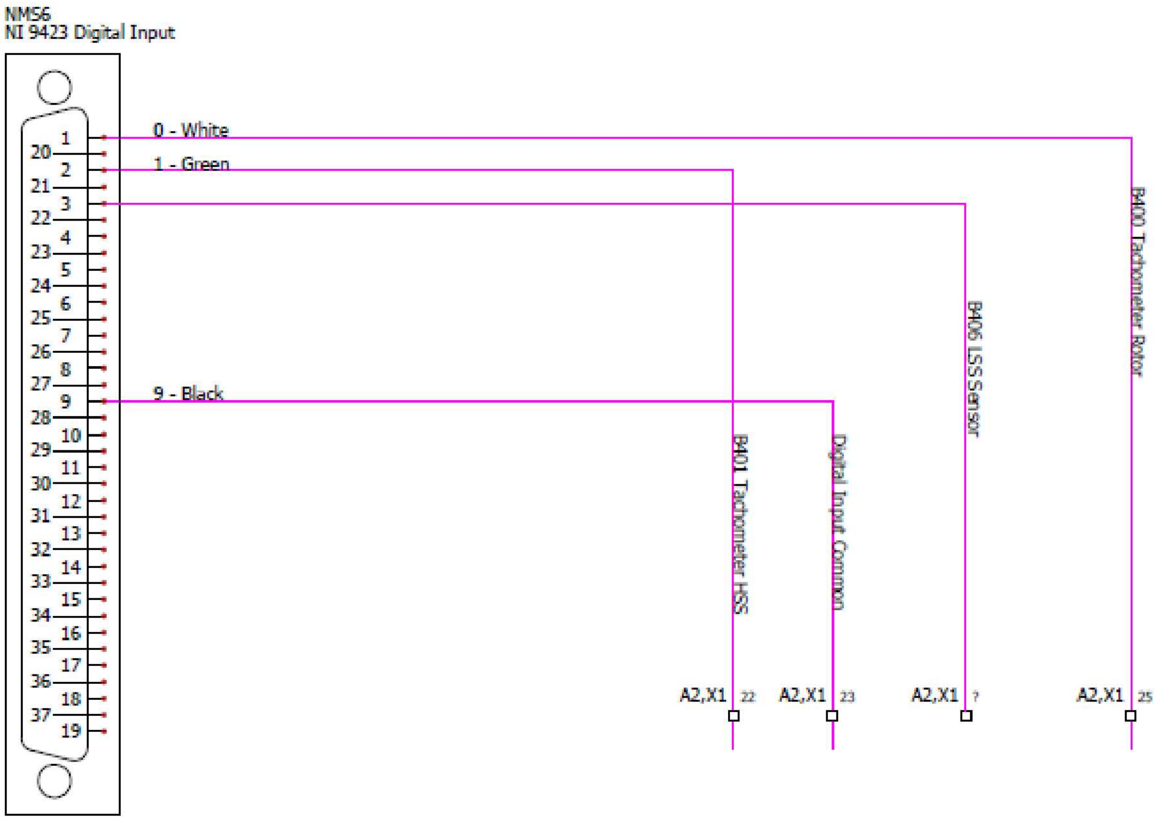


Figure 3-16. Control Master Slot 6

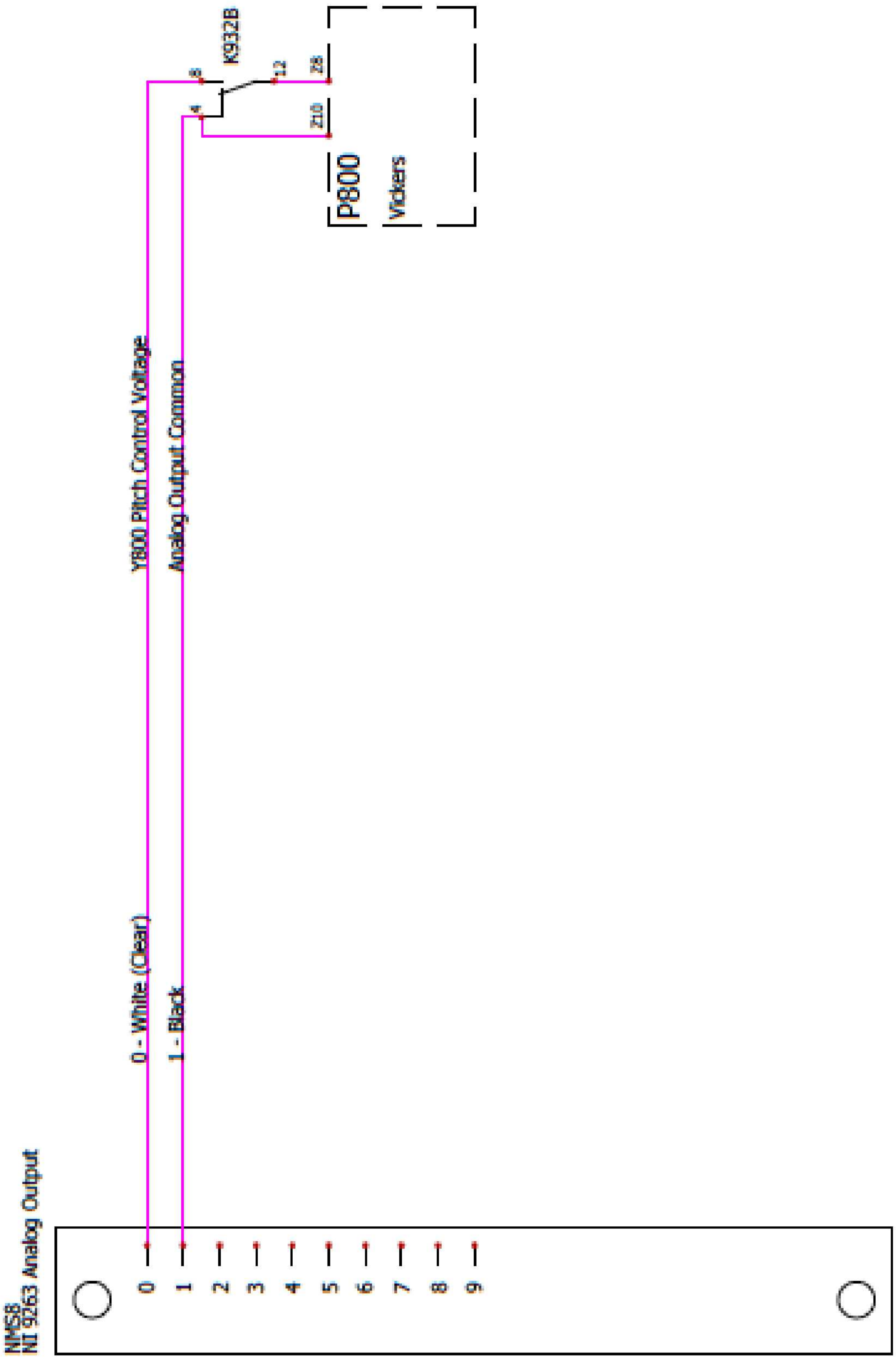


Figure 3-17. Nacelle Slave Slot 3

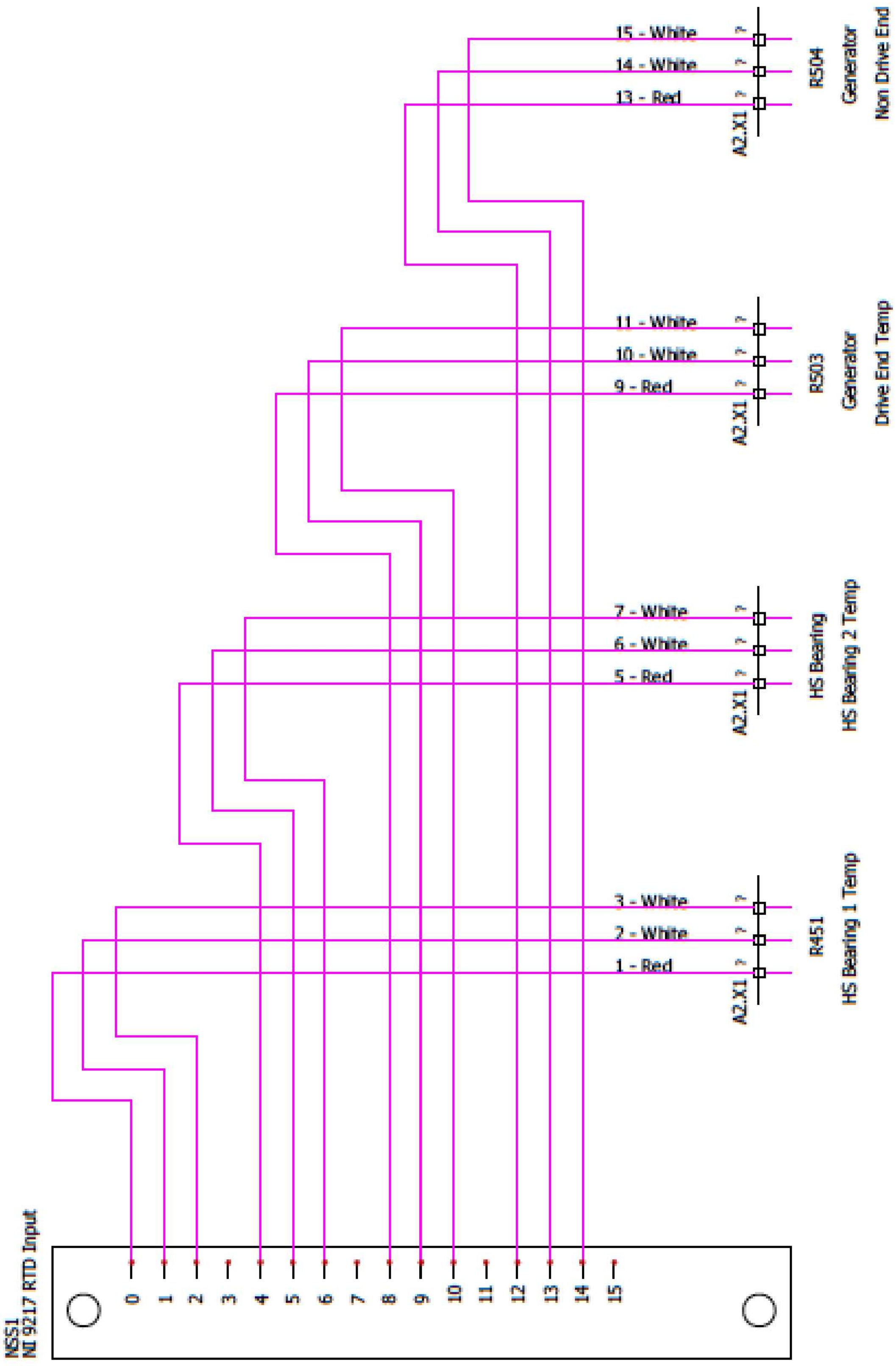


Figure 3-18. Nacelle Slave Slot 1

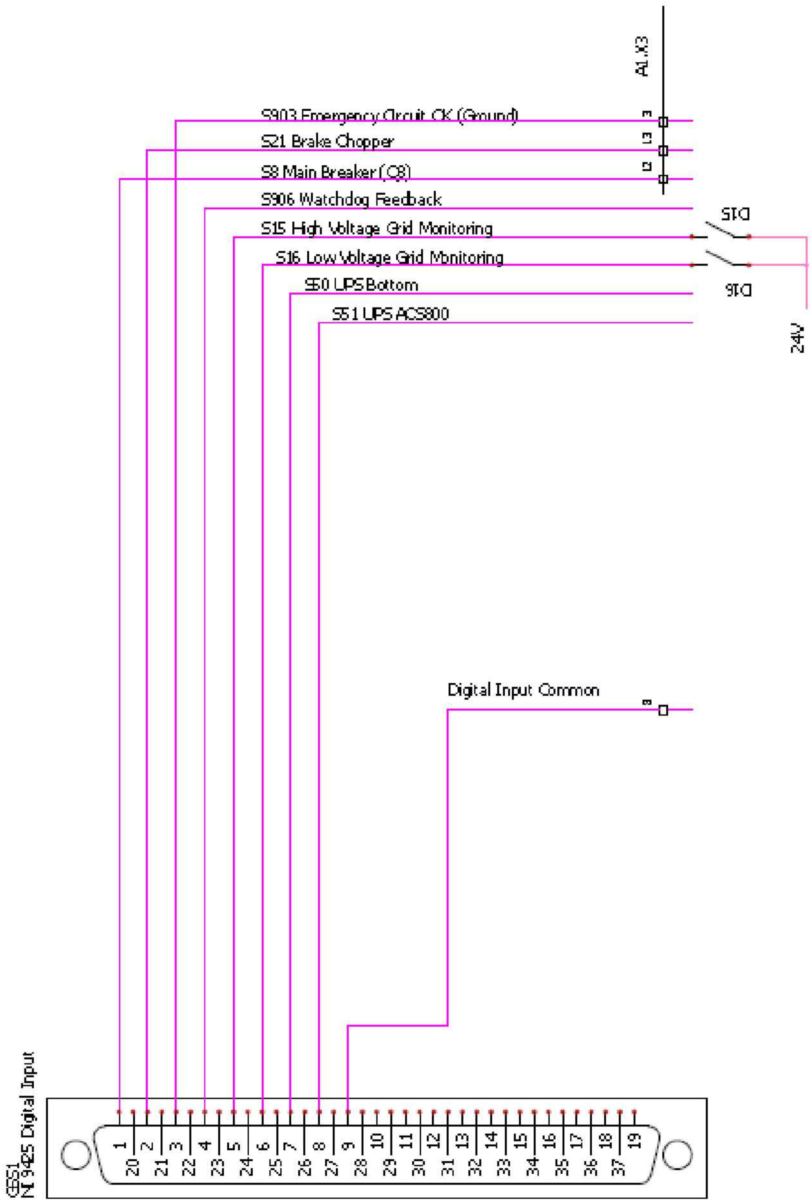


Figure 3-19. Ground Slave Slot 1

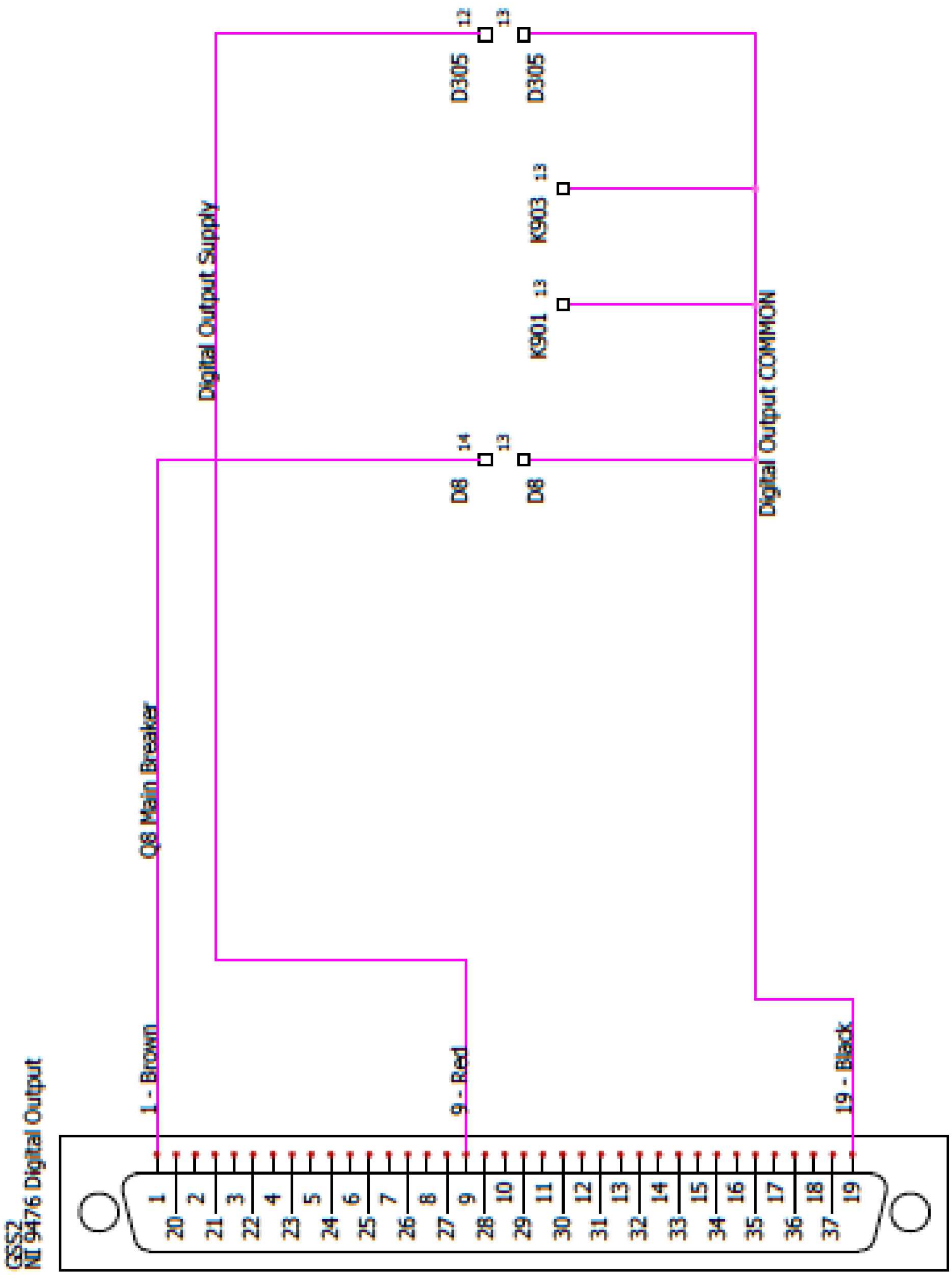


Figure 3-20. Ground Slave Slot 2

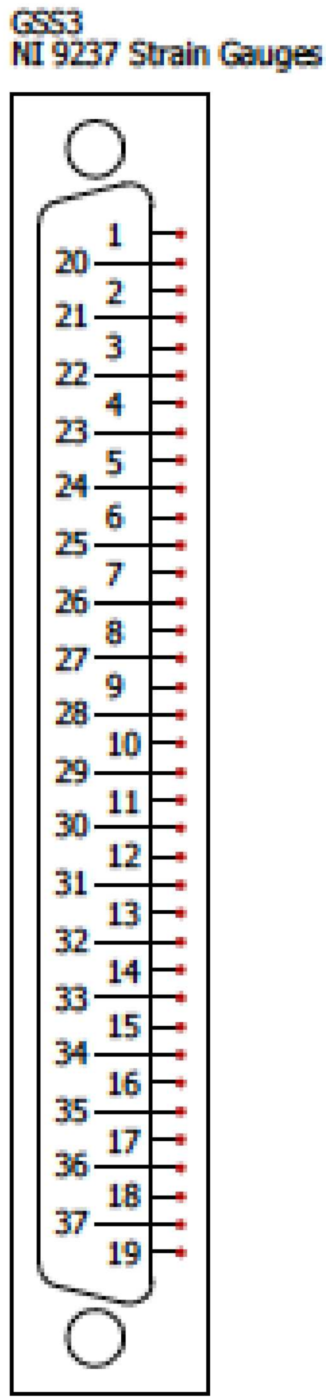


Figure 3-21. Ground Slave Slot 3

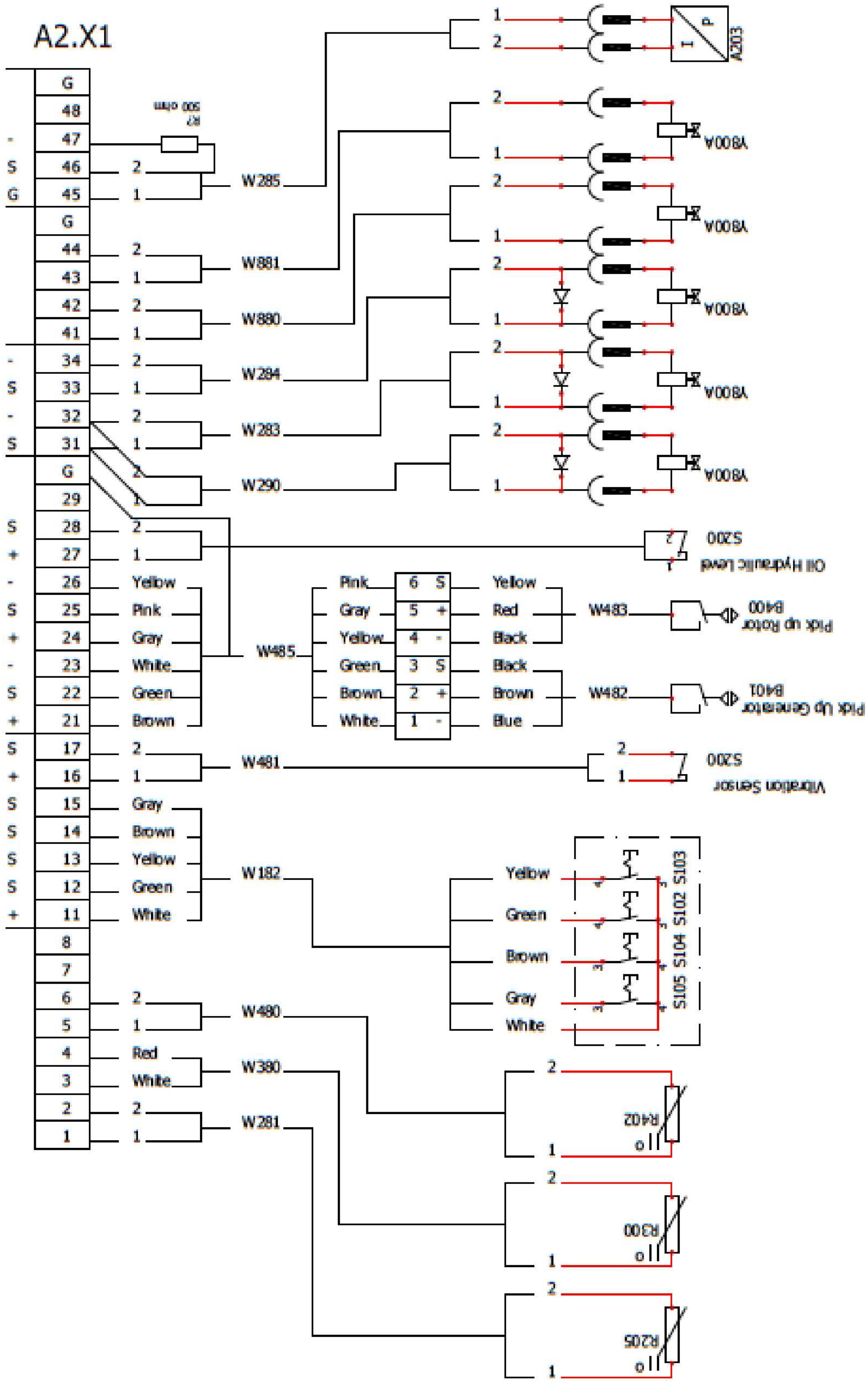


Figure 3-22. Top Controller External Connections 1

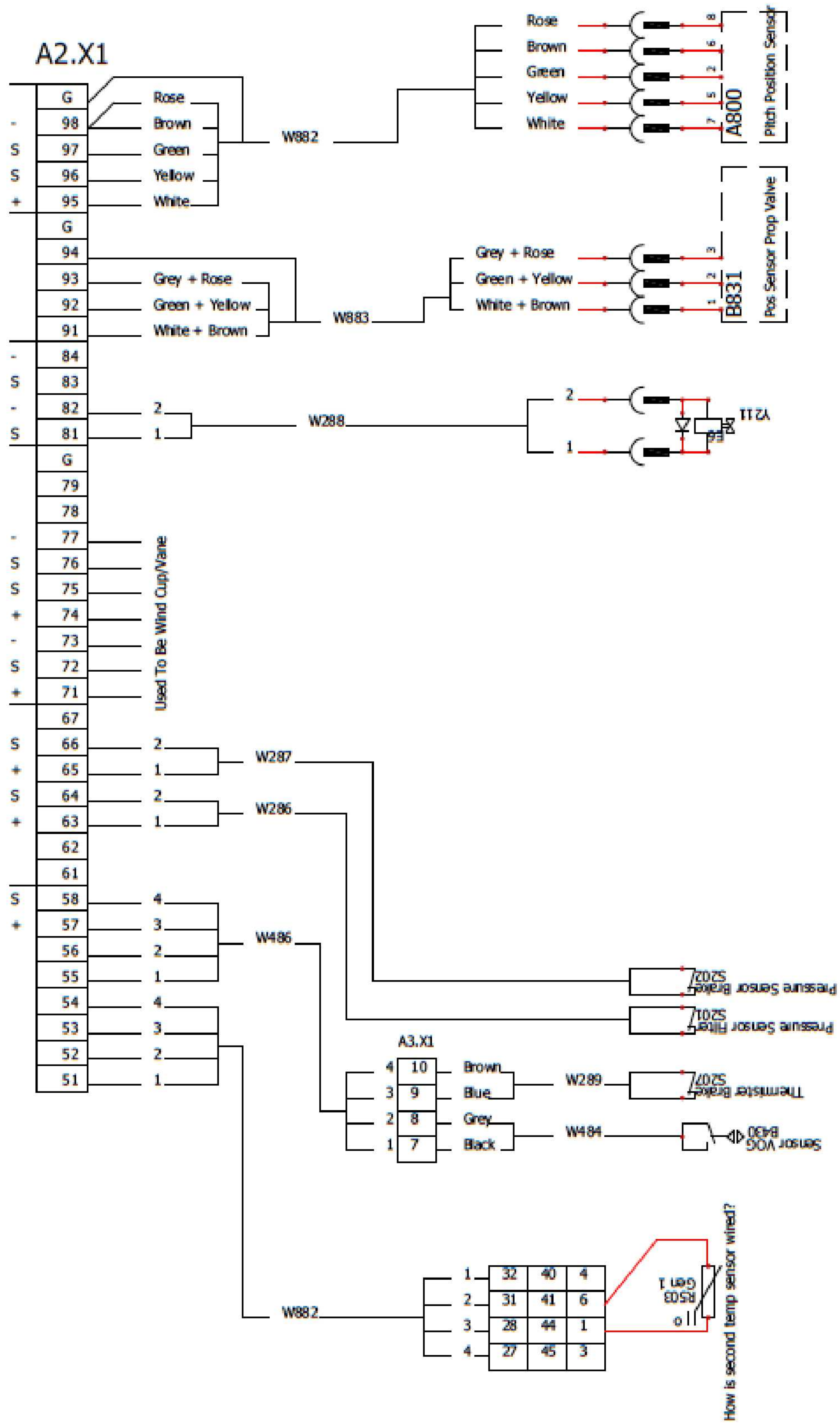


Figure 3-23. Top Controller External Connections 2

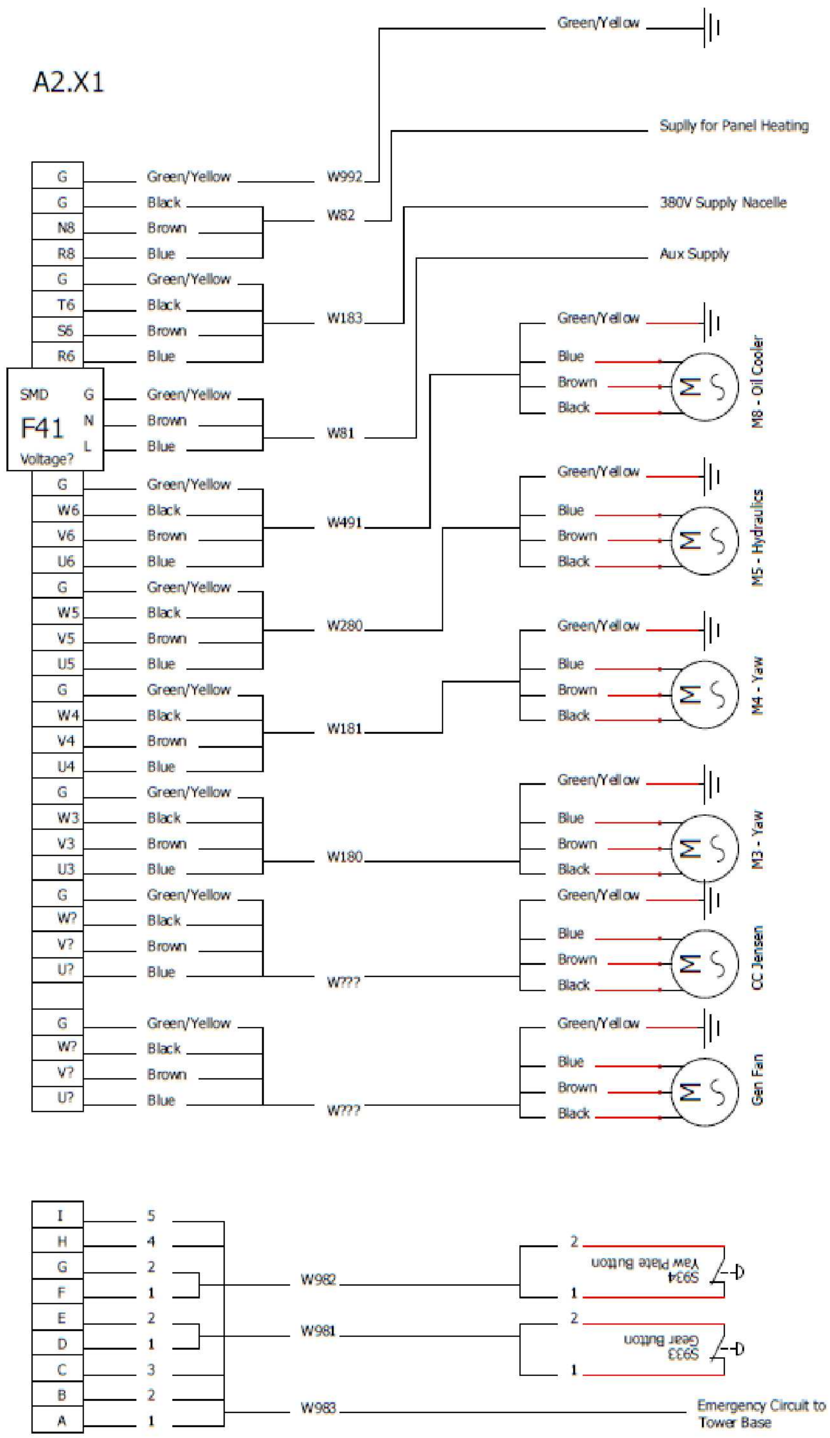


Figure 3-24. Top Controller External Connections 4

3.5. Grid Interconnect

Each SWiFT wind turbine's generator is connected to the grid through a series of power transmission components. The outermost, grid-facing component is the grid interconnect. The grid interconnect is a disconnect relay managed by the power company. It is connected via underground high voltage power lines to pad-mounted transformers at the base of each of the SWiFT wind turbines.

3.5.1. Grid Interconnect Overview

The grid interconnect comprises an overhead, three-phase line recloser, a station class arrester, and revenue meter. South Plains Electric Cooperative (SPEC) has remote access to operate the line recloser and reads the meter to track net power production.

3.5.2. Grid Interface Components

- Overhead three-phase line recloser
- Station class arrester (8.4 kV MCOV)
- Primary revenue meter

3.5.3. Calibration & Maintenance

All grid interconnect components are operated and maintained by SPEC.

3.5.4. Troubleshooting

All grid interconnect components are operated and maintained by SPEC.

3.5.5. Spare Parts

SPARE PARTS LIST [NUMBER] – EMERGENCY STOP SYSTEM				
POS	**Item No.**	**Description**	**Type**	**Manufacturer**
Q8	117023	Main circuit breaker	SACE SH630, R400	ABB
S8		Feedback, main circuit breaker (Q8)		
D8		Aux. relay trip main circuit breaker Q8	RY2S-U-DC24, 24VDC	Idec
F9-11	188516	Overvoltage protection	VM360FM	Desitek
F12-14	188562	Fuses for F9-11	63A, DIN00	Lindner
U15		Grid Feeding Monitoring Relay	CM-UFD.M33	ABB
D15		Aux. relay grid monitoring relay	RY2S-U-DC24, 24VDC	Idec
S15		Feedback, grid monitoring relay		
U16		Grid Feeding Monitoring Relay	VMD420	Bender
D16		Aux. relay grid monitoring relay	RY2S-U-DC24, 24VDC	Idec
S16		Feedback, grid monitoring relay		
F17		Fuse block for U15 and U16	1492-FB3C30	Allen-Bradley
U20		Variable frequency drive	ACS800-17-0400	ABB
U21		Brake chopper controller	NBBM-V460-A600	ABB/PowerOhm
U22		Brake chopper resistor	ABB-48431-424	ABB/PowerOhm
F30	117023	Circuit breaker aux. supply	SACE SH125, R32	ABB

F31	116562	Automatic fuse, light/socket top	STOTZ S261 B10	ABB
F32	116561	Automatic fuse, aux. supply	STOTZ S222 K2	ABB
F33a		Automatic fuse, yaw		
F33b		Automatic fuse: hydr, fans, filter		
F34	116565	Automatic fuse, voltage measuring	STOTZ S223 K0.5	ABB
F35	116615	Automatic fuse, contactor coils	STOTZ S261 B10	ABB
F36	116615	Automatic fuse, computer supply	STOTZ S261 B10	ABB
F37	116615	Automatic fuse, space heating	STOTZ S261 B10	ABB
		24V supply		
F40	188522	Varistor	SMD 220-10	Dan Delektron
F41	188522	Varistor	SMD 220-10	Dan Delektron ApS
K43	116253	Relay, supply control voltage	Izumi RH 1B-U, 24V	Brodersen
K44	93325	Contactor, supp. control voltage	BO 9-30-10/24 VDC	ABB
L45	116825	Choke coil	D-F2-11/3.5	A. Akerman
S44	117005	Service button panel switch box	AL 2 HM1L	Brodersen
S50		UPS Status, bottom		
S51		UPS Status, ABB logic		
S52		UPS Status, top		
S53		UPS Status, rotor		
W81	836801	Supply cable, control current	H07RN-F, 4x1.5mm^2	AEG
W82	836805	Supply cable, space heating top	H07RN-F, 4x1.5mm^2	AEG
W83	836788	Supply cable, light/socket top	H07RN-F, 4x1.5mm^2	AEG

3.5.6. Drawings

Drawing #	Version # (date)	Description	Filename
		Reference-stamped engineering drawing from Baker Electrical	

3.6. Turbine Transformer

Each SWiFT wind turbine features a ground-pad mounted 500 kVA transformer at its base that connects the turbine power production system to the grid interconnect via underground high voltage power line.

3.6.1. Transformer Overview

Each turbine is connected to a single pad-mounted transformer at its base. The transformers are connected to a pass-through system to connect all three to the collection grid. A 300A switch between each transformer and the collection grid isolates each turbine from the collection grid. There is also a 200A load break on each leg of the collection grid.

3.6.2. Transformer Components

- Pad-mounted GSU transformer (300 kVA, 12.47kV : 277/480 v loop fed)
- 300A switch
- 200A Load Break

3.6.3. Calibration & Maintenance

3.6.4. Troubleshooting

3.6.5. Spare Parts

SPARE PARTS LIST [NUMBER] – TOWER CABLES				
POS	**PCS**	**Item No.**	**Description**	**Notes**

3.6.6. Drawings

Drawing #	Version # (date)	Description	Filename

3.7. Full-scale Converter (ABB Drive Unit)

The full-scale converter added to the SWiFT wind turbines separates the generator frequency from the grid frequency, allowing the turbine generator to vary its speed to optimize production. Variable-speed operation is a key attribute for conducting rotor and wake research at SWiFT.

3.7.1. Full-Scale Converter Overview

A full-scale convertor from ABB (the ACS 800, a.k.a. ABB drive unit) at the base of each turbine tower is used in coordination with the turbine production controller (Section 3.4.) to actively sync the current frequency provided by the turbine's generator to that of the grid. (It replaces the duties of the power correction and thyristors in the legacy Vestas turbine.) The full-scale converter communicates with the controller over the EtherCAT communication chain (Section 3.4.).

The controller sends state change and torque control signals to the converter, commanding it to increase or decrease its state in coordination with the turbine state. The converter returns its current command state and generator status signals (torque, RPM, etc.) to the controller over the EtherCAT. The converter has its own internal set of alarms and warnings, which also are communicated back to the controller.

Full details on the capabilities of the ABB drive can be found in the manufacturer data sheet.

3.7.2. Full-Scale Converter Components

3.7.2.1. ABB ACS 800 Drive

See manufacturer data sheet.

3.7.2.2. EtherCat Communications Module

See manufacturer data sheet.

3.7.2.3. External Brake Chopper and Resistor Bank

See manufacturer data sheet.

3.7.3. Calibration & Maintenance

See the ABB ACS 800 manual.

3.7.4. Troubleshooting

See the ABB ACS 800 manual.

3.7.5. Spare Parts

See the ABB ACS 800 manual.

3.7.6. Drawings

See the ABB ACS 800 manual.

3.8. Tower Cables

Six cables hang from a high voltage terminal connection box mounted to the generator (Section 3.9) to the bottom of the tower, where they connect to the full-scale converter (Section 3.7). Because the generator is mounted inside the nacelle, the cables twist as the nacelle yaws. See Sections 3.4 and 3.12 for details about the turbine's cabling twist sensors and automatic yaw control.

3.8.1. Tower Cables Overview

The six tower cables connect at the generator end (top) by means of a high voltage terminal connection box and at the full-scale converter end (bottom) directly to the high voltage bus bar. This section describes the terminations/connectors, cable shielding, and cable bundling and fastening.

3.8.2. Tower Cable Components

3.8.2.1. Top Cable Termination/Connections

A custom three-phase junction box (pictured in Figure 3-25 below) is mounted to the generator for tower cable connections into the generator. Four conductors per phase connect into the generator. The low voltage connections are for the two resistance temperature detectors (RTDs) in the generator.

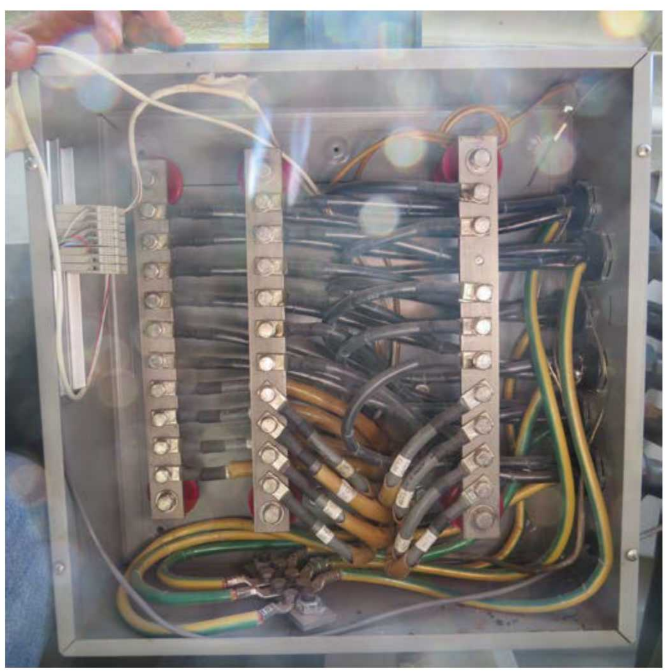


Figure 3-25. Generator-mounted junction box

3.8.2.2. Bottom Cable Termination/Connections

Six conductors per phase connect into the ABB drive junction box at the bottom of the tower. The ABB Drive features standard bus bars for mounting all six conductors and the ground wire. Shielding on the down-tower cables are grounded at the ground bar at the bottom of the junction box enclosure. There is not currently an image depicting these connections.

3.8.2.3. Cable Construction Specs

Conductor: Flexible red copper conductor Cl. 5, acc. to IEC 60228, DIN VDE 0295
Insulation: Special PVC/Nylon compound
Cores color: Four conductors (black conductors and green/yellow) or 3 black conductors + 3 earth conductors
Stranding: In layers
Screen: Aluminum tape + PETP foil and tinned copper braid + tinned copper drain wire
Ripcord: High strength ripcord under outer sheath
Outer Sheath: Black (similar RAL 9005), special PVC compound

3.8.2.4. Cable Tech Specs

Nominal voltage UL: 1000 V
Fixed laying: - 25 C up to + 90 C
Flexible installation: - 25 C up to + 90 C
Min. bending radius: 6 x D

3.8.3. Calibration & Maintenance

The tower cables should be inspected for fatigue, cracking, or fraying at regular inspection intervals. See Section 4.21.

3.8.4. Troubleshooting

3.8.5. Spare Parts

SPARE PARTS LIST [NUMBER] – TOWER CABLES				
POS	**PCS**	**Item No.**	**Description**	**Notes**

3.8.6. Drawings

Drawing #	Version # (date)	Description	Filename

3.9. Generator

Each SWiFT wind turbine is equipped with a three-phase, variable-speed, 60 Hz, 400 HP asynchronous generator directly connected to the grid through the tower cables (Section 3.8.), full-scale converter (Section 3.7.), transformer (Section 3.6.), and grid interconnect (Section 3.5.).

Mechanical energy from the turbine's blade-rotor assembly is transmitted into the generator through a two-stage gearbox (Section 3.10.). A 1775 rpm high speed shaft into the generator drives current production.

3.9.1. Generator Overview

The generator assembly includes the following electrical components:

- Three-phase variable-speed asynchronous generator
- Blower motor
- High voltage terminal connection box

3.9.2. Generator Components

3.9.2.1. Generator

BALDOR·RELIANCE Product Information Packet: IDDRPM364004 - 400HP,1775RPM,3PH,60HZ,L3614,DPG-FV,FOOT

Part Detail			
Model Number:	IDDRPM364004	**Environment:**	General Purpose
Voltage:	460	**HP:**	400
RPM:	1775/2400	**Efficiency:**	NA
Phase:	3	**Frequency:**	N/A
Inverter Duty:	Y	**Enclosure:**	DPG-FV
Frame Group:	360	**Frame Size:**	L3614
Features:	RPM AC	**Mounting:**	Foot Mounted
Service Factor:	1	**Enclosure Group:**	DPG-FV
Weight:	0	**Price Symbol:**	E2
Speed Range:		**Insulation Class:**	H
Nema Design:	A	**Encl. Enhancement:**	
Catalog Page:	M-217,	**Dimension Sheet:**	609998-1
Connection Diagram:	422927-1	**Electric Design:**	L0809A
Single HP:	400	**Get Notes:**	RPM AC
Revision:		**Instruction Manual:**	B-3682
Application:	Variable Speed-V*S	**Epact:**	Y
Scaled Drawing:		**Obsolete:**	N
Last Data Source:	RGG,MADD	**Bearing Type:**	
Electrical Type:		**Mounting Pos.:**	
Ambient:	40	**Duty:**	
Amps:		**Nominal Eff.:**	
Kva Code:		**Power Factor:**	
Poles:	00	**Literature:**	

3.9.2.2. Blower Motor

A fan blower cools the generator.

3.9.3. Calibration & Maintenance

3.9.4. Troubleshooting

3.9.5. Spare Parts

SPARE PARTS LIST [NUMBER] – GENERATOR				
POS	**PCS**	**Item No.**	**Description**	**Notes**

3.9.6. Drawings

Drawing #	**Version # (date)**	**Description**	**Filename**

3.10. Rotation System

The SWiFT wind turbine rotation system includes all rotating components, from the blade-rotor assembly to the high speed shaft that enters the generator (Section 3.9.). The rotation system includes sensors and active monitoring systems critical for turbine safety and proper operation, as well as a blade pitch control system (Section 3.11.) that actively positions the blades for optimum wind energy capture.

3.10.1. Rotation System Overview

The rotation system includes the following components associated with control and monitoring:

- Shaft bearing temperature sensors
- Gear oil cooling system
- Rotation speed control systems

3.10.2. Rotation System Components

3.10.2.1. Shaft Bearing Temperature Sensors

Two temperature sensors, one on each of the high speed shaft bearings, signal the main controller when bearing temperatures rise above the thresholds specified in the table below, prompting the following system responses.

Gearbox Bearing Temperature Thresholds & System Responses			
High speed shaft, front bearing		**High speed shaft, rear bearing**	
Temperature	**System Response**	**Temperature**	**System Response**
80°C (176°F)	Turbine state to Pause	80°C (176°F)	Turbine state to Pause

3.10.2.2. Gear Oil Cooling System

The gear oil cooling system monitors the temperature of the oil and activates the cooling fan to reduce oil temperature when it reaches a critical temperature. The activation schedule is listed in the table below.

Gear Oil Temperature Thresholds & System Responses			
Begin response sequence		**End response sequence**	
Temperature	**System Response**	**Temperature**	**System Response**
60°C (140°F)	P335 – Geartemp, fan start, low speed, turbine Run	55°C (131°F)	P337 – Geartemp, fan stop, hysteresis, turbine Run
70°C (158°F)	P52 Max temperature, gear, alarm, turbine Pause	55°C (131°F)	Manual (human) reset, turbine Run

3.10.2.3. Rotation Speed Control Sensors

The rotation speed (rpm) of both the high speed shaft and low speed shaft are monitored by the turbine controller by means of measurements from rotation speed sensors. These measurements allow for speed regulation and overspeed control, which is critical for turbine safety as an overspeed event can cause a catastrophic turbine failure. The system also detects low rotation speeds, at which the turbine isn't producing power, so that power production systems can be taken off line. In each case, based on shaft-speed measurements, the controller activates the turbine's Pause, Stop, or Emergency Stop operating states.

On the high speed shaft between the gearbox and generator, rpm is measured by an inductive sensor that produces three signal pulses per revolution.

On the low speed shaft between the hub and gearbox, rpm is measured by two independent inductive sensors called Low Speed Shaft (LSS) sensors that produce 14 pulses per revolution. The Overspeed Protection (OSP) systems, which are hardware-based relays, use these signals to detect possible overspeed events and, independent of the controller, trip the Emergency Stop circuit (Section 3.2.). This, in turn, results in activation of the turbine's pitch control system (Section 3.11.) and hydraulic brake (Section 3.13.) and a full stop of the turbine's rotation system. In normal operation, each OSP signals the processor (S414 and S407) that speed is nominal.

The turbine controller uses these signals to monitor for both low- and high-speed events, which in turn activates Pause, Stop, or Emergency Stop functionality. See the table below for an overview of shaft rotation speed thresholds.

Overview of Shaft Rotation Speed Thresholds	
Overspeeds	**Rated + X [RPM]**
Full load	0.8 %
Maximum generator RPM	10 %
Maximum rotor RPM	15 %
Overspeed protection	20 %

3.10.3. Calibration & Maintenance

3.10.4. Troubleshooting

3.10.5. Spare Parts

SPARE PARTS LIST [NUMBER] – ROTATION SYSTEM				
POS	**Item No.**	**Description**	**Type**	**Manufacturer**
B400	114264	Inductive sensor, rotor (OSPR)	DU10E-ELMC	Electromatic
B401	114259	Inductive sensor, generator	XS1M18PA370 Lt	Telemecanique
R402	114281	Temperature sensor gear oil	Pt-100 9624006054	Hansen
S403	114855	Vibration sensor	WLNJ-S2-G	Omron
S404		Latching 3-axis vibration sensor	685A08	PCB Piezotronics
B406		Inductive sensor, shaft (OSPS)	S3782	Fargo Controls
K407		OSPS (over speed protect, shaft)	1SVR430896R0000	Phoenix Contact

S407		Feedback, OSPS		
S408		Error Status, OSPS		
D410		Aux. relay, oil cooling motor	RY2S-U-DC24, 24VDC	Idec
K410		Contactor, oil cooling motor	A9-30-10-84, 110V/120V, 60Hz	ABB
S410		Feedback, oil cooling motor		
F411		Thermorelay, oil cooling motor	TA25DU3.1, 2.20-3.10A	ABB
S413		Feedback on F411		
K414		OSPR (over speed protect, rotor)	1SVR430896R0000	Phoenix Contact
S414		Feedback, OSPR		
S415		Error Status, OSPR		
R451		Temperature, Gear HSS Bearing		
R452		Temperature, Gear HSS Bearing		
D460		Aux. relay, CC Jensen oil filter	RY2S-U-DC24, 24VDC	Idec
K460		Contactor, CC Jensen oil filter	A9-30-10-84, 110V/120V, 60Hz	ABB
F461		Thermorelay, CC Jensen oil filter	TA25DU1.0, 0.63-1.00A	ABB
W480	836885	Cable, Pt 100 gear	RHEYFLEX-Y,2x0,75mm2	AEG
W481	836880	Cable, vibration sensor	RHEYFLEX –Y, 2x0,75mm2	AEG
W482		Cable, generator sensor		
W483		Cable, rotor sensor		
W484		Cable, VOG sensor		
W485	836889	Cable, box sensor rotor/gen.	LIYCY 6x0,381mm2	AEG
W486	836762	Cable. box VOG sensor/thermistor	RHEYFLEX-Y, 5x;0.75mm2	AEG
W487		Cable, Phoenix Contact overspeed sensor		
W491				

3.10.6. Drawings

Drawing #	Version # (date)	Description	Filename
	1.0 (9/18/15)	Rotation control	

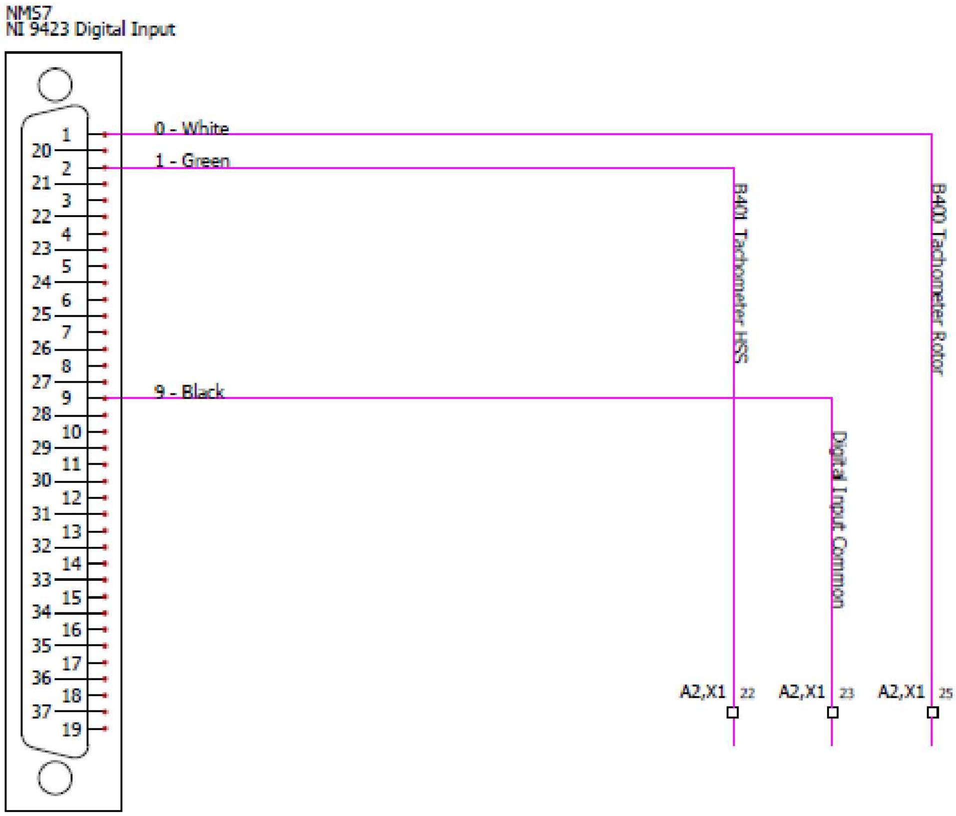


Figure 3-26. Rotation control

3.11. Pitch Control & Monitoring System

The SWiFT turbine blades pivot along their own longitudinal axes to achieve variable blade angles relative to wind direction, called “pitch.” This allows for optimum wind energy capture, variable rotor speed control, reduced load on the blades, and the ability to stop the turbine by “full feathering” the blades to 90 degrees relative to the wind direction.

Regulation of the blade position is performed by a hydraulic system (Section 3.13). When the turbine is in the Run operating state, the production controller determines the desired pitch angle of the blades based on the operating conditions. When the turbine is in the Stop operating state, the blades will be positioned at a pitch angle of 90° (Figure 3-27).

In quiet calm and when there is insufficient wind speed to begin rotation, the pitch angle will be 45°. As RPM increases with wind speed, the blades are turned progressively toward 0° so that the pitch angle always is optimum for wind energy capture. In this way the turbine starts without use of a motor.

3.11.1. Pitch Control & Monitoring System Overview

The pitch controller includes the following components:

- Pitch controller
- Servo system for pitch control
- Blade position sensor

3.11.2. Pitch Control & Monitoring Components

3.11.2.1. Pitch Controller

The pitch controller is the predetermined logic that manages the pitch angle of the turbine blades based on operating state and operating conditions. The pitch controller is described in Section 3.4.3.4.

3.11.2.2. Servo System for Pitch Control

The Vicker’s proportional valve control card translates the pitch velocity signal (Y800) to movement of the pitch rod. The Vicker’s card has an internal PID controller to ensure pitch velocity matches the velocity commanded. The Vicker’s card has a series of calibration settings (physical knobs) that need to be tuned during testing to ensure the velocity matches the command velocity. The desired output matches the plot below.

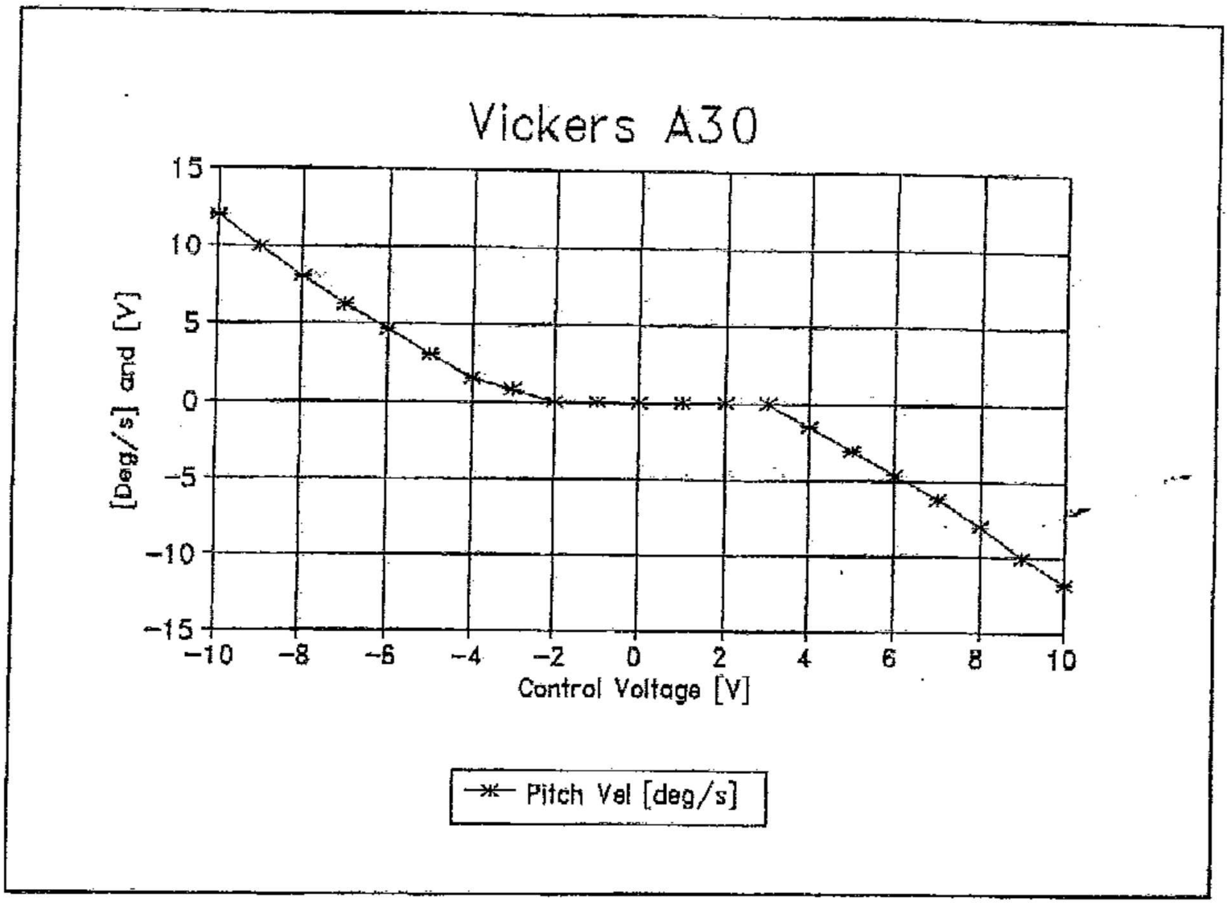


Figure 3-27. Vicker's card calibration settings

In the Run or Pause operating states, the solenoid valves are activated (24 V DC). Blade pitch is regulated by the proportional valve, which is controlled by an analog voltage signal in the range -10 V to +10 V.

In the Stop and Emergency Stop operating states, the solenoid valves are deactivated. In this situation, the proportional valve is without influence on the system; the control voltage to the proportional valve is set to 0 V.

See Section 3.13.6. for a circuit diagram of the hydraulic system.

3.11.2.3. Blade Position Sensor

The blade pitch angle position sensor measures linear length by sending a current impulse on the wave guide located inside a protective tube. When the current impulse is hit by the magnetic field from the magnet ring, a torque pulse arises, which is spread out with an ultrasonic velocity (approximately 2700 m/s). This pulse is detected by the wave guide with a permanent magnet in the coil located at the end. Blade position is determined by the time between pulse and detection.

Pitch table

Pitch [deg]	-> Pos [m]	-> Volt [V]
-5.0;	0.00000;	0.04000;
-4.0;	0.00434;	0.16777;
-3.0;	0.00872;	0.29639;
-2.0;	0.01312;	0.42577;
-1.0;	0.01754;	0.55579;
0.0;	0.02198;	0.68637;
1.0;	0.02643;	0.81740;
2.0;	0.03090;	0.94879;
3.0;	0.03538;	1.08043;
4.0;	0.03986;	1.21223;
5.0;	0.04434;	1.34411;
6.0;	0.04883;	1.47596;
7.0;	0.05331;	1.60771;
8.0;	0.05778;	1.73926;
9.0;	0.06224;	1.87054;
10.0;	0.06669;	2.00146;
11.0;	0.07113;	2.13195;
12.0;	0.07555;	2.26193;
13.0;	0.07995;	2.39133;
14.0;	0.08433;	2.52009;
15.0;	0.08868;	2.64813;
16.0;	0.09301;	2.77541;
17.0;	0.09731;	2.90187;
18.0;	0.10158;	3.02745;
19.0;	0.10582;	3.15211:
20.0;	0.11002;	3.27580;
21.0;	0.11420;	3.39848;
22.0;	0.11833;	3.52012;
23.0;	0.12243;	3.64069;
24.0;	0.12649;	3.76015;
25.0;	0.13052;	3.87849;
26.0;	0.13450;	3.99569;
27.0;	0.13845;	4.11173;
28.0;	0.14235;	4.22661;
29.0;	0.14622;	4.34030;
30.0;	0.15004;	4.45282;
31.0;	0.15383;	4.56415;
32.0;	0.15759;	4.67431;
33.0;	0.16128;	4.78330;
34.0;	0.16495;	4.89112;
35.0;	0.16858;	4.99780;
36.0;	0.17216;	5.10335;
37.0;	0.17572;	5.20778;

38.0;	0.17923;	5.31112;
39.0;	0.18271;	5.41338;
40.0;	0.18615;	5.51460;
41.0;	0.18955;	5.61480;
42.0;	0.19293;	5.71401;
43.0;	0.19627;	5.81226;
44.0;	0.19958;	5.90959;
45.0;	0.20286;	6.00602;
46.0;	0.20611;	6.10159;
47.0;	0.20933	6.19634;
48.0;	0.21252;	6.29030;
49.0;	0.21569;	6.38352;
50.0;	0.21884;	6.47603;
51.0;	0.22196;	6.56788;
52.0;	0.22506;	6.65910;
53.0;	0.22814;	6.74974;
54.0;	0.23121;	6.83984;
55.0;	0.23426;	6.92945;
56.0;	0.23729;	7.01860;
57.0;	0.24030;	7.10735;
58.0;	0.24331;	7.19574;
59.0;	0.24630;	7.28382;
60.0;	0.24929;	7.37164;
61.0;	0.25227;	7.45924;
62.0;	0.25524;	7.54667;
63.0;	0.25821;	7.63400;
64.0;	0.26118;	7.72126;
65.0;	0.26415;	7.80851;
66.0;	0.26711;	7.89581;
67.0;	0.27009;	7.98321;
68.0;	0.27306;	8.07077;
69.0;	0.27605;	8.15855;
70.0;	0.27904;	8.24661;
71.0;	0.28205;	8.33502;
72.0;	0.28507;	8.42384;
73.0;	0.28810;	8.51315;
74.0;	0.29116;	8.60300;
75.0;	0.29424;	8.69349;
76.0;	0.29734;	8.78469;
77.0;	0.30047;	8.87669;
78.0;	0.30362;	8.96957;
79.0;	0.30682;	9.06343;
80.0;	0.31004;	9.15838;
81.0;	0.31331;	9.25451;
82.0;	0.31663;	9.35196;
83.0;	0.31999;	9.45083;

84.0;	0.32340;	9.55128;
85.0;	0.32688;	9.65344;
86.0;	0.33041;	9.75749;
87.0;	0.33402;	9.86360;
88.0;	0.33771;	9.97196;

3.11.3. Calibration & Maintenance

See Volume 4, Mechanical Systems, for calibration and maintenance intervals for the pitch system.

3.11.4. Troubleshooting

Use the pitch service tests described in Volume 4, Mechanical Systems, to identify and diagnose issues with the pitch system components.

3.11.5. Spare Parts

SPARE PARTS LIST [NUMBER] – PITCH CONTROL & MONITORING SYSTEM				
POS	**Item No.**	**Description**	**Type**	**Manufacturer**
A800	114285	Linear transducer	BTL-A10-0340-SA56-S-32	Balluff/LJM
Y800A		Proportional valve		
Y800B		Proportional valve		
P800	91309	Controller for Vickers prop. valve	EEA-PAM-553-A-20	Vickers
F830	94219	Fuse for Vickers card	T 4A	
B831		Position sensor for prop. valve		
W880	194174	Cable, proportional valve A	RHEYFLEX, 2x0, 75mm2	AEG
W881	194174	Cable, prop. valve B	RHEYFLEX, 2x0,75mm2	AEG
W882	114500	Cable, linear transducer	NKT/PKLU, 7x0, 75mm2	NKT
W883	114500	Cable, position sensor, prop valve	NKT/PKLU, 2x0.75mm2	NKT

3.11.6. Drawings

Drawing #	Version # (date)	Description	Filename
	1.0 (9/18/15)	Pitch control	

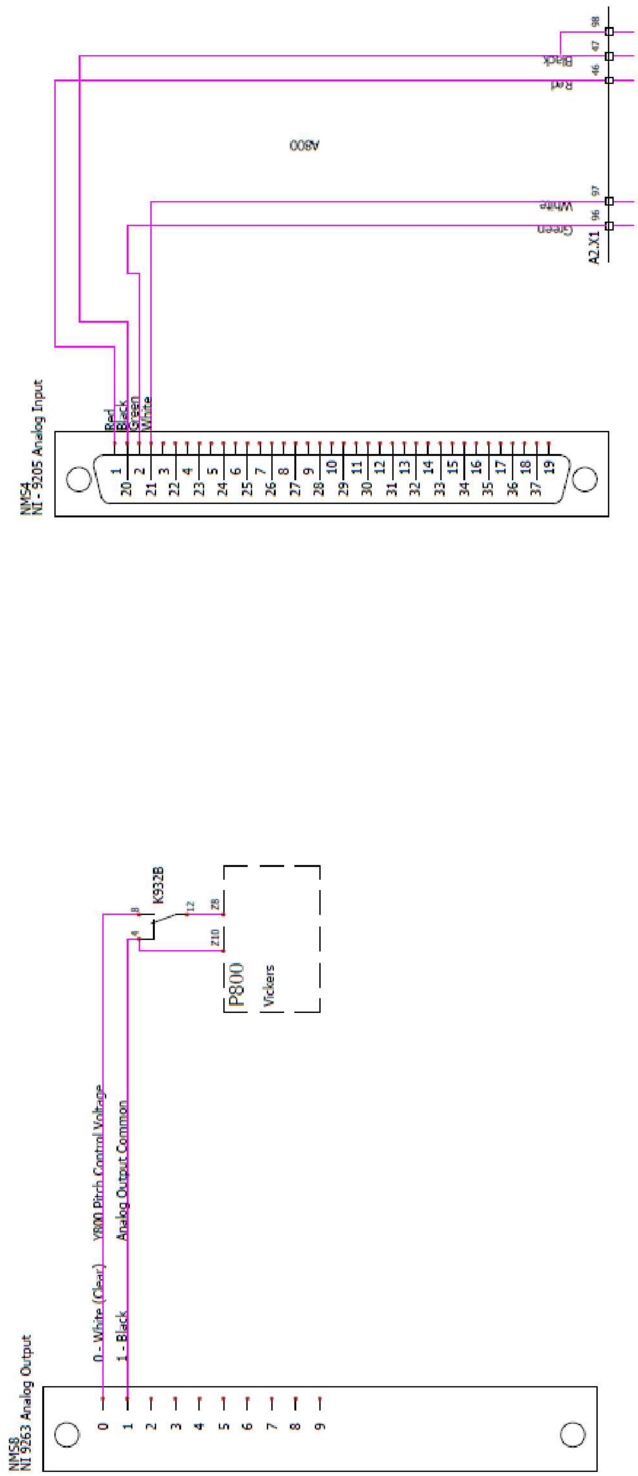


Figure 3-28. Pitch control

3.12. Yaw Control & Monitoring System

Each SWiFT wind turbine's nacelle is mounted on a yaw ring that rotates horizontally 360°. Gear teeth on the yaw ring mesh with two electric motors that control yaw direction. An automatic yaw system keeps the turbine blade-rotor assembly facing into the wind in the Run and Pause operating states; the yaw control system also limits twisting of the tower cables and performs untwisting rotations when needed.

3.12.1. Yaw System Overview

The yaw system includes the following electrical components:

- Two electric yaw motors
- Automatic yaw control system
- Automatic twist control system

3.12.2. Yaw System Components

3.12.2.1. Yaw Motors

Two electric motors mesh with the yaw ring gear teeth to drive nacelle rotation. The two yaw motors are six-poled 0.55/0.66 kW asynchronous electric motors.

3.12.2.2. Automatic Yaw Control System

The main controller receives information about wind direction from the wind sensor on the nacelle. The yaw control system tracks the 100-second exponential average of the wind direction. Using this filtered wind direction, the system will yaw the nacelle to a 0 heading if the nacelle is more than 18 degrees off this filtered wind direction.

The main controller also receives information about wind speed from the wind sensor on the nacelle, and about generator rotation speed from the high speed shaft sensor. Automatic yawing is deactivated (P71) when the mean wind speed is below 3.5 m/s (P77) or 75% of nominal generator rpm (P73). This is to prevent over-twisting of the tower cables when the turbine is not producing power.

3.12.2.3. Automatic Twist Control System

To prevent over-twisting of the tower cables (Section 3.8), four twist sensors on the yaw ring signal the main controller when the nacelle exceeds rotation thresholds. (Note: The Sandia SWiFT wind turbines have been modified to allow for one and two rotations compared to the legacy Vestas turbines' permitted two and four rotations, respectively.)

The main controller receives information about nacelle rotation from the yaw controller, which counts the number of rotations of the nacelle.

At less than one turn in either the clockwise (CW) or counterclockwise (CCW) direction, the turbine yaws freely and no automatic cable untwisting is carried out. At more than one turn in either direction, the sensor logic is as follows:

- Sensor S102 is a normal open contact (0=deactive). When activated (1=active), it indicates that the cables are twisted between one and two rotations CW. When the cables are twisted between one and two rotations, untwisting will begin the next time the turbine is not producing energy.
- Sensor S103 is a normal open contact (0=deactive). When activated (1 =active), it indicates that the cables are twisted between one and two rotations CCW. When the cables are twisted between one and two rotations, untwisting will begin the next time the turbine is not producing energy.
- Sensor S104 (twist stop) is a normal closed contact (l =active), which opens (0=deactive) when the cables are twisted more than two rotations in either the CW or CCW directions. This condition is called “Yaw Stop.” When this occurs, the turbine’s operating state will decrease to PAUSE and automatic cable untwisting will commence.
- Sensor S105 (yaw pulses) changes every 162° and the main controller uses this signal as a check of the yawing system.

Automatic cable untwisting can be tested by manually yawing the turbine beyond the above thresholds.

While the turbine is yawing, the four signals (S102, S103, S104, and S105) are logged in the run log as described below:

Possible Yaw Control Signal Combinations	
30000 error	TwistStop deactive without CW or CCW
30001 error	TwistStop deactive without CW or CCW
30010 OK	Neutral ± 1 rotations
30011 OK	Neutral ± 1 rotations
30100 OK	2 rotations CCW
30101 OK	2 rotations CCW
30110 OK	1 to 2 rotations CCW
30111 OK	1 to 2 rotations CCW
31000 OK	2 rotations CW
31001 OK	2 rotations CW
31010 OK	1 to 2 rotations CW
31011 OK	1 to 2 rotations CW
31100 error	CW and CCW active contemporary
31101 error	CW and CCW active contemporary
31110 error	CW and CCW active contemporary
31111 error	CW and CCW active contemporary

3.12.3. Calibration & Maintenance

3.12.4. Troubleshooting

3.12.5. Spare Parts

SPARE PARTS LIST [NUMBER] – YAW CONTROL & MONITORING SYSTEM				
POS	**Item No.**	**Description**	**Type**	**Manufacturer**
D100		Aux. relay, yaw motor CW	RY2S-U-DC24, 24VDC	Idec
K100		Contactor, yaw motor CW	A9-30-10-84, 110V/120V, 60Hz	ABB
S100		Feedback, yaw motor CW		
D101		Aux. relay, yaw motor CCW	RY2S-U-DC24, 24VDC	Idec
K101		Contactor, yaw motor CCW	A9-30-10-84, 110V/120V, 60Hz	ABB
S101		Feedback, yaw motor CCW		
		Contactor Interlock, K100-K101	VE5-1	ABB
S102-S105	91170	Cabletwist sensor	X/2FR6/150-091170 TER	Demex
F106-F107		Thermo relay, yaw motor	TA25DU2.4, 1.7-2.4A	ABB
M3	115255	Yaw motor	MT80B19F100-6, 0.55kW	ABB
M4	115255	Yaw motor	MT80B19F100-6, 0.55kW	ABB
W180	836798	Supply cable, yaw motor M3 on right	H07RN-F, 4x1.5mm^2	AEG
W181	836797	Supply cable, yaw motor M4 on left	H07RN-F, 4x1.5mm^2	AEG
W182	703537	Cable, twisting-sensor	H07RN-F, 5x1.5mm^2	AEG
W183	836800	Supply cable, hydraulic/yawing	H07RN-F, 4x1.5mm^2	AEG

3.12.6. Drawings

Drawing #	Version # (date)	Description	Filename
	1.0 (9/18/15)	Yaw power	
	1.0 (9/18/15)	Yaw control	

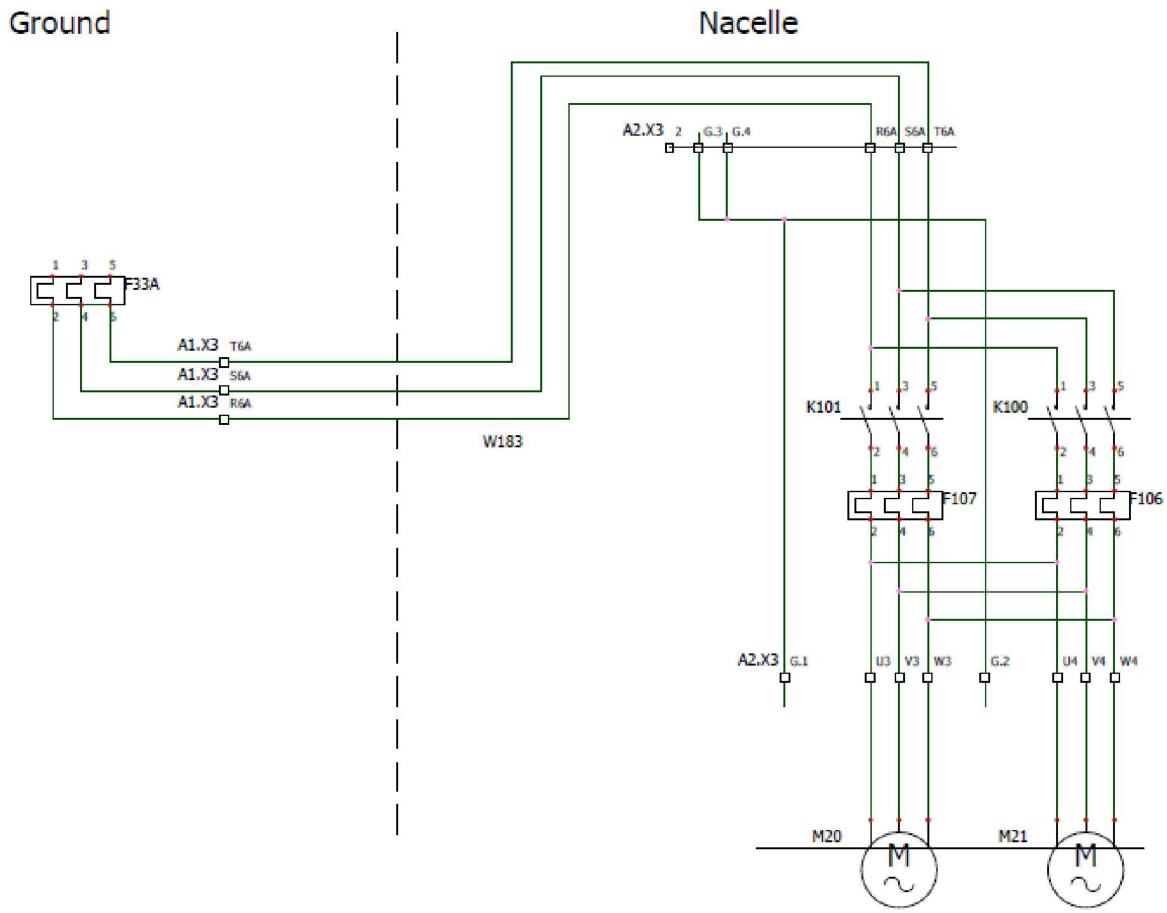


Figure 3-29. Yaw power

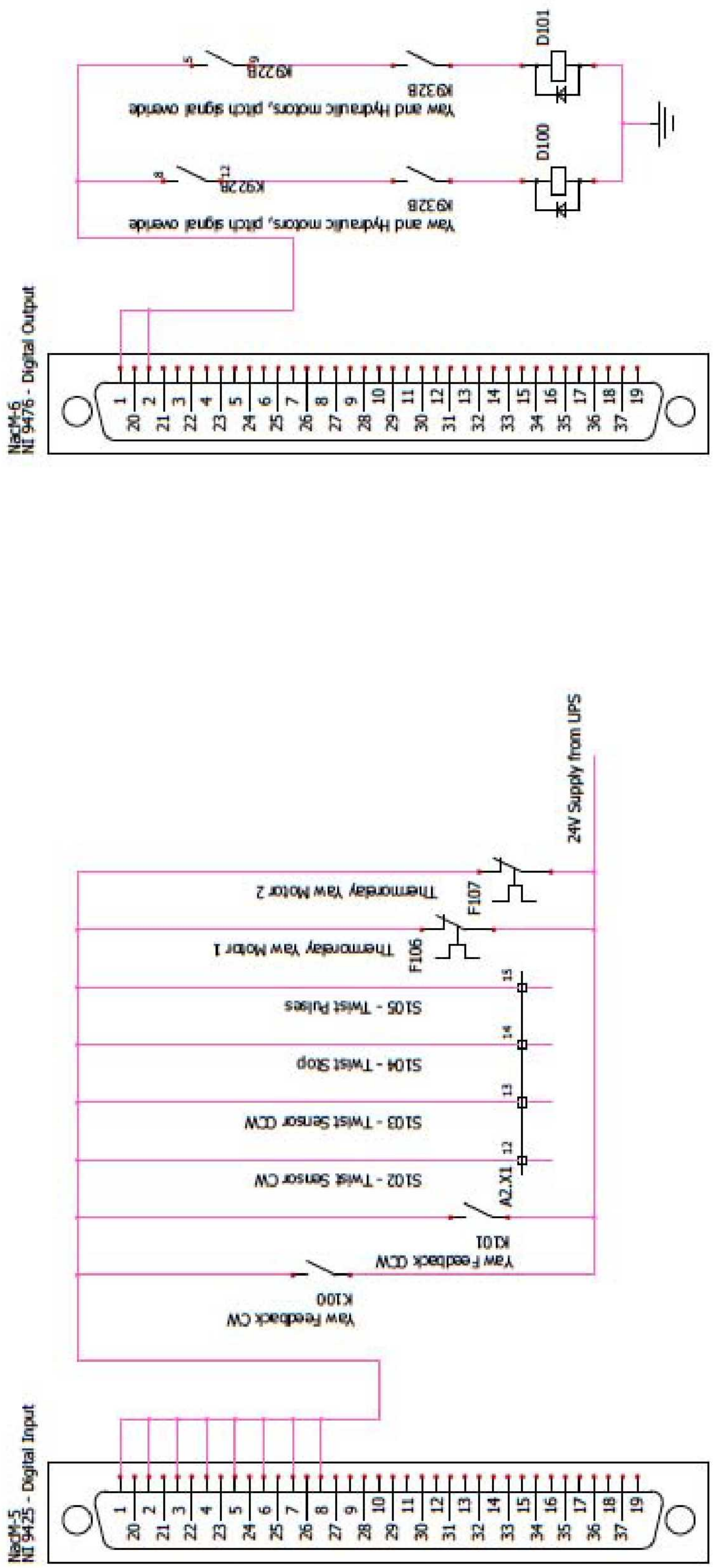


Figure 3-30. Yaw control

3.13. Hydraulic Control System

The hydraulic control system supplies oil pressure that regulates blade pitch (Section 3.11.). It also stores oil pressure for braking of the rotor system and full-feathering of the blade pitch (in an Emergency Stop, for example).

In the following discussion, “pos. x” refers to the positions on the hydraulic circuit diagram, Figure 3-31 in Section 3.13.6. Similar numbers have been stamped on the manifold block on the hydraulic power unit indicating the location of the components.

3.13.1. Hydraulic Control System Overview

The hydraulic control system includes the following electrical components:

- Pumping system
- Servo system for pitch control
- Pressure security valve
- Braking system

3.13.2. Hydraulic Control System Components

3.13.2.1. Pumping System

The pump (pos. 5) provides the system with oil pressure (4.5 1/min. at 100 bar) through the pressure filter (pos. 10). The system is designed for on/off operation. When the pump is off, oil pressure is available from the accumulator (pos. 16), which is pre-charged with 30 bar. The turbine controller starts and stops the pump, receiving pressure readings from the pressure sensor (pos. 12), which provides an analog signal (4 - 20 mA equal to 0 - 100 bar).

Other components of the pumping system:

- The oil level switch (pos. 2) is a safety function for protection of the pump.
- The Pt 100 temperature sensor (pos. 4) is a safety function for monitoring of the oil temperature.
- The pressure filter (pos. 10) includes a contamination indicator that provides an electrical signal when the filter is clogged. It is equipped with a bypass valve as well.
- The check valve (pos. 11.1) prevents reverse flow.
- The needle valve (pos. 18.1) is used for release of the accumulator (pos. 16) when the system is to be repaired.

3.13.2.2. Servo System for Pitch Control

See Section 3.11.2.2. for a description of the servo system for pitch control.

3.13.2.3. Pressure Security Valve

The pressure security valve (relief valve) in the manifold block on the cylinder (pos. 13) limits oil pressure for protection of the system if the pressure sensor fails. It also ensures that oil cannot leave the hydraulic cylinder if the hydraulic system becomes unpressurized, thus ensuring that the blades cannot pitch and accelerate the rotor.

In the Run or Pause operating states, the solenoid valve is active (24 V DC) and oil can pass freely in and out of the B-port on the cylinder.

In the Stop and Emergency Stop operating states, the solenoid valve is deactive and oil can get into the B-port of the cylinder (through the check valve) but not out as the solenoid valve is closed.

3.13.2.4. Braking System

The hydraulic system delivers oil pressure to the rotor braking system through a pressure reduction valve (pos. 24). The accumulator (pos. 27) and check valve (pos. 11.4) maintain (store) pressure for the braking system in case of a failure by the pumping system.

- The relief valve (pos. 29) is a safety valve that protects the system in case of failure or misadjustment of the pressure-reducing valve (pos. 24).
- The pressure switch (pos. 26) is an alarm pressure switch that monitors the pressure in the brake system.
- The needle valve (pos. 18.2) is used for release of the accumulator (pos. 27) when the system is to be repaired.

When the brake is released, the solenoid valve (pos. 19.3) is activated by 24 V DC, and brake calipers are drained to the tank. When the brake is set, the solenoid valve (pos. 19.3) is deactivated, providing pressure on the brake calipers.

3.13.3. Calibration & Maintenance

Periodic maintenance of the hydraulic system is described in inspection instruction 941275 and inspection record scheme 941276, both titled "V27/V29, Annually check."

The following precautions should be observed when performing maintenance on the hydraulic system:

- When taking apart any portion of the hydraulic system, pump motor should be stopped by pushing one of the Emergency Stop buttons.
- When taking apart any portion of the brake system, accumulators 16 and 27 should be depressurized by means of valves 18.1 and 18.2.
- When taking apart any portion of the pump system or pitch system, accumulator 16 is depressurized by means of valve 18.l.
- When using the test hose, please note that the hose at first has to be connected to test point M8 or an external pressure gauge. Then the other end of the hose can be connected

to any pressurized test point. If the hose is connected to a pressurized test point first, oil will be blown out of the hose by high pressure.

- Do not use tools to close needle valves. Tools may damage the valve seat and make it impossible to open the valve next time without using tools.
- Do not adjust valves without special permission from Vestas' Service Department. The valves have been adjusted at the test run of the hydraulic unit.
- Pay attention to the cleanliness of the system and surroundings when taking apart any portion of the hydraulic system. Fittings and other components should not be placed on the floor or where they can become contaminated. Take care that paint flakes and other debris do not enter the system.
- After each service of the hydraulic system, clean spillage or oil drips under fittings to make it easier to locate future leaks from the system.

3.13.4. Troubleshooting

3.13.4.1. Troubleshooting Hydraulic Unit

To troubleshoot the hydraulic unit, follow this procedure. (Unless otherwise specified, the pressure margins are ± 2 bar.)

1. Connect a digital pressure gauge to M3.
2. Start the hydraulic pump:
    a. Check rotation direction of the pump.
    b. Check that relief valve (pos. 13) opens up at between 100 bar and 105 bar and remains stable between 90 bar and 103 bar.
3. Stop the hydraulic pump.
4. After waiting a minimum of two minutes, release the pressure from the pitch accumulator (pos. 16) by opening needle valve 18.1.
    a. Check the precharge of the accumulator by observing when the pressure drops to 0 bar. The pressure should be within 30 bar ± 3 bar. List the observed value.
5. Connect the pressure gauge to M6.
    a. Check the pressure in the brake system. Correct pressure is 19 bar ± 1.5 bar. List the observed value.
6. After a minimum of two minutes, release the pressure from the brake accumulator (pos. 27) by opening needle valve 18.2.
    a. Check the pressure switch S202 (pos. 26). In the turbine user interface, S202 shall change from + to – when the pressure is 14 bar ± 1.5 bar. List the observed value.
    b. Check the precharge of the brake accumulator by observing when the pressure immediately drops to 0 bar. Correct pressure is 9 bar ± 1 bar. List the observed value.
7. Close needle valves at pos. 18.1 and pos. 18.2.
8. Connect digital pressure gauge hose to M3.
9. Switch pump to auto mode.
    a. Compare the pressure displayed on the pressure gauge with the pressure displayed on the service panel. Maximum deviation is ± 3 bar. List the two observed values.

10. Slowly release the pressure from the brake accumulator (pos. 27) by opening the needle valve (pos. 18.2).
    a. Check that the pump starts and stops correctly. List the observed start pressure and stop pressure.
11. Close needle valve at pos. 18.2.

3.13.4.2. Troubleshooting Proportional Valve

When troubleshooting the proportional valve, observe the following precautions and procedures:

- Check the LED readout on the Vickers power amplifier for the proportional valve in the top controller.
- Check the voltage from the processor to the Vickers amplifier. This can be measured on Vickers amplifier terminal K932B:4 to K932B:12. Check the conditioned command signal, which is an internal voltage in the Vickers amplifier. This can be measured on the two upper monitoring points on the front of the Vickers amplifier. Note different voltage ranges on Vickers A20 vs. Vickers A30 power amplifiers (refer to data sheets).
- Check LVDT signal, which is a measurement of the spool position in the proportional valve. This can be measured on the two lower monitor points on the Vickers amplifier. Note different voltage range on Vickers A20 vs. Vickers A30 power amplifiers (refer to data sheets).
- Check the pitch velocity/speed, which is computed by the controller. The pitch velocity is computed around 0°.
- If a valve is removed and then remounted later, the cooling oil will run out of the L-port. To refill the valve, remove the two small screws on the top of the valve. Then press hydraulic oil through the valve with an oilcan until fresh oil runs out without air bubbles. It does not matter which of the holes is used as filling hole. Replace the screws.

3.13.5. Spare Parts

SPARE PARTS LIST [NUMBER] – HYDRAULIC CONTROL SYSTEM				
POS	**Item No.**	**Description**	**Type**	**Manufacturer**
S200		Oil level sensor		
S201		Pressure switch, filter		
S202		Pressure switch, brake		
A203		Analog pressure transducer, hydraulic		
D204		Aux. relay, hydraulic pump	RY2S-U-DC24, 24VDC	Idec
K204		Contactor, hydraulic pump	A9-30-10-84, 110V/120V, 60Hz	ABB
S204		Feedback, hydraulic pump		
F205		Thermo relay, hydraulic pump	TA25DU4.0, 2.80-4.00A	ABB
R206		Temperature sensor, hydraulic oil	Pt-100	
S207	93189	Thermistor brake	UP62 UCHIYA T130	Traforno
K207		Relay, thermistor mechanical brake	RY2S-U-DC24, 24VDC	Idec
Y210A		Solenoid valve, emergency feathering		
Y210B		Solenoid valve, emergency feathering		

Y210C		Solenoid valve, pressure security valve		
D210		Aux. relay, emergency feathering	RH1B-U-DC24, 24VDC	Idec
Y211		Solenoid, disc brake		
D211		Aux. relay, disc brake	RH1B-U-DC24, 24VDC	Idec
F230	94217	Fuse, emergency feathering/disk brake	T 5A	Louis Poulsen
M240		Hydraulic Motor (M5)		
W280	836799	Supply cable, hydraulic motor M5	A07RN-F, 4xl,5 mm2	AEG
W281	194174	Cable, Pt-100 hydraulic oil	RHEYFLEX, 2x0,75mm2	AEG
W282	836890	Cable, oil level sensor hydraulic	RHEYFLEX, 2x0,75mm2	AEG
W283	836890	Cable, solenoid, emergency feathering	RHEYFLEX, 2x0,75mm 2	AEG
W284	836890	Cable, solenoid, emergency feathering	RHEYFLEX, 2x0,75 mm2	AEG
W285	836890	Cable, pressure transducer	RHEYPLEX 2x0,75mm2	AEG
W286	836890	Cable, pressure drop filter	RHEYPLEX, 2x0,75mm2	AEG
W287	836890	Cable, safety pressure	RHEYFLEX, 2x0,75mm2	AEG
W288	836890	Cable, solenoid/brake	RHEYFLEX, 2x0,75mm2	AEG
W289	194175	Cable, thermistor brake	PKL 105, 2x0,75mm2	NKT
W290	836896	Cable, security pressure valve	RHEYFLEX. 2x0,75mm2	AEG

3.13.6. Drawings

Drawing #	Version # (date)	Description	Filename
	1.0 (9/18/15)	Hydraulic system	
	1.0 (9/18/15)	Hydraulic power	
	1.0 (9/18/15)	Hydraulic control	

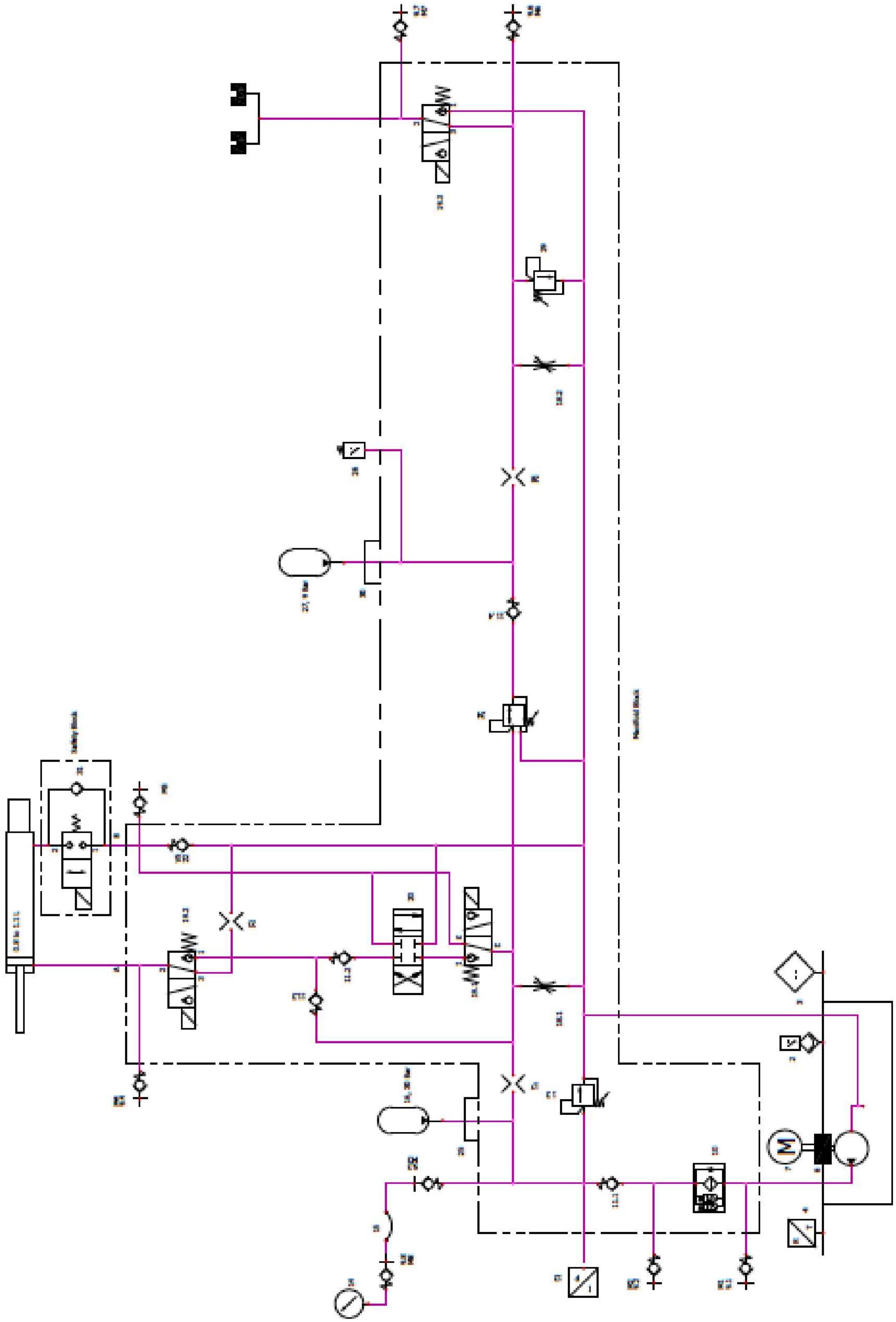


Figure 3-31. Hydraulic system

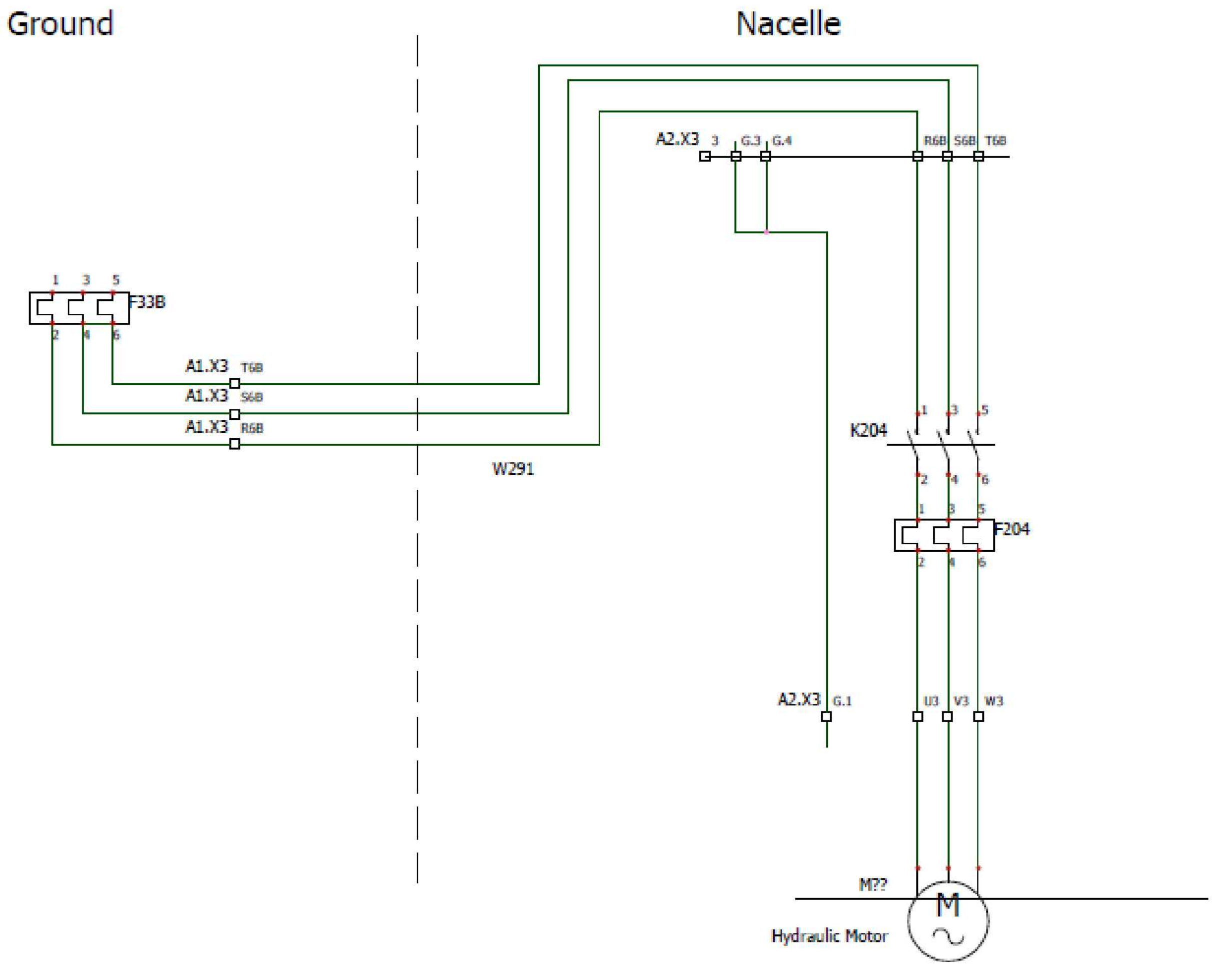


Figure 3-32. Hydraulic power

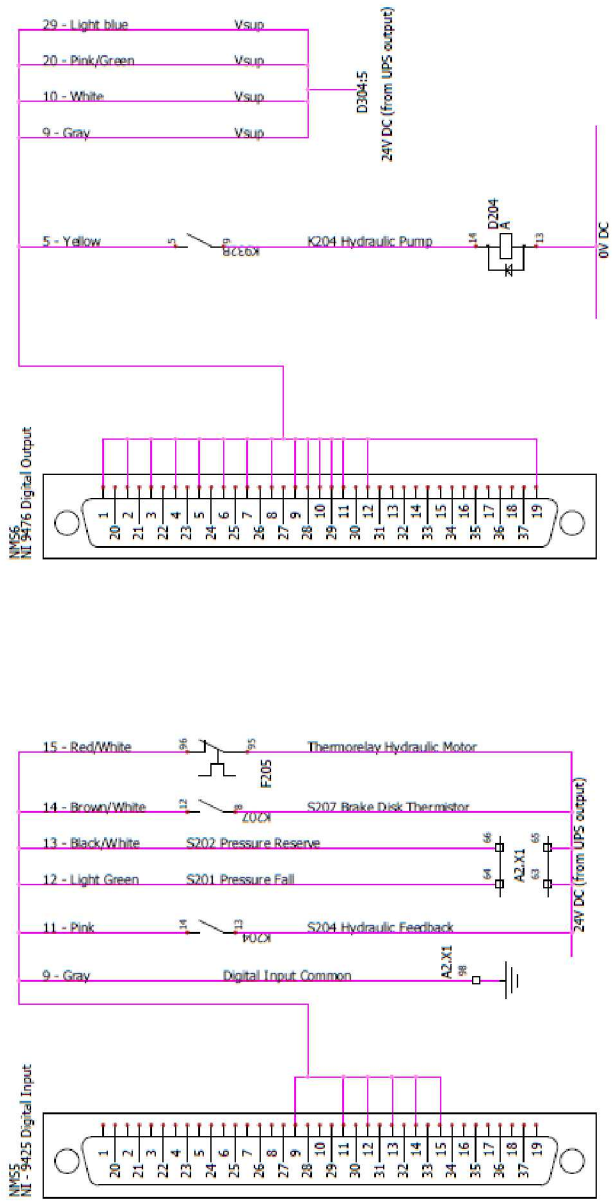


Figure 3-33. Hydraulic control

3.14. Research Sensors

The Sandia SWiFT wind turbines have been modified with a number of sensors distributed throughout the system for gathering research data. These sensors have been added to the system to add high resolution, time-synchronized data to meet the rigors of research work. The sensors log data synchronously with turbine control data, allowing detailed inspection and analysis. The system is designed so research sensors can be easily added for future research hardware configurations, and additional sensors are planned.

3.14.1. Research Sensor Overview

The following research sensors are being added or are soon planned. Each sensor will have a hardware description, wiring, signal description, and calibration information.

- Yaw absolute encoder (data not verified)
- Low speed shaft absolute encoder (not implemented yet)
- Nacelle inertial measurement unit (data not verified)
- Tower strain gauges (not logging data yet)
- Blade root bending gauges (not sending data yet)
- Low speed shaft torque sensors (not implemented yet)
- Slip ring (not installed yet)

3.14.2. Research Sensors

3.14.2.1. Yaw Absolute Encoder

3.14.2.2. Low Speed Shaft Absolute Encoder

3.14.2.3. Nacelle Inertial Measurement Unit

3.14.2.4. Tower Strain Gauges

3.14.2.5. Blade Root Bending Gauges

3.14.2.6. Low Speed Shaft Torque Sensors

3.14.2.7. Slip Ring

3.14.3. Calibration & Maintenance

3.14.4. Troubleshooting

3.14.5. Spare Parts

SPARE PARTS LIST [NUMBER] – RESEACH SENSORS				
POS	**PCS**	**Item No.**	**Description**	**Notes**

3.14.6. Drawings

Drawing #	**Version # (date)**	**Description**	**Filename**

3.15. Ambient Condition Sensor System

The ambient condition sensor system monitors the ambient conditions in which the turbine is operating, allowing its controllers to adjust to the environmental conditions.

3.15.1. Ambient Condition Sensors Overview

The Sandia SWiFT wind turbines currently include the following ambient condition/ environmental sensors:

- Wind vane and anemometer – 2D sonic
- Ambient temperature sensor

3.15.2. Ambient Condition Sensors

3.15.2.1. Wind Vane

3.15.2.2. Anemometer

Measurement method: Acoustic resonance (compensated against variations in temperature, pressure, and humidity)

Wind speed measurement:
Range: 0 – 50 m/s
Accuracy: ± 0.5 m/s (0 - 15m/s), ± 4% (>15m/s)
Resolution: 0.1 m/s

Wind direction measurement:
Range: 0 to 360°
Accuracy: ±2° (within ±10° of 0° datum), ±4° (beyond ±10° of 0° datum)
Resolution: 1°

Environment:
Temp Range: -40° to +85°C (operating), -40° to +85°C (storage)
Humidity: 0 - 100%

Data I/O - RS485 option:
Interface: Digital RS485, galvanically isolated from power supply lines and case
Format: ASCII data, polled or continuous output modes
Data Update Rate**:** 5 measurements per second

3.15.2.3. Temperature Sensors

The ambient temperature sensor is mounted below the nacelle.

PT-100 Temperature Sensors

T [°C]	R [ohm]
-20	92.2
-10	96.1
0	100.0
+10	103.9
+20	107.8
+30	111.7
+40	115.5
+50	119.4
+60	123.2
+70	127.1
+80	130.9
+90	134.7
+100	138.5
+110	142.3
+120	146.1
+130	149.8
+140	153.6
+150	157.3

Increase: 0.38 ohm/°C

3.15.2.4. Heating Elements

No controller heating is being used.

3.15.3. Calibration & Maintenance

3.15.4. Troubleshooting

3.15.5. Spare Parts

SPARE PARTS LIST [NUMBER] – AMBIENT CONDITION SENSOR SYSTEM				
POS	**Item No.**	**Description**	**Type**	**Manufacturer**
R300	114279	Pt-100 sensor, ambient	Pt100-180-5	Carlo Gavazzi
B301		Wind speed and direction	FT702LT-V22-PM	FT Technologies
B302-B303	875781	Windvane		Vestas
B306	93183	Fan thermostat, groundcontroller, 10-60°C	Hawa 31 50-0060-02-20	Begholm
K330	114332	Time relay computer cut out	SB 125 724, 8.1805 sec.	Electromatic
W380		Cable, Pt-100 ambient		
W381		Cable, wind sensor		FT Technologies

3.15.6. Drawings

Drawing #	Version # (date)	Description	Filename

3.16. Auxiliary Power System

The auxiliary power system provides electrical power to the turbine subsystems while the main generator power is disconnected. This is a requirement for inspection and maintenance operations.

3.16.1. Auxiliary Power System Overview

The auxiliary power system is activated using the service button (F30) in the ground electrical cabinet. The power is supplied even when the main circuit breaker (Q8) is disengaged. The power is supplied from the grid, so all of the transformer and grid disconnects must be closed for the power to be available.

3.16.2. Auxiliary Power System Components

The auxiliary powers system supplies power to the following subsystems:

- Tower lighting
- Nacelle lighting
- Down-tower 120VAC receptacles
- Nacelle 120VAC receptacles
- Communication equipment
- Controller power
- Sensor power (wind, IMU, encoders, etc.)

3.16.3. Maintenance

3.16.4. Troubleshooting

3.16.5. Spare Parts

SPARE PARTS LIST [NUMBER] – AUXILIARY POWER SYSTEM				
POS	**PCS**	**Item No.**	**Description**	**Notes**

3.16.6. Drawings

Drawing #	Version # (date)	Description	Filename
	1.0 (9/18/15)	Auxiliary power	

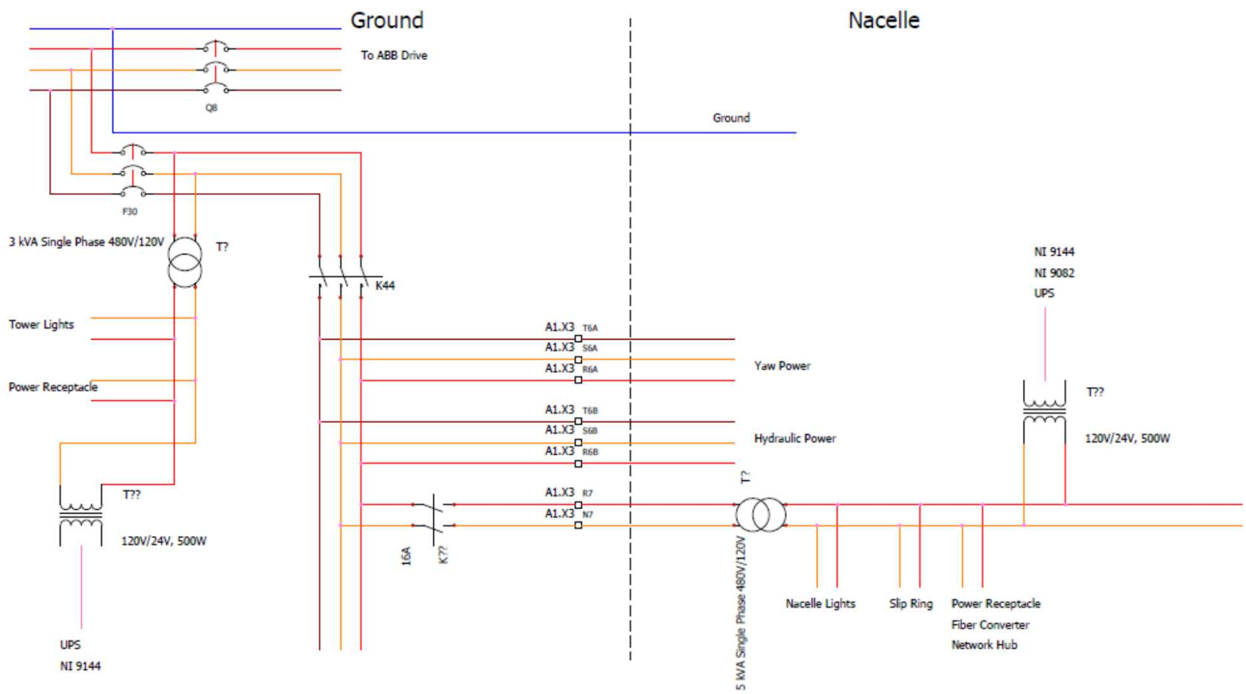


Figure 3-34. Auxiliary power

3.17. Power Disconnects

When power is needed for some systems but not others, such as for safe testing and maintenance activities on subsystems, a series of disconnects distributed throughout each turbine's main circuit allows for power disconnection and isolation.

3.17.1. Power Disconnects Overview

The following disconnects are distributed throughout the turbine's main circuit:

- Q8 main circuit disconnect located at the base of the turbine
- Q7 disconnect on the back of the ABB enclosure
- Q1 disconnect on the ABB drive
- 480V disconnect in the nacelle
- 220V/120V transformer disconnect in the nacelle

3.17.2. Power Disconnects

3.17.2.1. Q8 Main Circuit Disconnect

3.17.2.2. Q7 Disconnect

This disconnect is located on the back of the ABB drive unit enclosure.

3.17.2.3. Q1 Disconnect

This disconnect is located on the ABB drive unit.

3.17.2.4. 480V Disconnect

This disconnect is located in the nacelle.

3.17.2.5. 220V/120V Transformer Disconnect

This disconnect is located in the nacelle.

3.17.3. Calibration & Maintenance

3.17.4. Troubleshooting

3.17.5. Spare Parts

SPARE PARTS LIST [NUMBER] – POWER DISCONNECTS				
POS	PCS	Item No.	Description	Notes

3.17.6. Drawings

Drawing #	Version # (date)	Description	Filename

3.18. Lightning Protection

Sandia SWiFT wind turbines are equipped with redundant systems designed to protect the turbine's electrical systems from lightning damage.

3.18.1. Lightning Protection Overview

The SWiFT turbines' lightning protection includes the following systems:

- Potential equalizing system
- Earthing system
- Over-voltage protection

3.18.2. Lightning Protection Components

3.18.2.1. Potential Equalizing

All frames in the nacelle are bonded together. Electrical components in the nacelle and wind sensors are connected to this bonded frame network.

From the frame of the turbine, two ground cables (2x25mm^2) run to the tower. One ground cable continues to the bottom of the tower where it is bonded to the lower leg of the grounding system together with the ground cable from the electrical cabinet at the turbine base.

Internal signal cables in the turbine are shielded, and the shielding is connected to the potential equalizing system.

3.18.2.2. Earthing System

A ring electrode supplemented with earth rods (depth-electrodes) provides an earthing system. This provides two advantages: the ring electrode limits the potential for a person to be electrocuted if the turbine is struck by lightning, and the earth rods ensure a stable and low transition resistance for the earthing system.

The earthing system is installed as follows:

1. The ring electrode made of 50 mm^2 Cu is placed approximately l meter from the foundation of the tower base and approximately l meter underground.
2. The ring conductor is supplemented with two 6-meter long rods made of 50mm^2 Cu. The earthing electrodes are placed 180° apart along the ring electrode.
3. The ring electrode is connected to two tower legs. One of the wires is connected to the terminals where the control unit is connected to the tower.

If the transition resistance is not sufficiently low, the earthing system can be improved as follows:

1. The two earth rods can be extended to 10 meters in length.
2. Two extra earth rods, each 10 meters long, can be added, arranging the four rods 90° apart along the ring electrode.

3.18.2.3. Over-voltage Protection

At the grid connection in the bus bar, three or four over-voltage conductors (F9) are mounted to ground the over-voltage from the grid. The grid connection to the processor is protected by F40 and F41. The internal communication via the EtherCAT chain is protected by F956 and F957.

The remote control is protected against transients on the communication cable by F958A-B, F962A-B, or F965 depending of the remote control system.

3.18.3. Calibration & Maintenance

3.18.4. Troubleshooting

3.18.5. Spare Parts

SPARE PARTS LIST [NUMBER] – LIGHTNING PROTETION SYSTEM				
POS	**PCS**	**Item No.**	**Description**	**Notes**

3.18.6. Drawings

Drawing #	Version # (date)	Description	Filename

APPENDIX A. ERROR LOOKUP TABLES

APPENDIX B. LIST OF COMPONENTS

[Master list of electrical components to be provided (eventually) as Excel spreadsheets. Currently handled in this manual section by section as spare pasts lists corresponding to each subsystem.]

APPENDIX C. ELECTRICAL DRAWINGS TABLE

This is to be a master list of electrical system/subsystem drawings, including those not included in this volume's subsystem sections. Each drawing listed will correspond to a pdf file, with a live link to the full-size drawing file in the table below.

Drawing #	Version # (date)	Description	Filename

APPENDIX D. HARDWARE MANUALS & DATA SHEETS

Master list of non-Sandia equipment and hardware manuals and data sheets specific to this volume. Table to include live links to files hosted online.

Name	File	Revision Date	Description
ABB ACS 800 Firmware Manual	EN_ACS800_Standard_FW_L	8-25-2011	Full documentation of ACS 800 firmware

Volume 4:
Mechanical Systems

Sandia SWiFT Facility Site Operations Manual (SAND2016-XXXX) approved by:

Department Manager		SWiFT Site Lead	
Dave Minster (6121)	Date	Jonathan White (6121)	Date

SWiFT Site Supervisor

Dave Mitchell (6121) Date

VOLUME REVISION LOG			
Volume Title: Volume 4: Mechanical Systems, Sandia SWiFT Wind Turbine Manual (SAND2016-XXXX)			
Volume Owner(s): Dave Mitchell, SWiFT Site Supervisor			
Revision	**Date**	**Author(s)/Approval**	**Summary of Change(s)**
0			

CONTENTS

FIGURES

4. MECHANICAL SYSTEMS

4.1. Mechanical Systems Overview

This manual includes inspection and maintenance procedures necessary to operate and maintain research wind turbines safely, specifications for the turbine's mechanical subsystems and replacement parts, and drawings of the turbine's mechanical subsystems.

Figure 4-1. Photo of Sandia SWiFT wind turbine

This volume should be used in coordination with the Sandia SWiFT Facility Site Operations Manual, Sandia SWiFT Safe Work Planning Manual, Sandia SWiFT Software Quality Assurance Process, and Sandia SWiFT Meteorological Tower Operating and Maintenance Manual.

4.1.1. Mechanical Subsystems Overview

4.1.1.1. Rotation System

A Sandia SWiFT wind turbine's rotation system includes all rotating components, from the nose cone and blade-rotor assembly to the high speed shaft that enters the generator. See Sections 4.2-4.4 and 4.7.

4.1.1.2. Pitch System

Sandia SWiFT wind turbine blades pivot along their own longitudinal axes to achieve variable blade angles relative to wind direction, called "pitch." See Sections 4.5 and 4.6.

4.1.1.3. Power-Production System

The power production system of a Sandia SWiFT wind turbine includes the gearbox, brake, generator, and associated hardware. See Sections 4.7-4.13.

4.1.1.4. Hydraulic System

The hydraulic system supplies oil pressure that regulates blade pitch. It also stores oil pressure for braking of the rotor system and full-feathering of the blades. See Section 4.14.

4.1.1.5. Yaw System

Each SWiFT wind turbine's nacelle is mounted on a yaw ring that rotates 360°. Gears on the yaw ring mesh with two electric motors that control yaw direction. An automatic yaw system keeps the turbine blade-rotor assembly facing into the wind. The yaw system also limits twisting of the tower cables and performs untwisting rotations when needed. See Sections 4.15 and 4.16.

4.1.1.6. Infrastructural and Structural Systems

Infrastructural and structural systems include the nacelle, tower, cables, surfaces, and other systems necessary for the turbine's functionality. See Sections 4.17 and 4.19-4.23.

4.1.1.7. Sensors

Sandia SWiFT wind turbines have been modified with a number of sensors for gathering research data, including a 2-D sonic anemometer that provide information to the main controller about environmental conditions. See Sections 4.18.

4.1.2. How to Use this Volume

Each test section of this volume includes the following subsections:

4.1.2.1. Specifications

Operating specifications for the given mechanical subsystem as well as specifications for the individual components in that subsystem.

4.1.2.2. Maintenance Procedures

Stepped instructions for performing inspections and maintenance procedures on the given subsystem, as well as the recommended maintenance or inspection interval for the procedure and helpful notes or cautions relating to the procedure.

4.1.2.3. Troubleshooting

Tips on resolving common maintenance problems relating to the given mechanical subsystem.

4.1.2.4. Spare Parts

Lists of components and their related manufacturer part numbers, needed for ordering replacement parts.

4.1.2.5. Drawings

Drawing of the subsystem and its components and their physical relationships to one another.

4.1.3. Safety Precautions

Working with and near turbine mechanical systems presents a number of unique safety hazards. Critical safety precautions specific to mechanical systems are called out in the text of this document as follows (example):

Before entering the nose cone, check that the support frame is tightened and that there are no cracks that have weakened the bearing capacity of the nose cone.

For a more detailed discussion of turbine and SWiFT site and turbine safety hazards, see the Sandia SWiFT Facility Site Operations Manual, the Sandia SWiFT Test Planning Manual, and the volumes in the Sandia SWiFT Wind Turbine Manual series.

4.2. Nose Cone

Provides access to traverse system and pitch linkages. Provides aerodynamic flow around the hub.

4.2.1. Specifications

Function:	Cover
Material:	Glass-reinforced polyester
Coating:	Polyester gelcoat
Color:	White RAL 901;0 or customer requirement
Manufacturer:	Vestas
Length:	2.1 m
Base diameter:	1.6 m
Weight incl. fittings:	80 kg
Connection to hub ring:	Bolted
Bolt size:	M10 x 35, thread locker
Number:	6 pcs.
Tension:	To solid, do not crush GRP
Connection to the hub:	Bolted
Bolt size:	M20 x 110, 8.8 FZV
Number:	3 pcs.
Torque:	325 Nm (240 ft.-lbs.)

4.2.2. Maintenance

4.2.2.1. Inspect for Cracks

Interval: Three months after turbine startup, then yearly

Notes: Also do this during lubrication of the traverse pitching linkages. See Section 4.6.

Refer to Figure 4-2

Before entering the nose cone, check that the support frame is tightened and that there are no cracks that have weakened the bearing capacity of the nose cone.

Steps:

1. Place turbine in Stop.
2. Mount the security bolt in the brake disc.
3. Press the Emergency Stop button.

4. Inspect for cracks around the bolts between the nose cone (pos. 1, Figure 4-2) and the support frame (pos. 9, Figure 4-2).
5. Inspect the nose cone for cracks.
    a. Very fine-cracks are acceptable if they do not penetrate the material. If the areas around the bolts feature penetrating or lengthy cracks, the fibers are crushed, or the material is degraded, the nose cone must be repaired or replaced.

4.2.2.2. Check Bolt Torque

Interval: Three months after turbine startup

Note: In September 1990, the steel washer (pos. 2, Figure 4-2) and the PVCFLEX washer (pos. 3, Figure 4-2) were replaced with a stainless steel washer (pos. 5, Figure 4-2), which is mounted with Sika-flex (pos. 6, Figure 4-2) against the nose cone (pos. 4, Figure 4-2).

Refer to Figure 4-2

Steps:

1. Check to see if the nose cone can move in the bolt connection.
2. Visually inspect the bolt heads and mounting hardware for damage or corrosion.
3. If the old mounting system is in use, replace it with the new one.
4. If the bolts are removed, inspect them for damage and corrosion, clean them, and use thread locker during reassembly. Replace bolts if necessary.

> **Do not overtighten the bolts, which can crush the glass fiber.**

5. Retighten the three bolts (pos. 7, Figure 4-2) using torque wrench setting 320 Nm (236 ft.-lbs.).

4.2.2.3. Disassembly

Interval: As needed

Note: Removal for possible repairs

Refer to Figure 4-2

Steps:

1. Stop the turbine with one blade pointing downwards.
2. Put the turbine into “STOP”

3. Mount the security bolt in the brake disc.
4. Press Emergency Stop.
5. Replace the two upper M10 bolts with eyebolts.
6. Connect the crane to the eyebolts.

Do not lift the nose cone until Step 10 is completed.

7. Lean into the nose cone and disconnect the two lowest M20 bolts between the nose cone and hub.
8. Loosen the upper M20 bolt by one turn.
9. Tension the crane straps so that the weight of the nose cone is supported by the crane, approximately 65 kgs.
10. Disconnect the last M20 bolt. Be careful that the crane has the proper tension for a gentle separation.
11. Lower the nose cone to the ground.

4.2.2.4. Reassembly

Interval: As needed

Refer to Figure 4-2

Steps:

1. Stop the turbine with one blade pointing downwards.
2. Place the turbine in Stop.
3. Mount the security bolt in the brake disc.
4. Press Emergency Stop.
5. Connect the crane to the eyebolts.
6. Gently lift the nose cone into position.
7. Grease the M20 bolts.
8. Lean into the nose cone and install the upper M20 bolt into the hub. Do not tighten.
9. Install the other two M20 bolts and tighten all three, using torque wrench setting 325 Nm (240 ft.-lbs.).
10. Replace the eyebolts with M10 bolts.
11. Tighten the M10 bolts. Secure the M10 bolts with thread locker

4.2.3. Troubleshooting

4.2.4. Spare Parts

SPARE PARTS LIST 940550 – NOSE CONE				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	6	153230	Bolt, M10 x 35, 8.8 FZV	
2	6	156256	Washer, M10 FZV	
3	6	156057	PVCFLEX washer, Ø30 x Ø11 x 3	
4	1	833942	Nose cone, V27	
5	6	831313	Washer, V27 nose cone	
6	60g	149759	Sika-flex Bostik 2639, white	
7	3	153568	Steel bolt, M20 x 110 FZV	
8	3	156695	Plane washer, M20 FZV	
9	1	831025	Nose cone mounting, V27	

4.2.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Nose cone drawing	

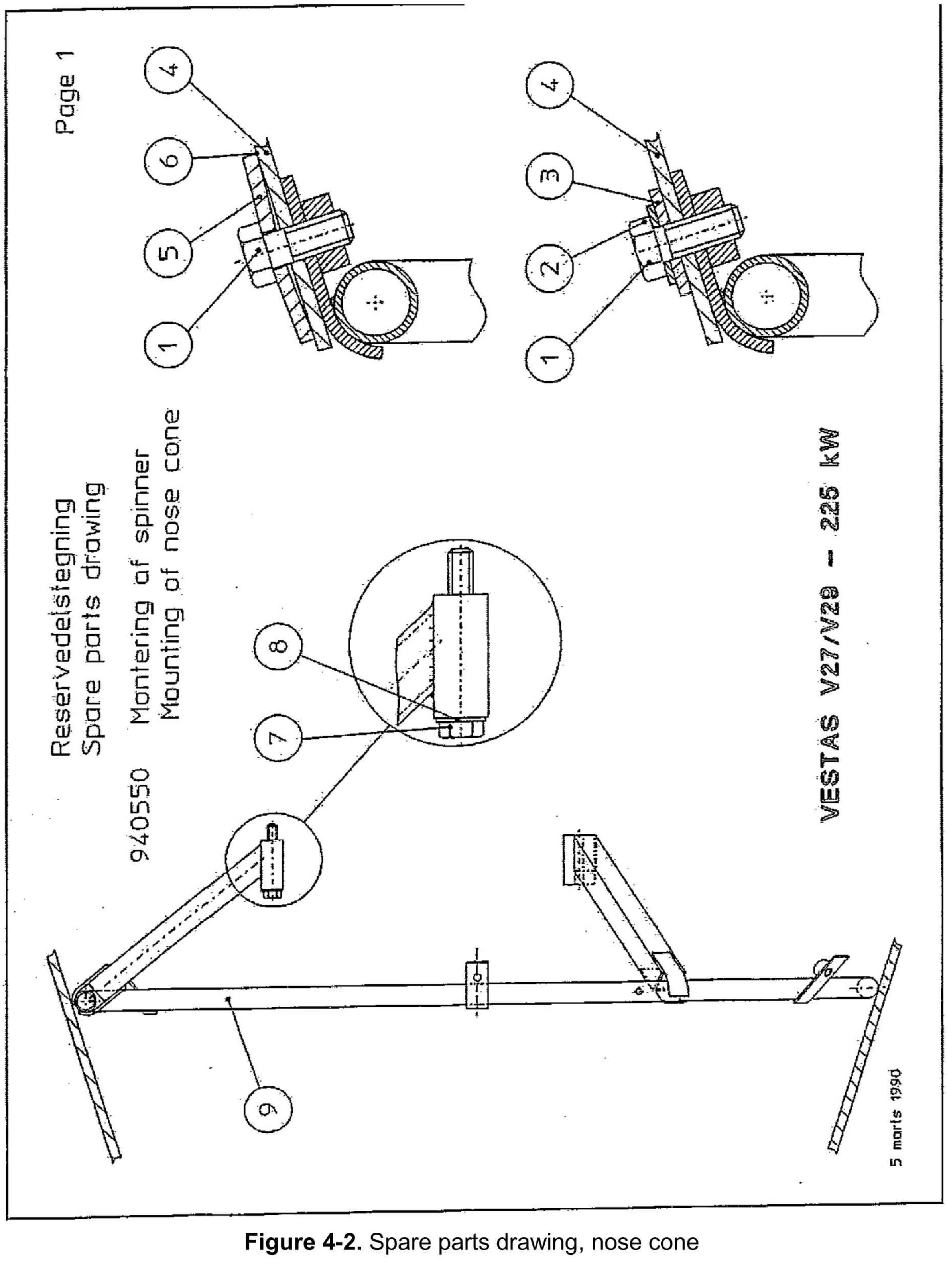


Figure 4-2. Spare parts drawing, nose cone

4.3. Blades

Sandia SWiFT wind turbines feature three blades made of reinforced polyester fiberglass, each consisting of two blade shells glued onto a supporting beam. The blades are fastened to the hub via a glued-in threaded bushing to a four-point ball bearing bolted to the rotating hub.

4.3.1. Specifications

Type. no.:	Vestas 13 m
Manufacturer:	Vestas
Material:	Glass-reinforced polyester
Coating:	Polyester gelcoat
Color:	White RAL 9010 or customer requirement
Overall length:	13.5 m
Weight:	600 kg, excl. bearing
Weight:	780 kg. incl. bearing, flange, bolts, and crank
Distance to center of mass:	4.0 m from bearing
Max. width:	1.3 m
Connection, blade to bearing:	Bolted
Bolt size:	M20 x 180, 10.9, 29 pcs.
Number:	29
Torque:	500 Nm (369 ft.-lbs.), bolts greased
Connection, bearing to hub:	Bolted through outer bearing ring
Bolt size:	M20 x 110, 8.8
Number:	36 pcs.
Torque:	325 Nm (240 ft.-lbs.), bolts greased
Connection, pitch crank to flange:	Friction joint
Bolt size:	M12 x 150, 12.9 DIN 912, black
Nut:	M12, qual. 10
Number:	3 pcs.
Torque:	130 Nm (96 ft.-lbs.), bolts greased

4.3.2. Maintenance

**The blades, when pitched 90°, get very close to the tower.
Before any blade repair or inspection, the blades must be secured by use of the lock bolt in the brake disc and secured against pitching, either by pushing Emergency Stop or by locking the traverse with the three lock bolts.**

4.3.2.1. Inspect for Cracks

Interval: Three months after turbine startup, then every six months

Refer to N/A

Steps:

1. Place the turbine in Stop.
2. Mount the security bolt in the brake disc.
3. Press Emergency Stop.
4. Inspect for cracks along the edge of each blade.
5. Register all cracks in the inspection log, indicating turbine number, blade number, position on the blade, and length, direction, and (if possible) type of failure. (Cracks in the coating must be registered, as well.)
6. If possible, make a mark at both ends of each crack and write the date of detection using permanent ink.
7. During subsequent inspections, use the inspection log to find and re-inspect all previously identified cracks. (No further action is needed if a small crack is not growing.)
8. Cracks found to be in the structure of the blade must be repaired. If the failure is small and the physical conditions are available for fiberglass repair, the repair can be done on site. If not, replace the blade and bring the defective blade to a repair shop. Repair must be done by trained personnel.
9. Note details of all repairs in the inspection log.

4.3.2.2. Check Bolt Torque

The bolt that holds the blade bearing to the blade is torqued during construction and will under normal conditions not have to be retightened. If the bolts are unscrewed, they must be lubricated with molycote grease prior to reinstallation and torqued to 500 Nm (369 ft.-lbs.).

Warning! The nut insert in the blade is made of stainless steel.
To keep the bolt from becoming fixed, it must be turned slowly.
Do not use impact wrench.

4.3.2.3. Disassembly

Interval: As needed

Refer to Figure 4-3, 4-4, 4-5, and 4-6

Steps:

4.3.2.4. Reassembly

Interval: As needed

Refer to Figure 4-3**,** 4-4, 4-5, and 4-6

Steps:

4.3.3. Troubleshooting

4.3.4. Spare Parts

SPARE PARTS LIST 920215 – BLADE MOUNTING PARTS				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	1	830570	Blade weight/KTM 13 m V27	
2	1	835808	Ball slewing ring, checked & mounted	
3	1	830585	Flange for pitch crank	
4	2	149446	D.B.I. Dut no. 37B	
5	1	834123	Pitch crank, machined, V27	
6	1	108874	D.B.I. Dut no. 127 red	
7	4	149497	Cap for grease nipple, 652912R	
8	4	149402	Grease nipple, M10 x1, H3	
9	2	108855	Thread cap, M10 x1	Only on pressure-tight bearings
10	2	108081	O-ring, Ø6.07 x 1.78 Viton	Only on pressure-tight bearings
11	2	105716	Nipple, M10 x 1	Only on pressure-tight bearings
12	2	108499	Seal, see 941914	
13	30	156662	Washer, hardened, DIN 6916 FZV M20	
14	30	153993	Steel bolt, 10.9 M20 x 180	
15			Seal, see 941914	
16	2.1 kg	149759	Sika-flex Bostik 2639, white	
17	2.5 m	137030	Sealing, bad poly Ø10	
18	3	151127	Allen screw, 12.9, M12 x 150 DIN 912	
19	3	155772	Washer, HB 200 FZV M12	
20	3	154360	Hexagon nut, M12 10 DIN 934	

4.3.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Blade mounting, drawing 1 of 4	
		Blade mounting, drawing 2 of 4	
		Blade mounting, drawing 3 of 4	
		Blade mounting, drawing 4 of 4	

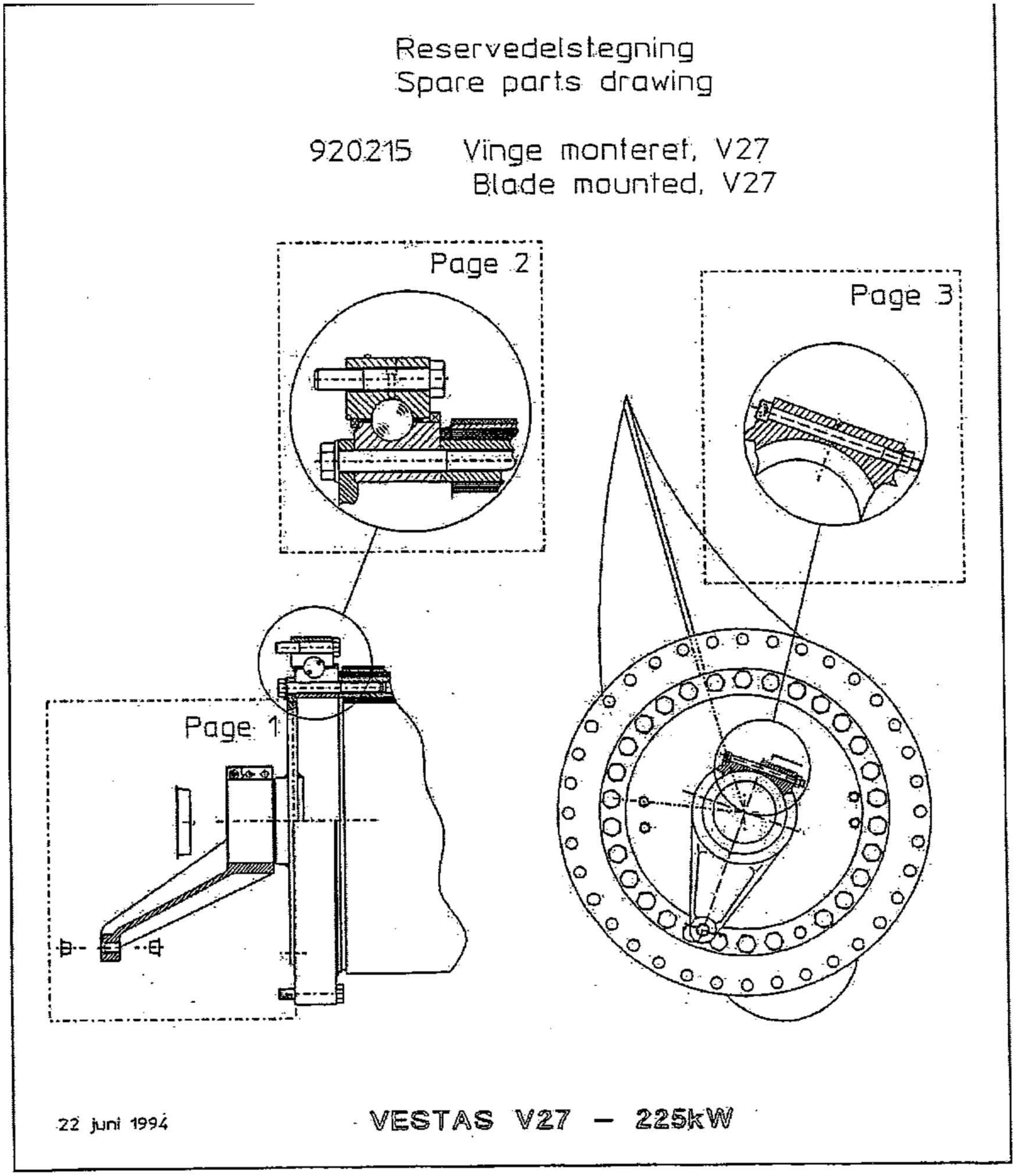


Figure 4-3. Spare parts drawing 1 of 4, blade mounting

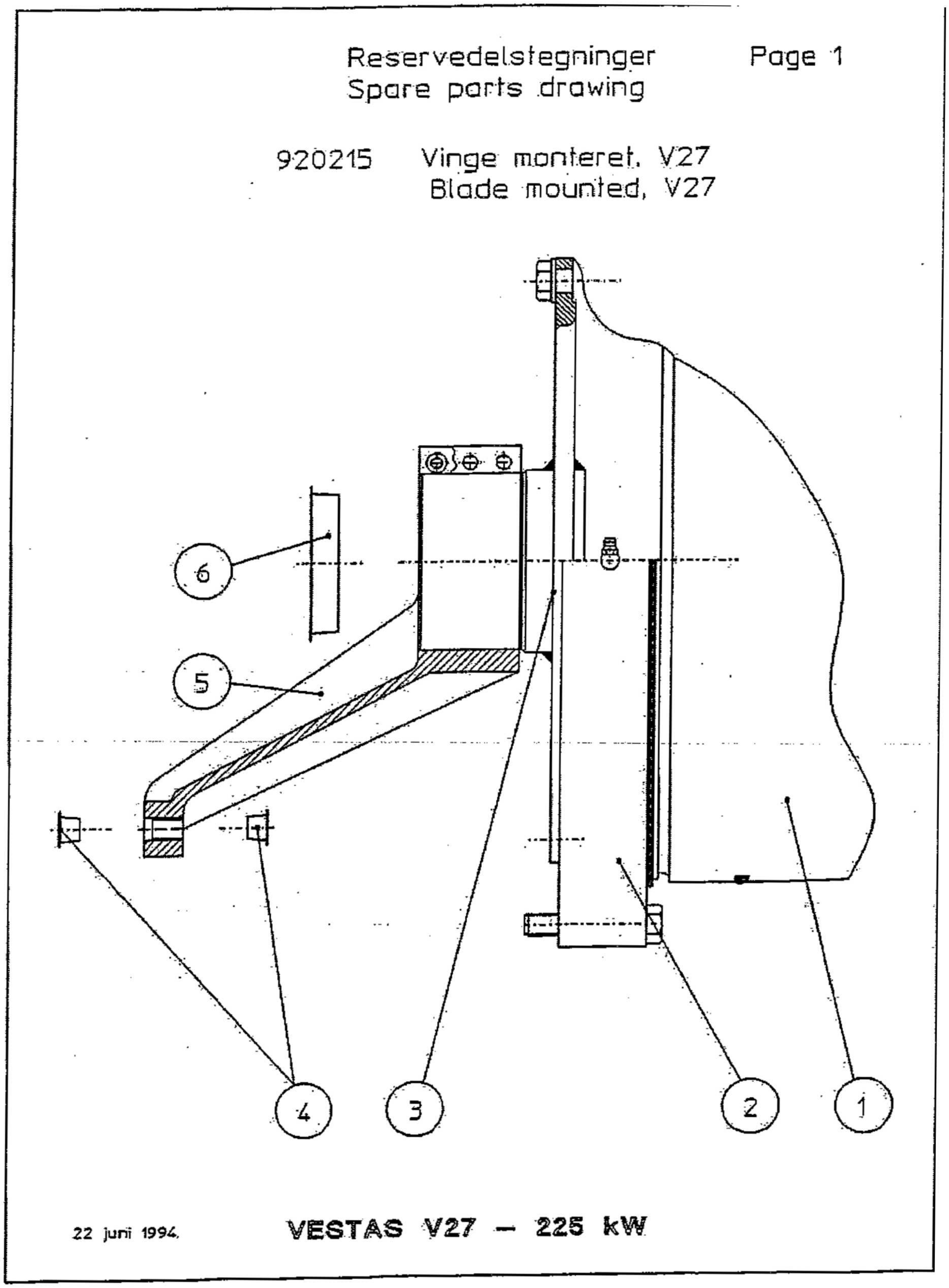


Figure 4-4. Spare parts drawing 2 of 4, blade mounting

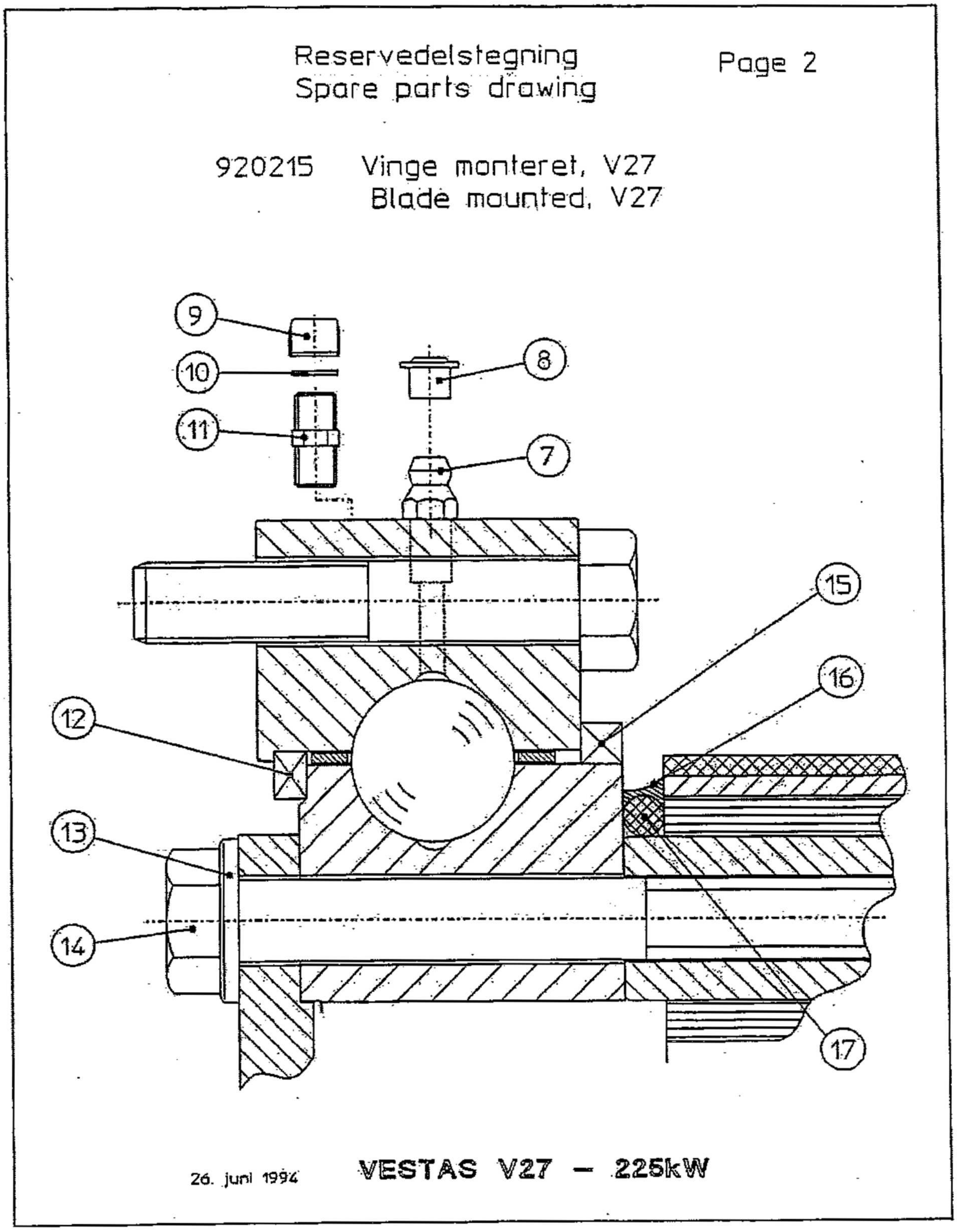


Figure 4-5. Spare parts drawing 3 of 4, blade mounting

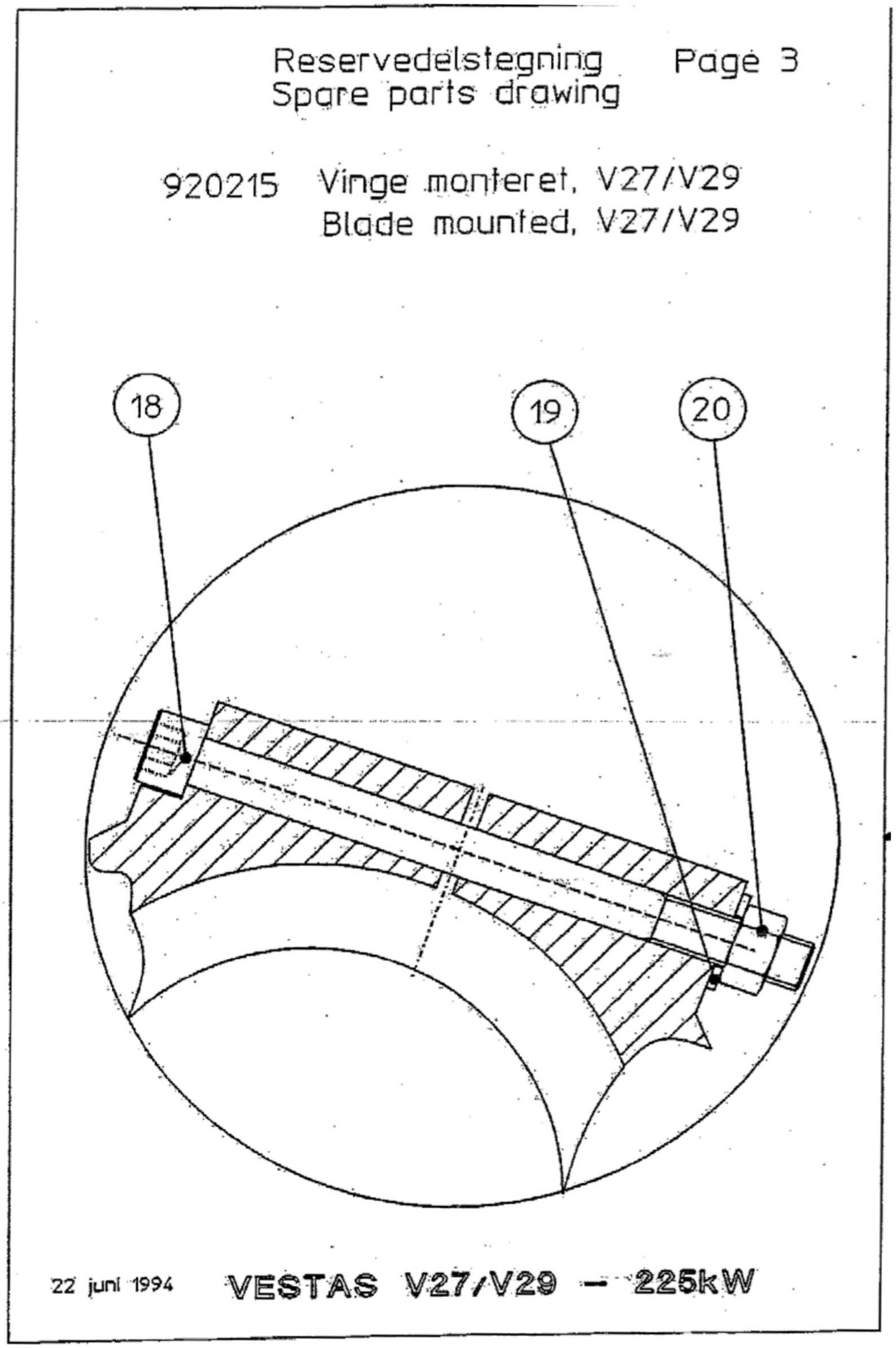


Figure 4-6. Spare parts drawing 4 of 4, blade mounting

4.4. Blade Bearing System & Hub

The hub serves as the connection point of the three blades of the rotor to the low speed shaft of the turbine. A bearing, described within, mounts the individual blades to the hub allowing rotation about the pitch axis of each blade.

4.4.1. Specifications

Hub:

Bolt circle size, pcs.:	480 mm, 28 bolts (used together with 34CrNiMo6 main shaft)
Material:	GGG 40
Weight:	450 kg

Blade bearing:

Type:	Ball slewing ring
Weight:	120 kg
Dimension:	Ø704 Ø468 x 93
Surface treatment:	Tectyl 127 CGW

4.4.2. Maintenance

4.4.2.1. Lubricate Blade Bearing

Interval: Every six months

Refer to Figure 4-7 and 4-8

Steps:

1. Identify the type of blade bearing and prepare the grease gun with the correct type of grease (see lubrication chart). Use approximately 200g/bearing.
2. Place the turbine in Stop.
3. Mount the security bolt in brake disc.
4. Press Emergency Stop and run a sinus test of pitch system as described in the Turbine Operating Manual.

Before entering the nose cone, check that the support frame is tightened and that there are no cracks that have weakened the bearing capacity of the nose cone.

5. Remove the blade bearing covers.
6. Bearings without air bleeding screws are to be lubricated as follows:
   6a. With the blades pitching, pump grease into each grease nipple 20-30 times.

6b. Lubricate the bearing until fresh grease flows out through the gap inside the hub.
6c. Grease that has leaked should be cleaned.

4.4.2.2. Treat Surface

Interval: Yearly

Refer to Figure 4-7 and 4-8

Steps:

1. Stop the turbine by pressing Pause.
2. Mount the security bolt in the brake disc.
3. Press Emergency Stop.
4. If the surface is rusted, bush the rust off with a steel brush.
5. Apply Tectyl 506 or similar rust prevention treatment.
   5a. Apply a thick layer in areas where the rust has been brushed off.
   5b. In other areas, apply a thin layer.
6. Treat the bolts as described above.

4.4.2.3. Inspect & Service Outer Bearing Seal

Interval: Three months after turbine startup, then every six months

Refer to Figure 4-5

Steps:

1. Stop the turbine by pressing Pause.
2. Mount the security bolt in the brake disc.
3. Press Emergency Stop.
4. Remove the blade bearing cover.
5. The outer bearing seal (pos. 12 and pos. 15, Figure 4-5) can vary. For bearings with a spring-loaded seal, ensure that the spring and lip are correctly positioned. If the seal is not positioned correctly, reposition it.
6. If bearings have leaked enough that grease is visible on the blade or inside the cover, examine the seal carefully. (Grease waste should be cleaned.)
7. Replace damaged seals. The type is identified in acc., instruction no. 941941. Cut the seal into the correct length and glue it in place with cyanoacrylate glue, with the seal encircling the blade. Be careful to cut straight and apply glue evenly; irregularities cause leaks. For seals with two lips, fill the gap between the lips with grease.
8. Refill bearings that have leaked. Lubricate the bearing through the grease nipples in the outer seal until fresh grease flows into the blade hub.
9. Check for excess grease inside the hub between the wall and the blade bolts in the same area as was lubricated. Wipe most of the extra grease off the seals.
10. Bearings with air bleeding screws should be lubricated as described in Section 4.4.2.1.

4.4.2.4. Inspect & Service Inner Bearing Seal

Interval: Three months after turbine startup, then every six months

Refer to Figure 4-5

Steps:

1. Normally, the bearing seal inside the hub will leak extra grease outside the bearing. (Bearings with air bleeding screws are pressure tight and should not leak grease.)
2. Inspect seal for damage and replace defective seals.
3. Wipe most of the extra grease off the seal.

4.4.2.5. Check Bolt Torque Between Slewing Ring & Hub

Interval: Three months after turbine startup

Refer to Figure 4-7

1. Lubricate the three bolts between the slewing ring and hub (pos. 2, Figure 4-7).
2. Tighten the bolts using torque wrench setting 325 Nm (240 ft.-lbs.).

4.4.2.6. Check Bearing Function

Interval: Yearly

Refer to Figure 4-7 and 4-8.

Steps:

1. Stop the turbine with one blade pointing downwards.
2. Put the turbine in Service state and run sinus test of pitch system.
3. Check that the blade rotation is uniform and that the bearings are not noisy.
4. Turn the next blade downward and repeat Steps 2 and 3.
5. Turn the last blade downward and repeat Steps 2 and 3.
6. Let the turbine idle slowly. Listen for noise when each blades passes vertical. If a clank is heard or the bearing visibly "rocks" when a blade passes vertical, measure the axial movement between the blade and outer seal. If the turning movement is not linear or the bearing backlash is greater than 0.5 mm, mark the bearing for replacement.

4.4.2.7. Check Slewing Ring Movement and Clearance

Interval: Six months after turbine startup

Refer to Figure 4-7 and 4-8.

Steps:

1. Check movement and clearance of slewing ring.

4.4.2.8. Retrofit Blade Bearing Cover

Interval: As deemed necessary

Note: The blade bearing cover ensures that water does not enter the blade bearing and that grease from the bearing does not contaminate the surface of the blade.

Refer to Figure 4-8

Steps:

1. Clean the blade bearing and blade with a rag and dry cleaner to remove any grease. (Take care not to remove the anti-rust protection on the blade bearing.)
2. Inspect blade bearing seals and, if necessary, replace damaged seals.
3. If the blade bearing has leaked significantly and the cover is filled with “diester” grease, it might be necessary to replace the cover. For small leakages, cleaning is typically sufficient. Use dry cleaner.
4. Hoesch Rothe Erde Bearings the protection disc./O-ring is removed at the filling plug of the bearing (see Figure 4-7).
5. Mount the V profile (115579) to the blade bearing so that it is in line with the edge of the blade bearing against the blade.
6. Place the seal block at the joint of the V profile. (Because the diameter of the blade bearing varies, it might be necessary to use two pieces.)
7. The sealing block must be mounted so that it does not touch the blade bearing cover (i.e. is in line with the edge of the V profile). Because the diameter of the blades varies, it might be necessary to make a custom adjustment.
8. Position the cover (114180) and the joint of the V profile so they don’t touch one another in the pitch area.
9. Mount the clips so it is possible to tighten both clips from the turbine.
10. Tighten the cover against the blade, taking care to tighten uniformly from both sides. It is secured that the cover ends soft against the V profile and it has its natural geometry after mounting.
11. If the cover “gaps,” adjust the locking device.
12. Conduct a pitch test to ensure that the cover mounting is positioned correctly.

4.4.3. Troubleshooting

4.4.4. Spare Parts

SPARE PARTS LIST 921637 – MOUNTING OF HUB				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	3	835808	Ball slewring checked & mounted	
2	108	153568	Steel bolt, 8.8 FZV M20-10	
3	1	834115	Hub, machined, V27	Type 1: Bolt circle 420 mm, 24 bolts
3	1	834116	Hub, machined, V27, DC 480	Type 2: Bolt circle 480 mm, 28 bolts

SPARE PARTS LIST – BLADE BEARING COVER RETROFIT				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	1/3	830639	Complete blade bearing cover retrofit	
2	1	108150	O-ring 44.2*3	
3	1	155437	Stainless steel bolt	
4	1	158783	Washer, nylon	
5	1	8831314	Cutoff washer	

4.4.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Mounting of hub	
		Mounting of the blade bearing cover retrofit	

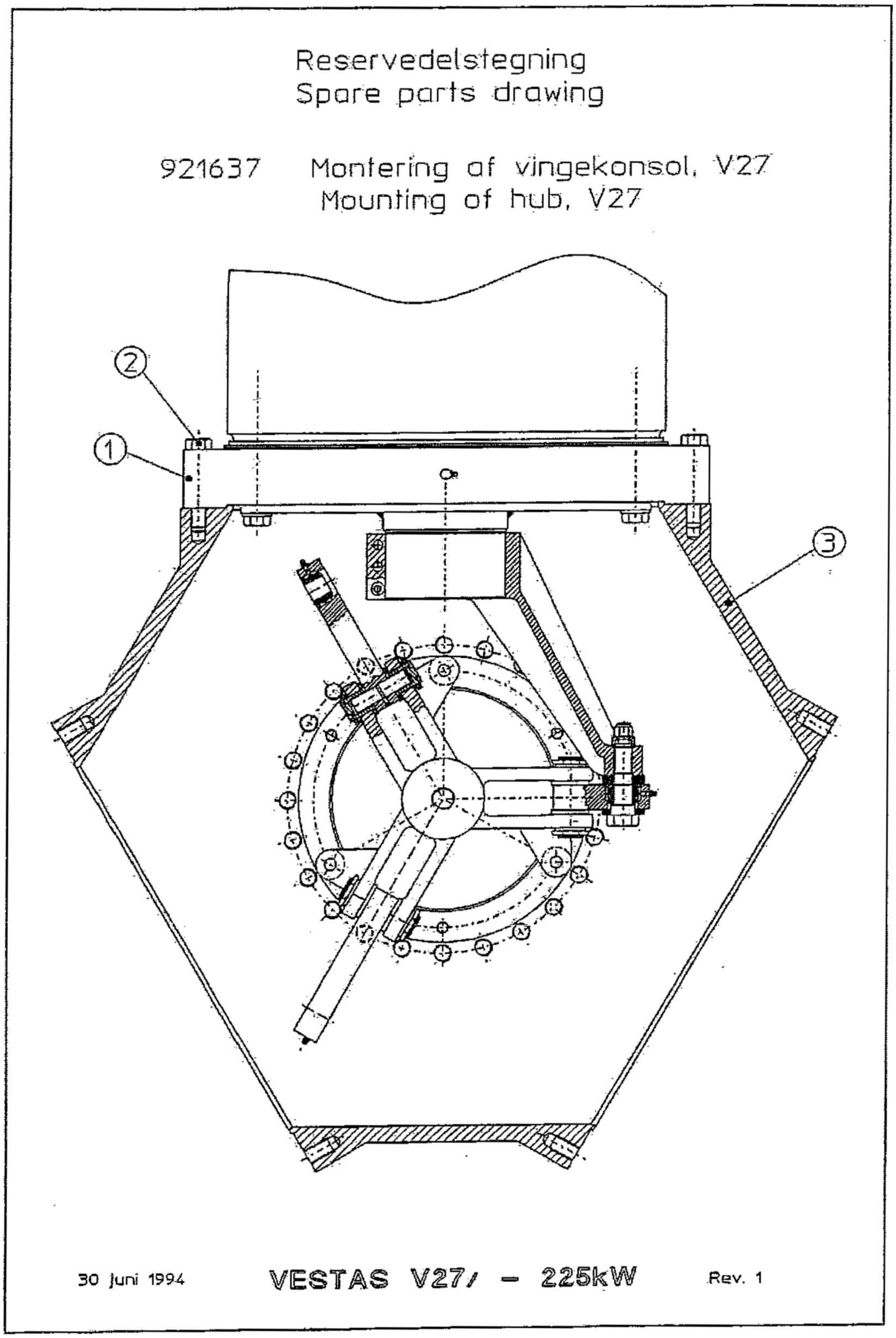


Figure 4-7. Spare parts drawing, mounting of hub

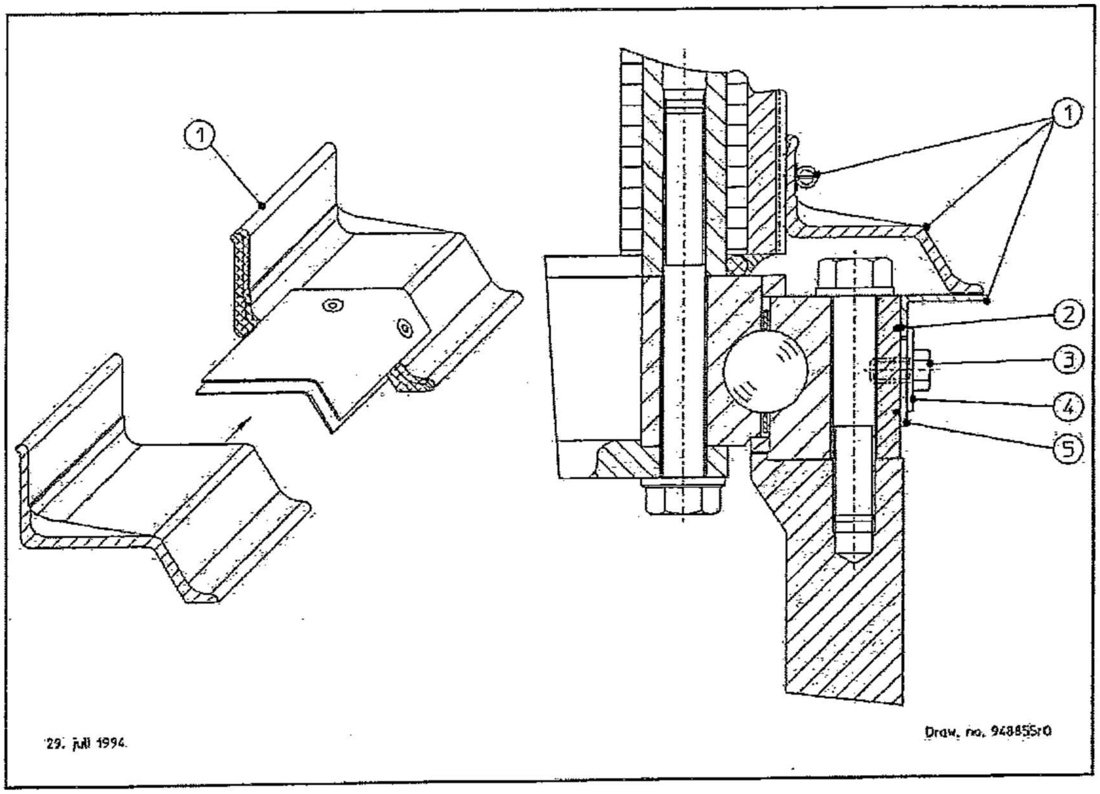


Figure 4-8. Mounting of the blade bearing cover retrofit

4.5. Traverse & Connecting Rod

The traverse is the means by which the blades are pitched from -5 degrees to 88 degrees. It is a series of tubes, linkages, and arms.

4.5.1. Specifications

Manufacturer:	Vestas
Glycodur bushings:	SKF GLY PG 202320F
Number:	6 pcs.
Stop screws:	M6 x 10 DIN 916 A4
Number:	3 pcs.
Nylon washers:	AN220 DIN 125A PA 6.6
Size:	Ø 20 X Ø 37 X 3
Number:	6 pcs.
Link bearings:	SKF GEH 25 ES-2RS
Number:	3 pcs.
Circlips:	147 x 1.75 DIN 472
Number:	3 pcs.
Mounting bolt:	M24 x 70 8.8 FZV
Number:	1 pcs.
Lock nuts:	
Size:	M33 x 1.5
Number:	6 pcs.
Torque:	275 Nm (203 ft.-lbs.)
Pitch crank shaft:	
Type:	M24
Number:	1 pcs.
Torque:	400 Nm (295 ft.-lbs.)
Weight:	30 kg (complete traverse)

4.5.2. Maintenance

4.5.2.1. Lubricate the Connecting Rod Bearing

Interval: Six months

Note: Use the exact grease specified in the lubrication chart, approximately 5g/bearing.

Refer to Figure 4-12

Steps:

1. Stop the turbine by pressing Pause.
2. Mount the security bolt in the brake disc.
3. Press Emergency Stop.

4. From inside the nose cone, remove the hub protective cover.
5. Apply grease via the three grease nipples in the end of the connecting rod (pos. 4, Figure 4-12).

4.5.2.2. Check Bolt Torque

Interval: Varies (see below)

Refer to Figure 4-7**,** 4-9, 4-10, 4-11, 4-12, and 4-14

Steps:

1. Place the turbine in Stop.
2. Mount the security bolt in the brake disc.
3. Press Emergency Stop.
4. **Center bolt in traverse (three months after startup)**: Check that the center bolt (pos. 53, Figure 4-14) is torqued to 567 Nm (418 ft.-lbs.). If it is possible to turn the bolt, it must be replaced with a new one.
5. **Bolt in crank, Type 1 (as needed)**: This M24 special bolt is locked with Locktite when the rotor is mounted (pos. 1, Figure 4-7). The bolts need not be checked unless you have a suspicion that they might be loose or in connection with a special torque inspection. Proper torque is 400 Nm (295 ft.-lbs.). If it is possible to turn the bolt, it must be replaced with a new bolt of Type 2 (see Step 6).
6. **Bolt in crank, Type 2 (as needed)**: This M24 special bolt is locked with an M16 counter nut. This bolt must be used for any replacement. The proper bolt torque is 400 Nm (295 ft.-lbs.), and the proper torque of the counter nut is 100 Nm (74 ft.-lbs.).
7. **Threaded bushings in traverse arms (three months after startup, then visual inspection every six months)**: M33 x 1.5 counter nuts (pos. 4, Figure 4-12, part 3need not be checked unless you have a suspicion that they might be loose or in connection with a special torque inspection. Proper torque is 275 Nm (203 ft.-lbs.). Be careful not to turn the bushings (pos. 3, Figure 4-12, part 4) when checking the torque wrench settings.
   - 7.2 If a counter nut can be turned and the opposite can't be turned, make the following adjustment: Tighten the bushing until it makes contact with the connecting rod, then turn it 1/12 turn backwards. Tighten the counter nut to the proper torque and lock it with Locktite.
   - 7.3 If both counter nuts can be tightened, make the following adjustment: Tighten the bushings until both counter nuts make contact with the connecting rod, then turn them 1/12 turn backwards. Tighten the counter nut to the proper torque and lock it with Locktite.
8. **Lock screw in connection rod (three months after turbine startup, then every six months):** If the lock screw (pos. 2, Figure 4-12, part 2 is loose, remove it, smear the thread with Locktite 243, and tighten it again.

4.5.2.3. Inspect Bearings

Interval: Yearly

Note: Before checking the bearings, pitch the blades backwards and forwards via the service mode to see how much play there is and if it is necessary to adjust with the above mentioned procedure.

Refer to Figure 4-12

Always press Emergency Stop before beginning work in the hub. When the pitch system is moved by use of the service box, under no circumstances should personnel enter the nose cone of the hub, as an Emergency Stop brings traverse tube and torque arms to the front of the hub hole.

Steps:

1. Stop the turbine by pressing Pause.
2. Mount the security bolt in the brake disc.
3. Press Emergency Stop.
4. **Connecting rod bearing in traverse**: Mount a dial indicator on a traverse arm with the sensor in the center of the connection rod and measure the radial play in the bushings (pos. 5, Figure 4-12). If the play is over 0.15 mm (0.006"), the glycodur bushings and the shaft will have to be replaced (pos. 13, Figure 4-12).
5. **Connecting rod link bearing**: Mount a dial indicator on the connecting rod with the sensor on the bolt head of the pitch crank shaft (pos. 1, Figure 4-9 and measure the radial play in the bearing (pos. 9, Figure 4-9. If the play exceeds 0.2 mm (0.008"), the bearing must be replaced. Remember to remove the seal rings.
6. Before trying to replace the link or slide bearings or the complete traverse, first lock the three turbine blades with mounting bolts to secure the traverse flange to the hub. (pos. 5, Figure 4-14).

4.5.3. Troubleshooting

4.5.4. Spare Parts

SPARE PARTS LIST XXX – SHAFT, CONNECTING ROD				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	3	833798	Pitch crank shaft	
2	3	158771	Washer, nylon, Ø55 x Ø31.8 x 1	
3	3	832936	Packing, nitrile rubber, Ø55 x Ø32 x 6	
4	3	831816	Connecting rod	
5	3	832928	Packing, nitrile rubber, Ø55 x Ø32 x 13	
6	3	834149	Bushing for pitch crank shaft	
7	3	834123	Crank	
8	3	834150	Clamping bushing for pitch crank shaft	
9	3	158054	Lock nut, M16, DIN 985, A4 80	

SPARE PARTS LIST 833207 – TRAVERSE MOUNTING				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	1	831433	Traverse with fittings, welded	Two types, welded or casted
1	1	833231	Traverse welded	Two types, welded or casted
2	3	151017	Allen screw, MSP FZB M6 x 10	
3	6	834182	Thread bushing f. traverse bearing	
4	6	834183	Counter nut for traverse bearing	
5	6	104296	Slide bearing, GLY.PG 202320F	
6	3	156082	Circlip, I47 x 1.75 DIN 472	
7	3	149306	Grease nipple, M6x1 H1M straight	
8	3	149497	Cap for grease nipple	
9	3	085421	Link bearing, GEH 25 ES-2RS	
10	3	831816	Connecting rod, V27	
11	6	834185	Nitril rubber, Ø35 x Ø50 x6	
12	6	158788	Nylon washer, AN220 Ø20 x Ø37 x 3	
13	3	833800	Shaft f. traverse – connecting rod	

4.5.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Shaft, connection rod crank	
		Traverse mounted	
		Link bearing in connecting rod	
		Traverse bearing unit	

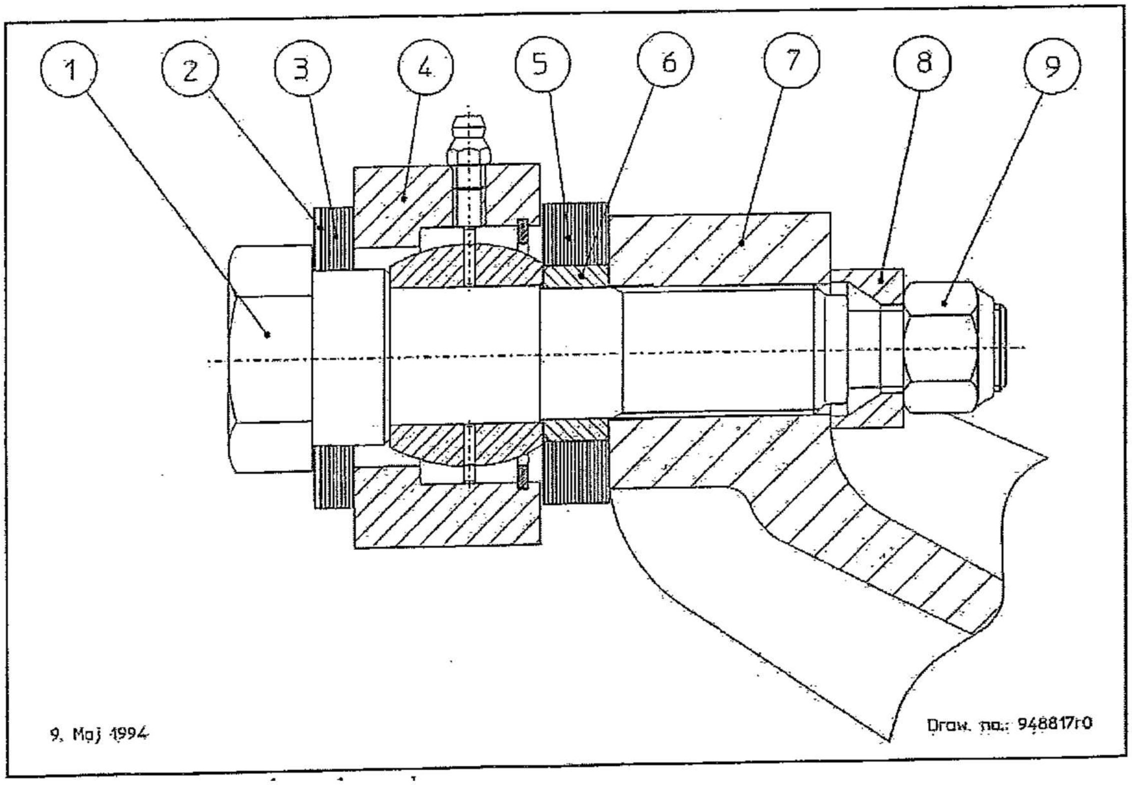


Figure 4-9. Spare parts drawing, shaft, connecting rod crank

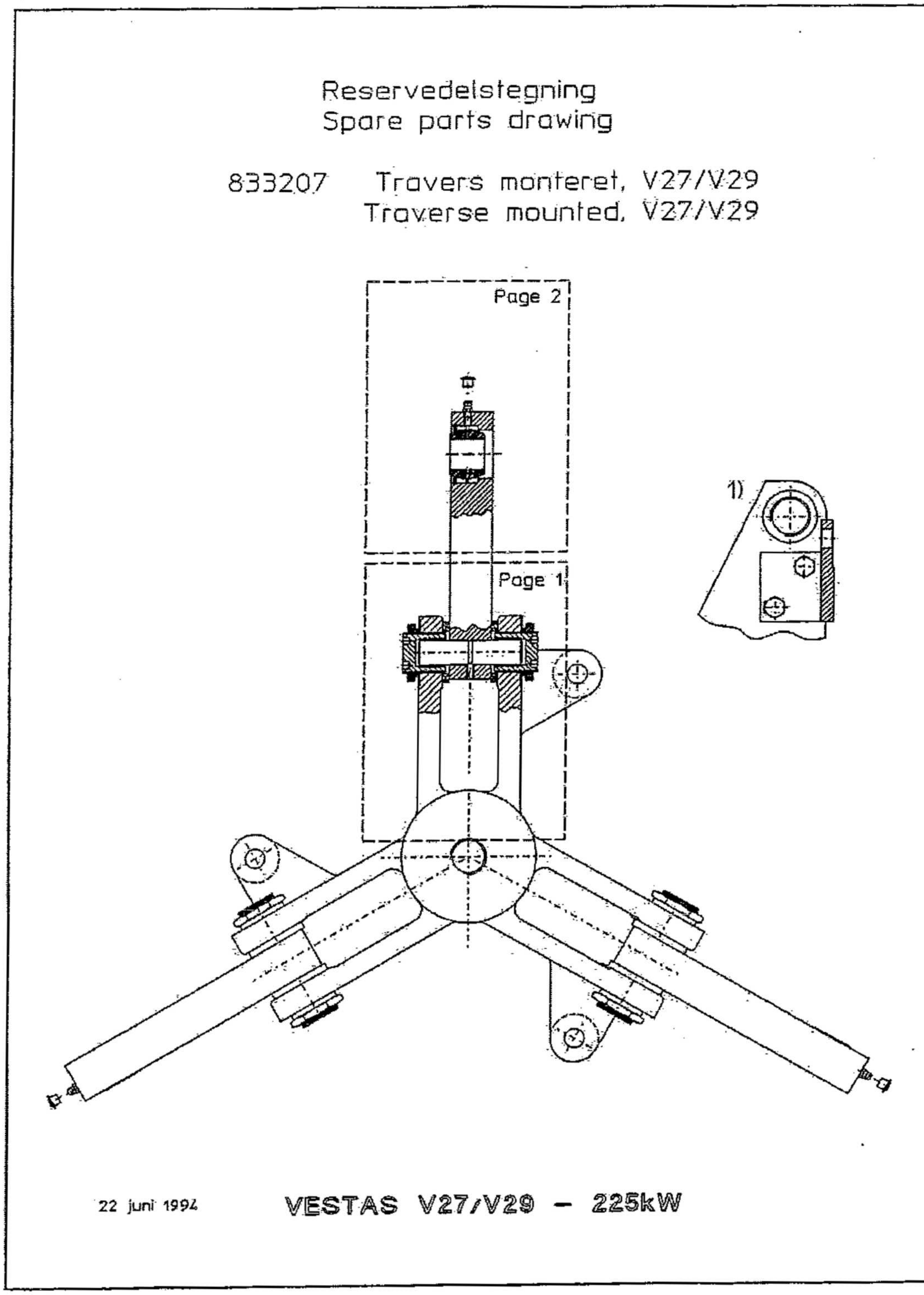


Figure 4-10. Spare parts drawing, traverse mounted

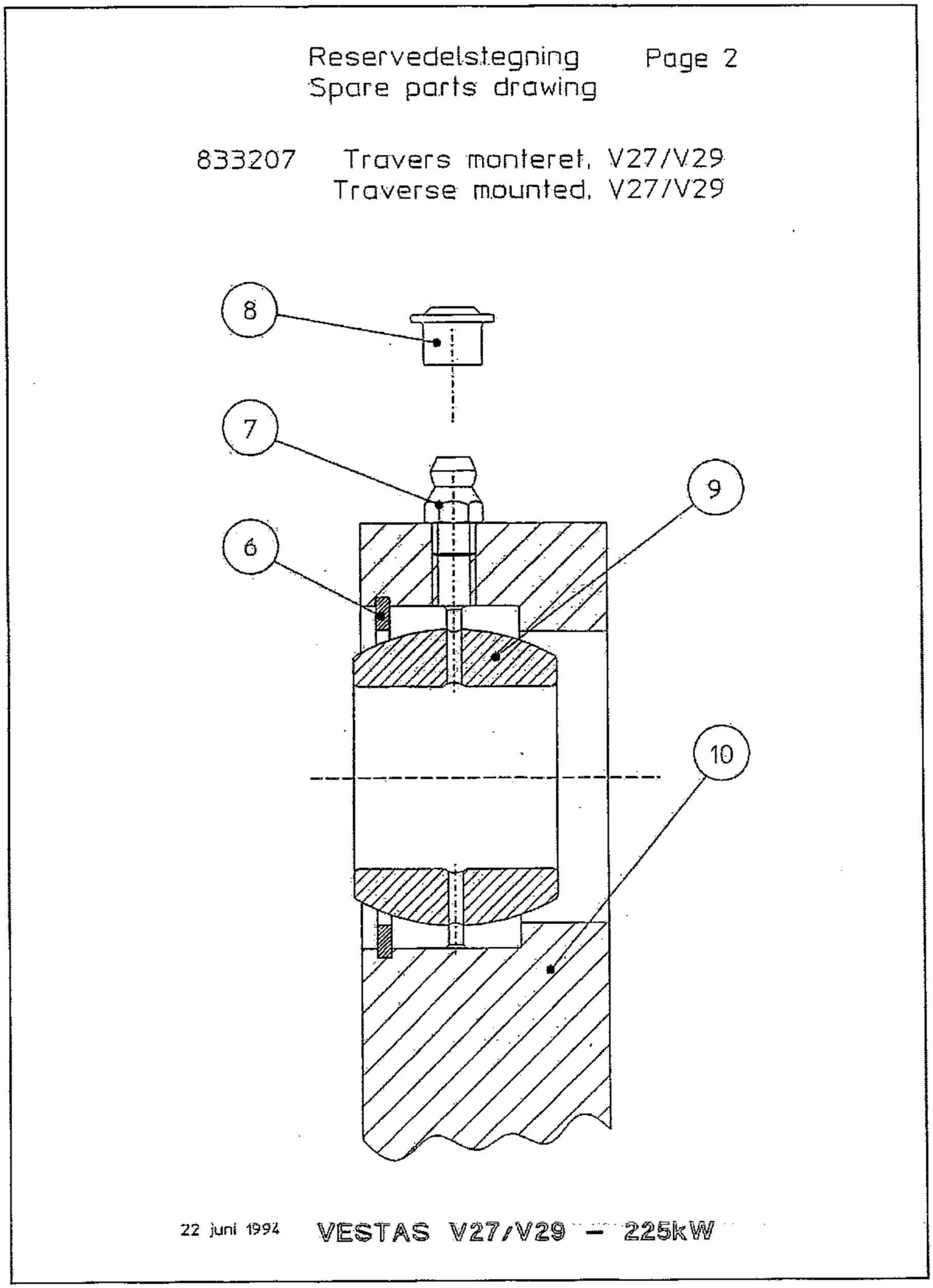


Figure 4-11. Spare parts drawing, link bearing in connecting rod

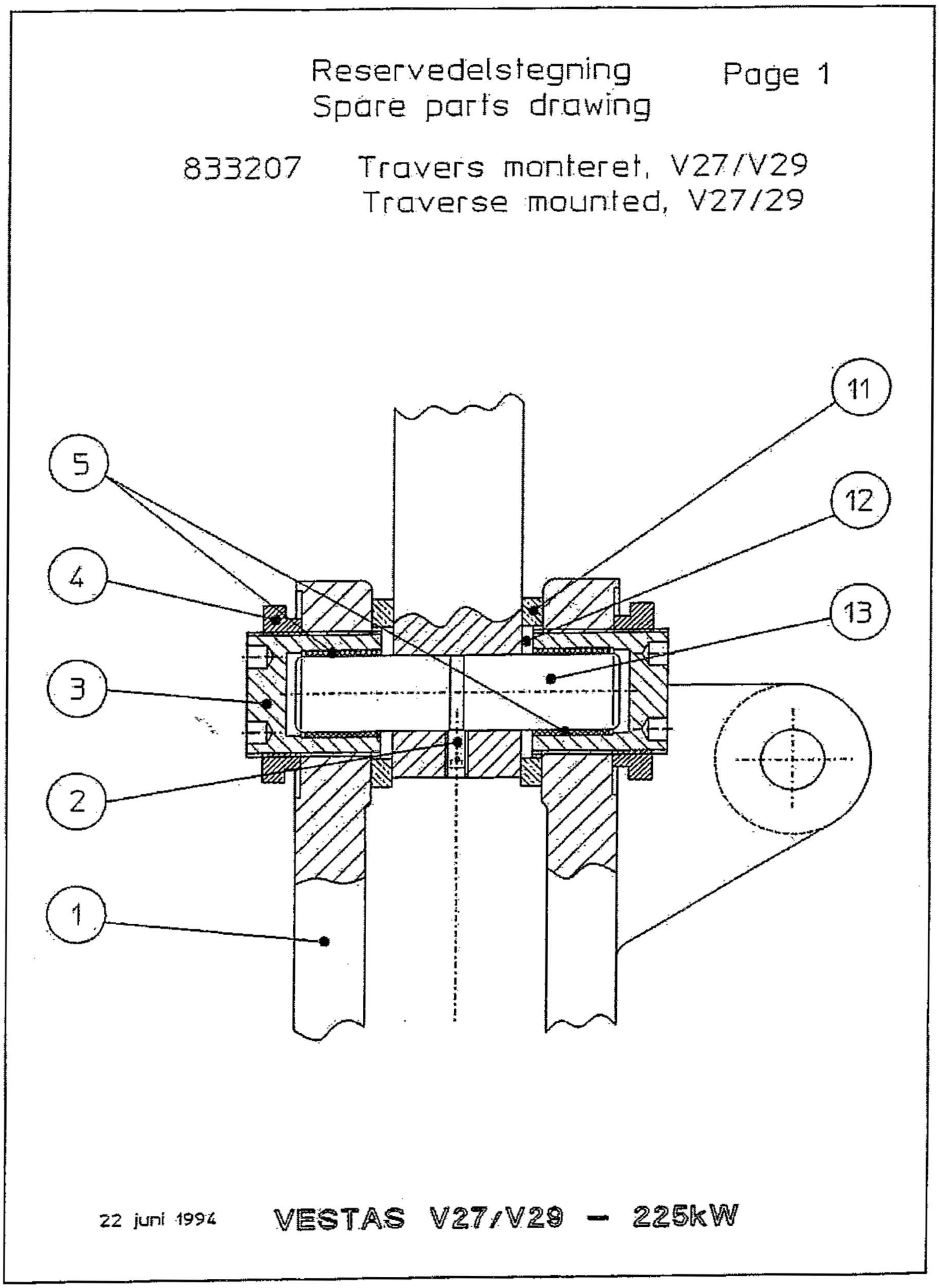


Figure 4-12. Spare parts drawing, traverse bearing unit

4.6. Pitch System

Sandia SWiFT turbine blades pivot along their own longitudinal axes to achieve variable blade angles relative to wind direction, called “pitch.” The turbine utilizes hydraulically controlled collective pitch control for optimum wind energy capture, variable rotor speed control, reduced load on the blades, and the ability to stop the turbine by collectively “full feathering” the blades to 90 degrees relative to the wind direction. This is accomplished by a single hydraulic actuator in the nacelle controlling a sliding traverse tube which rotates with the rotor. As the actuator extends and retracts the traverse tube, a mechanical traverse linkage converts the axial motion to a rotation of the blades about their pitch axes. A completely retracted pitch actuator translates to roughly -5 degrees of blade pitch, whereas a completely extended pitch actuator translates to roughly 90 degrees of blade pitch.

4.6.1. Specifications

Manufacturer:	Vestas
Glycodur bushings:	SKF GLY.PG 657050A
Number:	2 pcs.
Lip seals:	120 x 150 x 12 BA
Number:	2 pcs.
Coverplate:	MB19
KM-nut:	KM19
Pitch bearing:	SKF 7306 BECBP
Type:	Double angular contact ball
Arrangement:	O-device
Size:	Ø30 x Ø72 x 38
Carrying tube bearing:	SKF 23120 CC/W33
Type:	Spherical
Size:	Ø100 x Ø165 x 52
Nut for pitch bearing:	M24 x 2, DIN 985-8
Torque:	400 Nm (295 ft.-lbs.)
V-ring:	V-38A
Link bearings:	SKF GEG 25 ES
Number:	2 pcs.
Circlips (inner):	I42 x 1.75 DIN 472
Number:	4 pcs.
Circlips (outer):	U25 x 1.2 DIN 471
Number:	4 pcs.
Grease nipples:	M8 H1A, straight
Number:	2 pcs.
Grease nipples:	M6 x 1 H1M, straight
Number:	2 pcs.
Hydraulic cylinder:	
Manufacturer:	LJM
Type:	SNH30FD 63/30-337.5-g-(TN)
Thread on piston rod:	M24 x 2, length 50 mm

Oil feed thread:	2 pcs., ½" RG, inner
Flange diameter:	Ø95 h8
Number of bolts:	6 pcs.
Bolt circle:	115 mm
Bolt type:	M10 x 30 8.8 DIN 933 FZV
Rubber mounting:	
Manufacturer:	Schwing Metall
Type:	31660A
Size:	Ø30 x 30, M8 x 20.5
Weight:	95 kg

4.6.2. Maintenance

4.6.2.1. Lubricate

Interval: Six months

Note: Use the exact grease specified in the lubrication chart.

Refer to Figure 4-15**,** 4-16, 4-17, 4-18, and 4-22

⚠

When servicing the pitch system, take care not to put your fingers in the carrying tube as an Emergency Stop will make the parts in it move.

Steps:

1. Stop the turbine by pressing Pause.
2. Mount the security bolt in the brake disc.
3. Press Emergency Stop.
4. **Connecting rod bearing**: Remove the protective cover on the hub. Lubricate the visible part of the traverse tube with a brush dipped in grease. Use approximately 25g/bearing.
5. **Traverse pipe, rear bushing**: Remove the plastic cover (pos. 8, Figure 4-22) on the rear end of the gearbox. (On older types, the three upper M10 bolts in the hollow shaft are removed and the air filter is pulled to the side.) Lubricate with a grease gun through the upper air hole in the carrying tube bearing holder. Use approximately 25g/bearing. Pitch blades forwards and backwards before operating the turbine.
6. **Carrying tube bearing**: Remove the plastic cover on the rear end of the gearbox. Put the end of a plastic strip under the lip (pos. 6, Figure 4-15 and Figure 4-16) opposite the grease nipple. Lubricate via the grease nipple in the carrying tube. Use approximately 45g.
7. **Pitch bearing**: Yaw the turbine out of the wind to prevent any starting torque. Remove the Ø40 mm plastic plug (pos. 51, Figure 4-14), which is in the carrying tube. Put the

turbine in Pause and rotate the brake disc until the grease nipple in the pitch bearing housing is under the hole in the carrying tube. Lubricate via the grease nipple in the pitch bearing housing. Use approximately 25g.

8. **Link bearings, pitch bearing holder – cylinder**: Yaw the turbine out of the wind to prevent any starting torque. Remove the plastic tube (pos. 54, Figure 4-18) around the carrying tube. Put the turbine into Emergency Stop state. Lubricate via the two grease nipples in the end of the shafts. Use approximately 5g/bearing.

4.6.2.2. Check Bolt Torque

Interval: Three months after turbine startup, then yearly

Refer to Figure 4-16**,** 4-17, 4-18, 4-19, and 4-22

Steps:

1. Stop the turbine by pressing Pause.
2. Mount the security bolt in the brake disc.
3. Press Emergency Stop.
4. **Bolts to carrying tube holder**: Remove the plastic protection cover on the rear of the gearbox. Tighten the bolts (pos. 13, Figure 4-22) that hold the carrying tube holder (pos. 11, Figure 4-22) to the hollow shaft, using a torque wrench setting of 39 Nm (29 ft.-lbs.). If it is possible to tighten the bolts, they must be replaced.
5. **Bolts to carrying tube**: Tighten the bolts (pos. 15, Figure 4-16) that hold the carrying tube (pos. 33, Figure 4-17) to the carrying bearing housing (pos. 10, Figure 4-16), using a torque wrench setting of 39 Nm (29 ft.-lbs.). If it is possible to tighten the bolts, they must be replaced.
6. **Bolts to hydraulic cylinder**: Tighten the bolts (pos. 42, Figure 4-18) that hold the hydraulic cylinder (pos. 43, Figure 4-19) to the carrying tube (pos. 33, Figure 4-17), using a torque wrench setting of 39 Nm (29 ft.-lbs.). If it is possible to tighten the bolts, they must be replaced.

4.6.2.3. Replace Air Filter

Interval: Yearly or as needed

Note: In August 1990, the air filter (pos. 15, Figure 4-20) was replaced with a new type (pos. 9, Figure 4-22) mounted between the plastic protection cover (pos. 8, Figure 4-22) and the carrying bearing housing (pos. 10, Figure 4-20). Use this type with any replacement of the filter.

Refer to Figure 4-20 and 4-22

Steps:

1. Place the turbine in Stop.
2. Mount the security bolt in the brake disc.

3. Press Emergency Stop.
4. Remove one filter holder (pos. 14, Figure 4-22) and its three bolts (pos. 13, Figure 4-22) and cut away the air filter.
5. Tighten the three bolts again to prevent the pitch system from moving backwards if the wind affects the blades.
6. Remove the other filter holder, dismantle the filter and filter holder, and tighten all bolts, using a torque wrench setting of 38 Nm (28 ft.-lbs.).
7. Mount the plastic protection cover. Take care not to crush the cover.
8. Mount the air filter (pos. 9, Figure 4-20) as shown.

4.6.2.4. Check Bearings

Interval: Yearly

Note: Before the carrying bearing house is dismounted, Emergency Stop should be activated and the traverse should be locked with the three lock bolts.

Note: Check that there are no cracks weakening the mounting of the nose cone to the nose cone mounting and check that the nose cone mounting is correctly fitted before entering the nose cone.

Note: The pitch bearing has a calculated lifetime of 14 years; it is recommended that it be replaced after 10 years of operation.

Note: Take care not to get your fingers in the carrying tube as an Emergency Stop will cause the parts in it to move forward.

Refer to Figure 4-14**,** 4-15, 4-16, 4-17, 4-18, 4-20, 4-22, and 4-30

Steps:

1. Place the turbine in Stop.
2. Mount the security bolt in the brake disc.
3. Press Emergency Stop.
4. **Check of traverse tube and front bushing**: Check the visible end of the traverse tube (pos. 27, Figure 4-14) for damage. Measure the clearance between the traverse tube and the glycodur bushing (pos. 37, Figure 4-30). Mount a dial indicator on the cover for the traverse tube bearing (pos. 36, Figure 4-30) with the sensor on the traverse tube. Push the traverse sideways and measure the clearance. Note the clearance measurement in the inspection log. If the clearance is more than 0.3 mm between the traverse tube and the bushing, replace the glycodur bushing. Fill all holes in the glycodur bushing with grease before mounting. Also check the chromium plating on the traverse tube. If it is damaged, mark the item for replacement
5. **Check of traverse tube and rear bushing**: Check the visible end of the traverse tube (pos. 8, Figure 4-15 and Figure 4-16) for damage. Measure the clearance between the traverse tube and the glycodur bushing (pos. 8, Figure 4-15 and Figure 4-16). Mount a dial indicator on the carrying tube with the sensor through the upper M10 tapped hole on

the pitch bearing housing (pos. 29, Figure 4-17). Push the traverse tube up with a shaft through the lower M10 tapped hole and measure the clearance. If there is play between traverse tube and the bushing, the carrying bearing housing should be removed for further examination. Note the clearance measurement in the inspection log. If the clearance is more than 0.3 mm between the traverse tube and the bushing, replace the glycodur bushing (pos. 8, Figure 4-15 and Figure 4-16). Fill all holes in the glycodur bushing with grease before mounting. At the same time, check the chromium plating on the traverse tube. If it is damaged, mark the unit for replacement.

6. **Carrying tube bearing**: Remove the plastic cover (pos. 8, Figure 4-22) on the rear of the gearbox. Mount a dial indicator on the carrying bearing housing (pos. 10, Figure 4-15 and Figure 4-16), with the sensor on a bolt (pos. 13, Figure 4-22) on the hollow shaft. Pitch forwards and backwards by means of the service box and measure the clearance. Note the clearance measurement in the inspection log. If the clearance exceeds 0.45 mm, the bearing is noisy, or the bearing runs unevenly, mark the unit for replacement.
7. **Pitch bearing**: Remove the plastic tube cover (pos. 54, Figure 4-18) around the carrying tube. Pitch forward by means of the service box until the anti-rotation device (pos. 35, Figure 4-17) is under the four threaded holes in the carrying tube (pos. 33, Figure 4-17). Mount a dial indicator on the carrying tube with the sensor on the anti-rotation device (pos. 35, Figure 4-17). Press up and down on the splices (pos. 38, Figure 4-17) and measure the clearance. Note the clearance measurement in the inspection log. If the clearance exceeds 0.15 mm, if the bearing is noisy, or the bearing runs unevenly, mark the unit for replacement.
8. **Link bearings, pitch bearing holder – hydraulic cylinder**: Remove the plastic tube (pos. 54, Figure 4-18) around the carrying tube. Mount a dial indicator on the splice (pos. 38, Figure 4-17) with the sensor on the anti-rotation device (pos. 35, Figure 4-17). Pitch a few millimeters forwards and backwards by means of the service box and measure the clearance. Note the clearance measurement in the inspection log. If the clearance exceeds 0.2 mm, mark the unit for replacement Mount a dial indicator on the splice (pos. 38, Figure 4-17) with the sensor on the driving ring (pos. 46, Figure 4-18) on the piston rod. Pitch a few millimeters forwards and backwards by means of the service box and measure the clearance. If the clearance exceeds 0.2 mm, mark the unit for replacement.

4.6.2.5. Check Cylinder Mounting

Interval: Three months after turbine startup, then yearly

Refer to Figure 4-20

Steps:

1. Place the turbine in Stop.
2. Mount the security bolt in the brake disc.
3. Press Emergency Stop.
4. **Rubber mounting**: Check for cracks in the rubber mounting (pos. 9, Figure 4-20) and for rust on the metal parts. If the rubber mounting is damaged, replace it.

5. **Bolts**: Tighten the lock nuts (pos. 11, Figure 4-20) holding the rubber mounting to the angle hinge (pos. 12, Figure 4-20), the lock nuts (pos. 6, Figure 4-20) holding the angle hinge to the stay (pos. 14, Figure 4-20), and the stay to the rear nacelle bedplate. The cylinder mounting is lined up from Vestas, and the hinge, stay, and rear nacelle bedplate are locked in position with tubular rivet.

4.6.2.6. Check Hydraulic Cylinder for Oil Leaks and Damage

Interval: Three months after startup, then yearly

Note: Take care not to get dirt in the system.

Refer to Figure 4-24

Steps:

1. Place the turbine in Stop.
2. Mount the security bolt in the brake disc.
3. Press Emergency Stop.
4. Remove the plastic tube around the carrying tube.
5. Look for any leakage at the front seal of the hydraulic cylinder.
6. Check the piston rod for damage.
7. Check tubes and hoses for leaks.
8. If there is anything wrong with the hydraulic cylinder, replace the cylinder with a new seal and a new upper part with the new deflector type.

4.6.2.7. Check “Zero Position” for the Pitch System

Interval: Yearly

Note: When the turbine is delivered from Vestas, the pitch system is adjusted to its zero position, which corresponds with a tip angle of -5.0° and a distance between the end of the traverse tube and the mounting surface on the main shaft of 160.6 mm. During normal conditions this should not change. If repairs have changed the zero position, it must be readjusted.

Refer to Figure 4-17 and 4-18

Steps:

1. Place the turbine in Stop.
2. Mount the security bolt in the brake disc.
3. Press Emergency Stop.
4. **Locking of traverse**: Adjust the pitch to -5.0° by means of the service box. Mount at least two of the security bolts on the traverse (M16 bolt with a long welded T-piece), before you try to place the spacers. Place the spacers between the traverse and the hub. There are two types: For wind turbines with a welded traverse, it is a 10.9 mm long steel

bushing. For wind turbines with a casted traverse, it is a 2 mm thick washer. Lock the traverse to the hub by tightening the three security bolts smoothly in the traverse.

5. **Adjustment of link head**: Remove the protection tube (pos. 54, Figure 4-18) from the carrying tube (pos. 33, Figure 4-17). Press the piston rod in the hydraulic cylinder (pos. 43, Figure 4-18) against its rear stop. Loosen the two M8 Allen screws (pos 40, Figure 4-18) in the link bearing head (pos. 45, Figure 4-18) and check that the link bearing head can turn freely. Unscrew the link bearing head a few millimeters on the piston rod. Mount the hydraulic cylinder on the carrying tube (pos. 33, Figure 4-17) while adjusting the position of the link bearing head by turning the piston rod with the driving ring (pos. 46, Figure 4-18) until the mounting flange of the hydraulic cylinder and the carrying tube match. **During this operation the piston rod must be pressed against its rear stop**. Tighten the two Allen screws to lock the link bearing head. Mount the protection tube on the carrying tube. Remove the bolts and the spacers that lock the traverse.

4.6.3. Troubleshooting

4.6.4. Spare Parts

SPARE PARTS LIST 830320 – CYLINDER MOUNTING				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	3	153109	Steel set screw, 8.8 FZB M6 x 10	
2	3	155900	Washer, Ø6.4 x Ø18 x 1.6	
3	1	107280	Roller bear spherical, 23120CC/W33	
4	2	149306	Grease nipple, M6 x 1 H1M straight	
5	3	158160	Machine screw, UHJ FZB M6 x 25	
6	2	104512	Lip seal, 120 x150 x 12 BA	
7	1	834165	Bushing for lip seal	
8	1	104299	Slide bearing, GLY.PG 657050A	
9	1	831859	Carrying bearing cap	
10	1	831840	Carrying bearing housing	
11	1	831832	Carrying bearing cover	
12	1	156397	Coverplate, MB19	
13	1	08533	KM nut, KM19	
14	12	156256	Face washer, M10 FZV DIN 125A	
15	6	152235	Steel bolt, 8.8 FZV M10 x 70	
16	1	834808	Rail for anti-rotation device	
17	2	151036	Allen screw, MSP FZB M6 x 8	
18	1	157390	Lock nut, DIN 985-8 M24 x 2	
19	2	107034	Pitch bearing, 7306 BECBP	
20	1	107973	V-ring, V38A	
21	4	153141	Steel set screw, 8.8 FZV M8 x 20	
22	4	156663	Washer, HB200 M8 HDG	
23	4	151432	Allen screw, MC 8.8 FZB M8 x 20	
24	2	085423	Link bearing, GEG 25 ES	
25	4	156075	Circlip, U25 x 1.2 DIN 471	
26	4	832944	Nitrile rubber, Ø50 x Ø25 x 4 mm	
27	1	830771	Traverse tube	
28	1	831301	Seal washer for grease	
29	1	831808	Pitch bearing housing	
30	1	831794	Shaft for traverse tube bearing	

31	1	831311	Washer, Ø40 x Ø24 x 8	
32	1	836237	Thread plug for pitch bearing	
33	1	834719	Carrying tube, V27	
34	4	834155	Bushing for anti-rotation device	
35	2	834573	Anti-rotation device, V27	
36	2	149300	Grease nipple, M8 x 1.25 H1A straight	
37	2	862257	Shaft for gear mounting	
38	2	833269	Splice	
39	4	156078	Circlip, 142 x 1.75 DIN 472	
40	2	151338	Allen screw, MC 12.9 M8 x 30	
41	1	151567	Stop screw, M8 x 16	
42	6	154199	Steel bolt, 8.8 FZV M10 x 40	
43	1	108588	Hydraulic cyl. SNH30FD 63/30-337.5	
44	1	114285	Balluff sensor, 340 mm, V27	
45	1	833605	Link bearing, head f. hyd.-cylinder	
46	1	830318	Driving ring for piston rod	
47	1	836236	Thread plug for traverse tube	
48	4	149497	Cap for grease nipple	
49	4	149489	D.B.I. Dut No. 10	
50	2	149472	D.B.I. Dut No. 25	
51	1	149462	D.B.I. Dut H25	
52	1	831312	Ø 48.3 x Ø 25 x 10	
53	1	155349	Steel bolt, 8.8 FZV M24 x 70	
54	1	836401	Protecting tube, f. pitch mech.	
55	1	108282	O-ring, 164.7 x 3.53	
56	1	109630	Safety block, sc103300-000000-H-00	

SPARE PARTS LIST 921573 – CYLINDER MOUNTING				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	2	154785	Steel bolt, M8 x 70, 8.8 FZV	
2	2	897426	Washer, Ø8.5 x Ø28 x 4, FZV	
3	1	831507	Plastic holder for cyl. mounting	
4	2	831489	Thread bushing	
5	4	897388	Washer, Ø28 x 4, FZV	
6	6	157716	Locknut, M10 FZB	
7	4	154210	Steel bolt, M10 x 200, 8.8 FZV	
8	8	156256	Plane washer, M10 FZV DIN 125A	
9	2	114158	Rubber mounting	
10	2	156663	Plane washer, M8 FZV HB200	
11	2	157724	Locknut, M8 FZB	
12	1	831564	Angle hinge for cyl. mounting	
13	2	154199	Steel bolt, M10 x 40, 8.8 FZV	
14	1	831566	Stay for cyl. mounting	
15	1	836127	Plate for cyl. mounting	

SPARE PARTS LIST 921574 – CONNECTION GEAR PITCH				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	1	834130	Distance tube, anti-rotation device	
2	1	156695	Washer, M20, FZV	
3	8	151169	Allen screw, M20 x 55, 12.9	151169 is a Vestas item no., the Allen

				screw is mounted on Flender gearbox
4	8	153241	Steel bolt, M20 x 55, 8.8	153240 is a Vestas item no., the steel bolt is mounted on Hansen gearbox
5	1	834574	Anti-rotation device, carrying tube V27	
	1	709782	Anti-rotation device, carrying tube V29	
6	4	156455	Washer, M12, FZV	
7	4	155276	Steel bolt, M12 x 16, 8.8	
8	1	834407	Plastic protection cover	
9	1	137040	Air filter, 30x30x750	
10	1	831840	Carrying bearing housing	
11	1	831859	Carrying bearing cap	
12	6	156256	Washer, M10 FZV, DIN 125A	
13	6	153230	Steel bolt, M10 x 35, 8.8 FZV	
14	1	831508	Filter holder	
15	1	831509	Air filter	

4.6.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Pitch system	
		Traverse-traverse holder	
		Carrying bearing 1 of 2	
		Carrying bearing 2 of 2	
		Pitch bearing	
		Cylinder connection	
		Safety block	
		Cylinder mounting	
		Connection gear-pitch	
		Connection gear-pitch	
		Double-acting cylinder	
		Pitch cylinder	
		Pitch ram seals	
		Pitch ram	
		Pitch ram seals	

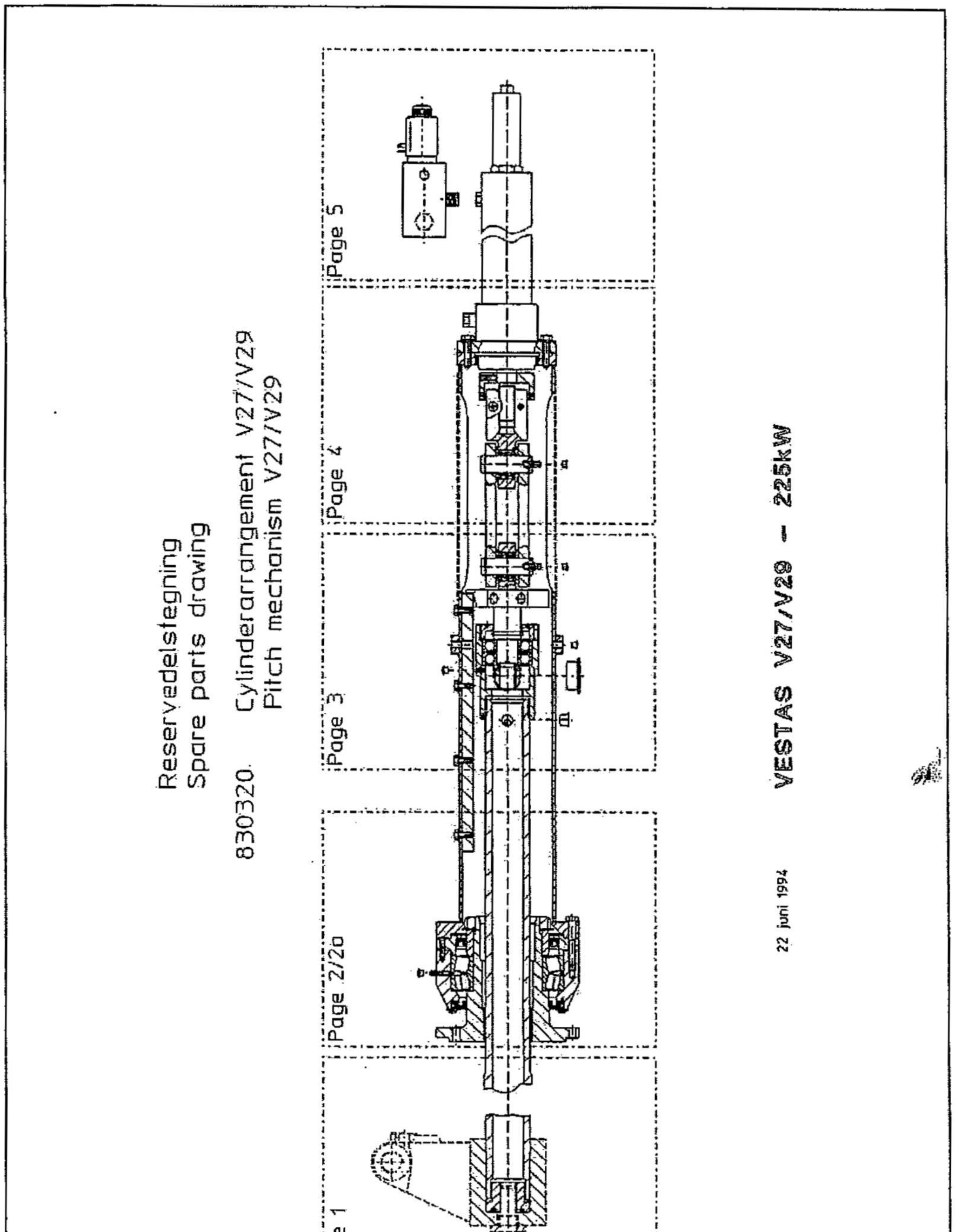


Figure 4-13. Spare parts drawing, pitch system

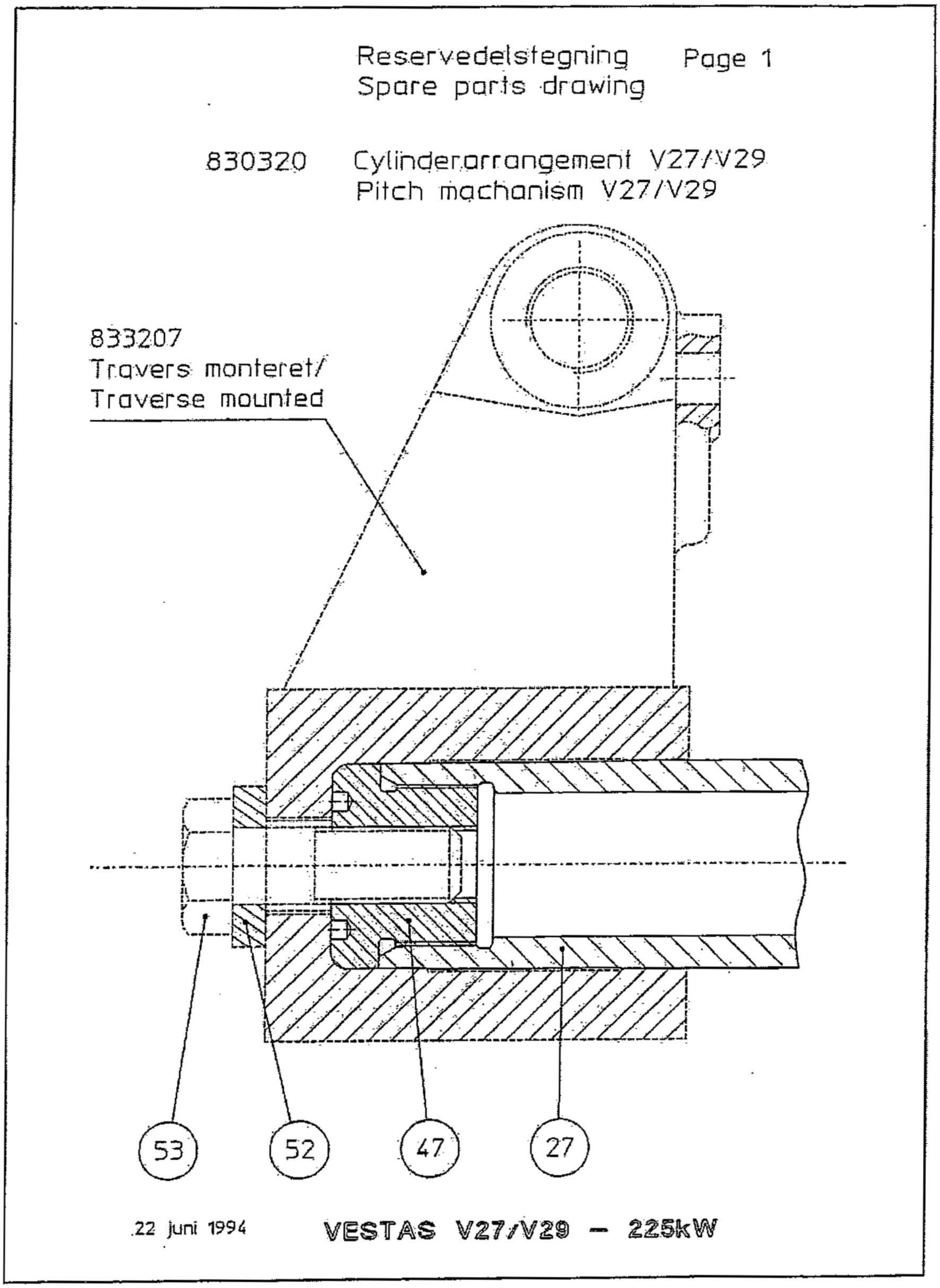


Figure 4-14. Spare parts drawing, traverse – traverse holder

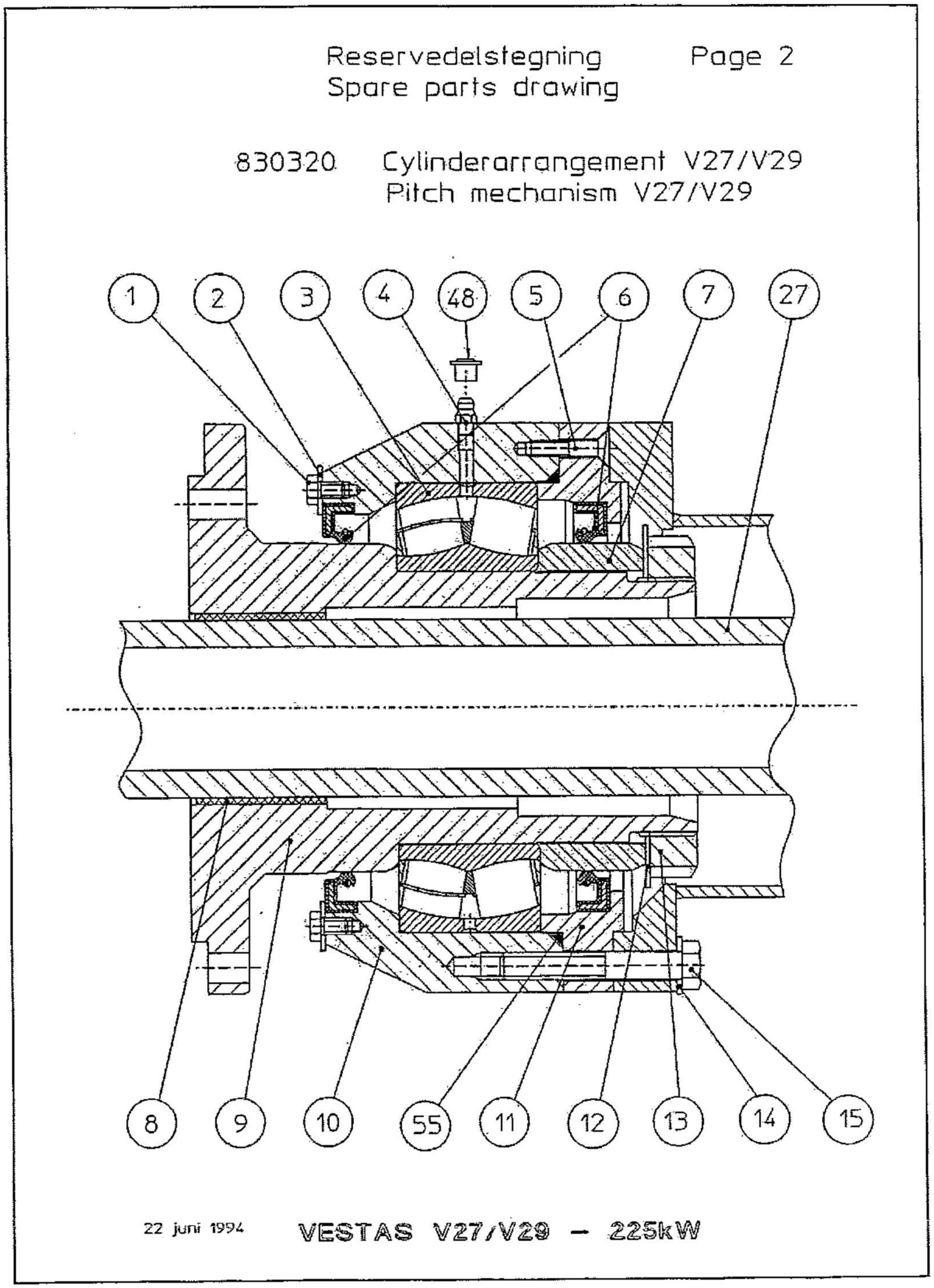


Figure 4-15. Spare parts drawing, carrying bearing 1 of 2

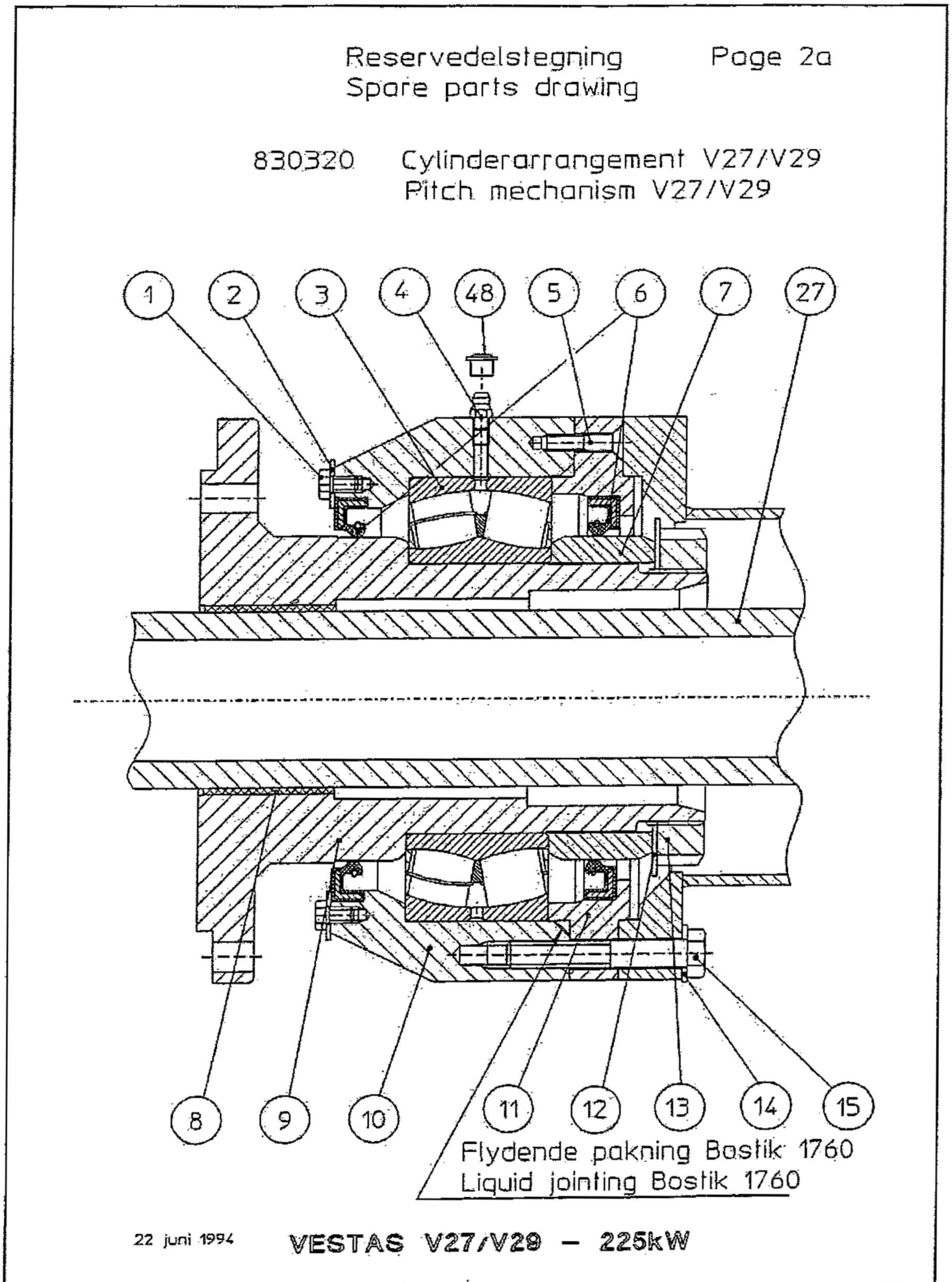


Figure 4-16. Spare parts drawing, carrying bearing 2 of 2

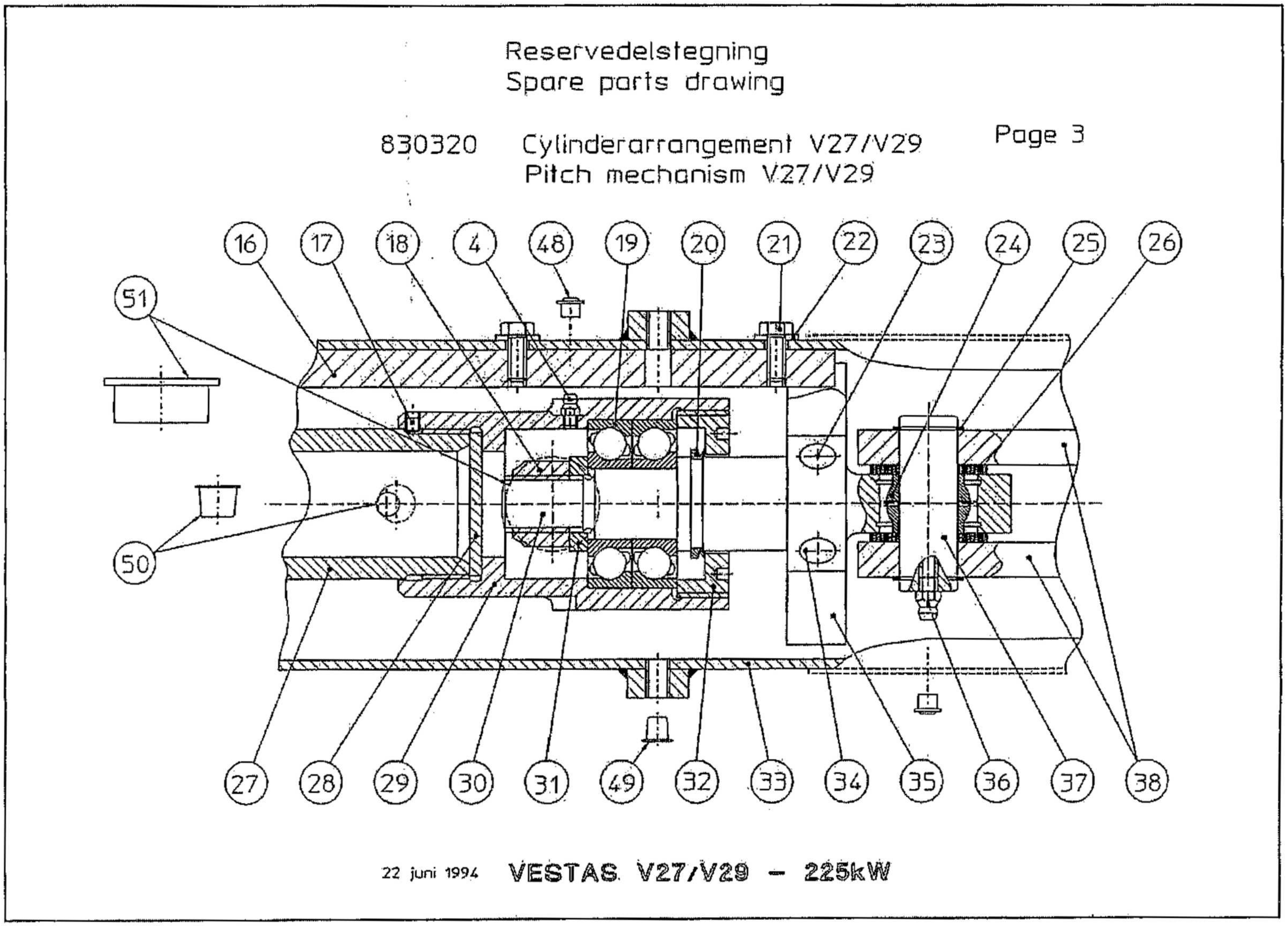


Figure 4-17. Spare parts drawing, pitch bearing

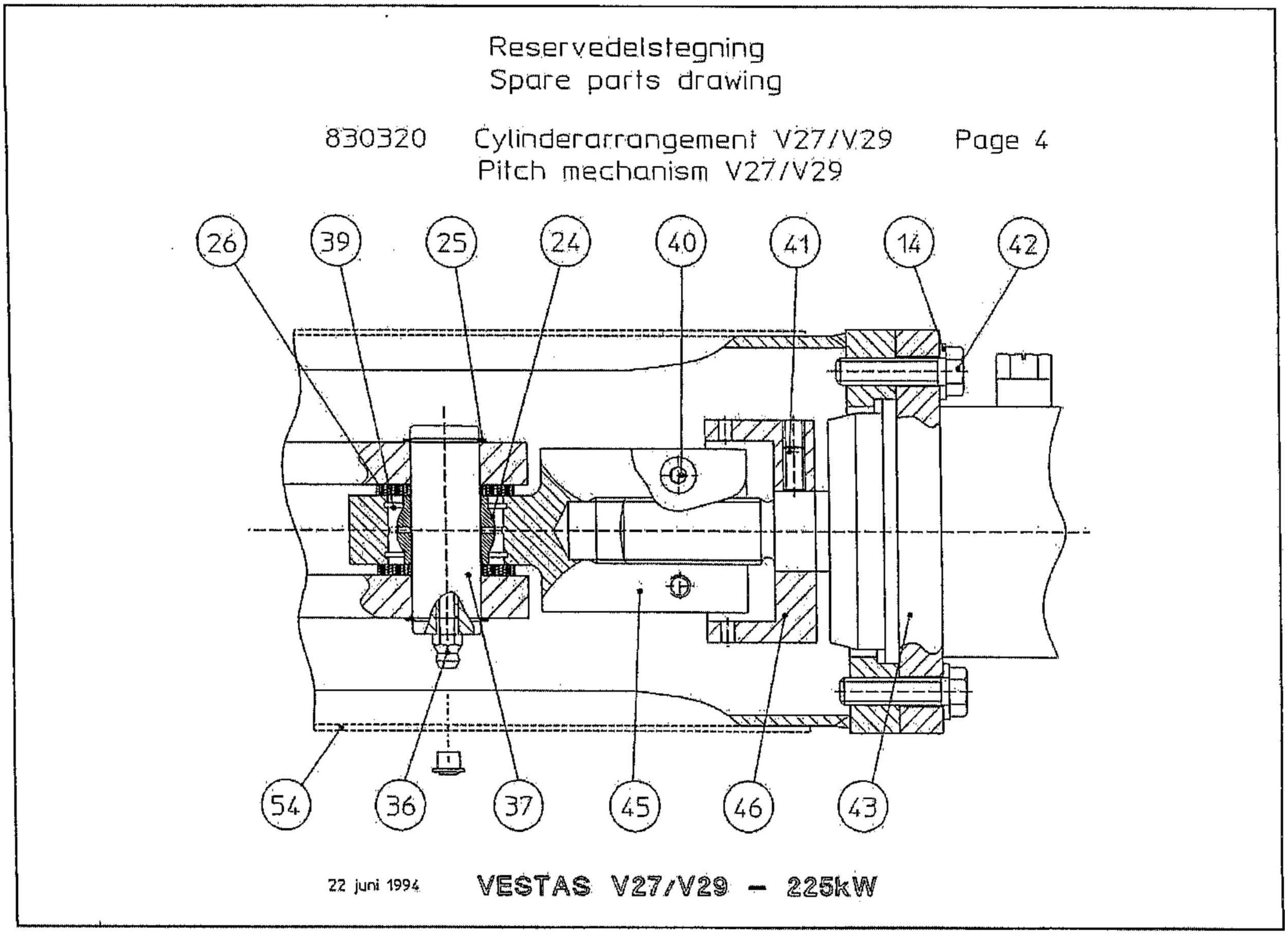


Figure 4-18. Spare parts drawing, cylinder connection

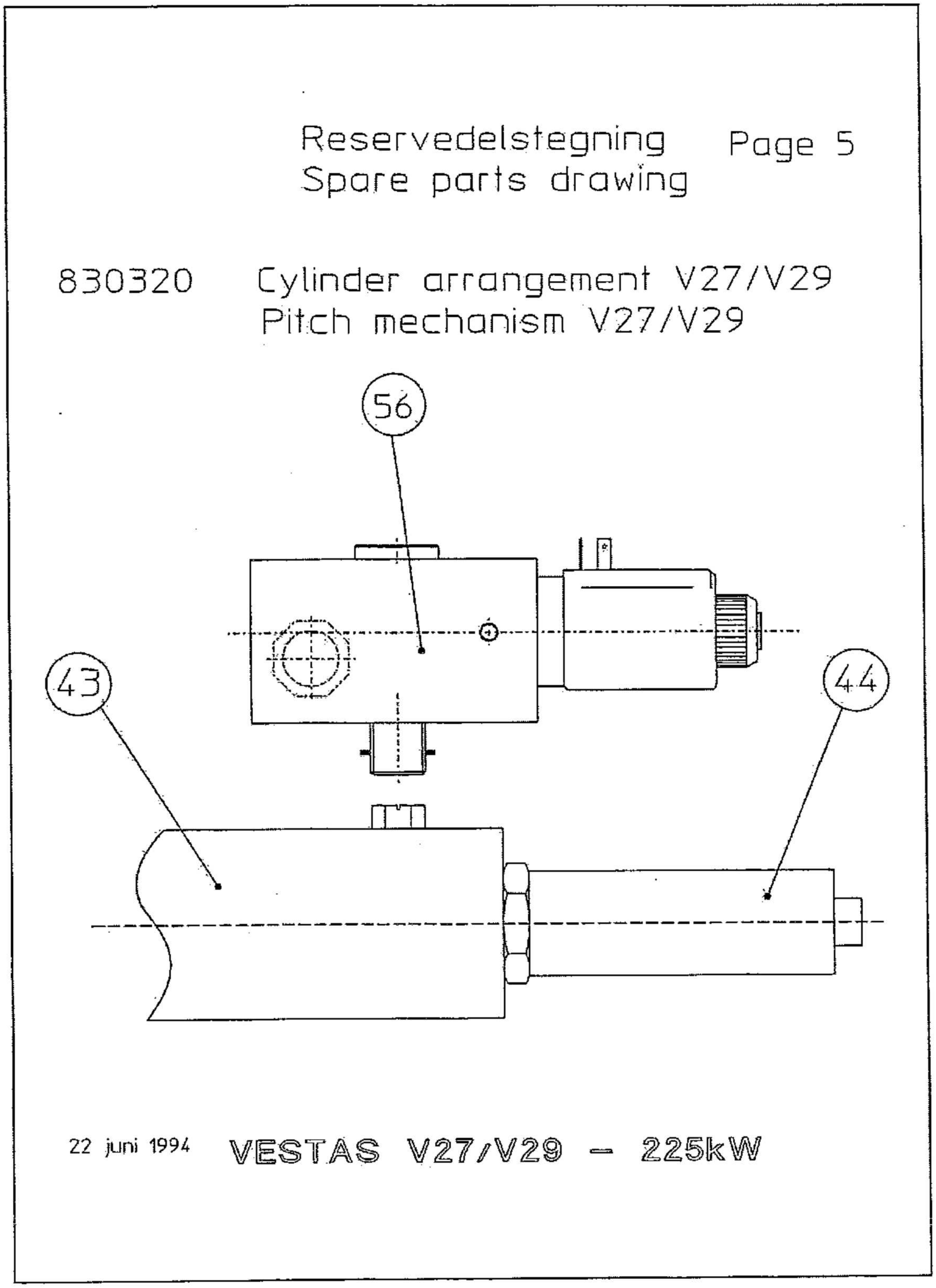


Figure 4-19. Spare parts drawing, safety block

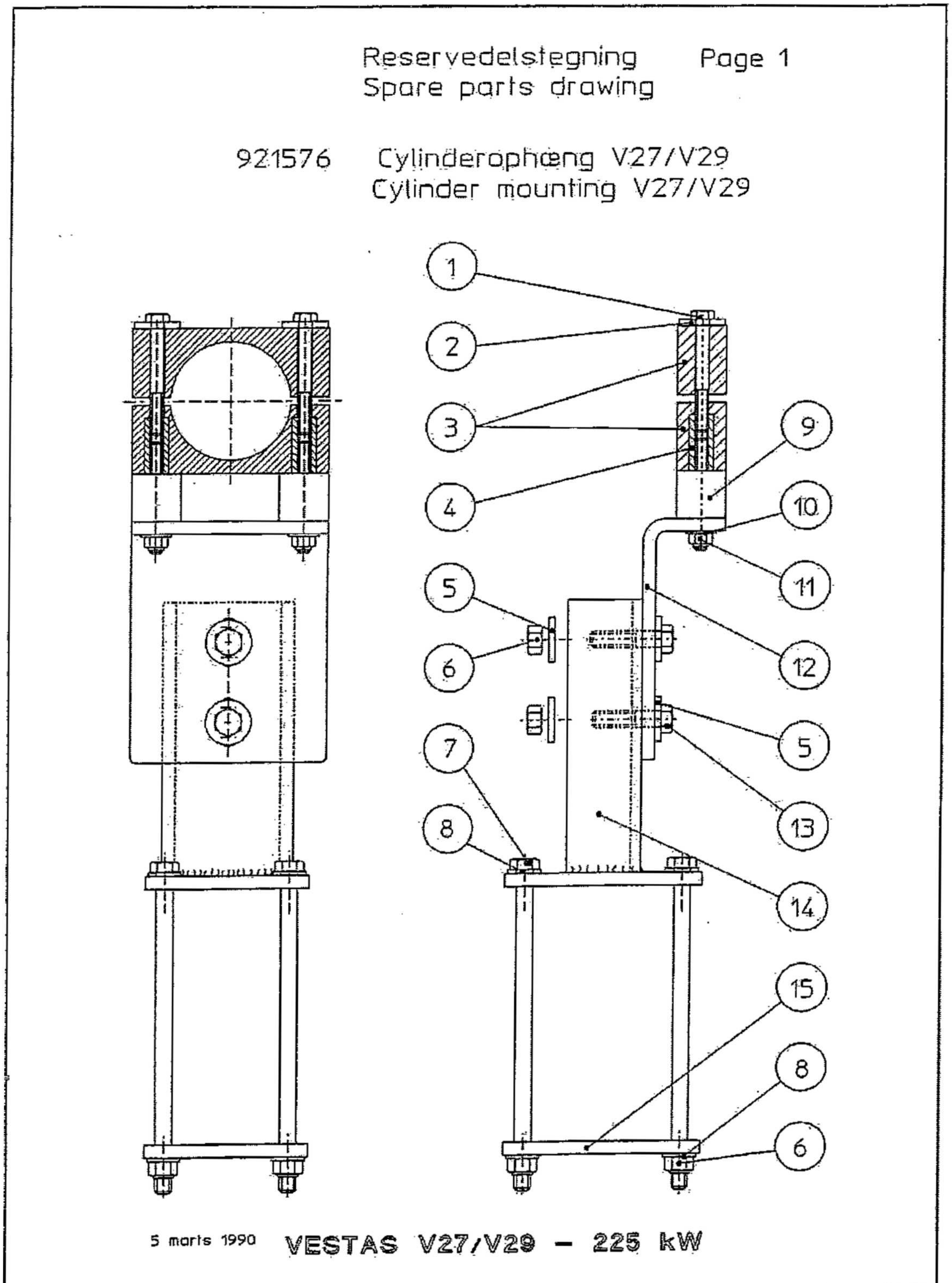


Figure 4-20. Spare parts drawing, cylinder mounting

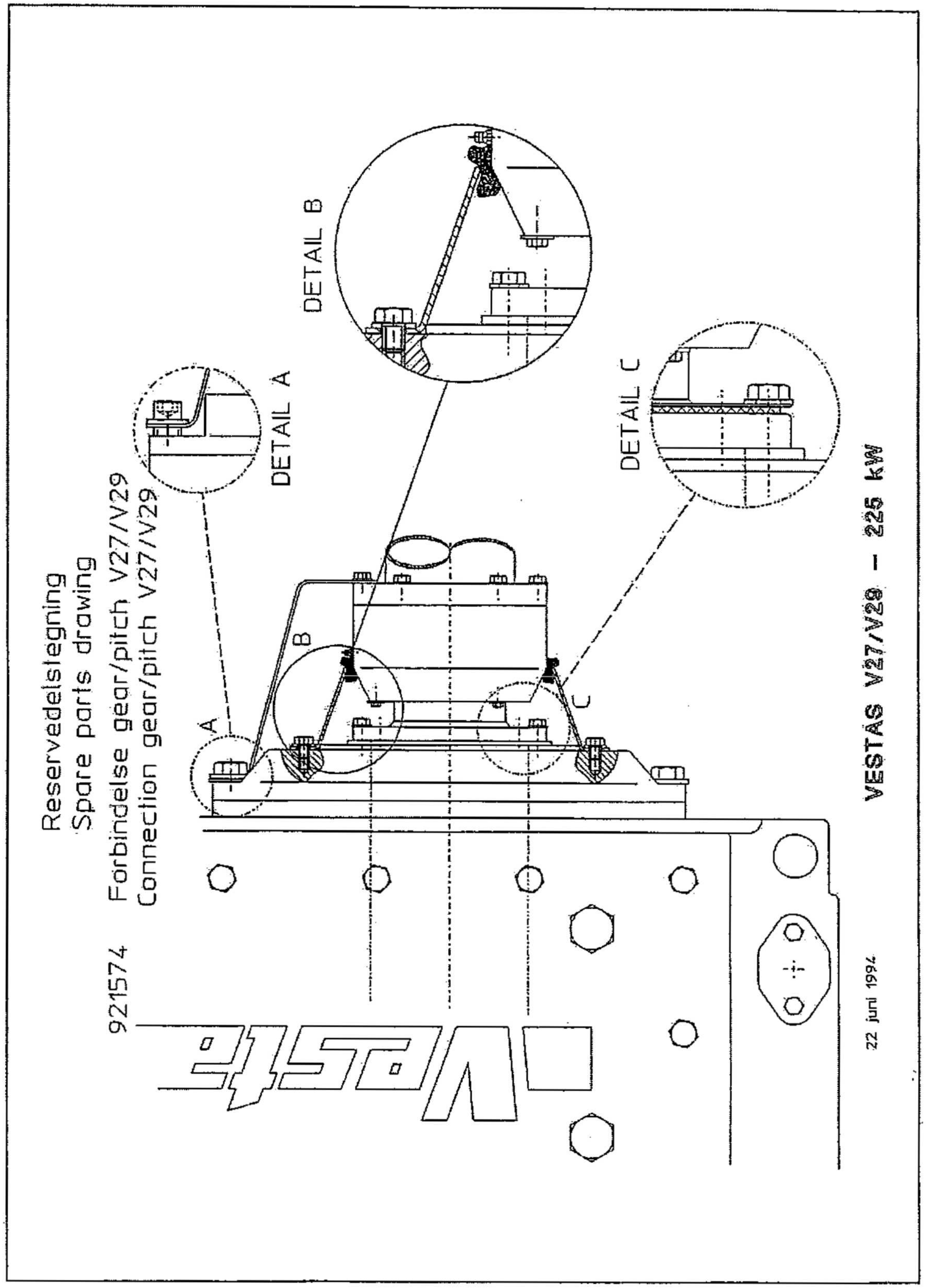


Figure 4-21. Spare parts drawing, connection gear-pitch

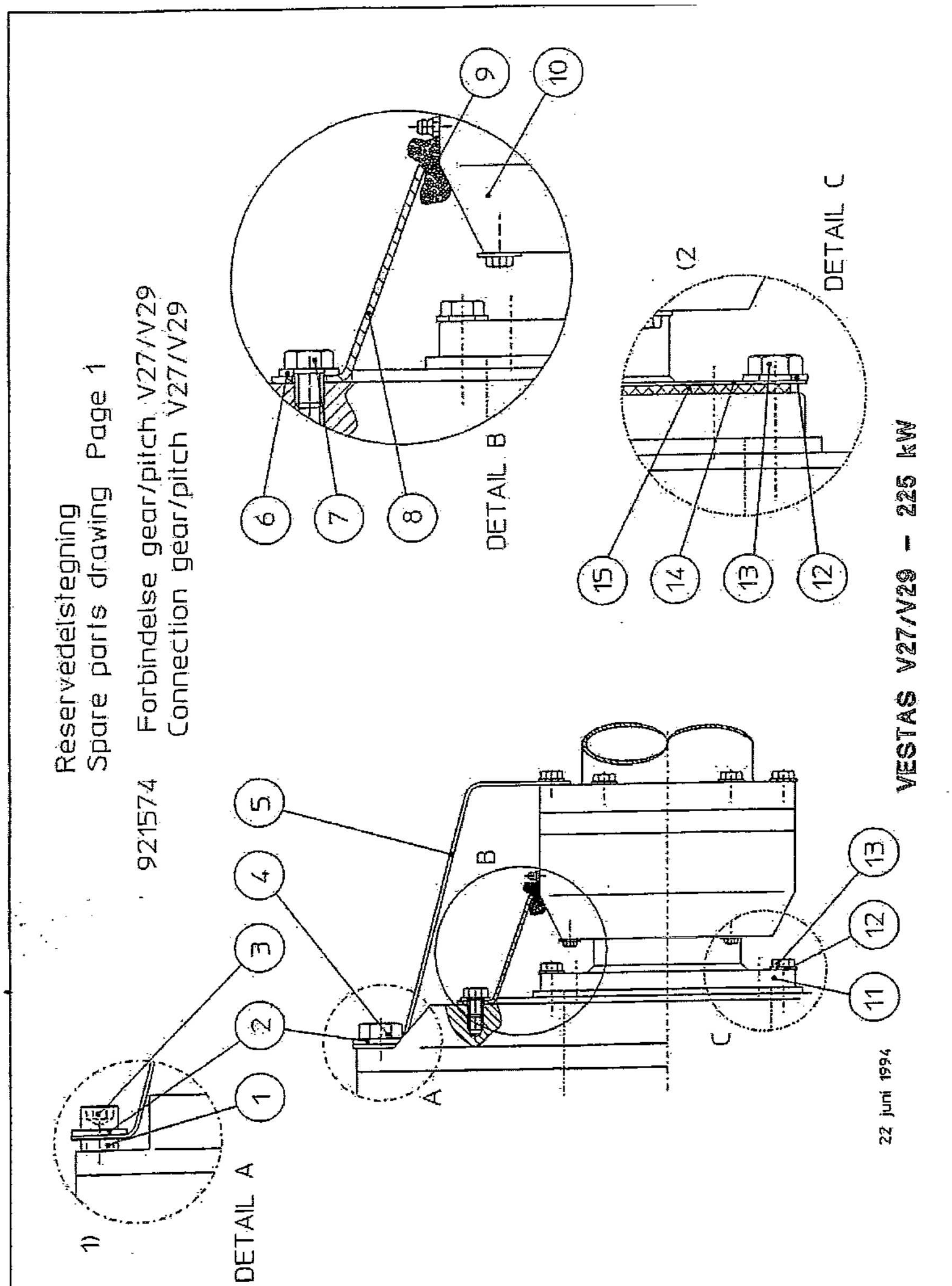


Figure 4-22. Spare parts drawing, connection gear-pitch

Styktal	Titel: SPAREPART LIST				Nr. 5.20 021-1890-0-R
	Emne: Double-acting cylinder				Blad.....1.......af
	Type: sNH30-FD- 63/ 30x337,5-g-(TN) 5036139				........1......blade
	Genstand	Tegn. nr.	Mrk. nr.	Dimension	Vare nr.
1	Cylinder barrel compl.	-1890-20	11+5+20		5320101
1	Rod compl.	-1890-10	10+1+2+8		5470135
1	Piston	-4088-5	15		5250058
1	Front end cover	2025003	9		2025003
1	Spacing washer	-3788-2	17		5270043
1	Magnet washer		18		35061
2	Screw		19	Acidproof UNBRACO M3x20	26017
1	Stopscrew		16	M5x5	27118
1	Balluff sensor		22	BTL-A10-0340-A-S-32	35090
1	O-ring		21	2,1 x 15,4	31055
1	Cable Socket			BKS-S 32-00	35091
	Sealings complete:				5265282
	Pos. 3+4+6+7+12+13+14				
					(5)

Dato	Rettelse	Dato	Rettelse	Dato	Rettelse	Dato	Rettelse

Skrevet.	03.05.90	MJ	LJM Lind Jensens Maskinfabrik A/S Højmark - 6940 Lem St. Telefon 97 34 32 00 Telefax 97 34 30 02	Erstat:
Godk.				Tg. nr.

Figure 4-23. Spare parts list, double-acting cylinder

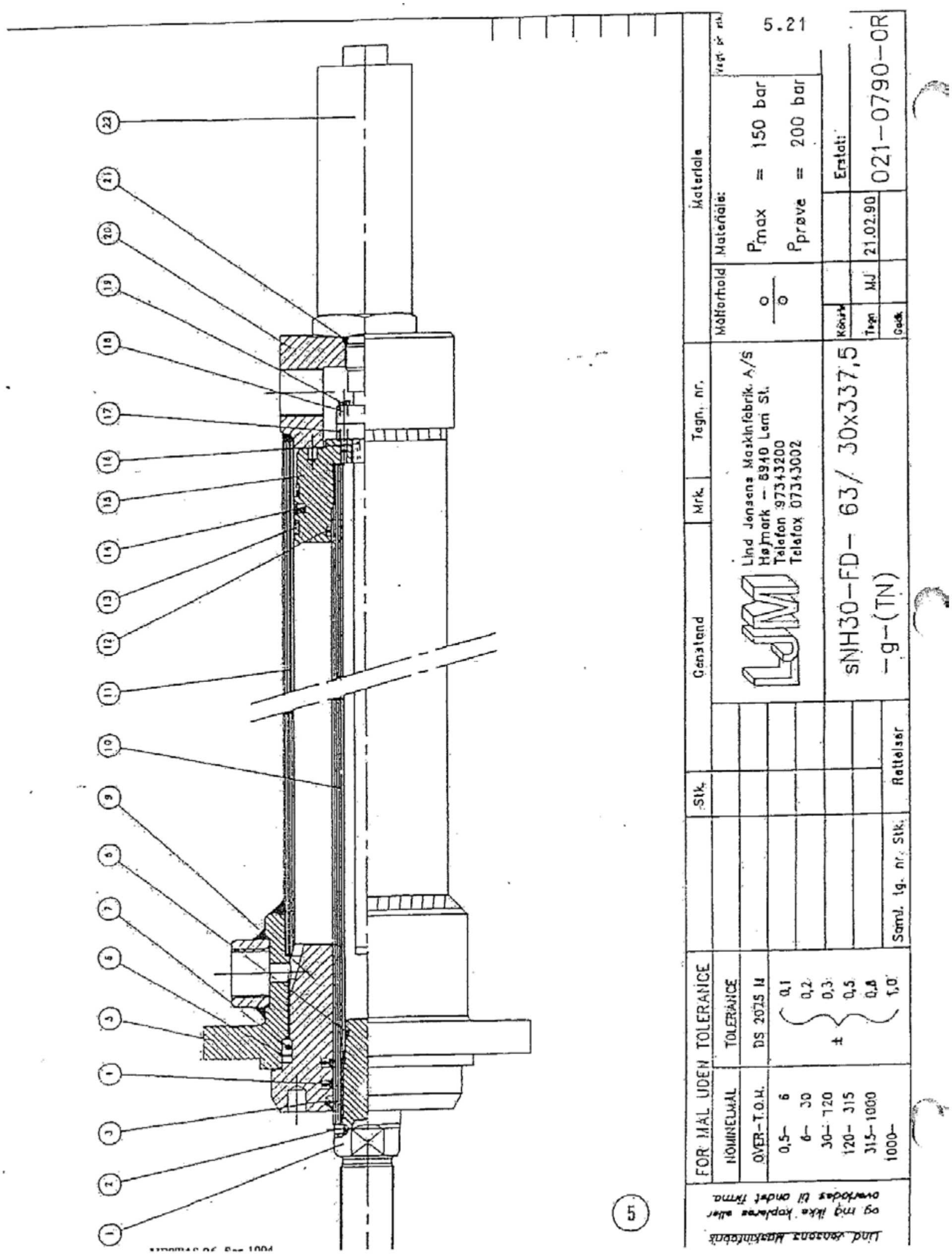
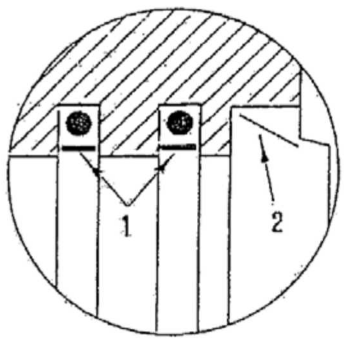
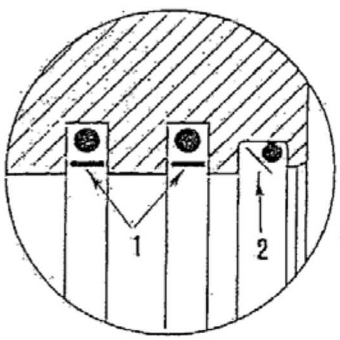


Figure 4-24. Spare parts drawing, pitch cylinder

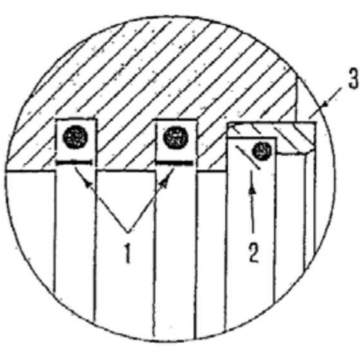
Upper part and deflector for hydraulic cylinder.
Type NH30-63/30-(TN)
Drawing no. 021-1890-0-R



Old type:
Upper part with TN sealing (1) + GA deflector (2).



New type:
Upper part with TN sealing (1) + TN deflector (2).



New type (replacement set):
Upper part with TN sealing (1) + TN deflector (2) and retainer (3).

5

Figure 4-25. Spare parts drawing, pitch ram seals

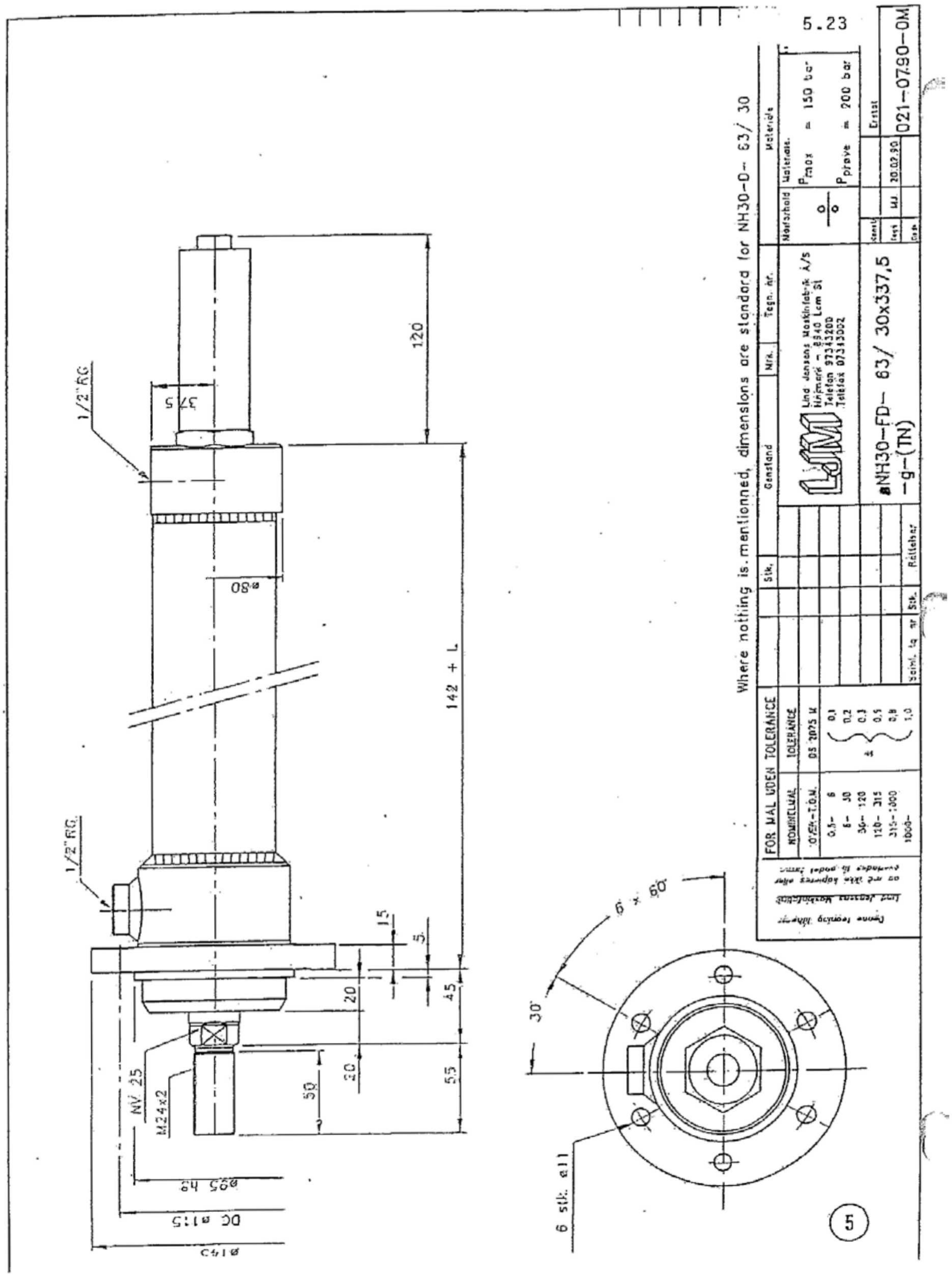


Figure 4-26. Spare parts drawing, pitch ram

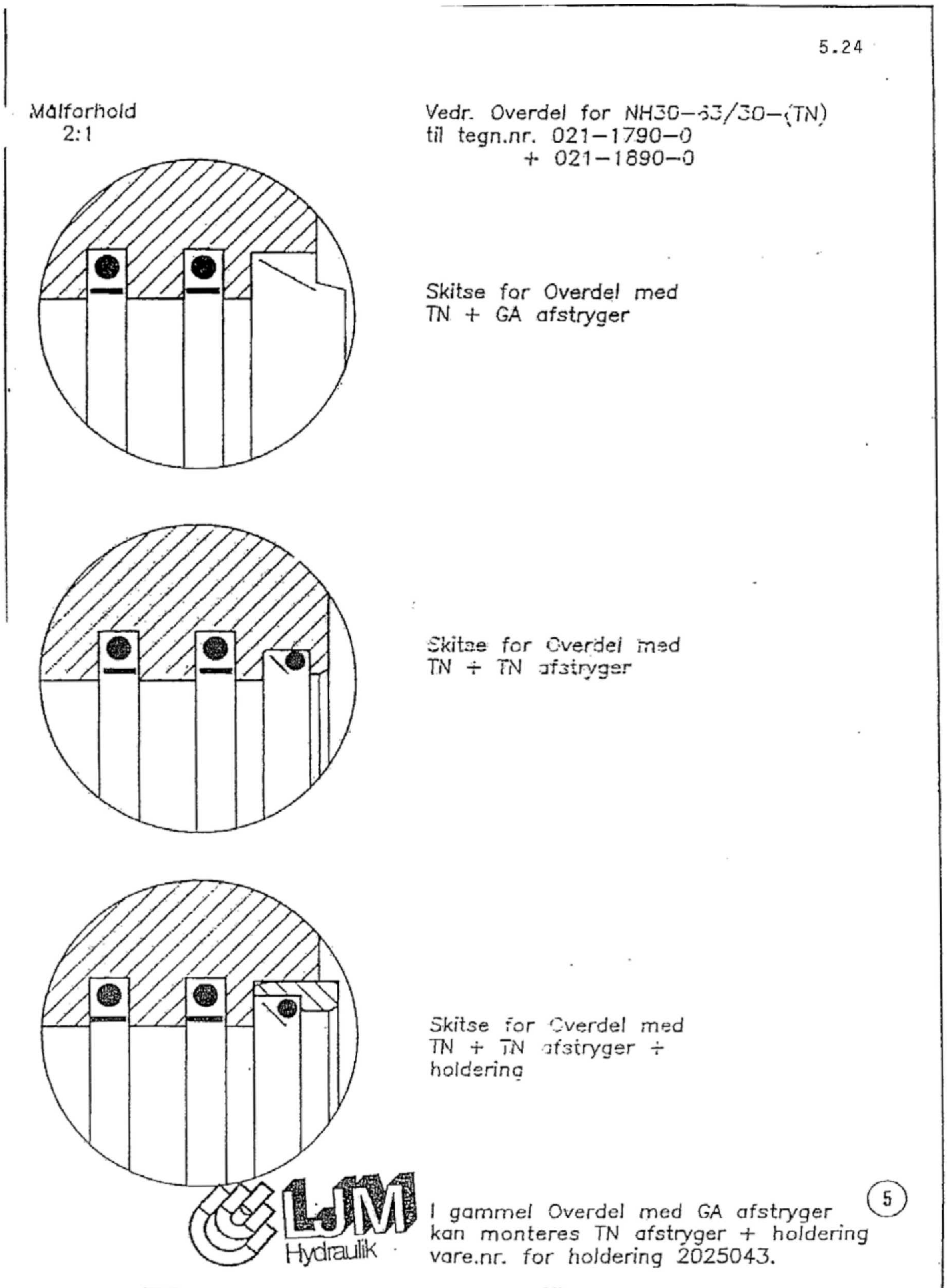


Figure 4-27. Spare parts drawing, pitch ram seals

4.7. Shaft Assembly

Transfers the rotor load to the gearbox assembly. Shaft supports the rotor assembly and transfers loads to the nacelle bedplate.

4.7.1. Specifications

Main Shaft:

Manufacturer:	Vestas
Material:	34CrNiM06 –DIN 17.200
Bolts:	480 mm
Type:	M24x110, 10. 9 FZV
Number:	28 pcs.
Torque:	800 Nm (590 ft.-lbs.)

Seal System:

Type:	V-Rings
Manufacturer	Vestas
Front:	
V-ring:	V 250A (NBR, inside)
Number:	1 pcs.
V-ring:	V250A (CR, outside)
Number:	1 pcs.
Support ring:	O-ring Ø236 x 10
Number:	1 pcs.
Cover:	
Material:	AISI 304
Bolts:	387 mm
Type:	M12 x 35, 8.8 FZV
Number:	8 pcs.
Torque:	66 Nm (49 ft.-lbs.)
Rear:	
V-ring	V 250A (CR, outside)
Number:	1 pcs.
V-ring:	V 250L (NBR, inside)
Number:	1 pcs.
Support ring:	O-ring Ø236 x 12
Number:	1 pcs.

Cover 1:	
Material:	St. 37-2-Din 17.100
Bolts:	387 mm
Type:	M12 x 40, 8/8 FZV
Number:	12 pcs.
Torque:	66 Nm (49 ft.-lbs.)
Cover 2:	
Material:	AISI 304
Bolts:	290 mm
Type:	M6 x 12, 8.8 FZV
Number:	8 pcs.
Torque:	8 Nm (6 ft.-lbs.)
Main bearings:	Spherical roller
Front:	SKF 23048 CC W33
Rear:	SKF 22240 CC W33
Main bearing housing:	Casted
Material:	GGG 40.3 – DIN 1693
Connection to bedplate:	Bolted
Bolts:	
Type:	M24 x 160, 8.8 FZV
Number:	16 pcs.
Torque:	558 Nm (412 ft.-lbs.)
Lubrication:	Grease, Mobil Mobilith SHC 460
Type:	SKF LGWM1
Quantity (total):	12 kg
Shrink disc:	
Manufacturer:	Ringfeder
Type:	RFN 4071 – 260x200
Bolts:	321 mm
Number:	14 pcs.
Torque:	370 Nm (273 ft.-lbs.)
Lubrication:	MoS2
Weight:	75 kg

4.7.2. Maintenance

4.7.2.1. Lubricate bearings

Interval: Six months

Refer to Figure 4-28**,** 4-29, 4-30, 4-31, 4-32, 4-33, and 4-34

Steps:

1. **Main bearing, front**: Use approximately 200g lithium-based grease (as specified in lubrication chart). Grease with a grease gun through the lubrication plug. Let the rotor rotate slowly to distribute the grease. Replace cover to grease nipple.
2. **Main bearing, rear**: Use approximately 200g lithium-based grease (as specified in lubrication chart). Grease with a grease gun through the lubrication plug. Let the rotor rotate slowly to distribute the grease. Replace cover to grease nipple.
3. **V-rings, front and rear**: (V-rings must not dry out.) Use lithium-based grease (as specified in lubrication chart). Lubricate the lip on the two outer V-rings using a brush dipped in grease.

4.7.2.2. Check Bolt Torque

Interval: Yearly

Refer to Figure 4-29**,** 4-30, 4-31, and 4-32

Steps:

1. **Bolts (28), hub to main shaft**: The bolts tightening the hub to the main shaft normally need not be tightened during ordinary inspections, but only in connection with a special torque inspection. Use a torque wrench setting of 800 Nm (590 ft.-lbs.). If it is possible to turn any of the bolts at this torque wrench setting, all 28 bolts should be checked. With a paint pen, replace lock torque marks when removing the bolts.
2. **Bolts (8), front bearing cover to main bearing housing**: Check all eight bolts (pos. 3, Figure 4-29) tightening the front bearing cover to the main bearing housing (pos. 14, Figure 4-30), using a torque wrench setting of 66 Nm (49 ft.-lbs).
3. **Bolts (12), rear bearing cover to bearing housing**: Check all 12 bolts (pos. 22, Figure 4-32), tightening the rear bearing cover (pos. 21, Figure 4-32) to the bearing housing, using a torque wrench setting of 66 Nm (49 ft.-lbs).
4. **Bolts (8), slide plate to rear bearing cover**: Check all eight bolts tightening the slide plate (pos. 25, Figure 4-31) to the rear bearing cover (pos. 21, Figure 4-32), using a torque wrench setting of 8 Nm (6ft.-lbs).
5. **Bolts, main bearing housing to nacelle bedplate**: The M24 x 160 (8.8) bolts tightening the main bearing housing to the nacelle bedplate normally need not be tightened during ordinary inspections, but only in connection with a special torque inspection. Use a torque wrench setting of 558 Nm (412 ft.-lbs). (Note that the maximum outside diameter of the socket wrench is 50 mm because of the limited space around the bolts.) If it is possible to turn any of the bolts at this torque wrench setting, all 16 bolts should be checked.
6. **Bolts (15), main shaft to gearbox**: Check all bolts on the shrink disk tightening the main shaft to the gearbox, using a torque wrench setting of 370 Nm (273 ft.-lbs). If it is possible to turn any of the bolts at this torque wrench setting, all 15 bolts should be checked.

4.7.2.3. Inspect Bearings

Interval: As needed

Note: Perform this check when experiencing bearing noise or vibrations in the bearing housing at low speeds.

Refer to Figure 4-29 and 4-31

Steps:

1. Allow the rotor to rotate slowly. Listen for noise and look for movement between the main shaft and the bearing housing covers.
2. Try to mount a dial indicator on the bearing housing covers with the sensor on the main shaft and look for movement in the dial indicator.
3. Excessive play should be noted in the log and the unit marked for replacement.

4.7.2.4. Inspect Seals for Leakage

Interval: Three months after turbine startup, then every six months

Refer to Figure 4-29and 4-31

Steps:

1. Inspect the seals at the front and rear bearings for leaks.
2. If there is leakage, clean the V-rings and empty the grease tray.
3. Inspect the lips on the V-rings and change them if necessary.
4. Lubricate the V-ring lips with a brush dipped in lithium-based grease (as specified in lubrication chart).

4.7.2.5. Inspect Main Shaft, Bolts, and Main Bearing Housing

Interval: Yearly

Refer to Figure 4-28

Steps:

1. Inspect the main shaft for corrosion, surface damage, and surface cracks.
2. Inspect all bolts for corrosion, surface damage, and surface cracks.
3. Inspect the main bearing housing for corrosion, surface damage, and surface cracks.
4. Replace any corroded, damaged, or cracked parts and report any repairs to Vestas.

4.7.3. Troubleshooting

4.7.4. Spare Parts

SPART PARTS LIST 830839 – SHAFT ASSEMBLY V27				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	0.5kg	149759	Sikaflex Bostic 2639 white	
2	1	107964	V-ring, V250A (NBR)	
3	8	152471	Steel setscrew, M12 x 35	
4	20	156455	Plane washer, M12 FZV	
5	0.75m	108328	O-ring, Ø236 x 10	
6	1	107348	Roller bearing, 23048 CC/W33	
7	2	158761	Nylonwasher, M8	
8	2	153133	St. setscrew, M8 M8 x 16, 8.8 FZV	
9	2	156663	Washer M8, HB200 FZV	
10	1	833101	Main shaft, machined St. 52	Two types
10	1	833102	Main shaft, machined 34CrNiMo6	Two types
11	1	833681	Cover for bearing housing, front	
12	2	149497	Cap for grease nipple	
13	2	149300	Grease nipple M8 x 1.25 H1A straight	
14	1	834093	Bearing housing, welded	Two types
14	1	834100	Bearing housing, GGG40	Two types
15	2	834513	Ring for bearing housing, machined	
16	4	151831	Stop screw, M10 x 16, 8.8 FZB	
17	4	108815	D.B.I Dut nr. 16	
18	1	103640	Aerations filter	
19	1	834270	Distance ring for bearing	
20	1	107379	Roller bearing, 22240 CCW33	
21	1	833683	Rear cover for bearing housing	
22	12	155138	Steel setscrew, M12 x 40	
23	8	153213	Steel setscrew, M16 x 12, 8.8 FZV	
24	2	159450	Nylon screw, M6 x 10	
25	1	833682	Slide plate for rear cover	
26	1	835669	Guide bushing for main shaft	
27	1	114260	Inductive sensor, DU 10 1425 EP	
28	2	831353	Holder for inductive sensor (St 52-shaft)	Two types
28	2	831354	Holder for inductive sensor (CrNiMo-shaft)	Two types
29	4	158852	Steel screw, M4 x 20, LHJ FZB	
30	1	114264	Inductive sensor, DU 10 EP	
31	1	832570	Holder for waste tray, front	
32	1	832571	Holder for waste tray, rear	
33	2	832057	Waste tray, V27	
34	4	153230	Steel bolt, M10 x 35, 8.8 FZV	

35	4	156256	Washer, M10 FZV	
36	1	833712	Cover for traverse tube bearing	
37	1	104299	Slide bearing, GLY PG 657050A	
38	1	166062	Paper gasket	
39	1	107956	V-ring, V250L	
40	2	107963	V-ring, V25A (CR)	
41	1	108285	O-ring, Ø236 x 12	

4.7.5. Drawings

Drawing #	Version # (date)	Description	Filename
		V27	
		Main shaft assembly, V27, roller bearing	
		Main shaft assembly, V27, front roller bearing and cover	
		Main shaft assembly, V27, rear roller bearing & cover	
		Main shaft assembly, V27, rear bearing & shrink disk	
		Drawing to be replaced with new sensor bracket	
		Main shaft assembly, V27, grease tray	

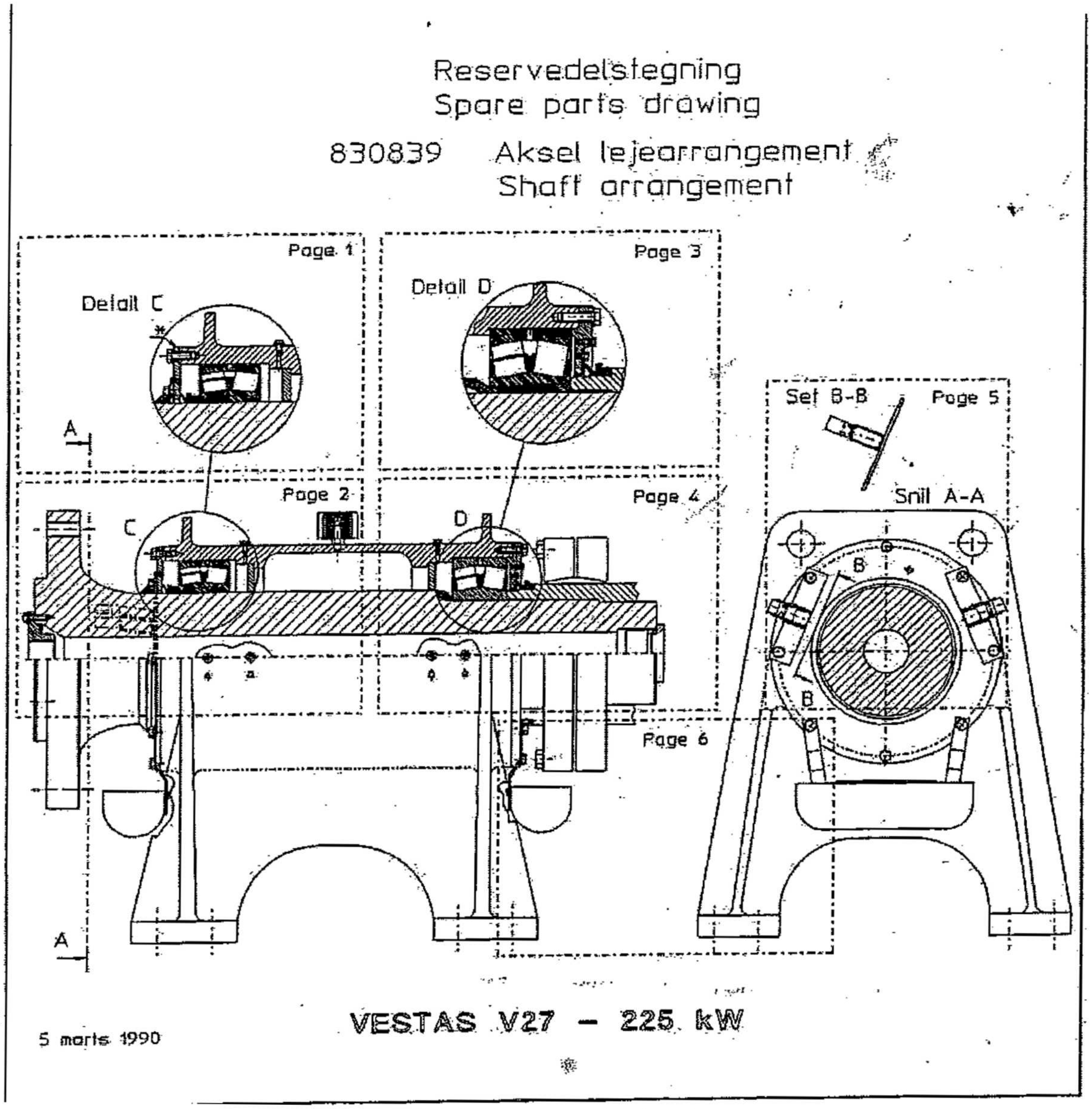


Figure 4-28. Spare parts drawing, V27

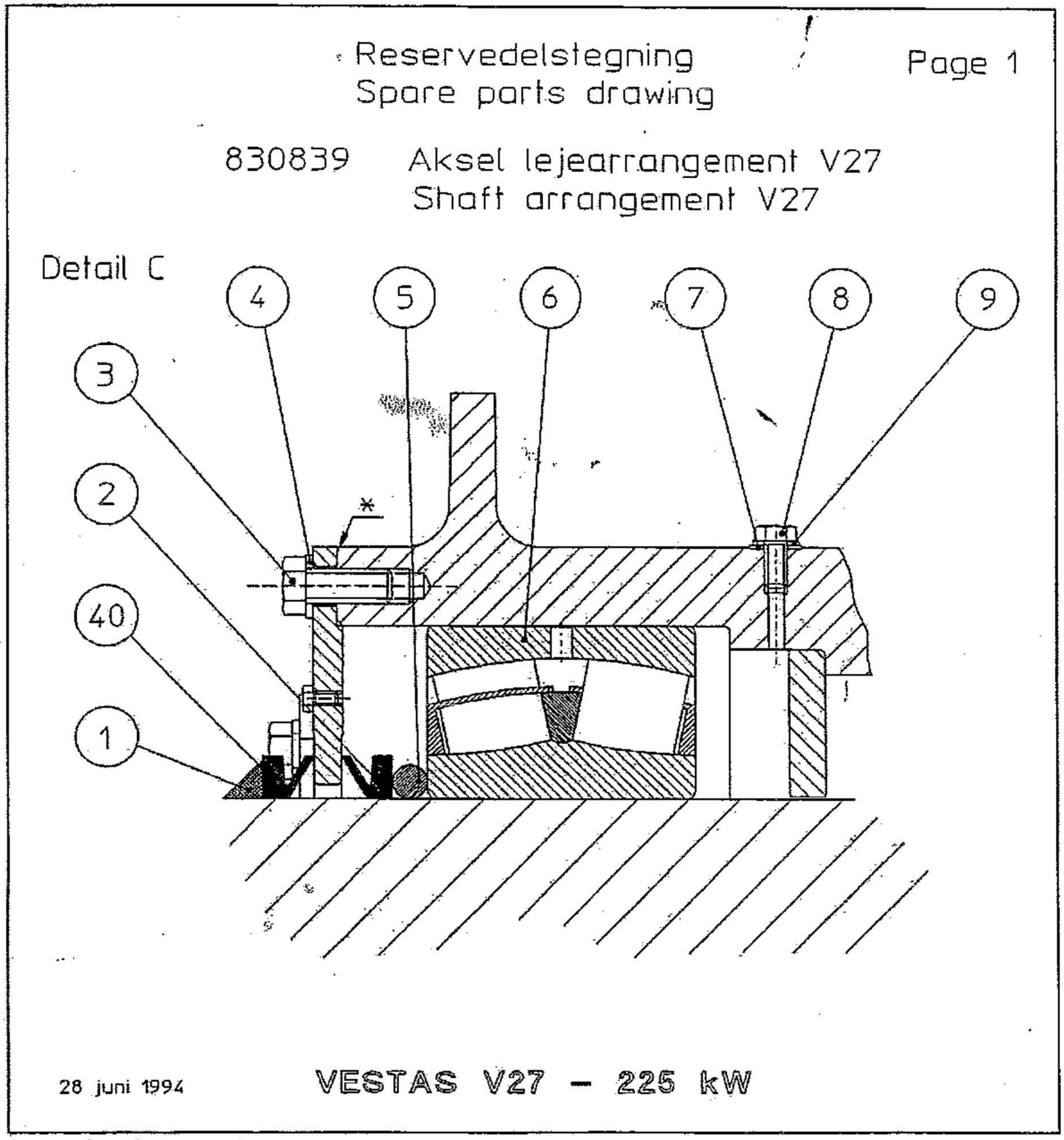


Figure 4-29. Spare parts drawing, main shaft assembly, V27, roller bearing

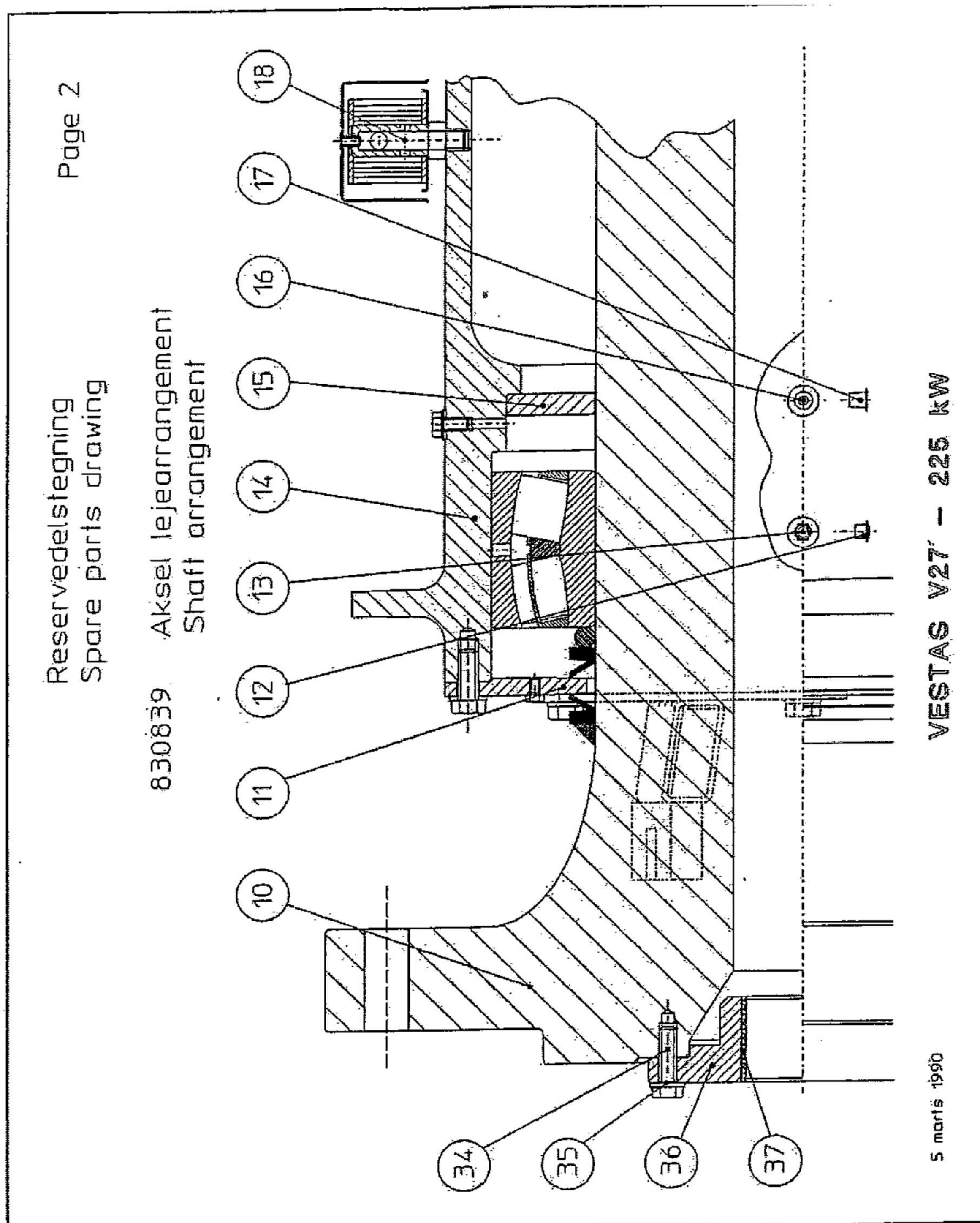


Figure 4-30. Spare parts drawing, main shaft assembly, V27, front roller bearing and cover

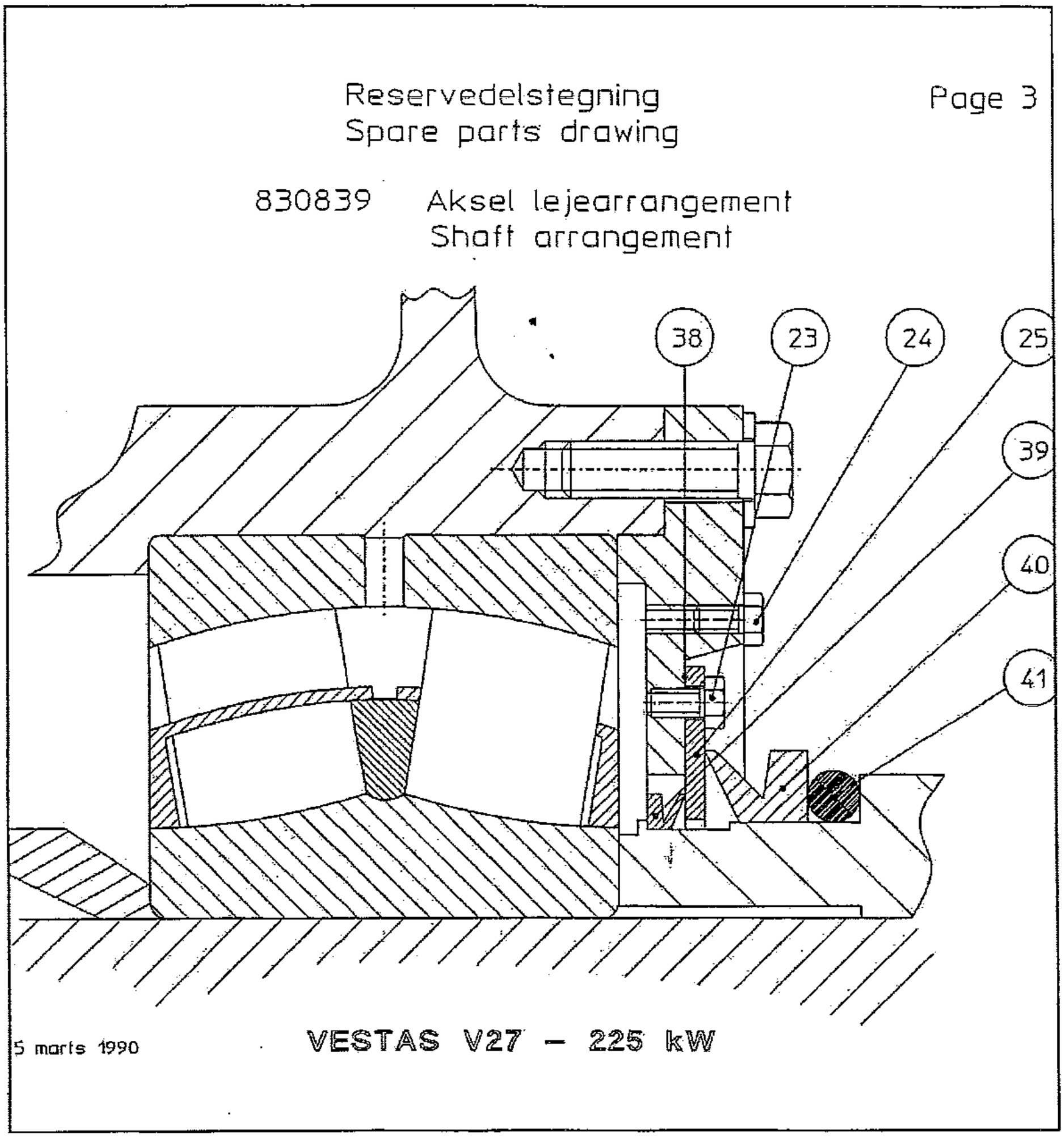


Figure 4-31. Spare parts drawing, main shaft assembly, V27, rear roller bearing and cover

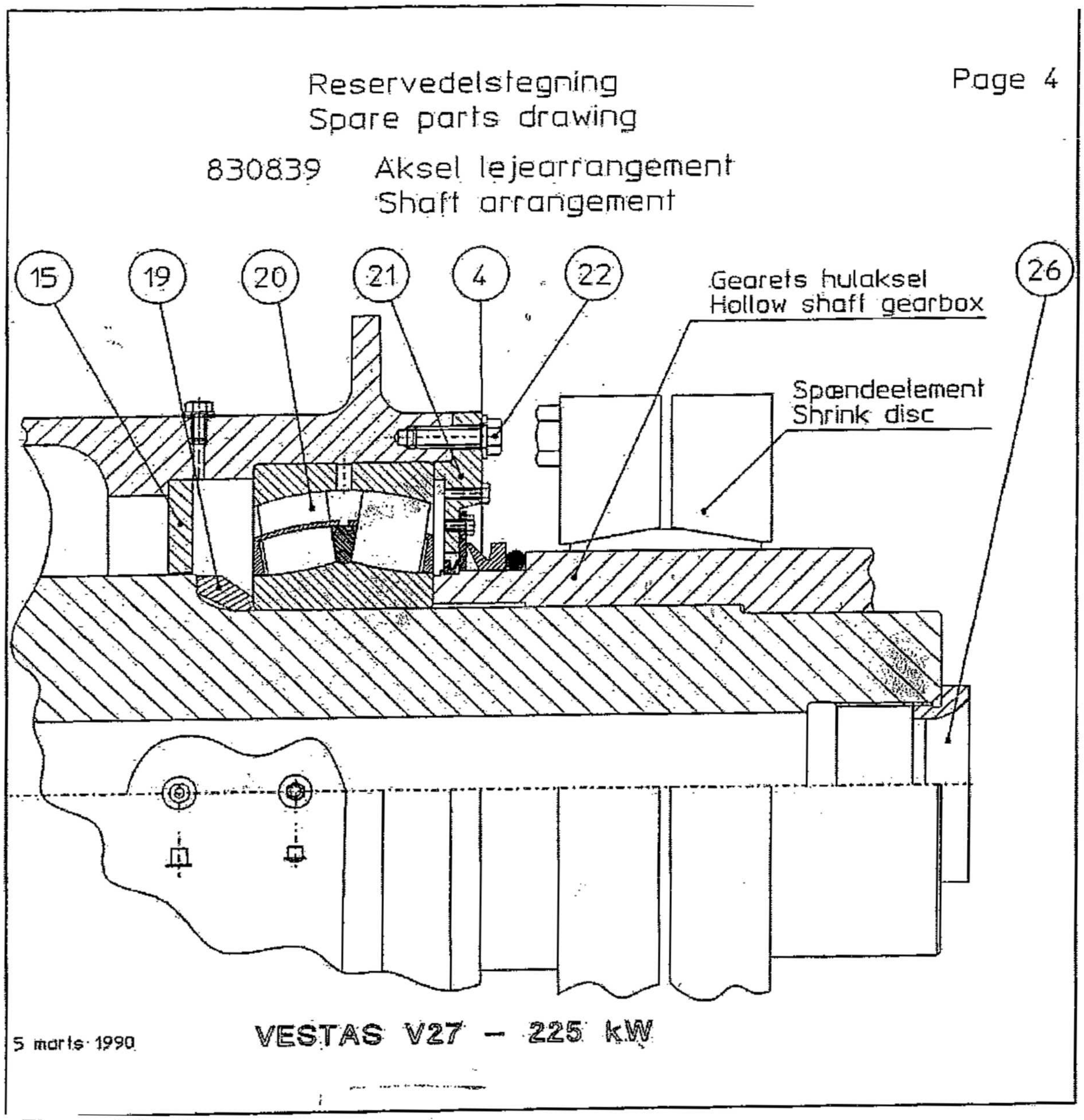


Figure 4-32. Spare parts drawing, main shaft assembly, V27, rear bearing and shrink disk

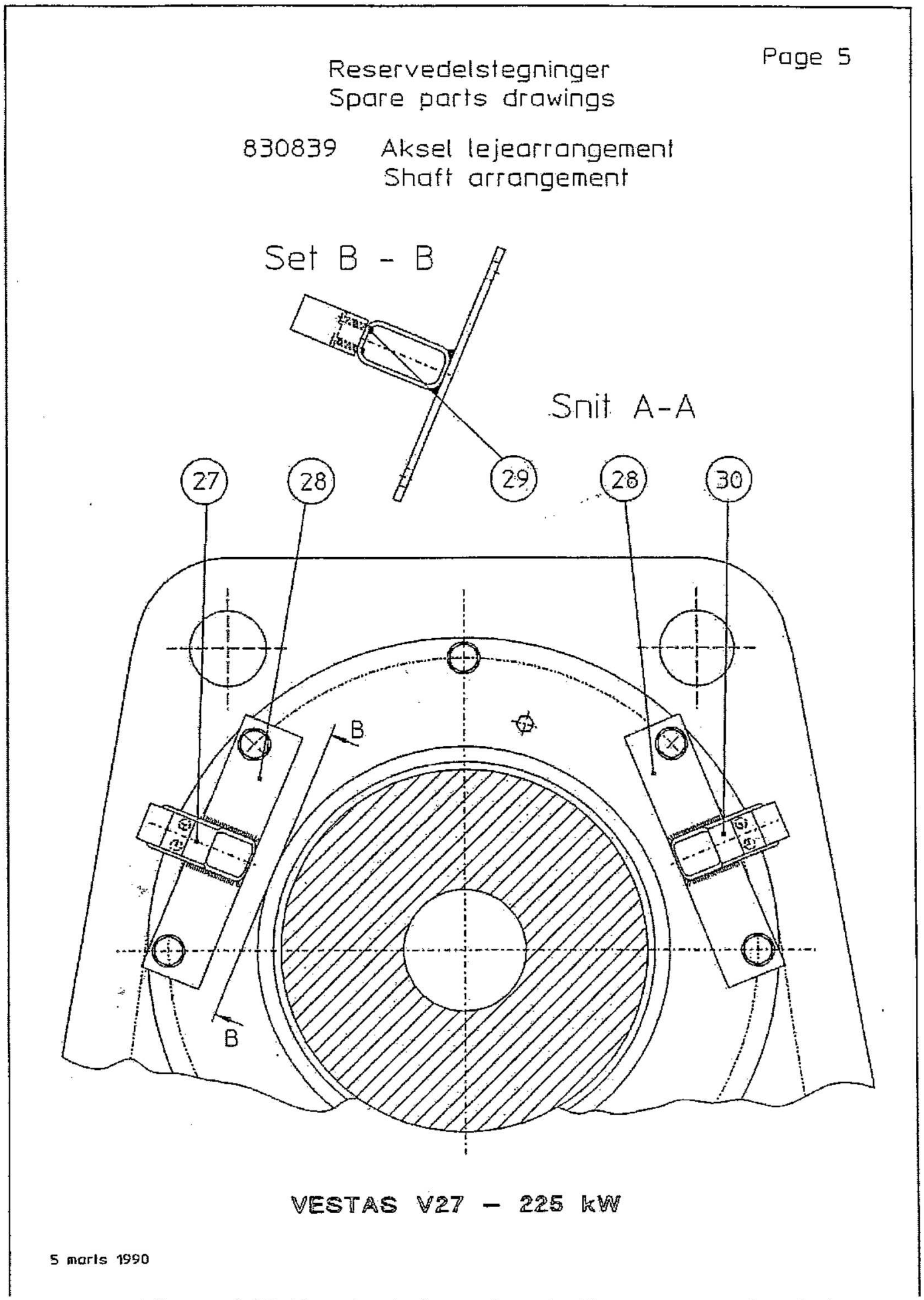


Figure 4-33. Drawing to be replaced with new sensor bracket

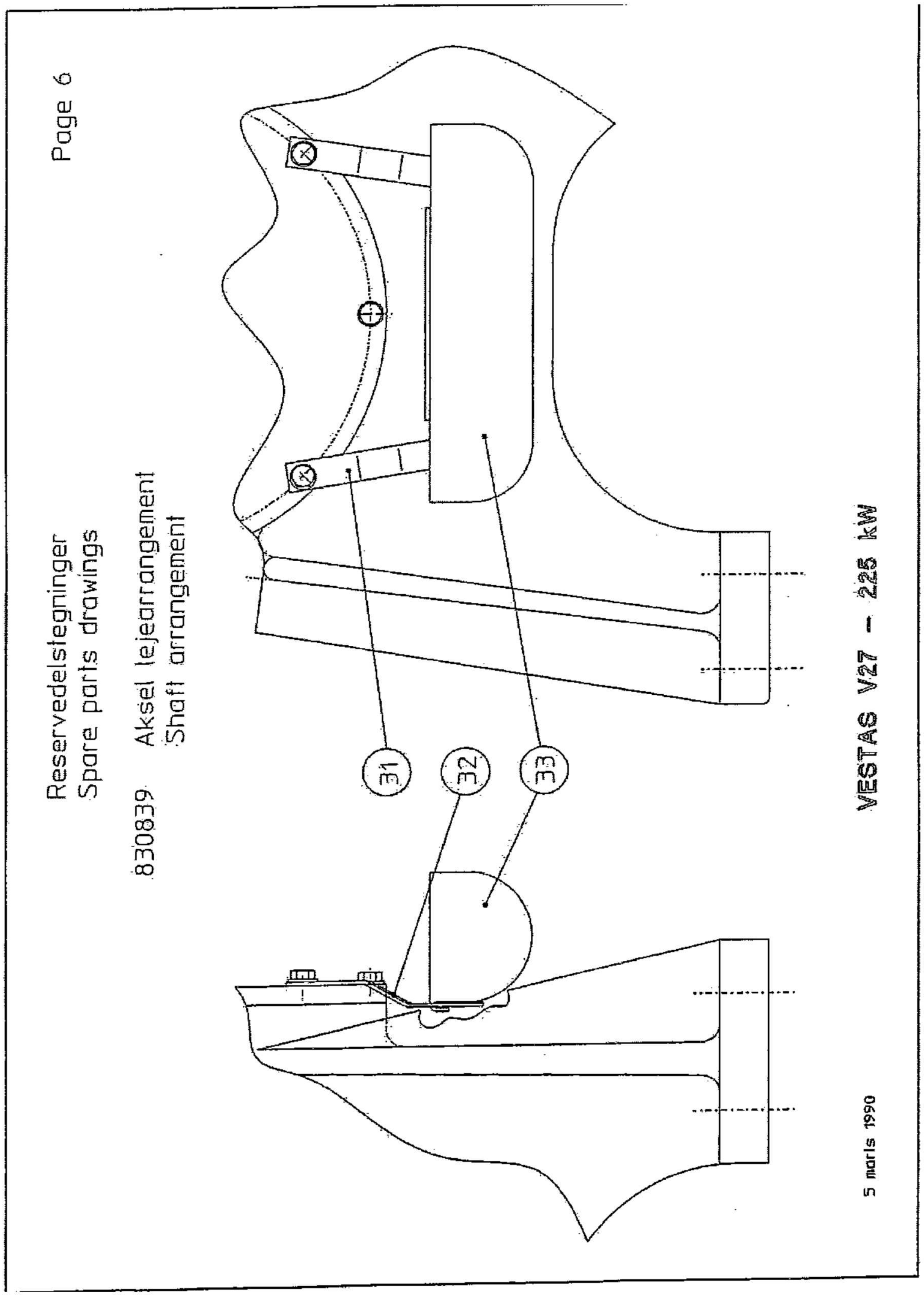


Figure 4-34. Spare parts drawing, main shaft assembly, V27, grease tray

4.8. Gear Mounting

The torque reaction linkage secures the gearbox to the bedplate but it allows movement of the gearbox in relation to changing loads from the rotor.

4.8.1. Specifications

Glycodur bushings (a):	SKF GLY.PG 353950F
Number:	2 pcs.
Glycodur bushings (b):	SKF GLY.PBG 252811.5F
Number:	4 pcs.
Link bearings:	SKF GE 35 ES-2RS
Number:	4 pcs.
Circlips (inner):	U35 x 1.5 DIN 471
Number:	8 pcs.
Circlips (outer):	U25 x 1.2 DIN 471
Number:	4 pcs.
Support spring, gear mount:	
Number:	1 pcs.
Bolts:	M20 x 110 8.8 FZV
Number:	8 pcs.
Bolts:	M24 x 130 8.8 FZV
Number:	6 pcs.
Bolts:	M24 x 60 8.8 FZV
Number:	12 pcs.
Bolts:	M16 x 45 8.8 FZV
Number:	2 pcs.
Bolts:	M20 x 50 8.8 FZV
Number:	2 pcs.
Grease nipples:	M8 H1A, straight
Number:	4 pcs.
Grease type:	Lithium-based grease (as specified in lubrication chart)
Quantity:	10g/bearing
Weight:	90 kg (incl. parts mounted on gearbox)

4.8.2. Maintenance

4.8.2.1. Lubricate Link Bearings

Interval: Six months

Refer to Figure 4-35

Steps:

1. Lubricate link bearings through the four grease nipples in the end of the shaft, two in the right side and two in the left side. Use 10g/link bearing of lithium-based grease as specified in the lubrication chart.

4.8.2.2. Check Bolt Torque

Interval: As needed

Note: If it is possible to tighten the bolts on the right side during two subsequent inspections, the bolts should be replaced.

Refer to Figure 4-36 and 4-37

Steps:

1. **M24 bolts on the gearbox**: The bolts on the gearbox need not be tightened during ordinary inspections, but only in connection with a special torque inspection. Two bolts (pos. 13, Figure 4-36) and (pos. 28, Figure 4-37) in each side are tightened using a torque wrench setting of 55 Nm (412 ft.-lbs.). If it is possible to tighten any bolt, all bolts should be checked.
2. **M20 bolts for the bearing bracket**: The bolts between the bearing bracket, the connection rod, and the nacelle bedplate need not be tightened during ordinary inspections, but only in connection with a special torque inspection. One bolt (pos. 20, Figure 4-36) in both sides are tightened using a torque wrench setting of 325 Nm (240 ft.-lbs.).

4.8.2.3. Check Bearing Clearance

Interval: Yearly

Refer to Figure 4-36**,** 4-37, and 4-38

Steps:

1. If there is total play in the gear mounting of more than 1.5 mm measured between the disc brake and the nacelle bedplate, the connection rod should be checked further to determine where the play occurs.
2. Check the radial clearance of the link bearings with a dial indicator. If there is more play than 0.30 mm (0.012”), the link bearings and the shafts should be replaced.
3. Check the shafts that fit in the cover splice bars (pos. 15, Figure 4-36) and forks (pos. 35, Figure 4-38) to the rigging screws. If there is more play that 0.02 mm, the shafts should be replaced.

4. Check the play between the shafts (pos. 16, Figure 4-36and pos. 24, Figure 4-37) and the glycodur bushings (pos. 36, Figure 4-38 and pos. 23, Figure 4-37). If there is more play than 0.20 mm (0.008”), the glycodur bushings and the shafts should be replaced.
5. Check the shafts that fit in the bearing brackets and torque arms. If there is more play than 0.02 mm, the shafts should be replaced.

4.8.2.4. Check Gas Springs/Support Spring for Gearbox Mount

Interval: Yearly

Refer to Figure 4-36 and 4-37

Note: Some turbines are not equipped with a shock absorber.

Steps:

1. Remove the shock absorber between the gearbox and bedplate if equipped (pos. 25, Figure 4-36) and check to see whether it provides appropriate resistance. Replace if needed. (Note: There shall no substitute mounting.)

4.8.3. Troubleshooting

4.8.4. Spare Parts

SPARE PARTS LIST 920160 – GEAR MOUNTING V27				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	1	833615	Lower gear support mounting	
2	2	151095	Allen screw, M10 x 90 12.9	
3	5	156256	Washer, M10 FZV DIN 125 A	
4	12	156071	Circlip, U35 x 1.5 DIN 471	
5	4	833626	Shaft for lever/support arm	
6	1	853620	Support spring f. gearmount	
7	1	832834	Splice for gear, right	
8	1	833603	Upper gear support plate	
9	2	152285	Bolt, M16 x 50 FZV 8.8	
10	2	156817	Washer, M16 FZV DIN 125A	
11	1	833617	Plate for gear support	
12	4	133108	Link bearing, GE35-ES-2RS	
13	6	154180	Bolt, M24 x 130 FZV 8.8	
14	18	155802	Washer, M24 FZV DIN 125A	
15	2	833602	Support arm for gear mounting	
16	2	833622	Shaft for bracket/lever arm	
17	2	833667	Bearing bracket for gear mounting	
18	2	833609	Lever arm for gear mounting	
19	10	156695	Washer, M20 FZV	
20	6	153568	Bolt, M20 x 110 FZV DIN 931 8.8	

21	4	156075	Circlip, U25 x 1.2 DIN 471	
22	2	833604	Joint link for lever arms	
23	4	104295	Glycodur bushing, SKF GLY.PBG 252811.5 F	
24	2	833624	Shaft for joint link for lever arms	
25	2	152960	Locknut, M10 FZB	
28	12	155349	Steel bolt, M24 x 70 DIN 933 8.8	
29	1	833267	Splice for gearbox, left	
30	4	149300	Grease nipple, M8 H1A	
31	1	834026	Mounting fork, left thread	
32	1	833061	Lock nut, right thread	
33	1	833062	Rigging screw, tie rod	
34	1	833060	Lock nut, right thread	
35	1	834027	Mounting fork, right thread	
36	2	104370	Glycodur bushing, SKF GLY PG 353950 F	
37	2	152129	Steel bolt, M20 x 50 FZV 8.8	
38	8	834185	Nitril rubber, Ø35 x Ø50 x 6	
39	4	834186	Nitril rubber, Ø60 x Ø80 x 6	
40	4	834184	Nitril rubber, Ø20 x Ø35 x 2.5	

4.8.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Gear mounting, 1 of 4	
		Gear mounting, 2 of 4	
		Gear mounting, 3 of 4	
		Gear mounting, 4 of 4	

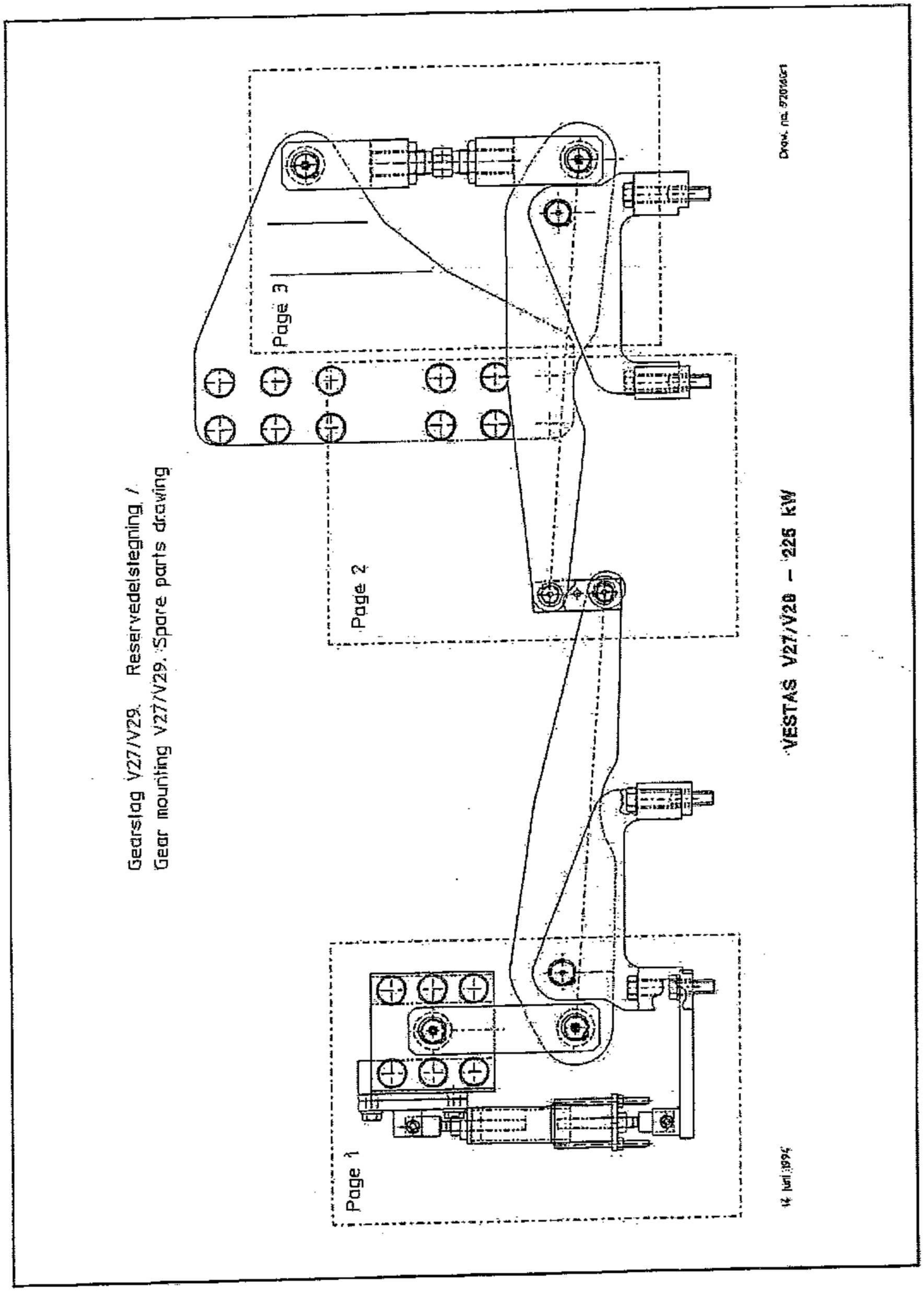


Figure 4-35. Spare parts drawing, gear mounting

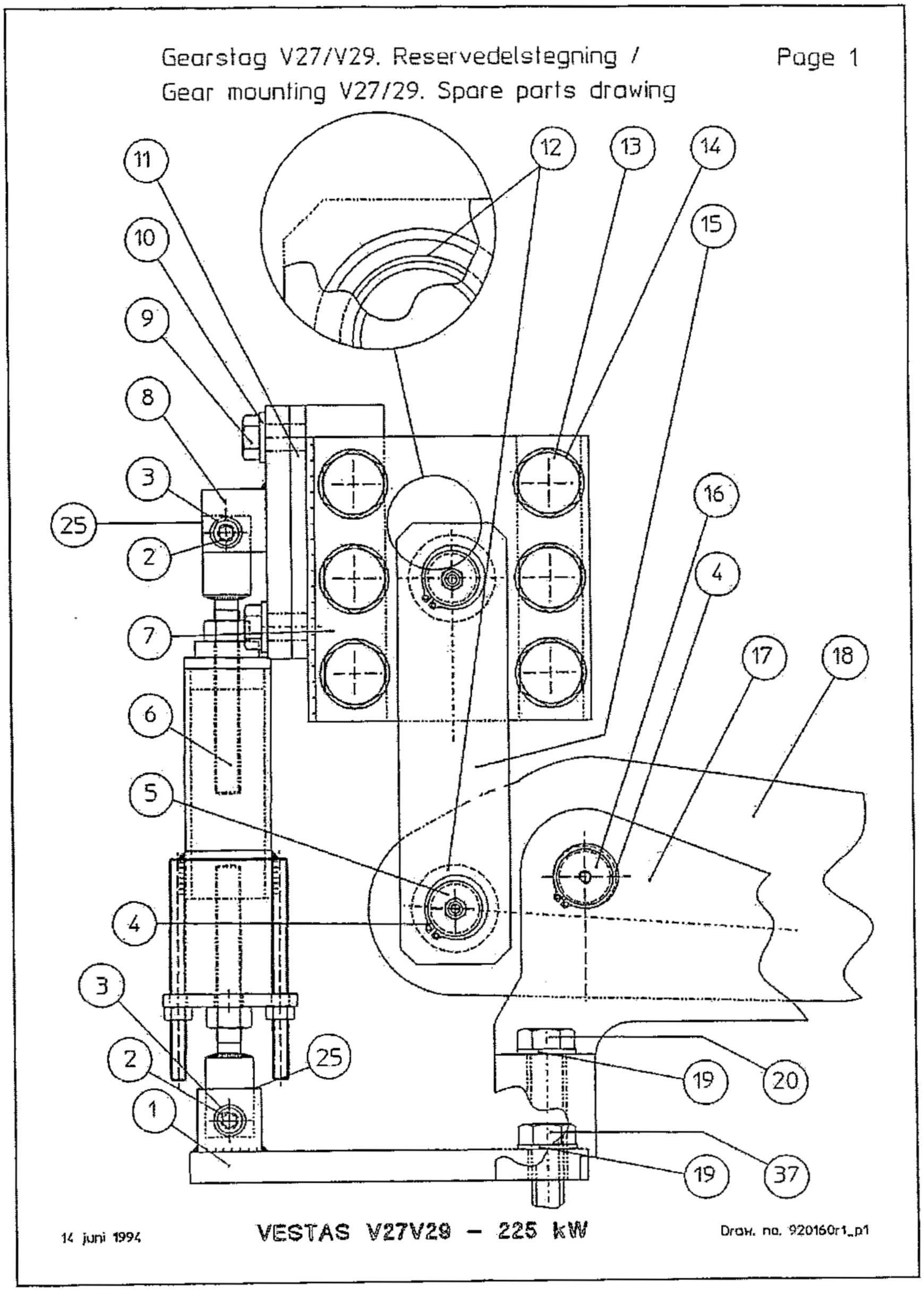


Figure 4-36. Spare parts drawing, gear mounting

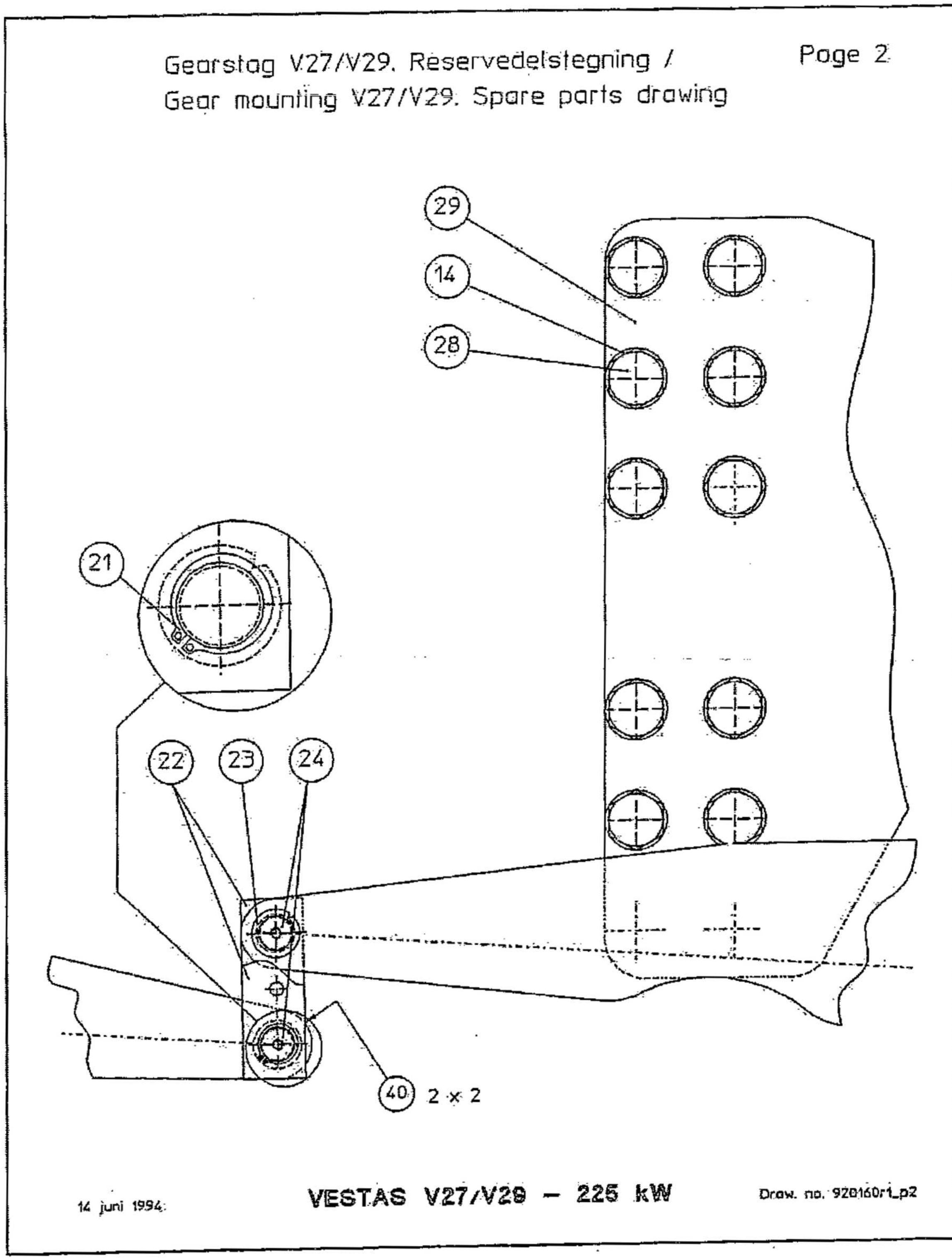


Figure 4-37. Spare parts drawing, gear mounting

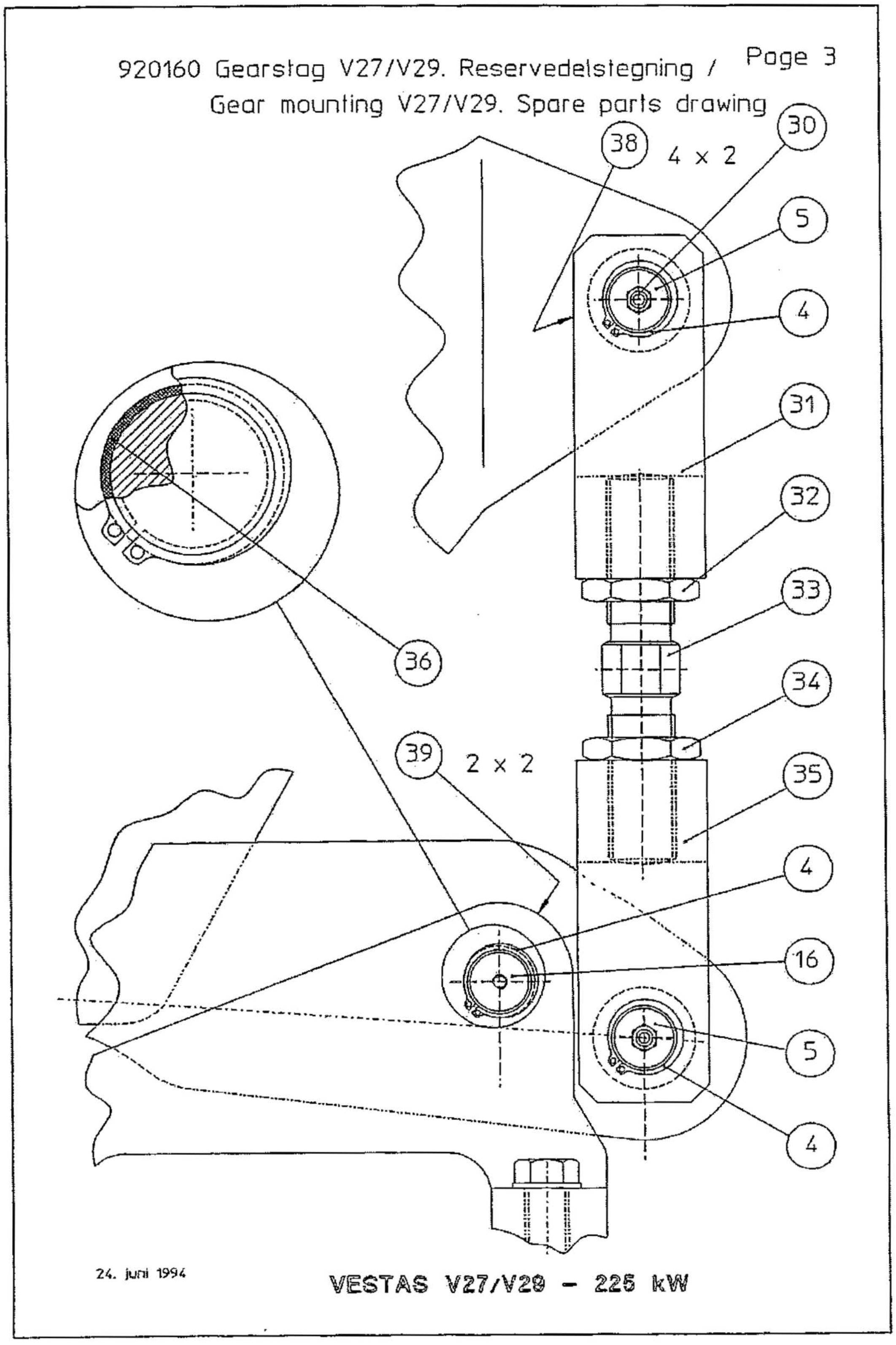


Figure 4-38. Spare parts drawing, gear mounting

4.9. Gearbox

Mechanical energy from the turbine's blade-rotor assembly is transmitted into the generator through a two-stage gearbox.

4.9.1. Specifications

Hansen gearbox:

Type:	RTH6A –BNC
Ratio (60 Hz):	1:27.565
Weight, ready for assembly:	1815 kg
Stage 1:	
Center distance:	408 mm
Number of teeth (Z1):	71
Number of teeth (Z2):	15
Metric module:	9 mm
Helix angle:	10°
Min. face width:	160 mm
Stage 2:	
Center distance:	299 mm
Number of teeth (Z1):	99 (60 Hz)
Number of teeth (Z2):	17 (60 Hz)
Metric module:	5 mm
Helix angle:	14°
Min. face width:	90 mm
Lubrication:	Oil splash
Oil viscosity:	VG320
Volume:	~72 litre (acc. to dipstick)
Supervision:	
Temperature:	Yes (aut.)
Volume:	Yes (sight glass + dipstick)
Magnet:	Yes
Low-speed shaft:	Hollow
Bearing:	Cylindrical roller
Type:	SL 28952
Number:	2 pcs.
Intermediate shaft:	Full shaft
Bearing (rotor side):	Cylindrical roller/spherical roller
Type:	SL 192322/22322 CC (change to 22322 CC from ROWA 18608 onward)
Number:	1 pcs.
Bearing (generator side):	Cylindrical roller
Type:	NJ 2316 E
Number:	1 pcs.
High-speed shaft:	Full shaft

Bearing (rotor side):	Spherical roller
Type:	22316 CC
Number:	1 pcs.
Bearing (generator side):	Cylindrical roller
Type:	NJ 2316 E
Number:	1 pcs.

Hansen RTH6_BNC 60 HZ
Ratio 1 : 27.565
Low speed gear 71 teeth
Intermediate gear 99 teeth
Intermediate pinion 15 teeth
High speed pinion 17 teeth

4.9.2. Maintenance

4.9.2.1. Check Oil Level

Interval: Three months after startup, then every six months

Note: Check oil level in the gearbox after it has been at rest for at least two minutes.

Note: Oil level varies with oil temperature and air bubbles in the oil. Use the table below to determine oil levels.

Refer to Figure N/A

Prescribed oil levels:

Hansen	
Normal:	Middle of the two indicators on the dipstick*
Warm gearbox:	Near upper indicator on the dipstick*
Cold gearbox:	Near lower indicator on the dipstick*

* Dipstick must be off-thread when checking oil level.

4.9.2.2. Take Oil Sample

Interval: Yearly

Note: Required only on gearboxes with synthetic oil (e.g. Tribol 1510).

Refer to Figure N/A

Steps:

1. Stop the turbine and remove the gearbox top cover.
2. Use a clean sample bottle.

3. Extract a 100 ml oil sample by immersing the sample bottle in mid oil sump or by use of sampling pump and a piece of clean new sampling hose.
4. Fill in a bottle label and attach it to the bottle.

4.9.2.3. Change Oil

Interval:

Gearboxes with mineral oil (e.g. Texaco Meropa)	**Gearboxes with synthetic oil** (e.g. Tribol 1510)
3 months after commissioning	According to results of oil analysis (see Section 4.9.2.2.)
18 months after commissioning	
Every subsequent 18 months	

Refer to Figure N/A

Steps:

1. Place the turbine in Stop.
2. Yaw the rotor out of the wind to ensure the rotor does not turn.
3. Install the suction hose connected to the drain valve and drain the oil through the drain valve. (The gearbox can also be emptied by use of the oil pump; run until it sucks air.)
4. Remove the top cover. If the gearbox is black or has metal shavings inside, wash it with a thin hydraulic oil or dry cleaner. Clean by use of a vacuum cleaner or pieces of cloth.
5. Remove the magnet and clean it.
6. Inspect the gearbox, gearwheels, and bearings and clean them. If rotation of the gearwheels is necessary for inspection, manually spin the gearbox using the high speed brake disk.
7. Close the drain valve and replace the suction hose.
8. Remount the magnet.
9. Fill with oil according to prescribed oil levels in Section 4.9.2.1. Use ~72 liter. Top up with an additional 1-2 liters to fill oil cooler and hoses. (Note: If you change oil types without cleaning, there must be no more than 1 percent of the old oil in the gearbox. Make sure to post a sign with the correct new oil type and viscosity.)
10. Check the seal between the gear housing and top cover and replace it if necessary.
11. Remount the top cover.

4.9.2.4. Check Bolt Torque

Interval: Three months after commissioning, then yearly

Refer to Figure N/A

Steps:

1. Choose approximately 10 percent of the bolts in the bearing covers and check them.

2. If it is possible to turn any of the chosen bolts, all bolts in the bearing cover must be checked and tightened.

4.9.2.5. Check for Noise and leakage

Interval: Three months after commissioning, then every six months

Steps:

1. During normal operation, listen for noise from the gearbox. If the noise is abnormal, mark the gearbox for repair.
2. Inspect gearbox for leakage.

4.9.2.6. Check Bearing Clearance

Interval: As needed

Note: Check gearbox bearing clearance only in case of abnormal noise from the gearbox, when there are metal shavings in the oil, or when the gearbox temperature is abnormally high.

Refer to Figure N/A

Steps:

1. Remove the top cover on the gearbox.
2. Measure the play on the gearwheel with a dial indicator, with the magnet holder mounted on the gear housing and the indicator on the side of the gearwheel and as close to the shaft as possible.
3. Push the wheel up to one side with a tool.
4. Put the dial indicator to zero.
5. Push the large wheel to the opposite side. Read the dial indicator.
6. Repeat the measurement a few times.
7. Measure the axial clearance. If the play is greater than the allowable shown in the chart below, report the issue to Vestas.

Measurement of axial movement	Less than 1 year of operation	More than 1 year of operation
Axial movement of low-speed shaft (A)		
Axial movement of bearing outer ring in housing (B)		
Axial movement (A-B)		
Allowable axial movement	0.3 mm	0.5 mm
Axial movement of intermediate shaft (C)		
Axial movement of bearing outer ring in housing (D)		
Axial movement (C-D)		
Allowable axial movement	0.6 mm	0.8 mm
Axial movement of high-speed shaft (E)		

Axial movement of bearing outer ring in housing (F)		
Axial movement (E-F)		
Allowable axial movements	0.6 mm	0.8 mm

8. Inspect the oil trays in the top of the gearbox for bearing lubrication. If they are filled with oil, check that the oil bore to the bearing is not blocked.
9. Check the torque of the bolts to the oil trays.
10. Inspect the magnet for metal shavings and clean the magnet.
11. Inspect the gear housing, bearing, and gear teeth for metal shavings and damage.
12. Report metal shavings or damage to Vestas.
13. Inspect the gasket between the top cover and the gear housing. Replace gasket if damaged.
14. Remount the top cover.

4.9.3. Troubleshooting

4.9.4. Spare Parts

SPARE PARTS LIST 833280 – GEARBOX READY TO BE MOUNTED				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	1	115176	Gearbox, 225 kW 50 Hz V29	
1	1	115180	Gearbox, 225 kW DK	
2	1	104400	Shrink disc, 1M5734870	
3	4	152129	Steel bolt, 8.8 HDG M20 x 50	
4	4	156695	Washer, M20 HDG	
5	1	835370	Anchor plate for brake	
6	2	835730	Spacer block for brake	
7	4	151784	Allen screw, 8.8 M24 x 180	
8	1	834459	Brake disc machined	
9	1	833959	Sensor complete	
10	3	154483	Bolt, 8.8 HDG M10 x 80	
11	3	156256	Washer, M10 HDG DIN 125A	
12	1	151564	Stop screw, DIN 916 M12 x 25	
13	1	833983	Bracket for sensor	
14	1	835585	Gearflange f. transmission shaft	
15	1	15322	Allen screw, MSP stainless M8 x 12	
16	4	158098	Machine screw, UHJ HDG M6 x 16	
17	1	835357	Grease plate for gear flange	
18	2	152496	Steel bolt, M12 x 30 HDG 8.8	
19	1	831365	Magnet for gearbox, complete	
20	1	115664	Nipple coupling, ¾ x 1/2RG	
21	1	130062	Copper washer, Ø26 x 32 x 1.5	
22	1	130064	Copper washer, Ø21 x 28 x 1.5	
23	1	114281	Temperature sensor, Pt100	
24	4	156663	Washer, HB200 M8 HDG	

25	2	153280	Steel bolt, 8.8 A4 M8 x 30	
26	2	153133	Steel bolt, 8.8 HDG M8 x 16	
27	8	158761	Washer, nylon 8	
28	2	109827	Caliper Brembo 20.802-34	
29	1	831469	Bracket for emergency stop	

4.9.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Gearbox, 1 of 5	
		Gearbox, 2 of 5	
		Gearbox, 3 of 5	
		Gearbox, 4 of 5	
		Gearbox, 5 of 5	

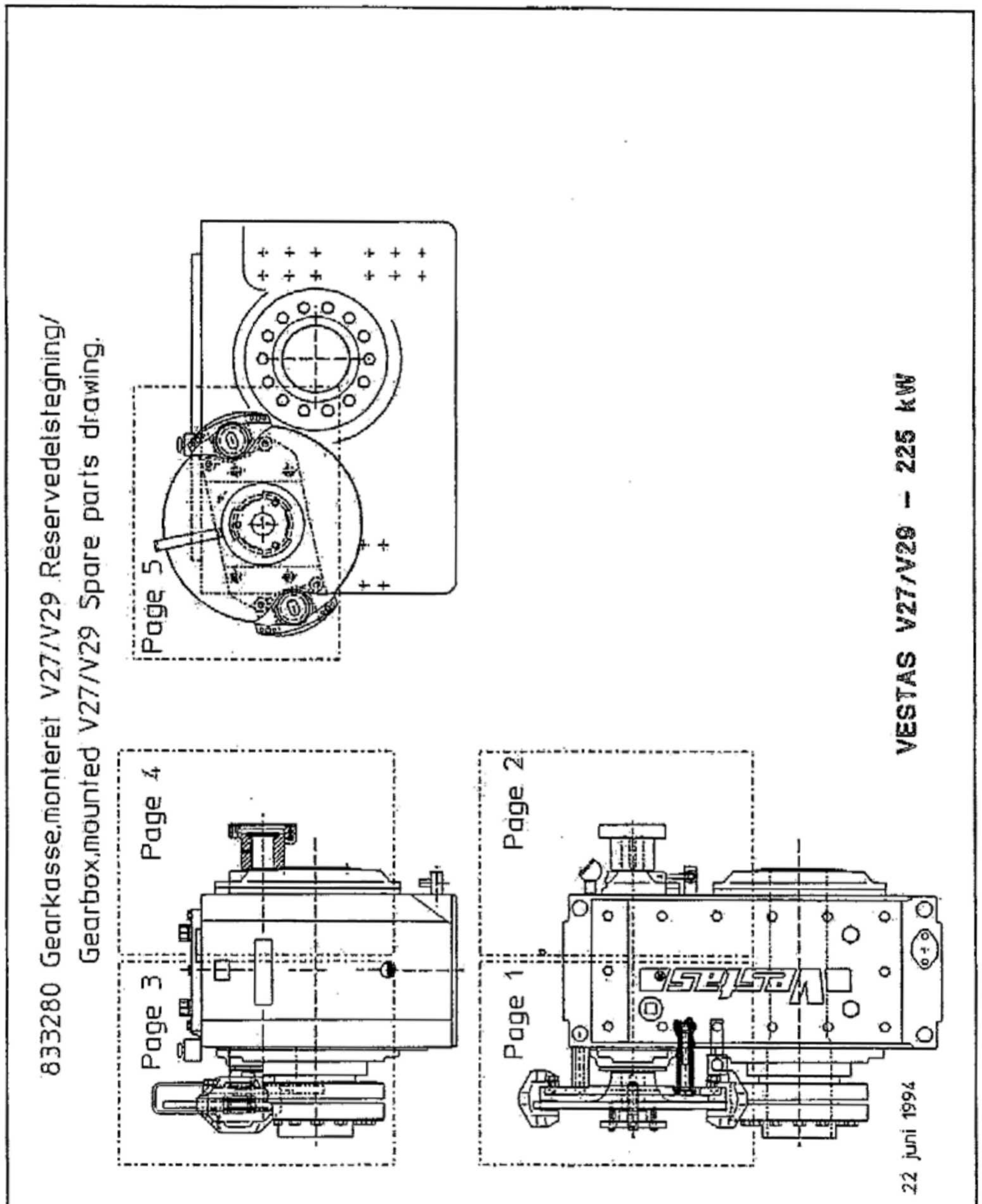


Figure 4-39. Spare parts drawing, gearbox

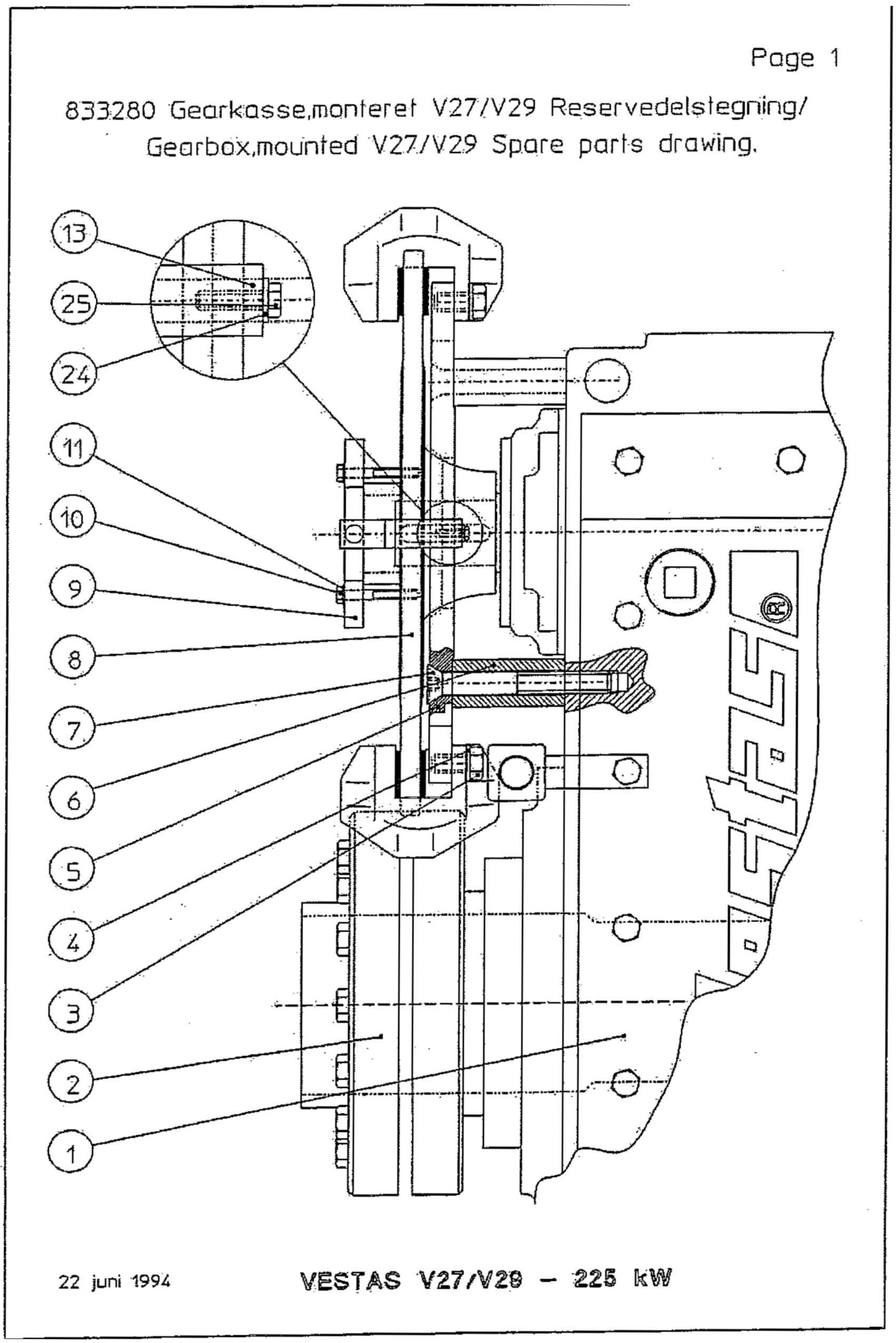


Figure 4-40. Spare parts drawing, gearbox

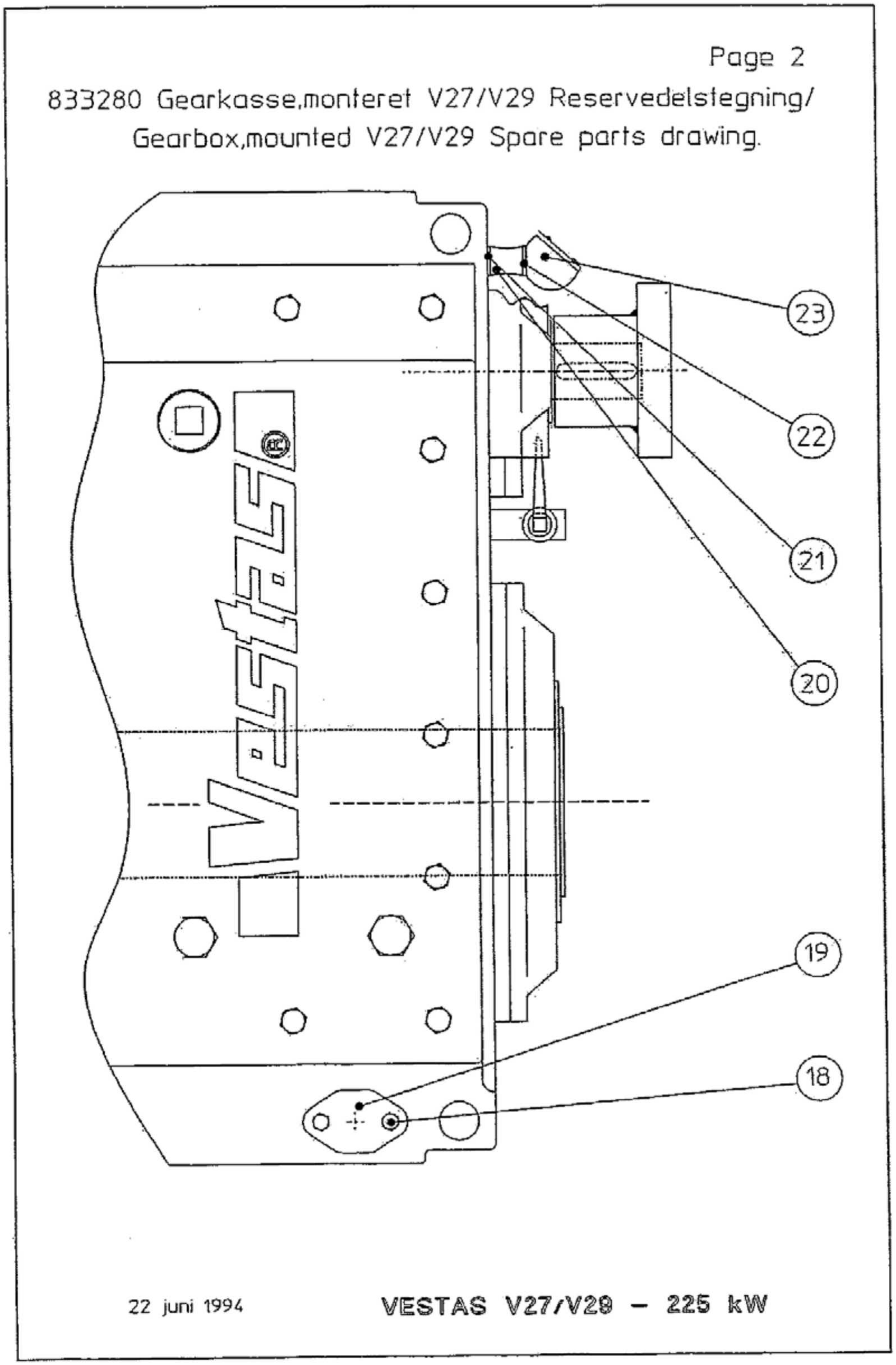


Figure 4-41. Spare parts drawing, gearbox

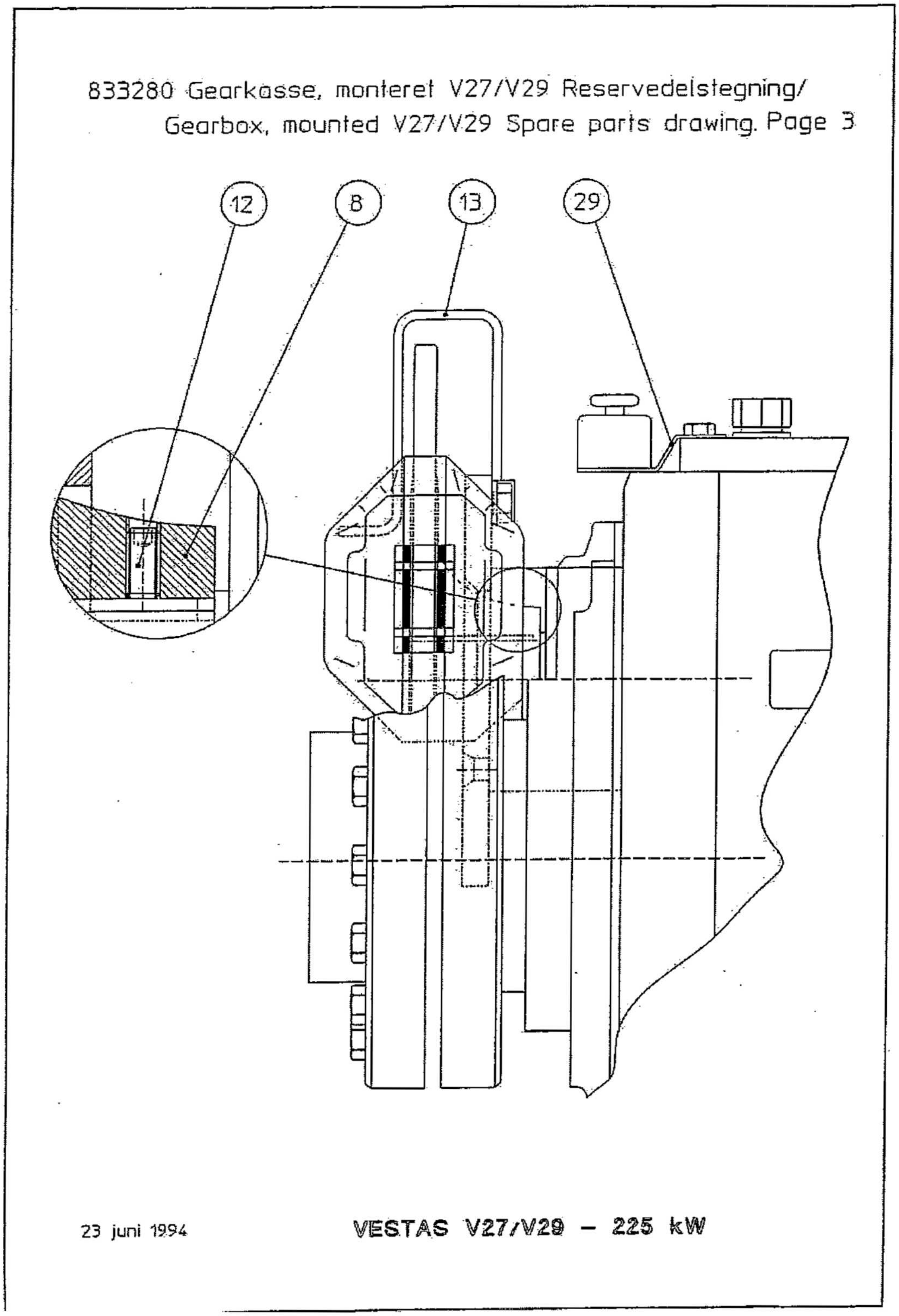


Figure 4-42. Spare parts drawing, gearbox

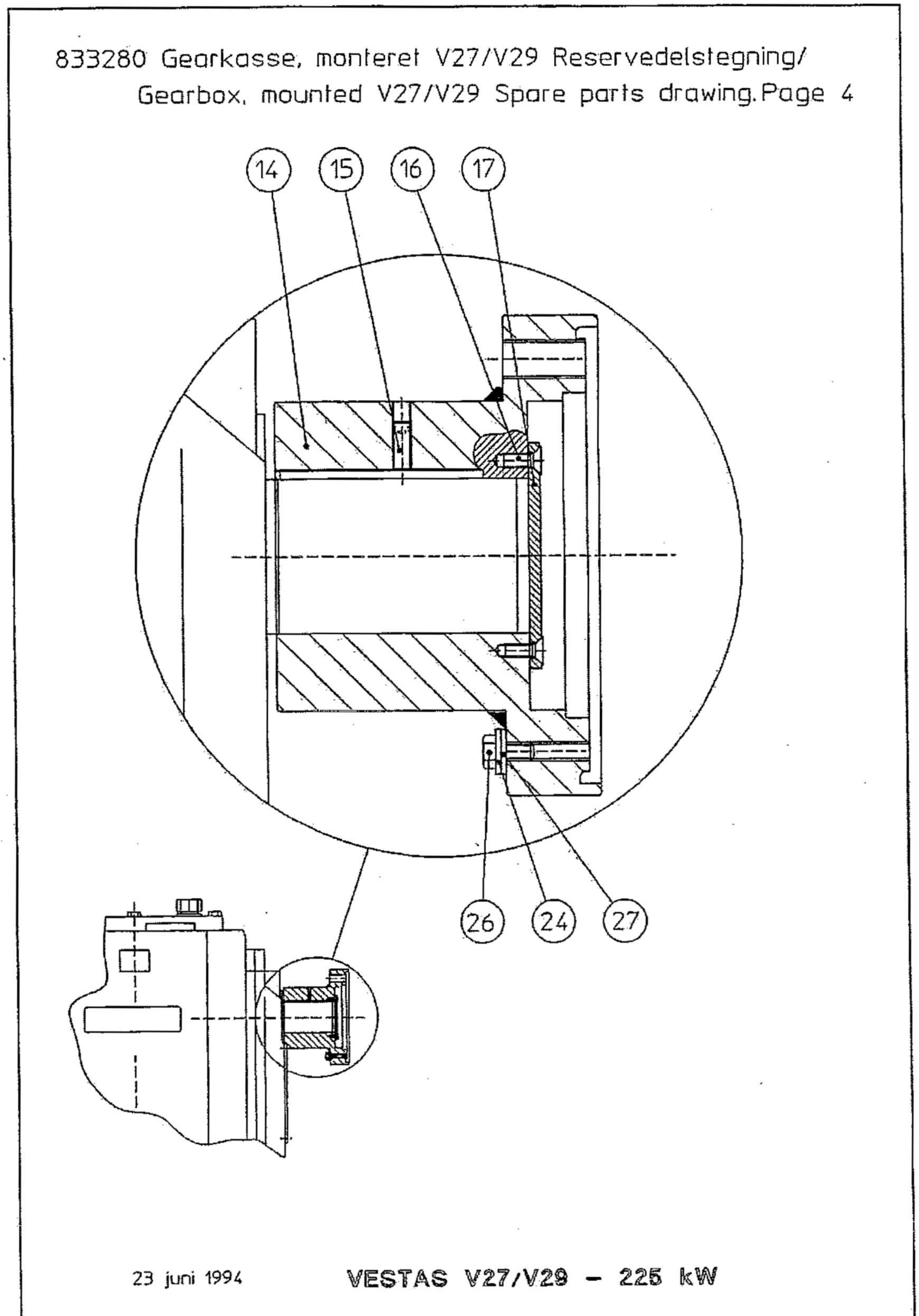
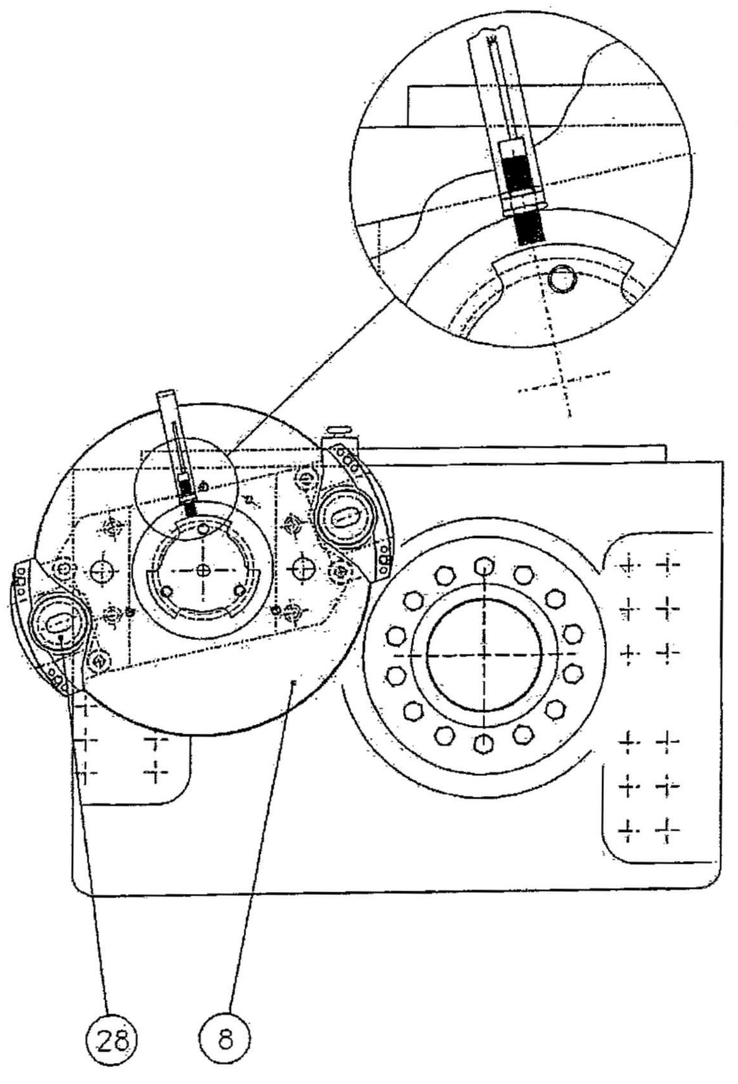


Figure 4-43. Spare parts drawing, gearbox

833280 Gearkasse,monteret V27/V29 Reservedelstegning/
Gearbox,mounted V27/V29 Spare parts drawing. Page 5



23 juni 1994 VESTAS V27/V29 – 225 kW

Figure 4-44. Spare parts drawing, gearbox

4.10. Brake

The hydraulic control system provides hydraulic working pressure for braking of the rotor system. The brake is a two-caliper system on the high-speed shaft of the gearbox.

4.10.1. Specifications

Brake disc:	
Manufacturer:	Vestas
Material:	GGG 50
Outer diameter:	600 mm
Braking surface:	Ø460 x Ø600 mm
Thickness of disc:	22 mm
Mounting diameter:	Ø70 J6
Weight:	60 kg
Brake caliper:	
Manufacturer:	Brembo
Type:	P2.I.44
Piston diameter:	75 mm
Pressure fluid:	Hydraulic oil
Type:	Mineral oil, VI > 150 (same as the pitch system)
Viscosity:	32 cSt v. 40°
Max. pressure:	150 bar
Lining area:	65 cm^2
Thickness:	11 mm
Mounting bolts:	M20 x 50
Number:	2 pcs.
Weight (each):	16 kg

4.10.2. Maintenance

4.10.2.1. Check Bolt Torque

Interval: Yearly

Note: The bolts in the anchor plate (pos. 7, Figure 4-40) need not be torqued during ordinary inspections, but only in connection with a special torque inspection.

Refer to Figure 4-46

Steps:

1. Tighten the bolt using a torque wrench setting of 567 Nm (418 ft.-lbs.).
2. If it is possible to tighten the bolts, note this in the inspection log.

4.10.2.2. Check Brake Pads & Calipers

Interval: Yearly

Refer to Figure 4-46

Steps:

1. Check the thickness of the brake pads (pos. 8, Figure 4-46) and note the measurement in the inspection log.
2. If there is less than 3 mm (1/8") lining, replace the pads.
3. Check the calipers for leaks and worn rubber sleeves (pos. 7, Figure 4-46).
4. If there is leakage or the rubber sleeves are worn, replace the calipers.
5. Clean and lubricate moving parts if needed.

4.10.2.3. Check Brake Disc

Interval: Yearly

Refer to Figure 4-46

Steps:

1. Check the brake disc (pos. 8, Figure 4-40) for the following.
   a. Distortion
   b. Deflection of more than 0.2 mm (0.008")
   c. Nacelle vibration when the brake is activated
   d. Cracks in the brake disc
   e. Cracks in the surface of the brake disc
   f. Damage to the braking surface
   g. Fitting to the gearbox shaft
   h. Loose brake disc. (If loose, check the gearbox high-speed shaft carefully.)
   i. Significant rust
   j. Deep grooves in the braking surface
   k. Wear to the brake disc
   l. Minimum thickness of the brake disc should be 20 mm

4.10.3. Troubleshooting

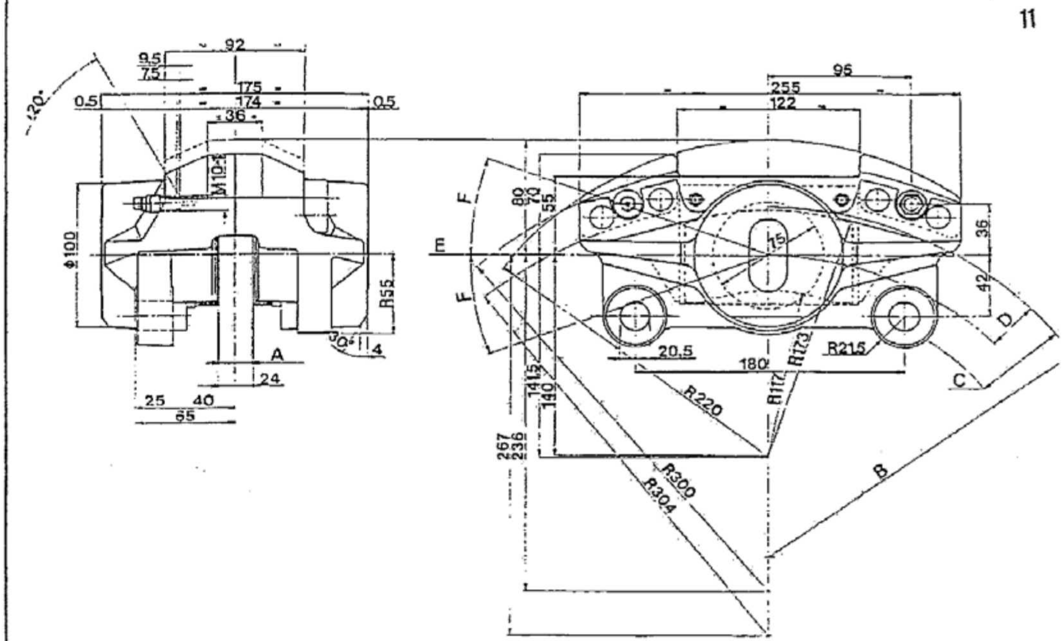
4.10.4. Spare Parts

4.10.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Brembo spare parts drawing, brake	
		Brembo spare parts drawing, brake	

BREMBO	PINZE IDRAULICHE POSITIVE POSITIVE HYDRAULIC CALIPERS	9.4	P2.I.44** 20.2802.10

11



NOTE	NOTES	
Il disegno rappresenta la versione destra - Rif.	Drawing shows R.H. version - Ref.	20.2802.10
La versione sinistra, simmetrica - Rif.	L.H. version, symmetrical - Ref.	20.2802.20
A = spessore max. disco	max. disc thickness	23
spessore min. disco	min. disc thickness	20
B = Ø max. disco	max. disc diameter	700
Ø min. disco	min. disc diameter	300
C = larghezza fascia frenante	braking surface width	60
D = per dischi sino a Ø 600 mm.	for discs up to 600 mm. diameter	33,5
per dischi oltre Ø 600 mm.	for discs over 600 mm. diameter	31
E = asse verticale	vertical axis	
F = scostamento ammesso rispetto all'asse verticale	permissible deviation as regards vertical axis	± 20°

Diametro di un pistoncino idraulico	Diameter of a hydraulic piston	Øp	mm	75
Area di un pistoncino idraulico	Area of a hydraulic piston	Ap	cm^2	44,16
Pressione di funzionamento massima	Max. line pressure	pf max.	bar	150
Volume di fluido assorbito in una frenata (alla pf max.)	Displacement	Vt	cm^3	10
Volume assorbito da un'usura completa del materiale d'attrito	Displacement with worn pad	Vu	cm^3	97
Forza di serraggio totale alla pressione massima	Total braking force (max. working pressure)	Fso	N	132480
Valore del coefficiente d'attrito del materiale d'attrito (vedi paragrafo 9)	Value of coefficient of friction of friction material (see paragraph 9)	μ		0,3 ÷ 0,4
Area della superficie di lavoro del materiale d'attrito di una pastiglia	Working surface area of friction material of a pad	Ag	cm^2	65
Spessore massimo utilizzabile del materiale d'attrito di una pastiglia	Max. thickness utilizable of friction material of a pad	Sg	mm	11
Massa della pinza	Caliper mass	M	kg	16

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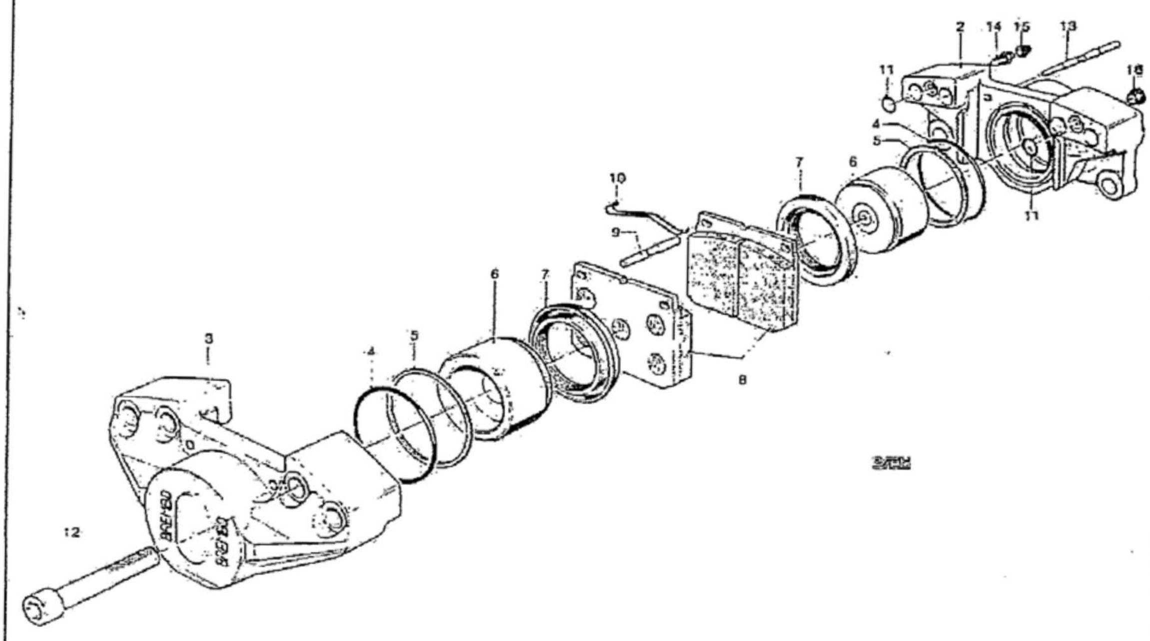
Figure 4-45. Brembo spare parts drawing, brake

P2.I.44**	PINZE IDRAULICHE POSITIVE POSITIVE HYDRAULIC CALIPERS	9.5	BREMBO
20.2802.10			

12



N. POS.		N. RIFERIMENTO CODE No.	DENOMINAZIONE	DESCRIPTION	Q.TA' Q.TY
1DN		20.2802.10	Assieme pinza destra (con guarnizione N)	Right caliper assembly (with N seal)	1
1SN		20.2802.20	Assieme pinza sinistra (con guarnizione N)	Left caliper assembly (with N seal)	1
1DS		20.2802.30	Assieme pinza destra (con guarnizione S)	Right caliper assembly (with S seal)	1
1SS		20.2802.40	Assieme pinza sinistra (con guarnizione S)	Left caliper assembly (with S seal)	1
	2	• 20.2804.10	Semipinza con orecchie	Half-caliper	1
	3	• 20.2803.10	Semipinza senza orecchie	Half-caliper	1
	4N	△ 909.11.25.414	Guarnizione (N) OR 6300	Seal (N) - OR 6300	2
	4S	◆ 909.11.15.414	Guarnizione (S) OR 6300	Seal (S) - OR 6300	2
	5N	△ 909.22.27.414	Anello antiestrusione (N)	Ring (N)	2
	5S	◆ 909.22.17.414	Anello antiestrusione (S)	Ring (S)	2
6		20.2806.10	Pistoncino	Piston	2
	7	△ ◆ 20.2807.10	Cuffia parapolvere	Boot	2
8		07.1710.10	Pastiglia	Pad	2
	9	□ 20.2810.10	Spina	Pin	1
	10	□ 05.1706.10	Molla	Spring	1
	11N	△ 909.11.25.203	Guarnizione (N) OR 112	Seal (N) - OR 112	2
	11S	◆ 909.11.15.203	Guarnizione (S) OR 112	Seal (S) - OR 112	2
12		901.08.54.392	Vite 16 x 90 UNI 5931	Screw - 16 x 90 UNI 5931	4
	13	□ 20.2808.10	Perno	Pin	2
	14	• 05.2812.10	Tappo di spurgo	Bleeder valve	1
	15	• 05.1502.10	Parapolvere	Boot	1
	16	• 05.2290.10	Tappo	Plug	1
	-	△ 20.3250.10	Gruppo di revisione guarnizioni (N)	Seals (N) kit	
	-	◆ 20.3250.11	Gruppo di revisione guarnizioni (S)	Seals (S) kit	
	-	□ 20.3248.10	Gruppo di revisione perni pastiglie	Pins kit	
	-	• 05.3246.10	Gruppo di revisione spurgo	Screws kit	

(Q)

Figure 4-46. Brembo spare parts drawing, brake

4.11. Transmission Shaft

Forged shaft with two homokinetic joints, axial displacement in the joints.

4.11.1. Specifications

Manufacturer:	Löbro
Type:	06 200 42 00 0554
Max. static moment:	1400 Nm
Max. rpm:	3000
Max. deflection angle:	10 degrees
Axial displacement:	± 24 mm
Installation length:	554 mm
Connection dimension:	Ø192 h9
Bolts:	
Type:	M16 x 1.5 x 110 10.9
Number:	2 x 8 pcs.
Bolt circle:	165 mm
Torque:	250 Nm (184 ft.-lbs.)
Weight:	30 kg

4.11.2. Maintenance

4.11.2.1. Lubricate Externally

Interval: Six months

Refer to Figure 4-47

Steps:

1. Loosen one of the clips from the rubber sleeve on the transmission shaft (pos. 10,Figure 4-28) and press 120 g grease in each joint. Use special MoS2 grease, Opti Temp PU035.
2. Remount the clips.

4.11.2.2. Disassemble and Lubricate Internally

Interval: Two years

Note: The transmission shaft must never hang in one cardan joint; this can destroy the rubber sleeve.

Note: Be careful not to get dirt in the cardan joints.

Refer to Figure 4-48and 4-49

Steps:

1. Remove the transmission shaft.
2. Remove the rubber sleeves on the cardan joints.
3. Remove old grease from the rubber sleeves, cardan joints, and flanges with lint-free paper.
4. Inspect the joints, rubber sleeves, packing, bolts, spring washers, and flanges very carefully at each inspection. Replace damaged or worn parts.
5. Lubricate the rubber sleeves, joint, and flange of each joint. Use 330g/joint of special MoS_2 grease, Opti Temp PU035.

4.11.2.3. Check Bolt Torque

Interval: Yearly

Note: The mounting bolts to the transmission shaft need not be tightened during routine inspections but only in connection with a special torque inspection.

Refer to Figure 4-48and 4-49

Steps:

1. Select two of the mounting bolts to the transmission shaft (pos. 10, Figure 4-48) in each joint and tighten them, using a torque wrench setting of 250 Nm (184 ft.-lbs.).
2. If any of the bolts can be tightened, all the bolts should be tightened.

4.11.2.4. Inspect Transmission Shaft

Interval: Six months

Refer to Figure 4-47

Steps:

1. Check all gaskets and rubber sleeves for leaks.
2. Check the intermediate shaft for rust or wear.
3. Scrape off any rust and protect the shaft with Tectyl.
4. If there is significant rust, mark unit for replacement.
5. Check that the shaft moves freely (axially) inside cardan joint.

4.11.3. Troubleshooting

4.11.4. Spare Parts

SPARE PARTS LIST 920436 – TRANSMISSION SHAFT				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	1	835585	Gear flange for transmission shaft	
2	4	159098	Machine screw, UHJ FZB M6 x 16	
3	4	899011*	Sealing rings	Included in repair kit 899011
4	8	899011*	Washer, M5	Included in repair kit 899011
5	8	899011*	Screw, M5 x 16, DIN 912	Included in repair kit 899011
6	1	835357	Grease plate for gear flange	
7	2	834190	Sealing ring for gear flange + coupling	
8	2	899011*	Circlip, A50x2, DIN 471	Included in repair kit 899011
9	6	899011*	Lock washer, B16 DIN 127	Included in repair kit 899011
10	6	152528	Steel bolt, M16 x 1.5 x 110, 10.9	
11	2	899011*	Clip	Included in repair kit 899011
12	2	899011*	Rubber sleeve	Included in repair kit 899011
13	2	899011*	Clip Ø118/9Zy	Included in repair kit 899011
14	2	899011*	Flange	Included in repair kit 899011
15	1	106240	Transmission shaft, 062004200-0554	
16	1	837061	Flange coupling – cardan	

4.11.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Transmission shaft	
		Transmission front end	
		Transmission rear end	

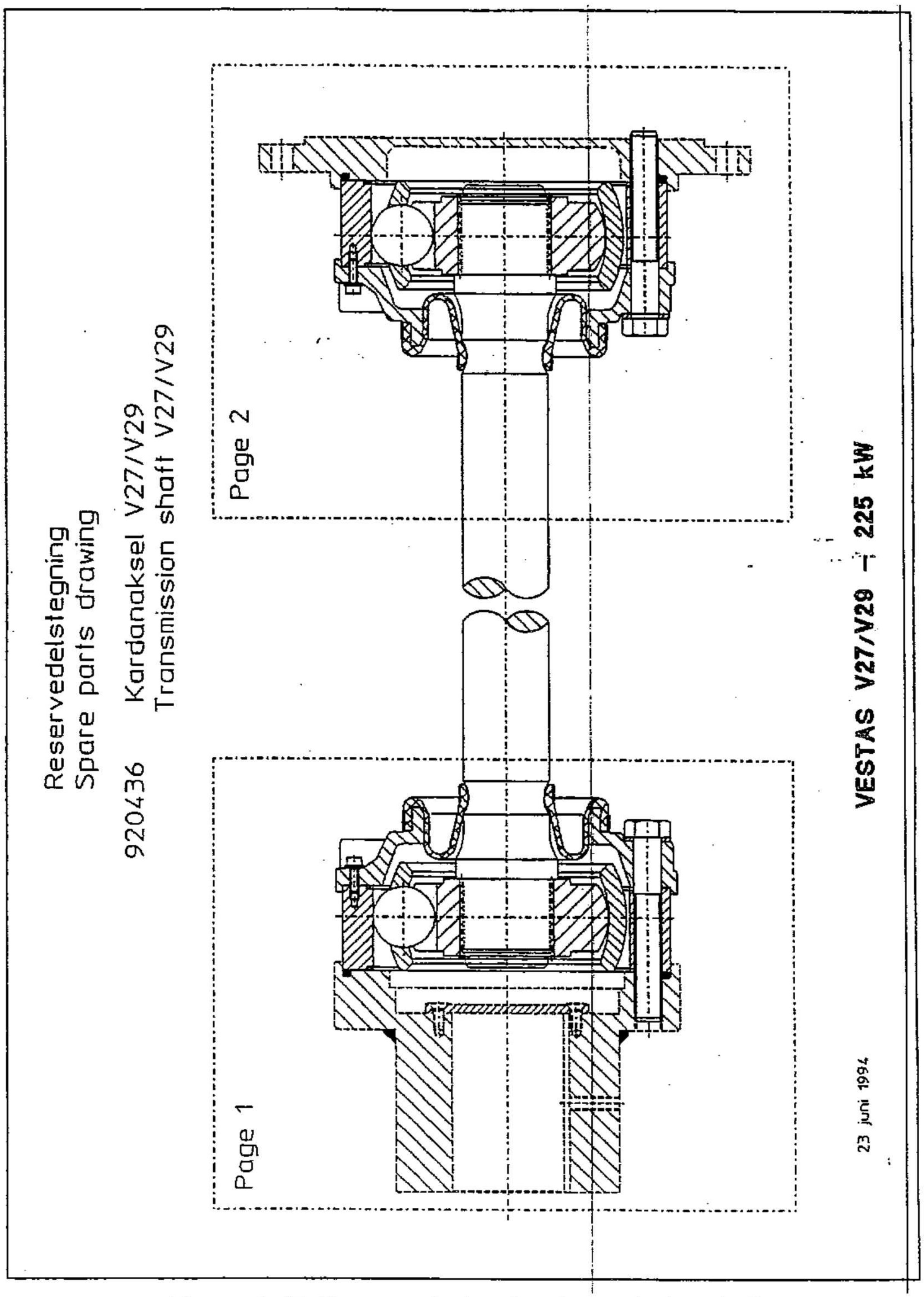


Figure 4-47. Spare parts drawing, transmission shaft

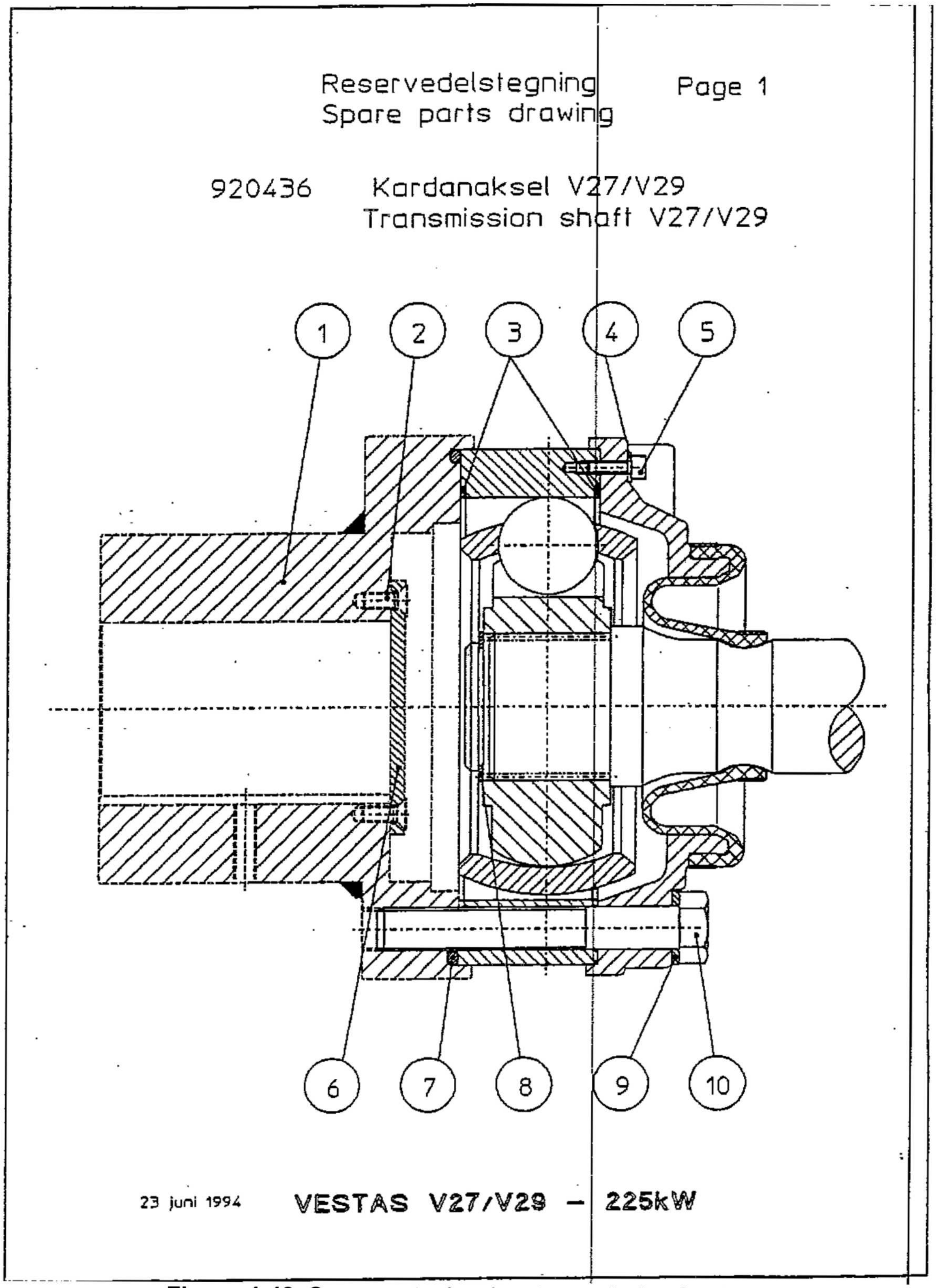


Figure 4-48. Spare parts drawing, transmission front end

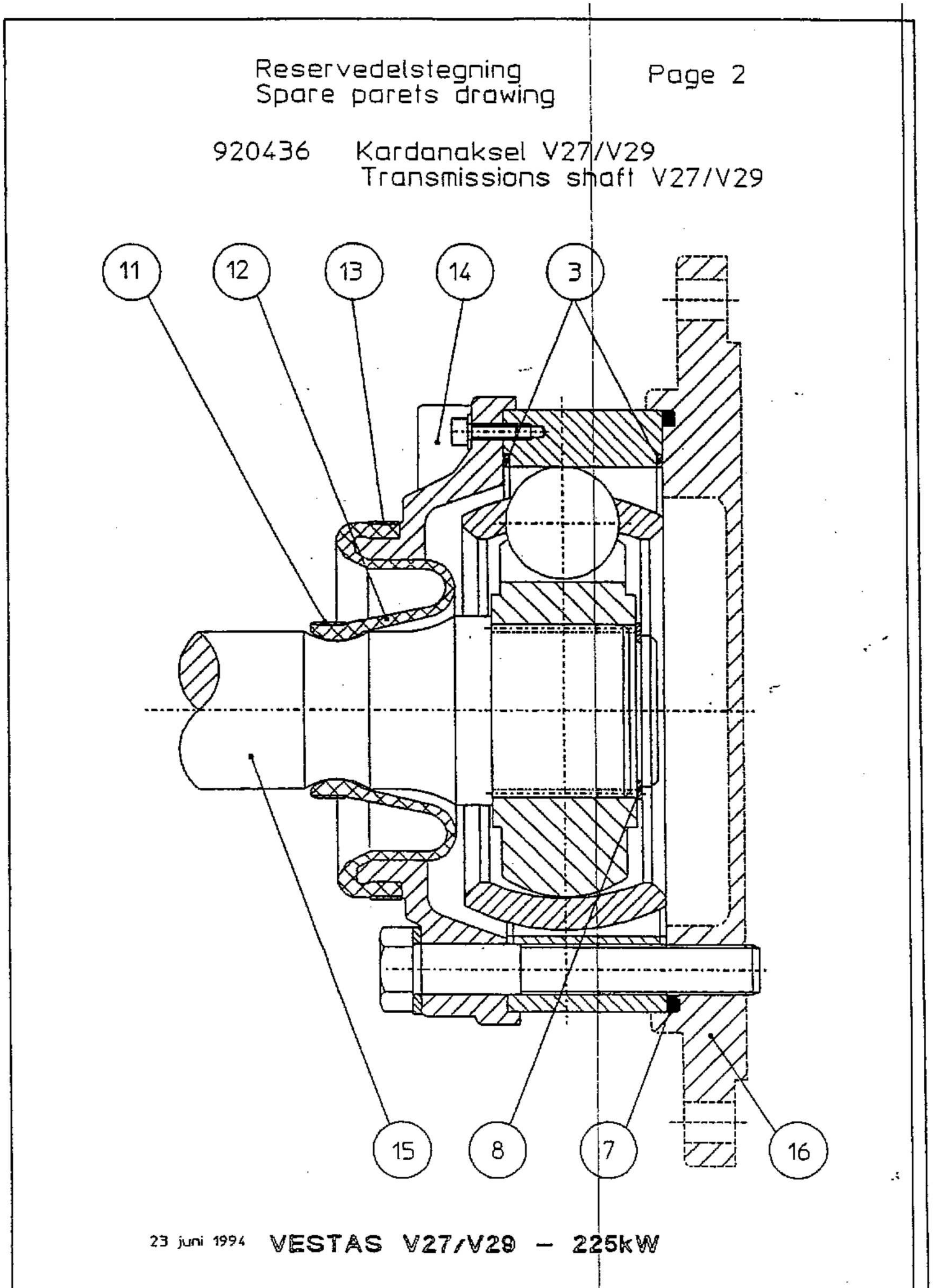


Figure 4-49. Spare parts drawing, transmission rear end

4.12. Slip Coupling

Mounted on the generator shaft. Prevents excessive torque from being applied to the generator.

4.12.1. Specifications

Manufacturer:	Vestas
:	
Torque moment at 1200 rpm:	3600 Nm (60 Hz)
Torque moment radius:	96.25 mm
Friction coefficient:	App. 0.3
Fit:	
Diameter:	Ø85 H7
Length:	128 mm
Disc. spring:	
Manufacturer:	SCHNORR
Type:	DIN 2093 – B 180
Dimension:	Ø180 x Ø92 x 6
Number:	2 pcs.
Friction material:	
Type:	MK101
Dimension:	Ø230 x Ø155 x 4.76
Number:	2 pcs.
Bolts:	M12 x 160 8.8 FZV
Number:	8 pcs.
Bolts:	M8 x 16 DIN 916 – 45H
Number:	1 pcs.
Weight:	70 kg

4.12.2. Maintenance

4.12.2.1. Check Bolt Torque

Interval: Yearly

Note: The bolts to the flange coupling-transmission shaft need not be tightened during routine inspections, but only in connection with a special torque inspection.

Refer to Figure 4-51 and 4-52

Steps:

1. Select and tighten two of the bolts to the flange coupling-transmission shaft (pos. 15, Figure 4-52, using a torque wrench setting of 66 Nm (49 ft.-lbs.)
2. If any of the bolts can be tightened, all the bolts should be tightened.

4.12.2.2. Adjust Slip Moment

Interval: XXX

Note: Adjustment of the slip moment takes place in two circumstances: the slip moment is too large, or the slip moment is too small.

Note: These directions are for a 225Kw generator. They will need adjustment to accommodate the derated 200 Kw generator.

Refer to Figure 4-51 and 4-52

Steps (slip moment too large):

1. When the measure marked “A” on drawing (837040) exceeds 0.5mm + the measure cut in the thrust plate.
2. It is measured with a thickness gauge through the holes in the distance piece.
3. Tighten the retainer to the hub (pos. 16, Figure 4-52with 2 pcs. M10 x 30 12.9 allen screws.
4. Remove the transmission shaft and the flange coupling-transmission shaft (pos. 7,Figure 4-52).
5. Tighten the nut (pos. 1,Figure 4-52) until the measure “A” is equal with the cut in the thrust plate (pos. 13,Figure 4-52).
6. Tighten the counter nut (pos. 2,Figure 4-52) using a torque wrench setting of 200 Nm (148 ft.-lbs.).

Steps (slip moment too small):

1. At adjustment, 1/6 rotation on the center nut corresponds to a change in the slip moment on app. 25 kW.
2. Adjust according to generator specifications.

4.12.3. Troubleshooting

4.12.4. Spare Parts

SPARE PARTS LIST 837040 – SLIP COUPLING*				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	1	833045	Nut for slip coupling	
2	1	833053	Counter nut for slip coupling	
3	1	831484	Threaded rod for slip coupling	
4	1	897268	Washer for coupling	
5	2	107796	Disk spring, Ø180 x Ø92 x 6	
6	8	152048	Steel bolt, 8.8 FZV, M12 x 160	
7	1	837061	Flange coupling-transmission shaft	

8	1	837083	Distance piece for coupling	
9	1	837086	Spring plate for coupling	
10	1	837085	Thrust plate for coupling	
11	1	834173	Brass bushing for slip coupling	
12	2	832960	Friction facing for coupling	
13	1	837084	Thrust disc for coupling	
14	8	156455	Washer, M12 FZV	
15	8	157775	Lock nut, M12 FZB	
16	1	837033	Hub for coupling-generator	
17	1	151567	Stop screw, M8 x 16	

* Not all parts to the slip coupling are delivered as single parts because of balancing. Figure 4-50 shows part numbers belonging together. Only the underlined EDB-no. should be ordered.

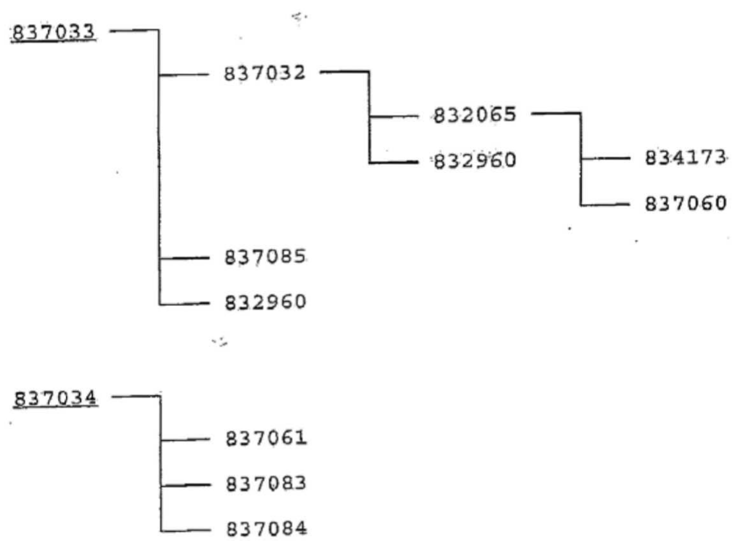


Figure 4-50. Connected slip coupling parts

4.12.5. Drawings

Drawing #	Version # (date)	Description	Filename
		V27 – 226 kW	
		Slip coupling	

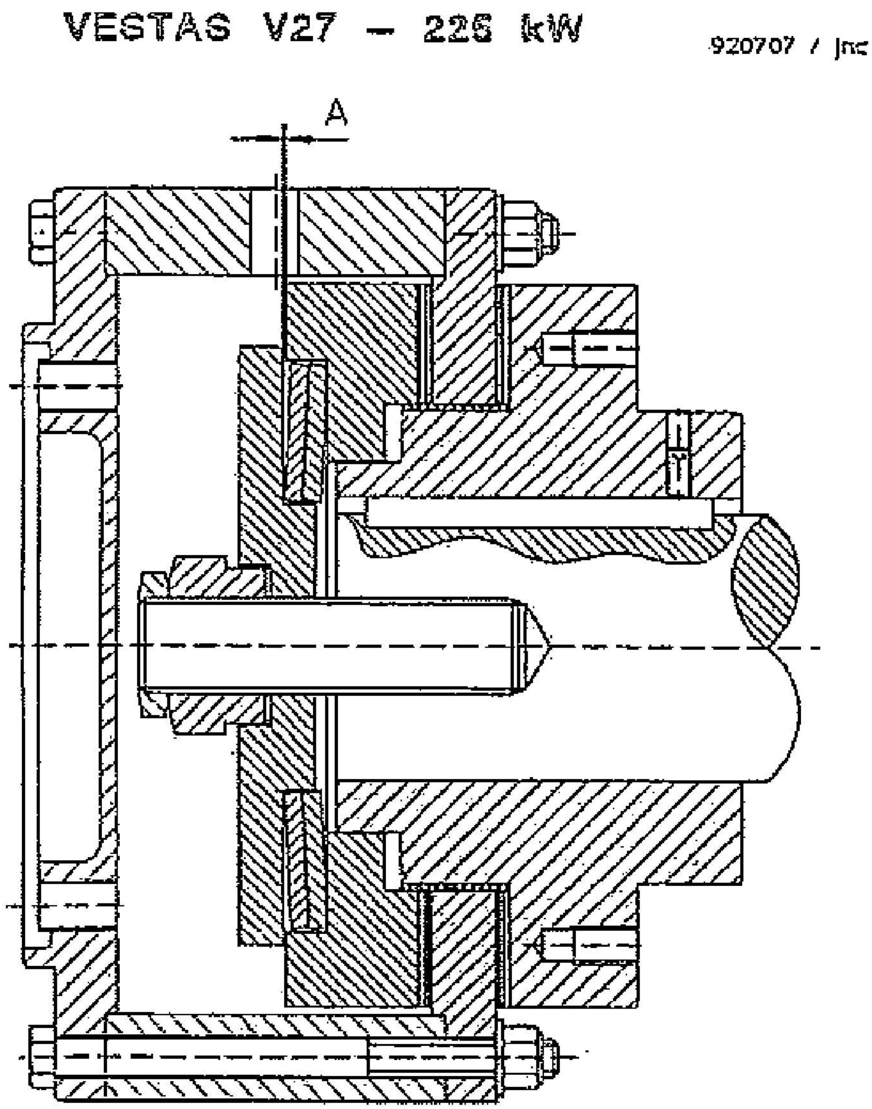


Figure 4-51. V27 – 226 kW

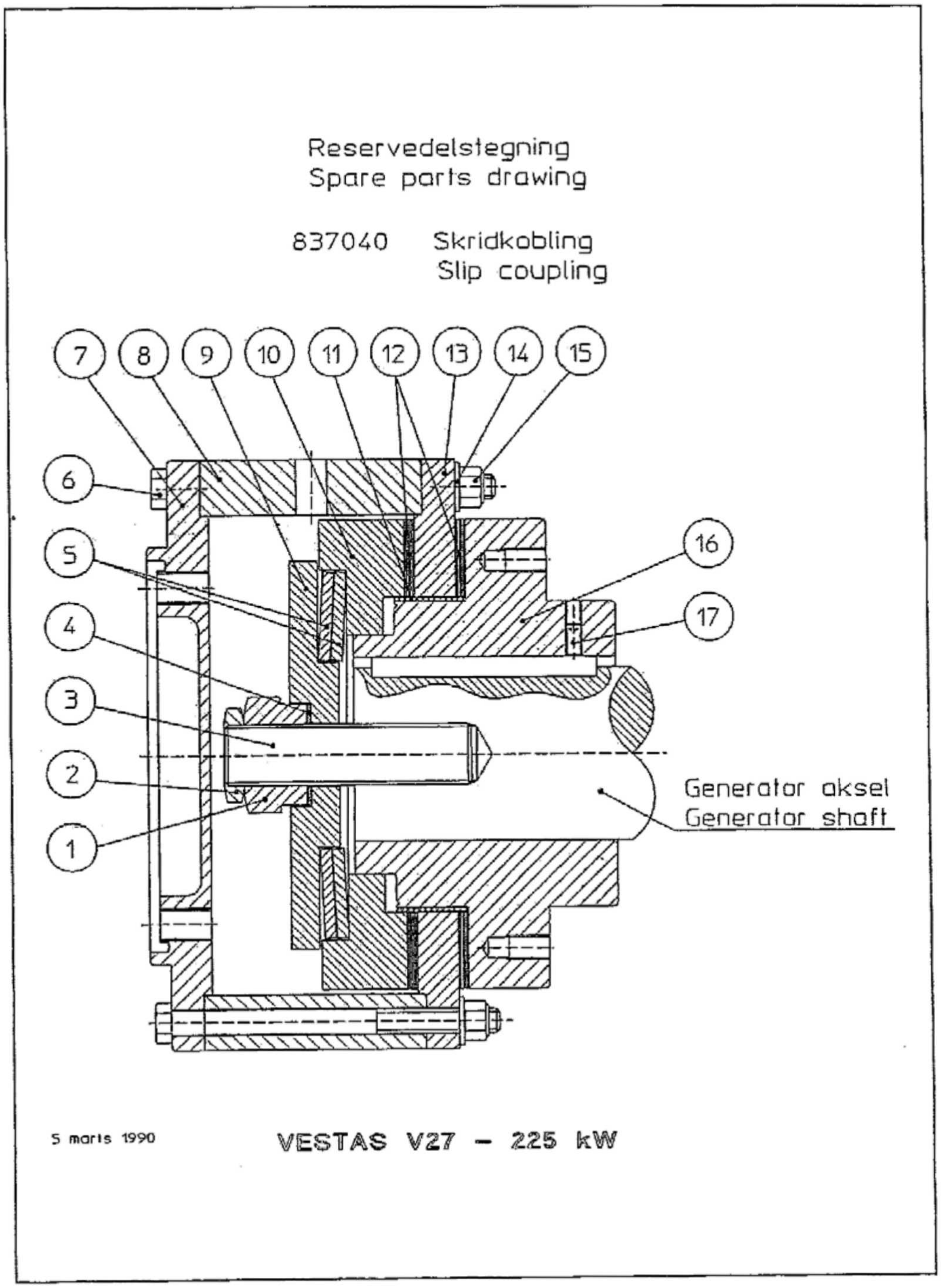


Figure 4-52. Spare parts drawing, slip coupling

4.13. Generator

Each SWiFT wind turbine is equipped with a three-phase, variable-speed, 60 Hz, 400 HP asynchronous generator. Mechanical energy from the turbine's blade-rotor assembly is transmitted into the generator through a two-stage gearbox. A 1775 rpm high speed shaft into the generator drives current production.

4.13.1. Specifications

Manufacturer & type:	Baldor Reliance IDDRPM364004
Frame group:	360
Nema design:	A
Insulation class:	H
Number of poles:	9
Voltage:	460 V
Frequency:	N/A
Rated power:	400 HP
Current:	144-692 A
Temperature sensors:	2 pcs.
Terminal box screw joints:	9 pcs., 00
Weight	App. 824 kg

4.13.2. Maintenance

4.13.2.1. Lubricate Generator Bearings

Interval: 1100 hours of operation

Note: Baldor motors are pregreased, normally with Polyrex EM (Exxon Mobil).

Refer to Figure 4-53

Steps:

1. Clean the grease fitting (or other area around grease hole, if equipped with slotted grease screws). If motor has a purge plug, remove it. Motors can be regreased while stopped (at less than 80C) or running.
2. Apply grease gun to fitting (or grease hole). Too much grease or injecting grease too quickly can cause premature bearing failure. Slowly apply the recommended amount of grease, taking 1 minute or so to apply. Operate the motor for 20 minutes, then reinstall purge plug if previously removed.
3. For frame size NEMA 360, add .81 ounces of grease (23.1 grams).

4.13.2.3. Check Bearings

Interval: Six months

Note: Be very careful when working in the nacelle when the turbine is in operation.

Refer to Figure 4-53

Steps:

1. Start the turbine and listen for abnormal noise in the bearing.
2. Replace the bearings if there is any abnormal noise.

4.13.2.4. Check Ventilator Guard & Surface Treatment

Interval: Six months

Note: Be very careful when working in the nacelle when the turbine is in operation.

Refer to Figure 4-53

Steps:

1. Check the air intake/ventilator guard for corrosion.
2. Check the surface of the generator for corrosion.

4.13.3. Troubleshooting

4.13.4. Spare Parts

SPARE PARTS LIST 834939 – GENERATOR MOUNTED V27				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	1	IDDRPM364004	Generator, 400HP, 1775 rpm	
2	2	153208	Steel bolt, M10 x 20 FZV 8.8	
3	2	156256	Washer, M10 FZV DIN 125A	
4	1	832714	Support for main cables	
5	8	157773	Lock nut, M8 FZB	
6	1	832732	Supporting block, V27	
7	1	834963	Plate for cable support, V25/V27	
8	16	156663	Washer, M8 FZV	
9	8	152005	Bolt, M8 x 100 FZV 8.8	
10	4	154199	Steel bolt, M10 x 40 FZV 8.8	
11	1	194484	Screwed cable entry, PG 11 250/11	
12	1	094293	Hole plug, PG 11 514/11	
13	1	094277	Hole plug, PG 36	
14	6	194423	Screwed cable entry, PG 36	
15	2	149403	Grease nipple, M10 x 1 H1, straight	
16	4	152528	Bolt, M16 x 100 FZV 8.8	*

16	4	153516	Bolt, M16 x 110 FZV 8.8	*
17	4	897434	Washer, Ø17 x Ø47 x 8	
20	8	157775	Lock nut, M12 FZB	
21	8	156455	Washer, M12 FZV	
22	8	897329	Washer, Ø13 x Ø34 x 3 FZV	
23	8	152226	Bolt, M12 x 50 FZV 8.8	
24	1	833127	Rear nacelle bedplate, machined	
25	1	837040	Slip coupling	

4.13.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Generator	

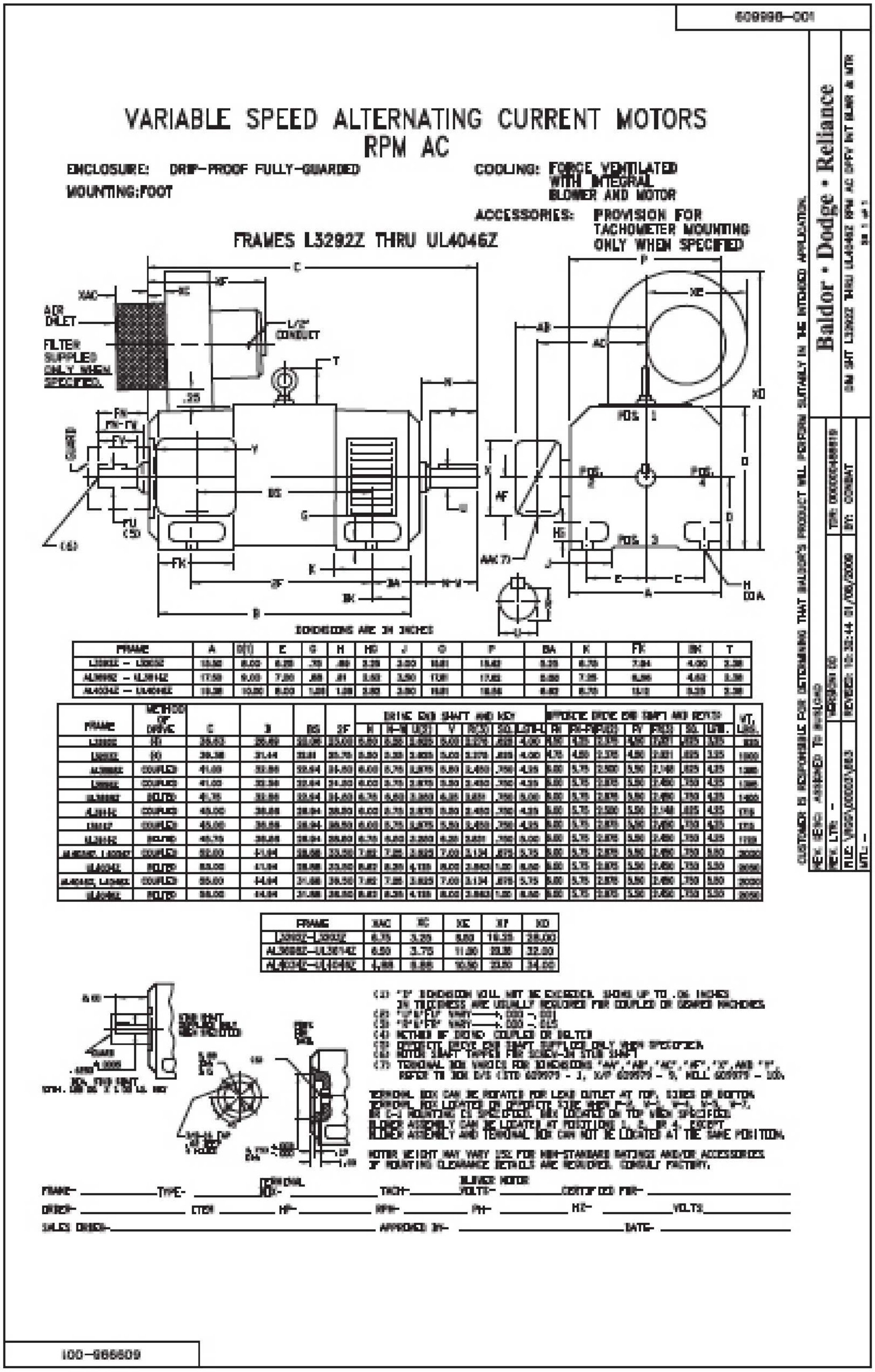


Figure 4-53. Spare parts drawing, generator

4.14. Hydraulic System

The hydraulic control system supplies oil pressure that regulates blade pitch and stores oil pressure for braking of the rotor system. It is located adjacent to the top control cabinet.

4.14.1. Specifications

Power Unit, 60 Hz:	
Manufacturer:	Islef + Hagen A/S
Assembly drawing:	Islef + Hagen A/S SC103432
Diagram + parts list:	Islef + Hagen A/S SC103087
Motor size:	1.5 kW
Number of poles/-rpm:	2/2800 rpm
Motor voltage:	3x380 VY (→ power unit 1221 →) 3x400 V /690V Y (power unit 1222 →)
Proportional valve:	NG 6, 13 1/min.
Cartridge solenoid valves:	NG 6
Voltage on:	
Cartilage solenoid valves:	
Control card:	
Pressure transducer:	
Filter contamination indicator:	
Level switch:	24 V DC
Pump flow:	4.3 – 5.0 1/ min. (loading dependent).
Pressure, pitch system:	75-90 bar
Pressure, brake system:	19 bar
Tank size:	30 l
Oil quantity (system):	27 l
Weight (without oil):	65 kg

Piping System:	
Arrangement drawing:	920282 hydraulic, pipework and fittings
Type of fittings:	DIN cutting ring type

4.14.2. Maintenance

Note: Periodic maintenance of the hydraulic system is described in instruction 941275 “V27/V29, check” and section 25 “Hydraulic.” Some of these procedures are described in more detail in this section.

Note: Whenever the test hose it used, it must at first be connected to test nipple M8 or an external manometer before it is connected to a test nipple with high pressure. Otherwise, oil may be blown out of the hose with high pressure.

Note: Do not use tools for closing the needle valves. The valve seat can be damaged and it can also be impossible to, in the future, open the valve without tools.

Note: Do not adjust valves without notifying the Vestas Service Department. All valves have been adjusted during testing of the hydraulic power unit.

Note: Before disassembly of the hydraulic power unit, stop the pump motor by activating one of the Emergency Stop buttons.

Note: Before disassembly of the brake system, accumulators 16 and 27 must be drained of all oil using needle valves 18.1 and 18.2.

Note: Before disassembly of the pumping system or the pitch system, accumulator 16 must be drained off using needle valve 18.1.

Note: Take care not to place fittings and other parts on the floor or other dirty places to ensure paint flakes and dirt do not enter the system.

Note: After any service of the hydraulic power unit, wipe off all grease waste and drips under fittings and valves to make finding leaks easier during future inspections.

4.14.2.1. Check Oil Level

Interval: Three months after commissioning, then every six months

Refer to Figure 4-54

Steps:

1. With hydraulic accumulators drained of all oil (needle valves 18.1 and 18.2 open) and the blades feathered, check that oil is just visible in the upper sight glass.
2. With the hydraulic power unit in Stop or Pause, oil should always be visible in the lower sight glass.
3. If necessary, top off using the oil type specified in the lubrication chart.

4.14.2.2. Take Oil Sample

Interval: On request from Vestas Service Department

Refer to Figure 4-54

Steps:

1. Extract a 100 ml oil sample from the reservoir in one of the following two ways:
   a. Stop the power unit and drain the accumulators of all oil. Remove the screw cap on the air breather filter. Extract oil through the strainer into the sample bottle using an oil sample pump and hose.

b. Stop the power unit and drain the accumulators of all oil. Connect the test hose to the test nipple M1. Close needle valve 18.1. Manually activate the contactor K204 to the pump motor. Pump oil through the test hose and into the sample bottle.
2. Write the turbine number and date on the bottle.

4.14.2.3. Change Oil

Interval: Every five years or when requested from Vestas Service Department

Refer to Figure 4-54

Steps:

1. Stop the pump motor and drain the accumulators of all oil.
2. Remove the hose from the rear end of the hydraulic cylinder and put it into a can.
3. Empty the power unit reservoir by manually activating the contactor K204 to the pump motor until the pump sucks air.
4. Remove the air filter housing (use a crosshead screwdriver).
5. Insert the suction hose through the air filter hole.
6. Drain off the tank using a drill motor.
7. Remove the high-pressure filter and drain off the filter bowl.
8. Top off oil through the air filter hole. See Section 4.14.2.1 for oil level.
9. Mount the air filter housing and a new filter element.
10. Mount the hose to the rear end of the hydraulic cylinder again.
11. Start the pump and let it run for 15 seconds with both needle valves open.
12. Close the needle valves and pitch three double strokes with the cylinder in order to let air out of the system.
13. Check the oil level according to Section 4.14.2.1.

4.14.2.4. Check & Change High Pressure Filter

Interval: Inspect every six months/change yearly or more frequently as needed

Refer to Figure 4-54

Steps:

1. Ensure that the oil temperature in the reservoir is above 20°C and, if possible, between 20°C and 30°C. If the temperature is too low, the oil should be heated by switching the pump on and waiting for the oil to be heated.
2. Turn on the pump motor and check whether the red contamination indicator button pops up. If it does, push it down again and see if it pops up again.
3. If the contamination indicator continues to pop up, replace the filter.
4. Drain and clean the filter bowl.
5. Replace the oil according to Section 4.14.2.3. Do not reuse contaminated oil.

4.14.2.5. Change Air Breather Filter Element

Interval: Five years

Refer to Figure 4-54

Steps:

1. Unscrew the cap of the filter housing
2. Remove the old filter.
3. Wipe off waste hydraulic oil in the filter housing.
4. Place a new filter element in the filter housing.
5. Replace the cap.

4.14.2.6. Check Nitrogen Precharge Pressure in Accumulators

Interval: Six months

Refer to Figure 4-54

Steps:

1. Stop the hydraulic power unit by pushing Emergency Stop.
2. Connect a digital manometer to test nipple M3.
3. Drain the pitch accumulator (pos. 16, Figure 4-54 slowly (this should take approximately 2 minutes) by opening needle valve 18.1.
4. Watch the pressure during drain off. The nitrogen precharge pressure is the same as the last pressure registered before the pressure suddenly drops to zero. Note reading in the inspection log.
5. Compare pressure readings with those in the table below. Because the nitrogen pressure varies with the temperature of the accumulator, it is necessary to feel the accumulator by hand and read the temperature of the hydraulic oil and the temperature of the nacelle on the service panel.
6. If the precharge pressure is outside the tolerances corresponding to the temperature readings of the accumulator, refill according to AI941918.
7. Move the digital manometer to test nipple M6.
8. Drain the brake accumulator (pos. 27, Figure 4-54slowly (this should take approximately 2 minutes) by opening needle valve 18.2.
9. Watch precharge pressure as described in Step 4. Note reading in the inspection log.
10. The approximate temperature of the accumulator is determined as described in Step 5; compare the measured nitrogen pressure using the table below.
11. If necessary, refill the accumulator according to AI941918.

Accumulator temperature	Pitch accumulator (pos. 16)	Brake accumulator (pos. 27) 50 Hz	Brake accumulator (pos. 27) 60 Hz
-20°C (-4°F)	26 bar	9.5 bar	7.8 bar
-10°C (+14°F)	27 bar	9.9 bar	8.1 bar
0°C (32°F)	28 bar	10.2 bar	8.4 bar
10°C (50°F)	29 bar	10.6 bar	8.7 bar
20°C (+68°F)	30 bar	11.0 bar	9.0 bar
30°C (86°F)	31 bar	11.4 bar	9.3 bar
40°C (+104°F)	32 bar	11.8 bar	9.6 bar
50°C (122°F)	33 bar	12.1 bar	9.9 bar
60°C (+140°F)	34 bar	12.5 bar	10.2 bar
Tolerance	± 3 bar	± 1 bar	± 1 bar

4.14.2.7. Check for Leaks

Interval: Six months

Refer to Figure 4-54

Steps:

1. Check all fittings and components on the manifold block and power units on the cylinder for evidence of leaks.
2. A slightly greasy surface is acceptable, but drop formations under fittings and seals is not.
3. In the case of drop formations, tighten fittings and change seals or fittings.
4. Always clean the area to make it easier to find leaks later.

4.14.2.8. Change Solenoid Valve

Interval: Six months

Refer to Figure 4-54

Steps:

1. When changing solenoid valves 19.1, 19.2, 19.3, or valve 2 on the manifold block on the cylinder, a special stripper, or "extractor" (tool number 733941), must be used.
2. After removal of the valve mounting screws, mount the stripper across the solenoid tube and tighten it using the tread on the end of the tool.
3. Pull the valve out by turning the nut slowly.

4.14.2.9. Disassemble the Pitch System

Interval: As needed

Refer to Figure 4-54

Steps:

1. Press Emergency Stop.
2. Drain the pitch accumulator (pos. 16, Figure 4-54by opening needle valve 18.1.
3. Drain oil from the rear end of the cylinder by activating the solenoid valve on the cylinder with a screwdriver while simultaneously pushing the piston rod back. Oil will flow from the rear end of the cylinder and back to the reservoir again at the same time as the front end of the cylinder is filled with oil from the reservoir.
4. If it is too difficult to move the piston rod, remove the hoses at the cylinder. Oil from the rear end of the cylinder (approximately 1 L) can then be emptied into a bucket.
5. After reassembling the pitch system, pitch the blades at least three times forward and backward from -5° to 88°.

4.14.3. Troubleshooting

4.14.4. Spare Parts

SPARE PARTS LIST XXX – HYDRAULIC SYSTEM				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	2	130958	Straight male stud	
2	1	833411	Brake tube right	V27
3	1	136891	Tee Ø6 x Ø8 x Ø6	
4	1	833428	Brake tube, left	V27
5	1	833405	Brake tube, hydraulic unit/calibers	
6	1	103923	Hydraulic hose, ¼” x 340 mm	
7	1	130966	Straight union, G8L	
8	1	105856	Straight male stud, GA8-LR ¼”	
9	3	132519	Straight male stud, GA10-LR ¼”	
10	1	103928	Hydraulic hose, 3/8” x 1900 mm	
11	1	132535	90° elbow SY 10 L	
12	1	132550	Straight male stud, GA10-LR ½”	
13	1	103929	Hydraulic hose, 2300 mm	

4.14.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Hydraulic system	

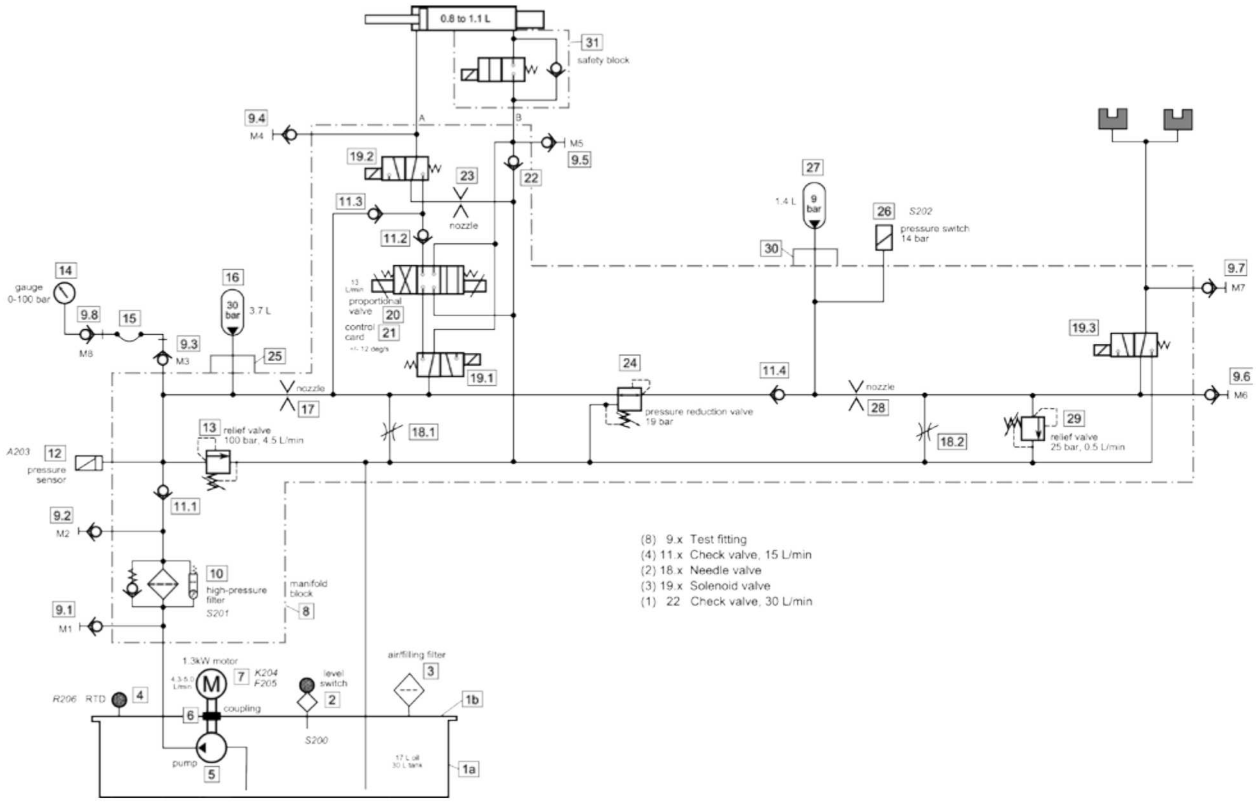


Figure 4-54. Hydraulic system

4.15. Yaw Drive Gears

Each SWiFT wind turbine's nacelle is mounted on a yaw ring that rotates 360°. Gears on the yaw ring mesh with two electric motors that control yaw rotation. An automatic yaw system keeps the turbine blade-rotor assembly facing into the wind in the Run and Pause operating states and untwists the tower cables when needed.

4.15.1. Specifications

Type:	Electric motor-operated worm and planetary gear drive
Manufacturer, motor:	ABB
Size:	MT 80B 19F100-6, IM3611
Number of poles:	6 poles
Power:	660 W 60 Hz 480 V
Manufacturer, worm gear:	Bonfiglioli
Size	MVF62/FC
Gear ratio:	1:30
Manufacturer, planetary gear:	Bonfiglioli Transmittal
Size:	705 T2
Gear ratio:	1:24.5
Driving pinion:	M=8, z=12
Gear lubricant:	Shell Tivela Compound A
Weight per unit:	60 kg

4.15.2. Maintenance

4.15.2.1. Lubricate Yaw Drive Gears

Interval: None

Note: The electric motor, the worm gear, and the planetary gear (pos. 14, Figure 4-56, 4-57, 4-58, 4-59) are lubricated for life. They require no service. Both gears are filled with Shell Tivela Compound A grease. In case of repair, use this lubricant.

Refer to Figure 4-55**,** 4-56, 4-57, 4-58, and 4-59

4.15.2.2. Check and Tighten Screws

Interval: Three months after commissioning

Refer to Figure 4-55**,** 4-56, 4-57, 4-58, and 4-59

Steps:

1. The gears are tightened to the nacelle bedplate with 12 pcs. Insex M10 x100 screws (qual. 10.9 or 12.9). Keyinsert 8 mm.

2. Tighten the screws using a torque wrench setting of 55 Nm (41 ft.-lbs.).
3. Note loose screws in inspection log.

4.15.2.3. Inspect Gears for Leakage

Interval: Following first three months of service, then every six months

Note: The gears are lubricated with Shell Tivela Compound A grease. The gears are lubricated for life and leaks are not acceptable. If the gear is leaking, the unit must be replaced.

Refer to Figure 4-55**, 4-56, 4-57, 4-58, and 4-59**

4.15.2.4. Listen for Noise

Interval: Following first three months of service, then every six months

Refer to Figure 4-55**, 4-56, 4-57, 4-58, and 4-59**

Steps:

1. Check the yaw gears/yaw motors for noise.

4.15.3. Troubleshooting

4.15.4. Spare Parts

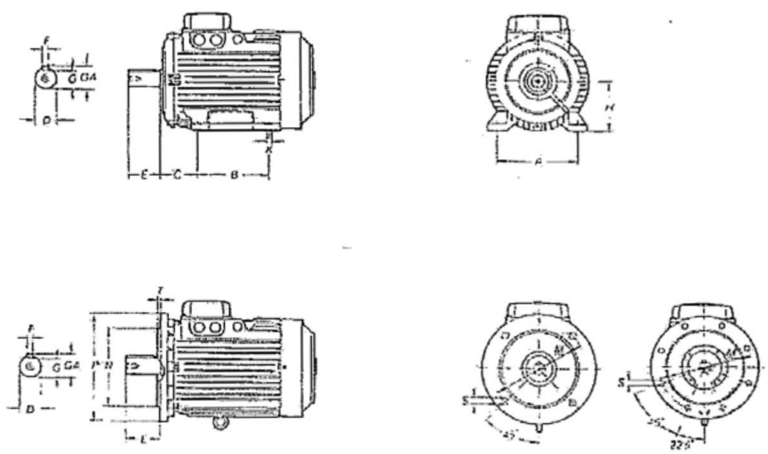
4.15.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Three-phase motors, dimension and power standards	
		Three-phase motors, dimension drawing	
		Three-phase motors, dimension drawing	
		Yaw drive planetary dimensions drawing	
		Yaw drive worm gear dimensions	

Three-phase motors
Dimension and power standards

CENELEC harmonisation document HD 231 (and Swedish Standard SS 426 04 02) lays down data for rated output and fixing dimensions for various degrees of protection and sizes. The position of the terminal box on the motor is also standardised. The centre of the terminal box must be within a sector from the topmost point of the motor down to 10° below the horizontal centre line of the motor. It must be on the right of the motor as seen from the D-end.

The standardised dimensions are shown in the illustrations below.



Size 56-225

Size 250-315

West European standardisation of sizes and rated output for four-pole totally-enclosed squirrel-cage motors for 50 Hz covers sizes 56 to 315 M with allocated rated output from 0.06 to 132 kW. The table on the right shows the relationship between shaft height and rated output for the motor sizes in question.

The meanings of the standardised letters that form part of the size designation for sizes 100 to 250 are: S = short, M = medium long, L = long version. National standards based on CENELEC may include motors with deviating rated output and shaft end dimensions.

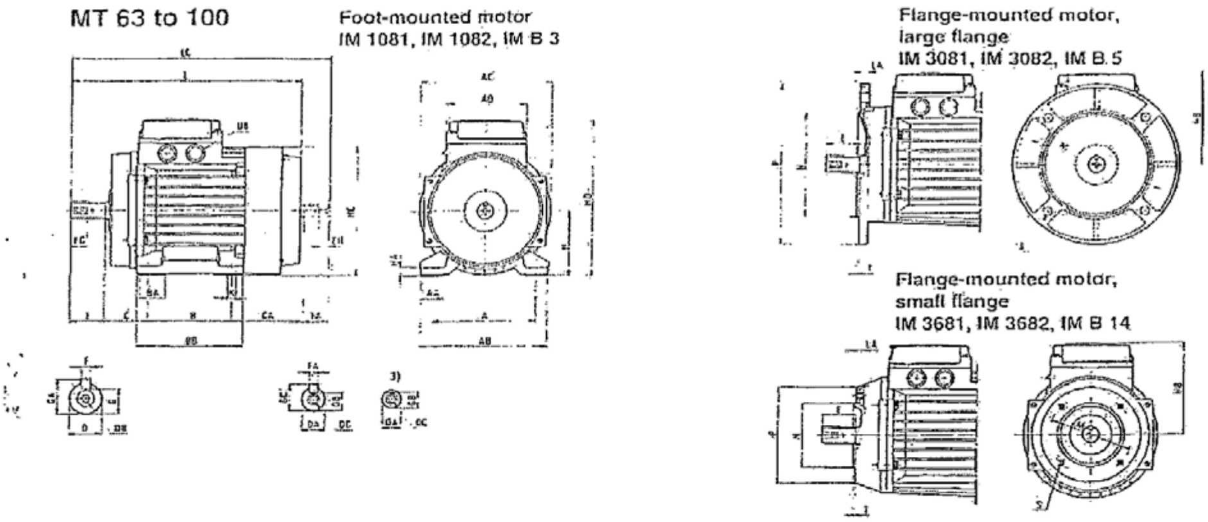
Shaft height mm	Rated output kW
63	0.12
63	0.18
71	0.25
71	0.37
80	0.55
80	0.75
90 S	1.1
90 L	1.5
100 L	2.2
100 L	3
112 M	4
132 S	5.5
132 M	7.5
160 M	11
160 L	15
180 M	18.5
180 L	22
200 L	30
225 S	37
225 M	45
250 M	55

Figure 4-55. Three-phase motors, dimension and power standards

Three-phase motors

Dimension drawings

MT 63 to 100



IM 1081, IM 1082, IM B 3

Type MT	A[1]	AA	AB	AC	AQ	B[1]	BA	BB	C[1]	CA	D[1]	DA[1]	DB	DC	E[2]	EA	EG	EH
63[2]	100	16	120	120	85	80	19	98	40	68	14	11	M5	M4	30	23	12.5	10
71	112	20	136	140	85	90	21	112	45	80	14	11	M5	M4	30	23	12.5	10
80	125	25	154	158	97	100	30	125	50	87	19	14	M8	M5	40	30	19	12.5
90 S	140	27	170	178	97	100	30	125	56	94	24	14	M8	M5	50	30	19	12.5
90 L	140	27	170	178	97	125	30	150	56	94	24	14	M8	M5	50	30	19	12.5
100 L	160	32	197	198	97	140	34	172	63	100	28	19	M10	M8	60	40	22	19

IM 1081, IM 1082, IM B 3

Type MT	F[1]	FA[1]	G	GA	GB	GC	H[1]	HA	HC	HD	K	L	LC	UB[4]
63[2]	5	-	11	16	9.5	-	63	7	123	150	7	213	241	Pr 18.6
71	5	-	11	16	9.5	-	71	9	141	172	7	240	268	Pr 22.5
80	6	5	15.5	21.5	11	16	80	10	159	192	10	272	307	Pr 22.5
90 S	8	5	20	27	11	16	90	10	179	212	10	295	330	Pr 22.5
90 L	8	5	20	27	11	16	90	10	179	212	10	320	355	Pr 22.5
100 L	8	6	24	31	15.5	21.5	100	12	199	236	12	358	403	Pr 22.5

IM 3081, IM 3082, IM B 5

Type MT	HB	LA	M	N	P	S	T
63[3]	88	9	130	110	160	10	3.5
71	102	9	130	110	160	10	3.5
80	112	10	165	130	200	12	3.5
90 S	122	10	165	130	200	12	3.5
90 L	122	10	165	130	200	12	3.5
100 L	136	11	215	180	250	15	4

M 3681, IM 3682, IM B 14

Type MT	HB	LA	M	N	P	S	T
63[2]	88	8	75	60	90	M5	2.5
71	102	10	85	70	105	M6	2.5
80	112	10	100	80	120	M6	3
90 S	122	14	115	95	140	M8	3
90 L	122	14	115	95	140	M8	3
100 L	136	16	130	110	160	M8	3.5

[1] Tolerances
A, B ISO js 14
D, DA ISO j6
F, FA ISO h9
H +0 -0.5
N ISO j6
C, CA ± 0.8

[2] MT 63 can be supplied with shaft extension D = 11, E = 23; F = 4 and GA = 12.5 mm, and without tapped hole DB.

[3] Alternative version of additional shaft extension for MT 63 and MT 71.

[4] Comparison of Pr and Pg
Pr 18.6 = Pg 11
Pr 22.5 = Pg 16

Figure 4-56. Three-phase motors dimension drawing

Single-speed motors

Output kW	Motor type		Cat. No.	Foot-mounted motor	Flange-mounted motor large flange	Flange-mounted motor small flange	Speed r/min	Efficiency %	Power factor cos φ	Current at 380 V A[2]	I_s/I	Torque M Nm	Torque M_s/M	Torque M_{max}/M	Moment of inertia J = ¼ GD² kgm²	Weight kg
6 poles = 1000 r/min																
0.12	MT	71	MK 110	024-•	064-•	104-•	930	55	0.6	0.55	2.5	1.2	2.1	2.4	0.0007	5
0.18		71 A		025-•	065-•	105-•	920	57	0.64	0.75	2.5	1.9	1.8	2.2	0.0007	5.5
0.25		71 B		026-•	066-•	106-•	920	62	0.68	0.9	3	2.6	1.8	2.2	0.0009	6.5
0.37		80 A		027-•	067-•	107-•	920	66	0.68	1.25	3.5	3.8	1.9	2.3	0.0017	8.5
0.55		80 B		028-•	068-•	108-•	920	67	0.7	1.75	3.5	5.7	1.9	2.3	0.0021	9.5
0.75		90 S		029-•	069-•	109-•	920	68	0.7	2.4	3.5	7.5	1.7	2	0.0032	12.5
1.1		90 L		030-•	070-•	110-•	920	70	0.7	3.4	3.5	11	1.7	2	0.0043	15.5
1.5		100 L		031-•	071-•	111-•	940	75	0.72	4.2	4	15	1.7	2.1	0.0082	23
2.2	MBT	112 M	MK 142	037-A •	037-B •	037-C •	930	81.5	0.77	5.6	5	22.6	1.9	2.5	0.012	31
3		132 S		038-A •	038-B •	038-C •	940	82.5	0.78	7.6	5.4	30.5	2	2.6	0.018	40
4		132 MA		039-A •	039-B •	039-C •	940	84	0.8	9	5.3	40.5	2.1	2.7	0.023	50
5.5[1]		132 MB		040-A •	040-B •	040-C •	920	82	0.8	12.7	4.7	57	1.9	2.6	0.025	52
7.5		160 M	MK 161	006-A •	006-B •		970	87	0.77	17	6.8	74	2	3	0.082	79
11		160 L		007-A •	007-B •		965	88	0.79	24	6.8	110	2	2.8	0.1	93
15		180 L	MK 171	012-A •	012-B •		970	88	0.81	32	6.5	148	2.3	3	0.22	145
18.5		200 LA		013-A •	013-B •		975	89	0.78	41	6.5	182	2.2	2.8	0.32	190
22		200 L		014-A •	014-B •		975	90.5	0.81	46	6.5	216	2.2	2.8	0.35	200
30		225 M		015-A •	015-B •		980	92	0.85	58	6.8	292	2	2.6	0.76	270
37		250 M		016-A •	016-B •		980	92.5	0.83	73	7	361	2	2.8	0.87	315
8 poles = 750 r/min																
0.055[3]	MT	63 B	MK 110	038-•	078-•	118-•	650	30	0.62	0.45	1.5	0.8	1.5	1.8	0.00028	4.5
0.09[3]		71 A		039-•	079-•	119-•	670	37	0.72	0.5	1.5	1.3	1.5	1.8	0.00073	5.5
0.12		71 B		040-•	080-•	154-•	670	42	0.72	0.6	2	1.7	1.5	1.8	0.00098	6.5
0.13		80 A		032-•	072-•	112-•	700	49	0.58	0.7	2.5	1.8	1.7	2.2	0.0017	8.5
0.18		80 B		033-•	073-•	113-•	700	52	0.58	0.9	2.5	2.5	1.8	2.3	0.0021	9.5
0.37		90 S		034-•	074-•	114-•	700	60	0.6	1.55	3	5	1.6	2.1	0.0031	12.5
0.55		90 L		035-•	075-•	115-•	700	64	0.62	2.1	3	7.5	1.6	2.1	0.0047	15.5
0.75		100 LA		036-•	076-•	116-•	700	71	0.62	2.6	3.5	10	1.8	2.4	0.0069	20
1.1		100 LB		037-•	077-•	117-•	700	72	0.64	3.6	3.5	15	1.8	2.4	0.0083	22.5
1.5	MBT	112 M	MK 142	041-A •	041-B •	041-C •	690	74	0.66	4.7	3.8	20.7	1.5	2.2	0.012	31
2.2		132 S		042-A •	042-B •	042-C •	700	75	0.66	6.6	3.9	30	1.6	2.3	0.018	40
3		132 M		043-A •	043-B •	043-C •	700	79	0.66	9	4.2	41	2	2.7	0.025	52
4		160 MA	MK 161	008-A •	008-B •		725	81.5	0.72	10.5	5.9	53	1.9	3	0.092	85
5.5		160 M		009-A •	009-B •		720	82	0.73	14.5	5.3	73	1.8	2.8	0.092	85
7.5		160 L		010-A •	010-B •		720	83.5	0.72	18.5	[illegible]	100	1.8	2.7	0.119	105
11		180 L	MK 171	017-A •	017-B •		715	85	0.76	26	5	147	1.4	1.9	0.21	145
15		200 L		018-A •	018-B •		725	86.5	0.79	33	6	200	1.8	2.5	0.31	185
18.5		225 S		019-A •	019-B •		730	90	0.74	43	[illegible]	242	2.1	2.3	0.76	270
22		225 M		020-A •	020-B •		725	90	0.81	46	5.2	292	1.7	1.9	0.76	275
30		250 M		021-A •	021-B •		730	90	0.78	66	[illegible]	392	2.2	2.5	0.87	315
12 poles = 500 r/min																
0.075	MT	80 A	MK 110	354-•	360-•	366-•	450	38	0.5	0.6	2	1.6	1.5	1.9	0.0017	8.5
0.11		80 B		355-•	361-•	367-•	450	40	0.5	0.85	2	2.3	1.5	1.9	0.0021	9.5
0.12		90 S		356-•	362-•	368-•	460	37	0.5	1	2	2.5	1.6	2	0.0032	12.5
0.18		90 L		357-•	363-•	369-•	460	42	0.47	1.4	2	3.8	1.6	2	0.0043	15.5
0.25		100 LA		358-•	364-•	370-•	470	43	0.47	1.9	2	4.7	1.6	2.1	0.0069	20
0.37		100 LB		359-•	365-•	371-•	470	50	0.47	2.4	2	7.2	1.6	2.1	0.0082	22.5

[1] Temperature rise: Class F
[2] Rated data according to codes S and D. See p. 32
[3] Rated voltage: 500 V, maximum

Recalculation factors

Recalculation factors for voltage ratings other than 380 V, 50 Hz

Rated voltage	Factor	Motor wound for	Code letter
220 VΔ 50 Hz	1.73	380-420 VY 50 Hz	S
415 VΔ 50 Hz	0.92	415 VΔ 50 Hz	H
415 V 50 Hz	·	380-420 V 50 Hz Complete data shown on p. 30 to 31.	S or D
500 VY 50 Hz	0.76	500 VY 50 Hz	E
500 VΔ 50 Hz	0.76	500 VΔ 50 Hz	E
660 VY 50 Hz	0.58	660 VY 50 Hz	D

ABB Motors 29

Figure 4-57. Three-phase motors dimension drawing

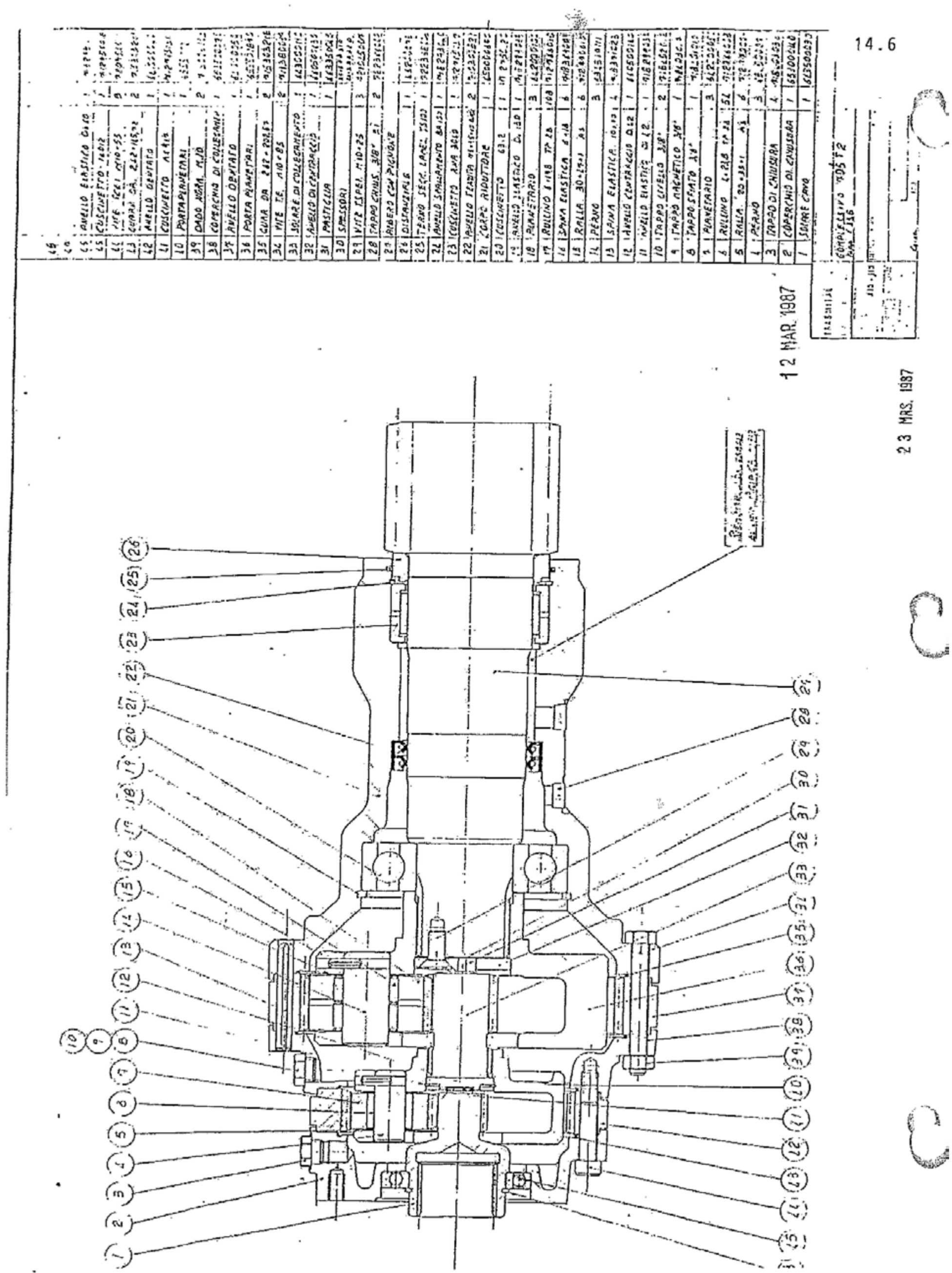


Figure 4-58. Yaw drive planetary dimensions drawing

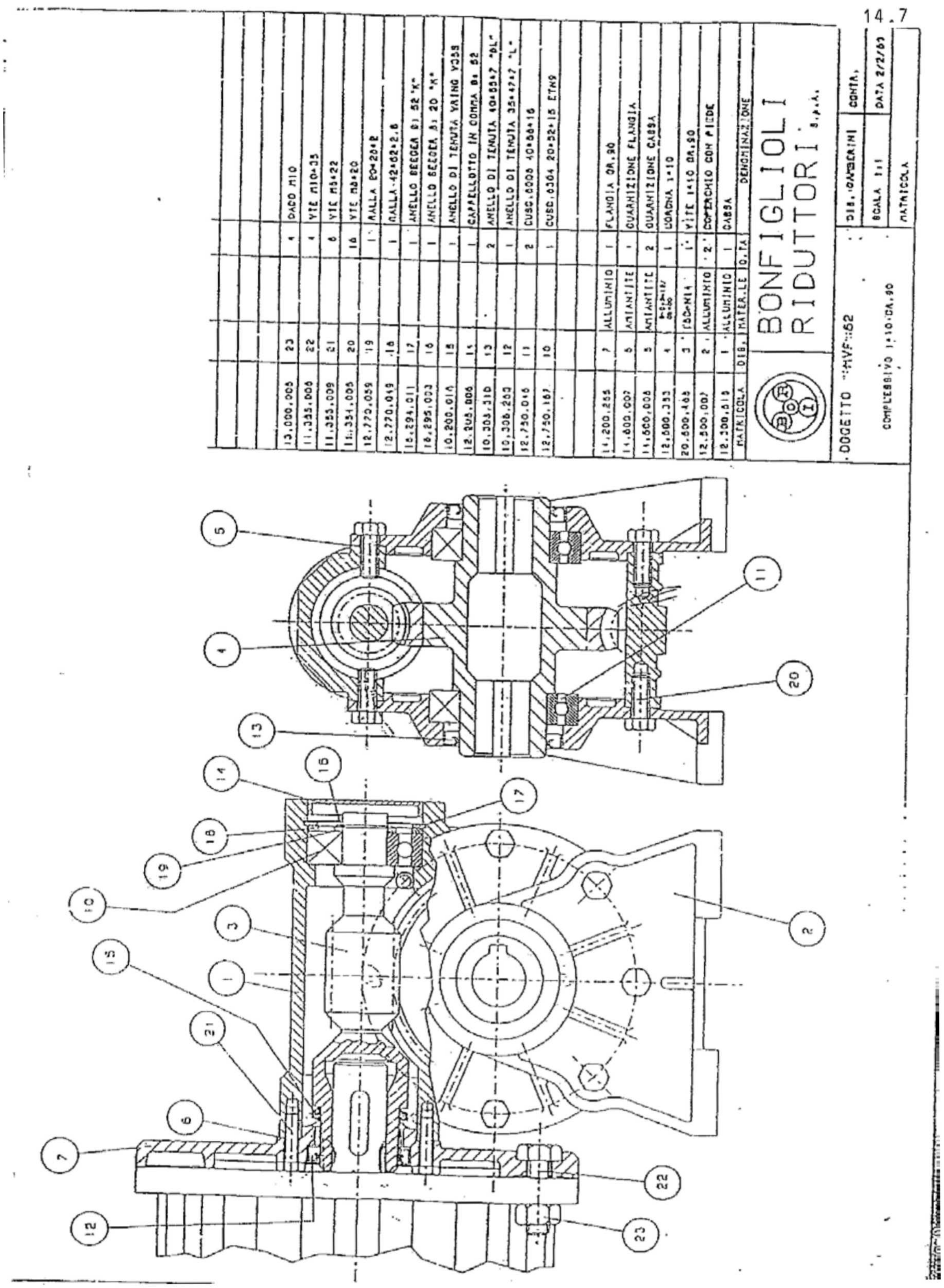


Figure 4-59. Yaw drive worm gear dimensions

4.16. Yaw Bearing System

Each SWiFT wind turbine's nacelle is mounted on a yaw ring that rotates 360°. The yaw ring is a sliding bearing between the nacelle and the tower. Gears on the yaw ring mesh with two electric motors that control yaw direction. An automatic yaw system keeps the turbine blade-rotor assembly facing into the wind in the Run and Pause operating states and untwists the tower cables when needed.

4.16.1. Specifications

Bearing types:	Axial, radial, and yawfinger
Lining material:	All types PETP
Yaw finger spring:	Disc spring Ø34 x Ø12.3 x 1.25
Spring columns:	5 in each foot
Spring mounting:	
Welded yawtop:	
Number of springs:	100 pcs., 5 in each column
Spring force:	2000 N/column, 400 kN total
Casted yaw top:	
Number of springs:	120 pcs., 6 in each column
Spring force:	4000 N/column, 80 kN total
Lubrication:	2 Autolube PERMA 6 dispensers
Lubricant:	OPTIMOL OPTIPIT

4.16.2. Maintenance

4.16.2.1. Lubricate Yaw Bearing System

Interval: Six months

Note: Replace only the most empty of the two Autolube PERMA 6 dispensers during each service.

Refer to Figure 4-61

Steps:

1. Press Emergency Stop.
2. Unscrew and remove the most empty of the two Autolube PERMA 6 dispensers.
3. Take the new Autolube dispenser containing OPTIMOL OPTIPIT grease. Replace the cap and disconnect the bottom plug.
4. Screw the dispenser into the fitting.
5. Check that the other Autolube dispenser is working.
6. Check that both dispensers are placed approximately 10 mm within the inner edge of the yaw top.
7. Add a thin layer of grease on the radial block and the yaw finger slide faces.

8. Note the date and dispenser replaced in the inspection log.

4.16.2.2. Lubricate Yaw Gear

Interval: Six months

Refer to Figure 4-63

Steps:

1. Press Emergency Stop.
2. Remove old grease with a stiff brush.
3. Add a thin layer of grease on the gear teeth (pos. 15.1,Figure 4-63). Use approximately 100 g of OPTIMOL OPTIPIT grease.

4.16.2.3. Check Bolt Torque

Interval: Three months after commissioning, then yearly

Note: Following the first three months of service, check only the three yaw gears in the middle row on the right forward yaw foot.

Warning! Do not tighten the adjustment bolts in the yaw finger (pos. 1, 3).

Refer to Figure 4-63

Steps:

1. Press Emergency Stop.
2. At the first three months service, tighten all five fastening bolts (pos. 23,Figure 4-63) in each yaw finger using a torque wrench setting of 551 Nm (406 ft.-lbs.).
3. During subsequent yearly inspections, check the three bolts (pos. 23,Figure 4-63) in the middle row on the right front yaw foot. If they do not move when they are torqued with 551 Nm (406 ft.-lbs.), the remaining bolts do not need to be tightened.
4. Check that all bolts are in place and tightened.

4.16.2.4. Radial Adjustment of Bearing System

Interval: Every two years

Refer to Figure 4-63

Note: The bearing system must be adjusted to compensate for wear on the bearing lining. Because the radial bearings (pos. 14,Figure 4-63) also determine the mesh of the yaw gear, the adjustment of the radial bearings must be performed in connection with the gear adjustment.

Note: The gears must have a proper mesh so that excessive load or wear on the gear teeth can be avoided. Too much gear clearance increases the impact on the teeth when the turbine yaws in high turbulent wind. Too little clearance can cause internal loads in the system.

Refer to Figure 4-63

Steps:

1. Press Emergency Stop.
2. Yaw the turbine 180° from prevailing wind direction. The gears must be tightly meshed.
3. Check that the radial clearance on the two rear radial linings (pos. 14, Figure 4-63) are zero. If they have clearance, yaw the turbine and check again.
4. Measure the clearance on the two front linings (pos. 14, Figure 4-63). If the clearance is greater than 1 mm play each, adjust as described in Steps 5-11. If the clearance is less than 1 mm, continue with the adjustment of the yaw fingers.
5. Disconnect the fan covers on the electrical yaw motors.
6. Loosen the radial adjustment bolts (pos. 18, Figure 4-63) three turns on the two front yaw feet.
7. Tighten the radial adjustment bolts synchronized on the two rear yaw feet while simultaneously turning the fans on the motors (so that the motor can turn freely to both sides). The nacelle will move forward until the gear clearance is zero.
8. Loosen the adjustment bolts so they are neither tight nor loose.
9. Adjust the two front radial bearings so that the lining has no clearance and the bolts begin pressing on the lining.
10. Loosen the adjustment bolts on the two rear yaw feet ½ turn (180 degrees counter clockwise) and jamnut (pos. 19,Figure 4-63) without the bolts rotating.
11. Tighten the adjustment bolts on the two front yaw feet 1/3 turn clockwise (120 degrees, or 2 bolt head corners) and snug the jamnut.
12. Remount the fan covers.
13. Let the turbine yaw a full turn clockwise. Have someone supervise the yaw system, listening and watching for sounds and irregular movements that could indicate that there are bindings in the system.
14. If there are irregularities, find the error and eliminate it by adjusting as described in Steps 5-11.

Note: A possible error is that the tower top is oblique and is pulling the yaw top oblique. The problem can be solved by loosening the bolts that hold the tower top to the yaw plate and mounting shims in the space between them.

4.16.2.5. Axial Adjustment of Bearing System

Interval: Yearly

Refer to Figure 4-61**,** Figure 4-62and 4-63

Steps:

1. Press Emergency Stop.
2. Measure the thickness of the upper lining (pos. 7,Figure 4-63). The thickness is 15.0 mm when new. If the lining is less than 13 mm or the difference between the thickest and thinnest section of the lining is more than 1 mm, replace the lining.
3. To replace the axial lining, loosen all five fastening bolts (pos. 23,Figure 4-63) on the yaw foot.
4. Remove the following parts as a unit (pos. 1-5, Figure 4-62, and pos. 14-21,Figure 4-63).
5. Lift the nacelle with the two bolts (pos. 24,Figure 4-61).
6. Place a plate between the bolt head and the yaw ring (pos. 6,Figure 4-61) and turn the bolts until the lining can be moved.
7. Replace the lining. Use two bushings (pos. 15,Figure 4-63) and two bolts (pos. 23,Figure 4-63) to hold it in position while the nacelle is being lowered.
8. Tighten the bolts (pos. 24,Figure 4-61) using a torque wrench setting of 250 Nm.
9. Replace the multi-part unit removed in Step 4. Be sure that the yaw finger pad (pos. 4,Figure 4-62) and disc springs (pos. 3,Figure 4-62) are well positioned before tightening the fastening bolts.

4.16.2.6. Adjust Yaw Finger

Interval: Every two years

Note: The yaw finger pads (pos. 5, Figure 4-62) are spring loaded. There are spring washers on each of the five adjustment bolts. The spring package (pos. 3, Figure 4-62) is correctly adjusted when the springs have 0.5 mm compression left from being fully compressed.

Refer to Figure 4-62

Steps:

1. Press Emergency Stop.
2. Loosen the counter nut (pos. 2, Figure 4-62
3. Turn bolt (pos. 1, Figure 4-62) clockwise until spring feels solid (do not force it).
4. If the point at which the spring becomes fully compressed is impossible to detect or the bolt turns with difficulty, move the bolts until they turn easily and full compression is detected.
5. Normally the full compression point is reached after approximately 90 degrees of turning. From this point, loosen the bolts by approximately 60 degrees counterclockwise (1/6 of a turn). Tighten counter nut without the bolt rotating.
6. Let the turbine yaw a full turn counterclockwise.
7. Listen for sounds that indicate that the system is too tight. In such cases, the system will vibrate. Adjust the system again until the turbine yaws smoothly.

4.16.2.7. Inspect Gear Teeth for Damage

Interval: Yearly

Steps:

1. Press Emergency Stop.
2. Inspect the gear on the yaw top and yaw driver pinions.
3. If excessive wear is found, report it to Vestas.

4.16.3. Troubleshooting

4.16.4. Spare Parts

SPARE PARTS LIST 921564 – YAW SYSTEM V25/V27/V29				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	20	834981	Adjustment bolt, V25/V27	
2	20	157619	Lock nut, M20 DIN 439	
3	120	107797	Disc spring, Ø34 x Ø12.3 x 1.25	
4	20	155970	Washer, Ø40 x Ø13 x 3, DIN 9021	
5	4	085464	Sliding shoe, V25/V27, PETP	
6	1	831005	Yaw top, V27, GGG 50	
7	4	085340	Sliding block, V25/V27, PETP	
8	1	833128	Nacelle bedplate, front bear.	
9	2	835010	Tube for Autolube	
10	2	835030	Holder for Autolube	
11	2	156455	Washer, M12 FZV 125A	
12	2	152496	Bolt, M12 x 30 8.8 FZV	
13	2	149040	Autolube, PERMA 6	
14	4	085367	Radial block, V25/V27, PETP	
15	12	834157	Bushing f. radial block	
16	12	831310	Washer, Ø60 V25/27	
17	4	833754	Clamp, f. radial block	
18	12	154156	Steel bolt, M16 x 60 8.8 FZV	
19	12	157996	Jamnut, M16 DIN 439	
20	4	833762	Stay for radial block	
21	4	833771	Yaw finger	
22	20	155802	Washer, M24 FZV DIN 125A	
23	20	152145	Bolt M12 x 140 8.8 FZV	
24	8	834980	Bolt for clamp to sliding block	
25	8	833790	Clamp to sliding block	
26	8	156695	Washer, M20 FZV DIN 125A	

4.16.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Yaw bearing system, 1 of 4	

		Yaw bearing system, 2 of 4	
		Yaw bearing system, 3 of 4	
		Yaw bearing system, 4 of 4	

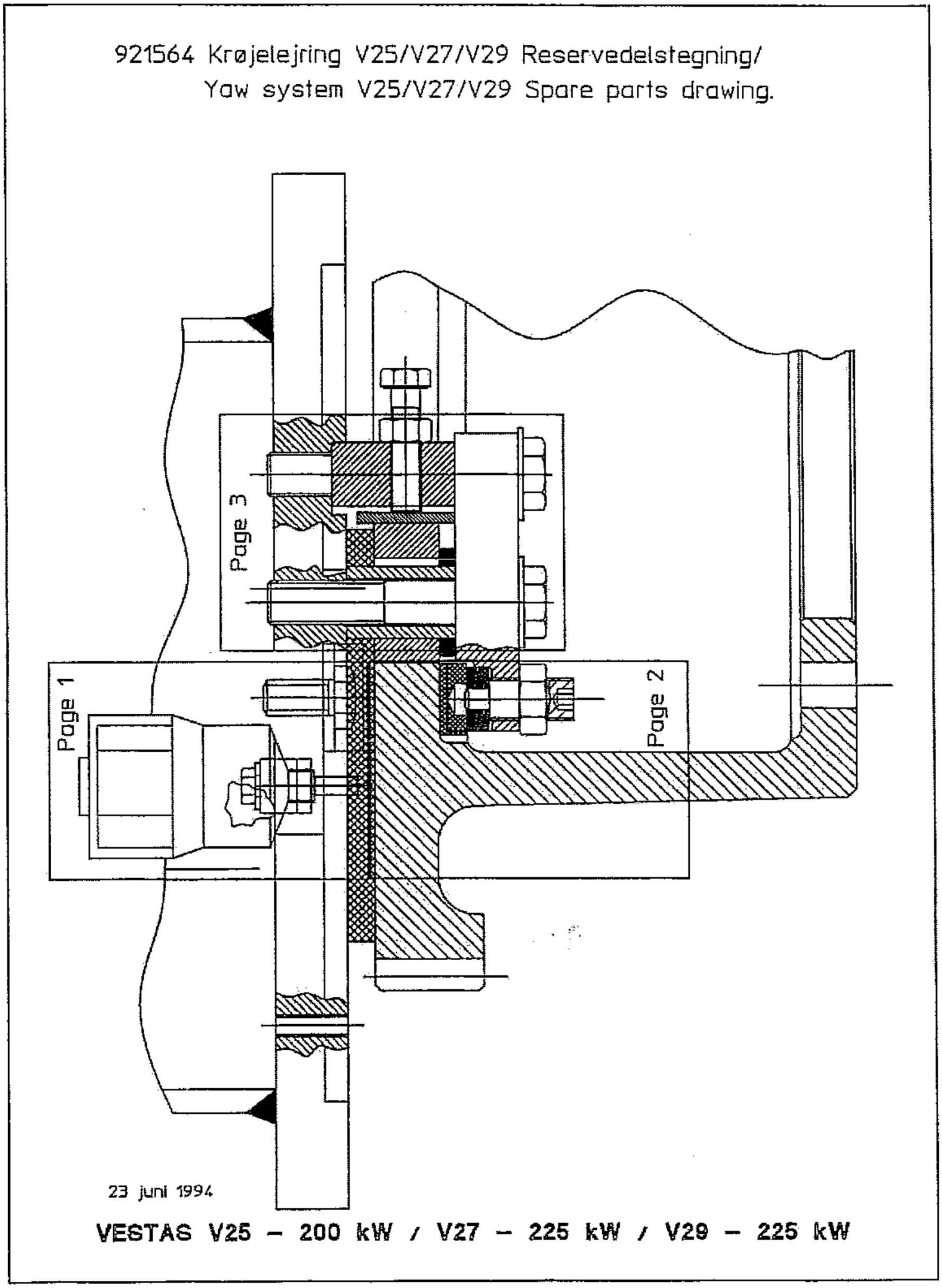


Figure 4-60. Spare parts drawing, yaw bearing system

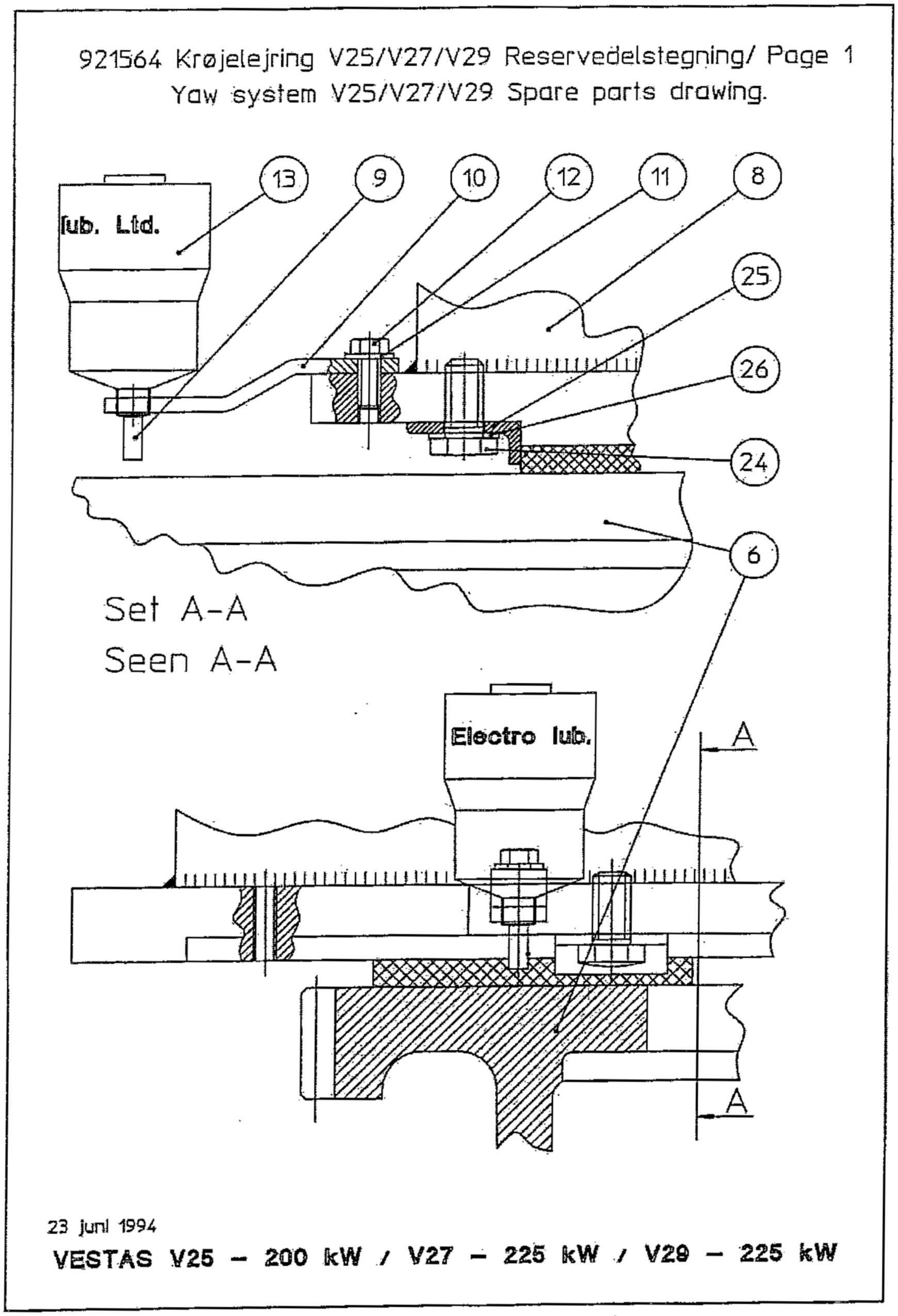


Figure 4-61. Spare parts drawing, yaw bearing system

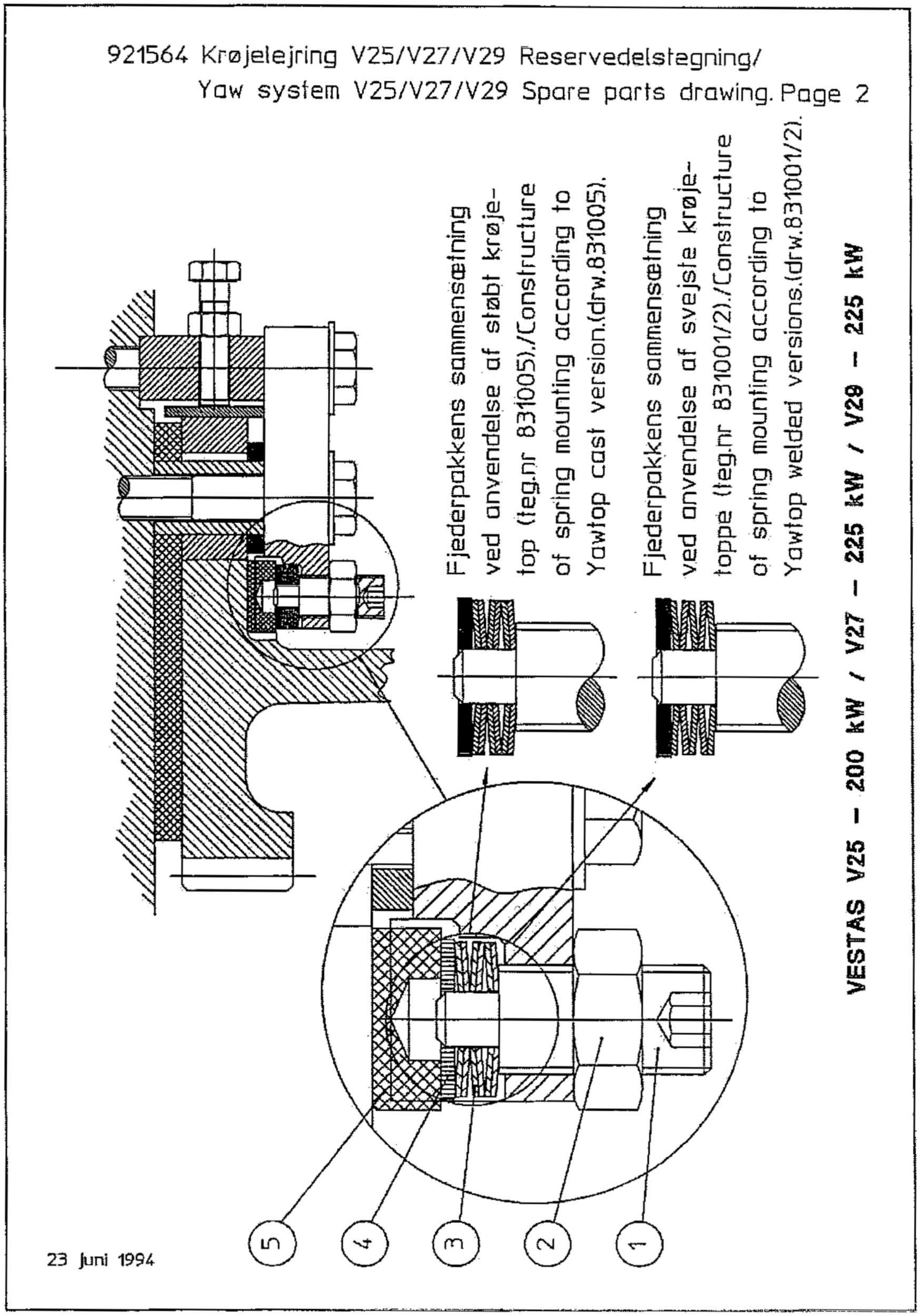


Figure 4-62. Spare parts drawing, yaw bearing system

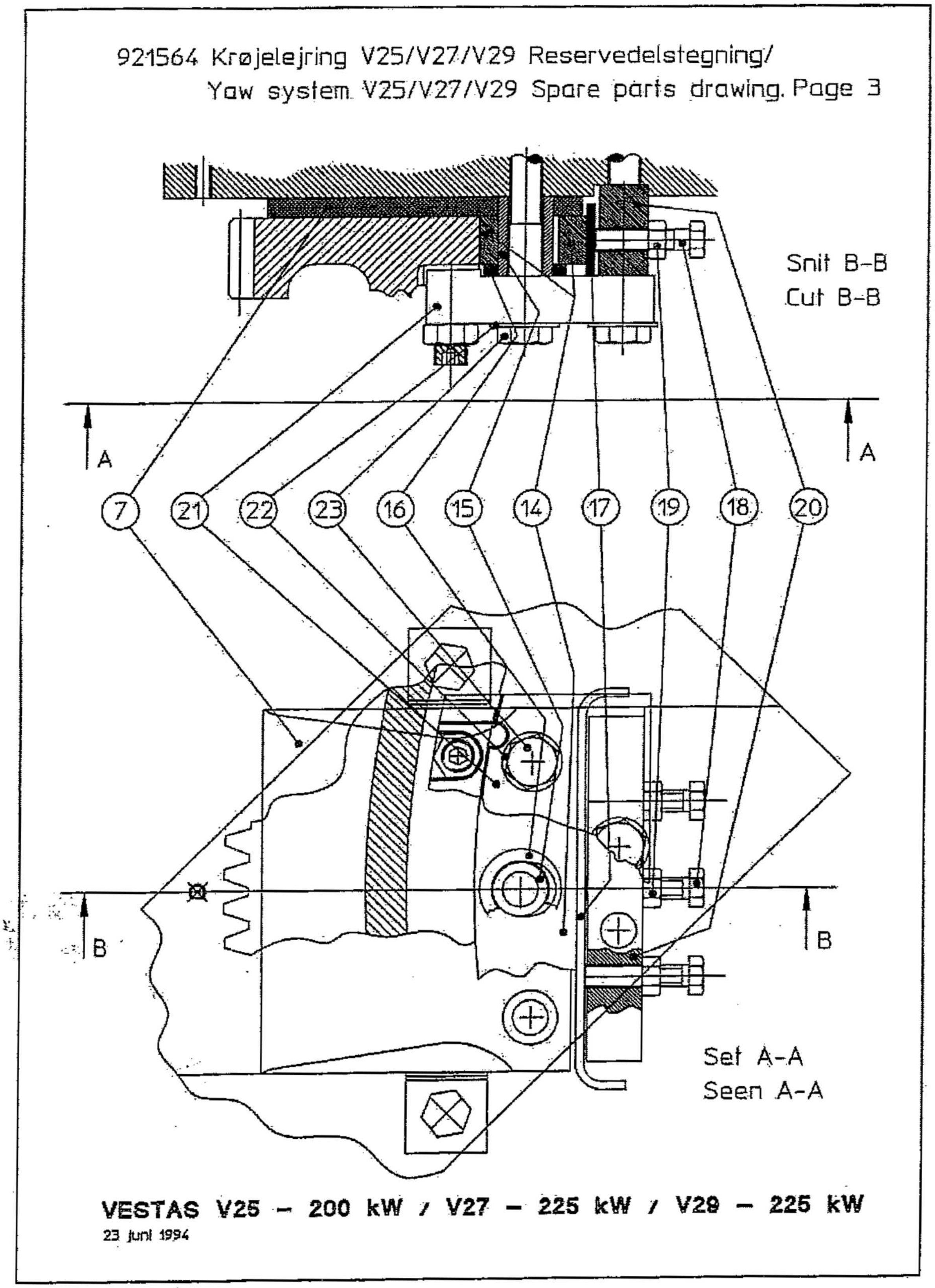


Figure 4-63. Spare parts drawing, yaw bearing system

4.17. Nacelle Bedplate

Two-sectioned framed construction that supports all the components of the nacelle.

4.17.1. Specifications

Manufacturer:	Vestas
Main girder (front):	
Type:	RHS-profile
Dimension:	300 x 200 x 10 mm
Length:	2000 mm
Main girder (rear):	
Type:	RHS-profile
Dimension:	200 x 200 x 10 mm
Length:	2000 mm
Maximum length:	4100 mm
Maximum width:	1700 mm
Weight:	1650 kg

4.17.2. Maintenance

4.17.2.1. Check Bolt Torque

Interval: Yearly

Note: Bolts connecting front and rear frame need not be tightened during ordinary inspections, but only in connection with an annual torque inspection.

Refer to Figure 4-64

Steps:

1. Tighten two of the bolts in the assembly, if they can be tightened, using a torque wrench setting of 325 Nm (240 ft.-lbs.).
2. If any of the bolts can be tightened, all bolts in the assembly should be tightened.
3. Visually inspect remaining bolts.
4. Note loose bolts in the inspection log.

4.17.2.2. Inspect Welds

Interval: Five years

Steps:

1. Clean the welds with a cleaning solvent for maximum visibility.

2. Check the welds
   2a. Where the RHS-profiles and the plates are connected on the front and rear frame.
   2b. At the front and rear yaw plate console.
   2c. On the profiled bottom plate.
   2d. On the yaw gear console.
   2e. On the plates for the gear mounting.
3. If any cracks are found, examine each carefully and report them to Vestas.

4.17.2.3. Check Hot Dip Galvanizing

Interval: Five years

Steps:

1. Check the nacelle bedplate for rust and damage to the zinc layer.
2. Repair damaged areas as described in Section 4.21.

4.17.3. Troubleshooting

4.17.4. Spare Parts

4.17.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Nacelle bedplate	

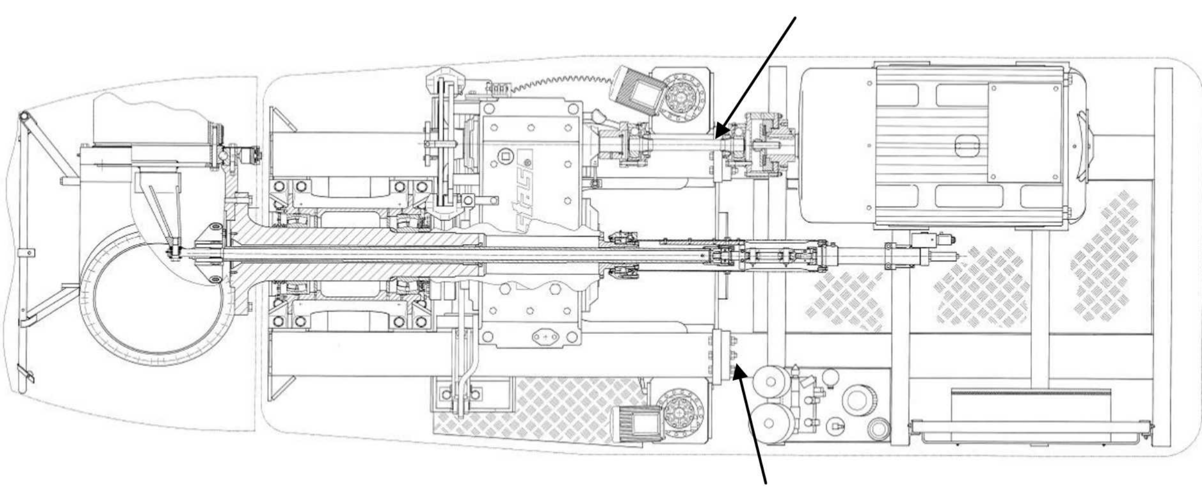


Figure 4-64. Nacelle bedplate

4.18. Control Sensors

Sandia SWiFT wind turbines have been modified with a number of sensors distributed throughout the system for gathering research data. These sensors have been added to the system to add high resolution, time-synchronized data to meet the rigors of research work. The sensors log data synchronously with turbine control data, allowing detailed inspection and analysis. The system is designed so research sensors can be easily added for future research hardware configurations.

4.18.1. Specifications

Turbine Control Wind Sensor:
  Manufacturer: FT Technologies
  Complete unit: Part no. FT702LT

4.18.2. Maintenance

Steps:

1. Check that the sonic is vertical. If not, loosen the fittings around the tube clamp, adjust the sonic to vertical, and retighten the fittings.

4.18.3. Troubleshooting

4.18.4. Spare Parts

4.18.5. Drawings

Drawing #	Version # (date)	Description	Filename
		FT Sonic	

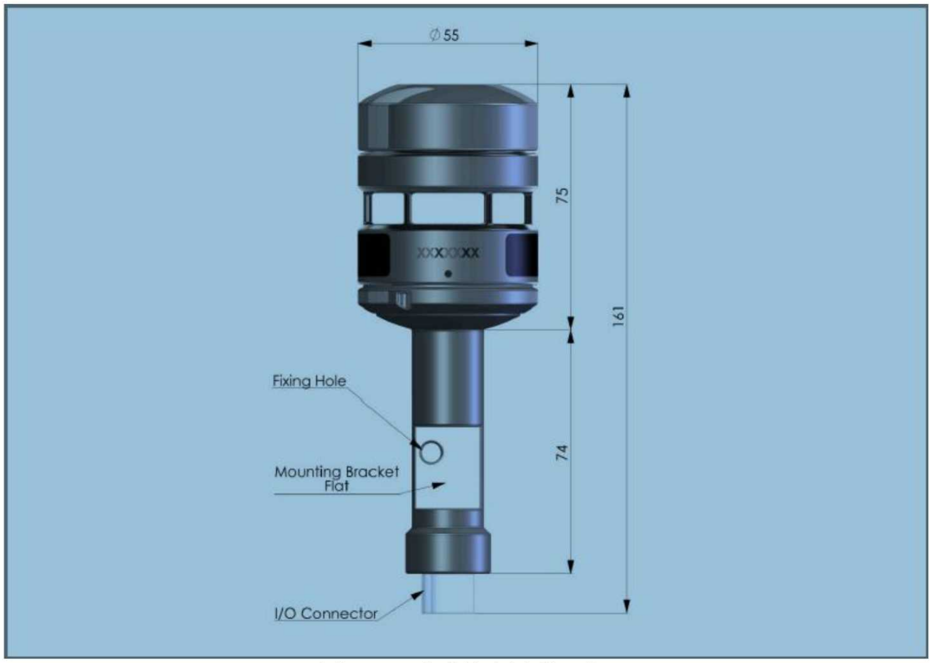


Figure 4-65. FT Sonic

4.19. Nacelle Cover

Fiberglass housing that protects all the components of the nacelle.

4.19.1. Specifications

4.19.2. Maintenance

4.19.2.1. Inspect Nacelle Cover

Interval: Three months after commissioning, then every two years

Refer to Figure 4-66 and 4-67

Steps:

1. Inspect the seam between the lower and upper parts of the nacelle cover. Check for missing or loose bolts and damage to the fiberglass.
2. Inspect the support plates under the seam, in front of the nacelle, and on the rear nacelle.
3. Check that the four bushings between the cover bottom and yaw feet are tight.
4. Check that the skylight hinges are positioned correctly and are functional.
5. Check the roof door hinges. Lubricate with Molycote grease.
6. Check that the sound absorption is positioned correctly in the sound sluices and that the air passage is clear from obstruction.
7. Check that the air inlets in front of the nacelle and drain are clear of obstruction.

4.19.3. Troubleshooting

4.19.4. Spare Parts

SPARE PARTS LIST XXX – NACELLE COVER FIBERGLASS PARTS				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	1	833572	Roof door left, machinery cover	
2	1	833573	Roof door right, machinery cover	
3	1	831940	Outside shield for V27 oil cooler	
4	(1)	831930	Extension piece for nacelle cover	
5	1	833569	Rear door, nacelle cover, V27	
6	2	114102	Hinge, stainless	
7	2	114189	Snap lock	
8	2	114170	Lock grip	
9	2	830980	Sound absorber	

SPARE PARTS LIST XXX – NACELLE COVER METAL PARTS				
POS	**PCS**	**Item No.**	**Description**	**Notes**
1	1	831620	Torsions tube, right welded	
2	1	831638	Torsions tube, left welded	
3	8	831530	Bracket for nacelle cover	
4	1	831492	Opening mechanism welded	

5	1	831557	Adjustment bracket	
6	1	831603	Thread rod welded V25	
7	1	831611	Tube for rigging screw, welded	
8	1	831549	Handwheel for opening	
9	1	831590	Thread rod, left th. welded V25	
10	2	833932	Joint link for opening	

4.19.5. Drawings

Drawing #	Version # (date)	Description	Filename
		Nacelle cover, fiberglass parts	
		Nacelle cover, metal parts	

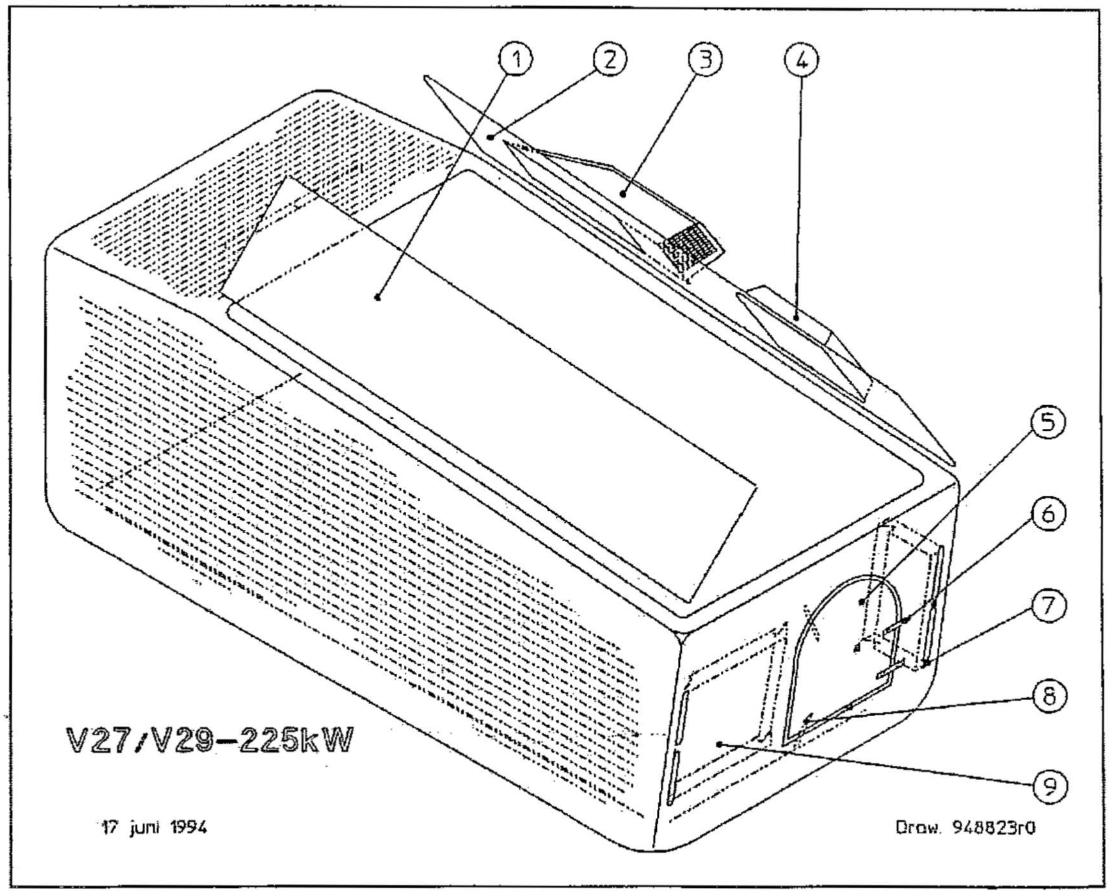


Figure 4-66. Nacelle cover, fiberglass parts

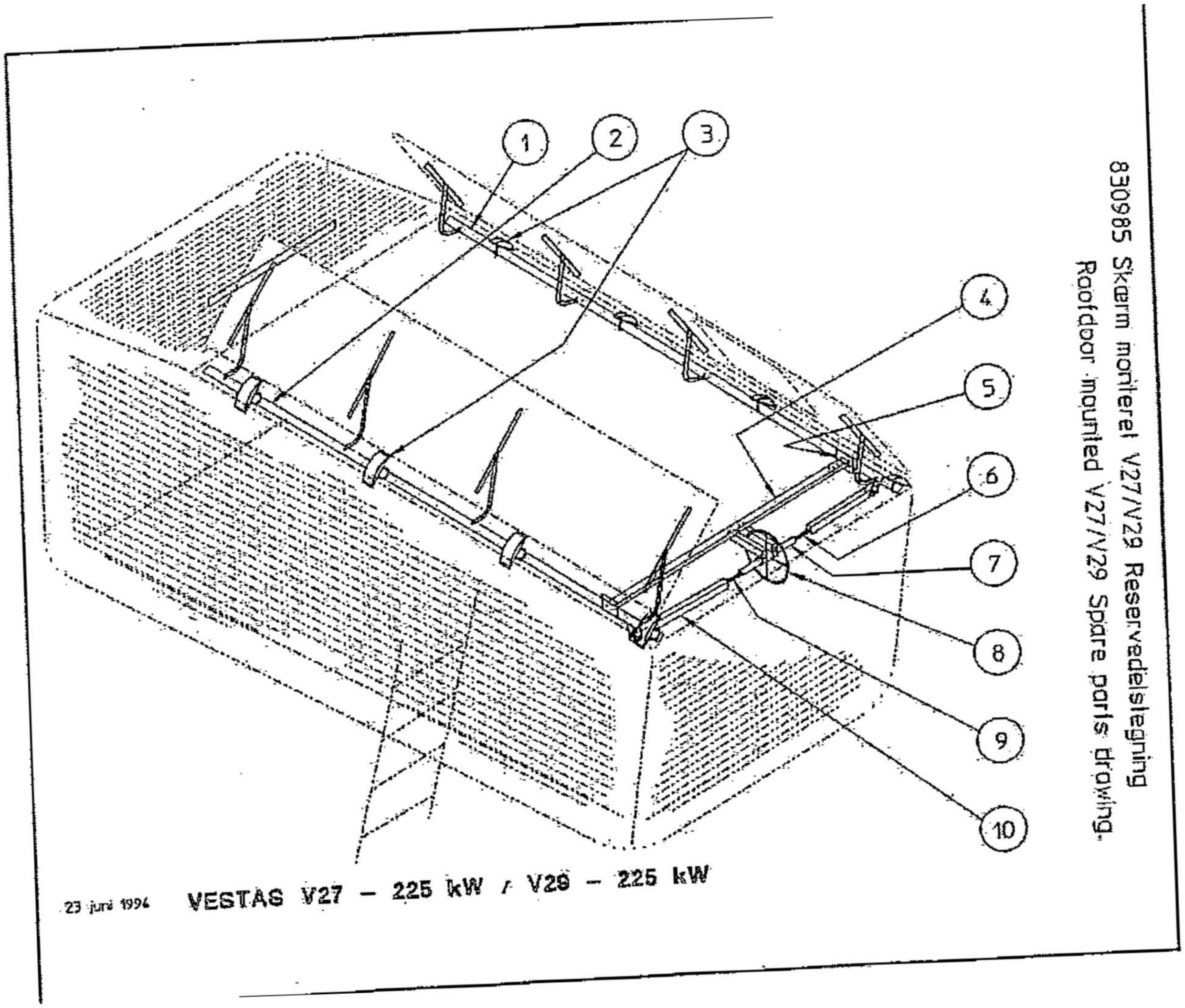


Figure 4-67. Nacelle cover, metal parts

4.20. Tubular Tower

Tower section that connects the ground foundation to the nacelle. It supports the weight of the nacelle.

4.20.1. Specifications

Manufacturer:
  Tubular tower: E. Roug, Valund (delivered from Vestas)
Drawings: See enclosure 941272

4.20.2. Maintenance

4.20.2.2. Tubular Tower – Spot Check Bolts

Interval: Three months after commissioning, then check visually every two years

Steps:

1. Spot check bolts in connection between flanges, paying attention to bolt quality.
2. Tighten bolts using torque wrench settings as follows: 657 Nm (484 ft.-lbs.) for quality 8.8 bolts and 800 Nm (590 ft.-lbs.) for quality 10.9 HV-bolts (DIN 6914 bolts, DIN 6915 nuts, and DIN 6916 washers).
3. Spot check bolts to ladders and other mountings. Tighten if needed.

4.20.2.3. Inspect Weld Quality

Interval: Two years

Steps:

1. Inspect welds around the door.

4.20.2.4. Check Platform Bolts and Nacelle Ladder Bolts

Interval: Two years

Steps:

1. Inspect and tighten bolts on all platforms.
2. Inspect and tighten bolts on the nacelle ladder.

4.20.3. Troubleshooting

4.20.4. Spare Parts

4.20.5. Drawings

Drawing #	Version # (date)	Description	Filename

4.21. Cabling

Six cables hang from a high voltage terminal connection box mounted to the generator to the bottom of the tower, where they connect to the variable frequency drive at the high voltage bus bar. Because the generator is mounted inside the nacelle, the cables twist as the nacelle yaws.

Cables also connect to the grounding system that is installed around the turbine.

4.21.1. Specifications

Cables are 4 conductor flexible red copper conductors with special PVC compound jacket. Nominal UL voltage rating is 1000 volts.

4.21.2. Maintenance

4.21.2.1. Visually Inspect Cable Connections

Interval: Six months after commissioning, then yearly

Steps:

1. Visually inspect cable strips.
2. Visually inspect cable connections to generator.
3. Visually inspect grounding system cable connections.

4.21.2.2. Tighten Cables

Interval: Six months after commissioning, then every five years

Steps:

1. Tighten cable connections to generator.
2. Tighten grounding system cable connections.

4.21.3. Troubleshooting

4.21.4. Spare Parts

4.21.5. Drawings

Drawing #	Version # (date)	Description	Filename

4.22. Surface Treatment

Surface treatment to protect the painted and metal surfaces of the turbine.

4.22.1. Specifications

Tectyl 511 M	
Type:	Thin, oil-wax based, moisture displacement treatment
Use:	Use on items that cannot be cleaned completely
Drying time:	1 hour at 25°C
Tectyl 127 CGW	
Type:	Thick wax-based, aluminum-colored, paint-like product
Use:	Use as paint on clean, dry items
Drying time:	24 hours at 25°C
Tectyl 175 GW	
Type:	Thick wax-based, colored, paint-like product
Use:	Use as paint on clean, dry items
Drying time:	24 hours at 25°C
Tectyl 506	
Type:	Semi-thick wax-based brown product
Use:	Use for corrosion protection on clean, dry items
Drying time:	1 hour at 25°C
Tectyl 151 A	
Type:	Clear, thin product
Use:	Paint over Tectyl 127 CGW and Tectyl 175 GW to protect against contamination. Use only in thin layers.
Drying time:	15 minutes at 25°C
Alternative surface product:	Chesterton Heavy Duty Rust Guard
Type:	Semi-thick, petroleum-based brown product
Use:	Spray or paint onto clean, dry items
Drying time:	12 hours at 25°C (including between coats)

4.22.2. Maintenance

General instructions for using Tectyl surface products:

1. Use when air temperature will remain between 10-35 degrees C during application and drying.
2. Items to be resurfaced must be clean and dry. If there are cracks in which moisture can collect, use a compressed air blower to dry the surface.
3. Tectyl products must not be diluted or blended.
4. Tectyl products must be stirred thoroughly before use.
5. Tectyl products should be stored in closed tanks.
6. Strictly follow recommended drying times between treatments.
7. Remove with rubbing alcohol.

8. Apply as a paint or a spray.

4.22.2.1. Surface Treat Metalized & Painted Items

Interval: Three months after commissioning, then every two years

Note: Apply Tectyl products in ambient temperatures of at least 10°C and only in dry weather.

Steps:

1. Inspect existing surface treatment and note any damage.
2. Remove damaged metallization and loose paint with a steel brush.
3. Clean area to be resurfaced with rubbing alcohol and allow to dry.
4. Prime area to be treated with Tectyl 506. Apply until the surface is saturated.
5. Apply 2-3 layers of Tectyl 127 CGW to metallized items and Tectyl 175 GW to painted items.
6. If it is not possible to thoroughly clean and protect a surface because of temperature or moisture conditions, protect the damaged areas with Tectyl 511 M to prevent rust from spreading until a thorough treatment can take place.

4.22.2.2. Surface Treat Slewing Rings & Tectyl-Treated Parts

Interval: Three months after commissioning, then every two years

Note: Apply Tectyl products in ambient temperatures of at least 10°C and only in dry weather.

Steps:

1. Inspect existing surface treatment and note any damage.
2. Remove damaged metallization and loose paint with a steel brush.
3. Clean area to be resurfaced with rubbing alcohol and allow to dry.
4. Prime area to be treated with Tectyl 506. Apply until the surface is saturated. If there are significant rust spots, prime them with Tectyl 511 M until the rust is saturated.
5. Apply 2-3 layers of Tectyl 175 GW or Tectyl 127 CGW.

4.22.2.3. Surface Treat Bolt Heads, Nuts, & Washers

Interval: Three months after commissioning, then every two years

Note: Apply Tectyl products in ambient temperatures of at least 10°C and only in dry weather.

Steps:

1. Brush bolt heads, nuts, and washers with a steel brush. If they have previously been treated with Tectyl that has rust under it, all Tectyl product should be removed by brushing and scraping prior to further treatment.

2. Clean area to be resurfaced with rubbing alcohol and allow to dry.
3. Prime area to be treated with Tectyl 506. The Tectyl must be "worked in" between bolt or nut and washer or between the washer and the item.
4. Apply 2-3 layers of Tectyl 127 CGW.
5. If it is not possible to thoroughly clean and protect a surface because of temperature or moisture conditions, protect the damaged areas with Tectyl 511 M to prevent rust from spreading until a thorough treatment can take place.

4.22.2.4. Surface Treat Transmission Shaft

Interval: Three months after commissioning, then every two years

Note: Apply Tectyl products in ambient temperatures of at least 10°C and only in dry weather.

Steps:

1. Clean the links with a steel brush.
2. Prime with Tectyl 506.
3. Clean the shaft with a steel brush and scraper. Prior to further treatment, carefully inspect the shaft for corrosion.
4. Prime the shaft with Tectyl 506.
5. Apply 2-3 layers of Tectyl 175 GW or Tectyl 506.
6. Because of the need to keep the shaft balanced, the surface treatment must be of uniform thickness.

4.22.2.5. Surface Treat Fittings & Hydraulic Pipes

Interval: Three months after commissioning, then every two years

Note: Apply Tectyl products in ambient temperatures of at least 10°C and only in dry weather.

Steps:

1. Clean fittings and hydraulic pipes with a steel brush. Be careful not to damage rubber tubes and electrical plugs.
2. Clean area to be resurfaced with Tectyl and allow to dry.
3. Prime area to be treated with Tectyl 506.
4. Apply 2-3 layers of Tectyl 127 CGW.
5. If it is not possible to thoroughly clean and protect a surface because of temperature or moisture conditions, protect the damaged areas with Tectyl 511 M to prevent rust from spreading until a thorough treatment can take place.

4.22.2.6. Surface Treat Generator

Interval: Three months after commissioning, then every two years

Note: Apply Tectyl products in ambient temperatures of at least 10°C and only in dry weather.

Steps:

1. Clean the ventilation gird with a steel brush and prime it with Tectyl 506.
2. Apply 2-3 layers of Tectyl 175 GW (blue color).
3. Clean the cooling girds with a scraper. Remove the scraped off paint and prime with Tectyl 506.
4. Apply 2-3 layers of Tectyl 175 GW (blue color). Because of the need for the generator to cool, surface treatments must not get too thick. Old layers might need to be removed at each repair.

4.22.3. Troubleshooting

4.22.4. Spare Parts

4.22.5. Drawings

Drawing #	Version # (date)	Description	Filename

4.23. Gear Oil System

The gearbox oil cooling system is located above the gearbox and vents through a duct in the nacelle cover. It chills the gear oil in order to prevent overheating during use prolonging the life and quality of the lubrication of the oil.

4.23.1. Specifications

Pump manufacturer:	Oiltech AB (former T&B Hydraulik AB)
Pump type:	Gerotor
Pump motor:	VEM KPER 80 G 4 60 Hz: 0.9 kW/480 V Y
Pump flow:	
	60 Hz: 18 1/min.
Pressure:	Max. continuously 10 bar Max. intermittent 15 bar
Cooler manufacturer:	Oiltech AB (former T&B Hydraulik AB)
Cooler size:	255 mm x 255 mm, fan Ø325 mm
Fan motor:	Fan driven by pump motor, see above

4.23.2. Maintenance

Note: After any service on the gear oil system, ensure that the ball valve on the suction line is left in the open position.

Note: After any service on the gear oil system, ensure that waste and drippings under fittings and valves are wiped clean to make it easy to find leaks later.

4.23.2.1. Lubrication

See Section 4.9.2.

4.23.2.2. Check for Leakage

Interval: Yearly

Refer to Figure 4-68

Steps:

1. Check all fittings, components on the manifold block, and the pump for leaks.
2. Pay special attention to the electric pump. In case of a leaking shaft seal, oil will flow out of the tapped holes next to the fittings screwed into the pump.

4.23.2.3. Check for Cooler Contamination

Interval: Yearly

Refer to Figure 4-68

Steps:

1. Check to see if the cooling elements of the gear oil cooler are clogged. If so, clean.

4.23.2.4. Changing Out Components

Interval: As needed

Note: Pay attention to cleanliness while changing components. Fittings must not be placed in dirty places.

Note: If it is necessary to remove hoses for a period of time, make sure to plug the ends either with plastic threaded plugs/threaded caps or with the following fittings that mate with the 2 x 37° JIC flare system (UNF-thread): 1" cap 16FNTXS (132430) or 1" plug 16PNTXS (132451). Common smooth plastic plugs should not be used for plugging female fittings as they often leave plastic shavings in the thread when removed.

4.23.3. Troubleshooting

4.23.4. Spare Parts

SPARE PARTS LIST 920136 – R2 MOUNTING V27 OIL COOLER				
POS	**PCS**	**Item No.**	**Description**	**Notes**
	1	100010	Cover for oil cooling system	
	1	103905	Pressure hose, oil cooling system	
	1	103907	Return line hose, oil cooling system	
	1	103908	Suction hose, Hansen gearbox	Only for Hansen gearbox
	1	115662	Adapter socket, 1 ¼"/ ¾"	
	1	130976	Oil cooler, EGO-07-4-15	
	4	131054	Male adapter, 16F40XS	
	2.73m	137011	Rubber railing, EPDM 15-602	
	1	147874	Clip, 26-38 mm	Only for Hansen gearbox
	1	148970	Hose connection, 1"	Only for Hansen gearbox
	4	152496	Steel set screw, HDG 8.8 M12x30	
	2	153133	Steel set screw, HDG 8.8 M8 x 16 DIN 933 -8.8	
	2	153744	Set screw, M20x55, 8.8 FZV DIN 933	
	2	154173	Steel set screw, 8.8 HDG M6x20	
	1	155143	Steel set screw, 8.8 M16x80 DIN 933	
	4	155752	Washer, HB200 M6 HDG	
	8	155772	Washer, HB200 HDG M12	

	16	156274	Facet washer, M5 DIN 125A	
	2	157468	Counter nut, M16, FZB 8 DIN 439B-04	
	2	157708	Lock nut, M16 DIN 985	
	4	157775	Lock nut, M12 DIN 985	
	4	158709	Chipboard screw, FZB 4x20	
	18	159638	Blind rivet, 5x25 stainless	
	1	831055	Support for oil cooler, left	
	1	831056	Support for oil cooler, right	
	1	831061	Threaded union, support leg	
	1	831062	Support block for support leg	
	1	831063	Vibration damper oil cooler	
	1	831064	Vandfang, V27 oil cooler	
	1	831940	Outside shield, for V27 oil cooler	

4.23.5. Drawings

Drawing #	Version # (date)	Description	Filename
		R2 mounting V27 oil coller	

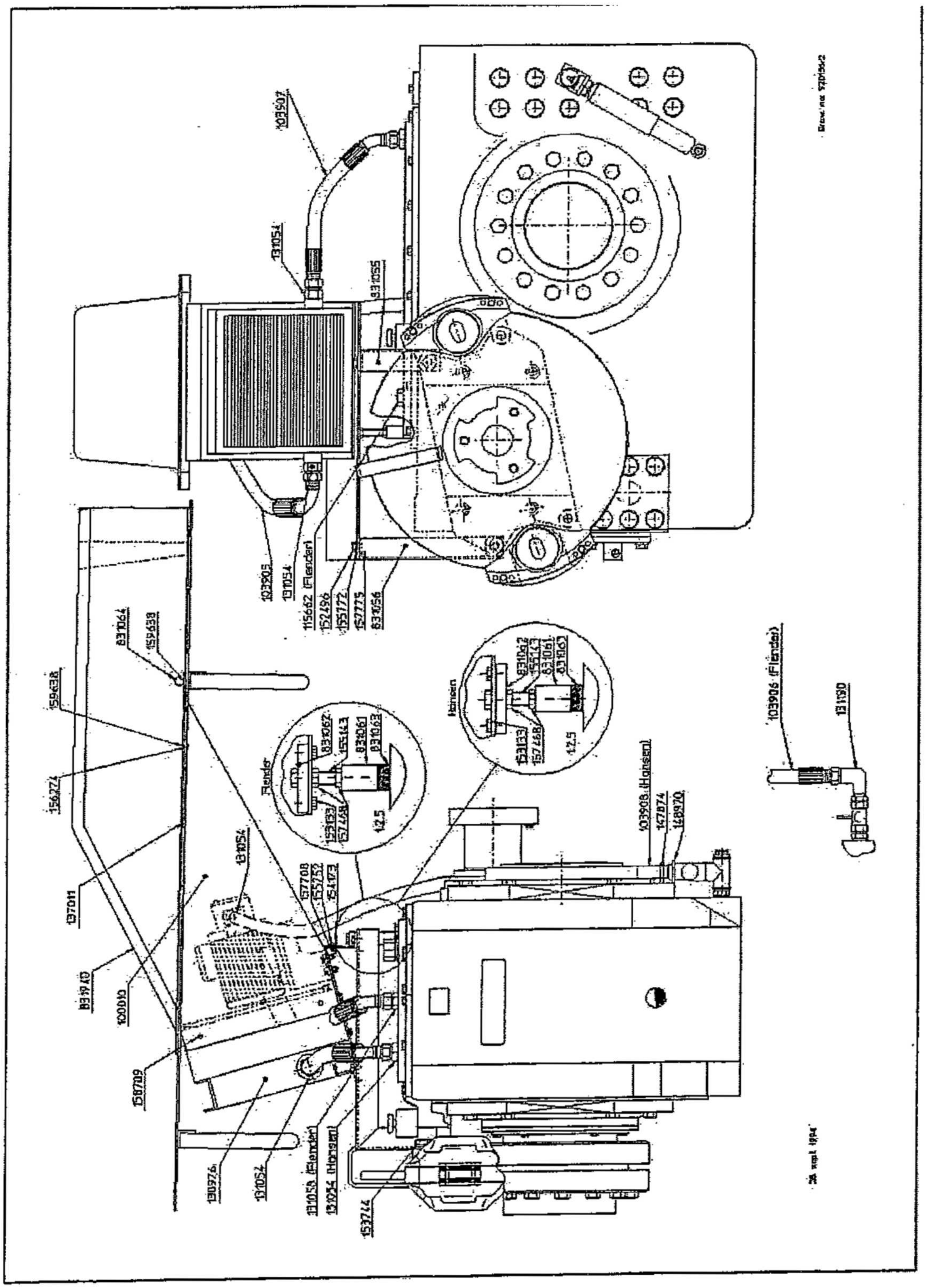


Figure 4-68. Spare parts drawing, R2 mounting V27 oil cooler

APPENDIX A. HARDWARE MANUALS & DATA SHEETS

Master list of non-Sandia equipment and hardware manuals and data sheets specific to this volume. Table to include live links to files hosted online.

Name	File	Revision Date	Description

SANDIA REPORT
SAND2015-XXXX
Unlimited Release
Printed Month and Year

Sandia SWiFT Turbine Erection Manual

Jonathan White

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

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Sandia National Laboratories

SAND2015-XXXX
Unlimited Release
Printed Month Year

Sandia SWiFT Turbine Erection Manual

Jonathan White
XXX Department 6121
Sandia National Laboratories
P.O. Box 5800
Albuquerque, New Mexico 87185-MS1124

Abstract

XXXX

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DOE	U.S. Department of Energy
SNL	Sandia National Laboratories

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This Sandia Vestas V27 Assembly and Startup Manual is part of a system of manuals required to safely build, operate, and maintain experimental Vestas V27 and V29 wind turbines and should be used in coordination with the following manuals and supporting documents:

Sandia Vestas V27/V29 Wind Turbine Operations Manual
Sandia Vestas V27/V29 Wind Turbine Electrical Maintenance Manual
Sandia Vestas V27/V29 Wind Turbine Mechanical Maintenance Manual
Sandia Vestas V27/V29 Wind Turbine Software Manual (pending)
Sandia Vestas V27/V29 Wind Turbine Instrumentation Manual (pending)
Sandia SWiFT Site Operations Manual

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Overview of commissioning

See the Sandia SWiFT Turbine Commissioning Manual (in major revision).

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APPENDIX B – XXX

DISTRIBUTION [can go on an even or an odd page]

[List external recipients names and addresses]

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P.O. Box 808, MS L-795
Livermore, CA 94551-0808

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Sandia National Laboratories

VOLUME 6. TURBINE COMMISSIONING

VOLUME REVISION LOG			
Volume Title: Volume 6: Turbine Commissioning, Sandia SWiFT Wind Turbine Manual			
Volume Owner(s): Jonathan White, SWiFT Site Lead, Bruce LeBlanc, Josh Paquette			
Revision	**Date**	**Author(s)/Approval**	**Summary of Change(s)**
0			

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6.1. Commissioning Overview

Turbine commissioning must be performed the first time a newly constructed wind turbine is operated or major changes are performed to the system. This document consists of the commissioning strategy and required procedures to perform the necessary tests. The tests described within are specifically to verify the mechanical systems and subsystems of the turbine are physically able to perform as designed and that each system is ready for full operation. All software development, turbine controller development and commissioning is covered in a separate procedure which can be found in the Software Quality Assurance Plan. This document is written with the understanding that the steps and procedures will be followed in the order they are presented in the document.

The turbine commissioning is broken into five main phases: Component Testing, Hardware Safety System Testing, Stage I Run-in Tests, Stage II Run-in Tests, Stage III Run-in Tests. The component testing and hardware safety system testing occur prior to installing the rotor. Once these two stages of testing are completed, a review of the results must be performed by the Wind Energy Technology Department at SNL and signed off by the Level 1 Manager.

Once approval is granted by the manager of the SNL wind department, the rotor may be installed on the turbine but must remain in a locked state with the rotor lock pin installed. This will signify the start of the “Run-in” tests. Stage I consists of a series of checks on the rotor installation and safety system operations. When this is complete the rotor lock pin may be removed, signifying Stage II. Stage II consists of a series of rotation speed control and emergency stop tests while not producing any power, wind speed limits are critical during these tests and are detailed in the individual sections. Stage III “Run-in” tests include generator stop tests, partial load operation in low wind speeds, and working the way up to full load automatic operation of the turbine.

For safety and successful completion of startup and run-in tests, all personnel who play a role in each procedure should be in contact with the SWiFT control room via two-way radio or other reliable communication system at all times. All personnel on-site must adhere to and understand the Sandia SWiFT Facility Site Operations Manual, especially in regard to climbing and personnel limits.

6.1.1. Prior to Rotor Installation

The process of beginning the commissioning of a SWiFT turbine begins with a series of component tests on the mechanical subsystems of the turbine. At this point, the rotor is not assembled on the machine, and power has not been turned on to the system. The component tests ensure all of the sub-systems are functioning properly. The Hardware safety system tests ensure the safety systems of the turbine are functioning properly and ensure the rotor can be installed on the turbine safely. SWiFT personnel and management review must be completed prior to installing the rotor.

6.1.2. Rotor Installation

Procedures for installing the turbine blades to the rotor assembly are found in the Sandia SWiFT Wind Turbine Assembly Manual, Volume 5 of this series. Rotor installation must be completed in accordance with the "Sandia SWiFT Wind Turbine Assembly Manual, Volume 5" and verified safe prior to commencing run-in tests found in Section 6.4 of this manual.

6.1.3. Run-in tests

Run-in procedures – to be used both for first-time commissioning of a new turbine and when new blade sets are installed – are found in Sections 6.4, 6.5, and 6.6 of this manual. Preconditions that must be in place prior to commencing all run-in tests are found at the beginning of Section 6.4. Please note that if power has been disconnected from the turbine for over 1 year, the capacitors in the ABB drive need to be reformed using a special charging procedure (see ABB's Capacitor Reforming Manual, at https://library.e.abb.com/public/37165e1130871216c1257b900048122a/EN_Capacitor_reforming_instructions_E.pdf, for more detail).

6.1.4. Using this manual

This manual should be used in coordination with the following volumes:

Sandia SWiFT Facility Site Operations Manual
Sandia SWiFT Wind Turbine Introduction, Volume 1
Sandia SWiFT Wind Turbine Operating Manual, Volume 2
Sandia SWiFT Wind Turbine Electrical Manual, Volume 3
Sandia SWiFT Wind Turbine Maintenance Manual, Volume 4
Sandia SWiFT Wind Turbine Assembly Manual, Volume 5

Every test should have a completed test log identifying the lead technician performing the tests and the date each test was performed. Test logs can be found in Appendix A – Testing Logs.

Each test procedure in this manual includes the following subsections:

6.1.4.1. Initial conditions

A table of initial conditions is provided at the beginning of each test procedure, identifying:

- How many technicians must be present and the location – control room, tower base, nacelle, etc. – at which each plays a role in the test.
- The state at the beginning of the test of each major turbine subsystem.
- Additional preconditions, if any, that must be in place prior to commencing the test procedure.

For safety and successful test completion, it is critical that all initial conditions be present and verified prior to commencing all tests. Ensure that all personnel are in contact with the SWiFT control room via two-way radio or other reliable communication system at all times during testing.

6.1.4.2. Required signals

A list of data channels that should be logged during each test is provided in each section. Logging takes place via the graphical user interface (GUI) and Veristand (see the Sandia SWiFT Wind Turbine Operating Manual, Volume 2, for more about the GUI and Veristand). Logged data should be reviewed after each test to determine whether test criteria were successfully met.

6.1.4.3. Procedures

Stepped procedures for each test are provided. For safety and successful test completion, it is critical that each step be performed in order, and that all test participants be informed, via radio, of each step's completion and of their role in the following step. Ensure that all initial conditions are in place prior to commencing each test procedure.

6.1.4.4. Success criteria

Criteria – data capture, visual verification, etc. – required for a successful test are provided following each test procedure. Inability or failure to capture and verify all information needed to deem a test successful indicates a possible problem with the turbine system. Do not proceed to a subsequent test procedure before resolving problems indicated during a test.

6.2. Component Tests

The following set of system checks cover the mechanical systems that are required for the turbine to function normally, and must be completed prior to system wide checks.

6.2.1. Power System Tests

The purpose of the auxiliary power system is to provide power to all of the systems required for the turbine to operate, log data, and transmit data to the control building. The tests of these systems are to ensure operation will occur as expected during periods of operation, service, and power outage.

6.2.1.1. Nacelle auxiliary power

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Tower base	EMERGENCY	Off	Off	Off	Off

Required signals

Voltage portals need to be checked with a volt meter.

Procedure

1. Tower base: Close the power disconnect on the back of the ABB enclosure (Q7 Pad Disconnect) per "Procedure to Close Disconnect on ABB".
2. Tower base: Close all breakers in right half of bottom controller cabinet.
3. Tower base: Close the controller circuit breaker (F30) in bus bar section.

Note: Up to this point there is no power to the nacelle. There is power to the tower lights, ground controller, and ground auxiliary receptacles.

4. Tower base: Press the service switch (S44) on the panel switch box in the processor section. Listen for K44 to engage, indicating there is power to the hydraulics, yaw system, contactor solenoid, and main controller in the nacelle.
5. Tower base: Ensure that the generator circuit breaker (Q8) is still off, and consequently no power on the generator and bus bars in the bus bar section.
6. Tower base: Ensure there is power to the ACS800 controller in the enclosure. If the keypad display is active, the ACS800 controller has power.

Note: All auxiliary power except the light supply can be turned off with one fuse (F32). When F32 is on, it powers the ground controller and communications to the control building. When F32 is turned off, the uninterruptible power supply (UPS) maintains power to the ground expansion chassis for a period of 5 minutes.

Note: The service switch function will be reset when the controller circuit breaker (F30) is in the off position or when generator circuit breaker (Q8) is turned from the on position to the off position.

Success criteria

Success criteria	Y/N
All controllers have power	
All network equipment has power	
Hydraulic contactors have power	
Yaw motors have power	
Cooling motors have power	

6.2.1.2. Test network connectivity

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Tower Base(1) Control room (1)	EMERGENCY	Off	On	Off	Off

Required signals

None

Procedure

1. Tower Base: Ensure F30 is closed and that the "Service" switch has been pressed to power the top controller.
2. Control room: ping the IP address of the main controller (cRIO 9082).
    a. Open a command window then ping the IP address of the turbine controller which can be found in the "Network Diagram", wait for response.
3. Control room: Verify that the NI network utility finds the turbine controller.
    a. Open NI Max
    b. Find the active NI 9082s on the network.
    c. Verify the IP addresses with the SWiFT Network diagram.
4. Control room: Deploy the Veristand project to the turbine.
    a. Using the turbine user interface, press the deploy command. Reference the "Sandia SWiFT Wind Turbine Operating Manual, Volume 2" Interface guide for details.
5. Control room: Verify the turbine user interface can be opened and sees live data.
    a. Under the Instruments tab, verify the live updating of wind speed.

Success criteria

Success criteria	Y/N
IP address of the main controller responds to a "ping" command	
NI Max registers the main controller on the network	

Veristand successfully deploys	
Wind speed is live updating in the turbine user interface	

6.2.1.3. Test uninterruptible power supply

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Tower Base (1) Control room (1)	EMERGENCY	Off	On	Off	Off
Radio communication exists between all participants.					

Required signals

Time from power disconnect (manual)
Time that turbine controller no longer responds to ping
Time when turbine user interface triggers a connection error
UPS "on battery" signals for each UPS

Procedure

1. Tower base: Ensure the LED indicator on front of each UPS signals a fully charged battery.
2. Tower base: Open F30 disconnect on the left side of the base controller.
3. Control room: Check that all control and communication components remain powered, with full connectivity to the control building.
4. Control room: Measure time until connectivity is lost. Note what component dropped out first. The connectivity should remain for 5 minutes.

Success criteria

Success criteria	Y/N
Did connectivity to the turbine remain for 5 minutes	

6.2.2. ABB Variable Frequency Drive Communication

This procedure uploads the current parameters to the ACS800 Variable Frequency Drive, which is responsible for controlling the generator, and interfacing with the grid.

6.2.2.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
ACS800 enclosure (1) Control room (1)	EMERGENCY	On	On	On	On

6.2.2.2. Required signals

- Turbine state
- ACS 800 state

6.2.2.3. Procedure

1. ACS800 enclosure: Follow the "Installation checklist and startup" from the ACS800 manual (Hardware Manual ACS800-17 Drives (55 to 2500kW/ 75 to 2800 HP).
2. ACS800 enclosure: Use either the ABB Drive Window 2.30 or the keypad on the ACS800 to upload the parameters.
    a. Refer to the "Sandia SWiFT Wind Turbine Electrical Manual, Volume 3" for the latest ACS800 drive parameters.
    b. NOTE: The drive may request that an "ID Mag" be run, if this is the case, do so.
3. ACS800 enclosure: Verify that the parameters listed in the ACS800 FS (0037-0933) have been correctly uploaded to the turbine.
4. Control room: In the GUI's Service Mode view, check that all service modes have been left (disabled).
5. Control room: In the GUI's Service Mode view, enable turbine state. If the turbine state is Run, Pause, or Stop, step the turbine state down to Emergency.
6. Control room: The parameter "ABB_Ready_Inc_State" should be 0. (Alarms will be present in the ACS800.)
7. Control room: In the GUI's Service Mode view, try to manually change the turbine state to Stop, then Pause, by pressing the "Set State" buttons.
8. ACS800 enclosure: Note the error that is active on the ACS800. Verify that the error (FF51: Fault on line side converter) is displayed in the GUI. The ACS800 should prevent the turbine from incrementing state.
9. Control room: In the GUI, acknowledge the alarm so the turbine is ready to return to Pause.

6.2.2.4. Success criteria

Success criteria	Y/N
Verify that the parameters listed in the ACS800 FS (0037-0933) have been correctly uploaded to the turbine	
Verify that the error (FF51: Fault on line side converter) is displayed in the GUI after manually changing the turbine state to Stop, then Pause, by pressing the "Set State" buttons.	

6.2.3. Test remote E-Stop buttons (individual turbine, inside master, outside master)

There are five remote E-Stop buttons, one for each individual turbine near their respective control terminal (S937C), one for site shutdown inside the control room (S937B), and one for site shutdown outside the door of the control room (S937A). The E-Stop buttons are connected to the emergency circuit via fiber optic contact closures. When depressed, the buttons will interrupt communication to the fiber optic receiver in the turbine, thereby causing relay K937 to open, breaking the emergency circuit and initiating an emergency stop.

6.2.3.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Nacelle (1) Turbine Base (1) Control room (2): -Control terminal -E-Stop button	EMERGENCY	On	On	Off	Off
Radio communication exists between all participants.					

6.2.3.2. Required signals

- Voltage across relay K932A terminals 13 and 14
- Voltage across relay K903A
- Controller E-Stop alarm

6.2.3.3. Procedure

Note: Perform this procedure three times, one for each remote E-stop button: individual turbine (at control terminal), inside master (inside control room), and outside master (outside control building).

1. Control room: enter into Hydraulic Service Mode.
2. Control room: turn off hydraulic motor operation.
3. Control room: Place turbine in STOP.
4. Nacelle: Attach digital multi-meter (DMM) leads to relay K932A terminals 13 and 14, located in nacelle control cabinet.
5. Nacelle: Visually verify that voltage across relay K932A terminals 13 and 14 is nominally 24V.
6. Tower Base: Attach digital multi-meter (DMM) leads to relay K903A.
7. Tower Base: Visually verify that voltage across relay K903A is nominally 24V.
8. Control room: Push E-stop button located at individual turbine control terminal.
9. Nacelle: Visually verify that voltage across relay K932A terminals 13 and 14 drops to nominally 0V.
10. Tower Base: Visually verify that voltage across relay K903A drops to 0 V.
11. Control room: Visually verify that E-Stop alarm is registered by controller.
12. Control room: Reset E-stop button.
13. Control room: Place turbine in STOP
14. Nacelle: Visually verify that voltage across relay K932A terminals 13 and 14 rises to nominally 24V.
15. Tower Base: Visually verify that voltage across relay K903A rises to nominally 24V.
16. Repeat Steps 1-8 for inside master (S937B, inside control room) and outside master (S937A, outside control building).

6.2.3.4. Success criteria

Success criteria	Individual Turbine Y/N	Inside Master Y/N	Outside Master Y/N
Voltage across relay K932A terminals 13 and 14 drops from nominally 24V to nominally 0V when each remote E-Stop button (inside individual, inside master, outside master) is pressed.			
Voltage across relay K903A drops from nominally 24V to nominally 0V when each remote E-Stop button is pressed.			
Controller E-Stop alarm is recorded when each remote E-Stop button (inside individual, inside master, outside master) is pressed.			
Voltage across relay K932A terminals 13 and 14 rises from nominally 0V to nominally 24V when each remote E-Stop button (inside individual, inside master, outside master) is reset and turbine is placed in STOP.			
Voltage across relay K903A rises from nominally 0V to nominally 24V when each remote E-Stop button (inside individual, inside master, outside master) is reset and turbine is placed in STOP.			

6.2.4. Test turbine E-stop buttons (tower base, yaw deck, gearbox, top controller)

There are four E-Stop buttons located in each turbine, one at the bottom cabinet (S936), one on the yaw deck (S934), one on gearbox (S933), and one at the top controller cabinet (S935). The E-Stop buttons directly wired in the emergency circuit. When depressed, the buttons will break the emergency circuit initiating an emergency stop.

6.2.4.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Nacelle (1) Turbine Base (1) Control room (1)	EMERGENCY	On	On	Off	Off
Wind speeds below 10 m/s.					
Radio communication exists between all participants.					

6.2.4.2. Required signals

- Voltage across relay K932A terminals 13 and 14
- Controller E-Stop alarm

6.2.4.3. Procedure

1. Control room: Enter into Hydraulic Service Mode.
2. Control room: Turn off hydraulic motor operation.
3. Control room: Place turbine in STOP.
4. Nacelle: Attach digital multi-meter leads to relay K932A terminals 13 and 14, located in nacelle control cabinet
5. Nacelle: Visually verify that voltage across relay K932A terminals 13 and 14 is nominally 24V.
6. Tower Base: Push E-stop button located at tower base control box.
7. Nacelle: Visually verify that voltage across relay K932A terminals 13 and 14 terminals drops to nominally 0V.
8. Control room: Visually verify that E-Stop alarm is registered by controller.
9. Tower Base: Reset E-stop button.
10. Control Room: Clear alarms and place turbine in STOP.
11. Nacelle: Visually verify that voltage across relay K932A terminals 13 and 14 terminals rises to nominally 24V.
12. Tower Base: Climb to yaw deck and repeat Steps 1-7 for yaw deck E-Stop button.
13. Tower Base: Climb to nacelle and repeat Steps 1-7 for gearbox E-Stop button.
14. Tower Base: Repeat Steps 1-7 for nacelle controller E-Stop button.

6.2.4.4. Success criteria

Success criteria	Tower Base Y/N	Yaw Deck Y/N	Gearbox Y/N	Nacelle Controller Y/N
Voltage across relay K932A terminals 13 and 14 terminals 13 and 14 drops from nominally 24V to nominally 0V when each turbine E-Stop button (tower base, yaw deck, gearbox, top controller) is pressed				
Controller E-Stop alarm is recorded when each turbine E-Stop button (tower base, yaw deck, gearbox, top controller) is pressed				
Voltage across relay K932A terminals 13 and 14 rises from nominally 0V to nominally 24V when each E-Stop button (tower base, yaw deck, gearbox, and top controller) is reset and turbine is placed in STOP.				

6.2.5. Hydraulic System Test

The hydraulic pressure tests are performed to ensure hydraulic system is functioning correctly without any significant leaks and can maintain working pressure safely during operation.

6.2.5.1. Hydraulic Oil Level and Pressure Test

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Nacelle (1) Tower Base (1) ACS800 Enclosure (1) Control room (1)	EMERGENCY	On	On	Off	Off
Radio communication exists between all participants.					

Required signals

- Turbine state
- Hydraulic pressure
- Hydraulic motor
- Hydraulic motor feedback

Procedure

1. Tower base: Turn on service button S44 for auxiliary power supply to the nacelle.
2. Control room: Ensure control software is deployed and monitoring hydraulic pressure.
3. Nacelle: Release the pressure from the pitch accumulator, using needle valve 18.1.
4. Nacelle: Release the pressure from the brake accumulator, using needle valve 18.2.
5. Nacelle: Check the oil level in the hydraulic reservoir. With blown accumulators, oil must be visible in the upper sight glass. The glass must not be completely filled up. If there is not sufficient oil, refer to the mechanical maintenance procedure to refill.
6. Nacelle: Close needle valves 18.1 and 18.2.
7. Nacelle: Check all E-stop buttons are released and climb to the tower top platform.
8. Tower base: Turn on breaker F33B.
9. Control room: Raise turbine state to STOP. Verify that the hydraulic pressure increases to nominal operating pressure of 75-90 bar.
10. Top platform: Wait one minute.
11. Nacelle: Re-enter the nacelle.
12. Nacelle: Inspect the hydraulics for any leaks and electrical systems for any damage.

Success criteria

Success criteria	Y/N
Hydraulic oil is just visible in upper sight glass	
Verify that the hydraulic pressure increases when hydraulic pump automatic mode is enabled.	
No leaks are visible in hydraulic system.	

6.2.6. Shaft Brake Test

This is a test to verify operation of the high-speed shaft brake.

6.2.6.1. Shaft brake

The shaft brake is located on front side of the gearbox. The brake system contains two calipers that are hydraulically actuated and released. The system also contains stored energy in the form of an accumulator.

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Tower base (1) Nacelle (1) Control room (1)	PAUSE	On	On	Off	On

Required signals

- Turbine state
- Hydraulic pressure
- Hydraulic motor
- Hydraulic motor feedback
- Brake accumulator
- Brake relay sensor

Procedure

1. Nacelle: Visually inspect the hydraulic system for leaks.
2. Nacelle: Spin the shaft brake disc to determine whether it is on or off.
3. Control room: In the GUI, display the brake service panel.
4. Nacelle: Step away from the shaft brake and confirm location with the control room.
5. Control room: Place the turbine in brake service mode.
6. Control room: In the brake service panel, turn off the brake by pressing the brake button.
7. Nacelle: Spin the shaft brake and check that it is off.
8. Nacelle: Step away from the shaft brake and confirm location with the control room.
9. Control room: In the brake service panel, turn the shaft brake on.
10. Nacelle: Spin the shaft brake disc and verify that it is on.

Success criteria

Success criteria	Y/N
Physical confirmation that shaft brake applies and shaft cannot be rotated as commanded.	
Physical confirmation that shaft brake releases and shaft can be rotated as commanded.	

6.2.7. Pitch System Tests

The goal of these tests is to verify the functionality and performance of the hydraulic pitch system.

6.2.7.1. Pitch position

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	Off	On
Auto-Yaw Disabled					

Required signals

- Turbine state
- Hydraulic pressure
- Hydraulic motor
- Hydraulic motor feedback
- Pitch control voltage
- Pitch position actual
- A800 – Pitch Position voltage
- Y800 - PitchActual
- Pitch service mode

Procedure

1. Control room: Verify that the nacelle camera is positioned to view the pitch rod. If not:
    a. Climb to the nacelle and reposition the camera.
    b. Return to the tower base.
2. Control room: Place the turbine in pitch service mode.
3. Control room: Press the "Dec. 1" and "Inc. 1" buttons 3 times and view the camera feed to verify that the pitch rod is moving.
4. Control room: In the pitch service panel, press the Pitch Test "-ve" button to the negative end stop and note the voltage (0.040V ±0.020V). If the sensor is out of calibration, adjust it and repeat Step 4.
5. Control room: In the pitch service panel, press the Pitch Test "+ve" button to the positive end stop and note the voltage (9.970V ±0.02V). If the sensor is out of calibration, adjust it and repeat Step 5.
6. Control room: Perform Steps 4 and 5 three times each, noting the voltage each time.

Success criteria

Success criteria	Test 1	Test 2	Test 3
Negative end stop voltages are nominal (0.040V ±0.020V)			
Positive end stop voltages are nominal (9.970V ±0.02V)			

6.2.7.2. Positive offset

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	Off	On
Auto-Yaw Disabled					

Required signals

- Turbine state
- Hydraulic pressure
- Hydraulic motor
- Hydraulic motor feedback
- Pitch control voltage
- Pitch position actual
- A800 – Pitch Position voltage
- Pitch service mode

Procedure

1. Control room: From the pitch service panel, press the Pitch Test "+OFF" button to start the test. For 6 seconds, the control voltage will be +2.000 V and the controller measures the pitch velocity. When the measurement is complete, the pitch will return to 0.0° and pitch velocity will be displayed. Every 10th second, the computer will perform a new test.
2. Control room: Record the pitch velocity (0.05°/sec, ±0.03°/sec).

Success criteria

Success criteria	Velocity	Y/N
Pitch velocity is nominal (0.05°/sec, ±0.03°/sec)		

6.2.7.3. Negative offset

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	Off	On
Auto-Yaw Disabled					

Required signals

- Turbine state
- Hydraulic pressure
- Hydraulic motor
- Hydraulic motor feedback
- Pitch control voltage
- Pitch position actual

- A800 – Pitch Position voltage
- Pitch service mode

Procedure

1. Control room: From the pitch service panel, press the Pitch Test "-OFF" button to start the test. For 6 seconds, the control voltage will be -2.000 V and the controller measures the pitch velocity. When the measurement is complete, the pitch will return to 0.0° and pitch velocity will be displayed. Every 10th second, the computer will perform a new test.
2. Control room: Record the pitch velocity (-0.05°/sec, ±0.03°/sec).

Success criteria

Success criteria	Velocity	Y/N
Pitch velocity is nominal (-0.05°/sec, ±0.03°/sec)		

6.2.7.4. Positive flow

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	Pause	On	On	Off	On
Auto-Yaw Disabled					

Required signals

- Turbine state
- Hydraulic pressure
- Hydraulic motor
- Hydraulic motor feedback
- Pitch control voltage
- Pitch position actual
- A800 – Pitch Position voltage
- Pitch service mode

Procedure

1. Control room: From the pitch service panel, press the Pitch Test "+Flow" button to start the test. For 6 seconds, the control voltage will be +9.000 V and the controller measures the pitch velocity. When the measurement is complete, the pitch will return to 0.0° and pitch velocity will be displayed. Every 10th second, the computer will perform a new test.
2. Control room: Record the pitch velocity (+8.5°/sec, ±1.0°/sec).

Success criteria

Success criteria	Velocity	Y/N
Pitch velocity is nominal (+8.5°/sec, ±1.0°/sec)		

6.2.7.5. Negative flow

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	Off	On
Auto-Yaw Disabled					

Required signals

- Turbine state
- Hydraulic pressure
- Hydraulic motor
- Hydraulic motor feedback
- Pitch control voltage
- Pitch position actual
- A800 – Pitch Position voltage
- Pitch service mode

Procedure

1. Control room: From the pitch service panel, press the "Pitch Test" -Flow" button to start the test. For 6 seconds, the control voltage will be -9.000 V and the controller measures the pitch velocity. When the measurement is complete, the pitch will return to 80.0° and pitch velocity will be displayed. Every 10th second, the computer will perform a new test.
2. Control room: Record the pitch velocity (-9.5°/sec, ±1.0°/sec).

Success criteria

Success criteria	Velocity	Y/N
Pitch velocity is nominal (-9.5°/sec, ±1.0°/sec)		

6.2.7.6. Sine test

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	Off	On
Auto Yaw Disabled					

Required signals

- Turbine state
- Hydraulic pressure
- Hydraulic motor
- Hydraulic motor feedback
- Pitch control voltage
- Pitch position actual

- A800 – Pitch Position voltage
- Pitch service mode

Procedure

1. Control room: From the GUI, begin logging the following signals:
    - PitchRef
    - PitchActual
    - PitchRef_Manual
    - PitchTest_Status
    - PitchRef_ToRESTmodel
    - Turbine_State_ID
2. Control room: From the pitch service panel, press the Pitch Test “sin” button to start the test. The pitch reference follows a sine function from -3.0° to 83.0° with a cycle time of 60 seconds.
3. Control room: After 2 minutes, stop the test and the data logging.
4. Control room: Verify that the actual pitch (PitchActual) follows the reference pitch (PitchRef). The steady-state deviation should be less than 0.2°.

Success criteria

Success criteria	Y/N
Steady-state deviation for Sine Test is nominal (±0.2°)	

6.2.7.7. Step test

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	Off	On
Auto-Yaw Disabled					

Required signals

- Turbine state
- Hydraulic pressure
- Hydraulic motor
- Hydraulic motor feedback
- Pitch control voltage
- Pitch position actual
- A800 – Pitch Position voltage
- Pitch service mode

Procedure

1. Control room: From the GUI, begin logging the following signals:
    - PitchRef
    - PitchActual
    - PitchRef_Manual

- PitchTest_Status
- PitchRef_ToRESTmodel
- Turbine_State_ID

2. Control room: From the pitch service panel, press the Pitch Test "step" button to start the test. The pitch reference moves in steps: 80.0° / 70.0° / 60.0° / 50.0° / 40.0° / 30.0° / 20.0° / 10.0° / 0.0° / 10.0° / 20.0° / 30.0° / etc. The value changes every 5 seconds.
3. Control room: After two full cycles, stop the test and the data logging.
4. Control room: Verify that the actual pitch (PitchActual) follows the reference pitch (PitchRef). The steady-state deviation should be less than 0.2°.
5. Control room: Disable pitch service mode.

Success criteria

Success criteria	Y/N
Steady-state deviation for Step Test is nominal (±0.2°)	

6.2.8. Yaw System Tests

The following tests verify the correct behavior of the yaw system and sensors.

6.2.8.1. Yaw direction

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	On	On
Auto-Yaw Disabled					

Required signals

- Turbine state
- Yaw clockwise (CW)
- Yaw counterclockwise (CCW)
- Yaw activity
- Yaw stop
- Yaw encoder

Procedure

Note: Yaw direction is from an aerial view.

1. Control room: From the yaw service panel, press the Yaw Service "enable" button.
2. Control room: Using the manual yaw buttons (CCW, Stop, and CW), visually verify that the yaw direction is correct.
3. Control room: Press the Yaw Service "disable" button.

Success criteria

Success criteria	Y/N
Visual verification of yaw direction (CW and CCW)	

6.2.8.2. Yaw untwist

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room	PAUSE	On	On	On	On
Auto-Yaw Disabled					

Required signals

- Turbine state
- Yaw clockwise (CW)
- Yaw counterclockwise (CCW)

- Yaw activity
- Yaw stop
- Yaw encoder

Procedure

Note: Yaw direction is from an aerial view.

1. Control room: From the yaw service panel, note the yaw start position.
2. Control room: From the yaw service panel, press the "CW" button to yaw the turbine clockwise. When S102=1, stop yawing and note the CW yaw position.
3. Control room: Press the "CW" button to continue yawing clockwise. When S104=0, the yawing should stop automatically. Note the CW yaw position when S104=0.
4. Control room: Press the "CCW" button to yaw the turbine counterclockwise. When S103=1, stop yawing and note the CCW yaw position.
5. Control room: Press the "CCW" button to continue yawing counterclockwise. When S104=0, the yawing should stop automatically. Note the CCW yaw position when S104=0.
6. Control room: Press the "CW" button to yaw the turbine back to the yaw start position.
7. Control room: Press the Yaw Service "disable" button.

Success criteria

Success criteria	Recorded position
Yaw start position:	
Short untwist S102 CW sensor on position:	
Long untwist S104 CW sensor on position:	
Short untwist S103 CCW sensor on position:	
Long untwist S104 CCW sensor on position:	

6.2.8.3. Yaw encoder sensor test and calibration

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	On	On

Required signals

Procedure

1. Place turbine into EMERGENCY.
2. Un-deploy controller software.
3. Redeploy controller software with yaw alarm limits set to ±390°.
4. Place turbine in STOP, then PAUSE.
5. Enter yaw service mode.
6. Yaw turbine to 0°.
7. Climb turbine and verify that turbine aligns with 0° mark on bull gear.

8. Climb down from turbine.
9. Place turbine in STOP, then PAUSE.
10. Enter yaw service mode.
11. Yaw turbine to 360°.
12. Climb turbine and verify that turbine aligns with 0° mark on bull gear.
    a. Note distance between 0° mark and current yaw position.
13. Climb down from turbine.
14. Place turbine in STOP, then PAUSE.
15. Enter yaw service mode.
16. Yaw turbine to 400° and ensure that yaw encoder limit alarm is reached at 390°.
17. Clear alarm and yaw turbine to -360°.
18. Climb turbine and verify that turbine aligns with 0° mark on bull gear.
    a. Note distance between 0° mark and current yaw position.
19. Climb down from turbine.
20. Place turbine in STOP, then PAUSE.
21. Enter yaw service mode.
22. Yaw turbine to -400° and ensure that yaw encoder limit alarm is reached at -390°.
23. Clear alarm and yaw turbine to 0°.
24. Place turbine into EMERGENCY, undeploy modified controller software, and redeploy original controller software.

Success criteria

Success criteria	Y/N
Turbine nacelle is aligned with 0° mark when encoder reads 0°	
Turbine nacelle is aligned with 0° mark when encoder reads 360°	
Turbine nacelle is aligned with 0° mark when encoder reads -360°	
Turbine yaw encoder limit alarm is reached at 390°	
Turbine yaw encoder limit alarm is reached at -390°	

6.2.9. Rotation System Tests

The rotation system as defined here contains the temperature sensors and cooling mechanisms for the gearbox and generator. These sets of tests verify each system is working properly.

6.2.9.1. Gear oil cooler

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1) Nacelle (1)	PAUSE	On	On	Off	On

Required signals

- Turbine state
- Gear oil cooler motor
- Gear oil cooler motor feedback

Procedure

1. Control room: Display the gear oil service panel (Views>>Service Mode>>Show Service>>Gear Oil Cooler).
2. Control room: Press the Gear Oil Service "enable" button to enable manual mode for the nacelle fan/cooler.
3. Control room: Press the Gear Oil Service "Stop" and "Run" buttons and verify, through the GUI that the nacelle fan/cooler turns on and off.
4. Nacelle: Verify that the gear oil cooler fan turns on and off when commanded.
5. Nacelle: Determine if air is being sucked into the cooler or blown out of it. Relay information to control room.
6. Control room: Press the Gear Oil Service "Auto" button to return the nacelle fan/cooler to auto mode.
7. Control room: Press the Gear Oil Service "disable" button to disable manual mode for the nacelle fan/cooler.

Success criteria

Success criteria	Y/N
Physical (audible) verification that nacelle fan/cooler turns on and off	
Verification of fan direction	
GUI verification that nacelle fan/cooler turns on and off	

6.2.9.2. CC Jensen motor

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	Off	On

Nacelle (1)					

Required signals

- Turbine state
- CC Jensen motor
- CC Jensen motor feedback

Procedure

1. Control room: Display the gear oil service panel (Views>>Service Mode>>Show Service>>Gear Oil Filter).
2. Control room: Press the Gear Oil Filter "enable" button to enable manual mode for the gear oil filter.
3. Control room: Press the Gear Oil Filter "Stop" and "Run" buttons and verify through the GUI that the gear oil filter turns on and off.
4. Nacelle: Verify that the gear oil filter pump turns on and off when commanded.
5. Control room: Press the Gear Oil Filter Mode "Auto" button to return the gear oil filter to auto mode.
6. Control room: Press the Gear Oil Filter "disable" button to disable manual mode for the gear oil filter.

Success criteria

Success criteria	Y/N
Visual or audible verification that the gear oil filter turns on and off	
GUI verification that the gear oil filter turns on and off	

6.2.9.3. Generator cooler

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1) Nacelle (1)	PAUSE	On	On	Off	On

Required signals

- Turbine state
- Generator cooler motor
- Generator cooler motor feedback

Procedure

1. Control room: Display the generator service panel (Views>>Service Mode>>Show Service>>Generator Cooler).
2. Control room: Press the Generator Service "enable" button to enable manual mode for the generator cooler.
3. Control room: Press the Generator Cooler "Stop" and "Run" buttons and verify through the GUI that the generator cooler turns on and off.

4. Nacelle: Verify that the generator cooler fan turns on and off when commanded.
5. Nacelle: Determine if air is being sucked into the cooler or blown out of it. Relay information to control room.
6. Control room: Press the Generator Cooler Mode “Auto” button to return the generator cooler to auto mode.
7. Control room: Press the Generator Service “disable” button to disable manual mode for the generator cooler.

Success criteria

Success criteria	Y/N
Visual verification that the generator cooler turns on and off	
GUI verification that the generator cooler turns on and off	

6.2.9.4. Temperature sensors

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Tower base / nacelle (1) Control room (1)	EMERGENCY	On	On	Off	On

Required signals

- Turbine state
- R206
- R300
- R402
- R503
- R504
- R451
- R452

Procedure

1. Tower base: Verify that the tower base E-stop button is not pressed and climb to the nacelle.
2. Control room: Display the temperature measurements (Views>>General I/O).
3. Nacelle: Test the following PT100 sensors. Apply a short circuit to each temperature sensor and verify that the temperature reading goes low:
    - R206: Hydraulic oil temperature
    - R300: Ambient temperature
    - R402: Gear oil temperature
    - R503: Generator drive-end temperature
    - R504: Generator non-drive-end temperature
    - R451: Gear HSS front bearing temperature

- R452: Gear HSS rear bearing temperature

4. Nacelle: Verify that all temperature sensors are at a reasonable level:
    - R206: Hydraulic oil temperature
    - R300: Ambient temperature
    - R402: Gear oil temperature
    - R503: Generator drive-end temperature
    - R504: Generator non-drive-end temperature
    - R451: Gear HSS front bearing temperature
    - R452: Gear HSS rear bearing temperature

Success criteria

Success criteria	Y/N
Short circuit reading of all temperature sensors goes low	
All temperature sensor readings are nominal	

6.2.10. Nacelle Meteorological system tests

The purpose of the following tests is to ensure the proper operation of the nacelle anemometry for use in the turbine controller.

6.2.10.1. Nacelle Wind speed

6.11.1.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	Off	On

Required signals

- Turbine state
- Wind speed
- Met tower hub height wind speed

Procedure

1. Control room: In the GUI, display the General I/O panel (Views>>General I/O).
2. Control room: Determine if the wind speed measurement seems to be reasonable based on other available data.
3. Control room: Record data for detailed comparison.

Success criteria

Success criteria	Y/N
Wind speed readings nominal based on other available data	

6.2.10.2. Nacelle Wind direction

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	Off	On

Required signals

- Turbine state
- Wind direction
- Met tower hub height wind direction

Procedure

1. Control room: In the GUI, display the General I/O panel (Views>>General I/O).
2. Control room: Determine if the wind direction readings seem to be reasonable based on other available data.
3. Control room: Record data for detailed comparison.

Success criteria

Success criteria	Y/N
Wind direction readings nominal based on other available data	

6.2.11. Generator setup and direction

6.2.11.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Tower base (1) Control room (1)	PAUSE	On	On	Off	On

6.2.11.2. Required signals

- Turbine state
- ACS 800 state
- ACS 800 torque
- ACS 800 power
- ACS 800 frequency
- High speed shaft rpm
- Low speed shaft rpm

6.2.11.3. Procedure

1. Tower base: The low speed shaft (LSS) bolt should already be marked, targets should be mounted on the LSS, and the nacelle camera should be positioned to view the LSS. If not:
    a. Climb to the nacelle.
    b. Mark the low speed shaft bolt.
    c. Reposition the camera on the control cabinet so it views the LSS bolt.
    d. Mount the targets on the LSS.
    e. Climb to the tower base.
2. Tower base: Verify that the ACS800 disconnect is engaged (ACS800 Q1).
3. Tower base: For the first time, turn on the generator circuit breaker (Q8). The generator is now live and the power cables are energized.
4. Control room: Display the brake panel (Views >> Service Mode >> Show Service >> Brake).
5. Control room: From the Brake Service panel, press the Brake Service “enable” button.
6. Control room: From the Brake Service panel, turn off the brake by pressing the “Brake” button.
7. Tower Base: Open Firmware Manual ACS800 Standard Control Program 7.x. Follow the instructions in the chapter to “run the assistant.”
8. Tower Base: From Firmware Manual ACS800 Standard Control Program 7.x, complete the “direction of rotation of the motor tests.”
9. Control room: Via the camera feed, verify that the shaft rotates in the expected direction. (With the camera mounted on the control cabinet, the bolt will move counterclockwise.)

6.2.11.4. Success criteria

Success criteria	Y/N
Verify that the shaft rotates in the expected direction when commanded	

6.3. Hardware Safety System Tests

The following tests are on the two independent hardware safety systems that function as the last line of defense for the turbine and do not rely on the turbine software controller for activation. These tests need to be performed prior to installing a rotor on the turbines. Following the completion of this set of tests a formal review must be made by a team of Sandia Wind Energy technical staff and approved by the Wind Energy Technologies Department manager. Following the completion and approval of the conducted tests, the rotor shall be ready to be installed on the turbine.

6.3.1. Emergency circuit tests

The purpose of the emergency circuit is to bring the turbine to a full stop as quickly as possible using all available stopping mechanisms: blade pitch, generator torque, and mechanical break torque. The circuit is normally powered by 24V DC, and consists of several sub-systems wired in series. When any one of the subsystems registers a fault, the circuit is broken, causing all of the stopping mechanisms to activate. Please refer to Volume 3 Turbine Electrical Manual for a diagram of the emergency circuit.

6.3.1.1. Test controller watchdog

The controller watchdog consists of a relay (D906) on the emergency circuit that must receive a pulse from the controller to stay closed. The relay is located in the bottom control cabinet. The purpose of the watchdog is to ensure that the controller is operational. The watchdog continuously looks for a signal from the controller with a period of 150 milliseconds or less. If the frequency varies the watchdog relay will open, causing the emergency circuit to activate. This is a test to verify operation of the watchdog.

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Tower Base(1) Control room (1)	STOP	On	On	Off	On
Wind speeds below 10 m/s.					
Radio communication exists between all participants.					

Required signals

- Voltage across relay K932A terminals 13 and 14
- Controller E-Stop alarm

Procedure

Note: Perform this procedure three times, one for each of the following watchdog signals: low constant output (watchdog railed "low"), high constant output (watchdog railed "high"), and low frequency (watchdog ramp from normal to low frequency).

1. Control room: Place turbine in STOP.
2. Nacelle: Attach digital multimeter leads to relay K932A terminals 13 and 14, located in nacelle control cabinet
3. Nacelle: Visually verify that voltage across relay K932A terminals 13 and 14 terminals is nominally 24V.
4. Nacelle: From controller, simulate watchdog railed "low":
5. Nacelle: Visually verify that voltage across relay K932A terminals 13 and 14 terminals drops to nominally 0V.
6. Control room: Visually verify that E-Stop alarm is registered by controller.
7. Control room: Reset controller watchdog.
8. Control room: Clear alarms and place turbine in STOP
9. Nacelle: Visually verify that voltage across relay K932A terminals 13 and 14 rises to nominally 24V.
10. Repeat Steps 3-9 for watchdog signals high amplitude (watchdog railed "high") and low frequency (watchdog ramp from normal to low frequency).
11. Record frequency at which controller watchdog trips.

Success criteria

Success criteria	Railed High Y/N	Railed Low Y/N	Low Frequency Y/N
Voltage across relay K932A terminals 13 and 14 terminals drops from nominally 24V to nominally 0V when low amplitude (watchdog railed "high"), high amplitude (watchdog railed "high") and low frequency (watchdog ramp from normal to low frequency) is simulated			
Controller E-Stop alarm is recorded when low amplitude (watchdog railed "high"), high amplitude (watchdog railed "high") and low frequency (watchdog ramp from normal to low frequency) is simulated			
Voltage across relay K932A terminals 13 and 14 terminals 13 and 14 rises from nominally 0V to nominally 24V when low amplitude (watchdog railed "high"), high amplitude (watchdog railed "high") and low frequency (watchdog ramp from normal to low frequency) is simulated			
Controller Watchdog Trip Frequency			

6.3.1.2. Test brake thermistor

The brake thermistor is located in one brake pad on the mechanical brake and is connected to relay K207 in the emergency circuit. The purpose of the thermistor is to prevent the turbine from operating when the brake system is at a high temperature, such as immediately after a braking event, like an emergency stop or due to certain brake system malfunctions. When the thermistor is in the presence of high temperature, the relay opens and the emergency circuit is activated. This is a test to verify operation of the brake thermistor.

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Nacelle (2) Control room (1)	STOP	On	On	Off	On
Wind speeds below 10 m/s.					
Radio communication exists between all participants.					

Required signals

- Voltage across relay K932A terminals 13 and 14
- Controller E-Stop alarm

Procedure

1. Control room: Place turbine in STOP.
2. Nacelle (1): Attach digital multimeter leads to relay K932A terminals 13 and 14, located in nacelle control cabinet
3. Nacelle (1): Visually verify that voltage across relay K932A terminals 13 and 14 is nominally 24V.
4. Nacelle (2): Remove brake pad containing thermistor from caliper and place on top of gearbox.
5. Nacelle (2): Install new or "dummy" brake pad into caliper to replace the thermistor brake pad being tested.
6. Nacelle (2): Use heat gun to raise the temperature of the brake pad material on the thermistor brake pad until E-Stop circuit is tripped (approximately 150°C internal temperature). (Note: Make sure to use proper PPE for this step, including wearing high temperature gloves)
7. Nacelle (2): Measure temperature of brake pad using infrared thermal measurement device.
8. Nacelle (1): Visually verify that voltage across relay K932A terminals 13 and 14 terminals 13 and 14 drops to nominally 0V.
9. Control room: Visually verify that E-Stop alarm was registered by controller.
10. Allow thermistor to cool and verify that voltage across relay K932A terminals 13 and 14 rises back to nominally 24V.

Success criteria

Success criteria	Y/N

Voltage across relay K932A terminals 13 and 14 drops from nominally 24V to nominally 0V when thermistor temperature is raised beyond 150°C	
Controller E-Stop alarm is recorded when thermistor temperature is raised beyond to 150°C	
Voltage across relay K932A terminals 13 and 14 terminals 13 and 14 drops from nominally 24V to nominally 0V when thermistor temperature falls to below 150°C	

6.3.1.3. Test OSPR and OSPS controllers

The Overspeed Protection System (OSP) controllers are connected in series in the emergency circuit. There are two of these controllers. OSPR is located in the top controller cabinet and OSPS is located in the small cabinet aft of the top controller cabinet. The purpose of these controllers is to measure the frequency of pulses emanating from sensors on the low-speed shaft, and initiate an emergency stop by opening a relay (K405 for OSPR, K209 for OSPS) on the emergency circuit if the frequency exceeds a pre-defined limit. Each controller must be manually reset by pressing a button that is located on the cabinet that the controller is in. This is a test to verify operation of the OSP controllers.

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Nacelle (1) Control room (1)	STOP	On	On	Off	On
Wind speeds below 10 m/s.					
Radio communication exists between all participants.					

Required signals

- Voltage across relay K932A terminals 13 and 14
- Controller OSP Alarms
- Controller E-Stop Alarm

Procedure

1. Control room: Place turbine in STOP.
2. Nacelle: Attach digital multi-meter leads to relay K932A terminals 13 and 14, located in nacelle control cabinet
3. Nacelle: Visually verify that voltage across relay K932A terminals 13 and 14 is nominally 24V.
4. Nacelle: Attach signal generator to OSPR Phoenix Contact controller.
    a. Ground lead to terminal “A2”, Positive lead to terminal “IN1”
5. Nacelle: Ramp frequency up from 0 to 15 Hz on signal generator until E-stop is triggered with a minimum of 0-24 VDC square wave.
6. Nacelle: Visually verify that voltage across relay K932A terminals 13 and 14 drops to nominally 0V.
7. Control room: Visually verify that E-Stop alarm is registered by controller.
    a. Turbine will be in EMERGENCY.

8. Control room: Record controller trip frequency.
9. Nacelle: Ramp frequency down to 0 Hz on signal generator and verify that voltage across relay K932A terminals 13 and 14 remains at nominally 0V.
10. Nacelle: Reset OSPR Phoenix Contact controller using blue button on side of large nacelle controller cabinet (for OSPS, yellow button on the small cabinet aft of large controller cabinet).
11. Control Room: Clear alarms and place turbine in STOP
12. Nacelle: Verify that voltage across relay K932A terminals 13 and 14 rises to nominally 24V.
13. Repeat Steps 4-13 for OSPS controller.

Success criteria

Success criteria	OSPR Y/N	OSPS Y/N
Voltage across relay K932A terminals 13 and 14 drops from nominally 24V to nominally 0V when frequency of 12.3 Hz is simulated in OSPR and OSPS controllers		
Voltage across relay K932A terminals 13 and 14 remains at nominally 0V when frequency is ramped from 12.3 Hz to 0 Hz in OSPR and OSPS controllers		
Controller OSPR/OSPS alarm is recorded when frequency of 12.3 Hz is simulated in OSPR and OSPS controllers		
Voltage across relay K932A terminals 13 and 14 rises from nominally 0V to nominally 24V when OSPR and OSPS controllers are reset and turbine is place in STOP		

6.3.1.4. Test controller E-stop activation

An emergency stop may be initiated by the turbine controller through the control terminal. The controller initiates the emergency stop by opening relay K900 in the emergency circuit.

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Nacelle (1) Control room (1)	STOP	On	On	Off	On
Wind speeds below 10 m/s.					
Radio communication exists between all participants.					

Required signals

- Voltage across relay K932A terminals 13 and 14
- Controller E-Stop alarm

Procedure

1. Control room: Place turbine in STOP.
2. Nacelle: Attach digital multi-meter leads to relay K932A terminals 13 and 14, located in nacelle cabinet.
3. Nacelle: Visually verify that voltage across relay K932A terminals 13 and 14 is nominally 24V.
4. Control room: Push E-stop button on control screen.
5. Nacelle: Visually verify that voltage across relay K932A terminals 13 and 14 drops to nominally 0V.
6. Control room: Visually verify that E-Stop alarm is registered by controller.
7. Control room: Clear alarms and place turbine in STOP.
8. Nacelle: Visually verify that voltage across relay K932A terminals 13 and 14 rises to nominally 24V.

Success criteria

Success criteria	Y/N
Voltage across relay K932A terminals 13 and 14 drops from nominally 24V to nominally 0V when controller E-Stop button is pressed	
Controller E-Stop alarm is recorded when controller E-Stop button is pressed	
Voltage across relay K932A terminals 13 and 14 rises from nominally 24V to nominally 0V when turbine is placed in STOP	

6.3.1.5. Test OSPR, OSPS, and HSS sensors, and turbine controller overspeed limits

The combined turbine controller and emergency system has three overspeed limits. The first is set nominally at 10% in the turbine controller, based on the signal from the high-speed shaft speed sensor located near the brake disk. The second is set nominally at 15% in the turbine controller, based on the low-speed shaft sensor located where the low speed shaft connects to the gear box. The third is set nominally at 20% in the emergency circuit, based on both the previously mentioned low-speed shaft sensor and a separate rotational sensor mounted on the hub to low-speed shaft mounting flange (each of these systems can activate the emergency circuit independently). The high speed shaft speed sensor and the two low-speed shaft speed sensors are also compared in the controller for consistency (i.e. low-speed sensors yield equal readings and are equal to the high speed sensor divided by the total gearbox ratio). This is a test to verify consistency of the speed reading throughout the operating range and up to slightly above the highest overspeed limit.

NOTE: IT IS CRUCIAL TO NEVER PERFORM THIS PROCEDURE WITH A ROTOR INSTALLED ON THE TURBINE!! SERIOUS STRUCTURAL DAMAGE MAY OCCUR. ALL FUNCTIONAL OVERSPEED PROTECTION SYSTEMS ARE BYPASSED FROM SENDING THE TURBINE TO EMERGENCY FOR THE NECESSARY COLLECTION OF THE REQUIRED DATA.

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)

Nacelle (1) Control room (1)	EMERGENCY	On	On	Off	On
Wind speeds below 10 m/s.					
Radio communication exists between all participants.					

Required signals

- Voltage across relay K932A terminals
- Controller E-Stop alarm

Procedure

1. Nacelle: Install jumpers across K405 and K209 relays.
2. Nacelle: Climb down from machine, go to control room, and sit or stand by turbine E-stop button.
3. Control room: Install special version of controller software with alarm actions for overspeed changed to not send the turbine to STOP or E-STOP when alarms are triggered
4. Control room: Open Drive Windows to manually control generator speed.
5. Control room: Ramp generator speed from 0 to 1662 rpm over 1 minute and then from 1662 to 0 over 1 minute.
6. Control room: Place turbine in E-Stop.
7. Control room: Verify that speed readings from OSPR, OSPS, and HSS sensors were consistent throughout entire speed range.
8. Control room: Verify that overspeed alarm was registered in turbine controller at 1331 rpm on generator from HSS sensor.
9. Control room: Verify that overspeed alarm was registered in turbine controller at 1392 rpm on generator from LSS sensor.
10. Control room: Verify that overspeed alarm was registered in turbine controller at 1452 rpm on generator from both OSPR and OSPS controllers.
11. Nacelle: Climb turbine and verify that both OSPR and OSPS controllers have activated by visually inspecting lights on controllers.
12. Nacelle: Reset OSPR and OSPS controllers.
13. Control Room: Uninstall special version of controller software installed in Step 3 and verify that alarm functions have been restored.

Success criteria

Success criteria	Y/N
OSPR, OSPS, and HSS speed readings are consistent throughout entire speed range	
Controller has registered an overspeed alarm at 10% overspeed.	
Controller has registered an overspeed alarm at 15% overspeed.	
Controller has registered an overspeed alarm at 20% overspeed.	
OSPR controller lights indicate activation	
OSPS controller lights indicate activation	

6.3.1.6. Test turbine E-stop actuation (without rotation)

Initial conditions

Technician	Turbine	Q8	F30	F33A	F33B

Location(s)	State	(Generator)	(Controller)	(Yaw)	(Hydraulics)
Control room (1) Tower Base (1)	PAUSE	On	On	Off	On
Wind speeds below 10 m/s.					
Radio communication exists between all participants.					

Required signals

- Pitch position
- System hydraulic pressure
- Brake hydraulic pressure
- Controller E-stop alarm

Procedure

1. Control room: Place turbine in pitch service mode.
2. Control room: Command pitch to 0°.
3. Tower Base: Visually verify that pitch ram retracts from front of nacelle.
4. Control room: Push E-stop button located near turbine control terminal.
5. Tower Base: Visually verify that the pitch ram extends from front of nacelle.
6. Control room: Reset E-stop button.
7. Control room: Clear alarms.

Success criteria

Success criteria	Y/N	Data
Visual verification of pitch ram extension to feather position		-
E-stop alarm is generated by controller		-
Record time for blade pitching to begin after E-stop alarm	-	ms
Blade pitch rate is 18-21 degrees/second		°/s
Record brake system pressure dip period	-	ms
Record time for full brake pressure to be achieved after E-stop alarm	-	ms

6.3.2. Stop circuit tests

The hardwired stop circuit is designed to place the turbine in full feather, disable yaw control, and engage the generator braking system. The primary purpose of this circuit is to stop the machine without using the mechanical brakes to produce a softer stop than emergency stop in the cases of extreme vibration, grid loss, or excessive cable twist. The secondary purpose of this circuit is to lock the blades in pitch and disable the yaw system from the control room via a switch to prevent accidental operation of the turbine while personnel are in and around the turbine. The circuit is nominally 24V and drops to 0V when any of the sensors on it break the circuit.

6.3.2.1. Stop inertial sensor

The inertial sensor on the stop circuit is a switch (S404) that opens in the presence of acceleration beyond a pre-set limit. The sensor is mounted to the main bed frame under the generator. The purpose of the sensor is to place the turbine into STOP if excessive vibration is detected. This is a test to verify that the inertial sensor activates the stop circuit when opened, the vibration level has been preset to a value of 0.3g prior to being installed by a third party group and is not tested in this procedure.

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Nacelle (1) Control room (1)	STOP	On	On	Off	On
Wind speeds below 10 m/s.					
Radio communication exists between all participants.					

Required signals

- Voltage across servo K933A
- Control room stop circuit inertial sensor alarm

Procedure

1. Control room: Place turbine in STOP.
2. Nacelle: Attach digital multi-meter leads to servo K933A terminals 13 and 14, located in nacelle cabinet.
3. Nacelle: Visually verify that voltage across servo K933A terminals 13 and 14 is at nominally 24V.
4. Nacelle: Remove round cover on top of inertial sensor.
5. Nacelle: Manually trip sensor by opening the magnetic contact.
6. Nacelle: Visually verify that voltage across servo K933A terminals drops to nominally 0V.
7. Control room: Visually verify that the stop circuit inertial sensor alarm is registered by controller.
8. Nacelle: Replace cover on inertial sensor and reset it by pushing button on case.
9. Nacelle: Visually verify that voltage across servo K933A terminals rises to nominally 24V.

Success criteria

Success criteria	Y/N
Voltage across servo K933A terminals drops from nominally 24V to nominally 0V when stop circuit inertial sensor is tripped.	
Controller Stop alarm is recorded when inertial sensor is tripped	
Voltage across servo K933A terminals rises from nominally 0V to nominally 24V when stop circuit inertial sensor is reset.	

6.3.2.2. Stop switch

This test is to verify that the stop switch for the turbine de-energizes the 24 VDC stop circuit when turned to OFF. The stop switches are located inside the control building on the east wall in a cabinet labeled "Service Stop". The purpose of the stop switches is to allow for the turbine to be placed in STOP manually outside of the controller.

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Nacelle (1) Control room (1)	STOP	On	On	Off	On
Wind speeds below 10 m/s.					
Radio communication exists between all participants.					

Required signals

- Voltage across servo K933A
- Controller Stop circuit activation alarm

Procedure

1. Control room: Ensure stop switch for turbine being tested is turned to ON.
2. Control room: Place turbine in STOP.
3. Nacelle: Attach digital multimeter leads to servo K933A, located in nacelle control cabinet.
4. Nacelle: Visually verify that voltage across servo K933A terminals is at nominally 24V.
5. Control room: Turn stop for turbine being tested to OFF.
6. Nacelle: Visually verify that voltage across servo K933A terminals drops to nominally 0V.
7. Control room: Visually verify that Stop alarm is registered by controller.

Success criteria

Success criteria	Y/N
Voltage across servo K933A terminals 13 and 14 drops from nominally 24V to nominally 0V when stop switch is turned from ON to OFF.	
Controller Stop alarm is recorded when stop switch is turned from ON to OFF.	
Voltage across servo K933A terminals 13 and 14 rises from nominally 0V to nominally	

24V when stop switch is turned from OFF to ON.	

6.3.2.3. Cable twist

The cable twist sensor on the Stop circuit monitors for excessive cable twist that is not detected by the controller. Relay S108 monitors the voltage from three signals within the cable twist sensor. When all signals are nominally 0V, the relay opens, causing the turbine to go to STOP. This is a test to verify that the cable twist sensor for the turbine de-energizes the stop circuit in the presence of excessive twist.

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Nacelle (1) Control room (1)	STOP	On	On	On	On
Wind speeds below 10 m/s.					
Radio communication exists between all participants.					

Required signals

- S102, S103, S104 Signals within controller
- Controller Stop circuit activation alarm

Procedure

1. Control room: Disable yaw alarms in controller based upon the S102, S103, S104 sensors.
2. Control room: Set yaw limit from encoder to +/-3.25 twists
3. Control room: Ensure that turbine is at 0° yaw position.
4. Control room: Place turbine in PAUSE.
5. Control room: Place turbine into yaw service mode.
6. Control room: Yaw turbine clockwise approximately 3 times (1080°) or until stop circuit is activated.
7. Control room: Verify controller has registered an alarm for stop circuit activation.
8. Nacelle: Climb turbine and install twist sensor relay jumper across terminals of relay S108.
9. Nacelle: Climb down from nacelle, turn on F33A, and go to control room.
10. Control room: Clear alarms.
11. Control room: Place turbine in PAUSE.
12. Control room: Place turbine into yaw service mode.
13. Control room: Yaw turbine to 0^o yaw position. **Be positive to yaw turbine COUNTER-CLOCKWISE as to not over twist the cables further!**
14. Nacelle: Climb turbine to remove yaw relay jumper.
15. Control room: Yaw turbine counter-clockwise approximately 3 times (1080°) or until stop circuit is activated.
16. Control room: Verify controller has registered an alarm for stop circuit activation.

17. Nacelle: Climb turbine and install twist sensor relay jumper across terminals of relay S108.
18. Nacelle: Climb down from nacelle, turn on F33A, and go to control room.
19. Control room: Clear alarms.
20. Control room: Place turbine in pause.
21. Control room: Place turbine into yaw service mode.
22. Control room: Yaw turbine to 0^{o} yaw position. **Be positive to yaw turbine COUNTER-CLOCKWISE as to not over twist the cables further!**
23. Nacelle: Climb turbine to remove yaw relay jumper.
24. Control room: Re-enable yaw alarm in controller.
25. Control room: Place turbine into EMERGENCY
26. Nacelle: Stop acquiring data from K933A and save data file.
27. Nacelle: Climb down from turbine and go to control room.
28. Control room: Set yaw limit from encoder signal back to nominal.
29. Control room: Enable yaw alarms from S102, S103, S104 signals.

Success criteria

Success criteria	Y/N
Controller alarm for stop circuit activation is registered when yaw angle exceeds 1080°.	
Stop Circuit activated when S102, S103, and S104 all registered low.	

6.3.2.4. Test grid loss

The grid monitoring device activates the stop circuit by opening relay S15 in the presence of over voltage, under voltage, or incorrect grid frequency. Additionally, three uninterruptable power supplies (UPS) are installed in the turbine: one for the variable frequency (VFD) drive located in the drive building, one for the bottom controller located at the base of the turbine, and one for the nacelle controller located in the top controller cabinet.

Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Nacelle (1) Tower Base (1) VFD House (1) Control room (1)	STOP	On	On	Off	On
Wind speeds below 10 m/s.					
Radio communication exists between all participants.					

Required signals

- Voltage across relay K933A
- Controller grid loss alarm
- Time for VFD UPS to stop supplying power
- Time for bottom controller UPS to stop supplying power
- Time for top controller UPS to stop supplying power

Procedure

1. Control room: Place turbine in STOP.
2. Nacelle: Ensure that top controller UPS is fully charged.
3. Tower Base: Ensure that bottom controller UPS is fully charged.
4. VFD House: Ensure that VFD UPS is fully charged.
5. Nacelle: Attach digital multimeter leads to servo K933A terminals 13 and 14, located in nacelle cabinet.
6. Tower Base: Use proper PPE to open the Q8 and F30 breakers.
7. Nacelle: Verify that voltage across K933A terminals 13 and 14 drops from nominally 24 V to nominally 0V.
8. Control room: Verify that controller alarm is registered for stop circuit activation from grid monitoring system.
9. Tower Base: Start stopwatch.
10. Tower Base: Stop when bottom controller UPS lights indicate full discharge and record time.
11. VFD House: Start stopwatch.
12. VFD House: Stop when bottom controller UPS lights indicate full discharge and record time.
13. Nacelle: Remove digital multimeter leads from K933A and return to control room.
14. Tower and VFD: Return to control room.

Success criteria

Success criteria	Y/N
Voltage across servo K933A terminals 13 and 14 drops from nominally 24V to nominally 0V when grid loss event occurs.	
Controller alarm is registered for stop circuit activation from grid monitoring system	
Top controller UPS supplies power for 5 minutes	
Bottom controller UPS supplies power for 5 minutes	
VFD UPS supplies power for 5 minutes	

6.4. Phase I Run-in tests

All tests in this section are to be performed following installation of the blades to the rotor. The following preconditions must be in place prior to commencing all run-in tests:

- Rotor installed on turbine
- Rotor must be locked from rotation
- Approval granted from Wind Department manager to begin testing
- Component and Safety System tests have been completed (Sections 6.2-6.3)
- All safety/protection system have been verified as functional
- Data collection is up and running
- Blade angle measurement has been calibrated
- All Phase I tests assume the wind speed is below 10 m/s

6.4.1. Emergency pitch rate

This test is to verify that emergency blade feathering works correctly. During the test, the blades are pitched into the wind and emergency feathering is then initiated.

6.4.1.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	STOP	On	On	Off	On
Rotor pin is in					
Wind speeds are below 10 m/s					
Auto-yaw is disabled					
Turbine is nominally pointed into wind					

Required signals

- Wind_Speed
- Wind_Direction_Filtered
- Wind_Direction
- PitchActual
- PitchRef
- Gen_RPM
- Turbine_State_ID
- Y210 (Emergency pitch)
- Wind_Direction
- Wind_Direction_Filtered

6.4.1.2. Procedure

1. Control Room: Place the turbine in Pause.
2. Control Room: Enter Brake Service Mode.

3. Control Room: Apply brake.
4. Control Room: Yaw the turbine to wind_direction_filtered = 0°.
5. Veristand: Begin logging the data channels listed in Section 6.13.1.2.
6. Control Room: Enter pitch service mode.
7. Control Room: From the Pitch Service panel, press the Pitch Test “sin” button to start the test.
8. Control Room: When PitchActual is below 0°, press the E-stop button on GUI
9. Veristand: Wait until the blades have stopped pitching and stop logging.
10. Repeat Steps 1-7 twice for pushing the E-Stop button on GUI, and three more times for pushing the Stop button on GUI.

6.4.1.3. Success criteria

Success criteria	Y/N
Time to accelerate to 20°/sec once Emergency Pitch is activated	
Emergency pitch rate is nominal (20°/sec ±1°) when E-Stop is pressed	
Emergency pitch rate is nominal (20°/sec ±1°) when Stop is pressed	

6.4.2. Emergency pitching with reduced hydraulic pressure

This test verifies that the blades can pitch from approximately negative end stop to positive end stop with hydraulic pressure reduced to 50 bar. This is to ensure that when issuing the pressure alarm, the blades will pitch out.

6.4.2.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	STOP	On	On	On	On
Rotor pin is in					
Wind speeds are below 10 m/s					
Auto-yaw is disabled					

6.4.2.2. Required signals

- Wind_Speed
- Wind_Direction_Filtered
- Wind_Direction
- PitchActual
- Gen_RPM
- Turbine_State_ID
- HydrPressure
- ProdCtrlState

6.4.2.3. Procedure

1. Control Room: Place the turbine in PAUSE.
2. Veristand: Begin logging the data channels listed in Section 6.13.6.2.

3. Control Room: Manually pitch the blades to 3°.
4. Control Room: Turn the hydraulic pump off.
5. Control Room: Reduce the hydraulic pressure to below 50 bar.
6. Control Room: Turn the hydraulic pump to auto.
7. Control Room: Exit hydraulic pump service mode.
8. Control Room: Wait until the blades have stopped pitching.
9. Veristand: Stop logging.

6.4.2.4. Success criteria

Success criteria	Y/N
Verify that the blades have pitched out with less than 50 bar hydraulic pressure	

6.4.3. Pitch response

The purpose of this test is to identify the stability margin for the pitch servo and retune the pitch servo to optimal performance – and thereby maximize the stability margin of a full-load controller.

6.4.3.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	STOP	On	On	Off	On
Rotor pin is in					
Wind speeds are below 10 m/s					
Auto-yaw is disabled					

6.4.3.2. Required signals

- Wind_Speed
- Wind_Direction_Filtered
- Wind_Direction
- PitchActual
- PitchRef
- Gen_RPM
- Turbine_State_ID
- Y210 (Emergency pitch)
- Wind_Direction
- Wind_Direction_Filtered

6.4.3.3. Procedure

1. Control Room: Place the turbine in PAUSE.
2. Control Room: Note the following parameter values:
    - PitchServoGainNegative
    - PitchServoGainPositive

3. Veristand: Begin logging the data channels listed in Section 6.13.2.2.
4. Control Room: Enter pitch service mode.
5. Control Room: From the Pitch Service panel, press the Pitch Test “sin” button to start the test.
6. Control Room: Wait 4 complete sine test periods (240 seconds)
7. Control Room: Stop the pitch sine test.
8. Veristand: Wait until the blades have stopped pitching and stop logging.
9. Control Room: Repeat Steps 2-8, increasing the controller gain until marginal instability is observed (i.e., the pitch system is limit-cycling or there is a jittery oscillation on top of the sine curve). The gain should not go above 2* default setting (e.g., 2*40=80).
10. Control Room: When instability is observed, note the following parameters:
    - PitchServoGainNegative
    - PitchServoGainPositive
11. Control Room: Modify the parameters in the controller to 0.5* the parameters at the first sign of instability.

6.4.3.4. Success criteria

Success criteria		Y/N
Identify instability point and select appropriate pitch servo gains.		
PitchServoGainNegative initial reading / instability readings:		
PitchServoGainPositive initial reading / instability readings:		

6.4.4. Yaw upwind control functionality

This test verifies that the turbine is able to yaw upwind in both directions when the turbine is outside the allowed yaw error (±18°).

6.4.4.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	STOP	On	On	On	On
Wind speeds at least 4 m/s					
Wind speeds are below 10 m/s					
Rotor pin is in					

6.4.4.2. Required signals

- Wind_Speed
- Wind_Direction_Filtered
- Wind_Direction
- PitchActual
- Gen_RPM
- Yaw_control
- Yaw_action
- Turbine_State_ID

6.4.4.3. Procedure

1. Control Room: Place the turbine in PAUSE.
2. Veristand: Begin logging the data channels
3. Control Room: Yaw manually clockwise (CW) such that the relative wind direction is in mean approximately 19°.
4. Control Room: Turn off yaw manual service.
5. Control Room: Verify that the turbine yaws upwind within 100 seconds and that the yaw is the shortest path to upwind (i.e., CCW direction).
6. Veristand: Stop logging.
7. Veristand: Restart logging of the data channels listed in Section 6.13.3.2.
8. Control Room: Yaw manually counterclockwise (CCW) such that the relative wind direction is in mean approximately 19°.
9. Control Room: Verify that the turbine yaws upwind within 100 seconds and that the yaw is the shortest path to upwind (i.e., CW direction).
10. Veristand: Stop logging.

6.4.4.4. Success criteria

Success criteria	Y/N
Turbine returns to upwind within 100 seconds and takes the shortest path	

6.4.5. Yaw upwind from back wind position

This test verifies that the turbine is able to yaw upwind when it begins in the "back wind" position (approximately 180° the prevailing mean wind direction).

6.4.5.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	STOP	On	On	On	On
Wind speeds at least 4 m/s					
Wind speeds are below 10 m/s					
Rotor pin is in					

6.4.5.2. Required signals

- Wind_Speed
- Wind_Direction_Filtered
- Wind_Direction
- PitchActual
- Gen_RPM
- Yaw_control
- Yaw_action
- Turbine_State_ID

6.4.5.3. Procedure

1. Control Room: Place the turbine in PAUSE.
2. Veristand: Begin logging the data channels listed in Section 6.13.4.2.
3. Control Room: Yaw manually clockwise (CW) to a position relative to mean wind direction of approximately -180°.
4. Control Room: Verify that the turbine yaws upwind.
5. Veristand: Stop logging.

6.4.5.4. Success criteria

Success criteria	Y/N
Verify that the absolute value of Wind_Direction_Filtered decreases towards 0	

6.4.6. Yaw untwist zero position

This test verifies that the parameter UnTwistTime (635 seconds) is set correctly.

Note: UnTwistTime is the duration of time that the turbine will continue to yaw from when the either untwist sensor (S102 or S103) changes from 1 to 0 and the turbine reaches a zero twist position. (This time was estimated from the yaw rate but can be tuned for the turbine.)

6.4.6.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	STOP	On	On	On	On
Wind speed is below 3 m/s (parameter can be increased if required)					
Rotor pin is in					

6.4.6.2. Required signals

- Wind_Speed
- S1301_10s_Ave (wind_speed 10-second average)
- Wind_Direction
- Wind_Direction_Filtered
- Yaw_control
- Yaw_action
- Turbine_State_ID
- S102
- S103
- S104

6.4.6.3. Procedure

1. Control Room: Place the turbine in PAUSE.
2. Veristand: Begin logging the data channels listed in Section 6.13.5.2.
3. Control Room: Place the turbine in yaw service mode.

4. Control Room: Manually yaw the turbine clockwise (CW) until sensor S102=1.
5. Control Room: Stop yawing.
6. Control Room: Exit yaw service mode.
7. Control Room: Wait for the turbine to commence short-untwist and wait for short-untwist to complete.
8. Veristand: Stop logging.
9. Control Room: Check that the turbine stops yawing at or close to the point of zero twist. If it does not, recalculate a value for UnTwistTime, substitute the value in, and repeat Steps 1-9.

6.4.6.4. Success criteria

Success criteria	Y/N
Verify that UnTwistTime is sufficiently accurate	

6.4.7. Switch from STOP to PAUSE turbine state

This test verifies that there is sufficient hydraulic pressure in the accumulators when changing from the Stop turbine state to the Pause turbine states.

6.4.7.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	STOP	On	On	On	On
Rotor pin is in					
Wind Speeds are less than 10 m/s					

6.4.7.2. Required signals

- Wind_Speed
- Turbine_State_ID
- HydrPressure
- PitchActual
- PitchRef
- ProdCtrlState

6.4.7.3. Procedure

1. Control Room: Place the turbine in STOP.
2. Control Room: Drain the hydraulic pressure to below 50 bar.
3. Veristand: Begin logging the data channels.
4. Control Room: Place the turbine in PAUSE.
5. Control Room: Manually pitch the blades to 45°.
6. Control Room: Wait 600 seconds after the blades have pitched, then place the turbine in Stop.
7. Veristand: Stop logging.
8. Repeat Steps 1-7, twice.

6.4.7.4. Success criteria

Success criteria	Y/N
As the turbine switches from STOP to PAUSE, the HydrPressure>= 75 bar	
Blades pitch from lock position (~ 90º) to the idle position (45º)	
Turbine steps from Stop to Pause and vice versa without alarms or warnings	

Note: Management review is required to move on to Phase II of commissioning.

6.5. Phase II Run-In Tests

6.5.1. Speed control with disconnected generator (step test)

This test verifies the performance of the speed controller when the generator is not connected to the grid. To test the performance of the speed controller, it is necessary that the wind speed is greater than 5 m/s.

Note: Because the turbine is disconnected from the grid during this test, there is a chance of gearbox torque reversals. If the gears start to knock loudly over a period of 10 seconds, the test must be aborted. Furthermore, the speed controller may become unstable if the tuning is bad. It is imperative that the rpm limit is observed during this test.

Note: There is no ramp into the sine or step tests; therefore a step might occur.

6.5.1.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	On	On
Wind speed greater than 5 m/s and less than 10 m/s					
Generator is disconnected					

6.5.1.2. Required signals

- Gen_RPM
- Turbine_State_ID
- Wind_Speed
- ProdCtrlState
- PitchActual
- PitchRef
- B400_RPM (rotor rpm)
- VC4_FB (filtered signal at drivetrain resonance frequency)

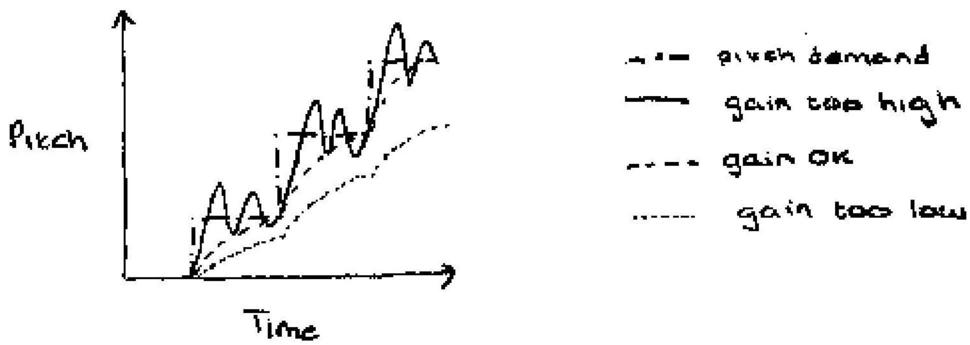
6.5.1.3. Procedure

1. Veristand: Begin logging the data channels listed in Section 6.13.8.2.
2. Control Room: Commence the generator step test.
3. Let the turbine run for 3 minutes.
4. Repeat Steps 2-3, twice, to obtain three stepped sequences.
5. Veristand: Stop logging.

6.5.1.4. Success criteria

Success criteria	Y/N
Pitch stroke rate not saturated	
Settling time < step time	

No excessive overshoot	
Check for oscillations in the rotor speed at the drivetrain natural frequency and estimate their amplitude	Est. amplitude:



Note: After completing this test, contact a control engineer to review the data before proceeding with any further start up tests.

6.5.2. Speed control with disconnected generator (sine test)

This test verifies the ability of the controller to control rotor speed with the pitch system over the full range of speed control.

Note: Because the turbine is disconnected from the grid during this test, there is a chance of gearbox torque reversals. If the gears start to knock loudly over a period of 10 second, the test must be aborted. Furthermore, the speed controller may become unstable if the tuning is bad. It is imperative that the rpm limit is observed during this test.

6.5.2.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	On	On
Wind speed less than 10 m/s					
Generator is disconnected					

6.5.2.2. Required signals

- Gen_RPM
- Turbine_State_ID
- Wind_Speed
- ProdCtrlState
- PitchActual
- PitchRef
- B400_RPM (rotor rpm)
- VC4_FB (filtered signal at drivetrain resonance frequency)

6.5.2.3. Procedure

1. Veristand: Begin logging the data channels listed in Section 6.13.9.2.
2. Control Room: Commence the generator sine test.
3. Let the turbine run for 3 minutes.
4. Veristand: Stop logging.

6.5.2.4. Success criteria

Success criteria		Y/N
Pitch stroke rate not saturated		
Check for oscillations in the rotor speed at the drivetrain natural frequency and estimate their amplitude	Est. amplitude:	

Note: After completing this test, contact a control engineer to review the data before proceeding with any further start up tests

6.5.3. Emergency stop during motoring

This test verifies acceptable stop behavior with respect to pitch rate and over speed.

6.5.3.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (2)	PAUSE	On	On	On	On
Wind speed is less than 5 m/s					

6.5.3.2. Required signals

- Wind_Speed
- PitchActual
- PitchRef
- Gen_RPM
- Turbine_State_ID
- Y210
- Y211
- ProdCtrlState

6.5.3.3. Procedure

1. Veristand: Begin logging the data channels listed in Section 6.13.10.2.
2. Control Room: Enter pitch service mode.
3. Control Room: Pitch blades to 30°.
4. Control Room: Enter Generator Service Mode.
5. Control Room: Through Drive Windows, motor turbine to 30 rpm.
6. Control Room: Push individual turbine E-Stop button
7. Wait for the turbine to stop.

8. Veristand: Stop logging.

6.5.3.4. Success criteria

Success criteria	Y/N
Emergency pitch rate is within 20±1°/second	
Brake is applied as soon as the Emergency Stop button is pressed	
Turbine comes to complete stop within XXs	

Note: After completing this test, contact a control engineer to review the data before proceeding with any further start up tests

6.5.4. Emergency stop during speed control

This test verifies acceptable stop behavior with respect to pitch rate and over speed.

6.5.4.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (2)	PAUSE	On	On	On	On
Wind speed greater than 5 m/s and less than 8 m/s					

6.5.4.2. Required signals

- Wind_Speed
- PitchActual
- PitchRef
- Gen_RPM
- Turbine_State_ID
- Y210
- Y211
- ProdCtrlState

6.5.4.3. Procedure

9. Control Room: Start the turbine.
10. Veristand: Begin logging the data channels listed in Section 6.13.10.2.
11. Control Room: Wait for the generator speed to stabilize.
12. Control Room: Press the individual turbine Emergency Stop button.
13. Wait for the turbine to stop.
14. Veristand: Stop logging.

6.5.4.4. Success criteria

Success criteria	Y/N
Emergency pitch rate is within 20±1°/second	

Brake is applied as soon as the Emergency Stop button is pressed	
Turbine comes to complete stop within XXs	

Note: After completing this test, contact a control engineer to review the data before proceeding with any further start up tests.

6.5.5. Switch from PAUSE to RUN and RUN to PAUSE

This test verifies normal behavior when switching from PAUSE to RUN and from RUN to PAUSE.

6.5.5.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	On	On
Test must be run first in partial load and then in full-load conditions					
Wind speed greater than 5 m/s and less than 10 m/s					

6.5.5.2. Required signals

- Wind_Speed
- ProdCtrlState
- Gen_RPM
- Turbine_State_ID
- Grid power
- Power ref
- PitchActual
- PitchRef
- Yaw error
- Torque demand
- Torque
- B400_RPM (rotor rpm)
- VC4_FB (filtered signal at drivetrain resonance frequency)

6.5.5.3. Procedure

Complete Steps 1-6 in partial-load wind conditions (greater than 5 m/s and less than 10 m/s):

1. Veristand: Begin logging the data channels listed in Section 6.13.11.2.
2. Control Room: Start the turbine and let it run for ~1 minute (and less than 2 minutes).
3. Control Room: Place the turbine in Pause and wait for the blades to stop pitching and the generator speed to decrease to 0 rpm (approximately 2 minutes).
4. Repeat Steps 2-3, three times.
5. Veristand: Stop logging.
6. Control Room: Review the drive train damping. If oscillations are noted, contact the control engineer for tuning instructions.

Complete Steps 7-12 with the generator connected to the grid:

7. Veristand: Begin logging the data channels listed in Section 6.13.11.2.
8. Control Room: Begin the generator step test.
9. Let the turbine run for 2 minutes.
10. Veristand: Stop logging
11. Repeat Steps 7-10.
12. Control Room: Review the drive train damping. If oscillations are noted, contact the control engineer for tuning instructions.

6.5.5.4. Success criteria

Success criteria	Y/N
Turbine steps from PAUSE to RUN and vice versa without alarms or warnings	

6.5.6. Turbine stop tests

The purpose of these tests is to verify that the turbine stop functions are performing as expected.

6.5.6.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1)	PAUSE	On	On	On	On
Full load: Wind speeds greater than 11 m/s					

6.5.6.2. Required signals

- Wind_Speed
- Wind_Direction_Filtered
- Wind_Direction
- PitchActual
- PitchRef
- Gen_RPM
- Turbine_State_ID
- Y210 (Emergency pitch)
- Y211
- ProdCtrlState

6.5.6.3. Procedure

Emergency stop:

1. Veristand: Begin logging the data channels listed in Section 6.13.12.2.
2. Control Room: Start the turbine.
3. Control Building: After 1 minute of production, push the individual Emergency Stop button in the control building.
4. Control Room: Wait for the turbine to stop, with blades in the positive end stop.
5. Veristand: Stop logging.

Protection stop:

1. Control Room: Place the turbine in PAUSE.

2. Veristand: Begin logging the data channels listed in Section 6.13.12.2.
3. Control Room: Place the turbine in RUN.
4. Control Room: After 1 minute of production, stop the turbine using the GUI
5. Veristand: Stop logging

6.5.6.4. Success criteria

Success criteria – Emergency stop	Y/N
Emergency pitch rate is within 20±1°/second	
Generator speed reaches 0 rpm within 30 seconds	
Maximum generator speed is less than 1331 rpm	
Brake is applied as soon as the Emergency Stop button is pressed	

Success criteria –Protection stop	Y/N
Emergency pitch rate is within 20±1°/second	
Generator speed reaches 0 rpm within 30 seconds	
Maximum generator speed is less than 1331 rpm	
Brake should not be applied	

6.5.7. Yaw error detection

This test verifies that the turbine will automatically stop if there is a large yaw error.

6.5.7.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1) Tower base (1)	STOP	On	On	On	On
Wind speed greater than 4 m/s					

6.5.7.2. Required signals

- Wind_Speed
- Wind_Direction_Filtered
- Wind_Direction
- PitchActual
- PitchRef
- Gen_RPM
- Turbine_State_ID
- Y210 (emergency pitch)
- Y211
- ProdCtrlState

6.5.7.3. Procedure

1. Control Room: Place the turbine in PAUSE.

2. Veristand: Update parameters as follows:
   - MaxYawErrorDeg = 10º
   - MinYawErrWindSpeed = 4 m/s
3. Veristand: Begin logging the data channels listed
4. Control Room: Yaw the turbine to a relative wind direction of 10º.
5. Control Room: Place the turbine in RUN.
6. Wait for the turbine to shut down.
7. Veristand: Stop logging.
8. Control Room: Reset the parameters to original settings:
   - MaxYawErrorDeg = 25º
   - MinYawErrWindSpeed = 15 m/s

6.5.7.4. Success criteria

Success criteria	Y/N
Turbine stops when Wind_Direction_Filtered > 10 º	

6.6. Phase III Run-In Tests

6.6.1. Generator Stop Test (with regenerative power)

6.6.1.1. 6.13.15.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (2)	PAUSE	On	On	Off	On

6.6.1.2. Required signals

- Generator speed
- Generator torque

6.6.1.3. Procedure

1. Control room (1): Sit or stand next to emergency stop button
2. Control room (2): Configure generator stop to have a stopping time of 20s, maximum stopping torque of 1600 Nm, and maximum regenerative power of 195kW
3. Control room (2): Place turbine in PAUSE and enter generator service mode
4. Control room (2): Start Drive Windows
5. Control room (2): Motor turbine to 45 rpm
6. Control room (2): Place turbine in STOP
7. Control room (2): Once turbine comes to a stop, analyze data file and record stopping time and stopping torque.
8. Control room (2): If signals are within limits, repeat steps 2-7 with stopping times of 10s, and 5s, waiting 5 min between tests. Leave stopping torque at 1600 Nm.
9. Control room (2): If signals are within limits, repeat steps 2-7 with stopping times of 20s, 10s, and 5s, waiting 5 min between tests. Raise stopping torque at 2400 Nm.

6.6.1.4. Success criteria

Success criteria	20s Y/N	10s Y/N	5s Y/N
Generator torque does not exceed 1600 Nm for stopping times of 30s, 20s, 10s, and 5s			
Generator torque does not exceed 2400 Nm for stopping times of 30s, 20s, 10s, and 5s			
	20s	10s	5s
Stopping time (at 1600 Nm setting)			
Maximum stopping torque (at 1600 Nm setting)			
Stopping time (at 2400 Nm setting)			
Maximum stopping torque (at 2400 Nm setting)			

6.6.2. Generator Stop Test (without regenerative power)

6.6.2.1. Initial conditions

Technician location(s)	Turbine	Shaft brake	Q8 breaker	Auto yaw	ACS800
Control room (2)	PAUSE	Off	On	Off	On

6.6.2.2. Required signals

- Generator speed
- Generator torque

6.6.2.3. Procedure

1. Control room (1): Sit or stand next to emergency stop button
2. Control room (2): Configure generator stop to have a stopping time of 20s, maximum stopping torque of 1600 Nm, and maximum regenerative power of 0 kW
3. Control room (2): Place turbine in PAUSE and enter generator service mode
4. Control room (2): Start Drive Windows
5. Control room (2): Motor turbine to 45 rpm
6. Control room (2): Place turbine in STOP
7. Control room (2): Once turbine comes to a stop, analyze data file and record stopping time and stopping torque.
8. Control room (2): If signals are within limits, repeat steps 2-7 with stopping times of 10s, and 5s, waiting 5 min between tests. Leave stopping torque at 1600 Nm.
9. Control room (2): If signals are within limits, repeat steps 2-7 with stopping times of 20s, 10s, and 5s, waiting 5 min between tests. Raise stopping torque at 2400 Nm.

6.6.2.4. Success criteria

Success criteria	20s Y/N	10s Y/N	5s Y/N
Generator torque does not exceed 1600 Nm for stopping times of 30s, 20s, 10s, and 5s			
Generator torque does not exceed 2400 Nm for stopping times of 30s, 20s, 10s, and 5s			
	20s	10s	5s
Stopping time (at 1600 Nm setting)			
Maximum stopping torque (at 1600 Nm setting)			
Stopping time (at 2400 Nm setting)			
Maximum stopping torque (at 2400 Nm setting)			

6.6.3. Partial load operation

This test verifies that the turbine operates normally in the partial load region of the production controller.

6.6.3.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1) Tower base (1)	PAUSE	On	On	On	On
Wind speed greater than 4 m/s and less than 11 m/s					

6.6.3.2. Required signals

- Speed setpoint
- Measured speed
- Torque setpoint
- Pitch demand
- Actual Pitch
- Yaw angle
- Wind speed
- ProdCtrlState

6.6.3.3. Procedure

1. Control Room: Place the turbine in RUN.
2. Veristand: Begin logging the data channels listed.
3. Control Room: After 10 minutes, stop the turbine.
4. Veristand: Stop logging.
5. Ask a controls engineer to review and approve the time track. When further operation has been approved, command the turbine to RUN.

Note: This review must be conducted by the Wind Energy Technology Staff at SNL

6. Veristand: Begin logging the data channels listed.
7. Control Room: After 2 hours, stop logging.

6.6.3.4. Success criteria

Success criteria	Y/N
Review the torque speed plot and data to ensure that all systems remained nominal	

Note: Manager Review is required before proceeding to Full Load Operation in wind speeds >10m/s

6.6.4. Switch from PAUSE to RUN and RUN to PAUSE Full Load

This test verifies normal behavior when switching from PAUSE to RUN and from RUN to PAUSE in wind speeds >10m/s and below 15 m/s.

6.6.4.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1) Tower base (1)	PAUSE	On	On	On	On
Wind speeds 11-15 m/s					

6.6.4.2. Required signals

- Wind_Speed
- ProdCtrlState
- Gen_RPM
- Turbine_State_ID
- Grid power
- Power ref
- PitchActual
- PitchRef
- Yaw error
- Torque demand
- Torque
- B400_RPM (rotor rpm)
- VC4_FB (filtered signal at drivetrain resonance frequency)

6.6.4.3. Procedure

1. Veristand: Begin logging the data channels listed
2. Control Room: Start the turbine and let it run for ~1 minute (and less than 2 minutes).
3. Control Room: Place the turbine in Pause and wait for the blades to stop pitching and the generator speed to decrease to 0 rpm (approximately 2 minutes).
4. Veristand: Stop logging.
5. Repeat Steps 13-16, three times.
6. Control Room: Review the drive train damping. If oscillations are noted, contact the control engineer for tuning instructions.

6.6.4.4. Success criteria

Success criteria	Y/N

Turbine steps from PAUSE to RUN and vice versa without alarms or warnings	

6.6.5. Full load operation

This test verifies the turbine will function properly under full load operation conditions (wind speeds > 11m/s). This test should be conducted with mean wind speeds of 11 to 15 m/s.

6.6.5.1. Initial conditions

Technician Location(s)	Turbine State	Q8 (Generator)	F30 (Controller)	F33A (Yaw)	F33B (Hydraulics)
Control room (1) Tower base (1)	PAUSE	On	On	On	On
Wind speeds 11-15 m/s					

6.6.5.2. Required signals

- Speed setpoint
- Measured speed
- Torque setpoint
- Pitch demand
- Actual Pitch
- Yaw angle
- Wind speed
- ProdCtrlState

6.6.5.3. Procedure

1. Control Room: Place the turbine in RUN.
2. Veristand: Begin logging the data channels listed in Section 6.13.15.2.
3. Control Room: After 10 minutes, stop the turbine.
4. Veristand: Stop logging.
5. Ask a controls engineer to review and approve the time track. When further operation has been approved, command the turbine to RUN.
6. Veristand: Begin logging the data channels listed in Section 6.13.14.2.
7. Control Room: After 2 hours, stop logging.

6.6.5.4. Success criteria

Success criteria	Y/N
No significant oscillations in generator speed around the tower natural frequency	
Turbine has been in upwind direction during entire time trace	

Note: There is very little drivetrain damping in the system, so have a vibration control. The vibration control takes the rotor speed and puts it through filter to get resonant frequency (2.7

Hz). The drivetrain proportional controller is switched off by default. Without testing we do not know what gain to put in. The units of gain are the percent of torque per rev per minute variation of drive train speed. Initial Gain = 0

6.7. Final pre-operation checks

Before leaving the nacelle prior to normal operation, check the following systems for any external leakages:

- Cooling system
- Gear oil system
- Hydraulics

Veristand: Enable automatic yawing by changing AutoYawActive from 0 to 1.

6.8. Appendix A – Testing Logs

Notes for testing:

- Store all data files created during testing on main control computer used for testing under a folder with the specified date. Within that folder create a “read me.txt” file that describes the date, tests performed, technicians present, and any relevant notes based upon the test.
- A copy of the completed test logs performed shall be maintained by the facility supervisor and shall include all of the logs and signatures for completed tests by the lead technician as well as a spreadsheet containing all personnel involved with dates worked on the project.

Personnel	Dates
Lead:	

6.2 Component Tests

6.2.1 Power System Tests

Nacelle auxiliary power

Success criteria	Y	N
All controllers have power		
All network equipment has power		
Hydraulic contactors have power		
Yaw motors have power		
Cooling motors have power		

Test network connectivity

Success criteria	Y	N
IP address of the main controller responds to a “ping” command		
NI Max sees the main controller on the network		
Veristand successfully deploys		
Wind speed is live updating in the turbine user interface		

Test uninterruptible power supply

Success criteria	Y	N
Did connectivity to the turbine remain for 5 minutes		

Technician Name: Date Complete:

6.2.2 ABB Variable Frequency Drive Communication

ABB drive communication and main controller

Success criteria	Y	N
Verify that the parameters listed in the ACS800 FS (0037-0933) have been correctly uploaded to the turbine		
Verify that the error (FF51: Fault on line side converter) is displayed in the GUI after manually changing the turbine state to Stop, then Pause, by pressing the “Set State” buttons.		

Technician Name: Date Complete:

6.2.3 Test Remote Turbine E-Stop Buttons

Success criteria	Individual Turbine Y/N		Inside Master Y/N		Outside Master Y/N	
Voltage across relay K932A terminals 13 and 14 drops from nominally 24V to nominally 0V when each remote E-Stop button (inside individual, inside master, outside master) is pressed.						
Voltage across relay K903A drops from nominally 24V to nominally 0V when each remote E-Stop button is pressed.						
Controller E-Stop alarm is recorded when each remote E-Stop button (inside individual, inside master, outside master) is pressed.						
Voltage across relay K932A terminals 13 and 14 rises from nominally 0V to nominally 24V when each remote E-Stop button (inside individual, inside master, outside master) is reset and turbine is placed in STOP.						
Voltage across relay K903A rises from nominally 0V to nominally 24V when each remote E-Stop button (inside individual, inside master, outside master) is reset and turbine is placed in STOP.						

Technician Name: Date Complete:

6.2.4 Test Turbine E-Stop Buttons

Success criteria	Tower Base Y/N		Yaw Deck Y/N		Gearbox Y/N		Nacelle Controller Y/N	
Voltage across relay K932A terminals 13 and 14 terminals 13 and 14 drops from nominally 24V to nominally 0V								

when each turbine E-Stop button (tower base, yaw deck, gearbox, top controller) is pressed								
Controller E-Stop alarm is recorded when each turbine E-Stop button (tower base, yaw deck, gearbox, top controller) is pressed								
Voltage across relay K932A terminals 13 and 14 rises from nominally 0V to nominally 24V when each E-Stop button (tower base, yaw deck, gearbox, and top controller) is reset and turbine is placed in STOP.								

Technician Name: Date Complete:

6.2.5 Hydraulic Pressure Test

Success criteria	Y	N
Verify that the hydraulic pressure increases when hydraulic pump automatic mode is enabled.		
No leaks are visible in hydraulic system.		

Technician Name: Date Complete:

6.2.6 Shaft Brake Test

Success criteria	Y	N
Physical confirmation that shaft brake applies and releases when commanded.		

Technician Name: Date Complete:

6.2.7 Pitch System Tests

Pitch position

Success criteria	Test 1	Test 2	Test 3
Negative end stop voltages are nominal (0.040V ±0.020V)			
Positive end stop voltages are nominal (9.970V ±0.02V)			

Positive offset

Success criteria	Velocity	Y	N

Pitch velocity is nominal (-0.05°/sec, ±0.03°/sec)			

Negative offset

Success criteria	Velocity	Y	N
Pitch velocity is nominal (-0.05°/sec, ±0.03°/sec)			

Positive flow

Success criteria	Velocity	Y	N
Pitch velocity is nominal (+8.5°/sec, ±1.0°/sec)			

Negative flow

Success criteria	Velocity	Y	N
Pitch velocity is nominal (-9.5°/sec, ±1.0°/sec)			

Sine test

Success criteria	Y	N
Steady-state deviation for Sine Test is nominal (±0.2°)		

Step test

Success criteria	Y	N
Steady-state deviation for Step Test is nominal (±0.2°)		

Technician Name: Date Complete:

6.2.8 Yaw System Tests

Yaw direction

Success criteria	Y	N
Visual verification of yaw direction (CW and CCW)		

Yaw neutral cable position (south facing)

Success criteria	Y	N
Visual verification of yaw direction (CW and CCW)		

Yaw untwist

Success criteria	Recorded position
Yaw start position:	
Short untwist S102 CW sensor on position:	
Long untwist S104 CW sensor on position:	
Short untwist S103 CCW sensor on position:	
Long untwist S104 CCW sensor on position:	

Yaw encoder sensor test and calibration

Success criteria	Y	N

Technician Name: Date Complete:

6.2.9 Rotation System Tests

Gear oil cooler

Success criteria	Y	N
Visual verification (camera) that nacelle fan/cooler turns on and off		
GUI verification that nacelle fan/cooler turns on and off		

CC Jensen motor

Success criteria	Y	N
Visual verification (camera) that the gear oil filter turns on and off		
GUI verification that the gear oil filter turns on and off		

Generator cooler

Success criteria	Y	N
Visual verification (camera) that the generator cooler turns on and off		
GUI verification that the generator cooler turns on and off		

Temperature sensors

Success criteria	Y	N
Short circuit reading of all temperature sensors goes low		
All temperature sensor readings are nominal		

Technician Name: Date Complete:

6.2.10 Meteorological System Tests

Wind speed

Success criteria	Y	N
Wind speed readings nominal based on other available data		

Wind direction

Success criteria	Y	N
Wind direction readings nominal based on other available data		

Technician Name: Date Complete:

6.2.11 Generator Setup and Direction

Success criteria	Y	N
Via the camera feed, verify that the shaft rotates in the expected direction when commanded		

Technician Name: Date Complete:

6.3 Hardware Safety System Tests

6.3.1 Emergency Circuit Tests

Test controller watchdog

Success criteria	Railed High Y/N		Railed Low Y/N		Low Frequency Y/N	
Voltage across relay K932A terminals 13 and 14 terminals drops from nominally 24V to nominally 0V when low amplitude (watchdog railed “high”), high amplitude (watchdog railed “high”) and low frequency (watchdog ramp from normal to low frequency) is simulated						
Controller E-Stop alarm is recorded when low amplitude (watchdog railed “high”), high amplitude (watchdog railed “high”) and low frequency (watchdog ramp from normal to low frequency) is simulated						
Voltage across relay K932A terminals 13 and 14 terminals 13 and 14 rises from nominally 0V to nominally 24V when low amplitude (watchdog railed “high”), high amplitude (watchdog railed “high”) and low frequency (watchdog ramp from normal to low frequency) is simulated						
Controller Watchdog Trip Frequency						

Test brake thermistor

Success criteria	Y	N
Voltage across relay K932A terminals 13 and 14 drops from nominally 24V to nominally 0V when thermistor temperature is raised beyond 150°C		
Controller E-Stop alarm is recorded when thermistor temperature is raised beyond to 150°C		
Voltage across relay K932A terminals 13 and 14 terminals 13 and 14 drops from nominally 24V to nominally 0V when thermistor temperature falls to below 150°C		

Test OSPR and OSPS controllers

Success criteria	OSPR Y/N		OSPS Y/N	
Voltage across relay K932A terminals 13 and 14 drops from nominally 24V to nominally 0V when frequency of 12.3 Hz is simulated in OSPR and OSPS controllers				
Voltage across relay K932A terminals 13 and 14 remains at nominally 0V when frequency is ramped from 12.3 Hz to 0 Hz in OSPR and OSPS controllers				
Controller OSPR/OSPS alarm is recorded when frequency of 12.3 Hz is simulated in OSPR and OSPS controllers				
Voltage across relay K932A terminals 13 and 14 rises from nominally 0V to nominally 24V when OSPR and OSPS controllers are reset and turbine is place in STOP				

Test controller E-stop activation

Success criteria	Y	N
Voltage across relay K932A terminals 13 and 14 drops from nominally 24V to nominally 0V when controller E-Stop button is pressed		
Controller E-Stop alarm is recorded when controller E-Stop button is pressed		
Voltage across relay K932A terminals 13 and 14 rises from nominally 24V to nominally 0V when turbine is placed in STOP		

Test OSPR, OSPS, and HSS sensor, and turbine controller overspeed limits

Success criteria	Y/N
OSPR, OSPS, and HSS speed readings are consistent throughout entire speed range	
Controller has registered an overspeed alarm at 10% overspeed.	
Controller has registered an overspeed alarm at 15% overspeed.	
Controller has registered an overspeed alarm at 20% overspeed.	
OSPR controller lights indicate activation	
OSPS controller lights indicate activation	

Test turbine E-stop actuation

Success criteria	Y	N	Data
Visual verification of blades pitching to feather			-
E-stop alarm is generated by controller			-
Record time for blade pitching to begin after E-stop alarm		-	ms
Blade pitch rate is 18-21 degrees/second			°/s

Record brake system pressure dip period		-	ms
Record time for full brake pressure to be achieved after E-stop alarm		-	ms

Technician Name: Date Complete:

6.3.2 Stop Circuit Tests

Stop inertial sensor

Success criteria	Y	N
Voltage across servo K933A terminals drops from nominally 24V to nominally 0V when stop circuit inertial sensor is tripped.		
Controller Stop alarm is recorded when inertial sensor is tripped		
Voltage across servo K933A terminals rises from nominally 0V to nominally 24V when stop circuit inertial sensor is reset.		

Stop switch

Success criteria	Y	N
Voltage across servo K933A terminals 13 and 14 drops from nominally 24V to nominally 0V when stop switch is turned from ON to OFF.		
Controller Stop alarm is recorded when stop switch is turned from ON to OFF.		
Voltage across servo K933A terminals 13 and 14 rises from nominally 0V to nominally 24V when stop switch is turned from OFF to ON.		

Cable twist

Success criteria	Y	N
Controller alarm for stop circuit activation is registered when yaw angle exceeds 1080°.		
Stop Circuit activated when S102, S103, and S104 all registered low.		

Test grid loss

Success criteria	Y	N
Voltage across servo K933A terminals 13 and 14 drops from nominally 24V to nominally 0V when grid loss event occurs.		
Controller alarm is registered for stop circuit activation from grid monitoring system		
Top controller UPS supplies power for 5 minutes		
Bottom controller UPS supplies power for 5 minutes		
VFD UPS supplies power for 5 minutes		

Technician Name: Date Complete:

Sandia Wind Energy Technology Department Rotor Installation Review

Staff Present	Approval Y / N	Comments	Signature	Date

General Comments:

Manager Approval for Rotor Installation: **Date:**

6.4 Phase I Run-in Tests

6.4.1 Emergency Pitch Rate

Success criteria	Y	N
Pitch rate is nominal (20°/sec ±1°/sec) when E-Stop is pressed		
Pitch rate is nominal (20°/sec ±1°/sec) when Stop is pressed		
Time for pitch rate to reach nominal from when pitch is actuated.		

Technician Name: Date Complete:

6.4.2 Emergency Pitching with Reduced Hydraulic Pressure

Success criteria	Y	N
Verify that the blades have pitched out with less than 50 bar hydraulic pressure		

Technician Name: Date Complete:

6.4.3 Pitch Response

Success criteria		Y	N
Identify instability point and select appropriate pitch servo gains.			
PitchServoGainNegative initial reading / instability readings:			
PitchServoGainPositive initial reading / instability readings:			

Technician Name: Date Complete:

6.4.4 Yaw Upwind Control Functionality

Success criteria	Y	N
Turbine returns to upwind within 100 seconds and takes the shortest path		

Technician Name: Date Complete:

6.4.5 Yaw Upwind from Back Wind Position

Success criteria	Y	N
Verify that the absolute value of Wind_Direction_Filtered decreases towards 0		

Technician Name: Date Complete:

6.4.6 Yaw Untwist Zero Position

Success criteria	Y	N

Verify that UnTwistTime is sufficiently accurate		

Technician Name: Date Complete:

6.4.7 Switch from Stop to Pause Turbine State

Success criteria	Y	N
As the turbine switches from Stop to Pause, the HydrPressure>= 75 bar		
Blades pitch from lock position (~ 90º) to the idle position (45º)		
Turbine steps from Stop to Pause and vice versa without alarms or warnings		

Technician Name: Date Complete:

Sandia Wind Energy Technology Department Commissioning Phase I Review

Staff Present	Approval Y / N	Comments	Signature	Date

General Comments:

Manager Approval to Begin Phase II: **Date:**

6.5 Phase II Run-in Tests

6.5.1 Speed Control with Disconnected Generator (step test)

Success criteria	Y	N
Pitch stroke rate not saturated		
Settling time < step time		
No excessive overshoot		
Check for oscillations in the rotor speed at the drivetrain natural frequency and estimate their amplitude		Est. amplitude:

Technician Name: Date Complete:

6.5.2 Speed Control with Disconnected Generator (sine test)

Success criteria	Y	N
Pitch stroke rate not saturated		
Check for oscillations in the rotor speed at the drivetrain natural frequency and estimate their amplitude	Est. amplitude:	

Technician Name: Date Complete:

6.5.3 Emergency Stop during Motoring

Success criteria	Y	N
Emergency pitch rate is within 20±1°/second		
Brake is applied as soon as the Emergency Stop button is pressed		
Turbine comes to complete stop within XXs		

Technician Name: Date Complete:

6.5.4 Emergency Stop During Speed Control

Success criteria	Y	N
Emergency pitch rate is within 20±1°/second		
Brake is applied as soon as the Emergency Stop button is pressed		
Turbine comes to complete stop within XXs		

Technician Name: Date Complete:

6.5.5 Switch from PAUSE to RUN and RUN to PAUSE

Success criteria	Y	N
Turbine steps from Pause to Run and vice versa without alarms or warnings		

Technician Name: Date Complete:

6.5.6 Turbine Stop Tests

Success criteria – Emergency stop	Y	N
Emergency pitch rate is within 20±1º/second		
Generator speed reaches 0 rpm within 30 seconds		
Maximum generator speed is less than 1331 rpm		
Brake is applied as soon as the Emergency Stop button is pressed		

Technician Name: Date Complete:

6.5.7 Yaw Error Detection

Success criteria	Y	N
Turbine stops when Wind_Direction_Filtered < 10 º		

Technician Name: Date Complete:

Sandia Wind Energy Technology Department Commissioning Phase II Review

Staff Present	Approval Y / N	Comments	Signature	Date

General Comments:

Manager Approval: **Date:**

6.6 Stage III Run-in Tests

6.6.1 Generator Stop Test (with regenerative power)

Success criteria	20s Y/N		10s Y/N		5s Y/N	
Generator torque does not exceed 1600 Nm for stopping times of 30s, 20s, 10s, and 5s						
Generator torque does not exceed 2400 Nm for stopping times of 30s, 20s, 10s, and 5s						
	20s		10s		5s	
Stopping time (at 1600 Nm setting)						
Maximum stopping torque (at 1600 Nm setting)						
Stopping time (at 2400 Nm setting)						
Maximum stopping torque (at 2400 Nm setting)						

Technician Name: Date Complete:

6.6.2 Generator Stop Test (without regenerative power)

Success criteria	20s Y/N		10s Y/N		5s Y/N	
Generator torque does not exceed 1600 Nm for stopping times of 30s, 20s, 10s, and 5s						
Generator torque does not exceed 2400 Nm for stopping times of 30s, 20s, 10s, and 5s						
	20s		10s		5s	
Stopping time (at 1600 Nm setting)						
Maximum stopping torque (at 1600 Nm setting)						
Stopping time (at 2400 Nm setting)						
Maximum stopping torque (at 2400 Nm setting)						

Technician Name: Date Complete:

6.6.3 Partial Load Operation

Success criteria	Y	N
Review the torque speed plot and data to ensure that all systems remained nominal		

Technician Name: Date Complete:

Sandia Wind Energy Technology Staff Production Review

Staff Present	Approval Y / N	Comments	Signature	Date

General Comments:

6.6.4 Switch from PAUSE to RUN and RUN to PAUSE Full Load

Success criteria	Y	N
Turbine steps from Pause to Run and vice versa without alarms or warnings		

Technician Name: Date Complete:

6.6.5 Full Load Operation

Success criteria	Y	N
No significant oscillations in generator speed around the tower natural frequency		
Turbine has been in upwind direction during entire time trace		

Technician Name: Date Complete:

Sandia Wind Energy Technology Department Commissioning Review

Staff Present	Approval Y / N	Comments	Signature	Date

General Comments:

Manager Approval: **Date:**

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