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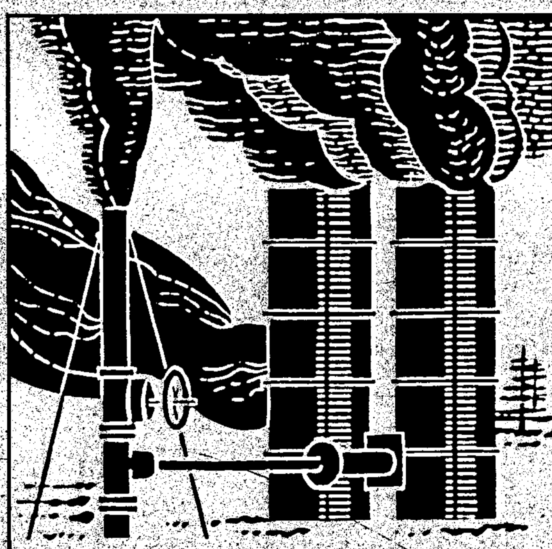

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DEVELOPMENT OF A DISTRIBUTED CONTROL SYSTEM (DCS) FOR GEOTHERMAL STEAMFIELD OPERATIONS AT KAWERAU, NZ

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SUMMARY-A distributed control system (DCS) has been developed for operation of the Kawerau geothermal field. The DCS functions include steam pressure control, steam flow billing, flow and pressure monitoring, remote well flow control and auto paging field operators. The system has evolved over a number of years from paper chart recorders to dataloggers to a desktop PC system to an industrial DCS.

1. INTRODUCTION

A Distributed Control System (DCS) has been developed for the operation and management of the steam supply production facilities and the monitoring of the Kawerau geothermal resource. The development took place over a number of years, taking the operation of the field from manual systems to a full DCS for field operations and data collection.

The Kawerau Geothermal field has been utilised since 1958 to supply steam to the Tasman Pulp and Paper Ltd (Tasman) mill for process and power generation. The geothermal production facilities are owned by the New Zealand Government's Geothermal Trading and operated by Works Geothermal Ltd (WGL).

Five two phase production wells are connected to 4 separation plants. These supply up to 320 t/h of steam at 7 and 9 bar.g to the Tasman mill and Timber drying kilns. The mill operations are 24 hours per day and the steam demand varies with the mill's operational requirements.

Separated water is supplied to two Ormat binary power plants. Two reinjection wells and two cooling ponds are used for waste water disposal. A number of investigation and former production wells are used for resource monitoring.

The field operations are carried out by two staff (operators) working a standard 40 hour week. The operators also supervise and manage field maintenance. One operator is always on call outside normal working hours.

For this paper the systems described by the acronym DCS could also be described as Supervisory Control and Data Acquisition, SCADA, systems.

2. DCS DEVELOPMENT HISTORY

2.1 Chart Recorders

WGL took over the operation of the Kawerau field in 1977. At this time the field was, apart from the steam vent, manually operated. The Tasman mill was the only user of the steam. No continuous monitoring of the field or steam production was being carried out. Earlier a remote monitoring system for the steam production system had been installed by Tasman but had been abandoned by 1977.

The only control loop used in the field was for steam pressure control. The two steam vent valves were used to control steam main pressure. The positioning signal came from Tasman and a local pneumatic controller provided local pressure control over ride in the event that Tasman's signal failed.

Barton paper chart flow and pressure meters were installed to measure the steam flows to the mill for billing under the steam supply contract. The paper charts were changed weekly and had to be interpreted manually to produce the billing totals.

Separation plant flows were recorded manually by the steamfield operators.

2.2 Datalogger

In 1983 electronic transmitters were installed on the billing flow meters and separation plant flow meters. These were connected to a Hewlett Packard bench datalogger. The datalogger calculated the flow rates and displayed these on a small VDU. The display was updated very 10 minutes although this scan rate could have been shorter. The datalogger produced accurate billing totals and provided the operators with an indication of the production well outputs. The Barton flow recorders remained in service as backups to the datalogger.

All the field transmitter 4-20 mA instrument loops were powered from the steamfield site office. The longest loops were more than 2000m from office to transmitter.

The small amount of real time information provided by the datalogger was useful for the steamfield operators The electronic collection of the billing data was saving time and the financial benefits of the increased accuracy were substantial. Unfortunately the datalogger was not reliable and it often had to be taken from site for repairs and parts became difficult to obtain and expensive.

A number of monitor well pressure transmitters were fitted with field dataloggers. These dataloggers required regular attendance to change batteries and down load data.

2.3 PC Based DCS

Options for replacing the datalogger with a more substantial system were carried out. Industrial systems available at the time were expensive and may not have been cost effective. To show the benefits or otherwise of a full field DCS a low cost PC based system was installed in 1987.

The PC based system consisted of an 8086 IBM compatible desk top PC with two floppy disk drives (no hard disk). The PC was connected to two Optomux 16 channel analogue I/O racks. One rack was installed next to the PC in the operator's office, the other at separation plant SP35 approximately 1500m from the office. The PC to/from rack serial communication was RS422 on two twisted pairs. The remote mounting of the I/O rack at SP35 reduced the number of long transmitter loops that needed to be run.

The software was written in-house using Basic language. The system was able to display real time field flows and pressures on a colour graphic and provide a 3 day trend of key field flows. Later output modules were installed that allowed the operators to remotely operate the production well wellhead flow control valves.

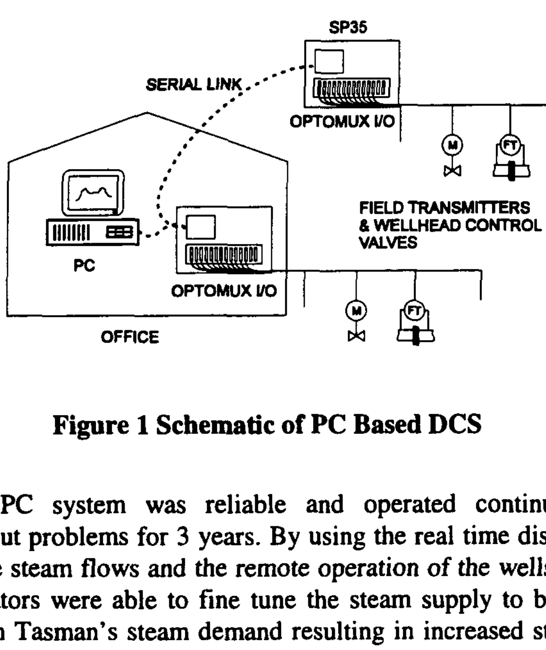

Figure 1 Schematic of PC Based DCS

The PC system was reliable and operated continually without problems for 3 years. By using the real time display of the steam flows and the remote operation of the wells the operators were able to fine tune the steam supply to better match Tasman's steam demand resulting in increased steam sales and less steam wastage from venting.

2.4 Full field DCS

The PC system demonstrated the benefits for field operation, resource monitoring and field management that a full DCS would provide. In 1991 a Rosemount System 3 (RS3) industrial DCS was purchased and installed. The physical installation and configuration was carried out by WGL staff. Installation coincided with a large increase in the number of systems operating in the field, more steam customers and increased demands for information for resource, environmental monitoring and reinjection trials.

Dispute increasing the steam flow to Tasman by 50% and the increased monitoring as above, the development of the DCS as allowed the number of field operators required to remain at two. There as also been a reduction in the time required to process data off site.

The RS3 system currently:

- Monitors and stores over 75 production and field variables
- Calculates and reports all steam flow billing totals.
- Calculates in real time two phase well production data i.e. total mass and fluid enthalpy.
- Carries out steam main pressure control with venting and well flow control.
- Provides the operators with graphical displays and trends (graphs) of the field operating variables.
- Provides alarms and warnings to the operators including automatic paging when the office is unattended
- Allows remote manual control of well output.
- Monitors the stand alone separation plant water level controls.
- Collects and exports data for reservoir studies and reinjection trials.

3. HARDWARE

The RS3 system at Kawerau consists of control cards and operator console in the operator's site office and I/O modules in the field.

Most of the field inputs are connected to 4 multiplex units (FEMs). Each FEM has capacity for 20 analogue inputs. The FEMs are mounted in weather proof cabinets distributed around the field. They communicate to and are powered from the base node on two paired cables. The FEMs do not provide transmitter loop power so there is a battery backed up 24V DC power supply installed with each FEM. The scan period to update all the FEM inputs is approximately 5 seconds.

Where high speed scanning and analogue output is required I/O cards called FICs are used. These cards each have 3 inputs one of which can be configured as an output. The FICs are required for the vent control loop and control of the wellhead flow control valves. One output channel is used for the operator automatic paging. The cost per I/O channel for the FICs is more expensive than the FEMs and remote communication with the base node is more difficult.

The term 'Distributed' in Distributed Control System (DCS) in this case is misleading. The Kawerau RS3 system has only one "smart" node, in the steamfield office, all the control functions are computed by this node.

Commutations with the FEMs and FICs and the real time data processing is carried out by two processor cards called

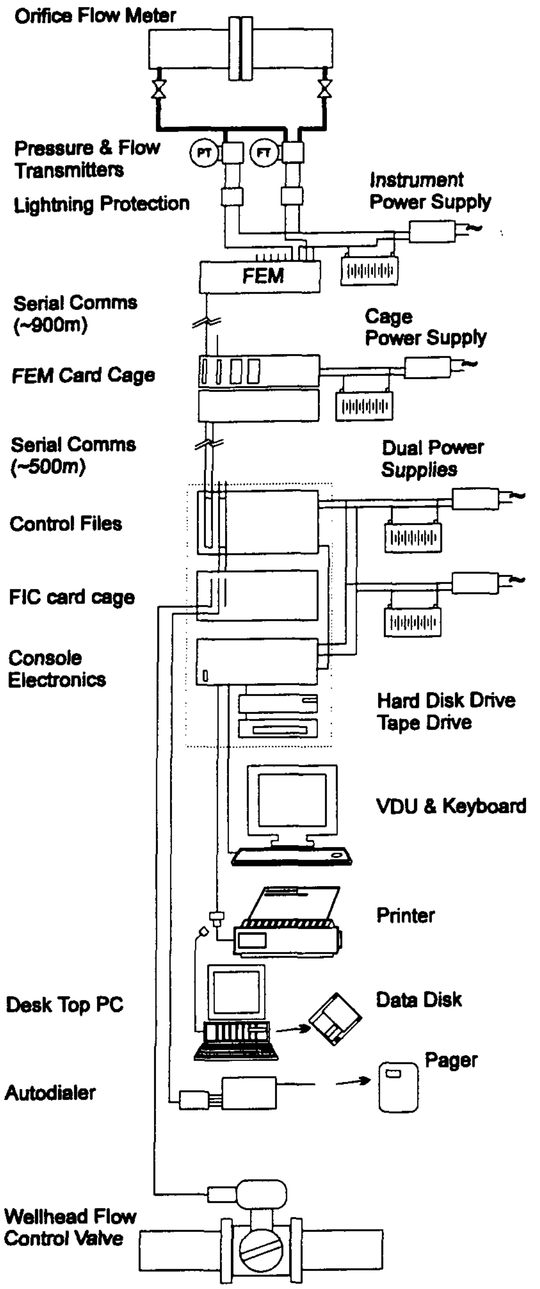

Figure 2 Rosemount System 3 DCS Hardware

'Control Files'. The Control Files are mounted in a cabinet in the site office.

The Control Files provide data to the Console Electronics. The Console Electronics includes a hard disk, tape drive, and a VDU. The hard drive stores data, I/O configurations, System software and reports. The tape drive is used for loading software and backup data. The 20" VDU displays graphics of the steamfield operations, graph data and provides the operator interface.

Two 24V DC power supplies with separate AC connections, power the Control Files and Console Electronics. Batteries provide 4 hours power supply in the event of both AC supplies failing. The operation of the Control Files is very secure, they do not have an off/on switch. All the DC power supplies used by the DCS are monitored by the DCS.

Standby redundant cards can be installed for the FICs and Control Files but these are not used at Kawerau.

4. STEAM PRESSURE CONTROL

Installing the RS3 DCS enabled improvements to be made to the steam main pressure control. The supply of steam to Tasman is load following. Decreasing load increases steam main pressure and vice versa. The pressure control loop opens steam vents to reduce pressure when load is being shed and closes the vents when Tasman require more steam. Tasman can also control venting with a separate signal to one of the vent valves.

The steam main pressure transmitter is located within the mill. The pressure signal is input by an FIC then PID control is carried out by the Control Files at the site office. The vent control signal is output by another FIC. The total wiring distance in this loop is more than 3km from pressure transmitter to Control Files and back to the vents.

The resource consent for air discharges from the field limits the length of time continuous venting can take place. The DCS monitors venting time and raises an alarm if venting is excessive.

One well is used for steam pressure control, this well's flow control valve operates the same as the vent valves to control steam main pressure. The operators can manually operate the other well flow control valves from the DCS. An algorithm for using all the wells sequentially for pressure control has been written for the DCS but is not used. The ease of controlling well output which the DCS provides allows for better matching of steam flow with Tasman's requirements, so there is less venting and more steam sold.

5. SEPARATION PLANT WATER CONTROL

Each of the five separation plants has water level controllers. These controllers operate independently of the DCS. The DCS monitors water levels, valve positions and the water level control power supplies.

6. OPERATOR PAGING

The Kawerau steam field operates 24 hours per day. The two operators are in attendance for only normal working hours, five days per week. The operators also carry out maintenance and are often away from the office. The control systems used in the field are fail safe but do waste steam in the event of a failure.

An automatic paging system has been installed to advise the operators of alarms when necessary. The pager consists of a low cost four channel autodialer used in intruder alarms. Selected alarms from the DCS activate one of the four pager channels. The autodailer contacts the operators numeric pager giving them a code for the alarm. The operator phones the dialler back to acknowledge the alarm and receive a recorded message advising the alarm type.

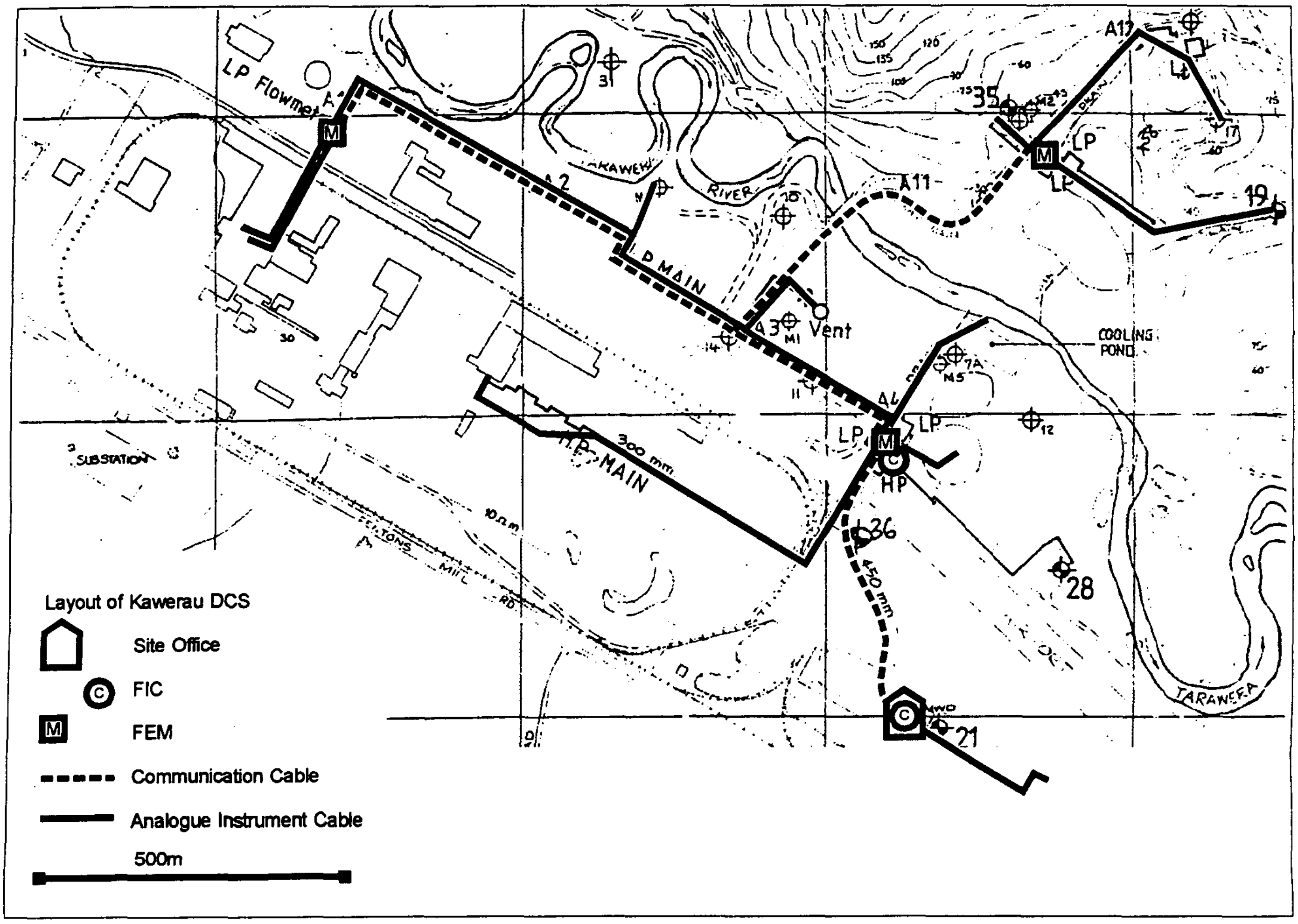

Figure 3 Layout of RS3 DCS

The pager is on the New Zealand Telecom national network so the operators can be a reasonable distance from the field when on standby outside normal working hours.

7. DATA TRANSFER

Steam meter totals, operational data and reservoir monitoring data is collected by the DCS. This data is also stored and processed at WGL's Wairakei offices. Transfering data from the Rosemount system to Wairakei is not a simple process.

The RS3 DCS uses an industrial version of the UNIX operating system. WGL's office systems are PC DOS. Interface hardware and software is available but this is expensive. To transfer data from the DCS the data is first compiled into a printable report. A PC is then connected to the DCS printer port and the report printed. The PC reads the report as ASCII data. A floppy disk of the data is then sent to Wairakei.
The DCS has only an 80Mb hard disk. While the DCS processes data to 16 bit, to save hard disk space the data is only stored to 8 bit (1 in 256 resolution). 8 bit data is not suitable for reservoir monitoring where small pressure fluctuations are anticipated. To overcome this limitation real time reports are generated using 16 bit data. These reports are stored and when required consolidated and transferred to PC format as above.

8. RELIABILITY

The RS3 system has been operating for 4 years. During this time there has been no major system failures.

A truck damaged a serial communication cable which gave problems with communication to some of the I/O. While the cable was repaired at the time, an undetected conductor break caused ongoing problems until it was located.

A lightning storm damaged an FEM and communication functions of one Control File. New equipment grounding has now been installed.

Some spare parts are held on site. In the above cases the system remained on line while the damaged components were replaced.

The system is only taken off line once per year for diagnostics and cleaning.

9. SYSTEM CAPACITY

The number of I/O the system can physically connect is limited by the installed hardware. Currently there are 4 FEMs and 8 FICs giving a total I/O capacity of 104 points. (85% used) This could be expanded to 133 I/O with additional FEMs and FICs. Increasing capacity would not be possible without major additional hardware.

Data processing is limited by the capacity of the two Control Files processor cards. These are running with 34% and 55% free processing time and the card memories are 99.9% and 63% full. A planned upgrade of the Control Files will increase free processing time and memory. This will allow the system to meet additional requirements in the short term.

The system hard disk is 80Mb. This in now full but does allow for data from approximately 80 points to be stored at 2 minute sampling for 2 years. A new larger hard disk is an option. The cost of new hard disk for this system is 10 times the cost of a similar unit if purchased for a desk top PC.

10. OPERATING SOFTWARE

The RS3 operating software has three basic parts. The operating system, Control File configuration and Console configuration.

The Control Files are user configured by defining the functions of software modules called control blocks. The control blocks can carry out a number of functions, PID control, mass/flow calculations, etc. Programming the Control Blocks follows a common format. The format requires some training to understand but allows good control and checking of the configuration. Alarms and warnings are part of the Control Block configuration.

The configuration of the Console defines how the data generated by the control blocks is used. The Console configuration includes display graphics, data trending (storage) and reporting.

All configuration changes are controlled and recorded with ISO9001 procedures developed by WGL.

11. INSTRUMENT WIRING

Before the remote I/O units were install, all the transmitter loops terminated at the steamfield site office. Some transmitters were more than 1500m from the office. Each transmitter loop requires at least one conductor and a common, but usually a twisted pair is used. Without remote I/O the required wiring would be more than 60,000m of twisted pair. With remote I/O the system uses about 16,000m.

The wiring is multiple strand copper with tin coating. Single strand conductors are used for the longest serial links. XPLE insulation has been used to prevent H_2S ingress. Armoured cable is not used.

The life of field wiring has been estimated to be five years, but in practise wiring is lasting longer than this.

Cables are run on the side of pipelines attached to the cladding.

12. FUTURE DEVELOPMENT

Development options for RS3 are limited by the high cost of components and the manufacturer who is developing new systems and not the RS3.

Technology in the area of DCS is developing quickly. New systems are able to deliver higher performance and increased capacity at lower cost. Replacement of the RS3 system is likely be to a better option than upgrading when system expansion is required.

Reviewing the requirements of the Kawerau DCS (See Table 1) identifies two function groups that duties of the DCS fall into.

Firstly there are items that require high reliability, high scan rates, short term data storage and often low accuracy. These are the control loops and monitoring associated with the operating of the supply of steam to Tasman. E.g. Controlling steam pressure and monitoring separation plant water levels. These are functions common to many industrial plants.

The second group have requirements different from above because of the nature of geothermal fields. These items require high accuracy/resolution and long data storage but low reliability. Managing geothermal wells and the resource requires data to be collected over long periods of time with only a low scan rate. Small changes need to be detectable but a few missed data points is not important. There are no control loops in this second group but the group includes most of the data collected and calculated by the DCS. E.g. well production data, monitor well pressures and environmental discharge recording.

This second group of data needs to be available to reservoir engineers and the field management. Data in PC format is most useful to these staff.

The next DCS to be developed for Kawerau is expected to consist of a small number of industrial controllers dedicated to the critical control loops and I/O modules connected to a desk top PC for the operator interface and data processing.

The controllers would provide the reliability required for the day to day operation of the steam supply to Tasman. The PC would provide the flexible data processing and storage required for reservoir monitoring and field management. The PC hardware would be low cost and easy to service.

Table 1 - DCS Requirements

Item	Accuracy/ Resolution	Frequency /Scan rate	Term of Data Storage	Reliability
Steam Billing totals	High/High	High	Med	High
Steam Pressure Control	Med/Med	High	Short	High
Remote Well Control	Low/Low	Low	Short	Low
Production wellhead pressures	Low/Low	Low	Long	Low
Well/SP output data	Med/Low	Med	Long	Low
Reinjection flows/pressures	Med/Med	Med	Long	Low
Monitor well pressures/water levels	Med/High	Med	Long	Low
Discharge Reporting	Low	Low	Med	Low
Operator Paging (Alarms)	Low/Low	Low	Short	Med