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**INDUSTRIAL POWER DISTRIBUTION (U)**

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by

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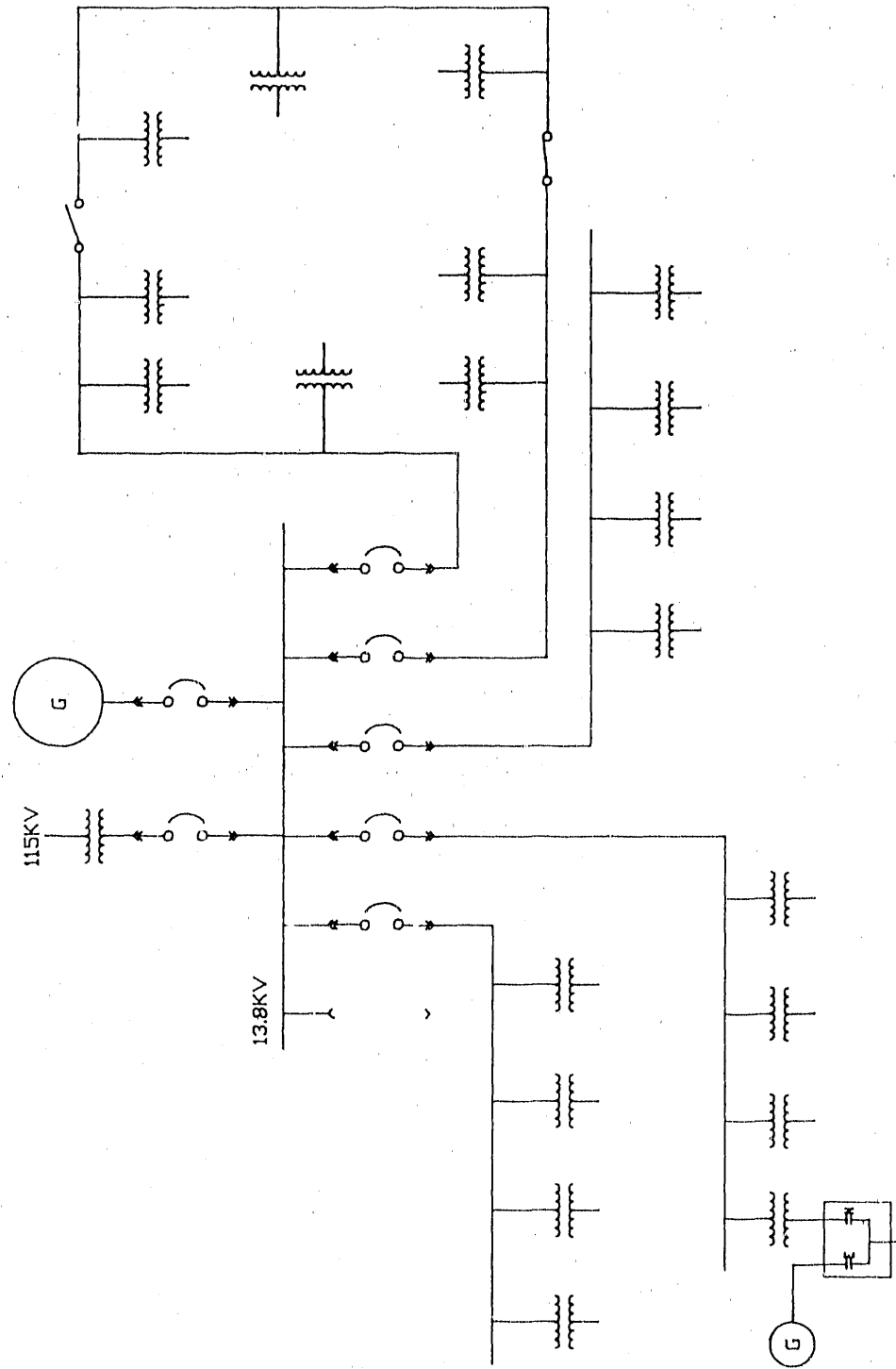
# **Industrial Power Distribution (U)**

Mark A. Sorrells

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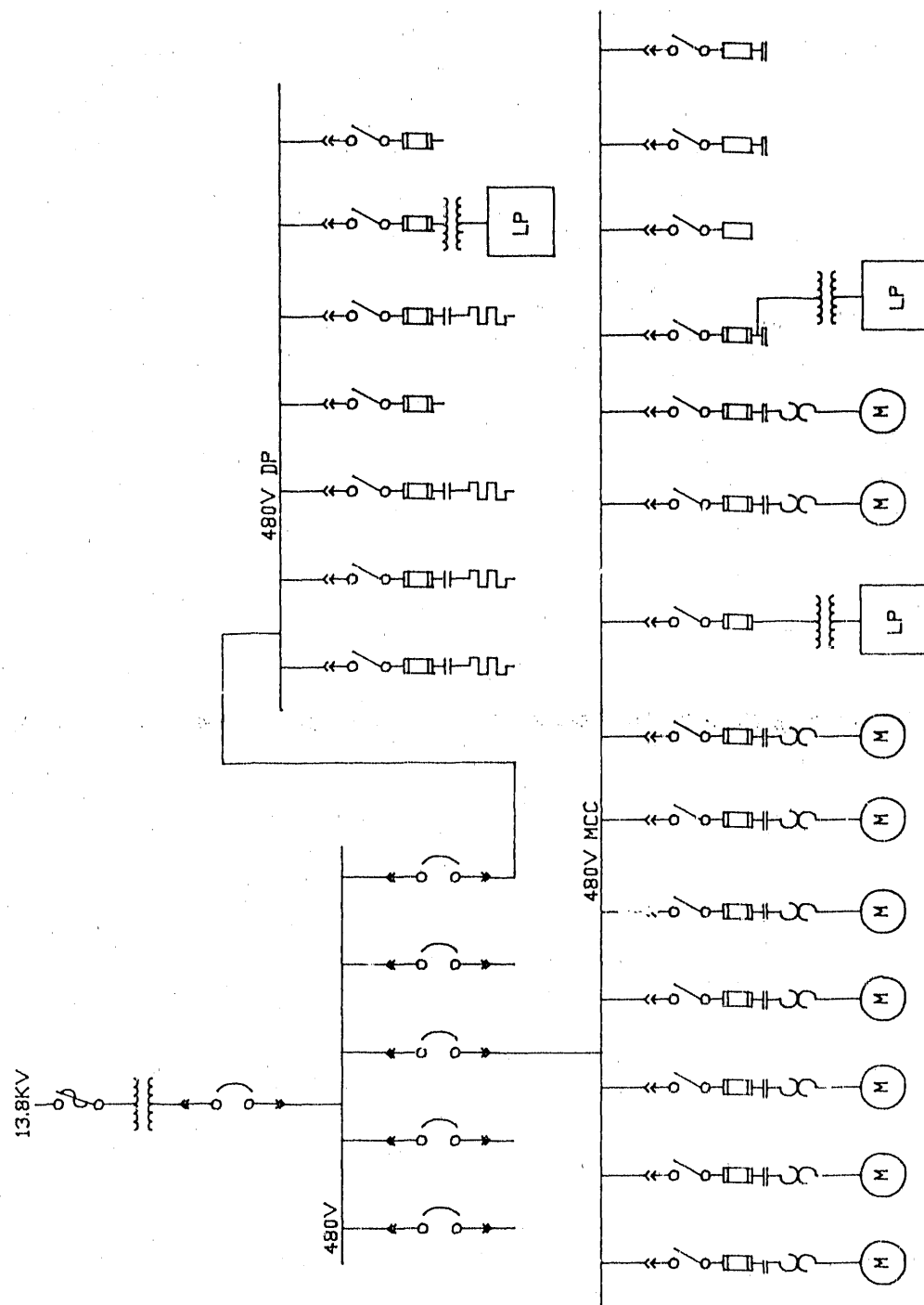
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# Single Line - Primary Distribution



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# Single Line - Secondary Distribution



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## Utilization Equipment

480V Most Prevalent in SouthEast

### Motors

1/2 - 150HP (Induction)

DC for Precision Control

### Lighting Loads

480 - 240/120 Single Phase

480 - 208/120 Three Phase

480 - 240/120 Three Phase (Hi Leg Delta)

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## Protection Devices

### Circuit Breakers

- Reset Capability

- Limited SC Capacity

### Fuses

- One Time Devices

- High SC Capacity

### Relays

- Motor Overloads

- Ground Fault Detectors

- Undervoltage Relays

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## **Standards**

NFPA 70 – National Electrical Code

ANSI C2 – National Electrical Safety Code

IEEE Color Series

Green Book – Grounding

Buff Book – Protection & Coordination

Brown Book – Power System Analysis

National Electrical Manufacturer's Association

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## Motor Circuit Considerations

Horsepower

< 1/2HP

1/2HP to 150HP

> 150HP

Voltage Available

120, 208, 240 Single Phase

208 or 460 Three Phase

NEMA MG-1 & MG-2

Starting Torque

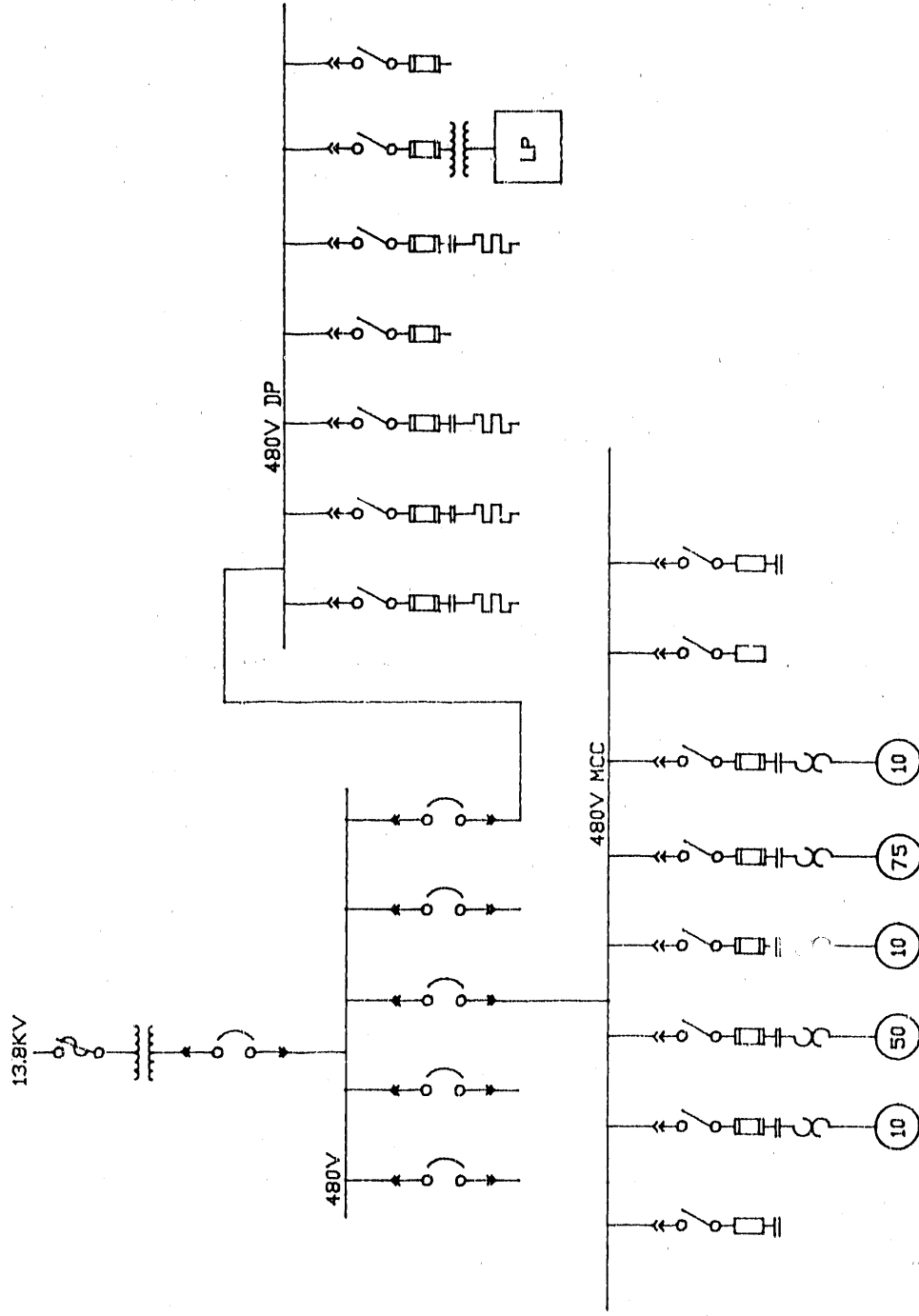
Orientation of Motor

Orientation of Terminal Box

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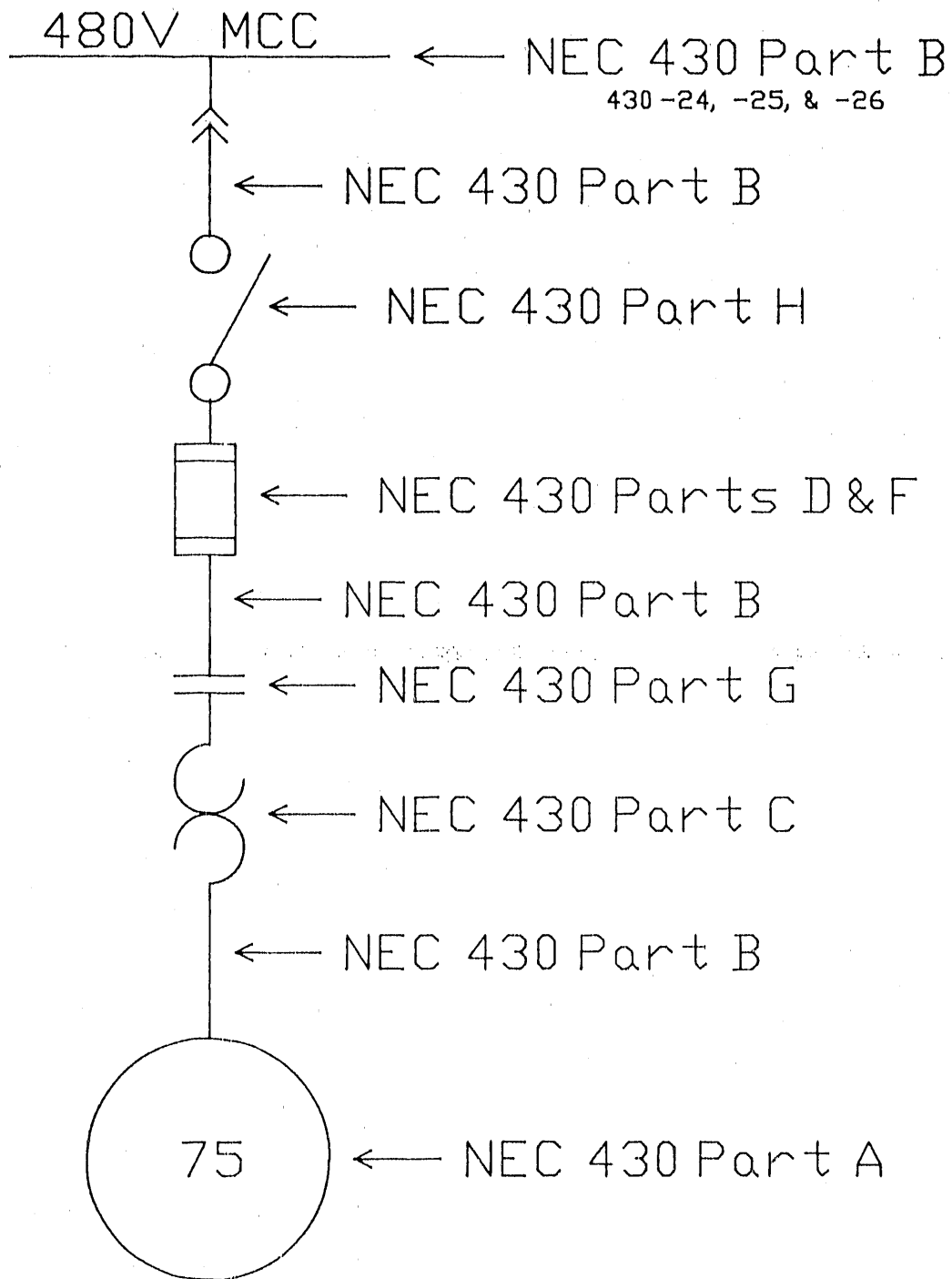


# Single Line - Case Study 75HP Motor



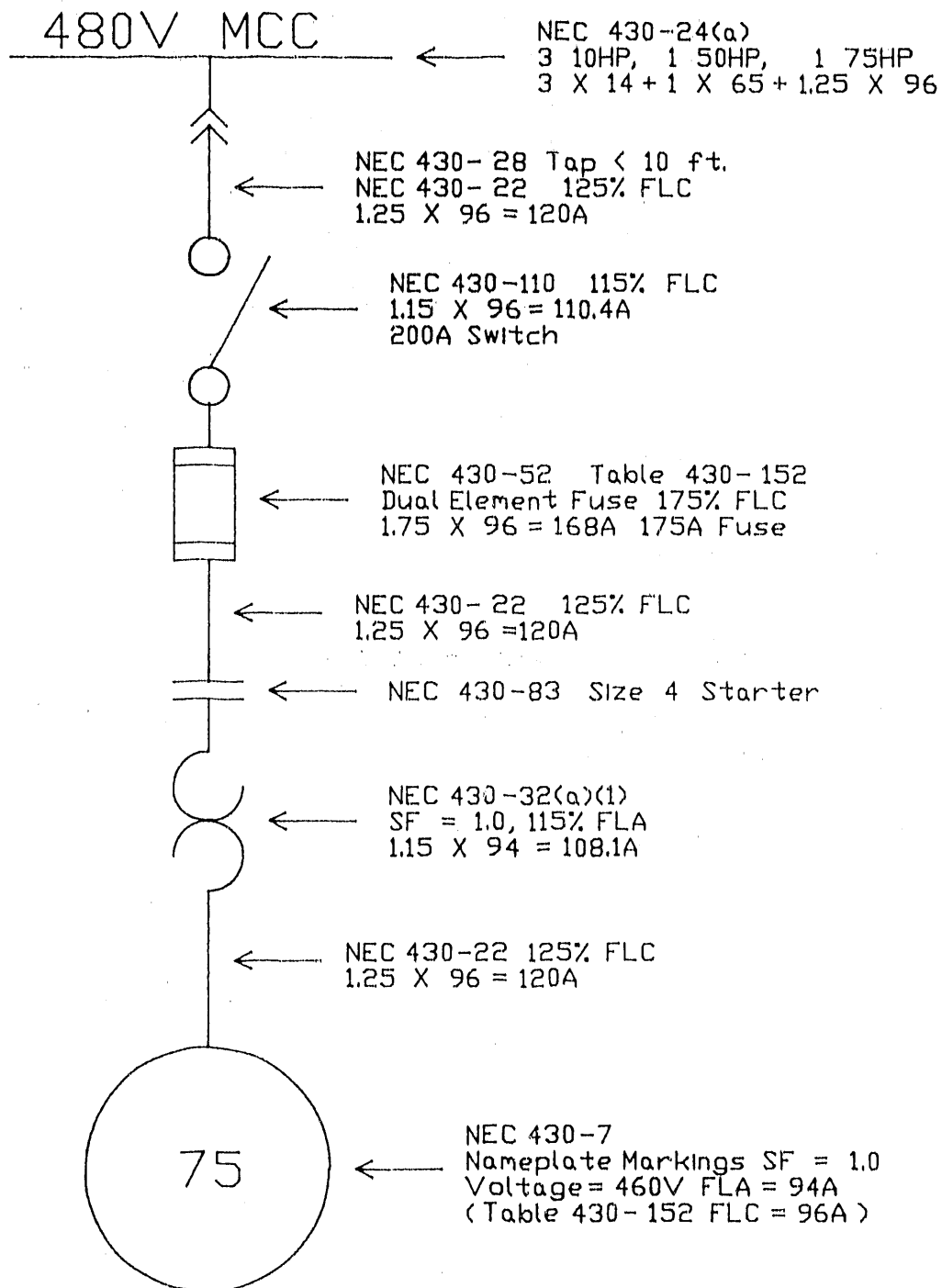
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## Case Study - 75HP Motor NEC Guide



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## Case Study - 75HP Motor Computed Values



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## Lighting Considerations

Common Voltage At Site

240/120 Single Phase

208/120 Three Phase

Common Transformer Sizes

Location of Transformer

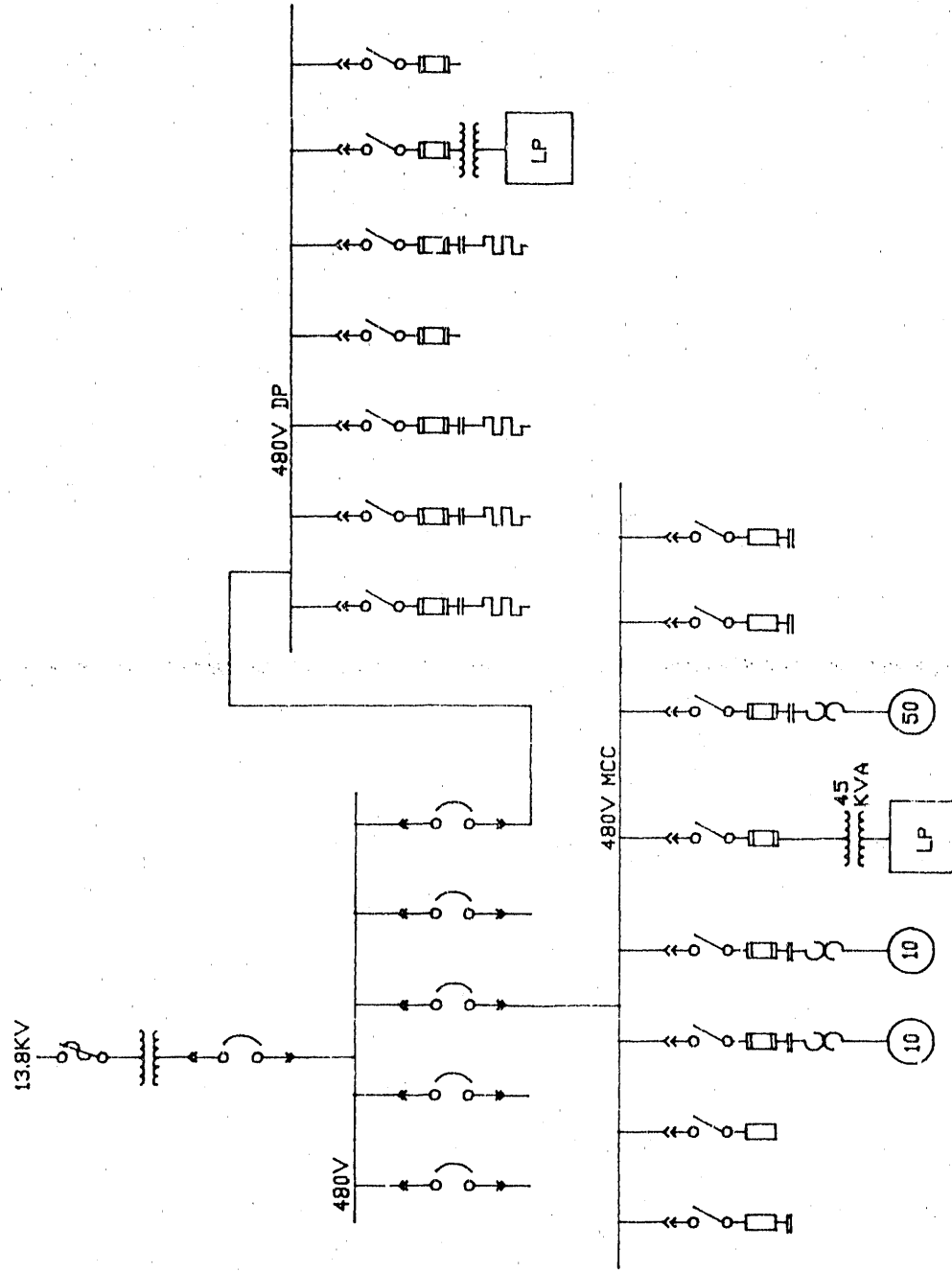
Inside or Outside

Corrosive Atmosphere

Heat Dissipation

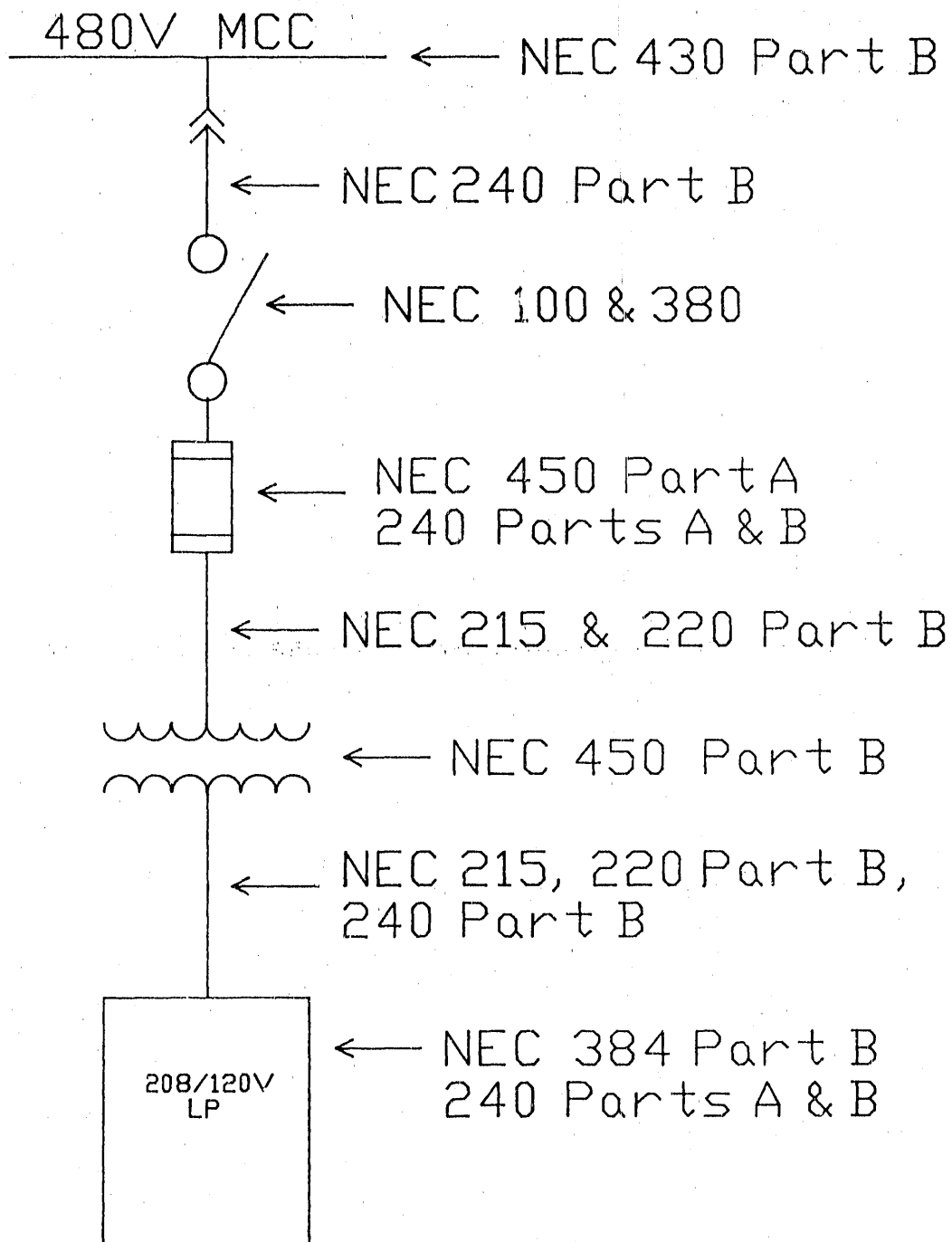
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# Single Line - Case Study 45KVA Transformer



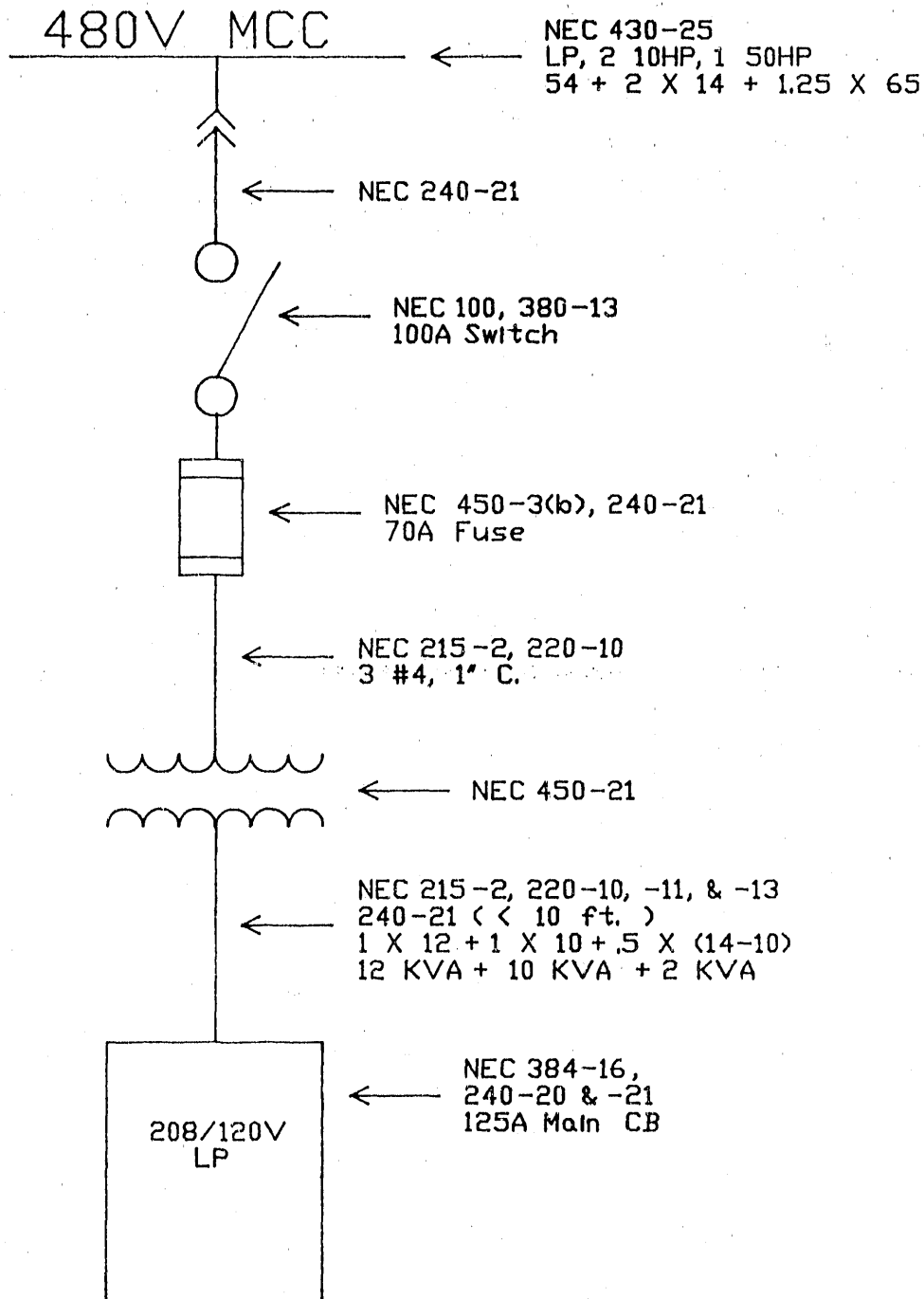
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## Case Study - 45 KVA Transformer NEC Guide



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# Case Study - 45 KVA Transformer Computed Values



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## Industrial Power Distribution (U)

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(Introductory Slide)

This talk will be a broad overview of industrial power distribution. Primary focus will be on selection of the various low voltage components to achieve the end product. Emphasis will be on the use of national standards to ensure a safe and well designed installation. (Read over outline.)

(Single Line Primary Distribution Slide)

The single line diagram is one of the most important, if not the most important, drawing the electrical power engineer uses. It shows how power is distributed to all electrical machinery in the plant.

Primary power is usually supplied at some medium voltage level (13.8KV to 69KV). Occasionally the power company will supply this voltage through a step-down transformer from some transmission level voltage such as 115KV. Distribution is then made at the selected medium level voltage. Onsite generation is a distinct possibility at many facilities. 5 MW to 30 MW is a typical range for the onsite cogenerator.

The medium voltage distribution may be done via overhead lines, underground lines, cable tray, or some combination of these methods. Distribution feeders may be in a loop, radial, or primary selective arrangement.



(Single Line Secondary Distribution Slide)

Transformers are used to step the medium voltage down to the final utilization voltage. This utilization voltage will depend primarily on the size of the equipment.

These transformers will usually range in size from 500 KVA to 2500 KVA. A number of factors affect this selection. What will be the load demand? Is there a possibility of future expansion? What size transformers are available within the necessary time frame? Is there a desire to have standard sizes in order to reduce replacement inventory?

Transformers come in two basic types - liquid immersed and dry-type. With liquid immersed types, the winding and core are totally submerged in a liquid that serves as a heat-transfer medium and as an insulating dielectric. With a dry type, the core and winding assembly operate in a gas (usually air). Each type has its advantages and disadvantages.

Transformers may be a part of a unit substation or separate from the secondary switchgear. Switch distribution is usually made through busbar to feeder breakers, which go in turn to additional secondary distribution gear.

One of the more common methods for final low voltage distribution is a motor control center. Motor control centers (MCC's) consist of stacks with vertical busbars from which the power is supplied. Cubicles have stabs which plug onto these busbars. The necessary motor control components are included in this bucket or can. MCC's are a very convenient method of

locating control for many motors in one centralized area.

Another method for low voltage distribution is a panelboard. These may use fuses or circuit breakers. They are similiar to your household lighting panel. They are used when the loads to be fed require only a power input, such as packaged HVAC units and transformers.

(Utilization Equipment Slide)

Motors are a large part of any industrial facility's load. By far the largest portion of motors in use in the United States are squirrel cage induction motors. They are simple, relatively maintenance free, and a proven technology. DC motors are used when a high degree of speed and/or motion control is desired.

Task lighting is an important part of getting the job done. Common practice is to utilize the main low voltage distribution to feed lighting transformers. The final lighting voltage is usually determined by company practice, and/or the anticipated equipment to be served.

(Protection Devices Slide)

There are two main types of short circuit protective devices available, fuses and circuit breakers. Each has its advantages and disadvantages. They each come in a variety of styles. Fuses come in various UL classes, with the main factors being size and interrupting capacity. Circuit breakers may be molded case, ACB, have interchangeable plug trips, and other assorted add-on functions.

While short circuits may be spectacular, they are not the only type of system disturbance. Many start out as an arcing ground fault. This type of fault is characterized by a high impedance to ground, often undetectable by the short circuit protective device.

Relays are available to detect ground faults, as well as a variety of other types of faults. These include undervoltage relays and thermal overloads.

(Standards Slide)

A large quantity of standards exist in the United States, and worldwide. These are most often driven by the need to, as the name suggests, standardize on a method of doing something, dimensions of certain products, or some other common thread.

The most important document the electrical power engineer uses is the National Electrical Code. It is not the only standard one needs to be aware of. There are others, such as the National Electrical Safety Code, the IEEE color series, and the National Electrical Manufacturer's Association (NEMA) standards.

(Motor Circuit Considerations Slide)

The first two factors usually considered in designing a motor hookup are 1) horsepower, and 2) the available voltage. Many companies have defined breakpoints at which they change the voltage and phase of the motor. For example, one possible breakdown would be 120V single phase for less than 1/2 HP, 460V 3

phase for 1/2 HP up to 150 HP, and 2300V for motors larger than 150 HP. On occasion, one may need to adjust the voltage of the motor due to the nonavailability of the usually preferred voltage. For example, a 200 HP motor may be required in a certain situation, but only 480V is readily available.

Sometimes other considerations come into play. NEMA MG-1, Motors and Generators, and NEMA MG-2, Safety Standard for Construction and Guide for Selection, Installation, and use of Electric Motors, can sometimes help in these situations.

(75HP Motor Single Line Slide)

Outlined in red is the power flow for consideration. Let us consider adding a 75 HP to a 480V motor control center. Let us also assume there will be three 10 HP motors and one 50 HP motor on this motor control center.

(75HP Motor NEC Guide Slide)

Here is the single line for the motor circuit, along with the various governing sections from NEC article 430.

(75HP Motor Computed Values Slide)

We know the horsepower and voltage. We take several paths to arrive at our final product.

Per NEC 430-24(a) our bus must be able to handle the FLC (full load current) of all other motors plus 125% of the largest motor. Doing our calculation, we get 227A. Vertical bus is

usually rated at 300A, and horizontal busbar is usually 600 or 800A.

Moving to our stab connection, per NEC 430-28, we have a tap less than 10 feet so our conductors may be sized for the branch circuit. NEC 430-22 defines the conductor size at 125% of the FLC for 120A.

The switch must be sized at 115% of the motor FLC. This figure is 110.4A. Switches come in standard sizes, 30, 60, 100, 200, etc. We will need a 200A switch.

To size the overcurrent device, we use Table 430-152. If we have a dual element fuse, it should be sized at 175% FLC. Fuses also come in standard sizes. Recognizing this, we can use an exception to go to the next higher standard size fuse, which is 175A.

Again, the feeder to the contactor must be sized for 125% FLC. Per NEC 430-83, the horsepower rating of the controller must greater than or equal to the nameplate horsepower of the motor.

Overloads are sized based on the actual motor nameplate data. Let us assume our Full Load Amps (FLA) equals 94A. Per NEC 430-32(a)(1) we size the overload for 108.1A. Motor overloads are selected from a manufacturer's chart.

The branch circuit again must be sized for 125% FLC. Per NEC 430-7, motors must carry a nameplate with various markings, some of which we used to calculate above values.

(Lighting Considerations Slide)

Some factors to consider in designing a lighting layout include the site's common voltage, the desire to standardize for inventory reduction, and the location of the transformer.

(45KVA Transformer Single Line Slide)

Outlined in red is the power flow for consideration. Let us consider adding a lighting transformer to a motor control center. Our lighting voltage will be 208/120V three phase. Let us also assume there will be two 10 HP motors and one 50 HP motor on this motor control center.

(45KVA Transformer NEC Guide Slide)

Here is the single line for the transformer and lighting panel, along with the governing sections from various NEC articles.

(45KVA Transformer Computed Values Slide)

Our first consideration is to determine the KVA load we will have. Computing the load per NEC 220, we must take 100% of the lighting load, 100% of the first 10 KVA receptacle load, and 50% of the remaining receptacle load. With a lighting load of 12 KVA and a receptacle load of 14 KVA, our computed load will total 24 KVA.

Some common three phase transformer sizes are 30, 45, and 75

KVA. With today's explosion in the computer arena, the receptacle load could quickly increase. Therefore it would be prudent to install a 45 KVA transformer, even though a 30 KVA would be adequate at present.

Since we are connecting to a MCC, our busbar must meet 430-25. We must size for all other motors, 125% of the largest motor, and other computed loads. 45 KVA works out to 54A on the 480V supply side. Doing our calculation, the busbar must be capable of handling 163A.

NEC 240-21 limits our tap conductor to the switch to less than 10 feet in length. Our switch is a knife type and is classified as a general-use switch per NEC 380-13. NEC 100 defines a general use switch as being rated in amperes, and capable of interrupting its rated current at its rated voltage. Therefore our switch must handle 54A.

Sizing the fuse per NEC 450-3(b)(1), the primary overcurrent device may be sized up to 125% of the primary current. This overcurrent device must be placed where the conductor receives its supply, in the MCC. We will use a 70A fuse. This means that our switch will need to be a 100A switch, even though a 60A switch would meet the necessary criteria.

Per 215-2, the transformer supply conductors must be protected at their ampacity from Tables 310-16 to 310-19. Section 220-10 states that the conductors must handle the computed load. Since we selected the fuse at 125%, the conductors must carry this current in order to be properly

protected. We will choose #4 AWG conductors.

The transformer will be of the dry-type, and must be installed in accordance with NEC 450-21. This article states that the transformer must be installed 12 inches from any combustible material. Once the transformer size gets over 112 ½ KVA, they must be installed in a special fire resistant room.

The conductors to the lighting panel will be less than 10 feet, so they will not require an overcurrent protection device. They must be sized to carry the computed load. Since we have chosen to use a 45 KVA transformer, we should use this rating to calculate the wire size and the panelboard size.

Per NEC 384-16, this panelboard must be protected on the supply side by an overcurrent device. In addition, it may not carry more than 80% of its rating where the loads are continuous. The exception to this rule states that all the devices must be rated for 100% duty. The full capacity of the transformer is 124.9A. We will therefore use a 125A panelboard.

#### **ACKNOWLEDGMENT**

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**- END -**

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