The Electrical Load List & Other Considerations

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Presentation Objectives

- Understand why we need electrical Load Lists (ELL).
- Where does the data come from to populate an ELL?
- Why are we stuck with spreadsheets?
- What is the data used for?
- How accurate is the ELL anyway?

Sometimes the objectives that I think are important are not necessarily the same that you think are important. Oops... Lets discuss so I can do better next time.

In the Beginning

At a high level there is a natural progression to every Petro-Chem project. First on the project is always the Process Engineer.

In a greenfield project, the Process Engineer has to create the process from input of basic ingredients, to mix everything together, to finished output. Until the Process Engineer is finished, nothing can happen.

The Process Engineer designs the process with a specific Maximum Process Capacity (MPC) in mind. This means the plant has a nameplate capacity of XX mbd.

Important concept!

Usually Client specified

In the Beginning... Cont.

In a brownfield project, the Process Engineer has to modify the process to accommodate the client's requests. Again, until the Process Engineer is finished, nothing can happen.

The process modification could result in an increase or decrease of electrical load.

The Process Engineer modifies the process with a specific Maximum Process Capacity (MPC) in mind. This means the plant has a new nameplate capacity of XX mbd.

Questions.

Question #1 Do we ever design a process that can be pushed to a higher capacity than nameplate capacity???

Question #2 Does the end users ever “push” the plant beyond nameplate capacity? I.E. get more throughput than what the nameplate says??? How does he do it?

Question #3 What does it mean to say the plant is running at 95% capacity?

Bonus Questions. What about Brownfield battery limits? Are they the same for electrical? What about studies?

In the Beginning... Cont.

The Process Engineer creates the process flow diagrams (PFD's) and the process and instrumentation diagrams (P&ID's). The Electrical Engineer has no hand in this work.

Once the PFD's and P&ID's are signed off / accepted / approved, the Electrical Engineer can start his work.

Let's make it clear, in Petro/Chem work, Electrical Engineers follow, they do not lead. A typical engineering order is like this.

Process Engineers,

Other engineering disciplines

Electrical Engineers

I&C Engineers

Our Job.

The data to populate an ELL comes from two sources.

1. **The P&ID's**
2. **Process Support Equipment and ancillary items.**

P&ID's.

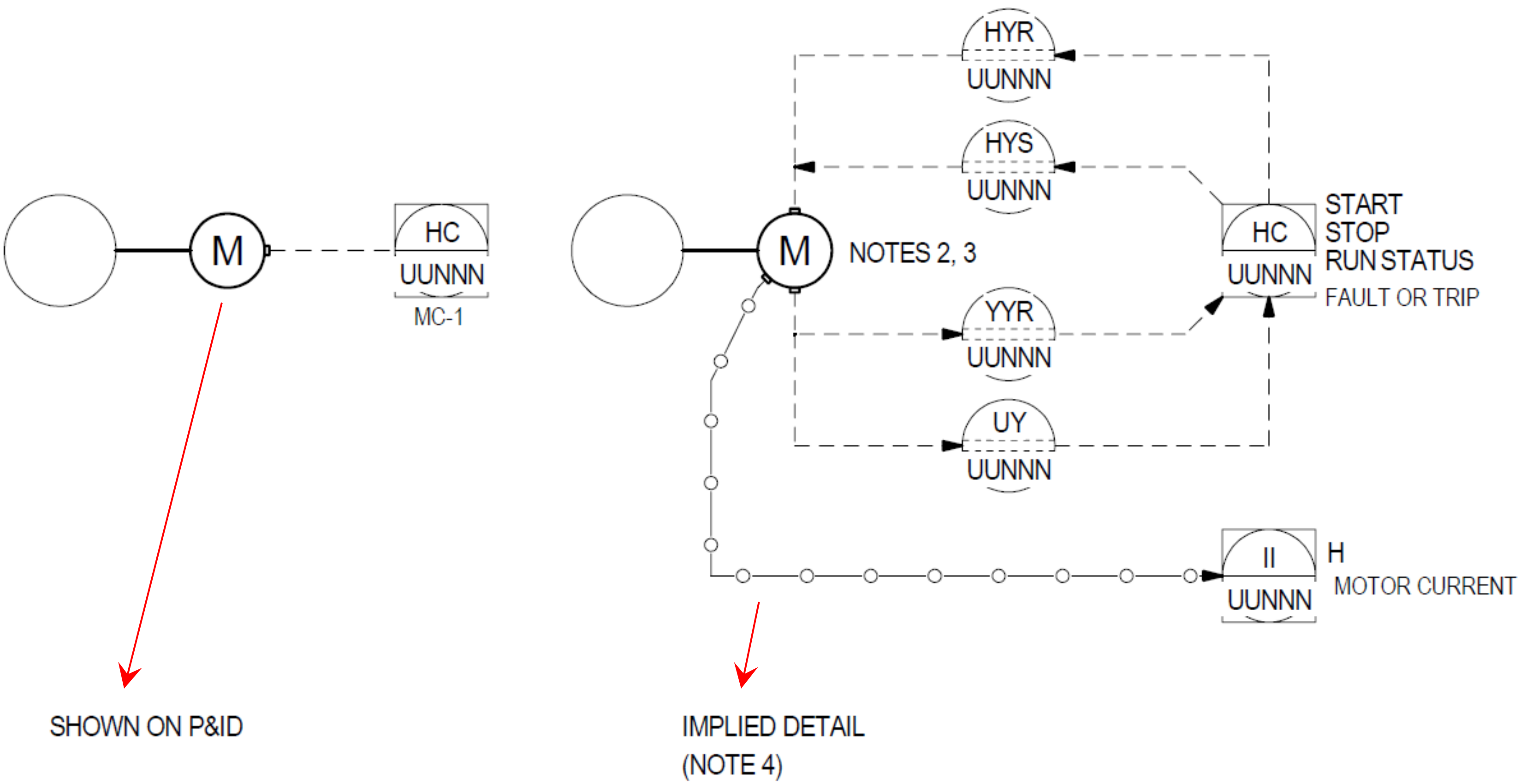
The P&ID's contain all the basic data on the various pieces of equipment and how they are controlled. For the electrical engineer the P&ID's have the following items.

1. Electric motors
2. Electric heaters
3. Pipes that require electrical heat tracing
4. Control schema's - sorta

Cleaning (steaming) out lines

P&ID's… Cont.

DETAIL MC-1
MOTORS UP TO 125 HP AND FROM 125 HP TO 250 HP @ 1800 RPM.



P&ID's... Cont.

GENERAL NOTES:

1. ALL INSTRUMENT TAG NUMBERS SHALL INCLUDE THE UNIT IDENTIFIER. REFER TO JOB SPECIFICATION 123939-60A3, INSTRUMENT SYMBOLS AND IDENTIFICATION. THE NUMERIC COMPONANT OF THE TAG NUMBER (UUNNN) SHALL NOT EXCEED FIVE (5) DIGITS. THIS NUMERIC COMPONANT SHALL BE DIFFERENT (UUNNN) FOR EXISTING UNITS.

2. MOTOR PROTECTION RELAY (MPR) TO BE INSTALLED AT MCC AND INTERCONNECTED TO DCS VIA FIBER OPTIC CABLE.

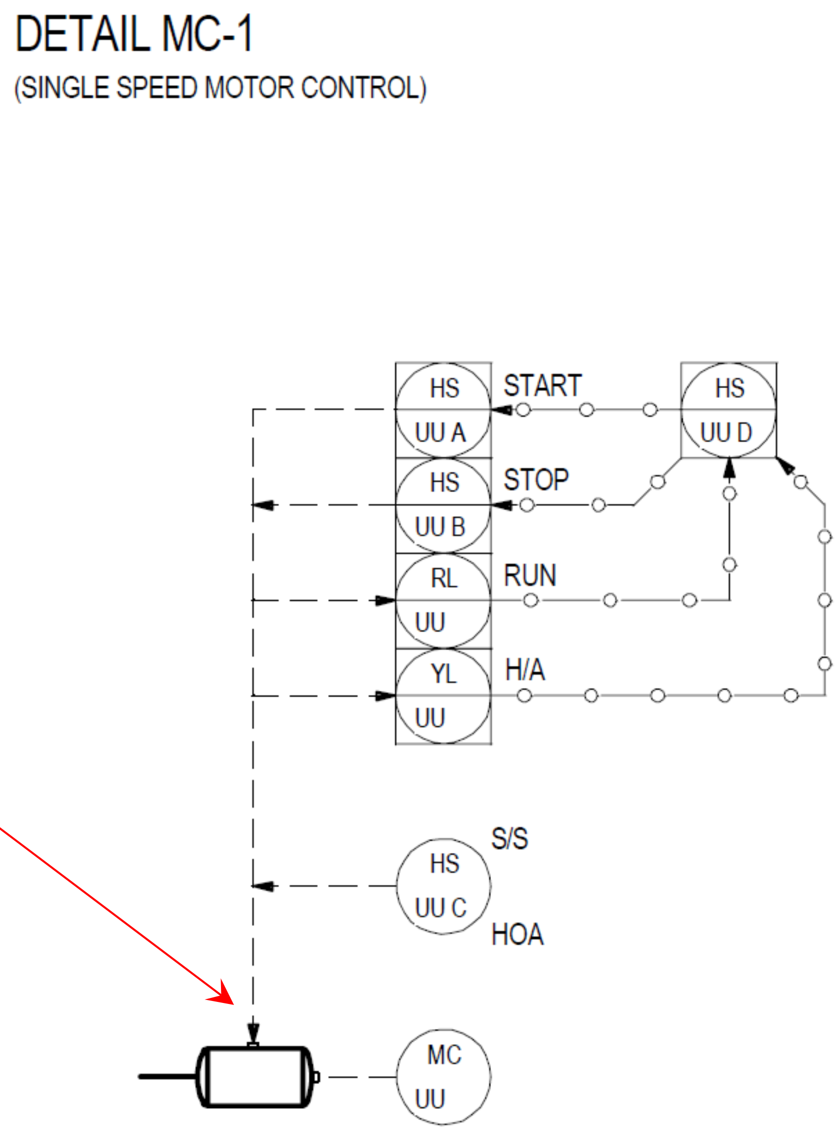
3. LOCAL CONTROL STATIONS SHALL BE PROVIDED AND SHALL CARRY THE MOTOR TAG NUMBER.

4. ALL INSTRUMENT TAG NUMBERS SHOWN ON THE IMPLIED DETAILS SHALL CARRY THE SAME CONSECUTIVE NUMBER (PPNNN) OF THE DCS INSTRUMENT TAG (HC-PPNNN) SHOWN ON THE MAIN EFD.

5. ESD PUSH BUTTONS ARE SHOWN IN THE MAIN EFD'S AS REQUIRED. DETAIL ENGINEERING CONTRACTOR SHALL VERIFY THE REQUIREMENT FOR INDIVIDUAL PUSH BUTTONS PER VALVE IN THE CONTROL ROOMS (LOCAL CONTROL ROOM AND REMOTE CONTROL ROOM) TO AVOID DUPLICATED FUNCTION.

6. MOTOR CONTROL DETAILS FOR MOTOR ABOVE 1000HP SHALL BE REVIEWED BY ELECTRICAL. ROTATING EQUIPMENT AND CONTROL SYSTEMS DISCIPLINES CASE BY CASE BASIS.

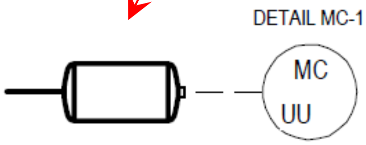
P&ID's… Cont.



Here is another version of a P&ID motor schema.

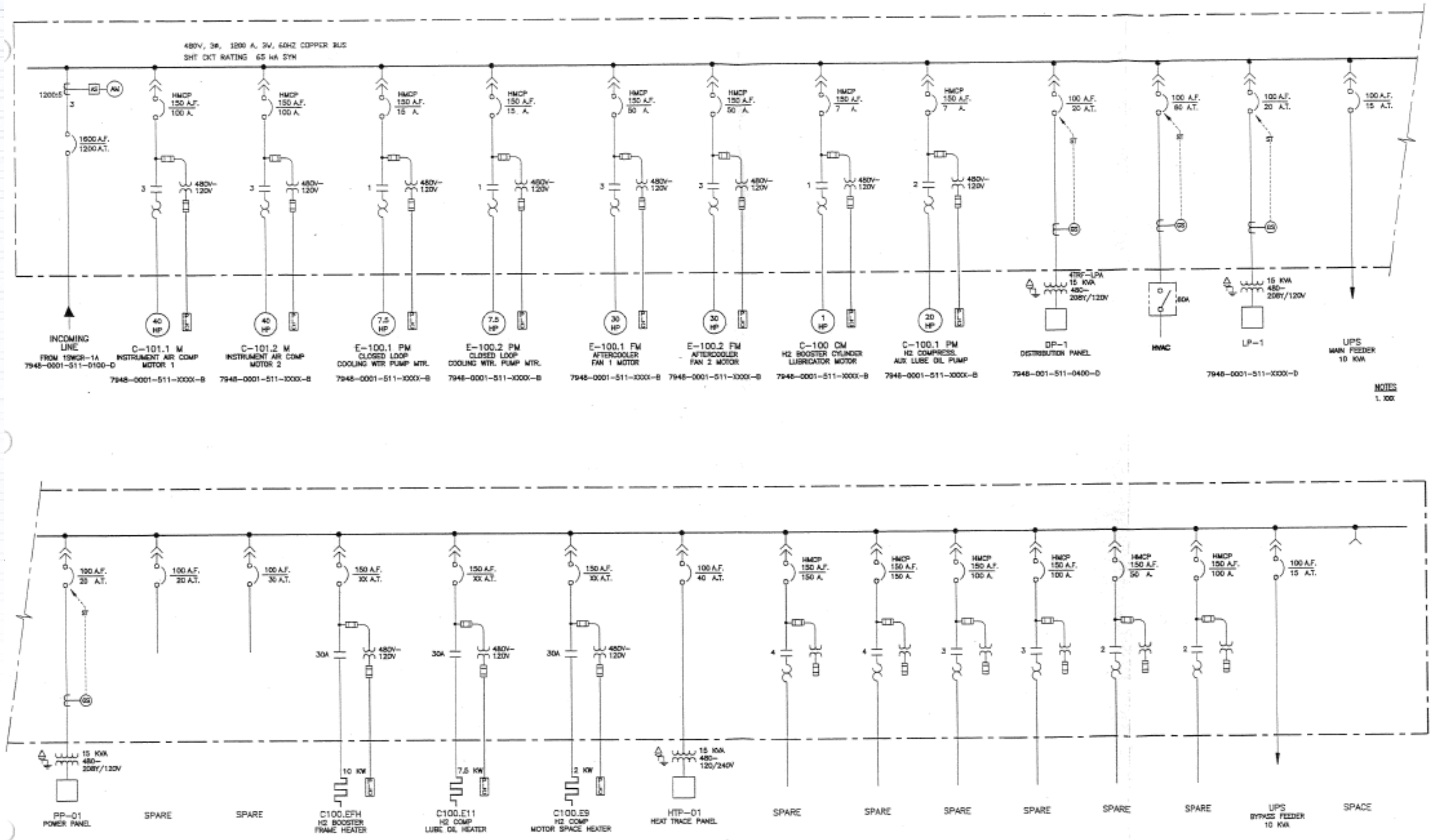
Implied

Shown



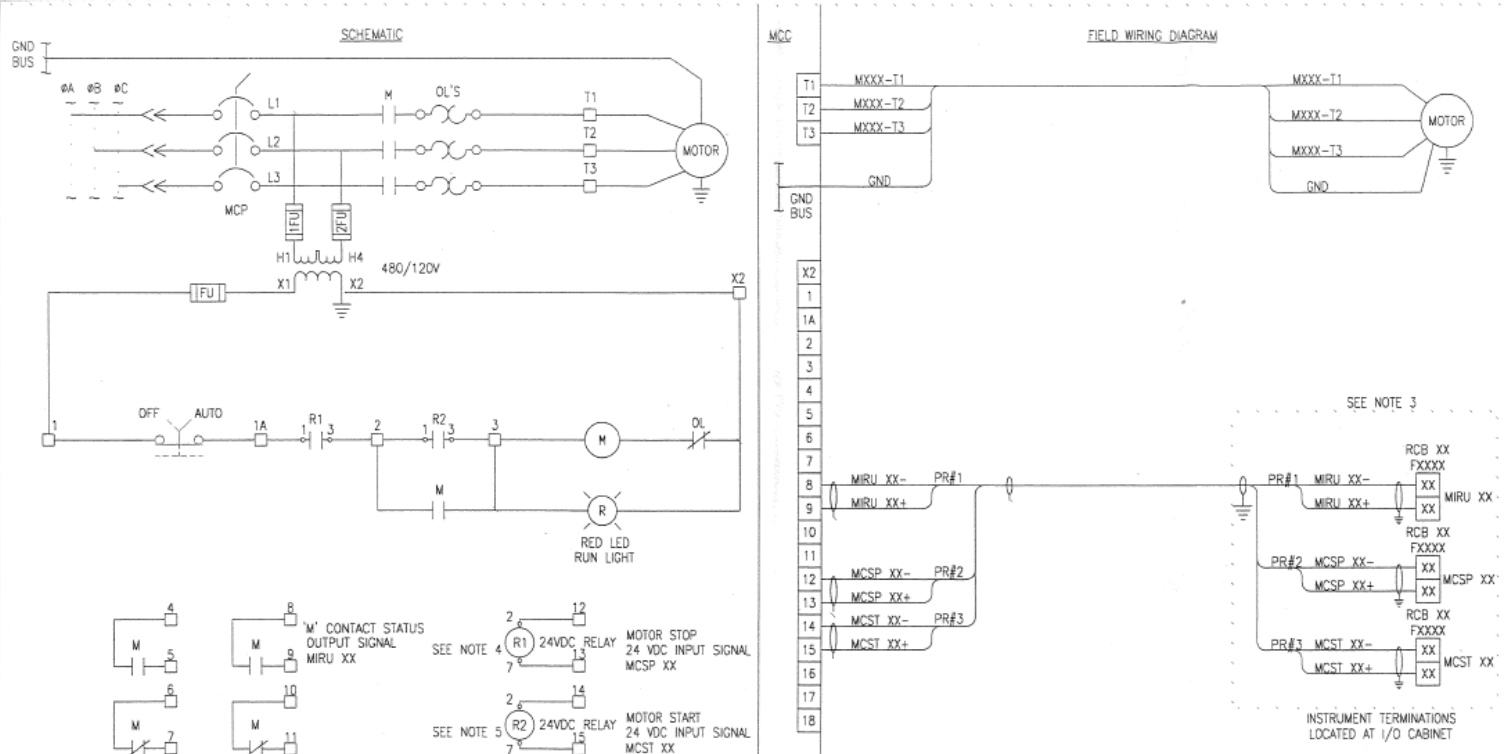
Slight Side Track

A 480V one-line diagram



Slight Side Track

Std motor wiring diagram



NOTES:

1. SHIELD TO BE TAPED BACK AT THE MCC END.
2. INSTRUMENT CABLE TO BE BELDEN 600V TC #16AWG.
3. INSTRUMENT CABLES FOR MIRU, MCSP & MCST SHALL BE INSTALLED INSIDE THE BUILDING BY THE BUILDING VENDOR. ALL OTHER FIELD CABLES SHALL BE INSTALLED BY THE E/I SUBCONTRACTOR.
4. RELAY R1 IS ENERGIZED FROM A MAINTAINED SIGNAL MCSP XX FROM DCS.(P&B #KRP-11DN-24, SOCKET #27E122)
5. RELAY R2 IS ENERGIZED FROM A PULSE SIGNAL MCST XX FROM DCS. (P&B #KRP-11DN-24, SOCKET #27E122)

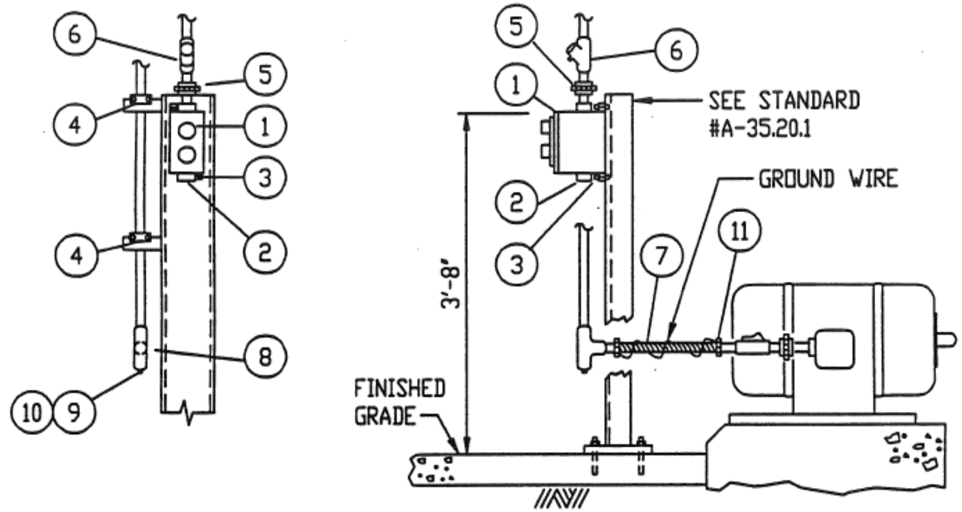
SCHEMATIC **FIELD WIRING**

Slight Side Track

This is a typical motor installation detail that the field would follow to install the power and control to a specific motor.

Grounding the motor frame is illustrated in another installation detail.

HORIZONTAL MOTOR - CLASS I, GROUP C & D, DIV. 2
W/SEPARATE POWER AND CONTROL CONDUITS



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BILL OF MATERIAL		
ITEM	DESCRIPTION	QUANTITY
1	CONTROL STATION-SEE JOB SPECS. FOR TYPE	1
2	PLUG, CROUSE-HINDS #PLG25 OR EQUAL	1
3	MACHINE SCREW, ROUND HEAD, 1/4"-20 X 1" LONG CAD. PLATED	2
—	WITH FLAT WASHER, HEX NUT, & LOCKWASHER	—
4	CONDUIT CLAMP, APPLETON TYPE PC OR EQUAL	2
5	UNION, CROUSE-HINDS #UNY205 OR EQUAL	2
6	SEAL, CROUSE-HINDS #EYD OR EQUAL	1
7	FLEXIBLE CONDUIT SEALTITE, SIZE AS REQUIRED (3 FT. MAX.)	1
8	TEE FITTING, CROUSE-HINDS #T TYPE OR EQUAL	1
9	REDUCER, CROUSE-HINDS #RE TYPE OR EQUAL	1
10	DRAIN, CROUSE-HINDS #ECD15 OR EQUAL	1
11	CONNECTOR, APPLETON #ST-L TYPE OR EQUAL, SIZE AS REQUIRED	2
		1

A3582.DWG

Back to P&ID's

To get the ball rolling the Process Engineer has done some preliminary pump sizing calculations.

One pump selection process is like this.

1. **Determine the capacity required in USGal or L/min**
2. **Determine the viscosity of the liquid**
3. **Determine the differential pressure of the system**
4. **Select the pump size**
5. **Determine the Pump Series and Characteristics**
6. **Determine Pump RPM and Required Horse Power.**

P&ID's... Cont.

Driving the pump is an electric motor. Hopefully the motor is started DOL as against a VFD starter. Motor starting and control method should be shown on the P&ID's.

The motor size could be shown on the P&ID's as BHP or HP.

BHP = Break Horse Power (Required Horse Power)

HP = Horse Power

The difference being, BHP is the calculated requirements needed to keep the process at maximum process capacity. HP is the size of a standard 460V NEMA frame motor.

Electric Load List.pdf

Process Support Equipment

The process support equipment consists of everything electrical to support and keep the facility running. The usual items are as follows.

1. Buildings include the main control building and a PCR
2. Outdoor racks for motors and misc. power
3. Inst. rack power
4. Lighting, Inst. & Misc. field power panels
5. Heat tracing panels
6. Motor & equipment heaters
7. 120V normal and 480V welding receptacles
8. Gai-Tronics power
9. CCTV power
10. Card readers
11. Security gates
12. UPS & DC power
13. Etc.,

Questions

Question #4 If the process support equipment list is not on the P&ID's, where does it come from?

Question #5 What design guide should we use?

Question #6 Is it safe?

Not Shown

Not shown on P&ID's or in the support equipment list is how this lot is to be…

1. **Electrically connected,**
2. **Relay protected,**
3. **Or controlled by the Electrical Network Monitoring and Control System (ENMCS) ,**
4. **With interface to the DCS,**
5. **With reliable power from…**

Panel Pitfall’s

The pitfall is to do with panels.

It is usual to put on the ELL the 480V xfmr feeding the 208/120V panel. For example, in the PCR is a lighting panel with a 30KVA xfmr feeding it. So I put 30KVA on the ELL and on I go.

Looking at the wiring diagram all I have is 7 lighting ckts out of a 36 ckt panel. How much of that 30KVA am I actually using???

The same PCR has a 15 KVA xfmr feeding 5 recepticle ckts out of a 30 ckt panel?

Or five areas of a new facility each assigned 1 X Lighting, 1 X recept & 1 X Misc. panels and xfmrs.

All done for conservatism to order the MCC’s.

Questions... More of Them!

Question #7. Who actually sizes the motor based on the P&ID data of process flow and head? Is it the Electrical Engineer? Electrical Designer? Process Engineer? If not this lot then who?

Question #8. When is the preliminary and final data available?

Question #9. Can motor size change between preliminary and final data?

Question #10. Who does not summate and list the loads on 480, 208, 240 & 120VAC panels?

ELL Basics

One of the few good places to go for ELL fundamental guidance is the *Handbook of Electrical Engineering Practioners…*, chapter 1. and

http://www.openelectrical.org/wiki/index.php?title=Load_Schedule

Also of note is the following IEC info.

http://myelectrical.com/notes/entryid/74/estimating-power-demand-using-iec-methods

Along with the Schneider “Electric Electrical Installation Guide”

ELL Basics… Cont.

Get all the P&ID's in a stack. Turn to the first P&ID and start at the left and work your way to the right of each drawing. Listed either at the top or the bottom of the drawing are the electric motors and heaters. Data listed is as follows.

1. **Motor Number (should be different from the pump)**
2. **Motor Description**
3. **BHP and/or HP**
4. **P&ID drawing number**

No_001.xlsx

In simple parlance, P&ID's rule the project.

ELL Basics… Cont.

Per standard practice the project electrical engineer selects motor voltage levels following project and company practices.

The customary NEC voltage levels for induction motors are as follows.

System is 480V	460V motors	1/2hp through 200hp or 250hp
4160V	4,000V motors	200 or 250 through 5000hp
13800V	13,200V motors	above 5000hp

The customary voltage levels for sync motors is as follows

13,800V Motors 8 - 10,000hp and above

12,470V is so 1960's and not used in new facilities.

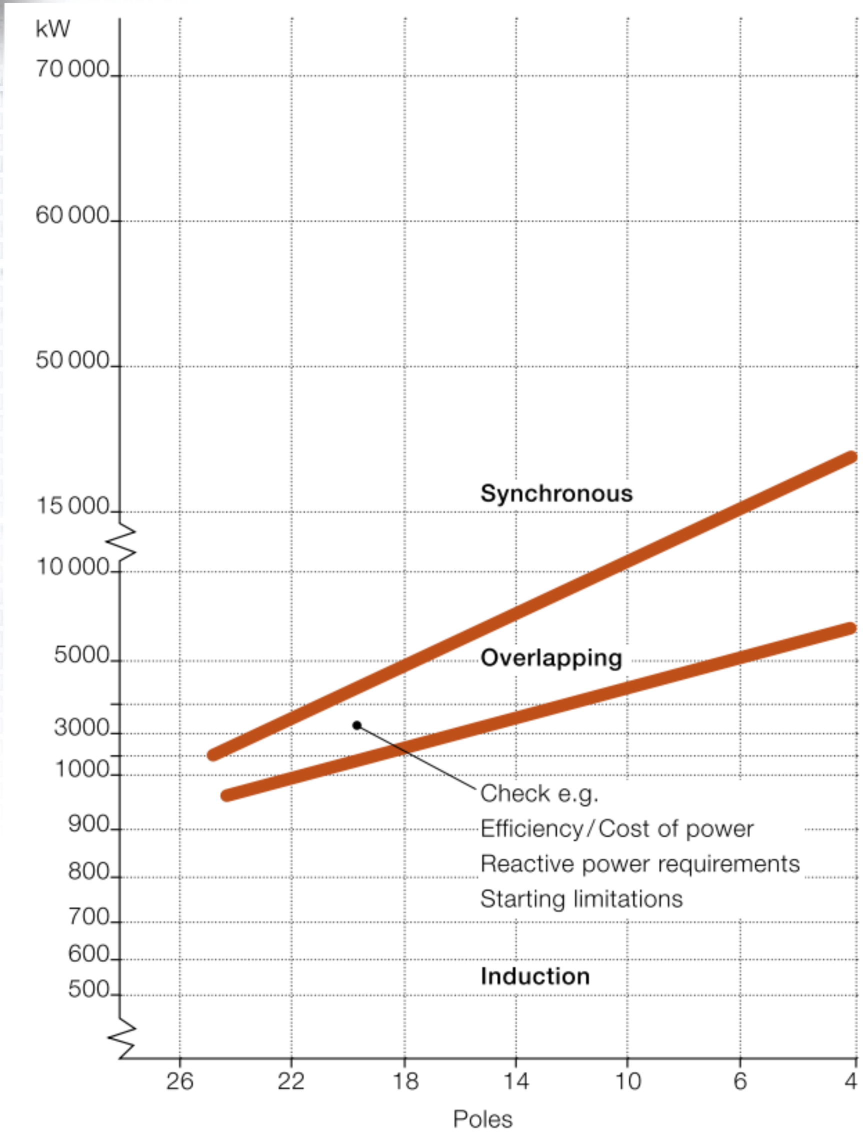
ELL Basics… Cont.

The selection of a Sync over an Induction motor is not necessarily selected only by the project electrical engineer. Items to consider are as follows.

1. **Cost**
2. **DOL - v- soft start**
3. **Driven equipment and starting pulsations**
4. **Operating complexity**
5. **VAR support: nice or needed?**

There is a size limitation on induction motors. Once past that point you have to go with a Sync motor.

ELL Basics… Cont.



A rough guide for motor selection between induction and sync motors.

ELL Basics… Cont.

The goal is to have order in the ELL making it simple and easy to locate equipment items.

1. **Keep the equipment in P&ID drawing order**
2. **Put the equipment in alphanumerical order**
3. **Put the equipment in MCC then numerical order**
4. **Put P&ID above process support equipment**
5. **Put motors then heaters followed by process support equipment**

Straight away we are facing the limitations of spreadsheets as against data base (Access, dBase, etc.,) work.

Spreadsheets are so 1980's. When will we progress on???

ELL Basics… Cont.

The customary approach for equipment separations is the following.

1. If an 'A' & 'B' motor - All 'A' motors on 'A' MCC/SWGR line-up and all 'B' motors on 'B' MCC/SWGR line-up.
2. If an 'A', 'B' & 'C' motor - 'A' & 'C' motors on 'A' MCC/SWGR line-up and 'B' motors on 'B' MCC/SWGR line-up.
3. If an 'A', 'B', 'C' & 'D' motor - 'A' & 'C' motors on 'A' MCC/SWGR line-up and 'B' & 'D' motors on 'B' MCC/SWGR line-up.
4. Single loads spread equally between 'A' & 'B' MCC/SWGR to balance out the overall loads.

Follow company design procedure, if not document it.

Important concept!

ELL Basics... Cont.

Why do we balance out the system loads?

Electrical equipment, especially motors and their controllers will not operate reliably on unbalanced voltages in a 3 ph system. Generally the difference between the lowest and highest voltage should not exceed 4% of the lowest voltage.

Got 3 ph voltage of 450V, 460V & 470V. 4% of 450V is 18V. The lowest to highest is 20V, so we have a problem.

First look at balancing out the 1 ph loads on the system before bothering the utility. Or start de-rating the motor to account for voltage imbalance resulting in heat generation.

I.E. Balance out the loads during design and avoid problems when running the facility. For long term viability best to be below 2% voltage imbalance.

Our Job

Our job is to assemble the ELL as quickly as possible since we have to order long lead items such as a fully populated and functioning PCR with associated SWGR, MCC's, bus duct for the various step-down transformers, relays, etc.,

To do our job we need the data to create an ELL that will feed data into the electrical studies that will ensure we are buying the correctly sized and rated equipment.

Our Job… Cont.

Greenfield – Since everything is new we are going to create a new electrical system all the way from power source to the lowest user. That means creating an ELL and doing studies from scratch.

Brownfield – Blending new work into an existing facility is always more challenging. Too often ELL's and studies are usually old, out of date and highly suspect.

Regardless of location type, we have a job to do. And to do that job we revert to good engineering practices and procedures which include default assumptions based upon sound justifiable judgment.

The key point is, it is documented.

Our Job… Cont.

Therefore, the ELL is usually started with default data, default calculations, default assumptions.

The key point is, it is documented.

As the job progresses the data will change as the P&ID's change. Once the P&ID's are issued for construction, more than likely, the ELL will not change much until final certified data is received and the ELL is updated along with the studies.

The key point is, it is documented.

This preliminary and final approach falls in line with the preliminary and the final electrical studies.

BHP

If the data on the P&ID's list motors in BHP, then we need to convert it to HP as that is how we look at things in the NEC world.

Say the P&ID lists the required motor value at 18BHP. What do I do now?

Assumption #1. The motor BHP is ≈ 85% of motor nameplate HP

This assumption is based upon the fact the motor starting curve has to be greater than the load curve to be able to accelerate the equipment up to full speed.

This assumption is also based on API 610 Table 12 middle value.

BHP

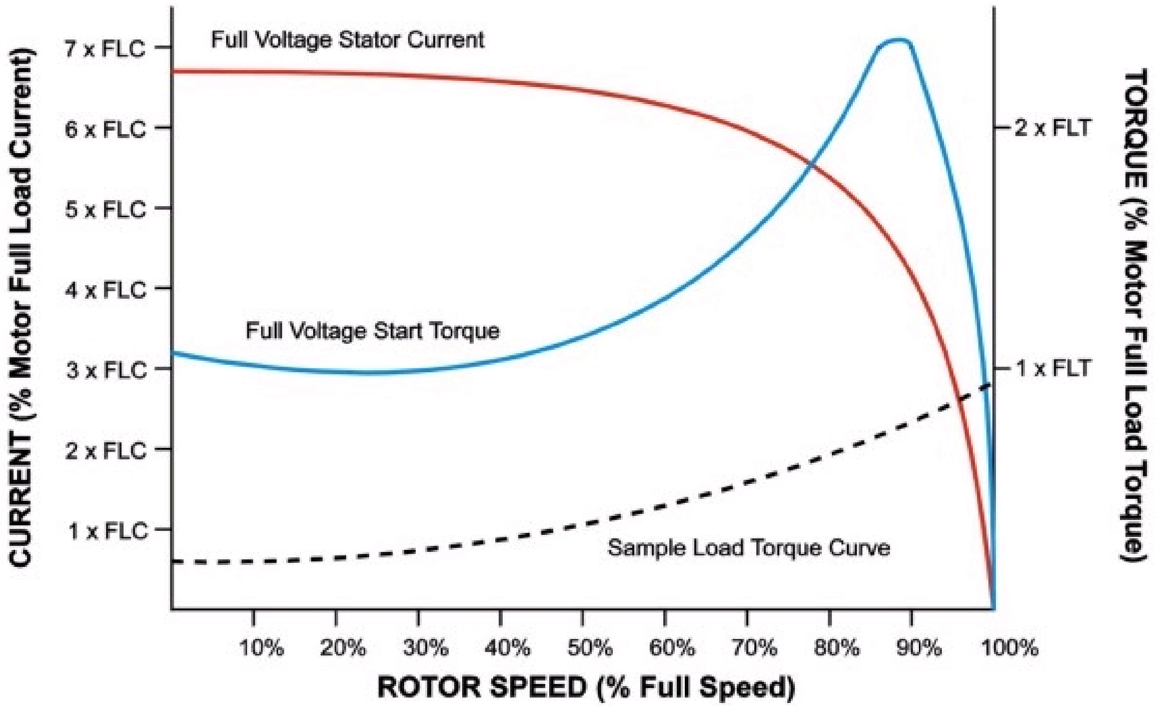
API 610 Table 12

Power ratings for motor drives

Motor nameplate rating		Percentage of rated pump power %
kW	hp	
<22	<30	125
22 to 55	30 to 75	115
>55	>75	110

HP

The rule of thumb is the motor nameplate HP should be about 10 – 15% above process required BHP.



HP

The corollary is:-

Assumption #2. The motor nameplate HP is ≈ 115% of BHP

This assumption is based upon the fact the motor starting curve has to be greater than the load curve to be able to accelerate the equipment up to full speed.

This assumption is also based on API 610 Table 12 middle value.

Assumption 1 & 2 are valid since we do not size motors: the pump vendor does. They tell us the correct size after the PO is placed and certified data is received. Until then everything is preliminary and all we are trying to do is get into the ballpark.

BHP

Say the P&ID lists the required motor value at 18BHP. What do I do now?

Assumption #2. The motor nameplate HP is ≈ 115% of BHP

Therefore 18BHP X 1.15 = 20.7HP

Our preliminary NEMA frame motor would be 25HP as it is the nearest standard NEMA frame motor <u>above</u> the calculated 20.7 value.

However, I would be willing to bet that there is some vendor out there that could use a 20HP motor to do the job. But I do the 25HP as that is per our design guidelines.

ELL… More Columns

Pushing along. I'm taking the equipment data off the P&ID's in drawing order.

A & B motors

TAG #	DESCRIPTION	FLOWSHT	load type hp/kva	HP/KVA VALUE	STATUS C X	I X	S X	LOAD FCTR	DIVERS FCTR
P-421102A	ORF FEED PUMP	20-0032-01	HP	40.0	X			0.85	1.00
P-421102B	ORF FEED PUMP	20-0032-01	HP	40.0			X	0.85	0.10
P-421103A	GF RECYCLE PUMP	20-0032-01	HP	15.0	X			0.85	1.00
P-421103B	GF RECYCLE PUMP	20-0032-01	HP	15.0			X	0.85	0.10
P-421104A	GF FROTH PUMP	20-0032-01	HP	3	X			0.85	1.00
P-421104B	GF FROTH PUMP	20-0032-01	HP	3			X	0.85	0.10

New terms:

1. **CIS**
2. **Load Factor**
3. **Diversity (yep, I'm dropping the word 'factor')**

Mode

It is customary to classify all electrical loads as either Continuous, Intermittent or Standby mode. This mode classification is purely arbitrary and is not based on any recognized or approved standard.

However, continuous and intermittent modes are remarkably similar to the NFPA 70 definitions. But NFPA 70 has nothing remotely close for standby mode.

The practice of classifying items as Continuous, Intermittent or Standby has become entrenched in the Petro/Chem world without any clear guidance or understanding.

Continuous Load

Continuous loads are usually defined as those that normally operate continuously for long periods of time.

Connection Practices

If there is an 'A', 'B' & 'C' motor, it is typical to consider the 'A' & 'B' motors as continuous and the 'C' motor as standby.

If there is an 'A' & 'B' motor, it is typical to consider all 'A' motors as continuous loads and all 'B' motors as standby loads.

If there is a single motor or load, after consultation with process, it shall be designated as continuous or intermittent load. Single motors or loads cannot be designated as standby mode.

Intermittent Load

Intermittent loads are usually defined as those loads that normally operate a fraction of a 24 hour period. The exact period of time is usually not defined or noted.

Don't get mixed up with Intermittent duty motors.

In the Petro/Chem world we always go with continuous duty motors for all motor operations.

Standby Load

Standby loads are usually defined as those loads that are off but ready to run. The most common standby use being illustrated as follows. If there are ‘A’ & ‘B’ motors, it is typical to consider all ‘A’ motors as continuous loads and all ‘B’ motors as standby loads.

Operation Practices

Under normal circumstances, the only time an ‘A’ & ‘B’ motor would run at the same time is during transition from using the ‘A’ pump to using the ‘B’ pump: as in the following example.

‘A’ pump is running; turn on ‘B’ pump resulting in ‘A’ & ‘B’ pump running at the same time; then shutting down the ‘A’ pump leaving only the ‘B’ pump running. The time period that ‘A’ & ‘B’ pumps are running at the same time is usually of a very short duration.

Load Factor (LF)

IEEE Std 141-1993 (Red Book) Clause 2.4.1.3.6 says "Load Factor: The ratio of the average load over a designated period of time to the peak load occurring in that period.

Note that although not part of the official definition, the term load factor is used by some utilities and others to describe the equivalent number of hours per period of the peak or average demand must prevail in order to produce the total energy consumption for the period."

In the Petro/Chem world the LF definition is modified/changed to read as follows. *The ratio of the process BHP value to the motor HP nameplate value. For other loads the load factor is assumed to be 100%.*

NOTE: This document uses the "unofficial" Petro/Chem version of load factor (LF).

Load Factor (LF)... Cont.

Say the P&ID lists the required motor value of 18BHP to achieve maximum process capacity, and our calculation says the provided motor will be 25HP, then the following applies.

Load Factor (LF) = (18/25) = 0.72

This LF value shall continue to be used until final certified data is provided. But by then the electrical equipment is bought, installed and close to full operation.

Load Factor (LF)... Cont.

Say the P&ID lists the motor as 25HP to achieve maximum process capacity . Then we assume the Load factor (LF) is 0.85. Which means we are assuming the motor to be operating at 21.25BHP.

Our default approach is to use a load factor (LF) of 0.85. This goes back to Assumption 1 & 2 previously stated.

Therefore, having the BHP can make a difference to the calculations.

Diversity (D)

IEEE Std 141-1993 (Red Book) Clause 2.4.1.3.5 says "Diversity Factor: The ratio of the sum of the individual non-coincident maximum demands of various subdivisions of the system to the maximum demand of the complete system. The diversity factor is always 1 or greater. The (unofficial) term *diversity*, as distinguished from *diversity factor* refers to the percent time available that a machine, piece of equipment, or facility has its maximum or normal load or demand (i.e. a 70% diversity means that the device in question operates at its nominal or maximum load level 70% of the time that it is connected and turned on)."

NOTE: This document uses the "unofficial" term and definition of diversity (D)

Diversity (D)... Cont.

At the moment there is no technical agreement as to the value of D, or to its application across Continuous, Intermittent and Standby loads, or to the values used during Feasibility (FEP-1), Concept (FEP-2) and Detailed Scope (FEP-3).

The problem is the EPC company is trying to get long lead electrical equipment on order based on preliminary and best guess data. If the EPC company selects high D values, they will be safe and conservative. But more than likely incurring higher CAPEX and ongoing OPEX costs. Both not good for the client.

So, what do you do???

Ask the client for guidance and document it.

Diversity (D)... Cont.

Continuous Mode - Diversity (D_C)

Continuous loads have a pretty clear definition as it has to do with loads that are continuously running. Therefore, continuous loads are assigned a diversity of 100% as follows.

$$D_C = 1.00$$

Diversity (D)… Cont.

Intermittent Mode - Diversity (D_I)

Intermittent loads are a challenge. The two referenced documents use a intermittent diversity of 50%.

1. **So, where does 50% come from?**
2. **What is the underlying justification?**
3. **Or, what operating mode at the plant would have all intermittent loads at 50%?**
4. **Are we doing a copy without thinking?**
5. **Or, is it all about conservatism?**

I'm thinking this way…

Diversity (D)… Cont.

Intermittent Mode - Diversity (D_I)

Defining the operation point with the following.

1. **D_I for lighting panels, D_I = 50% (day/night)**
2. **D_I for receptacle panels, D_I = 5% (little usage)**
3. **D_I for mixed usage panels, D_I = 30% (little maintenance)**
4. **D_I for UPS & DC systems, D_I = 5% (ripple charging)**
5. **D_I for welding receptacles, D_I = 5% (nothing going on)**
6. **D_I for HVAC, D_I = 50% (two units)**
7. **D_I for Heat tracing, D_I = 50% (part time usage)**

And so on as needed and identified.

Diversity (D)... Cont.

Standby Mode - Diversity (D_S)

Standby loads should be simple: but aren't. The two referenced documents use a standby diversity of 10%.

1. **So, where does 10% come from?**
2. **What is the underlying justification?**
3. **Or, what operating mode at the plant would have all standby loads at 10%?**
4. **Are we doing a copy without thinking?**
5. **Or, is it all about conservatism?**

I'm thinking this way... Standby loads are at 0.0% as they are not running.

Load Criticality

You will notice that I am avoiding the topic of Load Criticality which are normally considered to be as follows.

1. Normal Loads
2. Essential Loads
3. Critical Loads

Totally valid topic. Should be discussed in a full presentation and that is why not covered here.

Stepping Back a Moment

Let's step back a moment. What are we trying to do?

1. We are trying to size electrical equipment to provide a safe operating environment for the personnel using the equipment.
2. And provide a cost effective solution to the problem at hand.

Remember our goal as we diverge a bit.

Load Formulas

We are going to diverge a bit and discuss load formulas. The load formulas we are covering are generally accepted, but not clearly established by IEEE or NEMA.

That is why we have to establish/document what formulas we are going to use and what they mean.

Load Formulas (MNRL) #1

Maximum normal running load (MNRL) is the summation of all continuous loads (CL) and intermittent loads (IL) multiplied by diversity (D_I).

$$MNRL = \sum CL + \sum (IL \times D_I)$$

Where CL & IL are at the LF & D point.

Maximum Normal Running Load is assumed to occur when maximum process capacity is achieved.

Load Formulas (MNRL) #2

Maximum Normal Running Load (MNRL) is the summation of all continuous loads (CL), intermittent loads (IL) multiplied by diversity (D_I) and standby loads (SL) multiplied by diversity (D_S).

$$MNRL = \sum CL + \sum(IL \times D_I) + \sum(SL \times D_S)$$

Where CL, IL & SL are at the LF & D point

Maximum Normal Running Load (MNRL) is assumed to occur when maximum process capacity is achieved.

More conservatism leads to increased cost.

Load Formulas (MD)

Maximum demand (MD) occurs at maximum normal running load (MNRL) plus future demand (FD) plus a 10% margin (FD X 10%).

$$MD = MNRL + \sum FD + (\sum FD \times 10\%)$$

Where FD is a documented value.

Maximum Normal Running Load (MNRL) is assumed to occur when maximum process capacity is achieved.

Load Formulas (CD)

Connected demand (CD) is not a process operating point. It is a summation of all connected loads.

$$CD = \sum CL + \sum IL + \sum SL$$

Where CL, IL & SL are at equipment nameplate values

Connected loads only. Future demand not included.

Load Formulas… Why?

The question is, what are the Load Formulas for and when are they used?

1. **First and foremost is the point that MNRL #1, #2 & MD occur when the process is at Maximum Process Capacity. While CD is a theoretical point.**
2. **Have to select between MNRL #1 & 2 to establish Load Flow Study parameters.**
3. **MD is one way to project into the future, or list the spares. More common to list spares.**
4. **CD is usually used in Short Circuit studies. Have to list spares to get worst case scenario.**

Is it Time to...

Take a Break???

Motor Data

Moving on…

	load		STATUS					LOOKUP DATA			
FLOWSHT	type	HP/KVA	C	I	S	LOAD	DIVERS	SF	FLA	PF	EFF
	hp/kva	VALUE	X	X	X	FCTR	FCTR				
20-0032-01	HP	40.0	X			0.85	1.00	1.15	52.0	0.86	0.94
20-0032-01	HP	40.0			X	0.85	0.10	1.15	52.0	0.86	0.94
20-0032-01	HP	15.0	X			0.85	1.00	1.15	21.0	0.86	0.91
20-0032-01	HP	15.0			X	0.85	0.10	1.15	21.0	0.86	0.91
20-0032-01	HP	3	X			0.85	1.00	1.15	4.8	0.80	0.86
20-0032-01	HP	3			X	0.85	0.10	1.15	4.8	0.80	0.86

Since we are early in the ELL process, 480V motor data is usually provided from a lookup table of motor data. It is common to select a motor brand and copy motor data into the xls and use lookup commands to populate the lookup data values based upon motor size.

Motor Data… Cont.

	load		STATUS					LOOKUP DATA			
FLOWSHT	type	HP/KVA	C	I	S	LOAD	DIVERS	SF	FLA	PF	EFF
	hp/kva	VALUE	X	X	X	FCTR	FCTR				
20-0032-01	HP	40.0	X			0.85	1.00	1.15	52.0	0.86	0.94
20-0032-01	HP	40.0			X	0.85	0.10	1.15	52.0	0.86	0.94
20-0032-01	HP	15.0	X			0.85	1.00	1.15	21.0	0.86	0.91
20-0032-01	HP	15.0			X	0.85	0.10	1.15	21.0	0.86	0.91
20-0032-01	HP	3	X			0.85	1.00	1.15	4.8	0.80	0.86
20-0032-01	HP	3			X	0.85	0.10	1.15	4.8	0.80	0.86

Two Questions.

Question #11. Why do I need a SF of 1.15 when I have a LF of 0.72? Is it physically possible to push the motor into the SF area?

Question #12. If I want the project to be per the NEC, what does that mean for motor data? Where do I go to keep in compliance with the NEC?

Motor Data… Cont.

The following is per the 2014 NEC. Note, no Eff or PF.

460V MOTOR FLA FROM NEC TABLE 430-250		
VOLTAGE	HP	FLA
460	1/2	1.1
460	3/4	1.6
460	1	2.1
460	1 1/2	3.0
460	2	3.4
460	3	4.8
460	5	7.6
460	7 1/2	11.0
460	10	14.0
460	15	21.0
460	20	27.0
460	25	34.0
460	30	40.0
460	40	52.0
460	50	65.0
460	60	77.0
460	75	96.0
460	100	124.0
460	125	156.0
460	150	180.0
460	200	240.0

Electrical Design Criteria says to comply with NEC.

But is this really what I shall be buying?

If my standard is to get API 841 motors, what values do I use? And how close are they to the NEC?

Motor Data... Cont.

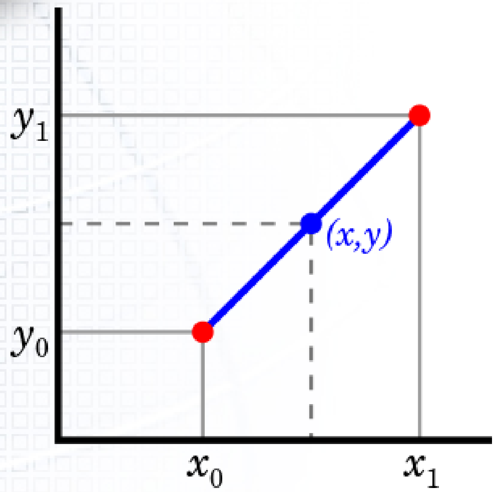
Taken from Siemens 2015-D81.2 NEMA Motors Catalog

Siemens SD100 IEEE 841 NEMA Premium AL Rotor						
HP	RPM	Frame	Voltage	FLA	Nom Eff	PF
1	1800	143T	460	1.40	85.50	0.78
1.5	1800	145T	460	2.10	86.50	0.77
2	1800	145T	460	2.80	86.50	0.77
3	1800	182T	460	4.00	89.50	0.78
5	1800	184T	460	6.50	89.50	0.80
7.5	1800	213T	460	9.70	91.70	0.79
10	1800	215T	460	12.50	91.70	0.82
15	1800	254T	460	19.00	92.40	0.80
20	1800	256T	460	25.00	93.00	0.81
25	1800	284T	460	30.00	93.60	0.83
30	1800	286T	460	35.00	93.60	0.86
40	1800	324T	460	46.00	94.10	0.87
50	1800	326T	460	58.00	94.50	0.85
60	1800	364T	460	68.00	95.00	0.87
75	1800	365T	460	85.00	95.40	0.87
100	1800	405T	460	113.00	95.40	0.87
125	1800	444T	460	143.00	95.40	0.86
150	1800	445T	460	170.00	95.80	0.86
200	1800	447T	460	226.00	96.20	0.86

PF calculated. Also note the difference from NEC ampacity.

Motors operate at maximum process capacity, not nameplate, so what do we do?

Motor Data... Cont.



Linear Interpolation...

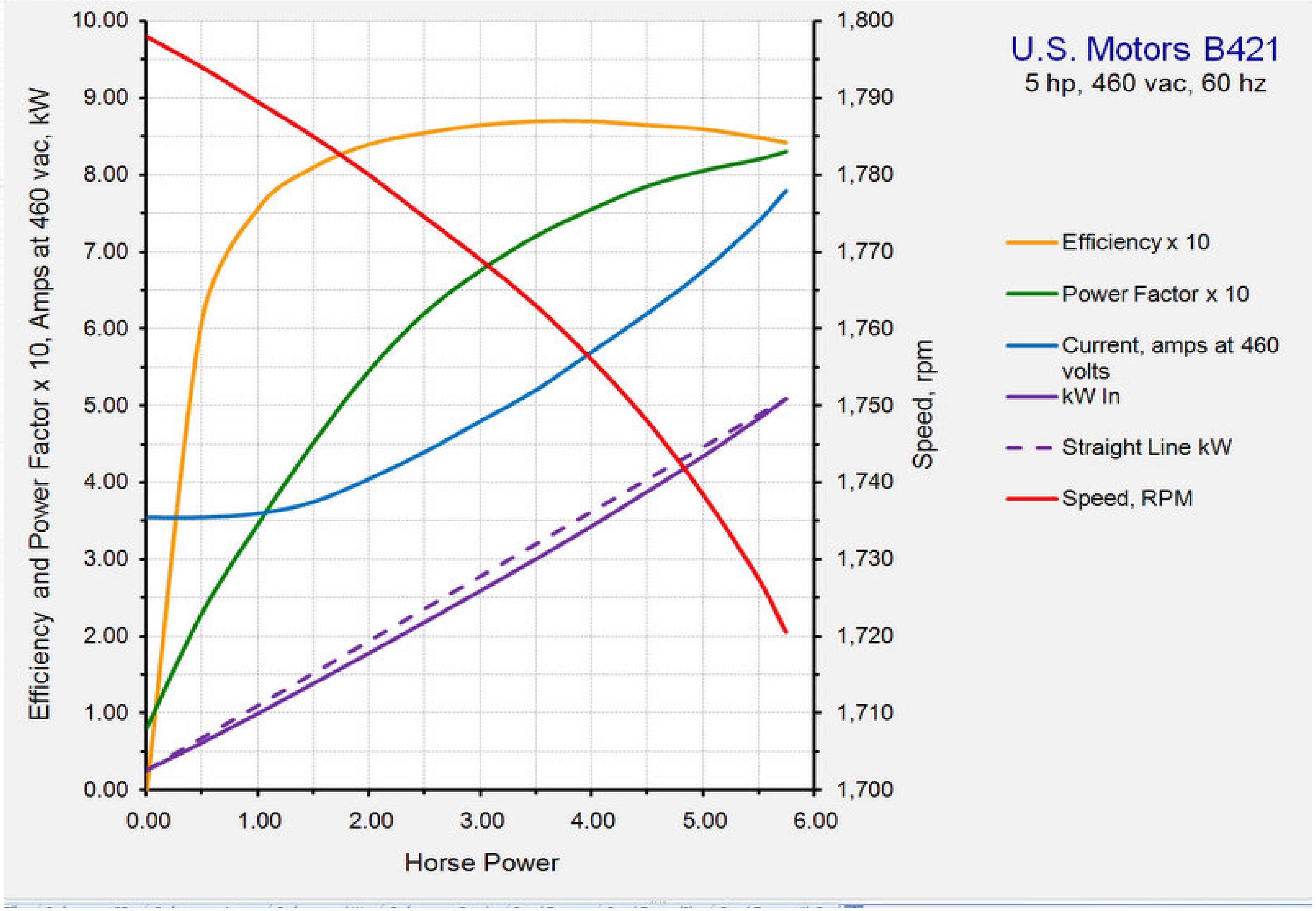
If the two known points are given by the coordinates and , the linear interpolant is the straight line between these points. For a value *x* in the interval , the value *y* along the straight line is given from the equation

$$\frac{y - y_0}{x - x_0} = \frac{y_1 - y_0}{x_1 - x_0}$$

The key point being along the straight line. If the line is not straight, then this formula is of no use.

Some people use linear interpolation when calculating motor power factor and efficiency at maximum process capacity. Since the power factor and efficiency curve are not straight, then a degree of error is introduced.

Motor Data... Cont.



Linear Interpolation

See the difference between eyeballing and calculated linear interpolation.

Eyeballing

BK HP	HP	RPM	PF 50%	PF 60%	PF 75%	PF 80%	PF 100%	Eff 50%	Eff 60%	Eff 75%	Eff 80%	Eff 100%	Guar Min
7	10	1755	63.80	67.00	76.20	78.00	81.70	91.70	91.95	92.20	91.95	91.70	90.20
13	20	1770	65.30	69.00	75.90	76.50	80.50	93.10	93.25	93.40	93.25	93.00	91.70
33	40	1780	75.00	78.00	83.00	83.50	86.00	94.30	94.18	94.10	94.10	94.10	93.60
77	100	1780	80.00	82.50	86.00	86.40	87.00	95.80	95.95	96.00	95.70	95.40	95.00
130	200	1785	76.00	78.50	84.00	84.80	86.00	96.20	96.35	96.50	96.37	96.20	95.80

Linear Interpolation

BK HP	HP	RPM	PF 50%	PF 60%	PF 75%	PF 80%	PF 100%	Eff 50%	Eff 60%	Eff 75%	Eff 80%	Eff 100%	Guar Min
7	10	1755	63.80	68.76	76.20	78.40	81.70	91.70	91.90	92.20	92.40	91.70	90.20
13	20	1770	65.30	69.54	75.90	77.74	80.50	93.10	93.22	93.40	93.56	93.00	91.70
33	40	1780	75.00	78.20	83.00	84.20	86.00	94.30	94.38	94.10	94.10	94.10	93.60
77	100	1780	80.00	82.40	86.00	86.40	87.00	95.80	95.88	96.00	96.24	95.40	95.00
130	200	1785	76.00	79.20	84.00	84.80	86.00	96.20	96.32	96.50	96.62	96.20	95.80

Table 1

Taken from the P&ID's

Row	ID	Description	P&ID	BK HP	BK KVA
1	P-101A	Bottoms Sump Pump	D-101-10001A	7	
2	P-101B	Bottoms Sump Pump	D-101-10001A	7	
3	P-102A	Bottoms End Pump	D-101-10001A	13	
4	P-102B	Bottoms End Pump	D-101-10001A	13	
5	P-103A	Recycle Pump	D-101-10001B	77	
6	P-103B	Recycle Pump	D-101-10001B	77	
7	P-104	Sump Pump	D-101-10002C	33	
8	P-105	Sump Bottoms Pump	D-101-10003A	130	
9	HTR-001	Heater 001	D-102-10001A		50
10	HTR-002	Heater 002	D-102-10001B		75

Table 2

Add in Non-P&ID data

Row	ID	Description	P&ID	BK HP	BK KVA	KVA
1	P-101A	Bottoms Sump Pump	D-101-10001A	7		
2	P-101B	Bottoms Sump Pump	D-101-10001A	7		
3	P-102A	Bottoms End Pump	D-101-10001A	13		
4	P-102B	Bottoms End Pump	D-101-10001A	13		
5	P-103A	Recycle Pump	D-101-10001B	77		
6	P-103B	Recycle Pump	D-101-10001B	77		
7	P-104	Sump Pump	D-101-10002C	33		
8	P-105	Sump Bottoms Pump	D-101-10003A	130		
9	HTR-001	Heater 001	D-102-10001A		50	
10	HTR-002	Heater 002	D-102-10001B		75	
11	LP-001	Lighting Panel				50
12	LP-002	Lighting Panel				50
13	UPS-001	Inst UPS				45
14	DC-001	DC Power				30
15	FDR-001A	Control Building Power				500
16	FDR-001B	Control Building Power				500
17	LP-003	Lighting Panel				20
18	LP-004	Lighting Panel				20
19	HVAC-001	HVAC Unit #1				100
20	HVAC-002	HVAC Unit #2				100

Table 2… Cont.

For non-process loads it is customary to use the transformer size associated with the load.

Again, this customary method can result in a large electrical load associated with panels. This load will not be known until the design is done and the panel loads are summated.

Remember the Panel Pitfalls slide previous!

Non-Rotating Loads

For non-rotating loads we are assuming Eff = 100% and the PF is assumed to be 85%.

The assumed 85% PF could be too low as it is easy to find PF references as follows.

Incandescent lamps & heaters ------------ 1.0
Fluorescent & Merc. Vapor lamps ------ 0.5 - 0.95

Therefore it might be more accurate to use a PF of 90% or higher depending on the number and size of lights and heaters.

ELL... Cont.

Adding in more data to the load list.

Row	ID	Description	P&ID	Voltage	BK HP	KVA	HP	MODE	D	LF	PF	EFF
1	P-101A	Bottoms Sump Pump	D-101-10001A	460	7		10	C	100%	70.00%	76.20%	92.20%
2	P-101B	Bottoms Sump Pump	D-101-10001A	460	7		10	S	0%	70.00%	76.20%	92.20%
3	P-102A	Bottoms End Pump	D-101-10001A	460	13		20	C	100%	65.00%	79.22%	92.75%
4	P-102B	Bottoms End Pump	D-101-10001A	460	13		20	S	0%	65.00%	76.22%	92.75%
5	P-103A	Recycle Pump	D-101-10001B	460	77		100	C	100%	77.00%	86.40%	95.78%
6	P-103B	Recycle Pump	D-101-10001B	460	77		100	S	0%	77.00%	86.40%	95.78%
7	P-104	Sump Pump	D-101-10002C	460	33		50	I	10%	66.00%	85.22%	93.08%
8	P-105	Sump Bottoms Pump	D-101-10003A	460	130		200	I	15%	65.00%	88.10%	96.76%
9	HTR-001	Heater 001	D-102-10001A	480		50		I	20%	100%	85%	100%
10	HTR-002	Heater 002	D-102-10001B	480		75		I	25%	100%	85%	100%
11	LP-001	Lighting Panel		480		50		I	50%	100%	85%	100%
12	LP-002	Lighting Panel		480		50		I	50%	100%	85%	100%
13	UPS-001	Inst UPS		480		45		C	3%	100%	85%	100%
14	DC-001	DC Power		480		30		C	3%	100%	85%	100%
15	FDR-001A	Control Building Power		480		400		I	40%	100%	85%	100%
16	FDR-001B	Control Building Power		480		400		I	40%	100%	85%	100%
17	LP-003	Lighting Panel		480		20		I	100%	100%	85%	100%
18	LP-004	Lighting Panel		480		20		I	100%	100%	85%	100%
19	HVAC-001	HVAC Unit #1		480		100		I	75%	100%	85%	100%
20	HVAC-002	HVAC Unit #2		480		100		I	75%	100%	85%	100%

480V MCC Spares

Before we move on we need to discuss spare spaces, spare 480V CB’s and spare motor starters and how they play into the big picture. If you have been observant I have ignored this issue so far.

First and foremost it is customary to add in spares for future growth and changes. Spares should be addressed in the Electrical Design Criteria document. If not then the project EE should suggest typical values. One typical value is to have 10% spares.

480V MCC Spares… Cont.

For example I have a project that consists of the following 480V loads and the design criteria says to have 10% spare. What does that actually mean?

100 X Size 1 starters	100 X 10% = 10 spare
50 X Size 2 starters	50 X 10% = 5 spare
20 X Size 3 starters	20 X 10% = 2 spare
15 X size 4 starters	15 X 10% = 1.5 go with 2 spare
5 X Size 5 starters	5 X 10% = 0.5 go with 1 spare
75 X 50A CB	75 X 10% = 7.5 go with 8 spare
100 X 100A CB	100 X 10% = 10 spare
40 X 200A CB	40 X 10% = 4 spare
18 X 100A CB	18 X 10% = 1.8 go with 2

480V MCC Spares... Cont.

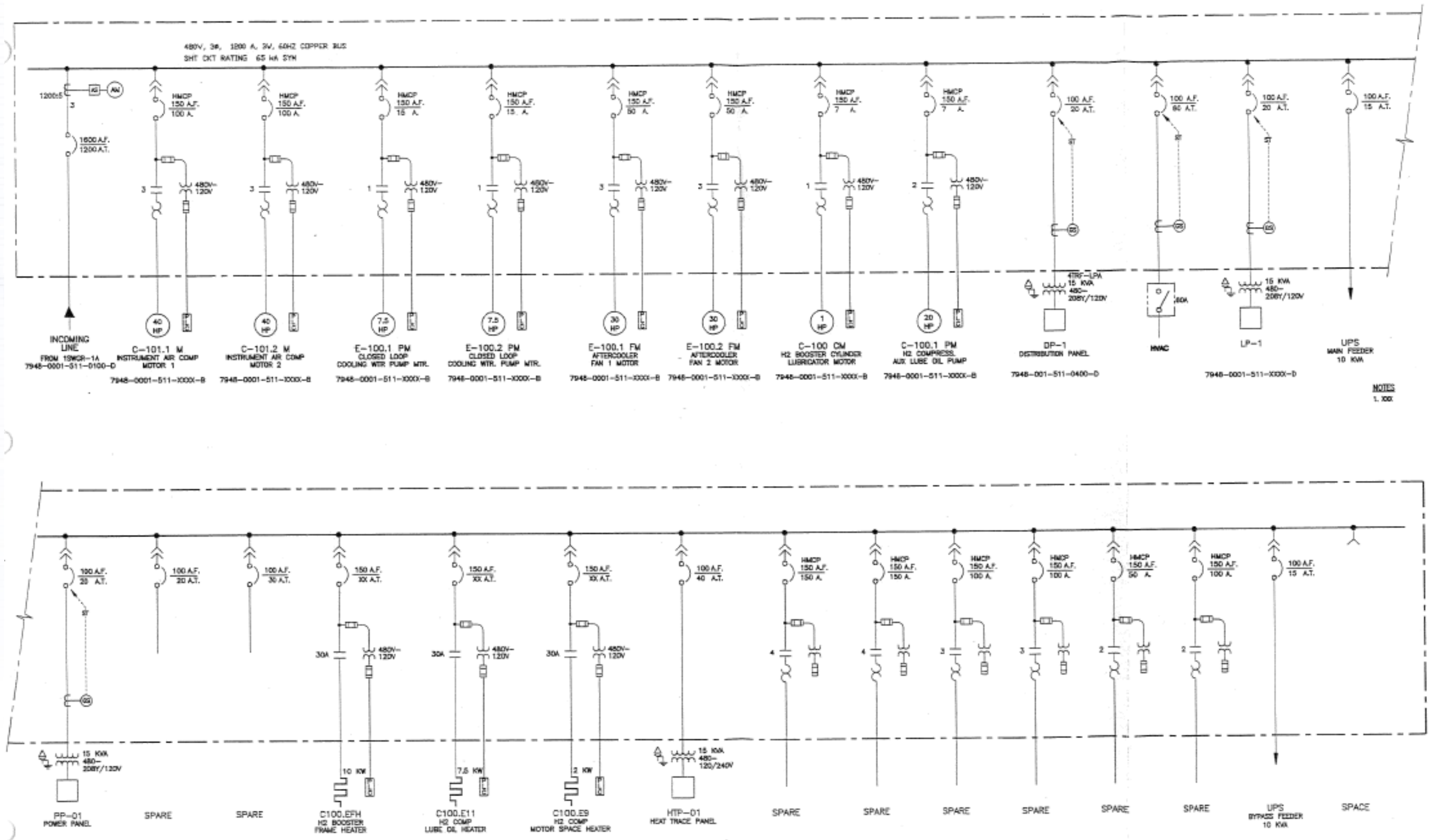
Now that I have the load list including the spare motor starters and CB's, now I have a good idea of how many vertical MCC sections I need to do the job. What about spare spaces? For example,

MCC-1	- 6 sections	6 X 10% = 0.6 go with 1 section
MCC-2	- 8 sections	8 X 10% = 0.8 go with 1 section
MCC -3	- 5 sections	5 X 10% = 0.5 go with 1 section

Conversely, you could reserve floor space for the spare MCC section(s) and install them later when they are actually needed. Pushing cash from CAPEX to OPEX.

These days it is highly unlikely to have a MCC with a large number of sections. The trend is smaller MCC's due to smaller xfmrs to keep arc flash values down.

480V MCC Spares…



Note the spare spaces, motor starters and ckt bkr's. Small project, small number of spares.

480V MCC Question

Do you want each CB in a bucket on it's own, or are you okay with two CB's in one bucket?

This is a cost -v- safety issue. Always check with the client and get this one clearly documented as it is not a common Design Criteria topic.

Adjust the Load List Sources

Originally we said, the data to populate an ELL comes from two sources. They are as follows.

1. **The P&ID's**
2. **Process Support Equipment and ancillary items.**

Now we should modify the statement to include a third source, 'spares'.

Spares – Sizes... Cont.

So how do we include spares in the ELL?

For motor starters go with the following motor sizes.

Size 1 - 10hp
Size 2 - 25hp
Size 3 - 50hp
Size 4 - 100hp
Size 5 - 150hp (some might say 200hp)

For CB's go with Design Criteria. Usually 80 or 100% of CB rating. This approach could result in added conservatism due to the difference between AF & AT.

Updating ELL

Going back to the ELL already used and add in the following spare equipment.

1 spare size 1 and use 10hp

1 spare size 2 and use 25hp

1 spare size 4 and use 100hp

1 spare size 3 and use 50hp

1 spare size 5 and use 200hp

1 spare 100AF CB

1 spare 150AF CB

1 spare 600AF CB

1 spare vertical section by illustrating 6 spaces on the one-line or reserving floor space on the layout drawing.

Do I really want to do this? Use good engineering judgment

Updating ELL... Cont.

Section 1	Section 2	Section 3
480V MCC main Incoming section	MP-111A 150 HP Recycle Pump Size 5 starter	Spare Size 5 starter

Question #13

If I had MP-111A & B, would you put a spare starter here?

Updating ELL… Cont.

On the other hand, the client's electrical engineer might have superior knowledge and direct you to use only a certain number of spare equipment. As illustrated from the client provided one-line diagram previously shown.

Following technical requirements and using good engineering judgment the complete ELL is about ready to be issued for review and comment.

Is it Time to…

Take a Break???

480V MCC's

Okay, we have completed our first pass on the ELL and we have done our first pass on allocating the various loads to the various MCC's we think we need. It is time to see how well we have done.

The caveat is, following the NEC is different from the ELL.

Sizing MCC's we tend to follow NEC 430:24 *Several motors or a motor(s) and other load(s)*. "Conductors supplying several motors, or a motor(s) and other load(s) shall have an ampacity not less than the sum of each of the following:

1. **125% of the full-load current rating of the highest rated motor, as determined by 430.6(A)**
2. **Sum of the full-load current ratings of all the other motors in the group, as determined by 430.6(A)**
3. **100% of the non-continuous non-motor loads**
4. **125% of the continuous non-motor loads**

480V MCC's... cont.

By following the NEC guidelines of the previous slide, a ampacity summation is possible. If you are with me, you will notice spares are not accounted for. They should be added in the calculation before selecting the bus size greater than that summation.

480V MCC's come in standard sizes (depending on vendor). 600A ,800A, 1200A, 1600A, 2000A, 2500A, 3200A, & 4000A

On a greenfield project I would go up to 80% of ampacity rating. Brownfield is up to 90% of ampacity rating.

Also depends on available physical space.

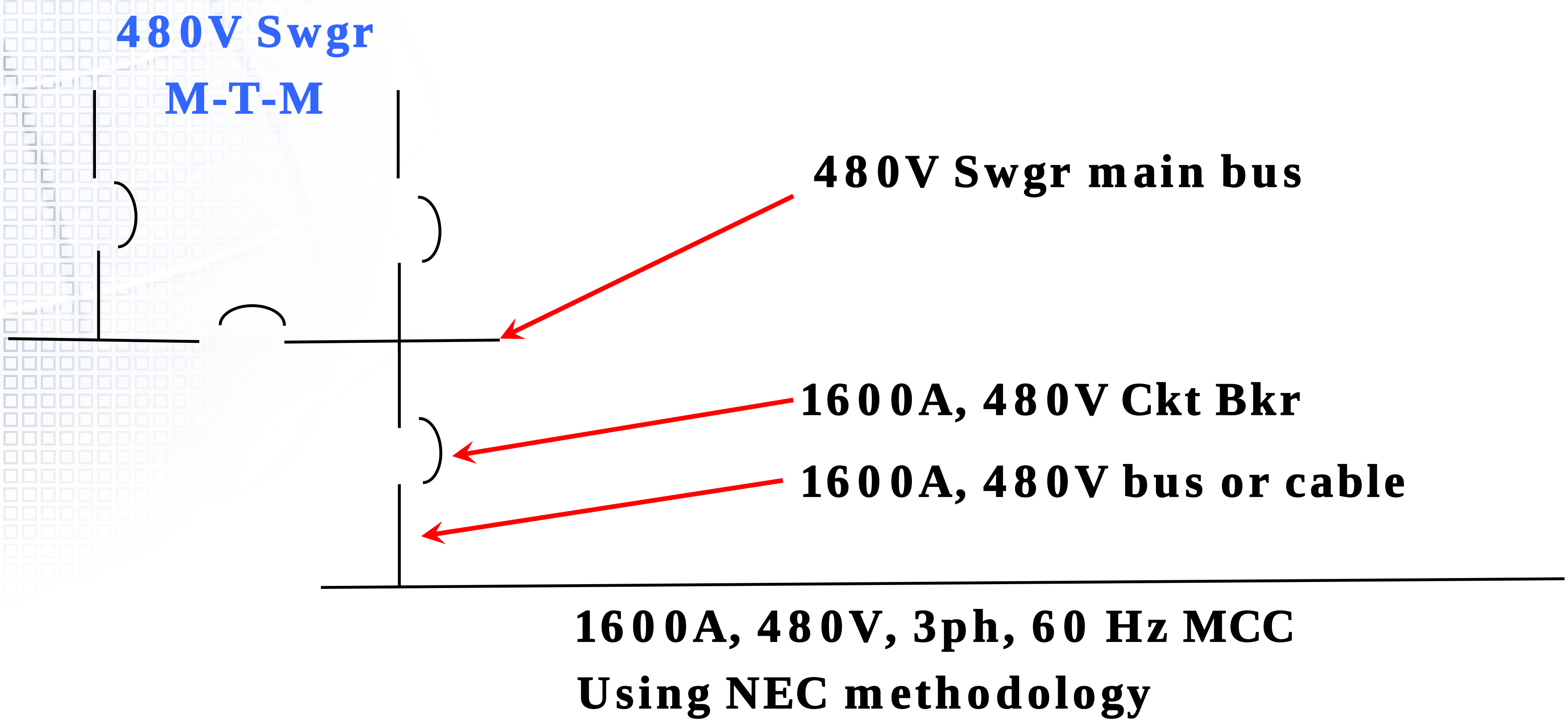
480V MCC's... cont.

Let's say our NEC summation comes to 1123A. Then a 1200A bus would be a good choice. If I went with my 80% guidance, the 1600A would be my choice.

1. **16ooA is more costly than 1200A.**
2. **What if the facility has only 1600A MCC's?**
3. **Is it worth talking about all the spares... are they really justified?**
4. **For budgetary purposes best to go with 1600A.**

So that settles how we size 480V MCC's. We do it the NEC way.

480V MCC's... cont.



480V SWGR

For 480V swgr we have a different approach. Why a different approach? Simple, the NEC has no guidelines for sizing the 480V swgr so we follow good engineering practices.

Trouble is defining what good engineering practices are.

So how do we do it?

480V SWGR... Cont.

Say I have four 480V MCC's, each with a Operating Load of 880A. I could go with 1200A (880 X 120%), but I selected 1600A because that is standard at the facility.

The EPC says the standard approach is to use 480V swgr in a M-T-M configuration to power the MCC's.

The EPC people put 2 X MCC's on side 'A' and 2 X MCC's on side 'B' of the 480V swgr. The goal is to continue balancing out the loads. Now, how to size the swgr bus?

a. Bus = 4 X 1600A = 6,400A - do they make this???

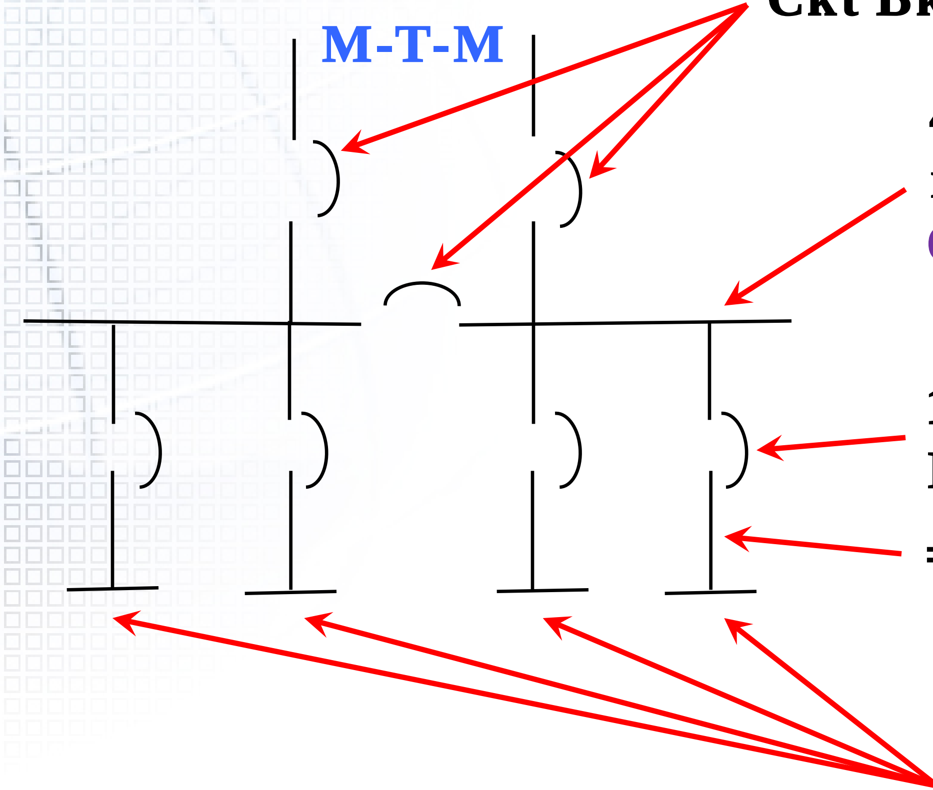
b. Bus = 4 X 1200A = 4,800A - go with 5,000A bus

c. Bus = 4 X 880A = 3,520A - 3,600A is close so go with 4,000A bus

Make sure you have a company approved procedure and are following it.

480V MCC's... cont.

480V Swgr M-T-M



4000A, 480V, 3ph, 60 Hz M-T-M Ckt Bkrs

4000A, 480V, 3ph, 60 Hz main Swgr Bus. Using Operating Load methodology

1600A, 480V, 3ph, 60 Hz Ckt Bkrs

=>1600A, 480V bus or cable

1600A, 480V, 3ph, 60 Hz MCC Using NEC methodology

480V SWGR... Cont.

2000 KVA
13.8-480V Xfmr
55/65C, ONAN/ONAF
2000 – 2300kva
2240 – 2576kva
3102A max

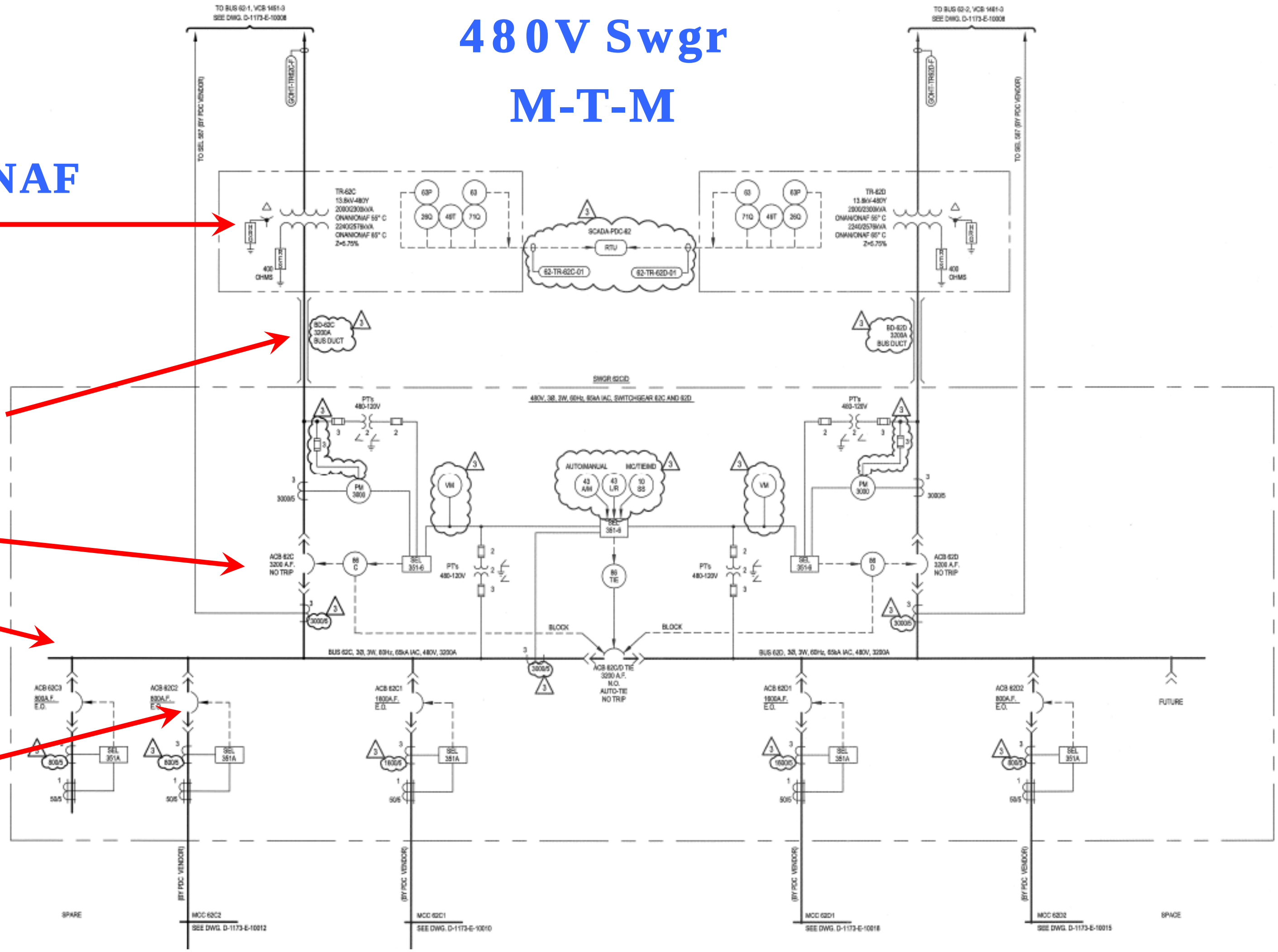
3200A Bus Duct

3200A Bkr

3200A Bus

1600A Bkr

480V Swgr
M-T-M



Is it Time to…

Take a Break???

The Other Side… Power Supply

I sat in a meeting with an old crusty electrical engineer who asked the project engineer if he wanted the utility connection to be high reliability, medium reliability or low reliability.

The project engineer said high reliability utility connection so he got a breaker-and-a-half configuration.

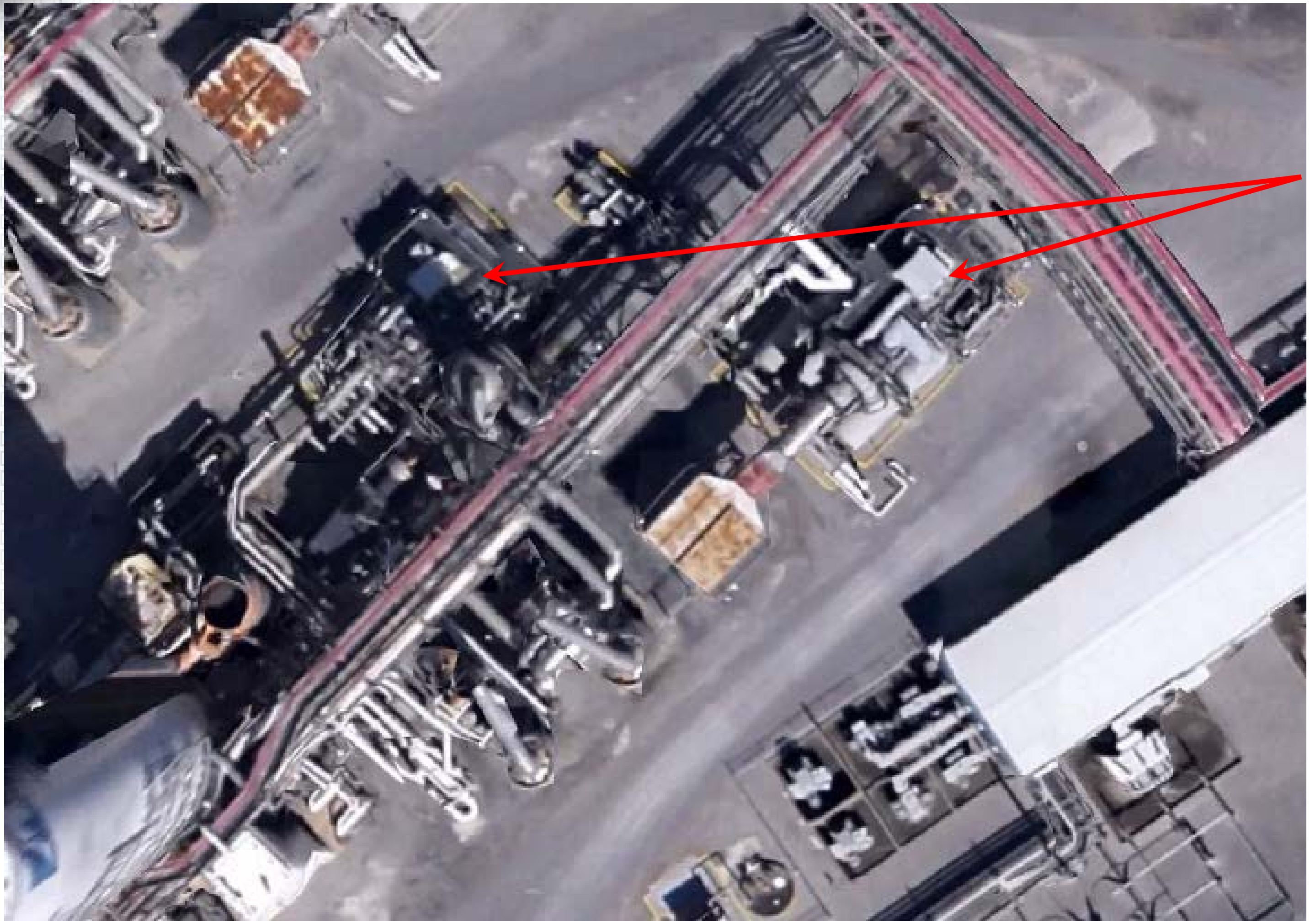
High reliability	= Breaker-and-a-half
Medium reliability	= Ring bus
Low reliability	= Tap etc.,

Where does our power come from? Hopefully someone is working from this end downward towards the loads.

138kV Breaker-and-a-Half

The Same - Updated

The Same – Motors



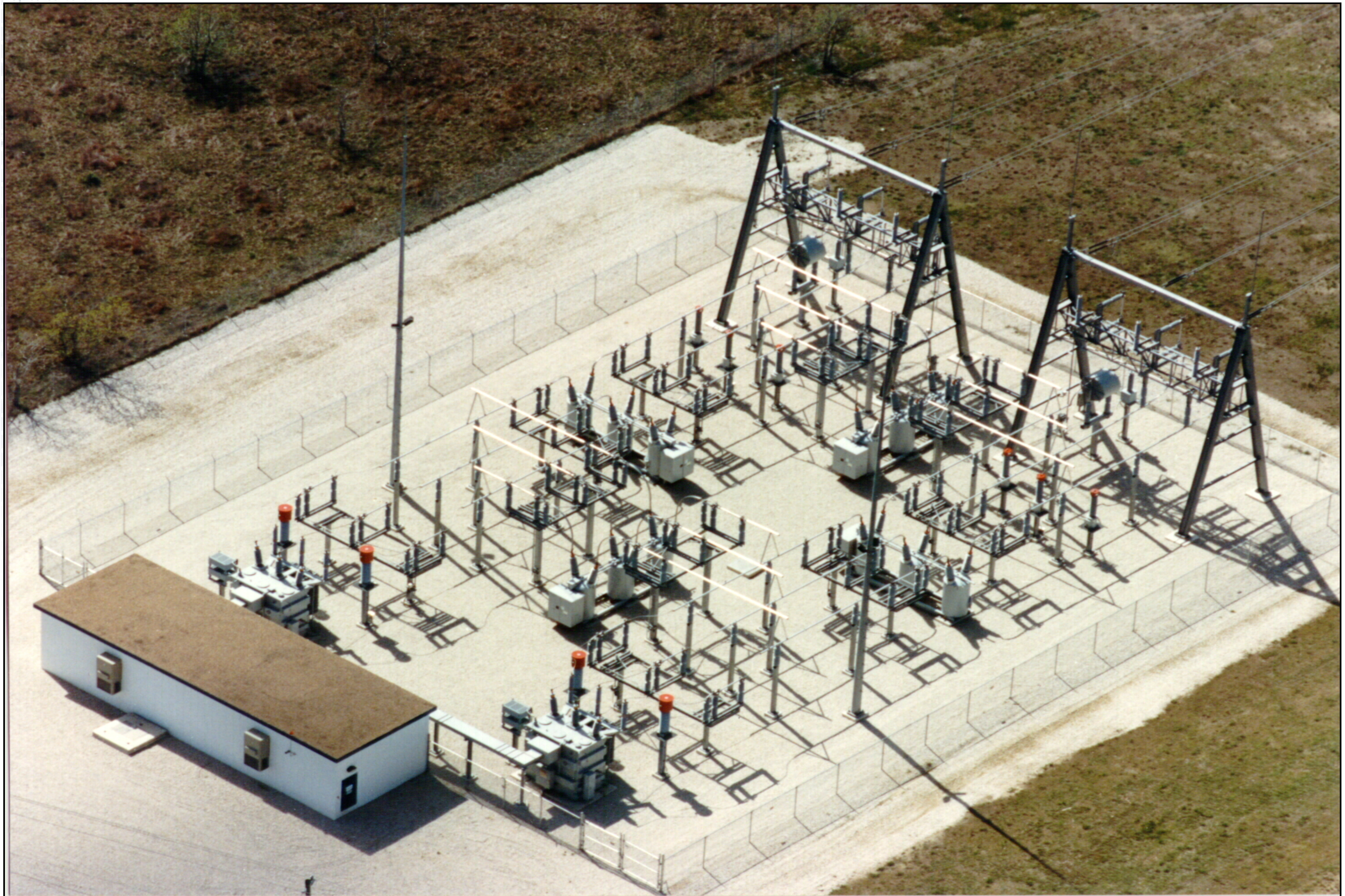
13.8kV
MOTORS

Ring Bus

A typical installation is a 138kV Ring bus arrangement with two 138kV lines in and two 13.8kV bus ducts out.

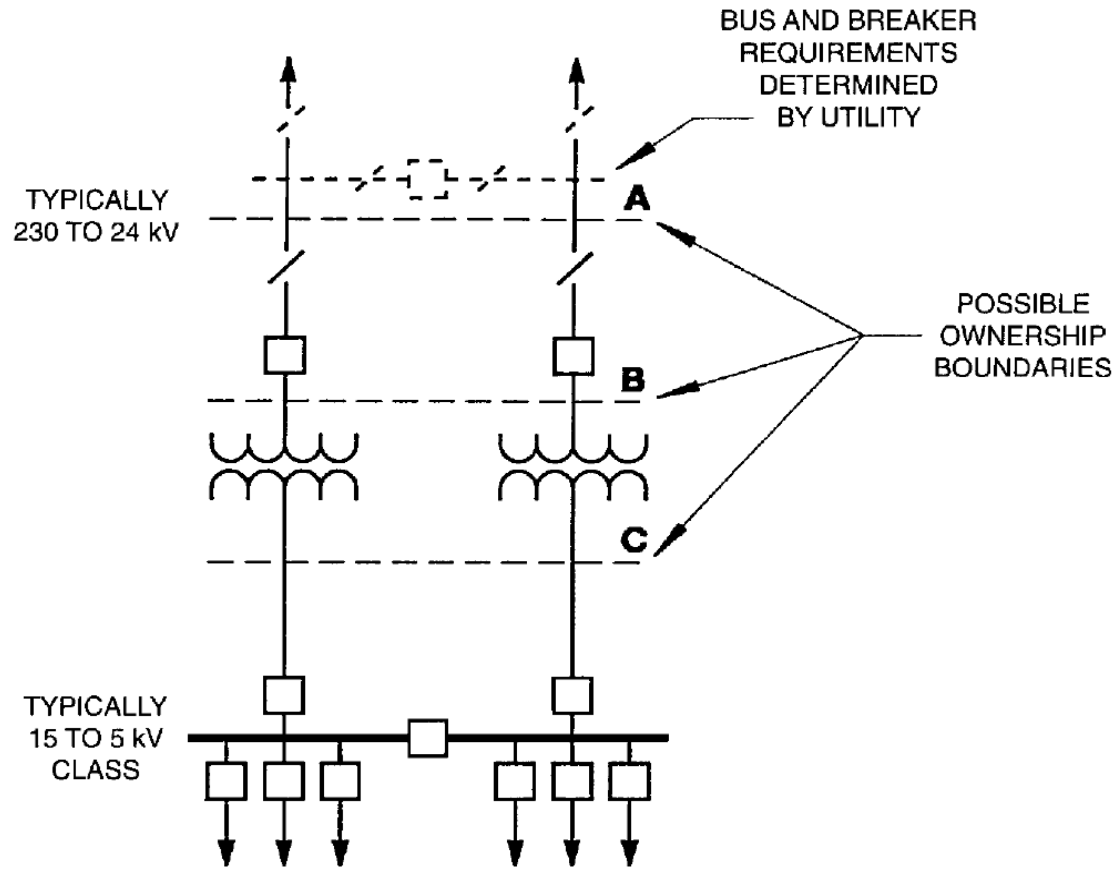
Another 138kV Ring Bus

Another older Ring Bus design.

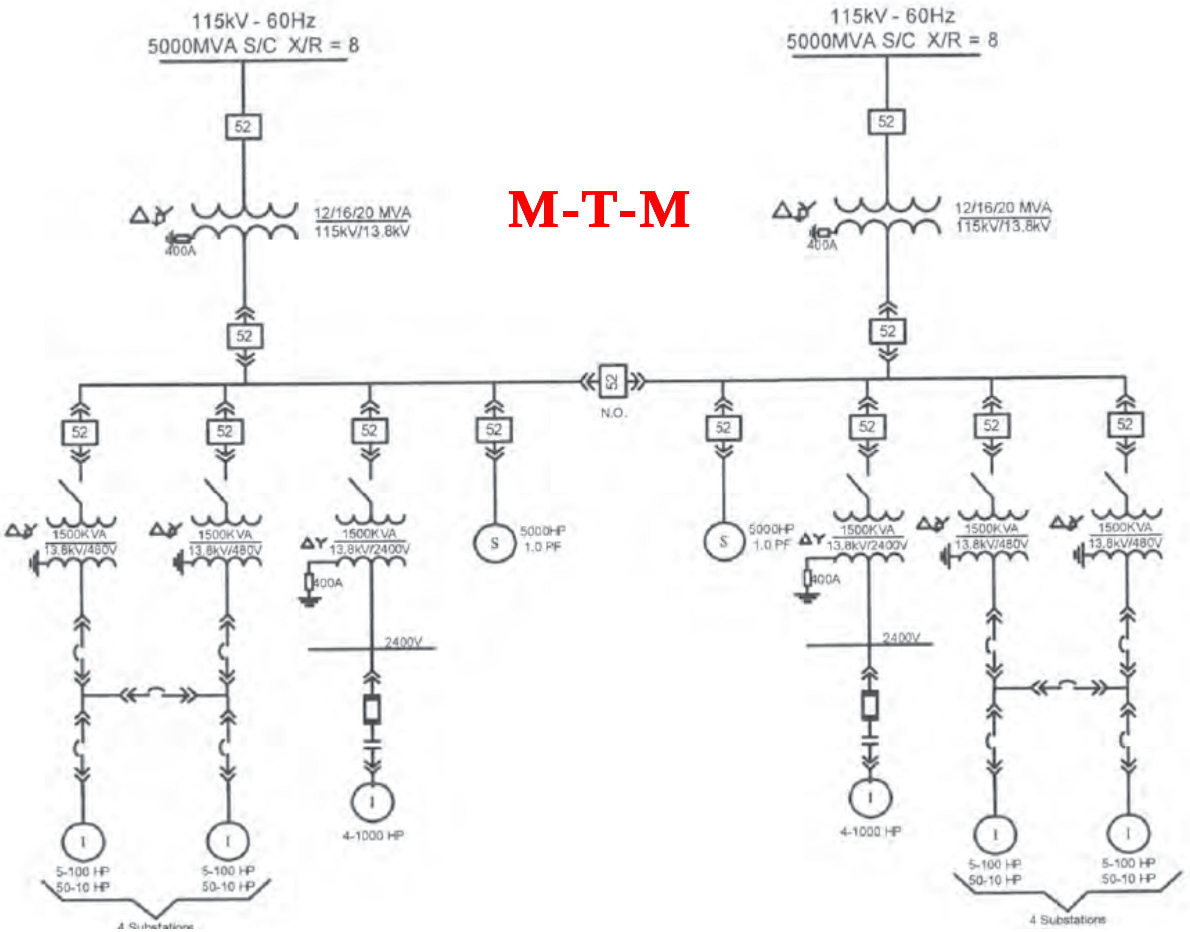


The Next Step

Typical two feeds from a ring bus to a typical 15kV or 5kV M-T-M arrangement.

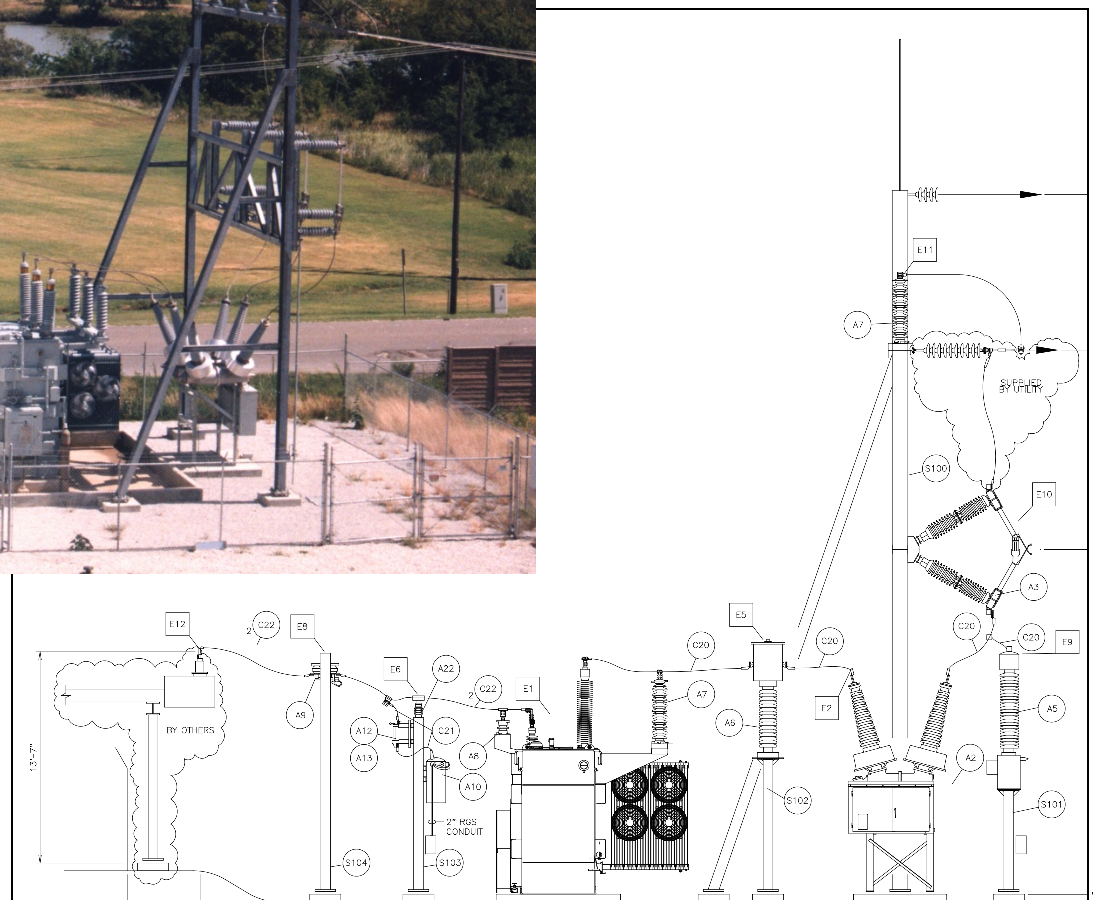


Conceptual MV M-T-M Design

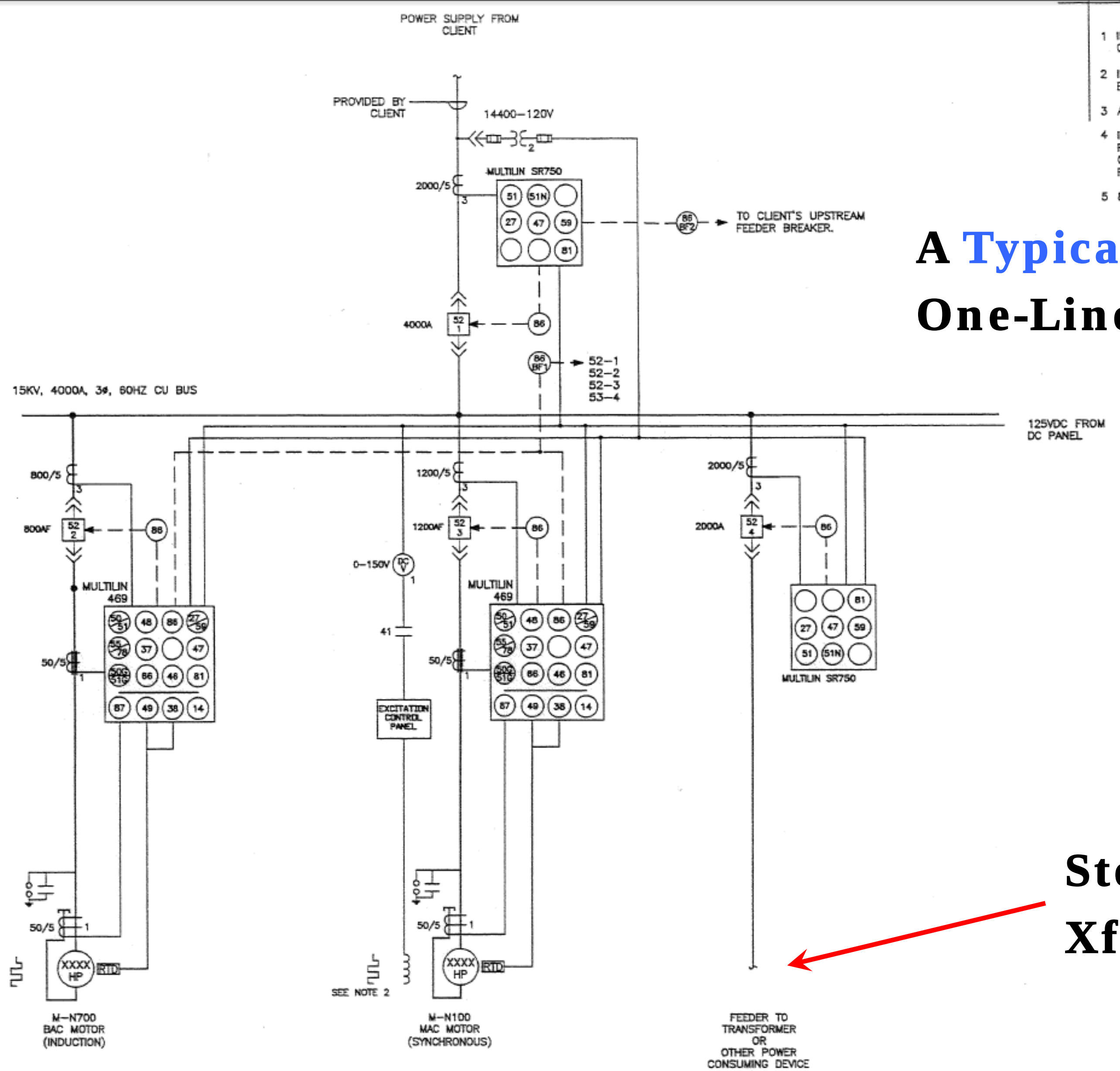


What is wrong with this conceptual design?

138kV Tap


E11
A7
SUPPLIED BY UTILITY
S100
E10
A3
C20
C20
E9
A5
A2
S101
E5
C20
C20
E2
A6
S102
A7
E1
C22
E6
A22
2
C21
A12
A13
A8
A10
2" RGS CONDUIT
S103
E8
A9
S104
E12
C22
2
BY OTHERS
13'-7"

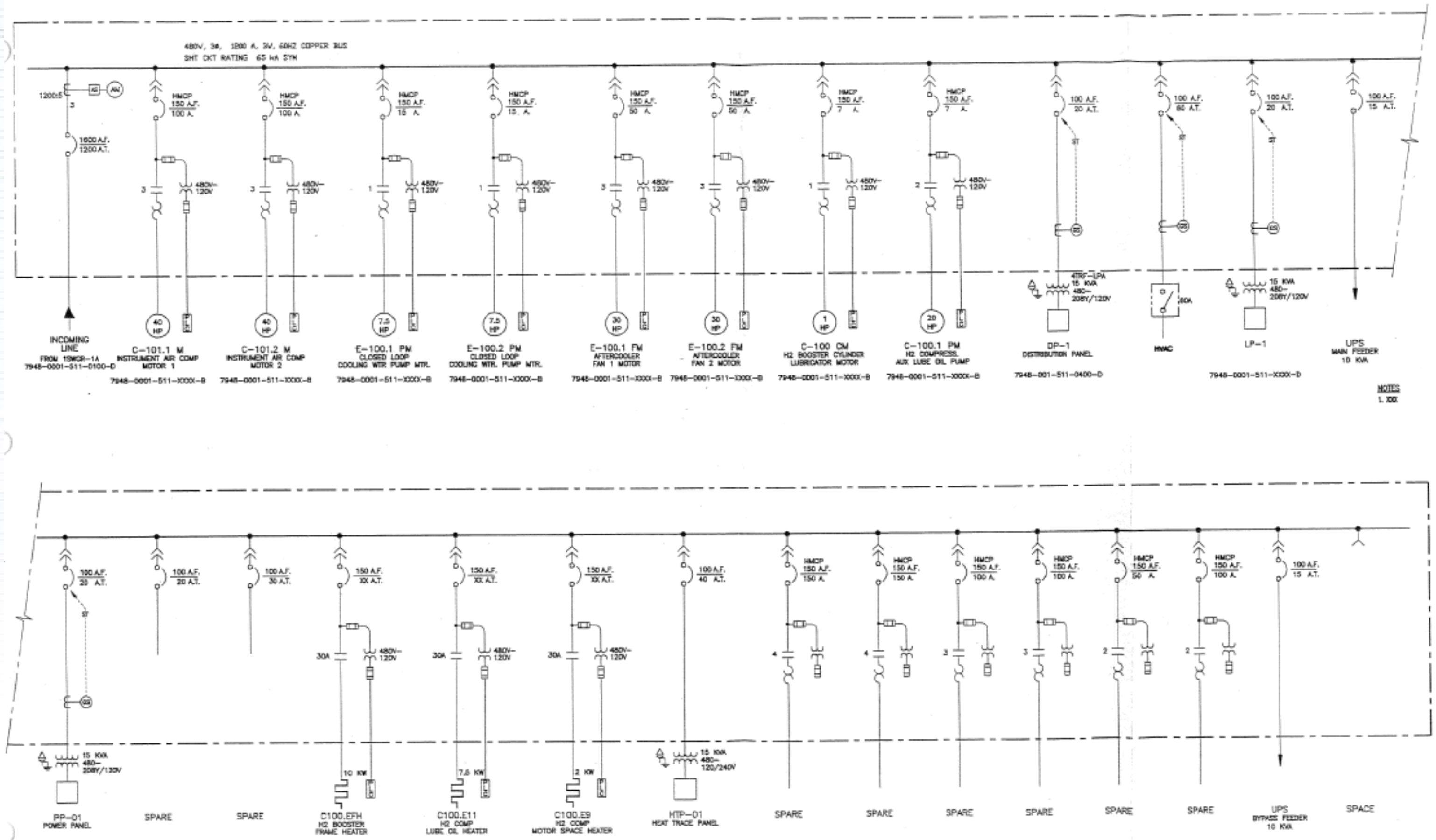
138kV Tap... Cont.



A Typical 15kV One-Line Diagram.

Step down Xfmr missing

138kV Tap. Cont.



Typical MCC drawing.

Is it Time to…

Take a Break???
Moving on…

Distribution System Development

The goal of the distribution system development is to create an electrical system that can deliver power to the loads at the correct voltage level, in a reliable and cost effective way.

1. Typical North American Petro/Chem MV & LV levels are 13.8kV, 4.16kV and 0.48kV

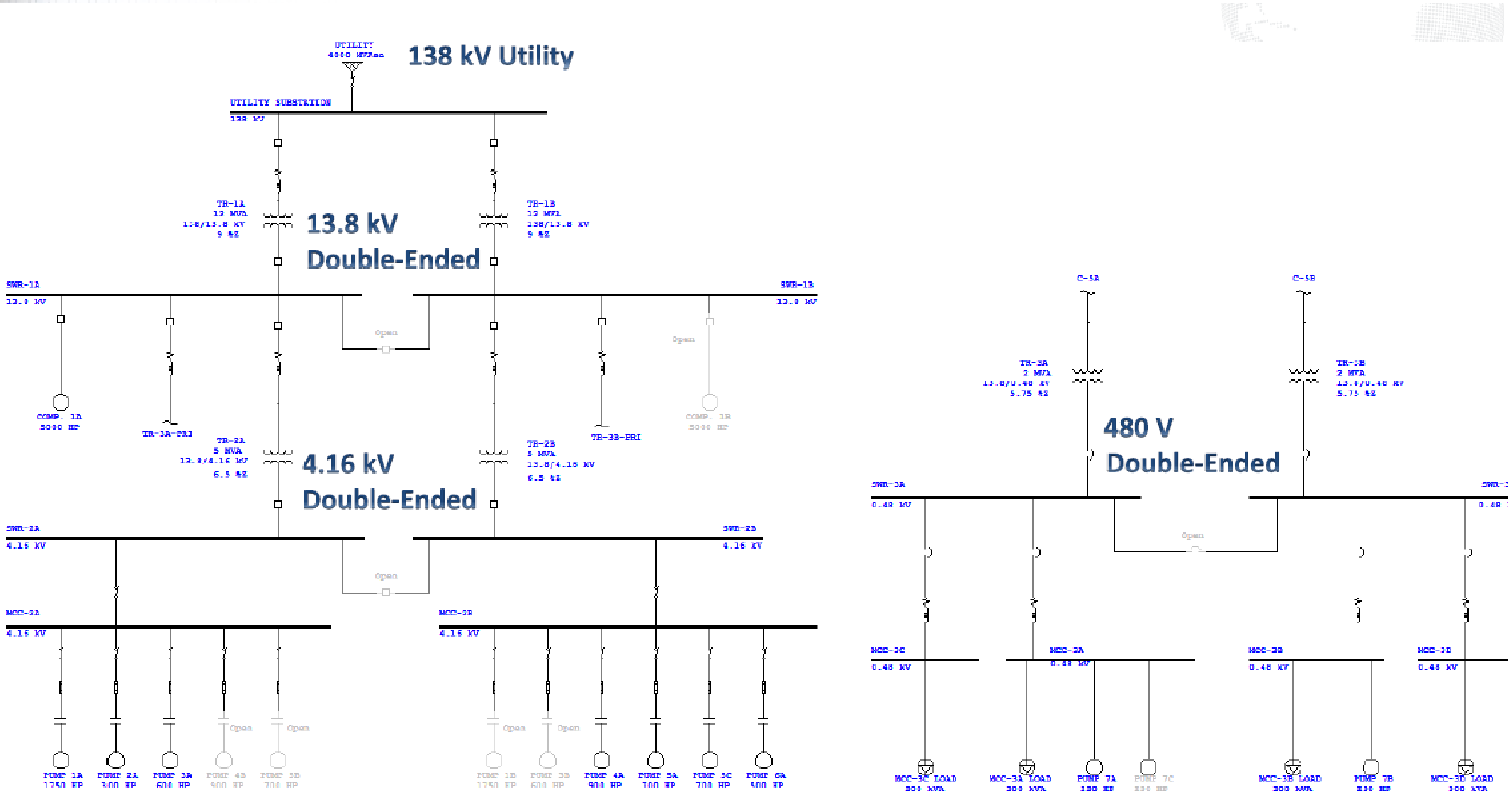
2. Typical design is to utilize the Main-Tie-Main design.

On a good sized project all three voltage levels could be utilized while smaller projects might only have 13.8kV and 0.48kV. The motor voltage level is dictated by the motor size which is dictated by the process, which is shown on the P&ID's.

At times compromises are made.

Distribution System Development

Classical 13.8, 4.16 & 0.48kV arrangement



Also covered in IEEE 141-1993 (Red Book) Chapter 5.

[SEL Plant Oneline Diag_PF00298.pdf]

Distribution System Development

Greenfield

1. Power from the local utility (contact early > 1yr)
2. On-site generation (platforms or remote location)
3. Utility & on-site generation to offset consumption
4. Onshore power feeding offshore platforms

Brownfield

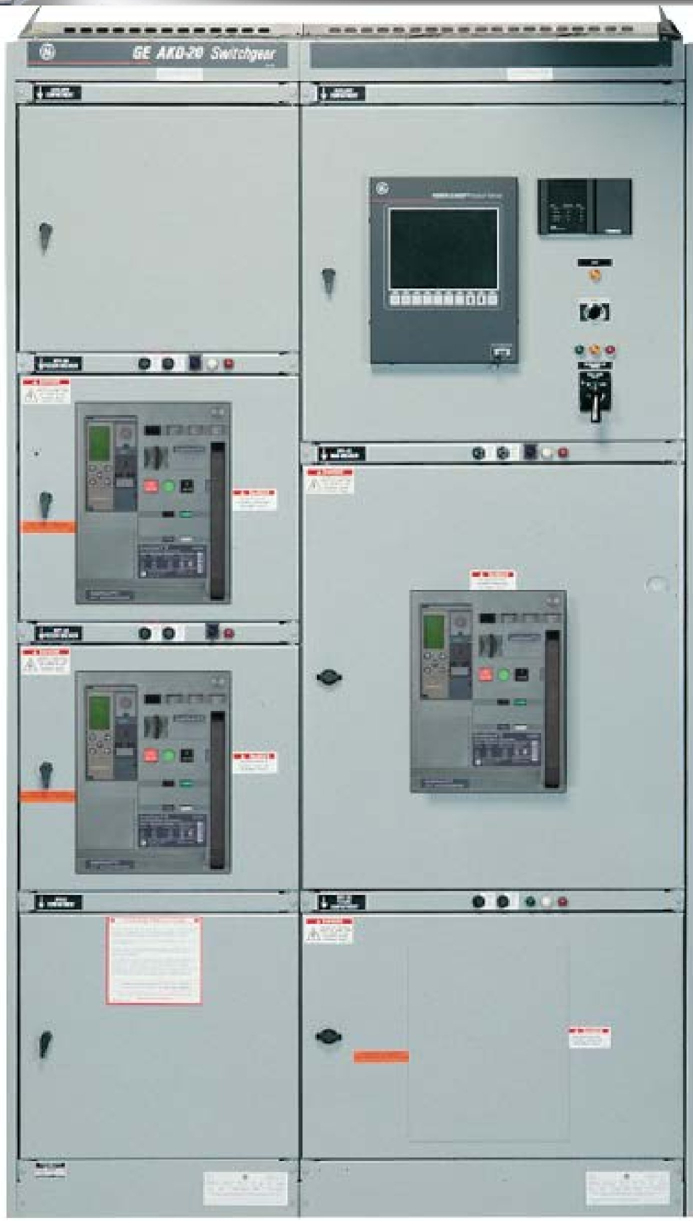
1. Usually brownfield work consists of expanding existing facilities. The assumption being there is spare capacity. This should be carefully validated by reviewing the latest certified/approved studies and visiting the site.
2. Maybe upgrading utility connection
3. Maybe expanding on-site generation

Distribution System Development

LV MCC ratings are per NEMA ICS 1 and ICS 2.

1. The typical highest continuous bus rating is 3000A.
2. The highest SC rating is 200kA although 65-100kA are much more common.

Distribution System Development



LV Swgr ratings are defined in IEEE C37.16

1. Continuous ratings up to 6000A w/ fans
2. The highest SC rating is 200kA w/ fuses
3. More common is 4000A at 65-100 kA
4. A 4000A bus is common for 2500KVA xfmr w/ fans
5. Due to arc flash the trend is to smaller LV xfmrs.

Electrical Studies

Electrical studies come in two varieties, preliminary and final. If you remember this falls in line with our preliminary and final data from the various vendors.

Preliminary Electrical Studies

1. Load Flow
2. Short Circuit
3. Motor Starting

Final Electrical Studies

1. Load Flow
2. Short Circuit
3. Motor Starting
4. Relay Coordination
5. Arc Flash
6. Harmonics
7. Transient Stability

Make sure the equipment being ordered is rated to handle the calculated current & Sht Ckt values.

Load Flow Study

What standard are you going to use for Load Flow Studies?

I would recommend following the IEEE 399 -1997 (Brown book) and chapter 6 Load Flow Studies.

"One of the most common computational procedures used in power system studies is the load flow calculation. The planning, design, and operation of the power systems require such calculations to analyze the steady-state (quiescent) performance of power system under various operational conditions and to study the effects of changes in equipment configuration.

The basic load flow question is this: Given the load power consumption at all buses of a known electrical power system configuration and the power production at each generator, find the power flow in each line and transformer of the interconnecting network and the voltage magnitude and phase angel at each bus."

Load Flow Study… Cont.

If you noticed, in the previous slide we talk about steady-state (quiescent) of the system.

We have skipped over the possibility of doing a load flow when we are switching from the 'A' motor to the 'B' motor. If you remember, during switchover, there is a time when both motors are running.

This situation is not studied… Why? Could it be that it is a transient not a steady-state condition?

Load Flow Study… Cont.

The common tools of the trade are ETAP, SKM, EasyPower, EDSA, ASPEN, IPSA, PSS®E, etc.

These tools are defined as static (offline) or dynamic (real time) studies. For most Petro/Chem work static studies are sufficient.

"A study normally begins with the preparation of base cases to represent the different operating modes of the system or plant. The operating condition normally chosen is maximum load. (Here maximum load refers to the maximum amount of coincident load, not the sum of all the loads.)

"When maximum load occurs at different times on different parts of the system, several base cases may be needed. The base case should represent realistic operating conditions. Abnormal conditions and worst-case scenarios will be addressed later in the study."

Where is this value found?

Important concept!

Operating not connected

Load Flow Study... Cont.

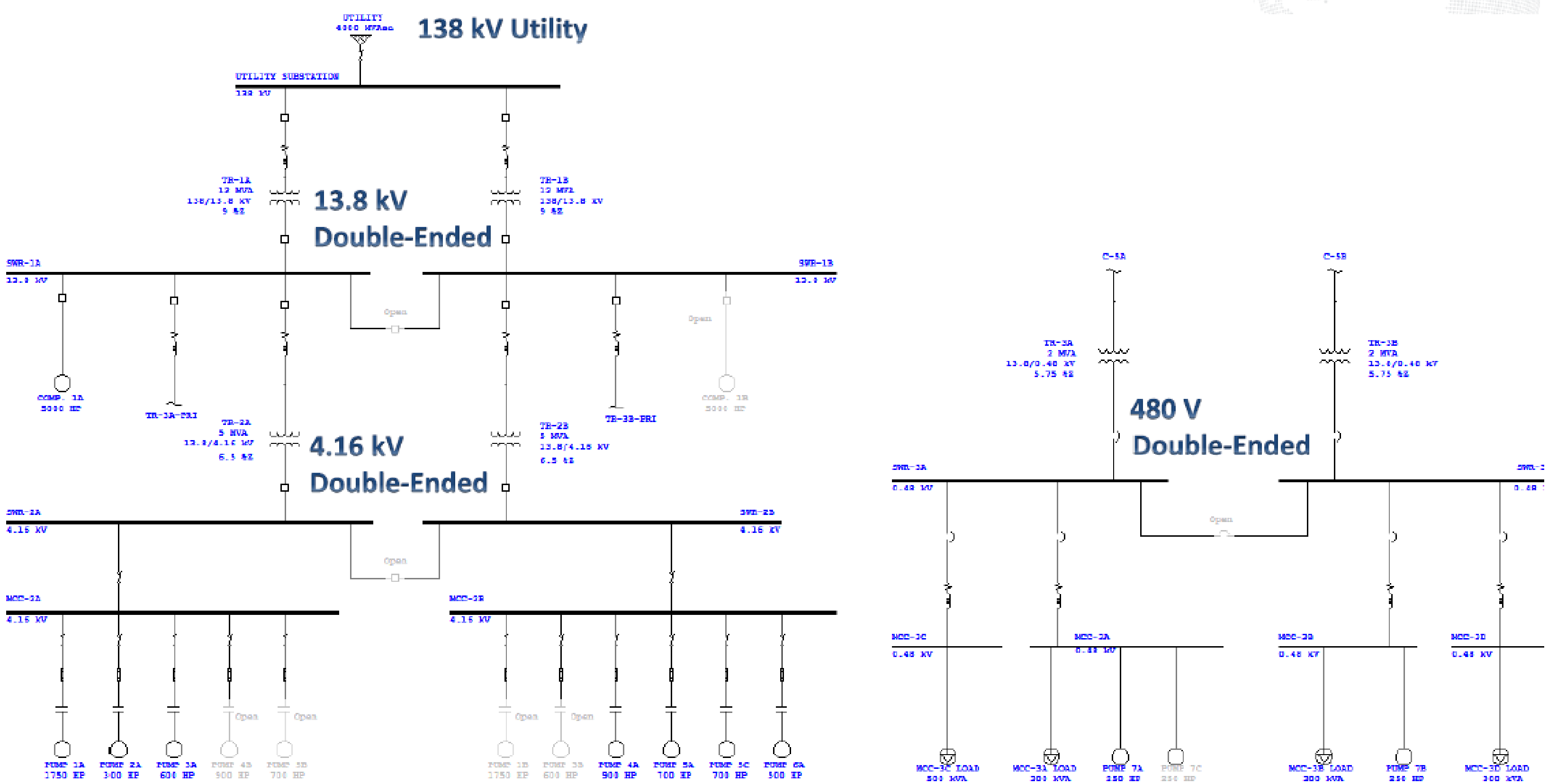
Maximum Load is the ELL Connected Load. This is the connection between ELL and Load Flow. ELL is the data required to do a Load Flow.

If you are using SmartPlant® Electrical (SPEL) you can import the SPEL ELL right into ETAP and off you go.

The Load Flow report should reflect the various Load Flow studies in a clear and concise methodology. Clarity is necessary to understand the subtle differences between each load flow study. For example...

Load Flow Study… Cont.

Using this one-line as the example…



Load Flow Study... Cont.

Normal Operation

1. All normally operated sources and distribution equipment are is service
2. Maximum (ELL Operating) load connected
3. Double ended substations are operated with both transformers in service and bus tie breakers are in the open position
4. Transformer tap changers are set to maintain nominal secondary voltage levels for normal operating load

Abnormal Operation

1. One or more sources and selected distribution equipment are out of service
2. Maximum (ELL Operating) load connected
3. Double ended systems are operated single-ended with one source out of service and bus tie breakers are in the closed position

Load Flow Study… Cont.

Case #1 : Base Case. Normal operation with all xfmr taps at nominal (0%)

Case #2 : Normal operation with main xfmr taps at -2.5%

Case #3 : Single-ended operation with main xfmr taps at -2.5%

Having all substations single-ended at the same time is a very remote operating condition, and this Load Flow study would produce a very conservative result.

And remember, these are preliminary Load Flow studies. A lot can change between now and the final studies.

Short-Circuit Study

What standard are you going to use for Short-Circuit Studies?

I would recommend following the IEEE 141-1997 (Red book) and chapter 4 Fault Calculations.

“Even the best designed electric systems occasionally experience short circuits resulting in abnormally high currents. Overcurrent protective devices, such as circuit breakers and fuses, should isolate faults at a given location safely with minimal circuit and equipment damage and minimal disruption of plants operation.

“The magnitude and short-circuit currents are usually estimated by calculations, and equipment is selected using the calculation results.

“System and equipment complexity and the lack of accurate parameters make precise calculations of short-circuit currents exceedingly difficult, but extreme precision is unnecessary. The calculations described provide reasonable accuracy for the maximum and minimum limits of short-circuit currents. These satisfy the usual reasons for making calculations.

Sht-Ckt Studies… Cont.

By using the methodology in IEEE 141-1997, the results will be directly applicable to the ANSI C 37 standards for LV and MV switchgear.

Actually, it is the software package that uses IEEE 141-1997 and produces the results that are applicable.

Questions.

1. Does anyone do hand calculations to verify the sht-ckt results are reasonable?
2. Or do we accept the printout as gospel and off we go?

Sht-Ckt Studies... Cont.

There are three types of electrical faults, but only one we are worried about at this time.

1. Three-Phase Fault (LLL or LLLG)
2. Single Line to Ground Fault (LG)
3. Line to Line Fault (LL or LLG)

Typically three-phase faults are the only one used in short-circuit analysis because it is the most severe (in most cases).

Sht-Ckt Studies… Cont.

Worst case Conditions

1. To minimize the number of cases, consider worst case scenario(s)
2. Maximum (ELL Connected) load connected
3. For utility fed systems typically consider the maximum sht-ckt MVA
4. For generator fed systems use the maximum number of units that can be online
5. For double ended substations with normally open ties, determine if the temporary parallel source condition during maintenance transfer will be considered?
6. When the maintenance condition is not considered, single-end substations so that all motor contributions are taken into account
7. Where applicable, include essential generators being exercised
8. Use applicable pre-fault voltage

Lumped Loads

1. Assume all constant-kVA if actual mix is unknown

If you have noticed, transitioning from the 'A' motor to the 'B' motor is not considered in the worst case scenario. Is that pushing happenstance a bit too far?

Short Circuit Calculations

Sht Ckt sources going into the fault.

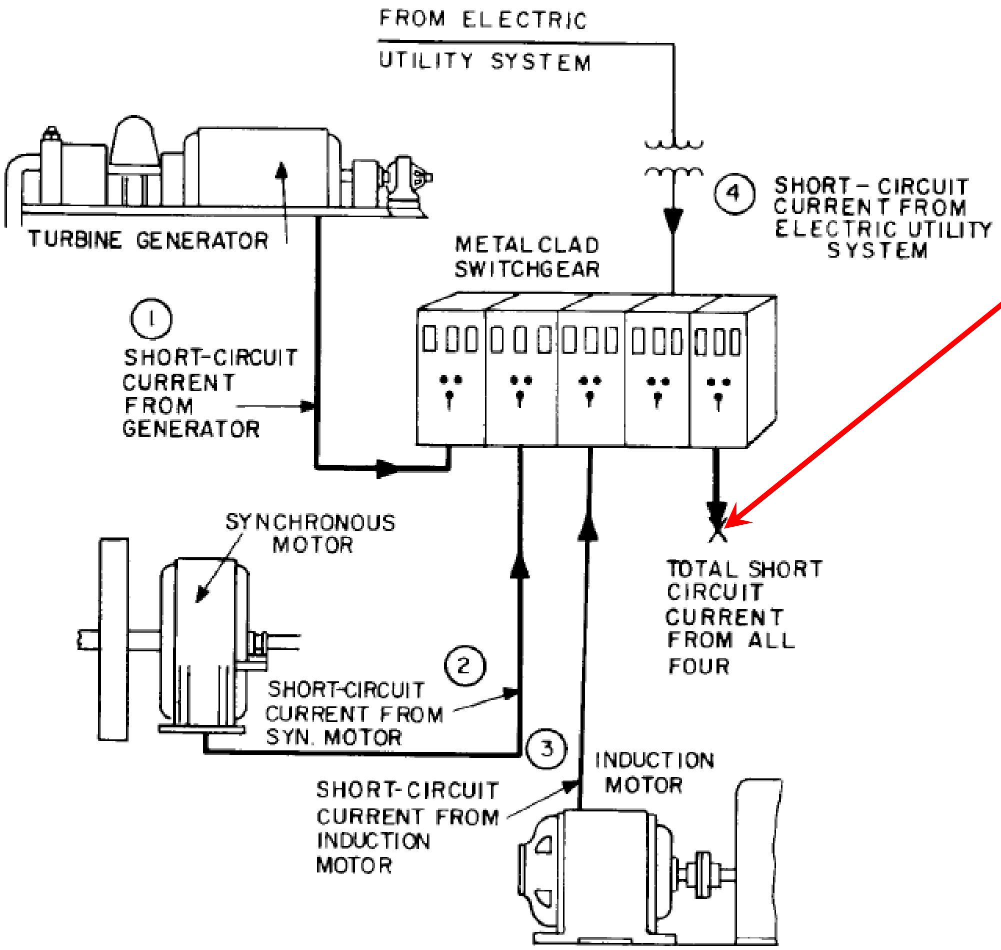


Fig. 2. Total short-circuit current equals sum of sources

Sht-Ckt Studies... Cont.

Case #1 : Base Case. Worst case scenario with all xfmr taps at nominal (0%)

Case #2 : Worst case scenario with main xfmr taps at -2.5%

Case #3 : Worst case scenario andsingle-ended operation with main xfmr taps at -2.5%

Having all substations single-ended at the same time is a very remote operating condition, and this Sht-Ckt study would produce a very conservative result.

And remember, these are preliminary Sht Ckt studies. A lot can change between now and the final studies.

Have we Achieved our Goal?

In Closing…

Have we Achieved our Goal?

1. From the P&ID's and other sources we have created a preliminary Electrical Load List (ELL).
2. Using an electrical software program (ESP) the electrical system was modeled.
3. The ELL data was put into an electrical software program.
4. The preliminary Load Flow and Sht-Ckt studies were run.
5. Now equipment data sheets can be filled out.
6. The equipment RFQ(s) can go out the door for quotes.

Have we Achieved our Goal?

Of course we are not finished. What we have is only the preliminary ELL and preliminary Load Flow with Sht Ckt.

Changes will continue until all items are ordered, purchased and final data is in.

The trouble is, long lead items need to ordered in time to be transported to the job site in time to be installed and wired up in time per the construction schedule.

The bottom line is, we have to meet the construction completion date to hand the facility over to the client on time and under budget.

The End.

Thank you for your attention and

are there any questions?