Institute of Integrated Electrical Engineers of the Philippines, Inc.

IIEE – Cebu Chapter

Technical Seminar Entitled

FIRE PUMP/S

May 1-2, 2015

Main Resource Speaker: Engr. Ronnie J. Magalang, PEE, BFP

6.95 Fire Pump/s

"Fire Pump is one of the main component of Fire Sprinkler System (FSS). It is part of the emergency system; essential to human life and protection to property".

- Code article's general philosophy is that circuit protection (i.e. overload device) will automatically shut down equipment before letting the supply conductors melt from overload due to dangerous overheating.
- But Art. 6.95 "Fire pump/s" is an exception.
- The idea is that the fire pump must run no matter what as it feeds water to facilities fire protection system (e.g. Automatic Fire Sprinkler System, fire hoses/ hydrants).

Introduction

- Art. 6.95 contains many requirements to ensure that water supply is uninterrupted:

1. Locating the pump so as to minimize its exposure to fire.
2. Reliable power supply to pumps (FP and JP).
3. Fire pump wiring must be kept independent.

Introduction

- **Other requirements seem wrong at first glance, until you remember why it is required in the first place.**

For example:

1. The fire pump disconnect must be lockable in the closed position and be supervised closed.

2. Fire pumps power circuits cannot have automatic protection against overload, over/under voltage relay, frequency sensitive device and other device the will prevent the automatic actuation of the fire pump and ground fault protection.

Introduction

- And the main objective or intent of Code Article 6.95 is:

" It's better to run the fire pump no matter what, until the fire is extinguished, fire pump is purposely shut down or pump itself is destroyed, than to protect or save the fire pump and lose the facility".

6.95.1.1 Scope

a) Covered

1) Electric power sources and interconnecting circuits

2) Switching and control equipment dedicated to fire pump drivers

b) Not Covered

1) The performance, maintenance, and acceptance testing of the fire pump system, and the internal wiring of the components of the system

2) Pressure maintenance (jockey or makeup) pumps

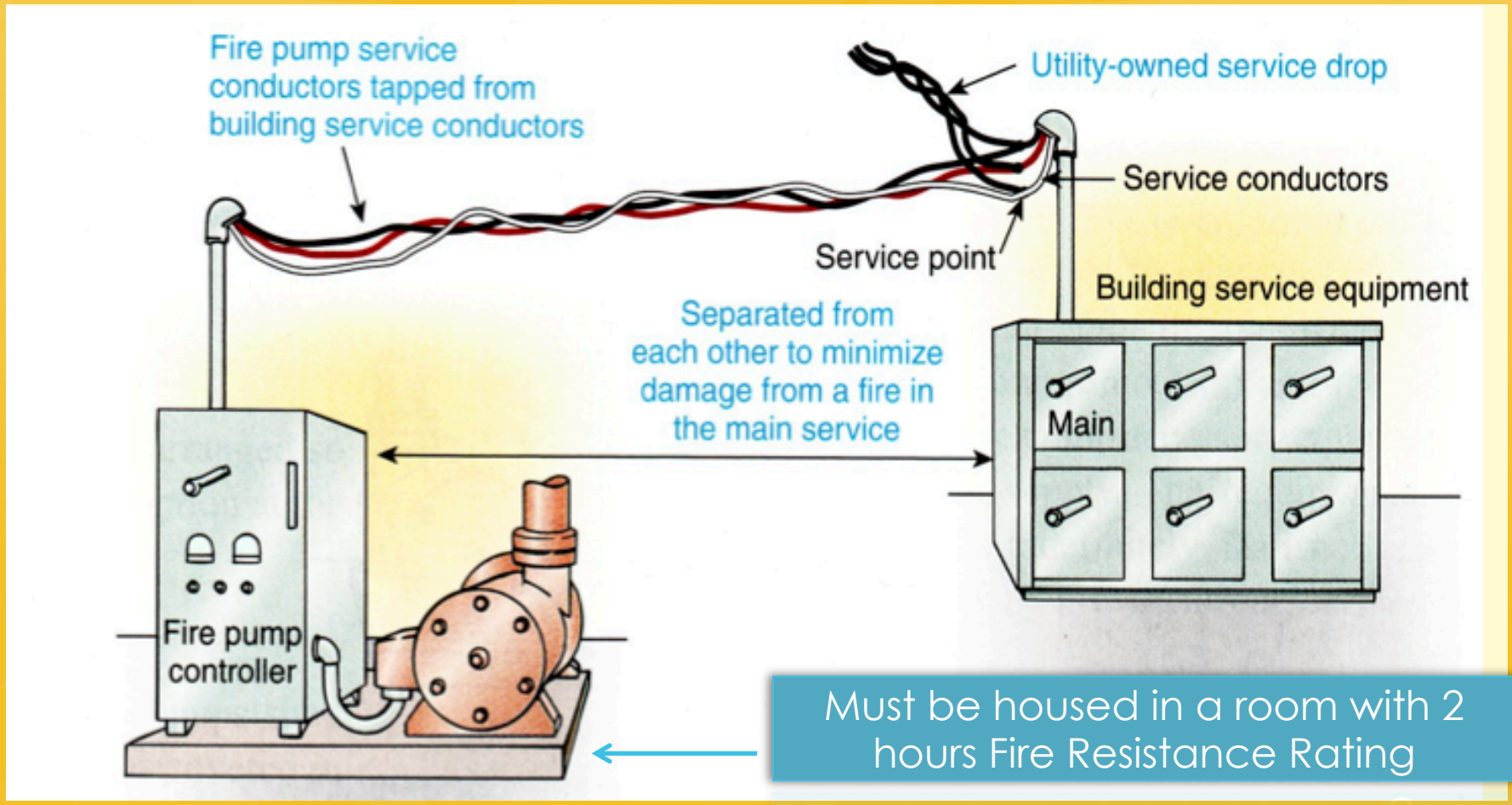
6.95.1.3 Power Sources for Electric-Motor Driven Fire Pump/s

a) Individual Source

1). Electric Utility Service. A separate service from a connection located ahead of but not within the service disconnecting means.

2). On-Site Power. An on-site power supply, such as Emergency/standby generator set , located and protected to minimize damage by fire is permitted to supply a fire pump.

Power Sources for Electric-Motor Driven Fire Pumps



1) Electric –Utility Service Connection

Question

- Why does the disconnect external to the controller require to be located remote from other building disconnecting means?

Ans.

- **They shall be located from other building disconnecting means to avoid confusion in the opening of multiple disconnects (i.e fire department staff during fire condition, inadvertent simultaneous operations is not likely, need to be readily identifiable during maintenance or fire condition.)**

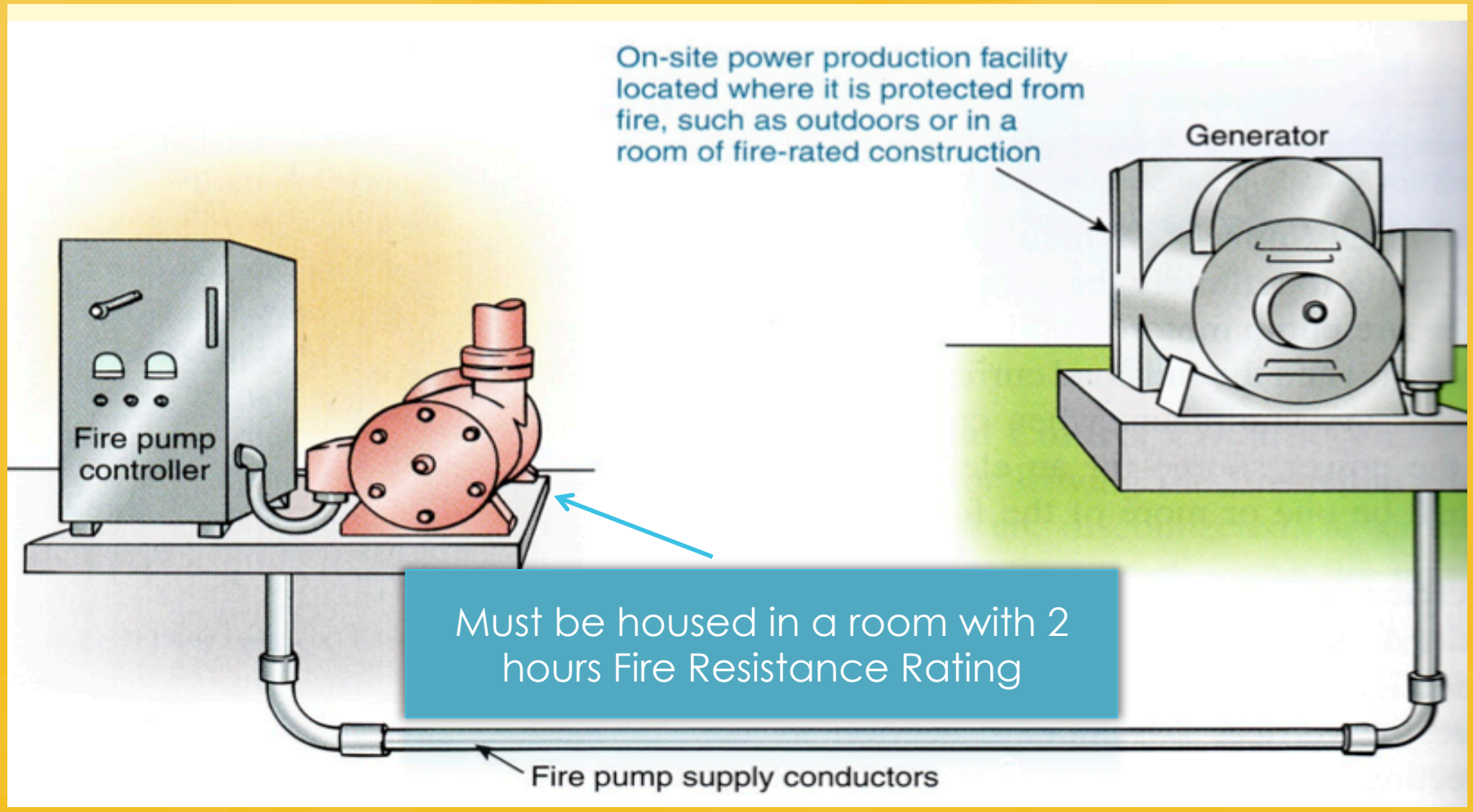
Question

- The plans for fire pump show the building electrical service equipment powering the fire pump. Is this permitted?

Ans.

NO, the fire pump must have dedicated service connection. During fire, the electric pump must remain energized. Having the fire pump connected to the main service may result in shutdown during fire fighting operations.

6.95.1.3 Power Sources for Electric-Motor Driven Fire Pumps



2). On-site/standby generator set

6.95.1.3 Power Sources continued

- b) Multiple Sources

1) Generator Capacity. It shall have sufficient capacity to allow normal starting and running of the motor(s) driving the fire pump(s) while supplying other loads simultaneously.

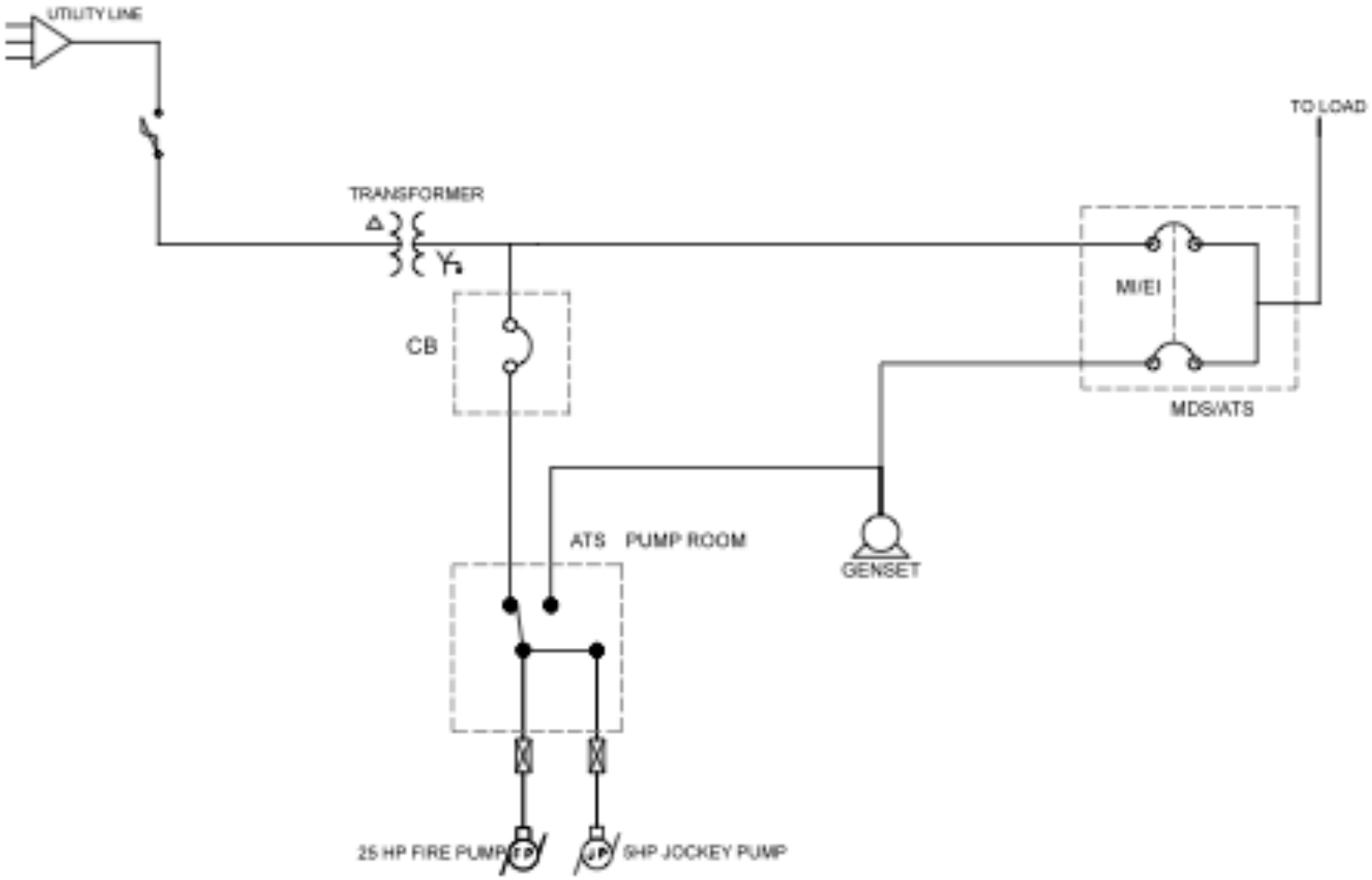
2) Feeder Sources.

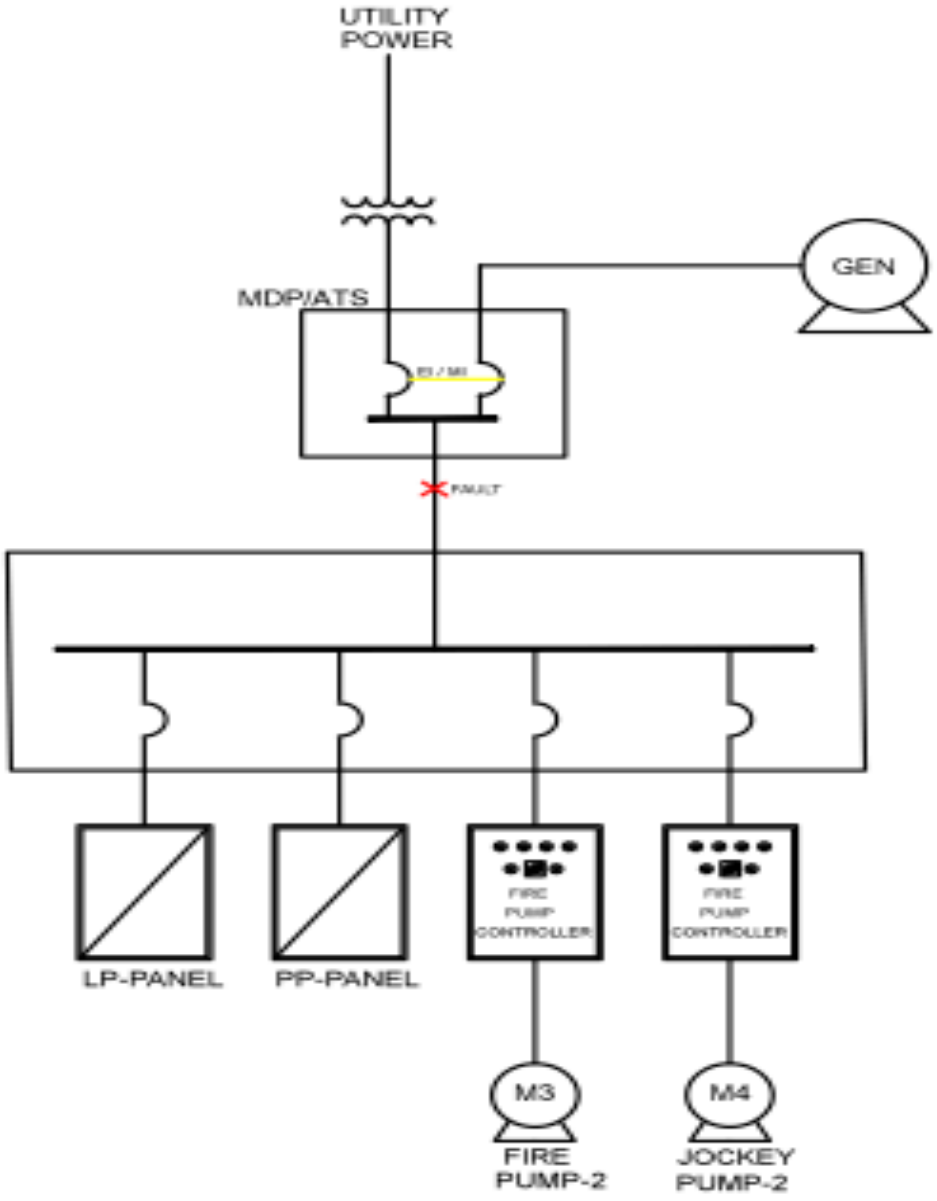
3) Arrangement. The power sources shall be arranged so that a fire at one will not cause an interruption at the other source.

Emergency Power System

- Emergency Power System: Defined in IEEE Std. 446-1995 as "an independent reserve source of electric energy that, upon failure or outage of the normal source, automatically provides reliable electric power within a specified time to critical devices and equipment whose failure to operate satisfactorily would jeopardize the health and safety of personnel or result in damage to property.

TYPICAL SINGLE-LINE DIAGRAM

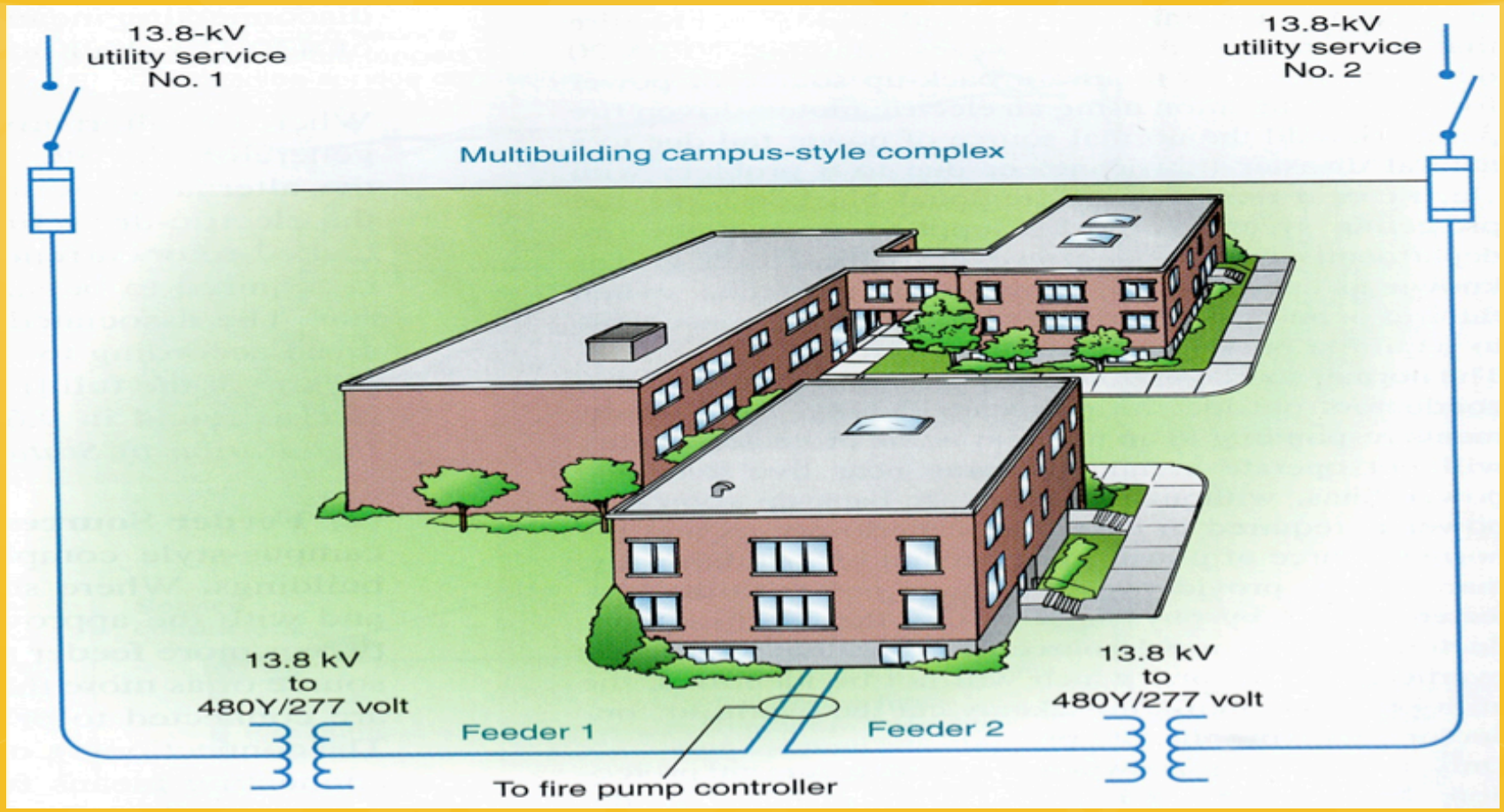



UTILITY
POWER
GEN
MDP/ATS
FAULT
LP-PANEL
PP-PANEL
FIRE
PUMP
CONTROLLER
FIRE
PUMP
CONTROLLER
M3
FIRE
PUMP-2
M4
JOCKEY
PUMP-2

Emergency Power cont'd.

- The PEC/NEC gives a slightly different definition for Emergency Systems as "those systems **legally required** and classed as emergency by municipal, state, federal, or other codes, or by any governmental agency having jurisdiction.
- These systems are intended to automatically supply illumination, power, or both, to designated areas and equipment in the event of failure of the normal supply or in the event of accident to elements of a system intended to supply, distribute, and control power and illumination **essential for safety to human life**."

6.95.1.3 continued



2) **Feeder Sources**

6.95.1.5 Transformers

(Where the service or system voltage is different from the utilization voltage of the fire pump motor/s)

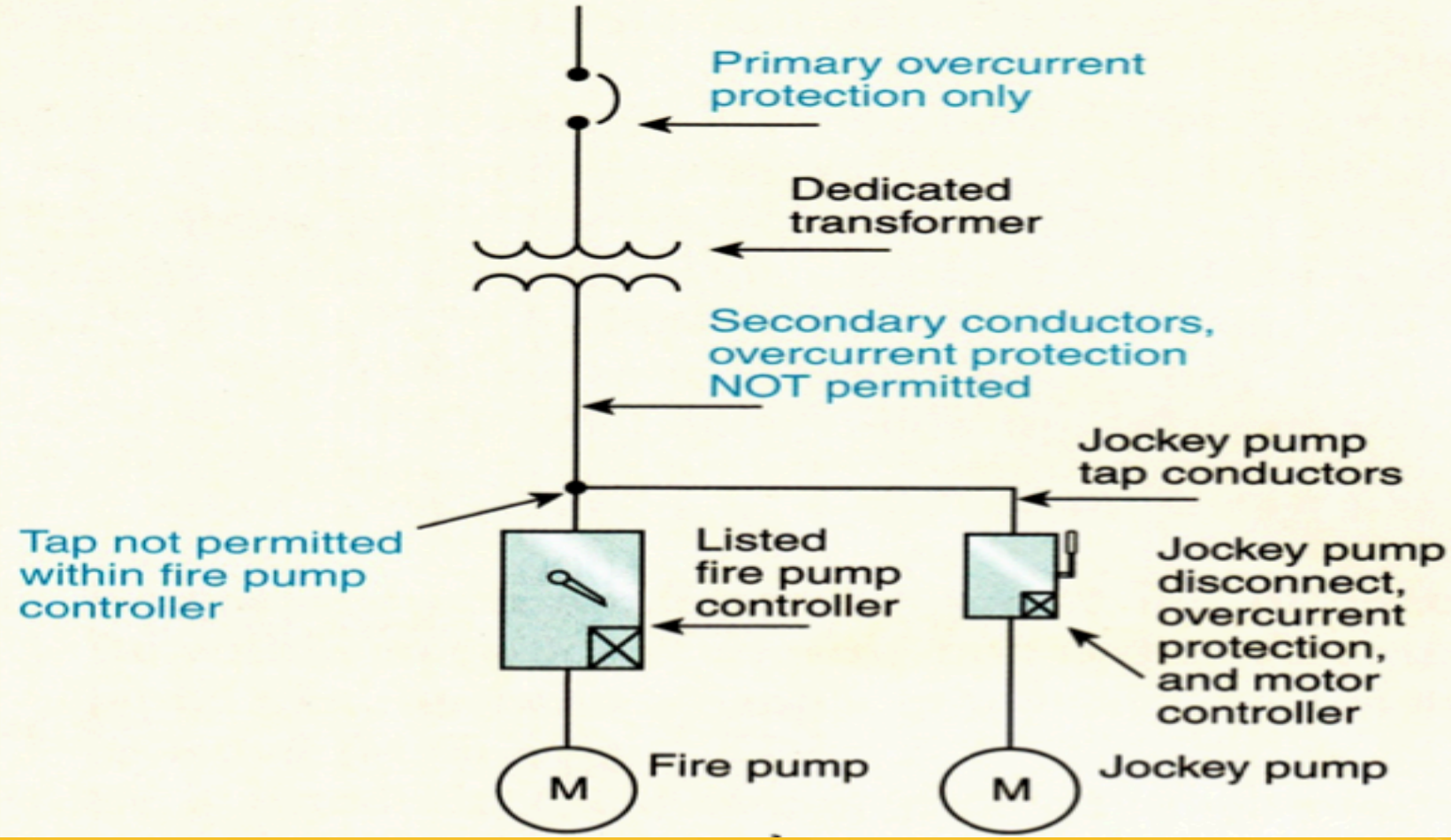
- Dedicated transformer and overcurrent protection sizing can be broken down into three requirements:

1. The transformer must be size to at least 125% of the sum of the loads.

2. The transformer primary overcurrent device must be at least a specified minimum size.

3. The transformer secondary must not contain any overcurrent device whatsoever.

6.95.1.5 Transformer cont'd



- The **overcurrent device** in the primary of a transformer supplying a fire pump installation is required to be sized to carry the **Locked-Rotor Current (LRC)** of motor(s) and associated fire pump accessory equipment (if any) indefinitely.

SAMPLE CALCULATIONS

- A 4160 /480v dedicated transformer supplies power to a 100 HP motor, 460 v, 3-phase Fire Pump and 1.5 HP, 3-phase Jockey Pump. Determine the size of dedicated transformer and its primary overcurrent protection.

First Step:

100-Hp, 3-phase motor = 124 A

1.5 Hp , 3-phase motor = 3 A

Total FLA = 127 A

CALCULATION CONTINUED

Transformer must be sized to at least 125% of the sum of the loads,

$1.25 \times 127 = 158.75$ A

Then size of the transformer as follows:

$$\text{Trans kVA} = \frac{\sqrt{3} \times I \times E}{1000}$$

$$\frac{\sqrt{3} \times 158.75 \times 480}{1000} = 131.98 \text{ kVA}$$

The minimum size is 131.98 and the next larger standard size is 150 kVA, however larger size is permitted.

CALCULATION CONTINUED

Step 2:

Calculate the primary overcurrent protection device permitted for transformer.

Assume LRC is not given but only the code letter.

100-Hp FP , 3-phase motor code letter G

1.5 Hp JP , 3-phase motor code letter H

$$LRC_{FP} = \text{motor HP x maximum Code Letter value x } \frac{1000}{\sqrt{3}\,V}$$

$$= 100\ HP \times \frac{6.29\ kVA}{HP} \times \frac{1000}{\sqrt{3}\ 460} = 789.49\ A$$

Hp and LRC motor designation

Horsepower and Locked Rotor Current Motor Designation for NEMA Design B Motors		
Rated Horsepower	Locked Rotor Current Three-Phase 460 v	Motor Designation (NFPA 70 Locked Rotor Indicating Code Letter) "F" to and including
5	46	J
7.5	64	H
10	81	H
15	116	G
20	145	G
25	183	**G**
30	217	G
40	290	G
50	362	G
60	435	G
75	543	G
100	725	G
125	908	G
150	1085	G
200	1450	G
250	1825	G
300	2200	G
350	2550	G
400	2900	G
450	3250	G
500	3625	G

LRC-INDICATING CODE LETTERS

LOCKED- ROTOR INDICATING CODE LETERS			
CODE LETTER	Kilovolt-Amperes per Horsepower with Locked -Rotor	CODE LETTER	Kilovolt-Amperes per Horsepower with Locked -Rotor
A	0 - 3-14	L	9.0 - 9.99
B	3.15 - 3.54	M	10.0 - 11.19
C	3.55 - 3.99	N	11.2 - 12.49
D	4.0 - 4.49	P	12.5 - 13.99
E	4.5 - 4.99	R	14.0 - 15.99
F	5.0 - 5.59	S	16.0 - 17.99
G	5.6 - 6.29	T	18.0 - 19.99
H	6.3 - 7.09	U	20.0 - 22.39
J	7.1 - 7.99	V	22.4 and UP
K	8.0 - 8.99		

PEC TABLE:
4.30.1.7(b)

CALCULATION CONTINUED

$$LRC_{JP} = 1.5\ HP \times \frac{7.09\ kVA}{HP} \times \frac{1000}{\sqrt{3}\ 460} = 13.35\ A$$

For the total LRC:

$$\text{Total LRC} = LRC_{FP} + LRC_{JP}$$

$$= 789.49 + 13.35 = 802.84\ A \text{ say } 803\ A$$

Now Calculate the equivalent LRC of the primary of transformer based on the LRC of the secondary:

$$LRC_{PRIMARY} = \frac{Secondary\ voltage}{Primary\ voltage} \times LRC_{SECONDARY}$$

$$\frac{480\ V}{4160\ V} \times 803\ A = 93\ A.$$

The value of 93 A represents the secondary LRC reflected to the primary side of transformer. Use standard size Over Current Protective Device (OCPD) of 100 A.

CONCLUSION

- The calculation for a 4160/480-volt, 3-phase transformer supplying a 100-HP fire Pump and 1.5 HP Jockey Pump, both 3-phase can be summarized as follows:

1. The smallest standard-size transformer that is permitted 150 kVA.
2. The minimum standard-size of OCPD permitted on the primary side is 100 A.
3. A secondary OCPD is not permitted.

QUESTION

- What is meant by dedicated transformer connection?

Ans.

A Fire Pump is permitted to be powered by a transformer if the latter is dedicated to the FP and does not serve other loads not associated with the FP. The exception is stated in 6.95.1.5(C) of PEC. "Where a feeder source is provided in accordance with 6.95.1.5(C), transformer supplying the fire pump system shall be permitted to supply other loads". This applies to multi-building campus-style complexes [see also NFPA#70/NEC 695.3(C)].

6.95.1.6 Power Wiring

a) Circuit Conductors.

- Fire pump supply conductors on the load side of the final disconnecting means and overcurrent device(s) must be kept entirely independent of all other wiring. They can be routed through a building using one of the following methods:

1) Be encased in a minimum 2 inches or 50 mm of concrete

2) Be within an enclosed construction dedicated to the fire pump circuit(s) and having a minimum of a 1-hour fire-resistant rating

3) Be listed electrical circuit protective system with a minimum 1-hour fire rating.

POWER WIRING CONT'D

b. Feeders to FP from on-site/standby Generator set.

1. Be kept independent of all other wiring.

2. Conductors to supply only loads that are directly associated with the FP.

3. Protected from potential damage by fire, structural failure and operational accident.

Where routed inside the building:

1. Be encased in a minimum of 50 mm (2 in.) of concrete.

POWER WIRING CONT'D.

2. Be protected fire rated assembly listed to achieve a minimum rating of 2 hours and dedicated to fire pump circuits.

3. Be listed electrical circuit protective system with a minimum of 2 hour fire resistance rating.

The difference between the 2 hour fire rating of electrical circuit (e.g. conduit wires) and 2 hour fire rating of a structural member (e.g. partition walls) is that at the end of 2 hour fire test on electrical conduit with wires, the circuit must function electrically (no short circuit, grounds and open circuit are permitted). The circuit and its insulation must be electrically functioning.

For a wall assembly, fire resistance must prevent a fire from passing the wall without regards to the damage to the latter.

Sizing of Conductors

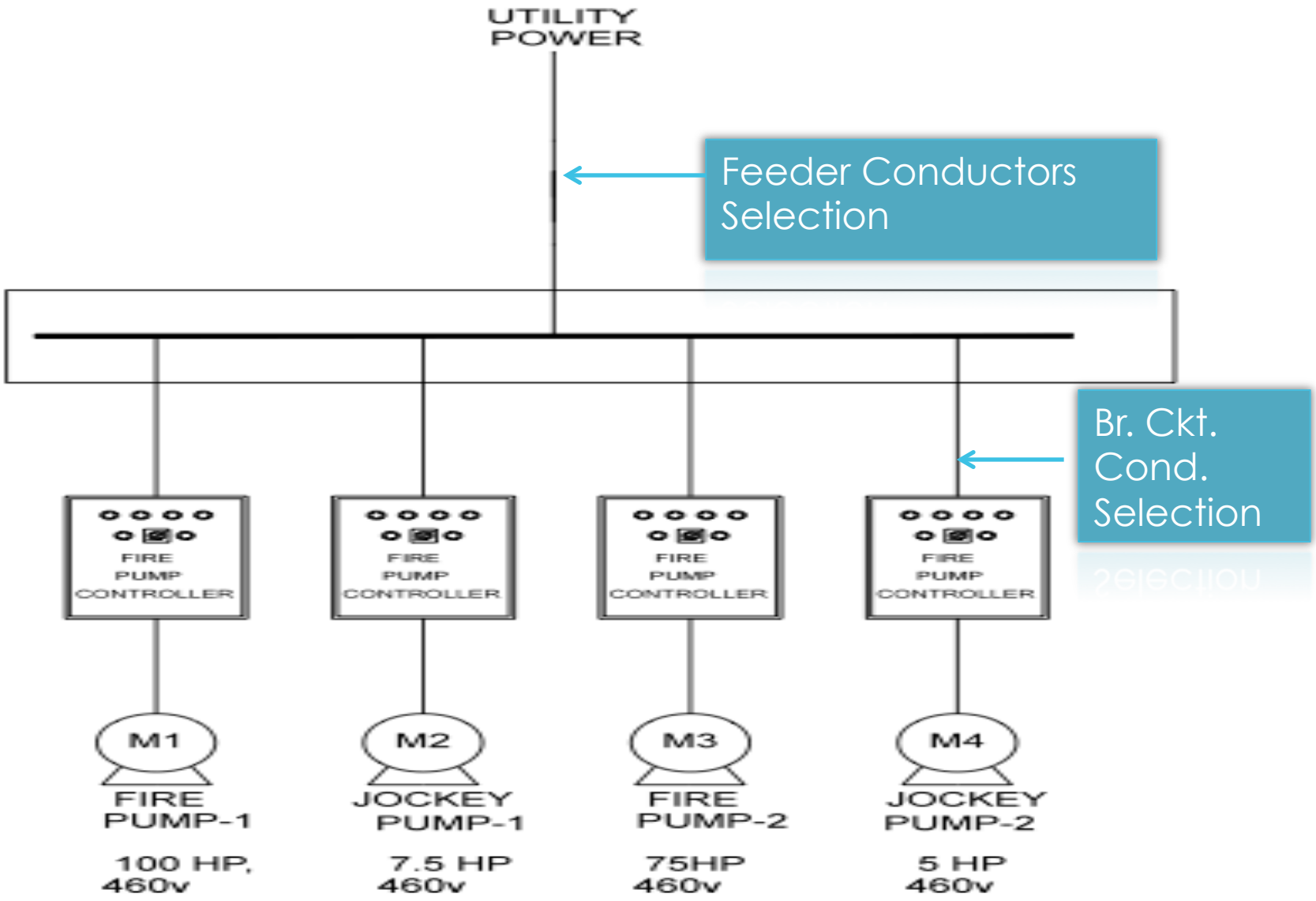
a). For Fire Pump Motors and Other Equipment.

Conductors supplying a fire pump motor(s), pressure maintenance pump/s, and associated fire pump accessory equipment shall have a minimum rating of 125 percent of the sum of the fire pump motor(s) and pressure maintenance pump motor(s)' full-load current plus 100 percent of the associated fire pump accessory equipment, PEC 6.95.1.6 (c)

Sizing of Conductor cont'd.

b). Fire Pump Motor only.

Conductors supplying only a fire pump motor shall have a minimum rating of 125 percent of the fire pump motor full-load current, PEC 6.95.1.6 (c) 2.


UTILITY POWER
Feeder Conductors Selection
Br. Ckt. Cond. Selection
FIRE PUMP CONTROLLER
FIRE PUMP CONTROLLER
FIRE PUMP CONTROLLER
FIRE PUMP CONTROLLER
M1
M2
M3
M4
FIRE PUMP-1
100 HP, 460v
JOCKEY PUMP-1
7.5 HP 460v
FIRE PUMP-2
75HP 460v
JOCKEY PUMP-2
5 HP 460v

Calculation of Feeder Conductors: (6.95.1.6 c)

FLA_{FP1} = 124 A

FLA_{JP1} = 11A

FLA_{FP2} = 96 A

FLA_{JP2} = 7.6 A

All motors @ @ 460v, 3-Ø

I_{FEEDER} = 125% [Fire Pump Motor/s FLA + Pressure Maintenance Pump/s FLA] + 100% [Fire Pump accessory equipment (if any)]

I_{FEEDER} = 1.25 [124 + 11 + 96 + 7.6] = 298.25 Amperes

Use 175 mm^2 conductors @ 75^0C

b. Calculation of Br. Ckt. conductors

PEC 6.95.1.6(2)

For $FP_1 = 1.25\ [FLA_{FP1}] = 1.25\ [124] = 155$ A

Use # 60 mm^2 conductors

For $JP1 = 1.25\ [FLA_{JP1}] = 1.25\ [\ 11\ ] = 13.7$ A

USE # 3.5 mm^2 conductors

For $FP_2 = 1.25\ [FLA_{FP2}] = 1.25\ [96] = 120$ A

Use # 50 mm^2 conductors

QUESTIONS

- Since the FP's operate infrequently, is any of the Fire Pump equipment rated for less than continuous duty?

Ans.

Although FP's are unexpected to run continuously, they can run for a long period of time, such as over a holiday weekend or for many ours when fire-fighting a high-rise building fire. Thus, no reliable method exist for sizing the power supply based on duty cycle other than that of continuous duty of 100%. In some instances, fire pump may operate for days in order to prevent rekindling of fire after main extinguishment is completed. The power supply is critical to both reliable and reliablek fire pump operation.

Voltage Drop

- There are two (2) requirements for voltage drop as far as the codes is concerned:

a). The operating voltage at the motor controller line terminals shall not drop more than 15 percent below the controller-rated voltage when the motor starts (Locked-Rotor Current).

VOLTAGE DROP Cont'd

- a) Another requirement is that the voltage drop at the motor contactor's load terminals to which the motor is connected shall not drop more than 5 percent below the voltage rating of the motor when the motor is operating at 115 percent of the full-load current rating of the motor.

The voltage drop calculation is mandatory requirement per PEC Table 2.20.1.3 p.97.

- The following formulas can be used to properly size conductors to prevent excessive voltage drop:

CM (single-phase) = (2 x K x I x D)/VD

CM (three-phase) = (1.732 x K x I x D)/VD

"CM" = The circular mils of the ckt. conductor as listed in Table 8, Chapter 9,

"K" = Direct Current Constant Value: Cu. is 12.9 ohms and 21.2 ohms for Al. conductors.

"I" : The load in amperes at 100 percent, not 125 percent for motors or continuous loads.

"D" = The distance the load is located from the power supply, not the total length of the circuit conductors.

"VD" = Volts Dropped: The voltage drop of the circuit conductors as expressed in volts.

- Given:

100 HP, 3phase, 460 v motor

D= 150 Ft., K = 12.9 Ohms, I_{FL} = 124 A

$I_{LRC@460v}$ = 725 A PEC Table .30.14.4 (also refer to NFPA # 20 Handbook)

VD = 460 v x 15% = 69 v

a) CM = 1.732 x 12.9 x 725 x 150 ft./69 v

= 35,214 CM

USE: # 4 AWG or 22 mm^2 conductors

(Table 8, chapter 9 NEC)

Question

- Why is voltage drop critical in the operation of FP?

Ans.

Excessive voltage drop results in magnetic contactor chattering, since the holding coil of magnetically operated devices are only required to hold the contacts closed at a minimum of 85% rated voltage. While some contactors are designed and tested to allow a much greater voltage drop, the minimum hold-in voltage is the minimum requirements for the contactor in general.

On Ground Fault Protection and GFCI

Ground Fault protection as specified in the Code (PEC/NEC) is not permitted to be used to protect components of fire pump installation. (The function of ground-fault protection of equipment should not be confused with the function of GFCI for personnel). Although the protection afforded to equipment by this type of protection is mandatory safety requirements in some circumstances, the need for uninterrupted source of power takes precedence for fire pump installation.

Table 8 Conductor Properties

Size (AWG or kcmil)	Area		Conductors						Direct-Current Resistance at 75°C (167°F)					
			Stranding			Overall			Copper				Aluminum	
			Quantity	Diameter		Diameter		Area	Uncoated		Coated			
	mm2	Circular mils		mm	in.	mm	in.	mm2	in.2	ohm/ km	ohm/ kFT	ohm/ km	ohm/ kFT	ohm/ km	ohm/ kFT
18	0.823	1620	1	—	—	1.02	0.040	0.823	0.001	25.5	7.77	26.5	8.08	42.0	12.8
18	0.823	1620	7	0.39	0.015	1.16	0.046	1.06	0.002	26.1	7.95	27.7	8.45	42.8	13.1
16	1.31	2580	1	—	—	1.29	0.051	1.31	0.002	16.0	4.89	16.7	5.08	26.4	8.05
16	1.31	2580	7	0.49	0.019	1.46	0.058	1.68	0.003	16.4	4.99	17.3	5.29	26.9	8.21
14	2.08	4110	1	—	—	1.63	0.064	2.08	0.003	10.1	3.07	10.4	3.19	16.6	5.06
14	2.08	4110	7	0.62	0.024	1.85	0.073	2.68	0.004	10.3	3.14	10.7	3.26	16.9	5.17
12	3.31	6530	1	—	—	2.05	0.081	3.31	0.005	6.34	1.93	6.57	2.01	10.45	3.18
12	3.31	6530	7	0.78	0.030	2.32	0.092	4.25	0.006	6.50	1.98	6.73	2.05	10.69	3.25
10	5.261	10380	1	—	—	2.588	0.102	5.26	0.008	3.984	1.21	4.148	1.26	6.561	2.00
10	5.261	10380	7	0.98	0.038	2.95	0.116	6.76	0.011	4.070	1.24	4.226	1.29	6.679	2.04
8	8.367	16510	1	—	—	3.264	0.128	8.37	0.013	2.506	0.764	2.579	0.786	4.125	1.26
8	8.367	16510	7	1.23	0.049	3.71	0.146	10.76	0.017	2.551	0.778	2.653	0.809	4.204	1.28
6	13.30	26240	7	1.56	0.061	4.67	0.184	17.09	0.027	1.608	0.491	1.671	0.510	2.652	0.808
4	21.15	41740	7	1.96	0.077	5.89	0.232	27.19	0.042	1.010	0.308	1.053	0.321	1.666	0.508
3	26.67	52620	7	2.20	0.087	6.60	0.260	34.28	0.053	0.802	0.245	0.833	0.254	1.320	0.403
2	33.62	66360	7	2.47	0.097	7.42	0.292	43.23	0.067	0.634	0.194	0.661	0.201	1.045	0.319
1	42.41	83690	19	1.69	0.066	8.43	0.332	55.80	0.087	0.505	0.154	0.524	0.160	0.829	0.253
1/0	53.49	105600	19	1.89	0.074	9.45	0.372	70.41	0.109	0.399	0.122	0.415	0.127	0.660	0.201
2/0	67.43	133100	19	2.13	0.084	10.62	0.418	88.74	0.137	0.3170	0.0967	0.329	0.101	0.523	0.159
3/0	85.01	167800	19	2.39	0.094	11.94	0.470	111.9	0.173	0.2512	0.0766	0.2610	0.0797	0.413	0.126
4/0	107.2	211600	19	2.68	0.106	13.41	0.528	141.1	0.219	0.1996	0.0608	0.2050	0.0626	0.328	0.100
250	127	—	37	2.09	0.082	14.61	0.575	168	0.260	0.1687	0.0515	0.1753	0.0535	0.2778	0.0847
300	152	—	37	2.29	0.090	16.00	0.630	201	0.312	0.1409	0.0429	0.1463	0.0446	0.2318	0.0707
350	177	—	37	2.47	0.097	17.30	0.681	235	0.364	0.1205	0.0367	0.1252	0.0382	0.1984	0.0605
400	203	—	37	2.64	0.104	18.49	0.728	268	0.416	0.1053	0.0321	0.1084	0.0331	0.1737	0.0529
500	253	—	37	2.95	0.116	20.65	0.813	336	0.519	0.0845	0.0258	0.0869	0.0265	0.1391	0.0424
600	304	—	61	2.52	0.099	22.68	0.893	404	0.626	0.0704	0.0214	0.0732	0.0223	0.1159	0.0353
700	355	—	61	2.72	0.107	24.49	0.964	471	0.730	0.0603	0.0184	0.0622	0.0189	0.0994	0.0303
750	380	—	61	2.82	0.111	25.35	0.998	505	0.782	0.0563	0.0171	0.0579	0.0176	0.0927	0.0282
800	405	—	61	2.91	0.114	26.16	1.030	538	0.834	0.0528	0.0161	0.0544	0.0166	0.0868	0.0265
900	456	—	61	3.09	0.122	27.79	1.094	606	0.940	0.0470	0.0143	0.0481	0.0147	0.0770	0.0235
1000	507	—	61	3.25	0.128	29.26	1.152	673	1.042	0.0423	0.0129	0.0434	0.0132	0.0695	0.0212
1250	633	—	91	2.98	0.117	32.74	1.289	842	1.305	0.0338	0.0103	0.0347	0.0106	0.0554	0.0169
1500	760	—	91	3.26	0.128	35.86	1.412	1011	1.566	0.02814	0.00858	0.02814	0.00883	0.0464	0.0141
1750	887	—	127	2.98	0.117	38.76	1.526	1180	1.829	0.02410	0.00735	0.02410	0.00756	0.0397	0.0121
2000	1013	—	127	3.19	0.126	41.45	1.632	1349	2.092	0.02109	0.00643	0.02109	0.00662	0.0348	0.0106

Notes:

1. These resistance values are valid only for the parameters as given. Using conductors having coated strands, different stranding type, and, especially, other temperatures changes the resistance.

Table 8 of Chapter 9 of NEC

THANK YOU