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Application Guide for Electric Fire Pump Controllers

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Foreword

This Application Guide was prepared by a technical committee of the NEMA Industrial Control and Systems Section. It was approved in accordance with the bylaws of NEMA.

This Application Guide provides practical information concerning the general technical considerations in the installation of electric fire pump controllers. It is intended to be used by specifiers, purchasers, installers, and owners of fire pump controllers.

This Application Guide represents the result of many years of research, investigation, and experience by the members of the NEMA Industrial Control and Systems Subcommittee on Fire Pump Control. It was written as a service in response to the many questions from the user public, specifiers, and inspection authorities regarding fire pump controller installations. The intent is to pursue excellence in design, manufacture, and service of products made by NEMA member companies. It has been developed through continuing consultation among manufacturers, users, and national engineering societies. It is not intended to instruct the user of fire pump control equipment except insofar as to provide recommendations and some application guidance.

This Application Guide is necessarily confined to providing recommendations for a successful installation. When equipment conforming with these recommendations is properly selected, is installed in accordance with the *National Electrical Code* (NFPA 70) and the *Standard for the Installation of Stationary Pumps for Fire Protection* (NFPA 20), and is properly maintained, the hazards to persons and property will be reduced. However, since any piece of industrial control equipment can be installed, operated, and maintained in such a manner that hazardous conditions may result, following the recommendation of this Guide does not by itself assure a safe installation.

NEMA publications are subject to periodic review. They are revised frequently to reflect user input and to meet changing conditions and technical progress. Users should secure the latest editions.

Proposed revisions to this Application Guide should be submitted to:

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1 GENERAL

1.1 SCOPE

This Application Guide is intended to provide general guidelines for the proper application of fire pump controllers. The emphasis of these guidelines is to stress those considerations specific to fire pump installations. Applicable NEMA standards and the standards of other standards developing organizations should also be consulted.

1.2 DEFINITIONS

There are no definitions unique to fire pump controllers.

1.3 REFERENCED PUBLICATIONS

NFPA 20-1999 *Standard for the Installation of Stationary Pumps for Fire Protection*[1]
NFPA 25-1998 *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*
NFPA 70-1999 *National Electrical Code*[2]
IEEE Standard 242-1986 *IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial power Systems*
NEMA Standards Publication 250 *Enclosures for Electrical Equipment (1000 Volts Maximum)*

1.4 SPECIAL CONSIDERATIONS FOR FIRE PUMP CONTROLLERS

Installation requirements of fire pump controllers, by virtue of their special considerations, are covered in Article 695 of the National Electrical Code (NFPA 70) and the performance, maintenance, and acceptance testing of the fire pump system and the internal wiring of the components of the system are covered in NFPA 20. Periodic testing of the complete fire protection system is addressed in NFPA 25. These requirements, in many significant ways, are uniquely different from those pertaining to industrial, commercial and residential installations in order to increase the reliability of the system. As an overview, some of these differences are:

a) Service Disconnects: Special rules pertaining to the service disconnects in order to minimize inadvertent disconnection. (NFPA 70, 695-3 which refers to 230-82(4), 230-2(a), and 230-72(b))

b) Conductor Protection:
   1. Special overcurrent and physical protection requirements for the power supply conductors exist to minimize potential interruption during a fire. (NFPA 70, 695-3(a), 695-4(b)(1), and 695-5(c)(2))
   2. Coordinated overcurrent protection of the motor branch circuit conductors to trip the circuit breaker in the fire pump controller rather than an upstream device. (NFPA 70, 240-12)

c) No Motor Overload Protection: Fire pump motor protection is limited to locked rotor and short circuit protection only. (NFPA 20, 7-4.3 and 7-4.4)

d) Critical Components: Certain conductors and electrical components are not protected from overcurrent in the interest of getting a distressed pump going. (NFPA 20, 7-4.3, 7-4.4, and 7-4.5; NFPA 70, 695-6(c))

e) No Ground Fault Protection: Ground fault protection is prohibited. (NFPA 70, 695-6 and 230-95 Exception 2)

[1] Particular attention should be given to Chapters 6 and 7.

[2] Particular attention should be given to Article 695.

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f) Control Circuits:

1. External control circuits that extend outside the fire pump room shall be arranged so that failure of any external circuit (open or short-circuit) shall not prevent operation of pump(s) from all other internal or external means. (NFPA 20, 7-5.2.5; NFPA 70, 695-14)
2. Failure of external control circuits may cause a motor run condition. (NFPA 20, 7-5.2.5; NFPA 70, 695-14)
3. Overcurrent protection in necessary control circuits is prohibited. (NFPA 20, 7-3.5)

g) Fire Pump Controller Circuit Breaker Settings:

1. The trip setting of the fire pump controller circuit breaker can be up to 20 times motor full load current. (NFPA 20, 7-4.3.3(6))
2. The fire pump controller circuit breaker shall have a continuous rating of not less than 115 percent of full-load current and shall not trip when carrying up to 300 percent of motor full-load current. (NFPA 20, 7-4.3.3(1), 7-4.4(2))
3. The fire pump controller circuit breaker shall trip between 8 and 20 seconds at motor locked-rotor current. (NFPA 20, 7-4.4)

h) Remote Control Stations: Remote control stations shall not be capable of stopping the fire pump. (NFPA 20, 7-5.2.3)

i) Supplying Other Equipment: Fire pump controllers may not be used as a junction box to supply other equipment (including jockey pumps). (NFPA 20, 7-3.4.4; NFPA 70, 695-6(f))

j) Automatic Non-pressure Switch-actuated Starting: A non-pressure switch-actuated automatic fire pump controller shall commence its starting sequence by the automatic opening of a remote contact. (NFPA 20, 7-5.2.2)

2 DESIGN CONSIDERATIONS

2.1 POWER CONDUCTORS CONNECTED TO THE FIRE PUMP CONTROLLER AND MOTOR

2.1.1 This is a suggested procedure for properly sizing power supply conductors to the fire pump controller and motor to meet the requirements of NFPA 20 and NFPA 70.

a) Determine the motor full-load current from the motor nameplate or NFPA 70, Table 430-150.

b) Multiply the full-load current by 1.25 per NFPA 70 695-6(c).

c) Select supply conductor size per NFPA 70 310-15 and Table 310-16, based upon current calculated in step b above. Use 75°C column as appropriate. See NFPA 70 110-14(c).

For conductors from the controller to wye-delta and part winding motors where six leads are required sizing should be as follows:

1. Part winding–Each conductor carries 50 percent of the motor full-load current. See NFPA 70 430-3.
2. Wye Delta–Each conductor carries 58 percent of the motor full-load current. See NFPA 70 430-22.

Parallel conductors may be required for large motors. See NFPA 70 310-4, and refer to controller manufacturers field connection instructions for conductor termination information.

d) Verify that the conductor size will provide compliance with the voltage drop limitations as outlined in NFPA 20 6-4 or NFPA 70 695-7.

NOTE–NFPA 70 *does not* require conductors to be sized to carry a minimum of 300 percent of motor full-load current nor locked-rotor current indefinitely. See NFPA 695-6(c)(1) and 695-6(c)(2).

e) Consult motor manufacturers connection diagram for proper connections to the controller.

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Example**:** 300 HP, 460 Volt, 60 hertz controller is located 500 feet from the utility supply and the motor is 25 feet from the controller. Example is based on the use of copper conductors. Refer to controller manufacturers field connection instructions for use of aluminum conductors.

a) Motor full-load current is 361 amperes.

b) 361 x 1.25 = 451 amperes.

c) 700 kcmil, 75°C, is rated for 460 amperes for three conductors in one conduit. For two conductors per phase, 2-4/0, 75°C, in two separate conduits is also rated for 460 amperes. For two conductors per phase, 2-300 kcmil, 75°C, in one conduit is rated for 456 amperes. See NFPA 70 Table 310-15(b)(2)(a).

NOTE**–**Had the ambient temperature been 40°C in the above examples the conductor sizes would have been 900 kcmil, 2-300 kcmil, and 2-400 kcmil respectively. See correction factors of NFPA 70, Table 310-16.

d) Maximum allowable voltage drop.
1) Method of calculating the motor running voltage drop for 700 kcmil copper conductor in 525 feet of steel conduit.

NOTE**–**Total voltage drop to the controller should not exceed 5 percent (5 percent x 460 = 23 volts (line-to-line)).

a) See NFPA 70, Chapter 9, Table 9, effective Z at 85 percent power factor for uncoated copper wire which equals 0.047 ohms/1000 feet.

NOTE**–**The value for 600 kcmil is used since the table does not list a value for 700 kcmil.

b) Divide 0.047 ohms/1000 ft. by 1000 and multiply the result by 525 ft. which equals 0.0247 ohms.

c) Multiply motor full-load amperes 361 by 1.15 which equals 415 amperes. Refer to NFPA 70 695-7 or NFPA 20 6-4.

d) Multiply 415 amperes by 0.0247 ohms which equals 10.2 volts.

e) Multiply 10.2 times 1.732 which equals 17.7 volts (line-to-line).

This equals 3.8 percent which is less than the 5 percent permitted. Using only effective Z provides a simplified estimate of voltage drop.

2) Method of calculating the motor starting voltage drop for 700 kcmil copper conductor in 500 feet of steel conduit.

NOTE**–**Total voltage drop to the controller should not exceed 15 percent (15 percent x 480 =72 volts (line-to-line)).

a) See NFPA 70, Chapter 9, Table 9, effective Z at 30 percent power for uncoated copper wire which equals 0.053 ohms/1000 feet.

NOTE 1**–**The value for 600 kcmil is used since the table does not list a value for 700 kcmil.

NOTE 2**–**The effective Z at 30 percent power factor is calculated in accordance with Note 2 of Table 9.

b) Divide 0.053 ohms/1000 ft. by 1000 and multiply the result by 500 ft. which equals 0.0265 ohms.

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c) Multiply motor full-load amperes 361 by 6 which equals 2,166 amperes. (The locked rotor current of a NEMA Design B 3-phase squirrel cage induction motor is approximately six times the full load current of that motor, and this approximation is used throughout similar examples in this Guide. For more precise calculations, use the actual motor data plate locked rotor current. *Maximum* locked rotor currents are provided in NFPA 20 Table 6-5.1.1.)

d) Multiply 2,166 amperes by 0.0265 ohms which equals 57.4 volts.

e) Multiply 57.4 times 1.732 which equals 99.4 volts (line-to-line).

This equals 20.7 percent which is not less than the 15 percent permitted. Use the next largest conductor size and recalculate. Using only effective Z provides a simplified estimate of voltage drop.

NOTE–Confirmation of voltage drop under motor starting conditions typically cannot be accomplished with a standard voltmeter. Special instrumentation is normally required.

2.1.2 Special attention should be given to the termination of approved wiring systems to the controller when applied with the recommendations of the manufacturer and the listing agency. In addition, attention should be given to the use of listed wire connectors at the motor.

2.2 ENVIRONMENTAL CONSIDERATIONS FOR ENCLOSURES

2.2.1 NFPA 20 7-3.3 requires the minimum enclosure rating to be a NEMA type 2 (see NEMA Standards Publication 250 *Enclosures for Electrical Equipment (1000 Volts Maximum)* for further details).

2.2.2 Where the equipment is located outside or where special environments exist, suitably rated enclosures are required.

2.2.3 Type 2 enclosures are intended for indoor use primarily to provide a degree of protection against limited amounts of falling water and dirt.

2.2.4 Type 3R enclosures are intended for outdoor use primarily to provide a degree of protection against rain, sleet, and damage from external ice formation.

2.2.5 Type 4 enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against windblown dust and rain, splashing water, hose-directed water, and damage from external ice formation.

2.2.6 Type 4X enclosures are intended for indoor or outdoor use primarily to provide a degree of protection against corrosion, windblown dust and rain, splashing water, hose-directed water, and damage from external ice formation.

2.2.7 Type 12 enclosures are intended for indoor use primarily to provide a degree of protection against circulating dust, falling dirt, and dripping non-corrosive liquids.

2.2.8 When controllers are placed into environments that are unusual service conditions such as direct sunlight, freezing, vandalism, infestation, etc., additional considerations should be given. See also NFPA 20 2-7.1. Consult controller manufacturers for recommendations

2.2.9 Top entry conduit fittings into the fire pump controller should be as a minimum watertight. Conduit fittings on other sides of the controller should be suitable for the environment and enclosure type.

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TABLE 1

COMPARISON OF SPECIFIC APPLICATIONS OF ENCLOSURES FOR INDOOR NONHAZARDOUS LOCATIONS[1]

Provides a Degree of Protection Against the Following Environmental Conditions	Type of Enclosure				
	2*	3R	4	4X	12
Indoor only	X	-	-	-	X
Indoor or outdoor	-	X	X	X	-
Incidental contact with the enclosed equipment	X	X	X	X	X
Rain	-	X	X	X	-
Falling dirt	X	X	X	X	X
Falling liquids and light splashing	X	X	X	X	X
Circulating dust, lint, fibers, flyings**	-	-	X	X	X
Windblown dust	-	-	X	X	-
Settling airborne dust, lint, fibers, and flyings**	-	-	X	X	X
Hosedown and splashing water	-	-	X	X	-
Oil and coolant seepage	-	-	-	-	X
Oil or coolant spraying and splashing	-	-	-	-	-
Corrosive agents	-	-	-	X	-
Occasional temporary submersion	-	-	-	-	-
Occasional prolonged submersion	-	-	-	-	-

* These enclosures may be ventilated. Consult the manufacturer.

** These fibers and flyings are nonhazardous materials and are not considered the Class III type ignitable fibers or combustible flyings. For Class III type ignitable fibers or combustible flyings see the *National Electrical Code*, Article 500.

2.3 TRANSFORMER SIZING

2.3.1 Where a transformer supplies an electric motor driven fire pump, it must be rated at a minimum of 125 percent of the sum of the fire pump motor(s) full-load current(s), and pressure maintenance pump(s) motor loads, and 100 percent of the associated fire pump accessory equipment current supplied by the transformer. See NFPA 70 695-5(a)

2.3.2 Regulation of the transformer should be adequate to meet the 5 percent motor running and 15 percent motor starting voltage drop limitations of NFPA 20 6-4 or NFPA 70 695-7.

2.3.3 Similar considerations should be given to transformers serving the fire pump and other system loads. See NFPA 70 695-5(c).

Example: Calculate the minimum transformer size for a transformer dedicated to a 300 HP, 460 volt fire pump motor. Assuming the transformer impedance is 5.75 percent, calculate the voltage drop during motor running and motor starting. Verify that these voltage drops do not exceed 5 percent during running or 15 percent during starting (NFPA 70 695-7 or NFPA 20 6-4).

[1] For additional information on enclosures or enclosure types, see NEMA Standards Publication 250 *Enclosures for Electrical Equipment (1000 Volts Maximum)*.

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a) Transformer minimum size (kVA) $= \frac{V_{L-L} \times MFLA \times 1.25 \times \sqrt{3}}{1000}$

= 460 x 361 x 1.25 x 1.732
= 360 kVA
The next available size is = 500 kVA

b) Percent voltage drop during motor running $= \frac{Z \times MFLA \times 1.15 \times V_{L\text{-}L} \times \sqrt{3}}{\text{Transformer size (kVA)} \times 1000}$

$= \frac{5.75 \times 361 \times 1.15 \times 460 \times 1.732}{500 \times 1000}$

= 3.8 percent

c) Percent voltage drop during motor starting $= \frac{Z \times MFLA \times 6 \times V_{L\text{-}L} \times \sqrt{3}}{\text{Transformer size (kVA)} \times 1000}$

$= \frac{5.75 \times 361 \times 6 \times 460 \times 1.732}{500 \times 1000}$

= 19.8 percent

d) Since the voltage drop during motor starting exceeds the NFPA limits, a larger transformer could be selected or a reduced voltage fire pump controller could be used.

e) Using across-the-line starting and a 750 kVA transformer for the above example the percent voltage drop during motor running equals 2.4 percent and the percent voltage drop during motor starting equals 12.7 percent.

f) Using the same 500 kVA transformer for the above example and a reduced voltage autotransformer type controller set at the 65 percent tap, the percent voltage drop during motor running remains equal to 3.8 percent and the percent voltage drop during motor starting changes to 8.3 percent.

NOTES–1. Even though the voltage drop of the transformer does not exceed the NFPA limits, care must be taken to ensure that the total voltage drop from the source, the transformer, and the power wiring added together does not exceed 5 percent during motor running or 15 percent during motor starting as required by NFPA 70 695-7 or NFPA 20 6-4.

2: Using the transformer impedance multiplied by the ratio of the motor current and the transformer full-load current provides a simplified estimate of the voltage drop.

2.4 TRANSFER SWITCH CONSIDERATIONS

2.4.1 Automatic transfer switches for fire pump control are applied per NFPA 70 695-3(b) and NFPA 20 7-8 as in Figure 1.

2.4.2 When an arrangement as shown in Figure 2 is used, special attention should be given to the following issues.

a) The combination fire pump controller/transfer switch must be listed for use with two utilities since the alternate side can be connected to the second utility.
b) The upstream transfer switch should comply with NFPA 20 7-8.2.2 and 7-8.3.

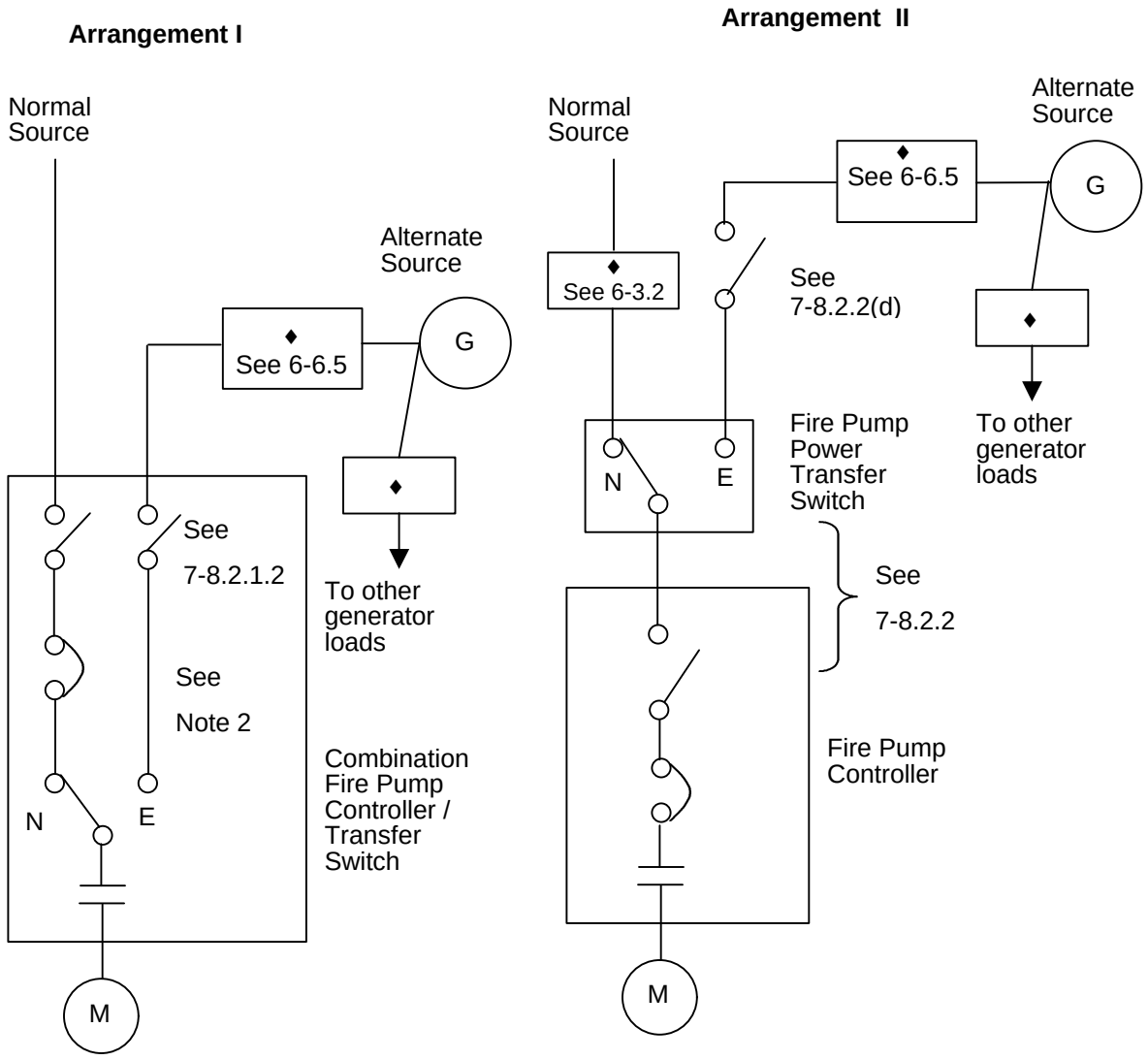
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c) Upstream overcurrent protection must be sized to carry the locked-rotor current indefinitely in accordance with NFPA 70 695- 4(b)(1). The transfer switch short circuit rating should be coordinated with the overcurrent protection device.

NOTE– In the event of a distressed pump causing locked-rotor currents of duration in excess of those permitted in NFPA 20 7-4.4, the locked-rotor protective device in the *controller* should be the only device to trip. This device can be readily reset since the controller is located within sight of the fire pump motor. Upstream overcurrent protective devices may be located in or beyond fire zones and must carry the locked-rotor current indefinitely in accordance with NFPA 70 695-4(b)(1).

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♦Disconnecting means and overcurrent protective device(s) – circuit breakers or fusible switches may be used.

NOTE 1–All references are to NFPA 20-1999.

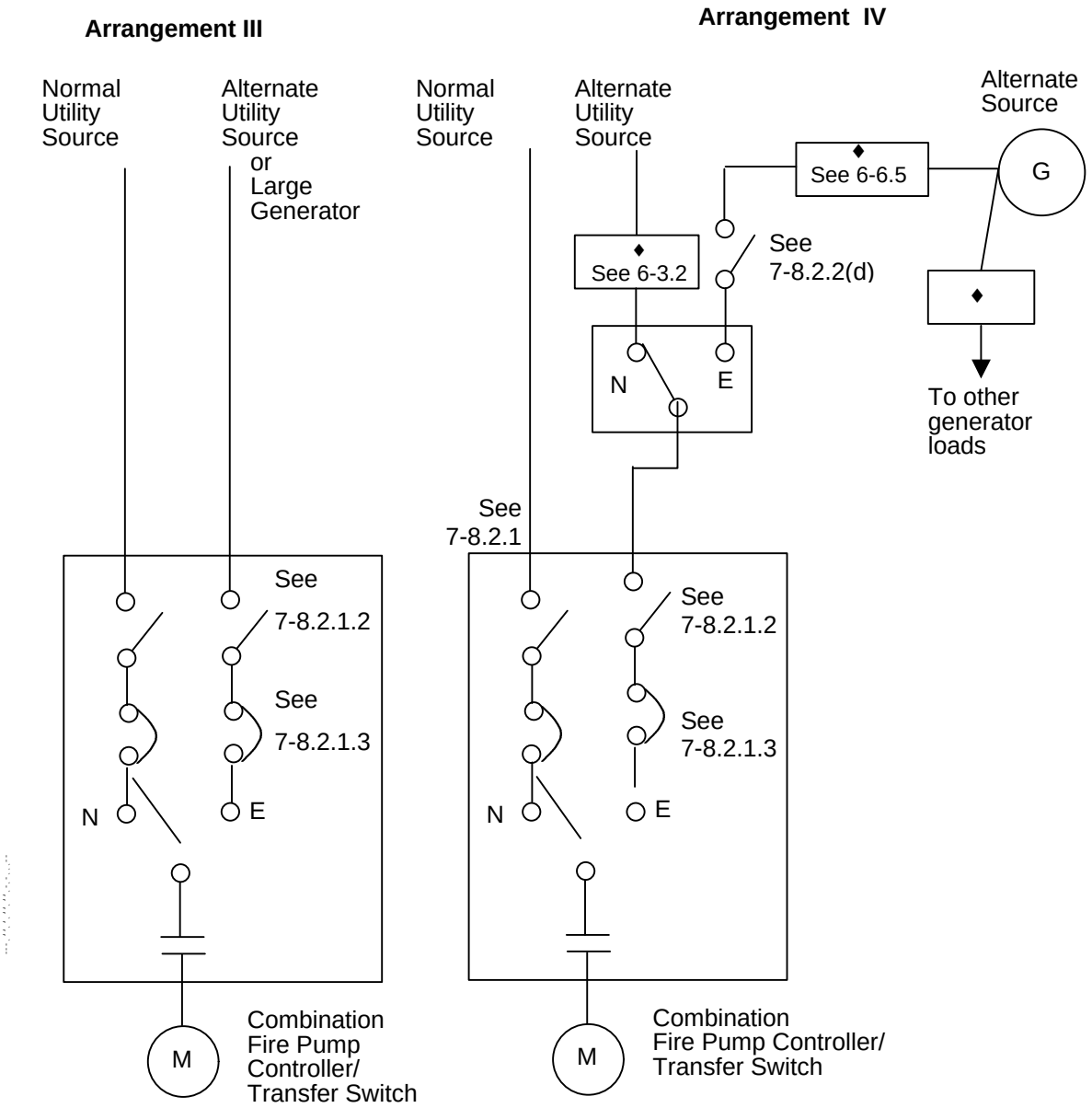
NOTE 2–A short-circuit study should be made to determine the possible need for Arrangement III, Figure 2.

Figure 1
TYPICAL FIRE PUMP CONTROLLER AND TRANSFER SWITCH ARRANGEMENTS I AND II NORMAL SOURCE FROM A UTILITY AND ALTERNATE SOURCE FROM AN ON-SITE GENERATOR

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♦ Disconnecting means and overcurrent protective device(s) – circuit breakers or fusible switches may be used.

NOTE 1–Examples where the combination fire pump controller/transfer switch must be suitable for use with two (2) utilities. See NFPA 20 7-8.2.1.3.

NOTE 2–All references are to NFPA 20-1999.

Figure 2
TYPICAL FIRE PUMP CONTROLLER AND TRANSFER SWITCH ARRANGEMENTS III AND IV NORMAL SOURCE FROM A UTILITY AND ALTERNATE SOURCE FROM A SECOND UTILITY AND ON-SITE GENERATOR

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2.5 CONSIDERATIONS FOR SPECIFYING SHORT CIRCUIT RATING (RMS SYM)

2.5.1 This is a simplified procedure, with examples, for specifying the fire pump controller short circuit rating. All calculations assume unlimited short-circuit current at the transformer primary.

2.5.1.1 "Method One" is the simplest, requiring limited calculations. Selection of the fire pump controller short circuit rating is made from Table 3. This method is applicable for systems with power transformers ranging from 500 kVA through 2500 kVA with standard impedance values of 2.0 percent and higher.

2.5.1.2 "Method Two" covers all other systems which cannot be established from Table 4. This is a simplified procedure for determining the available short-circuit current with a reasonable degree of accuracy.

2.5.1.3 Information required:

a) Transformer kVA and secondary voltage

b) Transformer percent impedance

c) Length of circuit and size of power conductor between the transformer and controller line terminals.

d) Motor full-load current (required for Method Two only)

NOTE–The above information can be obtained from nameplate data and the local power utility.

2.5.2 Method One: Fire pump controller short circuit rating selection from Table 3.

a) Select the appropriate transformer kVA rating and power cable column.

b) Note the minimum cable length for the appropriate secondary voltage that must be installed between the transformer and fire pump controller.

c) The required fire pump controller short circuit rating is then established from the fire pump controller short-circuit current rating column.

Example: A 200 HP, 460 volt, 60 Hz controller is located 100 feet from a 2000 kVA supply transformer (transformer impedance is 5.75 percent). The power conductor consists of one 350 kcmil cable per phase in a steel conduit.

d) Refer to Table 3 for a 2000 kVA transformer with a 480 volt secondary and a 350 kcmil power cable and note the minimum cable length. In this case it is 42.3 feet. Based on this, a fire pump controller with a 30,000 amp short circuit current rating can be used.

Conclusion: Since the installation used 100 feet of cable, which exceeds the 42.3 feet value found in table 3, a fire pump controller with a 30,000 ampere short-circuit current rating is suitable for use on this circuit.

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TABLE 3
FIRE PUMP CONTROLLER SHORT CIRCUIT CURRENT RATING

Transformer KVA	Transformer % Imped.	Secondary Volts	Transformer Sec. S-C Current	Controller S-C Current Rating	Minimum Length of Cable Between Transformer and Controller in Feet. Wire Size 500 kcmil	350 kcmil	300 kcmil	250 kcmil	4/0 AWG	3/0 AWG	1/0 AWG	1 AWG	2 AWG
500	2.00%	208	69,395	42000	20.4	18.3	16.7	15.2	13.9	11.7	8.1	6.6	5.4
		240	60,142	42000	18.0	16.1	14.7	13.4	12.2	10.4	7.2	5.9	4.7
		380	37,985	30000	27.8	24.9	22.8	20.8	18.9	16.0	11.1	9.0	7.3
		480	30,071	30000	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.1	0.1
		600	24,057	22000	24.4	21.8	19.9	18.2	16.6	14.0	9.7	7.9	6.4
750	5.75%	208	36,206	42000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		240	31,379	42000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		380	19,818	30000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		480	15,689	30000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		600	12,551	22000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1000	5.75%	208	48,275	42000	6.7	6.0	5.5	5.0	4.6	3.9	2.7	2.2	1.8
		240	41,838	42000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		380	26,424	30000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		480	20,919	30000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		600	16,735	22000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1250	5.75%	208	60,344	42000	15.7	14.1	12.9	11.7	10.7	9.0	6.2	5.1	4.1
		240	52,298	42000	11.8	10.5	9.6	8.8	8.0	6.8	4.7	3.8	3.1
		380	33,030	30000	12.1	10.9	9.9	9.1	8.3	7.0	4.8	3.9	3.2
		480	26,149	30000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		600	20,919	22000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1500	5.75%	208	72,412	42000	21.7	19.5	17.8	16.2	14.8	12.5	8.6	7.1	5.7
		240	62,757	42000	19.8	17.7	16.2	14.7	13.4	11.3	7.8	6.4	5.2
		380	39,636	30000	32.2	28.8	26.3	24.0	21.9	18.5	12.8	10.5	8.5
		480	31,379	30000	7.3	6.6	6.0	5.5	5.0	4.2	2.9	2.4	1.9
		600	25,103	22000	35.2	31.5	28.8	26.3	23.9	20.2	14.0	11.4	9.3

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TABLE 3
FIRE PUMP CONTROLLER SHORT CIRCUIT CURRENT RATING (CONT.)

Transformer KVA	Transformer % Imped.	Secondary Volts	Transformer Sec. S-C Current	Controller S-C Current Rating	Minimum Length of Cable Between Transformer and Controller in Feet. Wire Size 500 kcmil	350 kcmil	300 kcmil	250 kcmil	4/0 AWG	3/0 AWG	1/0 AWG	1 AWG	2 AWG
2000	5.75%	208	96,550	42000	29.2	26.2	23.9	21.8	19.9	16.8	11.6	9.5	7.7
		240	83,676	42000	29.7	26.6	24.3	22.2	20.2	17.1	11.8	9.7	7.8
		380	52,848	30000	57.2	51.2	46.8	42.7	38.9	32.9	22.7	18.6	15.1
		480	41,838	30000	47.3	42.3	38.7	35.3	32.2	27.2	18.8	15.4	12.4
		600	33,471	22000	97.7	87.4	79.9	72.9	66.4	56.1	38.8	31.7	25.7
2500	5.75%	208	120,687	42000	33.7	30.2	27.6	25.2	22.9	19.4	13.4	11.0	8.9
		240	104,596	42000	35.7	32.0	29.2	26.7	24.3	20.5	14.2	11.6	9.4
		380	66,060	30000	72.3	64.7	59.1	53.9	49.1	41.5	28.7	23.5	19.0
		480	52,298	30000	71.3	63.8	58.3	53.2	48.4	41.0	28.3	23.2	18.7
		600	41,838	22000	135.1	121.0	110.5	100.8	91.8	77.7	53.7	43.9	35.5

NOTE 1–Calculations based on a simplified method of determining short circuit currents.

NOTE 2–Values in the table above are approximate.

NOTE 3– Where the value in the table is zero (0), the short circuit rating of the controller is above the available short circuit current and therefore does not require any additional cable to educe the available short circuit current below the controller rating.

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2.5.3 Method Two: Use this method only when the transformer secondary voltage and available secondary short-circuit current is known.

Example: A 200 HP, 460 volt, 60 Hz controller is located 150 feet from a transformer having a 200,000 ampere secondary short circuit current availability. The motor has a full-load current rating of 240 amperes, thus requiring conductors capable of carrying 300 amperes (240 x 1.25 = 300). Table 310-16 of the NEC specifies 350kcmil cable. Refer to Table 4. Under the 350 kcmil cable column the minimum cable length between the transformer and the controller is 127.2 feet. Since the 150 foot cable length exceeds the allowable length of 127.2 feet, a controller having a 30,000 ampere short-circuit rating is suitable.

The calculations and data in Table 4 assume that the fire pump controller is connected in the preferred manner to a dedicated transformer supplied by a utility service (for calculation purposes, power availability from a utility source is considered to be infinite). It therefore assumes there are no motor contributions to the available short circuit currents. Where connected motors contribute to the available short circuit current, a more detailed analysis should be made. (See IEEE Std. 242.)

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TABLE 4
TRANSFORMER SECONDARY VOLTAGE AND AVAILABLE SECONDARY SHORT-CIRCUIT CURRENT

Transformer KVA	Transformer % Imped.	Secondary Volts	Transformer Sec. S-C Current	Controller S-C Current Rating	Minimum Length of Cable Between Transformer and Controller in Feet. Wire Size 500 kcmil	350 kcmil	300 kcmil	250 kcmil	4/0 AWG	3/0 AWG	1/0 AWG	1 AWG	2 AWG
		208	200,000	42000	40.9	36.6	33.4	30.5	27.8	23.5	16.2	13.3	10.8
		240	200,000	42000	47.2	42.2	38.6	35.2	32.1	27.1	18.7	15.3	12.4
		380	200,000	30000	112.5	100.7	92.0	83.9	76.5	64.6	44.7	36.6	29.6
		480	200,000	30000	142.1	127.2	116.2	106.0	96.6	81.7	56.5	46.2	37.4
		600	200,000	22000	253.7	227.0	207.4	189.2	172.4	145.7	100.8	82.4	66.7
		208	100,000	42000	30.0	26.9	24.5	22.4	20.4	17.2	11.9	9.8	7.9
		240	100,000	42000	34.6	31.0	28.3	25.8	23.5	19.9	13.8	11.3	9.1
		380	100,000	30000	92.7	82.9	75.8	69.1	63.0	53.2	36.8	30.1	24.4
		480	100,000	30000	117.0	104.8	95.7	87.3	79.5	67.3	46.5	38.0	30.8
		600	100,000	22000	222.3	199.0	181.8	165.8	151.1	127.7	88.3	72.2	58.5

NOTE 1–Calculations based on a simplified method of determining short circuit currents.

NOTE 2–Values in the table above are approximate.

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2.6 REDUCED VOLTAGE STARTING METHODS

TABLE 5
REDUCED VOLTAGE STARTING METHODS

Starting Method	Controller Operation	Starting Current	Starting Torque	Open Or Closed Transition
Across the Line	Initially connects motor directly to power lines	100%	100%	None
Primary Reactor	Inserts reactance in series with motor during starting.	50% 65%	25% 42%	Closed
Primary Resistance	Inserts resistance units in series with motor during starting.	50% 65%	25% 42%	Closed
Autotransformer	Uses auto-transformer to reduce voltage to motor	Tap / Current 50% / 25% 65% / 42% 80% / 64%	 25% 42% 64%	Closed
Wye-Delta	Starts motor with windings wye connected, then controller reconnects them in delta.	33%	33%	Open or Closed
Solid State Soft Start/Stop	Uses special soft start module to control current and voltage to motor.	Varies (35 - 100%)	Varies (12 -100%)	Closed
Part Winding	Starts motor with only part of winding connected, then adds remainder for running.	70 - 80%	50 - 60% Minimum pull-up torque 35% of full load.	Closed

NOTE 1–Consideration should be given to the method of starting and the power source. Consult the controller manufacturer for additional information.
NOTE 2–The voltage drop limitation requirements of NFPA 70 695-7 and NFPA 20 6-4 are not applicable when the manual emergency handle is used on reduced voltage controllers. Under that condition the power supply need only be capable of starting and running the motor as demonstrated during acceptance testing of the fire pump system.
NOTE 3–Consideration should be given to the effects of transition currents of open transition controllers on circuit breakers, generators, couplings, pump shafts and other components of the fire pump system.

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2.7 LIMITED SERVICE CONTROLLER LIMITATIONS

2.7.1 Limited service controllers (NFPA 20 7-7) are restricted application controllers for smaller fire pumps driven by electric motors. These controllers are restricted to those installations where their use is expressly acceptable to the Authority Having Jurisdiction (AHJ). [See 1-4 (and A-1-4), 1-8 "Approved" (and A-1-8, "Approved"), and 1-8, "Authority Having Jurisdiction" (and A-1-8, "Authority Having Jurisdiction").]

2.7.2 Express restrictions, beyond acceptability to the AHJ, are placed on Limited Service Controllers and the motors they control by NFPA 20 7-7. The controller must be automatic (non-automatic controllers are not permitted) for across-the-line starting (reduced voltage starting is not permitted) and the controller must be specifically marked "Limited Service Controller." The motor must be squirrel-cage rated 30 horsepower or less and 600 Volts or less.

2.7.3 Exception No. 1 to NFPA 20 7-7 permits the locked-rotor protection in a limited service controller to be accomplished by a standard thermal-magnetic circuit breaker in place of the instantaneous trip only circuit breaker and locked-rotor protector (see NFPA 20 7-4.3.3(b) and 7-4.4) required in an electric fire pump controller. Limited service controllers employing this exception should not be installed where the ambient temperature is not stable. It may also be not possible to reset the circuit breaker immediately after tripping, delaying the restoration of fire protection. Depending on the tripping characteristics of the circuit breaker it is possible to burn out the motor on the first automatic start under locked-rotor conditions, thus leaving no chance for manual recovery.

2.7.4 Exception No. 4 to NFPA 20 7-7 permits the omission of the isolating switch (see NFPA 20 7-4.2) in a limited service controller. For installations employing limited service controllers manufactured under this exception, it may be necessary to contact the utility providing electric power to disconnect that power when maintenance on or replacement of power components such as the circuit breaker and voltage surge arrester (see NFPA 20 7-4.1) in the controller is required.

2.8 LISTED FIRE PUMP MOTOR APPLICATIONS

2.8.1 NFPA 20 6-5 requires motors to be NEMA Design B, Code letters F or G for motors 15 HP and over, Code letters F, G, or H for 10 or 15 HP, and Code letters F, G, H or J for motors 5 HP and less [see NFPA 70 430-7(b)], and specifically Listed and Marked for Fire Pump Service. (There are some exceptions.) Standard squirrel-cage motors meeting these requirements are suitable for across-the line starting and autotransformer, primary reactor, primary resistor, and solid-state soft-start reduced voltage starting. Special motors, also meeting these requirements are suitable for Part-Winding and Wye-Delta reduced voltage starting. Motors for part-winding starting must be specified to the motor manufacturer as being of the "50%-50%" starting type.

2.8.2 Because full load current and locked rotor current for the same rated motor can vary considerably among various manufacturers, it is helpful to provide to the fire pump controller manufacturer the Code letter, full-load current and locked-rotor current of the selected motor to assure accurate locked-rotor motor protection. If this information is not provided at the time of order entry, it should be expected that the locked rotor protection will be provided in accordance with the specified motor horsepower and voltage and NFPA 70 Table 430-7(b), Code “G” for motor locked rotor current and Table 430-147, 430-148, 430-149, or 430-150, as appropriate, for motor full load current.

2.8.3 Motors used at altitudes above 3300 feet (1000 meters) shall be operated or derated according to NEMA Standards Publication MG 1, *Motors and Generators*, Part 14.

2.8.4 Direct-current, high-voltage (over 600 volts), large-horsepower (over 500 horsepower), single-phase, universal-type, or wound-rotor motors shall be permitted to be used where approved.

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2.9 PRESSURE RECORDERS

2.9.1 A listed pressure recording device is required to sense and record the pressure in each fire pump controller pressure-sensing line at the input to the controller (see NFPA 20 7-5.2.1(e)).

2.9.2 A pressure recording device in a listed controller meets the requirements of 2.9.1 and the requirements of NFPA 20 7-5.2.1(e).

2.10 CONTROLLING ENGINE DAMPERS

2.10.1 Ventilation is required to control the maximum air temperature, supply combustion air, remove hazardous vapors, and supply air necessary for radiator cooling when required (See NFPA 20 8-3.2)

2.10.2 Sometimes powered louvers or dampers are used as part of the ventilation. When they are, they should be controlled by the Fuel/Water signal or the Engine Running signal. (See NFPA 20 A-8-3.2.1 and A-8-3.2.2.). To access these signals from the controller, auxiliary relays or outputs should be ordered with the controller.

2.11 STAND-BY GENERATOR SIZING FOR FIRE PUMPS

2.11.1 The sizing of stand-by generators for driving fire pump motors needs to consider a number of special requirements unique to fire pump installations. These requirements are contained in NEC Article 695 and NFPA 20 Chapters 6 and 7.

2.11.2 Exact calculations suitable for specifications and purchasing decisions require calculations that take all factors affecting burden on the generator into account. For rough estimating purposes, one can approximate the gen-set size in kW by multiplying the fire pump motor horsepower by 6 if across-the-line starting is used or by 4 if reduced voltage starting is used. This is a very conservative estimate and may result in a gen-set size larger than required for a specific application. For more precise sizing calculations, consult the fire pump controller manufacturer for additional information on reduced voltage starting and the gen-set supplier for information on sizing.

2.11.3 To properly size the gen-set for a fire pump application, it is necessary to know the starting kVA, the starting kW, the running kVA, the running kW, and the allowable voltage dip. For across-the-line motor starting applications, these numbers can be approximated by the following calculations:

Starting kVA = Locked Rotor Code value x the Rated Motor HP

NOTE–See NFPA 70-1999 Table 430-7(b) for locked rotor codes and values.

Starting kW = Starting kVA x Starting Power Factor

NOTE–The starting power factor of a typical motor is 0.4.

Running kVA = Full Load Motor Current x Motor Service Factor x Rated Motor Voltage x 1.732 ÷ 1000

NOTE–The motor service factor is typically 1.15.

Running kW = Running kVA x Running Power Factor

NOTE–The running power factor is typically 0.8.

2.11.4 Voltage dip cannot exceed 15 percent as defined by NFPA 20-1999 paragraph 6-4 and NFPA 70-1999 paragraph 695-7. However, the exceptions to these paragraphs eliminate the voltage dip limitation if the emergency run mechanical starting control is used.

2.11.5 If reduced voltage starting is used, the locked rotor motor current can be reduced according to the type of starting (see Table 5). However, consideration should be given to the following:

a) The effects of open transition starting on gen-sets.

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b) The available starting torque required to accelerate the fire pump, under the specified load, to full speed before the transition to full voltage running takes place.

c) The combined starting power factor when primary resistor starting is used.

3 INSTALLATION CONSIDERATIONS

3.1 PHASE SEQUENCE

3.1.1 Electric fire pump controllers are phase sequence sensitive and will cause an alarm to be issued if connected to a power source incorrectly. (See NFPA 20 7-4.7 (c) and 7-4.8.) If incorrect phase sequence is detected upon initial installation, the proper action at this juncture is to disconnect incoming power and correct for proper phase rotation. Proper motor rotation must be verified after proper controller phase sequence is established.

3.1.2 Motor rotation correction may be accomplished as follows:

a) Three lead motors: Interchange any two motor leads on the load side terminals of the main contactor.

b) Six lead motors used with part-winding or wye-delta controllers: Interchange any two motor leads on the load side terminals of both the start and the run contactors. i.e., interchange phase 1 and phase 2 on the run contactor and the start contactor or phase 2 and phase 3 on each contactor.

3.1.3 On controllers having multiple power sources, the alternate source is also phase sensitive.

3.2 NORMAL STARTING WITH ON-SITE GENERATORS

3.2.1 Where on-site generator systems are used to supply power to fire pump motors, they shall be of sufficient capacity to allow normal starting and running of the fire pump motor(s) while supplying all other simultaneous loads. (See NFPA 20 6-6.1.) Automatic shedding of one or more optional standby loads is permissible. (See NFPA 70 695-3(2)(b)(1)).

3.2.2 Normal starting is determined by the type of motor starting provided in the fire pump controller. If across-the-line starting is provided, then the full locked rotor motor current should be used to calculate the motor starting voltage drop. (See NFPA 206-4 and NFPA 70 695-7.) If reduced voltage starting is provided, then the locked rotor motor current can be reduced by the appropriate amount shown in Table 5 of 2.6 of this document.

3.2.3 Use of the Emergency-Run Mechanical Control provides across-the-line starting even on reduced voltage controllers. Since it is an emergency control, it is not considered a means of normal starting. Furthermore, the exception to NFPA 20 6-4 and NFPA 70 695-7 states that the motor voltage drop requirements do not apply during Emergency-Run Mechanical starting.

3.3 INDUCED VOLTAGES ON CONTACTS FOR REMOTE SIGNALING

3.3.1 High impedance circuits, such as computer alarm systems, that monitor “dry” or “voltage free” contacts can pick-up induced voltages on these contacts.

3.3.2 A simple method to determine if this is an induced voltage is to use an analog voltmeter to read across the contacts. If the voltage disappears, then the voltage is likely an induced voltage. This is beyond the normal service conditions of the equipment and is difficult to correct in the field. Contact the controller manufacturer for further advice.

3.3.3 Users intending to monitor alarm and status circuits with high impedance sensors, such as computers, must so advise the manufacturer before the fire pump controller is manufactured and shipped. The limits of induced potential in those circuits is a matter of agreement between user and manufacturer.

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4 OTHER CONSIDERATIONS

4.1 LISTED AND APPROVED EQUIPMENT

Controllers that bear the mark of a nationally recognized testing laboratory have been evaluated to be in compliance with NFPA 20 when installed in accordance with NFPA 70 (see NFPA 70, 90-7). Each fire pump controller has been evaluated for each horsepower and voltage rating to the satisfaction of Listing/Approval agencies whose Mark appear thereon. This evaluation includes a review of the component rating, conductor sizes and relay functions/logic to assure compliance with applicable Codes and Standards.

4.2 TESTING AND MAINTENANCE

The procedures as stated in NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems* should be followed for proper maintenance and periodic testing.

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