PDHonline Course E174 (3 PDH)

2005 National Electric Code

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Course Content

INTRODUCTION

This three hour online course reviews the 2005 version of NFPA 70, the National Electric Code, as a design guide, in common English. Because the book is so massive, a list of key changes and critical requirements precedes the sequential review of Code.

You must have access to a copy of the 2005 National Electric Code to check the exact wording of requirements for your interpretation on design and construction questions. It is not intended that a copy is needed at your computer when you take this course and quiz, but it will help.

Optional Narrative	In response to users' requests, narrative material is included in this revision of the PDHonline National Electric Code course. Paragraphs in boxes like this one contain references to previous versions of the Code, reports of field experience with Plans Examiners and Contractors and extraneous opinions. Content is not included in the quiz.

The National Electric Code changes substantially with each revision and gradually as trends in enforcement spread across the country. This course has a strong component of focusing on the changes that first appear in the 2005 NEC. Also included are critical sections that cause problems - both to provide a reference to the relevant Code section and to point out both the problems and solutions.

Optional Narrative	The Code, the Code making body, this course and the Authority Having Jurisdiction. The reason we follow the National Electric Code is to get Building Permits, get Occupancy Permits, avoid fires and injuries and avoid liability when we have to explain to a Judge. A Building Permit is among the first steps in almost any construction or remodeling project. It is necessary to release funding monies in most cases because it is a document of feasibility of the project and concurrence to the concepts of the project by a public authority. A superficial view of the process suggests that following the Code should be easy. Unfortunately, there are many forms of the Code. The written Code, available for about $65, paperback (www.NFPA.org) is the basis for everyone.

	Unfortunately, the language requires interpretation. The National Electric Code Handbook, available for about $100 (www.NFPA.org) is the interpretation of an editor who was involved in writing and approving the Code. The Handbook is NOT ENFORCEABLE. That means that it indicates to the engineer, to the contractor and to the Inspector what was intended, but each user can interpret for himself and go to an appeals hearing to get legal enforcement. The Code Handbook, again, is recognized by everyone in the field, but discounted because of its lack of enforceability. There is an International Association of Electrical Code Inspectors (www.iaei.com) is a very highly respected voluntary organization which interprets difficult Code sections and share enforcement issues with its members. Membership in IAEI and publication are available to interested persons. Again, the content is persuasive, but not directly enforceable. There are many more sources for Code interpretations, with less and less authority and more and more errors introduced. This course is one of these. The author is sharing his professional engineering interpretations, but our course opinions are not enforceable and probably not too persuasive to an appeals board. Serious design questions deserve time investment in studying the NEC, the NEC Handbook and talking to the Plans Examiner or Inspector (Authority Having Jurisdiction). Building permits are issued by Plans Examiners in Departments of Building Standards. Occupancy permits are issued after passing all building inspections. Each examiner and inspector has a different set of experiences and has encountered different problems which he wishes to avoid on this job. Examiners and inspectors regularly impose requirements not in the Code, using the broad wording of "general workmanship" or other sections. These interpretations are enforceable, but appealable.

Optional Narrative	Should you buy a paperback copy of the NEC? Yes. Nothing matches underlining and high-lighting important sections. It is very portable and makes copies or scans easily. Should you buy the hardback NEC Handbook? Some people can't live without it. I prefer the CD Handbook (Folio Views) or CD NEC (.pdf). Both are searchable, which is VERY valuable. The 2005 CD NEC Handbook is copy protected, so it works on only one desktop or on your laptop until you get a new laptop. The 2005 CD NEC is not copy protected and sits nicely on your office PC, your home PC, your laptop and on the machine you use at the construction trailer. It is very efficient to do a screen-print and paste it into e-mail or a WORD document.

The quiz at the end is designed to enhance your understanding of the course materials and increase your confidence in applying the Code.

COURSE CONTENT

KEY CHANGES AND CRITICAL REQUIREMENTS OF THE 2005 NATIONAL ELECTRICAL CODE (Article indicated in parentheses) **- paraphrased requirement in ordinary English, followed by discussion.**

Requirement for Short-Circuit Study (110.9, 110.10) - Protective equipment intended to interrupt fault currents shall have an interrupting rating sufficient.

The overcurrent protective devices, the total impedance, the component short-circuit current ratings shall be selected and coordinated to clear a fault without extensive damage.

Optional Narrative	There are many places in the code where it is clear that equipment selected must be capable of doing the intended job. For protective devices, opening a short-circuit fault requires a rating higher than the fault available. To meet this Code requirement, you must know the fault available. That is what you get from a short-circuit study. There is no other way to get this value except from a short-circuit study. More and more, Owners and Plans Examiners are demanding to see the available short circuit currents. Selectivity and coordination are discussed in the later sections.

Present Interpretations of the requirement for Arc-Flash Labeling (110.16) - Field mark switchboards, panelboards, industrial control panels, meter socket enclosures and motor control centers to warn of arc flash hazards. The label must be visible before examination, adjustment, servicing or maintenance of equipment.

Optional Narrative	The Code requires a warning label. A generic warning label meets this requirement. A non-enforceable Fine Print Note suggests reading NFPA 70E-2004. 70E gives a range of labels. 1) No information, just warning, 2) Broad-brush information and warning and 3) Detailed information and warning. The detailed information section is in an Appendix to 70E, and is non-enforceable within 70E. However, consultants and vendors are strongly recommending the purchase of $10,000 software and hours of trained persons to perform the detailed calculations and preparation of detailed warning labels. Their justification is that OSHA went after a major auto manufacturer who let an electrician get killed because of old and defective protective equipment. Your instructor has strong opinions that the workplace should be safe for

	construction and maintenance persons. An operating safety program with daily work planning sessions and discussion of hazards is essential. No label can deliver as much protection. Generic labels are more readable than detailed labels. None of the samples offered actually tell the maintenance person what personal protective equipment to put on.

A Good Fix for Arc Fault Problems may increase the Hazard to Workers and to the Plant(110.16) -

Optional Narrative	Arc Flash magnitude is determined by the amps available and the milli-seconds or seconds for which they are available. An excellent way to limit the milli-seconds is to install current limiting fuses. This may not eliminate the arc flash, but will reduce the severity and, possibly reduce the level of personal protective equipment required for the worker. The downside is that current limiting fuses do not coordinate with circuit breakers. A low level arcing fault, much more common, will burn longer before being cleared. The goal was to reduce high level arc energy. It worked. The side effect was to increase low level arc energy .

Access Space around Electrical Equipment (110.26) - There are at least three concerns which must all be met. 1) Open space must be reserved for all points on electrical equipment requiring access. The safe number is 42-in from the edge of the opening to the first piece of equipment, mechanical, electrical, wall or waste basket. If energized equipment is the first piece, then the distance is increased to 48-in (avoid this).

This requirement does not apply to blank sides or backs without removable panels.

2) 30-in width must be clear in front of the equipment for access. A power panel or motor starter may not be placed on the back wall of a 24-in closet or between a hot water heater and the wall if the space is less than 30-in. Specifically, swing-out doors must be able to open full 90-degrees.

3) Dedicated space above and below electrical equipment must be kept clear of other electrical equipment, mechanical equipment, and, especially ducts and piping. The space below goes to the standing floor for the equipment. The space above goes to 6-ft above the equipment or to the structural ceiling, whichever is lower. A drop ceiling or building structural member is permitted. There is also a 6-in addition for equipment associated with the electrical equipment. That is a 12-in x 12-in trough can run below a row of 6-in deep panelboards or starters.

Optional Narrative	There are other Code requirements to be able to stand up (6-1/2-ft, 110.26.E) and to see (no automatic lighting controls, 110.26.D) .

Computations which require 43.3-in Clearance in Front of 480V Equipment (90.9.C.4, 110.26) - Where safety is involved, soft conversion shall be used. Soft conversion is direct mathematical conversion.

The exact wording in 110.26, discussed above, is 1.1m (3-1/3-ft) clear space. The NEC uses metric as the primary standard. 110cm x (1-in / 2.54-cm) = 43.31-in, not 42-in. Some persons experienced with unfriendly Inspectors expect problems from this.

The change in the 1200A, 10-ft Rule for Electric Rooms (110.26) - For equipment rated 1200A or more containing overcurrent devices, switches or control, there must be one door at least 24-in(w) x 78-in(h) at each end. Door(s) must open in the outgoing direction and have panic bars, etc, that are normally latched but open under simple pressure.

There is an exception that permits a single door if extra access space is provided, but the outward swinging door with panic bar, etc, is still required.

Labeling of Wire Color Codes on all Panels (210.5.C) - Where more than one nominal voltage system is present in the building, each hot conductor must be identified by color coding, marking tape, tagging or other means. A legend of the systems and colors used must be posted at each panel. Newer buildings often have both 120/208V and 277/480V. Older buildings often have 120/240V and 120/208V or 120/240V and 240V delta.

The color-coding requirement is long-standing. The legend sheet at panels is new.

The Change in "grandfathering" regarding GFCI Receptacles (210.8.B) - 406.3.D.2 is the old section, still valid, which says that any replacement receptacles must be GFCI if a GFCI is required in the location by the current Code. This "grandfathers" old standard receptacles until they must be replaced.
422.51 says that new or remanufactured vending machines, after 1/1/05, must have integral GFCI or be connected to a GFCI outlet. This says that when a vending machine is installed or replaced, the receptacle behind it may have to be replaced with a GFCI unit.

New GFCI requirements for Commercial Kitchens and Outdoor Public Spaces (210.8.B) - For non-dwelling locations, all 120V receptacles in locations 1) through 5) must have ground-fault-circuit-interrupters.

1) Bathrooms
2) Commercial and institutional kitchens
3) Rooftops
4) Outdoors in public spaces
5) Outdoors for maintenance of HVAC equipment

The requirement for commercial kitchens is reworded in the 2005 Code, but has been in previous versions and largely ignored. There is a lot of leakage current in kitchens, because of the good ground through piping and large amount of moisture. Also, refrigeration equipment cycles frequently and the inrush can trip a GFCI. A dedicated receptacle behind the refrigerator is NOT excluded from this requirement.

Optional Narrative	How to handle this? Warn the Owner. There will be false trips of appliance receptacles. GFCI's tend to fail completely when they are called upon to trip frequently. It is likely that refrigerators will trip off.

Outdoors in public places refers to any outdoor receptacle in a location accessible to the general public. Employees contractors, and visitors need not be protected.

The 2008 requirement for Bedroom Arc Fault Circuit Interrupters (AFCI) (210.12.B) - The rule applying to construction today is that all 120V outlets supplying lights and cord-connected equipment must be protected by AFCI. Until 1/1/08, this requirement can be met by an AFCI in the panel.

The "80% Rule" (210.19.A.1) - The branch-circuit conductor size shall have an allowable ampacity not less than 125% the continuous load. [Exception: overcurrent device listed for 100% can be applied for 100% the continuous load.]

In the special reasoning and language of the Code, it is better to say, "choose the protection for 125% the load" instead of "use not more than 80% of the protection device rating rating". Everyone calls it the "80% rule" even though those words do not appear in the Code.

Optional Narrative	100% protective devices are available in switchboards and stand-alone enclosures. Typically, they are high-end circuit breakers with electronic trip units. Note that the stand-alone enclosures are much larger than standard units and cannot be easily retrofitted.

Calculate Acceptable Voltage Drop (210.19, FPN4) - Branch circuit voltage drop is limited to 3% to the farthest outlet. Total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5%.

The quick, clean and easy solution is to upsize the conductor size for distances over 100-ft. That is, the classrooms closest and second-closest to the panel use #12 AWG copper, but the third-closest is fed by #10 AWG copper.

A more rigorous method uses the following table:

3% DROP		Technology Receptacle		General Receptacle		HVAC Rooftop Unit or Heater		Perimeter Lighting		Room Lighting	
AWG	OHM PER 1000-FT	1-PH, 120V DED NEUT		3-PH, 208V, 1-PH, 120V BAL NEUT		3-PH, 240V NO NEUT		1-PH, 277V DED NEUT		3-PH, 480V 1-PH, 277V BAL NEUT	
		A-FT	FT16A	A-FT	FT16A	A-FT	FT16A	A-FT	FT16A	A-FT	FT16A
12	1.7	998	60	2080	130	2200	140	2404	150	4800	300
10	1.1	1580	100	3280	205	3489	220	3806	240	7569	470
8	0.7	2450	150	5110	320	5405	340	5901	370	11792	740
6	0.45	3800	240	7850	490	8303	520	9153	570	18115	1130

This table is used for sizing circuits from the branch panel to the load for 3% maximum voltage drop.

AWG is copper wire size. Ohm per 1000-ft is from Table 9 in the back of the NEC.

The first set of data is for a single-phase 120V circuit with a dedicated neutral, an example being a technology receptacle. The A-FT column permits you to determine the voltage drop for any loading. The FT16A column is the feet permitted for 16A (20A circuit breaker). It says that you can go 60-ft before requiring an upsize to #10.

Similarly the second set of data is for a 3-phase 208V load, or 120V loads on a common, balanced neutral, as a general purpose receptacle or 208V heater. It says you can go to 130-ft before requiring an upsize to #10.

The third set of data is for a 240V 3-phase load, as a heater. It says you can go 140-ft before requiring an upsize to #10.

The fourth set of data is for a 277V single-phase load, as perimeter lighting. It says you can go 150-ft before requiring an upsize to #10.

The fifth set of data is for a 277V single phase load on a balanced neutral or for a 480V load. It says you can go 300-ft before requiring an upsize to #10.

These calculations are for full-capacity use of the 16A (20A cb). For a 12A load, you can use the A-FT column, or provide spare capacity for change out of the load in the future.

These calculated distances are for a #12 AWG copper conductor at 16A(20A CB). They also work for #10 AWG copper at 24A (30A CB) and #8 AWG copper at 32A (40A CB).

Optional Narrative	This section has been in the Code for many revisions. The location, in a Fine Print Note, makes it unenforceable. However, exactly the same requirement now appears in ASHRAE 90-86(99,02,etc), which is mandated by ALL States.

Renewable Fuses are Outlawed for New Installations (240.60.D) –Class H renewable cartridge fuses are only permitted for replacement where there is no evidence of overfusing or tampering. The key concept is that oversized one-time fuses can easily be identified by their marking. Oversized renewable fuses can only be identified by disassembling the cartridge and closely examining the elements.

Ground Detector on Floating Power Systems (250.21) - Several cases are indicated where ungrounded power systems are permitted. A ground detector system is required when the voltage is 120V or higher. It does not say that the ground detector must trip off the power.

For years, it was common for 240-delta power systems to have three incandescent lamps at the transformer, each connected from a phase to ground. When leakage current to ground was balanced, all three lamps glowed dimly. When a ground fault occurred, the lamp on the affected phase went out and the other two glowed brightly. Of course, the same result can be obtained with relays or a semi-conductor board potted in epoxy.

Ground and Bond the Electric Power Service Entrance (250.50) - All grounding electrodes described in 1) through 6), that are present, must be connected together.

1) Metal underground water pipe
2) Metal frame of the building or structure
3) Concrete-encased electrode
4) Ground ring encircling the building
5) Rod or pipe electrodes
6) Plate electrodes

This is interpreted to mean that you MUST provide all six on a new structure. The electrical contractor must arrange to lay ground cables during the foundation pour. You must install a ground ring. You must install a conventional ground rod, and another if it measures above 25 ohms and you must install a plate electrode and another if the first measures above 25 ohms.

Concrete may Explode if you Ground to Foundation Rebar Steel (100, Wet Location) - The previous section requires concrete-encased grounds in new construction. Section 100, Definitions, recognizes that installation in concrete are wet locations. The water content of concrete is what makes it a good grounding conductor. Unfortunately, when water conducts large amounts of electricity, it heats to boiling and expands enormously. The rapid expansion appears to be an explosion of the concrete.

Optional Narrative	So, who cares and what do you do if you care. First, the State Department of Transportation cares. They require TWO ground connections to each highway light pole. Splitting any lighting current in two directions has to help. The same remedy applies to electric service grounding. Yes, ground to the concrete-encased electrode, but also drive ground rods, bury a ground plate and install a building perimeter ring.

Grounding requirements for Remote Transformers, etc (250.30.A.4) - Where more than one separately derived system (transformer, generator, photovoltaic system, etc) over 1kva is installed, it is OK to run a tap conductor to the common grounding electrode conductor. The common grounding conductor must not be smaller than 3/0AWG copper. The tap is sized by section 250.66, based upon the derived system phase conductors.

Optional Narrative	Previous revisions had been very sticky about running independent ground conductors from the remote transformer back to the system ground. With the current wording, a single ground conductor can wander around a facility to pick up all transformers.

Splicing Grounding Electrode Conductor and Ground Bus (250.64.C) - Splicing of the grounding electrode conductor(s) is permitted by irreversible compression-type connectors listed for grounding and bonding. Splicing of the grounding electrode conductor(s) can also be done by exothermic welding.

Must Ground Natural Gas Indoor Piping (250.104.B) - Accessible grounding jumpers must be installed building structure and metal piping systems, specifically including natural gas systems. Interestingly, 250.52 specifically forbids connecting to external gas piping.

Underground Cables May be Spliced without a Box or Enclosure (300.5.E) - Direct-buried conductors or cables may be spliced or tapped without the use of splice boxes. There are epoxy kits available for this purpose, most are REA approved, but UL-approval is required in order to satisfy the National Electric Code

Provision for Settling or Heaving for Direct Buried Cables and Conduits (300.5.J) - Where direct-buried conductors, raceways or cables are subject to movement by ground settlement or frost heaving, they must be arranged to prevent damage. Some benefit is achieved by an S-loop near the ground exit. Special expansion/contraction joints are available, but attention is required to repair the underground electric when motion exceeds the allowance provided.

Currents Do Not Split Equally on Multiple Conductors per Phase (310.4) - Conductors 1/0AWG or larger may be connected in parallel to increase the power delivered to the load. The Code has two restrictions, as follows: 1) Size the individual conductors per their normal rating (Table 310.15.B.2.a) and 2) equipment grounding conductors, if used, must be placed each conduit and sized on the TOTAL current, not the parallel segment (250.122.F,G).

Many designers and contractors are unhappy that they can split the phase current flow but cannot split the equipment grounding current.

Optional Narrative	What the designers, contractors and Code writers don't realize is that currents do not split equally on multiple conductors per phase. Numerous field measurements on service transformers and generators confirm this fact. The remedy successfully applied has been the application of conductive paste and re-tightening the lugs. The problem does not disappear, but diminishes sufficiently that all conductors are operating within their current and temperature ratings.

Increase Conductor Size when routing through in Industrial Ceiling Space (Table 310.15 Adjustment Factors) - There are two well-know adjustment factors which require larger conductors under certain circumstances. 315.B.2 addresses the assumption that no more than three current-carry conductors are in a conduit. The adjustment factors in Table 310.15.B.2. are as follows (with the addition of the upsizing column):

Number of Current-Carrying Conductors	Percent of Rated Ampacity which Is Available	Required Upsizing Of Conductors Required for Same Load
4-6	80	1.25
7-9	70	1.43
10-20	50	2.00
21-30	45	2.22
31-40	40	2.50
41 and up	35	2.86

Note that the presence of harmonics, from VFD's, HID lighting, or computers causes substantial neutral currents, producing 4 current carrying conductors in a 480/277 V or 208/120V circuit (210.4.B). Conductors (and conduits) must be upsized.

Exception 1 to this section specifically excludes control conductors routed with power conductors from the count computation.

Table 310.1 addresses the assumption that the conduit runs through a normal industrial area. It includes temperature adjustment factors for each cable type. For 90C conductors (THW-2, THWN-2, XHHW) the factors are as follows:

Temp Deg-C	Temp Deg-F	Resulting Effect on Normal Conductor Rating	New Ampacity Required Multiplier	Comment
21-25	70-77	1.04		
26-30	78-86	1.00		"normal"
31-35	87-95	0.96	1.04	
36-40	96-104	0.91	1.10	NEMA limit for electrical equip
41-45	105-113	0.87	1.15	
46-50	114-122	0.82	1.22	
51-55	123-131	0.76	1.32	
56-60	132-140	0.71	1.41	
61-70	141-158	0.58	1.72	Common industrial ceiling space
71-80	159-175	0.41	2.44	

Optional Narrative	One prominent Code consultant and instructor claims that nearly all industrial spaces have undersized conductors in conduits near the ceiling. Your teacher had the opportunity to do cable pulling in tunnels under a major State university. The measured temperature at the ceiling of the tunnel / top of the ladder was 140-F.

Shielded Medium Voltage Cable above 2.0 kV (310.6) - Conductors operated above 2.0kV must be shielded unless they have a metallic armor cover. Problems with shielded cables are much less likely to result in fire or continued arcing, due to the good return path provided by the shield. The return current will trip the protective device.

Handholes (314.30) - Handholes must withstand all loads likely to be imposed. They must be sized according to the pullbox table, 314.28.A. Bottomless handholes are recognized, but any splices or terminations must be listed for wet locations. Covers must be identified as "electric" and require tools to open or weigh more than 100 lb. Metal covers must have a grounding conductor connected.

Handholes are commonly specified every 100-ft in a underground raceway system to avoid over stressing the cable during the initial pull. They also provide a test point for later maintenance.

Industrial Panel Requirements that apply to Building Automation (409) - This new section covers industrial control panels for general use operating at 600V or less. An industrial control panel is an assembly of motor controllers, overload relays, fused disconnect switches, circuit breakers and related devices.

The supply conductor(s) must be sized at least 125% of the full-load rating of resistance heating and the highest motor plus 100% of all other equipment, based upon their duty-cycle. The panel must have and external or internal disconnect, the same as motor starters (430.52). There must be a single grounding point or bus. Wireway space is defined as used in panelboards and starters (312.6 and 430.10.B).

The panel must be marked with manufacturer's name, supply voltage, phase, frequency and full-load current. Short-circuit withstand must be indicated. There must be a wiring diagram or an index to the location of the wiring diagram in the drawing set.

Optional Narrative	Panel fabrication is an intensely competitive business. Many buyers encourage the fabricator to forgo safety components which would be required by FFPA 79 (Industrial Control Panels). This new section of the Code reinstates many (but not all) details. It will be very interesting to see if this section is enforced against Temperature Control Contractors, who fabricate HVAC control panels.

Electrical Protection requirements for Variable Frequency Drives

(430.122) - Overload protection for variable frequency drives must be 125% of the controller rated current. Note that the HP rating of the motor is not considered, nor tables 430.248, 249 or 250.

Variable frequency drives and solid-state reduced-voltage starters are rated in line amps. The simple conversion from motor HP to line amps is NEC Table 430-250 and protection from NEC 430-52. for NEMA B squirrel cage motors, as follows:

Type of Motor	Percentage of Full-Load Current			
	Nontime Delay Fuse	Dual Element (Time –Delay) Fuse	Instantaneous Trip Breaker (MCP)	Inverse Time Breaker (Molded Case Breaker)
Squirrel cage	300	175	800	250

Note that much less current can flow through 125% protection for a VFD than 250% protection for a full-voltage-non-reversing (FVNR) starter. This is great for applications where the motor starts unloaded, as a fan of simple pump. It means there will be trouble for any load that really needs very high initial torque, like a compressor. There is a protection problem, but there is an underlying VFD problem. The VFD cannot deliver the initial torque - that's why it doesn't have a problem with the associated current.

The problem is worse in heavy industry. For years, 1.15 and 1.25 service factor motors were purchased for high reliability and long life. These motors will take a continuous 115% or 125% overload. They will may require new overloads in a FVNR starter, but will trip off internal safety circuits in a VFD.

Optional Narrative	A long-time complaint of your teacher is the application of molded case breakers, in panelboards, to protect motors. Correct sizing of the MCB is 250% of full-load current, with wiring for 250%of full-load current. Too many designers simply use Table 430-250 and size the MCB and wiring for 125%. Because so many loads are over-motored, there are no consequences.

Changes in Exit signs and Emergency Lighting for Auditoriums

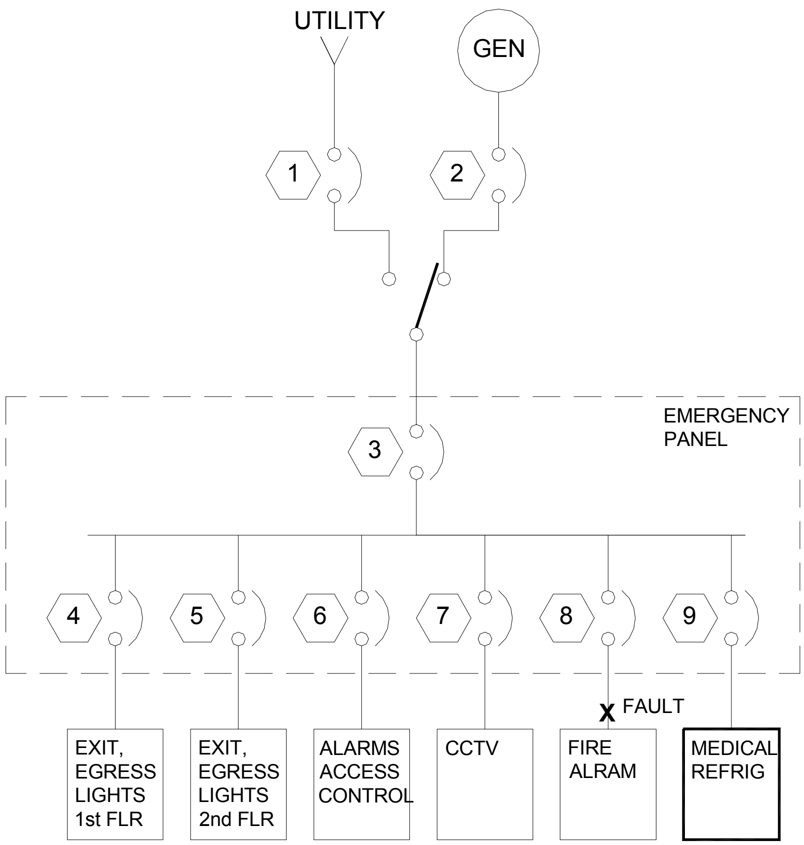
(700.6.A) - Transfer switches for emergency services must be automatic and listed.

This is being interpreted in many jurisdictions to mean that UL listed life-safety relays must be used any time an emergency lighting system is controlled. For instance, NFPA 101, the Life Safety Code, permits dimming or turning off exit signs and egress lights during theatrical performances. However, during a power interruption, the signs and lights must come back to full brightness. This is easily done, using a normally-closed, held-open relay.

The relay "holds" the connection to the dimmer panel so long as utility power is present. If utility power fails, the relay closes and power is returned to the emergency lights and exit signs. A recent installation was red-tagged for lack of a UL life-safety relay. It was easily and economically corrected, but would have been better avoided.

Selective Coordination on Emergency Power Systems (700.27) - Emergency system overcurrent devices shall be selectively coordinated with all supply side overcurrent protective devices.

This is not fault withstand (though the immediately preceding discussion is of a section which requires fault withstand on emergency and all other systems). This is selective coordination, which means adjusting protective devices so that only the one closest to the fault trips. Consider the following diagram of an emergency power system:



EMERGENCY POWER SYSTEM

Circuit breaker #1 protects the utility from any faults downstream and takes the faulted system off-line to minimize damage. Circuit breaker #2 has the same use for the generator. Circuit breaker #3 is the panel main. It is not required, but is usually installed to provide the maintenance person with a disconnect so that he can work on the panel de-energized. Circuit breakers #4 – 9 are for branch circuits to the emergency loads.

For a small installation, circuit breaker1 #1-3 might be 60A and #4-9 be 20A. For a large installation, circuit breakers #1-3 might be 1200A and #4-9 be 400A.

For our discussion, consider a fault at the fire alarm. The fire alarm has batteries and no one will notice a yellow trouble light during a power outage, or, they might figure that was a normal fire alarm response to a power outage. Which breaker or breakers trip?

If circuit breakers #2,3 and 8 are molded case, it is unpredictable. All will see the short-circuit current. All will try to trip. Any of the three may be first. Either or both of the others may complete the trip action, as well. Molded case circuit breakers within 10x rating of each other cannot be coordinated. Above 10x, it is iffy.

This is a selective coordination failure. We wanted only circuit breaker #8 to trip. Somehow, we must slow down #2 and #3 for instantaneous operation. [The reasoning also applies to #1.]

The solution, of course, is to buy more expensive circuit breakers which have more adjustments. A very popular electronic trip unit for circuit breakers is the Square D MicroLogic, shown below:

SQUARE D

Micrologic® Trip Units
Class 612

Powerpact® circuit breakers may be specified with any of the following Micrologic Electronic Trip Units.

Micrologic (Standard) 3.0 and 5.0 Trip Units

- True RMS sensing
- LI, LSI trip configurations
- Field-interchangeable long-time rating plugs

The "LSI trip configurations" refers to Long-Time, Short-Time and Instantaneous adjustments. Set the Instantaneous high, reducing protection, and set the Short-Time low, trying to recover the lost instantaneous protection, but with a time delay.

Optional Narrative	The numeric values for "set Instantaneous high and set Short-Time low" are problematical. Long ago, vendors of high-cost protective devices would recommend settings. Today, for many reasons, the service available is severely curtailed and less reliable. Try to get through to the relaying person at your electric utility.

Course Summary

This course attempted to review new and critical sections of the 2005 National Electrical Code. It did not include exercises in calculating the minimum size for junction boxes, based upon number and size of conducts and number of terminations. Unfortunately, space was not available to review many of the very basic principles which have not changed for many, many revisions, such as sizing motor circuits and proper motor controls. Fortunately, though, PDHonline.org offers a wide range of electrical courses which do address these needs. After you have recovered from the current exercise, please spend a few minutes reviewing the other PDHonline.org courses available.

Internet Resources

www.NFPA.org - The National Fire Protection sell the Code, Code Handbook, related standards and training materials

www.iaei.com - The International Association of Electrical Inspectors is a very highly-regarded voluntary organization with excellent publications and many local chapters

www.neca-neis.org - The National Electrical Contractors Association (associated with the International Brotherhood of Electrical Workers) publishes a series of very readable guides on the installation of different types of equipment. ANSI/NECA 1-200, *Standard Practices for Good Workmanship in Electrical Contracting* is sited in 110.12 as a recommended reference.

www.**mikeholt**.com - Mike Holt writes extensively on electrical design and construction issues and has a library of training materials available.

www.**joetedesco**.org - Joe Tedesco is another prolific expert in electrical construction.

www.**phillips**engineers.com - Jim Phillips has a training organization focused on very current, somewhat difficult electrical design problems. He has a remarkable ability to focus on core objectives and translate problems into cookbook solution. He also writes for NFPA publications.

ANNOTATED TABLE OF CONTENTS OF THE 2005 NATIONAL ELECTRICAL CODE

(Abbreviated)

ARTICLE 90 - Introduction - (not enforceable)

CHAPTER 1 - General
ARTICLE 100 - Definitions - (excellent content, many rulings based upon definition of "accessible", "readily accessible", "qualified person", etc. Worth close reading.)
ARTICLE 110 - Requirements for Electrical Installations - (study closely 110.26, Spaces About Electrical Equipment)

CHAPTER 2 - Wiring and Protection
ARTICLE 220 - Branch-Circuit, Feeder, and Service Calculations - (There are a few basic rules that are used many hundred of times in each design, but a number of special application rules that are easy to overlook until the Inspector underlines it for you)
ARTICLE 230 - Services (This gets interesting for large industrials with multiple services)
ARTICLE 240 - Overcurrent Protection - (Basic principles and a few special cases)
ARTICLE 250 - Grounding and Bonding - (Note the course discussion of new requirements)
ARTICLE 280 - Surge Arresters - (Lightning protection is critical in many part of the US)
ARTICLE 285 - Transient Voltage Surge Suppressors - (especially protection and location at service or panel)

CHAPTER 3 - Wiring Methods and Materials
ARTICLE 320 - Armored Cable: Type AC (note that contractors will not support flexible cables as required - especially at boxes)
ARTICLE 344 - Rigid Metal Conduit: Type RMC - (formerly RGS)
ARTICLE 350 - Liquidtight Flexible Metal Conduit: Type LFMC - (formerly Sealtite)
ARTICLE 358 - Electrical Metallic Tubing: Type EMT - (the almost universal, economic raceway)
ARTICLE 386 - Surface Metal Raceways - (very flexible method for delivery large quantity of power and data - rules apply to cubicle interior raceways)
[there are many, many more raceway types described and limitations for each]

CHAPTER 4 - Equipment for General Use
ARTICLE 400 - Flexible Cords and Cables - (extension cords must not be run through walls or doorways - why don't restaurants and stores understand this?)
ARTICLE 404 - Switches - (Up is ON in the US, except when down or right or whatever)
ARTICLE 406 - Receptacles, Cord Connectors, and Attachment Plugs (Caps) - (note split receptacles and strain reliefs on attachment plugs)
ARTICLE 408 - Switchboards and Panelboards - (note requirements for gutter space, conductor count on terminals and prohibition on splices in box)
ARTICLE 409 - Industrial Control Panels - (requirements apply to HVAC and BAS panels)

ARTICLE 410 - Luminaires (Lighting Fixtures), Lampholders, and Lamps - (store lighting is very interesting)
ARTICLE 422 - Appliances - (It is interesting how the NEC has expanded to include cord-connected appliances)
ARTICLE 430 - Motors, Motor Circuits, and Controllers - (For industrial designers and contractors, this section deserves reading and re-reading)
ARTICLE 450 - Transformers and Transformer Vaults (Including Secondary Ties) - (As so often, there are a few key rules that handle most situations but many, many special cases)

CHAPTER 5 - Special Occupancies
ARTICLE 500 - Hazardous (Classified) Locations, Classes I, II and III, Divisions 1 and 2 - (a specialty area, but be warned - any space below grade where fumes may collect …)
ARTICLE 511 - Commercial Garages, Repair and Storage - (shows up as a section in many commercial buildings)
ARTICLE 516 - Spray Application, Dipping and Coating Processes - (surprisingly readable, but requires strict adherence - consider lights outside space with wire mesh windows)
ARTICLE 517 - Health Care Facilities - (only the beginning of requirements - state licensing and insurance certification add many more)
ARTICLE 518 - Assembly Occupancies - (Over 100 persons [cf. some States say 50], includes temporary wiring for exhibition halls)
ARTICLE 545 - Manufactured Buildings - (yes, pole barns, but also manufactured housing and modular school rooms)
ARTICLE 590 - Temporary Installations - (widely disregarded for carnivals, events and Christmas lighting - until there is a tragedy)

CHAPTER 6 - Special Equipment
ARTICLE 604 - Manufactured Wiring Systems - (some contractors have adopted connectorized wiring, claiming great savings)
ARTICLE 620 - Elevators, Dumbwaiters, Escalators, Moving Walks, Wheelchair Lifts, and Stairway Chair Lifts - (Note ASME A17.1 and local elevator inspector requirements)
ARTICLE 645 - Information Technology Equipment - (See also NFPA 75 for IT rooms)
ARTICLE 670 - Industrial machinery - (cf. NFPA 79)
ARTICLE 680 - Swimming Pools, Fountains,, and Similar Installations -
ARTICLE 690 - Solar Photovoltaic Systems - (vendors don't know this section exists and make no effort to provide even rudimentary safety devices)
ARTICLE 695 - Fire Pumps - (study this section again and again when you install one - be especially careful with the jockey pump and fine print on the main pump controller)

CHAPTER 7 - Special Conditions
ARTICLE 700 - Emergency Systems - (Not just diesel generators)
ARTICLE 705 - Interconnected Electric Power Production Sources - (parallel the grid)
ARTICLE 720 - Circuits and Equipment Operating at Less than 50 Volts - (sections are referenced in communications and data sections)
ARTICLE 760 - Fire Alarm Systems - (cf. NFPA 72)

CHAPTER 8 - Communications Systems

CHAPTER 9 - Tables
TABLE 9 - Alternating-current Resistance and Reactance for 600-volt Cables, 3-Phase, 60 Hz, 75C --Three Single Conductors in Conduit … more…)

ANNEX A-G - (there is a bunch of weird stuff here. Table B.310.1, ampacity of different sizes of different insulated cables is in this section - the section on underground ducts is confusing, see the examples in the NEC Handbook)

INDEX - (NFPA is very picky about copyrights on their Index. Much better to use SEARCH facility within electronic version of NEC or NEC Handbook.)