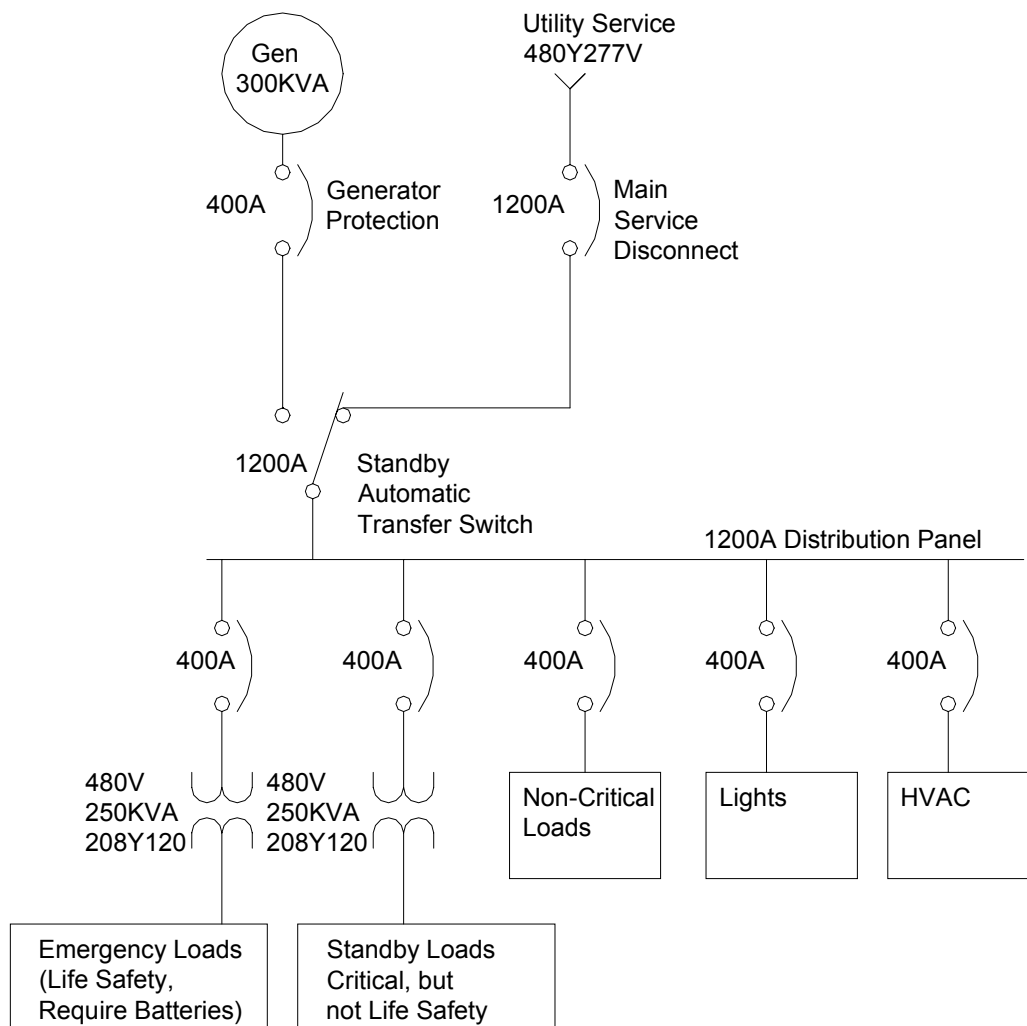


## Emergency and Standby Generator Application

Thomas Mason, P.E.

### Course Content

An emergency or standby generator system has a number of essential components, whether supplying power to a school, high-rise apartment, water plant or individual residence. Two schemes and some of the essential components and generator and power distribution nomenclature are illustrated below:



### Most Simple Distribution on Single Generator

The *Most Simple Distribution on Single Generator* scheme is what most building owners want. It is intuitive, appears to meet all needs and appears economic. Net cost should be below \$150,000, including the generator and all installation.

Unfortunately, it is only marginally legal and almost certainly unusable. The first problem is that emergency (life safety) wiring must not be combined with standby wiring (2002NEC 700.9.A). Same generator is OK. Same wiring after the transfer switch is forbidden. The solution is to keep the batteries in the exit signs and emergency egress lights and consider the wiring to be normal wiring, not emergency wiring. This, of course, negates the battery-elimination justification for the project.

The second problem is sizing the generator and transfer switch. The actual building load is very hard to determine. The utility records 15-minute demand load, but the generator must supply instantaneous demand load. Starting a big fan doesn't bother the utility (much) but may stall the generator. The NEC permits sizing based upon a 30-day measurement of actual load, but installing a 1200A logger now requires use of arc-flash protection, and, of course, removing panel covers to get at the busbars. Contractors will not install a \$500 logger with flexible CT; only a \$5000 disturbance analyzer with split-core CT's.

Regarding the building instantaneous demand load. The main circuit breaker and panel are 1200A. Doesn't that mean the load is 1200A? No. Good design leaves available capacity. Conventional design leaves massive excess, unused capacity. It is common for a school building with 1200A mains to never exceed 300A load.

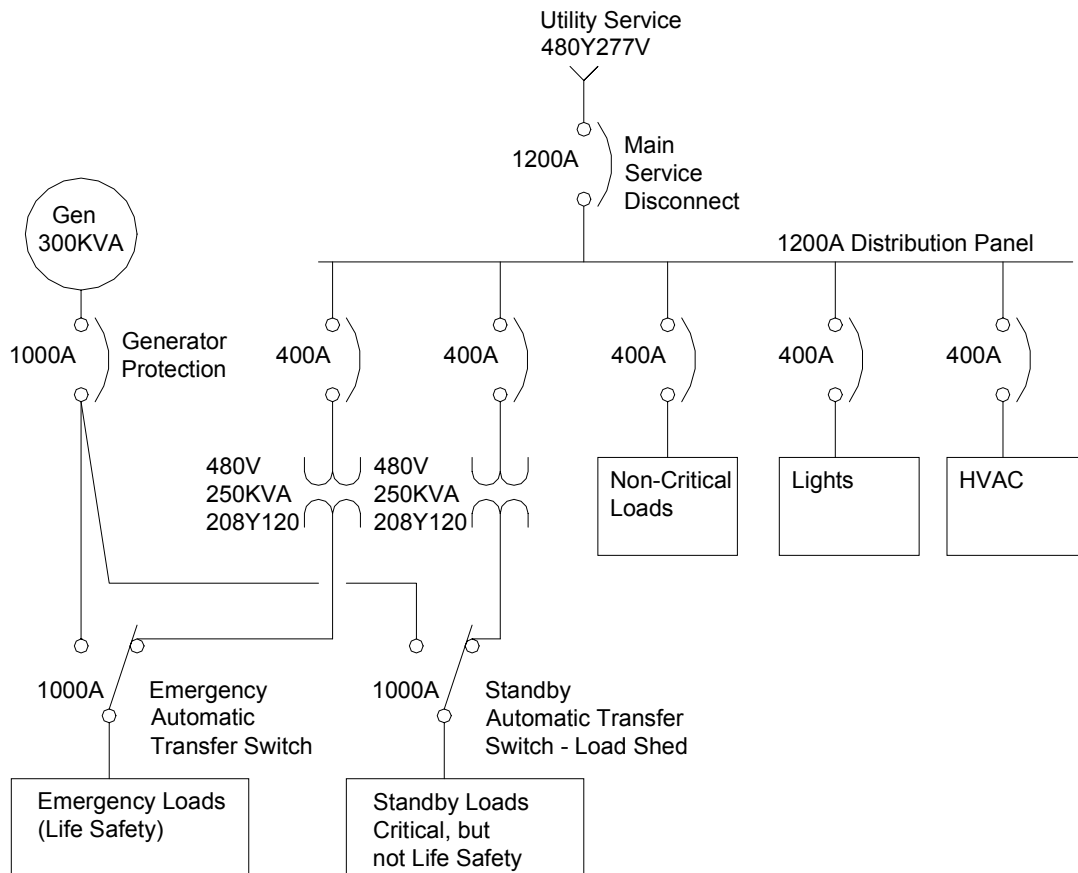
So what? Buy a generator with the large capacity and the problem goes away. No. Generators don't run well at low load. They build up carbon internally and malfunction when needed. Further, diesel fuel doesn't age well. It goes bad in three years and becomes a hazardous waste. Not a good idea to oversize the generator. Try to put in one that will run at 80% capacity, never less than 60% for extended periods.

The third problem with this scheme is that the failure mode is system shutdown. A big system and a small generator means that system problems will trip the generator protective circuit breaker. The generator is protected, but the building is dark. This is part of the reason that life-safety circuits may not be combined with normal wiring.

A major advantage of the *most simple* scheme, however, is that you don't have to rewire the building. Since ALL loads are moving to the generator, you don't have to buy a new emergency panel and extend wiring to it. You don't have to think through load-shedding or buy shunt trip circuit breakers or additional automatic transfer switches.

There are problems with the simple scheme, but with high risk-tolerance, it is usable. One large government agency has standardized upon this design, with the addition of a \$500 digital meter that operates an alarm for manual load-shedding when generator load rating is approached.

The two transfer switch scheme, presented below, addresses the problems with the most simple scheme.



### Combined Emergency and Standby Distribution on Single Generator

The two transfer switch scheme, labeled *Combined Emergency and Standby Distribution on a Single Generator*, is very practical and has been installed at many locations and performs well.

The good parts are that the emergency loads are treated like true emergency loads and battery packs on exit signs and egress lights can be eliminated. The standby loads are treated like standby loads and substantial building functionality can be maintained without utility power.

The bad parts are that we completely lose normal building lighting and HVAC. There should be standby power receptacles, which can source portable lights, but no HVAC is a bad thing. Florida in the summer and the North Country in the winter. How long can you keep seniors in their apartments with no heat and -20F outside?

The cooling problem can be addressed with selective window air conditioners. The heating problem can be addressed in a number of ways. A perimeter hot water heating system lends itself very well to generator operation. A commercial natural gas boiler and circulating pump require about 10KVA - not a problem on

the sample 300KVA generator. The remaining problem is getting generator power to the controls so the electric valves will open to let the perimeter hot water flow. This is doable.

Building fans are the problem. The first part is that the horsepower rating is often 40-100HP. This is a big load on a 300KVA generator. The second problem is that, today, most large fans have variable frequency drives. Variable frequency drives draw harmonic currents and force derating of the generator. The third problem is that building fans draw in outside air. Outside air must be heated or cooled just to get back to the original building temperature. Solutions and work-arounds will be addressed in greater detail later in this course.

Another solution to the heating problem is electric salamanders. Salamanders are a standard construction tool in the north. Most frequently, they burn propane from a portable tank and use an electric fan to drive heat into the construction area to dry plaster and paint and such. Electric salamanders do the same, only no fumes, completely electric. Two 15 KVA electric salamanders costs \$800 each and will heat a large meeting room, filled with cots or people sleeping on the floor.

### Key Concepts List

Key concepts that must be addressed are listed below:

Generator sizing and voltage rating

UPS Load

Emergency Power

Standby Power

Combination of Emergency and Standby Power

Manual Transfer Switch (DPDT Center Off)

Automatic Transfer Switch

Switched Neutral

Neutral Bonding

NFPA 70.700 requirements

NFPA 70.701 requirements

NFPA 70.702 requirements.

NFPA 110 requirements

HVAC requirements

HVAC load characteristics

HVAC intakes and generator exhaust stacks

Specifications

Governor, exciter and voltage regulator

Generator enclosure

Generator exhaust silencer

Generator fuel location and routing

Generator pad requirements

Authority having jurisdiction

Installation requirements

Testing requirements

Continuing exercise requirements

Common Generator System Design

## Key Concepts Discussion

The topics are discussed in some detail below:

**Generator sizing and voltage rating** - It is easy to find a construction contractor to install a generator and modify your building electric system to accept the generator power. A very functional avenue is to talk to the generator salesman. He will be extremely knowledgeable about generators and have good relations with contractors who do good work.

The hard part is choosing the system architecture, generator size and voltage. This is well illustrated by the two illustrations which introduce this course. If you can confidently select the loads to be supported by the generator, you can size the generator and estimate the cost of rewiring to get the power from the generator to the loads. Size the generator by adding up the KVA of the loads, multiply by 1.25 and buy the next larger standard size. Be very, very careful about adding more loads to the generator without increasing the size of the generator.

You add up the KVA of the load using the nameplate information. Watts = VA and Volts x Amps = VA. 1000VA = 1KVA. Nameplate information is the maximum that a device can draw. Nothing except electric heaters and heating appliances actually draw nameplate load. Well designed equipment draws about 60% of nameplate and some draw less than 20% of nameplate. (For example, rule-of thumb is to use 250-400 watts for a personal computer and monitor. Measured value for a new Dell and LCD screen is 50 watts.) This means that summing nameplate is safe and conservative. It does not mean that unlimited additional loads can be added. Be especially careful about adding elevators, which have frequent motor inrush currents.

Generator vendors are very careful to use computer software that lists continuous load, motor load and starting the largest motor. This is good stuff, but it is still not more accurate than the input data.

To repeat the recommendation of this course, sum the nameplate KVA of the loads, multiply by 1.25 and buy the next larger standard generator size. If you have individual motor loads that are larger than 10% of the generator, you should put time delays on the automatic restart of the motors so they do not start immediately when the generator starts and they do not start together. Use incremental delays of 30-seconds. (Delayed restart relays can be added to magnetic motor starters for \$50-100 each.)

**UPS Load** - A popular safety purchase today is an uninterruptible power system. This permits computer controls to continue to operate in the period between the power interruption and availability of the generator. (Some computers have a long restart period and problems restarting.) There are three problems with UPS. First, the batteries in low-cost UPS have a three-year life. More expensive UPS have batteries with a life of 6-10 years. This means that there is a good chance the UPS will not function when needed and you get to test the restart capability of your computer controls.

The second problem is that after the computer starts, the UPS switches the load to generator power and switches itself into charging mode. In the worst-case, the generator must support the nameplate of end-user load along with roughly the same load of charging current. Some high-end UPS now include charging delay and throttling of charging to be more compatible with generators. A nasty detail of UPS charging is that it is high-harmonic current, which loads the generator more than the obvious volts x amps.

The third problem can be a big problem. The logic in the UPS senses the quality of the power source and switches when the voltage or frequency is outside a very narrow band. If the generator is operating, even briefly, off-voltage or off-frequency, the UPS switches back to batteries. If the generator stabilizes, the UPS switches back to generator and applies the harmonic charging load. A big UPS will momentarily pull down the voltage and frequency of the generator, and the UPS cycles again. Again, some high-end UPS now permit broadening the transfer parameters or accept a signal that the generator is online and the device should not be so picky.

**Emergency Power** - The formal definition of emergency power in NFPA 70.700.1 is a little complicated. This is to accommodate special circumstances,

like electric refrigerators for medicine and elevators for evacuation of handicapped persons. The key words are, "power and illumination essential for safety to human life." Until recently, emergency power was limited to lighted exit signs, emergency egress lights, fire alarms and fire pumps.

**Standby Power** - Legally required standby systems are defined in NFPA 72.701.1. The key words are, "aid in fire fighting, rescue operations, control of health hazards." Many governmental agencies and quasi-governmental agencies require standby power in order to certify operation of hospitals, water treatment plants, airports, police stations and prisons.

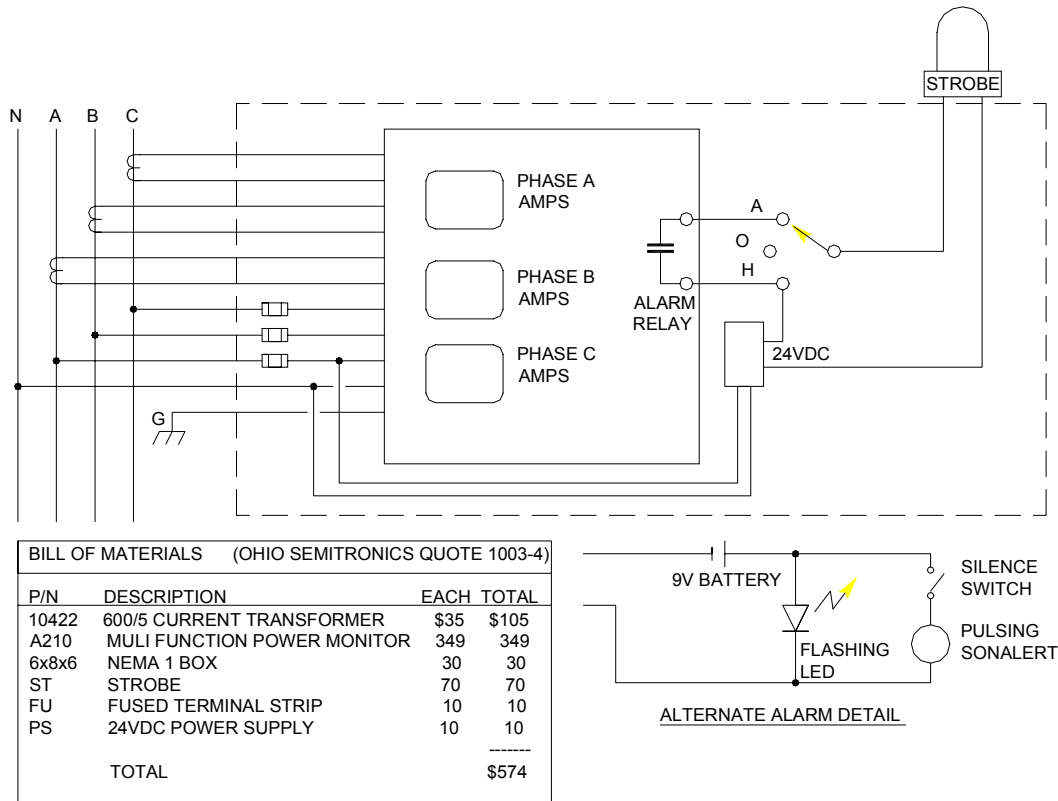
Optional standby systems are defined in NFPA 70.702.2. The key words are, "public or private facilities or property where life safety does not depend on the performance of the system."

**Combination of Emergency and Standby Power** - Emergency loads are life-safety. The design and operation must maintain life-safety devices - lighted exit signs, emergency egress lights and fire alarm. A fire pump is a life safety device, but the interactions with an emergency generator are too complex to be covered in this course.

The National Electrical Code encourages the safe addition of standby loads to an emergency generator. The reasoning is that exercising the generator is good and the owner may be more interested in the standby loads than the life-safety loads. Putting standby loads on the emergency generator is acceptable and encourages. Putting the load on properly is not well understood and often not done. The 100% right way is a separate automatic transfer switch that is slaved to the emergency ATS for load-shedding. If the generator is approaching overload or has problems, the standby load is dumped.

The 90% right way is a circuit breaker with shunt-trip for the standby load. An overload alarm meter operates the shunt-trip to protect the life-safety load.

The 40% right way is a written procedure to manually operate the circuit breakers which feed the standby load. An overload alarm meter operates a flashing light and sounder to notify the operator that action is required to protect the life-safety load. The overload alarm meter is illustrated below:



FEDERAL SIGNAL AV1-120 STROBE WITH HORN, \$123

The digital power meter shown, from Ohio Semitronics, can display and alarm on KW or KVA. Amps will annunciate generator overload and predict circuit breaker operation accurately. KW and KVA are aggregate measures and may not respond to a single phase overload.

**Manual Transfer Switch (DPDT Center Off)** - Large manual switches are available for 120V, 240V and 480V power. These are sometimes called disconnect switches or safety switches. They are available in a form with UP-ON, CENTER-OFF, and DOWN-ON, where UP and DOWN are connected to different circuits. In theory, UP could be utility power and DOWN could be generator. They are not recommended for two reasons. First, really bad things happen when a spinning motor is connected to a power source. If manual switching is to be done, a delay for spin-down to rest is necessary. You certainly don't want to be standing in front of contacts which might be closing into this dangerous situation. [The reason for the problem is that every motor is also a generator. After just a little spin-down, the motor is generating at something less than 60Hz. When directly connected to an exactly 60Hz source, fault currents are driven by the motor and by the source. The point of connection will receive extreme stress, usually resulting in severe arcing and possible explosion from the rapidly expanding gasses.]

A second, very significant reason for using an automatic transfer switch instead of a manual double-throw switch is cost. In the 30-400A range, an automatic transfer switch is only slightly more expensive than a manual switch. In the 600-2000A range, the automatic transfer switch is less expensive. The reason is that



the double-throw manual switch is a specialty item, motor-rated for a very large number of cycles; the automatic transfer switch is a commodity item intended for a very few cycles. By tradition, motor switches may not have arc chutes - so that maintenance persons can verify the open circuit. The automatic transfer switches have arc chutes, sharply reducing the contact requirements.

**Automatic Transfer Switch** - There are three key parts to the automatic transfer switch - the voltage sensing logic, the generator start contacts and the power contacts. Until recently the voltage sensing was performed by protective relays connected to control relays. As protective relays became dedicated microprocessors with digital signal processing, the voltage sensing logic became a dedicated microprocessor with digital signal processing. Microprocessor systems do not require calibration, though checkout and periodic testing are recommended. Self-test is a common feature of microprocessor systems.

The voltage sensing logic compares the utility power with a set of standards for acceptable duration and magnitude of voltage and frequency aberration. These parameters are usually adjustable to match experience with the local utility.

Note that a very common form of utility interruption is a fault with loss of power, a reclosing event to reestablish power, the continuing fault interrupts power again, the recloser tries a second time, the fault remains and the recloser locks out. This up-and-down of utility power is accompanied by transient over voltages as the utility and customer systems resonate. If this is the experience of the local utility serving the present location, then early transfer to generator is desirable. If, however, faults are usually cleared before the third recloser action, then it is desirable to hang on to the utility. The disturbance will be gone before the generator comes up to speed.

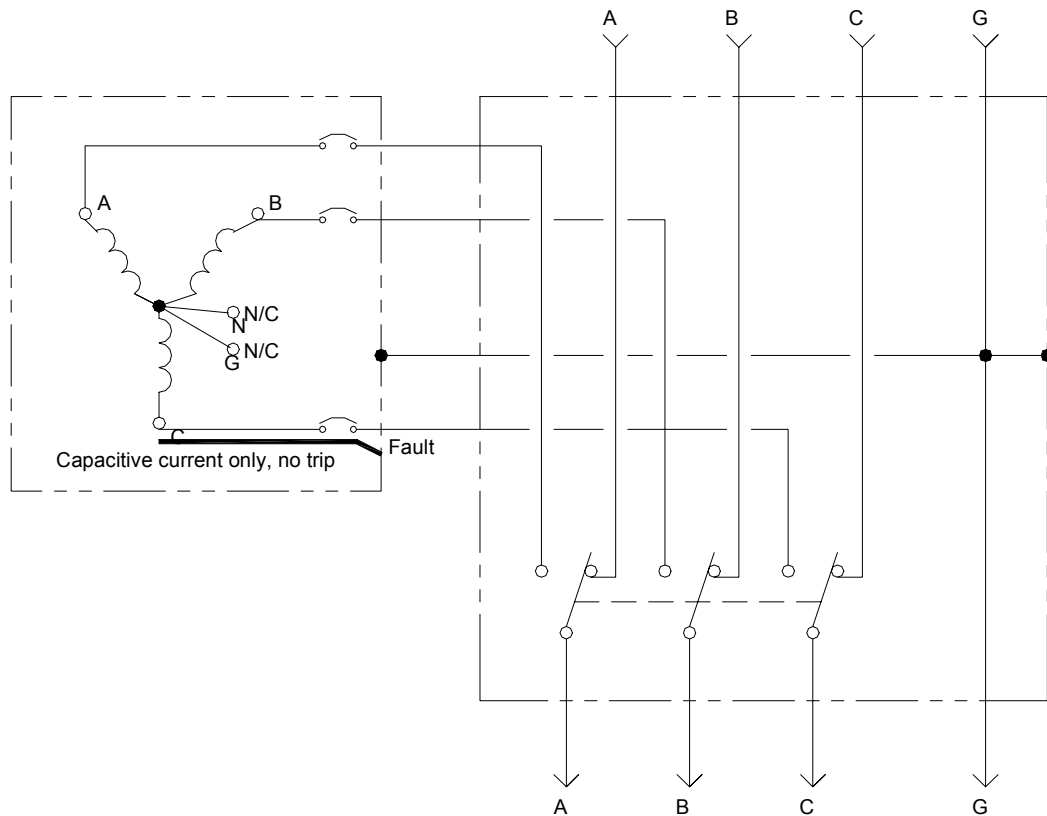
Statistical analysis of utility disturbances is extremely interesting and not intuitive. A 1950's Bell telephone study provides the most comprehensive information available. Utilities are required by law to record quality of service measures. They are, however, very reluctant to share with users.

The generator start contacts are a critical output of the voltage sensing logic. They are mentioned here because many people expect the generator to decide when to start. Not so. The transfer switch decides when the generator should start.

When the voltage sensing logic is satisfied with the offering from the generator, it opens the utility supply contacts and closes the generator power contacts.

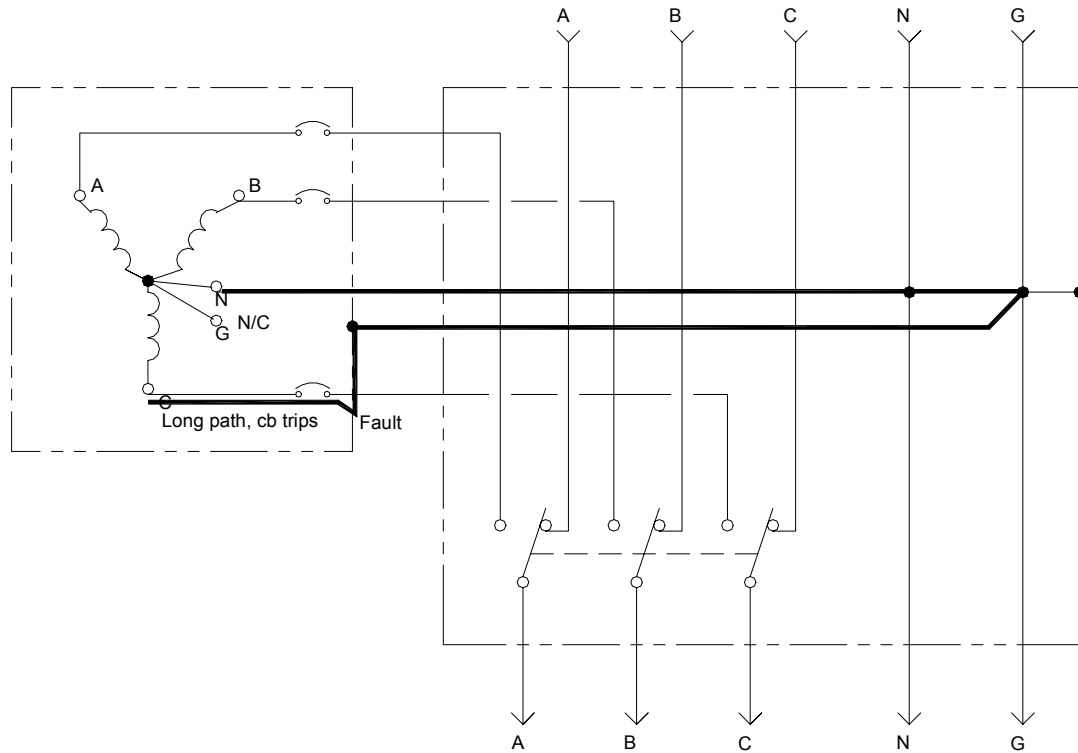
Additional functions of the automatic transfer switch logic are retransfer to the utility, cool-down period for the generator, generator shutdown and periodic exercising of the generator. These parameters, too, must be adjustable to meet local needs.

**Switched Neutral** - A three-phase automatic transfer switch (or double-throw manual switch) is available in three-pole or four-pole form. The four-pole switches the neutral. Conventionally, almost all transfer switches are purchased in the three-pole form. Your instructor recommends choice of a four-pole switch for 480Y277 and 208Y120 systems. Supporting reasoning follows:



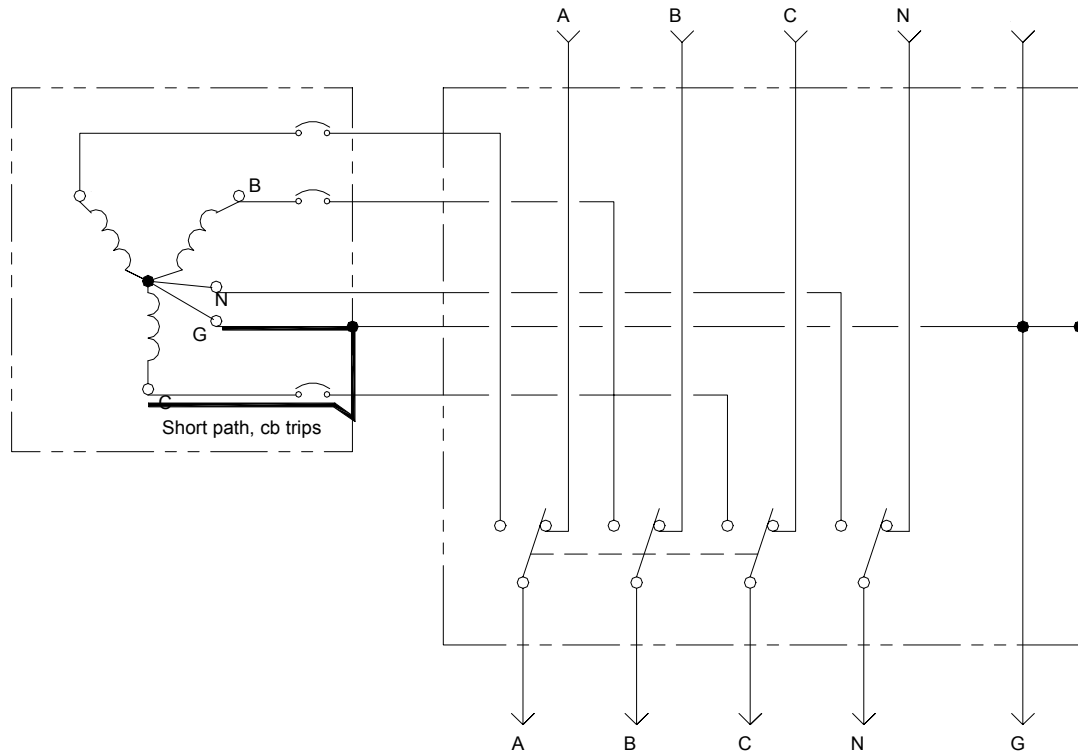
Three-Phase, Three-Wire Service and Generator, Three-Pole Transfer Switch

This is a three-wire system with no neutral on the utility service or the generator. A fault at the generator energizes the enclosure with reference to other phases, but only very small capacitive current flows. The protective circuit breaker does not trip. This is normal operation of a 3-phase, 3-wire power system. Because the transfer switch is in the utility position, any ground sensing devices in the facility are not connected.



Three-Phase, Four-Wire Service and Generator, Three-Pole Transfer Switch

This is a three-phase, four-wire system with a neutral on the utility service and a neutral on the generator. A fault at the generator energizes the enclosure and causes current to flow through the ground conductor to the neutral-earth bond at the service entrance and back through the neutral to the generator. It is illegal to have two neutral-earth bonds. The generator neutral cannot be connected to ground so long as the neutral is connected to the facility neutral. The fault shown means that a large current will flow and the circuit breaker at the generator will trip. If, however, it is a high-impedance fault, then less current flows. The long single-wire return path has moderately-high impedance. The case remains energized, but the circuit breaker does not trip. The voltage on the case is the voltage drop of moderate current over a long a moderately-high impedance. It can be lethal.



Three-Phase, Four-Wire Service and Generator, Four-Pole Transfer Switch

This is a three-phase, four-wire system with a neutral on the utility service and a neutral on the generator. A fault at the generator energizes the enclosure and causes current to flow to the neutral-earth bond at the generator. Current flows and the circuit breaker trips. If it is a high-impedance fault, the current may not be enough to trip the breaker, but the maximum fault voltage on the case is limited to the voltage drop of a small current across a short length of large diameter wire (the bonding conductor).

**Neutral Bonding** - NEC 250.24 requires that the return path (neutral conductor) for utility service be connected to earth (ground), the water piping system, building steel, technology systems (telephone and data) and other systems, such as HVAC ducts and natural gas piping. The reason for this is safety. A fault which accidentally connects a power conductor to any of these systems has a very good return path to the source. A good return path means that high current will flow, rapidly operating protective devices.

There are a very few exceptions to the neutral bonding rule. An obsolete power system, 240V-delta, has no neutral. There can be no neutral-ground bonding. Many buildings still have 240V-delta service for their boilers, chillers and HVAC systems. Generators are available for 240V-delta and transformers can be used to create 240V-delta from a 480Y277 generator. There will be no substantial current from a fault between a power conductor and an enclosure, pipe, or support.

Another obsolete power system is 480V-delta. This is 480Y277 with the neutral left unconnected. It is not recommended by the IEEE, but legacy systems exist and legacy practitioners install new 480V-delta.

**NFPA 70.700 requirements** - Emergency systems provide power to loads essential for safety to human life. Examples are illumination, fire pumps, operating room and life-support equipment in hospitals. See NFPA 99 for hospitals.

The entire National Electrical Code applies. The authority having jurisdiction must witness a test of the complete system and periodically afterward. (not real-world) Tests must be performed during maximum anticipated load conditions.

The alternate power source may supply emergency, required standby and optional standby loads only when load-shedding is present.

An automatic transfer switch is required. Bypass switches may be provided. The emergency load automatic transfer switch must supply only emergency loads.

If a 3-pole switch is used, then the system grounding electrode location must be indicated at the generator.

**NFPA 70.701 requirements** - Legally required standby systems are installed to meet governmental requirements. The entire National Electrical Code applies. The authority having jurisdiction must witness the test and must approve the periodic testing plan.

A required standby system may also supply optional standby loads only where load shedding is present. Separate transfer switches are not required. An automatic transfer switch is required. Bypass switches may be provided.

If a 3-pole switch is used, then the system grounding electrode location must be indicated at the generator.

**NFPA 70.702 requirements** - Optional standby systems include portable generators connected, as needed, to the facility power system. This is very common for public utilities, waste-water treatment lift stations, clear water pump stations and public buildings in times of crisis.

Life safety is not involved, but failure can result in physical discomfort, interruption of industrial process, damage to process equipment or disruption of business. Your instructor has been installing optional standby systems at jails so that prisoners need not be released during a power interruption.

Portable generators can use either a 3-pole or 4-pole transfer switch.

**NFPA 110 requirements** - The 2002 Edition of NFPA 110, *Standard for Emergency and Standby Power Systems*, represents a set of compromises among vendors and public agencies. SBC is the only end-user on the nineteen member committee. The new name for an emergency or standby generator is **Emergency power supply system (EPSS)**, which is a nice acronym.

EPSSs are divided into two groups - Level 1 and Level 2. Level 1 is defined as "failure of the equipment to perform could result in loss of human life or serious injuries." This means exit signs, egress lights, the hospital operating room and certain other hospital areas not defined by this standard. Level 1 has a maximum 10-second startup.

Level 2 is defined as "less critical to human life and safety..." The standard sets determination of level to be by the authority having jurisdiction (see that entry below).

Not mentioned is normal power. By NFPA 70, there must be careful isolation between emergency power and normal power. There is no such isolation between Level 1 and Level 2.

A battery charger and block heater are required. A low-fuel alarm is required. The engine must have an oil pressure gauge, temperature gauge, hour meter and battery ammeter. Controls must include automatic remote start, run-off-automatic switch, shutdown for high oil temperature, failure to start, over speed, low oil level, high engine temperature and remote stop command.

Requirements for the automatic transfer switch are included. Remote controls and alarms are required. Equipment must be provided for safe manual nonelectric transfer. It is not clear if over current protection is a required feature of the transfer switch. It is almost universally not provided, so the vagueness of the standard is interesting. The definition of the EPSS says that it includes over current protective devices.

The generator must have an ac voltmeter and ammeter for each phase or a phase selector switch, a frequency meter and a voltage-adjusting rheostat  $\pm 5-0\%$ .

Schematic, wiring and interconnection diagrams must be supplied.

Generators installed indoors must have battery powered emergency lighting providing 30 ft-candles.

Acceptance testing on actual load is required and the authority having jurisdiction must be notified to permit witnessing.

Routine maintenance and operational testing are mandated but no enforcement exists.

**HVAC requirements** - Be aware that many building owners and regulatory bodies are willing to ignore HVAC during emergency or standby generator

operation. The reasoning includes two prominent factors - expected duration and suspicion regarding HVAC needs.

Historically, utility power interruptions have been for seconds or minutes - rarely hours. Required air changes per hour are listed in the regulations. If the interruption is less than an hour, then enforcement is moot. Recall, however, that the 8/03 Northeast Blackout left large areas without power for three days.

Another predictable source of utility power interruption in the Northeast is ice storms. With utility deregulation, maintenance crews have been drastically reduced. A widespread ice storm could cause local power interruptions for days, as well.

The International Building Code requires 15 cubic feet per minute of fresh air per person. What happens if only 14 cfm is provided? What happens if no cfm is provided? People stink. Equipment stinks. Cooking odors accumulate. Bathroom fans do not evacuate the space. People overheat. Computers overheat and go into protective shutdown.

Computers cannot be permitted to overheat and go into protective shutdown. Usually, portable fans at the computer room door will keep them running, but IT managers insist upon stand-alone air conditioners to operate from the generator.

**HVAC load characteristics** - Heating is usually provided by hot water or by electric - rarely by direct-fossil-fired units. Hot water requires a boiler, combustion air fan, circulating pump(s) and controls. Fans and pumps are well-understood loads. They have high inrush currents and are sensitive to voltage imbalance and harmonic voltages. Variable frequency drives (VFD's) are less sensitive to the supply voltage and have much less inrush but generate harmonic currents which require derating the generator.

Heating controls may be critical. Newer heating system controls are computerized and the power source was usually carefully considered and documented. The generator must source the controls if the system is to work. Older heating systems typically take heating control power from receptacle or lighting panels.

Ventilation means the big fans that move conditioned air into the occupied space, return the air to the heating/cooling coils and exhaust fans, mostly for the bathrooms and sometimes process areas.

If the big fans are not operated by the generator, then the central heating and cooling coils cannot affect the temperatures in the occupied space. The big fans, themselves, follow the same considerations as the combustion fans discussed previously - high inrush, sensitivity to voltage imbalance and VFD's that require generator derating.

Air conditioning is provided by central chillers, and circulating refrigerant or chilled water or rooftop direct expansion refrigeration units. A very few central chillers use steam or natural gas and an absorption cycle. The vast majority use large motors. As indicated previously, cooling doesn't happen without the ventilation fans. The discussions of motor characteristics are directly applicable to chillers

and rooftop units. Central chillers tend to be in the 100-2,000 HP range and starting them, even unloaded, is a tremendous strain on a generator.

**HVAC intakes and generator exhaust stacks** - Diesel generators require substantial cooling air. For an outdoor installation, this is provided by a fan in front of the radiator. It blows air across the coils and across the engine block. (A small portion of the outside air is used for combustion.) For an indoor installation, an intake duct larger than the fan diameter is required to a location that can supply outside air. The fan moves the air at high velocity. A lower velocity is required in the intake duct to avoid pressure drop and starving the fan. The lower velocity also reduces air noise, but the intake grille will still be a noisy place. An HVAC designer should select the duct if it is over 10-ft or has turns. Direct mounting the fan grill into the building wall works well and saves space, if it provides an acceptable place for the intake grille. If a vertical intake is attempted, keep it away from the exhaust and provide a goose-neck to avoid rain intake and accumulation.

Exhaust stacks are discussed following the sample specification, below.

**Specifications** - There are a few key points which must be prominently addressed in the generator specification - UL 2200, NFPA 110, NFPA 70, voltage, amps, enclosure, silencer, 4-pole switch, identification of auxiliaries, start-up and warranty. These will be discussed individually after a bare-bones specification from the design guide for a Midwestern State funding agency.

## SECTION 16220

### EMERGENCY GENERATOR SYSTEM

#### PART 1 GENERAL

##### 1.01 SECTION INCLUDES

- A. Packaged generator system

##### 1.02 QUALITY ASSURANCE

- A. Compliance with NFPA 110
- B. Factory testing
- C. Field testing
- D. NFPA 70 - National Electrical Code
- E. UL 2200 - Stationary generators
  - UL 142 - Subbase fuel storage tanks\
  - UL 1008 - Transfer switches



F. Engine: NFPA 37

G. Fuel supply system: NFPA 30, 37

## PART 2 PRODUCTS

### 2.01 PACKAGED GENERATOR SYSTEM CHARACTERISTICS

A. Type: Standby automatically started engine coupled to an AC generator unit.

B. Ratings: Voltage, frequency, and power output ratings suitable for use.

C. Maximum transfer time to assume full load: Per NEC.

D. Fuel type: Diesel or natural gas dependent upon application.

E. Fuel supply: Minimum per NEC.

### 2.02 PACKAGED GENERATOR SYSTEM COMPONENTS

A. Engine

B. Cooling system: liquid-cooled unit mounted radiator.

C. Subbase diesel double wall fuel storage tank with leak monitor or natural gas supply.

D. For outdoor generator set provide weatherproof steel housing, louvers, and dampers.

E. Transfer switches: Automatic, three pole, applicable to service required.

F. Provide vibration isolators.

### 2.03 MANUFACTURER

A. Kohler

B. Caterpillar

C. Generac

D. Or equal

## PART 3 EXECUTION

### 3.01 NOT USED

END OF SECTION

UL standards are largely voluntary. It does not work to say, "Comply with UL." There are loose and there are stringent UL standards for generators and generator components. UL 2200 is the stringent one. Vendors will attempt to get you to relax the requirement in order to supply their bare-bones, standard unit. The UL 2200 is fully NEC compliant and does not require additional devices in order to satisfy a diligent electrical inspector.

NFPA 110 is the universal standard for generator sets. There should be no problem in all vendors meeting it. NFPA 70 is the National Electrical Code and places stringent requirements only on fast-starting for emergency (egress lighting) use and voltage dip for fire pumps (not discussed here).

The reference specification includes additional UL and NFPA standards. Your instructor concurs, with no special experience to contribute.

Voltage and amps define compatibility with the building. You tell the bidders that it is for a 480Y277V system with 1000 Amps full load, the biggest motor is 40HP and the load will be balanced within 30%. Identify any computer rooms, elevators or VFD fans in the rating section.

Vendors want to talk to you about the KW rating of the generator. Avoid this. It is often necessary to upsize the generator to accommodate unbalanced loads, harmonics or motor starting. Tell them what you need to run and what you need to start. Let them choose the part number unless you are extremely sophisticated in this area. Amps are easily communicated and measured.

The sample specification above avoided giving ratings. It is totally satisfactory to refer to a generator schedule on the drawings for Volts, Amps, Largest Motor and any comments. This is good, even if there is only one generator. The Contractors read the drawing. You must indicate volts, phase, amps, largest motor and anything special that you really want to work when the generator is installed.

Enclosure and silencer are common problem areas. The first warning is to look closely at the physical siteing. It is trouble to duct in cooling air and trouble to build insulated exhaust stacks. Generators need a lot of fresh air. An outdoor location makes installation and service easy and avoids the air problem, but requires a weatherproof sound-rated enclosure. Some engineers and vendors are very careful about motor-operated dampers, gravity dampers and louvers. It is better to avoid moving parts and let the manufacturer design the air flow

Sound rating can be very detailed or just say, "residential sound rating." Offices and the office portion of a factory are sources of complaints about the monthly testing of generators. Sound-deadening design and enclosure represent money well spent.

"Silencer" is generator-talk for "exhaust muffler". A unit with high noise reduction will be heavy and requires supports whether the generator is located outdoors or inside. With the prominence of lawsuits by neighbors, it is prudent to carefully make the noise/cost evaluation. . Even 15-minute monthly tests bring objections, whether 10AM, 2PM or another time. It takes an engineering team or

a very broadly knowledgeable person to address the acceptable noise level and the net costs of various silencer choices

Insulated stacks are readily available and not overly costly. They are not attractive, however, and are vulnerable to many forms of damage. Remember that a 300KW diesel is a truck engine. The exhaust is exactly the same as a delivery truck. A common objection, however, is that the diesel generator emits a puff of carbon on start-up, exactly like a delivery truck.

The question of 3-pole or 4-pole (3-phase) transfer switch was discussed in detail in the Switched Neutral section previously. The sample specification calls for 3-pole, no equal. Your instructor has objected to the funding agency responsible for these specifications, but received no reply. Cost reduction favors 3-pole; equipment and personnel safety favor 4-pole.

Generator auxiliaries are often a surprise after installation of the generator. All generators need a battery charger power source. Most need a block heater power source. It is almost universal to have the transfer switch start the generator and a minimum of a twisted pair control cable is required. If a remote alarm annunciator (required by Code) is provided, then a data cable or a multi-conductor cable is required. For unknown reasons, generator manufacturers and vendors are very hesitant to provide installation requirements. A 120V, 20A single-phase circuit is usually adequate for charging. Use a maintenance receptacle only if tapped before the ground fault circuit interrupter. A 120/208V, 30A three-phase circuit for the block heater is adequate for all but the largest generators. Annunciator wiring is model dependent.

Start-up and warranty are critical items and a bit sensitive among the specification team working on the project. All project materials and labor are warranted by the installing contractor, per the front-end sections of the specification book. It is possible and not too difficult to put a "Special Provisions" section in the generator specification and require a 2-years warranty instead of the front-end one-year warrant.

Start-up costs the contractor money. He will provide only the most limited service, within the front-end requirements unless details are provided in the generator specification.

The first requirement is to schedule start-up so that the Owner's maintenance people can participate or visit at their convenience. Schedule at least two-weeks in advance to let the maintenance people know. Normal business hours cost the Owner no overtime premium for the training value delivered. Remember, start-up problems frequently recur as operating problems. Knowing how to respond is very valuable and knowing it happened before helps with warranty claims.

Governmental bodies and large industrials usually require that a factory representative be present. With travel, lodging and meals and sometimes awkward flight schedules, this is a substantial cost. The local authorized repairman will have all the skills needed, unless you are accepting an early production model. The local authorized repairman is also a good person to have listed in your emergency call-out phone list. And yes, architects and engineers get calls from Owners when all the lights are out.

Selection of manufacturer is a commercial and sometimes political decision, rarely a technical decision. The three large national firms in the sample specification deliver consistently good products with excellent factory support. Almost all local dealers are qualified and conscientious. The national specification services, MasterSpec and SpecLink, add a paragraph limiting the vendor for a project to a selling organization with a parts depot within 50-miles of the site. This is impractical for rural installations and possibly questionable for urban installations. A qualified service organization is essential, but 2-hr travel is not an impediment if the repair truck is fully stocked and the technician knows which model unit he will be working on.

Until UL2200, there was a thriving business packaging truck engines with electric generators. The standard has just about eliminated this and is a reason for objections to the standard. In addition, there is a very active business in used generators.

**Governor, exciter and voltage regulator** - Before microprocessors were generally adopted, there were three big problems on generators - speed control, excitation power to permit the generator to function and control of voltage during disturbances. The conventional solution was to buy specialized hardware from the third-party specialty manufacturers. Today, with microprocessors, the three functions are provided by integrated engine-generator controls from the system manufacturer. Essentially, they have become non-issues.

One area still requiring close attention is paralleling of generators or paralleling the generator with the utility. Proper control software and careful start-up permit smooth, reliable operation in these scenarios, as well. Public utilities have very parochial attitudes towards back feeding their systems, especially when line crews are working. Early contact with the Utility and consideration are required for a successful project.

**Generator enclosure** - Generator enclosure was discussed in some detail in the specifications section. Outdoor siting with a weatherproof enclosure is recommended.

**Generator exhaust silencer** - Generator exhaust silencer was discussed in some detail in the specifications section

**Generator fuel location and routing** - Consult the generator dealer for recommendations on fuel tank location and details of fuel piping. A subbase fuel tank, pre-piped from the factory is a very common solution. If any question remains, contact the Authority Having Jurisdiction (see below)

**Generator pad requirements** - There are three ways to permanently install an engine-generator set - concrete pad, structural steel base and fiberglass pad. For over 100 years, stationary engines have been anchored to concrete pads. The form is a 4-6 inch pad, 60-inches larger than the generator base in each direction with rebar both ways, 4-in in from the edges and at 8-in centers. Epoxy studs are the preferred anchors, with shimming, as required, at start-up. One firm recommends a volume of concrete equal to 1.5x the weight of the generator set, which results in a 18-in deep pad. One Owner wanted a footer below frost

depth, 42-in in the locality. The floating pad works well as long as a little flexibility is available in the piping (as required by Code).

A very satisfactory alternative is a structural steel base. All large generator manufacturers have a rental division. They place an especially rugged generator and engine on a steel base and anchor it to a highway flatbed truck. They make really good money responding to emergencies for three years, then sell the ex-rental generators, often with low usage hours, at about 1/2 new cost of a standard unit. Savvy users have the ex-rental unit delivered to the right corner of the parking lot and the physical installation is complete.

It is also possible to hire a structural engineer to design and specify fabrication of a structural steel base. Design, fabrication and installation are costly.

A recent innovation is a fiberglass floating base for a structurally sound generator of 100KW or less. The small engines have much lower shaft stresses and do not require the degree of dimensional stability offered by concrete or structural steel. However, the familiarity of contractors with poured concrete bases, the low cost and the many years of successful performance have limited use of the fiberglass bases. As labor rates continue to increase, it is expected the fiberglass will be adopted more.

**Authority having jurisdiction** - The person or office who ultimately accepts or rejects the generator installation is very dependent upon what the generator is used for. If it keeps a hospital operating room lights on, then the hospital accrediting organization is the authority having jurisdiction. Their requirements will be more stringent than a city building department or fire inspector.

If the use is to provide exit signs and egress lights in the same hospital during a power interruption (Emergency Generator), then the city building department, which works closely with the fire prevention bureau are the authority having jurisdiction.

If it is a veterans hospital operated by the federal government, then Government Services Agency (GSA) is the authority having jurisdiction. [There are certainly other government agencies, but GSA has orchestrated approvals on jobs done by your instructor.]

The 2005 NFPA 70, National Electrical Code, states that the commander of a military base is the authority having jurisdiction there.

The question of identifying the authority having jurisdiction and requirements are critical to project success. The Owner often wants to make his own decisions, but at start-up or within six-months, a cease-and-desist order is extremely unwelcome and the designer is at fault.

**Installation requirements** - The standards limit installation requirements to following the manufacturer's instructions. This is consistent with the National Electric Code. No special, or measurable installation requirements are made.

**Testing requirements** - Testing requirements are to use the maximum expected load and record times for each step of an automatic start and return to normal power. Some authorities having jurisdiction require running, shutting down and restarting or cranking without start, cranking with start, then startup.

**Continuing exercise requirements** - Continuing exercise requirements are to use the maximum expected load. Most localities require monthly testing, but hospitals require weekly or bi-weekly testing. Vendors recommend load banks to test the generator without connection to the building, but most safety officials prefer to test the entire system, including the building connections. Also, load banks are expensive, for 15-minutes per month use. Most Owners prefer unloaded tests, which are not currently legal - but there is no enforcement.

**Common Generator System Design Errors** - There are three kinds of design errors frequently encountered in generator installations - installation cost oversights, installation interferences and start-up problems, and operational problems which could have been avoided.

Common installation cost oversights are lack of ventilation supply and relief, lack of power for battery charger and block heater, lack of control wiring for start command and annunciator.

Common start-up problems are lack of access for refueling, exhaust near an HVAC intake, incompatible generator and load (like 120/240 loads on a 120/208 generator), false-tripping of building protective relays.

Common operational problems which could have been avoided in design include noise, vibration, exhaust odor and unavailable maintenance support. Noise, vibration and exhaust have limited remedies during design, but thorough review with stakeholders can move these in the direction of non-problems. Maintenance support is closely related to the manufacturer and model selected. A moderate sized generator based upon a standard GM or Ford truck engine can easily be repaired for 30-years. Sizing a single monster unit is a good reason to carefully review multiple units and paralleling. There is controversy regarding reliability improvement or degradation from multiple units.