Liquid Cooled Generator Sets

Generator sets

- Preliminary Design.- Preliminary considerations for a generator set project. Equipment and installation requirements vary depending on the reasons for having the generator set and its intended use. When designing a generator set installation.

  Reviewing and understanding these reasons is useful as a starting point for the system design and equipment choices.
- Electrical Load Impact on Generator Sizing explains various load types, their characteristics and their impact on the generator set size, operation and equipment choices. Also covered the topic of sequence of load connection.
- Equipment Selection explains the fundamental parts of a generator set and related equipment, their functions and interrelationships, and criteria for choices. Functional characteristics, criteria for choices and optional equipment needed.
- Electrical Design covers installation design of the generator and related electrical systems, their interface with the facility along with load and generator protection topics. The electrical design and planning of the on–site generation system is critical for proper system operation and reliability.
- Mechanical Design covers installation design for the generator set and related mechanical systems along with their interface with the facility. The mechanical design and planning of the on–site generation system is critical for proper system operation and reliability. Topics include foundation and mounting, exhaust systems, cooling systems, ventilation, fuel systems, noise reduction, fire protection and equipment room.

General Requirements

- Mandatory installations for emergency and standby power follow, from building code requirements referenced by the regulations of federal, state, local, or any other governmental authority. These installations are justified on the basis of safety to human life, where loss of the normal power supply would introduce life safety or health hazards.
- Voluntary installations of standby power for economic reasons are typically justified by a mitigation of the risk of loss of services, data, or other valuable assets.
- Mandatory and voluntary installations of on–site generation may be justified on the basis of favorable load curtailment rates offered by the electric utility. The same on–site generation system may be used for both of these general needs, provided that life safety needs have priority, e.g. generator capacity and load transfer arrangements.

Specific Requirements

- *Lighting: Egress lighting for evacuation, illuminated exit signs, security lighting, warning* lights, operating room lighting, elevator car lighting, generator room lighting, etc.
- *Control Power: Control power for boilers, air compressors, and other equipment with* critical functions.
- *Transportation: Elevators for fire department use.*
- *Mechanical Systems: Smoke control and pressurization fans, waste water treatment, etc.*
- *Heating: Critical process heat.*
- *Refrigeration: Blood banks, food storage, etc.*
- *Production: Critical process power for laboratories, pharmaceutical production* processes, etc.
- *Space Conditioning: Cooling for computer equipment rooms, cooling and heating for* vulnerable people, ventilation of hazardous atmospheres, ventilation of pollutants or biological contamination, etc.
- *Fire Protection: Fire pumps, jockey pumps, alarm and annunciation.*
- *Data Processing: UPS systems and cooling to prevent data loss, memory loss, program* corruption.
- *Life Support: Hospitals, nursing homes, and other health care facilities.*
- *Communications Systems: 911 service, police and fire stations, hi–rise building public* address systems, etc.
- *Signal Systems: Railroad, ship, and air traffic control.*

System Types and Ratings

- On–site power generation systems can be classified by type and generating equipment rating. The generating equipment is rated using standby, prime, and continuous ratings.

  The ratings definitions are important to understand when applying the equipment.

  The type of on–site generation system and the appropriate rating to use is based on the application.
- **Emergency Systems**

  Emergency systems are generally installed as required for public safety and mandated by law. They are typically intended to provide power and lighting for short periods of time for three purposes: to permit safe evacuation of buildings, for life support and critical equipment for vulnerable people, or for critical communications systems and facilities used for public safety. Code requirement typically specify the minimum load equipment to be served.
- **Legally–Required Standby**

  Legally–required standby systems are generally installed as mandated by legal requirements for public safety. These systems are typically intended to provide power and lighting for short periods of time where necessary to prevent hazards or to facilitate fire–fighting operations. Code requirements typically specify the minimum load equipment to be served.
- **Optional Standby**

  Optional Standby systems are generally installed where safety is not at stake, but loss of power could cause an economic loss of business or revenue, interrupt a critical process, or cause an inconvenience or discomfort. These systems are typically installed in data centers, farms, commercial and industrial buildings, and residences. The owner of the system is permitted to select the loads connected to the system.

System Types and Ratings

In addition to providing a standby source of power in case of loss of a normal power supply, on–site generation systems are also used for the following purposes.

- **Prime Power**

  Prime power installations use on–site generation in lieu of a utility electricity supply, typically where utility power is not available. A simple prime power system uses at least two generator sets and a transfer switch to transfer supply to the loads between them.

  One or the other of the generator sets runs continuously with a variable load, and the second generator set serves as backup in case of a failure, and to allow downtime for required maintenance. A changeover clock within the transfer switch alternates the lead generator set on a predetermined interval.

- **Peak Shaving**

  Peak shaving installations use on–site generation to reduce or flatten peak electricity use for the purpose of saving money on energy demand charges. Peak shaving systems require a controller that starts and runs the on–site generator at the appropriate times to flatten the user's peak demands. Generation installed for standby purposes may also be used for peak shaving.

System Types and Ratings

- **Rate Curtailment**

  Rate curtailment installations use on–site generation in accordance with electric energy rate agreements with the serving electric utility. In exchange for favorable energy rates the user agrees to run the generators and assume a specified amount of load (kW) at times determined by the utility, typically not to exceed a specified number of hours per year. Generation installed for standby purposes may also be used for rate curtailment.

- **Continuous Base Load**

  Continuous base load installations use on–site generation to supply a constant power (kW) typically through interconnection equipment into a utility grid. These installations are usually owned by electric utilities or under their control.

- **Co–Generation**

  Often, continuous base load generation is used in Co–Gen application. Simply put, Co–Gen is utilizing both the direct electricity generation and waste exhaust heat to substitute for utility supplied energy. The waste heat is captured and either used directly or converted to electricity.

System Types and Ratings

System Type	Generator Set Rating		
	Standby	**Prime**	**Continuous**
	Emergency	Prime Power	Base Load
	Legally–required Standby	Peak Shaving	Co–Gen
	Optional Standby	Rate Curtailment	

Table 2–1. Rating and System Types

The One–Line Diagram

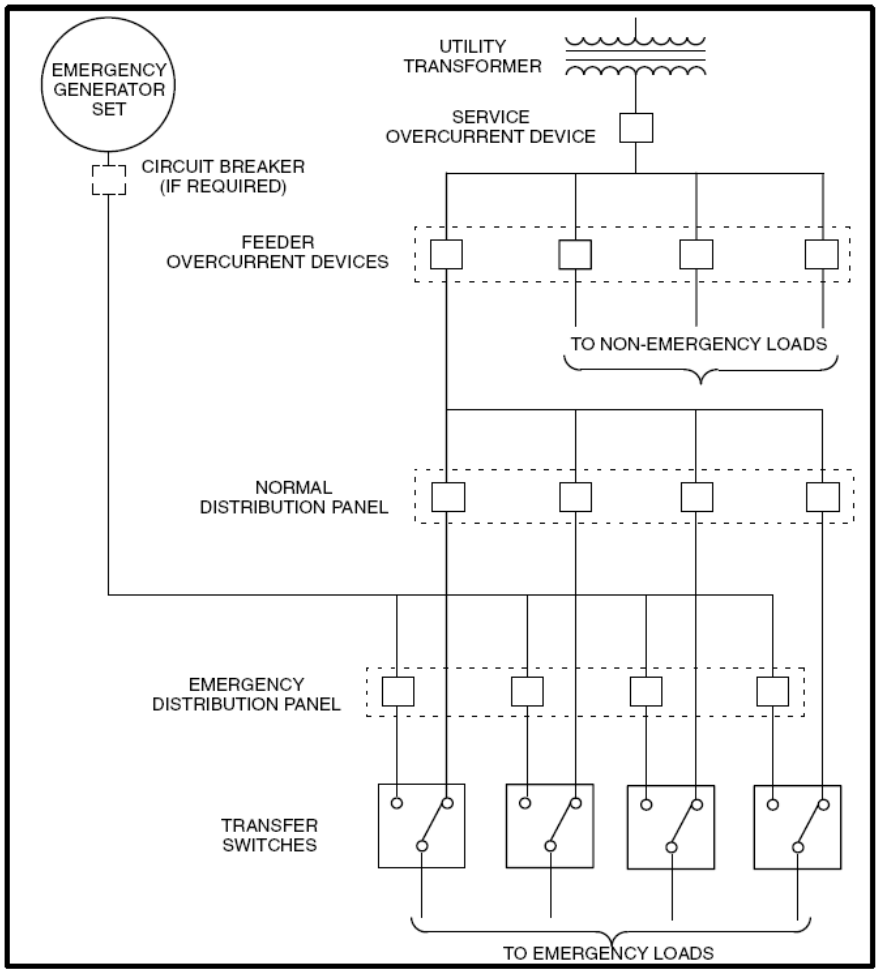


Figure 2–1. Typical One-Line Diagram of an Electrical Distribution System

Guidelines for Generator Set Power Ratings

- Power ratings for generator sets are published by the manufacturers. These ratings describe maximum allowable loading conditions on a generator set. The generator set will provide acceptable performance and life (time between overhauls) when applied according to the published ratings. It is also important to operate generator sets at a sufficient minimum load to achieve normal temperatures and properly burn fuel.
- Cummins Power Generation recommends that a generator set be operated at a minimum of 30% of its nameplate rating.
- The following explanations describe the ratings types used by Cummins Power Generation. The associated **Figures, 2–2 thru 2–5, depict the load levels (P1, P2, P3,** etc.) and time at that load level (T1, T2, T3, etc.) allowed under the various ratings.

Standby Power Rating

- The standby power rating is applicable to emergency power applications where power is supplied for the duration of normal power interruption. This rating is applicable to installations served by a reliable normal utility source.

  This rating is only applicable to variable loads with an average power output of 70 percent of the standby rating over 24 hours of operation for a maximum of 200 hours of operation per year. In installations where operation will likely exceed these limits, the prime power rating should be applied. The standby rating is only applicable to emergency and standby applications where the generator set serves as the back up to the normal utility source. No sustained utility parallel operation is permitted with this rating. For applications requiring sustained utility parallel operation, the prime power or base load rating must be utilized.

Standby Power Rating

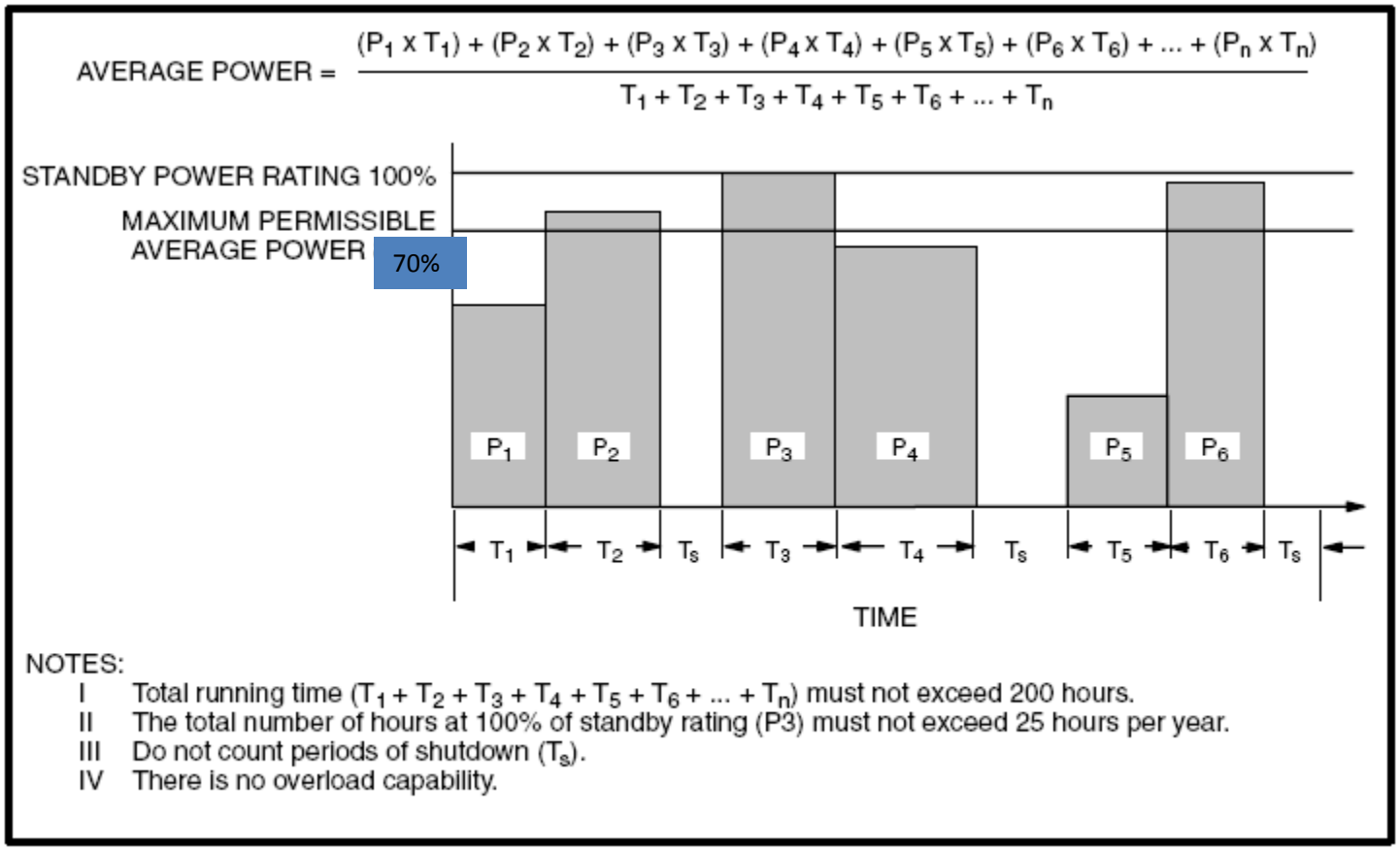


Figure 2–2. Standby Power Rating.

Prime Power Rating (PRP)

- The prime power rating is applicable when supplying electric power in lieu of commercially purchased power. The number of allowable operating hours per year is unlimited for variable load applications but is limited for constant load applications as described below under Limited Running Time Prime Power. In variable load applications the average power output should not exceed 70 percent of the Prime Power Rating over 24 hours of operation (Equivalent to Prime Power in accordance with ISO8528). A 10 percent overload capability is available for a period of 1 hour within a 12–hour period of operation, but not to exceed 25 hours per year.(Over Load Power in accordance with ISO3046, AS2789, DIN6271 and BS5514.)

Prime Power Rating (PRP)

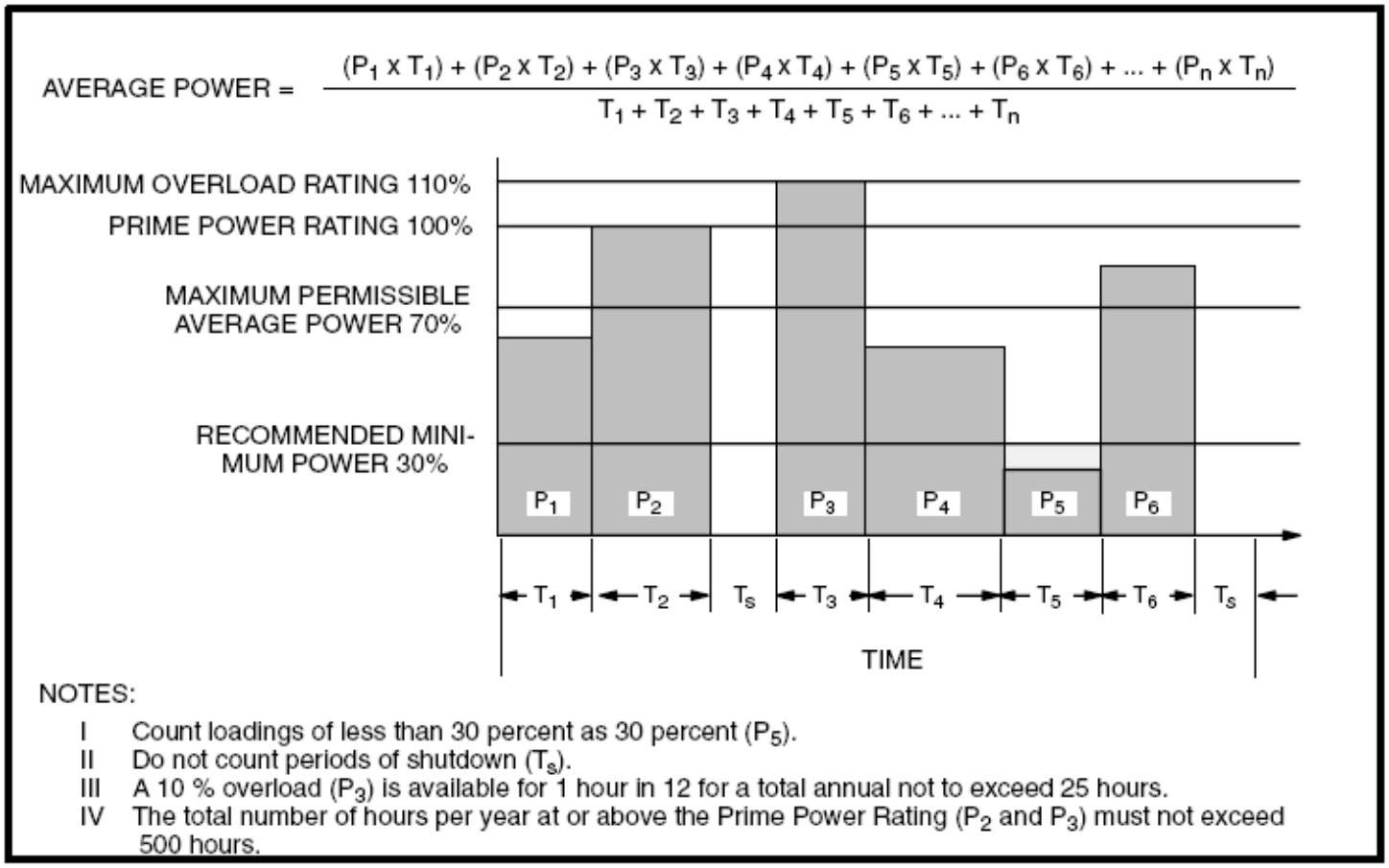
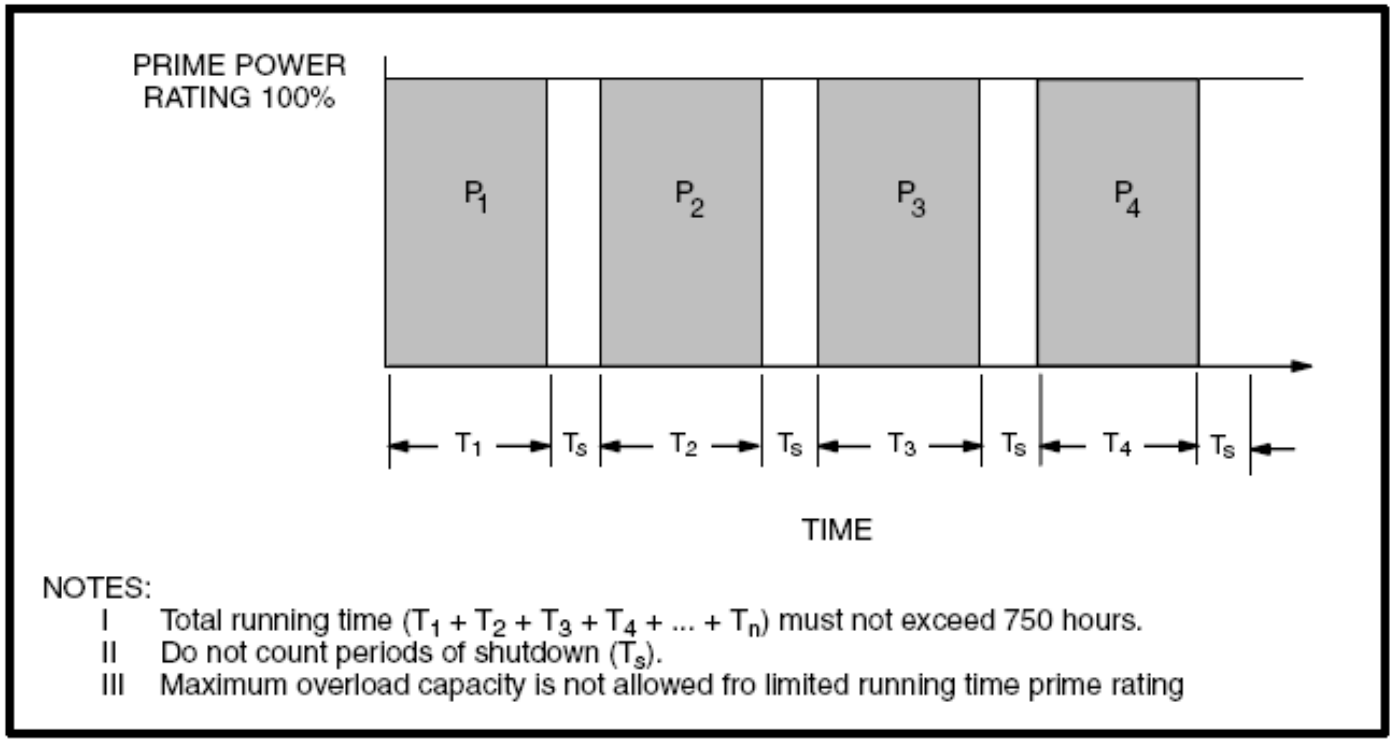


Figure 2–3. Prime Power Rating (PRP)

Limited Running Time Prime Power (LTP)

- Prime power is available for a limited number of annual operating hours in constant load applications such as interruptible, load curtailment, peak shaving and other applications that normally involve utility parallel operation. Generator sets may operate in parallel with the utility source up to 500 hours per year at power levels not to exceed the Prime Power Rating. It should be noted that engine life will be reduced by constant high load operation.
- Any application requiring more than 500 hours of operation per year at the Prime Power Rating should use the Base Load Power Rating.

Limited Running Time Prime Power (LTP)



NOTES:

I Total running time ($T_1 + T_2 + T_3 + T_4 + ... + T_n$) must not exceed 750 hours.

II Do not count periods of shutdown (T_s).

III Maximum overload capacity is not allowed fro limited running time prime rating

Figure 2–4. Limited Running Time Prime Power (LTP)

Continuous Power Rating (COP)

- The base load power rating is applicable for supplying power continuously to a load up to 100 percent of the base rating for unlimited hours. No sustained overload capability is available at this rating (Equivalent to Continuous Power in accordance with ISO8528, ISO3046, AS2789, DIN6271 and BS5514). This rating is applicable for utility base load operation. In these applications, generator sets are operated in parallel with a utility source and run under constant loads for extended periods of time.

Continuous Power Rating (COP)

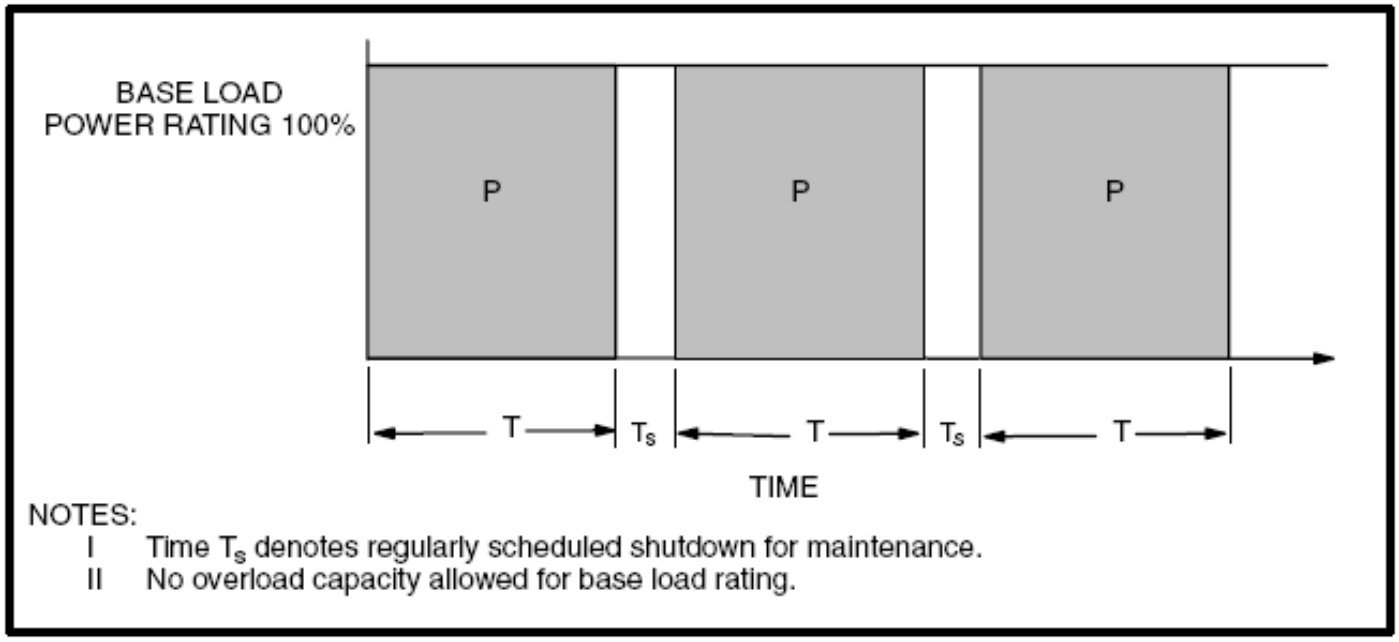


Figure 2–5. Continuous Power Rating (COP)

Sizing

- For preliminary estimation purposes some conservative rules of thumb may be used:
  - Motors – HP per kW.
  - UPS – 40% oversize for 1Ø and 6 pulse, or 15% oversize for 6 pulse with input filters and 12 pulse UPS.
  - VFD – 100% oversize unless pulse–width–modulated, then 40% oversize.
- When loading the generator set, division of the loads into discrete steps or blocks of load may have a favorable effect on the size of generator set required. Use of multiple transfer switches or some other means (time delay relays, PLC, etc.) would be necessary to allow the generator set voltage and frequency to stabilize between steps.
- Depending on the total load (generally above 500 kW), it may be advantageous to parallel generator sets. Although technically feasible, it is usually not economically feasible to parallel generator sets when the total load is 300 kW or less.

ELECTRICAL LOAD IMPACT ON GENERATOR SIZING
Overview

This section focuses on the impact of loads on generator set sizing. It is important to assemble a reasonably accurate load schedule early in the design phase of power generation projects because the load is the single most important factor in generator sizing. If all the load equipment information needed for sizing is not available early in the project, the first sizing calculations will have to be based on estimates and assumptions.

This should be followed by recalculations when actual, more accurate information becomes available. Different load types – motors, uninterruptible power supplies (UPS), variable frequency drives (VFD), medical diagnostic imaging equipment and fire pumps, have considerable and different influences on generator set sizing.

Understanding Loads

Load Running and Starting Requirements

The power required by many load types can be considerably higher while starting the load than required for continuous steady state running (most motor driven loads that don't employ some type of soft start equipment). Some loads also require higher peak power during operation than while running (welding and medical imaging equipment, for example). Still other loads (non–linear loads like UPS, computers, VFDs and other electronic loads) cause excessive generator distortion unless the generator is sized larger than what is required to power the load. The power source must be capable of supplying all operating power requirements of the load.

During starting or peak load operating conditions, sudden load transients can cause voltage and frequency disturbances harmful to the connected load or large enough to prevent successful starting or proper load operation if the generator is undersized. While some loads are quite tolerant of short term transient voltage and frequency disturbances, other loads are quite sensitive. In some cases, the load equipment may have protective controls that cause the load to shut down under these conditions. Although not as critical, other effects like lights dimming or momentary surging of elevators can be, at the least, disturbing.

A generator set is a limited power source both in terms of engine power (kW) and generator volt–amperes (kVA), regardless of the type of excitation system. Because of this, load changes will cause transient excursions in both voltage and frequency. The magnitude and duration of these excursions are affected by the characteristics of the load and the size of the generator relative to the load.

Typical Electrical System Designs

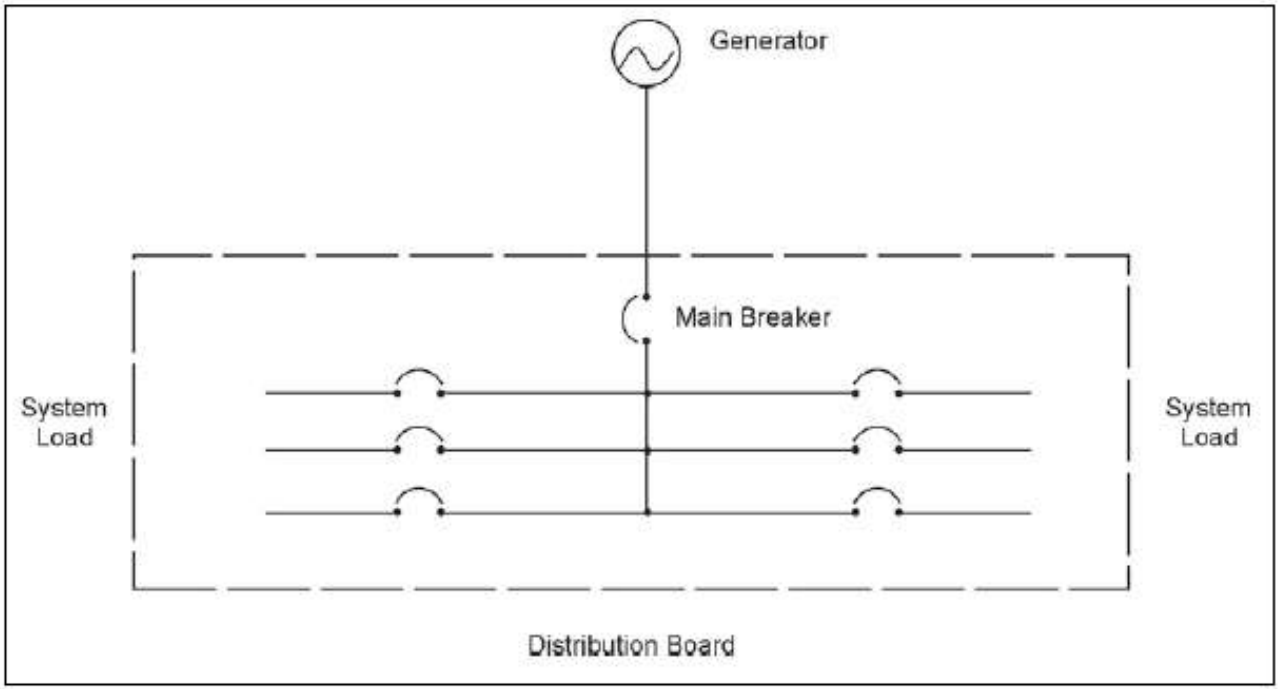


Figure 5–1. Generator Set Serving Common Loads

Typical Electrical System Designs

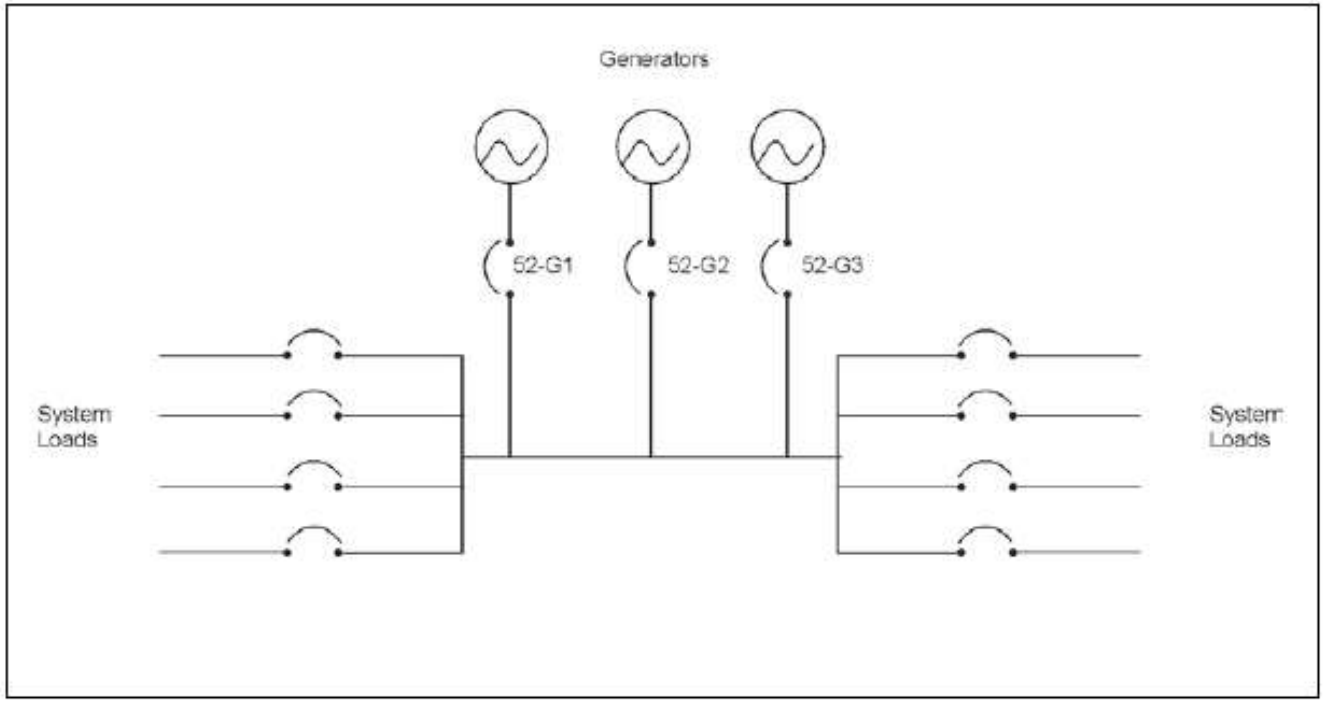


Figure 5–2. Multiple Generator Sets Serving Common Loads

Typical Electrical System Designs

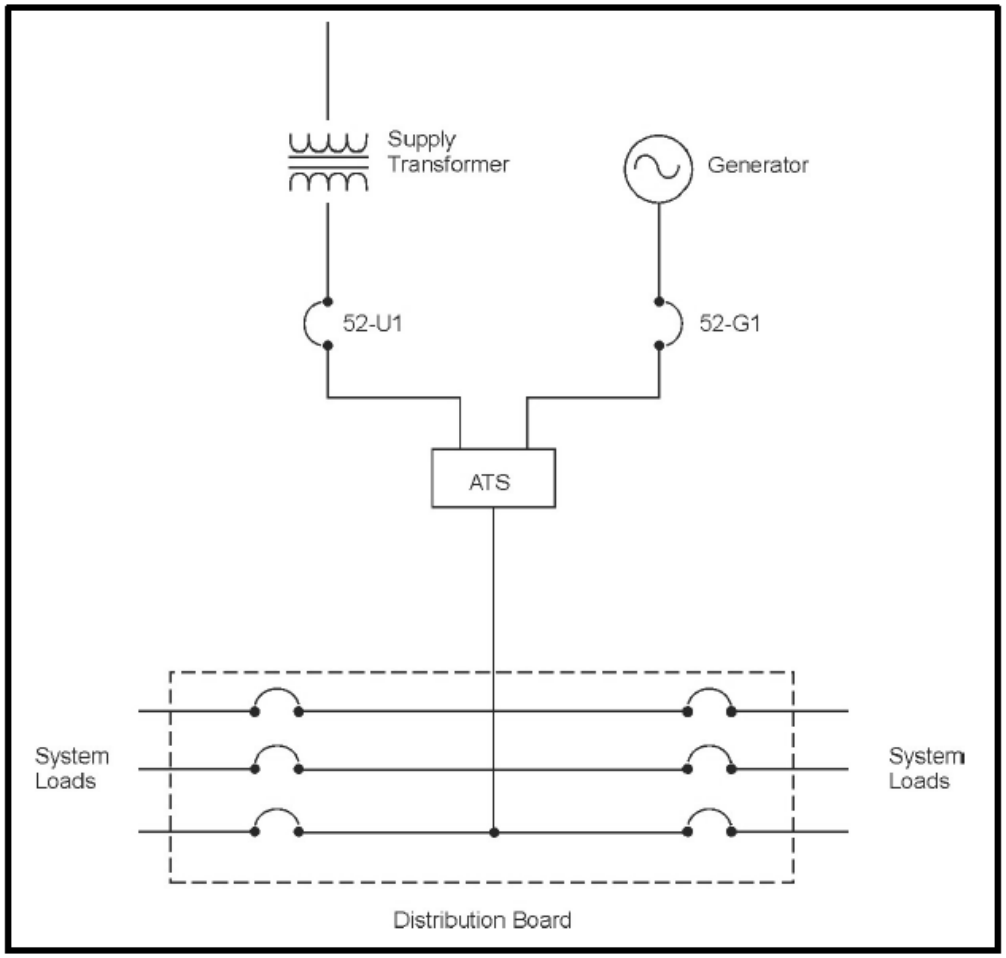


Figure 5–3. Single Generator Set Standby Applications

Typical Electrical System Designs

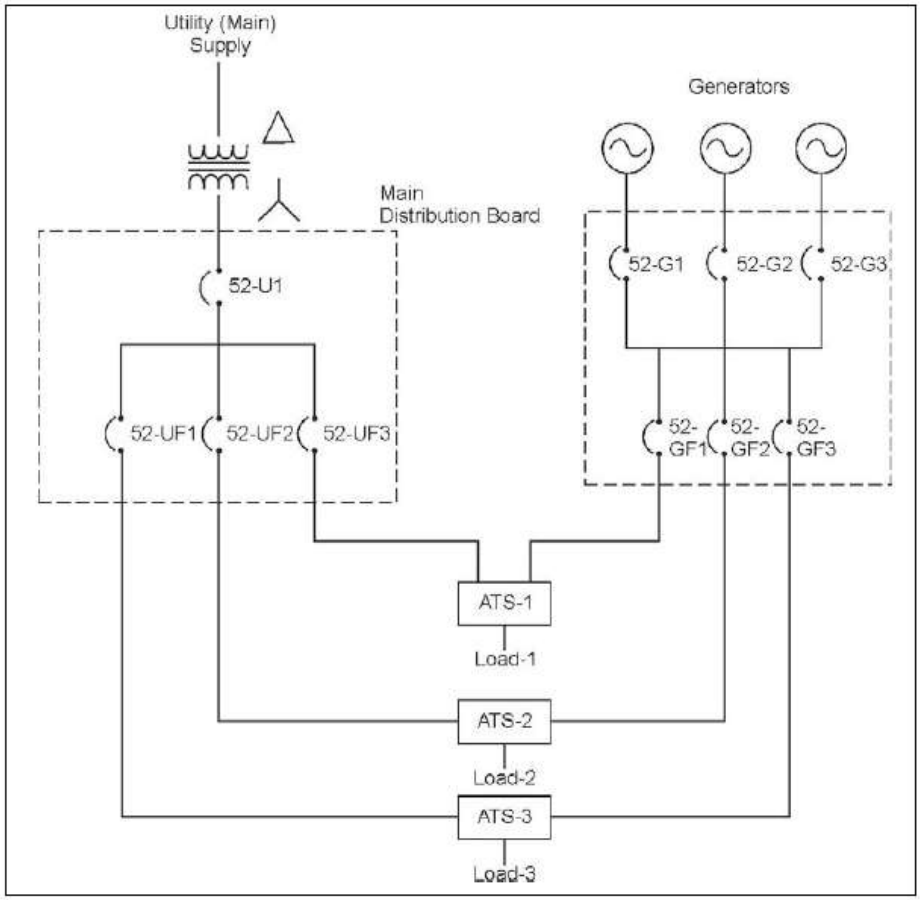


Figure 5–4. Multiple Generator Sets, Multiple ATS Applications

Typical Electrical System Designs

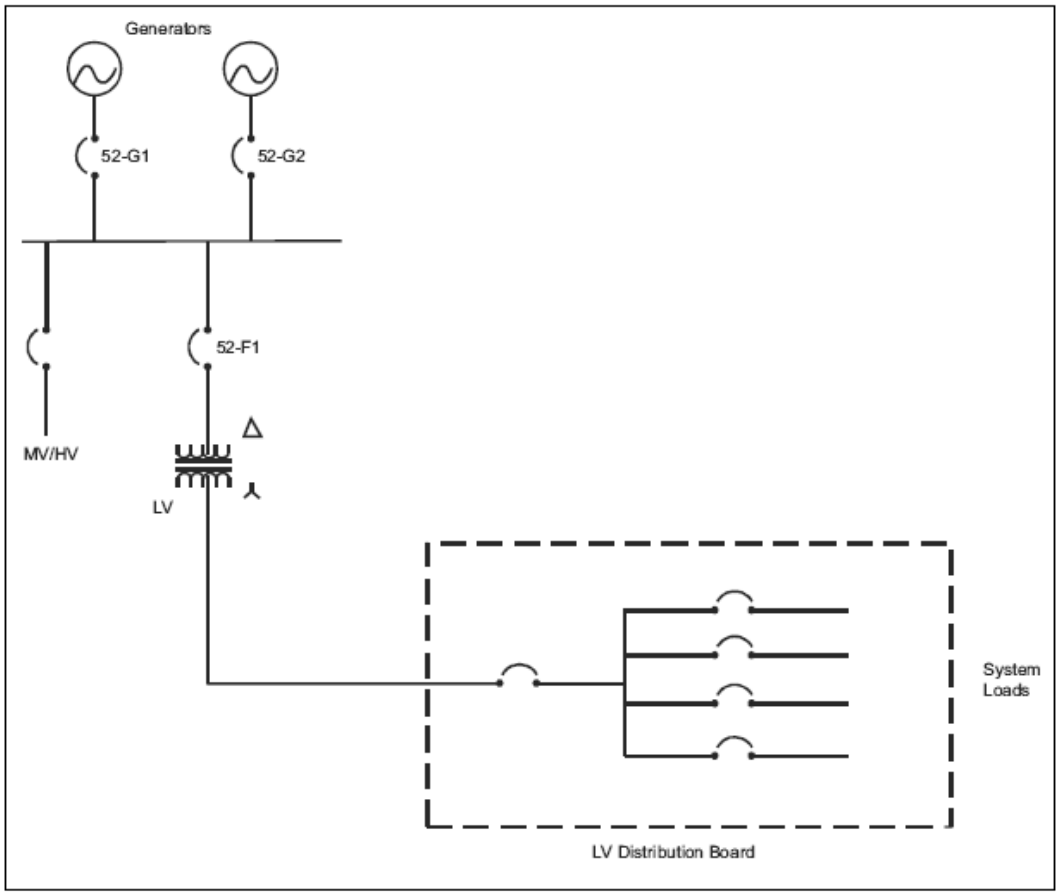


Figure 5–5. Simple MV/HV Generator System For Prime Power

Typical Electrical System Designs

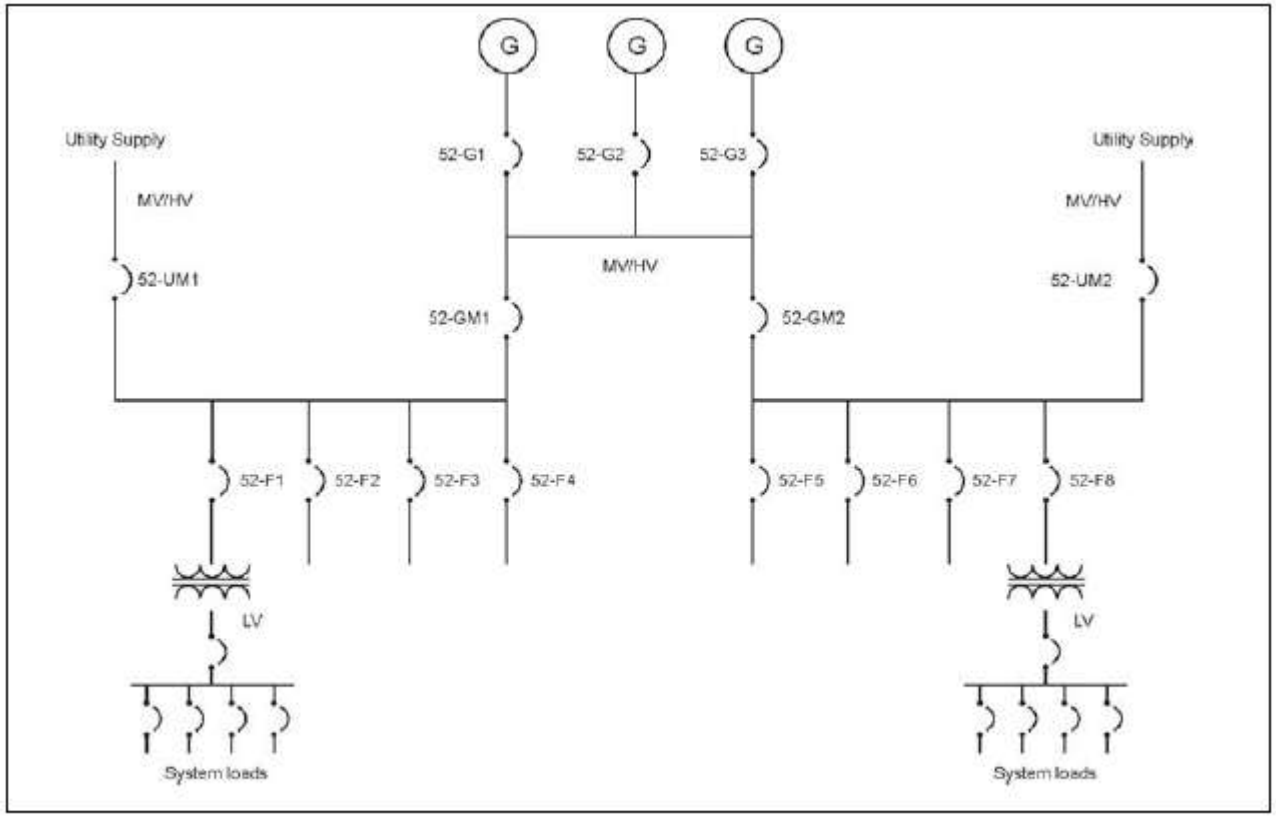


Figure 5–6. HV/MV Scheme For Multiple Generators / Utility Supplies And Loads

Typical Electrical System Designs

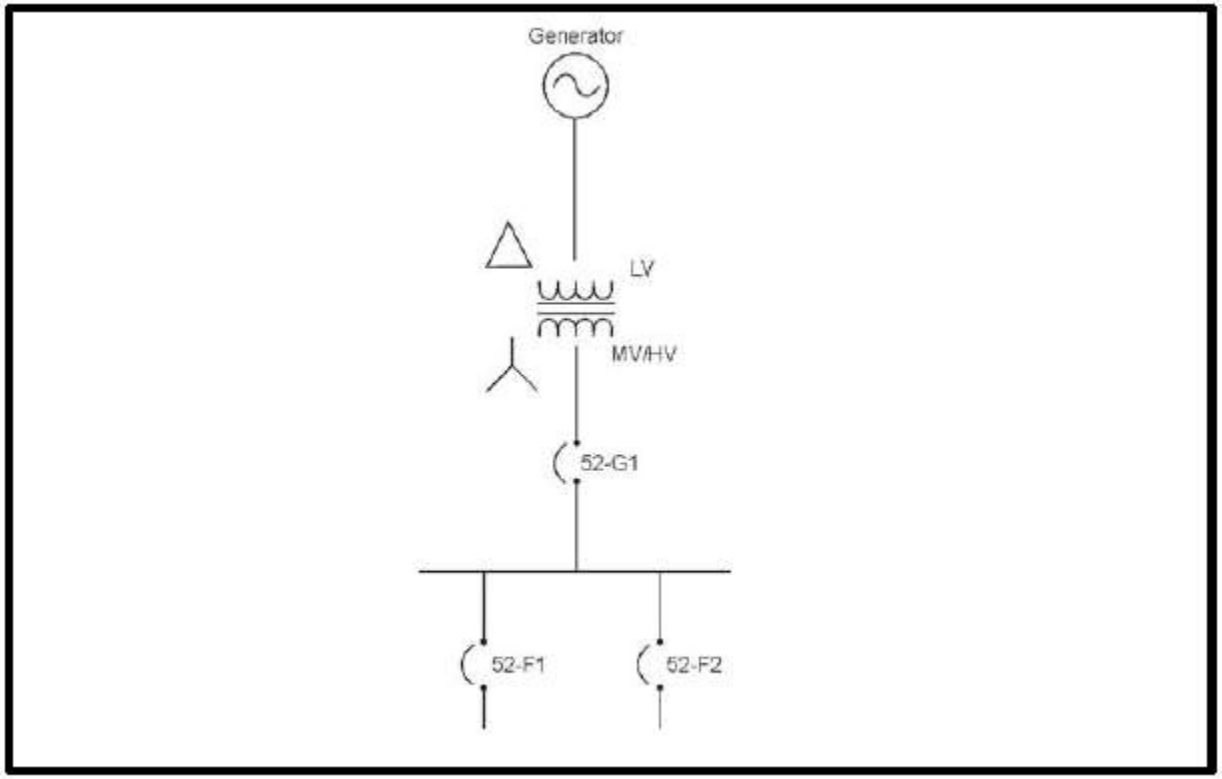


Figure 5–7. Low Voltage Generator For MV/HV Application

Typical Electrical System Designs

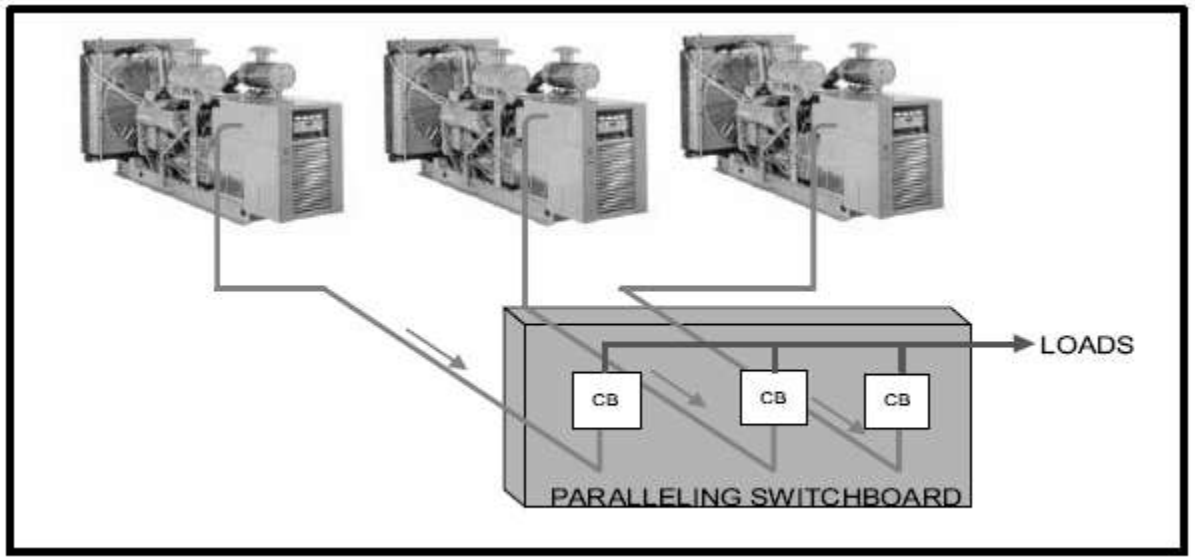


Figure 5–8. Parallel Generators

Typical Electrical System Designs

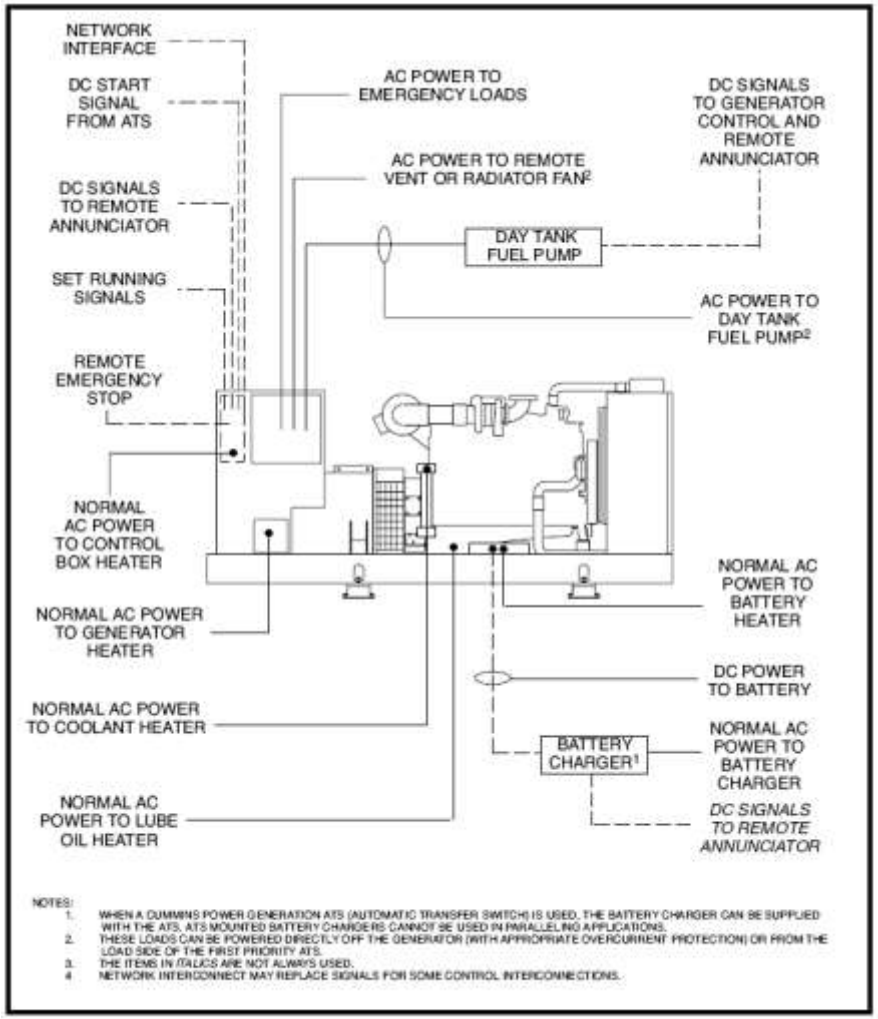
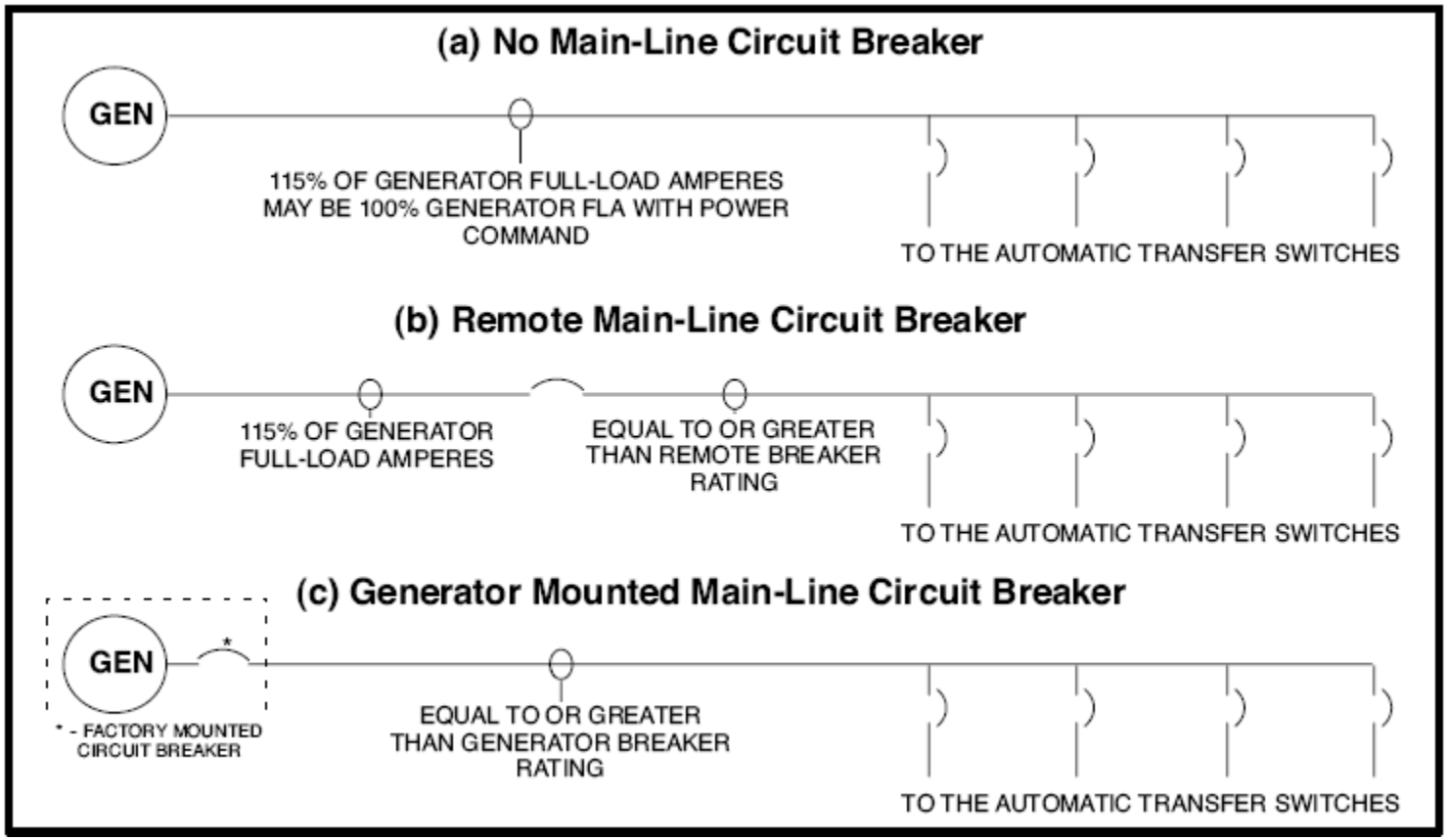


Figure 5–10. Typical Generator Set Control and Accessory Wiring

Typical Electrical System Designs



Typical Electrical System Designs

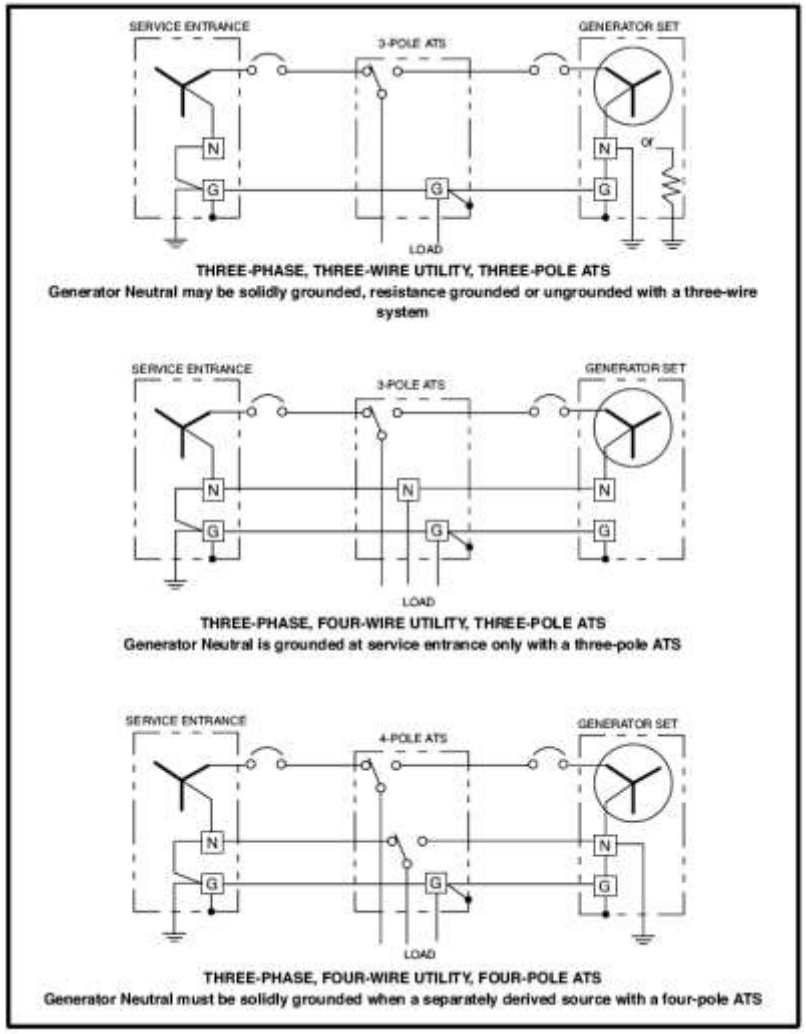


Figure 5–14. Typical One-Line Diagrams of Alternative System Grounding Methods