Paralleling generators of different makes, models and manufacturers

Key Considerations in Setting up Parallel Systems

- Setting up a parallel system is a complex process. The complexity of installation increases if different Suppliers have manufactured the individual generators. They have different governors, voltage regulators and the controllers are based on a combination of analog and digital technologies. The basics are discussed below. For a detailed discussion and customer specific solution, please contact customercare@eslpk.com and ask for a testimony of scores of complicated installations it has performed for Companies in the Telecom, Beverages, Poultry, Manufacturing sectors and the Hospitals etc

Synchronizing Basics:

1. Two Voltmeters Method:

- To successfully synchronize a generator to a bus requires some degree of instrumentation to tell the operator what the phase relationships are between the two sources. The simplest is two voltmeters connected to read voltage between the same phases of the incoming generator and the bus. When the two sources are in phase and at equal voltage, both Va and Vb will read 0 volts. The breaker closure must occur when the voltage difference is at, or very near, 0. This condition occurs when the phase angles are within about ± 15° of true synchronism.

2. Dark Lamps Method:

- Two synchronizing lights can be used in place of voltmeters. When the lights are out, the phases are synchronized. When the phases drift out of sync, the lights will come on due to the voltage difference. It is usual to use three lights to cater to the possibility of one burned bulb. Bulbs must be rated for 2 x voltage.

3. Synchroscope Method:

- A synchroscope is a pointer-type meter that incorporates the two-voltmeter movements with a single pointer. The pointer moves to a circular position dependent on the voltage difference. At zero volts, it will be located at top dead centre. Any area within about 30° to 45° of top dead centre represents a fairly small voltage difference corresponding to a fairly small phase-to-phase displacement and will initiate breaker closure.

4. Manual Synchronization:

- All of the foregoing are instrumentation devices which will allow an operator to observe when synchronism occurs and to initiate breaker closure accordingly. The operator must adjust the incoming generator speed (and voltage if necessary) to obtain synchronized conditions.

5. Automatic Synchronization:

- For automatic systems, an automatic device must be used to obtain synchronized conditions and initiate breaker closure at the proper time. There are a wide variety of automatic synchronizers available to interface with various types of governors. The synchronizer can also be utilized to match voltages as well as speed.

Protection devices:

1) Reverse Power Relay :

- When a synchronous generator is connected to an external electrical source, it is capable of acting as though it were an electric motor. In the case of generator sets operating in parallel, if the engine output power fails for any reason, such as shutdown, the generator will motor the engine at bus frequency. The required power, usually about 10 to 20% of rated power, will be provided by other machines. To prevent this occurrence, all paralleled generators must be fitted with a reverse-power relay. The relay is set to open the generator breaker at about 5 to 10% reverse power.

2) Generators Breakers : The generator breaker must be rated to withstand and interrupt the available fault currents from the load bus. This may require special breaker considerations when paralleling to an infinite bus.

3) There are many additional protective devices that can be applied to single or parallel-operated generators e.g load and voltage balance relays etc

Technical considerations for automatically synchronized systems:

1) **The generator output: must be the same as the bus; that is:**
   - Same number of phases
   - Same phase-to-phase voltage
   - Same phase rotation (e.g. ABC or ACB)
2) **AC waveforms :** The generators and bus AC waveforms must be in identical phase relationship at the time of breaker closure to connect them. This is called the in phase or synchronized condition. If the phase rotations are opposite then synchronism of all 3 phases can never be achieved. If the breaker is closed to connect the two sources based on only one phase being in synchronism, major damage can immediately occur.
3) **The synchronization is accomplished and the two sources are connected together only when the two sources are in phase (each phase voltage matched, phase rotations matched and phase angles matched).**
4) **The Synchronization sustains for as long as the two sources have been connected together. They will remain in synchronism no matter what (unless the breaker(s) open and disconnect one of the sources). The two sources are effectively "geared" together by electrical forces.**
5) **If the two sources are two equal generator sets, say for example 2 x 500 kWe as soon as they are in parallel, the system should now behave as though it were a single 1000 kW generator, which means the whole is equal to the sum of the parts.**
6) The key to parallel operation is to make the system behave just like single generator. The challenge comes from the fact that this "single" generator has two regulator exciters and two governor systems. The characteristics of the two machines must be matched for the "whole" system to function correctly.
7) The voltage and frequency controls of a paralleled generator not only control voltage and frequency but:
   a) Voltage control (excitation control) now controls the reactive power output of the generator. If the generator is over excited, instead of the voltage rising the excess excitation will result in generation and delivery of excess kVARs to the bus. If it is under-excited it will "absorb" kVAR's from the bus. When the excitation level is exactly correct for the actual bus voltage the generator will share the kVAR's required by the load.
   b) Frequency control (governor speed control) now controls the real power output of the generator set (kWe output). If the governor frequency (speed) setting is higher than the actual bus frequency, the governor will sense an under-speed condition and attempt to correct the condition by increasing the fuel. This can only result in increased
   power output. Likewise, if the governor frequency setting is below the actual bus frequency, then the governor will sense over-speed and react by reducing the fuel.
8) In the case of two or more engine generator sets operating in parallel, it is readily apparent that the regulators and governors must function together to achieve system control.
9) **Generator paralleled to an infinite bus:** In the case of an engine generator paralleled to an infinite bus, it is not possible to control the infinite bus. Its regulators and governors are not accessible, and even if they were, other considerations (such as other connected customer needs) would prevent adjusting the bus controls to satisfy an insignificantly small paralleled generator. For paralleling considerations, a bus can start to be considered as infinite when the bus capacity is about 5 times the paralleled generator capacity. Thus if a 500 kW generator is paralleled to a bus powered by a 2500 kWe generator, it is essentially being connected to an infinite bus.
10) This is a classic case of **"two halves do not necessarily make a whole"**. However, the control of paralleled generator(s) is in fact simple, reliable and extremely versatile.

- **Load Control:**
  1) **Load Add / Shed Control:** Whenever engine / generators are paralleled, the loads should be divided and controlled so that the system will not be overloaded. Overloading an emergency system will cause voltage and frequency deviations and possibly cause the failure of the complete system. The loads can be grouped into blocks consistent with the prime mover size. This means that load prioritization is necessary. The system can then control the connection of load to the bus in a prioritized sequence as generators are placed on line. Similarly, the system must disconnect, or shed loads in reverse order of priority, to ensure maximum continuity of power to the highest priority loads if bus capacity reduces due to loss of generating units.
  2) **Load Add / Shed Switching Function:** Having established the basis for load adds and shed, it is necessary to consider the means to achieve this switching. There are several ways to switch the loads. In an emergency power system, one convenient means is to utilize the automatic transfer switches for load connect and load dump operation. Another method involves the use of remote-control switches, or contactor to open and close, adding and shedding the loads. Downstream circuit breakers can also be tripped to shed load.

- **Load Share Basics:**
  1) Governor speed adjustment controls generator set load (kW) after the generator is paralleled to a bus. If a diesel generator with droop governing is paralleled to the utility bus, the generator frequency will be exactly the same as the utility bus at the moment that paralleling occurs. If no change in set speed occurs, the generator will run in parallel with the utility, but will not produce any load.
  2) A more normal parallel generator set condition is the parallel operation of 2 or more engine generators onto a common bus. The considerations are identical to the infinite bus except that speed (or voltage) set point adjustments on one generator will in fact result in a speed or voltage change on the bus along with the expected change in real or reactive load. Increasing the load on one generator will correspondingly decrease the load on the other bus-connected generators. To maintain the bus frequency and load share requires adjustments of both governors. Likewise, to maintain bus voltage and kVAR share requires adjustment of both regulators.
  3) Electronic load sensing governors can be used for parallel operation with isochronous speed (frequency) control and electronically controlled load levels. The electronic load signals from all the paralleled generators can be interconnected and used to bias each governor so that it carries its share of the total load. The sets do not have to be equal size. Each will carry its proper portion of the total load.

- As you can see, running generators in parallel has some clear advantages and should be a consideration for any company looking to get high level, redundant, backup power. However, technical expertise is an absolute must to design and install a properly configured parallel system.

- For more information on paralleling of generators of any make, model, manufacturer and fuel mix, please consult ESL at customercare@eslpk.com