Information Sheet #77

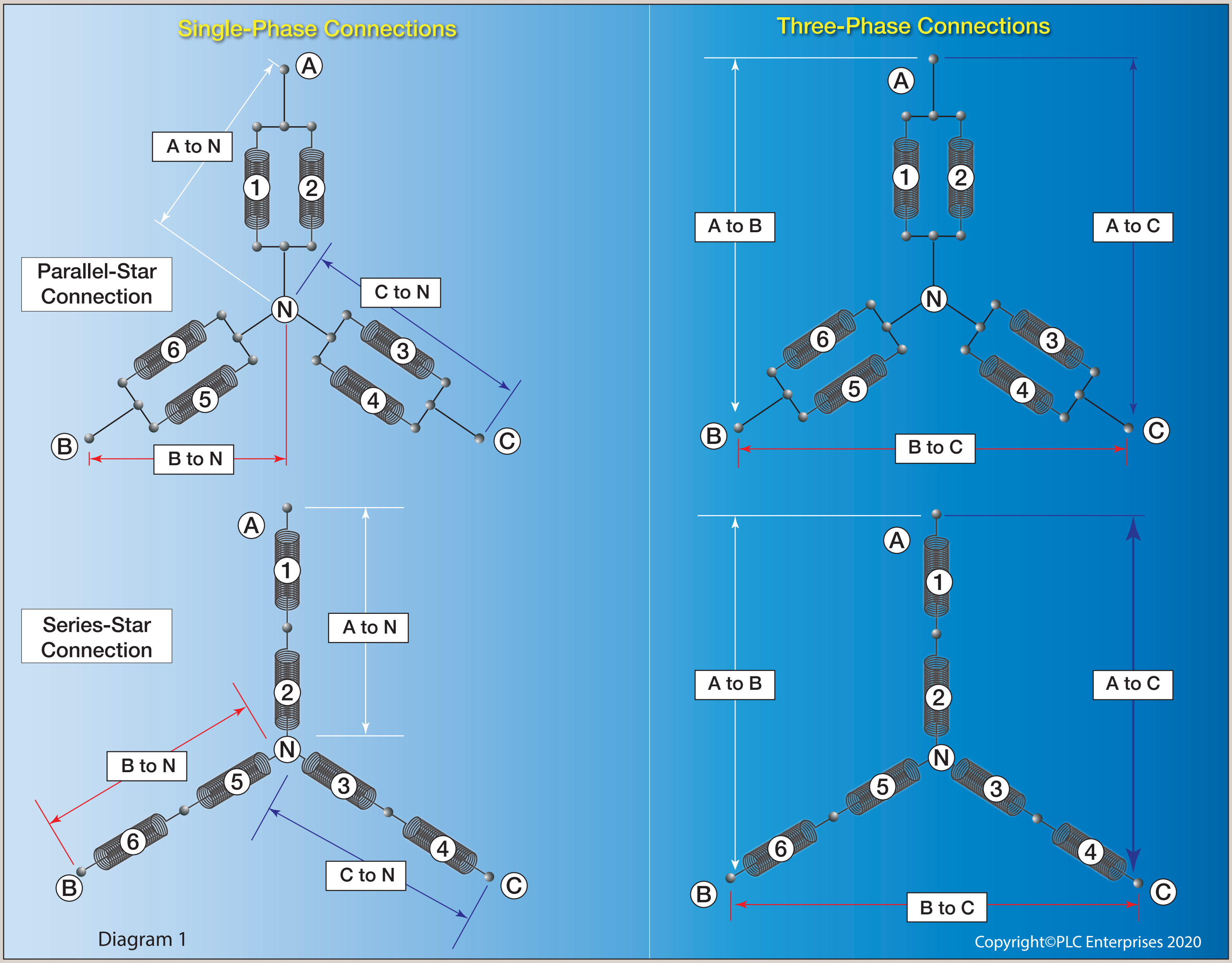
The ultimate solution for maintaining your nationwide generator network

Balancing Loads on Three-Phase Generator Systems

1.0 Introduction:

Generator systems, whether to a standby or prime power application are generally configured to supply single and three phase electrical output. While most generator systems below 15 kW are single-phase, a high percentage of those supplied above 15 kW are configured to provide three-phase electrical power output. Even though the power output is three-phase it does not mean all the connected load is three-phase, in fact, in most facilities a high percentage of the connected load is single-phase.

The following information will cover the importance of balancing the loads connected to a three-phase generator system and issues that can occur if the connected load is not balanced across all phases.



To fulfill our commitment to be the leading network service provider in the Power Generation Industry, the USA, Inc. team maintains up-to-date technology and information standards on Power Industry changes, regulations and trends. As a service, our **Information Sheets** are circulated on a regular basis, to existing and potential Power Customers to maintain awareness of changes and developments in engineering standards, electrical codes, and technology impacting the Power Generation Industry.

2.0 Definition of a Three-Phase Generator System:

Most three-phase generator systems have a brushless generator connected to a gas or diesel engine running at 1800 rpm for a 60 Hz alternating current (AC) output. Before addressing the issues associated with balance loads connected to three-phase generator systems we should consider the design of a brushless three-phase alternator.

2.1 Brushless Generator Design – The fundamental of power generation is the principal that an electrical current is induced in a wire when it is turned within a magnetic field. Brushless generators have the wires stationary in the outside stator wires, with the rotor wound to give the magnetic field.   Instead of the wires rotating in a magnetic field, the brushless generator has the magnetic field rotating between the static stator wirings. The rotating magnetic field induces an electrical current into the outside static stator windings. This method does away with the necessity for brushes to pick up the power from the commutator if the stator was the magnetic field and the electrical current was induced into the rotor.

2.2 Brushless Generator Stator Windings – In a standard three-phase brushless generator system, there are six individual wire coils wound into the stator. The pairs can be connected several ways, the most common are parallel or series star. (See diagram-1) Depending how these wires are connected determines the three and single phase voltage output. An equal amount of electrical power is induced into each coil as the magnetic field rotated through the six coils wound into the stator.

2.3 Generator Rating – The electrical power the generator produces is a function of the size of engine connected and the size and amount of copper to carry the electrical current in the alternator. Each coil is wound to produce its equal share of electrical output. As such a generator rated to produce a total of 60kW will have each of the six coils producing 10kW.

3.0 Connecting Load to the Generator:

A brushless generator is frequently referred to as a 12-wire rotating field brushless generator. This refers to two wires at the end of each of the six coils, for a total of 12-wires. Depending on how the wires are connected at the terminal outlets dictates the voltage out of each of the phases. The connections will be in line with the voltage configuration of the connected load. Examples of loads are:

3.1 Three-phase loads – A three-phase load can be from many sources, but the most common will be a three-phase electric motor or transformer. Typically a three-phase connected load, provided it is within the power output of the generator system, does not result in a out of balance load situation, unless additional single-phase loads are also connected to the generator. See diagram-1 for details of a connected three-phase load.

3.2 Single-phase loads – Three separate single-phase loads can be connected when the three pairs of coils within the stator are connected or parallel or series star. (See diagram-1) When the generator is rated at 60kW each pair of coils should be loaded with no more than 20kW, caution should be made that all connected single-phase loads are balanced across each single-phase outlet from the generator.

4.0 Issues Resulting from Unbalanced Connected Loads:

When a system designer determines load distribution on a generator system, the first strategy is to evenly balance the load across the coils. However, this is an ideal situation that is not always achievable. As such the effect on a generator should be considered by having coils overloaded and/or power distributed unequally across the coils. These effects include:

4.1 Overload – Various loads within a given application will pull varying amps of load. If one single leg pulls more than a third of the total power produced by the generator, and it is not possible to redistribute the load across other phases, then a larger generator will have to be selected than the combined load on all three phases. This will ensure the individual coils on one single phase leg are not overloaded.

4.2 Voltage Regulation – The automatic voltage regulator (AVR) senses the voltage changes and sends more or less current to the excitation system to increase or decrease the magnetic field and to maintain the level of voltage within set limits. Unbalanced loads can affect the AVRs ability to regulate output voltage within set limits. This in itself can have a detrimental effect on connected single and three-phase loads. This occurs particularly when the motor starts and demands increased amps to start the motor.

4.3 Wave Form and Harmonics – An alternating current (AC) generator produces output in a sine wave. In the case of a 60Hz system, sixty cycles per minute. It is important that the sine wave is smooth and any transient harmonics are kept within limits. Some connected loads, such as silicon-controlled rectifiers (SCRs), do not respond well to harmonic input outside of their design limits. Unbalanced loads can produce adverse harmonics.

4.4 Unbalanced Single-phase loads effecting connected Three-phase loads – When a generator is connected to both three-phase loads, such as motors, and single-phase loads, any out of balance can create electrical supply problems to the motor load. NEMA recommends to avoid overheating a motor should be derated by 25% when a 5% out of balance load is applied. NEMA recommends motor voltage unbalance should be maintained within 1%.

5.0 Issues Resulting from Unbalanced Connected Loads:

When potential connected unbalanced loads are determined to be an issue when connecting a facility's load to the generator the system engineer should consider the following:

5.1 Rebalancing the Connected Load – Determine if existing loads could be redistributed within the facility to enable balancing of the facility's load across the three-phase. This would be easier to undertake when a system is under construction.

5.2 Over sizing the Generator – Select a generator size where the connected load across any individual coils does not exceed the designed output of the coil.

5.3 Derate Size of Motors – Loading motors below 80% of their full load rating.

6.0 Further Information:

When connecting loads to a three-phase generator consult with your authorized generator distributor and the relevant codes recommended by NEMA and other electrical standards.

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