

Recommendations on optimized design of the Interconnection Switchgear for the power systems with Distributed Generators (DG).

Many DG used in the United States would be operating in parallel with the utility grid.

In order to be able to take full advantage of the DG resource, it is important to optimize the interconnection switchgear to minimize the impact of the disturbances in the utility grid on the served loads.

The following are the recommended steps in the electrical design of the DG installation:

1. DG installation objectives:

The design engineer needs to have clear understanding of the purpose and customer expectations of the DG system.

2. Power System evaluation:

Existing power system needs to be thoroughly reviewed and evaluated. The following are the typical existing power system parameters to consider:

- a. One-line diagram of the existing power system.
- b. Size and type of the existing service equipment.
- c. Typical system active and reactive load levels.
- d. Size, impedance and group of connection of the utility service transformer.
- e. Utility available fault currents. Positive and zero sequence fault levels are of the main importance.
- f. Nature of the customer's loads. Harmonics levels in currents and voltages.
- g. Normal service voltage levels for each phase.
- h. Presence of the automatic reclosing in the utility service.

3. System one-line diagram:

The one-line diagram of the proposed power system incorporating the DG units should be developed. Neutral grounding scheme should be developed. Third order harmonic circulating currents, introduced by the addition of the DG units, and its impact on ground fault sensing and equipment sizing need to be considered in development of the neutral grounding scheme.

4. Coordination with local utility company:

Local utility company representative needs to be contacted to discuss utility company's interconnection requirements based on the desired operation of the DG units (duration of parallel operation, need to export power, etc.). Potential change in the utility company's rate structure as a result of installation of the DG needs to be also addressed with the utility company's representative. In some cases additional utility metering or relocation of the existing utility revenue metering may be required.

5. Protective relaying.

Protective relaying scheme will need to be designed to protect the utility distribution system, site loads, local distribution system and DG units from the harmful effects of short circuits and other abnormal conditions. DG and interconnection protection relaying shall meet the following needs:

- a. Meet the utility company's requirements for interconnection protection.
- b. Protect customer's electrical equipment (loads).
- c. Protect the DG units.
- d. Allow for the power system (including DG) to provide the continuity of service required by the user. In other words, allow to meet the DG installation objectives.

In order to meet these requirements the interconnection protection relaying, DG protection relaying, local distribution protection relaying and utility company's upstream relaying needs to be properly coordinated.

6. Automatic load control.

When utility source is not available and the connected site load exceeds the capacity of the connected DG, automatic load control in the form of load shed is required to keep the more critical site loads energized. This is achieved by automatic shedding (disconnecting) the least critical loads upon detection of the DG bus under-frequency. Several stages of load shed are typically employed for maximum operational flexibility.

7. Equipment selection.

- a. Combined system positive, negative and zero sequence fault currents need to be calculated to establish the required interrupting ratings of the new and existing switchgear.
- b. New load flow study needs to be conducted to verify and establish proper ratings for the new and existing transformers, cables, switchgear and other power system components.
- c. Switching devices intended for supervised synchronizing, should be verified to have proper electric closing time capability. Typical closing time for synchronizing shall not exceed 80 – 217 mS.

- d. If feeder circuit breakers are intended to be used for load shed, they need to be verified to be properly equipped.

8. Metering.

Metering requirements at various points of the power system need to be established. If changes to the utility revenue metering or additional utility revenue metering is required for the project, new utility metering compartments may need to be designed and submitted for approval by the utility company.

9. Control system.

Control system needs to be designed to implement intended sequence of operation of the DG installation. This will typically include automatic starting, stopping and synchronizing of the DG units, circuit breakers switching, load transfer and load shed control, DG loading control, including power Import/Export control, heat recovery system control, data logging, alarming, events recording as well as system integration with the remote monitoring and control computers.

Minimizing the impact of the disturbances in the utility grid on the served loads.

One-line diagram of the typical simplified DG installation is shown in Figure 1. The DG are connected to the grid at the primary distribution voltage.

Normal operation in parallel with the utility:

Upon receipt of an automatic start signal initiated locally by the operator or remotely by customer SCADA or DCS system (via closure of a dry contact), the switchgear shall verify that utility phase voltages and frequency are within acceptable tolerances and issue a start signal to the generator sets. At that time, generator set's speed and voltage shall be controlled by the switchgear. The generator set's voltage shall be automatically matched with the utility bus and each genset shall be automatically synchronized with the utility under the supervision of the synchronizing check relay. When all the synchronizing conditions are met the generator synchronizing circuit breaker shall close. At that time, the generator set shall be gradually (soft) loaded to the desired active and reactive loading levels and remain at those levels until signaled to unload. If the unit is signaled locally by the operator or remotely by customer SCADA or DCS system (via closure of a dry contact), to operate in Import/Export control mode of operation, the desired utility kW contribution to the site load (import) or generator kW contribution to the utility grid (export) shall be automatically maintained.

Generator set loading (kW) setpoint, Import/Export setpoint, reactive power (kVAR) setpoint, loading and unloading times and loading dynamics setpoints shall be viewable and adjustable from the operator interface panel mounted on the switchgear front door.

The switchgear shall constantly monitor utility bus to ensure constant presence of the utility at the utility side of the utility circuit breaker (52U). The utility interconnection protection (included in the switchgear) shall sense if there is a severe fault on the utility side of the utility circuit breaker (52U) as well as operation of the upstream distribution

recloser, or any other disconnection of the DG from the utility upstream from the utility circuit breaker (52U). Upon sensing of any of the above conditions, the utility incoming circuit breaker (52U) shall immediately trip open and generator set shall continue supplying power to the site load.

The following are the important aspects of minimizing the impact of the disturbances in the utility grid on the served loads:

- a. In order to achieve immediate tripping of the utility circuit breaker (52U) upon fault in the utility system, careful coordination of the generator overcurrent, ground overcurrent, over/under voltage and over/under frequency protection with the utility overcurrent, ground overcurrent, directional current, directional power, over/under voltage and over/under frequency protection is required.
- b. It is important to selectively trip the utility circuit breaker (52U), while the generator circuit breakers (52G) remain closed, so the generators can continue supplying power to the site loads.
- c. We will define fault as remote fault, when the combined power system and fault impedance between the point of interconnection and the fault is high enough that each generator fault contribution is negligible in relation to the generator's full load current. In case of the remote fault, the utility protective relaying should open one of the network protectors upstream from the fault. At this time an unintentional island may be created. Interconnection over/under frequency protection will typically open 52U within 200 mS, before quality of power to the load is noticeably affected. In this case the load may experience voltage fluctuation within 10% and frequency fluctuation within 0.3 Hz. These fluctuations are well within the tolerance level for most even sensitive loads.

Note: In order to achieve fast detection of the unintentional island condition by the interconnection over/under frequency relaying it is typically necessary that the total load connected to DG during unintentional island is greater or less than the DG load levels immediately before the unintentional island condition by at least 5-8% of the DG rating.

- d. We will define fault as local fault, when the combined power system and fault impedance between the point of interconnection and the fault is low enough that each generator fault contribution is comparable to or greater than the generator's full load current. In case of the local fault, the interconnection overcurrent, directional current or directional power protection shall trip the utility circuit breaker (52U). Local fault will typically introduce voltage sag, which will last from the time of the fault

occurrence to the time the 52U circuit breaker is open. In this case the tripping needs to occur very fast, to minimize the impact of the local fault on the power quality at the point of the interconnection. After the utility circuit breaker (52U) is open the generators will continue supplying power to the site loads.

It is extremely difficult to eliminate the short term (typically less than 200 mS in duration) impact of the local fault on the power quality experienced by the loads. Additional, more complex measures need to be taken to further minimize the impact of the local fault on the power quality.

Upon receipt of an automatic stop signal initiated locally by the operator or remotely by customer SCADA or DCS system (via closure of a dry contact) the switchgear shall gradually (soft) unload the generator set. When the genset load is reduced to the level of the unload trip setpoint (adjustable from the operator interface panel mounted on the switchgear door), the generator synchronizing breaker shall trip open and the genset shall be put in the cooldown mode of operation.

Bumpless load transfer operation:

Upon receipt of an Isolate signal initiated locally by the operator or remotely by customer SCADA or DCS system (via closure of a dry contact), the switchgear shall verify that utility phase voltages and frequency are within acceptable tolerances and issue a start signal to the generator set. At that time, generator set's speed and voltage shall be controlled by the switchgear. The generator set's voltage shall be automatically matched with the utility bus and the genset shall be automatically synchronized with the utility under the supervision of the synchronizing check relay. When all the synchronizing conditions are met the synchronizing circuit breaker shall close. At that time, the generator set(s) shall be gradually (soft) loaded to assume the entire site load and utility circuit breaker shall be tripped open. At this time the site load has been transferred to the generator power.

When utility source is disconnected the generator sets shall operate as isochroous load sharing machines, supplying the isolated site load.

Upon receipt of an automatic stop signal initiated locally by the operator or remotely by customer SCADA or DCS system (via closure of a dry contact) the generator(s) shall be synchronized with the utility source and when in synchronism (as determined by the synchronizing check relay), close the utility circuit breaker. At this time soft unloading of the generator set shall begin. When the genset load is gradually reduced to the level of the unload trip setpoint the generator synchronizing breaker shall trip open and the genset shall be put in the

cooldown mode of operation. At this time the site load has been transferred to the utility power.

Automatic standby with closed transition return operation:

Upon sensing of the utility failure (utility voltage or frequency are not within set tolerances) the utility circuit breaker shall trip open and the Time Delay Generator Start timer shall start timing. If utility failure condition remains upon expiration of the Time Delay Generator Start timer the generator sets shall be automatically started and brought up to speed and voltage. The load feeder breakers shall be tripped and the generator sets shall automatically parallel and energize the bus. The load feeder breakers will be reclosed in the order of the load priority at this time. Now the generators are supplying power to the site load. Upon sensing of utility return (utility voltage and frequency are within set tolerances) the Time Delay Emergency to Normal timer shall start timing. If utility power remains healthy (utility voltage and frequency are within set tolerances) upon expiration of the Time Delay Emergency to Normal timer the soft close transition of the load to the utility shall begin. The generators shall be synchronized with the utility source and when in synchronism (as determined by the synchronizing check relay), close the utility circuit breaker. At this time soft unloading of the generator sets shall begin. When the genset load is gradually reduced to the level of the unload trip setpoint the generator synchronizing breaker shall trip open and the genset shall be put in the cooldown mode of operation.