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POWER QUALITY ISSUE AND OPERATING CONFLICT BY DISTRIBUTED GENERATION

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Abstract- *One of the solutions to meet the growing load demand in rural and remote areas is to introduce Distributed Generation (DG) within the existing network. There are several definition available for distributed generation in various literature . According to this DG is simply the generation at site or near to load as per requirement and capacity. This distributed generation is obtained by various conventional and non-conventional methods available in market. Introduction of DG in existing system improve the reliability, stability ,voltage and current profile etc and thus improve the power quality(PQ) .As the existing system designed for specific load and capacity introduction of DG created power quality issues and also operating conflict. This power quality issues and operating conflict are discussed in this paper.*

Keywords- Power quality(PQ), Distributed generation(DG), Harmonics, Disturbances, Voltage sag, conflict

I INTRODUCTION

With the growth of power demand, finding alternative arrangements to support this increase is vital. One possible solution, especially in rural and remote areas, is the introduction of Distributed Generation (DG) within the network.

Distributed Generation is also termed as decentralized generation because the energy generated and distributed using small scale technologies closer to its end. Distributed generation simply means small scale generation. Although DG is not a new concept, the application of DG is continuously changing. Initially, DG systems were mostly utilized for shaving peak power or providing power where electrical networks could not reach. At present, DG systems (in addition to initial applications) are used for voltage support, providing load relief for transmission lines, supporting consumers under conditions of mains failure and toward the improvement of networks PQ issues. DG also provide means of utilizing renewable energy resources. However, DG systems tend to have some disadvantages in regards to Power Quality(PQ), especially when utilizing renewable energy such as wind, hydro and solar power to support rural networks.

It is understood that in some cases the distribution network shows significant levels of PQ problems, such as voltage sags and/or voltage distortion regardless of where DG systems are connected in the network or not. The causes of network based PQ problems arise from both utility and customer equipment. In this paper various power quality issues and operating conflict discussed as it arises on introduction of DG in existing network.

II DISTRIBUTED GENERATION (DG) SYSTEMS

The exact definition of distributed generation (DG) varies somewhat between sources and capacities; however, it is generally and summarily defined as any source of electric power of limited capacity, directly connected to the power system distribution network where it is consumed by the end users. Distributed generation should not to be confused with renewable generation. Distributed generation technologies may be renewable or not; in fact, some distributed generation technologies could, if fully deployed, significantly contribute to present air pollution problems Distributed Generations provides a reliable and better power quality than conventional system.

Distributed Generation have a number of technologies, some technologies are used for high efficiency. In most of the rural areas still electricity does not reach because it is not economical to set up large transmission lines in that case distributed generation is a better option to fulfill the requirement. In India, the deregulation of the power sector has not made much alternative but the transmission and distribution losses, grid failure and the problem of remote and inaccessible regions have led to distributed generation. Distributed Generation system can employ both renewal and non-renewal technologies it can be either off grid or on grid.

III DISTRIBUTED GENERATION TECHNOLOGIES

The increased market penetration of distributed generation has also been the advent of an electric power production industry. These resources have lower energy density than fossil fuels and so the generation plants are smaller and geographically widely spread. The distributed generation may be based on fuel cells, photovoltaic system, wind turbines, mini/micro hydro turbines, gas turbines and micro turbines.

Table 1. Distributed generation capabilities and system interfaces

Technology	Capability Ranges	Utility Interface
Fuel cells	A few tens of kW to a few tens of MW	dc to ac converter
Micro turbines	A few tens of kW to few MW	ac to ac converter
Combustion turbine	A few MW to hundreds of MW	Synchronous generator
Combined cycle	A few tens of MW to several hundred MW	Synchronous generator
Internal Combustion Engine	A few hundred kW to tens of MW	Synchronous generator or ac to ac converter
Ocean	A few hundred kW to a few MW	Four-quadrant synchronous machine
Geothermal	A few hundred kW to a few MW	Synchronous Generator
Wind	A few hundred W to a few MW	Asynchronous Generator
Solar, photovoltaic	Solar, photovoltaic	dc to ac converter

IV POWER QUALITY ISSUE

There are certain power quality issues when DG insterted in existing system which are discussed here.

A Sustained interruptions

Much of the DG that is already in place was installed as backup generation. The most common technology used for backup generation is diesel gensets. The bulk of the capacity of this form of DG can be realized simply by transferring the load to the backup system. However, there will be additional power that can be extracted by paralleling with the power system. Many DG installations will operate with better power quality while paralleled with the utility system because of its large capacity. However, not all backup DG can be paralleled without great expense. Not all DG technologies are capable of significant improvements in reliability. To achieve improvement, the DG must be capable of serving the load when the utility system cannot.

Utilities may achieve improved reliability by employing DG to cover contingencies when part of the delivery system is out of service. In this case, the DG does not serve all the load, but only enough to cover for the capacity that is out of service. This can allow deferral of major construction expenses for a few years. The downside is that reliance on this scheme for too many years can ultimately lead to worse reliability. The load growth will overtake the base capacity of the system, requiring load shedding during peak load conditions or resulting in the inability to operate the system at acceptable voltage after a fault.

B Voltage regulation

It may initially seem that DG should be able to improve the voltage regulation on a feeder. Generator controls are much faster and smoother than conventional tap-changing transformers and switched capacitor banks. With careful engineering, this can be accomplished with sufficiently large DG. However, there are many problems associated with voltage regulation. In cases where the DG is located relatively far from the substation for the size of DG, voltage regulation issues are often the most limiting for being able to accommodate the DG without changes to the utility system.

Some technologies like are unsuitable for voltage regulation and for most utility interactive inverters that produce no reactive power. Also most utilities do not want the DG to attempt to regulate the voltage because that would interfere with utility voltage regulation equipment and increase the chances of supporting an island. Multiple DG would interfere with each other. Finally, small DG is simply not powerful enough to regulate the voltage and will be dominated by the daily voltage changes on the utility system. Small DG is almost universally required to interconnect with a fixed power factor or fixed reactive power control.

Large DG greater than 30 percent of the feeder capacity that is set to regulate the voltage will often require special communications and control to work properly with the utility voltage-regulating equipment. One common occurrence is that the DG will take over the voltage-regulating duties and drive the substation load tap changer (LTC) into a significant bucking position as the load cycles up and down. This results in a problem when the DG suddenly disconnects, as it would for a fault. The voltage is then too low to support the load and takes a minute or more to recover.

Large voltage changes are also possible if there were a significant penetration of dispersed, smaller DG producing a constant power factor. Suddenly connecting or disconnecting such generation can result in a relatively large voltage change that will persist until recognized by the utility voltage-regulating system.

C Harmonics

There are many who still associate DG with bad experiences with harmonics from electronic power converters. If thyristor-based, line-commutated inverters were still the norm, this would be a large problem. Fortunately, the technologies requiring inverters have adopted the switching inverters like the one described previously in this chapter. This has eliminated the bulk of the harmonics problems from these technologies.

One problem that occurs infrequently arises when a switching inverter is installed in a system that is resonant at frequencies produced by the switching process. The symptom is usually high-frequency hash appearing on the voltage waveform. The usual power quality complaint, if any, is that clocks supplied by this voltage run fast at times.

Harmonics from rotating machines are not always negligible, particularly in grid parallel operation. The utility power system acts as a short circuit to zero-sequence triplen harmonics in the voltage, which can result in surprisingly high currents.

D Voltage sags

The most common power quality problem is a voltage sag, but the ability of DG to help alleviate sags is very dependent on the type of generation technology and the interconnection location. Figure 1 illustrates a case in which DG is interconnected on the load side of the service transformer.

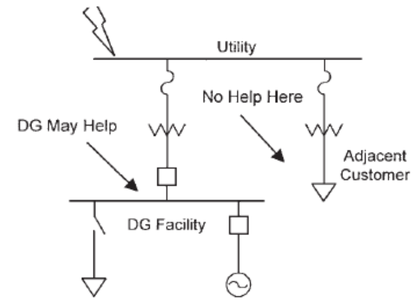

Figure. 1 DG is interconnected on the load side of the service transformer.

During a voltage sag, DG might act to counter the sag. Large rotating machines can help support the voltage magnitudes and phase relationships. Although not a normal feature, it is conceivable to control an inverter to counteract voltage excursions.

The DG influence on sags at its own load bus is aided by the impedance of the service transformer, which provides some isolation from the source of the sag on the utility system. However, this impedance hinders the ability of the DG to provide any relief to other loads on the same feeder.

V OPERATING CONFLICTS

Deploying generation along utility distribution systems naturally creates some conflicts because the design of the system assumes only one source of power. A certain amount of generation can be accommodated without making any changes. At some point, the conflicts will be too great and changes must be made.

A Utility fault-clearing requirements

Figure 2 shows the key components of the over current protection system of a radial feeder. This is the least costly protection scheme that is able to achieve acceptable reliability for distributing the power. One essential characteristic is that only one device has to operate to clear and isolate a short circuit, and local intelligence can accomplish the task satisfactorily. In contrast, faults on the transmission system, which easily handles generation, usually require at least two breakers to operate and local intelligence is insufficient in some cases.

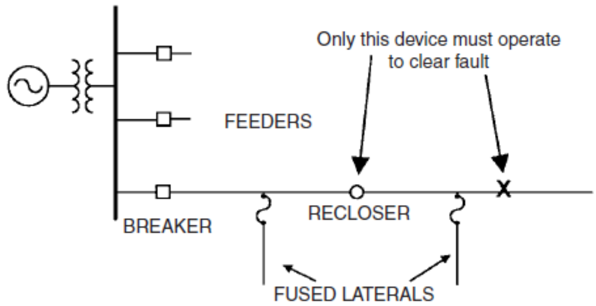

Figure. 2 Typical overcurrent protection of a utility distribution feeder.

In contrast, faults on the transmission system, which easily handles generation, usually require at least two breakers to operate and local intelligence is insufficient in some cases. With only one utility device operating to clear a fault, all other DG devices must independently detect the fault and separate to allow the utility protection system to complete the clearing and isolation process. This is not always simple to do from the information that can be sensed at the generator.

B Reclosing

Reclosing utility breakers after a fault is a very common practice. Most of the distribution lines are overhead, and it is common to have temporary faults. Once the current is interrupted and the arc dispersed, the line insulation is restored. Reclosing enables the power to be restored to most of the customers within seconds.

Reclosing presents two special problems with respect to DG:

1. DG must disconnect early in the reclose interval to allow time for the arc to dissipate so that the reclose will be successful.
2. Reclosing on DG, particularly those systems using rotating machine technologies, can cause damage to the generator or prime mover.

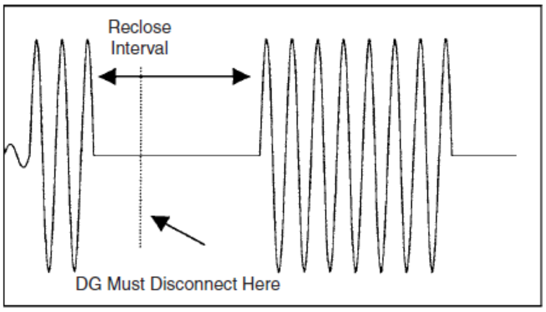

Figure. 3 DG must disconnect early in the first reclose interval to allow the fault-clearing process to proceed.

Figure 3 illustrates the reclose interval between the first two operations of the utility breaker. The DG relaying must be able to detect the presence of the fault followed by the opening of the utility fault interrupter so that it can disconnect early in the reclose interval as shown. However, some transformer connections make it difficult to detect certain faults, which could delay disconnection.

A greater complicating factor is the use of instantaneous reclosing by many utilities. This is used for the first reclose interval for the purpose of improving power quality to sensitive customers. The blinking clock problem can be largely averted, and many other types of loads can ride through this brief dead time.

The interval for instantaneous reclose is nominally 0.5 s, but can be as fast as 0.2 s. This is in the range of relaying and opening times for some DG breakers. Instantaneous reclose is very likely to be incompatible with DG. A reclose interval of at least 1.0 s is safer when there is DG on the feeder. Many utilities use 2.0 or 5.0 s for the first reclose interval when DG is installed. This minimizes the risk that the DG will not disconnect in time. If it is deemed necessary to maintain the instantaneous reclose, it is generally necessary to employ direct transfer trip so that the DG breaker is tripped simultaneously with the utility breaker.

C Interference with relaying

Three of the more common cases where DG can interfere with the over current protection relaying on distribution feeders. 1. Reduction of reach. 2. Sympathetic tripping of feeder breakers. 3. Defeat of fuse saving.

Figure 4 illustrates the reduction-of-reach concept. Each over current relay device has an assigned zone of protection that is determined by its minimum pickup value. DG in eed can reduce the current that the relay sees, thereby shortening its reach. When the total DG capacity increases to a certain amount, the infeed into faults can desensitize the relays and leave remote sections of the feeder unprotected. A low-current (high-impedance) fault near the end of the feeder is more likely to go undetected until it does sufficient damage to develop into a major fault. The power quality consequences of this are that voltage sags will be prolonged for some customers and the additional fault damage will eventually lead to more sustained interruptions. Solution to this problem is decrease the relay minimum pickup current to increase the zone. This may not be practical for ground relays that are already set to a very sensitive level.

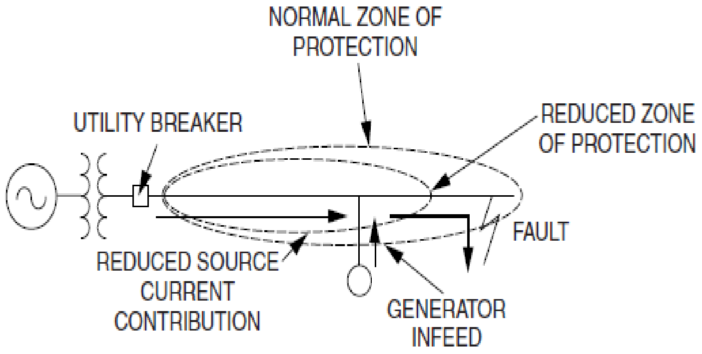

Fig.4 Infeed from DG can reduce the reach of the relay.

Sympathetic tripping describes a condition where a breaker that does not see fault current trips "in sympathy" with the breaker that did. The most common circuit condition on utility distribution feeders is back feed into a ground fault. For the situation shown in Figure 5 the source of the back feed current is the DG.

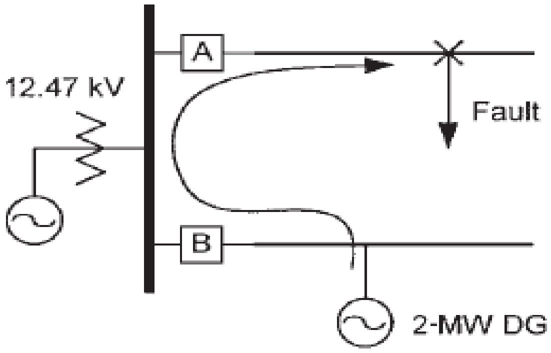

Figure. 5 Sympathetic tripping of feeder breaker (B) for DG in feed into faults on other feeders.

Most utility feeder breakers do not have directional sensing. Therefore, the ground relay sees the DG contribution as a fault and trips the breaker needlessly. This situation is exacerbated if the service transformer for the DG has a grounded wye-delta connection. The main solution to this problem is to use directional over current relaying. If appropriate potential transformers are not already present, this could end up being an expensive alteration.

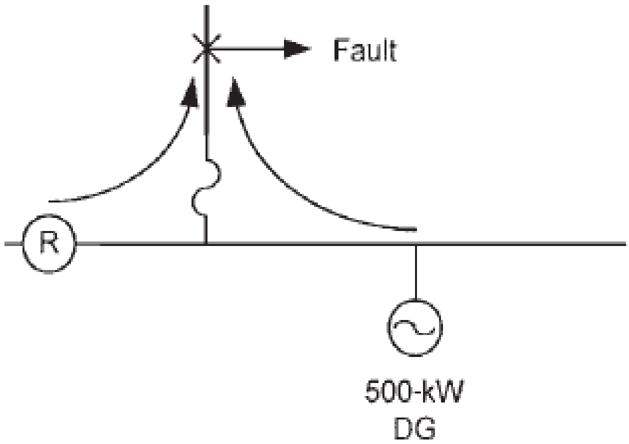

Fig.6 Infeed from DG can defeat fuse saving.

Fuse saving is commonly practiced in utility overcurrent protection schemes, particularly in more rural regions. The desired sequence for the situation depicted in Figure 6 is for the recloser R to operate before the lateral fuse has a chance to blow. If the fault is temporary, the arc will extinguish and service will be restored upon the subsequent reclose, which normally takes place within 1 or 2 s. This saves the cost of sending a line crew to change the fuse and improves the reliability of customers served on the fused lateral.

D Voltage regulation issues

Figure 7 illustrates one voltage regulation problem that can arise when the total DG capacity on a feeder becomes significant. This problem is a consequence of the requirement to disconnect all DG when a fault occurs.

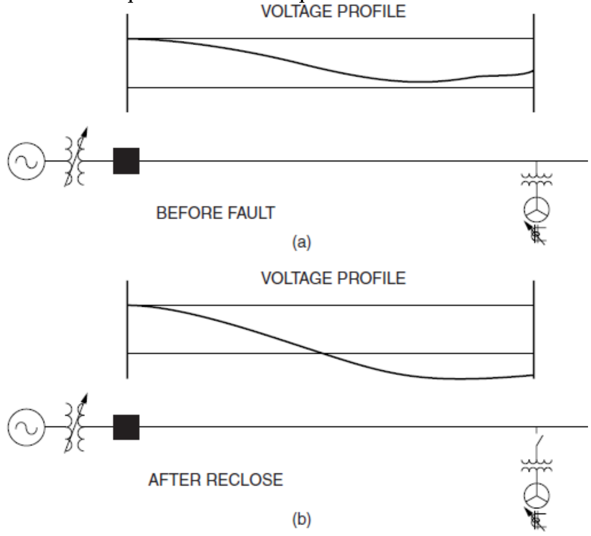

***Figure. 7 Voltage profile change when DG is forced off to clear faults*.**

Figure 7(*a)* shows the voltage profile along the feeder prior to the fault occurring. The intent of the voltage regulation scheme is to keep the voltage magnitude between the two limits shown.

When the fault occurs, the DG disconnects and may remain disconnected for up to 5 min. The breaker recloses within a few seconds, resulting in the condition shown in Fig.7(*b)* The load is now too great for the feeder and the present settings of the voltage regulation devices. Therefore, the voltage at the end of the feeder sags below the minimum and will remain low until voltage regulation equipment can react. This can be the better part of a minute or longer, which increases the risk of damage to load equipment due to excessively low voltages.

Another voltage regulation issue involving step-voltage regulators is illustrated in Figure 8. Utility voltage regulators commonly come with a reverse-power feature that allows the regulators to be used when a feeder is supplied from its alternate source.

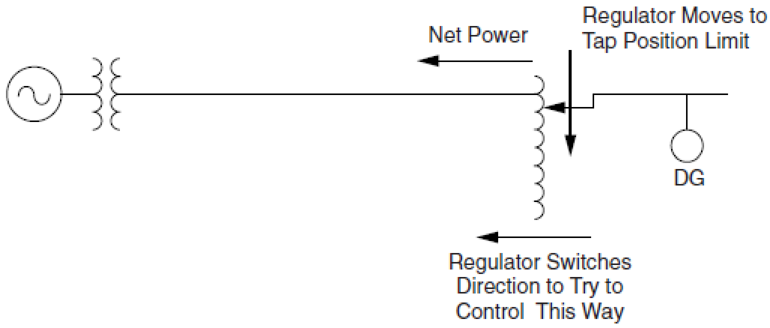

Figure. 8 Excess DG can fool reverse-power setting on line voltage regulators.

Generation technologies whose output varies rapidly can be difficult to handle on a distribution feeder. Wind-turbine generation is the most difficult because there is seldom a substation near the proposed site. The generation is typically sited several miles from the nearest substation on a feeder that already may have several switched capacitors and a voltage regulator.

E Harmonics

Harmonics from DG come from inverters and some synchronous machines. In the earlier discussion on inverters in this chapter, the measures to eliminate the larger, low-order harmonics were described. The PWM switching inverters produce a much lower harmonic current content than earlier line-commutated, thyristor-based inverters.

One new distortion problem that arises with the modern inverters is that the switching frequencies will occasionally excite resonances in the primary distribution system. This creates non harmonic frequency signals typically at the 35th harmonic and higher riding on the voltage waveform.

F Islanding

DG protective relays will generally perform their function independently of any outside knowledge of the system to which they are connected. Perhaps the greatest fear of the utility protection engineer is that DG relaying will fail to detect the fact that the utility breaker has opened and will continue to energize a portion of the feeder. Therefore, much attention has been paid to detecting islands or forcing islands to become unstable so they can be detected.

Another concern is the DG itself. Since reclosing is common, it is essential that the DG detect the island promptly and disconnect. If it is still connected when the utility breaker recloses, damage can occur to prime movers, shafts, and components of machines due to the shock from out-of-phase reclosing.

G Ferroresonance

Ferroresonance is a special kind of resonance in which the inductive element is the nonlinear characteristic of an iron-core device. Ferroresonance occurs when the magnetizing reactance of a transformer inadvertently is in series with cable or power factor capacitance.

One interesting case occurs for DG served by cable-fed transformers. It is common practice for the larger DG installations to have their own transformer. The circuit is shown in Fig. 9. Underground cable runs are normally fused at the point where they are tapped off the overhead feeder line. This is variously called the riser pole or dip pole.

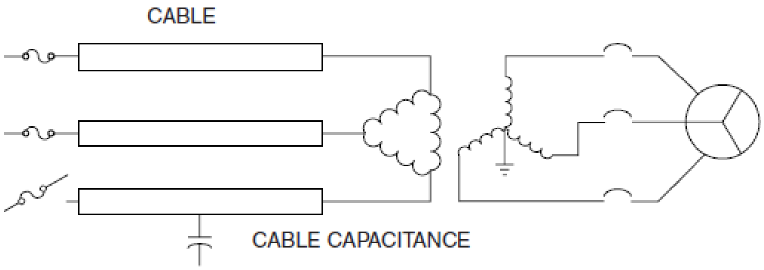

Figure. 9 DG breaker is required to open when riser-pole fuse blows, leading to ferroresonance.

This leaves the transformer isolated on the cable with one or two open phases and no load. Either condition is conducive to ferroresonance because the cable capacitance in an open phase, or phases, now appears in series with the transformer's magnetizing impedance as in figure 10.

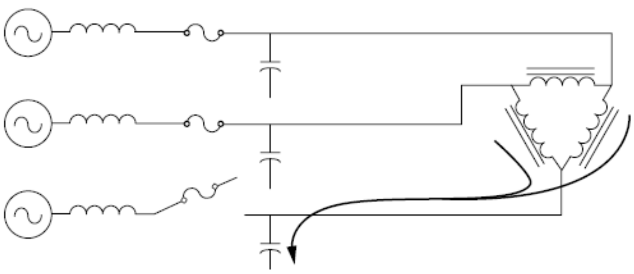

Figure. 10 Schematic showing magnetizing impedance of a delta-connected transformer in series with cable capacitance when fused cutout is opened.

H Shunt capacitor interaction

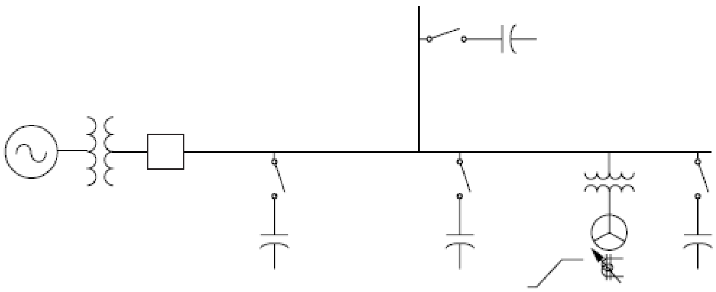

Figure. 11 A typical distribution feeder may employ numerous switched capacitor banks

Utilities use switched capacitors to help support the voltage during high-load periods. These banks are mostly controlled by local intelligence, switching at predetermined times or at loading levels as measured by either voltage, current, or kvar. Some types of DG can also produce reactive power (vars), and this can create control hunting and other difficulties. There can be several capacitor banks on the feeder as illustrated in Figure 11.

There can easily be conditions in which the total reactive power output of the generators and capacitors is too great, resulting in high voltages. This is particularly likely when capacitors are switched by time clock or by current magnitude.

I Transformer connections

The service transformer used for interconnection can have a great influence on the impact DG will have on the power quality.

Grounded wye-wye connection.

It is favored because of its reduced susceptibility to ferroresonance on cable-fed loads and fewer operating restrictions when being switched for maintenance. It is also generally well behaved with respect to DG interconnection, but there are a couple of issues.

It allows DG to feed all types of faults on the utility system. Also does not inhibit the flow of zero-sequence harmonic currents that might be produced from certain kinds of generators. Because of these two concerns, it may be difficult to parallel some generators using this transformer connection. If the DG is a synchronous machine, it may produce a small amount of third-harmonic voltage distortion, depending on the winding pitch of the machine.

Delta-wye connection.

It would probably be favored for serving loads in nearly all cases if it were not for the susceptibility of the connection to ferroresonance in cable-fed systems. In this connection it is difficult to detect some SLG faults from the secondary side by voltage relaying alone. It is susceptible to ferroresonance in cable-fed installations. Third harmonics in the DG may cause excessive current in the secondary side neutral. With this connection if arresters are islanded on an SLG fault and there is little load, resonant over voltages can result. This connection prevents third harmonics from the generator from reaching the utility system, it does not prevent their flow on the DG side.

Delta-delta or ungrounded wye-delta connection.

Both have similar behavior with respect to serving DG. Neither would be the preferred connection for serving most new DG installations, but could be encountered in legacy systems where a customer wishes to parallel DG. Some inverter-based systems (fuel cells, photovoltaic , micro turbines, etc.) require an ungrounded connection on the DG side because the dc side of the inverter is grounded.

This is often accomplished by use of a separate isolation transformer rather than the main service transformer. However, either of these connections would also suffice. With this connection difficult to detect SLG fault. Also Utility arresters are subjected to high steady-state over voltages if islanded on an SLG fault (see Figure 12). This is true for delta-wye connections as well. susceptible to ferroresonance in cable fed installations.

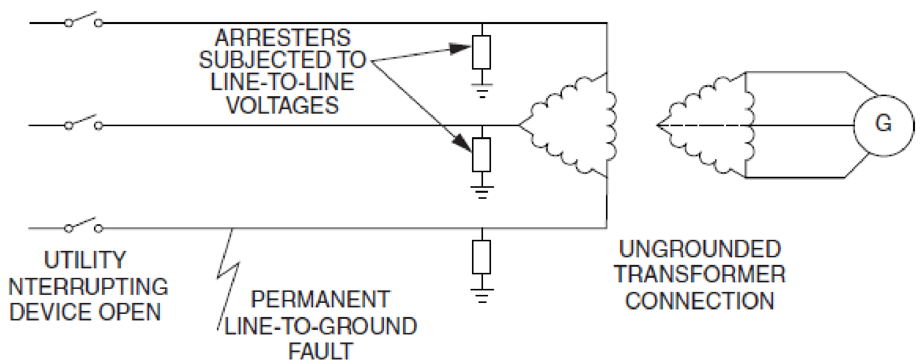

Figure. 12 Isolating DG with ungrounded service transformer connection on an SLG fault can lead to arrester failure.

The prompt detection of SLG utility faults using voltage relaying is a problem with these connections. This will delay fault detection until after the utility breaker has opened, resulting in at least a brief island. This can result in over voltages and a resonant condition common to all ungrounded primary connections.

Grounded wye-delta connection.

The connection is often referred to as a "ground source" because it contributes to ground faults and will generally disrupt the ground fault relaying coordination on the feeder. Other feeders connected to the same substation bus may be disrupted also. Figure 13 shows how the connection contributes to an SLG fault on a four-wire, multigrounded neutral distribution system.

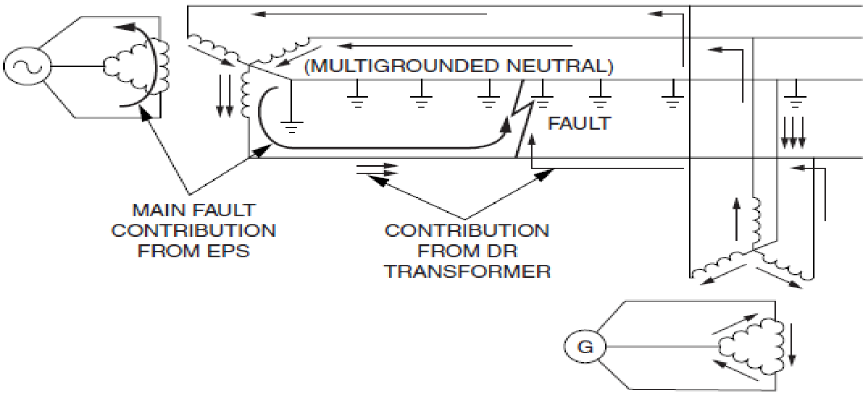

Figure. 13 Grounded-wye-delta connection acts as a "ground source" feeding ground faults.

VI CONCLUSION

Different issues related to power quality when DG is integrated with the existing power system has been discussed in the paper. It can be concluded from this discussion that when interconnecting DG to the power system, these issues must be considered which could affect power quality and smooth operation. Penetration of DG can be successfully integrated with the power system as long as the interconnection designs meet the basic requirements that consider not only power quality but also system efficiency , smoother operation ,power reliability and safety.

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