Impact of Distributed Generation on Electrical Power Network

Umar Naseem Khan

***Abstract*—In today's world, the demand for the electric power is growing rapidly; to overcome this, many power generation resources are constructing in all over the globe. But the problem arises when the new generation is integrated with the power network and distribution, as the existed power network was not designed by keeping in mind the new integration of generation in the future. The objective of this paper is to discuss some of the problems associated with distribution resources on the power and network.**

***Index Terms*—distributed resources, distributed generation, power system, transmission and distribution.**

I. Introduction

THE power system faces many problems when distributed generation is added in the already existing system; this is because the power system is not designed with distributed generation in mind. The addition of generation could influence power quality problems, degradation in system reliability, reduction in the efficiency, over voltages and safety issues. On the other sides the power system distribution are well designed which could handle the addition of generation if there is proper grounding, transformers and protection is provided. But there are limits to the addition of distributed generations if it goes beyond its limit then it is important to modify and change the already designed distributed system equipment and protection, which could in a result facilitate the integration of new generation. This addition of the equipment could involve protection relays, switchgears, change of the voltage regulation system, revised grounding and transfer trips [1].

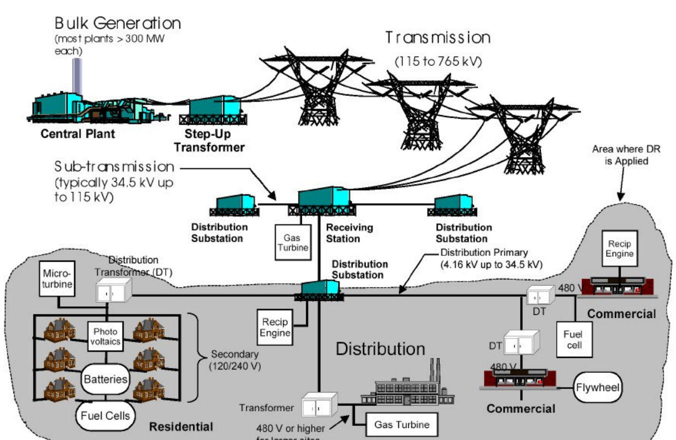

Figure 1, Distributed Resources on the Power Network

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A wide range of power generation technologies are currently in use or under development, these technologies includes: small combustion turbines and micro turbines, small steam turbines, fuel cells, small-scale hydroelectric power, photovoltaic, solar energy, wind turbines, energy storage technologies etc, as shown in Figure 1. The benefits which we can get from distributed resources (DR) in relation to Transmission and Distribution (T&D) could include reduction in T&D system losses, enhanced service reliability and quality, improved voltage regulation, relieved T&D system congestion [2].

On the other hand, interconnected DR could worsen the performance of the power system leading to negative support benefits. For example, the reliability of the power system may be degraded if the DR is not properly coordinated with the electric power system protection. The integration of DR could influence the power quality due to poor voltage regulation, voltage flickers and harmonics. These conditions can have a serious impact on the operation and integrity of the electric power system as well as cause damaging conditions to equipment.

II. The Impact of Distribution Resources on Distribution Network

Before evaluate the system impacts such as voltage regulation, faults levels, power quality, reliability, harmonics, stability and other performance characteristics one has to first collect the data that can properly describe both the DR and the utility system to which it will be connected.

Data needed to evaluate DR impacts:

- Size rating of the proposed DR
- Type of DR power converter (static or rotating machine)
- Type of DR prime energy source (such photovoltaic, wind or fuel cell
- Operating cycles
- Fault current contribution of DR
- Harmonics output content of DR
- DR power factor under various operating conditions
- Location of DR on the distribution systems
- Locations and setting of voltage regulation equipment on distribution system
- Locations and settings of equipment for over current protection on distribution system

In the following sections, some solutions are presented to overcome the issues relation to the integration of the DR [1].

III. Interconnection transformer connections

The selection of the interconnection transformer connection has a major impact on how the dispersed generator will interact with the utility system. The type of transformer employed has an impact on the grounding perceived by the utility primary system and for the generator to appear as a grounded source to the utility primary distribution systems, the transformer must be able to pass a ground path from the low voltage to the high voltage side, which is commonly called as zero-sequence path.

There is no universally accepted “best” connection. Figure 2 shows four commonly used connections. Each of these connections has advantages and disadvantages to the utility with both circuit design and protection coordination affected. Each connection should be addressed by the utility as they establish their interconnect requirements.

In Figure 2, top two arrangements shown can provide a grounding path to the primary. Furthermore, for the transformer with grounded wye, the generator neutral must be grounded to make the source appear as grounded. The top two arrangements are preferred for four-wire multi-grounded neutral systems. The bottom two arrangements shown act as grounded sources and are best used on the three-wire, ungrounded distribution systems. An important point is that a DR site can be configured to acts as a well-grounded source on the low-voltage side of the transformer, but the system may still appear to the utility primary to be ungrounded an the high side. Delta connection on the high side and grounded-wye connection on the low side can achieve this effect [1], [2].

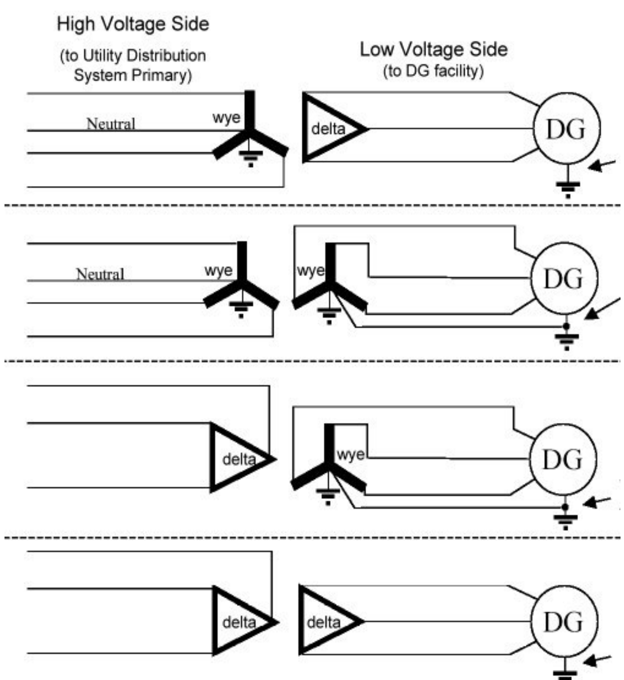

Figure 2. Interconnection Transformer Connections

IV. Generation with ungrounded transformer primary windings

If the DR is connected to the utility by a transformer with an ungrounded primary (delta or ungrounded wye connection); the utility substation transformer may be the only ground current source on the feeder. When a line to ground fault occurs on the utility feeder, the utility breaker may trip with the generator still connected. The resulting system is not effectively grounded. line to neutral voltages on the un-faulted phases approach the normal line to line voltages. This can cause a severe over voltage of line to neutral connected equipment. If the insulation of the connected equipment has not been selected for those voltage levels, the result will be serious damage to the equipment. The connected distribution transformers will become saturated and damaged, insulators and lightning arrestors will likely flash over and the breaker bushings may fail. It is generally accepted that if the connected generator is rated at less than half of the minimum load on the circuit, it will be unable to sustain more than line to ground voltages. Therefore the ungrounded primary connections should only be considered if the distributed generator is rated at less than half of the load on the circuit. If this type of transformer connection is used, voltage relays must trip the DR for an over voltage condition.

V. Loss of primary source to substation power transformer

The loss of primary power to the utility substation transformer(s) means complete loss of the utility supply to the station. As can be shown in Figure 3, primary power can be lost via a switching or interrupting device at the station, or at the remote line terminal breakers. Loss of primary power presents some relaying challenges and introduces some operational issues.

A. *Protection for High Side Faults*

In Figure 3, the station C transformers isolated via its high voltage disconnect. There is a small section of bus from the high voltage side of the transformer to the isolating device. If there is a possibility of the DR back energizing the transformer, protection must be considered for this bus, in particular for ground faults. This will require the addition of ground fault detection. For situations of this type, it is common to use a ground overvoltage relay on the transmission system to isolate the DR from the fault. Other schemes could involve a transfer trip of the DR whenever the high side disconnect switch is open.

B. *Requirements for Line Protection at the Utility Substation*

The DR will be a source for transmission line faults. For DRs, where the size of generation is very small compared to the minimum load, line protection may not be required as voltage and frequency collapse (after CBs 1 and 2 are tripped in figure 3) will cause the DR relay protection to operate. Where there is any possibility that the DR will not separate, a transfer trip system from station B to station C or the DR may be required. Some schemes may use under voltage relaying at station bus “C” to detect loss of system source. A thorough analysis of these situations should be done a part of the interconnection study.

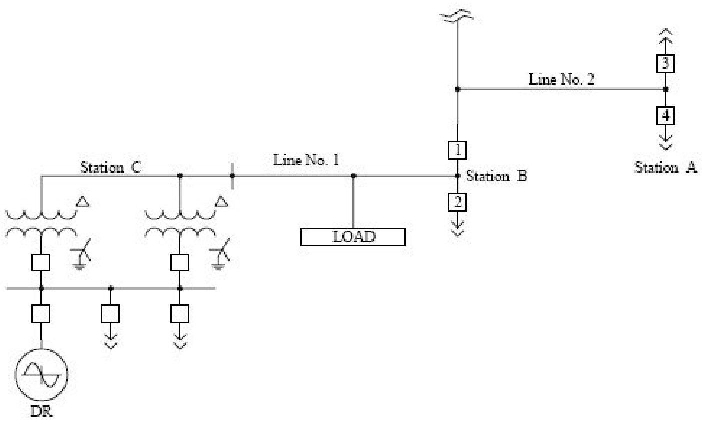

Figure 3. Single Line representation of System

C. *System Over voltage Issues*

Over voltages can result from transmission line single line to ground faults that are only fed from the utility distribution substation (station C in Figure 3). In extreme cases, line protection tripping at Station B for line no. 1 will have to be delayed to ensure that DR generation is tripped off before the utility breakers are tripped [3].

VI. Fault Current from Distributed Resources

When a DR is connected to a utility feeder, three different systems must be considered for fault currents. These are the utility system without the DR, the combined utility and DR system and the DR alone. It is desirable to maintain proper coordination of relays, reclosers and fuses on the utility system with and without the DR on line. Although the DR would not normally be connected to the distribution feeder without the utility source; this can occur due to sequential tripping during a fault. wye grounded (HV) – delta (LV) transformer can be a source of current for line to ground faults even when the DR is off line. When modeling the impedance of the DR for determining relay operation for fault current, consider the speed of operation of the protective relays. If the protection does not operate in the time frame of the sub transient impedance for the DR the transient impedance may need to be used. This will reduce the current contribution from the DR.

A. *Increased Duty*

There are three considerations for fault currents. The fault current must not exceed equipment short time ratings. Over current devices must be sized appropriately for the level of fault current. Proper coordination of relays, reclosers, fuses and other over current devices must be based on the available fault current. Depending on the interconnection transformer connection, some or the entire feeder fault current levels will be increased due to the DR. Equipment ratings, such as re-closer withstand capabilities, should be examined as part of the interconnection study.

B. *Direction of Power Flow*

In many cases, the substation transformer is a much stronger source of fault current than the DR installation. In this case, the fault current from the utility substation will not be significantly decreased for faults between the utility substation and the DR. As long as the current does not exceed equipment capability, this can increase coordination margins between substation relays and feeder fuses. If the DR is between the utility substation and the fault, the DR may cause a decrease in fault current from the utility substation, which needs to be investigated for minimum tripping or coordination problems.

If the DR source (or combined DR sources) is strong compared to the utility substation source, it may have a significant impact on the fault current coming from the utility substation. This may cause failure to trip, sequential tripping, or coordination problems.

VII. Effects on Relay Application and Settings

It is desirable to leave other connected loads and resources largely unaffected by the addition of a DR. At issue is the effect of DR on distribution relay protection, particularly coordination problems.

A. *Coordination Problems*

The introduction of DR into a system usually designed for serving only load radically causes a number of problems with the protective device coordination. A simple system is depicted in figure 7. An actual system would have numerous load tap along the circuits and may have more than one protective device in the line between the substation and the DR. Any protective devices downstream from the DR will likely benefit from improved coordination from the extra current contribution. Faults between the downstream protective device and the substation will experience reverse current flow in the protective device which can prevent the primary source from clearing the fault unless the protective device is allowed to trip for reverse current before the primary source is re-closed. Consideration for faults on adjacent circuits must take in account the added contribution and in-feed effect from the DR. The circuit feeding the DR will experience reverse flow for these faults and must be coordinated to ensure reliability. Some of these coordination issues are covered in more detail in this section.

B. *Relay, Fuse, and Line Recloser*

The addition of DR requires that time coordination is maintained between protective devices on adjacent circuits as the effects of DR on coordination is not limited to the circuit to which it is connected. Faults on an adjacent circuit can cause protective devices on the DR circuit to operate. This is undesirable because service can be interrupted to customers who would normally be unaffected by this scenario.

VIII. Voltage and Frequency

In considering the impact of DR on the power system voltage and frequency, it should be recognized that Dr has a greater impact on the system voltage than it does the frequency. This is because it can locally change the voltage where it is applied without having to change the voltage across the entire power system. Whereas, to change the system frequency requires a system-wide impact and so the capacity of the DR needs to be significant relative to the total system capacity. The largest individual DR units (10-50MW) are very less in percent in total

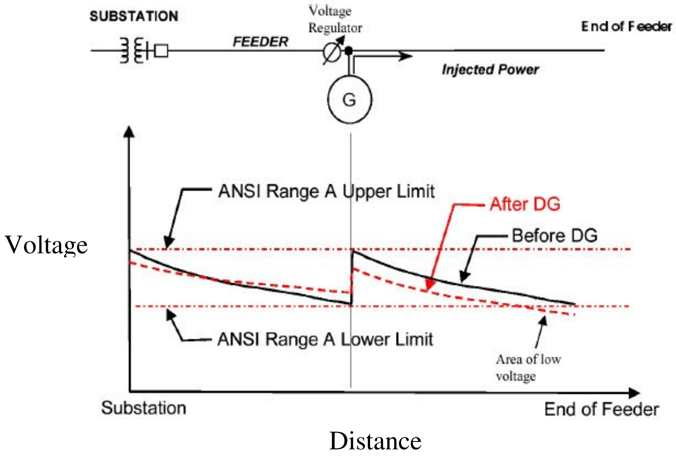

Figure 4. Voltage Regulation

generation so any single DR does not significantly impact frequency.

Maintaining adequate operating voltage at all the customer delivery points is critical to proper system operation. The acceptable range of voltage at the customer end should be +/- 5% on the nominal level, but +/- 6% or +/-8% is also acceptable for occasional or short term events [1].

A. Voltage regulation

As DR units are added to distribution systems and aggregated capacity builds up to a significant portion of total feeder load, coordinating DR with distribution system regulators becomes extremely important. Several possible modes of interaction exist depending on the type of DR and its control configuration. In addition, the presence of DR will directly affect voltage profiles along a feeder by changing the direction and magnitude of real and reactive power flows. The directional characteristics of voltage regulation circuitry must also be considered. In Figure 4, voltage profile on a distribution feeder with distributed resource added near a voltage regulation station is shown.

IX. Sags and Swells

Sags, swells and momentary interruptions are short term variations in system voltage that are usually associated with faults. The switching of large loads or the starting or stopping of motors and other large equipment can also cause sags and swells.

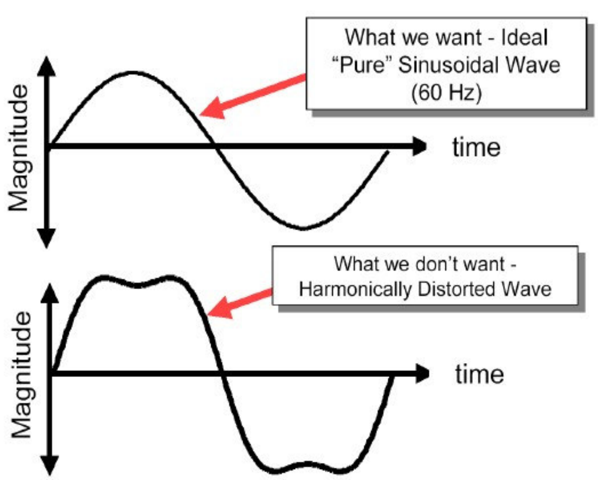

Figure 5. Comparison of pure sinusoidal wave and distorted wave

Sags, swells and other transients have potential to damage extremely sensitive customer equipment in some circumstances. DR can cause such transients if a large capacity unit is turned on all at once, or number of units are turned on simultaneously, or if a resource comes on-line before synchronizing with the grid. These events can lead to out-of-step conditions for rotating equipment that may place undue mechanical stress on the equipment leading to damage.

X. Harmonics

A harmonically distorted wave is one that does not follow a pure sinusoidal pattern as shown in Figure 5. Harmonics are always present on utility systems to some extent. They can be caused by non-linearity in transformer exciting impedance or loads such as fluorescent lights, AC-to-DC conversion equipment, variable-speed drives, switch-mode power equipment, arc furnaces, welders, and other equipment. Installation of DR can, in some cases, increase harmonics on a utility distribution system from acceptable to objectionable levels.

XI. Conclusions

The solution to the problems associated with DR when added in the power network could best be achieve when one has the proper data about the system and proper identification of the problems on the network due to distributed resources. The purpose of the paper was also about the proper identification of the problems associated with DR and power network.

XII. References

[1] EPRI White Paper, "Integrating Distribution Resources into Electric Utility Distribution System" Technology Review, December 2001.

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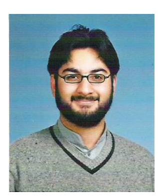
[3] IEEE PSRC Working Group Report, "Protective Relaying and Power Quality".

XIII. Biographies



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