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Distributed generation : technical aspects of interconnection

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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. This paper aimed to analyses the technical aspects of interconnection of distributed generators with the electrical power system.

Keywords : Distributed Generation, Interconnection, Technical issue, Islanding

I. INTRODUCTION

In most of cases power plants are nuclear, fossil fuel, or hydro plants. These plants are of hundreds of MW or GW. At the same time the application of renewable sources such as wind or sun is becoming economical and feasible. These installations are placed closed to customers have been called as embedded or distributed generators. In fact, studies have predicted that distributed generation may account for up to 20% of all new generation going online by the year 2010. With so much new distributed generation being installed, it is critical that the power system impacts be assessed accurately so that these DG units can be applied in a manner that avoids causing degradation of power quality, reliability, and control of the utility system. This paper is reviewing technical issues concerning to DG interconnection connected to the distribution side of the network because of their small rating. These installations with power system.

II. INTERCONNECTION OF DG

While Interconnecting DGs to the utility, many goals need to be set forth. Foremost among them are

(*i*) Safety of utility personal working on electrical system
(*ii*) Safety of utility customers and general public
(*iii*) Protect and minimize possible damage to electrical power system (EPS) and other customer's property
(*iv*) Ensure proper operation to minimize adverse operation conditions on EPS.

A. Issues related with interconnection of DG

Even though DG is a viable option to meet the power demand of the industry, there are varieties of technical, operational, commercial, and regulatory issues that have to be considered before the DG plants are interconnected with the main grid. Interconnection is basically meant for back wheeling the excess power produced by a DG plant to the grid. The interconnection issues have enough potential to prevent distributed generation projects from being developed. Interconnection issues are broadly classified as :

(*i*) Technical issues
(*ii*) Operational issues
(*iii*) Economical issues

The primary focus of this paper is to introduce the main technical issues 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.

III. TECHNICAL ISSUES

The main technical issues for DG connection relate to reliability and power quality of supply, protection, islanding and stability of the system.

A. Reliability and power quality issue

The large-scale deployment of distributed energy resources expected deterioration of power quality is expected and on the other hand, an adverse effect on the existing power quality of the distributed energy resources is also found.[1]

The definition of power quality given in IEEE Standard 1100 [2] reads :

"Power quality is the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment*."*

Power quality is important because electronic devices and appliances have been designed to receive power at or near certain voltage and frequency parameters, and deviations may cause appliance malfunction or damage. In addition to simple voltage and frequency ranges, discussions of power quality include on harmonics, power factor, DC injection, and voltage flicker.

(*a*) Over voltage and under voltage. A typical definition is given as "A measured voltage having a value greater than or less than the nominal voltage for a period greater than 1 min when used to describe a specific type of long duration variation." Typical values are 1.1 to 1.2 p.u. for over voltage and 0.8 to 0.9 p.u. for under voltage. [3]

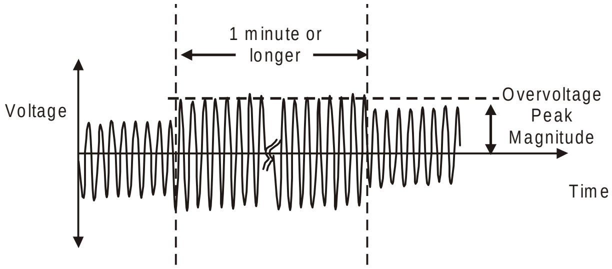

Fig.1. Typical overvoltage waveform [4].

(*b*) **Voltage fluctuations.** The term "voltage fluctuations" is used to cover a wide range of changes in the voltage magnitude. The severity of voltage fluctuations is quantified through the "short-term flicker severity" and the "long-term flicker severity".

(*c*) **Low-frequency and high-frequency harmonics.** The power-electronic interfaces of DG units contribute to waveform distortion. The current waveform contains frequency components at integer multiples of the power-system frequency and at integer multiples of the switching frequency. The former is referred as "low-frequency harmonics" and the latter as "high-frequency harmonics".

B. Protection issue

The presence of DG can cause various problems related to incorrect operation of system protections. The conflicts between DG and protection schemes are as[5] :

(*i*) Lack of coordination in the protection system;

(*ii*) Ineffectiveness of line reclosing after a fault using the ARD and difficult lines back-feeding;

(*iii*) Unforeseen increase in short circuit currents;

(*iv*) Undesired islanding and untimely tripping of generators interface protections.

Traditional distribution systems were not designed to have active power generating units in them. Power is supplied by the transmission system and power flow is mainly unidirectional. But with the DG in the system, power flow can be bi-directional.

(*d*) **Impact of coordination on Protection System.** Coordination can be understood by the following example [6]

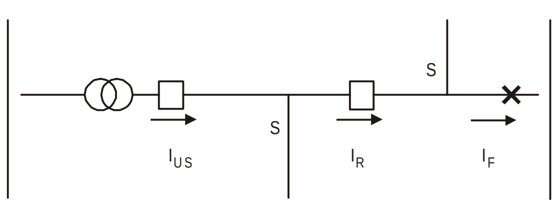

Fig.2. Typical feeder with addition of DG up line recloser.

I_{US} is the current from the utility source

I_R fault current seen by the recloser.

I_F the fault current at the fault location.

Without DG

$$I_{US} = I_R = I_F$$

With the DG connected

$$I_F = I_{US} + I_{DG} \text{ and } I_R = I_F$$

However, $I_R \neq I_{US}$

The condition indicated is not seen in the typical radial distribution system. I_{US} without the DG does not equal I_{US} with the DG. With the DG connected the fault current seen by the recloser (I_R) will be greater than without the DG connected. This would normally not cause a problem with the recloser size as long as the new greater I_R does not exceed the recloser maximum interrupting rating. However, it is very likely that coordination between the recloser and any down-line fuses will be lost. Because both the recloser and fuses operate faster at higher fault currents, the required margins between the recloser fast curve and the fuse minimum melt curve could be reduced enough to lose coordination.

(*e*) **Instantaneous Reclosing.** The fig shows the principle by showing the fault currents and the reclose interval (dead time) between "shots". [5] It shows first Two Shots of a Typical Utility Distribution System Reclosing Sequence During a Short Circuit Fault.

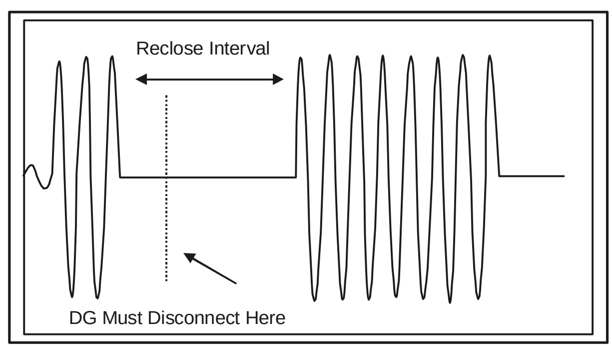

Fig.3. Fault current and Reclose interval.

Many utilities use "instantaneous" reclose for power quality purposes and complicate the issue. The reclose interval is nominally 0.5s but can be as short as 0.2s. The utilities that use this short interval have done so because they wanted to improve the power quality for their customers. However, this increases the probability that the DG may not disconnect in time. The conflict between needs of DG and use of instantaneous reclose will become important with increasing penetration of DGs. Hence it is recommended against using instantaneous reclose on feeder sections that contain DG. A reclose interval of 1.0s or more would be preferable. This will dramatically reduce the chances that the DG will fail to disconnect in time, but will also result in reduced power quality to a certain segment of customers.

(*f*) **Increase in short circuit currents.** DG may affect the operation of existing distribution networks by providing flows of fault currents which were not expected when protections were originally designed.

The contribution of some generators short circuit currents may increases the short circuit current[7]. It was verified that a few changes in network parameters could cause an excessive increase in short circuit current. Generally speaking, fault current increase largely depends on a number of factors, such as capacity, penetration, technology, interface and connection point of DG, besides other parameters such as system voltage prior to the fault, etc.

In the next future, it will become impossible to neglect fault level increase in presence of DG. Besides the trivial solution of replacing inadequate devices with others of greater current interrupting capacity when technically possible, various solutions to the problem are viable, as suggested in literature, such as the use of solid state fault current limiters [8,9] or superconducting fault current limiters [10-12].

Coordination in the protection system. Commonly, protection of power systems is tuned in such a way that only the faulted part of the system is isolated when a fault occurs. This tuning is called protection coordination, which can be negatively affected by the presence of DG [13].

Undesired islanding and untimely tripping for faults on different feeders. This issue is very important and discussed independently in the next section.

C. Islanding issue

An island is "That part of a power system consisting of one ore more power sources and load that is, for some period of time, separated from the rest of the system."

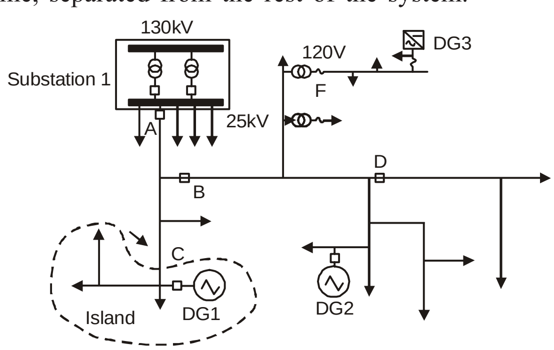

Fig.4. Islanding of a DG.

In the Fig. a substation is shown which steps down transmission voltage into distribution voltage and is the sending end of several distribution feeders. One of the feeders is shown in detail. There are many customer connection points in the feeder. Large distributed generators are typically connected to the primary feeders (DG1 and DG2). These are typically synchronous and induction generators at present. Small distributed generators such as inverter based PV systems are connected to the low voltage secondary feeders (DG3). Island operation can be Intentional Islanding or Unintentional islanding**.** In intentional islanding, the islanding has been planned in advance and the system and equipment has been designed to cope with the situation. The DER is then well suited to control voltage and frequency in the islanded grid. Intentional islanding is become progressively popular especially [14, 15] in the wake of blackouts. Unintentional islanding occurs if the switching device between the DER and the rest of the utility grid is opened and the DER continues to feed the distribution grid. The DER equipment may not at all be suited to control voltage and frequency. This means that the power quality can not be guaranteed by the utility. The voltage and frequency can even get so out of range that installed custom equipment is destroyed.

D. Stability

A small number of quite small-size DG units, compared to the large centralized power stations, will not influence the operation of the power network and hence their impact can be neglected. When networks begin to contain large numbers of DG units with higher capacities, the dynamics of the distribution system effect distribution system's stability.[16]

(***a***) **Transient stability.** Transient stability issues, also referred to as the first swing stability, are among the most important practical concerns in power system operation and planning studies. It has been observed [17] that the utilization of DG units reduces the magnitude of the maximum power-angle deviation. This indicates that the existence of the DG units improves significantly the transient stability of the system. This also means that the increase of the penetration level of DG units within power systems provides the opportunity to handle larger disturbances. In some critical cases and with more severe faults, the use of DG units can maintain synchronism due to the reduction of the maximum power-angle deviation between generators.

(***b***) **Oscillatory stability.** The oscillatory instability occurs usually due to the insufficient damping of the electromechanical oscillations.

Increasing penetration of DG causes lower damping and higher frequency with small numbers of DG units near some of the load nodes, the DG controllers have only local action and the global damping of the controller mode is worsened.

The use of a large number of DG units, which are uniformly dispersed in the low voltage area, extends the controller action to cover most of the load nodes. Hence, the performance of this mode is slightly improved with the high penetration levels of the DG units.

(***c***) **Frequency stability.** Frequency stability refers to the ability of electrical power systems to maintain fixed frequency after being subjected to a severe disturbance [18]. The frequency will not cause a stability problem if the equilibrium between generation and load is restored. This requires sufficient generation reserve and adequate response from the control and protection devices. If the disturbance results in sustained frequency oscillations, generating units will be sequentially tripped out of the network and the stability will be lost. It has been suggested [17] to increase the percentage reserve power of the synchronous generators when DG units are utilized to maintain the total absolute reserve power of the network at acceptable levels.

(*d*) **Voltage stability.** It is defined as the ability of a power system to maintain the voltages at all nodes within acceptable limits after being subjected to a disturbance [18].

It was concluded that the analysis of the system performance with regard to voltage stability shows that DG can support and improve the voltage profiles at load terminals. This can extend the stability margin of dynamic loads, *i.e.*, induction motors, which can lose their stabile operating point with large voltage [17].

IV. CONCLUSION

DG has much potential to improve distribution system performance and it should be encouraged. However, distribution system designs and operating practices are normally based on radial power flows and this creates a special challenge to the successful introduction of distributed generation. This paper has described a few of the issues that must be considered to insure that DG will not degrade distribution system power quality, safety or reliability.

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