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Research Article

DG Interfaces and its Issues in a Smart Grid Environment

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Abstract

This paper highlights the change over from a uni-direction to a bi-directional system and the issues which affect the grid with interconnection of distributed energy resources (DER). The types of DER's, level of penetration and the power electronic interface all require a balance to ensure maximum benefit to the consumers with minimum possibility of malfunction of protective devices. The methods which render the DER grid independent or grid parallel are islanding methods, which are critical. Some of the technical challenges faced are due to the complications arising with aging grid infrastructure, involvement of responsive loads and integration of less-dispatchable distributed generation resources. These, along-with implications for a smart grid and requirements to be met with for interconnection have been discussed in the paper.

Keywords: *Distributed generation, distributed energy resource, islanding, interconnection, microgrid, power systems power electronic interface, smart grid.*

1. Introduction

Traditional grids are designed to cater to a small number of centralized generating units which meet the demand of a large number of distributed loads. The scenario where power flow was essentially uni-directional has now changed. To meet the growing demand for power, small generating units are now being added to the distribution networks, even though these networks were not designed to accommodate power generators. This shift from traditional grids to the grids which no longer have unidirectional power flow as seen in Fig.1 & Fig.2 has been driven by the need to i) increase the use of renewable energy which is more suitable for distributed use ii) restructuring and iii) advances in technology.

Most of the studies carried out say that upto 15% penetration of distributed generation can be done without much change in the grid with the only concern being control of interconnection. For the interconnection of a DER, the unit can be 'grid parallel', 'grid independent' or a combination of both. While the normal operation is the grid parallel mode, a grid failure results in the formation of an island, allowing the DER to operate independently (F. A. Farret *et al,*2006; M.Vaziri *et al,*2011; Sheng-Yi Su *et al,*2011; IEEE Std. 1547-2003; K. Moslehi *et al*,2011).

The process of integration involves the addition of a renewable energy source to the power grid at the system level.

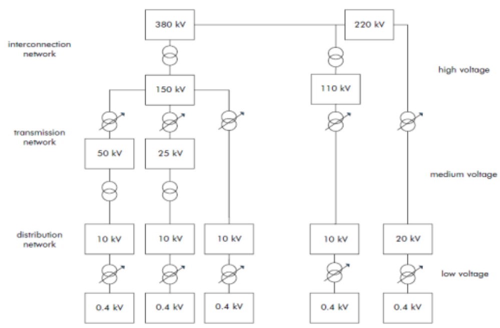

Fig. 1 Traditional network with centralized generation (unidirectional power flow)

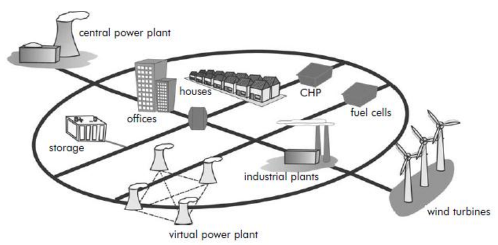

Fig. 2 Smart energy web concept (bi-directional power flow)

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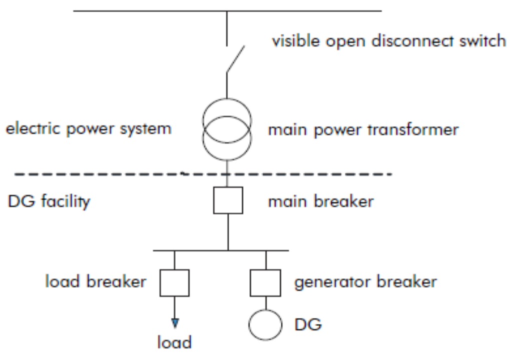

Fig. 3 Interconnection with DG's

These additions to the grid bring about issues which are important and can be summed as:

1) Protection
2) Standards of connection
3) Power electronic interface an
4) Power quality issues

As seen from the Fig.3, a typical arrangement of the interconnection of the DG to an MV network. Depending on the size of the plant, the grid side can be disconnected with the help of a circuit breaker. Based on the voltage level, a transformer is used. Smaller units may be connected directly to the grid.

2. Integration and interconnection

The nature of the alternative source needs to be considered while integrating it to the grid to ensure reliability and maintain good power quality. With the significant advantages such as low cost and being environment friendly, much research is being done to harness the energy from DER's and to improve the efficiency of these sources.

The primary objectives of interconnection are i) to ensure reliability, safety, and service quality of the power systems and ii) to provide uniform technical requirements, procedures, and agreements which are transparent and to ensure interconnections are timely, predictable, and as cost effective as possible (J. M. Carrasco *et al*,2006).

A. Aspects

With the migration to a smart grid from the old/traditional grid, there are various advantages to be gained from this. The use of locally available resources, within the range of 1kW to 10MW, allows the integration of distributed generation at the distribution as well as the customer levels. The incorporation of distributed storage also adds value for change over to a smart grid scenario.

i) Distributed Generation

Distributed generation DG is defined by the IEEE Std 1547 as facilities which generate electricity upto 10MW which allow interconnection anywhere in the power system. Such small sources which are located and interconnected at the consumer or distribution level are called DER''s. The DG's may be powered by renewable or fossil fuels (L. Goldstein *et al*,2003; Benjamin Kroposki *et al*,2010). As these units are not centrally planned nor dispatched they are usually connected to the distribution network.

ii) Energy Storage

This is an essential feature as many renewable sources are intermittent in nature. The combination of energy storage and DER's meet the peak demands if carefully planned and help enhance the potential of these DER's. The additional advantage of energy storage is its ability to maintain the supply voltage and frequency within the limits. Its use helps improve the power quality, stability, voltage regulation and to maintain peak load. The electrical energy storage system is categorized based on the type of energy used.

B. Requirements

The interconnection of DG's to the grid involve many aspects but at a micro-level, these aspects are related to the capacity, power generated, network connection and the like. A flowchart in Fig. 4 shows the requirements that need to be met with for interconnection.

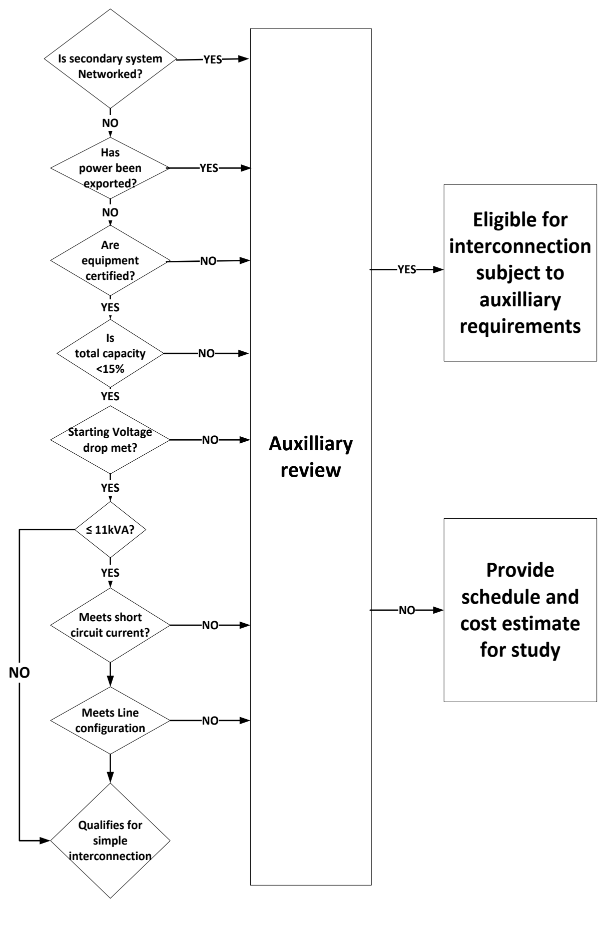

Fig. 4 Requirements for interconnection

C. Issues

The impact on the EPS is felt when there is a shift from a traditional system to a smart system. Amongst the issues of availability and the amount of energy to be harnessed lies the more critical issues of generation, network and operation which have to be such that all standards are met with.

i) Generation

The proximity of distributed power to the customer has led to an interest in on-site generation. Environment friendly photo-voltaics, micro-turbines, wind turbines, fuel cells, and other advanced distributed power technologies together with the upsurge in demand has been a driving force. This has led to customer based generation to support economic operation of the traditional grid or both. With the proximity to the customer comes reliability and improved power quality and with combined heat and power CHP comes improved efficiency. Thus, integration of renewable to the traditional grid promises cheaper, safer, more reliable, less polluting energy for consumers, generators, suppliers and the decision/policy makers.

ii) Operator

To maintain the integrity of the distribution system, the responsibility lies with the operator. It is imperative that the utility interconnection requirements are met with as per the norms laid down by the regulatory authorities. The analysis of power flows and protection systems are done to ensure safety, reliability and power quality.

iii) Network

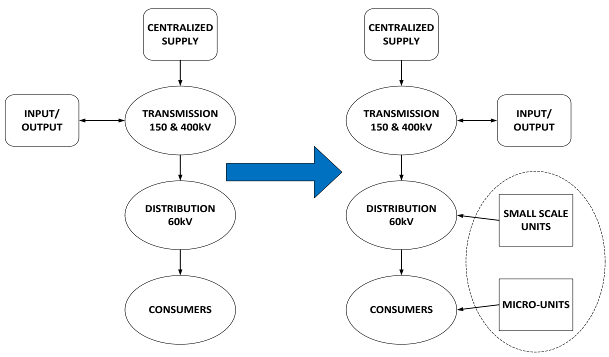

Fig. 5 Move from Unidirectional to Bi-directional system

The shift from a one-direction to a bi-direction network as seen in fig.5 brings about a lot of changes and some of the concerns are:

1) Congestion in the system due to varied load levels
2) Change in voltage profiles along the network which is different from a unidirectional network
3) Voltage transients
4) Load losses depending on the production and load levels
5) Short circuit levels
6) Increase in short circuit levels
7) Change in reliability and power quality
8) Need for change in protection of both utility and DG.

Thus, it is necessary to ensure that the design standards meet with those which have framed when the networks were uni-directional in nature. For those interconnections which are above 10MW, there are more considerations to be kept in mind.

1) Voltage regulation – the generation unit may be required to absorb or provide power (reactive) depending on the generation unit, and the point of interconnection. The additional resource must be able to maintain the requirements of the grid. Voltage changes due to tripping must be monitored closely and accurately and microgrid formation should be according to the IEEE Standard.
2) Isolation devices – the location of the isolation devices for the formation of microgrid should be located between the PCC and generating source and rating should be as per the current and voltage requirement.
3) Energization of power system, faults and reclosing – the operator has to follow the regulations as per the written agreement and requirements for intentional formation of a microgrid. The decision to disconnect or ride through a fault has to also be taken. The coordination with protection devices lie with the operator depending on the grid situation. Increase in the reclosing time may sometimes adversely effect on other consumers so this has to be done with dead line checking or transfer trip to ensure isolation of source before any automatic reclosure
4) Frequency and harmonics – these have to be maintained to ensure good power quality. Multiple DG's may be connected at different points and have individual distortion effect to be within the permissible limits, however the combination may not be within limits.
5) Unintentional islanding – transfer trip may be meet the IEEE standards of unintentional islanding. However, for >10MW distributed generation, the detection time should be within 10 seconds of its formation.

Implication for smart grid development

The smart grid has many interpretations and these are entirely based on the perspective of reference. The significance of the smart grid is in how we perceive it and how it reflects the changes in terms of generation, transmission and the use of electrical energy. The smart grid is the solution to many of the existing problems of the traditional grid as discussed in the reports for various implications with regard to communication technologies and standards (NREL CP-550-47000,2009; Basso *et al*,2011; Vehbi C *et al*,2001). The technical specifications and standards for interconnection are as per the IEEE Standard 1547. Smart grid is an integrated solution to four main issues which are a) operational efficiency b) energy efficiency c) satisfaction to customers and d) green agenda. For all the issues taken care of while creating a 'smart grid' the use of distributed generation is important.

Regulations specified for most of the interconnections have been designed for low penetration of DG. However, with the need to meet the power demand, higher penetration is being experienced. Fig.6 shows the changes which need to be brought about to the DG for smarter interconnection and better delivery of electrical energy.

With the evolution/changes in the DG's there are changes which are made to interconnection rules of the area/state. The advantages of the smart grid include:

a) Easy deployment – the accessibility information (real time) from the smart grid to the operator allows for simple interconnection and greater flexibility for manage applications.

b) Improved management of bi-directional flow – in cases where the generation by the DG's exceeds the load demand, this power can be rerouted to the utility. The voltage regulation and protection systems have to be managed and with the smart grid monitoring function this task is simplified.

c) Higher penetration level – provisions/modifications can be made to facilitate higher concentration of distributed generation. This is based entirely on the knowledge about the feeders, grid and DGs.

d) Dynamic integration–remote monitoring and generation of reports from distributed resources allow operators to dispatch other sources to meet the load demand.

e) Reduced down-time–improved inverter design interfacing the DG's to the smart grid allows operational problems in the utility to be detected and may allow operation during some of these disturbances.

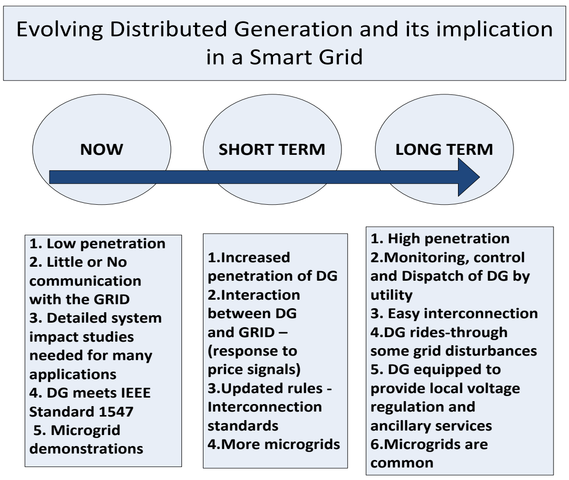

Fig. 6 DG evolution for Smart Grid interconnection

f) Power maintenance during system outages – the formation of micro-grids are allowed by the smart grid where the loads disconnect automatically and automatic re-closure occurs when the conditions are normal. Within the microgrid the DG's continue to meet the load demand.

g) Ancillary services – the smart grid's infrastructure enables the operator to provide ancillary services under certain circumstances in addition to allowing the operator to manage the DG.

All these together make for a requirement of an evolution of distributed generation and the short term and long term need for evolution is highlighted in Fig.6.

Conclusion

The complexity of interconnection and integration of DG's into the existing electricity system involves various challenges to achieve goals of the society at large. These technical challenges are towards better power quality and protection, load balancing during operation, proper regulation of access and policies which address the customers' needs first. Newer technologies and reformed standards will change the scenario of distributed generation interconnection in the future which will in turn affect the smart grid. However, the benefits such as the ability to use of naturally dispersed renewable sources make it essential that its adoption is achieved in a short time. Advanced technology for better inverters and smart grid deployments are also needed. This will help in easier, faster interconnection without any detailed impact studies. To add to it all, states will need to update and renew their technical interconnection standards and procedures and provide additional facilities and change operating practices to permit potential owners of distributed generation to connect their "1547-compliant" systems to the electric grid.

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