Connection criteria for distributed generation

Cigré task force C6.04.01 was formed by study committee C6 with the title “Connection Criteria at the Distribution Network for Distributed Generation (DG).”

In this regard, Cigré has produced a brochure, whose contents include:

- A review of the current connection criteria and protection practices applied in various countries for DGs, with special emphasis on the case of wind generators/wind farm integration.
- A review of existing international standards.
- A description of simplified methods applied to DG connection in various countries.
- Connection analysis techniques and identification of inadequacies and new requirements.
- Formulation of recommendations

Identification of issues
The main issues that should be considered with the advent of DG on distribution networks are:

Steady state and short-circuit constraints
The power delivered by a DG unit may lead to an increase in the current flowing on the distribution grid to which it is connected, depending on where it is connected and the size of the installation. Moreover, in faulted situations, the DG plant contributes to the fault currents on the network. This contribution may be more or less significant depending on the technology used and in particular on the “coupling system” used (e.g. machine directly connected to the grid or coupled through power electronics converters).

Power quality issues
Depending on the primary energy source and on the technology used for the conversion process, the connection of DG units to the grid may reduce the quality of supply on the network [1]. The degradation of the power quality may affect the installations of the network users and prevent the network operator from meeting its obligations. The impact also depends on the technology used, especially for the coupling with the grid: for instance, coupling systems making use of an electronic interface may help to limit or even to avoid voltage fluctuations or flicker but may carry a risk in terms of harmonic pollution. Fluctuations of the power delivered by DG plant, switching operations (start up), the power conversion (e.g. the wind turbine tower shadow effect) and power electronic conversion may cause:

- Slow voltage fluctuations
- Fast voltage fluctuations or voltage step changes
- Harmonic and Interharmonic Emissions
- Unbalance
- Disturbance of the signaling system

Reactive power and voltage control
The connection of a DG unit changes the voltage profile on the grid due to the change in the active and reactive power flows in the network impedances. Generally, the voltage increases at the connection point and on the feeder. It should be noted that a voltage increase (or decrease) on a given voltage level may affect the voltage profile on lower voltage levels. The control of the voltage or the reactive power is therefore an important issue for the Distribution Network Operator (DNO), which leads to requirements concerning the contribution of DG plants to the voltage or reactive power regulation on the distribution network. The larger the capacity of the DG unit, the greater its impact will be on the grid and therefore the greater the potential to contribute to the voltage control. Consequently, large DG plants are generally requested to provide more “complex” contributions than smaller ones.

Contribution to ancillary services
Definition of ancillary services may be rather different from country to country, however, they may generally be classified in the following main categories expressed in terms of contribution to specific system requirements:

- voltage control
- frequency control
- stability control
- system restart

Ancillary services were and are still mostly provided by centralised power plants connected to the transmission network and therefore the definition and characteristics of ancillary services were devised in this context. With the advent of DG on distribution (and transmission) networks, these definitions might need to be adapted, extended or revisited, in order to answer questions like: What are or what should be the ancillary services for distribution grids? How should these be related to the transmission grid? Who could/should provide them and how?, etc. As far as DG is concerned, depending on the technology involved and on the primary energy source, the capability to contribute to ancillary services will be quite variable.

Stability and capability of DG to withstand disturbances
Stability of DG units and their capability to withstand disturbances become a more and more important issue. Following the occurrence of disturbances on the network (short-circuits, important line outages, voltage dips, loss of generation plants, or important load variations), the loss of DG plants results in a loss of generation and of support to the network. Depending on the amount of lost DG generation, the situation on the grid may worsen and in some case lead to very severe stability problems. In distribution grid connection criteria, requirements are already often specified concerning the capability of DG to operate under specific voltage and frequency ranges that can occur in degraded conditions.

Protection aspects
The connection of DG units may affect the sensitivity and selectivity of the protection system as a whole. For instance, some faults may be undetected by the protection normally dedicated to their detection or their clearing may require the tripping of much larger parts of the network than necessary. Besides, the presence of DG units must not lead to unwanted tripping of parts of
the network (such as neighboring feeders not affected by the fault) and it should not prevent the proper operation of the automatic or manual reclosing scheme that may be implemented. Generally, detailed case by case studies have to be done to determine whether the protection system will still operate properly after the connection of DG.

Islanding and islanded operation

Unwanted islanding is not desirable because this may cause large voltage and frequency variations on the islanded grid and the supply of power to the customers under abnormal conditions until either the system collapses (or the DG units are disconnected) or the balance between generation and consumption is obtained. Since detection of islanding is not easy, anti-islanding criteria rely on variations of electrical quantities which may be due to other phenomena and then lead to “nuisance tripping”; There is also a possibility that an islanded situation will not be detected, in which case, there may be a risk for the safety of people and equipment.

On the one hand, islanded operation may sometimes be useful and even desirable. For instance, in the case of blackouts or long duration cuts of supply for distribution feeders (due to important problems on the transmission grid), islanded operation of distribution feeders would allow supply of power to the customers until the system is restored. As another example, in certain areas where the transmission network is often subject to disturbances (e.g. strokes of lightning) and voltage dips, islanded operation may be interesting to provide higher quality of supply.

There is always a cost associated with the integration of DG as there is with the introduction of any generation source. The utilities in different countries choose to either absorb this cost, charge the producers or share the cost. Various countries implement different strategies and this affect the level of DG integration. Whereas cost is a major source of conversation, the benefits of DG are not as often discussed and rarely, if ever, are they quantified. Some countries have incentive programs for alternative energy sources and in some isolated cases are compensated for ancillary services, in general, the cost-benefit relationship and methods for their determination have yet to be understood and implemented.

Key issues and recommendations for further research and standardisation activities

Determination of DG installed capacity

A clear procedure for the definition of the requirements to calculate the possible DG capacity to be installed at one point of the network. The adoption of simple rules might not be appropriate, while more detailed calculations can often show that more generation can be connected with no difficulties. A probabilistic approach is shown to provide an objective assessment of the possible constraint violations, while a deterministic approach based on worst case situations leads to conservative results.

Deep versus shallow charges

The allocation of “deep vs. shallow charges” for possible reinforcements required to facilitate the connection of DGs should be re-examined. Several countries apply “deep connection” charges having a major impact on the ability of new DG installations. Possible allocation mechanisms should be detailed and evaluated.

Active distribution networks

The overall performance of a distribution system with a significant penetration of DG maybe optimised, if DGs are considered by the DNOs as one more control parameter in scheduling their network operation. For example, in some cases, the voltage rise can be limited by reversing the flow of reactive power (Q). In these cases, the DNO should clearly define under which conditions this should be allowed. Market mechanisms and pricing policies for the participation of DGs in ancillary services at the distribution level are lacking in most countries.

Current connection criteria in various countries for DGs

This Section reviews the current connection criteria applied in 12 countries for DGs, namely France, Spain, Italy, Canada, Greece, Croatia, Portugal, the Netherlands, Germany, Austria, Norway and USA. The considerations include the interconnection requirements, protection practices, capacity assessment techniques, and the cost of the interconnection. While these issues are important in order to guarantee safe and reliable operation of the power system, they may also lower its growth and present themselves as barriers to the integration of DG. Whereas regulatory aspects can differ greatly between countries, in general interconnection requirements are similar, usually the result of collaborative efforts in the development of internationally accepted standards.
Unintentional islanding

With increasing penetration levels of DG intended to support reactive power, voltage or frequency control, the potential risks associated with unintentional creation of an island may not be neglected. Hence additional protection methods to the standard voltage and frequency monitoring are required in order to detect a loss of mains at the generator and ensure the safety of customers and maintenance personnel.

Controlled islanding - microgrids

One of the potential key benefits of DG, being connected at the MV and LV networks, is increase in service quality, reliability and security. A radical shift from traditional central control philosophy to a more distributed control paradigm is provided by Microgrids. These systems can be operated in a non-autonomous way, if interconnected to the grid, or in an autonomous way, if disconnected from the main grid. The operation of Microgrids requires significant efforts in research, development and deployment of new technologies and required information and communication infrastructure, but is likely to deliver significant benefits over the traditional control policy in the long term.

DG behaviour during network disturbances

Most current DG related standards do not require a defined response of DG during typical network disturbances, such as voltage sags. This has led to a general lack of awareness towards these phenomena in context of DG and an unacceptably low level of equipment immunity. Moreover, the safe and secure operation of networks based on a high penetration of DG requires a defined response of the generation units during critical conditions and network disturbances. Of specific significance in this context are issues such as LVRT (low voltage ride through) capability or voltage support during disturbances.

DC injection into the LV network by DG inverters

Currently the maximum levels of DC current which maybe injected by distributed inverters according to various national and international codes vary in a wide range from levels as low as 20 mA up to 1 A or 0,5% up to 5%. Applying a fixed level is explicitly recommended to avoid imposing unnecessary requirements on micro-scale DG.

Conclusions

While there have been major developments in distributed generation over the past couple of decades, the industry is not yet mature. Pushed forward by policy changes which favour renewables, new technologies are only now being adopted, with many new planned wind projects worldwide, many of the new turbines, like many DG, employing power electronics as a means of interfacing with the grid.

Utilities, governments, and regulatory bodies have addressed this growth by developing interconnection requirements aimed specifically at these types of generation. International, such as the IEC and IEEE, standards are now in place, that dictate conditions which interconnecting that DG must abide by covering normal operation and contingencies. However, the majority of these standards have been developed from the point of view of ensuring that DG does not negatively impact the grid rather than integrating DG and making it a functional unit of the modern power system.

This paper compares the connection requirements followed by 12 countries and identifies key issues that may unnecessarily limit the penetration of DG. This is subsequently followed by recommendations for further standardisation activities that will lead to integration of DG. These include a clear procedure for the determination of DG installed capacity, the operation of active distribution networks, the prevention of unintentional islanding and the conditions for controlled islanding, the DG behaviour during network disturbances and the limits of DC injection into the LV network by DG inverters.

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References