

Review of the Distributed Generation Concept: Attempt of Unification

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Abstract. This paper is a review of the different distributed generation concepts of the bibliography. It presents the most known concepts of international and regional institution, and summarizes and characterizes all concepts to make an inclusive concept like results and conclusions of this paper.

Key words

Definitions, distributed generation, distributed resources, distributed energy resources, embedded generation.

1. Introduction

When the electricity supply industry began its activity the need for electric energy in a place was, in general, satisfied by local companies that installed generators located according to the distribution needs. This way, the history of the electrical power system began using distributed generation (DG), in other words, generation directly installed in the distribution network, very near to the demand [1].

Later on, the increasing electricity demand was satisfied installing huge generation plants, generally near the primary energy sources (e.g. coal mines, rivers, etc.), and the growing needs of electricity and security the use of complex transmission system to delivery the electricity to consumers, gave as result the traditional conception of the electrical power system. This conception, that has been in existence for more than fifty years, and has been characterized for: big generation plants, generally placed far from where the power demands is, and great transmission networks that carry the generated power to the demand sites. One of the main elements in this development logic is that the taking of decisions comes

from a centralized planning generally placed inside a vertically integrated industry. [2] Evolutionary changes in the regulatory (stimulating the competence) and operational climate of traditional electric utilities and the emergence of smaller generating systems such as micro turbines have opened new opportunities for on-site power generation by electricity users [3]. Moreover the electric market growth, the financial market's development and the accelerated technical progress have made the optimum size in new investments in generation to decrease, in relation to the market's size and to the private financial capacity [2]. As a result, there have appeared new conditions in the generation sector, making it able to be co-ordinated by the market [4].

In this context, distributed energy resources (DER) - small power generators typically located at users' sites where the energy (both electric and thermal) they generate is used - have emerged as a promising option to meet growing customer needs for electric power with an emphasis on reliability and power quality [3].

This paper provides a bibliography review of the distributed generation concepts provided for international and regional institutes over worldwide. And the conclusion of this paper is a compressive and simple concept, that summarize the most important and relevant characteristic of all concepts showed in this paper.

2. DG Definitions: Brief Summary

A. Distributed Power Coalition of America (DPCA)

Distributed power generation is any small-scale power generation technology that provides electric power at a site closer to customers than central station generation. A

distributed power unit can be connected directly to the consumer or to a utility's transmission or distribution system [5].

B. International Conference on High Voltage Electric Systems (CIGRE)

Distributed generation is [6]:

- Not centrally planned.
- Today not centrally dispatched.
- Usually connected to the distribution network.
- Smaller than 50 or 100 MW.
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C. International Energy Agency (IEA)

Distributed generation is generating plant serving a customer on-site, or providing support to a distribution network, and connected to the grid at distribution level voltages. The technologies generally include engines, small (including micro) turbines, fuel cells and photovoltaic. It does not generally include wind power, since most wind power is produced in wind farms built specifically for that purpose rather than for meeting an on-site power requirement [7].

D. US Department of Energy (US. DOE)

Distributed generation - small, modular electricity generators sited close to the customer load - can enable utilities to defer or eliminate costly investments in transmission and distribution (T&D) system upgrades, and provides customers with better quality, more reliable energy supplies and a cleaner environment [8].

Another definition of US DOE establishes that Distributed energy resources (DER) refers to a variety of small, modular power-generating technologies. DER systems range in size and capacity from a few kilowatts up to 50 MW. They comprise a portfolio of technologies, both supply-side and demand-side, that can be located at or near the location where the energy is used [9].

E. Electric Power Research Institute (EPRI)

EPRI make the DG definition implicit in an overview of the integrating distributed energy resources. This establishes that the new system would also be able to seamlessly integrate an array of locally installed, distributed power generation (such as fuel cells and renewables) as power system assets. Distributed power sources under 20 MW per unit could be deployed on both the supply and consumer side of the energy/information portal as essential assets dispatching reliability, capacity and efficiency. Today's distribution system, architecture, and mechanical control limitations, prohibit, in effect, this enhanced system functionality [10].

On other hand, another EPRI definition of distributed resources includes small generation (1kW to 50MW) and/or energy storage devices typically sited near

customer loads or distribution and sub-transmission substations [11].

F. Institute of Electrical and Electronic Engineers (IEEE)

The Standard for Interconnecting Distributed Resources with Electric Power System of IEEE, define distributed generation like electric generation facilities connected to an area EPS (electrical power system) through a point of common coupling; a subset of distributed resources. Some others definitions are implicit in this. EPS area are facilities that deliver electric power to a load (this can include generation units) that serves Local EPSs. Each Local EPS is contained entirely within a single premises or group of premises. The point where a Local EPS is connected to the Area EPS, receive the name of point of common coupling. Finally IEEE, define distributed resources as sources of electric power that are no directly connected to a bulk power transmission system. And the DR includes generator and energy storage technologies [12].

G. American Gas Association (AGA)

Distributed generation (DG) is the strategic placement of small power generating units (5 kW to 25 MW) at or near customer loads. Situated at a customer's site, distributed generation can be used to manage energy service needs or help meet increasingly rigorous requirements for power quality and reliability. Located at utility sites such as substations, distributed generation can provide transmission and distribution (T&D) grid support and expand the utility's ability to deliver power to customers in constrained areas. Distributed generation technologies include such resources as industrial gas turbines, reciprocating engines, fuel cells, micro turbines, wind-power, and photovoltaic [12].

H. California Energy Commission

Distributed energy resources are small-scale power generation technologies (typically in the range of 3 to 10,000 kW) located close to where electricity is used (e.g., a home or business) to provide an alternative to or an enhancement of the traditional electric power system [13].

I. Arthur D. Little

Distributed generation is the integrated or stand-alone use of small, modular electricity generation resources by utilities, utility customers, and/or third parties in applications that benefit the electric system, specific end-user customers, or both. Co-generation and combined heat and power (CHP) are included. From a practical perspective, it is a facility for the generation of electricity that may be located at or near end users within an industrial area, a commercial building, or a community [14].

3. Implications of DG Definitions

A large number of definitions to dispersed, distributed or embedded generation already exist. Some countries have high penetration of DG, and they have technical rules or regulations for connecting this to the EPS, therefore have a clear concept or a formal definition about DG. But in spite of the great quantity of definitions, no clear consensus exists at present. Only few characteristics are common to a particular group of concepts.

Some countries used a definition based on voltage level while others consider the location and connectivity of dispersed generation into the EPS. Certain definitions relied on the type of prime mover, eg. Renewable or co-generation (CHP), while other definitions are based on the generation not being dispatched. Finally some definitions are based on a maximum power rating [1].

The non-exhaustive inventories of existing DG definitions showed on section II, and consider the brief summary on [15] and [1] clarify a thing: a large number of definitions already exist and there is no clear consistency between them.

A. Rating range

Checking summary of the definitions, we noted the difficult to extract a common view. In terms of range power rating, there is no consistency between definitions. For the time being, there is no legal definition of DG based only in power rating range. Of fact, electrical power is not used consistently to distinguish DG from central generation. Then it turns out specially attractive and suitable, to take in qualitative form the range of power rating of the DER, considering them like: generation of electricity by facilities sufficiently smaller than central generating plants.

B. Connection

The connection of DER to the EPS can be considered from several points of view. In some countries simple rules are applied to define the voltage level at which dispersed generation may be connected depending on its rated output, but this is a wide range of voltage of connection voltage. On the other hand, some definitions consider the device used to connect, or interface to the grid, in other world, the way to supply power to the grid. This criteria include the use of three type of interface to connect DG to the grid: dc/ac converters (power electronic conditioner), synchronous and asynchronous generator. But some DER uses transformer to make the connection to high voltage grids.

The most of DG connection is to the distribution network, but some countries (almost on Europe) consider the possibility of DG connected to the transmission network. Except in France and The Czech Republic most of DG connection is to the distribution network. In

France, connection to 400 kV is reported. In The Czech Republic, DG is mostly connected to the transmission network. However, for the latter, the voltage range to which DG is connected is up to 110 kV. This highest limit corresponds to the voltage level of distribution networks in other European countries. Therefore it is concluded that, if not stand-alone, DG is connected to a "distribution" level which is up to 150 kV. Therefore the connection can not used to characterize a DER definition explicitly. And as mentioned on the rating range section, the size: power or voltage is not clear indicator to characterize a DG definition. It is necessary to be just, and say, in past, the DG rating voltage was around the secondary distribution levels; today, the power conditioner, and transformer become a wider range of voltage rating.

C. Location

Geographical location is not relevant parameter to distinguish DG from central generation, through; last one generally is located not coincidental by the location of consumers. Whereas the majority of DG technologies are propitious to be installed near the consumer. Therefore this not use clearly to characterize a DG, and has led to decision that is appropriate include in the DG definition a pseudo ambiguous location, defined like generally in or near the consumer.

D. Dispatchability

Some DG technologies are dispatchables. Fossil fuel driven technologies, like reciprocate engine, micro turbines, and other like fuel cell, can guarantee the energy supply predictable. The renewable energy sources alone are generally not. In general, DER may be or not dispatchable, for this reason this feature is not included to characterize the DG definition.

4. Conclusion

A brief summary of DG definitions was presented, from different institutions around the world. The really non convergent implication in the definitions, reveal a difficult to make a unified definition: When the definition is detailed, the concept is rigid and close. For this reason the author inclines for a wide open definition, qualitative, that assimilate the contextual validity of all the other in force concepts. Finally, the distributed generation is consider as a source of electric power connected to the distribution network or to the customer site, that is sufficiently smaller than central generating plants.

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