Definitions for Distributed Generation: a revision

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1. Introduction.

The current electricity supply structures, which are characterised through large, centralised power stations, will develop into a system consisting both of centralised and decentralised electricity suppliers. The European integrated grid system will be subject to substantial restructuring due to the ongoing liberalisation of the energy market and the planned increase of the share of renewables in electricity production to 22 % by 2010. Reduction in gaseous emissions (mainly CO2), energy efficiency or rational use of energy, deregulation or competition policy, diversification of energy sources, national power requirement and commercial considerations (availability of modular generating plant, ease of finding sites for smaller generators, short construction times and lower capital costs of smaller plant and the fact that this generation may be sited closer to load, which may reduce transmission costs). have been reported [1,2,3] as some of the drivers of this new philosophy of generation.

Different studies (EPRI, Natural Gas Foundation, etc) indicates that by 2010, 25-30% of the new generation will be "distributed".

But different definitions for distributed generation (DG) are used in the literature, and as been recognised, some of them are not consistent, probably because there derive from industry practice, different experiences and objectives. For the time being, there is no legal definition of DG. Nevertheless, the term Distributed Generation is widely extended as an industry practice in the electrotechnical sector.
There are legal implications (legal support), financial, economical social, technological aspects involved.

In Spain, for instance, the term Distributed Generation or similar (Distributed/Dispersed/ Decentralised Generation/Power) is not literally mentioned in any legislative documents. The closest term employed is Special Regime (Régimen Especial; RR.DD 2818-1998, 416 2004), which comprises the following power sources –under 50 MW-: renewable (solar thermal, photovoltaic, wind, hydraulic, biomass, marine, geothermal), small cogeneration, residues and wastes. (No explicit mention to microturbines, reciprocating engines or fuel cells). Power generation accepted under Special Regime is entitled to a complementary bonus. There is a specific standard for the connection of PV installations to the low voltage grid (R.D. 1663/2000)

2. Revision of the definitions

Many authors claim for an unique definition in order to everybody understand the same. But the solution to that problem does not seem easy, because, as stated in [ ]

1. DG is, in general, not power or voltage dependent.
2. The DG technologies can be categorised as renewable and non-renewable. DG is not synonym for Renewable source.
3. Geographical location is not a relevant parameter to distinguish DG from central generation.
4. DG can be both stand-alone or grid connected.
5. DG is connected to the grid either directly or using transformers or power electronics. These include protection systems as well as measuring and metering devices.
6. In most countries DG is connected to the distribution network. In future however, large offshore wind farms larger than 110 MW could be connected to the transmission grid.
7. The benefits of DG are environmental protection, power quality, reduction of T&D losses and investments, use of domestic fuels and diversified resources, back up and peak shaving, CHP

applications, network reinforcement and energy supply for remote areas, and increase of local employment.

Let´s think in a power system in any country, some years ago. There was electrical generation scattered (dispersed) in the territory: not every power station were in the same place. The centralised and usually big generation units were where the resources were (e.g. hydro, thermal plants with coal…) or where good technical conditions (refrigeration, evacuation, etc.) exist. They were linked by transmission lines and the energy is absorbed by consumers (big consumers and small consumers) scattered also in the whole territory.
What is different now? The number of generation units has been growing; there are a lot of different ratings: big units, medium, small and even microgenerators; some of them are connected to a high level of voltage, some of them to the lowest; there are many different technologies, different sources, renewables or not: some of them are centrally planned and controlled, and some of them are not.

Let´s have a look on some of the existing definitions:

DPCA (Distributed Power Coalition of America)1
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.

CIGRE (International Conference on High Voltage Electric Systems)2
Distributed generation is
- Not centrally planned
- Today not centrally despatched
- Usually connected to the distribution network
- Smaller than 50 or 100 MW

IEA (International Energy Agency)3
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 photovoltaics. 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.

US Department of Energy4
Distributed generation - small, modular electricity generators sited close to the customer load that can enable utilities to defer or eliminate costly investments in transmission and distribution (T&D) system upgrades, and provide customers with better quality, more reliable energy supplies and a cleaner environment.

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.

Swedish Electric Power Utilities and T. Ackermann et al 5
Distributed generation is a source of electric power connected directly to the distribution network or on the customer site of meter.

Amended proposal of the Directive 96/92/EC
Distributed generation shall mean generation plants connected to the low-voltage distribution system.

ENIRDGnet WP1
Distributed Generation is a source of electric power connected to the distribution network or to the custormer site

Other various definitions of DG proposed by some companies of the different countries in Europe are based on different parameters (rating range, location, connection, dispatchability etc). A brief summary of each definition is given below [ ]:
- Standardised and modular generation source using RES in a range of up to MW (Austria)
- Co-generation connected to the distribution network (Belgium)
- Source less than 10 MW, not centrally planned and connected to the Distribution Network (Bulgaria)
- Source not operated by utility (Czech Republic)
- Source without agreement between the owner and the TSO (Denmark)
- Source less than 50 MW for local consumption and/or for selling to the utility (Estonia)
- Source less than 20 MW, not centrally planned and not centrally dispatched, and connected to the Distribution Network (Finland)
- Electricity generation plant owned by a third party, connected to the grid (France)

- Integrated or stand-alone modular source close to the point of consumption (Germany)
- Small scale power generation connected to distribution grid (Greece)
- Source less than 10 MW using RES or co-generation used mainly for Heat (Hungary)
- Co-generation less than 1 MW rating and close to the end user (Italy)
- Generation not active in system balancing (The Netherlands)
- Source connected to the Distribution Network (Norway)
- Electricity or Heat source connected to the user (Poland)
- Decentralised source less than 50 MW rating (Romania)
- Source less than 100 MW, not centrally planned and dispatched, and connected to the Distribution Network (Slovakia)
- Modular generation less than 50 MW located at the customer site (Spain)
- Source connected to the Distribution Network or to the customer site (Sweden)
- Source not connected to the Transmission system (UK)
- For the Republic of Ireland, the definition deals with 'small generators' or 'embedded generators' but not directly to distribution generation.

As conclusion, we can consider that a large number of definitions already exist; there is no clear consistency between them.
Too many criteria are used and it is difficult to extract a common view. The principle of matching local supply to local demand, which appears in number of definitions, leads to the exclusion of hydro and wind power as explicitly stated in the IEA definition.

3. Characteristics of the new generation

This multiple, diverse and dispersed generation can provide a number of services to customers and utilities. From the utility side: grid support and avoidance of expensive upgrades. From the customer side: standby generation, peak shaving, stand-alone generation

Prime movers for these generation systems include internal combustion engines, combustion or gas turbines, steam turbines, microturbines, wind turbines, solar (photovoltaic and thermal), fuel cells, hydro and ocean (tidal and marine current).
The engine and turbine based prime movers (except wind) are capable of burning a variety of fuels, including natural gas, coal and oil, and alternative fuels such as wood, biomass, black liquor and process gas. All types of fuels (non-renewable and renewable) are used allowing for wind, hydro, ocean. The generation technologies can be classified into renewable and non-renewable. This classification means that DG is not a synonym for Renewable Energy Source. The DG technologies based on renewable are:
- wind,
- photovoltaic and solar thermal,
- ocean (tidal and marine current),
- hydro (small).

The non-renewable DG technologies are:
- micro turbine, combustion turbine, steam turbine,
- combined cycle,
- internal combustion engine.

Fuel cells can be classified as renewable (using hydrogen) or non-renewable (using natural gas or petrol).
A consensus about large hydro should not be part of DG exists but this limit is not clear.
When convenient, instead of DG, we must tell renewable (or not renewable) energy.

The ranges of electrical rating of DG technologies are:
Wind A few W to few MW
Photovoltaic and solar thermal A few W to few MW
Fuel cell A few tens of kW to few tens of MW
Ocean A few hundred kW to few MW
Micro turbine A few tens of kW to few hundred of kW
Combustion turbine A few MW to hundreds of MW
Gas turbine A few hundred kW to few hundred of MW
Steam turbine A few tens of kW to several hundreds of MW
Combined cycle A few tens of MW to several hundreds of MW
Internal combustion engine A few kW to tens of MW

Electrical power rating is not used consistently to distinguish DG from central generation.
If the power output is used only within the local distribution network, Ackermann suggested the term embedded (distributed) generation.

For most of the analysed countries there is a wide range of connection voltage, from BT to 132kV. Therefore voltage range can not be used to characterise a DG.
Three types of interface arrangements are used to connect DG to the grid: dc/ac converter, synchronous and asynchronous generator. Transformers are used to connect DG to higher voltage grids. These elements are completed by

protection systems, measuring and metering. Many countries have a specific standard for connection of DG to the grid although they have no official definition of DG (Austria, Belgium, Czech, Denmark, Estonia, France, Greece, The Republic of Ireland, The Netherlands, Sweden and UK).

Therefore it is convenient to introduce categories of generation in:
Renewable/not renewable
Micro/Small/Medium/Large
Centrally dispatched/Decentralised
Embedded/exporting
Stand alone/Connected to the grid
From an utility point of view, it could be interesting to indicate also the capacity for reactive power control, voltage control, sag response, range of prediction, etc., and take into account the ratio and level of penetration.

4. Grid integration

So we must admit that a lot of different generation units, with their own characteristics are going to be connected to the grid. The network have to be designed to accept this multiple, diverse and dispersed (distributed, if you want) generation. The process will place new demands on equipment technology and electrical engineering as a rising number of decentralised micro generators makes their increasingly tight integration into the grid control system necessary. For the realisation of this “distributed electricity generation”-scenario it will be necessary to develop novel management units and communication concepts.

In this changing environment, which will be characterised through low reserve capacities on the one hand and increasing numbers of fluctuating generators on the other hand, future R&D efforts must contribute to securing network stability and supply reliability. One of the related pre-conditions is the right energy mix. This will however have to be complemented by bi-directional energy management, efficient communications structures and trading systems as well as novel grid deployment planning processes, altogether based on advanced information and communications technologies.
The following technical constraints to this multiple, diverse and dispersed generation are reported:
- Technical restriction on the network (mainly due to voltage limitations on rural networks and fault level restriction on urban networks. The connection of a DG often requires upgrading of an existing network because of its operating close to the existing fault level. If rotating machines are used in the DG system, they will contribute to increase the fault level. Moreover, the connection of a DG to a network means a voltage rise)
- Existing network design procedures
- Safety issues
- Potential disturbance and the need for auxiliary devices
- Need for sophisticated metering and control protocols

In the future the utilities should be able to:
• control, schedule and dispatch DG in an economically optimal manner; intelligent control of generators, load and storage systems, integration concepts regarding fluctuating renewable energies and decentralised electricity generation units into the grid (communications interfaces, output forecasting etc.), energy storage (thermochemical heat storage, redox flow batteries, flywheels, supercapacitors, pressurized air, superconductive coils etc.),
• connect to a large number of DG to check the availability of capacity across a wide area,
• connect to and collect site demand loads,
• develop modelling and simulating tools for the design of highly decentralized energy supply systems
• improve the quality and safety of the electricity supply in lower voltage grid segments in the presence of excess of local electricity generation, management of bi-directional energy flows, harmonic levels/ flicker etc.
• re-design and strengthening of the energy grids to ensure an adequate capacity for levelling out fluctuations, including upgrading and extending trans-national links
• sort out any problems, diagnose faults, and analyse data and faults remotely,< failure detection, overcurrent protection, avoidance of islanding etc

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