SPECIFIC ISSUES OF DISTRIBUTED GENERATION IN POWER SYSTEMS

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Abstract – Distributed Generation Systems (DGS) gets lately more and more importance in the context of concepts re-thinking within the electricity distribution networks. Understanding the key issues of DGS such as definition, technology and integration is important for the researchers and for the workers in the field as well. This paper aims to synthesize the DGS specific issues and finally conclusions are presented.

Keywords: distributed generation, centralized generation, distributed generation system, renewable resources, DGS integration to power systems

1. INTRODUCTION

Electricity production has developed continuously since XIX century, passing through various stages. At first, power generates locally, servicing small consumers by single phase networks. With the passage of three phase networks, it was moved to a new phase, which consumers become more and more diversified. Immediately power demand increased rapidly, thus appearing the great power plants on fossil fuels. Those plants were located at the beginning near the primary energy resources, but with the development of the transport networks, these place dependence was eliminated.

Until recently, power generation was based on a following paradigm: electricity was generated in large centralized power plants, transmitted than to the consume areas through national power transport networks and finally arriving at the consumer via distribution networks. The interconnection between different national power networks has allowed the import and export of the produced electricity. Fig. 1 illustrates this model and it can be noticed that power flows in one direction, from higher level of voltage, represented by the transport power network, to the lower level of voltage, which is usually located the consumers.

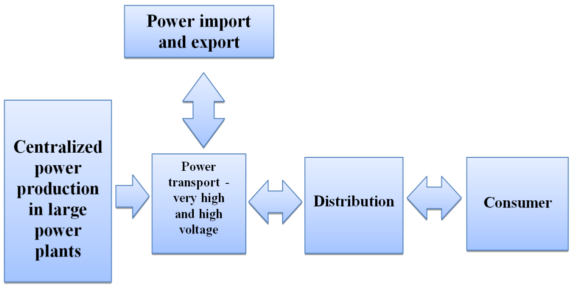

Fig. 1. Power flow in centralized generation [1]

This model is named under the generic name of “centralized generation” (CD).

When small generation capacities are connected in certain network points, usually closer to the consumer, this paradigm changes, the power flow become bidirectional and it is named “distributed generation” (DG), such model being illustrated in fig. 2.

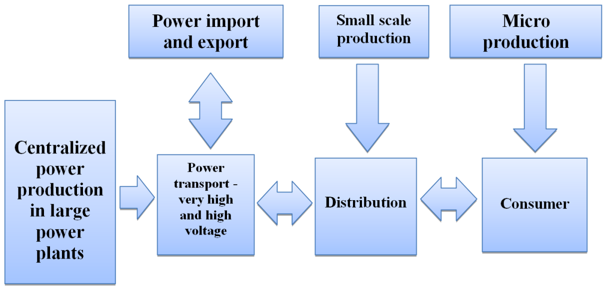

Fig. 2. Power flow in distributed generation [1]

2. THE PROBLEM IN DEFINING OF DISTRIBUTED GENERATION SYSTEMS

To give a unified definition of the distributed generation system (DGS), it must be overcome the following barriers [2, 3, 4, 5, 6] which the immediate reality imposes:

- *The variety of terms used* - only for exemplification, the Anglo-American countries use for the DGS the term of “embedded generation”, while the European and part of Asia countries utilized for the same systems the term of “dispersed generation”;
- *The purpose of the system* - there is an agreement between different organizations regarding the purpose, which is to provide active power and not necessarily reactive power;
- *The connection point* - it differs from case to case: some of the systems being connected on medium voltage, some at low voltage and others even at high voltage;
- *The installed power* – also differs from country to country, for example some of the countries consider DGS any power plant under 100 MW and other consider DGS a wind farm of 1500 MW ;
- *The power delivery area* – a DGS must serve local consumers, but in some countries, the same DGS which serve local consumer during the day, inject power in network during the night, in this mode the

power delivery area engulfed the whole distributed network;

- *The technology used* – there is a variety of technologies used in DGS, covering both conventional resources and renewable one;
- *The environmental impact* – a reduced impact on environment is realized only by the DGS based on renewable resources, the rest of the systems may reduce the negative impact only by reducing losses in transport lines;
- *The mode of operation* – some countries impose that a DGS with installed power over 100MW must submit on the market regimentations, other countries consider different;
- *The ownership* – there are cases that a DGS is owned by a private company as well an national one;
- *The degree of penetration* – the covered power at the consumer of a DGS is influenced by the network area and its operating regime so, on a specific moment, the DG penetration degree reach a certain level.

A generally valid definition of the DGS which make no reference to installed power or to the voltage level of connection, which didn't bound such systems to a certain power delivery area or a particular ownership or degree of penetration, which didn't refer to the technologies used, were give by [2]: *an electric power source system connected directly to the distribution network or on the customer site of the meter*. This definition leaves the distinction between distribution and transport networks to specific regulations of each country or power market.

It is noticed that the factors described above has no relevance in defining a DGS, being at most a classification criterion.

3. THE TECHNOLOGIES USED IN DGS

Current practice has shown that in case of DGS there is a variety of technology used, the range of these technologies are described by the International Energy Agency [7] and can be synthesized in table 1.

Table 1: Range of DGS technology

No.	Technology	Typical installed power per module
1	Reciprocating engine	5 kW - 10 MW
2	Micro turbine	35 kW-1 MW
3	Combined cycle gas turbine	35-400 MW
4	Small hydro	1-100 MW
5	Micro hydro	25 kW-1 MW
6	Wind turbine	200W-3 MW
7	PV systems	20W-100 kW
9	Biomass	100 kW-20 MW
10	Fuel cells	10 KW -200 MW
11	Geothermal	5-100 MW
12	Ocean energy	0,1-1 MW
13	Hybrid systems	> 5 kW
14	Battery storage	500 kW-5 MW

Table 1 show that the technologies from 1 to 3 utilized conventional fuels and can be called "environmental friendly" only if it run on biofuels, while the technologies from 3 to 13 utilized renewable resources with low negative impact on environment. In all of these cases, the DGS utilize usually the following types of generators: synchronous generator (wound rotor or permanent magnet), asynchronous generator and (wound rotor or squirrel cage) and power electronic converter interface.

4. ISSUES IN DGS INTEGRATION TO POWER SYSTEMS

The problem of DGS integration to power systems presents an increasing relevance due to increasing in number of these systems and its operators in the context of power market liberalization. Several important key issues of in the integration of DGS in power systems can be synthesized as follows [1]:

Concept definition:

Just as in the case of DGS definition, having a clear concept of DGS integration in power systems offers a clear view on the issue: *DGS integration in power systems means connecting DGS generators to the power network taking into account that DGS operate correctly and safely with optimum capitalization of the power resources* [8].

Regulatory issues:

This problem appears when there is a separation between power supplier and network operator, which is the case for most of the European Union countries. In these situation, the suppliers operates on a free market and the network operator on a regulatory one, so it is a clear need to be developing by these countries an appropriate regulatory policies in order to support the future growth of the DGS integration in their power systems [9].

Operation and control:

The higher the number of the DGS connected to a network the greater are the effects on it. Furthermore, these systems are not dispatchable and the electric energy produced is often unpredictable, especially in case of DGS based on renewable resources.

Acceptability:

Basically there are two factors of acceptability when a DGS is connected to a power network: *short circuit power* in the connection point and the *power of the DGS electric generator*.

The short circuit power in the connection point is given by the relation [1]:

$$R_{sc} = I_{scDGS} / I_{maxDGS} \tag{4.1}$$

Where:

I_{scDGS} = Short circuit current on DGS site;
I_{maxDGS} = Maximum current generated by DGS.

International experience reveals that if $R_{sc} > 200$ it is unlikely to appear flicker or voltage variations in stabilized regime, but if $R_{sc} < 50$ it is possible to appear power quality problems in electrical network. Also if the DGS is based o renewable resources and $R_{sc} \geq 100$ it must be impose more severe connecting conditions [8].

Maximum power of the DGS electric generator is given by the fact that generator influence on network at connection point is acceptable, table 2 showing values of maximum generator power on different network area with the corresponding voltage.

Table 2: Voltage levels for DGS connection with maximum generators power [8]

Network location	Maximum power of the DGS electric generator
0,4 kV networks	50 kVA
0,4 kV bar	200 – 250 kVA
(11-11,5) kV networks	2 – 3 MVA
(11-11,5) kV bar	8 MVA
(15-20) kV networks+bars	(6,5 - 10) MVA
(63-90) kV networks	(10 - 40) MVA

Voltage connection level of the DGS:

It is important to notice that the higher is the connection voltage level the higher are the costs of the equipment needed for DGS connection. On the other hand, if an DGS owner try to connect it at lower voltage levels, it might be possible that the network operator didn't accept it due to the bigger influence of DGS generators in that network area.

Voltage profile modifications:

A DGS connection in a certain network point leads to the increase of voltage both in the connection point and in nearby network areas, fig. 3.

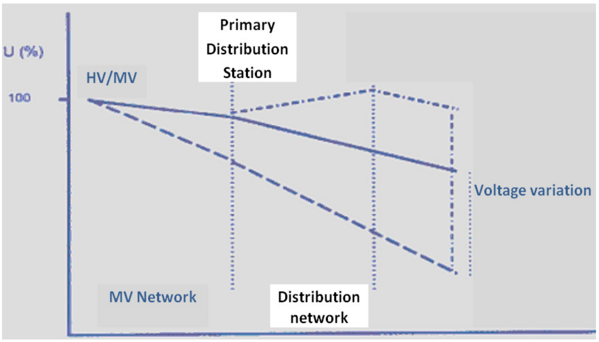

Fig. 3. Voltage variation in connection point and nearby areas [8]

If these increases are beneficial or not, depend on the following factors [1, 8]:

- Penetration level of DGS;
- Network characteristics;
- Consumption characteristics.

Increasing of short circuit power:

When a DGS is connected to an existing network, the short circuit current increases, especially when synchronous generators are involved, fig. 4.

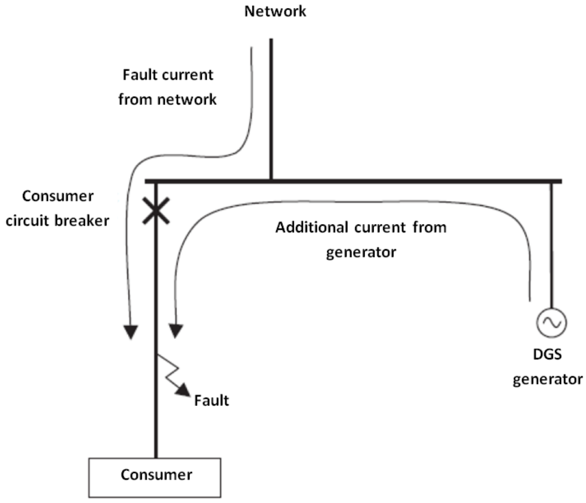

Fig. 4. The increasing current through consumer circuit breaker [8]

Fig. 4 shows that in case of a fault, the synchronous generator contribute to the fault current and the maximum fault current which the circuit breaker can break can be exceeded. That involves supplementary cost to modernize this circuit breaker or even to replace it.

Power flow changing:

When a DGS is connected to a network it injects a supplementary power so the power flow it's modifying in sense of it can increase, decrease or even invert. But the power flow involve a current circulation, it can happen that due to current flow modification the maximum thermal limit of the network elements to be exceeded. In this way it can be a limitative factor in DGS penetration to power networks.

Improper operation of network protections:

If a DGS is connected to a MV network a coordination of its synchronous generator protections with the network protections it's a must. Lack of protections coordination leads to a series of negative situations such as [1,8]:

- The network relays cannot detect the injected current of the DGS generator;
- The DGS generator cannot be isolated in case of fault;
- Incorrect operation of the network relays.

Power quality of the network:

There are four effects which the DGS connection to a network can produce [1,8]:

- ➢ Voltage fluctuation, especially to the DGS on renewable resources, due to modifications of the produced power with the resource fluctuations. If these fluctuations are fast and cyclic it may lead to flicker;
- ➢ Overvoltage due to big DGS generators;
- ➢ Voltage dips due to protections functioning. If there are several DGS with big generators which the protections are kicking out, it can reach loosing the stability of the network;
- ➢ Harmonic pollutions due to power electronics of the DGS.

CONCLUSION

The internationally increasing interest in DGS was due to technological innovations and changes in the legislative and economic environment. However there are three important issues to keep in considerations when we are dealing with such systems: a clearly defined concept, technology within DGS and integration in power systems. The last issue has an increasing relevance due to increasing DGS penetration in existing networks bringing various technical and economical challenges [1, 7, 9].

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