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THE IMPACT OF SMALL WIND FARMS ON POWER DISTRIBUTION GRIDS. ROMANIAN STUDY CASE

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ABSTRACT
Nowadays, the wind represents one of the most used renewable energy resources. Worldwide, at least 11 kWh can be obtained annually from wind energy per square meter of land. Nowadays, the connection of DG (particularly of wind farms) to the public distribution grids is an important item, due to the impact of these DG technologies on the power distribution grid. This paper presents the effects of small wind farms connection to the distribution grid. Consequently, general aspects and issues (faults, short-circuits, power quality) about the impact of wind farms are described. Paper also includes a study case describing the impact of a real Romanian wind farm. The permanent and transient operating state of the power grid is considered, and some conclusions regarding the analyzed system are finally presented.
Keywords: distributed generation, wind farms, connection to public networks, study case in Romania

1. INTRODUCTION

During last several decades, Renewable Energy Sources (RES) and their practical implementation as Distributed Generation (DG) have attracted a lot of attention all over the world. Both are considered to be important in improving the security of energy supplies by decreasing the dependency on imported fossil fuels and in reducing the emissions of greenhouse gases. Nowadays, the first issue is of special interest if the spectacular rise of the oil and natural gases prices is taken into consideration. On other hand, distributed generation refers to the local generation of electricity and, in the case of a cogeneration system, of heat for industrial processes or space heating etc.

Most renewable energy systems are modular, allowing flexibility in matching load growth. Today's markets for renewable energy technologies range from specialized niche markets to centralized energy production.

The main advantages of renewable energy systems are:

- the intrinsic zero contribution to the exhaust of greenhouse gases as there are no fossil fuels involved;
- the insensitivity to fuel prices;
- additional energy-related benefits (improved security of supply, avoidance of overcapacity, peak load reduction, possible reduction of grid losses – Figure 1) and network-related benefits (distribution network infrastructure cost rescheduling, power quality support, reliability improvement).

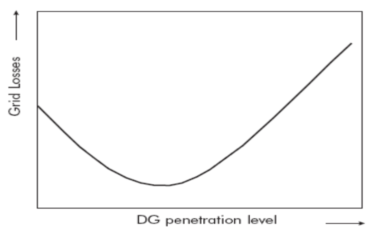

Figure 1. Grid losses related to the penetration of DG

The following disadvantages have to be considered:

- larger initial investment;
- specific requirements of the site (sometimes raise environmental issues);
- unpredictability of the power generated (that means a higher cost for balancing the electricity grid and maintaining reserve capacity);
- the costs of connection, metering and balancing (from about 10% to up to 30% of the total investment cost);

- influences on electrical network performances.

Main features of DG include [1]:

- Generally, it takes place close to the point where the energy is actually used;
- Not centrally planned and mostly operated by independent power producers or consumers;
- Not centrally dispatched (although the development of virtual power plants, where many decentralized DG units are operated as one single unit, infringes on this definition);
- Smaller than 50 MW (although some sources consider certain systems up to 300 MW to be classed as DG);

Connection to the electricity distribution network generally refers to the part of the network that has an operating voltage of 240/400 V up to 110 kV (although it may vary by country).

2. GRID CONNECTION

2.1. General Aspects

The connection of DG (including RES-based DG) to the distribution grid is an important item; the liberalization of the electricity market and the separation between electricity supplier and network operator in the EU, where the electricity supplier operates in a liberalized market and the network operators in a regulated market, have drawn attention to the subject of connecting DG to the grid (costs, barriers, benefits).

Connecting a lot of small power production units to the distribution network will inevitably have some sort of effect on both the distribution network and, if the share of DG becomes large enough, the high voltage transmission network. DG plays a special role in the power balance since – to a great extent – it is neither dispatchable like conventional generating units nor predictable like the load.

Due to the predomination of centralized power, electricity grids in Europe are laid out rather uniformly as a top-down supply system. For many years the electric power industry has been driven by a paradigm where most of the electricity was generated by large, central power plants, sent to the consumption areas through the transmission lines, and delivered to the consumers through passive distribution infrastructure at lower voltage levels. In this system, power flows were only in one-direction, from higher to lower voltage levels; nowadays this model is changing from one-directional central delivered power generation to bi-directional distributed generation network - Figure 2 [2]. The transmission grid (operated by the transmission system operator or TSO) is a high voltage grid for high power flows. It operates typically at voltage levels higher than 110 kV. The distribution grid can be divided into a high voltage distribution grid (typically 60-110 kV), a medium voltage distribution grid (typically 10-50 kV) and a low voltage distribution grid (240/400 V). Distribution grids are operated by distribution network operators (DNOs) and at that level are connected most of RES based DG [1].

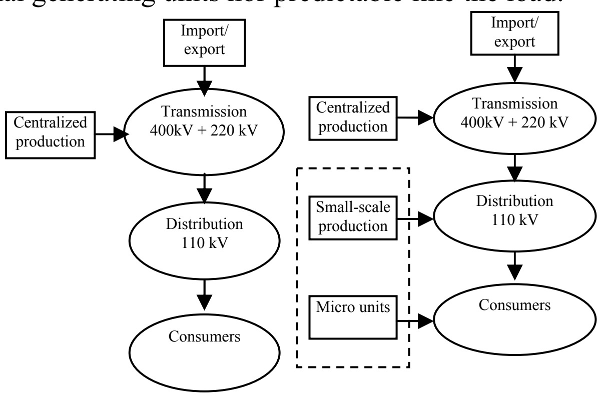

Figure 2. One-directional central delivered power generation and a bi-directional distributed generation network

Interconnection of DG units can be grid independent or grid parallel as well as a combination of both. In the latter case a grid failure means that the DG unit is disconnected from the grid and continues to operate independently from the grid and thus creates an 'island' (islanding, island mode operation). Connection and disconnection of the generator is made by the circuit breaker at the generator side of the main power transformer (main breaker). Depending on the size of the plant the disconnector on the grid side of the transformer may be replaced by circuit breaker. The general scheme presented in Figure 3 [2] illustrates interconnection of DG technologies based on synchronous (or asynchronous) generator. Other DG technologies apply slightly different interconnection arrangements. In all cases the voltage level at the interconnection point determines the need for a transformer. Smaller units can be directly connected to the low voltage network.

Considering only the electrical characteristic, there are three different DG types:

- Synchronous generator;
- Asynchronous generator;
- Inverter.

The first two types represent the traditional technology based on rotating electrical machines. The last type refers here various arrangements applying modern power electronic converters. From the interconnection point of view these three types have different impacts on the distribution network.

Concerns related to grid connections [3]

Several main impacts can be identified in the operation of a distribution system with a large amount of distributed generation:

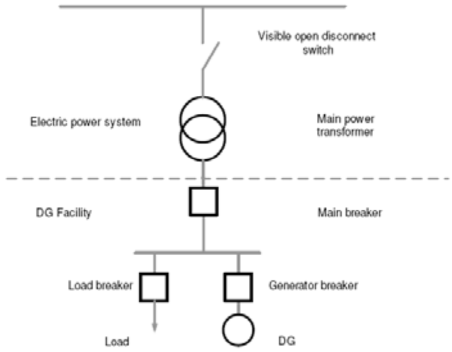

Figure 3 Interconnection of DG technologies based on synchronous (or asynchronous) generator

- Voltage profiles change along the network, depending on the power produced and on the consumption levels, leading to a behavior different from the typical one;
- Short circuit levels increase;
- Losses changes as a function of the production and load levels;
- Congestion in system branches is a function of the production load levels;
- Power quality and reliability may be affected;
- Utility protection need to be coordinated with the ones installed in the generator's side.

3. STUDY CASE OF A ROMANIAN SMALL WIND FARM [4]

The studied wind farm is located in village of Cutca, Romania, at 623 meters altitude. It includes three generators of 90 kVA connected to the public distribution grid through a transformer of 400 kVA, 20/0.4 kV; at the connection point, a capacitor bank produces the necessary reactive power.

Stady state analysis

Figures 4 and 5 present line currents flow in feeders of the studied grid, for different values of active power generated by the wind farm. These figures highlight the influence of generated power on the grid power flow: according as the produced power increases, more and more consumers in the vicinity of the injection point will be supplied by the wind farm.

In all situations, the voltages level at consumers' bus bars does not exceed the imposed limits of ±10% existing in Romania for MV networks.

Table 1 presents the variations of active and reactive power losses in the distribution grid, as functions of the power generated by the wind farm. In this particular case, the power losses diminish with the growth of the power generated by the wind farm, and this represents very positive information for both owner and utility company.

Operating state analysis under short-circuit conditions

Figure 6 shows the behavior of distribution grid under short-circuit condition at an arbitrary point of MV distribution network; the power flow towards the faulted point can be observed.

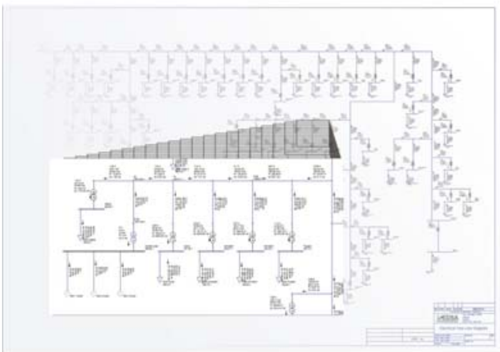

Figure 4 Powers flow in the distribution grid without the wind generators

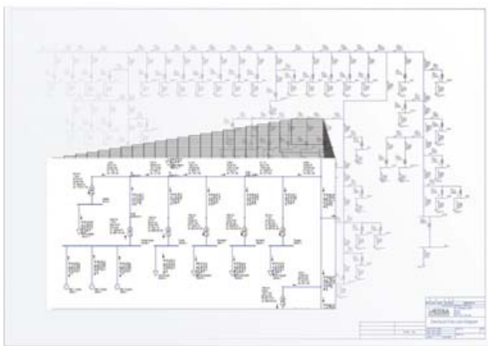

Figure 5 Powers flow in the distribution grid when the wind generators inject 270 kW

Stady state without reactive power compensation

The case of wind generators without capacitor banks (or failure of the existing ones) was also studied. Figure 7 illustrates the power flow, while active and reactive power losses in the studied grid are presented in table 2; in this case, the reactive power losses are a bit greater than in the previous scenario.

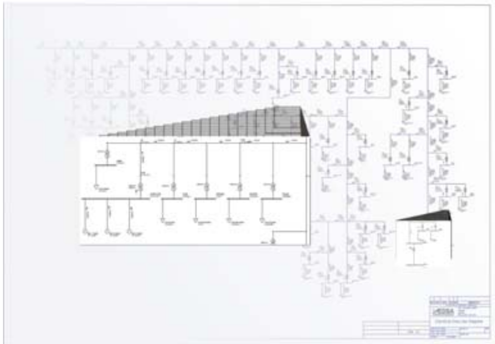

Figure 6. Short-circuit at the MV bus bars

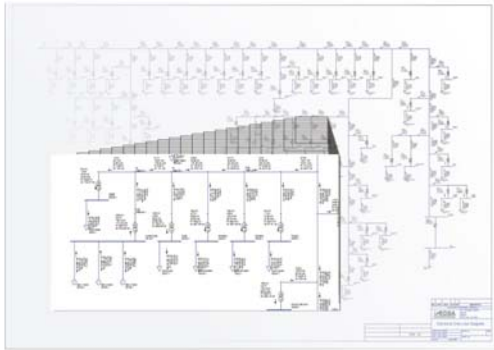

Figure 7. Power flow in the distribution grid when the wind generator inject in the system 225 kW

Table 1. Power losses variation in the power distribution grid

S_{wind} [kVA]	ΔP [MW]	ΔQ [MVar]
0	0.59	0.819
45	0.584	0.816
90	0.577	0.814
135	0.57	0.81
180	0.562	0.807
225	0.556	0.807
270	0.549	0.805
315	0.545	0.805

Table 2. Power losses variation in the distribution network

S_{wind} [kVA]	ΔP [MW]	ΔQ [MVar]
0	0.59	0.819
45	0.587	0.817
90	0.582	0.816
135	0.577	0.816
180	0.574	0.816
225	0.571	0.814
270	0.566	0.814
315	0.563	0.815

4. CONCLUSIONS

During last several years, the practical implementation of small wind farms have attracted a lot of attention in Romania and the study of their impact on public distribution networks became compulsory for distribution network operators. The paper presents some results obtained by studying such a wind farm located in the northern part of Romania, and the main conclusions are as follows:

- the wind farm assures the reduction of power losses in the distribution network and the level of diminution increases when the injected power also increases;
- the behavior during short-circuit faults is strongly influenced by the location and the type of fault;
- there are no significant interferences between the network protection and the generator protection.

5. REFERENCES

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