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Power Quality Issues in Dispersed Generation and Smart Grids

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***Abstract*—The world today is moving toward smart distribution grids and dispersed generation. Those tendencies are caused by different reasons. These include the decrease of fossil fuel consumption, EU directives of CO_2 emissions and climate objectives etc. Innovation and change in technology is a highly welcomed trend but one must not forget that there are drawbacks as well as benefits. One of the most important issues in future grids are the power quality and supply reliability issues. This paper describes how the change to dispersed generation and smart grids should look like and what are the main problems, that need quick and active solutions, so that future grids would be fully functional and reliable.**

***Index Terms*—Power distribution faults, smart grids, power system dynamics, harmonic distortion.**

I. INTRODUCTION

If centralized generation is characterizing factor for nowadays energy systems, then smart grids of the future mean also the spreading of dispersed generation. The cause of these changes is the strict environmental norms and liberalization of electricity markets [1].

Dispersed generation has been recommended as one of the environmentally friendly solutions for improving the energy system, decreasing the losses and increasing effectiveness [2]. In addition increasing the ratio of small producers in electricity generation has been proposed.

Connecting new producers and generators to the distribution network can drastically change the working parameters of the grid. This situation is extremely important when the new connected power plant is equal to or even greater than the load in this particular area. In such case the new power plant affects the voltage adjustment and power flux. It is important to evaluate the existing grid, capacity and loads in this certain area of the distribution network [2].

Dispersed units affect the current quality and through the grid also the voltage quality as experienced by other customers [2]. Power quality concerns the electrical interaction between the network and its customers. It consists of two parts: the voltage quality concerns the way in which the supply voltage impacts equipment; the current quality on the other hand concerns the way in which the equipment current impacts the system [3].

For these reasons it is important changing of the loads have to be observed in smart grids as well as the growth of dispersed generation. In addition loads are getting more and more nonlinear which means that the cooperation of untraditional generation and loads affect the grid in unpredictable ways.

One of the key aspects of electricity production and distribution is the power quality and supply reliability for the customers. Traditionally the problems have been solved but as the world is moving towards smart grids and dispersed generation, those problems need more active and precise control.

As it can be expected, a great number of small generation units will be connected to distribution grids in quite near future. Most probably it would require certain online diagnostic systems to secure the full functionality and reliability of those units.

As due to the rise of harmonics in the grid, the machines would become more vulnerable, their faults become even more difficult to detect, so one could expect a growing number of unexpected downtimes due to different faults of the generators. This is the issue why real time condition monitoring is of utmost importance in the dispersed generation situation.

II. DISPERSED GENERATION

Dispersed generation is the production of electricity at or near the point of use. Most or part of consumed energy is produced at point of use and rest of the electricity goes into the distribution grid [3].

In most cases it is assumed that the electrical current and voltage have a sinusoidal wave shape. But if hundreds or thousands of small power production plants are connected to

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a grid, it could mean that the sinusoidal current and voltage waveform are distorted and the waveform is no longer sinusoidal. Also, all small generators themselves produce harmonics. So the large-scale use of renewable energy sources for the production of electricity will bring major challenges for the electricity network.

Generators are typical electrical devices that are usually setup together with frequency converters to drive them and different inverters to synchronize their work with the grid. Not only generators themselves but also frequency converters and other electronic devices produce a vast number of harmonics that can be a problem to electrical machines they are set up with and also the grid they are working in. Due to financial benefits usually no additional filters are used to lessen the amount of induced harmonics. A typical harmonic distortion of a frequency converter is shown on Fig. 1.

As dispersed generation means also a growing number of small power plants such as small hydro and wind applications, this harmonic problem can become a serious issue for the power quality and supply reliability in smart grid or dispersed generation situation.

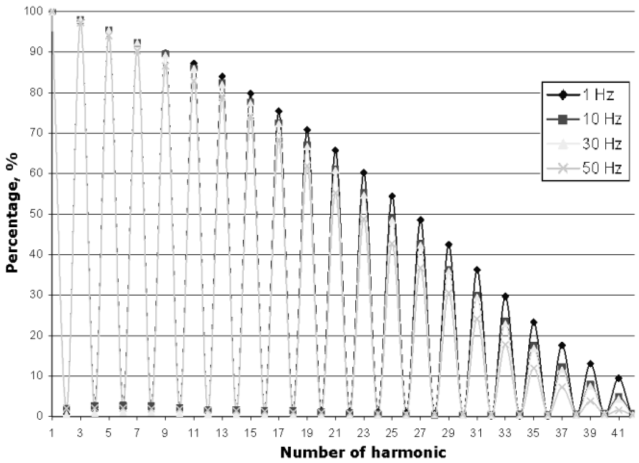

Fig. 1. Typical harmonic distortion of frequency converter.

For showing the probability of large extent of distributed generation in near future the potential is pointed out. The Estonian potential for dispersed generation, which currently is greater than the annual electricity consumption, is chosen as the example [3]. The potential of different energy sources in Estonia are shown in Table I.

TABLE I. ESTONIAN POTENTIAL OF DISPERSED GENERATION [3].

Name	Energy MWh/year	%
Wind energy	6 224 400,00	53
Litter oddments (biomass)	1 280 400,00	11
Wood (biomass)	1 279 800,00	11
Boiler plant reconstruction to CHP	1 179 000,00	10
Energy brush (biomass)	1 079 133,30	9
Solar Energy	224 000,00	2
Dung (biogas)	185 435,20	2
Hydropower	102 514,00	1
Reed (biomass)	50 000,00	0
Landfill gas (biogas)	25 974,40	0
Wastewater sludge (biogas)	21 201,60	0
Total:	11 651 858,50	100

III. POWER QUALITY

Connection of dispersed resources and changing dispersed generation to the distribution grid can affect the power quality in a great amount [2]. Smart distribution grid must secure the end users with power that has the demanded quality [4]–[6]. This is why the modern control systems, that are monitoring the important components of the distribution grid, must react precisely to the changes in power quality.

Power quality can be controlled and improved in whatever point of the electric system beginning from the means in the system or the grid and ending with single devices at the consumer level.

Connection of the dispersed generation of renewable energy to distribution grid can have both positive and negative effects to the power quality. It depends on possibilities of information and communication systems to control and maintain voltage in the feeders, turn the loads in or out and replace lost power with the reserves.

For example small amounts of wind power have negligible effects on electricity networks, but when electricity generation from wind power exceeds a certain threshold level, investments in the power system will be required. This threshold level is known as the hosting capacity [4].

The principle of hosting capacity is explained at Fig. 2. Hosting capacity does not say anything about how much generation from renewable energy sources that is connected to the grid, only how much can be connected without having to invest in measures to strengthen the grid.

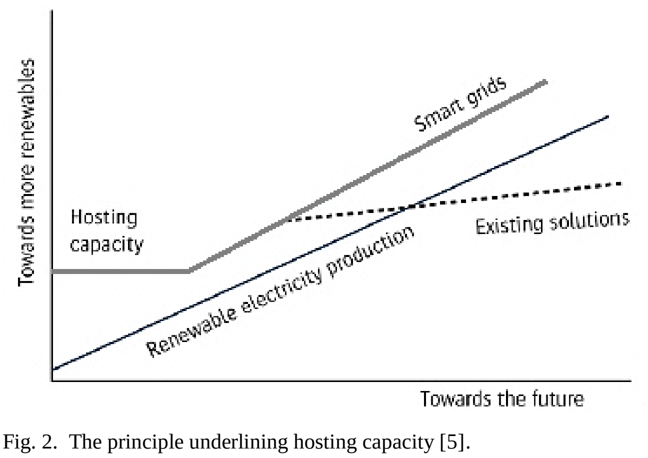

Fig. 2. The principle underlining hosting capacity [5].

IV. HARMONIC DISTORTION DUE TO DIFFERENT LOADS

Electrical devices, which are coming onto market, are becoming more and more complex. They may help to reduce energy consumption, but their performance regarding power quality is still rather improper.

The problem is that their current curve is not a perfect sinusoid. The widespread use of nonlinear loads may implicate significant reactive power and problems with higher harmonics in a grid [6].

Harmonic currents produced by nonlinear loads are injected back into the supply systems. These currents can interact adversely with a wide range of power systems equipment causing additional losses, overheating and overloading. These harmonic currents can also cause interference with telecommunication lines and errors in power metering [7]–[9]. That problem may come more important when smart grid solutions where communication is very important are adapted.

Typical current curves of nonlinear loads are shown at Fig. 2. While the applied voltage is almost perfectly sinusoidal, the resulting current is heavily distorted.

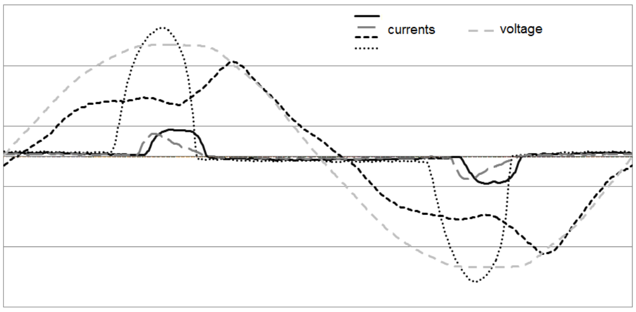

Fig. 3. Currents of typical nonlinear loads versus voltage.

Harmonics generated by consumer's appliances must not cause voltage rise in the connection point [6]. Fixing limits may become important before using numerous harmonics emitting devices together. In some papers [8] measurements with nonlinear loads are done when 5% current´s total harmonic distortion value at connection point is followed. For example most of the common compact fluorescence lamps have the total harmonic distortion over 100% [9].

Harmonic currents injected from individual end users on the system should be limited. These currents propagate toward the supply source through the system impedance, creating voltage distortion. Thus by limiting the amount of injected harmonic currents, the voltage distortion can be limited as well. This is the basic method of controlling the overall distortion levels proposed by IEEE standard 519-1992. Example for illustrating nonlinear loads influence on distribution grid a study with compact fluorescence lamps (CFLs) is made [8], [9].

V. Possible Solutions for Power Quality Fall in Smart Grid

Equipment responds very differently to harmonic distortions, depending on their method of operation. For example incandescent lights and different household heaters are not affected by them. On the other hand, induction motor windings are overheated by harmonics, causing accelerated degradation of insulation and so the lifetime of the machine can shorten in an abrupt way. The problem is that harmonic voltages can give correspondingly higher currents than do 50 Hz voltages and one can easily underestimate the degree of additional heating in the motor [10].

It is a widely known fact that faults such as the broken rotor bars induce sideband harmonic components to the stator current spectrum of the induction machine. Those harmonics can be used for detecting the faults. As most of electrical machines today are used in hand with frequency converters, then those converters add additional variables to the problem. Frequency converter causes supply frequency to vary slightly in time and, as a result, some additional harmonics in the current spectrum are induced and sidebands are reduced [11] or even hindered. This phenomenon also raises the amount of noise in the test signals, which makes the faults more difficult to detect.

In that sense it could prove to be useful to use a certain on-line diagnostic system in the grids with dispersed generation and the wind generators that are integrated to this system. This could be a helpful tool to detect the faults at an early stage where the repairing of the machines is still possible and reasonable. Also it would help to differentiate the deviations and harmonic distortions in the grid from the faulty cases of the machines.

VI. Conclusions

Irrespective of how the term smart grid is defined, one can safely state that electricity networks will face new challenges in the future, and that current and future challenges can be solved by a set of technologies that either exist today, or are being actively developed.

If more and more dispersed generation is going to be installed all over the power networks like it seems to go then it is most important to find measures for guarantying quality and security of supply.

From the example of Estonia we can see that the potential of dispersed generation is extensive. The impacts of using distributed generation may be massive even if bulk of that potential will not be installed.

In the situation where generation as well as consumption produces decrease of power quality in the grid, it is essential to analyze both generation and consumption in a very thorough way. If it proves to be necessary it might make sense to limit the usage of new plants and appliances or use some other methods to decrease their negative effect to power quality.

Usage of nonlinear loads like compact fluorescent lamps has risen rapidly in the last decade, but their harmonic emission, reactive power consumption and other drawbacks have been ignored.

Beside the problem that harmonics are extremely dangerous to electrical motors, distorted supply makes the diagnostics of them more difficult. A growing number of machines are driven through frequency converters. This means that also diagnostic for appropriate setups with frequency converters should be investigated. Frequency converters add additional noise and harmonics to the traditional current spectrum of the machines and thus such drives need a slightly different approach in diagnostics than traditional grid supplied machines. Nevertheless, appropriate on-line diagnostics of dispersed generation units must be applied to guarantee sufficient power quality, supply reliability and overall safety of customers and different facilities connected to the grid.

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