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REVIEWS - LETTERS - REPORTS

LARGE SCALE INTEGRATION OF RENEWABLE ELECTRICITY PRODUCTION INTO THE GRIDS

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This article demonstrates the options for larger scale integration of wind power and other Renewable Energy Sources (RES) into the grids. The German and Greece experience is reported.

Keywords: power system, grid, renewable energy sources, wind energy, wind farm

1 INTRODUCTION

The development of wind power installations now includes planning of large-scale wind farms ranging in magnitudes of 100 MW, and is considered to constitute a significant part of the renewable power production planned in Europe and in the world.

The visionary targets of the European Community are to increase the share of renewable energy resources between 1997 and 2010 from 14 to 22 % as well as to double the contribution of cogeneration plants for heat and power (CHP) to the total electricity production from 9 to 18 %. Consequently, the share of Dispersed and renewable Energy Resources (DER)

will cover 40 % of the whole electricity production in 2100. All countries have set their own targets to gain the common goal.

The DER in distribution systems will achieve an additional growth of more than 300 TWh/a to meet the challenging European targets. The wind power will grow primarily by large wind farms centrally feeding the transmission grids with 20 to 30 GW installed power until 2010.

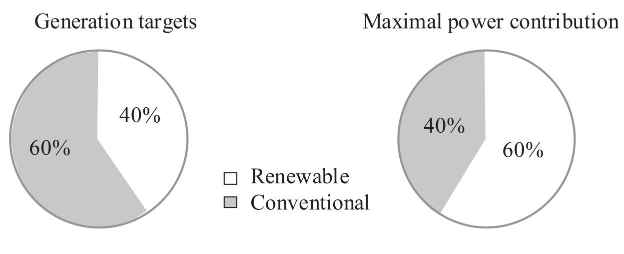

Fig. 1. Generation targets of the European Communities for 2010 and the related maximum power contribution of renewable and CHP generation.

Thus, if the contribution of DER in the electric energy generation achieves 40 %, their maximum possible contribution in the power balance must achieve 60 % of the European system load. A possible scenario is shown in Fig. 1.

The status of integrating renewable electricity into the grids in Europe, their progress, developments and proposals in some European countries will be critically analyzed, discussed and reviewed. In some countries new guidelines are in development or already exist, one example is Germany.

2 THE GERMAN EXPERIENCE OF THE GRID INTEGRATION OF RENEWABLE ENERGY SOURCES

In Germany, the fast growth of renewable generation and cogeneration of heat and power is co-financed. Beginning from 2007, the future growth will focus primarily on off-shore locations, where large wind farms with some 1000 MW of installed power will be erected. Such a large scale penetration of "renewables" into the power balance will lead to sustainable restructuring of the present operation practice in power systems.

3 PERSPECTIVE DEVELOPMENT OF RENEWABLE ENERGY GENERATION

In Germany today the annual energy generation of 520 TWh/a comes from approximately 56 % from coal fired power plants, 28 % from nuclear power plants, 8.5 % from renewable energy sources, 7.5 % from gas and oil fired power plants. It is a political goal that only a part of the traditional power stations will be substituted by fossil fired generation plants. In this situation the targeted growth of renewable and dispersed generation plays a significant role. In the field of renewable energy the intended goals are to achieve shares of 12.5 % in 2010 and 20 % in 2020 of the overall electric energy generation. However, this process runs faster than planned and the targets will be achieved in 2007 and 2015, respectively.

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As presented the share of hydro power will be kept on the actual level because of the lack of possible locations for new large hydro power stations. But all other renewable sources will grow significantly.

An especially high growth is expected in the wind power sector, where Germany today has a share of 50 % of the whole European capacity. Beginning from 2007, the further growth will be concentrated mainly in off-shore locations, where large wind farms with some hundred MW of installed power capabilities, and taking into account the achievable full load hours of the different generation technologies, the contribution of renewable energy sources in the whole energy balance of Germany will achieve 30 % in 2020.

The generation of renewable energy is co-financed by fixed prices on high levels for different renewable power sources, and with subsidies for heat and power cogeneration.

4 DISPERSED GENERATIONS IN DISTRIBUTION SYSTEMS

Besides the connection of large on-shore and off-shore wind farms to the transmission grid, a fast growth of dispersed energy resources (DER) in distribution systems is expected. The problems to be solved at the distribution level are:

- Ensuring network conformity in accordance with the special rules of DER connection in medium and low voltage networks, *eg* regarding voltage quality, avoidance of equipment overloads, short circuit withstandability, influence on ripple control, *etc.*
- Contribution for the reliability of supply trough provision of high availability and support of network recovery after faults.
- Compensation of power fluctuations and dispatch of a stabile power balance on clusters of different DER, storage units and controllable loads.

At present, DER units are operated without higher level control, feeding a maximum of power as supported by current political and regulatory framework conditions. The transmission system operated is obliged to ensure the power balance. This task will become more and more difficult under the conditions of a growing contribution of uncertain and intermitting power output of DER.

5 INTEGRATING RENEWABLE ELECTRICITY PRODUCTION IN GREECE

Greece, as a member of the European Union, follows the European policy regarding compliance with the Kyoto Protocol as expressed by the draft directive of 2001 "A framework for greenhouse gas emissions trading within the European Community". Greece is a country with a strong wind and solar power potential.

Greece is also a country with the maximum duration of sunshine within the European Countries introducing favorable conditions for solar heater and PV installations. There are sites with significant geothermal potentials not only for heating purposes — low enthalpy, but also sufficient for producing electricity. Biomass potential is significant as well either for waste water treatment plant or for biomass using agricultural residues.

Greece has also many rivers that are exploited by larger hydroelectric stations but can be further exploited for the installation of small hydroelectric units.

6 LEGAL FRAMEWORKS

The legal framework established in Greece (see laws 2244/94, 2773 /99) has provided a significant stimulus to the private sector to invest in RES.

Any private body can invest in RES obtaining authorization for this purpose from the Regulatory Authority of Energy (RAE) that takes into account the financial robustness of the investment and any environmental constraints. The interconnection of RES to the medium and high voltage networks is compliant with the utility grid codes as provided by the Hellenic Transmission System Operator (HTSO) or Public Power Corporation (PPC).

7 THE GREECE ENERGY PRODUCTION AND TRANSMISSION SYSTEM

It consists of the Hellenic Transmission System (HTS) in the mainland to which some of the Aegean Sea as well as Ionian Sea islands are connected. The HTS is also interconnected with Albania, FYROM and Bulgaria via AC lines, and with a HVDC line with Italy. The HTSO is the operator of the system. The installed power capacity in Greece is 12 138 MW and the total energy production during 2003 was 52.2 TWh. 1.7 % of the demand is met by wind turbines production and 6.7 % from hydroelectric stations.

Though Greece is a the country with the maximum duration of sunshine within the European Countries, the installed capacity in photovoltaic (PV) is rather low. PV installations at autonomous regions for houses, telecommunication etc reach 49 % of the installed capacity. Most of the grid connected applications are installed on Greek islands, mainly on Crete.

The best practices for wind power installations in Greece come from autonomous power systems, where the installed RES capacity is 133 MW of which 128 MW from wind parks. Good examples of power systems are Crete, Kythnos and Lesvos islands.

Kythnos is a small non-connected island, three hours from the Pireaus port. On Kythnos, the first European wind park was installed in 1982. Now, the installed wind power capacity is 665 kW and also a 100 kW PV station exists. The total demand of the island in 2002 was

5630 MWh, where the peak demand during summer (August) was 1605 kW. The minimum demand was 120 kW during October. 10.2 % of the island demand is met by the wind turbines production and 1 % is met by the PV station production. The total annual renewable penetration exceeds 11 % but some times the RES penetration reaches 100 %. For more than 1000 hours per year, RES penetration exceeds 40 %.

Crete is the largest autonomous system in Greece with 660 MW of installed thermal capacity in 3 different power stations with a variety of thermal units, steam turbines, diesel units, one combined cycle unit and some gas turbines, all of them running on imported fuel oil. The installed wind farms capacity is 81 MW and their production accounts for the 10 % of the annual energy demand. The instantaneous energy penetration has reached 39 %.

Also a significant regeneration about 10 % has been recorded on the island of Lesvos since the installation of new wind parks with total capacity 10 MW in 2003.

The cases show that the wind power penetration especially in Greek islands can be significantly increased.

8 HELLENIC ITERCONNECTED SYSTEM

In the first case unit commitment and economic dispatch have been performed

In the first case unit commitment and economic dispatch have been performed assuming two levels of spinning reserve, 10 % and 15 % of the load respectively and no power produced from RES. In the other two cases, the same two levels of spinning reserve, 5 % and 10 % of RES penetration during the days of total energy demand have been assumed. In this way the financial effects of RES can be evaluated as well as the amount of CO_2 emissions avoided. We can conclude that in most cases the use of RES reduces the operating costs of HTS, and can significantly reduce CO_2 gar emissions.

9 CONCLUSIONS

The analysis of RES status in Greece has shown good examples of RES applications that do not only help reducing CO_2 emissions but also may reduce the operating cost of the power system, especially in island power systems.

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