Grid integration of renewable energy sources

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I. INTRODUCTION

The growing lack of fossil fuels, the increasing demand for electricity and the harmful effect of carbon dioxide output on the climate force nations - especially industrialized countries and their governments - to find new ways of producing the amount of energy in demand. The integration of alternative energies to reduce emissions and to conserve available fossil sources is a known political aim. EU directive 2001/77/EC requires feeding in renewable energies into electricity grids. Although the potential of renewables is very high and the technical conditions to produce electricity are achieved, the current generated rates are clearly lower. A key problem is the integration of renewable energies into the existing grid. This paper analyzes the reasons for this deficit and assesses possible solutions.

II. RENEWABLE ENERGY SOURCES

There are different options for producing electricity from renewable energy sources. Consequently, there are several ways of connecting the gained electricity with the existing grid. Preferred sources are wind, hydro, solar, biomass, photovoltaic cells, bio fuels and geothermic (*illustration 1*). The electricity is induced by asynchronous or synchronous generators except for photovoltaic cells. This operation creates co-current flows and gets through an inverted rectifier into the power grid.

III. INTEGRATION IN EXISTING GRID / BARRIERS

To understand the problem of why the potential of renewable energy sources is not exhausted, you have to consider the actual grid conditions and the resulting barriers. The public electricity supply in most European countries presents an extensive central configuration. Grids are designed to transmit electricity generated by large conventional power plants. An aggregation occurs by using transformers between the transmission and the distribution grid. At the end is the consumer. *Illustration 2* demonstrates that the load flow mainly takes place in one direction from the highest voltage of the transmission grid with less bulk consumer to the lower ones in the distribution grid with many small consumers.[1]

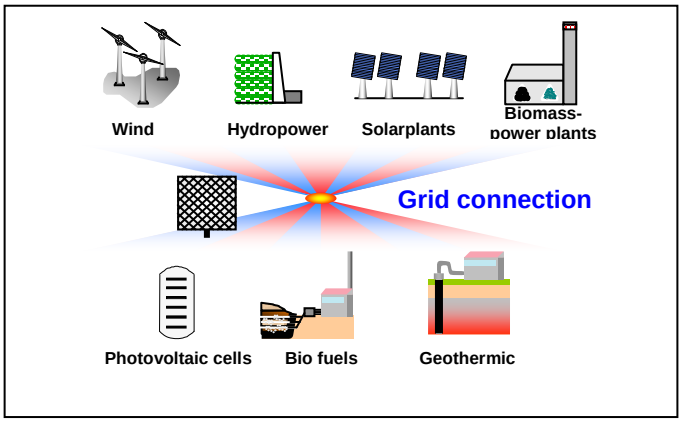

Illustration 1: in dependence on BITSCH, R.; GJARDY, G.; WOLDT, T.: Aspects of large scale RES/DG integration in existing energy supply systems -considering as example the situation in Germany, in: International Journal of Distributed Energy Resources, Volume 2, Number 1, 2006, S. 59-81)

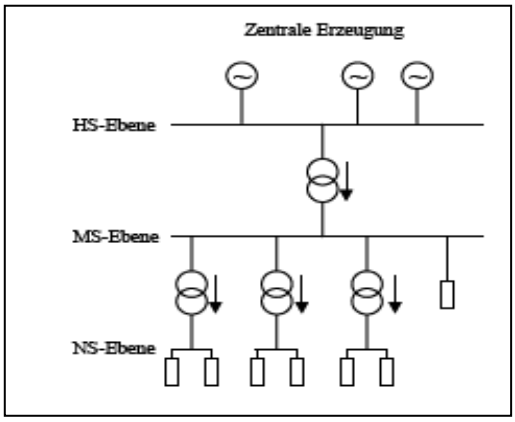

Illustration 2: B. HASCHE; R BARTH; D. J. SWIDER (Verteilte Erzeugung im deutschen Energiesystem) centralizedl energy supply and the electricity direction (source: Barth 2006)

The interconnection directly or indirectly allocates the electricity to connected users in a central way. In the distribution grid the voltage falls in the direction of the current flow. The decline depends on resistance and inductance in the cable. These two factors grow with rising cable length. To provide all consumers with enough voltage, a transformer slightly increases the voltage at the beginning of a cable. Energy generation from renewable sources requires an installation of the plant in locations with a high energy supply, for example, in areas with a grand wind velocity. Therefore, the installations are connected at different local points to the grid. In contrast to large power plants, renewable plants have less capacity and are integrated in lower grid levels. When decentralized generators integrate electricity in low-voltage lines, conditions can change and the power flows in the direction of the transformer. In this case voltage levels increase at the end of a line shown in *illustration 3*. Voltage rise aggravates in practice if more and more distributed generators, especially in pastoral areas with mostly weak grids, are integrated. This barrier of insufficient grid capacity available for renewable energy is the main problem.[2]

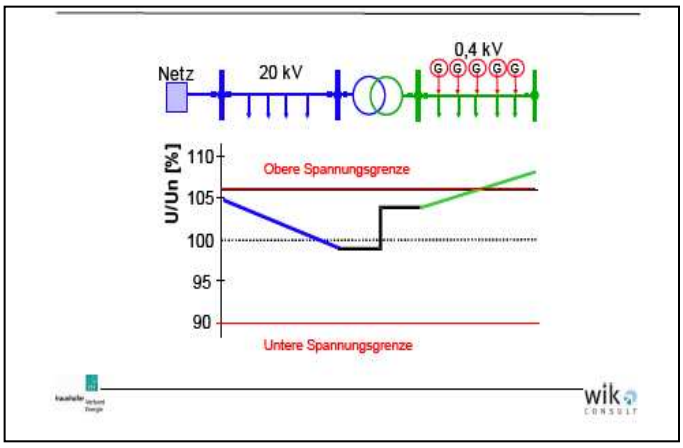

Illustration 3: voltage curve by integration of renewable energy in low voltage level
(source: Fraunhofer ISE; wik consu Studie für das Bundesministerium für Wirtschaft und Technologie (BMWi))

The integration of distributed energy producers seriously influences the operation of the whole grid and calls for new requirements of the mains operation. For example, in Germany the "Erneuerbaren-Energien-Gesetz" (EEG) requires the permanent input of available energy from distributed renewables plants. Thus central large power plants are forced to work in part load and have additional starts. These actions have negative effects on materials, efficiency, costs of generation and lead to additional input of fossil fuels and output of carbon dioxide.[3] To avoid voltage rises, the grid has to be partly extended. The costs of grid reinforcement are often very high. The benefits of producing energy from renewable sources are often considered less important than the costs. Moreover, alternative power developers have highlighted that it is impossible to determine the available grid capacity so that they are unable to verify the technical and cost data of the grid connection presented to them by the grid operator. Furthermore, Distribution System Operators (DSO) are often linked to electricity generation companies. It is disputable whether such a DSO is fully objective towards independent renewable energy producers when the electricity generation company is involved in developing alternative energy programs. The insufficient transparency of grid connection causes long lead times to obtain grid connection authorization. Polls show that stakeholders' perceptions of grid barriers per renewable energy source are very high.[4]

IV. DECENTRALIZED GENERATION / FUTURE INTEGRATION

The trend for additional energy supply systems (especially by using renewable sources) in the medium and low voltage level is highly visible. But to solve all mentioned barriers and to afford integration of renewable energy sources, many changes are necessary, including the configuration of an intelligent distributed electricity system as the most important alteration. However, there is no clear definition of this concept. In Europe it is called "decentralized generation". Decentralized energy supply aims at generating the energy where it is required, or respectively consuming the energy where it is generated.

It is necessary to supply the available energy – in particular supply-dependent renewable energy – to that load which at the moment of occurrence has the most urgent demand or is being used for the optimum purpose. Additionally, supply of an area has to be economically and ecologically optimized according to criteria which yet have to be specified.[5] The character of a distribution grid will move from the pure allocation of electricity to the consumer to an orientation of the generation measured on the demand of the complete system due to the accession of distributed generation. *Illustration 4* shows the modification of the whole grid. The main difference is the generation and integration of distributed producers in the medium and low voltage level and possible input of electricity in higher sections if the demand falls below the supply.[6]

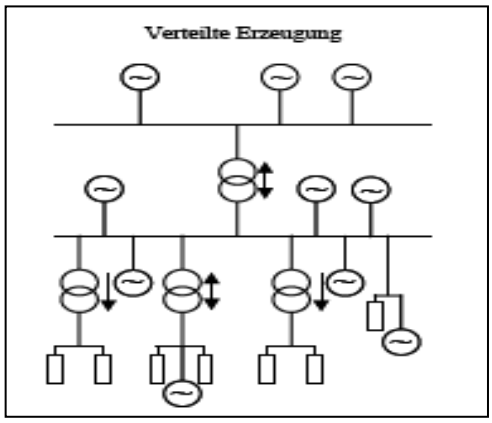

Illustration 4: B. HASCHE; R BARTH; D. J. SWIDER
(Verteilte Erzeugung im deutschen Energiesystem)
decentralized energy supply and the electricity direction

To avoid interferences and overcharge in circuits, storage facilities such as accumulator systems, capacitors or compressed-air stores have to be developed and used. This operation requires that network operators actively incorporate distributed generators in the grid management. Energy management can facilitate such interactions between different electricity levels. Functions like communication, information, control, metering, services, planning, optimization and forecast will be of high importance to manage the grid system error-free.[7]

The integration of many decentralized generators can be concentrated in a "virtual plant" to increase the efficiency. Such projects contain the optimization of the energy mix of different renewable energy source characteristics in one area. This concentration of many small generators allows the supply of huge quantities of electricity by considering them as one large power plant. Such an integration of renewable energy sources not only supplies additional energy but is a part of the grid's capacity. Virtual plants can also act as "microgrids" and work independently from the main grid. Such network expansions which are not grid-controlled do not aggravate mains power failure but help to hold the grid steady. Projects in this vein help to increase the total benefits from renewable generation and integration by smoothing and fullfillment of planning.[8]

IV. SUMMARY

Energy supply will pass through a technological change from a so far generation-dominated, security- and reserve-thinking centralized grid to a demand-oriented, economically-/

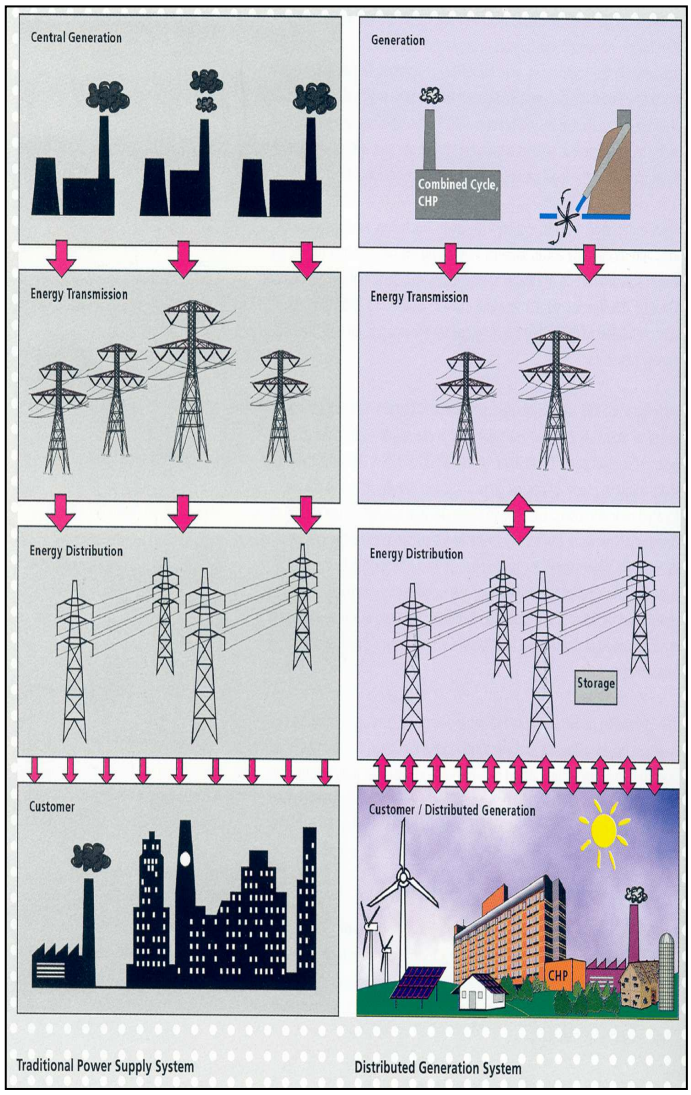

Illustration 5: EU Research 2002
comparison of available grid systems

ecologically-optimized decentralized grid with many distributed generators, especially using renewable energy sources. The plants have to be part of the grid system so that renewable sources do not only produce energy but are actively incorporated into grid management and capacity. The allocation of technologies to store the excess electricity and control the different processes in the grid with adequate communication ports is one of the basic requirements for a better integration of alternative energy sources. A future task will be to find solutions for a better operation mode of large power plants, especially in part load so that the benefits of using renewable energy will not be lost because of low efficiency. If these conditions are achieved, the integration of alternative energy sources can help to stabilize the current grid in perturbations and do not aggravate the situation.

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