Wind: intermittent Power: continuous

Handling an electrical grid with a high proportion of renewable energies

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Concerns over CO_2 emissions, climatic change and reliability on fossil fuels are leading to an increased interest in renewable energies. As the importance of these energy sources is increasing, grid operators and power generators are having to adapt operating practices and strategies.

Wind and sun are almost ideal sources of energy. They are clean, sustainable and have huge growth potential compared with all other types of renewable energy. Today in particular wind power is utilized more and more. But there is also a down side; when the wind stops blowing, rotors stop turning and energy stops flowing.

Wind energy supplies are subject to rapid and often unpredictable fluctuations. The consumer, however, is not prepared to adapt to the wind: Lights must stay lit and industry must produce. Power system operators are required to assure security of supply.

Besides having to compensate the availability of wind and solar power stations, grid operators must also handle other changes resulting from renewable sources. Power is often fed into the grid at locations where the capability of the transmission net is traditionally weak. The creation of new transmission corridors is a slow and costly process that often meets public opposition. Grid operators must adopt new strategies to maintain security of supply at the level the customer expects.

Renewable energies are doubtlessly a key measure for securing a sustainable energy supply. Electrical energy is especially important in this context because no other energy form is so universally usable and because new sources can be integrated into existing supply networks in an incremental and evolutionary manner. Consequently, renewable energy is an important component of the energy policy of many countries and its advancement is strongly promoted.

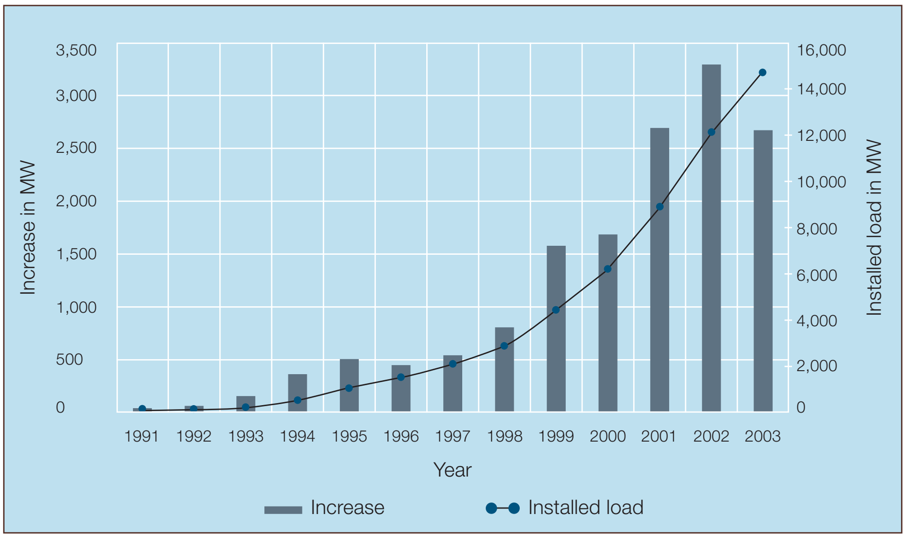
The principal renewable sources are solar, wind, water, biomass and geothermal energy. These differ significantly in terms of availability, form and cost-effectiveness.

Hydro has always been an attractive source and has constituted an important share of primary energy since the early days of electricity grids. Under suitable conditions, its principle strengths are its good economic competitiveness, its benign form and positive perception, the predictability and continuity of supply, and the convenience of being able to store water and hence indirectly, electrical energy. Its principle weakness as far as future expansion is concerned is its limited scope for growth due to the scarcity of suitable sites.

Biomass and geothermal sources can equally supply electricity without short-term fluctuations of the primary source. They are very location dependent and attractive provided certain conditions are fulfilled.

The situation for solar and wind energy is different. The sun's insolation on the Earth's surface exceeds human energy needs by far, and is – in principle – available everywhere. Wind energy, although not equally distributed, is at least available in coastal areas. The low power density of both sources leads to comparatively high generation costs that have difficulty competing with today's low energy prices. However, due to growing concerns over CO_2 emissions and the human contribution to the greenhouse effect, many countries have implemented promotional policies rendering wind power more attractive economically. At the end of 2003, the worldwide wind power generation capability had reached about 39,000 MW, of which Germany, the country with the greatest installed power, had 14,000 MW 1. In 2003, the German plants generated 19.1 TWh, accounting for 3.8% of total grid load.

1 Wind power generation in Germany. In 2003, 19.1 TWh of wind energy were generated, accounting for 3.8 % of the total grid load.
(Source: Federal association of Wind Energy)



Consequences of a high proportion of renewable sources

Besides the economic aspects, further characteristics set wind and solar energy apart from the other renewable sources; they are available in many places, but often away from the principal areas of demand – where the grid is consequently weak. Power generated from them is subject to rapid fluctuations. With a high proportion of installed wind power as is already the case in Germany, this has sweeping consequences for the electrical supply system.

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The location of solar and wind parks is dictated by the availability of the primary energy source (especially if the costs of grid usage are independent of the point where energy is fed into it). Frequently, this is in sparsely populated areas. In Germany, for example, most wind power generators are concentrated in the northern regions close to the coast – areas where the transport capacity of the electricity grid is weak. Today's production already calls for an upgrading of existing transmission lines. If the construction of offshore wind parks proceeds according to plan, a further 3,000 MW will be installed in the German Bight (area of the North Sea) by 2010. At times when this runs at full load, the interconnecting feeders between Germany, the Netherlands and Denmark would be used to capacity by wind power alone [1]. Such a situation would be untenable, both for European power trading and for mutual support among regional grid operators. First investigations into the necessary grid upgrades show that some 1000 km of new alignments are necessary [2] for 400 kV and 110 kV lines in the North-West of Germany alone.

A high proportion of wind power does not only present new challenges for transmission, but also for generation management. Wind power stations on land can provide only 10 to 15% of

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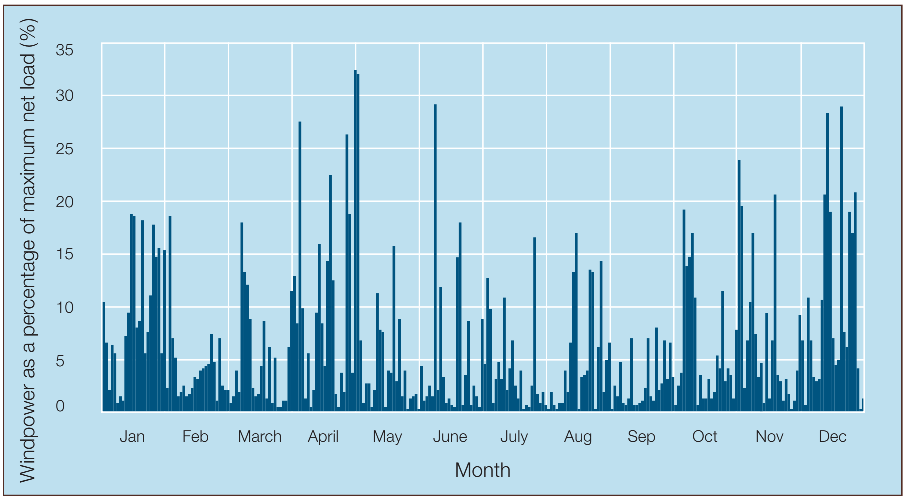
Contribution of wind power to total load in E.ON grid in 2003. How does one assure a continuous supply despite the unpredictable fluctuations of the primary source? (Source: E.ON)



their installed rated power at the reliability that is expected from thermal plants [3]. The rest must be covered by sources independent of supply fluctuations – so called 'shadow power plants'. The provision of sufficient generating capacity is not normally a problem in existing grids into which wind power is incrementally integrated.

Besides these considerations, short and medium term reserves must also be assured. Principally, a grid with a high proportion of renewable sources must be able to match demand with supply

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Increasing the height of a transmission tower while the line is live.

with the reliability of a conventional grid. A proportion of the load, the so-called control band, is covered by plants running at partial load and able to vary their output to match demand fluctuations at very short notice. Because their full potential can rarely be tapped, and because their required dynamic responsiveness needs sophisticated control installations, high costs are involved and consequently the control band should be kept as narrow as possible. The band's size is determined by the expected amplitude of non-schedulable load fluctuations. The output of the largest generating block must equally be taken into account in order to be able to compensate its potential failure. Transmission coordinating bodies, such as for example the European UCTE, lay down mandatory specifications on the width of the control band and the required power adaptation rate that the plants in the band must be able to deliver.

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A high proportion of wind power increases the required size of the control band significantly. In Northern Germany, for example, the wind-generated share of the load fluctuates between 0 and 35% 2. This poses a significantly larger challenge than a thermal system, in which the largest block may represent a few percent of the peak load and the load fluctuation is in itself more predictable. First experiences in Germany (admittedly leaving room for improvement in the forecasting of wind generation) have shown that an average minute reserve of 25% of the installed wind power is required [2]. With this background the UCTE requirements for system control probably have to be adapted.

Technical measures for boosting the transmission grid

A high proportion of renewable energy modifies the core duties of a transmission net compared to systems with local compensation of load and generation. The site-dependence of renewable energy generation increases the need to transport energy over long distances. Reactive power is consequently of greater concern than on conventional systems.

There are different ways of strengthening the grid for such transmission requirements. One option is the construction of new lines. This is often time consuming and difficult to obtain approval for. Achieving a better throughput on existing lines and corridors is an interesting alternative: Voltages, conductor cross-sections or operating temperatures of existing three-phase transmissions can be raised. Generally, official assent is not required for such measures [4]. The raising of tower heights which may be necessary in conjunction with temperature increasing can be performed while the line is live 3.

For larger transmission requirements, the use of high voltage DC (HVDC) is an interesting option. This allows higher power to be transmitted without increasing land requirement while also eliminating reactive power. High costs have disadvantaged HVDC in the past; but this has changed in recent years, especially through the use of IGBTs.

As grids transmit more and more renewable energy, they must not only adapt their transmission structures, but must also face greater and faster changes in load flow caused by intermittent output of the new energies. Better and faster information about the status of grid components is necessary for effective grid management. New wide area monitoring systems [5] make this possible – distributed phasor measuring units capture current and voltage vectors at high sampling rates. Time synchronization is achieved by GPS and accurate status data is constantly available for grid management.

4 EdF's Blénod power plant. A notable improvement of deployment possibilities was achieved here through the modernization of the control system.

Challenge for the control systems of power stations

Assuring a continuous supply in a system with fluctuating primary energy places higher demands on control technology. This concerns primary and secondary reserves as well as minute reserves and is of special relevance in systems where coal fired plants are used as control reserves. The application of modern control technology in existing plants represents a considerable yet easily achievable potential for improvement. The model-based ABB systems MODAN and MODAKOND comprehensively optimize operating characteristics of turbines and boilers in steam power plants, leading to a softer operation (hence extending their economic lifecycle) and reducing auxiliary demand of the plant in the magnitude of percentages. In throttled operating mode – vital for providing spinning reserves – efficiency gains of 0.48% have been demonstrated. This increase is principally achieved because the required rate of power change is realized under minimum turbine throttling. Such improvements, which permit current UCTE requirements to be amply surpassed, grow further in significance in systems with a high proportion of renewable energies.

On account of the incertitude in forecasting wind energy, the importance of minute reserves increases. The reinforcing of existing plants can be both a technical necessity for assuring supply and an economic opportunity for the plant operator – in a liberalised energy market reserve capacity is a valuable commodity. A systematic modernization of control technology often unlocks considerable potential. For example, the coordinated modernization of the turbine, boiler and block of the Blénod plant 4 boosted the maximum power adaptation rate from 2 MW/min. to 50 MW/min. and the control accuracy from +/-5% to +/-0.5%. Furthermore, since modernization, the power plant can be used for primary and secondary reserve control.

Perspective

The geographic factor and fluctuating supply from renewable sources will present new challenges to conventional generation and transmission systems. For key aspects a range of solutions already exists: The increased demands on the control system and the raising of the capacity of transmission lines are examples discussed in this article. It will be necessary to select suitable solutions based on a comprehensive understanding of the system – and to opportunely integrate these into the system.

In many respects, the large scale harnessing of renewable energies is advancing into unknown territory. The next large growth phase for European wind power must be built off-shore and face wholly new, harsh environmental conditions. Another unresolved issue, which will have to be addressed at some point, is the use of wind power in system control.

Many technical challenges remain. For power technology this is nothing new – throughout its history it has advanced into new fields and mastered these successfully.

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References

[1] **Keussen, U.,** Folgen der Windenergieeinspeisung und Verteilung ihrer Lasten. Aachener Beiträge zur Energieversorgung (Band 96): Jahrestagung 2003 der Forschungsgesellschaft Energie an der RWTH Aachen e.V., Markt und Netze – Rechtsrahmen, Effizienz und Qualität der Stromversorgung, Aachen, S. 48–55, Aachen, 2003.

[2] **Dany, G.,** Systemtechnische Weiterungen der Netzintegration von Windkraftwerken. Aachener Beiträge zur Energieversorgung (Band 92): Jahresbericht 2003 des Instituts für Elektrische Anlagen und Energiewirtschaft der RWTH Aachen in Verbindung mit der Forschungsgesellschaft Energie an der RWTH Aachen e.V., S. 105–107, Aachen, 2003.

[3] **Dany, G.; Haubrich, H. J.; Biermann, D.; Krabs, M.; Machate, R. D.; Sierig, J.,** Wert der Windenergieeinspeisung. Energiewirtschaftliche Tagesfragen, 50. Jg. (2000), Heft 1/2, S. 48–52.

[4] **Luttmann, H.:** Mehr Leistung über vorhandene Trassen. Vortrag beim ZVEI/VDEW-Forum 'Life Needs Power', Hannover Messe 2004, 22.04.2004.

[5] **Bertsch, J.; Carnal, C.; Suranyi, A.:** The big picture. Detecting power system instabilities and optimizing asset utilization with Inform^{IT} Wide Area Monitoring PSG 850. ABB Review, Issue 4/2003, pp. 32–36.