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A. Miege, T. Luschtinetz, M. Wenske, F. Gamallo

This document appeared in

Detlef Stolten, Thomas Grube (Eds.):
18th World Hydrogen Energy Conference 2010 - WHEC 2010
Parallel Sessions Book 3: Hydrogen Production Technologies - Part 2
Proceedings of the WHEC, May 16.-21. 2010, Essen
Schriften des Forschungszentrums Jülich / Energy & Environment, Vol. 78-3
Institute of Energy Research - Fuel Cells (IEF-3)
Forschungszentrum Jülich GmbH, Zentralbibliothek, Verlag, 2010
ISBN: 978-3-89336-653-8

Wind-Hydrogen-Biomass – The Hybrid Power Plant of ENERTRAG AG

A. Miege, **T. Luschtinetz**, Fachhochschule Stralsund, Germany
M. Wenske, **F. Gamallo**, ENERTRAG AG, Germany

Abstract

The ENERTRAG Hybrid Power Plant is designed around the following components: three wind turbines of 2 MW each, an electrolyser of 500 kW, a hydrogen storage system, and two CHP units of 350 kW each, able to run with variable mixtures of biogas and hydrogen. The use of the electrolyser - acting as a deferrable load, and running under variable power - and the possibility of reconverting the hydrogen again into electricity will allow a feeding-in of the produced electricity to the grid, free of any of the changing characteristics of the wind power. Besides of that renewable electricity, the Hybrid Power Plant will also be able of delivering hydrogen as a clean fuel for the transport sector, as well as oxygen and heat. The project will show that renewable energy sources, like wind and solar, will be able, in the future, of producing back-up power without any support of fossil sources; and also of feeding electricity to the grid as a part of the base-load demand. As a first step towards this direction, the project has the goal of assuring that the energy production of the three wind turbines will be in accordance to the 24-h-forecasted wind power values.

1 Wind Energy within the Electrical Energy Mix

The natural variability of the instantaneous power supplied by wind turbines can seriously affect the stability of voltage and frequency in power grids. This influence largely depends on the penetration level (fraction of wind power present in the instantaneous energy mix), and will produce no noticeable consequences if maintained below a value of 10 % of installed capacity [1]. At present, this level has already been exceeded, and prognoses show that in 2020, in Germany, the electricity produced by renewable sources will even exceed the total demand during several hours a year [2].

In consequence, the base power generation demand will decrease, while intermediate and peak power generation demand will increase within the following years. However, even if only based on conventional sources, electricity systems – supply and demand – are inherently highly variable, and are influenced by a large number of planned and unplanned factors. The issue, therefore, is not one of variability or intermittence *per se*, but how to predict, manage and compensate variability, and what tools can be utilised to improve the grid efficiency by using additional energy storages [3, 4].

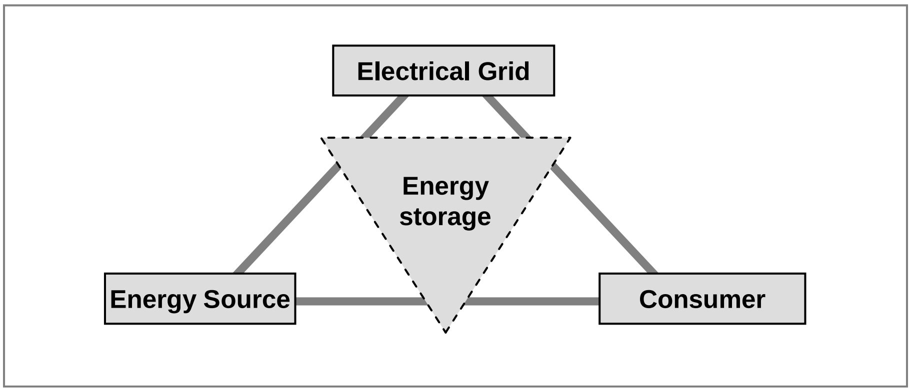

Figure 1: Integration of energy storages.

The already-established controls method and backup available for dealing with variable demand and supply are more than adequate for dealing with the additional variable supply such as wind power at penetration levels up to around 20 % of gross demand, depending on the nature of the specific system. For larger penetration levels, changes are needed both in the structure of the power systems and in their methods of operation, in order to be able of accommodating the further integration of wind energy.

2 Integration of Wind Energy by Coupling with Some Energy Storage System

A wind-hydrogen-system is designed as in the model of figure 3. In this case, the wind energy is partly converted into hydrogen by an electrolyser (PV5). As a fuel, it can also be sold to the market. This option could be a further step towards a global hydrogen infrastructure based on renewable energies.

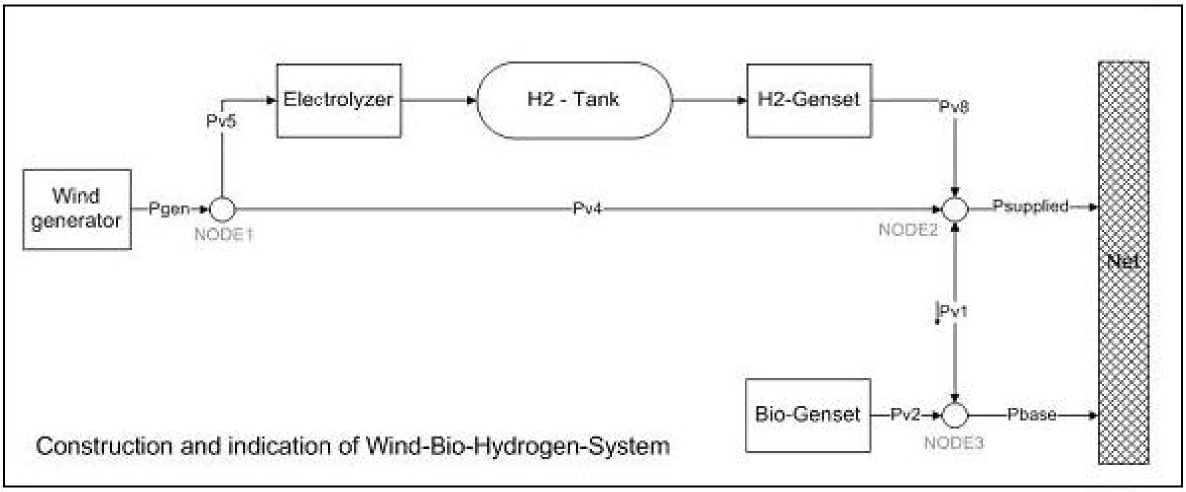

Figure 2: Configuration of model for H2-storage integration.

On the other hand, the hydrogen is used by a genset (PV8) to improve the electrical output characteristic of the overall system. Wind energy which is not used by the electrolyser is fed directly to the grid (PV4). A genset based on biogas works as the third power source (PV2) within that system. This power, in addition to a part of the wind power, forms the base power (node3) that is fed to the grid.

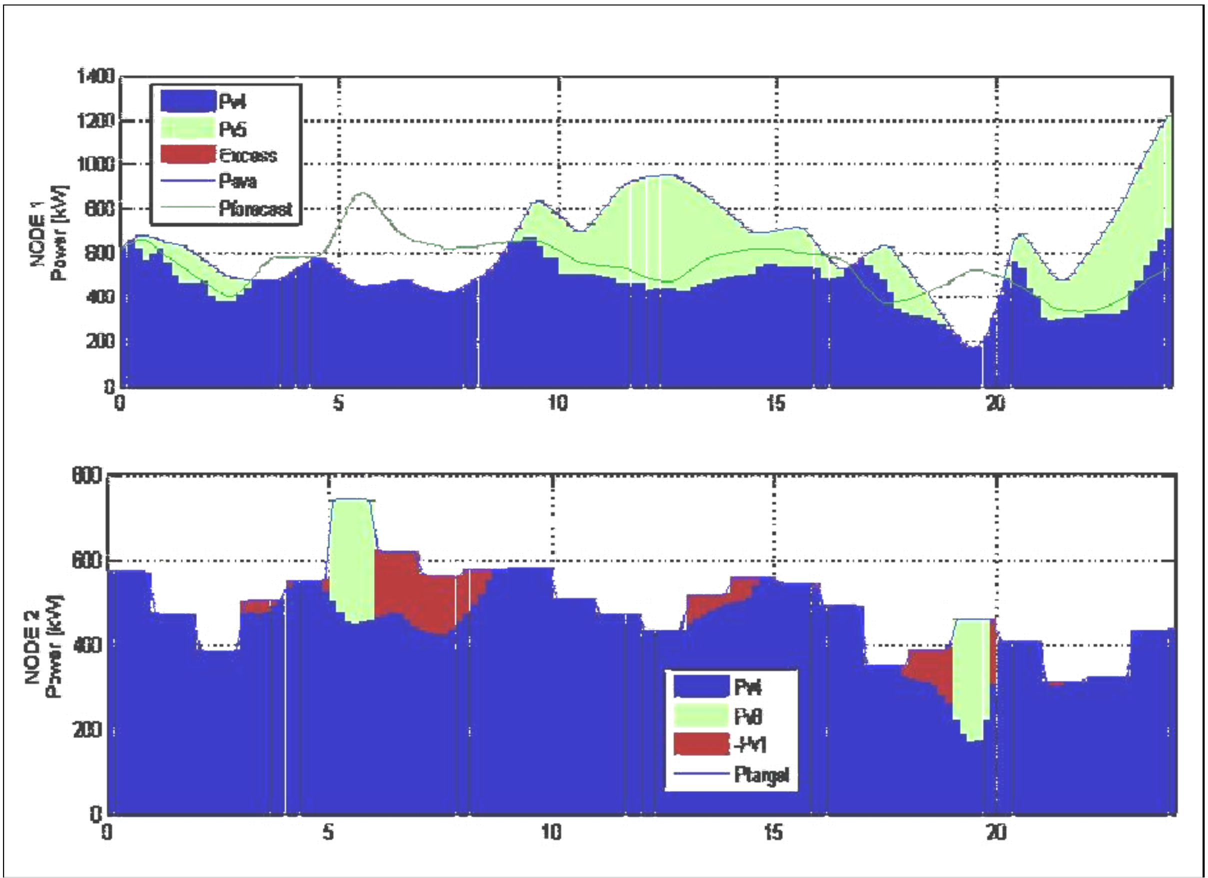

Figure 3: Simulation results for 24h.

The dynamic part of power supply (node2) is defined 24 hours ahead, taking into account wind forecast, H2-tank status and biogas potential. Related to the real wind power yield, the power difference is supplied by the gensets. The lower diagram in figure3 displays the situation for one day. Both gensets with a minimum activation level (step-in limit) are controlled following a priority class.

One strategy of hydrogen production is simulated in the upper diagram in figure 3. Within this day the power forecast and the real power input differs in positive and negative directions. The gaps are filled as explained before. The wind power above the target value is used by the electrolyser running under a variable power mode.

3 Practical Tests of Variable-power Electrolysis

Currently, the most extended electrolysis technology is that of the bipolar, alkaline units, using an aqueous solution of KOH, around 28 % v/v. The average efficiency of the currently available electrolysers is between 75 % and 80 % (HHV), even when efficiency values higher than 80 % under full power (up to 90 % at 20 % load) have been reached on experimental, industrial-sized units.

Despite being a long-term established industrial technology, the production of H_2 by electrolysis will still require some research, in order to be capable of dealing with the natural variability of the wind-generated power. Almost all the experience already acquired about water electrolysis is valid only for steady operation. The industrial utilisation of electrolysers is largely based on stable, nominal-power operation, with very seldom and controlled start and shut-down cycles, performed in comparatively extended time periods. So, the concrete experience in operating electrolysers under a non-steady power regime, with relatively sudden power fluctuations; still seems not to be enough for allowing this technology to widely enter the commercial market. Even when several wind-hydrogen pilot plants were already built and tested, definitive results were still not attained [5].

Some specific research works, however, showed that such a variable-power-mode operation is possible, if attention is paid to certain specific parameters. Further activities are currently being developed toward this direction.

From a theoretical point of view, there are no problems for the electrolysis process to be performed under variable power conditions. However, the behaviour of the real devices not only depend on the cell stack (the core of the electrolyser, where the water splitting takes place), but also on the dynamic characteristics of all the peripheral components. So, the real performance of the whole system, working under a service condition completely different from those for which the electrolyser was designed, is sometimes difficult to predict. Furthermore, the scale factor produces also an important difference: Small electrolysers, designed, for example, for laboratory service, or for small hydrogen supplies to industrial processes; present some technological differences with the large, production-oriented units. For this reason, experimental results obtained from small units, can difficultly be extrapolated to larger units, being the direct work on industrial-sized units a much better alternative.

4 The ENERTRAG Hybrid Power Plant

One of the technical goals to be achieved is the balance of the energy inputs and outputs over a certain time. Also, the overall grid situation has to be taken into consideration. The economical characteristics of the market are the second important group of aspects to focus on while operating a combined wind-hydrogen-system. Depending on the attainable price for electricity and for hydrogen, the more lucrative energy form should be produced at any moment. Furthermore, the price distribution pattern over a day or a week is considered in such a way that the periods of price peaks are preferred for the sale of electricity.

About two years ago, ENERTRAG AG, a leading company in the field of wind energy production, started, in cooperation with the University of Applied Sciences of Stralsund and some other academic institutions; the design of a hybrid power plant, comprising several wind turbines, a biogas generator, an electrolyser, and several other components; oriented to balance the electrical output of the wind turbines in such a way that it could be easily admitted by the grid. The plant is already under construction, and it is expected to enter into full service in the upcoming year.

The hybrid power plant will be integrated in the ENERTRAG's own energy grid. So, during the periods when the grid cannot accept all the available wind power, the non-dispatchable surplus will be used for producing hydrogen, in order to reduce the net electricity offer, bringing it near to the demanded values.

On the opposite, during periods of high electricity demand, the hydrogen will be mixed with biogas, and used to fuel two 350 kW, high-efficiency CHP (combined-heat-and-power) units; in which it will be converted again into electricity, in a CO_2-neutral way, for serving the grid. Simultaneously, the CHP units will also produce heat, out of that hydrogen-biogas mixture, that will also be utilized.

In accordance to several different operation strategies, it will not only be possible to produce hydrogen for reconverting it into electricity, but also for furnishing some kind of external demand (i.e. the transportation sector). So, the hybrid power plant could be not only able of supplying electricity and heat, but also pure hydrogen to be used as fuel. The possibilities of using the co-generated oxygen (eventually for non-energetic purposes as waste water treatment, water purification, air enrichment, etc.) is also considered [6].

5 Summary

Hydrogen production, by means of water electrolysis, can undoubtedly offer a suitable alternative for dampening the severe power fluctuations that could take place in electrical grids having a high penetration of wind energy; consequently reducing or even avoiding the need of wind power curtailment. Such an operation mode could allow a wind park to deliver firm, ensured power to the grid, thus contributing to the stability of the whole system. The option of hydrogen production could be a further step towards a global hydrogen infrastructure [7] based on renewable energies.

Simulations show the benefits of such combined systems and allow testing in advance a variety of different operations modes. Tests and analysis under a variable power regime have been performed only at laboratory and pilot-project scales. For properly knowing the dynamical behaviour of such systems, long-term testing of industrial-sized units is necessary.

A factor seriously affecting a fast integration of the electrolysis technology to the energy market, is the fact that the current offer of industrial-scaled electrolysers is low (a comprehensive list of manufacturers can also be found at [8]). For this reason, prices are high, and delivery times may often be quite long.

Once the dynamic operation of electrolysers had been sufficiently tested, grid-independent wind-hydrogen systems could also be built, both for fuel supply and for decentralized cogeneration; attaining competitive costs.

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