Wind generation stabilization of fixed speed wind turbine farms with hydrogen buffer

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Abstract. The wind power generation, given the stochastic nature of its source, raises a number of disadvantages when it is integrated into the power system. To cope with these problems, a combination of wind power generation together with an energy storage system based on hydrogen is analysed in this work. The aim of the work is to study the presented issues and to analyse the symbiosis between the wind generation and a centralised energy storage system for a particular wind farm. To get this objective they will be modelled the wind park with an energy storage system based on hydrogen. The modelled energy storage is based only on hydrogen but it may carry also other storage systems that would improve the dynamic behaviour of the farm -response to disturbances, voltage dips, etc. The simulations carried out show that hydrogen buffer is a solution to the raised problem of the integration of wind farms in a market situation where compromises on the power to supply must be taken at least with 24 hours in advance.

Keywords: Wind energy, energy storage, distributed generation, grid integration, fuel cells

1. Introduction

The wind has become in recent decades one of the renewable sources of higher level of development and expansion. In the power generation plan published by the Spanish government, called **"Prospectiva de Generación Eléctrica 2030"**, it is expected that by 2030 the installed wind power will be 35% of the overall installed electrical generating power in Spain.

Apart from the benefits of a source of clean and sustainable energy, a high level of penetration of wind power in the overall electrical system also includes a series of new problems and challenges to be tackled.

The wind power generation, given the stochastic nature of its source, raises a number of disadvantages when it is integrated in the power system. To cope with these problems, a combination of wind power generation together with an energy storage system would improve considerably the security of supply to the grid [1] and, as a consequence, the overall operational efficiency of the utilities that now make the role of supporting (mainly thermal) will be improved.

Different storage technologies with sufficient dynamic responses have been investigated. But, in general, these systems have low storage capacity and they accumulate energy in the range of seconds or minutes: hydraulic pumps [2], super capacitors, flywheels, electrochemical batteries, etc. There is also varied literature that has investigated the symbiosis between wind generation, photovoltaic generation and storage in autonomous systems and microgrids. For these systems higher storage capacity systems are required such as diesel engine generators, fuel cells as an emerging technology, or combinations of them.

However, in the case of wind farms that are integrated into the electric power system, a number of peculiarities that characterize such systems must be taken into account: (1) under the current legislation, the entire electricity production of this type is injected into the power system, (2) the electric system is operated by calculating the electric generation with a day in advance, in view of the planned consumption, randomness of the wind poses serious problems in regard to this anticipated prediction, (3) is necessary supply voltage drops of wind farms "instantly" (increasing the production of thermal power), otherwise could happen electrical blackouts of the system, and (4) the so-called voltage dip is one of the biggest drawbacks of wind turbines. When this phenomena occurs in the system, the wind turbines with Squirrel Cage Induction Machines (SCIM) are disconnected from the electrical grid to avoid being damaged and thus causing further disruptions in the system, in this case, lack of supply.

The research work proposed here, aims to study the presented problematic and analyse the symbiosis between the wind generation and a centralised energy storage system based on hydrogen for a particular wind farm integrated in the power system.

2. Main contributions

A. Model

The first step of this study is the mathematical modelling of a wind farm with fixed speed asynchronous generators, an electrolysis based hydrogen generation system, a storage tank for that combustible and a solid oxide fuel cell (SOFC) for electrical power generation from hydrogen (Fig. 1). Simulation of the complete system has been addressed using MatLab© and Simulink©.

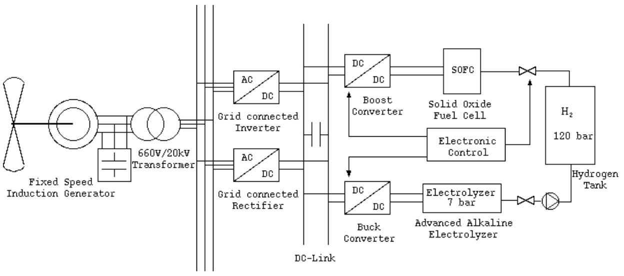

Fig. 1. Schematic of the modelled wind farm with hydrogen storage system.

The developed overall model allows the running of simulations that provide: (1) the farm's response to different situations in which the forecasts of wind have not been realistic and the hydrogen based system of storage-generation has to compensate the mismatches (quasi-stationary study), and (2) the dynamic response of the system to disruptions (transient study).

For the modelling of the wind farm the aggregated model [3] will be used. The aggregated approach represents a wind farm by one equivalent machine with re-scaled power capacity. This simplification is perfectly acceptable under normal operation of wind farms, given the constant speed characteristic of the SCIMs. This wind farm considered consists of 40, 500 kW and 690 V, generators with 125 kVAR capacitive compensation. After a step-up Ynyn transformer of 690/20000 V, each induction machine is connected through subterranean lines with the common bus at 20 kV.

The SOFC model developed in this work has been based on [4]. The most striking quality of SOFCs is that the electrolyte is in solid state and is not a liquid electrolyte. The operating temperature of the SOFC is in the range of 900–1000 ºC, the electrical efficiency is 55–60% [13], and its durability is of more than 40 000 h for stationary power applications. They are very suitable for large-scale generation, rising to 50 MW of rated power. The rated power of the modelled SOFC is 4 MW (20% of the rated power of the park). Model inputs are hydrogen flow, oxygen flow and current supplied to the load. The model output is the voltage (V) generated by the fuel cell.

The energy storage proposed in this paper needs of an electrolyzer to store surplus electricity. The modelled type is a so-called advanced alkaline electrolyzer [5]. It operates at a pressure of 7 bar and at temperatures up to about 80 ºC. The nominal power of the Electrolyzer is the same as the SOFC, 4 MW. Model inputs are T^a (constant, 80 ºC) and current (I). Outputs are voltage (V) and H_2 flow.

Given that both the SOFC and the electrolyzer work with DC, are required Power Conditioning Systems (PCS) to integrate these elements and the electrical network, which works with AC. In this paper it has been assumed that the PCSs are ideal, making the conversion AC/DC and DC/AC with a yield of 100% and unity power factor.

B. Results

With the developed models, simulations were performed to analyse the behaviour of the wind farm when working in a market situation, where the compromise of power to supply must be taken at least with 24 hours in advance. Usually, the prediction error for one day wind forecast is about 10%-15%. Faced with a setpoint of active power imposed by the previous forecast, the aim is to see what is the response of the modelled farm. Three different cases were considered: (1) the active power required by the power system exceeds the power of wind, (2) the power required is less than the power from wind, and (3) the power required is equal to the average power of wind. In Fig. 2 is shown the system response obtained for an input wind power of 0.5 p.u. average value and a power requirement of 0.6 p.u. for one hour -the first proposed case. Fig. 3 shows the power supplied by the fuel cell.

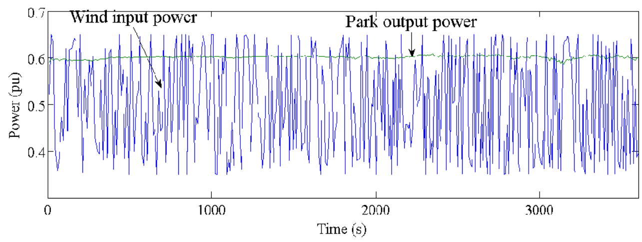

Fig. 2. Response of the wind farm when required setpoint power is greater than actual wind input power.

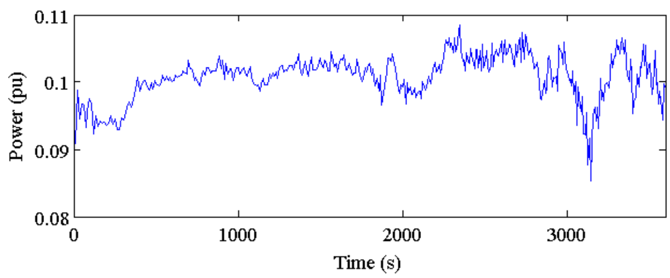

Fig. 3. Power supplied by the fuel cell.

C. Conclusions

The simulations performed with the developed model show that the wind farm equipped with a buffer system based on hydrogen gets an uniform active power output in all studied cases. Furthermore, when the actual wind power and the target output power for the farm are compatible with the dynamics of the SOFC, there is a good tracking response of the overall system. The steady state error that appears otherwise is a consequence of the slow response of the SOFC with regard to a general control scheme for the power curve of the wind farm. To cope with this problem there is a need for additional energy buffers with extra response dynamics.

3. References

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