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Reducing the Undesirable Effects of Wind Farms High-Penetration on Frequency

Mohammad Taghi Ameli
Power and Water University of Technology (PWUT)
ameli@pwut.ac.ir

Saeid Moslehpour
University of Hartford
moslehpou@hartford.edu

Vahid Sotudehnegad
Power and Water University of Technology (PWUT)
mtameli@yahoo.com

Abstract

This paper reviews the effects caused by a high penetration of wind farms on network frequency. Energy generation in wind farms that use induction generators (as installed in Manjil Power Plant) is simulated, and, assuming that wind farm units provide %10 of the network power, the effect on frequency is studied, and it is shown that such a high penetration of the wind farms has a destructive effect on network frequency. It will be shown that the negative effects can be compensated for by using stored energy, but in the absence of energy storage equipments like SMES (Super Magnetic Energy Storage), this solution is beyond reach. An alternative method is presented that is based on Rotary Frequency Converter (RFC), and, as can be seen in the simulations, the wind farm output creates less disturbance, and frequency variations can be controlled considerably.

Introduction

With the increasing fuel costs the cost of electricity generation in conventional power plants is also increasing. The wind farm industry, which has no fuel cost, is welcomed by sharply growing demand. The growing demand has in turn empowered the development of wind farm technology, leading to further and wider use of wind energy. However, wind power generation is rather unpredictable and cannot be controlled. Therefore, its high penetration into power network systems raise difficulties such as unreliability in planning for wind farm output power and, more importantly, increased frequency oscillations and reduced suitability of system governors for maintaining stability against major load fluctuations.

When load changes, system governors spontaneously change the generating power to equalize supply and consumption of energy, thereby returning frequency to its nominal value. When a high percentage of power is supplied by wind farms (like Germany and Ireland where 10% of total energy is delivered by wind farms),

then the fluctuations of this quantity of energy engage the governors and cause an increase in frequency fluctuations.
To decrease the fluctuations of wind farm output power, part of their output should be stored to deliver the power with less fluctuations and lower frequency changes. To some extent, variable-speed wind farm units can control their output power via electronic devices and instruments; therefore, the variation of wind velocity does not directly reflect in their output power. But for fixed-speed wind farm units, any change in wind velocity entails a change in output power. For this reason, the frequency fluctuations caused by wind farms with fixed-speed units are higher than those caused by wind farms with variable-speed units. Thus, this paper deals with fixed-speed units.

Two kinds of energy storage are considered here:

1. Ideal Energy Storage (Storing energy in rotating mass, flywheel)
2. Rotary Frequency Converter

Using MATLAB/SIMULINK software, a power network is simulated that consists of conventional power plants and fixed-speed wind farm units, with or without these kinds of energy storage, and the simulation results are discussed.

Energy Storage Types

An energy storage system should have the capability of storing the power generated from wind and its transmission to the network at a good speed. Besides, its capacity should be large enough to handle the huge quantities of power that may be as high as 10% of the total network power if a single storage unit is used. Therefore, battery-based plans are unacceptable due to their limited capacities. Of other types of energy storage, the Super Magnetic Energy Storage (SMES) requires long coils and superconductivity. These kinds of coils are in the research phases of development and are not available at industrial scale. A third type of energy storage is based on utilization of rotating masses or flywheels.

For this purpose, the flywheel should be integrated in the wind farm in such a way that the wind power is delivered to the network via a rotating mass. Actually, the rotating mass acts as a low-pass filter that requires a suitable electrical machine. The electrical machine that is utilized here consists of a synchronous machine and a doubly-fed induction generator with their rotors linked together. The masses of these two rotors act as the rotating mass. The synchronous machine is connected to the induction generators of the fixed-speed units, and the output of the doubly-fed induction generator is connected to the network (Figure 1).

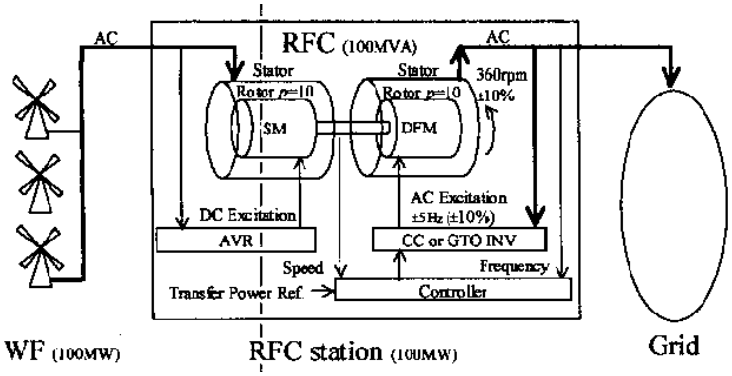

Figure 1: RFC system and its connections to the network and the wind farm

Since 20% to 30% of the output of the doubly-fed induction generator is transmitted via the rotor, it is possible to increase or decrease the output of the doubly-fed induction generator and thereby control the total output power of the wind farm. The portion of the energy that is not transmitted to the network will increase the kinetic energy of the rotor, and the rotor plays its role as good energy storage. More theoretical analysis of different Methodes for Reducing the Undesirable Effects of Wind Farms High-Penetration on Frequency are in reference No.5 disscused.

Simulation

The simulated system consists of 15% steam power plants, 75% hydroelectric turbines and 10% wind farm units. Simulation of the steam and hydroelectric turbines is based on Reference [3]. The reason these units are selected for simulation is that Tavanir Co. is presently installing 100 fixed-speed units of 660 kW in Manjil. Simulation is based on Ref [4]. The data related to these units are obtained from the Sadid Saba Niroo Company and used for simulation purposes [5]. A low variation load is assumed. Energy storage types considered are the Ideal (Flywheel) and RFC. Simulation of RFC is based on Ref [2], and the block diagram of the system is shown in Figure 2.

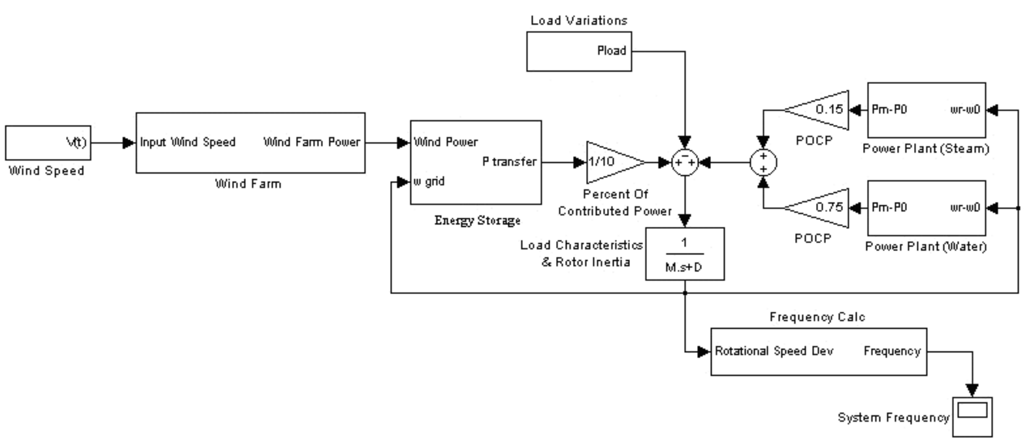

Figure 2: Block Diagram of the Simulation

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Wind velocity is assumed at 8.7 m/s for Manjil, and its variations are based on Weibull distribution as shown in Figure 3. The variations of the wind farm have output power is shown in Figure 4. Load fluctuations are according to Figure 5.

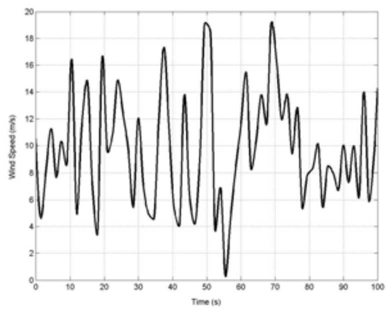	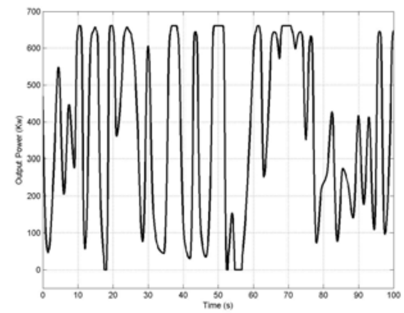
Figure 3: Wind Velocity	Figure 4: Output Power of a Unit Under Installation in Manjil

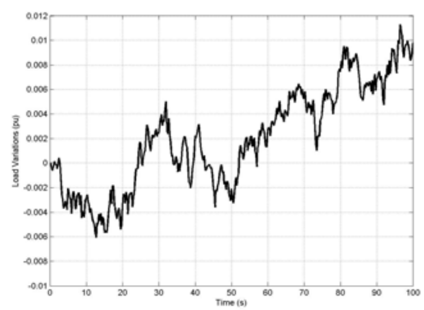

Figure 5: Load Fluctuations in p.u.

By comparing results given by production manufacture and our simulation, we can support the result of this simulation. By analyzing results of various method of simulation we can observe improvement in reduction of frequency fluctuation.

Conclusion

It is shown that using RFC improves the frequency fluctuation, but at the same time it has a transmission loss of about 20%. Besides, its price is rather high because it is not commercially available and should be custom made. However, it has the following advantages:

1. It solves the problem of voltage fluctuations due to repeated start/stop operation of the induction generators.

2. The cost of this RFC is considerably lower than the cost of other equipment for energy storage or parts of the HVDC.
3. Linking of RFC to the power system is simple and creates no shock to the network.

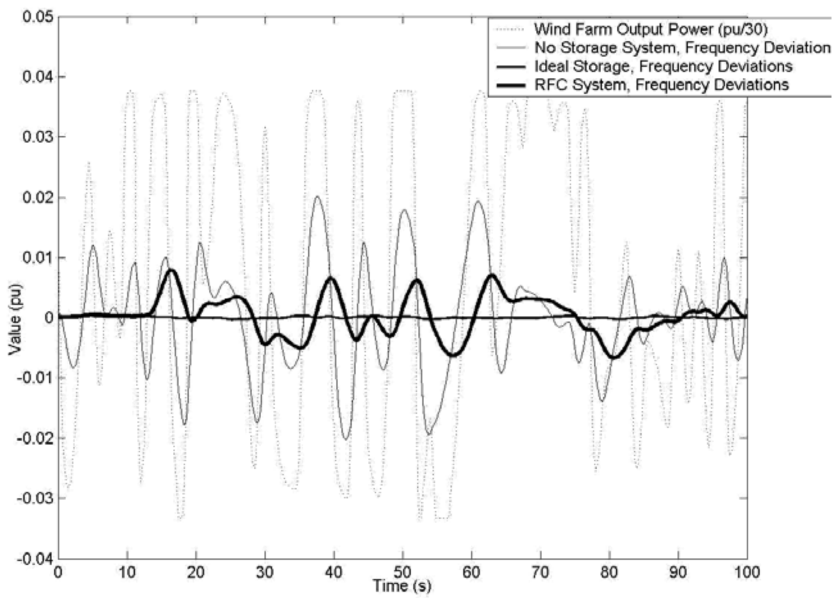

Figure 6: Fluctuations of the Wind Farm Output Power and the Frequency Fluctuations under various types of Energy Storage in p.u.

Nevertheless, its dynamic performance in an actual environment remains to be studied, and if its utilization in fixed-speed wind farms proves to be more economical than the variable-speed wind farms, then its implementation seems to be advisable.

Since centralized wind farms similar to what is described in this paper do not exist yet, continued research on this system may prove its economical superiority, leading to development of much larger wind farms within the power systems.

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Authors Biography

Mohammad T. Ameli Received BS in Electrical Engineering from Technical College of Osnabrueck in Germany 1988. Msc & PhD from Technical University of Berlin in Germany 1992 &1997. Since then He teaches and searches as an Assistant Professor in EE Dept of Power & Water University of Technology. He was general director of areas of research: Power system Simulation, Operation, Planning & Control of power system.

Saeid Moslehpour is an Assistant Professor in the Electrical and Computer Engineering Department in the College of Engineering, Technology, and Architecture at the University of Hartford. He holds PhD (1993) from Iowa State University and Bachelor of Science, Master of Science (1990), and Education Specialist (1992) degrees from University of Central Missouri. His research interests include logic design, CPLDs, FPGAs, electronic system testing and distance learning.

Vahid Sotudehnegad has received his Master of Science in Electrical Engineering from Power & Water University of Technology.