Effects of DFIG Wind Power Generation on Vietnam Power System Operation

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***Abstract*—Nowadays, renewable energy sources are more reliable and developed than before in which wind power is a considerable factor. Therefore, A thorough comprehensive knowledge about modeling, control and responses of wind generators to practical disturbances is very necessary and vital. The double fed induction generator (DFIG) is popular and effective for a wind turbine with the noticeable characteristics of variable pitch control and rotor-side converter including. Typically, the paper tries to describe and explain the DFIG wind turbine control model built in PSS/E before the model is applied to a bulk power system - the reduced equivalent power system in Soc Trang, Vietnam. It wants to observe, analyze and evaluate dynamic responses to disturbances such as loss of a generator. During the simulation, due to using an uninterrupted operation and fast control of DFIG converter, the DFIG wind turbines response successfully to each disturbance. It wants to understand that under transient fault conditions, both the voltage and the system frequency are important to the assessment of influences of wind power on the overall power system.**

***Index Terms*—DFIG, PSS/E, wind turbine, dynamic model, Vietnam power system.**

I. Introduction

In recent years, the society and economics in the world is more and more developing. The demand for power energy in manufacturing, farming and serving the daily human life become enormous which need to be solved by supplying the different power sources.The fossil fuel energy become exhausted and scarce. Besides, the considerable influences of fossil fuel energy on the environment such as green house effects causing the global warming is a urgent issue. Wind power is now the huge potential energy being studied by many researchers and being worldwide applied in many developing and developed countries.

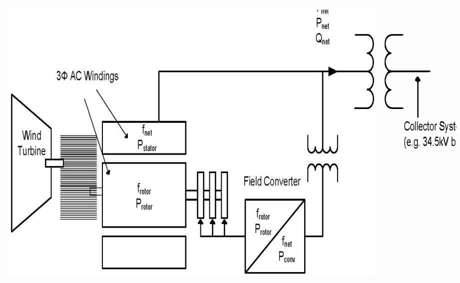
According to the World Wind Energy Association, Global Wind Energy Council and Renewable Energy Policy Network for the 21st century, the total installed worldwide wind energy capacity at the end of 2013 is about to reach to 318GW. The continent obtaining the largest market is Asia occupying about 52% of the total capacity in sixth consecutive year, followed by Europe (roughly 32%) and North America (less than 8%) [1]–[5]. In Southeast Asia, Vietnam has the largest wind power potential with total desired capacity of 513,360 MW untill 2020 [6], [7]. Specifically, the southern area and south central coasts in Vietnam have the big capability of exploiting the wind power potential thanks to the strong wind more than 7m/s and the sparse population density [8]–[10]. The goal is that 5% of total Vietnam energy comes from the renewable energy untill 2020. Each year 100MW-200MW of wind power is sent to national power system [4], [10]–[12].

The effects and requirements for connecting wind farms to power systems are interesting and exciting topics for many researchers in the world [13]–[17]. The study system is taken from the large Vietnam power system with a planning data untill 2015. The main objective of this paper is to observe and assess the dynamic responses of wind power on the reduced equivalent power system of Vietnam. The justification is that description and explanation of DFIG wind turbine control models built in PSS/E are mentioned. The dynamic performances of wind turbines during various disturbances such as short circuit, loss of a generator and so on... The voltage and the system frequency are specially considered to evaluate the impact of wind power on the system stability.

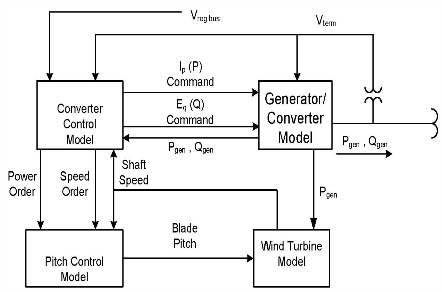
II. Double Fed Induction Generator or Variable Speed, Double Fed Asynchronous Generators with Rotor-Side Converter and Modeling

Seen from Figure 1.a) the wind turbine generator contain the field converter or power converter in which its rotor winding is connected with the power converter and its stator winding is connected with the grid. The main purpose of the power converter is to maintain the output real and reactive power and bus voltage independently and instantaneously and allow the machine to run in different speeds. Under normal working condition, the stator output is controlled by the power converter thanks to the electromagnetic coupling between stator and rotor separated by the air gap.

Nevertheless, when the system is under the severe disturbances, the crowbar mechanism in power converter is applied to protect DC bus from over voltage and also short the rotor winding to consider the generator as a squirrel cage induction one.



(a)



(b)

Fig. 1: Connectivity of wind turbine generator in type 3 a) Doubly fed induction generator, b) communication among generic wind models

III. Test Model and Effect of Wind Power on Power System

A. DFIG Modeling and Network Model

1) DFIG Modeling: The test system, the different electrical components of the system as well as the chosen parameters are presented in this part. The test system based on power flow to simulate the effect of wind power on the system shows an aggregated model of wind farm by connecting a single machine to a single equivalent unit of transformer. The wind farm has a total active power of 105 MW, which combines 42 wind turbines with each turbine rated at 2.5MW. The DFIG generator is a well known wind turbine technology occupying about 70% of total installed amount of wind farm in the world. The 2.5MW DFIG in PSSE version 32 is a reduced two-mass model and has the detailed representation of both rotor and stator magnetic fluxes to simulate the responses of the turbine. Besides, DFIG model is supported by full converter to limit the maximum output power of the generator and pitch controller to adjust rotor speed, which plays an important role in dynamic characteristics to the system disturbances. Subsubsection text here.

2) Full Network Model: The study system is taken from the large Vietnam power system with a planning data untill 2015. The system is used to connect the 220kV buses at Bac Lieu, Soc Trang, O Mon and Rach Gia. The total active power of wind farm connecting to the system is 105 MW taking up 16.8% of the total active power of the study system. Specifically, the equivalent 220kV network connecting the power plants around Soc Trang province consists of 4 main buses : a Soc Trang 220kV power plant shown by

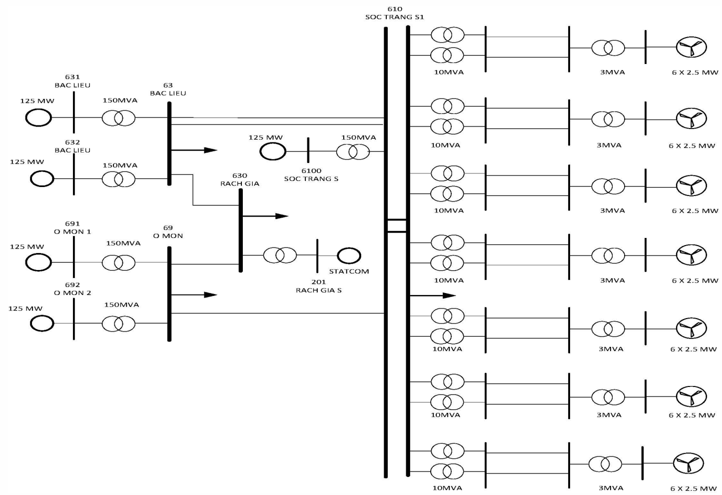


Fig. 2: The connection diagram of wind turbine in Soc Trang province

a 130MVA generator bus, a O Mon 220kV power plant shown by a two-130MVAgenerator bus, a Bac Lieu 220kV substation represented by a two-130MVA-generator bus and a Rach Gia intermediate bus to connect Bac Lieu to O Mon and a synchronous compensator considered as a synchronous generator at bus 201. Wind machines are identified as follows [18].

B. Effect of Wind Power on Power System

The DFIG model is implemented in power flow and dynamic simulation to observe and analyze the responses of wind plant to the test system under different disturbances such as loss of load and generator source as well as the requirements for connecting wind farm. Under different transient faults, both the voltage and frequency should be considered to evaluate the effects of wind power on the power system stability.

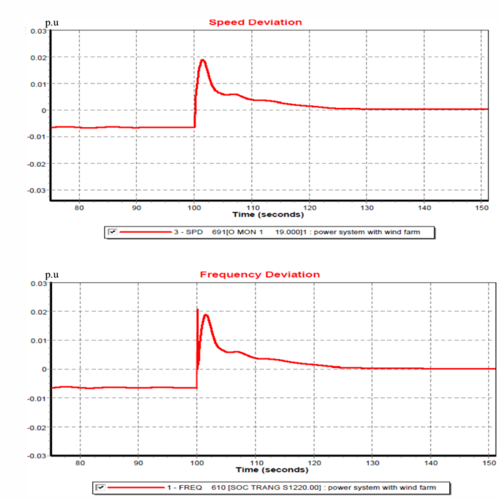


Fig. 3: The responses of system frequency and generator speed when connecting wind turbines

1) Connecting wind power: Direct connecting wind farm into the grid causes the transients to the network: the changing frequency, dipping voltages, flicking speed.

Figure 3 shows system frequency as well as the angular generator speed get more overshoot when the wind farm is connected. Specifically, the percentage overshoot is 2% and the settling time is about 25 second. Initially, the frequency deviation grows up to 0.02pu (about 51 Hz) before it goes around 0 pu which means that power system recovers the new operating condition after 25 seconds.

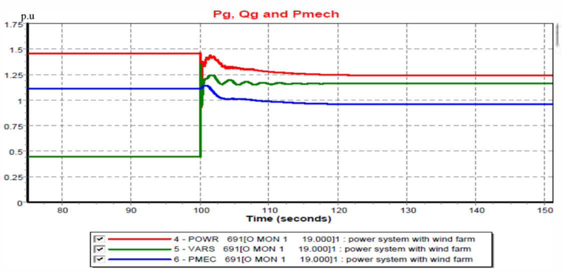


Fig. 4: The transients of active, reactive and mechanical power of generators with wind farm

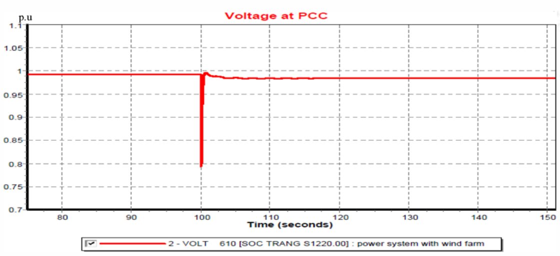


Fig. 5: The oscillation of PCC voltage with wind farm

Seen from Figure 4 and 5, there is a small oscillation of voltage at PCC, real and reactive power at generator buses in the first 10 second. It can be seen that generator reactive power significantly increases from about 0.5pu to about 1.2pu that means the wind generators absorb the reactive power from the system, which also explains decreasing the voltage at PCC when connecting wind farm.

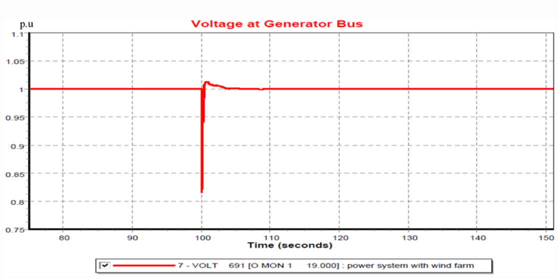


Fig. 6: The transients of active, reactive and mechanical power of generators with wind farm

Figure 6 presents the relatively large fluctuation of voltages at generator buses in the first second before becoming steady state when wind farm is connected. When power system is connected with wind farm, voltage at bus PCC significantly reduces from nearly 1pu to 0.8pu before moving initial steady state.

2) Loss of a generator on power system: The simulation time lasts 25 seconds and the loss is applied at 15th second on a generator at bus 6100 which separates the generator from the system. The main objective of this simulation is to observe the responses of wind turbines to changes of power flow. The results are shown as followings:

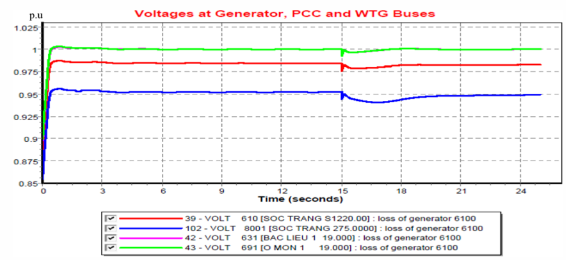


Fig. 7: The responses of voltages at PCC, generator and WTG buses

Firstly, it can be seen from Figure 7, the terminal voltages at generators and wind turbines changes a little with the small decrease in 5 seconds before becoming the original steady state condition while Figure 8 shows the increase in active power and as well as generator rotor angle to supply the load that the lost generator at bus 6100 was in charge of.

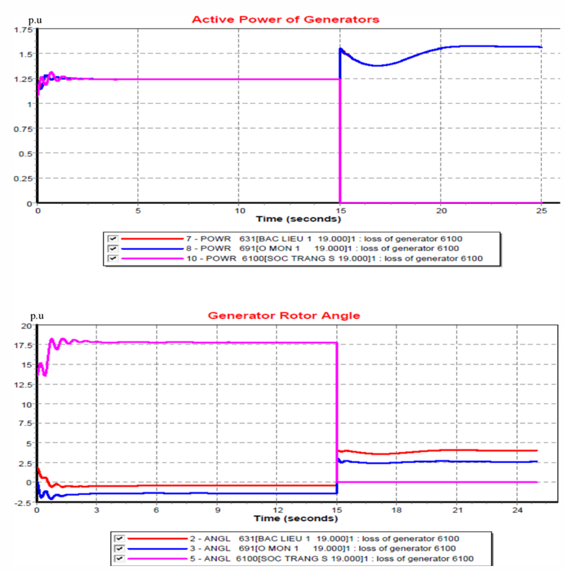


Fig. 8: The responses of voltages at PCC, generator and WTG buses

Figure 9 also represents the way to control wind turbine to increase active power sending to the system by adjusting the pitch angle. The smaller the pitch angle is, the higher active power is generated. The power obtains the maximum value when pitch angle reach to zero.

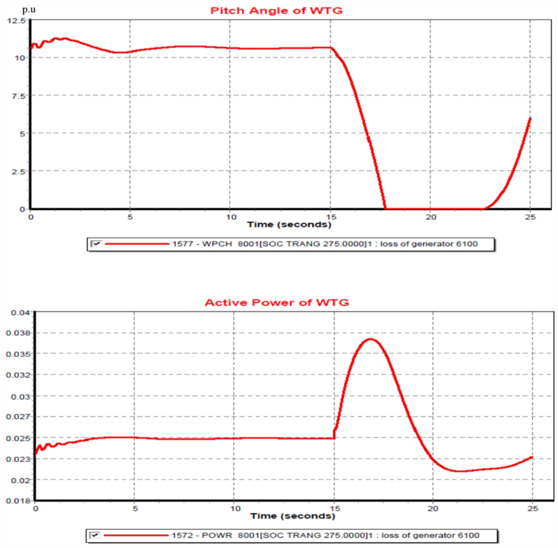


Fig. 9: The increasing of wind turbine active power by adjusting pitch angle

IV. Conclusion

DFIG wind turbines have successfully been simulated along with the reduced equivalent network model of 220kV power system in Soc Trang. The dynamic responses of the wind turbines are well performed to understand their effects on the study power system. Besides, the simulation setting, description and explanation for the control models of wind turbines are also mentioned in this thesis.

From the simulation, it can be seen that the voltage and frequency play the important role in power system stability. When any disturbance appears, the system frequency and voltage move to new operating condition to maintain power system stability. During the faults, the difference between the mechanical and electrical power results in the change in rotor speed as well as the system frequency while reactive power is always controlled to maintain the desired terminal voltage. A noticeable characteristic of DFIG wind turbines is the capability of controlling the pitch angle to obtain the expected power output. Specifically, the smaller pitch angle is, the larger electrical power of wind turbines is. Moreover, the AC/DC/AC converter needs to consider here. Rotor side converter can be blocked to limit the over current in the rotor when disturbances appear and after that it is restarted to connect to the system after grid side convert (GSC) have attempted to recover the terminal voltage.

The results show that: the system frequency always changes to get power system stability such as moving to new condition of system frequency in connecting wind farm and loss of a generator while voltage at PCC, real power and reactive power significantly reduce. Besides, the simulation of loss of a generator proves that wind turbine can control real power sending to power system by adjusting pitch angle to get the desired output power.

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