ANALYZING SMALL DISTURBANCE BY WIND GENERATOR IN POWER SYSTEM

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ABSTRACT

In recent years, the wide integration of renewable energy lead power system facing some issues which is required to investigate carefully. Thus, the comprehensive knowledge about the response of wind generators to practical disturbances is necessary Obviously, the double fed induction generator (DFIG) which includes variable pitch control and rotor-side converter is used commonly because of its efficiency. In this paper, the authors observe, analyze and evaluate dynamic responses to disturbances such as connect and loss of wind generator on the voltages and frequency on the overall power system. The model was built in PSS/E and test to a bulk power system – the reduced equivalent Soc Trang network, Viet Nam. The result show that because of using an uninterrupted operation and fast control of DFIG converter, the DFIG wind turbines response successfully to each disturbance.

Key words *Double Fed Induction Generator (DFIG), renewable energy, dynamic modelling, small disturbance, Vietnam power system*

Introduction

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 while the number has increased eight times in the past decade compared with that in 2008 which proves that in the past six years (from 2008 to 2013) the growth rate of wind energy is extremely high. 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], [2], [3], [4], [5]. In Southeast Asia, Vietnam has the largest wind power potential with total desired capacity of 513, 360 MW until 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], [9], [10].. In 1999, Vietnamese Government issued the action planning for renewable energy with the cooperation between Vietnam Electricity (EVN) and World Bank [7] The planning has attempted to help international organization to promote and develop the renewable energy usage in rural area and network connection. The goal is that 5% of total Vietnam energy comes from the renewable energy until 2020 Each year 100MW-200MW of wind power is sent to national power system [4], [10], [11], [12]

The effects and requirements for connecting wind farms to power system is an interesting and exciting topic for many researchers all over the world [13], [14], [15], [16]. Under different disturbances such as short circuit, loss of generators, loss of load, etc. which are applied to observe and evaluate the responses of wind turbines, the voltage and system frequency play the very important role [17], [18], [19], [20], [21], [22]. If faults occur in the system, there are transients of voltage and frequency. Depending on how the transient level is, operators can allow wind farms to continue to connect or disconnect and when the power system become stable, wind farm is reconnected before the faults are fixed.

Due to increasing in the size and quality of wind farms in recent years, the market of wind turbine become hot with many suppliers, namely GE, SIEMENS,

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ENERCON, VESTAS and so on... competing each other and produce the practical wind turbine model as well as simulation software to apply, observe and assess the effects of wind turbines on power system One of the popular software is PSS/E abbreviated from power system simulator for engineering produced by SIEMENS company [23]. PSS/E is a powerful integrated interactive and comprehensive program to simulate, analyze and optimize the performances of power system as well as provide dynamic models used in designing and planning power system [24], [25].

In this paper, DFIG is selected to simulate the effects of wind turbines on reduced equivalent power system - Vietnam. Wind turbine model of DFIG is a doubly fed induction generator or a variable speed, doubly fed asynchronous generator with rotor-side converter called DFIG wind turbine.

The study system is taken from the large Vietnam power system with a data in 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 In this paper, the dynamic performances of wind turbines during connect and disconnect with power system. The voltages and the system frequency are specially considered to investigate the impact of those disturbances on power system.

The overview of Vietnam power system

The diagram of transmission line in Vietnam power system is shown in Figure 1 According to the geography and climate, the Vietnam power system includes 3 parts northern, central and southern, which are connected by 500 kV transmission lines [11]. The transmission system consists of different voltage levels: 500kV, 220kV and 110kV The 500kV transmission lines with the total line length of 4437km runs from the northern to southern area, which transport the electricity forth and back among the areas The circuit 1 of this transmission line has operated since September, 1994 and in 2005 the second circuit was successfully built and until now these lines are still in the good working condition

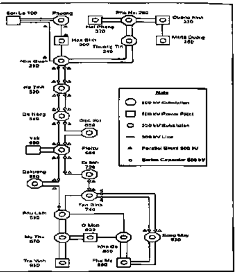

Figure 1: *Diagram of Vietnam power system: 500 kV transmission lines [12]*

From 2004, Vietnam power system was imported from the 110kV transmission lines of China Southern Power Grid. Until the 2012, the imported electricity was increasing to 3 6% of the amount of national energy. Hydro power accounts for 48.72%, coal fired 19 75%, diesel 1.92%, combined open cycle gas turbine 25 94% and renewable 0.19% [11].

In 2012, the total electricity capacity including produced and imported electricity has archived about 120,257 billion kWh. The consumed one in the whole country is almost 119,033 billion kWh increasing 10.61% in comparison with that in 2011. This growth is relatively low within the past 10 years whose average growth from 2001 to 2011 was 13.22%

Double Fed Inductor Generator (DFIG)

Wind turbine model of doubly fed induction generator or a variable speed, doubly fed asynchronous generator with rotor-side converter called DFIG wind turbine. The DFIG wind turbine is connected through a mechanical shaft system which includes a low speed shaft and a high spseed shaft with a gearbox in the middle. The asynchronous generators are fed by stator and rotor side- the former is directly connected to the network and the latter is connected to the grid via the AC/DC/AC converter. Thanks to an uninterrupted operation scheme and the fast control of the AC/DC/AC converter, DFIG brings some benefits in operation and control as well as maintaining power system transient performance and stability.

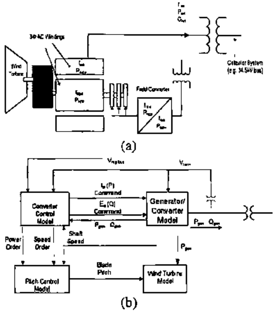

Figure 2: *Connectivity of wind turbine generator in type 3 a) Doubly fed induction generator, b) communication among generic wind models*

As we can see from Figure 2 a), the wind turbine generator contains the field converter or power converter in which its rotor winding is connected to the power converter and its stator winding is connected to 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 short the rotor winding to consider the generator as a squirrel cage induction one.

Test model

The case study is developed based on Vietnam Power System in PSSE version 32. Here, the total capacity of wind farm is 105 MW, in which consist 42 wind turbines with 2 5 MW for each The case study simulates the wind generator as DFIG, because it is occupying about 70% of total installed amount of wind farm in the world. It should be noted that 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 uses full converter to limit the maximum power of the generator and pitch controller to change rotor speed, which is very important in dynamic characteristics to the system disturbances.

Network Model

The Vietnam power system includes the different voltage levels as presented in Section 2; Therefore, the case study has chosen the medium voltage (220 kV), shown in Figure 3. The equivalent 220kV network connecting the power plants around Soc Trang province consists of 4 main buses. a Soc Trang 220kV power plant, a O Mon 220kV power plant, Bac Lieu 220kV substation, a Rach Gia intermediate bus to connect Bac Lieu to O Mon The total capacity of wind generator is 130MVA for Soc Trang, two-130MVA-generators for O Mon, two-130MVA-generators for Bac Lieu, and a synchronous compensator considered as a synchronous generator at bus 201.

Line model

The parameters of the overhead power lines and cables are various series resistance, reactance and shunt capacitive line charging depending on the branches and the length of the lines according to the material of Vietnam Electricity EVN [12].

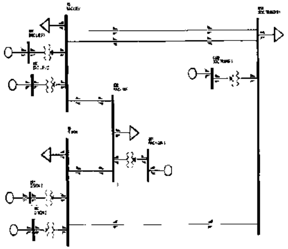

Figure 3: *The online layout of study system in Soc Trang*

Load model

The system includes four loads and they are considered as the constants during all simulations, which makes the simulation simpler and reasonable due to the low sensitivity to changes in load size. In both Bac Lieu and Soc Trang, the real and reactive power occupy 100MW and 30MVAR, respectively while the values in O Mon is relatively large, about 300MW and 50MVAR. The other is 150MW of real power and 40 MVAR of reactive power in Rach Gia.

Transformer model

Most transformer used in this simulation is two winding transformers. The preferred 5kV/ 35kV transformers have 3MVA apparent power using for the connection wind generator to network and there are some 19kV/ 220kV transformers with different capacities to connect generators to 220kV power system. Especially, the tap changer position in the transformers is unchangeable in the simulation.

Result

The case study is run by different disturbances to observe and analyze the responses of wind plant with small disturbance when the system connects or losses one wind generator. Under both the voltage and frequency should be considered to evaluate the effects of wind power on the power system stability. The case study is run by two cases: (i) the connection of wind generator and (ii) the loss of wind generator at bus 610 in the system. The simulation is carried out in 25 seconds for all cases.

Connecting wind generator

Figure 4 shows that the frequency and the angular generator speed increase when the wind farm is connected, in which the blue line shows the benchmark and the red line indicates the connection of wind farm. For the first fifteen seconds, the fluctuation of frequency and speed is significant and they reach the steady state after 20 seconds. Apparently, the frequency deviation climbs to 0.004pu (about 50.2 Hz) before it goes around 0.0005pu (approximately 50.025 Hz) which means that the frequency still is in the allowable range of 49.5 Hz and 50.5 Hz

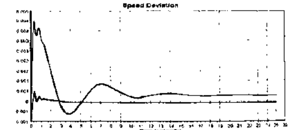

Figure 4: *The responses of system frequency and generator speed when connecting wind turbines*

From Figure 5 and 6, there is a small oscillation of voltage at PCC, active and reactive power at generator buses in the first second. Generator reactive power significantly increases from 0.25pu to 1.125pu when connecting the wind generator, while the voltage at PCC bus is decreasing about 0.005pu. The reason is that the wind generators absorbed the reactive power from the system

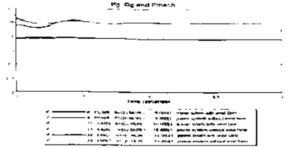

Figure 5: *The transients of active, reactive and mechanical power of generators with and without wind farm*

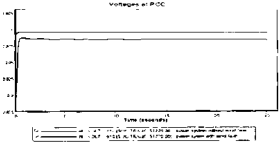

Figure 6: *The oscillation of PCC voltage with and without wind farm*

Figure 7 presents the relatively large fluctuation of voltages at generator buses in the first second before reaching the steady state since the wind farm is connected. When power system is connected with wind farm, the settling time is 1 second compared to 0.45 second in case of without wind farm. The generator bus voltage far away from PCC possess less transient than those near PCC and when wind farm is connected, the transient is more.

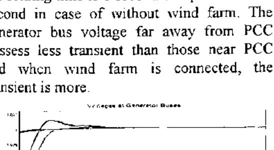

Figure 7: *Voltages at generator buses with wind and without farm*

Loss of wind generators

The simulation is carried out to demonstrate and compare the transient performances of power system when some wind turbines are lost. Specifically, bus 6101 is disconnected to simulate the loss of wind turbine with total lost power capacity of 15MW. The disconnection is applied at 12th second. After the disconnection, the system changes to new operation condition shown in Figure 8.

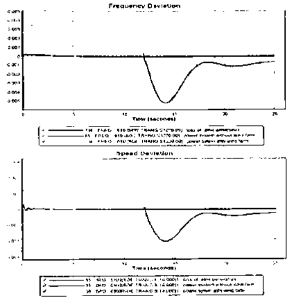

Figure 8: *The fluctuation of system frequency and generator speed with loss of wind generators*

It is easy to observe that after bus 6101 is disconnected at 12th second, the system frequency deviation decreases by 0.005 p.u (0.25 Hz) before coming back a new steady state operating frequency (about 49.95 Hz). Similarly, the generator speed deviation experiences the same trend, which demonstrates the accuracy of this simulation due to the synchronization of the control system between generators and power system.

Figure 9 shows the transient responses of generator power and voltage. When some wind turbines are disconnected, the real power as well as mechanical power increase to supply more load (15MW) which lost wind turbines was in charge of before, on the other hand, the generator reactive power reduces due to the characteristic about the reactive power consumption of wind turbines. At that time, generator voltage only meets the small transient at 30th second before becoming back the original operation point. A overshoot (approximately 1.01pu) of generator voltage at bus 6100 appears

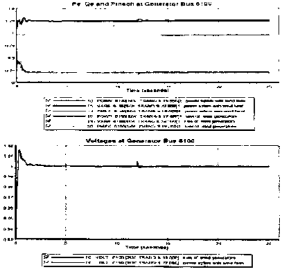

Figure 9: *The responses of active, reactive, mechanical power and voltages at generator bus 6100 when some wind generators are disconnected*

Conclusion

Model test have successfully been simulated. The dynamic responses of the connection and disconnection of wind turbines are performed to evaluate the effect on the power system. Obviously, it can be seen that the voltage and frequency play the important role in power system stability. When small disturbance appears, i.e. connect and disconnect wind generator, the system frequency and voltage move to new operating condition to maintain power system stability while voltage at PCC, active power and reactive power significantly reduce.

For the further work, the authors would like to apply STATCOM to improve the dynamic performances of wind turbine and analyzing the harmonics in the system when STATCOM is installed as well as finding out solutions to mitigate the harmonics.

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TÓM TẮT
PHÂN TÍCH CHẤN ĐỘNG NHỎ DO MÁY PHÁT ĐIỆN GIÓ TRONG HỆ THỐNG ĐIỆN

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Trong những năm gần đây, sự lan tỏa rộng rãi của năng lượng tái tạo đã đưa hệ thống điện đối mặt với một vài vấn đề mà cần phải được phân tích một cách kỹ lưỡng Do đó, kiến thức toàn diện về sự phản ứng của máy phát điện gió đến sự chấn động trong thực tế là hết sức cấp thiết Rõ ràng, Máy phát cảm ứng hai mặt (DFIG) được tích hợp bộ phận kiểm soát sự thay đổi và bộ phận biến đổi ở phía Roto đang được sử dụng một cách rộng rãi bởi vì sự hiệu quả của nó mang lại Trong bài báo này, nhóm tác giả đã quan sát, phân tích và đánh giá sự phản ứng động của sự xáo trộn như kết nối hoặc ngắt kết nối của máy phát điện gió trên điện áp và tần số hệ thống điện. Mô hình mô phỏng đã được xây dựng trong phần mềm PSS/E và kiểm tra với lưới điện ở Sóc Trăng Việt Nam Kết quả chỉ ra rằng bởi vì sử dụng hoạt động liên tục và kiểm soát nhanh chóng của DFIG chuyển đổi, các máy phát gió DFIG phản ứng thành công cho mỗi sự xáo trộn

Từ khóa. *Máy phát cảm ứng hai mặt (DFIG), năng lượng tái tạo, mô hình động, xáo trộn nhỏ, hệ thống điện Việt Nam*

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