GRID CODE MAINTENANCE WHEN WIND DG INTEGRATES WITH THE GRID USING STATCOM

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ABSTRACT

The importance of Distributed Generation (DG) is a well known fact for power system engineers. The power system with integrated DG has to follow grid codes in order to maintain a safe and reliable electricity supply throughout the area. The question may arise, which all areas in power system require the aid of DGs and their effect on power system when integrated. So here the importance of Flexible AC Transmission systems(FACTS) comes into picture. Static Synchronous Compensator (STATCOM) one of the FACTS controller is an ideal controller to improve the capabilities of wind farms as they offer an easy solution to two of the important requirements of the expected grid code – namely dynamic reactive power compensation and fault ride through capabilities. A case study is carried out to know the effect of wind DG and how STATCOM helps the system to improve its qualities under fault conditions. An IEEE test system is considered here and using MATLAB/SIMULINK the test system is modelled. For this system a wind farm is integrated at some assumed position and the behaviour of the system is studied when wind DG integrates the system. Scopes are obtained and analyzed the effect of wind DG when connected to the grid. To overcome the voltage dips at the point of common coupling a STATCOM is connected and observed the scopes. Significant improvement of voltage is seen from the scopes with STATCOM and hence maintenance of grid code can be achieved.

KEYWORDS: *Distributed Generation, FACTS, Power System, STATCOM, Grid Codes*

I. INTRODUCTION

For a large and dispersed rural country, decentralized power generation systems, where in electricity is generated at consumer end and thereby avoiding transmission and distribution costs, offers a better solution. The concept of DG has been taken as decentralized generation and distribution of power especially in the rural areas. In India, the deregulation of the power sector has not made much headway but the problem of T&D losses, the unreliability of the grid and the problem of remote and inaccessible regions have provoked the debate on the subject. As people in many of the electrified villages are very much dissatisfied with the quality of grid power, such villages also encouraged to go ahead with the Distributed Generation Schemes [1]. Though India has made considerable progress in adopting technologies based on renewable sources of energy these are not yet capable of commercial application on a large scale. Since last decade, technological innovations and a changing economic and regulatory environment have resulted considerable revival of interest in connecting wind generation to the grid [2].

It is estimated that in India with the current level of technology, the 'on-shore' potential for utilization of wind energy for electricity generation is of the order of 65,000 MW. India also is blessed with 7517km of coastline and its territorial waters extend up to 12 nautical miles into the sea. Potential areas can be identified on Indian map using Wind Power Density map. C-WET, one of pioneering Wind Research organization in the country is leading in all such resource studies and has launched its Wind Resource map. Fig. 1 shows the wind power potential in India. According to MNRE's achievement report, The cumulative installed capacity of Grid Interactive Wind Energy in India by the end of September 2011 was 14989MW (of which 833MW was installed during 2011-2012 against a target of 2400MW). MNRE has estimated state wise wind power potential in the country. Fig 2 highlights the installed capacity in various states of India. The ever increase in demand in energy can be met with the potential of wind energy which need to be installed in upcoming years and plan is ever going on.

The growth of Wind potential makes one to think about the problems associated with wind power when it integrates with the grid. As of now to maintain grid codes capacitor banks have been installed and operated by mechanical switches. But as these switches introduces harmonics into the system. Smooth operation of centralized grid is possible only if grid codes are maintained and it's possible with STATCOM as switching operation of capacitor banks introduces harmonics into the system [3]. A case study simulated with STATCOM and without STATCOM is shown and scopes are observed to know how the effect of STATCOM helps to maintain grid codes and also improves the performance of the system.

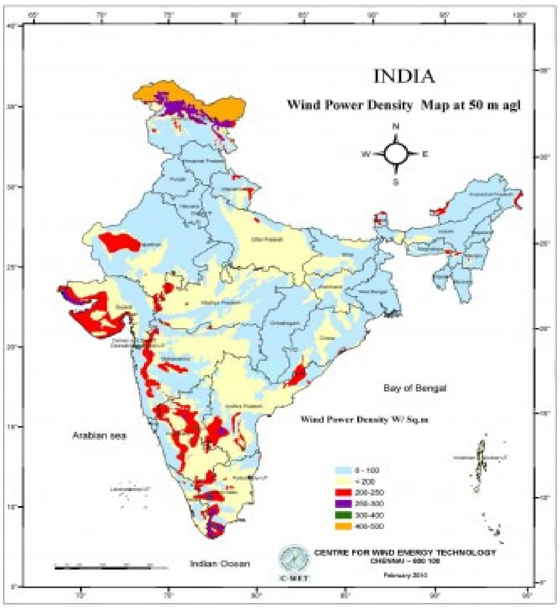


Fig.1 Wind energy potential in India

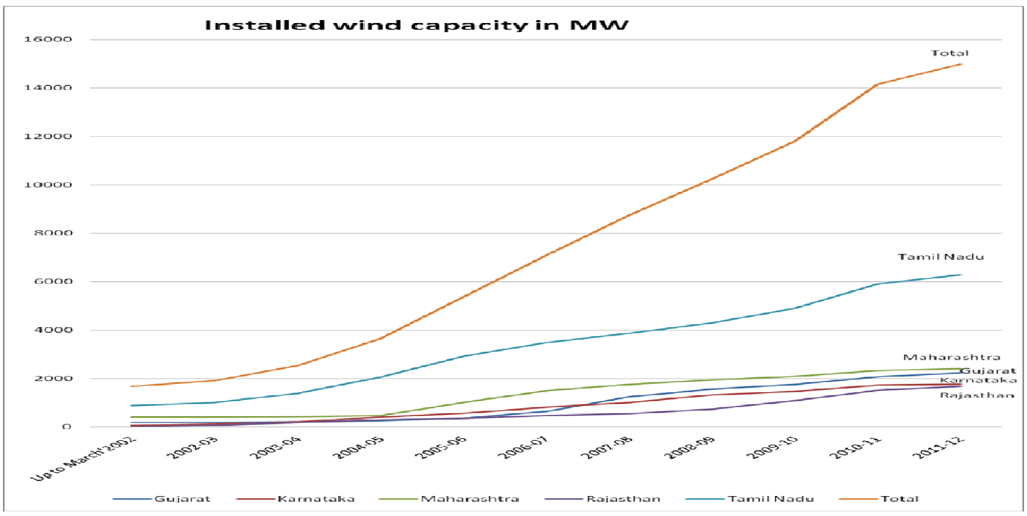


Fig.2 Installed wind capacity in India

II. GRID CODES

Many of the current wind farms use conventional capacitors to reduce the reactive power drawn from the grid. The capacitors, though economical, cannot provide a robust and flexible performance. As the penetration of wind energy is increasing, grid operators all over the world are putting in place appropriate Grid Interconnection Codes. Higher penetration of renewable will have higher impact on the grid. Since the output of the wind and solar power is varying in nature, it poses integration challenges.

The grid operators would like to see the wind and solar farms operate as conventional power plants, meaning that they provide a steady state of power without any intermittencies or fluctuations. Since wind and solar as well as other renewable are intermittent sources of energy, technology needs to them to "look like" fossil fuels. Many regions have adopted special interconnection standards called "grid codes" to integrate renewable into the grid. The grid codes help in establishing a standard operating practice to minimize the impacts on the grid while providing a platform for uniform requirement that maximizes benefits for the grid and the developers alike.

In INDIA it is expected to increase renewable energy as the government continues to focus on and encourage renewable energy generation. However, as the use of renewable energy increases, it becomes imperative on the part of the government and regulatory boards to introduce standards that ensure a safe and reliable connection. Without these standards, India's grid cannot be improved. Because the penetration of the wind energy is already substantial in India, there is an urgent need for grid codes to be maintained as high level of penetration of wind power in future is expected. As solar energy generation will be the next big wave in India, it is logical to prepare for the future and appropriately plan all renewable into the Grid Code so that the grid operators can maintain a safe and reliable electricity supply throughout India. Major criteria are to maintain poor voltage and that's why the importance of reactive compensation comes into picture.

2.1. Reactive Power Compensation

Present day technique for the reactive power compensation required to maintain grid codes is by capacitor banks. The reactive support required by induction generators varies continuously as wind is, by nature, a variable source of energy. Capacitors come in predefined steps and need to be switched off and on several times continuously to handle these variations. This recurring switching function puts pressure on the capacitor banks, switches and the life of the capacitors. Operation of capacitor banks in large enough steps introduces step voltage in the system which can affect the equipment connected to the grid. For induction machine wind generators, a large and frequent step voltage change introduces a torque or a twisting force on the gear box of the wind turbine, which increases wear and tear with every capacitor bank switching event [4].

There are many instances when the grid voltage rises higher than the limit and needs to be brought back down to the limit. Instead of reducing the voltages at these instances, capacitors increase the voltages causing further harm. This, then, requires inductive support to ensure continuity of operation. Alternatively, the grid faces extreme low voltage during events such as fault situations. Additionally, the transformers and other equipment connected to the grid consume reactive power from the grid, which is not always offset by just the capacitors. So what is the solution?

By providing continuously variable capacitive and inductive support as needed and acting as a smooth integrator, STATCOM offers solutions to these issues. These are the major key benefits of FACTS over capacitors that are being currently used in wind farms. STATCOM systems are used to seamlessly integrate wind energy to the grid. They enable wind farms to look more like conventional power plants from the power grid's perspective. This means that the voltage provided to the grid is always steady even when the wind slows and also additional benefits to wind farm owners in terms of longer life of the wind turbines reduced maintenance requirements and maximized power outputs by the implementation of STATCOM [5]. D-VAR system is deployed in more than 100 locations around the world, including over 70 wind and solar farms. In many instances, local requirements dictate the use of such devices due to the unique nature of their grid systems. STATCOMs are advanced power electronics and control systems implemented at individual wind turbines [6, 7, 9]. During a grid high voltage situation the wind farms with only capacitors are likely to increase the voltage further, making the situation worse [8]. Additionally, the availability of the wind farms to the grid reduces as the turbines require more maintenance. During the grid faults, wind farms without a dynamic reactive compensation device disconnect from the grid[10]. This can wreak havoc on the grid and can cause a very weak grid to collapse. The absorption or generation of reactive power depending upon the situation of the demand can be easily achieved by STATCOM.

2.2. STATCOM

The second generation of FACTS that is based on voltage source converters (VSC), known as STATCOM, has a very promising future application. It is recognized to be one of the key advanced technologies of future power system. STATCOM has several advantages of being compact, high response speed and no harmonic pollution etc

The STATCOM and its variant, the D-STATCOM, are based on VSC, and so are voltage sources where amplitude, phase and frequency are entirely controllable. The dc bus capacitor applies a dc voltage at the input of the inverter. Its output is connected to the AC grid via an inductance. While adjusting the converter voltage (U2) with respect to the network voltage (U1), the converter can very quickly supply or absorb reactive power thanks to the gating signals set to the switches of the converter. The response time is mainly influenced by the switching frequency (typically 1 to 2 kHz) and by the size of the inductance.

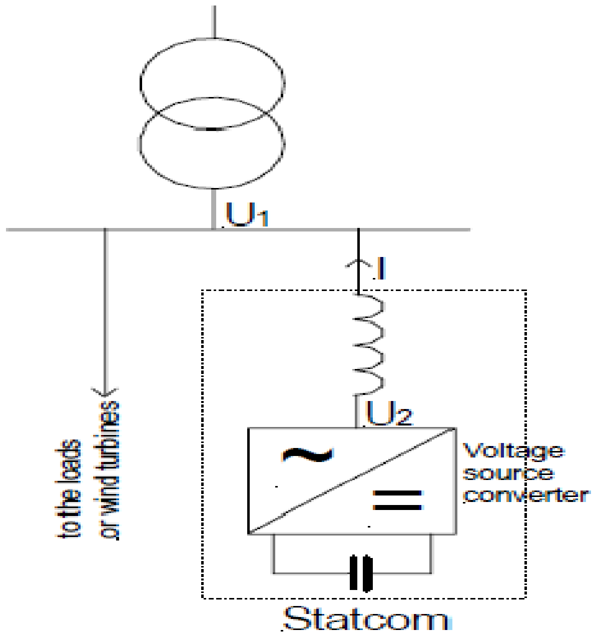


Fig. 3 Connection of a STATCOM at the Point of Common Coupling

In theory, the STATCOM can help mitigating the flicker due to variations of reactive power absorbed by induction machine-based wind farms. The reactive power required by the farm is evaluated and a controller drives the STATCOM inverter so as to generate the adequate quantity, permitting to reduce drastically reactive power flows towards the grid and therefore, the associated flicker. Fig. 3 represents how STATCOM can be connected at the point of common coupling.

III. CASE STUDY AND DISCUSSION

A modified IEEE 16 node test bus system is selected to perform simulation as shown in Figure 4 and to analyze the system with wind integration it is assumed that, feeder 3 is also fed by Wind energy DG along with grid supply.

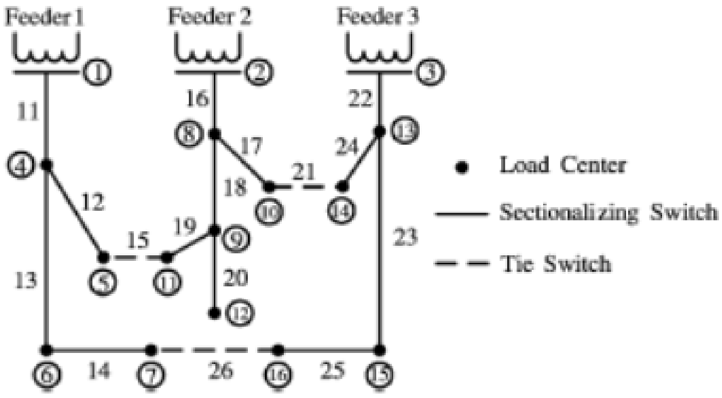


Fig. 4 IEEE 16 Bus Test System

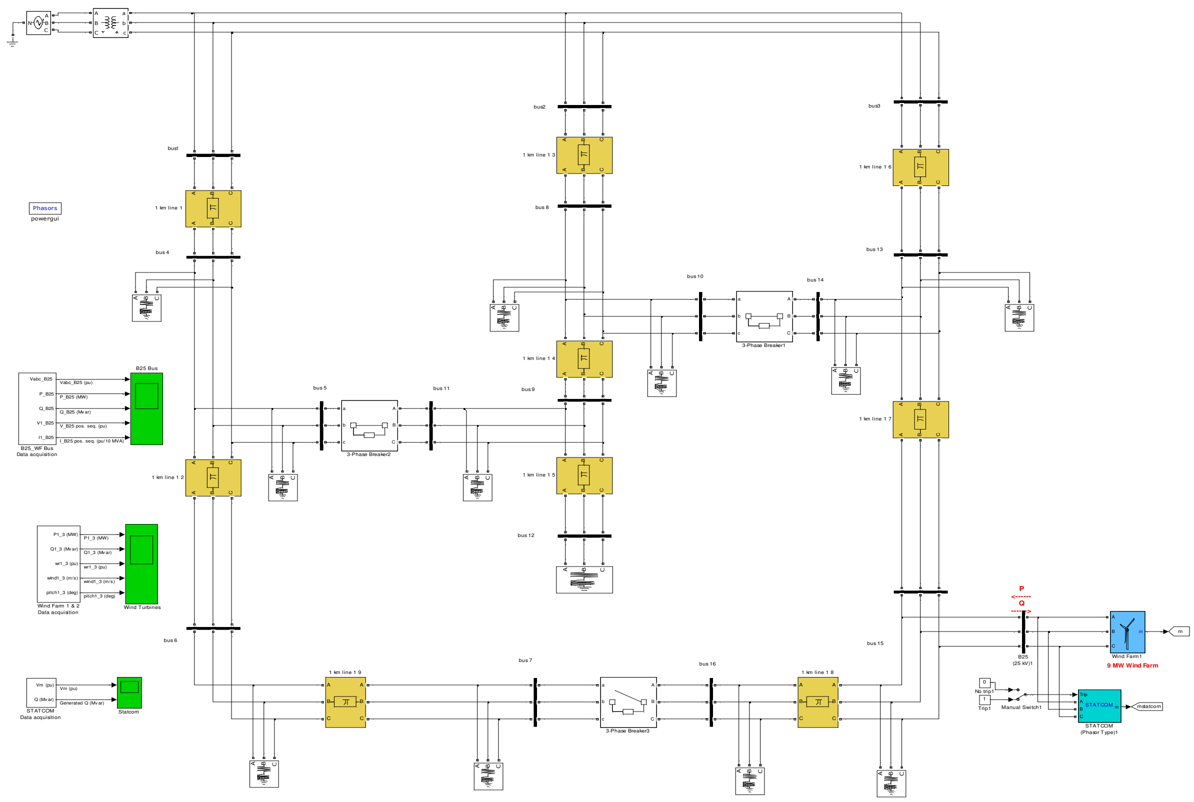


Fig. 5 MATLAB/ Simulink Model of the IEEE test system

The Simulink model of the above mentioned IEEE test system is as shown in Figure 5. For this position system is studied.

Simulation was carried out for 20 sec to study the system behaviour. For this model simulation is carried out for the different case studies such as (i) with STATCOM with LLG FAULT (ii) without STATCOM with LLG FAULT (iii) With STATCOM without LLG FAULT and (iv)Without STATCOM without LLG FAULT. To understand the system behaviour under fault a LLG fault is created to occur at 15 seconds at one of the wind turbine of the wind farm considered in the test case. To study the performance of the system the above said four different combinations of case studies were carried out.

Interestingly improvement of voltage profile and overall performance is observed from the scopes when STATCOM is connected at the point of common coupling. Fig.6 gives bus and wind turbine details for the case without STATCOM and with LLG fault. Fig.7 depicts bus and wind turbine details for the case without STATCOM and with LLG fault. Fig 8 and 9 are the scopes depicting bus, wind turbine and STATCOM details with and without STATCOM respectively under faulty condition.

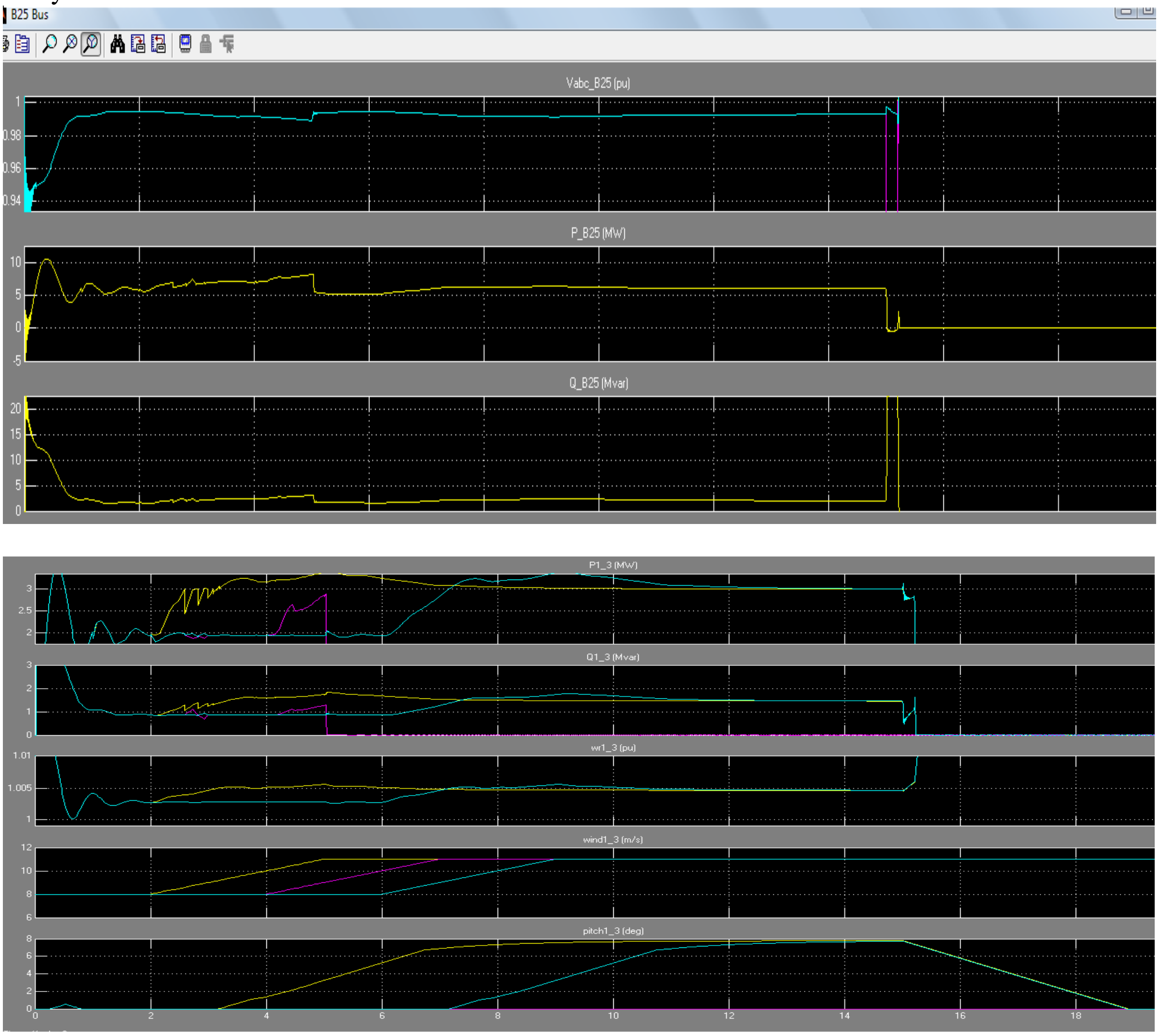
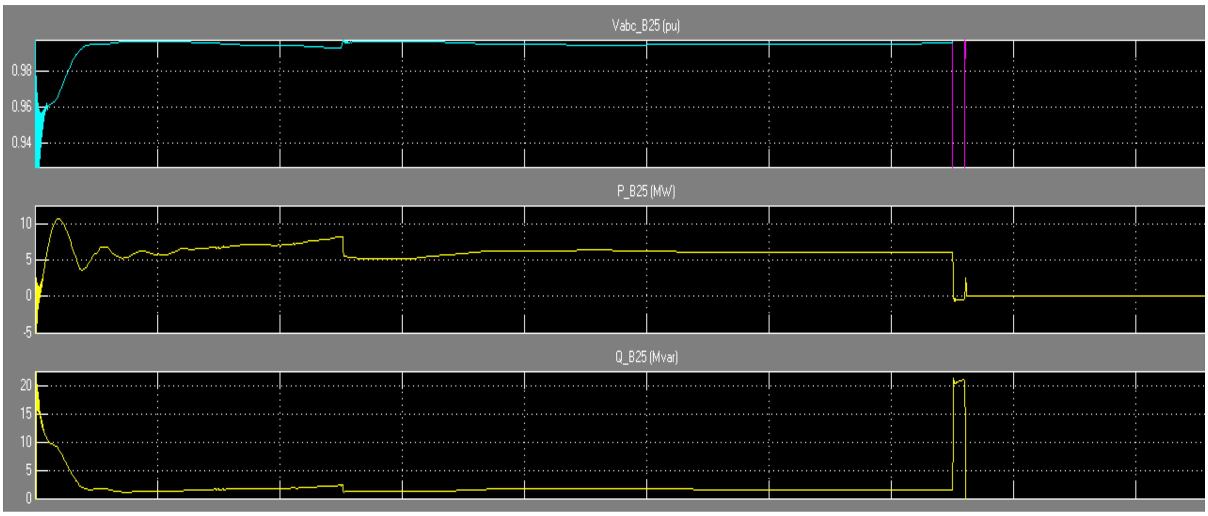
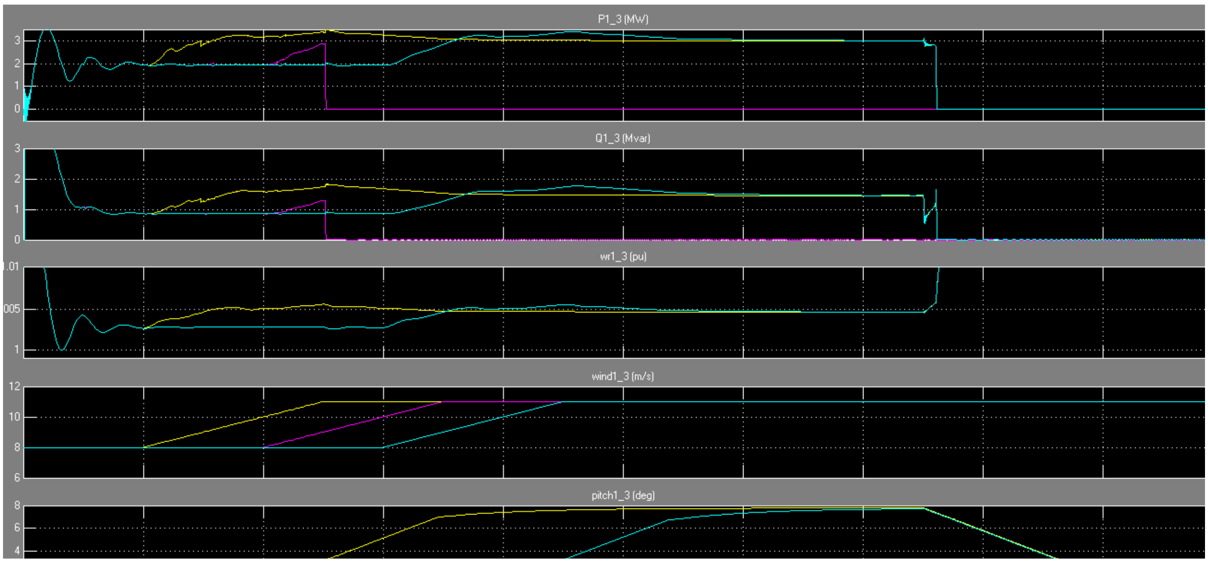


Fig.6 Bus and wind turbine details for the case Without STATCOM and with LLG fault

Bus Details



Wind Turbine Details



STATCOM Details

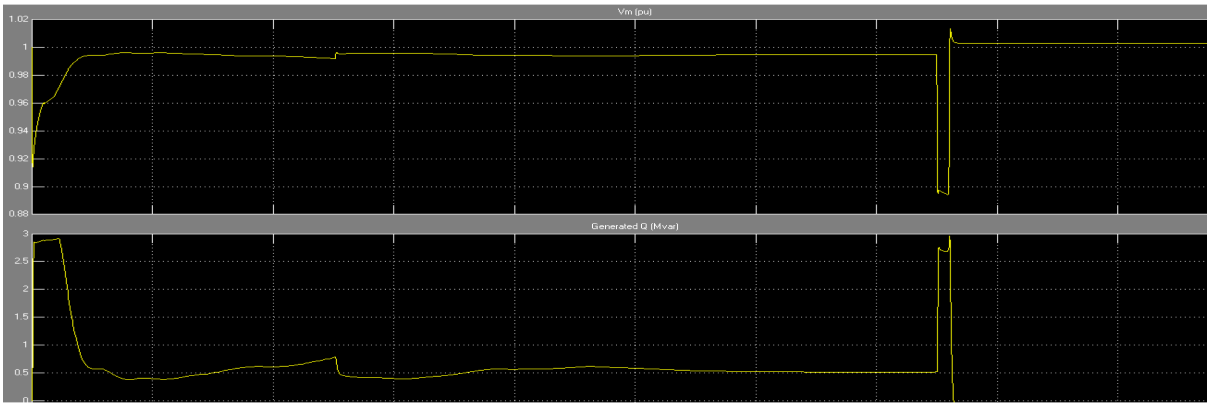
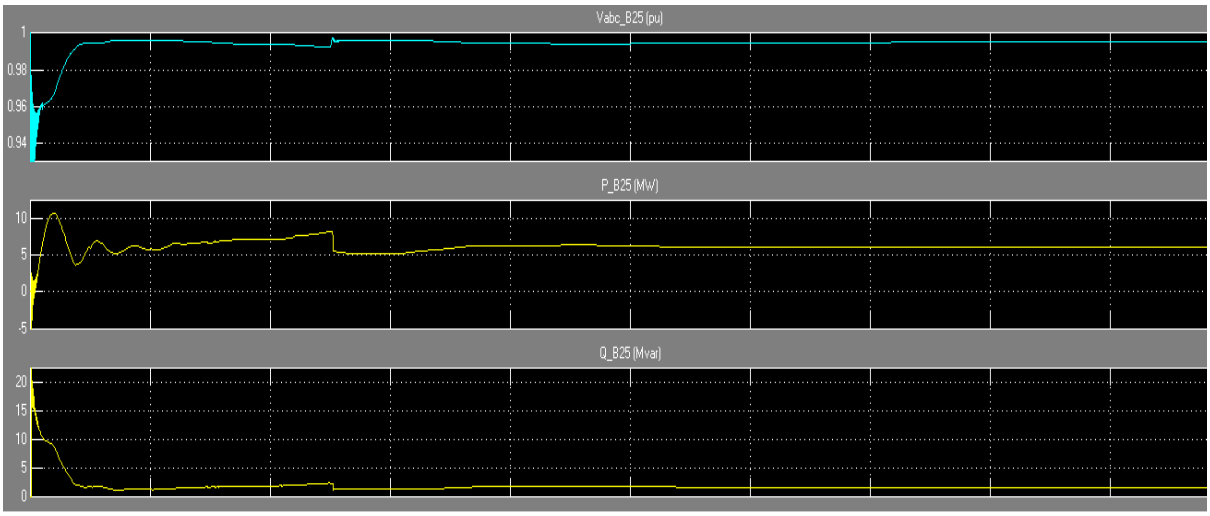
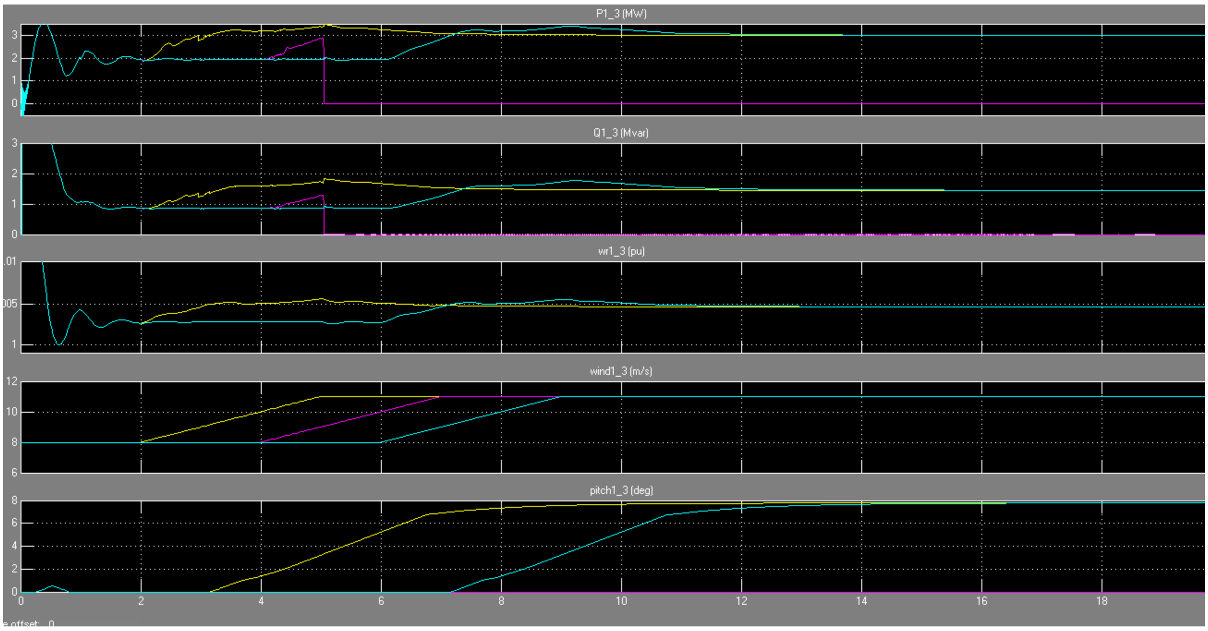


Fig. 7 Bus, wind turbine, STATCOM details for the case with STATCOM with LLG FAULT

Bus Details



Wind Turbine Details



STATCOM Details

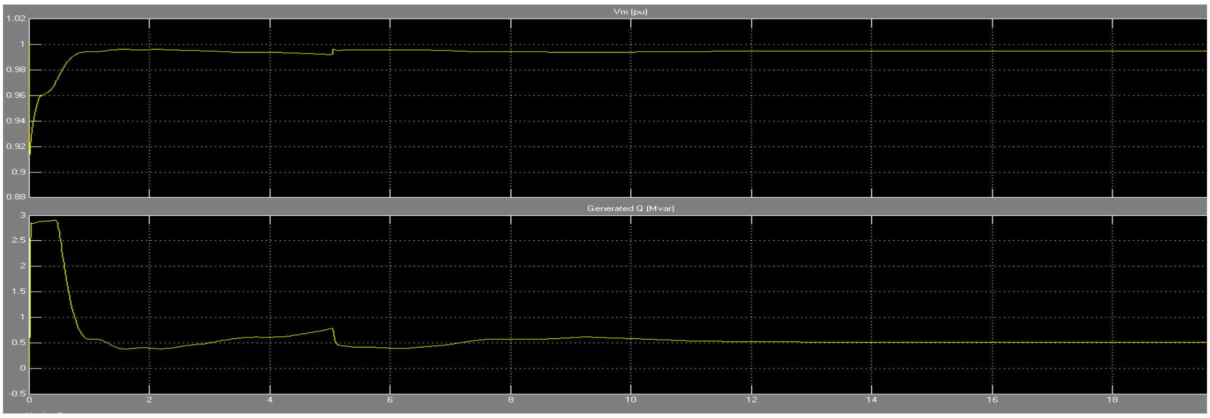
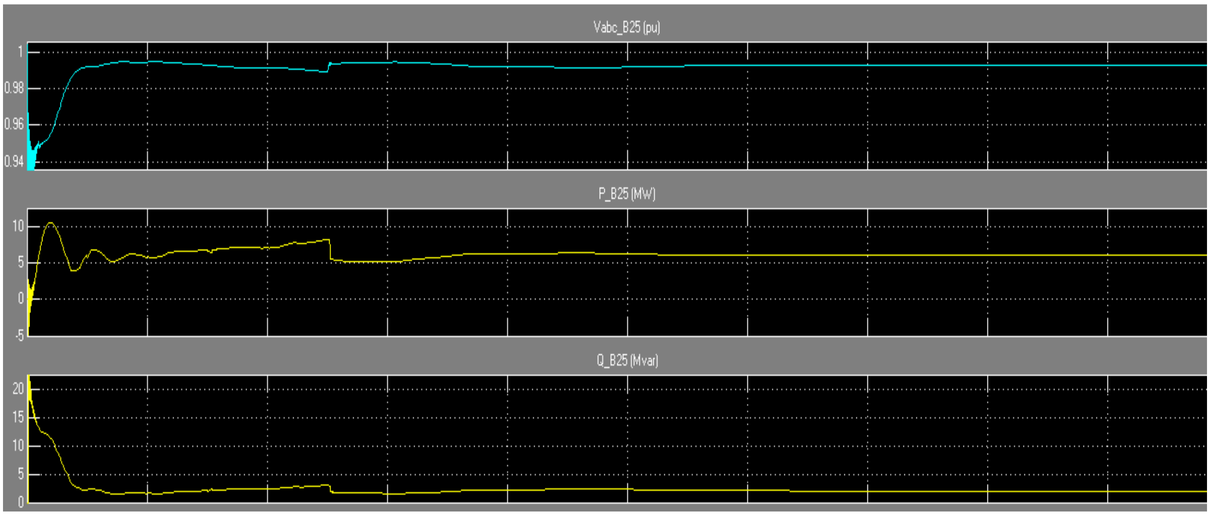


Fig 8. Bus, wind turbine and STATCOM details for the case with STATCOM without LLG FAULT

Bus Details



Wind Tuubine Details

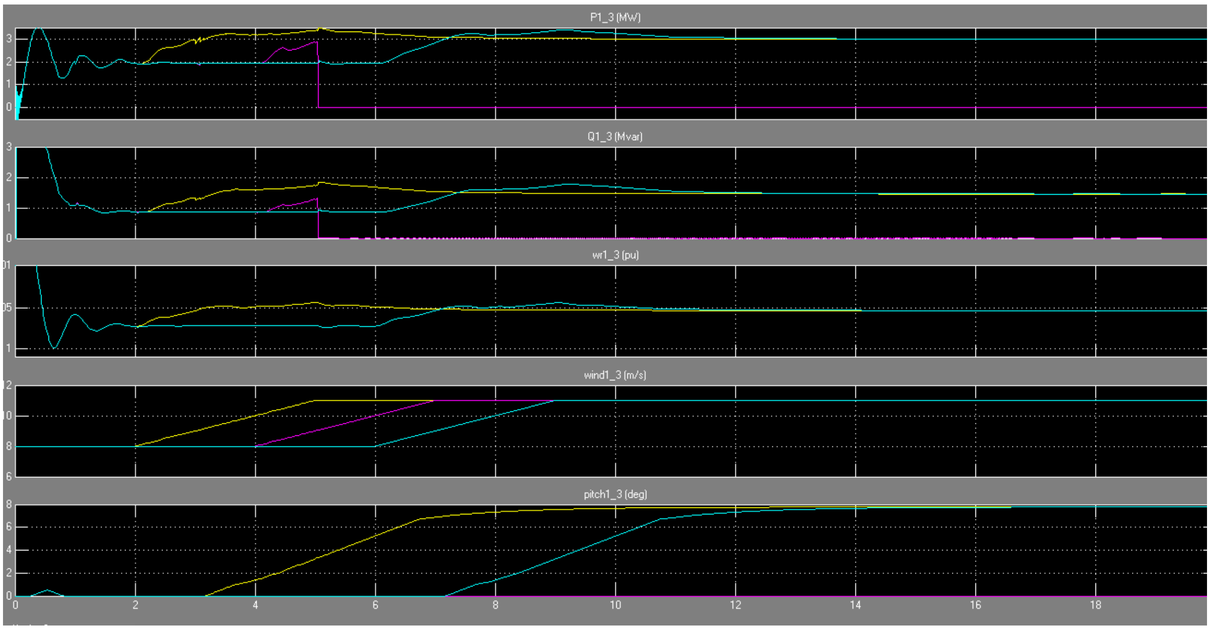


Fig.9 Bus and wind turbine details for the case without STATCOM without LLG FAULT

IV. CONCLUSIONS

The comparative study of performance of wind farm integrated with grid for different cases were carried out in this paper and found that when STATCOM is connected at the point of common coupling the overall improvement of the system performance. Ultimately the aim to improve the grid capacity without affecting the performance of the system is achieved.

The results found were satisfactory from the case study. The scopes were compared with and without STATCOM and it is seen very clear that the improvement in the voltage profile when STATCOM connected. Hence it can be concluded that FACTS controller implementation plays a vital role in the improvement of overall performance of the power system. As the wind integration causes the system voltage deterioration, if a suitable FACTS controller is placed at the point of coupling helps the system to uplift the voltage and hence helps to maintain grid codes. With this test study it has been proven the uplift of voltage profile and fault ride through is possible with FACTS controller. The same has been planned to implement on a real system where in the problem of choosing the position of wind DG can be solved by simulation studies and finally will be able to maintain the grid codes.

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