

Compensation of Impacts of Distributed Generation Using Smart Grid Technology

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Abstract- The evolution of current centralized generation in the form of distributed generation and Smart Grids provide a great opportunity to eradicate several issues associated with energy efficiency, energy security, power quality and the drawback of aging power system infrastructures. In order to meet the rising electrical power demand and increase service quality as well as reduce pollution, the existing power grid infrastructure should be developed into a Smart Grid that has the flexibility to allow interconnection with the distributed generation.

However, integrating distributed generation to power systems causes several technical issues, especially system stability. Therefore, to fully address the issue, current existing power systems should be up-graded to Smart Grid. To make the power grid become 'smarter', particularly in terms of stability and flexibility, Flexible AC Transmission System (FACTS) devices, especially Static Synchronous Compensators (STATCOM) are used.

This paper discusses the need and impacts of distributed generation in Smart Grid technology, in particular it identifies and determines whether the system remains stable or not after installing distributed generation into Smart Grid systems. Further, an attempt has been made to show that the STATCOM makes the grid become smarter. It is actually a voltage-source converter which can act as either a source or sink of reactive AC power to an electricity network.

Index Terms- power quality issues, distributed generation, smart grid, FACTS, STATCOM

I. INTRODUCTION

Currently, the main source of electrical power generation is fossil fuel producing carbon dioxide (CO₂) emission and other gases, which leads to global warming. Due to environmental issues in reducing greenhouse gases (GHG), the utilization of renewable energy sources (RES) is now growing rapidly and is being widely accepted as an alternative power supply. An important phenomenon in this regard for further future electric power generation is distributed generation, which is also known as embedded generation, dispersed generation or decentralized generation. Distributed generation in simple term can be defined as a small-scale generation. It is active power generating unit that is connected at distribution level. In order to meet the rising electrical power demand and increasing service quality demands, as well as reduce pollution, the existing infrastructure should be flexible for interconnectivity with distributed generation, such as wind turbines and solar power. However, integrating this concept of distributed generation into Smart Grid systems will increase many complex issues on real time operation, such as on power flow direction, protection, voltage profile, power quality and stability.

II. IMPACTS OF DISTRIBUTED GENERATION

The following is a simple model of power flow diagram in a transmission system with two power generators with voltages E_1 and E_2 integrated by a transmission line, which may be interconnecting points or may have load. The transmission line is assumed lossless and represented by the reactance X . The corresponding phasor diagram is also shown below.

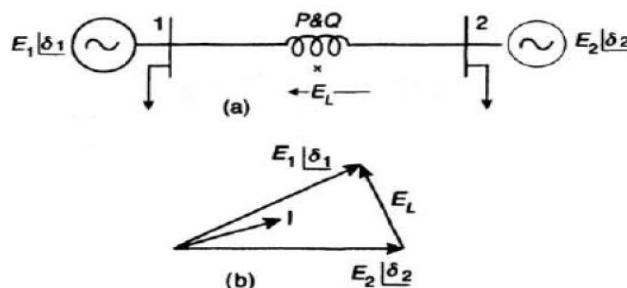


Figure 1: Line Diagram

As per the earlier work carried out on Distributed Generation and Power Quality, Some of the Various Issues involved with distributed generation are: Voltage Regulation, DG Grounding Issue, Harmonic Distortion, Flicker, Islanding, Protection System, False tripping of feeders, Fuse coordination problems, Unwanted tripping of production units, Blinding of protection, Increased or decreased fault levels, Unwanted islanding, Prohibition of automatic reclosing etc.;

III. POWER QUALITY ISSUES

Moreover, the major issue that would have an immediate effect on the performance of the electrical system in terms of the power system stability can be put in to the following categories:

- Rotor Angle Stability
- Frequency Stability
- Voltage Stability

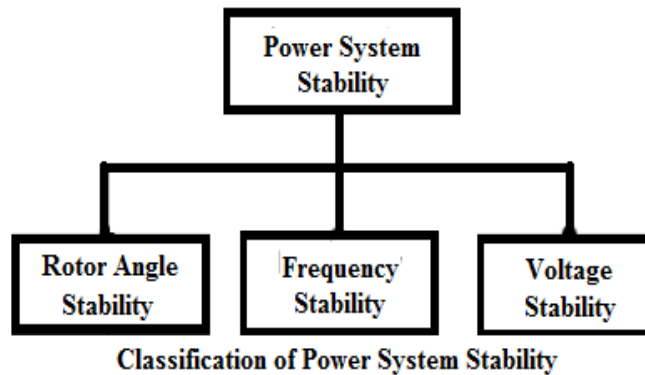


Figure 2: Stability Block diagram

IV. COMPENSATION USING SMART GRID TECHNOLOGY

STATCOM is a Voltage-Source Inverter (VSI), which converts a DC input voltage into AC output voltage in order to compensate the active and reactive power needed by the system. Figures show the Basic structure and typical steady state V-I characteristic of STATCOM. From figure, STATCOM is a shunt-connected device, which controls the voltage at the connected bus to thereference value by adjusting voltage and angle of internal voltage source.

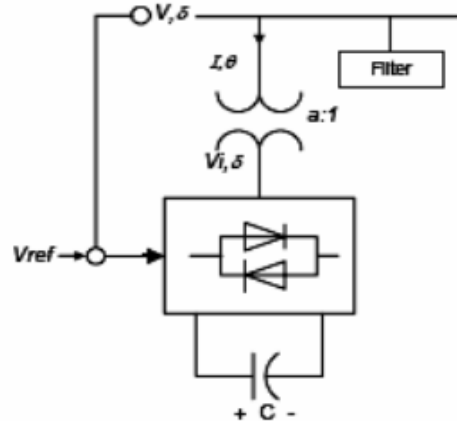


Figure 3: STATCOM Structural Diagram

As seen in figure 3, The VSC is the basic electronic part of a STATCOM, which converts the dc voltage into a three-phase set of output voltages with desired amplitude, frequency, and phase. There are different methods to realize a voltage-sourced converter for power utility application. Based on harmonics and loss considerations, pulse width modulation (PWM) or multiple converters are used. Inherently, STATCOMs have a symmetrical rating with respect to inductive and capacitive reactive power.

For example, the rating can be 100 Mvar inductive and 100 Mvar capacitive. For asymmetric rating, STATCOMs need a complementary reactive power source. This can be realized for example with MSCs

The fundamental Block diagram which represents the controlling action of a FACTS based semiconductor device namely STATCOM is also shown below.

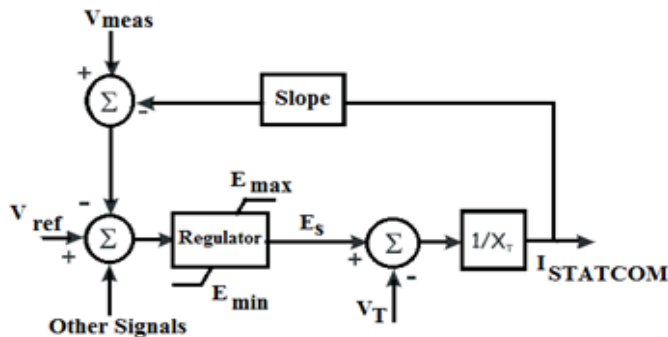


Figure 4: STATCOM Block Diagram

In a real installation, the magnitude of the source voltage is controlled through dc voltage across the capacitor. Since this loop is very fast, the dc capacitor does not need to be modelled for dynamic stability studies. The regulator keeps the STATCOM current within the current limit (IMAX).

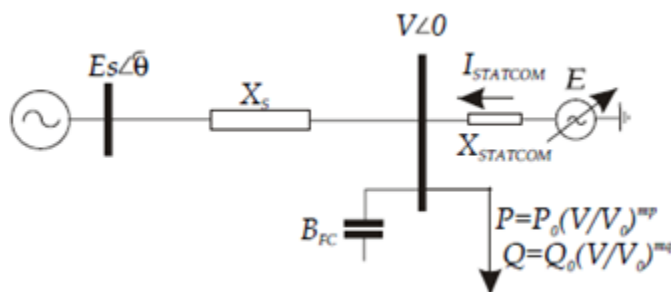


Figure 5: One line diagram of STATCOM system

A similar control of the other two parameters of stability, namely rotor angle and frequency stability can be obtained and analysed which indicates that the variations in these parameters are controlled, and also helps in improving power quality of the system. Below shown are the typical V-I characteristics of a STATCOM in figure 6. Here, STATCOM exhibits constant current characteristics when the voltage is low/high under/over the limit. This allows STATCOM to deliver constant reactive power at the limits compared to SVC.

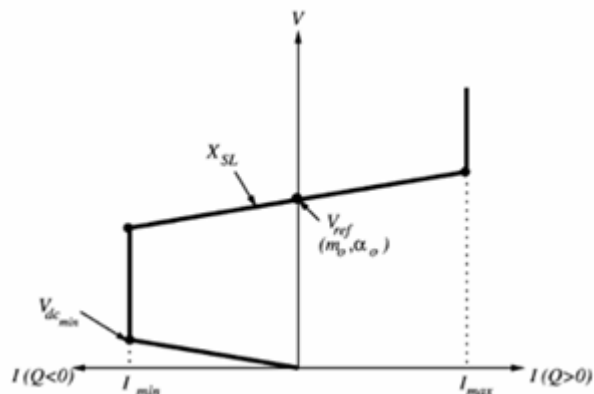
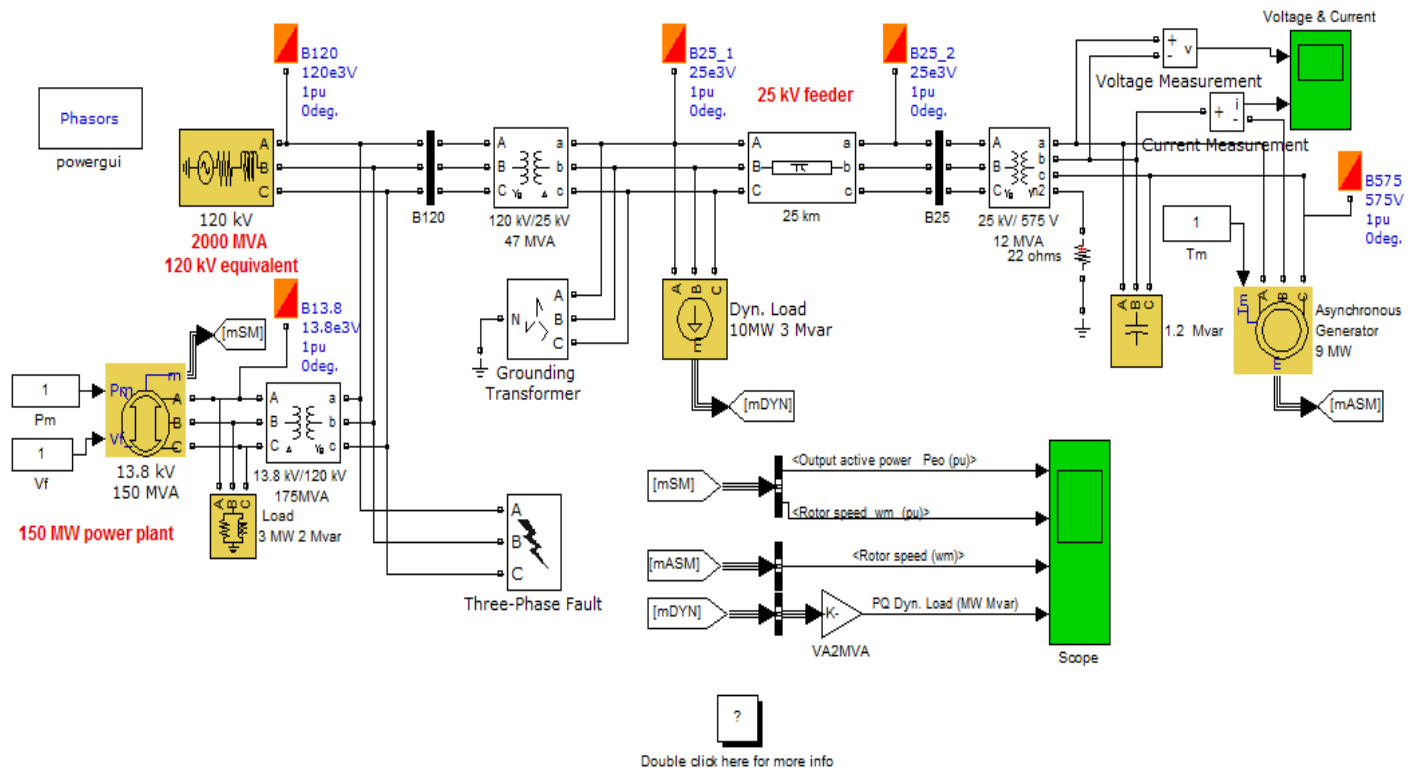


Figure 6: Typical V-I Characteristics of a STATCOM

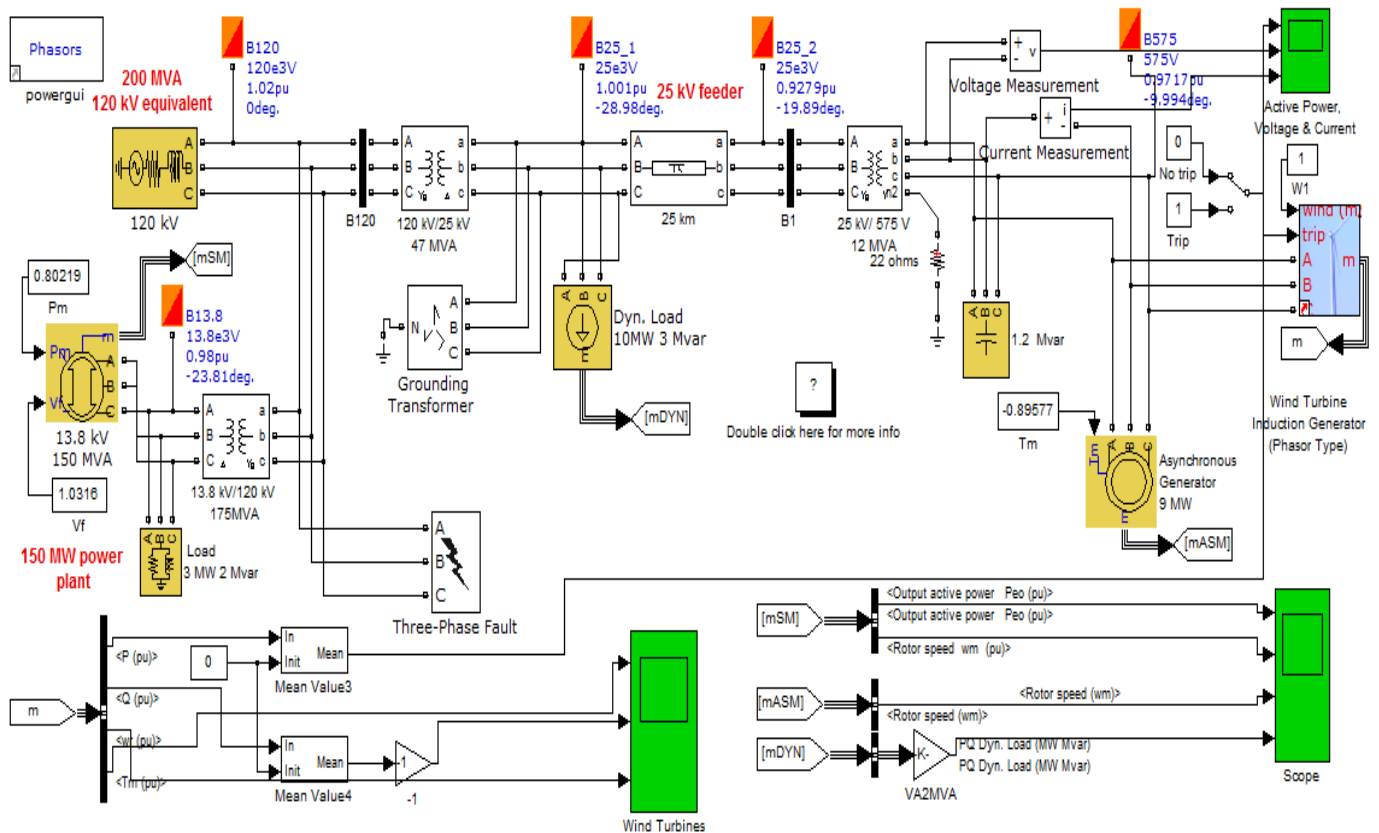
V. METHODOLOGY DIAGRAMS

The following are the methodology diagrams drawn in three stages:

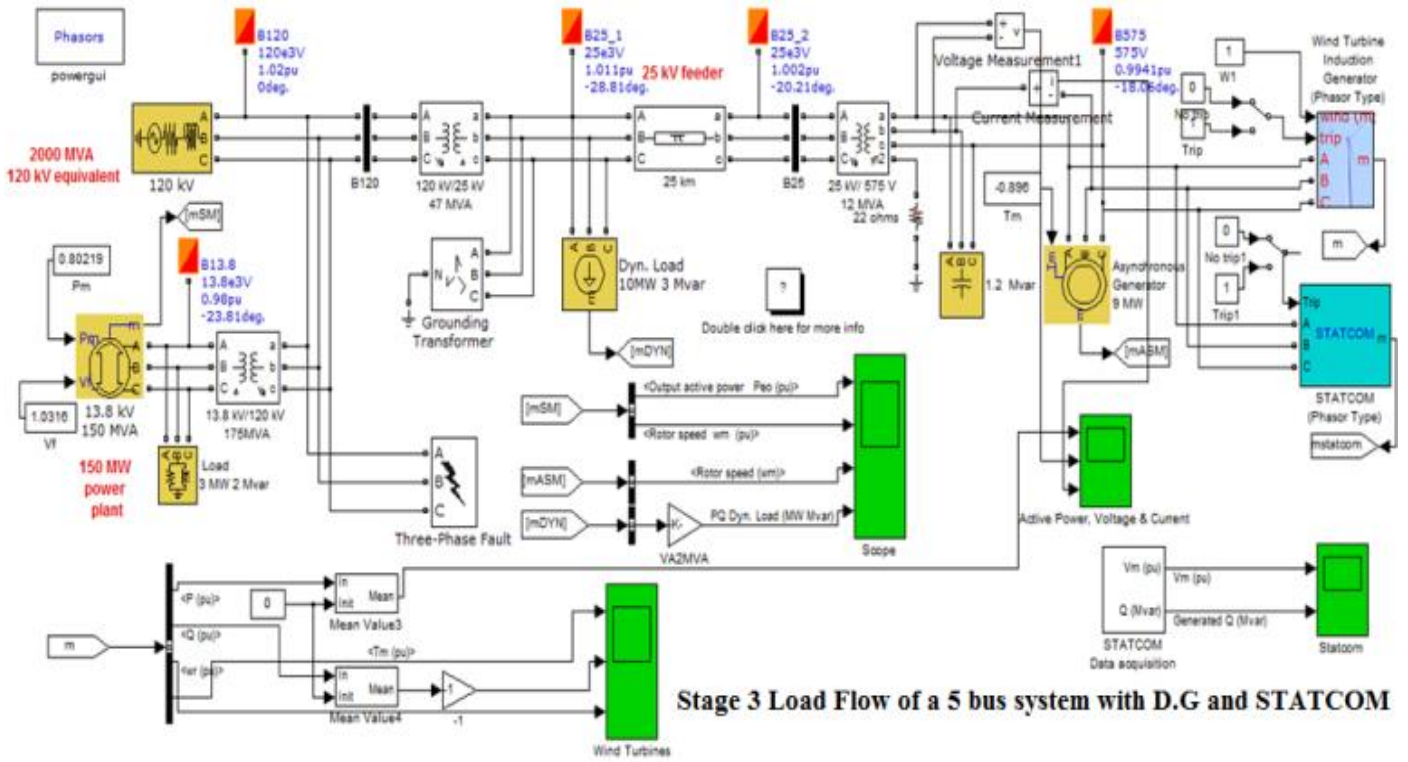
- Stage 1: 5 Bus system without distributed generation and STATCOM
- Stage 2: 5 Bus system with distributed generation and without STATCOM
- Stage 3: 5 Bus system with distributed generation and STATCOM



Stage 1 Loadflow study of a 5 Bus Test system without D.G

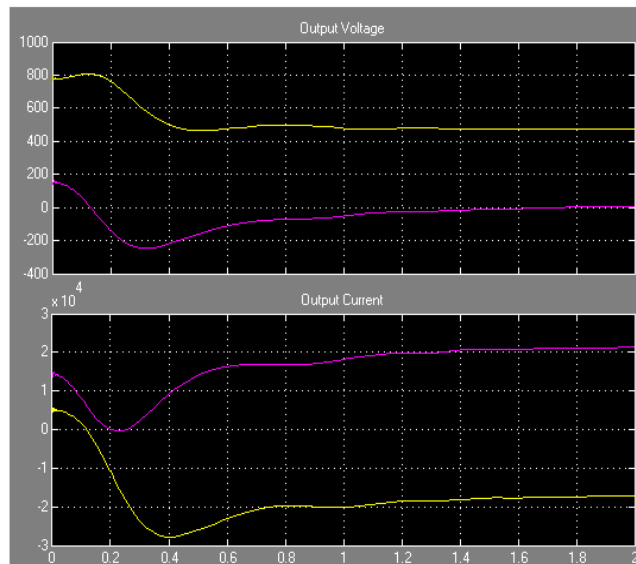


Stage 2: Loadflow study of a 5 Bus Test system with D.G

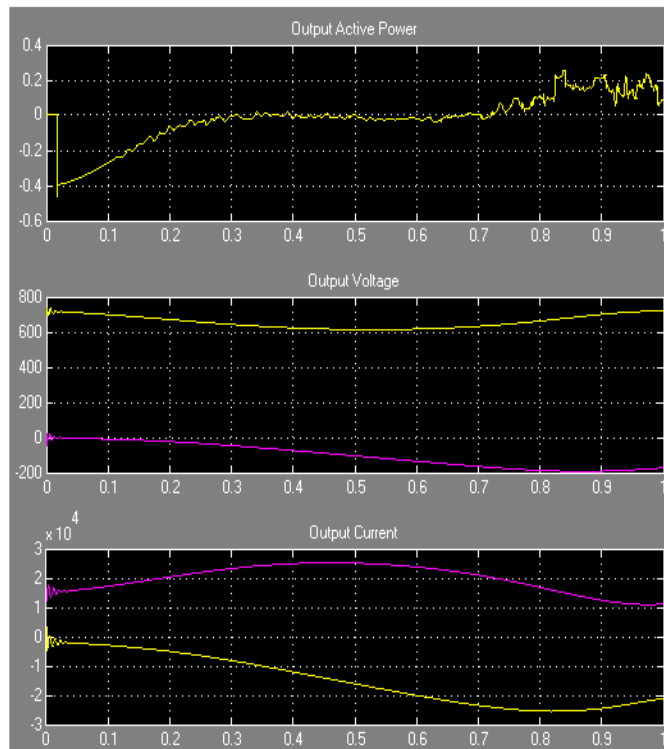


VI. RESULT & ANALYSIS

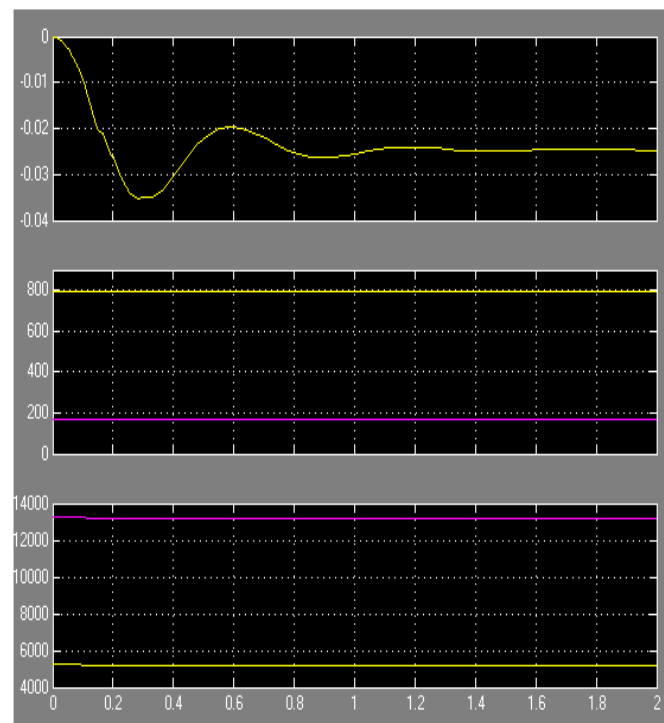
The following are a set of graphs that have been plotted from the MATLAB Simulink platform in an attempt to summarize the impacts of a distributed generation on a simple 5 bus system. Also the ability of a STATCOM to overcome the distorting effects caused by the distributed generation i.e.; a wind turbine induction generator after its insertion has been observed stage by stage. Graph 1 show the normal output voltage and current waveforms which are obtained after the simulation of a 5 bus system. Further, another graph has been plotted which shows the output active power, voltage and current waveforms which are traced just at the point of common coupling of the wind turbine induction generator. It is observed that, during the point of contact of the distributed generation to the smart grid, the voltage experiences a considerable amount of fluctuation.



Graph 1: Output Voltage & Current of 5 Bus system without D.G



Graph 2: Output after introduction of D.G in to 5 Bus system



Graph 3: Output of 5 Bus System with D.G and STATCOM

But when the STATCOM controls applied to the system and compensation is carried out, there is a near stable voltage profile as indicated in the third graph shown above. Here also, the same parameters namely active power, voltage and current have been plotted. The above work has actually been carried out using MATLAB Simulink starting with the load flow analysis and then the parameter measurement was done and was later on captured on the scope

VII.CONCLUSION

With the presence of distributed generation the power flow is no longer radial but it can be reserved or meshed with the distributed generation sending power in any directions from where it is coupled.

This occurrence definitely has created a series of new problems, some of them closely related to system reliability, power quality and stability.

It is concluded that the introduction of distributed generation in a power system causes power stability issues in terms of the voltage, frequency and load angle of the grid to which the DG is connected.

It is obvious that integrating distributed generation in a network requires an advanced control device which is critical to ensuring high reliability and stability of the power system.

The simulation result clearly indicates that the utilization of STATCOM is able to maintain the voltage, frequency and voltage angle of the system in stability margins, following the connection of distributed generation and fault.

The result also shows the feasibility of integrating distributed generation on Smart Grid while its operation is in PV mode. Hence the bus voltage and frequency of distributed generation is regulated by its own controller. The implementation of STATCOM with proper control allows the grid to be smarter, especially in terms of stability. This is because of the capability of STATCOM to provide voltage enhancement by absorbing and/or supplying reactive power during integration of distributed generation and post fault conditions.

Hence, we could finally conclude that from the above made study and implementation of the impacts and compensation of a 5 bus system using smart grid technology, the distributed generation in spite of the vast range of applications and the kind of advantages it would offer in a power system, more often than not, it introduces certain amount of distortion in to the power system under operation. In order to overcome these distortions caused in the waveforms, especially that of the active power, voltage and current, it is advisable to use FACTS based devices like STATCOM.

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