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Impact of Distributed Generation on Voltage Profile in Deregulated Distribution System

Ramji Prasad[1], Dr. Sourabh Maheshwary[2], Ameer Faisal[3]
Student M.Tech (Electrical Power System)[1], Dean Academic[2], Assistant Professor[3]
Department of Electrical and Electronic Engineering
Doon College of Engineering and Technology Saharanpur, Uttar Pradesh, India[1, 2]
Krishna Institute of Engineering and Technology Ghaziabad, Uttar Pradesh, India[3]

Abstract:
Distributed Generation (DG) is confined by limited size (roughly 10 MW or less) and interconnected at distribution feeder, substation, or customer load levels. In order to meet the rising electrical power demand, reliability, service quality and pollution reduction, the existing power grid infrastructure should be developed into a Smart Grid that has the flexibility to allow interconnection with the distributed generation. Although the expansion of DG has positive impacts on voltage profile in Grid system, the introduction of DG affiliated with distribution network makes the voltage profile of buses in a fluctuating state and hence makes the system unstable. An attempt has been made to demonstrate the FACTS device to make the grid connected system stable and more reliable. In general FACTS devices are voltage-source converters which act as either a source or sink of reactive AC power to an electricity network. The paper presents a comparative study of voltage profile improvement of a grid connected distributed generation (DG) with the help of UPFC and SVC. Simulation results are provided to confirm the above said statements.

Keywords: Distributed Generation, Distributed Network, Flexible alternating current transmission system , Unified power flow controller, Static var compensator, Static synchronous compensator.

I. INTRODUCTION

Distributed Generated system (DGS) based on various renewable energy resources is the important approach to the development of clean energy, improving the reliability of power supply and enlargement of the power system capacity. Compared to the traditional centralized power supply system, DGS has many advantages: simple start-stop, good peak shaving, to load balance and less investment, yield quicker result, and able to fulfill power supply demand in the special occasion and less transmission loss, improving disaster level [7].

The large-scale increase of DG into the DN has a major effect on DN planning and operation. This makes network planning a difficult task. Connection of DG fundamentally modifies DN operation and brings a variety of chronicle impacts with voltage rise being the major effect, especially in weak DN. This is because the commercial as well as the technical operating and planning framework within which DN's are presently managed were not conceived with DG in mind. This significantly limits the amount of DG that can be interconnected. Traditionally DN's were designed to operate radically without any generation on the network.

The interconnection of DG on the DN may have an important impact on the flow of active and reactive power, on voltage and on fault current levels. Conventionally voltage control of radial DN is achieved by using an in-line tap changer at the HV/MV substation and reactive power compensation. In the case where an enormous amount of DG is connected into the DN, the feasibility of voltage regulation may be lost [8]. In an attempt to overcome negative dynamic impacts caused by wind speed changes, the voltage regulation and reactive power compensation problem is approached here not only for a conventional aspect, but also a FACTS based as well [1]. Wind power plant induction generator is viewed as a consumer of reactive power. Its reactive power consumption depends on active power production. Traditionally, shunt capacitor banks are connected at the generator terminals to compensate its reactive power consumption. In some designs, shunt capacitor banks could be mechanically switched on/off by using feedback signal from generator reactive power. The switching of is triggered through an algorithm if a generator reactive power is outside an allowed dead-band for a particular specified time period. In addition, continuous voltage control and reactive power compensation at the point of the WECS network connection is provided by using FACTS-based device [10].

Among FACTS devices, the Unified Power Flow Controller (UPFC) is chosen due to its adaptable regulating abilities [9]. The UPFC consists of shunt and series branches, which could be used interchangeably. Being placed at the point of the WECS connection to the distribution network, it is made feasible simultaneously to control the WECS bus voltage magnitude and/or series reactive power flow that WECS exchanges with the network [13]. This counter measure is expected to contribute in making wind sites possible for connecting larger number of wind turbines.

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 E1 and E2 connected by a transmission line, which can be interconnecting points or may have load [14]. The assumption used is lossless transmission line and represented by the reactance *X*. The corresponding phasor diagram is given below.

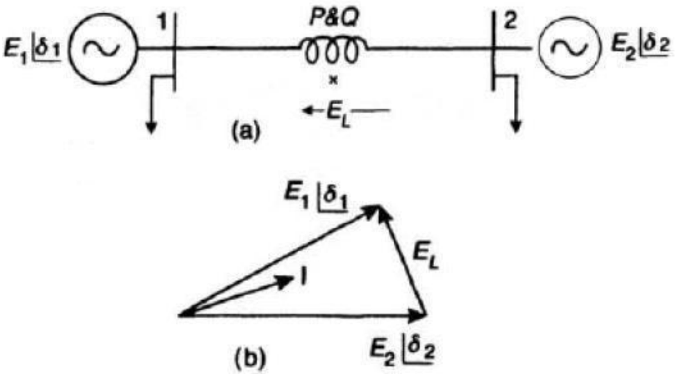

Figure.1.Line diagram

According to the prior work completed on Distributed Generation and Power Quality. A portion of the Different Issues included with Distributed Generation are: Voltage Regulation, Harmonic Distortion, Islanding, Protection System, DG Grounding Issue Flicker, 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

Additionally, the real issue that would have a prompt impact on the execution of the electrical framework regarding the force framework dependability can be placed into the accompanying classifications are:

- Rotor Angle Stability
- Frequency Stability
- Voltage Stability

IV. COMPENSATION USING SMART GRID TECHNOLOGY

The Unified Power Flow Controller (UPFC) is the most member of the Flexible AC Transmission Systems (FACTS) versatile family using power electronics to control power flow on power grid [11]. The UPFC uses a combination of a shunt controller (STATCOM) and a series controller (SSSC) attached through a common DC bus as shown on the figure below.

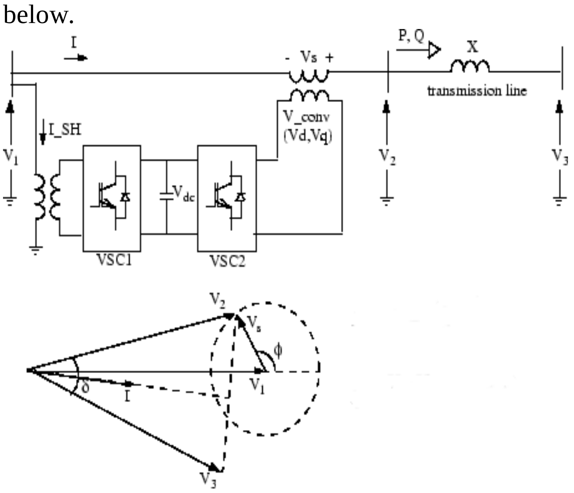

Figure.2.Single –line diagram of a UPFC and phasor diagram of voltages and currents

Real power and Reactive Power is given by

$P=V_2V_3\sin\delta/X$

$Q=V_2(V_2-V_3\cos\delta)/X$

This FACTS topology implements much more flexibility than the SSSC for controlling the line active and reactive power because active power can now be transferred from the shunt converter to the series converter, through the DC bus. In contrast to the SSSC where the injected voltage Vs is constrained to stay in quadrature with line current I, the injected voltage Vs can now have any angle with respect to line current. If the value of injected voltage Vs is kept constant and if its phase angle ϕ with respect to V_1 is varied from 0 to 360 degrees, the locus described by the end of vector V_2 ($V_2=V_1+Vs$) is a circle as shown on the phasor diagram. if ϕ is varying, the phase shift δ between voltages V_2 and V_3 at the two line ends also varies. It results that both the active power P and the reactive power Q transmitted at one line end can be controlled. The UPFC has distinct possible operation modes [2]. Of these possible operation modes voltage control mode is most important. In this mode, the voltage unified by the series connected VSC has the phase angle equal to 0◦ or 180◦ with respect to the PCC voltage. Simulation results of a conventional UPFC used to control the output voltage of a substation are presented in [3]. An UPFC based on single-phase VSC units were suggested by the authors in a previous work for controlling the voltage in distribution systems [4]. The use of single-phase converters grants voltage compensation even under unbalanced condition and each phase voltage can be restrained independently to balance the grid voltage.

V. SYSTEM CONFIGURATION

The network, shown in Fig.4. Is the single line diagram of a 5-bus system connected to grid under investigation. Model 1: - The system, connected in a loop configuration, consists of five buses (B1 to B5) interconnected through transmission lines (L1, L2, L3) and two 500 kV/230 kV transformer banks Tr1 and Tr2.Line L1 is used as double circuit line to increase the power transfer capacity by lowering the inductance of line. Two power plants located on the 230-kV system generate a total of 2200 MW which is transmitted to a 500-kV 15000-MVA equivalent and to a 200-MW load connected at bus B3. A speed regulator, an excitation system as well as a power system stabilizer (PSS) is included plant models. In normal operation, most of the 1200-MW generation capacity of power plant 2 is exported to the 500-kV equivalent through three 400-MVA transformers connected between buses B4 and B5.

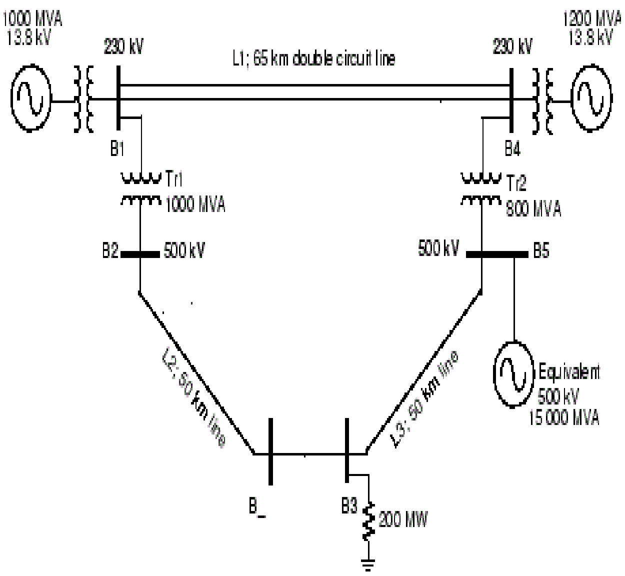

Figure.3. Single Line diagram of 5-bus system

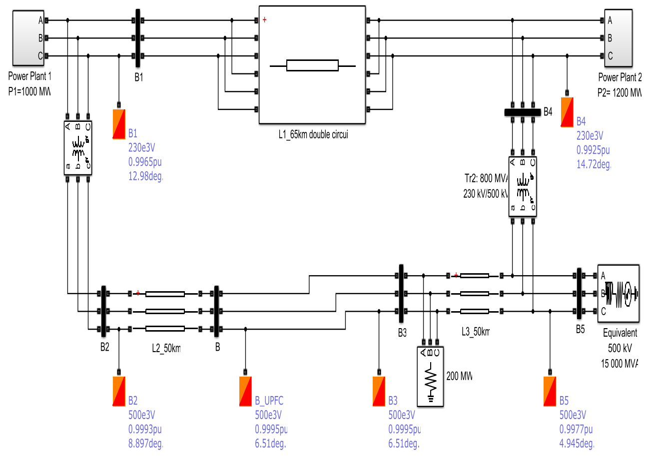

Figure.4. Simulink model for 5-Bus system without distributed generation and UPFC

Model2:-In this model we have replaced power plant of 1200 MW with a distributed generated system(Wind Farm) of 9 MW, taking other parameters and devices same as in Model1.

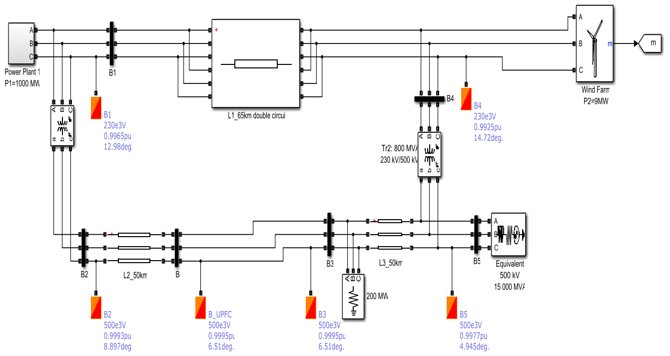

Figure.5. Simulink Model for 5- Bus system with distributed generation

Model3:- In this model UPFC is connected between transmission lines L2 and L3 in addition to Model 2.

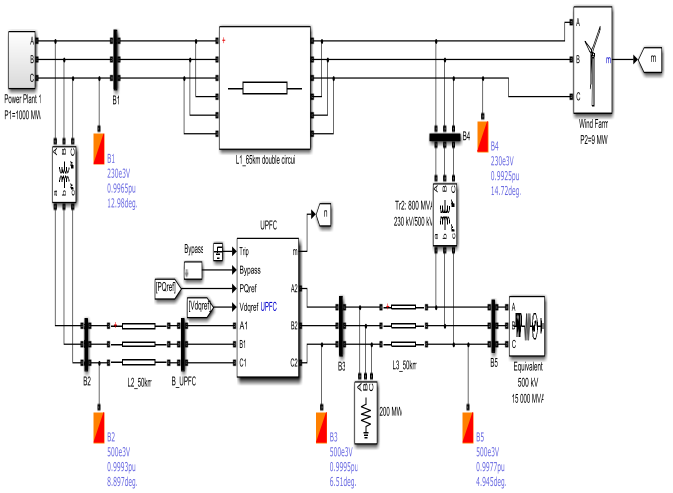

Figure.6. Simulink Model for 5-Bus system with distributed generation and UPFC

Model4: - similarly, we replace UPFC with SVC between the transmission lines L2 and L3. The main theme behind modeling is to inspect the voltage profiles of different buses of the system.

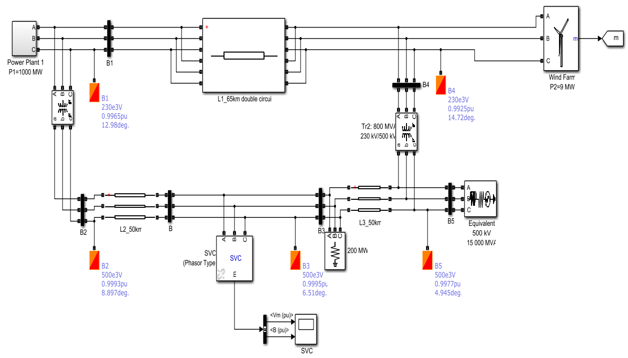

Figure.7. Simulink Model for 5-Bus system with distributed generation and SVC

The reduction in voltage can be improved by either decreasing the reactive load or by increasing the reactive power supply before voltage collapse point. control and operation of various FACTS devices can be completely used for this scheme. Out of various existing FACTS devices SVC and UPFC are installed at the weakest bus to improve voltage profile [12]. FACTS devices can be Classification in two generations. Thyristor valve are employed in older generation, whereas newer uses Voltage Source Converters (VSC). In both categories there are corresponding devices performing similar services. Generally speaking, VSC technology offers faster control over a broad range [5]. Moreover, new generation does not need cumbersome reactors, thus size of these devices is considerably smaller than the thyristor controlled ones. However, VSC technology requires use of self-commutating semiconductor devices which are more costly, have higher losses and low voltage ratings when compared to the thyristors [6].

VI. RESULTS AND ANALYSIS

The following are a set of graphs that have been plotted from the MATLAB Simulink platform. It is an attempt to summarize the impacts of a distributed generation on a simple 5 bus system as shown in Fig.9. We can see from Fig.9. and Fig.10. that introduction of DG in grid improves voltage profile of all buses in the system. It is observed that, during the point of contact of the distributed generation to the grid, the voltage experiences a considerable amount of fluctuations in all the buses. By application of FACTS devices like UPFC and SVC the transient effects caused by the distributed generation (wind farm) can be eliminated, as observed in Fig. 11and Fig.12. By comparing the results, we observe that UPFC takes less time (1.5sec.) as compared to SVC and eliminates all transients and all buses' voltage approaches to 1 p.u so we can say that UPFC works best for above said grid connected distribution generation system.

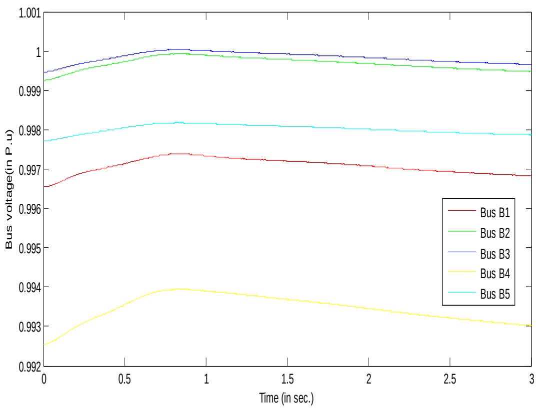

Figure.8. 5- bus system Voltage Profile of grid Without DG

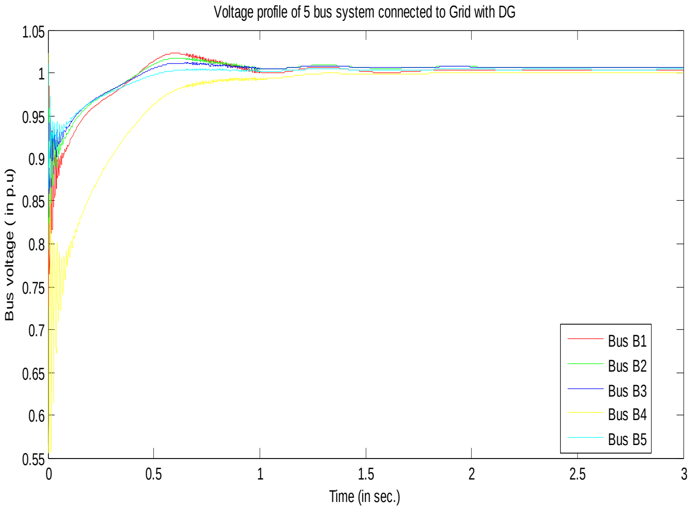

Figure.9. 5- bus sytem Voltage Profile of grid connected with DG

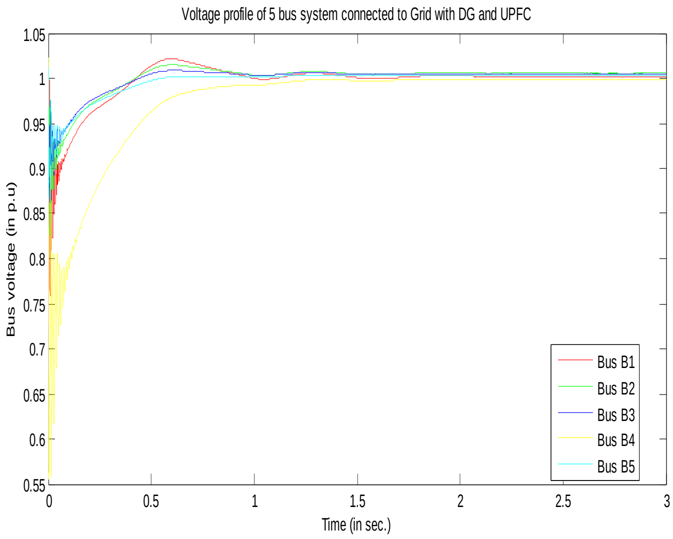

Figure.10. 5- bus system Voltage Profile of grid connected With DG and UPFC

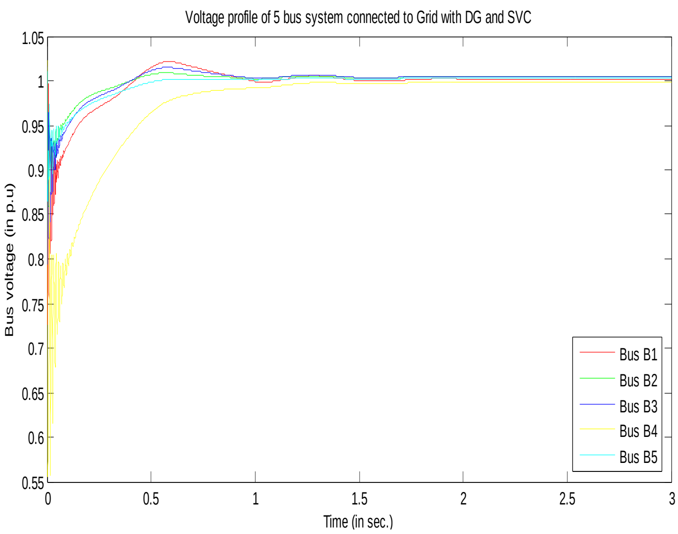

Figure.11. 5-bus system Voltage Profile of grid connected With DG and SVC

VII. CONCLUSION

With the existence of distributed generation, the power flow is no longer radial, but it can be inverted or meshed with the distributed generation sending power in any direction from where it is connected. This situation has set up a series of new problems, some of them firmly related to system power quality, reliability 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 connecting distributed generation in a network requires an advanced control device which is demanding to secure high reliability and stability of the power system. The implementation of distributed generation provides a vast range of applications and advantages it would offer in a power system; its only single drawback is it introduces certain amount of distortion in to the power system under operation. The simulation results clearly imply that with the help of FACTS devices, we can eliminate transients and therefore its leads to voltage profile improvement of buses connected to system. FACTS devices have different specifications and are used according to some conditions.

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