International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 12, December-2019

# Increasing the Loadability of Power System Network using DSTATCOM

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***Abstract*— Due to the rapid increase in the loading a major problem is manifested known as the voltage which has gained a world wide interest. Most of the power systems are operated closer to their stability limits considering the economic operation. When huge quantities of power is transferred over long distance and due to the inadequate supply of reactive power the voltage instability problems arise and eventually lead to voltage collapse. Hence in the real time system voltage stability assessment the knowledge of appropriate loadability of the power system is important. This paper investigates the enhancement of voltage stability using Distribution Static synchronous Compensator (DSTATCOM) in a wind integrated power system. In the scenario of development of renewable energy the wind generation has attained a large growth because of the availability and affordable cost. Wind generation requires some device to smoothen the output from a wind turbine and a STATCOM connected to the bus performs this operation along with the property of voltage stability enhancement. The studies made in this paper are done with power system analysis toolbox (PSAT), a powerful toolbox in MATLAB for power systemanalysis.**

***Keywords*— *Voltage stability, P-V curve, maximum loading point, STATCOM, wind integrated power system.***

## I. INTRODUCTION

Rapid growth in the power consumption has lead to a large complex inter connected power system. The system that consists of many buses and generators. To meet the increase in demand, various proposals are implemented, either new generating stations are to be installed, or the existing system operation has to be expanded. The counterpart is that the existing transmission lines are heavily loaded than ever before and this may lead to loss of stability following a disturbance. Stable operating conditions are beneficial for all power system. Angle stability and voltage stability are the two major the stable operating conditions.. In this paper in order to maintain the stability and to enhance the voltage stability of the system the usage of Flexible Alternating Current Transmission Systems (FACTS) which is the latest technology in providing reactive power compensation is considered. Various reactive power compensators are available like Static Synchronous Compensator (STATCOM), StaticVAR Compensator (SVC), Thyristor Controlled Series Compensator (TCSC), Static Synchronous Series Compensator (SSSC) etc [1]. This paper concentrates on DSTATCOM for reducing the variations such as sags, surges and instability caused by rapidly varying reactive power demand.

DSTATCOM is a FACTS device used for correction of bus voltage sags. The DSTATCOM is a voltage source inverter based static compensator The DSTATCOM is connected to the power networks as a remedy to the voltage-quality problems.. The placement of DSTATCOM has to be placed in an optimal location in a power system , as optimal locations only provide maximum voltage enhancement and increased loadability[4].

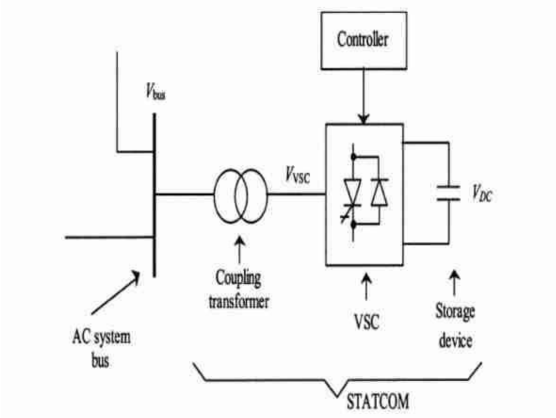


Figure1. Schematic diagram of DSTATCOM

The Central Travancore grid considered in this paper is a large network which extends over four districts Alapuzha, Pathanamthitta, Idukki and Kottayam in Kerala. Major generating stations are Idukki and Sabarigiri Hydro Power Plants, Kayamkulam Thermal Power Plant, Brahmapuram Diesel Power Plant and Ramakkelmedu wind farms. Among the different voltage levels in the transmission and distribution grid system the highest is 220 kV which is stepped down to 110 kV in the substations.

The simulations are performed using Power System Analysis Toolbox (PSAT) which is a comparatively newer software (developed in about 2004-2005) employing the excellent matrix-oriented computation techniques of MATLAB. This toolbox (MATLAB) or software-package is designed for electric power system analysis and control. To grant ease to the user, it exploits Simulink library as a graphical tool, which allows drawing of pictorial or schematic blocks to represent different components of a power system [5]. One unique point about PSAT is that, it can also run in GNU/ Octave environment and is free software for performing numerical experiments using a language that is mostly compatible with MATLAB. It is also remarked as one of the active Free and Open- Source Software (FOSS) projects for power systems [6]. Besides basic power flow analysis, PSAT offers several other static/dynamic analyses like Continuation Power Flow (CPF), Optimal Power Flow (OPF), Small-signal stability analysis, Time-domain simulations etc [7].

This paper is organized as follows. Section II illustrates about the voltage stability of a system and the analysis of the system using P-V curve. Section III describes about the DSTATCOM In section IVa wind integrated power system is discussed. In section

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V IEEE standard 14 bus system which is considered as the test-system is explained. A portion of the Kerala grid is considered for the analysis of the wind integrated system in this paper and this system modeled in PSAT is given in section VI. The results and discussions are made in section VII and the section VIII discusses the conclusions derived in the paper

## II. VOLTAGESTABILITY

The ability of a power system to maintain steady state voltages at all the buses after being subjected to a disturbance is known as voltage stability. Voltage instability causes system voltage collapse, which makes the system voltage to decrease to a level that is unacceptable and is unable to recover leading to interruption of the power supply in the system. Slow variations in the power system eventually lead to voltage collapse which can be analyzed in the steady state voltage study. This can be seen from the "PV" curve or "nose" curve which is the plot of the power with the voltage at the bus. Figure 1 is a typical P-V curve plot obtained from the equation 1 shown.

$$V = \{(E^2/2) - QX \pm \sqrt{[(E^4/4) - P^2X - E^2QX]}\}^{1/2} \quad (1)$$

where V is the bus voltage, E is the terminal voltage, Q is the reactive power, P is the active power and X is the reactance.

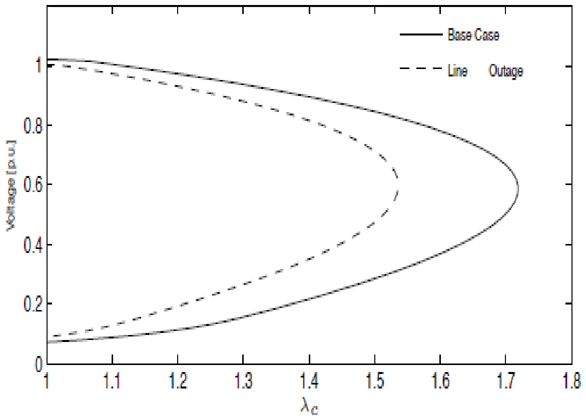


Figure 2. P-V Curve

In Fig.1 λc is the loading parameter in per unit (pu). In the given graph λc (loading parameter in p.u.) is marked along the X axis and V (bus voltages in p.u.) is marked along the Y axis. It can be seen from the figure that as the power transfer increases, the voltage at the receiving end decreases, eventually reaching a nose point where any further increase in the power transfer leads to a rapid decrease in voltage magnitude. The large voltage drop due to heavy reactive power losses can be observed before reaching the critical point [8]. The region above the nose point is referred to as the stable region and region below is the unstable region. Analysis of the power flow equations reveal that the nose point occurs at the value at which the corresponding Jacobian is singular and is mathematically associated to saddle-node bifurcation point. This nose point is also known as the maximum load ability point and hence the problem of voltage collapse can be defined as an optimization problem, where the objective is to maximize certain system parameters typically associated to load levels [8]. The voltage reduction can be improved by either decreasing the reactive load or by increasing there active power supply before voltage collapse point.

## III. DSTATCOM

DSTATCOM is a FACTS device used for shunt reactive power compensation. . The DSTATCOM system is comprised of three main parts: a Voltage Source Converter (VSC), a set of coupling reactors and a controller. The basic principle of a DSTATCOM installed in a power system is the generation of a controllable ac voltage source by a voltage source inverter (VSI) connected to a dc capacitor (energy storage device).The active and reactive power transfer between the power system and the DSTATCOM is caused by the voltage difference across this reactance. [1].All required voltages and currents are measured and are fed into the controller to be compared with the commands. The controller then performs feedback control and outputs a set of switching signals to drive the main semiconductor switches (IGBT's, which are used at the distribution level) of the power converter accordingly.

Compared to the old style reactive power support methods using capacitor banks and thyristors, DSTATCOM can offer much higher dynamic performance. Compared to Static Var Compensator (SVC) and other conventional reactive power compensators, DSTATCOM has several advantages. It has a dynamic performance far exceeding the other Var compensators. The overall system response time of DSTATCOM can reach 10ms and sometimes less. STATCOM has the ability to maintain full capacitive output current at low system voltage,which also makes it more effective than SVC in improving the transient stability. The installation space for DSTATCOM is lesser[4].

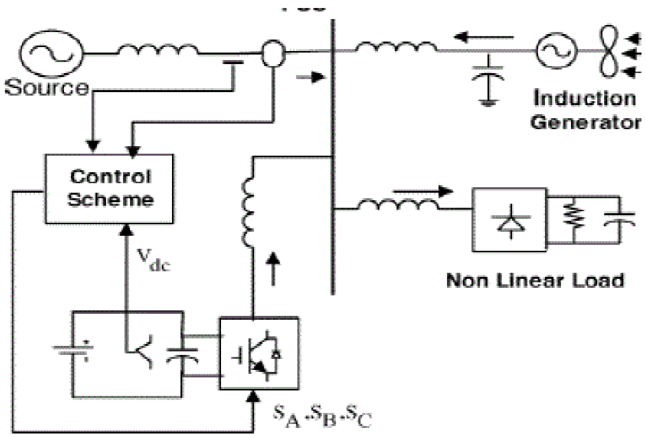


Figure 3.D STATCOM connected to power system

## IV. WIND INTEGRATED POWER SYSTEM WITH STORAGE

Wind resource is a kind of renewable energy and becomes more and more important in many countries. The terms "wind energy" or "wind power" describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power is given to a generator which can convert this mechanical power into electricity. Wind energy is a free, renewable resource, Wind energy is also a source of clean, non-polluting, electricity. Unlike conventional power plants, wind plants emit no air pollutants or greenhouse gases. These are the main reasons for the growing interest in wind energy.

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Wind energy is the kinetic energy of air in motion, also called wind. Total wind energy flowing through an imaginary area *A* during the time *t*is

$$E=At\rho v^3/2 \qquad (2)$$

where*ρ* is the air density; *v* is the wind speed; *Avt*is the volume of air passing through *A* (which is considered perpendicular to the direction of the wind); *Avtρ*is therefore the mass *m* passing per unit time. Note that ½ $\rho v^2$ is the kinetic energy of the moving air per unit volume. Power is energy per unit time, so the wind power incident on *A* (e.g. equal to the rotor area of a wind turbine)is

$$P = E/t = A\rho v^3 \qquad (3)$$

Wind power in an open air stream is thus proportional to the third power of the wind speed; the available power increases eightfold when the wind speed doubles. Wind turbines for grid electricity therefore need to be especially efficient at greater wind speeds.

Wind turbines used with fixed speed induction generators provide a cost effective solution for wind power generation. The increase in the penetration of wind generation into the power system will increase further due to the use of variable speed wind generation to accommodate the maximum power in the power system. Increase in penetration will cause instabilities in the power system because of the property of induction machine which is commonly used generator in wind turbines.

## V. TEST SYSTEM

The IEEE standard 14 bus system modeled in PSAT is the test system is shown in Fig.3. A wind farm is incorporated into the system in third bus since it was analyzed that the system is not having voltage stability if it is loaded above 1.4 p.u. It is because the system is lacking power. This additional power required could be provided by the wind generation. This system was analyzed for small signal stability and voltage stability. The voltage stability analysis was done by increasing the loads in all the buses to find the maximum loading point and the P-V curves were plotted. The increase in load resulted in decrease in bus voltages. With the help of P-V curves the optimal location for the placement of DSTATCOM for improving the voltage stability was found.

## VI. REAL SYSTEM

The real system was modeled in PSAT is shown in Fig. 4 with two hydro generating stations Idukki and Sabarigiri, thermal station at Kayamkulam, diesel generating station at Brahmapuram and the wind farms at Ramakkelmedu. The model consists of fifteen buses including load buses and PV buses. The Pallom substation consists of a 40 MVAR compensator which is shown in the model. This system was analyzed for small signal stability and voltage stability

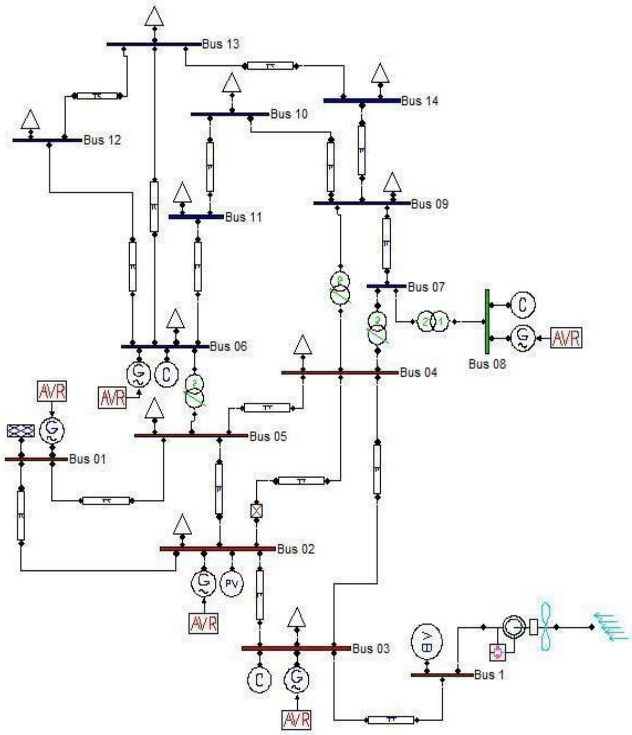


Figure 3. Wind integration into the IEEE Standard 14 bus system

. The maximum loading point was found by plotting P-V curves for variations in loads at the buses. As in the test system the optimal location for the placement of DSTATCOM was found with the help of P-V curve.

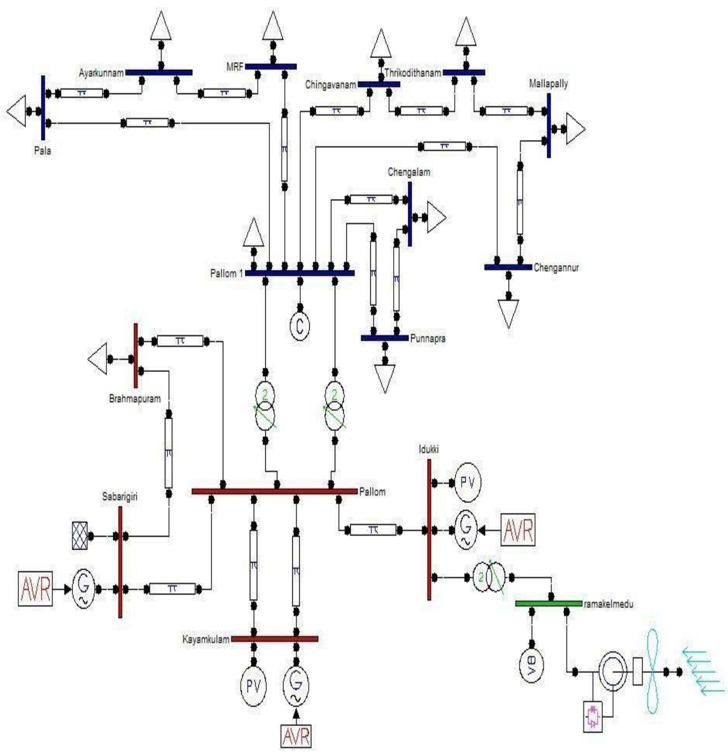


Figure 4. The Central Travancore Grid of Kerala integrated with wind energy

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## VII. RESULTS AND DISCUSSIONS

The maximum loading capacity of the IEEE standard 14 bus system is 1.3 pu which is shown in Fig. 6 and if the system is operated such that the load in the bus is beyond this value the bus voltages reduces abruptly leading to voltage collapse with further increase in load. The loading point of the IEEE standard 14 bus systems can be increased by integrating wind generation in to it. Usage of FACTS devices helps to improve the loading point further.

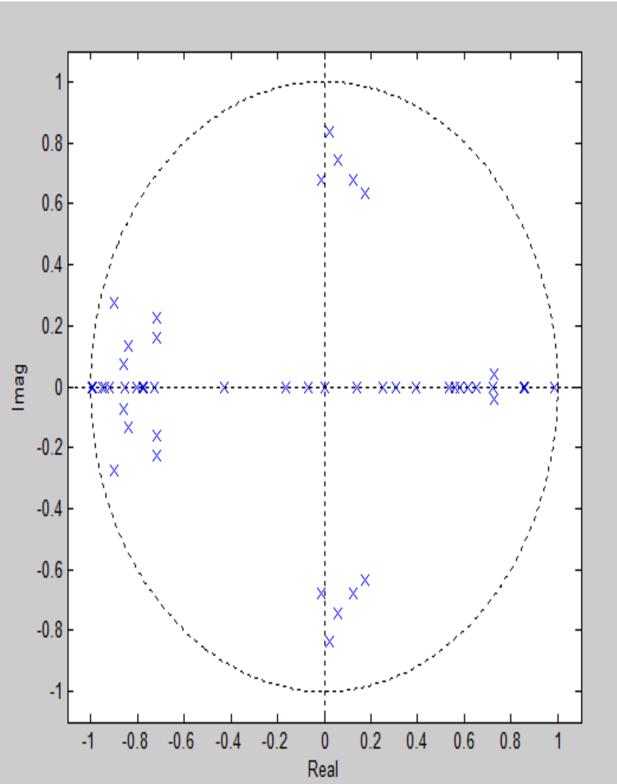


Figure 5. Eigen value analysis in z-domain for small signal stability analysis of the test system

The weakest bus was selected for the placement of FACTS device and from the P-V curve it was clear that the weakest bus was bus number 14 and a STATCOM was placed in that bus for improving the voltage stability of the entire grid. This system was checked for small signal stability and voltage stabilities and showed that the maximum loading point has improved to 1.6 pu which is shown in Fig.7. The eigen value analysis of the system proves that this system is having small

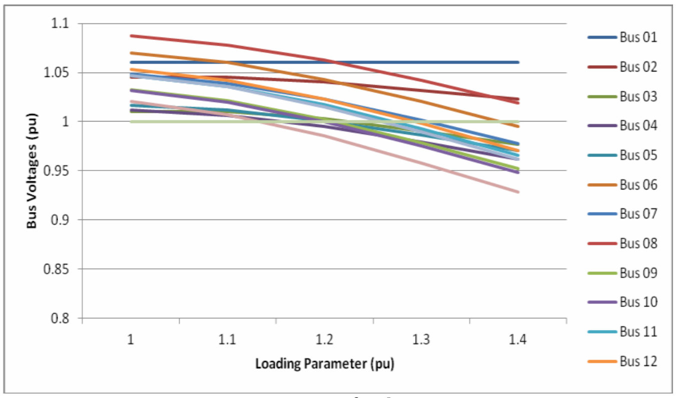


Figure 6. P-V curve for the testsystem

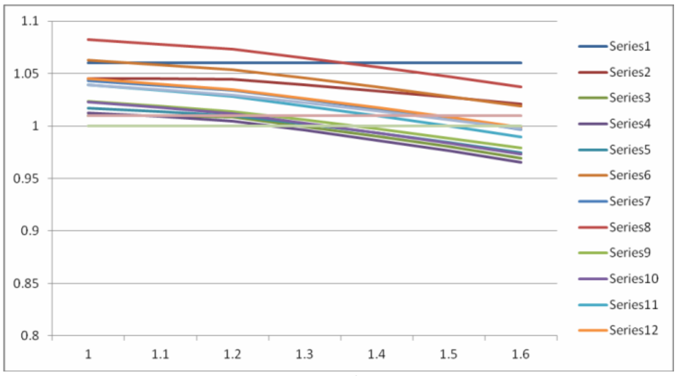


Figure 7. P-V curve for the testsystem

As a DSTATCOM is added to the wind integrated power system the maximum loading point has improved. In the normal system the maximum loading point was only 1.3 p.u.in the test system but on adding the DSTATCOM to the system it has been improved to 1.6 pu as seen in P-V curve in figure7.

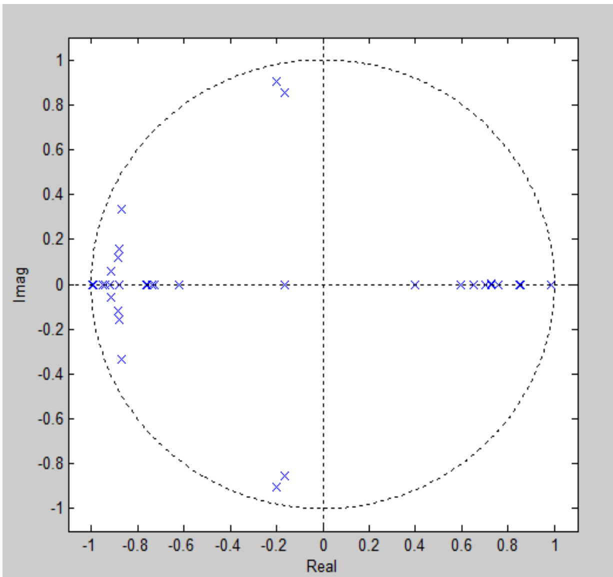


Figure 8. Eigen value analysis in z-domain for small signal stability analysis of the Central Travancore grid

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The small signal stability analysis and voltage stability analysis are to be done in the Central Travancore grid in Kerala, a wind integrated power system. The Fig. 8 shows the eigen value analysis of the system. In the figure all the eigen vectors are within the unit circle which means that the system has small signal stability. The loading point of the Central Travancore grid was 1.4 p.u. It could be improved to 1.6 p.u, on adding a DSTATCOM to the weakest bus of the system. The weakest bus was found with the help of the P-V curve which was plotted for finding the voltage stability of the above system. This P-V curve is shown in the Fig.9.

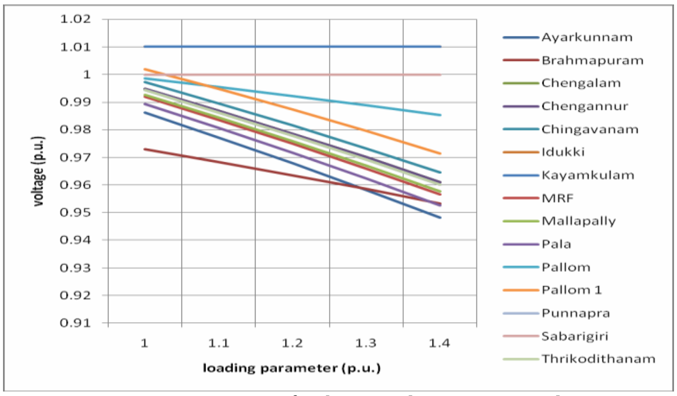


Figure 9. P-V curve for the Central Travancore Grid

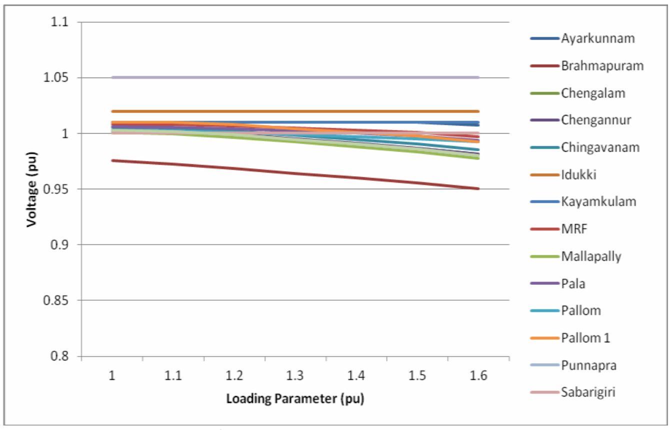


Figure 9. P-V curve for the Central Travancore Grid with DSTATCOM

As a DSTATCOM is added to the Central Travancore grid the maximum loading point has improved. In the normal system the maximum loading point was only 1.4 p.u. but on adding the DSTATCOM to the system it has been improved to 1.6 p. u. as seen in P-V curve in figure10.

## VIII. CONCLUSION

In this paper, voltage stability analysis of a modeled grid is analyzed and found that on increasing the load demand the grid may lose its stability and may even go to black out if the system is not properly handled. Incorporating DSTATCOM at the optimal location in the grid helps to increase the loadability of the system, so that the system may have enhanced voltage stability. By incorporating DSTATCOM the loadability of the present grid was improved to1.6 p.u. form 1.4 p.u. The result seemed to be quite promising when tested on IEEE 14-bus system.

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