# Load Ability Improvement by Placing STATCOM in A Wind Integrated Power System

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*Abstract:* **Voltage instability is one of the major sources of power system insecurity. Modern power systems are operated to closer to stability limit due to economic and environmental constraints. The current scenario of modern power system is that, they are heavily loaded due to continuously increasing demand. Wind energy generation is the best solution to meet the continuously increasing demand. STATCOM, one of the FACTS device is the solution for voltage instability problems. The main purpose of the paper is to find the optimal location for the placement of STATCOM in a wind integrated power system for the enhancement of voltage stability. The analysis made in the paper is done with the power system analysis toolbox (PSAT), a powerful toolbox in MATLAB. Also this paper investigates the enhancement of voltage stability using STATCOM in a wind integrated central Travancore grid.**

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

## I. INTRODUCTION

The Power system is a highly complex network, which supplies electrical energy generated at remote places in bulk and transmitted over long distances to the load centers through transmission lines, feeders and distribution lines. At any point of time a power system operating condition should be stable, meeting various operational criteria and it should also be secure in the event of credible contingency. The present scenario of modern power system is that they are always heavily loaded due to continuously increasing demand. Due to weak system links and long lines, voltage instability and voltage collapse are of much concern. FACTS technology is the best options to mitigate voltage instability problems by reactive power compensation and voltage control criteria. The various FACTS devices such as Static Synchronous Compensator (STATCOM), Static VAR compensator (SVC), Thyristor Controlled Series Compensator (TCSC), Static Synchronous Series Compensator (SSSC) etc[1]. In this paper STATCOM has been used for the enhancement of voltage stability in a wind integrated power system.

STATCOM is a second generation FACTS device used for shunt VAR compensation. The principle of STATCOM is reactive power compensation where reactive power and voltage magnitude could be adjusted. It consists of 3 parts: shunt (coupling) transformer, voltage source converter (VSC) and capacitor. STATCOM should be placed in an optimal location in order to have effective enhancement in voltage stability and maximum loading point.

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, Kyamkulam Thermal Power Plant, Brahmapuram Diesel Power Plant and Ramakkelmedu wind farms. Among different voltage levels in 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 analysis toolbox (PSAT). PSAT is a MATLAB toolbox for static and dynamic analysis and control of electric power systems. PSAT is provided free of charge. PSAT, an open source

MATLAB and GNU/octave based software package for analysis and design of small to medium size electric power system. PSAT performs power flow, continuation power flow, optimal power flow, small signal stability analysis and time- domain simulation, as well as several static and dynamic models including non – conventional loads, synchronous and asynchronous machines, regulators and FACTS. PSAT is provided with a complete set of user friendly graphical interface and a Simulink based editor to draw one-line network diagrams.

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 explains the basics of a STATCOM and Section IV describes about wind integrated power system with storage. In Section V IEEE standard 14 bus system is considered as the test system and 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 paper is concluded in the Section VIII.

## II. VOLTAGE STABILITY

At any point of time, the operating condition of the power system should be steady, meeting different operational measures and it should be invulnerable at the event of contingency. Then such a system is called secured power system. Contemporary power systems are being operated closer to their stability boundaries due to commercial and ecological restraints. Voltage stability refers to the aptitude of a power system to retain steady tolerable voltages at all buses in the system beneath a normal operating condition and also after being exposured to a disturbance. Voltage stability of the power system depends on its ability to maintain/restore equilibrium between demand and supply. Voltage instability means a gradual decrease or rise of voltages at some buses. The resultant of voltage instability is load curtailment at the consumer side or outages of transmission lines and other corresponding components by their protective systems leading to cascaded failures. The outcome of these outage is voltage collapse. From these events the system enters in to the system black out. The key factor for the impact of voltage inability is the voltage drop that occurs, when active and reactive power flows through inductive reactance of the transmission line while transferring the power. Voltage stability gets affected when the disturbance causing more reactive power demand than the available reactive power reserve. So the necessary voltage support has to be provided. There are various analytical tools used for the steady state voltage study and one among them is nose curves or P-V curve method. This method gives the amount of active power that can be transmitted over a line without causing stability problem. It is the plot of power with the voltage of the bus.Fig.2.1 is the P-V curve obtained from the equation (2.1), 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.

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

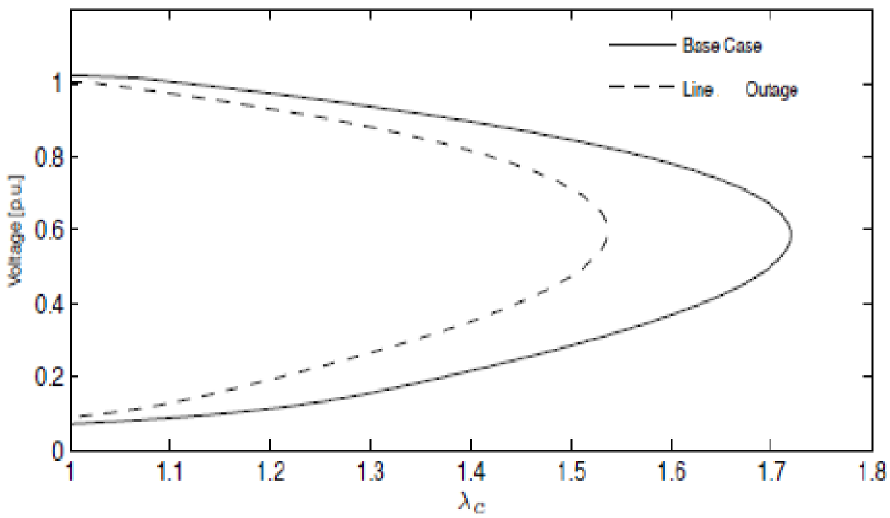


**Fig. 1 P – V Curve**

In fig 1, λc is the loading parameter in per unit (p.u.). λc is marked along X-axis and voltage is marked along the Y-axis. From the figure it can be observed that as the power transfer increases the voltage at the consumer end decreases. There is large voltage drop due to high reactive power losses before reaching the critical point. The region above the nose point is stable region and the region below the nose point is unstable region. The system should be loaded only up to the nose point which is also known as maximum loading point for the stable operation. The voltage reduction can be improved by either decreasing the reactive loads or by increasing the reactive power support.

## III. TEST SYSTEM

The test system IEEE standard 14 bus system is modeled in PSAT as shown in Fig. 2. A STATCOM being connected to the tenth bus since it was analyzed that system is not having voltage stability if it is loaded above 1.7118 p.u. with the help of P-V curves. The additional power required could be provided by wind farm incorporation into the third bus of the system. Also this system is analyzed for small signal stability and voltage stability. The voltage stability analysis was done by plotting P-V curves by increasing loads in all the buses to find the maximum loading point.

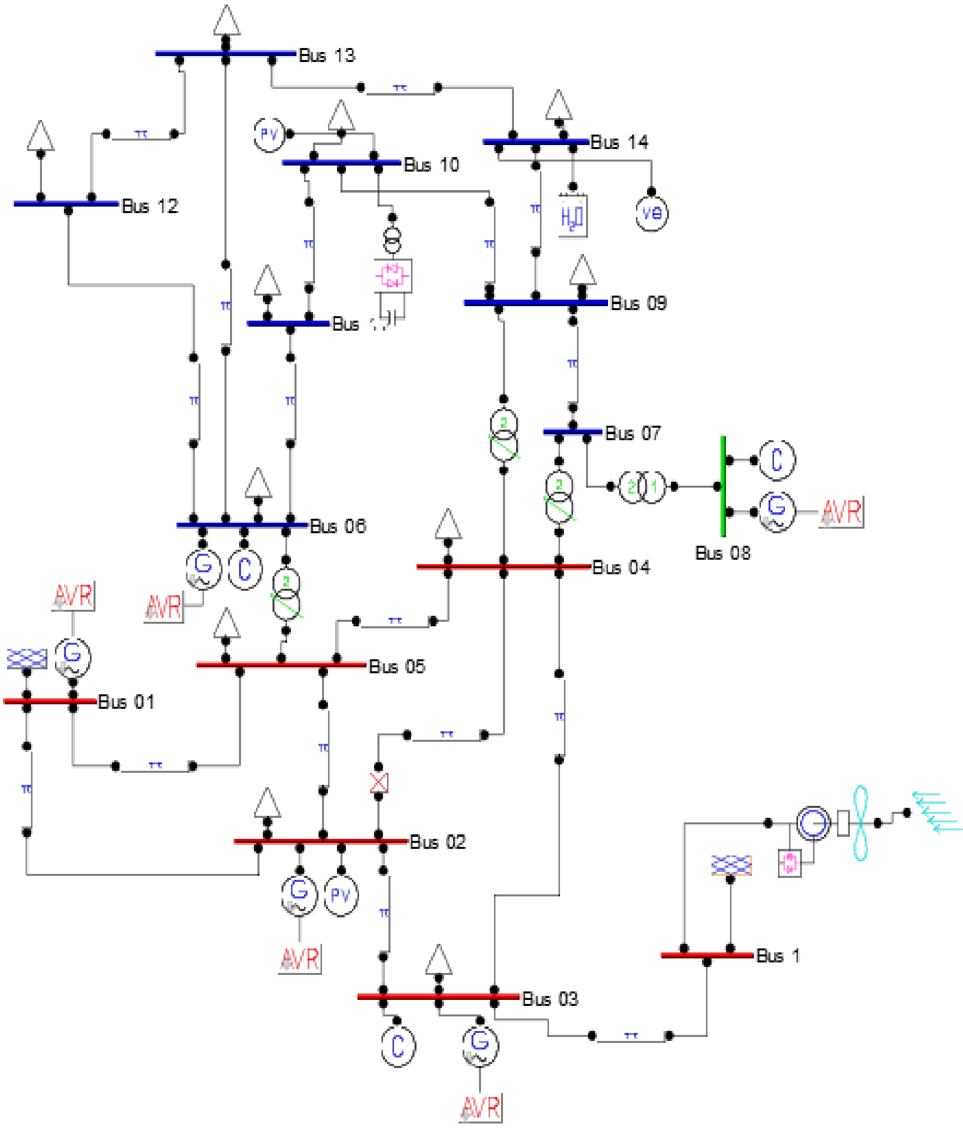


**Fig. 2 Wind integration into the IEEE standard 14 system and storage.**

## IV. REAL SYSTEM

The real system Central Travancore grid is modeled in PSAT which consists of two hydro generating stations Idukki and Sabarigiri, Thermal station at Kayamkulum, diesel generating station at Brahmapuram and wind farms at Ramakkelmedu. It consists of 14 buses. This is analyzed for voltage stability and small signal stability. The maximum loading point is found by plotting P-V curves for the variations in loads at the buses. With the help of P-V curves optimal location for the placement of STATCOM was found.

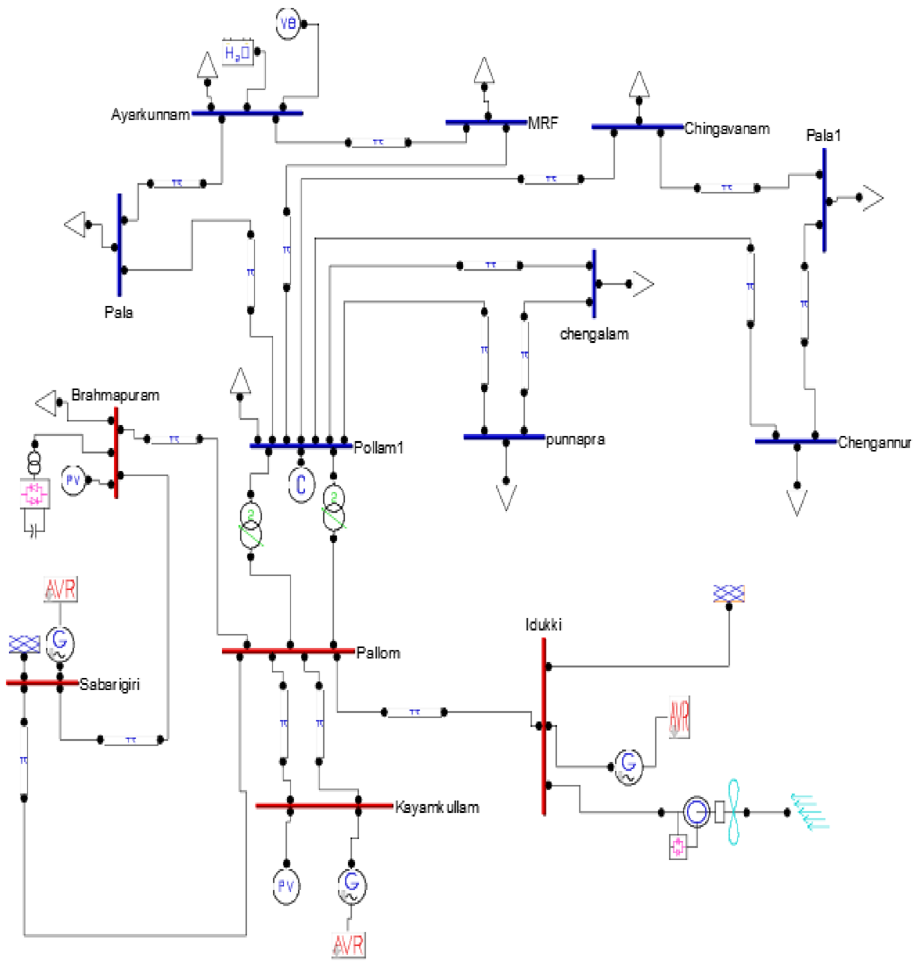


**Fig.3 The Central Travancore Grid of Kerala integrated with wind energy and storage.**

## V. RESULTS AND DISCUSSIONS

The maximum loading capacity of the IEEE standard 14 bus system is 1.7118 p.u. and if the system is operated such that the load in the bus is beyond this value the bus voltage 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 into it. Usage of FACTS devices helps to improve the loading point further.

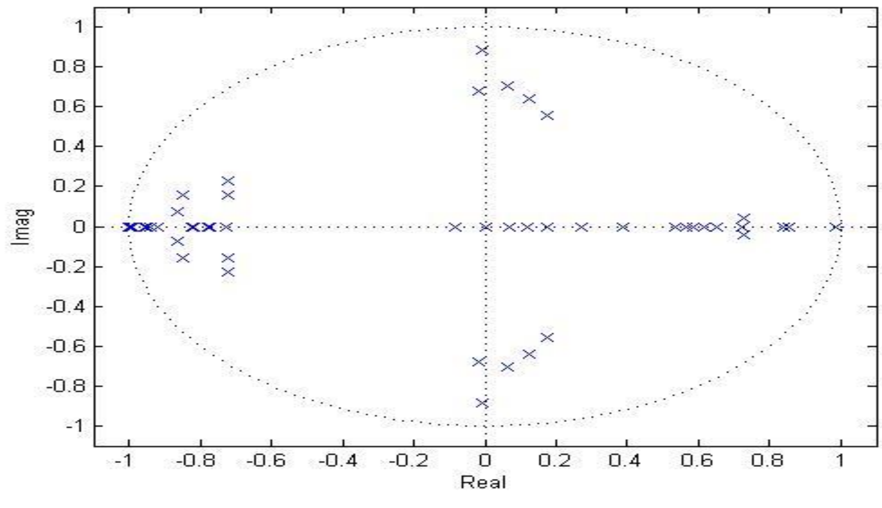


**Fig.4 Eigen value analysis in Z-domain for small signal stability analysis of the test system**

The weakest bus selected for the placement of FACTS device and from the P-V curve it was clear that weakest bus was bus no. 10 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 stability and showed that the maximum loading point has improved to 2.0899 p.u.. The eigen value analysis of the system proves that the system is having small signal stability. In the Z-domain analysis all the eigen vectors were within the unit circle and proves that the system has small signal stability.

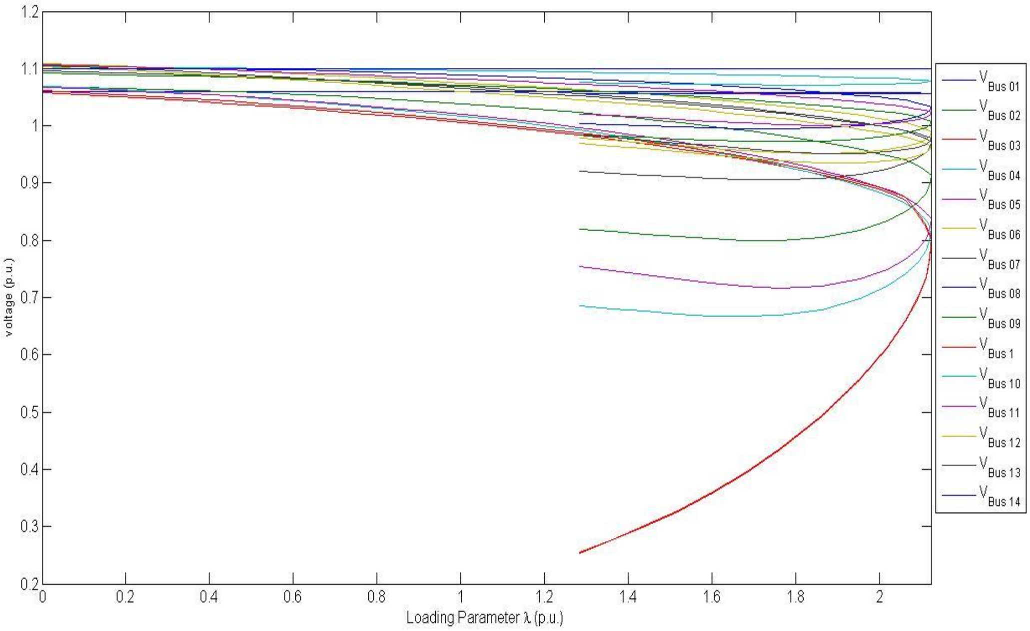


**Fig.5 P – V curve for IEEE standard 14 bus wind integrated system with STATCOM**

As STATCOM is added to the wind integrated power system, the maximum loading point has improved. In normal system the maximum loading point was only 1.7118 p.u.. In a wind integrated test system on adding STATCOM it was improved to 2.1241 p.u..

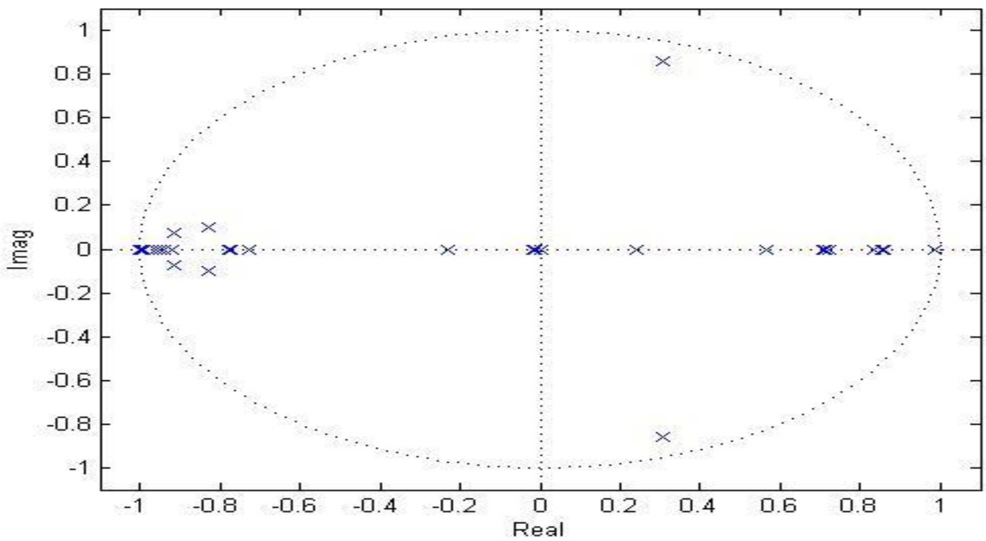


**Fig.6 Eigen value analysis in Z-domain for small signal stability analysis of the real system**

The small signal stability and voltage stability analysis are to be done in the Central Travancore grid in Kerala, a wind integrated power system. The fig. shows the eigen value analysis of the system. In the figures all the eigen vectors are within the unit circle which means that the system has the small signal stability.

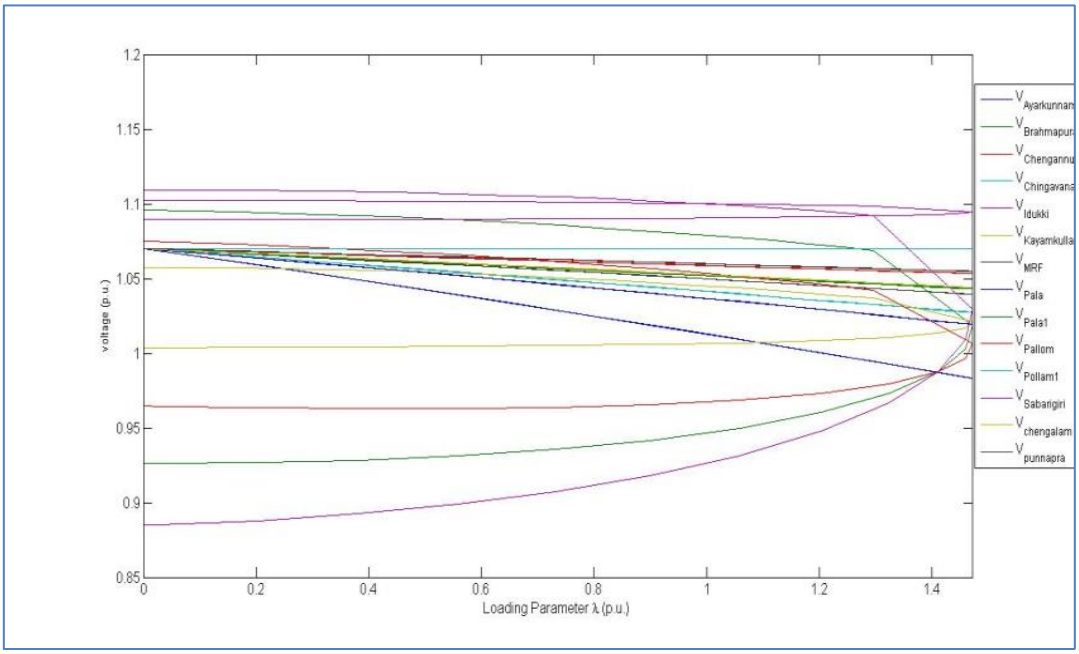


**Fig.7. P – V curve for Central Travancore Grid without STATCOM**

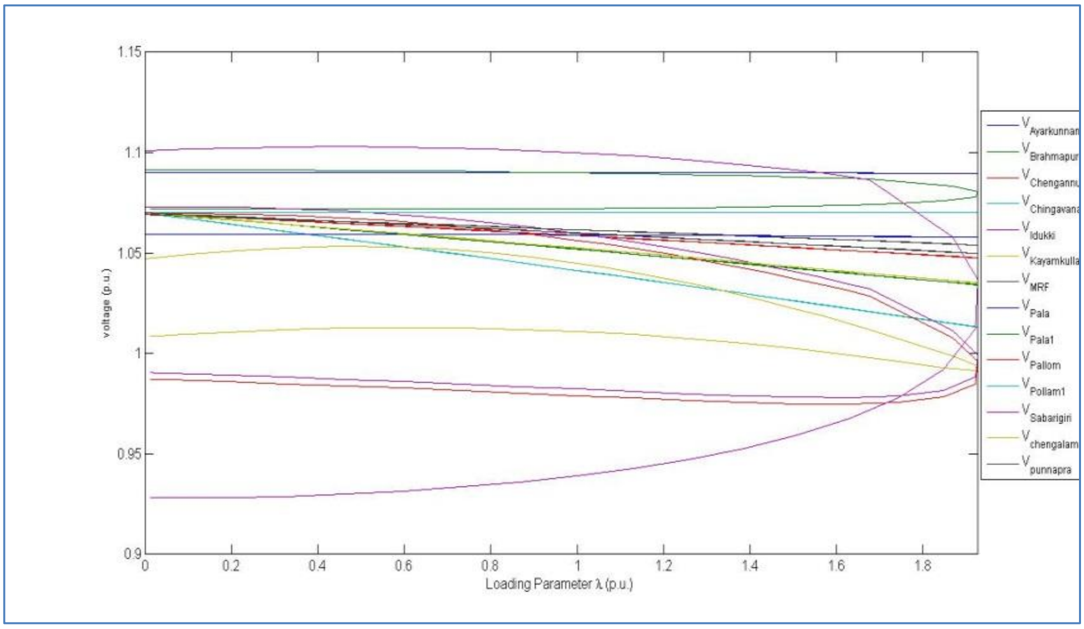


**Fig.8 P – V curve for Central Travancore Grid with STATCOM**

The loading point of the Central Travancore grid was 1.4712p.u. It could be improved to 1.9253 p.u. on adding STATCOM to the weakest bus of the system. The weakest bus found with the help of P-V curve which was plotted for finding the voltage stability of the above system

## VI. CONCLUSION

In this paper, voltage stability analysis of Central Travancore grid in Kerala is analyzed and found that on increasing the load demand the grid may lose its stability and even may go to black out if the system is not properly handled. This paper explores the prospect of connecting a STATCOM to the wind integrated power system with the intention of providing increased loading margin. In this paper, IEEE 14 bus test system and Central Travancore grid of Kerala is modelled in PSAT. Continuation power flow results are obtained showing the enhancement in the maximum loading point. The weakest bus was identified from the simulation studies with the help of P-V curves, thus the location for the placement of STATCOM was found. By incorporating STATCOM in Central Travancore grid the maximum loading point has improved to 1.9253p.u. From 1.4712 p.u. The result seemed to be quite promising when tested on IEEE 14-bus system. From the Eigen value analysis in Z-domain, showing all the Eigen values lied inside the unit circle. Thus proved the system has small signal stability.

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