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Improving the loadability of the wind integrated power system using STATCOM placed at an optimal location

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Abstract: Voltage instability is a major problem that is attracting worldwide interest because of its consequence of voltage collapses. These days' Kerala power system operate closer to their stability limits because of the economic considerations, making large amount of power transfer from long distance and an inadequate supply of reactive power which contribute to system voltage instability that eventually leads to voltage collapse. So the stability margin has to be estimated and to know the loadability of the power system is essential in the real time system for voltage stability assessment. This paper investigates the enhancement of voltage stability using Static Compensator (STATCOM) in a wind integrated Central Travancore wind integrated power system.

Wind energy is gaining attention among a variety of renewable energy resources mainly because it is a clean source of energy, renewable and also its running cost and maintenance cost is very less compared to other energy sources. 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 system analysis.

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

INTRODUCTION

Power system is a large complex network, interconnected together that consists of many buses and generators. The power system network is developing day by day in order to meet the increase in power demand which increases every day. The increase in power demand is met either by installing new generating stations, or by extending the limits of the existing infrastructure operation. As a result, the existing transmission lines are heavily loaded than ever before and one consequence of this is the threat of losing stability following a disturbance.

Every power system should operate under stable operating conditions and the stable operating conditions include both angle stability and voltage stability. The voltage stability is an unavoidable factor in the normal operation of a power system.In this paper the stability of Central Travancore grid is analyzed and the maximum loading point is found. In order to maintain the stability and to enhance the voltage stability of the system Flexible Alternating Current Transmission Systems (FACTS) which is the latest technology in providing reactive power compensation is used. Various reactive power compensators are available like Static Synchronous Compensator (STATCOM), Static VAR Compensator (SVC), Thyristor Controlled Series Compensator (TCSC), Static Synchronous Series Compensator (SSSC) etc .

This paper concentrates on STATCOM for enhancement of voltage stability and reliability of the Central Travancore grid. STATCOM is a modern FACTS device which is used for shunt reactive power compensation. The principle of STATCOM is the reactive power compensation where the reactive power and voltage magnitude of the system could be adjusted. It consists of three parts: shunt (coupling) transformer, voltage source converter (VSC), and capacitor.

The STATCOM has to be placed in an optimal location in a power system, as the STATCOM is expensive, and only optimal locations would provide maximum voltage enhancement and increased loadability

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 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 . The important feature of 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. 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 ..,

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TEST SYSTEM

The IEEE standard 14 bus system modeled in PSAT is the test system is shown in below figure . 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 STATCOM for improving the voltage stability was found.

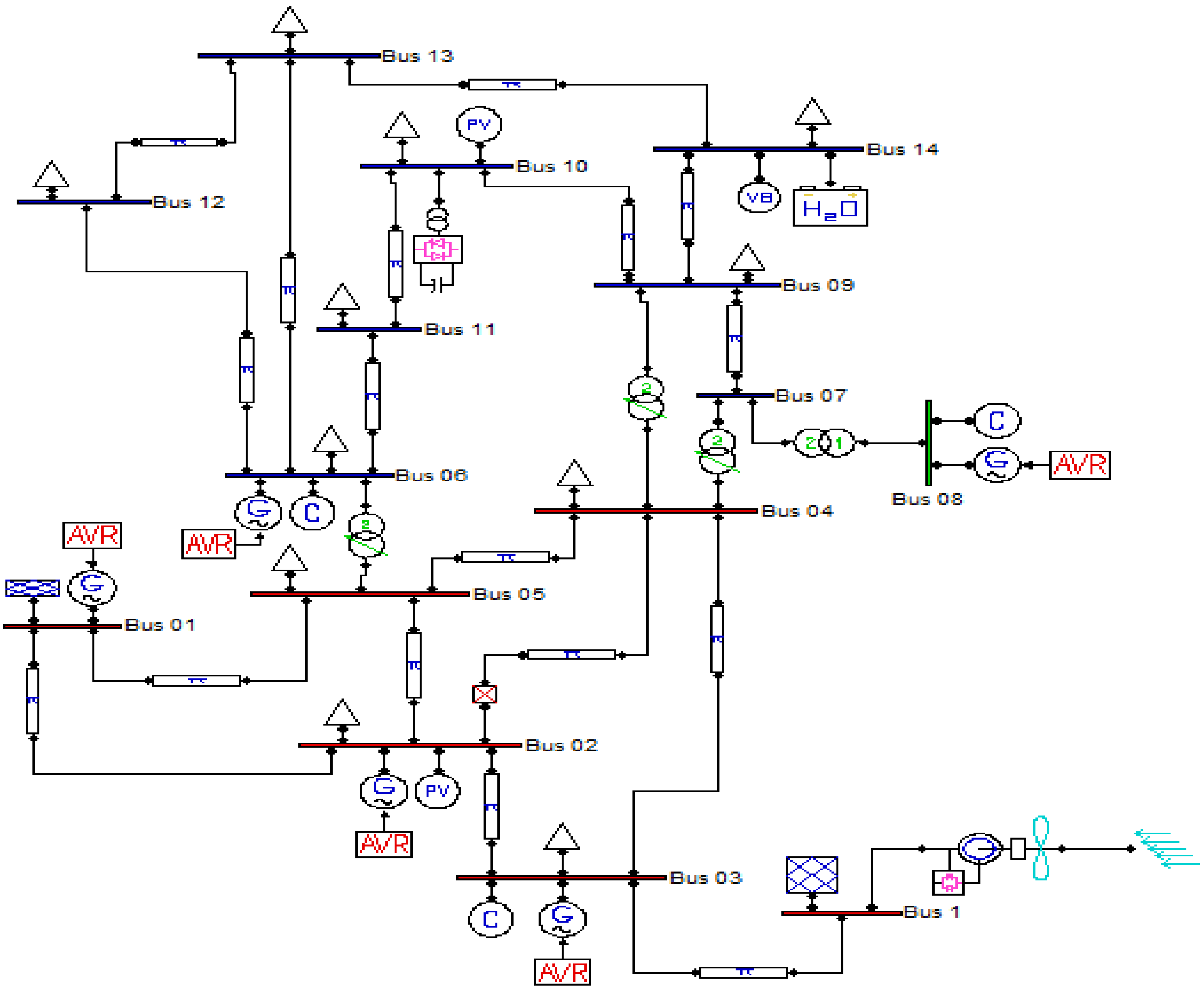

Fig 1:Wind integration into the IEEE Standard 14 bus system (test system)and storage

REAL SYSTEM

The real system was modeled in PSAT is shown in below figure 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. 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 STATCOM was found with the help of P-V curve.

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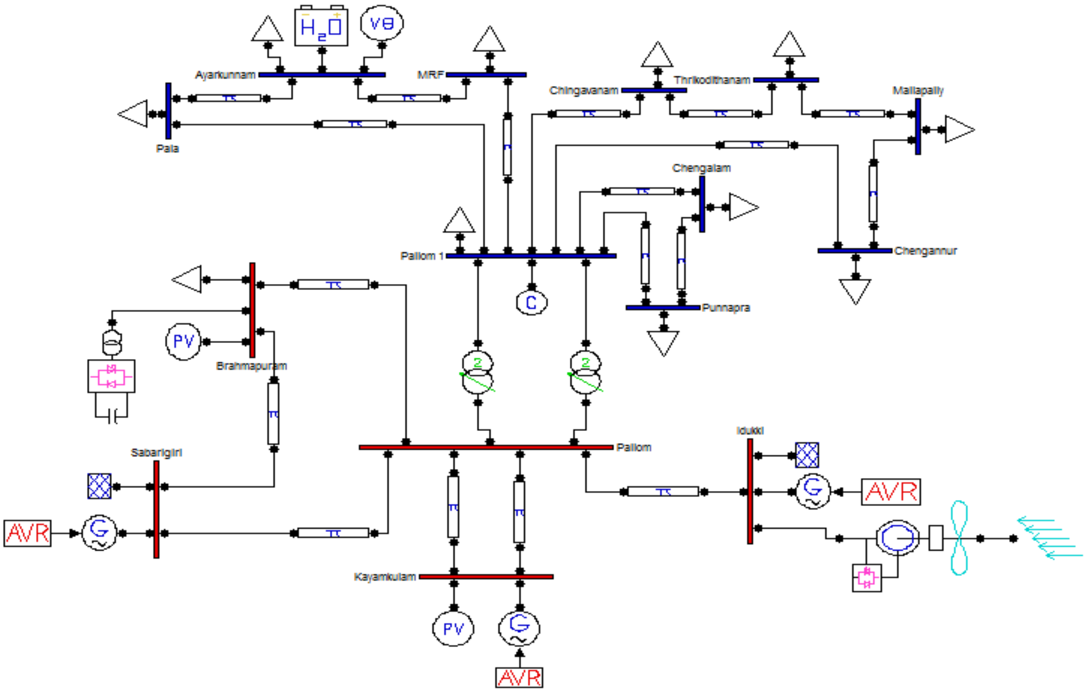

Fig 2: The Central Travancore Grid of Kerala integrated with wind energy and storage.

RESULTS AND DISCUSSIONS

FOR TEST SYSTEM:

The maximum loading capacity of the IEEE standard 14 bus system is 1.3 pu which is shown in Fig1 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 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

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 3. The eigen value analysis of the system proves that this 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. As a STATCOM 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 STATCOM to the system it has been improved to 1.6 p.u as seen in P-V curve

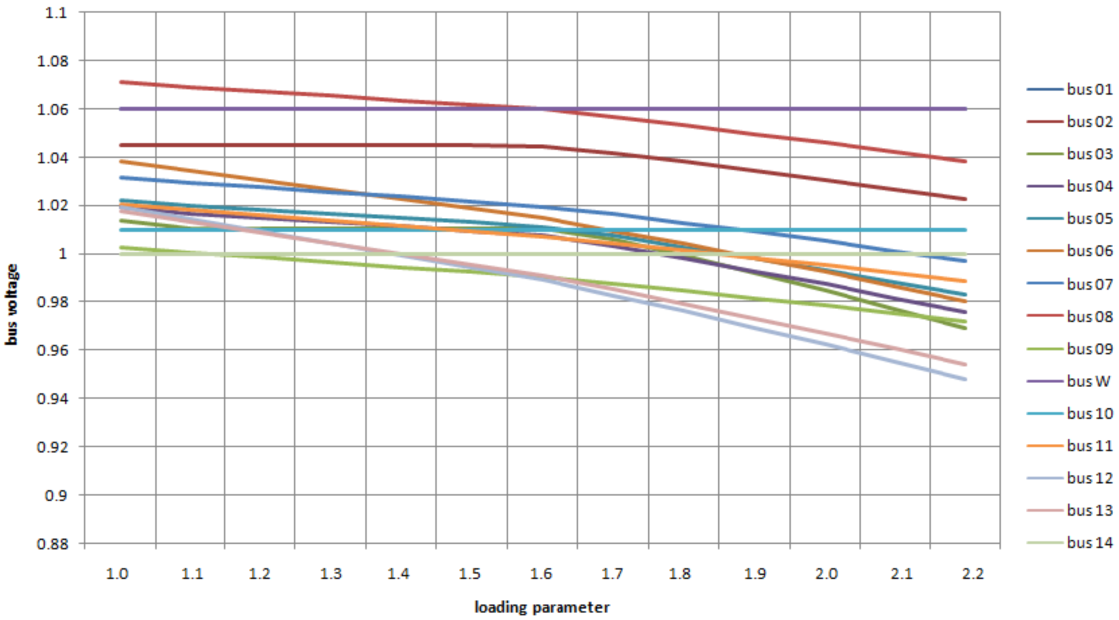

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Fig 3: P-V Curve for test system

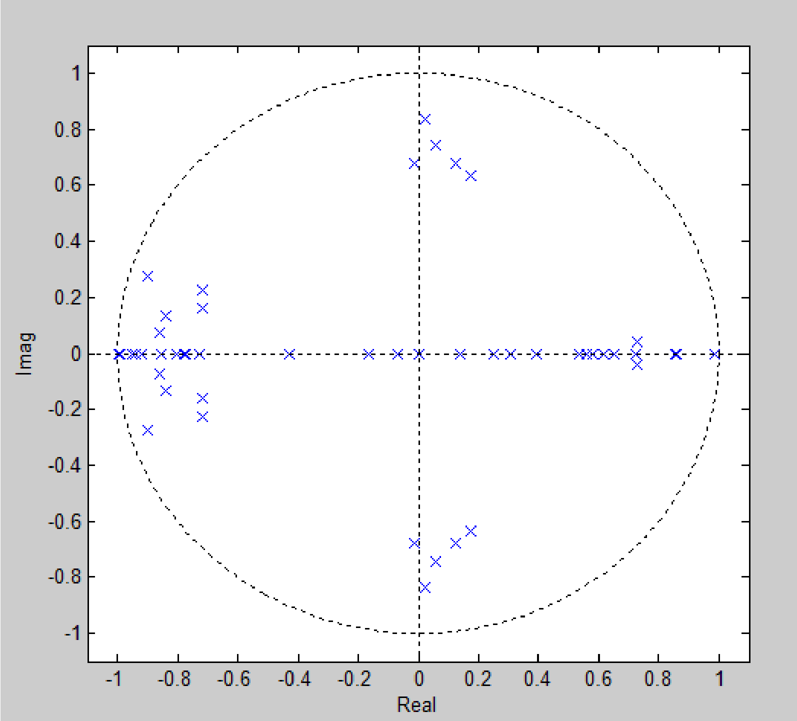

Fig. 5 Eigen value analysis in z-domain for small signal stability analysis of the test system

FOR CENTRAL TRAVANCORE GRID:

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. 7 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 STATCOM 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..

As a STATCOM 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 STATCOM to the system it has been improved to 1.6 pu as seen in P-V curve in figure 6.

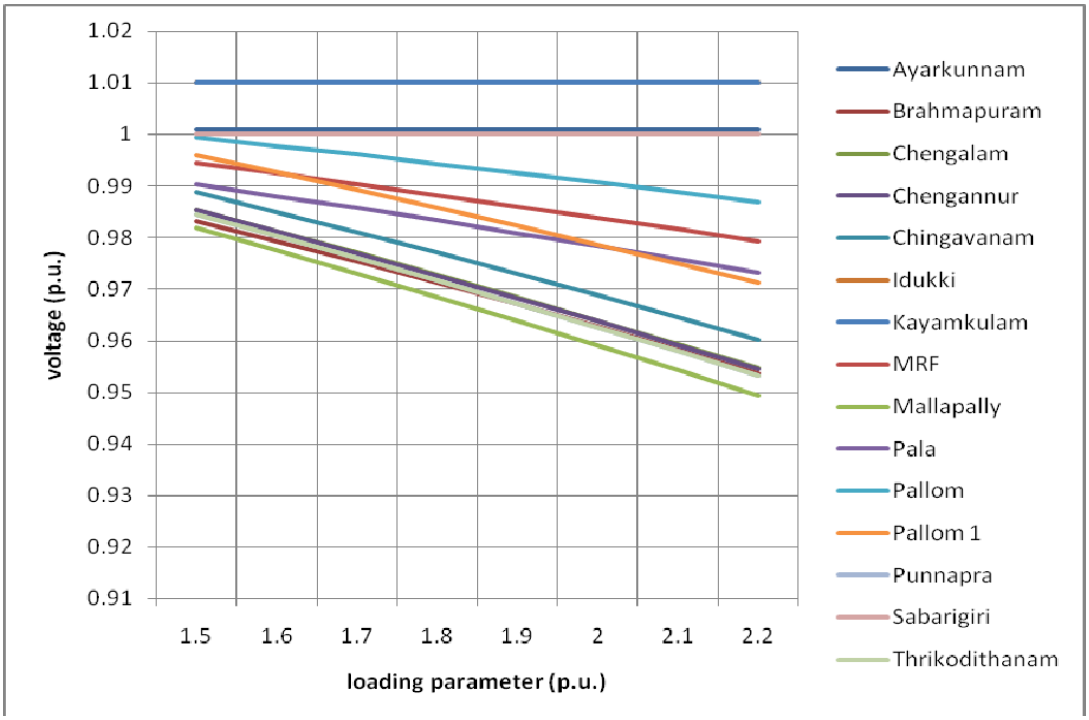

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Fig. 6: P-V curve for the Central Travancore Grid with storage and STATCOM

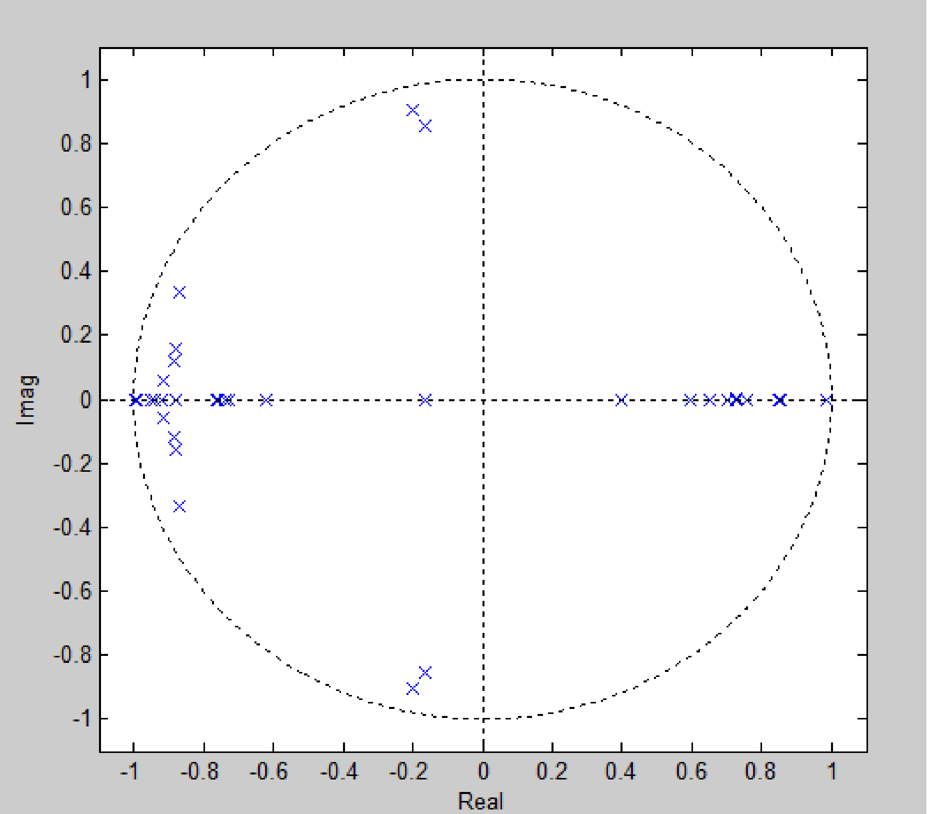

Fig. 7: Eigen value analysis in z-domain for small signal stability analysis of the Central Travancore grid

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 may even go to black out if the system is not properly handled. Incorporating STATCOM 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 STATCOM the loadability of the present grid was improved to 1.6 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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