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Research paper

Improvement of large power system with facts devices placement to maxim-IZE the system load ability

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Abstract

Voltage instabilities and/or collapses have been recognized as one of the major causes of power system blackouts. The main objective of this paper is to provide some solutions to prevent large power systems from voltage collapse. The FACTS (Flexible AC Transmission Sys-tems) devices placement gives new opportunities for enhancing voltage stability. The calculation of the loadability point is based on the con-tinuation power flow technique (CPF) to choosing the optimal placement of STATCOM (Static Synchronous Compensator) in order to improve voltage stability by increasing the loading parameter, maintaining bus voltages at desired level and minimizing losses in a power system network.

A 39-bus New England power system is chosen as test case in order to illustrate this approach. The obtained results show the efficiency of the proposed method for the planning of the Static Synchronous Compensator optimal placement and the voltage stability enhancement.

Keywords: *STATCOM Placement; CPF Analysis; Voltage Stability Enhancement.*

1. Introduction

The stability of the power system may be defined as the property of the power system which allows it to remain in a state of operating equilibrium under normal operating conditions and to return to an acceptable equilibrium state after being subjected to disturbance [1].

The instability of the voltage is mainly associated with the imbalance of the reactive power. The loadability of a bus in the power system depends on the reactive power support that the bus can receive from the system. As the system approaches voltage collapse point (maximum loading point), the real and reactive power losses increase rapidly.

Therefore, reactive power supports must be local and adequate [1]. Power electronics based equipment, or FACTS, provides proven technical solutions to voltage stability problems.

Particularly, due to the increasing need for rapid response for power quality and voltage stability.

The recent development and use of FACTS controllers in the power transmission system has led to many applications of these controllers not only to improve the voltage stability of existing power network resources, but also to provide operational flexibility to power system [2]. By using FACTS controllers, variables such as voltage amplitude, phase angle and line impedance on the selected bus can be controlled.

Many studies have been done to locate FACTS based on the operation of these devices in the power system such as controlling the power flow in the transmission lines or improving the loadability [3].

A number of voltage stability analysis methods have been proposed, such as: Continuation power flow (CPF), modal analysis etc. A number of voltage stability indices such as a voltage collapse indicator, the minimum singular value of the Jacobian matrix of power flow, the minimum eigen value of the reduced Jacobian matrix has been proposed in the literature to estimate the proximity of the power system to voltage stability and voltage collapse. The application of the CPF consists in evaluating the stability of the voltage of a power system for various loading conditions and contingencies.

In this work, a Continuation Power Flow Analysis (CPF) methodology is used to evaluate the effects of FACTS devices, precisely the STATCOM (Static Synchronous Compensator) for shunt connected controlled reactive-power source. It produces a balanced set of three-phase sinusoidal voltages at the fundamental frequency with rapidly adjustable amplitude and phase angle on the system maximum loading point in voltage stability study.

Various implementations of the continuation method have been proposed to improve voltage stability in power systems with FACTS devices.

In Ref. [4], CPF is used to determine the size and location of the series compensators in order to increase steady state power transmission capability in the power system.

The continuation power flow analysis consists of a prediction step, which is performed by calculating the tangent vector, and a corrector step, which can be obtained either by a local parameterization, or by a vertical intersection.

The aim of this paper is to find the optimal placement of Static Synchronous Compensator, namely the STATCOM of large power system, in order to achieve the static voltage stability margin using CPF technique. CPF objective function to be maximized is the loading parameter which modifies load powers.

The rest of the paper is organized as follows: Section II introduces mathematical representation of voltage stability study. In section III, some interesting results are presented along with detailed discussion. Finally, our contributions and conclusions are summarized in Section IV.

2. Voltage stability study with statcom device using CPF

2.1. Statcom device

The implemented STATCOM model is a current injection model [5]. The STATCOM current is always kept in quadrature in relation to the bus voltage so that only reactive power is exchanged between the ac system and the STATCOM. The dynamic model is shown in Fig1. The mathematical model of the differential equation and the reactive power to be injected at the STATCOM node are given, respectively as follows:

$$\dot{i}_{SH}=\left(k_r\left(v_{ref}+v_S^{POD}-v\right)-i_{SH}\right)/T_r \qquad (1)$$

$$Q=i_{SH}*v$$

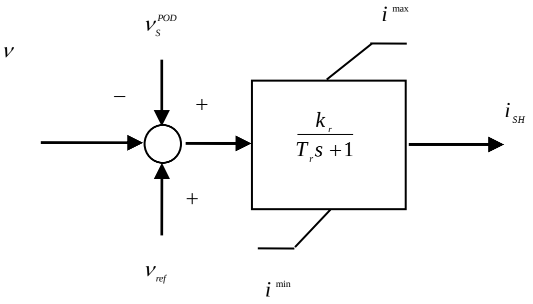


Fig. 1: STATCOM Structure.

where v is bus voltage magnitude, v_S^{POD} is signal output of the power oscillation damper, v_{ref} is reference voltage, k_r is regulator gain, T_r is regulator time constant, $i^{\max}$ is maximum current, $i^{\min}$ is minimum current and i_{SH} is total current.

2.2. Continuation power flow

CPF techniques are a very robust tool for calculating variable trajectories state in a system dependent on one or more parameters. Different methods exist and we will focus here on the method developed by C. Canizares in [6]; then the process is manipulated according to the following power flow equation:]the process is manipulated according to the following power flow equation:

$$\begin{aligned}0&=f(x,y,\lambda)\\0\le\lambda&\le\lambda_{critical}\end{aligned} \qquad (2)$$

Where x is the vector of bus voltage angles, y is the vector of bus voltage magnitudes and λ is loading parameter.
The problem is solved by the CPF technique and iterative process involving predictor and corrector steps as shown in figure 2.

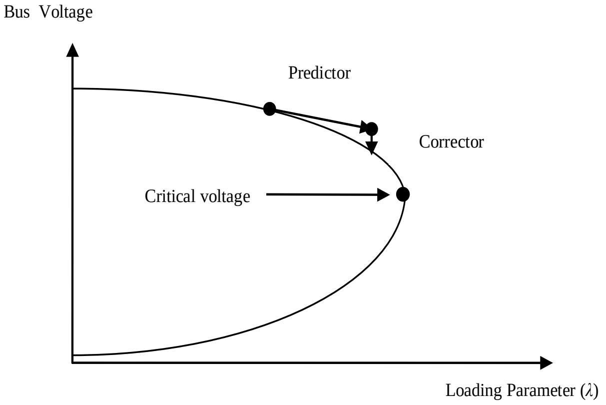


Fig. 2: CPF Technique.

2.3. Objective function

In this paper, our goal is to obtain the best utilization of the existing large power network with STATCOM placement to maximize the loading parameter denoted by (λ).
This goal can be expressed as follows:

$$\text{Maximize } (\lambda) \qquad (3)$$

The Flowchart of voltage stability with FACTS using the CPF method is illustrated in Fig 3. From Fig. 3, it can be observed that equations of FACTS devices are added in the load flow equations. The new load flow equations are then used in the corrector step in CPF process.

3. Case studies

A 39-bus test system is used for the objective of this study (figure 4). This large power system represents a simplification of the transmission network of the New England Region (Northeastern United States). It is composed of 10 machines, 39 nodes, 34 lines, and 12 transformers. It has three areas; the base voltage of each bus is 100Kv. The original system data can be found in [7].
Voltage stability analysis is performed by starting from an initial stable operating point and then increasing the loads by a factor λ until singular point of power flow linearization is reached. The loads are defined as:

$$\begin{aligned}P_1&=\lambda P_0\\Q_1&=\lambda Q_0\end{aligned} \qquad (4)$$

Where P_0 and Q_0 are the active and reactive base loads, whereas P_1 and Q_1 are the active and reactive loads at bus l for the current operating point as defined by λ.

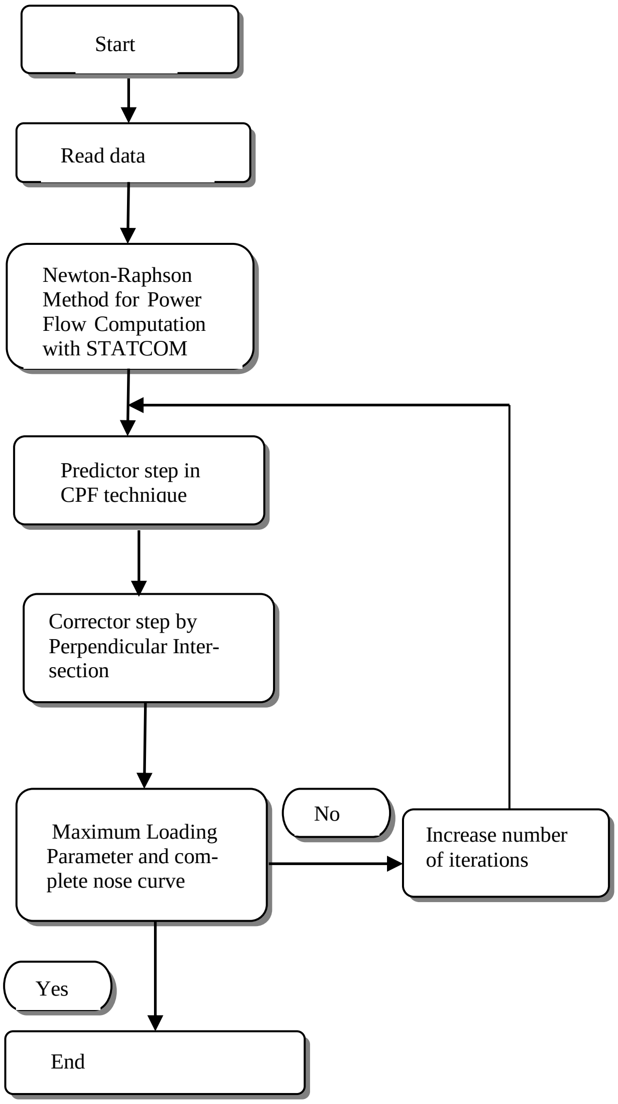


Fig. 3: Flowchart of the Proposed Method

3.1. Location of statcom

The behaviour of the test system with and without STATCOM under different loading conditions is studied.

The location of the STATCOM device is determined through CPF technique.

Figure 5 represents the voltage profile for the system without the STATCOM.

Figs. 6, 7 and 8 represent respectively PV curves for the critical buses for the three areas for 39-bus test system without STATCOM.

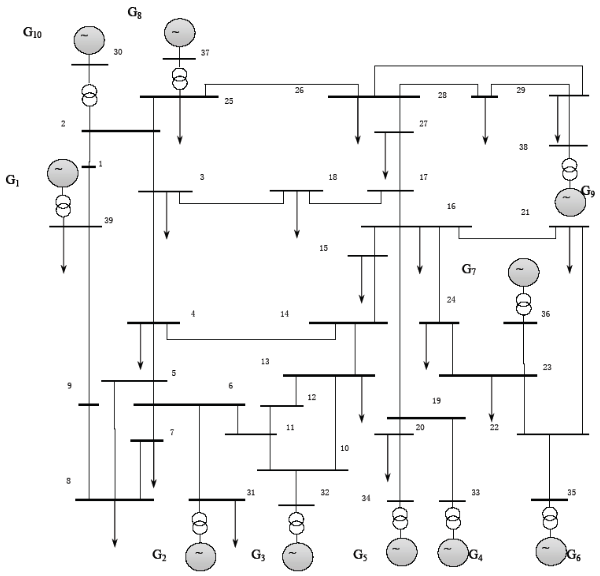


Fig. 4: The IEEE-39 Bus System.

From the CPF analysis which is shown in the figure 5 and PV curves figures for the three areas composed our large power system, the buses 3 (area 2), 8 (area 1) and 15 (area 3) are the most critical buses.

Maximum loading point or bifurcation point where the Jacobian matrix becomes singular occurs at $\lambda = 2.28 p.u$.

Bus 8 is indicated as the most critical voltage bus needing Q support.

After the optimal location of the STATCOM was determined to be at bus 8 and the corresponding size of STATCOM is – 380 Mvar /+ 420 Mvar according to (1).

Locating an STATCOM at the best position reduces both real and reactive power losses.

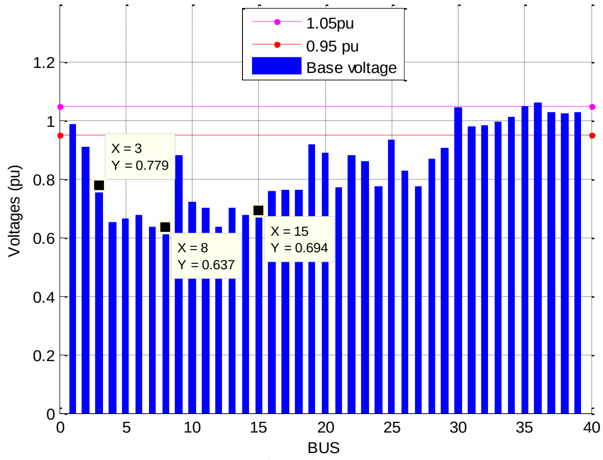


Fig.5: Voltage Profile of IEEE 39 Bus System.

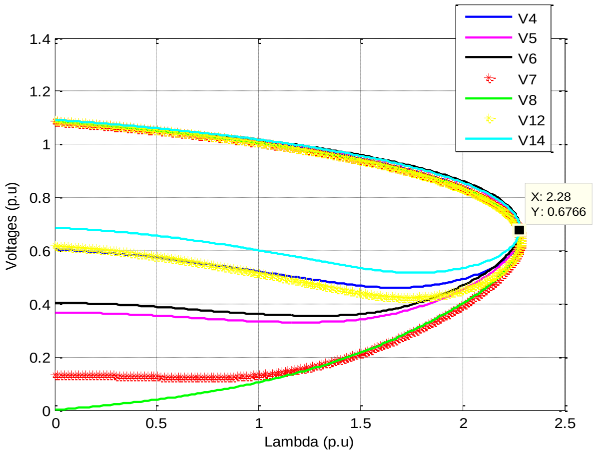


Fig. 6: PV Curve for 39 Bus System without STATCOM (Area1).

3.2. Impact of statcom

Voltages profiles of base case and system with STATCOM are illustrated in figure 9. It is obviously from fig. 9 STATCOM provides a better voltage profile at the collapse point. This is due to the reason that the STATCOM is installed at the weakest bus.

The PV curve for the system with the STATCOM at bus 8 is shown in figure 10. As expected, the bifurcation for the system with the STATCOM placed at bus 8 occurs at a higher load value, i.e., $\lambda = 2.31 p.u.$

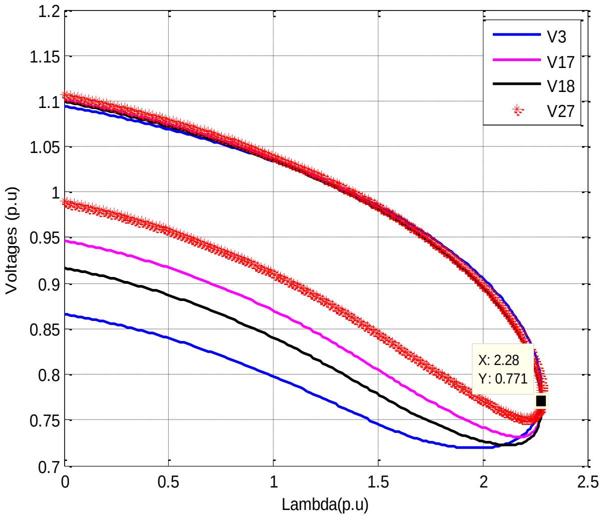


Fig. 7: pav curve for 39-bus system without statcom (area 2**).**

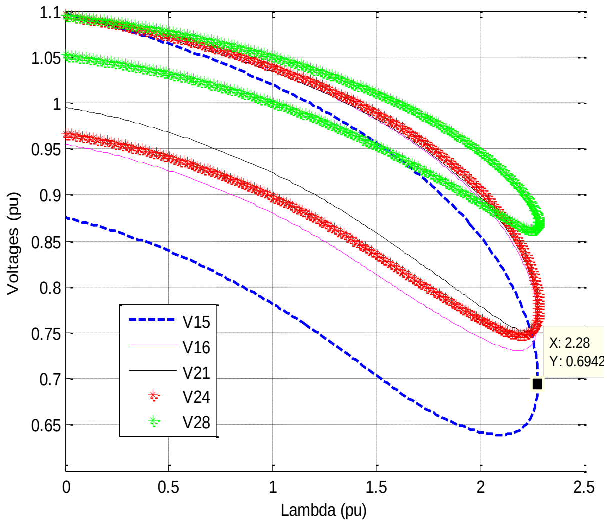
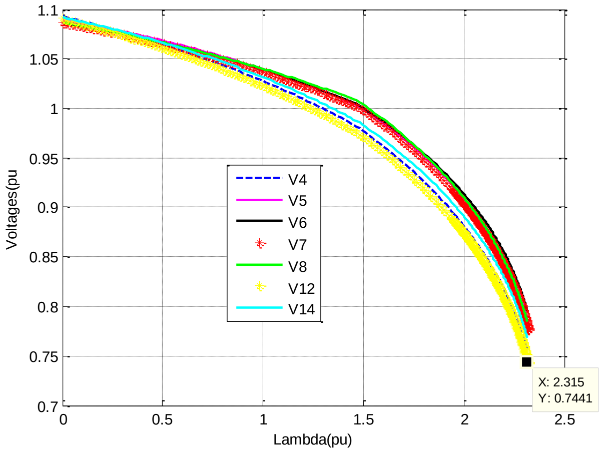


Fig. 8: PV Curve for 39 Bus System without STATCOM (Area 3).



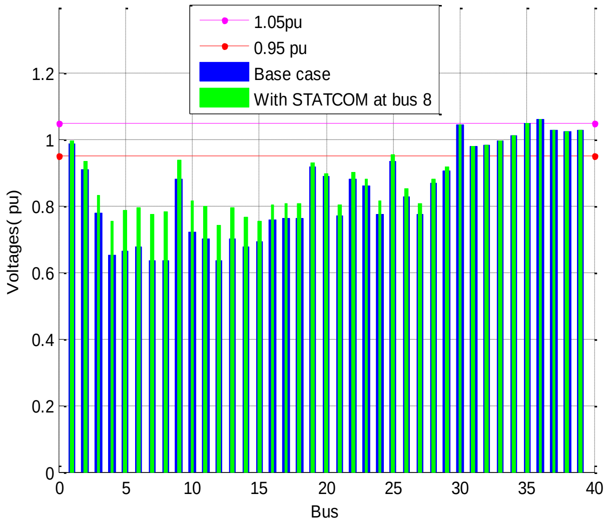


Fig. 9: Voltage Profile of System with STATCOM at Bus 8.

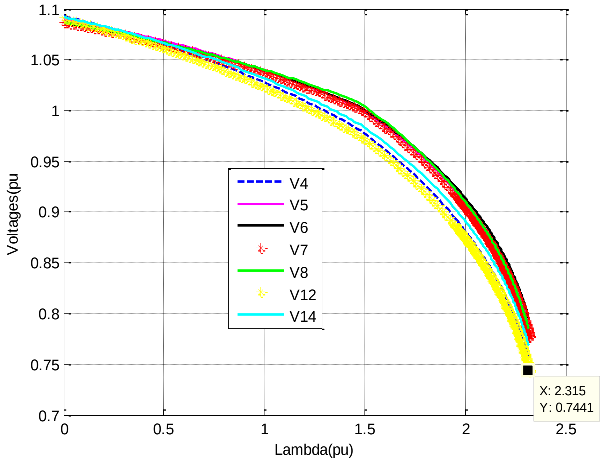


Fig. 10: PV Curve For 39 Bus System with STATCOM at Bus 8.

Figure 11 and Figure 12 Show Respectively the Active and Reactive Power Losses Profiles of the System (without and with STATCOM), the increase of Losses Near the Collapse Point is Lower with a STATCOM Connected to a Power System.

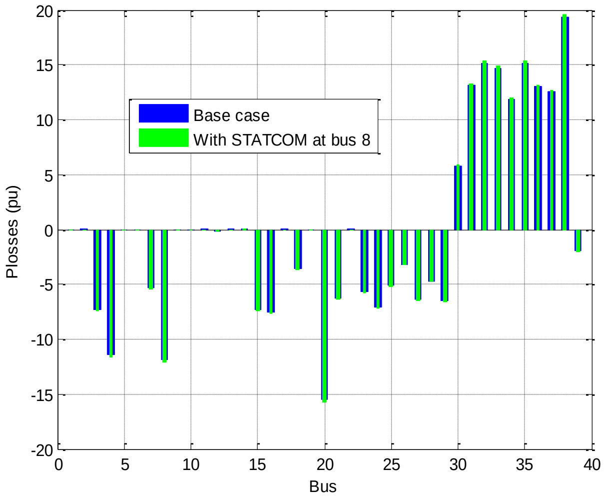


Fig. 11: 39-Bus System Active Power Losses Profile without and With STATCOM at Bus 8.

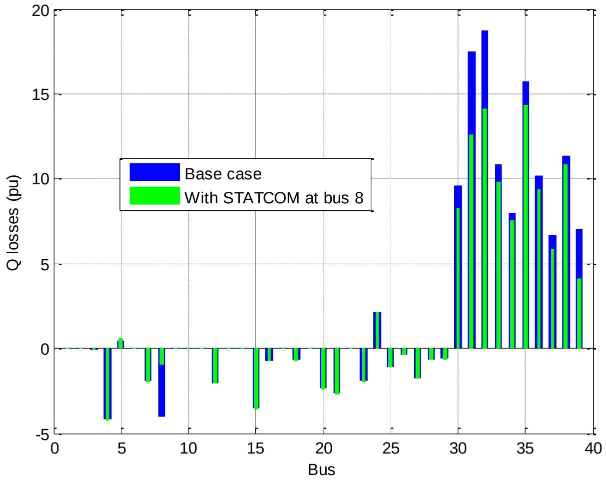


Fig. 12: 39-Bus System Reactive Power Losses Profile without and with STATCOM at Bus 8.

4. Conclusion

This paper implements a proposed CPF analysis to determine the optimal location of FACTS devices. This is for the purpose of improving the stability margin of the large system voltage. STATCOM device is used to improve the performance of power system. The simulation results on the IEEE 39 bus validate the optimal placement efficiency of this device.

The results obtained show:

- The potential of the CPF algorithm to solve the problem of the optimal placement of STATCOM.
- Improving the stability of the voltage by maximizing the loading parameter.
- The best voltage profile and the lowest active and reactive power losses at collapse point when the placement of the STATCOM is optimized.

This work can be extended to solve the problem of the optimal location of multiples FACTS devices to improve the stability of the voltage in practical power systems.

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