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Optimal Allocation of FACTS Devices for Enhancement of Voltage Stability Margin

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ABSTRACT— Nowadays, with increase in demand for electricity, power generation is increased which leads to increase in power transfer. Due to a lack of network growth in the generating and transmission sectors, the demand for electrical power has increased over the past ten years. This gives arise to various problems such as voltage stability issues and contingency problems. The transmission network that is available is overburdened. Voltage instability is brought on by the transmission network becoming overloaded. When a system is heavily loaded, instability leads to voltage collapse, which results in power loss. This phenomenon makes it important to monitor voltage instability and prevent voltage collapse. Voltage collapse mostly happens because reactive power isn't always available. Reactive power is added to the system using a power electronic device called the Flexible AC Transmission System (FACTS), which improves the voltage profile and reduces the likelihood of voltage collapse. This paper aims to discuss the generalized method of optimization technique for the allocation of FACTS devices for enhancement in voltage stability margin.

Keywords— FACTS devices; TCSC; STATCOM; UPFC;Optimal FACTS Placement

I. INTRODUCTION

Electrical safety is a fundamental factor to consider in electrical design and processes. An enormous and intricate structure, the power system connects many producing units and substations. The system is overwhelmed because it is already being operated at its maximum capacity and the demand for power is rising daily. In the event of a contingency, the situation is not secure. These errors or contingencies cause voltage instability in the system. Voltage instability arises in the system, which means that even a single disturbance can cause the voltage to drop or surge above predetermined levels, leading to blackouts and voltage collapse. Reactive power generation falls short of demand, which contributes to voltage instability issues. These days, the power transmission system talks about the two crucial variables of load and power quality. These have to do with a sudden rise in power demand to keep the system secure and nonlinear loads like machines and various electronics equipment that are connected to the transmission system. Demand and generation contribute to voltage instability because of the fluctuation in the voltage profile. The reactive power, which is unstable, is the cause of this instability. Because the load changes, reactive power consumption cannot be managed. The transmission system must be expanded, which takes time, money, and right-of-way. Instead of putting in new transmission lines or replacing existing ones, a FACTS device will be installed. The need for additional electricity in all power systems is very important as electricity consumption is increasing year by year and power production has to regulate fuel consumption. The maximum value that the busbar can transmit depends on the reactive power it receives from the system. When the system reaches full load, the operation and response losses become very high. In this case, the system can be stabilized by reducing the reactive power load or by introducing a reactive power source (such as a capacitor or FACTS device) into the correct situation before the system voltage collapse point is reached.

The use of FACTS devices has the advantage of reducing reactive power from the mains to the load, reducing current harmonics, reducing busbar voltage drops and swelling, and reducing all active energy losses. There is always a problem with a faulty FACTS device. Due to the high price of this equipment, precise placement is crucial for proper operation. The advantage of including a FACTS device is that it will increase the actual power delivered without the need to add to the generator. FACTS devices not included in other expansions can improve safety by adding electrical controls and reduce accidents through power management. The important thing about the FACTS device is that it does not force the electrical and electronic control system in any way. This article focuses on the best placement of the FACTS device in transmission. Objectives for optimal placement of the FACTS device:

1. Reduce cost and power loss in special line.
2. Better use of existing network
3. Delay or eliminate congestion problems
4. Current control
5. Increase the load capacity of the system but with a limit
6. Increase the margin of safety within the stress limit.
7. Reduce reactive power loss.
8. Congestion management in the system
9. Its necessary to strengthen the power transmission capacity.

Different load flow analysis techniques, including steady state analysis, the continuation power flow method (CPF), the optimal power flow (OPF), etc., are utilized to prevent the system from experiencing voltage collapse. In a power system made up of several transformers, circuit breakers, transmission and distribution lines, as well as many types of loads with various power factors, reactive power is crucial. The current and voltage measurements in VARs are shifted by these devices as a result of their inherent properties. The voltage profile changes as a result of the reactive power (volt-ampere reactive, or VAR) changing. When a system receives a high volume of VARs, the system's losses increase and its capacity for power transfer decreases, and when a system receives a low volume of VARs, voltage sag results. An adequate amount of reactive power will be injected into a system to make it in a stable position. Reactive power compensation enhances voltage profile, transmission ability, and power flow control to operate the system with flexibility.

Due to the existence of various generating and utility appliances, the power network has a varied transmitting and receiving voltage. The magnitude and phase angles of these gadgets vary. We must adjust the system voltage if we want the voltage magnitude and phase to be within the desired range between the sender and receiver points or to be in a stable position. Different techniques are employed to make up for the system. For instance, adding a capacitive load in parallel can provide reactive power, which lowers the line's current drop and raises voltage. Installing a compensator in the system, which is used to reduce voltage changes by automatically managing reactive power, is the second way to adjust a system.

II. LITERATURE REVIEW ON FACTS DEVICES

A current IEEE publication [3] defines the terms and definitions of several FACTS devices. If the temperature limit allows for the same level of stability to be maintained while maintaining, the FACTS devices are highly helpful and can increase a line's capacity for power transfer [4]. The basic goals of FACTS technology are to maintain system control, move more electricity from one place to another, and increase system stability.

FACTS systems may be connected to a transmission line in a number of situations, including a series, shunt, or combination of series and shunt. For instance, a connection exists between a static var compensator (SVC) and a static synchronous compensator (STATCOM). For instance, in shunt, the static synchronous series compensator (SSSC) and thyristor-controlled series compensator (TCSC) are connected in a series, and the unified power flow control (UPFC) and thyristor-controlled phase-shifting transformer (TCPST) are connected in series and shunt combinations.

Strong performance, rapid response, and lowest cost among other devices are just a few benefits of the TCSC. One of the top FACTS devices is TCSC. TCSC may be used as a capacitor or an inductor.

Therefore, there is only a finite amount that can be used to regulate the reactance of the transmission line.

FACTS controller are one of the important part of EPS in regards to maintain voltage stability, reducing total losses, increase in loadability margin and maintain power system transfer capability. Although FACTS devices are expensive, decrease in even 0.5% stability margin can be detrimental to the system. Thus for continuous power flow along with financial constraints these are the different parameters for optimal allocation of FACTS devices:

1. Location of device
2. We can use types, different type of FACTS or only one type in the body.
3. Financial issues, regulations, etc.

In general, electrical power can be measured by the frame load capacity and/or the body loss if the node voltage magnitudes remain within the applied limits and the thermal constraints of the system components are not violated. The technique that has been used to study the power flow in various branches before and after the placement of these devices is one of several strategies to decide where to place FACTS devices. By changing the line's impedance, these FACTS devices, which are installed between two buses, have the potential to adjust the power. A number of conditions must be satisfied for the placement of FACTS devices. They mostly consist of:

1. Either a load bus or a generator bus without regulating generation must be the transmitting end bus.
2. There must not be a switched shunt controlling the voltage locally to a predetermined point on the sending end bus.
3. The sending end bus cannot be connected to another bus that disobeys points 1 and 2 above through a zero impedance line.

4. A switched shunt cannot be connected to the terminal end bus.
5. A converter bus of a DC line cannot be the terminal end bus.

A. Types of FACTS Devices

Different types of FACTS controller In general FACTS controllers can be divided into four categories:
(a) Series controllers: Static Synchronous Series Compensator (SSSC) and Thyristor Controlled Series Capacitor (TCSC) are examples of series FACTS controllers.
(b) Shunt controllers: Static VAR Compensator (SVC) and Synchronous Compensator (STATCOM) are examples of shunt FACTS controllers.
(c) Combined series–series controllers: Interline power flow controller (IPFC), Thyristor-Controlled Voltage Limiter (TCVL) and Thyristor-Controlled Voltage Regulator (TCVR) are examples of series–series FACTS controllers.
(d) Combined shunt-series controllers: Thyristor Controlled Phase Shifting Transformer (TCPST) and Unified Power Flow Controller (UPFC) are examples of shunt-series FACTS controllers
TCSC can have one of two types of products, capacitive or inductive depending on the decrease or increase in total reactance of the transmission line. It is modeled with three ideal switching elements connected in parallel:
a capacitor, an inductor and a simple short switch when not needed in the circuit. Capacitors and inductors are different and their value depends on the reactance and power transmission capacity of the lines connected to the device. To avoid noise, only one of the three items can be changed at a time. In addition, the maximum capacity value is set to -0.8XL to avoid overcompensation of the line. For inductors, the maximum is 0.2XL.
2. TCPST works by adding a quarter current to the busbar to increase or decrease its angle. Model series used for this
This device is an ideal zero impedance phase shifter. The needle is inserted into it and can make an angle from -5 degrees to +5 degrees. Zero is also useful for TCPST.
3. TCVR works by adding a non-inverting voltage to the vehicle's mains voltage to change its amplitude.
As a model for this controller, the authors of [3] used an ideal stepping-shift transformer with no series impedance. The value of this ratio is given by the ratio v1/v2. It determines the variability beyond the nominal variability and its value varies from 0.9 to 1.1.

4. SVC can have two functions:

It can take the injection value or absorb 1 p.u energy. power. These values range from -100 MVAr to 100 MVAr. Depending on inductive or capacitive claim. In the first case it absorbs reactive power and in the second case it transmits reactive power. The SVC model is represented by two well-connected transformers: a capacitor and an inductor. With SVC, the line is divided into two equal parts and the equipment is placed in the middle. In TCSC [6], the difference along the compensated line is modeled as reactance, while the SVC is modeled as an additional field on the line. UPSC is modeled as a combination of SVC on a bus and TCSC on lines connected to the same bus.

In [7], TCSC can have one of two performance: capacitance or inductance instead of decreasing or increasing the total reactance of the transmission line respectively. The TCSC's capacitance or inductance value is expressed in X. TCPST adjusts its angle by adding an orthogonal device to the existing bus. This device is modeled as an ideal transformer with zero series impedance. It is placed on the transmission line and can take the value of angle θP. TCVR works by increasing the voltage level. The controller is modeled using an ideal tapping transformer with no series impedance. The price report is displayed on the TV. SVC is also available in two types: Inductance or capacitance. In the first case, it absorbs energy passively and in the second case it transfers energy passively. The amount of reaction energy introduced or absorbed is expressed in Qs. Below table gives summary of above discussion.

FACTS Control Mechanism			
Devices	Voltage control	Impedance control	Angle control
SVC	YES	—	—
STATCOM	YES	—	—
TCSC	—	YES	—
SSSC	YES	YES	YES
UPFC	YES	YES	YES
IPFC	YES	YES	YES
TCPST	—	—	YES

Table 1: Different FACTS control mechanism

The problem is to increase the load capacity of the system. The choice is therefore between a "series" device [46] such as the TCSC and a "parallel series" device [46] such as the UPFC. The best home tool to solve this problem is TCSC [3]. However, UPFC achieves lower capacity than TCSC at the price [6] so TCSC is an economically sound choice and will be used in this paper.

B. Modelling of TCSC

The TCSC capacitive reactance stabilizer consists of a series of capacitors connected in parallel with a thyristor controlled reactance to provide smooth control of series capacitive reactance. The TCSC model is shown in Figure 1. The TCSC is a capacitive reactance compensator consisting of a series of capacitors connected in parallel with a thyristor controlled reactance to provide smooth control. capacitive series reactance. The TCSC model is shown Fig. 1.

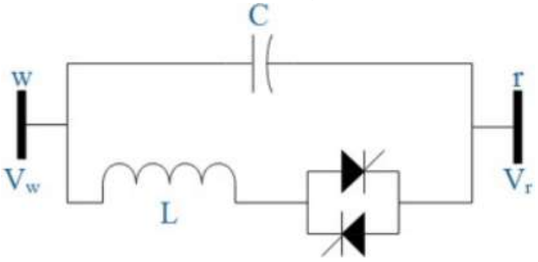

Fig. 1 TCSC schematic diagram.

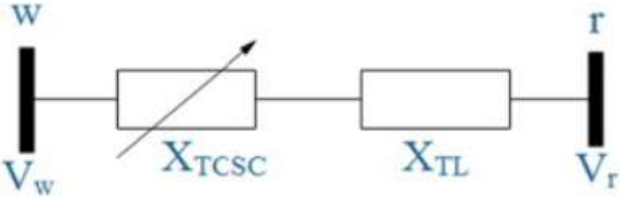

Fig. 2 TCSC equivalent circuit

C. Brief Survey Of Optimization Techniques

Optimization methods can be divided into classical methods and cognitive methods. The traditional method has the following disadvantages:

1. In general, mathematical design must be easy to solve, because its ability to solve large force problems on earth is limited.
2. They do not tolerate negative constraints.
3. They can only find one correct solution in a simulation.
4. If the number of changes is large, they happen very slowly and involve spending a lot of money to solve big problems. The main advantage of

The peculiarity of AI methods is that they are capable of resolving various quality constraints such as thermal and stability limitations. By running a single simulation, AI methods always yield rather better solutions than their counterpart, i.e. classical methods. Therefore, they are very suitable for solving multi-objective optimization problems. Often they can find the best solution in relatively less time and more efficiently. The following sections give a brief overview and explanation of the optimization techniques used in the EPS applications presented in [13].

i) Linear programming method

It requires linearization of the objective function and limits to non-zero values.[14] provide a method to restore operation to reduce line losses and have a good view of the electrical equipment in the generator. E. Lobato et al. [15] proposed an LP-based OPF to reduce transmission amplitude and reactive power in the Spanish power system. F. Lima et al. Metin [16] used integrated numerical methods to design and study integrated thyristor controlled phase shifters (TCPST) in large power systems. Find the number of conversion levels, network settings, and settings that maximize system performance.

ii) Quadratic Planning (QP) Methodology

It is a special form of nonlinear programming in which the objective function is quadratic and the constraints are linear.

J. A. Momoh [17] proposed an extension of the first stage of Kuhn-Tucker and obtained a general formula for OPF. The structure of the OPF algorithm includes the conditions of feasibility, convergence, and efficiency. N. Grudinin [18] proposed an energy optimization model based on quadratic programming (SQP). GP Granelli et al. [19] proposed a securely optimized logistics system using two-step quadratic programming. X. Lin et al. [20] performed integrated cost analysis and power factor analysis using OPF model for competitive market and solved it by quadratic method. Berridge et al. [21] proposed the Ultimate Security Optimization Framework (SCOPF) to determine the optimal placement and performance of UPFCs and TCPARs.

iii) Nonlinear Programming (NLP) Methods

Non-linear programming (NLP) solves problems involving non-linear objectives and/or functional constraints.[22] propose a new non-linear convex network flow programming (NLCNFP) model and algorithm to solve the problem of Multi-Area Security Enhanced Export (MAED). D. Pudjianto et al. [23] Distribution (auction) of reactive power among competing generators in a ruleless environment using reactive OPF based on LP and NLP. Torres et al. [24] and Zhu Jianzhong [25] have proposed a method to calculate the guaranteed energy cost of electrical energy in multipoint energy. These methods are cost-benefit analysis (CBA) and traffic planning in off-grid networks.

A. K. Sharma [26] proposed a method to determine the optimal number and location of TCSCs using mixed non-linear programming (MINLP) in the liberalized electricity market..

Karmarkar in 1984 proposed a new method that can very well solve large-scale linear programming problems. This is called the inside method because it sees the progression of a search as close as possible.

iv) Artificial Intelligence (AI) Method

AI methods are better than traditional optimization methods:

1. Artificial intelligence, continuity, presence of objects, etc. It is not limited to other traditional methods such as

b. Smart tools use changing rules rather than decisions.

The Artificial Neural Network (ANN) method is a collection of artificial neurons that are connected together using a number or a computational pattern as a combination of calculations for processing. Chowdhury [25] proposed the concept of Optimal Scheduling with Integrated Safety Constraints (ISCOD), which can solve the OPF problem when subjected to both static and non-safety related conditions. .

III. METHODOLOGY

MATPOWER (version 7.1) is used for power flow analysis as well as for optimization purpose. MATLAB's Optimization Toolbox [29, 58], available from The MathWorks, provides a number of high-performance solvers that MATPOWER can take advantage of. It includes fmincon for nonlinear programming problems (NLP), and linprog and quadprog for linear programming (LP) and quadratic programming (QP) problems, respectively. For mixed-integer linear programs (MILP), it provides intlingprog. Each solver implements a number of different solution algorithms. The primary functionality of MATPOWER is to solve power flow and optimal power flow (OPF) problems. This involves (1) preparing the input data defining the all of the relevant power system parameters, (2) invoking the function to run the simulation and (3) viewing and accessing the results that are printed to the screen and/or saved in output data structures or files.For optimization purpose, objective function is to minimize the total loss that is, it should minimize the objective function:

Total system loss = Sum of Actual loss of all equipment System Line = Sum of Actual Lines (S_f + S_t) (3rd method). Where S_f and S_t are the complex powers of the "from" and "target" terminals, respectively.

Total losses are calculated using MATLAB m-file MATPOWER [47] for calculating the load flow of the system and calculate the number of actual losses.

As mentioned earlier, the goal is to make the right choice of location, number and measurement of TCSCs to increase their ability to not violate voltage and current limits. It is done in two ways:

1) First is to use minimum loss as objective function

2) Second is to use minimum loss from equipment as intended work.

The system being examined is the WSCC 3 machine, which has a 9 Bus test system and a 100 MVA base. It is made up of three two-winding transformers that are connected to buses 1, 2, and 3.Three generators are connected to buses 1, 2, and 3, six transmission lines with a base impedance of 100 MVA, and three PV loads are connected to buses 5, 6, and 8.The swing bus is number 1 bus.

Step 1: Create a single-line diagram of the test system as the first step.

Step 2: Enter the necessary data for each and every test system component.

Step 3: Load the data file after saving it.

Step 4: Without taking into account any contingencies, solve the power flow for the test system using Newton-Raphson.

Step 5: Simulate the findings for the Power Flow.

In order to determine the maximum loading parameter for each transmission line, perform a step-by-step removal of each transmission line before simulating the Power Flow and Continuation Power Flow.

Step 7: Sort the results according to how much the maximum loading parameter () for each transmission line can be loaded.

Step 8: Determine the most important transmission line based on the state of the backup plan.

Step 9: Use TCSC for reactive power compensation and repeat the process from step 4.

Step 10: Compare and study the power flow analysis with and without TCSC.

IV. MODELLING OF THE TRANSMISSION SYSTEM

Real power P in MW (expended) and Reactive power Q in MVAr (injected) at nominal voltage of 1 p.u. at angle zero and the static loads are modelled as real power P and reactive power Q injection, i.e. P_r and Q_r respectively. The shunt admittance of any constant shunt elements at bus is specified[51].

$$Y_{sh} = \frac{G_{sh} + B_{sh}}{base\ MVA} \qquad (1)$$

Having series resistance R including inductive reactance X_l and total shunt capacitance X_c in series with an ideal transformer, the branch whether transmission line or transformer or phase shifter are to be modelled as π-model XL line at the from end, with transformer tap ratio Tau and alternator phase shift angle $\theta_{shift.}$ and also the differernt branch voltages and currents of 'from' and 'to' ends of the branch are inter-linked by the branch admittance matrix Y_{branch} as follows:

$$\begin{bmatrix} I_f \\ I_t \end{bmatrix} = Y_{br} \begin{bmatrix} V_f \\ V_t \end{bmatrix} \qquad (2)$$

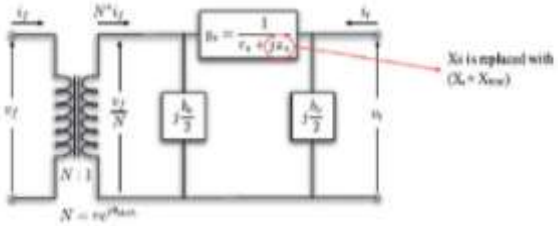

Fig 3 π-model of transmission

$$Y_{br} = \begin{bmatrix} (Y_s + j\frac{B_c}{2})\tau^2 & -Y_s\frac{1}{\tau e^{j\theta} shift} \\ -Y_s\frac{1}{\tau e^{-j\theta} shift} & (Y_s + j\frac{B_c}{2}) \end{bmatrix} \qquad (3)$$

For a network with n_b buses, all constant impedance elements are incorporated into complex n_b x n_b matrice that relates the complex noda ccurrentl injections I_{bus} to complex nodal voltages V_{bus}.

$$I_{bus} = Y_{bus} V_{bus} \qquad (4)$$

Associated to bus voltages of n_1 x 1 vectors I_f and I_t of branch currents at the 'from' and 'to' ends respectively. Correspondingly for network with n_1 branches, the n_1 x n_b system branch admittance matrices Y_f and Y.

$$I_f = Y_f V_{bus} \qquad (5)$$

$$I_t = Y_t V_{bus} \qquad (6)$$

$$S_{bus} = diag(V_{bus}) I_{bus}^* \qquad (7)$$

$$S_f = diag(V_f) I_f^* \qquad (8)$$

$$S_t = diag(V_t) I_t^* \qquad (9)$$

Total active loss = sum of real of $(S_f + S_t)$

Where S_f and S_t are MVA ratings of 'from' and 'to' ends respectively. The total vectors representing currents and voltages can be expressed as shown in equation.

V. IEEE 9-BUS SYSTEM CASE STUDY

This WSCC 3-machine, 9-bus test case (known as the P.M. Anderson 9-bus) represents a simple Western System Coordinating Council (WSCC) approximation of an equivalent system with 9 buses and 3 generators.

This test case consists of 9 buses, 3 generators, 3 two-winding power transformers, 6 lines and 3 loads.

Basic KV values are 13.8kV, 16.5kV, 18kV and 230kV. The power of each line complex is about several hundred MVA. As a test case, the WSCC 9 bus has few voltage control devices and is easy to control. Following are the details of 9 Bus, 3 Machine WSCC test system components:

BUS	Y(pu)	X(pu)	R(pu)
4 TO 5	0.079	0.092	0.017
4 TO 6	0.079	0.092	0.017
6 TO 9	0.179	0.17	0.039
5 TO 7	0.153	0.161	0.032
7 TO 8	0.0745	0.072	0.0085
8 TO 9	0.1045	0.1008	0.0119

Table 2 Bus data of IEEE 9-bus

Bus no.	P(MW)	Q(M VAR)	V (pu)
5	125	50	1
6	90	30	1
8	100	35	1

Table 3 Load data

GEN.	P(MW)	Q(MVAR)	V (pu)
G1	72	28	1.04
G2	163	5	1.025
G3	85	-11	1.025

Table 4 Generator data

This is the Single Line Diagram(SLD) of IEEE 9-bus benchmark system.

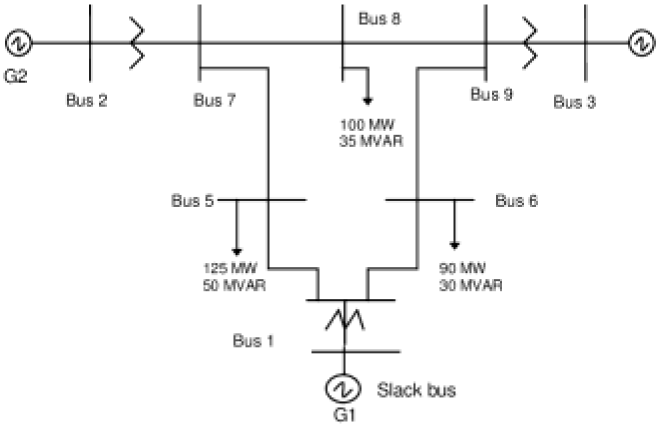

Fig: 4 Single line diagram of IEEE 9 bus system

VI. RESULTS

Results for power flow of base case i.e. without TCSC is carried out through MATPOWER wherein power flow solution is obtained through Newton Raphson method. Table 5 and Table 6 shows the results.

POWER FLOW RESULTS						
Bus	**V**	**phase**	**P gen**	**Q gen**	**P load**	**Q load**
Bus 1	1.025	0.161967	1.63	0.066537	0	0
Bus 2	1.04	0	0.71641	0.270459	0	0
Bus 3	1.025	0.081415	0.85	-0.1086	0	0
Bus 4	1.025769	0.064921	1.71E-14	1.48E-14	0	0
Bus 5	1.015883	0.012698	-7.1E-15	-3.9E-16	1	0.35
Bus 6	1.012654	-0.06436	-4.4E-16	6.61E-15	0.9	0.3
Bus 7	1.025788	-0.03869	-6.8E-15	-8.9E-15	0	0
Bus 8	0.995631	-0.06962	-3.1E-15	1.16E-14	1.25	0.5
Bus 9	1.032353	0.034326	6.16E-15	7.55E-15	0	0

Table 5 Power flow solution of IEEE 9-bus

LOAD FLOW RESULTS WITHOUT TCSC						
From Bus	**To Bus**	**Line**	**P Flow**	**Q Flow**	**P Loss**	**Q Loss**
Bus 5	Bus 9	1	-0.24095	-0.24296	0.00088	-0.21176
Bus 5	Bus 4	2	-0.75905	-0.10704	0.004753	-0.11502
Bus 6	Bus 9	3	-0.59463	-0.13457	0.013538	-0.31531
Bus 8	Bus 4	4	-0.8432	-0.11313	0.023	-0.19694
Bus 7	Bus 8	5	0.409374	0.228931	0.002575	-0.15794
Bus 7	Bus 6	6	0.307037	0.0103	0.001664	-0.15513
Bus 4	Bus 1	7	-1.63	0.091782	-2.2E-16	0.158318
Bus 9	Bus 3	8	-0.85	0.149553	0	0.040956
Bus 7	Bus 2	9	-0.71641	-0.23923	-1.1E-16	0.031228

Table 6 Line flow data of IEEE 9-bus

By adding TCSC with 30% to 70% compensation as limit, as shown in fig 5 bus 9 is most affected by introduction of TCSC. Thus it is concluded that bus 9 is the weakest bus. The power flow solution is obtained in MATPOWER.

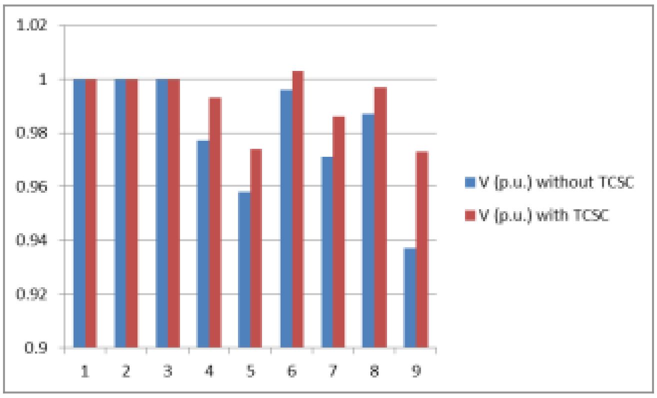

Fig 5 Voltage profile comparison of IEEE 9-bus

	With TCSC	Without TCSC
Reactive Power (injected)	132.3 MVAr	127.9 MVAr
Vmin	0.973 p.u.	0.937 p.u.
Delta $_{min}$	-3.78 °	-9.41 °
V max	1.003 p.u.	1 p.u.
Delta $_{max}$	6.21 °	3.51 °
P loss max	1.63 MW	1.93 MW
Q loss max	16.71 MVAr	17.14 MVAr

Tsble 7 Specific parameters comaprison of IEEE 9-bus

Similarly, for better analysis and further optimization the IEEE 9-bus is studied in MATLAB SIMULINK environment . Altough the estimated time is more than MATPOWER static report can be export for further analysis as well as the load flow solution obtained can be easily modified making it convenient for the research purposes.

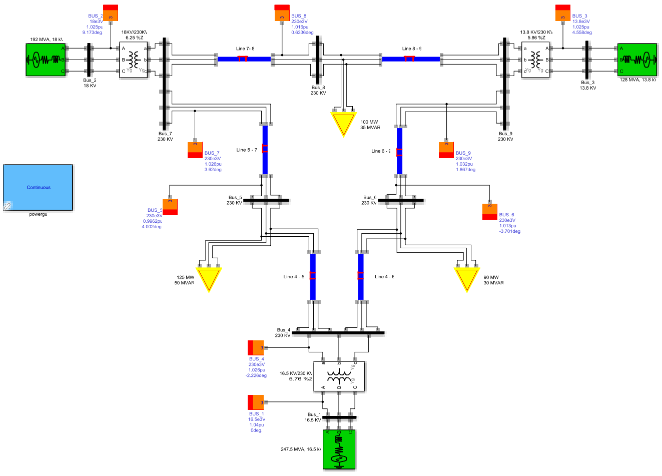

Fig 6 MATLAB SIMULINK model of IEEE 9-bus

VII. CONCLUSIONS

To summarize the results obtained by performing optimal power flow using MATPOWER on IEEE 9-bus benchmark system with TCSC, some conclusions according to table 7 are as follows:

1. Increasing the minimum voltage by 3.84 %, i.e. the minimum voltage became far from the lower limit by 3.84 %.
2. Decreasing Ploss max. by 15.54%.
3. Decreasing Qloss max. by 2.51 %.
4. Decreasing total P loss by 5.33%.
5. Decreasing total Q loss by 40 %.
6. Reducing Qg by 37.85 %.
7. Reducing Pg by 0.075 %.
8. Increasing V max by 0.3% i.e. from 1 to 1.003 p.u.
9. Line flows became within their loading limits.

The scope of this research can further be expanded for various studies such as,

1. Taking into consideration directly cost of FACTS and generation cost.
2. Using the FACTS with system in transient state.
3. Using the advance optimization techniques such as PSO and GA with larger systems.

Finally, proper selection of FACTS devices with their optimal allocation in transmission system using optimal power flow method voltage stability margin has been improved.

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