POWER SYSTEM CONTROL THROUGH OPTIMAL PLACEMENT OF STATCOM FOR IMPROVING VOLTAGE STABILITY

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Abstract: facts devices have the capability to control voltage, impedance and the phase angle in transmission circuit and hence control the power flow. FACTS devices are located at different places to give the reactive power support. There is a possibility of deprived co-ordination among devices if FACTS devices are placed at inapt locations and because of this disoperation of FACTS devices, the reactive power not supplied properly, consequently the operating voltage will go down. In our work Among the converter based facts devices static synchronous compensator (statcom) is considered. Comparative results for placement of statcom devices in the system network before and after placement of statcom device are analyzed. To determine voltage magnitude and phase angle at every node of the ieee 14 bus system with and without statcom newton raphson (NR) approach is used and to finds the optimal location for placing the statcom in system network genetic algorithm (GA) is used. It is observed that after insertion the statcom at proper location, the losses are reduced. The proposed method is tested on ieee 14 bus system at matlab software. The result of network are compared with and without placing of statcom device in network and in terms of active and reactive power flows in the line and at the bus to analyze the performance of the devices injected voltage, injected phase , phase distortion.

***IndexTerms* - Flexible AC Transmission System (FACTS), Newton Raphson (NR), Power flow, Static Synchronous Controller (STATCOM), Genetic Algorithm (GA).**

I. INTRODUCTION

The power systems are required to work at stressed state by reason of the unremitting increase in the load demand and limited scope for the expansion of the existing network. The technology such as flexible ac transmission system (FACTS), can facilitate to search the solution. Facts devices give voltage support. The static synchronous compensator (STATCOM) is a GTO based device of Flexible AC Transmission Systems (FACTS) family. The STATCOM is a static synchronous generator operated as a static VAR compensator which can bring in lagging or leading VAR into the system, when they connected in shunt position. The facility of the transmission system to send out power turn out to be impaired by one or more of the following steady state and dynamic limitations: (a) angular stability, (b) voltage magnitude, (c) thermal limits, (d) transient stability, and (e) dynamic stability. Simulation is carried out by using MATLAB/ Simulink program package to verify the validity of the proposed model. The paper is structured as follows. **Section 2** presents the system, characteristics, working principle and control structure of the facts device. **Section 3** describes the studied genetic algorithm (GA) which was use to find the optimum location for placing the fact device in system network.. In **Section 4**, Load flow is discussed. **Section 5** described the newton-raphson method (NR), in **section 6**, simulation results and discussions for STATCOM response are presented. Finally, main conclusions are illustrated in **section 7**.

II. FLEXIBLE AC TRANSMISSION SYSTEM (FACTS)

The concept of Flexible AC Transmission Systems (FACTS) was first defined by N.G. Hingorani, in 1988.A Flexible Alternating Current Transmission System (FACTS) is a system comprised of static equipment used for the AC transmission of the electrical energy. It is meant to enhance controllability and increase power transfer capability of the network. It is generally a power electronic-based device.FACTS is defined by the IEEE as "a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability"

2.1 ADVANTAGES OF FACTS

- Reduces the losses
- Voltage fluctuation is controlled with the help of STATCOM.
- Power carrying capacity of the line is improved.
- Transient stability is ameliorated.
- Improves quality of supply
- Superior use of the existent transmission system
- Diminishes the reactive power flow

STATCOM is converts DC input voltage into AC output voltage in order to compensate the active and reactive power desirable by the system network. STATCOM is considered as an sophisticated static VAR compensator in which a voltage source converter (VSC) is used in place of the switched capacitors and controllable reactors [11]. The STATCOM is a shunt-connected apparatus of FACTS family using power electronics to manage powerflow and get better transient constancy on power-grid.

The STATCOM regulates voltage at its terminal by controlling the quantity of reactive power bring in to or engrossed from the power system network STATCOM generates reactive power (STATCOM capacitive) ,When the system voltage is low and it soak up reactive power (STATCOM inductive) when the system voltage is high,

III. GENETIC ALGORITHM (GA)

In 1960 I. Rechenberg introduced the idea of evolutionary computing in his work Evolutionary strategies. In computer science and operations research, a genetic algorithm (GA) is a metaheuristic inspired by the process of natural selection that belongs to the larger class of evolutionary algorithms (EA).GA's are computerized search and optimization algorithms based on mechanics of natural genetics and natural selection. They are frequently used to create high-quality solutions for optimization problems and search problems. The solutions to optimization are generated by using this selection technique such as, mutation, crossover and selection.

InitializationThe population size depends on the nature of the problem, but typically contains several hundreds or thousands of possible solutions. Often, the initial population is generated randomly, allowing the entire range of possible solutions (the search space). Occasionally, the solutions may be "seeded" in areas where optimal solutions are likely to be found.

Selection: Selection is the part of GA where the individual's genes are selected from population.

Crossover: It is used for changing chromosomes from one generation to another. It is the process where different individuals are selected as parent solutions and they produce children solution.

Mutation: It is used to maintain genetic diversity from one generation to next generation. Mutation changes one or more gene values from their initial ones in chromosome and a result obtained in mutation is totally different from the last solutions.

Fitness Function: Due to the Fitness function result is in the form of single figure called figure of merits. After every round of testing, previous worst design solutions are deleted and new ones are raised.

Termination: This generational process is repeated until a termination condition has been reached. Common terminating conditions are:

- A solution is found that satisfies minimum criteria
- Fixed number of generations reached
- Allocated budget (computation time/money) reached
- The highest ranking solution's fitness is reaching or has reached a plateau such that successive iterations no longer produce better results
- Manual inspection
- Combinations of the above

Advantages of GA:

- It can vary both the values and structure and the desired result can be obtained.
- Quick response for acceptable solution
- It deals with the large number of solution

IV. POWER FLOW CONTROL

Load flow studies are the backbone of power system analysis and design. Load flow studies are necessary for planning, economic scheduling and exchange of power between utilities. In power systems, the move of power from one part to another part of the system may take inadvertent routes, depending on voltages and impedances of transmission lines making up the grid. Facts devices are a useful means for optimizing power flow amid parts of the grid, as well as flow between parallel power corridors where voltages as well as line impedances be different. Some Benefits will result as Minimizing system losses, Elimination of line overload Optimizing load sharing between parallel lines Reduction of undesired loop flows and directing power flows along contractual paths.

Load flow equations are nonlinear and can be solved by an iterative method. In this paper Newton Raphson method is used, as the number of iterations is independent of the size of the system, and convergence characteristic is independent of selection of slack bus. power flow analysis is required for many analyses such as transient stability and contingency studies. The load flow solution gives the nodal voltages and phase angles and hence the power injection at all the buses and power flows through interconnecting transmission lines.

Through the load flow studies we can obtain the voltage magnitudes and angles at each bus in the steady state. This is rather important as the magnitudes of the bus voltages are required to be held within a specified limit. Once the bus voltage magnitudes and their angles are computed using the load flow, the real and reactive power flow through each line can be computed. Also based on the difference between power flow in the sending and receiving ends, the losses in a particular line can also be computed. Furthermore, from the line flow we can also determine the over and under load conditions.

The steady state power and reactive powers supplied by a bus in a power network are expressed in terms of nonlinear algebraic equations. We therefore would require iterative methods for solving these equations. In this chapter we shall discuss two of the load flow methods. We shall also delineate how to interpret the load flow results.

4.1 REAL AND REACTIVE POWER INJECTED IN A BUS

For the formulation of the real and reactive power entering a bus, we need to define the following quantities. Let the voltage at the i^{th} bus be denoted by

$$V_i = |V_i| \angle \delta_i = |V_i| (\cos\delta_i + j\sin\delta_i) \quad \ldots(1)$$

Also let us define the self admittance at bus-*i* as

$$Y_{ii} = |Y_{ii}|\angle\theta_{ii} = |Y_{ii}|(\cos\theta_{ii} + j\sin\theta_{ii}) = G_{ii} + jB_{ii} \quad \text{...(2)}$$

Similarly the mutual admittance between the buses *i* and *j* can be written as

$$Y_{ij} = |Y_{ij}|\angle\theta_{ij} = |Y_{ij}|(\cos\theta_{ij} + j\sin\theta_{ij}) = G_{ij} + jB_{ij} \quad \text{.... (3)}$$

Let the power system contains a total number of *n* buses. The current injected at bus-*i* is given as

$$I_i = Y_{i1}V_1 + Y_{i2}V_2 + \cdots + Y_{in}V_n$$

$$= \sum_{k=1}^{n} Y_{ik}V_k \quad \text{...... (4)}$$

It is to be noted we shall assume the current entering a bus to be positive and that leaving the bus to be negative. As a consequence the power and reactive power entering a bus will also be assumed to be positive. The complex power at bus-*i* is then given by

$$P_i - jQ_i = V_i^* I_i = V_i^* \sum_{k=1}^{n} Y_{ik}V_k$$

$$= |V_i|(\cos\delta_i - j\sin\delta_i)\sum_{k=1}^{n} |Y_{ik}V_k|(\cos\theta_{ik} + j\sin\theta_{ik})(\cos\delta_k + j\sin\delta_k) \quad \text{..........(5)}$$

$$= \sum_{k=1}^{n} |Y_{ik}V_iV_k|(\cos\delta_i - j\sin\delta_i)(\cos\theta_{ik} + j\sin\theta_{ik})(\cos\delta_k + j\sin\delta_k)$$

Note that

$$(\cos\delta_i - j\sin\delta_i)(\cos\theta_{ik} + j\sin\theta_{ik})(\cos\delta_k + j\sin\delta_k)$$

$$= (\cos\delta_i - j\sin\delta_i)[\cos(\theta_{ik} + \delta_k) + j\sin(\theta_{ik} + \delta_k)]$$

$$= \cos(\theta_{ik} + \delta_k - \delta_i) + j\sin(\theta_{ik} + \delta_k - \delta_i)$$

Therefore substituting in (5) we get the real and reactive power as

$$P_i = \sum_{k=1}^{n} |Y_{ik}V_iV_k|\cos(\theta_{ik} + \delta_k - \delta_i) \quad \text{.......... (6)}$$

$$Q_i = -\sum_{k=1}^{n} |Y_{ik}V_iV_k|\sin(\theta_{ik} + \delta_k - \delta_i) \quad \text{....... (7)}$$

Where,
Vi = voltage at ith bus
Vj = voltage at jth bus

V. LOAD FLOW BY NEWTON-RAPHSON METHOD (NR)

Let us assume that an *n*-bus power system contains a total number of n_p P-Q buses while the number of P-V (generator) buses be n_g such that $n = n_p + n_g + 1$. Bus-1 is assumed to be the slack bus. We shall further use the mismatch equations of ΔP_i and ΔQ_i given in (5.9) and (5.10) respectively. The approach to Newton-Raphson load flow is similar to that of solving a system of nonlinear equations using the Newton Raphson method:at each iteration we have to form a Jacobian matrix and solve for the corrections from an equation of the type given in. For the load flow problem, this equation is of the form

$$J\begin{bmatrix} \Delta\delta_2 \\ \vdots \\ \Delta\delta_n \\ \frac{\Delta|V_2|}{|V_2|} \\ \vdots \\ \frac{\Delta|V_{1+n_p}|}{|V_{1+n_p}|} \end{bmatrix} = \begin{bmatrix} \Delta P_2 \\ \vdots \\ \Delta P_n \\ \Delta Q_2 \\ \vdots \\ \Delta Q_{1+n_p} \end{bmatrix} \quad \text{........ (8)}$$

where the Jacobian matrix is divided into submatrices as

$$J = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix} \quad \text{....... (9)}$$

It can be seen that the size of the Jacobian matrix is $(n + n_p - 1) \times (n + n_p - 1)$. For example for the 5-bus problem of Fig. 5.1 this matrix will be of the size (7 × 7). The dimensions of the submatrices are as follows:
J_{11}: $(n - 1) \times (n - 1)$, J_{12}: $(n - 1) \times n_p$, J_{21}: $n_p \times (n - 1)$ and J_{22}: $n_p \times n_p$
The submatrices are

$$J_{11} = \begin{bmatrix} \frac{\partial P_2}{\partial \delta_2} & \cdots & \frac{\partial P_2}{\partial \delta_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial \delta_2} & \cdots & \frac{\partial P_n}{\partial \delta_n} \end{bmatrix} \quad \text{.......... (10)}$$

$$J_{12} = \begin{bmatrix} |V_2|\frac{\partial P_2}{\partial |V_2|} & \cdots & |V_{1+n_p}|\frac{\partial P_2}{\partial |V_{1+n_p}|} \\ \vdots & \ddots & \vdots \\ |V_2|\frac{\partial P_n}{\partial |V_2|} & \cdots & |V_{1+n_p}|\frac{\partial P_n}{\partial |V_{1+n_p}|} \end{bmatrix} \qquad \ldots\ldots\ldots \quad (11)$$

$$J_{21} = \begin{bmatrix} \frac{\partial Q_2}{\partial \delta_2} & \cdots & \frac{\partial Q_2}{\partial \delta_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_{1+n_p}}{\partial \delta_2} & \cdots & \frac{\partial Q_{1+n_p}}{\partial \delta_n} \end{bmatrix} \qquad \ldots\ldots \quad (12)$$

$$J_{22} = \begin{bmatrix} |V_2|\frac{\partial Q_2}{\partial |V_2|} & \cdots & |V_{1+n_p}|\frac{\partial Q_2}{\partial |V_{1+n_p}|} \\ \vdots & \ddots & \vdots \\ |V_2|\frac{\partial Q_{1+n_p}}{\partial |V_2|} & \cdots & |V_{1+n_p}|\frac{\partial Q_{1+n_p}}{\partial |V_{1+n_p}|} \end{bmatrix} \qquad \ldots\ldots\ldots\ldots (13)$$

VI. RESULTS

The comparative result before the application of STATCOM and after optimal placement of STATCOM in the system network has been discussed. NR method is used to determine voltage magnitude and phase angle at every node of the IEEE 14 bus system with and without STATCOM. GA finds the optimal location for placing the STATCOM. After placing the STATCOM the losses got reduced.

6.1 *DETERMINE VOLTAGE, PHASE ANGLE AND LOSSES USING GA*

The voltages, phase angles and losses of the system are calculated using GA with and without STATCOM for Optimal Location of STATCOM.

VOLTAGE AND PHASE ANGLE USING STATCOM AND WITHOUT STATCOM

Bus No	Without STATCOM		With STATCOM	
	V(pu)	Angle(degree)	V(pu)	Angle(degree)
1	1.0600	0.0000	1.0600	0.0000
2	1.0030	-3.8599	1.0130	-4.0861
3	0.9203	-12.0999	0.9531	-11.9713
4	0.938	-9.4368	0.9781	-9.6527
5	0.9499	-7.9019	0.9866	-8.1623
6	0.9438	-14.5815	1.0235	-14.101
7	0.9278	-13.1554	0.9979	-12.9954
8	0.9278	-13.1554	0.9979	-12.9954
9	0.913	-15.2095	0.9981	-14.7567
10	0.9099	-15.4674	0.9948	-14.9521
11	0.9226	-15.1825	1.0053	-14.6634
12	0.9258	-15.6629	1.0140	-15.1334
13	0.9194	-15.7184	1.0141	-15.4546
14	0.8949	-16.7605	1.0360	-17.4728

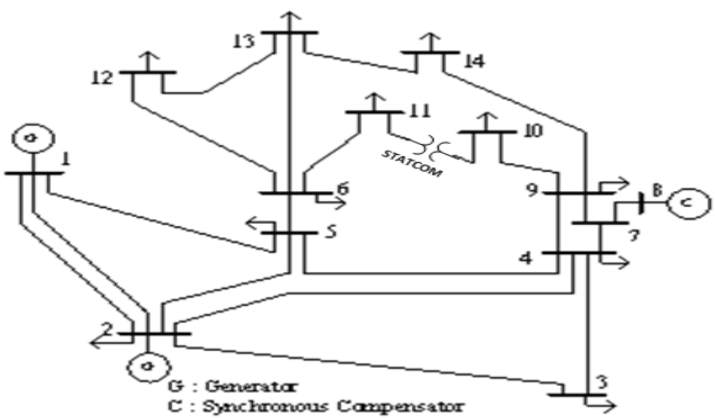

Figure:IEEE 14 bus system with STATCOM

In this 14 bus system the statcom location has been identified by the help of genetic algorithm, it can be seen that the voltage(pu) is increases at the bus no 14 and loses are reduced when statcom are used in power system.

VII. CONCLUSION

In this paper, a technical aspect is considered to find the optimal placement of statcom. The backbone of power system is load flow analysis and so understanding of load flow analysis and studies is very necessary for increase the voltage stability in any power system network. and design Load flow studies are. Load flow studies are necessary for planning, economic scheduling and exchange of power between utilities. Simulation results shows that by using STATCOM the voltage is enhanced and the losses are reduced, system is secured, stable and performance is improved. From the overall results it can be concluded that Statcom can effectively control the power system voltage as well as reactive power.

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