Power System Control through STATCOM Devices

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*Abstract- F***acts devices have the capability to control voltage, impedance and the phase angle in transmission circuit and hence control the power flow. Among the converter based facts devices static synchronous compensator (statcom) is considered in this paper. This paper discusses the comparative result before application of statcom and after optimal placement of statcom in the system network. In the first stage newton raphson (nr) method is used to determine voltage magnitude and phase angle at every node of the ieee 14 bus system with and without statcom. In the second stage genetic algorithm (ga) finds the optimal location for placing the statcom. After placing the statcom the losses is reduce. The proposed method is tested on ieee 14 bus system using matlab. The result of network with and without using statcom is compared 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 are also shown graphically.**

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

1. INTRODUCTION

The technology such as flexible AC transmission system (FACTS) can help to find the solution. Facts devices provide voltage support at critical buses in the system shunt connected controllers) and regulate power flow in critical lines (with series connected controllers). The need for these power flow controllers capable of increasing transmission capability and controlling power flows is increasing.

The ability of the transmission system to transmit power becomes 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.

2. 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.

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

3. Genetic Algorithm (GA)

In 1960 I. Rechenberg introduced the idea of evolutionary computing in his work Evolutionary strategies. GA's are computerized search and optimization algorithms based on mechanics of natural genetics and natural selection.

In the domain of artificial intellect, GA is a search heuristic that follows the natural selection process. This heuristic approach is also called meta-heuristic i.e. used to form serviceable solutions to optimization and search problems. The solutions to optimization are generated by using this selection technique such as, mutation, crossover and selection.

1. **Selection:**

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

2**. 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.

3. **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.

4. **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.

3.1 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

4. 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 addition, 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.

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.

4.1REAL 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

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

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

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

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

$$I_i = Y_{i1}V_1 + Y_{i2}V_2 + \cdots + Y_{in}V_n = \sum_{k=1}^{n} Y_{ik}V_k \quad \ldots\ldots \quad (4)$$

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

$$\begin{aligned} P_i - jQ_i &= V_i^* I_i = V_i^* \sum_{k=1}^{n} Y_{ik}V_k \\ &= |V_i|(\cos\delta_i - j\sin\delta_i) \sum_{k=1}^{n} |Y_{ik}V_k|(\cos\theta_{ik} + j\sin\theta_{ik})(\cos\delta_k + j\sin\delta_k) \\ &= \sum_{k=1}^{n} |Y_{ik}V_iV_k|(\cos\delta_i - j\sin\delta_i)(\cos\theta_{ik} + j\sin\theta_{ik})(\cos\delta_k + j\sin\delta_k) \end{aligned} \quad \ldots\ldots\ldots(5)$$

Note that

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

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

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

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

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

5. 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. For the load flow problem, this equation is of the form

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

where the Jacobian matrix is divided into submatrices as

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

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

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

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

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

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

6. 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.

6.2 *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 with and without STATCOM using

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

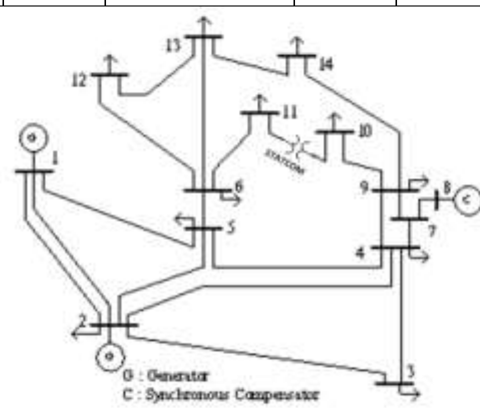

Figure:IEEE 14 bus system with STATCOM

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.

7. CONCLUSION

The aim was to improve the voltages at the bus so that the losses can be reduced. Table shows that by using STATCOM the voltage are enhanced and the losses are reduced, system is secured, stable and performance is improved.

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