An Improved Power Flow Analysis Technique

Dr. Deepak P. Kadam
Department of Electrical Engineering
BKC-MET- Institute of Engineering Nashik- 422003, Maharashtra India

Abstract— Reactive power optimization is important to power system stability and power quality. How to use the reactive power control method to improve the voltage level and decrease system loss is of value both in theory and application. The adjustment of generator voltages, transformer taps, shunt capacitors and inductors will control the reactive power distribution and affect voltage profiles and power losses. The objective is to find proper adjustments of these control variables that would maintain acceptable voltage profiles and minimize power losses. Reactive power optimization has commonly been formulated as a complicated constrained optimization problem with non-differentiable nonlinear objective function Reactive Power consumption increases losses in the system, which reduces the total system real power. Optimizing reactive power in the system can minimize total system real power loss. This can be done by optimally setting the terminal voltage of generating plant, transformer tap settings, output of compensating devices such as capacitor bank and synchronous condensers. Conventional Optimal Reactive Power Dispatch (ORPD) formulations utilize minimization of total system real power loss or voltage deviation as an objective to compute optimal settings of reactive power output or terminal voltage of generating plants, transformer tap settings and output of compensating devices. The present work has considered the setting of Flexible AC Transmission System (FACTS) devices as additional control parameters in the ORPD formulation and studies its impact on system loss minimization. Static models of FACTS devices consisting Static VAR Compensator (SVC) have been included in the present ORPD formulation.

Key words: Optimal Reactive Power Dispatch, (ORPD), Voltage Control, SVC

I. INTRODUCTION

The optimal power flow problem is to minimize the fuel cost, system losses or some other appropriate objective function while maintaining an acceptable system performance in terms of limits on generator real and reactive power output, output in compensating devices, transformer tap settings or bus voltage levels etc.

When only total fuel cost is minimized the optimal power flow problem corresponds to an Economic Load Dispatch (ELD) sub problem. As the system transmission loss depends on reactive power injection, the minimization of loss problem corresponds to the Optimal Reactive Power Dispatch (ORPD) sub problem condenser. To solve this complex problem several methods based on sensitivity relationship are used.

II. OPTIMAL REACTIVE POWER DISPATCH

The main task before utility is to meet the load demand of system most economically while ensuring desired quality of supply to consumers. The quality of supply is judged in terms of constant voltage. Extra reactive power demand from load increases magnitude of current in the system due to which real power loss is increased. Thus voltage drop in the system is increased, which reduces terminal voltage. Reactive power developed in transmission line is proportional to voltage drop in the system. If the extra reactive power demand of load is supplied separately instead of providing it from generator keeps current magnitude constant in the system. Thus maximum real power can be transmitted in a system by reducing the supply of reactive power from generator. This can be achieved by suitably adjusting the following controllable variables:

- Transformer taps
- Generator voltage
- Switchable shunt capacitor and inductor

III. CONVENTIONAL ORPD FORMULATION

The conventional ORPD problem has been formulated as to minimize total system real power loss while satisfying the network performance constraints and the operating limits of control variables. The control variables considered in this formulation include generator terminal voltage and transformer tap settings, which are used to determine the optimal reactive power settings of generator and other VAR sources.

IV. METHOD OF VOLTAGE CONTROL

The following methods are used for voltage control in power system:

- Tap changing transformer
- Shunt reactor
- Synchronous phase modifier
- Shunt capacitor
- Series capacitor
- Static VAR systems

V. ORPD CONSIDERING FACTS DEVICES

Using sensitivity relationship method can solve the complex problem of ORPD. But this is a time consuming method. Also control obtained is not fast due to mechanical switches. In recent years, the fast progress in the field of power electronics and microelectronics has resulted into a new opportunity for more flexible operation of power system. The Flexible AC Transmission System (FACTS) program was launched to develop a number of controllers for this purpose. These new devices have made the present transmission and distribution of electricity more reliable, more controllable and more efficient.

VI. MODELING OF FACTS

A. Static VAR compensator (SVC)

FACTS are a concept promoting the use of thyristor-controlled devices in power system with the objective of optimally utilizing the existing transmission system facilities.

Hingorani first defined the concept of FACTS and FACTS controllers, 1988. They are high power electronics devices used to control the power flow and enhance stability, have become, not only common words in the power industry, but they have started replacing many mechanical control devices. They are certainly playing an important and a major role in the operation and control of modem power systems.

In the late 1980s, the Electric Power Research Institute formulated the vision of the Flexible AC transmission System (FACTS) in which various powers electronic based controllers regulate power flow and transmission voltage. The main objective of FACTS is to increase the usable transmission capacity of lines and control power flow over designated transmission routs.

B. Working of SVC

The elements of a TCR-FC type Static VAR Compensator are shown. They include a reactor in series with a bi-directional thyristor valve pair. The reactor is split into two units, with one unit on either side of a valve, in order to limit valve fault currents. The valves conduct on alternate half cycle of the supply frequency depending on their firing angle. Full conduction at a conduction angle of 180 degrees is obtained with a firing angle of 90 degrees. The zero crossing of valve voltage defines the zero valve of firing angle. In this case the current is the same as that obtained if the valve were short-circuited. Partial conduction is achieved with firing angle between 90 degrees and 180 degrees. The firing angle is controlled to maintain the ac voltage at the set point Vref. Firing angles between 0 and 90 degrees are not permitted as they produce asymmetrical currents with DC components, which saturate the transformer core.

C. Prospective Applications of an SVC

The SVC supplies reactive power on an instant-to-instant basis just as it is required.
Its prospective applications are

- Reduction of voltage flicker due to spiked and rapid excursion MVAR loads like arc furnaces.
- Intermediate bus support to increase transmission capacity and enhance stability.
- Damping system swings thus increasing system dynamic, stability.
- Control of steady state over voltages.
- Local Var supply, reducing system losses and increasing supporting voltages.
- Improved HVDC performance during abnormal and recovery situation.
- Damping sub-synchronous oscillations.
- Balancing out-of-phase loads and compensating irregular single-phase traction loads.
- Correcting p.f. On single pole switching of loads.

VII. OPTIMAL PLACEMENT OF FACTS DEVICES

The addition of FACTS devices to the transmission system is likely to impact the losses associated with transmitting power in the system. The insertion of FACTS devices need not increase overall system losses but it may significantly reduce losses. While installing FACTS devices three main issues must be considered as,

- What type of devices should be use?
- How much capacity should it have and
- Where in the system should it be place?

Assuming that the cost of a particular device is a function of power transfer capability. It would not be desirable to install a device that is overly large for its intended purpose. Anything larger than the rating of transmission line in which it is installed would not be economically as line limit prohibits the device from being used to its full potential. If the device is too small then it cannot handle as much power as the transmission line. Therefore the size of the FACTS device should be determined by the rating of the associated transmission line.

A. Problem Statement

The 9-bus power system network of an Electric Utility Company is shown. The load data is tabulated below. Voltage magnitude, generation schedule and the reactive power limits for the regulated buses are tabulated below. Bus 1, whose voltage is 11KV specified as $V_1=1.03 \angle 0^0$, is taken as the slack bus.

Load Data		
Bus No.	Load	
	MW	Mvar
1	0	0
2	20	10
3	25	15
4	10	5
5	40	20
6	60	40
7	10	5
8	80	60
9	100	80

Table 1: Load Data

Generator Data				
Bus No.	Voltage Mag.	Generation MW	Mvar Limits Min.	Max.
1	1.03			
2	1.04	80	0	250
7	1.01	120	0	100

Table 2: Generator Data

B. Types of buses

All the buses in the power system network are generally classified into three categories as:

- Generation Bus (or Voltage Controlled Bus): This is also called P-V bus and here the voltage magnitude |V| and the real power |P| are specified.
- Load bus: This is also called P-Q bus and here real power |P| and reactive power |Q| are specified.
- Slack or Swing Bus: This is also known as reference bus and the voltage magnitude |V| and phase angle Φ are specified here. This bus is selected to provide additional real and reactive to supply the transmission losses since these are unknown until the final solution is obtained. If the slack bus is not specified then a generation bus usually with maximum real power |P| is taken as slack bus.

C. Bus Classification

- Slack Bus: Bus No.1
- Generator Buses: Bus No.2 & 7
- At these buses voltage and real power magnitudes are specified.

- Load Buses: Bus No.3, 4, 5,6,8,9.
- At these buses real and reactive powers are specified.

VIII. SIMULATION RESULTS

The IEEE 9-Bus system is used for computer simulation studies. The system has 3 generators, 9 buses and 11 tie lines. Bus 1 is selected as slack bus and designated to correct transmission loss changes, and its reactive power cost is not included in the optimization procedure. The system base capacity is 100MVA. The character of the system is that power is sent from the generation area (generators on bus 2 and bus 7) to the main load center through long transmission lines. The zones in which the loads increase are bus 8 and bus 13. Other loads outside the zone are fixed. Table 7.2 gives generator data, which are usually used for reactive power opportunity cost analysis.

Compensators need to the installed to improve the voltage stability margin, and we select load buses either three, four, five, six, eight and nine as candidates for compensator installation. First of all we simulate the selected model on ‘ETAP 5.0 software’ for load flow analysis based on Gauss Seidal method with maximum number of iteration equal to 2000 and precision of 0.000001,of given system without any static voltage compensator used. The load flows are shown in following figure 1.It is observed that total active losses were 25.23MW and total reactive losses were 76.39 MVAr.

Now, SVCs were installed on respective buses in steps of one at each time,It was observed that both active and reactive power losses goes on decreasing thus increasing line capability and achieving reactive power optimisation. Detailed results of simulation are tabulated below.

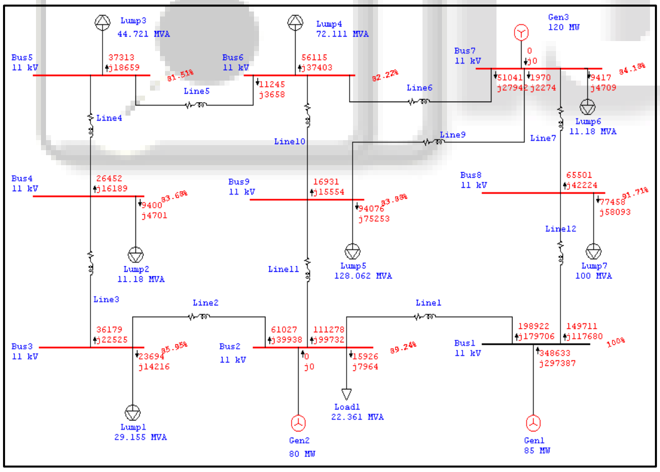

Fig. 1: Load flow Analysis Without SVC

IX. FINAL RESULT

Result of active and reactive losses after installing SVC’s on various buses is as given in the table 3.

SVC’s on Bus No.	Active Losses (MW)	Reactive Losses (MVAr)
3	24.826	75.235
3,4	24.247	73.474
3,4,9	23.733	71.876
3,4,9,8	23.574	71.408
3,4,9,8,6	22.958	69.497
3,4,9,8,6,5	22.668	68.607
Without SVC	25.23	76.79

Table 3: System losses computed using simulation

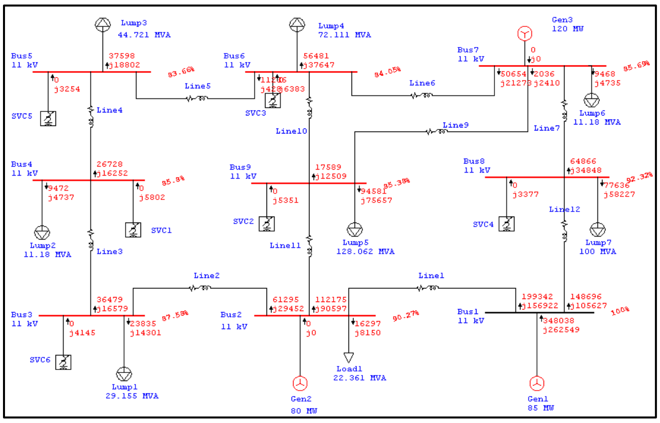

Fig. 2: Load flow Analysis With SVC

X. CONCLUSION

From the results of ORPD obtained in this work on the 9-bus system, the following main conclusion can be drawn,

- Conventional ORPD with reactive power generation and transformer tap settings adjustment effectively reduces the total active power loss in the system. By including the FACTS devices in the complex ORPD problem, additional reduction in the total active power loss in the system have been achieved as compared to the conventional ORPD.
- Thus improvement using ORPD with FACTS would be significant in terms of MW loss reduction and the revenue saving per annum.

REFERENCES

[1] Preecha Preedavichit, S.C. Srivastava, ‘Optimal Reactive Power Dispatch Considering FACTS Devices’, Electrical Power Sys. Res. 46 (1998) 251-257.
[2] K.R.C. Mamandur, R.D. Chenoweth, ‘Optimal Control of Reactive Power Flow For Improvements in Voltage Profiles and For Real Power Loss Minimization’, IEEE transactions on Power Appararus and Systems, Vol. PAS-100, No.7, July 1981.
[3] Xingbin Yu, Sasa Jakovljevic, ‘Total Transfer Capability Considering FACTS And Security Constraints’, IEEE transactions.