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Summarization of Loss Minimization Using FACTS in Deregulated Power System

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Abstract: The losses are an important constituent of consideration for mitigation and thereby enhancing the available transfer capability of power system. Loss mitigation is two stage processes - the first is the planning phase and the second stage is the operational phase. The paper discusses briefly planning phase activities. The various method of mitigating the losses in the operational phase has been presented in the paper with emphasis on one technique- the Flexible Alternating Current Transmission System devices. The Flexible Alternating Current Transmission System device sere the latest power electronic devices by which the losses can be reduced and power transfer capability enhanced. Thyristor Controlled Series Compensator is used to reduce the losses. The method is tested on IEEE 9 bus, 14 bus 30 bus systems and validated. Results have been presented and analyzed in this paper.

Keywords: Available Transfer Capability, B-Losses Coefficients, Flexible Alternating Current Transmission System, Thyristor Controlled Series Compensator.

I. INTRODUCTION

The quantification and the minimization of the losses is important because it can lead to more economical operation of a power system. if we know how the losses occur, we can take steps to limit the losses. Hence if more losses can be minimized the power can be consumed efficiently. Losses results from current flow with resistive material and magnetizing energy in the transformers and motors. Other sources such as the dielectric and rotational loss three facts considering for minimized the unnecessary losses associated with resistive material are

- Either reducing the resistance/impedance.
- Or decrease the current.
- Or increase the voltages.

Magnetizing loss can be minimized by minimizing the line voltage(in per unit terms).several paper has been written in the 1950s and 1960s ,which gives the comparison of actual measured of the transmission loss in an power system with consideration of the loss coefficient. Modern power system being highly interconnected over the long distance to carry power from sources to loads. The Electric power transmission efficiency-enhancing actions and technology includes:-

- FACTS(flexible alternative current transmission system).
- Distributed generation/micro grid.
- underground distribution lines.
- Power electronic transformer.
- High efficient energy storage devices.
- Higher transmission voltages.

India's electricity grid suffer from highest transmission and distribution losses in the world-nearly 27%.this is attributed to technical losses and theft. The paper presents the interest of the others discussing few planning and determining the losses in transmission system under various condition presenting an effective method of mitigating the losses.

II. LOSSES IN POWER SYSTEM

Losses is define

$$P_{Loss} = P_G - P_R \quad (1)$$

Where P_{Loss} = total losses P_G = power generation
P_R = power received

A. Classification of losses

Mainly there are two types of losses:-

1. Technical losses

It is internal losses, and occurs due to the power system component. They occur naturally .it is function of the system design parameter and the dynamic state of the power system. It can control by two ways:

- By proper design of system parameters, under planning stage.
- Controlling the parameters during power system operation by use of devices such as FACTS, under controlling stage.

2. Nontechnical losses

It is losses caused by some external action to the power system and consist primarily of electrical theft, error in accounting and record-keeping.

B. Effect of the Losses

Losses cause various harmful effects. Common effects are as follows:-

- Losses increase the operating & maintenance cost of running a power system.
- Thermal losses reduced the overall lifetime of the electrical equipment's.
- Losses responsible for the poor power factor.
- Losses minimized the reliability of the power system.
- Losses reduced the efficiency of performance of the system.

C. Management of technical losses

Management of technical losses is a two stage operation:- 1.Planning Stage 2. Monitoring Controlling & Maintenance Stage

D. Modeling methods of technical losses

1. Fundamental method

Power loss is proportional to the resistance of the wire & the square of the current

$$\mathbf{P_{loss} = RI^2} \quad \textbf{(2)}$$

For system which delivers a certain amount of power (p), over a particular voltage (V), the current (I) flowing through the cables is given by

$$\mathbf{I=P/V} \quad \textbf{(3)}$$

Thus the power lost in the line is

$$P_{loss} = RI^2 = R(\frac{P}{V})^2 = \frac{RP^2}{V^2} \quad \textbf{(4)}$$

Power loss is proportion to resistance & inversly proportional to the voltage. HVDC is used to reduces yhe current and increase the voltage and minimised the power lost in the during transmission line. HVDC is used to transmit large amount of power over long distances or for interconnections between asynchronous grids.When electrical energy is require to be transmitted over a long distance, it can be more echonomical to transmite using direct current DC instead of AC for long transmission line, reduce the losses and the construction cost.

2. Conventional method

B-Loss Coefficients are the commonly adopted conventional method to calculate the incremental loss. The B-Loss Coefficients expressed transmission losses as a function of the output of all the generation plants. The B matrix Loss is practical method for loss calculation since 1950. We can calculate the line loss as:-

$$\mathbf{P_{LOSS} = 3\ I^2 R}$$

$$\mathbf{P_G/\{(3^{1/2})V_G COS\ \ _G\}} \quad \textbf{(4)}$$

Where VG is the magnitude of the generated voltage(line-to-line)

$\cos ø_G$=generated power factor

$$\mathbf{PLOSS = (PG2)\frac{R}{[VG\ COSøG]}} \quad \textbf{(5)}$$

For fixed voltage & power factor

$$\mathbf{P_{LOSS} = BP_G^2} \quad \textbf{(6)}$$

Losses can be expressed by

$$\mathbf{P_L=P_1B_{11}+2P_1P_2B_{12}+P_2B_{22}} \quad \textbf{(7)}$$

$$\sum_{m=1}^{k} \sum_{n=1}^{k} \mathbf{Pm\ Bmn\ Pn} \quad \textbf{(8)}$$

P_m & P_n is the power generation from all sources

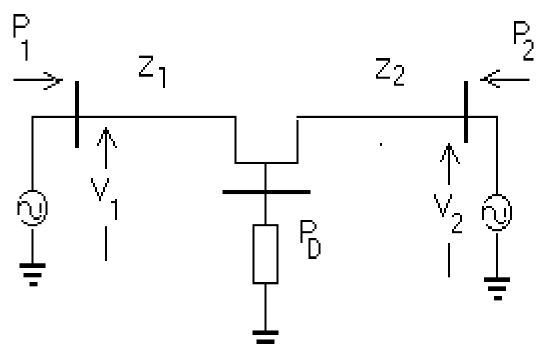

Fig 1: FACTS Devices and Its practical Implementation.

As shown in fig 1 FACTS provide very effective and economic performance to control the power transfer into the large interconnected AC transmission system. FACTS consists improvement of dynamic behavior & thus enhancement of system reliability. It reducing the power losses & improved the voltage profile. Operating margins can be reduced due to fast controllability. So the power transfer capability enhance up to the thermal limits. The transient stability limit is increased therefore the dynamic security is improved and reduced the system blackouts caused by cascading outages. The low frequency oscillations are damped with the help of auxiliary stabilizing controllers to enhance the steady state stability. FACTS Controllers overcome the problem voltage fluctuations & dynamic over voltages. FACTS device increase the system load ability too. It plays very important role in control and operation regulated power systems.

E. Modeling of FACTS Devices

There is several types of model are proposed FACTS Device. This types are termed A,B and here for convenience (3).Fig.[3] the block diagram of the FACTS Devices:- (a) TCSC (b) TCPST (c) UPFC (d) SVC. Shown in fig.4 the reactance of the line can be changed by the TCSC. Therefore FACTS can be used to control power flow by changing parameters of power system and generation cost can also be reduced.

F. Practical implementation of TCSC

The rated value of TCSC is vary with the reactance of the transmission line where it was located. Degree of compensation is existing in the range of 0.2 X_{line} to 0.7$X_{line.}$ In India, two TCSCs have been installed on the Rourkela-Raipur twin circuit 400kV power transmission inter connecter between the Eastern and Western regions of the grid. The length of the inter connecter is 412km. The main purpose of this major AC inter connecter is to enable export surplus energy from the eastern to the western regions of India during normal or abnormal conditions. The TCSC are located at the Raipur end of the lines. The TCSC enable damping of inter area power oscillations.

III. OPTIMAL ANALYSIS

A. Optimal Location of the TCSC Base on the Real Power Loss

The objectives for device placement may be one of the following 1) Reduction of power loss in particular line. 2) Reduction in total system real power loss. 3) Reduction in total reactive power loss. 4) Maximum relief congestion in the system. For the first objective the TCSC is placed were maximum loss is occur. For next 3 objectives the method base on the sensitivity approach is used.

B. Approach Proposed

Power Flow Analysis carried out by MATLAB and Power World Simulation. TCSC was implemented by increasing the reactance of the line by 20% to 70%. After placement of the TCSC power flow analysis done and compared with the base case data.

IV. RESULTS ANALYSIS

FACTS devices improve the power transfer capacity by reducing the power losses. Just like that 1) Objective function value is reduced by the 1.31$/hr. 2) The power flow analysis converged in 0.14sec with FACTS as compared to without FACTS. 3) For the 9-Bus system total 10.6MW losses occur without FACTS. TCSC is located where the loss is maximum. From fig 2 to 4, the transmission line suffer with maximum losses between busses 5&6, so the TCSC is placed between buses 5&6.Total MW losses is reduced up to 9.9MW. Thus the total losses are reduced by 6.6% with placement of FACTS Devices. As shown in fig 5 in 14-bus the maximum MW losses is occur in the transmission between the buses 1&2.Hence the FACTS Device, TCSC is located between the buses 1&2. The reduction in losses was observed to be 17%.1n 30-Bus system also the lines having maximum losses were detected and TCSC located. The power loss was reduced 9.4%. 4) The Table 2 below shows the % reduction

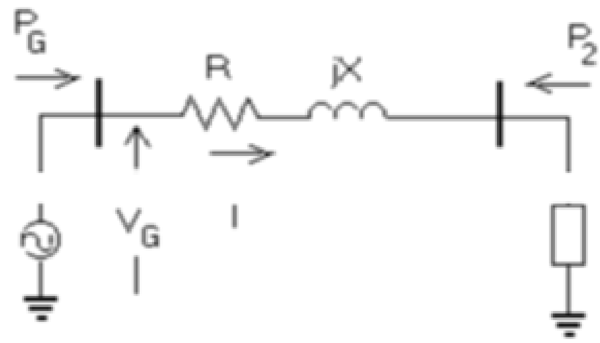

Fig. 2: Stages of Management of Technical Losses.

TABLE 1: TYPES OF FACTS DEVICE MODELS

Type Designation	Parameter Controlled	FACTS Devices
Type A	Series P and Q	UPFC
Type B	Series P	TCSC ,phase angle regulator
Type C	Series Q	SVC,STATCO

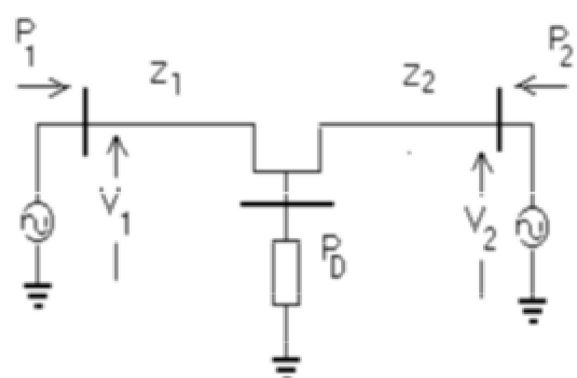

Fig. 3: Radial Line with One Generation.

in loss with FACTS Devices. 5) The graph of the Losses Vs Line No 9-Bus is shows in Figure 6 and 7. 6) The graph of losses Vs Line No of 30-Bus in Figure 8.

TABLE 2: % LOSS REDUCTION WITH FACTS

Power System	Real Power Loss Reduction
9-Bus	6.6%
14-Bus	17%
30-Bus	9.4%

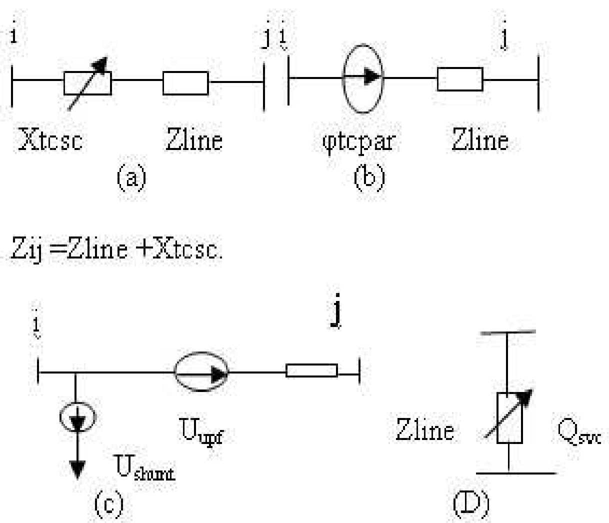

Fig. 4: Block diagrams of the considered FACTS devices (a) TCSC (b) TCPST (c) UPFC (d) SVC.

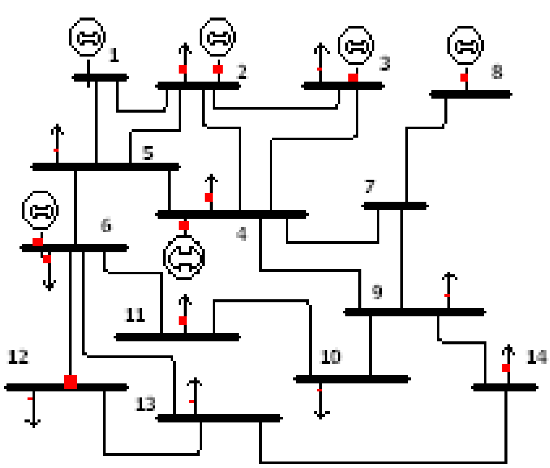

Fig. 5: IEEE 14-Bus Test System.

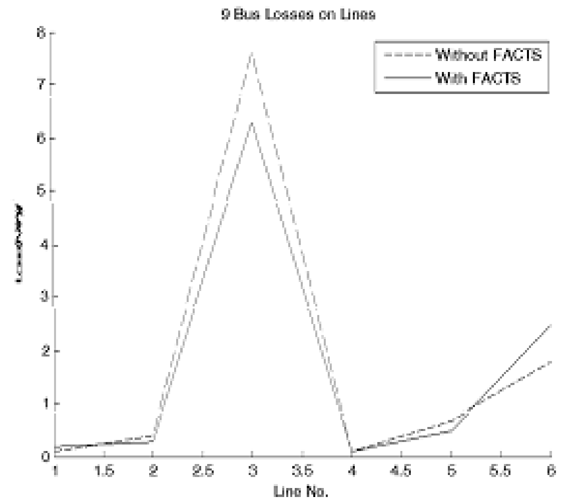

Fig. 6: 9-Bus System Losses before FACTS.

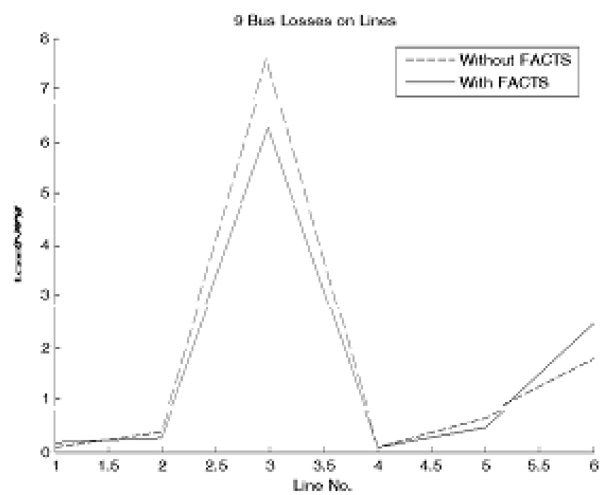

Fig.7: 9-Bus System Losses after Placing FACTS.

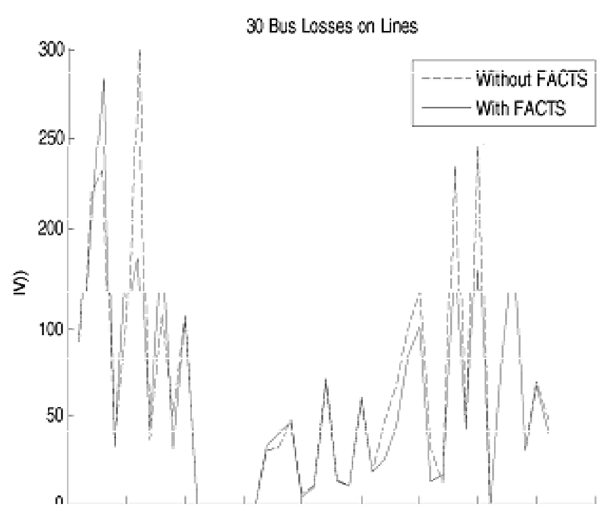

Fig. 8: 30-Bus System Losses with and without FACTS

V. CONCLUSION

Most research focuses on the large transmission system. This research project addresses this shortcoming. Losses increase the cost of operation of a power system. Hence, loss minimization would be very advantageous goal to use to optimize the generation &delivery of electrical energy. FACTS devices have provide most effective method for loss reduction. The effectiveness of TCSC is demonstrated on IEEE 9- bus, 14- Bus System & 30-bus IEEE Power System. Main conclusion of the paper are:**1)** The simple and direct method of placing TCSC in the line having maximum power loss has shown effective results in loss mitigation &enhancement ATC. 2) The placement of the FACTS devices increase system ATC & mitigation real power loss. 3) Time of convergence is less.

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