Optimal Location of Thyristor Controlled Series Compensator (TCSC) for Loss Minimization in Power System using Optimal Power Flow

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Abstract—Flexible Alternating Current Transmission Systems (FACTS) devices signify a modern technological advance in electrical power systems. FACTS devices offer so many benefits like transient stability improvement, subsynchronous resonance (SSR) mitigation, damping of power swings, avoiding voltage collapse, enhancing power system reliability, minimize the loss in power system. Though FACTS controllers offer many advantages, their installation cost is very high. Hence the ideal placement and the optimal parameter settings of these devices in the power system are of key issues. In this paper OPF method is proposed to find optimal location and optimal parameter setting considering power loss minimization in power system. The proposed method is carried out on IEEE-30bus power system.

Keywords: Flexible Alternating Current Transmission Systems (FACTS) Thyristor controlled series capacitor (TCSC) Optimal Power Flow (OPF)

I. INTRODUCTION

In present era due to industrial and commercial enlargement and up gradation of standard of living, the load demand is increasing day by day and generation level is not increasing up to the level of load. Due to liberalized market environment in power system, there is a competition. There are numbers of operating problems related to power system. Examples of operating problems to which tolerant power flows may give rise are: loss of system stability, power flow loops, high transmission losses, voltage limit violations, an inability to utilize transmission line capability up to the thermal limit, and cascade tripping. Power system problems have been conventionally solved by building new power plants and transmission lines, install a new transformer and/or advancement system component, a Solution that is expensive to implement and that involves long creation times. To solve these Problems, FACTS technology was proposed. FACTS device is a fast acting and self-commutated power electronics converter introduced in 1988 by Hingorani. Thyristor controlled series capacitor (TCSC) is one of the most Prime FACTS devices that provide smooth and flexible control of line impedance, which offers to minimize loss in power system. Fig 1 is a schematic representation of TCSC. In TCSC branch of capacitor is connected in parallel with series connection of anti-parallel thyristor with inductor.

II. MODELING OF TCSC

A. Variable Series Impedance Power Flow Model:
The TCSC power flow model has been defined in this paper is based on the simple concept of adjustable series reactance, the value of which is adjusting it in order to limit the power-flow across the branch to a specified value. The changed reactance would give the resultant effect as either inductive or capacitive zone.

![Fig-1: TCSC diagram](image)

Fig 1: TCSC diagram

![Fig-2TCSC Model as variable impedance](image)

Fig-2 TCSC Model as variable impedance
(a) Reactor (b) Capacitor

TCSC are connected in sequence with the lines. The effect of TCSC on network can be seen as controllable reactance inserted in related transmission line, that compensate reactance of line. It may have one of two features; capacitive, inductive.
III. OPTIMAL POWER FLOW

The optimal power flow gives us a framework to have many control variables adjusted in the effort to optimize the operation of the transmission system. Optimal Power Flow [10] is a successful algorithm and was first introduced in 1962 by Carpentier. All the equality and inequality constraints like maximum and minimum limit of P and Q generation, transmission line MVA constraint are to be satisfied while getting the solution of each equation. OPF programs formulated with mathematical programming approaches are used daily to solve very large OPF problems.

MATPOWER is having inbuilt standard formulations for Optimal Power Flow (OPF). The constraints are observed during iteration process. The standard and generalized formulations have been specified with standard constraints and user defined constraints.

Standard OPF formulations are given as:

\[ \text{min}_x f(x) \]

Subject to

\[ g(x) = 0 \]
\[ H(x) \leq 0 \]
\[ x_{\text{min}} \leq x \leq x_{\text{max}} \]

Where \( x \) is the vector of control and state variables of the system, represented by the magnitude \( |V| \) and angle of voltages. The objective function \( f(x) \) represents the real power losses in the transmission (PL). This function is non-separable and permits no simplification. The equality constraints, \( g(x) \), represent the real \( (P(x)) \) and reactive \( (Q(x)) \) power flow equations, which are obtained by means of the conservation of energy principle at all buses of the system. The inequality constraints, \( H(x) \), represent the functional constraints of power flow, e.g. limit of real and reactive PFs in the transmission lines and transformers, limits of reactive power injections for reactive control buses. \( X_{\text{max}} \) and \( X_{\text{min}} \) are the upper and lower limits of the state variables and control systems.

The above equations are with reference to equality and inequality constraints, which need to be observed during iterative process for satisfactory operation of power system. The above equation can be further specified and explained as:

\[ \text{min}_{\theta_P,P,Q} \sum_{i=1}^{n_g} \left[ f_P^i (p_i) + f_Q^i (q_i) \right] \]

Subject to

\[ g_P(\theta_P, v, p) = 0 \]
\[ g_Q(\theta_P, v, Q) = 0 \]
\[ h_P(\theta, V) \leq 0 \]
\[ h_Q(\theta, V) \leq 0 \]
\[ \theta_{\text{ref}} \leq \theta_i \leq \theta_{\text{ref}} \]
\[ v_{i_{\text{min}}} \leq v_i \leq v_{i_{\text{max}}} \]
\[ p_{i_{\text{min}}} \leq p_i \leq p_{i_{\text{max}}} \]
\[ q_{i_{\text{min}}} \leq q_i \leq q_{i_{\text{max}}} \]

IV. SIMULATION RESULT

The power-flow analysis has been done by Optimal Power Flow using Newton’s method. It has been executed by programming using MATPOWER for IEEE-30-bus system.
Simulation result shows that the optimal location of TCSC in the system is in branch no 5 (from bus 2 to bus 5) and TCSC reactance $X_{tcsc} = -0.03966$

Fig. 4 shows active power loss without and with TCSC. Table 1 shows simulation results.

V. CONCLUSION

This paper has presented OPF method to optimally locate TCSC for loss minimization in power system. TCSC’s reactance is taken to be the state variable. By varying TCSC reactance, loss minimization is achieved. And Including
TCSC in branch 5 total active power losses reduced from 17.557 MW to 11.717 MW in power system.

REFERENCES


http://www.ee.washington.edu/research/pstca/