

TRANSMISSION LOSS MINIMIZATION USING ADVANCED UNIFIED POWER FLOW CONTROLLER (UPFC)

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ABSTRACT

The capability of transmission loss minimization of the power system network by advanced unified power flow controller (UPFC) is the main focus in this paper. An important factor effecting power transmission systems today is power flow control. The increment of load variation in a power transmission system can lead to potential failure on the entire system as the system has to work under a stressed condition. Thus, the Flexible AC Transmission System (FACTS) are integrated in power system to control the active power and reactive power simultaneously in specific lines and improve the security of transmission line without violating economic generation dispatch. This paper presents Advanced Unified Power Flow Controller (UPFC) which can provide functional flexibility for loss minimization and voltage profile monitoring in a power system network. The UPFC devices are installed in the system based on voltage stability index in order to enhance the system security, performed on the IEEE 30-bus RTS for several loading conditions. Simulations were carried out using MATLAB software to check the performance of UPFC.

KEYWORDS – Active power, reactive power, Unified power flow controller, voltage profile.

INTRODUCTION

Nowadays, the power transmission systems have been facing many problems. The voltage deviation due to load variation and power transfer limitation were found due to reactive power unbalances, has drawn attention for better utilization of the existing transmission line. It also causes a higher impact on power system security and reliability in the world. But, the electrical energy demand increases continuously from time to time. This increase should be monitored or observed because few problems could appear with the power flows through the existing electric transmission networks. If this situation fails to be controlled, some lines located on the particular paths might become overloaded. Due to the overloaded conditions the transmission lines will have to be driven close to or even beyond their

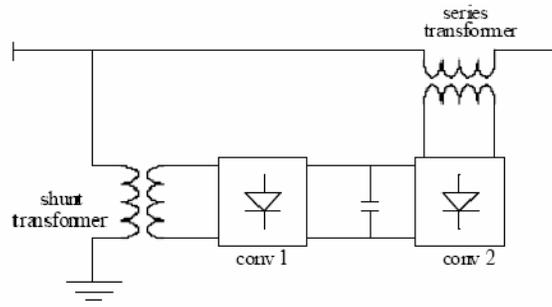
transfer capacities. Building a new transmission line will not be an effective way to solve the problems since it is quite complicated and also due to the environmental and political reasons. Therefore the only way to overcome this major problem is by developing a new way of transmitting more efficient and economical supply using the existing transmission network. In olden days, the electromechanical equipments were used. Those equipments were switched inductors or capacitors banks and phase-shifting transformer. However all this equipments are not reliable or not efficient enough due to the certain problems related to this equipments. They are not only relatively slow but they also cannot be switched frequently because they tend to wear out quickly. In this context, one possible solution to improve the system operation was the use of Flexible AC Transmission Systems (FACTS) technologies [1]. It opens up new applications for controlling the power, decreasing the losses and enhancing the stable capacity of existing transmission lines. However not all can be provided by FACTS devices and it is important to select the type of devices in order to achieve the purpose. FACTS devices are solid state converters that have the ability to control various electrical parameters in transmission networks [2]. Unified Power Flow Controller (UPFC) is a FACTS device and it is one of the suitable approaches to be chosen according to the purpose. UPFC can effectively control both the active and reactive flows on the lines and voltage magnitudes at the buses [3]. In addition, UPFC can independently provide either positive or negative reactive power injections. Basically the UPFC concept was proposed by Gyugyi in 1991. The UPFC was devised for the real time control and dynamic compensation of ac transmission systems, providing multifunctional flexibility required to solve many of the problems facing the power delivery industry. Within the frame work of traditional power transmission concepts, the UPFC is able to control simultaneously or selectively, all the parameters affecting power flow in the transmission line and alternatively it can independently control both the real and reactive power flow in the line. This paper presents the application of UPFC to minimize transmission line losses along with the improvement of voltage profile in power system. The technique determines the location of UPFC installation based on voltage stability index as the fitness and their optimal sizing. This method performed on the IEEE 30-bus reliability test system indicates that the proposed method is worth in loss minimization scheme.

PROBLEM FORMULATION

Flexible AC transmission system (FACTS) devices have several types namely, Unified Power Flow Controller (UPFC), Static VAR Compensator (SVC), static compensator (STATCOM), Thyristor Controlled Phase Angle Regulator (TCPAR) and Thyristor Controlled Static Compensator (TCSC). The optimization of UPFCs for solving reactive power control constraints and inequality constraints. The equality constraints are the nodal power balance equations, while the inequality constraints are the limits of all control or state variables. The objective function is optimization of real power losses in the power system.

UPFC DESIGN

UPFC mode is illustrated in Fig. 1. It consists of two voltage-source converters, which is connected back to back through a DC capacitor. Fig 1:



UPFC model In this study, the UPFC is modeled by the simultaneous presence of several FACTS devices in the same power transmission line [4]. A TCSC in the line and SVC at a bus in an adjacent branch incorporated as an UPFC in this paper. The mathematical models of TCSC, is shown in Fig. 2. TCSC can be operated as the inductive or capacitive compensation by decreasing or increasing the reactance of the transmission line branch. Its value is function of the reactance of the line XL where the TCSC is located. $Z_{ij} = ZL + jX_{TCSC}$ and $X_{TCSC} = rTCSC XL$ (1) where ZL is the impedance of the transmission line, X_{TCSC} is the reactance of the line where TCSC is located and $rTCSC$ is the coefficient which represents the compensation degree of TCSC.

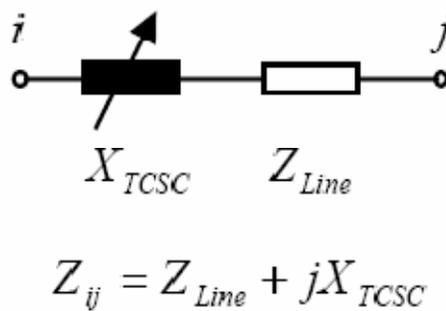


Fig 2: Block diagram of the TCSC devices

The SVC can be operated as both inductive and capacitive compensation which can control bus voltage by absorbing or injecting reactive power. The SVC is modeled as a shunt variable susceptance added at both ends of the line. Hence, it is modeled as ideal reactive power injections to perform the steady-state condition at bus i , as shown in Fig. 3.

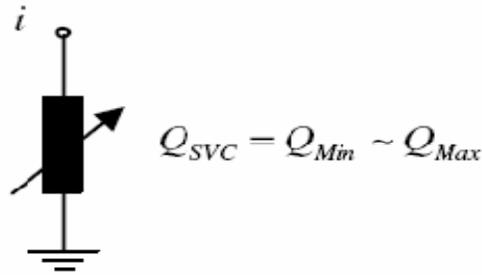


Fig 3: Block diagram of the SVC devices

The injected power at bus i is: $\Delta Q_{is} = Q_{SVC}$ (2) Where Q_{SVC} is the reactive power injected by the SVC placed bus in MVAR. Hence the UPFC device constraint limit is given by: $-0.8XL \leq XTCSC \leq 0.2XL$ (3): $-200MVAR \leq Q_{SVC} \leq 200MVAR$ (4)

UPFC PLACEMENT

The placement of the UPFCs in the network must be determined and then, the setting of the control parameters of UPFC is optimized by controlling the device parameters. Locations of FACTS devices in the power system are obtained based on the performance using the voltage system. The Static Voltage Stability Index ($SVSI$) technique was applied as the tool to indicate the UPFCs location into the network. When the load flow program was run, stability indices are calculated for UPFC placed in every line one at a time for the same operating conditions and the system identified five line buses with the highest $SVSI$ for the purpose of installing the UPFC. The concept of the $SVSI$ is demonstrated through a simple two-bus system model. The mathematical formulation for $SVSI$ is given as in equation: $SVSI_{ji} = 2 \{(X_{ji}^2 + R_{ji}^2)(P_{ji}^2 + Q_{ji}^2)\}^{0.5} / |V_i^2 - 2X_{ji}Q_{ji} - 2R_{ji}P_{ji}|$ (5) Where i is the sending end bus, j is the receiving end bus, R_{ji} is the line resistance, X_{ji} is the line reactance, P_{ji} is the real power at the receiving end, Q_{ji} is the reactive power at the receiving end and V_i the sending end voltage. $SVSI$ has a value between 0 and 1, in which 0 represents the no-load condition and 1 represents unstable condition. Therefore, to obtain stability in the system, $SVSI$ has to be maintained far below 1.

LOSS MINIMIZATION BY UPFC

Generally series converter provides the main function of UPFC by injecting an ac voltage with controllable magnitude and phase angle in series with the transmission line via a series transformer. The basic function of shunt converter is to supply or absorb controllable reactive power and provide independent shunt reactive compensation for the line [5-7].

Suppose a series connected voltage source is located between nodes i and j in a power system voltage source converter can be modeled with an ideal series voltage V_s in series with a reactance X_s . consider V_i' represents a fictitious voltage behind the series reactance. Then: $V_i' = V_s + V_i$ (6) The series voltage source V_s is controllable in magnitude and

phase, i.e. : $V_s = r \cdot V_{ie} \gamma$ (7) Where $0 < r < r_{max}$ and $0 < \gamma < 2\pi$. By properly selecting the control parameters r and γ UPFC can regulate the power flow and minimize the total power losses simultaneously.

RESULTS AND DISCUSSIONS

The proposed method has been tested on a IEEE 30-bus RTS system, which consist of 5 voltage control buses, 24 load buses, 1 slack bus, 41 interconnected lines and 4 transformer tap changers. The base power is 100MVA. There were two constraints assigned before the UPFCs sizing is optimized. The constraints were total loss to be less than the $loss_{set}$ and voltage at the loaded bus higher than V_{set} . The $loss_{set}$ and V_{set} are the total loss and voltage at the loaded bus before the optimization process was conducted. Result for losses minimization and voltage profile improvement at bus 26 is tabulated in Table 1 and 2 and shown in Fig. 4&5. Bus 26 was subjected to variation of loading conditions and loading factor, λ is increased gradually in order to observe the effect of total losses with the installation of UPFC to the system. The loading factor, λ was increased up to 3.2 p.u. The five locations of UPFCs installation in the network are also identified by using SVSI technique. Different loading condition shows a different location for UPFCs placement in the system as it depends on which line are the weakest subjected to loading factor variation. The application for minimization of losses as the objective function has significantly reduced the losses and increased the voltage profile value at the loaded bus, hence improving the voltage stability in a system as shown in Table 2. It is observed that the total losses value decreased accordingly and the voltage profiles for post-UPFC are higher with the increment in the loading factor. This implies that with the implementation of UPFC , voltage $r \cdot V_{ie} \gamma$ (7) Where $0 < r < r_{max}$ and $0 < \gamma < 2\pi$. By properly selecting the control parameters r and γ , UPFC can regulate the power flow and minimize the total power losses simultaneously.

Table 1 Transmission loss profile

LOADING FACTOR(P.U)	PREUPFC LOSS (MW)	POSTUPFC LOSS (MW)
2	20.3	18.3
2.5	22.3	18.7
3	26.2	19.1
3.2	28.9	19.5

Table 2 Voltage profile

LOADING FACTOR(P.U)	PREUPFC VOLTAGE (P.U)	POSTUPFC VOLTAGE (P.U)
2	0.845	1.115
2.5	0.783	1.013
3	0.688	1.153
3.2	0.636	1.08

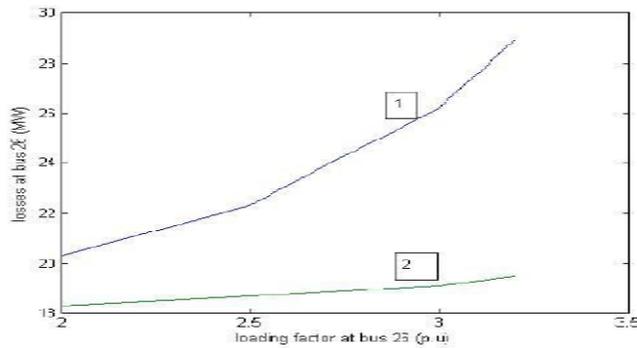


Fig 4: Transmission loss profiles

- 1. Losses before installation of UPFC
- 2. Losses after installation of UPFC

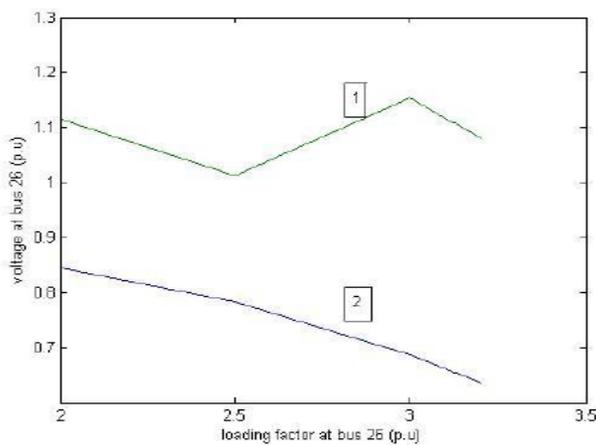


Fig 5: Voltage profiles

CONCLUSION

This paper has presented the application of advanced unified power flow controller for loss minimization and voltage profile improvement in a network without violating the economic generation dispatch. In this paper, the location where voltage stability index is high is determined and UPFC is connected for the minimization of real power loss and regulating power flow. Simulations are carried out on the IEEE 30-bus RTS system without and with UPFC. Simulation results shows that advanced unified power flow controller is feasible for loss minimization scheme and voltage profile improvement in power system network and can regulate the power flow with the properly selected control parameters of UPFC.

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