Efficient Techniques to Improved Power Quality in Unified Power Flow Controller System : A Brief Survey

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Abstract:* The focus of this research paperis a FACTS device known as the Unified Power Flow Controller (UPFC). With its unique capability to control simultaneously real and reactive power flows on a transmission line as well as to regulate voltage at the bus where it is connected, this device creates a tremendous quality impact on power system stability. These features become even more significant knowing that the UPFC can allow loading of the transmission lines close to their thermal limits, forcing the power to flow through the desired paths. This will give the power system operators much needed flexibility in order to satisfy the demands that the deregulated power system will impose. The most cost-effective way to estimate the effect the UPFC has on a specific power system operation is to simulate that system together with the UPFC by using one of the existing simulations packages. Specifically, the objective of this research paperis to (1) develop a UPFC model that can be incorporated into existing MATLAB based Power System Toolbox (PST), (2) design basic UPFC controllers, and (3) design on supplementary damping control scheme based on fuzzy logic to enhance power system stability. The proposed tools will be tested on the two-area-four-generator system to prove their effectiveness.

Key Words:- Flexible, ac, transmission, system(FACTS), unified, power, flow, controller(UPFC), total, harmonic, distortion, power factor (PF)design, analysis, unified, power, flow, controller, Matlab/Simulink, by using fuzzy logic.

I. INTRODUCTION

Power system in general is interconnected for economic, security and reliability reasons. Exchange of contracted amounts of real power has been in vogue for a long time for economic and security reasons. To control the real flow on tie lines connecting controls areas, power flow control equipment such as phase shifters are installed. They direct real power between control areas. The interchange of real power is usually done on hourly basis. On the other hand, reactive power flow control on tie lines is also very important. Reactive power flow control on transmission lines connecting different areas is necessary to regulate remote end voltages. Though

Local control actions within an area are the most effective during contingencies, occasions may arise when adjacent Control areas may be called upon to provide reactive power to avoid low voltages and improve systemsecurity.

Fixed series capacitors help in increasing stability limits in an interconnected power system. With transmission open access, each transmission system owning utility will increase their transmission capacity to attract more utilities to use its transmission facilities. Many existing power systems have already made the use of series compensation to increase their transmission capacity. By series compensation, the amount of reactive power consumed by the line is reduced hereby increasing the amount of reactive power transferred to the receiving end and improving the voltage profile at the receiving end. This is one of the secondary benefits of using series compensation. Under system disturbance conditions like three phase faults or line tripping, controllable series compensation helps in damping power system oscillations.

The power system is an interconnection of generating units to load centers through high voltage electric transmission lines and in general is mechanically controlled. It can be divided into three subsystems: generation, transmission and distribution subsystems. Until recently all three subsystems were under supervision of one body within a certain geographical area providing power at regulated rates. In order to provide cheaper electricity the deregulation of power system, which will produce separate generation, transmission and distribution companies, is already being performed. At the same time electric power demand continues to grow and also building of the new generating units and transmission circuits is becoming more difficult because of economic and environmental reasons. Therefore, power utilities are forced to rely on utilization of existing generating units and to load existing transmission lines close to their thermal limits. However, stability has to be maintained at all times. Hence, in order to operate power system effectively, without reduction in the system security and quality of supply, even in the case of contingency conditions such as loss of transmission lines and/or generating units, which occur frequently, and will most probably occur at a higher frequency under deregulation, a new control strategies need to be implemented.

UPFC Basic Operation and Characteristics

Basics of Voltage Source Converters and Pulse Width Modulation Technique

Typical three-phase VSC is shown in Fig.1.

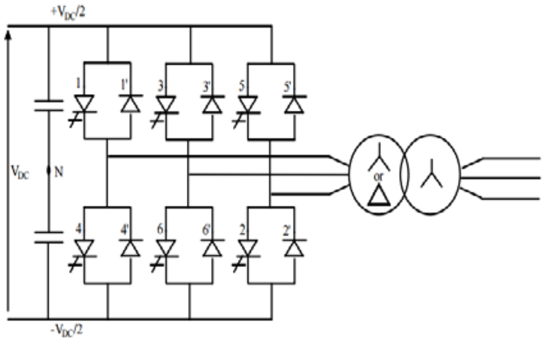

Fig.1 Three-phase voltage sourced-converter

It is made of six valves each consisting of a gate turn off device (GTO) paralleled with a reverse diode, and a DC capacitor. An AC voltage is generated from a DC voltage through sequential switching of the GTOs. The DC voltage is unipolar and the DC current can flow in either direction.

Controlling the angle of the converter output voltage with respect to the AC system voltage controls the real power exchange between the converter and the AC system. The real power flows from the DC side to AC side (inverter operation) if the converter output voltage is controlled to lead the AC system voltage. If the converter output voltage is made to lag the AC system voltage the real power will flow from the AC side to DC side (rectifier 8 operation). Inverter action is carried out by the GTOs while the rectifier action is carried out by the diodes. Two switches on the same leg cannot be on at the same time.

Controlling the magnitude of the converter output voltage controls the reactive power exchange between the converter and the AC system. The converter generates reactive power for the AC system if the magnitude of the converter output voltage is greater than the magnitude of the AC system voltage.If the magnitude of the converter output voltage is less than that of the AC system the converter will absorb reactive power.

UPFC Description and Operation

The UPFC is a device placed between two busses referred to as the UPFC sending bus and the UPFC receiving bus. It consists of two Voltage-Sourced Converters (VSCs) with a common DC link. For the fundamental frequency model, the VSCs are replaced by two controlled voltage sources as shown in Fig.2. The voltage source at the sending bus is connected in shunt and will therefore be called the shunt voltage source. The second source, 10 the series voltage source, is placed between the sending and the receiving busses. The UPFC is placed on high-voltage transmission lines. This arrangement requires step-down transformers in order to allow the use of power electronics devices for the UPFC.

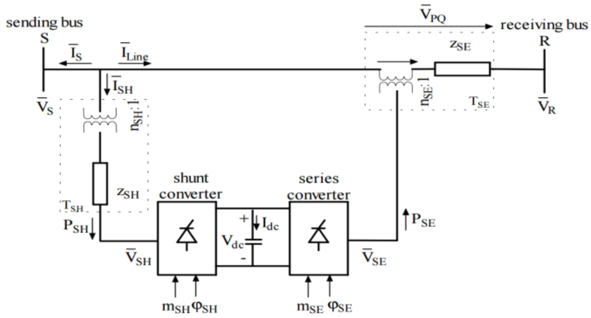

Fig. 2 Fundamental frequency model of UPFC

Applying the Pulse Width Modulation (PWM) technique to the two VSCs the following equations for magnitudes of shunt and series injected voltages are obtained

$$V_{SH} = m_{SH} \frac{V_{DC}}{2\sqrt{2} n_{SH} V_B}$$

$$V_{SE} = m_{SE} \frac{V_{DC}}{2\sqrt{2} n_{SE} V_B}$$

Where:

m_{SH} – amplitude modulation index of the shunt VSC control signal

m_{SE} – amplitude modulation index of the series VSC control signal

n_{SH} – shunt transformer turn ratio

n_{SE} – series transformer turn ratio.

II. SYSTEM MODEL

The construction and operation of a unified power controller consists of two voltage source inverters (VSI) connected back to back with a common DC coupling capacitor as shown in Fig.4. Such an arrangement allows for dl the three functions namely series, shunt and phase angle compensation to be unified into one unit. Inverter-1 is connected to the power system through a transformer Ti in shunt and the inverter-2 is connected to the power system through another transformer TT such that the secondary of the transformer T2 is in series with the transmission line. The transformers Ti and T2 would be referred to as shunt and series transformers respectively for the purpose of clarity.

Fig.3 Unified power flow controller configuration

Of the load flow models described the model given .where the shunt inverter and series inverter of a UPFC

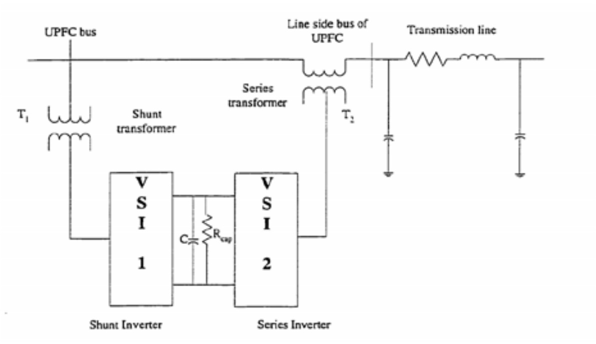

Fig.3 Unified power flow controller configuration

are modeled as a voltage source in series with their transformer reactance is the simplest of al1 the models. The model provides for detailed interaction between the series and the shunt inverter. Fig. 4 shows the UPFC model. X_{rh} and X_{se} represent the reactance of transformers Ti and T2 respectively. V_{sh} and V_{se}, represent the voltage generated by the shunt and the series inverter respectively. Bus-E and bus-F represent the UPFC bus and the transmission line side bus of UPFC respectively.

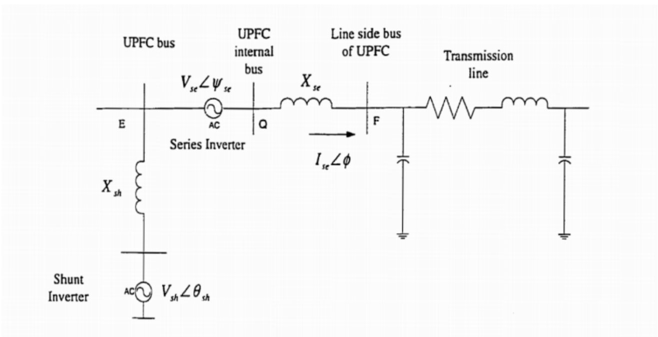

Fig.4 UPFC model

For performing load flow studies with UPFC, the series and the shunt inverters are assumed to producebalanced 60 Hz voltages of variable magnitude and phase angle. The shunt and the series voltagesources phases can be mathematically represented as

$$\bar{V}_{sh} = V_{sh}(\cos\theta_{sh} + j\sin\theta_{sh})$$
$$\bar{V}_{se} = V_{sem}(\cos\psi_{se} + j\sin\psi_{se})$$

Where V_{sh} and V_{se} are the root mean squared magnitudes of the shunt and the series voltage sources B_{rh} and 'Y, are the shunt and the series voltage source angles with respect to a reference frame.

III. LITERATURE REVIEW

Fang ZhengPeng, Shao Zhang, Shuitao Yang, D. Gunasekaran and U. Kark[1]Specified thatthe conventional unified power flow controller (UPFC) that consists of two back-to-back inverters requires bulky and often complicated zigzag transformers for isolation and reaching high voltage. This paper proposes a completely transformer-less UPFC based on an innovative configuration of two cascade multilevel inverters (CMIs). The unique configuration and control of the two CMIs as a power flow controller make it possible to independently control active and reactive power flows over a line. The new UPFC offers several advantages over the traditional technology, such as transformer-less, light weight, high efficiency, high reliability, low cost, and fast dynamic response. The transformer-less UPFC is thereby very suited for fast and distributed power flow control, such as wind and solar power transmission. A simulation model is built to demonstrate the operating principle of the proposed transformer-less UPFC.

L. Gyugyi, C. D Schauder, S. L. Williams, T. R. Rietman, D. R. Torgerson and A. Edris[2] was discovered that "The unified power flow controller: a new approach to power transmission controlAbstract: This paper shows that the unified power flow controller (UPFC) is able to control both the transmitted real power and, independently, the reactive power flows at the sending- and the receiving-end of the transmission line. The unique capabilities of the UPFC in multiple line compensation are integrated into a generalized power flow controller that is able to maintain prescribed, and independently controllable, real power and reactive power flow in the line. The paper describes the basic concepts of the proposed generalized P and Q controller and compares it to the more conventional, but related power flow controllers, such as the Thyristor-controlled series capacitor and Thyristor-controlled phase angle regulator. The paper also presents results of computer simulations showing the performance of the UPFC under different system conditions.

A. Rajabi-Ghahnavieh, M. Fotuhi-Firuzabad, M. Shahidehpour and R. Feuillet[3] are founded that "UPFC for Enhancing Power System Reliability," This paper discusses various aspects of unified power flow controller (UPFC) control modes and settings and evaluates their impacts on the power system reliability. UPFC is the most versatile flexible ac transmission system device ever applied to improve the power system operation and delivery. It can control various power system parameters, such as bus voltages and line flows. The impact of UPFC control modes and settings on the power system reliability has not been addressed sufficiently yet. A power injection model is used to represent UPFC and a comprehensive method is proposed to select the optimal UPFC control mode and settings. The proposed method applies the results of a contingency screening study to estimate the remedial action cost (RAC) associated with control modes and settings and finds the optimal control for improving the system reliability by solving a mixed-integer nonlinear optimization problem. The proposed method is applied to a test system in this paper and the UPFC performance is analyzed in detail.

H. Fujita, Y. Watanabe and H. Akagi, "Control and analysis of a unified power flow controller [4] observed that thepaper presents a control scheme and comprehensive analysis for a unified power flow controller (UPFC) on the basis of theory, computer simulation and experiment. This developed theoretical analysis reveals that a conventional power feedback control scheme makes the UPFC induce power fluctuation in transient states. The conventional control scheme cannot attenuate the power fluctuation, and so the time constant of damping is independent of active and reactive power feedback gains integrated in its control circuit. This paper proposes an advanced control scheme which has the function of successfully damping out the power fluctuation. A UPFC rated at 10 kVA is designed and constructed, which is a combination of a series device consisting of three single-phase pulse-width modulation (PWM) converters and a shunt device consisting of a three-phase diode rectifier. Although the dynamics of the shunt device are not included, it is possible to confirm and demonstrate the performance of the series device. Experimental results agree well with both analytical and simulated results and show viability and effectiveness of the proposed control scheme.

L. Liu, P. Zhu, Y. Kang and J. Chen, "Power-Flow Control Performance Analysis of a Unified Power-Flow Controller in a Novel Control Scheme [5]," In this paper, real, reactive power, and voltage balance of the unified power-flow control (UPFC) system is analyzed. Two important results related to UPFC control are shown in this paper. First, the shunt converter provides all of the required reactive power during the power-flow changes if the UPFC bus voltage is constant. Second, the UPFC bus voltage can be controlled both from the sending side and from the receiving side. Based on the analysis, a novel coordination controller is proposed for the UPFC. The basic control strategy is such that the shunt converter controls the transmission-line reactive power flow and the dc-link voltage. The series converter controls the transmission-line real power flow and the UPFC bus voltage. The real/reactive power coordination controllers in the UPFC control system can obtain good performance both during transient and stable conditions. Experimental works have been conducted to verify the effectiveness of the proposed controlstrategy.

IV. PROBLEM DESCRIPTION

The existing research paper presents the operation and analysis for an improved T-shape transformer less UPFC. The existing system is not steady state and not a dynamic model. Furthermore, its converter rating has been compared with original transformer-less UPFC. The improved transformer-less TUPFC has the following features:

1) Same hardware requirement and more control freedom make a system complicated.

2) Our proposed methodology is to reduce shunt current rating and reduced total converter rating compared to original transformer-less UPFC.

V. CONCLUSION

This research paperdeals with the FACTS device known as the Unified Power Flow Controller that is used to maintain and improve power system operation and stability. It presents UPFC steady-state, dynamic and linearized models, algorithm for interfacing the UPFC with the power network and UPFC basic and damping controller design.

To demonstrate various advantages of having the UPFC in the power system two-areafour-generator test system was simulated using the Power System Toolbox (PST). Since PST does not come with the UPFC included the software was modified in order to incorporate the proposed tools. The main advantage of the PST over other simulation packages is that its open frame allows new device models to be included simply by inserting a few new functions within the existing steady-state, transient stability and small signal analysis programs. Further on, conventional as well as intelligent control schemes can be applied easily. The tradeoff is the simulation time. The simulation time is function of the number of the time steps. Adding the new devices and increasing the system size increases the simulation time leading to the quite time consuming simulations.

REFRENCES

[1]. Fang ZhengPeng, Shao Zhang, Shuitao Yang, D. Gunasekaran and U. Kark

[2]. L. Gyugyi, C. D. Schauder, S. L. Williams, T. R. Rietman, D. R. Torgerson and A. Edris

[3]. A. Rajabi-Ghahnavieh, M. Fotuhi-Firuzabad, M. Shahidehpour and R. Feuillet,

[4]. H. Fujita, Y. Watanabe and H. Akagi, "Control and analysis of a unified power flow controller

[5]. L. Liu, P. Zhu, Y. Kang and J. Chen, "Power-Flow Control Performance Analysis of a Unified Power-Flow Controller in a Novel Control Scheme

[6]. S.Kannan, S.Jayaram, and M.M.A.Salama,"Real and reactive power coordination for a unified power flow controller," IEEE Transactions on Power Systems, vol. 19, pp. 1454-1461, 2004.

[7]. F.Z.Peng,J.S .Lai,J.W .McKeever, and J.Van Covering, "A multilevel voltage-source inverter with separate DC sources for static V AR generation ,"IEEE Transactions on Industry Applications, vol.32,pp. 1130-1138, 1996.

[8] P. K. Dash, S. Mishra, and G. Panda “Damping multimodal power system oscillation using a hybrid fuzzy controller for series connected FACTS devices,” IEEE Trans. Power System, vol. 15, pp. 1360–1366, Nov. 2000.

[9] Y. Morioka, Y. Mishima, and Y. Nakachi, “Implementation of unified power flow controller and verification of transmission capability improvement,” IEEE Trans. Power System, vol. 14, pp. 575–581, May 1999.

[10] Narain G.Hingorani, Laszlo Gyugyi “Understanding FACTS: concepts and technology of flexible AC transmission systems”, IEEE Press,2000.