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Review on Design and Simulation of UPFC Power System Fact Device Grid with Power Quality Improvement

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Abstract- In these paper, we discuss and study about the placement of one of the most versatile flexible alternating current transmission system (FACTS) device which is unified power flow controller (UPFC). By using unified power flow controller we can control all power system parameters individually or simultaneously. But without placing these device in its critical position it is impossible to get a better power flow improvement. The purpose of this paper is to present a comprehensive survey of UPFC controller incorporated in load flow analysis for optimal power flow control. We also discuss different optimization techniques for the optimal placement.

Index Terms- FACTs, optimization, UPFC, Versatile, TTC.

I. INTRODUCTION

The major task of transmission lines is to transmit large amount of electrical power. Less transmission capacity necessitate installation of more generating stations. In view of the fact that the electrical energy cannot be reserved in large amount, there is a need to balance the demand and generation of this power. The supply voltage and frequency values will be reduced, if the production is a lesser amount than the demand. This reduction in voltage or frequency values degrades the quality of electric power. The Available Transfer Capability [ATC] is limited by complications in erection of new transmission lines and the line losses. Biological and monetary considerations limit the erection of new generating stations. Hence interconnection of transmission lines is compulsory to minimize per unit cost of electrical power.

In early days electrical equipment's was designed in such a way to withstand different types of disturbances such as causes of lightning, short circuits problem, and sudden overloading without extra expenditure. But these devices are replaced by power electronic devices and the prices of these devices are much higher if the equipment was designed using these power electronic devices with the same robustness [1,2].

Power electronics is a fast switches but have nonlinear in nature and creates more problems in power system [3, 4, 5].

A huge variation like a large raise or reduction in the load, disconnection of generators, short circuit faults in transmission system will cause instability and insecurity in interconnected power system. The potential to manage the state of balance under normal and disturbed condition is a measure of strength of power system and the instantaneous testing of performance of subsequent interruption is named as transient stability examination. The review of stability is a compulsory implement in power system organization, utility and arrangement. As the existing transmission lines are required to work near to their upper limit, the stability of the power system decreases during dynamic fault conditions. During dynamic fault condition, the voltage, current and frequency of the power system may deviate from the desired limits which worsen the quality of power. The loads which make use of semiconductors have turned into more delicate to deviation in the quality of power. It is common experience that electric power of poor quality has detrimental effects on the performance and life of different equipments and systems. Furthermore, this creates instability, discontinuity and unreliability of electric supply. In this situation, quality assurance of electric power has become more important and it demands a profound research and study on the analysis of "Electric Power Quality".

To improve the power quality the power conditioners and power compensators are playing a vital role [1]. H. Akagi defined the power conditioning as reduction, elimination or isolation of harmonics, power flow control, reactive power control, power factor correction, voltage regulation and/or their combination [1]. With the increasing difficulty in power systems and the necessity to provide steady, secure, controlled, economic and high-quality electric power, the Flexible AC Transmission System (FACTS) controllers are playing significant responsibility in power transmission systems [2]. FACTS devices improve the stability of the power system together with its dynamic control characteristics and regular compensating potential. The major aim of FACTS technology is to manage power flow and to enlarge the transmitting capacity over an active transmission environment. FACTS refer to structures with power electronic devices such as the Static Compensator (STATCOM), Static Synchronous Series Capacitor (SSSC), Thyristor Controlled Series Capacitor (TCSC) and phase angle shifter.

II. CONVENTIONAL POWER FLOW CONTROLLERS

In order to control the real and reactive powers on the lines traditionally the following methods were adopted. They are

- Automatic Generation Control
- Excitation control
- Transformer Tap-changing Control
- Phase shifting transformers

1. Automatic Generation Control

Conventionally the generator output power is changed by controlling the steam/water input to the turbine. Whenever there is a mismatch between the generation and demand, the speed governing system senses the change in the speed of the generator and adjusts the mechanical torque to bring the power system to the balanced position. This process includes more number of amplifiers and mechanical system.

2. Excitation Control

The main object of this method is to vary the exciter voltage to control the field current, which further changes the generator output voltage. Such operation is also termed as automatic voltage regulation. A power system stabilizer (PSS) is designed by adding auxiliary damping signals which are obtained from shaft speed or terminal frequency.

3. Transformer Tap-Changing Control

In this method the designed output voltage can be achieved by charging tap position of on-load or off-load tap changing transformer. These are normally used for obtaining voltage profile. Since transformer tap-changers vary the voltage values, these may be used as reactive power control devices. Generally their operating speed is very low and is affected by wear and tear.

4. Phase Shifting Transformers

Three phase transformers whose secondary sides are connected in series with the line, injects a voltage which is in phase quadrature with the phase voltages of the system. Hence the resultant voltages will be shifted in phase. Hence phase shifting transformers results in a phase shift without an appreciable change in the voltage magnitudes. Therefore these are used to mitigate circulating power flows in interconnected systems. The variation of voltage magnitudes and/or their phase by injecting a controllable voltage in series has given a basis to FACTS devices.

III. FLEXIBLE AC TRANSMISSION SYSTEM DEVICES

The development in power electronic based controllers enhanced the controllability of power systems. FACTS are the one of the best solutions to solve the problem in the limitations of constructing new transmission lines and to meet the increased demand of electric power. The key objective of FACTS is to enhance the power transfer thermal and limit capability of existing transmission lines near the thermal limit and to effectively control the power flows in the selected corridors [4].

1. Static Series Compensation

The very objective of series compensator is to reduce the effective impedance of the line by adding suitable capacitive reactance in series with the line.

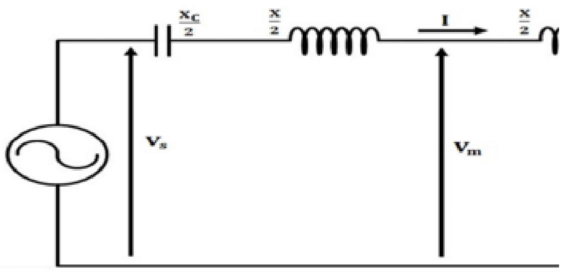

Fig 1: Two machine system with series capacitive compensation

2. Combined Shunt and Series Compensators

To reduce the line reactance and to control the bus voltage simultaneously both the series and shunt compensators are used in the system. In that case shunt compensator injects suitable current in the line and a series compensator injects appropriate voltage in series with the bus voltage. It consists of two power electronic based converters which are coupled each other with a dc capacitor. The real power drawn or absorbed by the series compensator is supplied from the capacitor and is balanced by the shunt compensator. In other terms, the real power required by the series converter is supplied or absorbed by the shunt converter. These converters exchange only real power between them, where as the reactive power can be controlled independently by them. There are basically two types of series-shunt compensators. They are Unified Power Flow Controller(UPFC) and Unified Power Quality Conditioner(UPQC). The main objective of UPFC is to control power flows and voltage regulation whereas UPQC is to generate harmonic currents near the loads. The UPFC is used generally in transmission system and UPQC is used near the distribution system.

3. Unified Power Flow Controller

In order to control all the trapnsmission line elements all together or individually, then UPFC is preferred. The UPFC

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consists of the features of shunt, series compensation devices and phase angle regulator. Hence UPFC not only controls real and reactive powers but also controls the bus voltage. Because of its controlling ability it can be used for improving both dynamic and steady state performance of the power system. By injection of required voltage in series with the bus voltage in either direction, it can absorb or supply real and reactive powers through the lines. Hence UPFC can be used for power flow control, bus voltage control, to increase the transmission capacity of the existing lines, improving stability margin etc.

IV. BASIC PRINCIPLE OF UPFC

UPFC consists of two power electronic voltage source converters linked mutually with a common dc link. To provide electrical isolation and to match the line and inverter voltages, two transformers are necessary. One of the transformers is coupled in series with the line and the other is coupled in parallel with the line.

The main purpose of UPFC is to not only manage the power flow on a specified transmission line but also to maintain constant bus voltage at point of common coupling (PCC). This can be achieved by injecting a controlled voltage in series with the transmission line voltage. The magnitude and phase angle of the newly introduced voltage can be changed simultaneously or separately. The series connected converter acts as a controllable voltage source and the shunt connecter converter acts as a controllable current source as shown in figure 2.

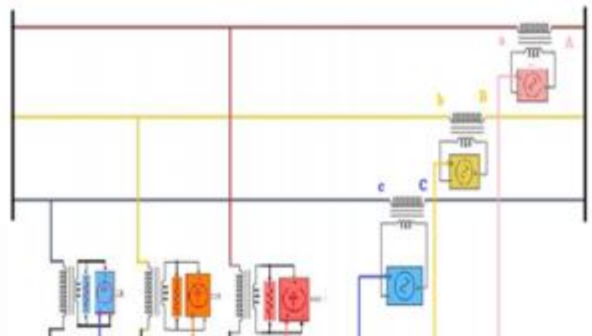

Fig 2: Equivalent circuit of UPFC

The converter which is connected in series with the line can generate a voltage which is adjustable in magnitude and phase. The real and reactive powers through the line can be varied by controlling this series injected voltage.

The real power required by the series converter is supplied or absorbed by the shunt converter through dc link. Besides this, the shunt converter can take up or provide reactive power autonomously.

V. RESEARCH MOTIVATION

Power disturbances are the main sources for decreasing the power transfer capability from source to load. The disturbances such as line to ground (LG), line to line (LL), double line to ground (LLG), triple line (LLL), triple line to ground (LLLG) faults, not only drive the power system into inconsistency state but also deviates the sinusoidal nature of the voltage profile. This in turn causes power flow problems. The external or internal disturbances in power system also cause transient instability, over voltages, under voltages, harmonics and so on. Therefore, there is every possibility of network breakdown unless the consequential effects of power disturbances are identified and minimized. Thus study and analysis of power flow and its conditioning plays a very significant role to transmit power from source to load with its estimated capacity. FACTS devices are the most suitable controllers to improve the power transfer capability and control the power flows by employing appropriate control strategies during disturbances. The regulating approach must take care of dynamic variations of transmission line parameters namely voltage, impedance and phase angle for superior transmission system management through improved transient power system constancy.

There are two distinctly different approaches to realize the controllers of FACTS devices which aim to address targeted transmission system compensation and control problem. In Static VAr Compensator (SVC) and TCSC, the capability to generate reactive power and exchange of real power are separated. If these are employed for reactive power adjustment they are incompetent to swap over real power with ac system. To exchange real power, if SVC and TCSC are utilized, these are unable to supply reactive power to the system. In case of STATCOM, SSSC controllers have inherent capability of handling exchange of both real and reactive powers with ac system without ac capacitors or reactors. Here the real and reactive power regulating methods are reliant.

VI. LITERATURE REVIEW

Deepro Sen et al. [1] A unified power flow controller (UPFC) is a versatile compensator providing multi-variable control for the critical power systems (CPS). In an attempt to reduce the search space for optimal allocation of UPFC thereby standardizing the deliberation over UPFC placement, zone-wise segregation of the network into weak and healthy zones is logically executed by an advanced network power stability indicator (NPSI). The UPFC performance is ascertained by a new line flow margin index (LFMI), power loss index and its economic benefit. The latter is derived by the cash outflow reduction (COR) and the internal rate of return (IRR), calculated by practical aspects like installation and maintenance cost, considering inflation and interest on amortization. For optimization, an improved version of the wind-driven optimization algorithm is proposed with finite-mass air parcels and intra-particle forces.

Sudhir Sharma et al. [2] The most critical feature of current energy management systems is ORPD, which is used to maintain safe and reliable working conditions for power networks. Currently, due to their economic and technological advantages, HVDC transmission systems are commonly used in modern electrical power systems. The incorporation of DC link introduces more complexity in ORPD computation. Therefore, an attempt is made to optimally place and size the UPFC. In the transmission network, the UPFC is an efficient multi-purpose FACTS controller for handling the reactive as well as the physical power individually in a rapid manner.

VII. CONCLUSION

Using various techniques, optimal allocation of UPFC can be done to enhance stability of power system. Some of the applications of the UPFC are as under

- Improving the active and reactive control power flow of the power systems / optimal power flow control.
- Increasing the transient stability, Increasing the damping of oscillations.
- Controlling the steady state or dynamic performance.
- Optimizing power flow / minimization of power loss
- Minimizing the operational costs of the electrical grid.
- Enhancement of system load ability / transmission capability
- Enhancement of voltage profile It is also found from the case study that the UPFC is more effective for improving power system stability as compared to other FACTS devices.

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