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Design and simulation of a different innovation controller-based UPFC (unified power flow controller) for the enhancement of power quality

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ABSTRACT

The UPFC (unified power flow controller) is one of the modern power electronics devices that can be used for the control of real and reactive power in a transmission line. The UPFC uses VSC (voltage sourced converter) technology to inject a series voltage with the sending end ac source to achieve its control objective with high speed, making it suitable for maintaining the voltage and mechanical stability of a network. There are frequent disturbances in a power system due to its dynamic nature. These disturbances must be controlled so that they cannot lead the system to an unsteady condition. Recently developed FACTS (flexible alternating current transmission system) provide steadfast solutions to avert these issues in power quality. Due to the improvements in these solutions, some critical issues have been come to sight pertaining to power quality, dependability and permanence. The most effective and potential technologies among recently developed FACTS devices are STATCOM (static synchronous compensator) and UPFC (unified power flow controller) that can significantly enhance the operations of power systems and associated power quality problems. In order to control entire flow of load and voltage sags/flickers; while eliminating harmonics simultaneously, this paper presents an inventive systematic approach on the basis of optimal control and tracking with a PI (proportional integral) controller, the desired steady state behavior, and a linear quadratic tracker. Moreover, a MATLAB/Simulink model is also established in the paper for the UPFC in the environment of Simulink, once its principles are analyzed. After monitoring the simulation results, it was concluded that UPFC based controller systems can efficiently manage the load flow and voltage sags/flickers. Test results using different power system models are presented throughout the thesis to illustrate the effectiveness of Unified Power Flow Controller.

1. Introduction

Disturbances in power quality is derived from multiple factors including arcing devices, sensitive equipment, damage related to environment, large motor starting, power electronic devices, embedded generation, network design and equipment's, etc. Developing the energy quality (power quality) is very significant especially when the production routes become complex and require accountability for the purpose of providing energy devoid of interruption and for harmonic deformation with tension regulation amid thin boundaries. Thus, several developing countries having greater interconnected networks are sharing generation reserves for the purpose of relying more on the power system. On the other hand, the growing complications on large interconnected networks have caused instabilities and decreased the dependability of the power supply, system fluxes, and power flow, and safekeeping issues have caused many blackouts in various places in the world. These issues and concerns are mainly caused by systematic errors in planning and operation, excess load on the network, frail interconnections on the power system, or maintenance deficiencies. The solution to these issues to grant the preferred power flow with system stability and dependability is to install and set up new transmission lines.

Nevertheless, installing new transmission lines has obstacles, such as environmental problems and financial cost. Because of these concerns, power engineers try to find a method so that the power flow can be increased using current transmission lines devoid of any decline in stability and security of the system. There are various definitions and meanings for the word power quality. First of all, at the generator, the ability to produce power specifically

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at 50 and 60 Hz provided a few amount of variation is defined as power quality. While at the distribution and transmission level, power quality is the outstanding voltage contained by a range of plus or minus five percent. According to Ref. [33] in "Electric Power Quality", it can be defined as the measure, evaluation, and enhancement of bus voltage, generally a load bus voltage, in order to preserve that voltage to be sinusoidal at rated voltage and frequency [32]. Moreover, power quality can be determined not only by the supplier but also by the user's consumption of electricity. As electrical and electronic equipment such as computers and speed drives are more developed and advanced, a decrease in power quality will occur, which will cause the industrial and commercial consumer to waste time and money [32,33].

Consequently, the control strategy that has been espoused for these devices and the extent of input signals so as to damp power oscillations in an effectual, professional and vigorous manner is a vital question here. In order to accomplish improved utilization of the transient constancy and damping of the power system by UPFC devices; discontinuous control or speed-based BBC (Bang–Bang Control) is adopted [23]. Lately, it has been understood that the BBC (Bang–Bang Control) has various drawbacks; hence, it cannot be the full area of deceleration when balancing the area of acceleration; thus, this control method makes the most of the area of deceleration required to counterbalance the area of acceleration subsequent to greater disturbances, thus providing a smaller stability limit [23]. Furthermore, the transient stability limit can be greatly enhanced with a mixture of control and discontinuous control techniques that reference [24] has shown lately and proven. First, in discontinuous mode, the overshoot of subsequent peaks and settling times can be decreased; therefore, the devices based on FACTS (flexible alternating current transmission system) technology are mostly based on the concepts of power electronics; and have other stagnant controllers to improve the factor of controllability, amplify the power transfer and offer control of a single or additional parameters of AC transmission system as stated by the standards and definition of IEEE [25].

The roving controller performance is determined by choosing the correct and appropriate value of the controller gain. However, in continuous mode, the damping torque given is relative to the controller gain. The proportional controller is normally used [26]. In addition, for the power system dynamic stability to tune the PSS (power system stabilizer) parameters, a diversity of methods have been suggested, such as the damping torque concept, pole placement, different optimizations, artificial intelligence techniques, and variable structure. The potential of these algorithms for ideal designs of PSS has been proven by extremely good results, which were obtained due to the heuristic methods for PSS tuning [26]. Thus, the utilization of PSO (particle swarm optimization) technique has been encouraged in order to improve the gain of controller.

There has been extensive research work done on the UPFC including several research articles published recently; these articles discussed the modeling of UPFC, its analysis, applications and control methods. Moreover, to study the steady state features through state space computations, devoid of taking into account the potential impacts of the converters, and the dynamics of the generator; several mathematical models of UPFC are also developed [6,7]. Hence, this paper provides a comprehensive presentation of UPFC model in practical circumstances; while the paper also discusses the control strategy and transient model of the UPFC. The control system presented in the paper is able to control the voltage flickers/sags; while eliminating the harmonics at the same time. The paper additionally presents a supplementary control system in order to balance the line current. The potential features and efficiency of the control strategy being presented in the paper is demonstrated by the simulation results.

2. Literature review

Although a considerable amount of research has been done in the field of FACTS, very little literature exists with specific reference to UPFC. This is because UPFC is a relatively new FACTS device and power system problems associated with it have not been investigated thoroughly. UPFC has the flexibility to incorporate any operation functionality. For example, as explained, UPFC can be made to operate as a SSSC (static synchronous series compensator) or a phase shifter based on the strategy used. Different control strategies for UPFC and their control systems for power flow control have been discussed.

2.1. Review

Given the integrated nature of the research, the relevant literature review has been divided into two sections. Accordingly, a section on review of control strategy and control systems for UPFC and a section on load flow and dynamic models for UPFC have been presented here.

2.1.1. Review on control strategy and control systems for UPFC

Very little work has been published in the area of UPFC control strategy for power flow control and control system design to achieve the control strategy. Three different types of strategies for real and reactive power flow control have been found in the literature and are described below.

2.1.2. SSSC (static synchronous series compensator strategy)

This strategy is based on injecting the series voltage in quadrature with the transmission line current allowing it to function similar to that of a variable series capacitor. This fixes the phase angle of the series injected voltage to be in quadrature with the transmission line current. By varying the magnitude of the series injected voltage that is in quadrature with the transmission line current, the real power flow can be controlled [13]. The reactive power flow/transmission line side voltage is controlled by adjusting the phase angle of the series injected voltage. This has been achieved by introducing a component of the series injected voltage to be in-phase with the transmission line current [19].

Combining the quadrature component and the in-phase component, the magnitude and phase angle of the series injected voltage are obtained.

Concentrating on simultaneous control of real and reactive power flow/line side voltage using the above described strategy, control systems based on linear control techniques have been used [19]. The control system design based on this strategy requires a supplementary controller to damp out the real power flow oscillations when controlling the transmission line side voltage simultaneously using a high gain PI controller [14,16]. The design of coordination feedback between the series and the shunt inverter control systems has not been considered in the control system design [17,18]. The need for coordination controller comes from the fact that the real power demand of the series inverter has to be supplied by the shunt inverter. If there is no coordination between the series and the shunt inverter operation, the DC link capacitor voltage could collapse leading to the removal of the UPFC from the power system. The strategy also has the problem that if the in-phase injected voltage is out of action, the line side voltage could be very high causing reactive power flow problems. Further the problem of deterioration of the control system performance at operating points other than the one at which it is designed is a point to be considered.