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Research Article

Performance Analysis of Unified Power Flow Controller

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Abstract The unified power flow controller (UPFC) is the most versatile and advanced member of flexible ac transmission systems (FACTS) devices capable of controlling active-reactive power flows, as well as providing voltage magnitude control in power networks. This project presents a study on investigating steady-state analysis of UPFC and its performance on power systems.

Unified Power Flow Controller (UPFC) is the most widely used Flexible acTransmission system (FACTS) device to control the power flow and to optimize the system stability in the transmission line**.** It should be installed to control the voltage, as well as to control the active and reactive power flow through the transmission line.

This project is using MATLAB software to model and to verify the UPFC system in order to improve its performance in power system. MATPOWER in MATLAB software used to run the power flow of IEEE 14 bus power system network.

This research deals with digital simulation of 14-bus power system using UPFC to improve the power quality. The UPFC is also capable of improving transient stability in a power system. It is the most complex power electronic system for controlling the power flow in an electrical power system. The real and reactive powers can be easily controlled in a power system using a UPFC system. The circuit model for UPFC is developed using rectifier and inverter circuits. The control angle is varied to vary the real and reactive powers at the receiving end. The Matlab simulation results are presented to validate the model.

Keywords unified power flow controller, flexible ac transmission systems, MATLAB

1. Introduction

Unified Power Flow Controller (UPFC) is the universal and most flexible FACTS (Flexible ac Transmission System). It is used to control the power flow in the transmission systems by controlling the impedance, voltage magnitude and phase angle.

This device can allow the path of power as we desire. UPFC consist of two Voltage Supply Inverters, one series converter and one shunt converter. This device is actually a combination of two FACTs device which are STATCOM (Static Synchronous Compensator) and SSSC (Static Series Synchronous Compensator). SSSC is used to add controlled voltage magnitude and phase angle in series with the line, while shunt converter STATCOM is used to provide reactive power to the ac system, besides that, it will provide the dc power required for both inverter [1]. The reactive power can be compensated either by improving the receiving voltage or by reducing the line reactance.

The fact that the demand for electrical energy has continued to grow in many countries has necessitated construction of new power stations and transmission systems. But a number of factors such as environment and cost considerations continuously delay such expansions. This situation urges more interest in providing already existing power systems with greater operational flexibility and better utilization. FACTS technology, which has been developed for less than a decade, offers flexibility and utilization which have the capability of making transmission and distribution of electricity both more reliable and more controllable [2].

2. Review of Related Works

The power-transfer capability of long transmission lines are usually limited by large signals ability. Economic factors, such as the high cost of long lines and revenue from the delivery of additional power, give strong incentives to explore all economically and technically feasible means of raising the stability limit. On the other hand, the development of effective ways to use transmission systems at their maximum thermal capability has caught much research attention in recent years. Fast progression in the field of power electronics has already started to influence the power industry. This is one direct outcome of the concept of Flexible AC Transmission Systems (FACTS) aspects, which has become feasible due to the improvement realized in power-electronic devices. In principle, the FACTS devices could provide fast control of active and reactive power through a transmission line. The Unified Power-Flow Controller (UPFC) is a member of the FACTS family with very attractive features. This device can independently control many parameters, so it is the combination of the properties of a Static Synchronous Compensator (STATCOM) and Static Synchronous Series Compensator (SSSC) [3].

These devices offer an alternative mean to mitigate power system oscillations. Thus, an important question is the selection of the input signals and the adopted control strategy for these devices in order to damp power oscillations in an effective and robust manner. Much research in this domain has been realized [4].

2.1. Unified Power Flow Controller (UPFC)

The cost of losing synchronous through a transient instability is extremely high in modern power systems. Consequently, utility engineers often perform a large number of stability studies in order to avoid this problem. A unified power flow controller (UPFC) is the most promising device in the FACTS concept [5]. It has the ability to adjust the three control parameters such as the bus voltage, transmission line reactance, and phase angle between two buses, either simultaneously or independently. A UPFC performs this through the control of the in-phase voltage, quadrature voltage, and shunt compensation. UPFC can control the three control parameters either individually or in appropriate combinations at its series-connected output while maintaining reactive power support at its shunt-connected input. The mechanism of the three control methods of a UPFC in enhancing power system damping. It was shown that a significant reduction in the transient swing can be obtained by using a simple proportional feedback of machine rotor angle deviation. It is generally accepted that the addition of a supplementary controller to the UPFC can significantly enhance power system damping [6].

3. Methodology

3.1. Algorithm for optimal rating of the UPFC

Operation of the UPFC demands proper power rating of the series and shunt branches. The rating should enable the UPFC carrying out predefined power flow objective. The flow chart of Figure 1 shows algorithm for UPFC rating. The algorithm starts with definition of the series transformer short circuit reactance, xk, and the system base power, SB. Then, the initial estimation is given for the series converter rating power, SS, and the maximum magnitude of the injected series voltage, rmax. The effective reactance of the UPFC seen from the terminals of the series transformer, (xS), can be determined in the next step.

Load flows are computed changing the angle between 00 and 3600 in steps of 100, with the magnitude r kept at its maximum value rmax. Such rotational change of the UPFC parameter influences active and reactive power flows in the system. The largest impact is given to the power owing though the line with UPFC installed. Therefore, the regulation of the active and reactive power flow through the series branch of the UPFC could be set as initial pre-defined objective to be achieved within the UPFC steady state operation. Then, the load flow procedure is performed to check whether the predefined objective is achieved with satisfactory estimated parameters. If the load flow requirements are not satisfied at any operating points, it is necessary to go back in the algorithm, estimate again SS and rmax, and perform new rotational change of the UPFC within the load flow procedure. This loop is performed until the load flow requirements are completely fulfilled. When the power SS

is minimized, the load flow procedure is performed with smaller step of rotational change of the angle, in order to get maxi-mum absolute value of the series/shunt converter active power, max jPconv1j.
The value given by max jPconv1j is considered to be minimum criterion for dimensioning shunt converter rating power, whereas the power SS represents series converter rating power as a function of the maximum magnitude rmax.

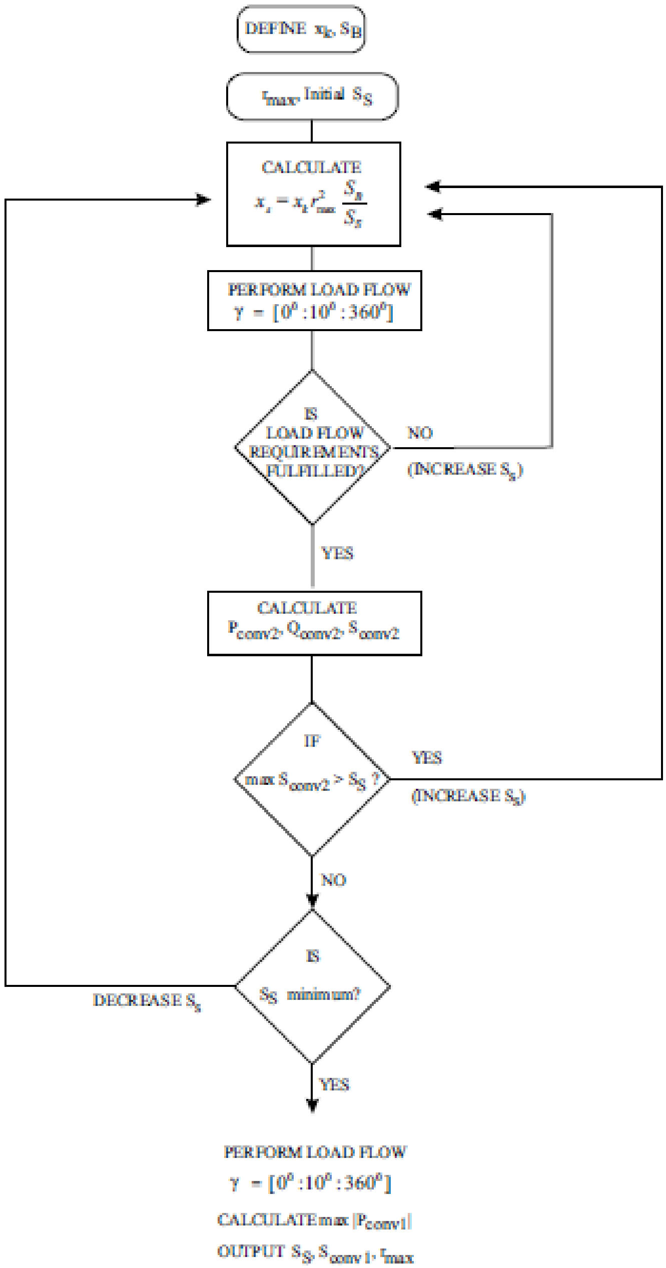

Figure 1: Algorithm for optimal rating of the UPFC

In addition, the active, reactive and apparent power of the series converter are calculated for each step change in the angle .With the load flow requirements fulfilled and the series converter powers calculated, it has to be checked whether the maximum value of the series converter apparent power max Sconv2, is larger than initially estimated power Ss. If max Sconv2 is not larger than the power SS, it is necessary to check whether the power SS is at an acceptable minimum level. If not, the value of SS is reduced and the loop starts again. The acceptable minimum is achieved when two consecutive iterations do not differ more than the pre-established tolerance.

3.2. Materials and Methods

A simplified scheme of a UPFC connected to an infinite bus via a transmission line is shown in Fig 2. The UPFC consists of a parallel and series branches, each one containing a transformer, power-electric converter with turn-off capable semiconductor devices and DC circuit.

Inverter 2 is connected in series with the transmission line by series transformer. The real and reactive power flows in the transmission line can be quickly regulated by changing the magnitude (Vb) and phase angle (*b) of the injected voltage produced by inverter 2. The basic function of inverter 1 is to supply the real power demanded by inverter 2 through the common DC link. Inverter 1 can also generate or absorb controllable power [7]. New method for improving transient stability is given by Saadate [8]. Application of UPFC is given by Huang (2000) [9]. Enhancement of transient stability using Fuzzy control is given by Schoder *et al*. (2000) [10]. Comparison of field results and simulation results of VSI based FACTS converter is given by Sen and Keri (2003) [11].

The current through the DC link is as follows:

DC current = (VR –Vi) / R (1)

VR = 1.35 VS cosα (2)

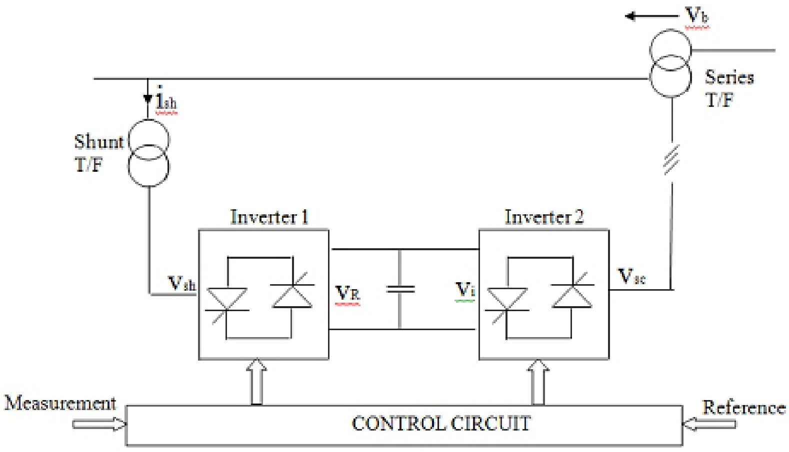

Figure 2: UPFC installed in transmission line

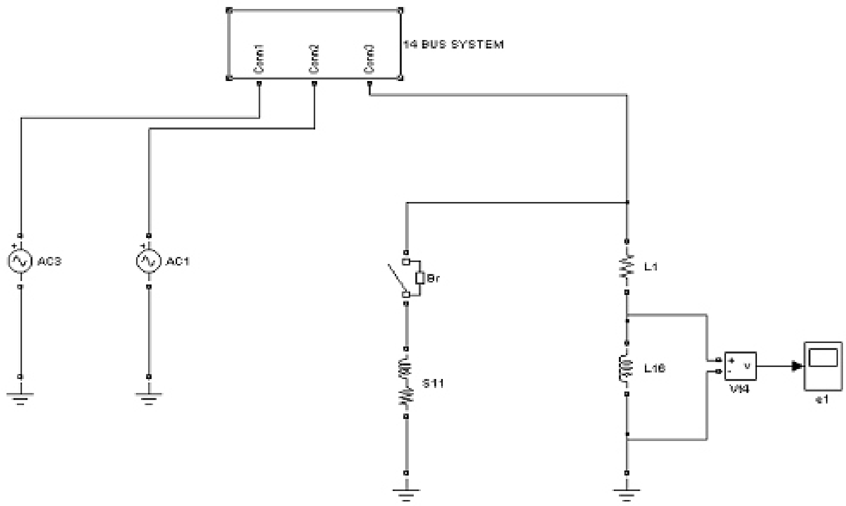

Figure 3: 14 bus system using UPFC

Where; VR – output of the rectifier

Vi– input to the inverter

3.3. Simulink Model

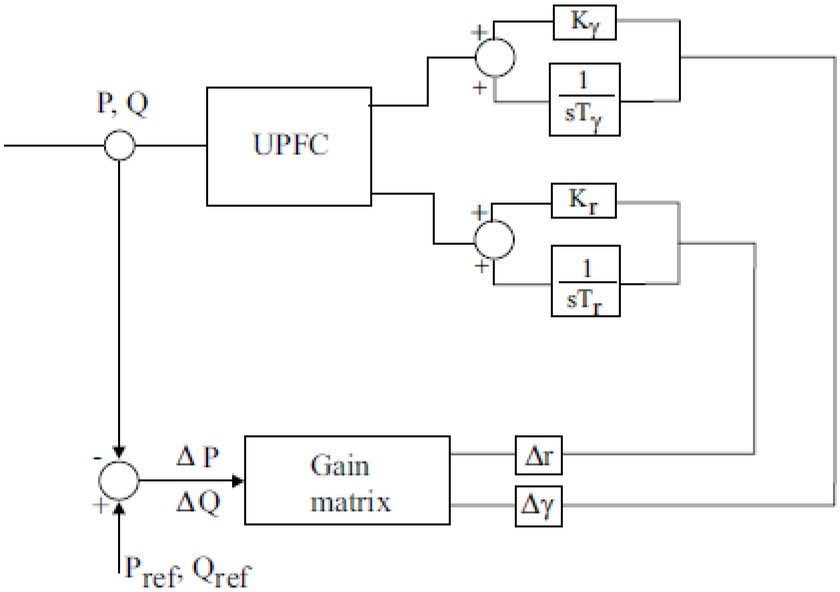

Figure 4: General form of the UPFC control system

3.4. Design and Working Operation of Unified Power Flow Control

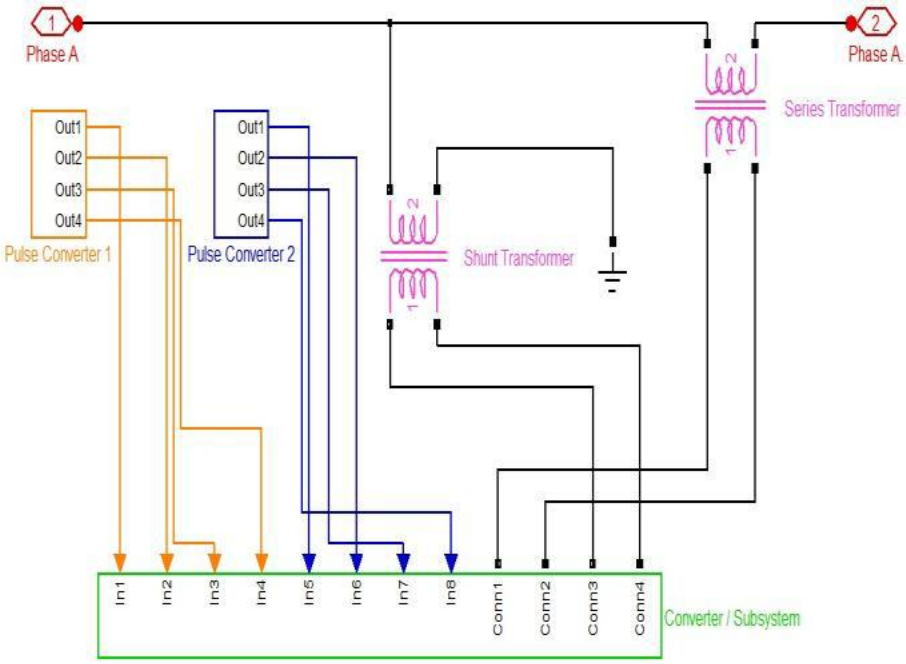

Figure 5: Unified Power Flow Diagram

The components of UPFC are two voltage source converters sharing a common DC storage capacitor and connected to the power system through coupling transformers. DC link creates path for active power exchange between the converters. In unified power flow controller the transmitted power can be controlled by changing three parameters, they are as follows:

1. Transmission magnitude voltage
2. Impedance
3. Phase angle

The unified power flow controller is the most gifted version of FACTS devices and it serves to control simultaneously all the above three parameters [voltage, impedance and phase angle] at the same time. The Phase [A] design of UPFC [Unified power flow controller] is shown in figure.3.5.Voltage source converter 1 connected in shunt through shunt transformer. The shunt inverter operates as a STATCOM and generates or absorbs reactive power to regulate voltage magnitude at connection point. Voltage source converter 2 connected in series through series transformer and generates or absorbs reactive power to regulate current flow. UPFC can also provide simultaneous control of all basic power system parameters through transmission voltage, impedance and phase angle.

3.5. Procedure to Build Up a Unified Power Controller test System

Step 1: Design a Test system and create three phase faults near infinite bus as shown in figure 6

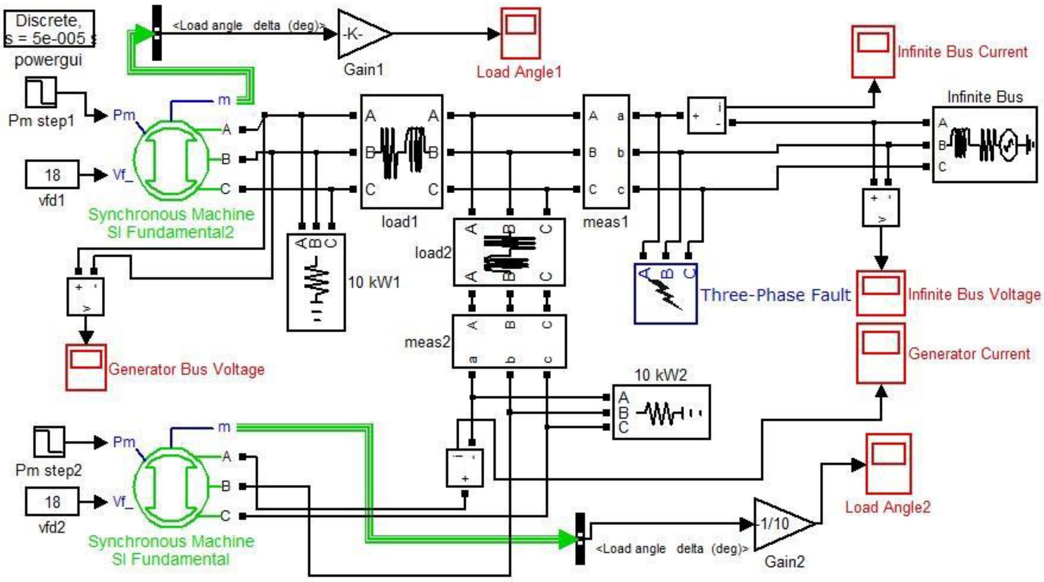

Figure 6: Three Phase Fault

Step 2: Measure the generator voltage, generator current, Bus voltage, Bus current and generator load angle.

Step 3: Design a Thyristor controlled series compensation and connect to the test system as the resulting model is shown in figure 3.7

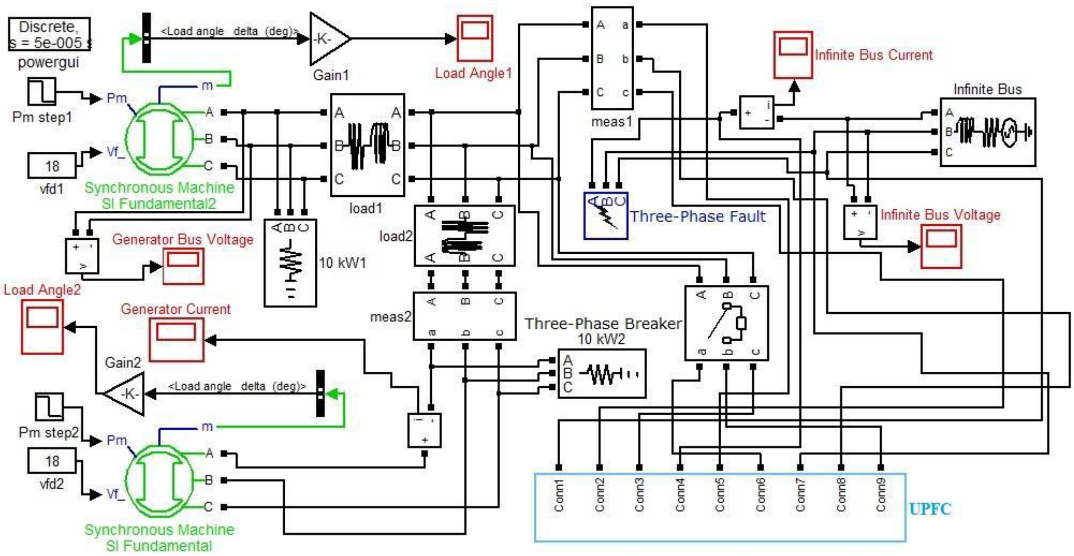

Figure 7: Thyristor controlled series compensation with a test system

Step 4: Measure the generator voltage, generator current, Bus voltage, Bus current and generator load angle.

Step 5: Compare both the result of test system as shown in table.1

4. Conclusion

This research shows that UPFC is an effective device to improve the power quality. The UPFC parameters can be controlled in order to achieve the maximal desired effect in solving first swing stability problem. This problem appears for bulky power systems with long transmission lines.

UPFC should be installed to control the voltage, as well as to control the active and reactive power flow through the transmission line. However, the right transmission line to be injected by UPFC and the effect of injection will only know by doing the analysis using MATLAB software.

Thus, this project presents the active and reactive power control through a transmission line by placing the UPFC using computer simulation. MATLAB program are used to model and to verify the performance of UPFC in order to increase the ability of the system.

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