Performance Analysis for Control of A Unified Power Flow Controller (UPFC) Using MATLAB Simulink

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Abstract: The long transmission system is required to transfer generated power to distribution system. Hence, maximum power transfer devices with flexible operation are essential in transmission system. Thus, it is necessary to add Flexible AC Transmission System (FACTS) devices at the proper locations. Unified Power Flow Controller (UPFC) is the best FACTS transmission system device for ensuring adequate power flow between generating and distribution via transmission lines. The UPFC consists of two converters which likely to work as STATCOM and SSSC to make a proper power flow. In this paper modeling and analysis of UPFC is presented under platform of MATLAB/Simulink. Extensive responses are incorporated in results section with proper analysis under various operating conditions.

Keywords: FACTS, UPFC, Power Flow, STATCOM, SSSC, DQ Theory.

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1. INTRODUCTION

A long Alternating Current (AC) transmission system is required to transmit electrical power between generation units and distribution system. A Flexible AC Transmission System (FACTS) device should be installed at the proper position due to the lengthy power transmission to increase the efficiency and effectiveness of the system.[1-3]. In order to control the shunt and series impedances, load angle, maximum power etc, a power electronic devices with proper control methods needs to me included in FACTS devices. These restrictions cannot be otherwise overcome while preserving the necessary system stability. FACTS controllers can enable a line to transport power closer to its thermal rating by demonstrating increased flexibility. VAR compensations must be achieved using power electronics with the appropriate controlling mechanisms. [4-6]. The VAR parameters such are voltage, impedance, phase angle etc can be determine the flexible power flow. The voltage can be regulated at its reference so that VAR compensation can be done at any instant. Generally VAR compensation will perform similar to static synchronous condenser which is realistic equaling circuit technically. Generally gate turn-off thyristors(GTO) are using in VAR compensating devices to achieve variable operating conditions effectively. The unified power flow controller (UPFC), among other FACTS devices, is one of the finest for achieving proper power flow with minimal losses [5-7].
The UPFCis designed by connecting two Voltage Source (VS) converters which are operating with power electronic switches [8-11]. A shared DC-link connects these two VS converters. As a result, power regulation can be done for real power as well as reactive power. Real power can be handled by regulating voltage at dc-link while the voltage can be changed by regulating reactive power. This arrangement makes the system a perfect AC-AC conversion system where the easy flow of real power is achievable.

The major goal of this research is to use the MATLAB/SIMULINK modelling platform to create an efficient control approach for UPFC. As a result, a detailed analysis with corroborating findings is offered at the end of the publication. The following characteristics are generally preferred for UPFC control strategies:

1. The objectives related to flow of reactive and real power in the transmission system. Which are called as steady state objectives?
2. By changing or adjusting modulation index of the controllers, a transient and dynamic stability can be improved.

The designing procedure of series and shunt compensators are included in designing aspects of UPFC. Each time, the external system is represented by a straightforward equivalent circuit. In MATLAB, the full model of the UPFC can be created by merging several subsystems. Figure 1 shows the model schematic of the UPFC with two converters.

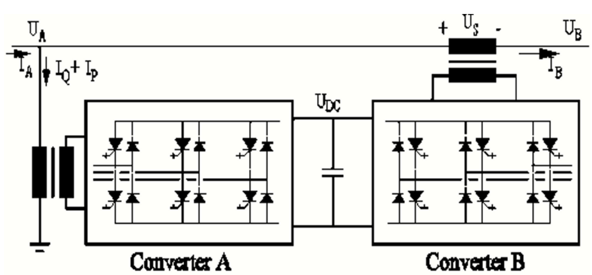

Fig. 1: Model of UPFC

The report of the work done is or gained as follows: a brief explanation of circuit arrangement of UPFC is discussed in Section-II which is placed after the introduction part. Proposed control strategy in MATLAB is presented in Section-III by using a three-phase to D-Q transformation [1] along with mathematical modeling. The modeling of UPQC using Simulink is provided in Section-IV and results are given in Section-V.

2. UNIFIED POWER FLOW CONTROLLER (UPFC)

In 1991, professor Gyugyi was proposed the concept of UPFC model. A real time control characteristics can be obtained by UPFC device during changes in the system. This UPFC can do the multi objective functions such as adjusting voltage, angle, reactive power compensation, real power transmit etc [1-3]. Generally, UPFC can be able to control the power flow according to requirement which can make maximum utilization. Alternatively, the real and reactive powers can be regulated independently based on requirement. In order to regulate real and reactive power, a three phase to two phase transformation is required. A model representation of a three phase to two phases is given in Fig. 2 which developed in Simulink.

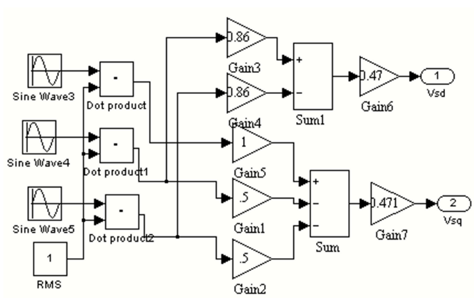

Fig. 2: Basic model of ABC to DQ transformation.

As already stated that UPFC is consists of two VS converters connected by common dc-link. From Fig. 1, one inverter is connected in series and other in parallel. Series can regulate voltage and parallel is able to control current [12-15]. However, both are established a common dc-link, hence the real power won't get any losses; even it can make to flow maximum real power from generation end to distribution end.

3. CONTROL STRATEGY FOR UPFC

The control strategy of the UPFC is divided into two parts, one for regulating DC voltage another is to manage voltage at AC bus. Corresponding MATLAB models of control strategies are depicted in Fig. 3 and Fig. 4 respectively. These two control methods are used to control both the converters. However, a study of the disturbances, distortions, unbalanced nature, dynamic behaviors also observed by making modeling of the UPFC. By vector interpreting the instantaneous values of the circuit variables, the definition of instantaneous reactive voltage is produced.

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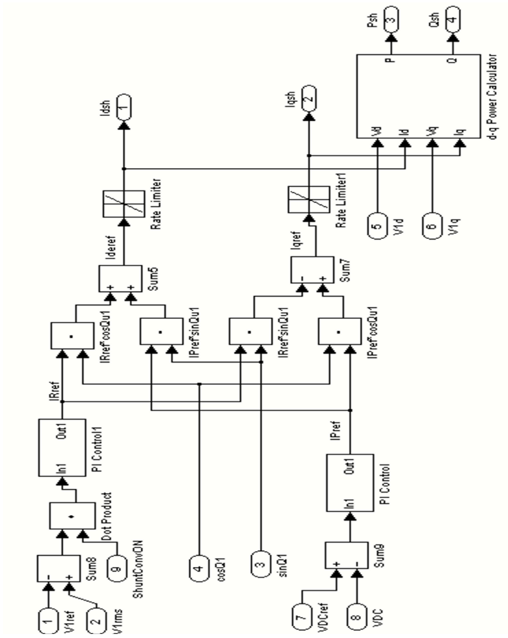


Fig. 3: Control method of VS converter-1 (shunt converter)

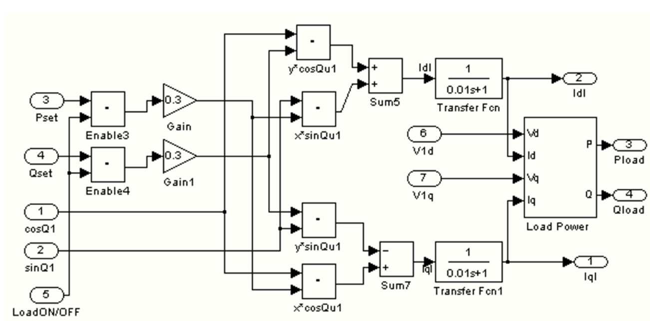


Fig. 4: Control method of VS converter-2 (series)

4. MODELING of UPFC

MATLAB/Simulink library blocks are using to model the UPFC design. The complete control block of proposed UPFC is provided in Fig. 5.

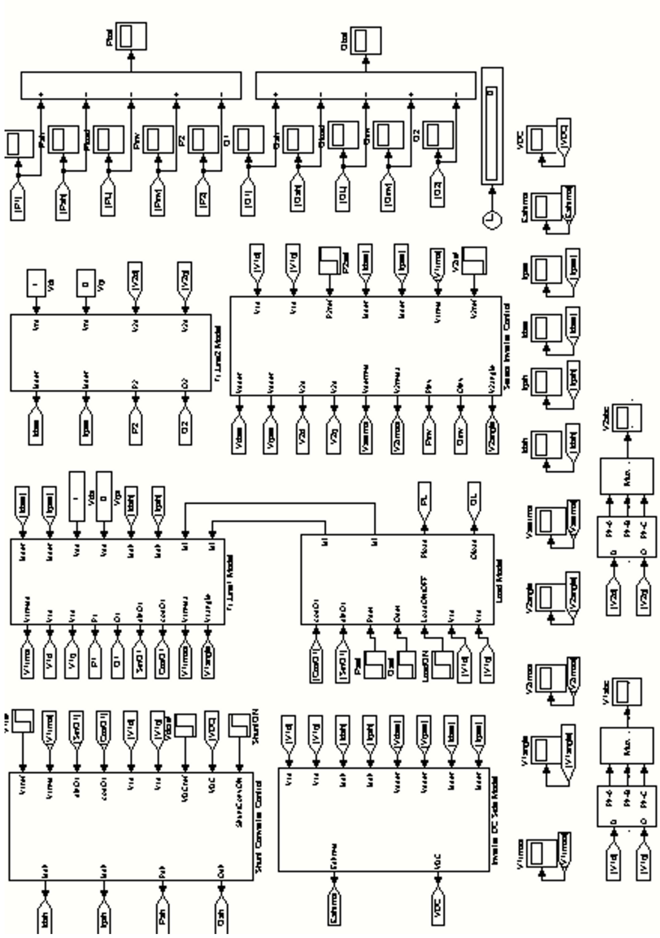


Fig. 5: Matlab Simulink model of UPFC control diagram.

The UPFC's port 1 is subjected to an electrical load. Transforms of d-q components are used to communicate and calculate the necessary actual power. References to real and reactive power serve as the load model's inputs. However, a small delay is employed to the system to achieve realistic responses. Using series converter, required reactive currents are injected to maintain constant voltage at the terminal of UPFC.

5. Results

MATLAB Simulink based results are extracted from various scopes to present and discussion in this section. A huge load is connected at t=0.08 sec. Due to this load which consumes both real and reactive powers from transmission line, the RMS voltage will be reduced. However, the proposed control of UPFC is maintaining constant RMS voltage. A Correspinding RMS voltage is shown in fig. 6(a). The zoomed version of Fig. 6(a) is also provided in Fig. 6(b) for better clarity. However, the load is disconnected at t=0.25 sec. Respective voltage profile is depicted in Fig. 6(c).

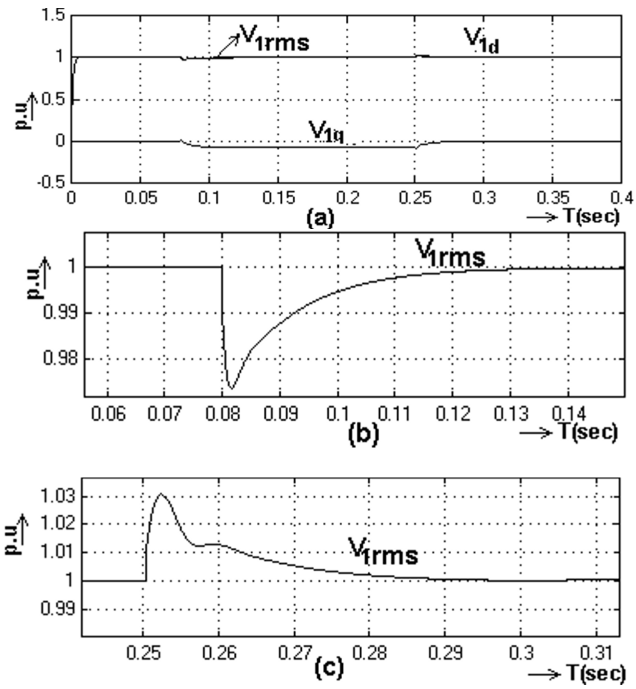


Fig. 6: (a)-(c) Voltages under changing in load condition.

Under this operation, the RMS voltage at 2nd terminal is shown in Fig. 6(d). While Appling and disconnection of heavy load, the responses of voltages are also provided in Fig. 6(e) and (f) respectively.

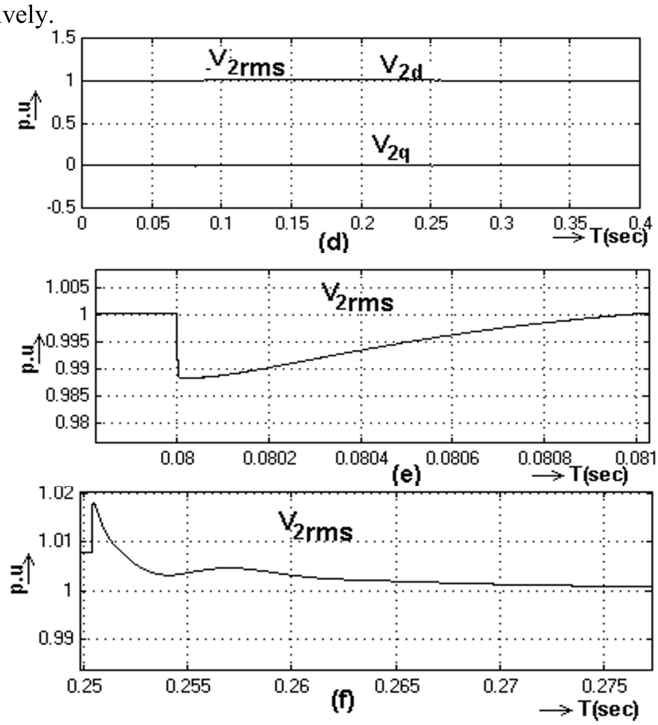


Fig. 6: (d)-(f) Voltages at terminal 2 under change in load.

However, in order to get clear idea, the shunt and series RMS values are also depicted in Fig. 6(g) and (h) respectively under above conditions.

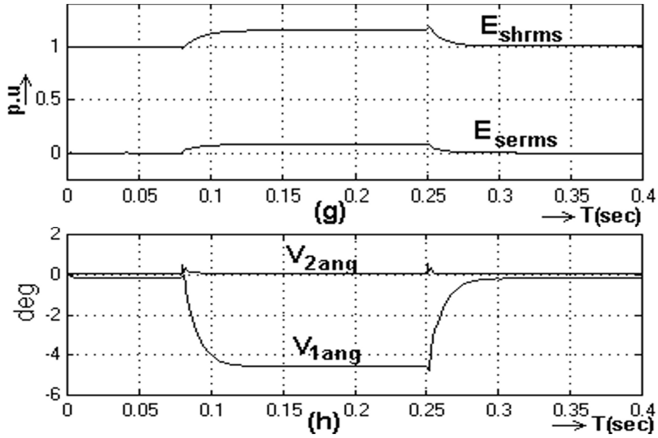


Fig. 6: (g) and (h) Voltages at series and shunt terminals under change in load.

The instantaneous phase voltages (in p.u) is depicted in Fig. 6(i), corresponding DQ components of currents are shown in Fig. 6(j).

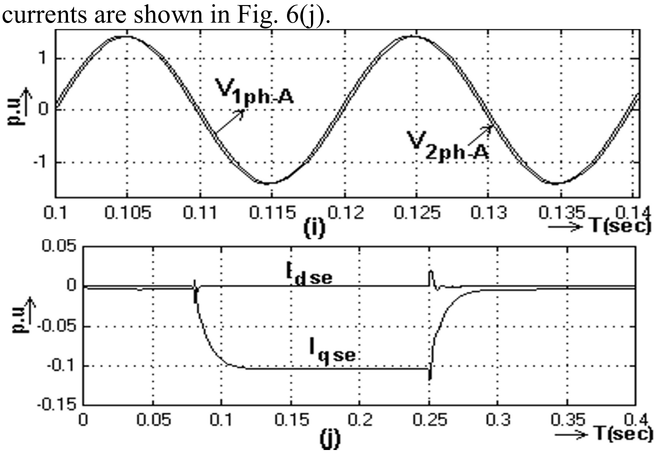
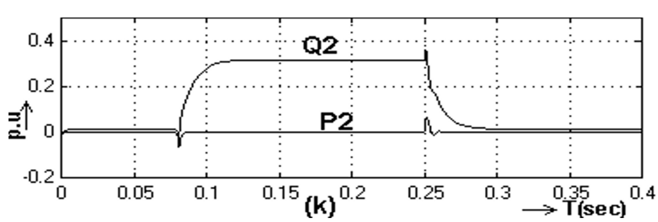


Fig. 6: (i)-(j) Instantaneous Voltages and DQ currents.

However, under above changes the real and reactive power flow is depicted with and without control of UPFC are depicted from Fig. 6(k) to (q).



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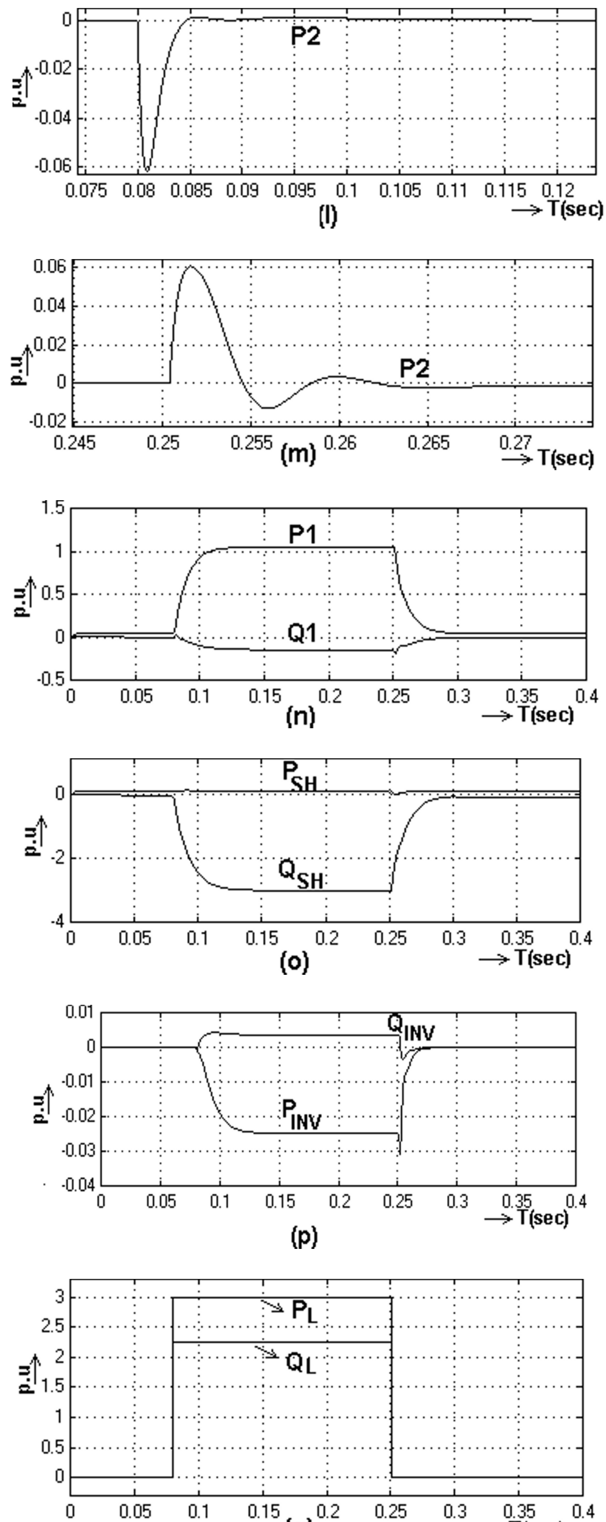

Fig. 6: (k)-(q) Real and reactive power flow at various points in UPFC.

However, a fine control of voltage at dc-link should be required to achieve the full functionality of UPFC. Hence, the response of voltage at dc-link under above changes is depicted in Fig. 6(r).

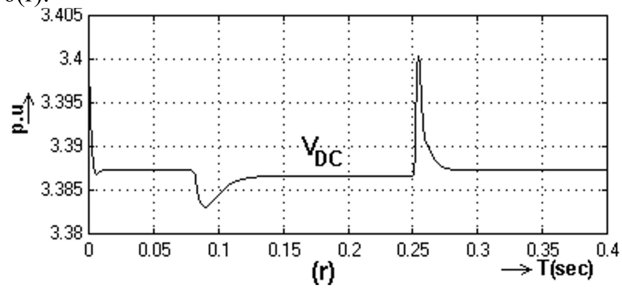

Fig. 6(r): Response of voltage at dc-link.

6. Conclusion

An efficient control method for UPFC is presented in this paper by connecting two VS converter with a common dc-link. A proper flow of real and react power is achieved to make transmission system more flexible than conventi9oan system. D-Q theory based controllers are developed to regulate both voltages at dc-link as well as AC terminals. The flows of real and reactive power are managed based on constant voltages at utility points. Detailed modeling of UPFC using MATTLAB/Simulink is presented well for more understanding purpose. Findings are analysed under various operating settings and the results are extracted at various times.

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