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CLOSED LOOP CONTROL FOR REACTIVE POWER COMPENSATION USING COMBINED FACTS DEVICES

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ABSTRACT

This paper deals with improvements of reactive power using Flexible AC transmission system controllers. UPFC and TCSC are the two FACTS devices which are used as compensators in this work. UPFC and TCSC models are developed with closed loop control. The PID controller is used to control the UPFC and TCSC performance based in thirty bus systems and shows the comparison of open loop and closed loop.

Keywords: FACTS, MATLAB, Simulink, UPFC, TCSC, PID.

INTRODUCTION

Power electronics or Flexible AC Transmission Systems (FACTS); provide proven technical solutions to address these new operating challenges today. FACTS technologies allows the improvement of transmission system operation with minimal cost and time compared to the construction of new transmission lines.

Z.Duan, H.Bao, H. Shen deals the Characteristics of FSC (Fixed Series Compensation) and TCSC (Thyristor Controlled Series Capacitor) damping power-angle oscillation and increasing the limit of power transmission were analyzed. In the cases of only FSC, only TCSC and the two combined controller shows that thyristor controller series capacitor is more effective than FSC in damping power-angle oscillation. A.Radha Krishnan and CH. Kasi Rama Krishna Reddy explain the problems that are due to poor Power Quality in electrical systems and show their possible financial consequences and improvement of power quality. Power Quality is characterized by parameters that express harmonic pollution, reactive power and load unbalance. Anulekha Saha *et al* investigates the enhancement in voltage stability margin as well as the improvement in the power transfer capability in a power system with the incorporation of fixed capacitors, Static Synchronous compensator (STATCOM) and static var compensator (SVC). S. Marlin, S. D. Sundarsingh Jebaseelan, B. Padmanabhan and G.Nagarajan deals with power quality improvement by using FACTS devices UPFC and TCSC. The scope of present work is the digital simulation of combined TCSC and UPFC in thirty bus system. This has reduced the reliability and increase the power quality. Models for the UPFC and TCSC for thirty bus system with open loop control are developed by using MATLAB Simulink.

The above literature does not deal with improving the power quality using UPFC and TCSC in closed loop system. In the previous work power quality has been improved using UPFC and TCSC in open loop system. The present work deals with improving the power quality using UPFC and TCSC in closed loop system.

In this work Combined FACTS devices UPFC and TCSC control system that includes the real and reactive power coordination controller has been designed and its performance are evaluated. The basic control strategy and control system for UPFC and TCSC are described and also the details of the real and reactive power coordination controller are provided

FACTS

FACTS technology consists of high power electronic based equipments with its real time operating control. There are two groups of FACTS controllers based on different technical approaches, both resulting in controllers able to solve difficulties in the systems. The tap-changing transformers with thyristor switches as controlled elements; the second group employs self-commutated voltage source converters. The thyristor Controlled Series capacitor, (TCSC) and Phase Shifter, belong to the first group of controllers while static synchronous compensator (STATCOM), Static Synchronous Series Compressor (SSSC) [4], Unified Power Flow Controller (UPFC) and inter Interline Power Flow Controllers (IPFC) belong to the group[1-2]. FACTS technologies provide advanced solutions as cost-effective alternatives to construct new transmission line. The advantage of FACTS controller are now widely recognized by the power systems engineering.

The FACTS technology to greatly enhance the value of power systems and thereby unleashe an array of new and advanced ideas to make it a reality. It is also worth pointing out that, in that in the implementation of FACTS technology, as power semiconductor devices continue to improve particularly the devices with turn - off capability.

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METHODOLOGY

Existing system

The existing method is an open loop which has shunt and series transformers each connected with an voltage source and a controller which is the UPFC and TCSC is connected to the load, where TCSC has a controller to control it. The power quality has been improved in thirty bus system using UPFC and TCSC in an open loop system [5].

Proposed system

In my work the power quality has been improved by using combined FACTS devices UPFC and TCSC in a closed loop system which has Proportional Integral and derivatives controller. The below Figure-1 shows the block diagram of proposed system.

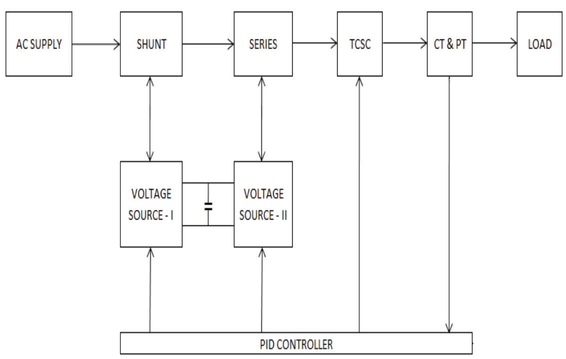

Figure-1. Block diagram of proposed system.

Unified power flow controller *(UPFC)*

UPFC can be used to regulate the power flow through the line and improve utilization of the existing transmission system and aid in the first swing stability of interconnected power systems. An uncompensated active and reactive power flow in a transmission line is not optimal. When the active power flow in the line is less, the freed up capacity of the line can be effectively utilized to carry an increased amount of active power [6].

The second direction is concerned with the power electronic realization of the UPFC and its performance characteristics. The UPFC has three independent degrees of freedom, by which the real power through a radial line and the reactive powers at both ends of the line can be simultaneously controlled [8]. It has also the reassuring internal flexibility that its shunt converter can be used as a stand-alone STATCOM its series converter as a stand-alone series capacitor compensator (SSSC) or combinations of the two. The latter utilize the SVS concept to provide a unique comprehensive capability of transmission system control. The UPFC is able to control simultaneously or selectively all the parameters affecting power flow patterns in a system. The capabilities make the UPFC the most powerful device in the present day transmission and control systems [3].

Thyristor controlled series capacitor (TCSC)

An actual TCSC system usually comprises a cascaded combination of many such TCSC modules, together with a fixed - series capacitor, and it is primarily to minimize cost. The capacitors - C1, C2….., Cn- in the different TCSC modules may have different values to provide a wider range of reactance control. The inductance in series with the anti-parallel thyristors is split into two halves to protect the thyristor valves in case inductor short circuits.

PID controller is used in the feedback path [7].The value of P is 10 and I is 1000. PID controller is used to increase speed of response and to eliminate the steady state error.

SIMULATION RESULTS

Thirty bus system without FACTS devices

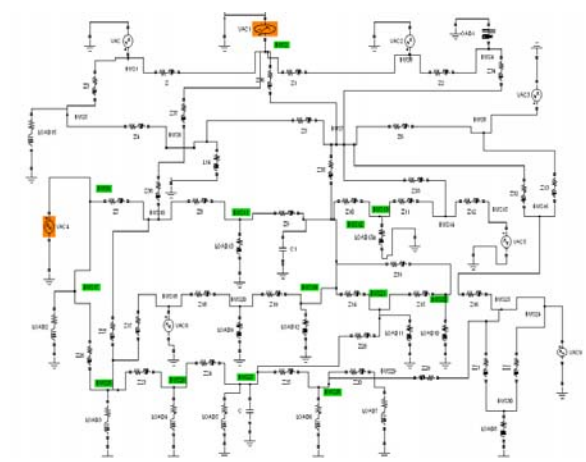

Figure-2. Simulation circuit for thirty bus system without FACTS devices.

The simulation is done by using MATLAB Simulink and the results are presented. Each line is moduled by its series impedance. The load at the load buses are represented by the combination of R and L. The shunt capacitances of the line are neglected. The circuit model of thirty bus system without controller is shown above Figure-2. The voltage across at bus 21 without FACTS devices is shown in Figure-3. The real and reactive power at bus 21without FACTS devices controller is also shown in Figure-4.

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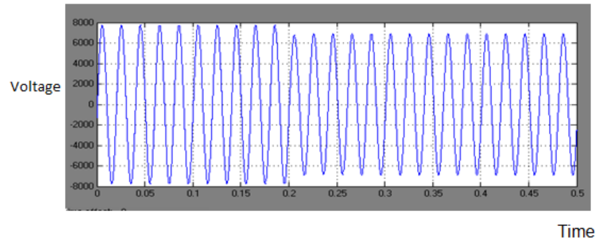

Figure-3. Voltage waveform of bus 21 without FACTS devices.

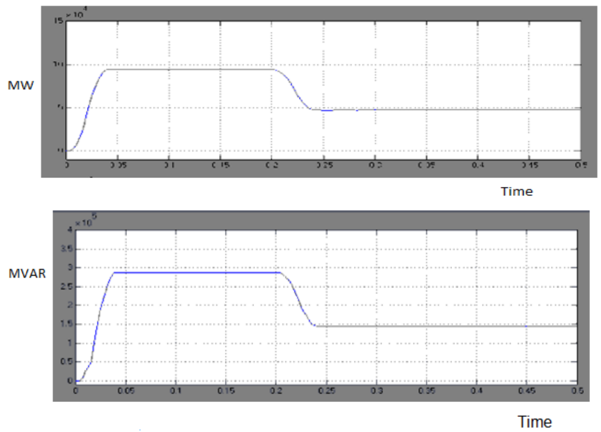

Figure-4. Real and reactive waveform at bus 21 without FACTS devices.

Thirty bus system with FACTS devices using closed loop system

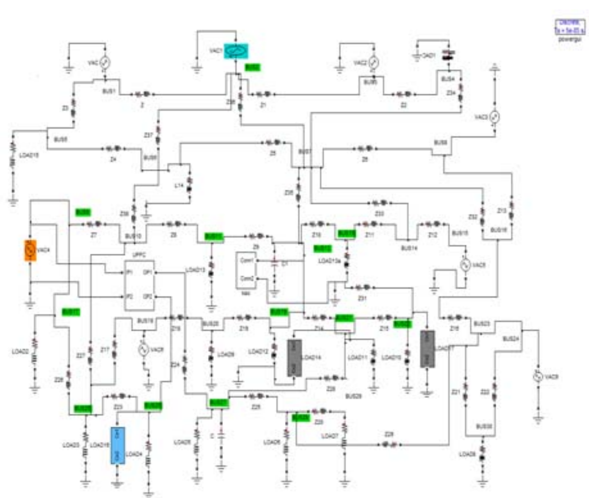

Figure-5. Simulation circuit for thirty bus system with FACTS devices using closed loop system.

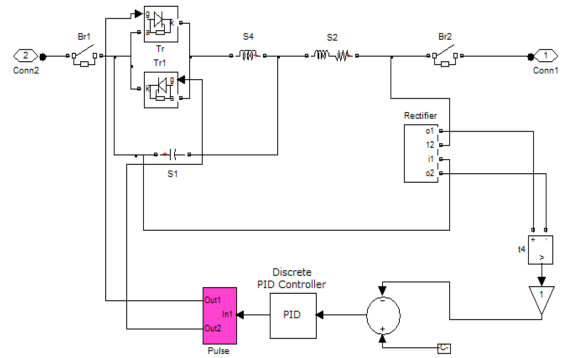

Figure-6. Simulation diagram of TCSC using PID controller.

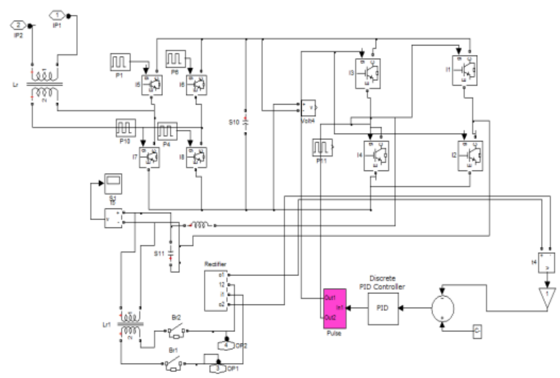

Figure-7. Simulation diagram of UPFC using PID control.

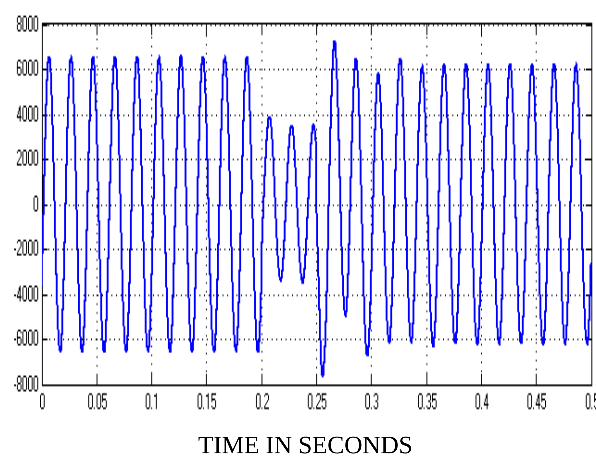

Figure-8. Voltage waveform at bus 21 with controller.

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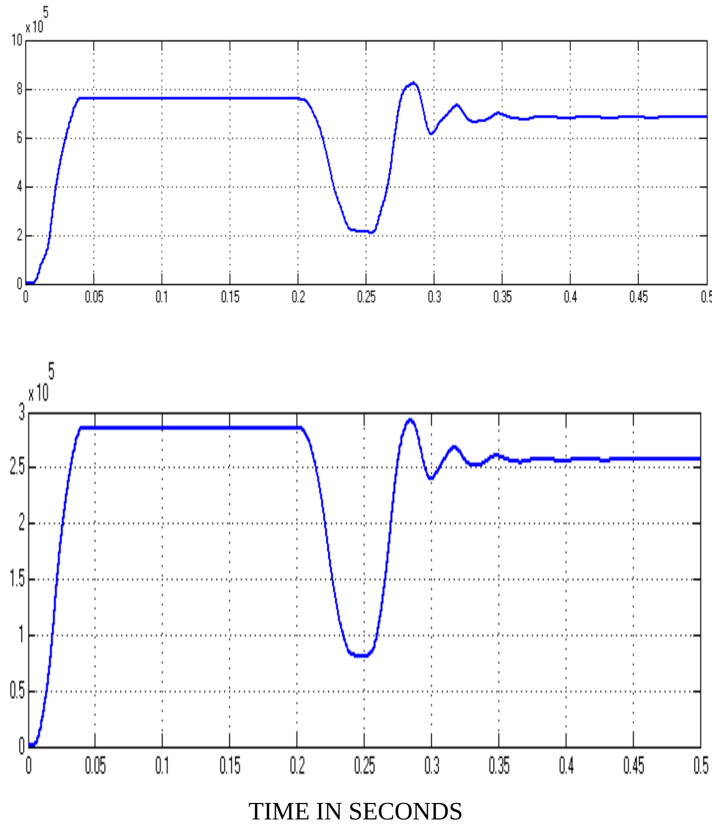

Figure-9. Real and reactive power waveform at bus 21 with controller.

The simulation diagram of TCSC with PID controller is shown in Figure-6 and the simulation diagram of UPFC with PID controller is shown in Figure-7. The voltage across at bus 21 with UPFC and TCSC controller using closed loop system is shown in Figure-8. The real and reactive power at bus 21 with UPFC and TCSC controller using closed loop system is also shown in Figure-9.

Table-1. Comparison of real and reactive power in thirty bus system with open loop and closed loop.

Bus No	Open loop				Closed loop			
	Real power (P) MW		Reactive power (Q) MVAR		Real power (P) MW		Reactive power (Q) MVAR	
	Without controller	With controller	Without controller	With controller	Without controller	With controller	Without controller	With controller
7	0.263	0.273	0.042	0.051	0.118	0.221	0.131	0.137
11	0.36	0.421	0.113	0.132	0.173	0.183	0.206	0.261
13	**0.287**	**0.34**	**0.901**	**0.067**	**0.338**	**0.34**	**1.065**	**1.067**
19	0.267	0.346	0.105	0.136	0.341	0.346	0.134	0.136
21	**0.169**	**0.304**	**0.055**	**0.0991**	**0.286**	**0.304**	**0.0934**	**1.072**
25	0.377	0.394	0.485	0.491	0.39	0.394	0.429	0.523
26	0.257	0.283	0.807	0.889	0.273	0.283	0.857	0.889

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Table-2. Comparison of voltage in thirty bus system with open loop and closed loop.

Bus No	Open loop		Closed loop	
	Voltage (KV) **without controller**	**Voltage** (KV) **with controller**	**Voltage** (KV) **without controller**	**Voltage** (KV) **with controller**
7	6120	6226	6783	6798
11	6299	6798	6386	6398
13	**5582**	**6075**	**6069**	**6362**
19	6088	6176	6868	6876
21	**5837**	**6497**	**6295**	**6479**
25	6402	6554	6520	6568
26	6286	6348	6448	6469

The comparison of real and reactive power at various busses in thirty bus system using open loop and closed loop is given in Table-1. The comparison of voltage with and without controller for thirty bus system using open loop and closed loop system is given in Table-2. From the table it is clearly shows that voltage and reactive power is increased due to the presence of UPFC and TCSC in bus no 13 and 21 for closed loop controller.

CONCLUSIONS

In the proposed system, the performance of UPFC and TCSC connected to a transmission line has been designed and evaluated. This also describes the control strategy for real and reactive power of the transmission line using UPFC and TCSC. The behavior of UPFC and TCSC was analyzed in both open loop and closed loop control for thirty bus system. TCSC is connected in bus no 13 and UPFC is connected in bus no 21. After injecting TCSC in bus no 13 the reactive power increased from 0.34 to 1.067 and in Bus number 21 after injecting UPFC the reactive power increased from 0.0991 to 1.072. From the above table I it concludes closed loop system shows 82.3% improvement than open loop system for the improvement of reactive power.

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