Proportional Resonant Controlled Shunt Active Filter in IEEE Thirty Bus System with Improved Dynamic Time Response

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Abstract

This paper points on enhancing the dynamic time reaction of a Wind Energy- Conversion System (WE-CS) associated with IEEE thirty bus system utilizing Permanent Magnet-Synchronous Generator(PM-SG) in closed-loop controlled-active-power-filter with PR. This paper manages modeling and simulation of IEEE Thirty bus system utilizing PR based shunt active filter. The shunt active filter is actualized with voltage source inverter (VSI) and the switching pulses are produced utilizing PR controller. The simulation comes about are introduced to discover the impact of shunt active filter utilizing PR controller. Open loop controlled thirty bus system with change in voltage is reenacted. The simulation comes about with PI and PR controller based SAF are looked at and the relating time-domain parameters are exhibited. The outcomes show that PR Controller system has preferable reaction over PI controlled system.

Keywords: 'Shunt-Active-filter', 'IEEE-Thirty-bus-system', 'Proportional-Resonant Controller-(PRC)', 'PI-controller', 'Voltage-Source-Inverter', 'Reactive-power', 'Time-domain –parameters', 'Mat-lab'.

1. Introduction

The non-linear loads are widely utilized such as adjustable speed drives, traction-drives, and so on.The Power-converters have contributed for the decay of the power- quality and this has brought about to an extraordinary economic misfortune. To get good quality of power we need to develop the hardware and it mitigate all the power quality issues and must operate in all the conditions. Good quality of Power (PQ), is characterized as the supply voltage should be sinusoidal and balanced, it should not contains harmonics, frequency deviation etc. Bad quality of power results increase or decrease of voltage, current or frequency which creates disoperation of the consumer equipment. One of the bad quality of power is harmonics. Harmonics may be voltage or current but most severe issue is current harmonics.

When the load receives the current is proportional to the applied voltage and tracks the input is called linear loads. In some load current does not follow the voltage and non sinusoidal current it is called non-linear loads. Examples of linear loads are resistive loads, constant speed induction motor. Examples of non-linear loads are diode bridge rectifiers, induction heating. This non-sinusoidal current create problems in customer side like voltage fluctuations, harmonics, low power factor, electro-magnetic interference (EMI) and so on. So that to reduce the issues of poor power quality, a compensator is needed. The major issue of poor power quality is current harmonics. To mitigate harmonics filters are used. The filters classified as active, passive filters and hybrid. Passive filters have some draw backs like operate at particular frequency, resonance problem and so on. To avoid these drawbacks active filters are used. A shunt active filter is used to reduce the current harmonics. According to IEEE the THD value should be less than 5%. A Hybrid filter is combination of both (passive and active).

2. Shunt Active Filters

Fig. 1 shows the schematic representation of Shunt active filter (SAF) feeding a non-linear load. These non-linear loads influence source voltage and source current, so solidarity power-factor isn't sustained at source. Consequently shunt active-filters are required to keep up solidarity-power-factor in the power-systems. The SAF provides compensation current equal and opposite of the current receives by the load and injects in PCC. So that the supply current forced to be sinusoidal and the power factor is sustained at unity. The shunt-active-filter comprises of a 'three-leg-IGBT' based 'voltage-source- inverter'(VSI), 'interface-inductor' and a 'direct- current-bus-capacitor'.
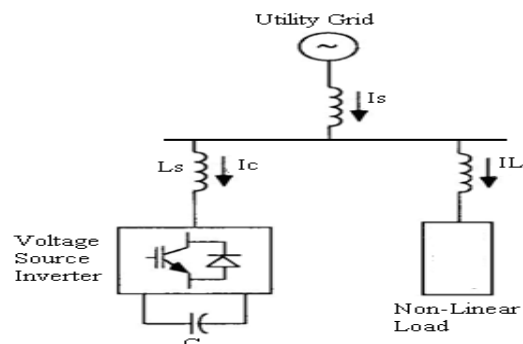

Fig. 1: Schematic representation of SAF

The APF is organized by utilizing 'PI-controller' and 'Proportional Resonant controller' (PR), to draw or supply the 'repaying current' from or to the load to counteract the current-harmonics on alternating current side, to keep up the direct

current-interface voltage consistent by keeping up the real-power-stream in the system and reactive-power-flow-out of or to the source, in this way making the source-current in-phase with source-voltage.
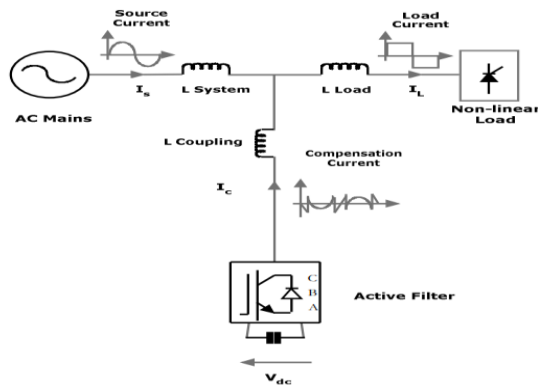

Fig. 1.1: Compensation-Principle-of a-SHAF

Fig. 1.1 demonstrates the essential compensation standard of the active- power- filter and it fills in as energy-storage component to supply the real-power contrast amongst load and source amid the transient time period. At the point when the load condition changes, the real- power in the system i.e. between the mains and the load likewise changes. Because of this unbalance of the real-power in the system the inappropriate working of the system happens and in this manner the real-power unsettling influence is obvious by the direct current-connect-capacitor and in doing as such the voltage over the direct current interface-capacitor changes from the reference-voltage. To acquire the ideal execution of the system, the peak-value of the reference source current must be acclimated to relatively change the real-power drawn from the source. In the event that the DC capacitor voltage is recuperated and accomplishes the reference voltage, the real- power provided by the source should be equivalent to that load consumed. Here, the peak-value of the reference-source-current can be obtained by managing the normal-voltage of the direct-current capacitor.

3. PI and PR Controller

3.1. Shunt-Active- Filter with PI-Controller

Generally PI controller is widely used in the industry due to their simple control structure and ease of implementation. These controllers pose difficulties where there are some control complexity such as nonlinearity, load disturbances and parametric variations. Moreover PI controllers require precise linear mathematical models. Fig-2.1 represents the block-diagram of the SAF with PI controller. The PI controller operation with shunt active filter is, the DC capacitor voltage is compared with a set reference value. The error signal is then processed through PI controller .The reference currents and actual currents are compared to a PWM, which gives the error signal for the modulation technique. This error signal decides the operation of the converter switches. The inverter circuit triggering depends on the control circuit output. The proposed system use PWM control to produce the pulse to trigger gate of MOSFET.
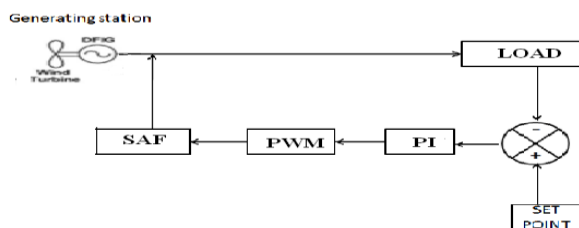

Fig. 2.1: Block-diagram of Shunt-Active-Filter with PI-controller

3.2. Shunt Active Filter with PR Controller

Proportional-Resonant (PR) controller is reasonable for the DC connect voltage control systems in SAF. In conventional systems, PR controller achieves better current tracking execution and gives lower THD in the general proposed plot. Fig-2.2. represents the block-diagram of the SAF with PI controller.
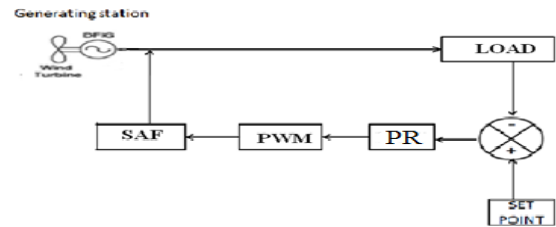

Fig. 2.2: Block-diagram of Shunt-Active-Filter with PR-controller

A perfect PR controller can be scientifically acquired by changing a perfect synchronous casing PI controller to stationary frame and gives infinite-gain at full recurrence as to compel the DC interface voltage error to zero and no phase move and gain at different- frequencies. The Proportional -Resonant (PR) current controller is defined as

$$G(s)=K_p+K_I[\omega/S^2+\omega^2] \tag{1}$$

Thus a PR controller is same as that of PI controller. The difference consists only in the way the integration action takes part. The integrator will only integrate frequencies very close to the resonance frequency and will not introduce phase shift. By properly tuning of the proportional gain K_p is as for the PI controller. This value determines the dynamics of the system in terms of bandwidth, phase and gain margin.

4. IEEE Thirty Bus System with SAF

The one line diagram of IEEE thirty bus system with SAF is shown in fig.3 and consists of six generator buses.In this system a disturbance,i.e change in voltage is given in generator bus at 25.SAF is connected at bus no 27 and its dynamic time domain parameters are measured at that bus.
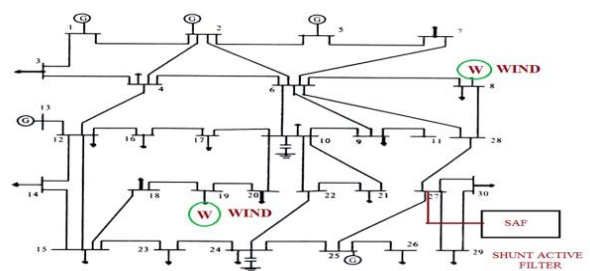

Fig. 3: One line diagram of IEEE 30-bus with shunt active filter

5. Simulation Results

5.1. SAF of Open loop IEEE 30 Bus System with Disturbance

The simulink of open loop IEEE thirty bus system as shown in fig 4.The shunt active filter is connected at bus 27 . Representation of voltage at bus-27 is appeared in Fig.4a. and its value is 4000V. Representation of RMS voltage at bus-27 is appeared in Fig.4b and its value is 2835 V. Representation of real power at bus-27 is appeared in Fig.4c and its value is $1.043* 10^5$ Watts. Representation of reactive power is appeared in Fig.4d and its value is $1.945 *10^5$ VAR.
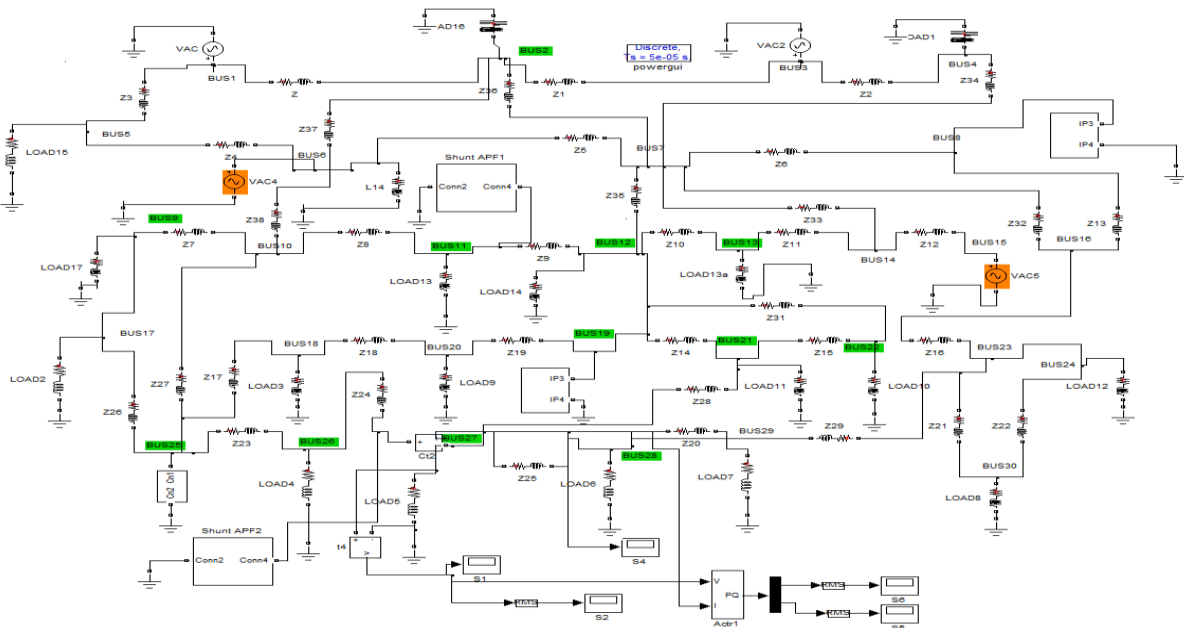
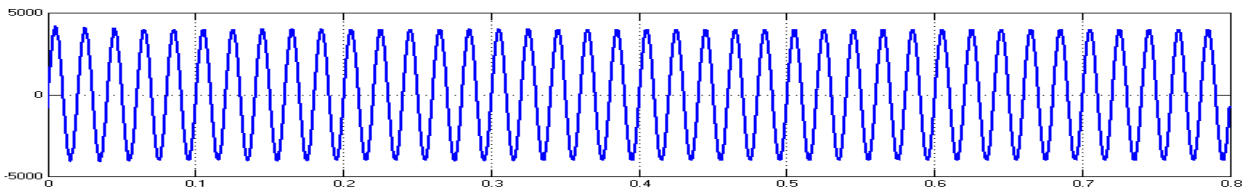**Fig. 4:** Simlink of Open loop 30-bus system with disturbance

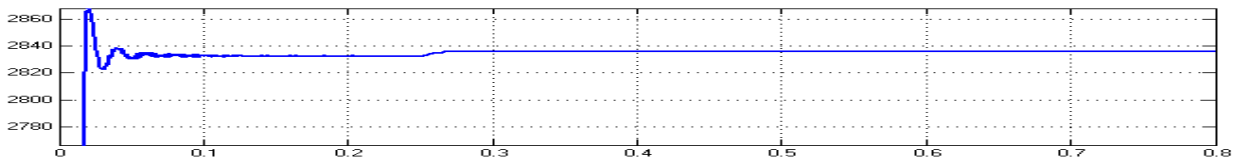**Fig. 4a:** Representation of voltage at bus-27

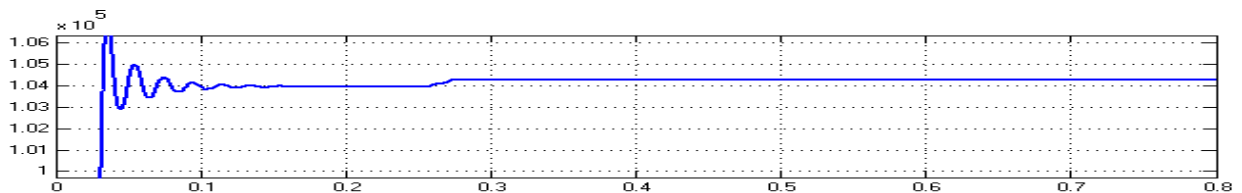**Fig. 4b:** Representation of RMS voltage at bus-27

Fig. 4c: Representation of real power at bus-27
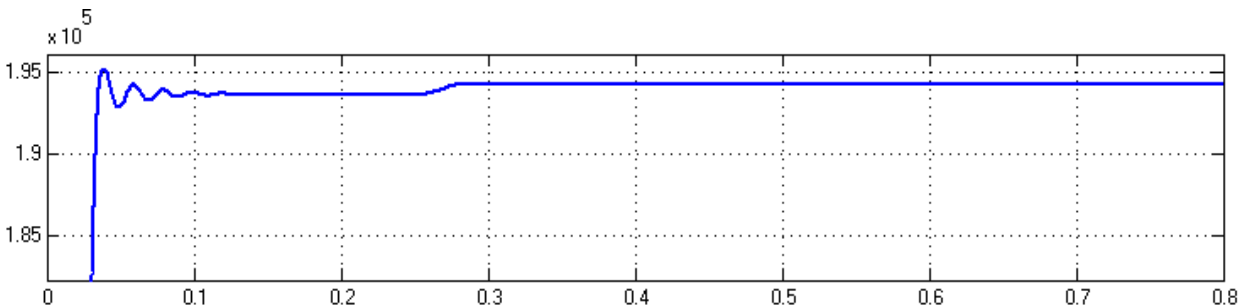

Fig. 4d: Representation of reactive power at bus-27

5.2. Closed Loop IEEE 30-Bus System with PI Controller

Closed loop 30-bus system with PI controller is shown in Fig.5. voltage at bus-27 is appeared in Fig.5a. and its value is 4000V. RMS voltage at bus-27 and expanded view are appeared in Fig.5b

& Fig.5c and its value is 2900 V.Real power at bus-27 is appeared in Fig.5d and its value is $1.04*10^5$ W.Reactive power is appeared in Fig.5e and its value is $1.93*10^5$ VAR.
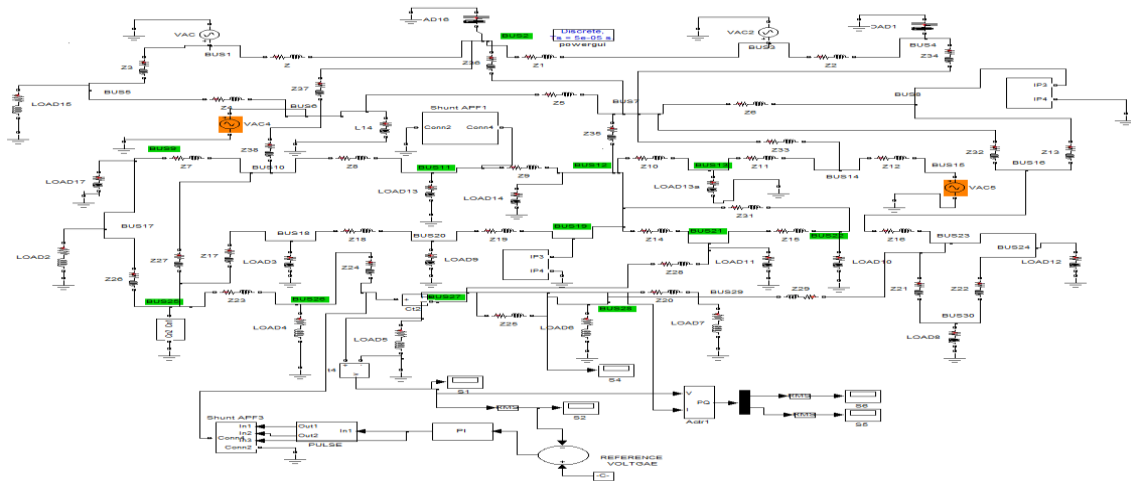
Fig. 5: Simulink of Closed loop 30-bus system with PI controller
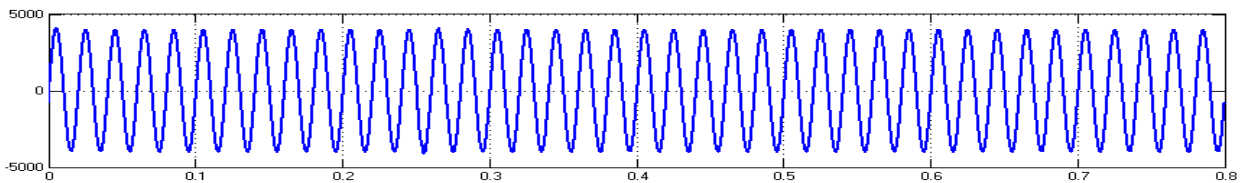

Fig. 5a: Representation of voltage at bus-27
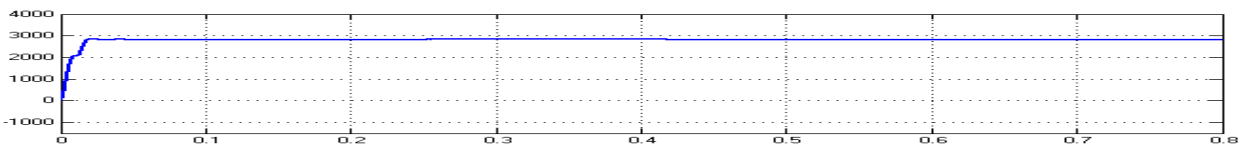

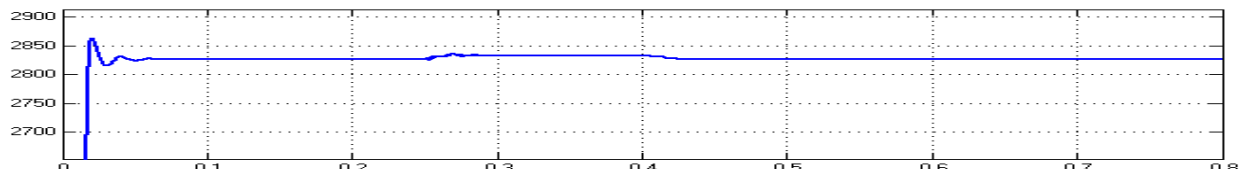**Fig. 5b:** Representation of RMS voltage at bus-27

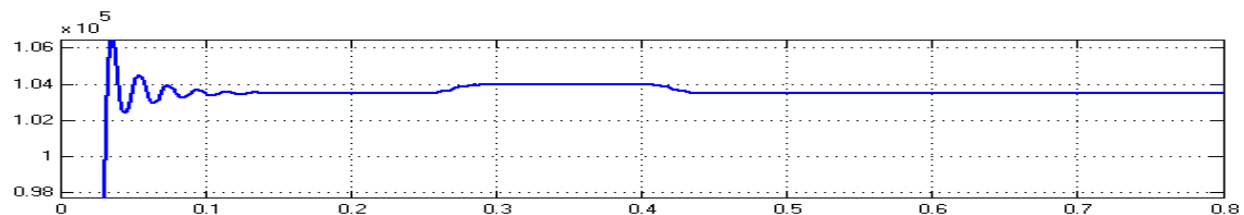**Fig. 5c:** Representation of RMS voltage (expanded)

Fig. 5d: Representation of real power at bus-27

Fig. 5e: Representation of reactive power at bus-27

5.3. Closed Loop IEEE 30 Bus System with PR Controller

Closed loop 30-bus system with PR controller is shown in Fig.6. Representation of voltage at bus-27 is appeared in Fig.6a. and its value is 4000V.

Representation of RMS voltage at bus-27 and expanded view are appeared in Fig.6b & Fig.6c and its value is 2835 V. Representation of real power at bus-27 is appeared in Fig.6d and its value is $1.04* 10^5$ W. Representation of reactive power is appeared in Fig.6e and its value is $1.93 *10^5$ VAR.

Fig. 6: Simulink of Closed loop 30 bus system with PR controller

Fig. 6a: Representation of voltage at bus-27
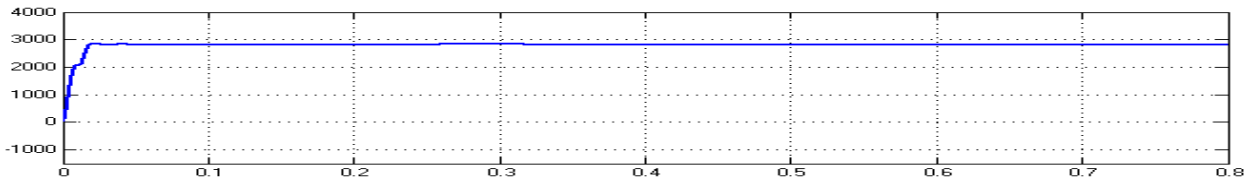
Fig. 6b: Representation of RMS voltage at bus-27
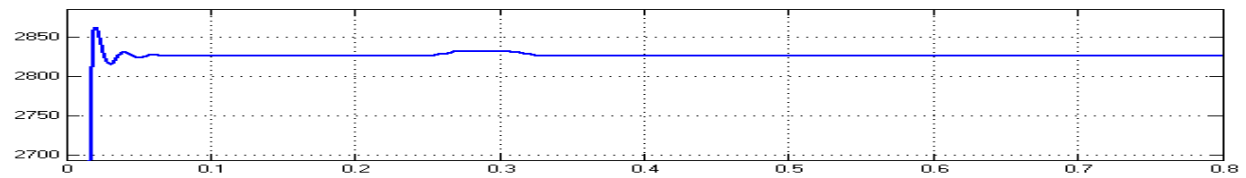
Fig. 6c: Representation of RMS voltage (expanded)
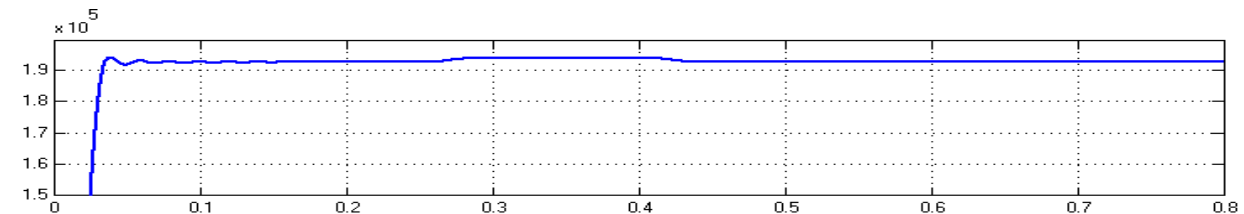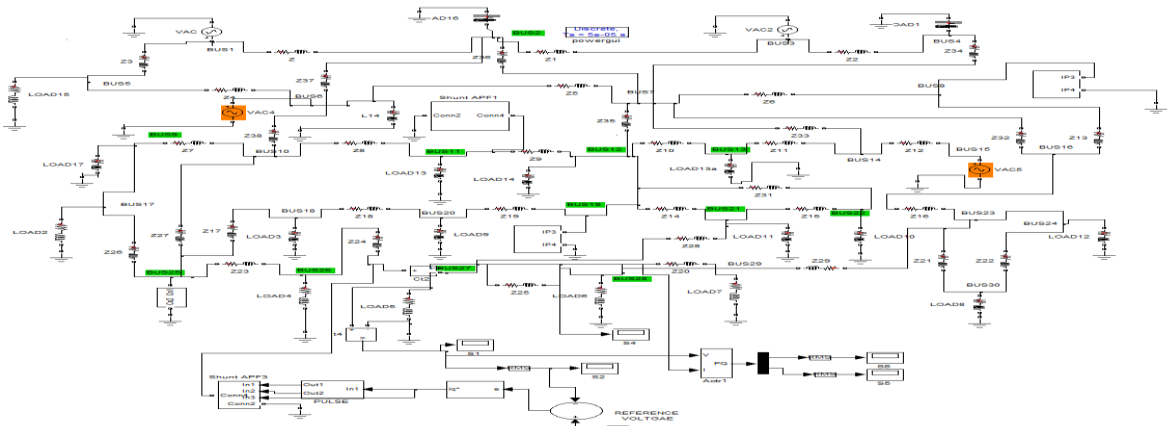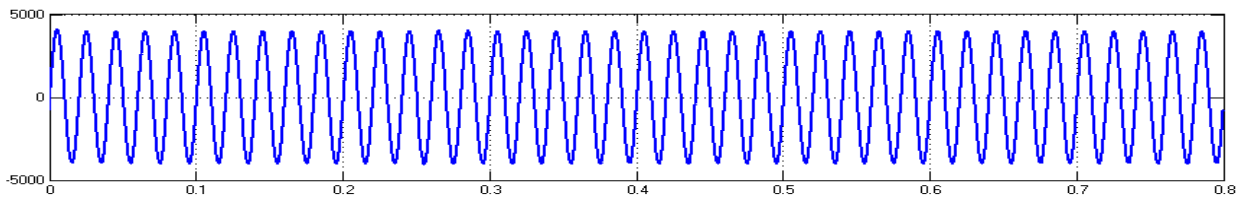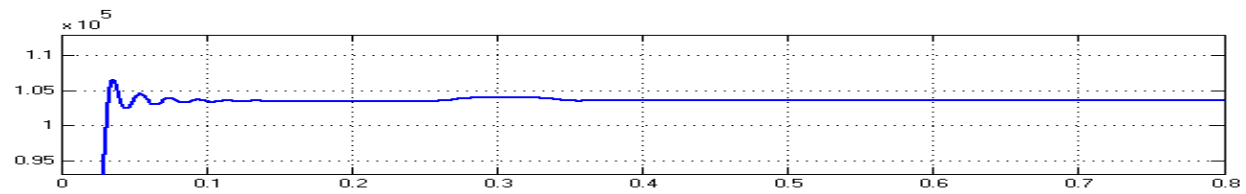

Fig. 6d: Representation of real power at bus-27

Fig. 6e: Representation of reactive power at bus-27

Comparison of time domain parameters is shown in table 1.By using PR controller, rise time is reduced from 0.27 to 0.26 sec; peak time is reduced from 0.39 to 0.32 Sec; settling time is reduced from 0.42 to 0.34 Sec; Steady state error is reduced from 4.23 to 2.10 V. Hence, closed loop 30-bus system with PR controller is superior to closed loop 30-bus system with PI controller.
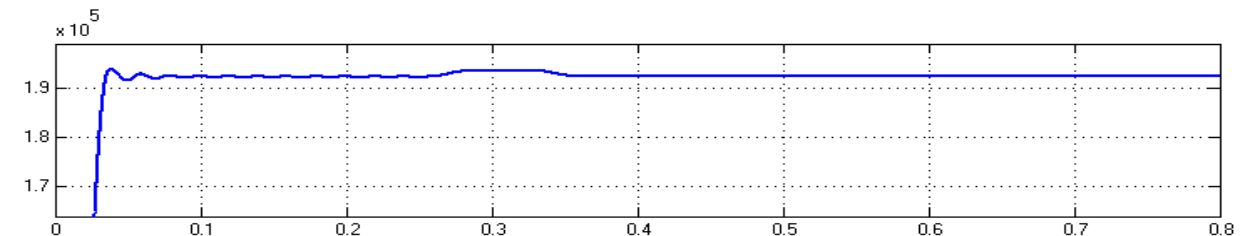
Table 1: Comparison of time domain parameters

Controller	Rise time (s)	Peak time (s)	Settling time (s)	Steady state error (V)
PI	0.27	0.39	0.42	4.23
PR	0.26	0.32	0.34	2.10

6. Conclusion

IEEE thirty bus systems in closed loop are simulated and the results with PI and PR are presented. The steady state error is reduced from 4.23V to 2.10V by replacing PI with PR. Therefore PR based active filter may be a viable alternative to the existing-controller. The reduction in settling time and steady state error are very high in the case of PR controller system. The settling time is reduced from 0.42 seconds to 0.31 seconds. The benefits of proposed-system are reduction in losses, line- drop, steady-state-error and settling-time. The disadvantage is that SAF requires large inductor and capacitor.

The present-work deals with the investigation on thirty-bus-system. The improvement in power-quality of Fifty seven bus system using PRCSAF will be done in future.

Appendix I: Line and Load Parameters

	VOLTAGE	LOAD IMPEDANCE			LINE IMPEDANCE	
		RESISTANCE	INDUCTANCE		RESISTANCE	INDUCTANCE
bus 1	6.3kv	-	-	bus 1-2	1Ω	30mH
bus 2	-	10Ω	100mH	bus 2-5	3Ω	38mH
bus 3	6.3kv	-	-	bus 5-7	6 Ω	40mH
bus 4	-	85Ω	120mH	bus 3-1	13 Ω	37mH
bus 5	-	200Ω	300mH	bus 4-2	15Ω	30mH
bus 6	6.3kv	-	-	bus 6-2	23 Ω	26mH
bus 7	-	125 Ω	180mH	bus 6-7	45 Ω	56mH
bus 8	6.3kv	-	-	bus 13-4	54 Ω	63mH
bus 9	-	135 Ω	167mH	bus 12-4	43Ω	100mH
bus 10	-	58 Ω	127mH	bus 12-16	36Ω	113mH
bus 11	-	100Ω	100mH	bus 16-17	24 Ω	55mH
bus 12	-	10Ω	100mH	bus 17-10	36 Ω	85mH
bus 13	-	48Ω	100mH	bus 10-9	78 Ω	125mH
bus 14	-	67 Ω	97mH	bus 9-11	85 Ω	79mH
bus 15	6.3kv	-	-	bus 10-6	96 Ω	150mH
bus 16	-	33Ω	65mH	bus 6-9	110 Ω	138mH
bus 17	-	78 Ω	125mH	bus 6-28	108Ω	124mH
bus 18	-	10Ω	100mH	bus 15-14	89 Ω	119mH
bus 19	6.3kv	120Ω	150mH	bus 18-19	76Ω	106mH
bus 20	-	120Ω	168mH	bus 19-20	79 Ω	98mH
bus 21	-	125Ω	130mH	bus 20-10	86 Ω	110mH
bus 22	-	25Ω	90mH	bus 22-21	55Ω	103mH
bus 23	-	110 Ω	138mH	bus 21-10	40 Ω	75mH
bus 24	-	10Ω	100mH	bus 27-28	55Ω	69mH
bus 25	6.3kv	10Ω	100mH	bus 28-30	64Ω	78mH
bus 26	-	10Ω	100mH	bus 27-30	81 Ω	93mH
bus 27	-	10Ω	100mH	bus 15-18	112 Ω	97mH
bus 28	-	10Ω	100mH	bus 15-23	106Ω	136mH
bus 29	-	89Ω	189mH	bus 23-24	93Ω	131mH
bus 30	-	115Ω	198mH	bus 24-22	89 Ω	124mH
				bus 24-25	40 Ω	75mH
				bus 25-26	55Ω	69mH
				bus 28-27	64Ω	78mH
				bus 27-29	81 Ω	93mH
				bus 29-30	112 Ω	97mH

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