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SMC Shunt Active Filter in IEEE Thirty Bus System with Improved Dynamic Time Response

S.Dhandayuthapani, K.Anisha

Abstract: This paper aims on improve the dynamic performance of closed loop controlled shunt active filter with PI, SMC is connected to IEEE 30 bus system. It has been drawn that with none control mechanism, the output voltage cannot be controlled and it will provides a giant deviation in output voltage in terms of error signal and that will decline the output current, as a result steady state error will increase, which will reduce the performance. So, it is mandatory to maintain the output voltage and that can be achieved by a proper feedback control system. This Paper, demonstrates the comparison of time domain parameters and how the results improve in presence of controller circuit for the IEEE 30 bus system.

Index Terms: IEEE Thirty bus system; Slide Mode Controller (SMC); Time domain parameters.

I. INTRODUCTION

The extensive scale utilization of the non-linear loads, for example, flexible speed drives, traction-drives, and so on .Power-converters have contributed for the decay of the power- quality and this has brought about to an extraordinary economic misfortune. In this way it is essential to build up the hardware that can alleviate the issue of poor power quality. Power Quality (PQ) , is characterized as "Any power issue built up in voltage, current or frequency- deviation which prompts harm, breaking down, disoperation of the consumer equipment". Poor power quality makes numerous harms to the system, and has an opposite efficient effect on the utilities and clients. Profoundly programmed electric hardware, specifically, causes huge economic loss consistently.

Now a day's people are tremendously dependent on use of nonlinear loads. Controlled/uncontrolled rectifiers, inverters, UPS, SMPS, TVs, coolers are some examples of nonlinear loads. These nonlinear loads creates harmonic distortion. In electrical engineering, voltage and current waveforms plays a pivotal role in the reliability of electrical devices. There are assorted problems caused due to voltage and current harmonic distortion, such as increase in losses static devices, conduction losses in motors, premature damage of electrical devices, etc. Therefore power quality engineers are mainly focus on the mitigation of harmonics from voltage and current wave forms.

Passive filters are used to compensate voltage and current harmonics, but they are not prefer due to high cost, large size and resonance effect. These issues will be overcome by use of active power filter (APF).APF not solely mitigates harmonics from voltage and current waveforms however additionally improve power factor issues, compensates the reactive power, and reduces the impact of voltage sag, swell and flicker.

II. CONCEPT OF SHUNT ACTIVE POWER FILTER

The performance of the active power filter is to inject the compensation current to the point common coupling point, in order that current supplied from the main is nearly a sine wave and in phase with the mains voltage, in spite of the waveform of the load current. Block diagram representation of shunt APF is shown in Fig.1.

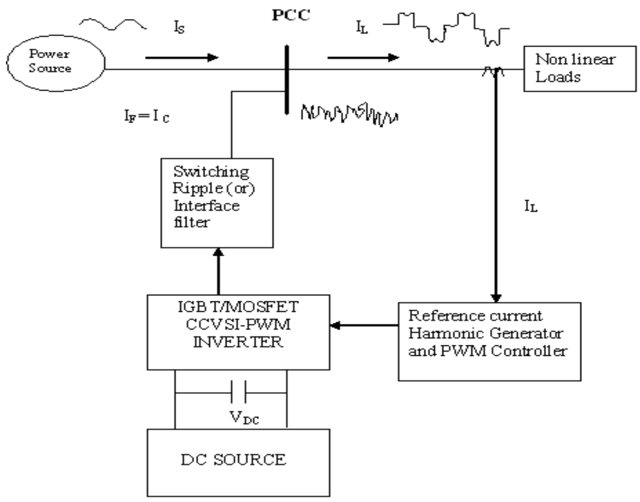

Fig. 1 Block diagram representation of shunt APF

Assuming the mains voltage is expressed as

$$V_S(t) = V_S \sin(\omega t) \quad (1)$$

The non-linear load current can be expressed as

$$i_L(t) = \sum I_n \sin(n\omega t + \theta n) \quad (2)$$

where n = 1 to ∞

For the performance of the active power filter, the current supplied from the mains is expressed as

$$I_S(t) = I_1 \cos\theta_1 \sin(\omega t) \quad (3)$$

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S.Dhandayuthapani, Research Scholar, Dept of Electrical and Electronics Engineering, SCSVMV University.

K.Anisha, Assistant Professor, Dept of Electrical and Electronics Engineering, SCSVMV University.

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From Fig.1, it can be found that the desired compensation current generated by the power converter can be represented as

$I_{com}(t) = i_L(t) - i_S(t)$ ………………………. (4)

If the power converter is loss less, the mains supply the demanded real power of the load, and the power converter supplies reactive power of the load in the steady state. Hence the DC capacitor is the buffer for reactive power flow. Therefore no real power is supplied from the DC capacitor. The average voltage of the DC capacitor is maintained at a constant value, but the voltage fluctuations cannot be avoided due to the reactive power flow. The reactive power supplied from the power converter can be assumed as pc (t) = $\sum P_n \cos(n\omega t + \Phi n)$ where n = 1 to ∞

The fluctuation voltage of the DC capacitor voltage can then be expressed as

$v_c(t) = 1/CV_C \sum P_n / n\omega . \sin(n\omega t + \Phi n)$ …………………(5)

where n = 1 to ∞

It can therefore be found that the fluctuation voltage of the DC capacitor depends on the harmonic order and magnitude of the AC power injected into the DC capacitor. In addition, the average voltage and the capacity of the DC capacitor would also affect it.

III. DESCRIPTION OF SAF WITH PI CONTROLLER

For the most part PI controller is generally utilized in the business because of their uncomplicated control structure and simplicity of execution. This controller presents troubles, for example, nonlinearity, load unsettling influences and parametric varieties. Besides PI controllers require conclusive straight numerical models. Fig-2 shows to diagram of the SAF with PI controller. The PI controller task with shunt dynamic channel is DC capacitor voltage which is contrasted and a set reference esteem. The yield from the comparator is given to PI controller. The reference currents and actual currents are compared with a PWM, which produces the error signal. This error signal chooses the task of the gadget switches.

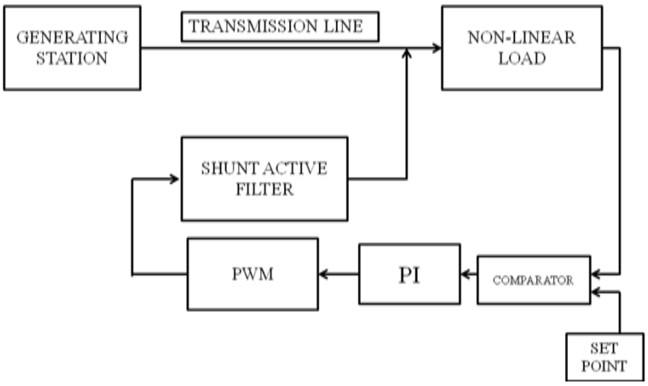

Fig. 2 Block diagram of SAF with PI controller

IV. DESCRIPTION OF SAF WITH SMC

Sliding mode control (SMC) is a nonlinear control frame work including remarkable 'properties of exactness', 'robustness', 'simple tuning' and 'execution'. -Once the 'sliding-surface' is accomplished, SMC keeps the states on the 'adjacent neighbor-hood of the sliding-surface'. Along these lines the 'SMC' is a two-segment controller-layout. This standard stretches out to show parameter-vulnerabilities, unsettling influence and non-linearity that are restricted. From a useful perspective SMC takes into account controlling nonlinear procedures subject to outer disturbances and overwhelming model vulnerabilities.

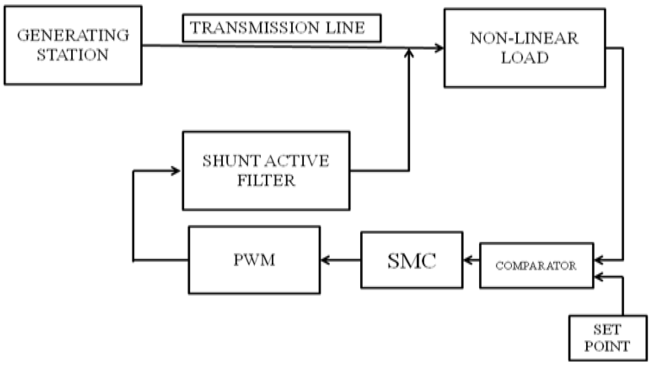

Fig.3 Block diagram of SAF with SMC controller

Utilizing the above portrayed smooth approximations, a few issues are constringed, at the cost of loss of robustness. Second order sliding mode control calculations are a capable elective that totally explains the gabbing issue without trading off the strength properties too. Some great references about second order sliding mode control (2-SMC) calculations are the accompanying:

$$u = -\lambda\sqrt{|\sigma|}\,\mathrm{sgn}(\sigma) + w \quad \text{……………………. (6)}$$

$$\dot{w} = -W\,\mathrm{sgn}(\sigma) \quad \text{……………………… (7)}$$

The following-pair of relationships is a appropriate way for tuning its parameters

$$\lambda = \sqrt{U} \qquad W = 1.1U$$

………………………. (8)

Where, U is a 'positive-constant' to be taken adequately big. In order to get excellent performance in closed-loop-system, 'U' is progressively increased. This is a "trial and error" method suitable for practical implementation.

V. IEEE THIRTY BUS SYSTEM WITH SAF

The one line diagram of IEEE thirty bus system with SAF describes a transmission line network is shown in fig.4 This transmission line network , bus data and line data is modelled as per IEEE Standard thirty bus system data.This network consists of wind generator buses and load buses. The loads are represented by the series connection of R and L. Each line is modelled by its series impedance. The transmission line network data for the buses are tabulated in the Appendix-I.In this system a disturbance,i.e change in load is given in bus at 27 and corresponding dynamic time domain parameters are measured at that bus.In this work the voltage is brought back to original value using closed loop PI ,sliding mode controlled SAF.

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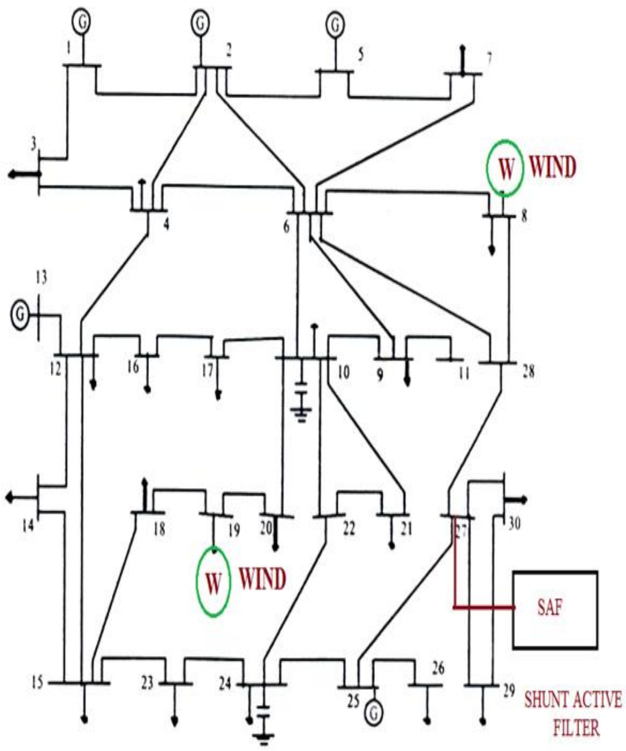

Fig. 4 One line diagram of IEEE 30-bus with shunt active filter

VI. SIMULATION RESULTS

A. Open loop IEEE 30 bus system with load disturbance

Open loop thirty bus system with increase in load at bus no 27 is appeared in Fig.5.Representation of voltage at bus 27 is appeared in Fig.6. and its value is 2000V. RMS voltage at bus 27 is appeared in Fig.7 and its value is 1420 V. Real power at bus 27 is appeared in Fig.8 and its value is 0.019MW.Reactive power is appeared in Fig.9 and its value is 0.022MVAR. Representation of current at bus 27 and THD is appeared in Fig.10 and Fig.11 respectively.

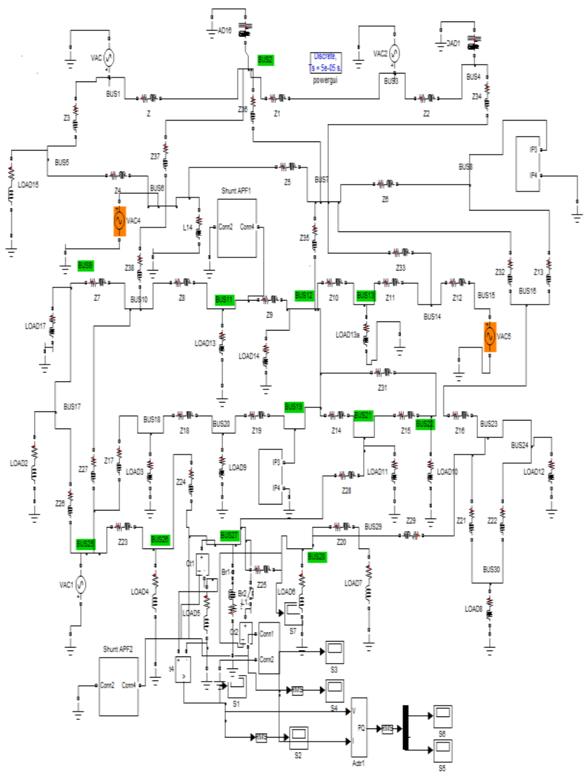

Fig. 5 Simulink of Open loop thirty bus system with increase in load

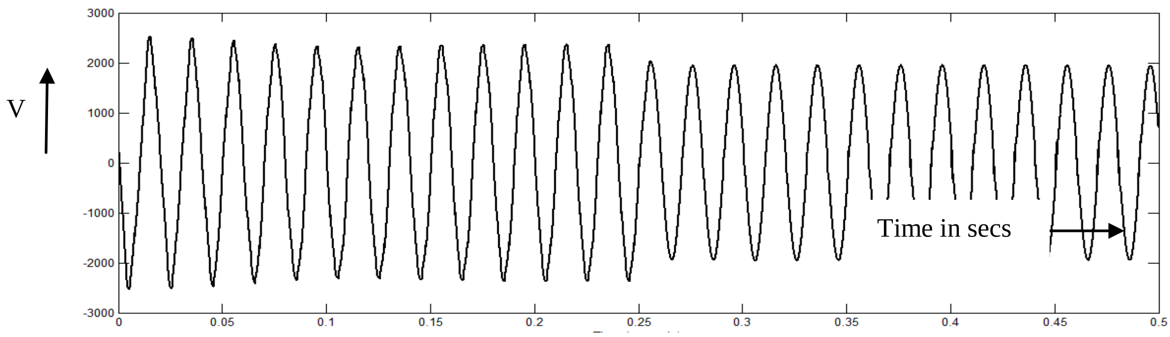

Fig. 6 Representation of voltage at bus-27

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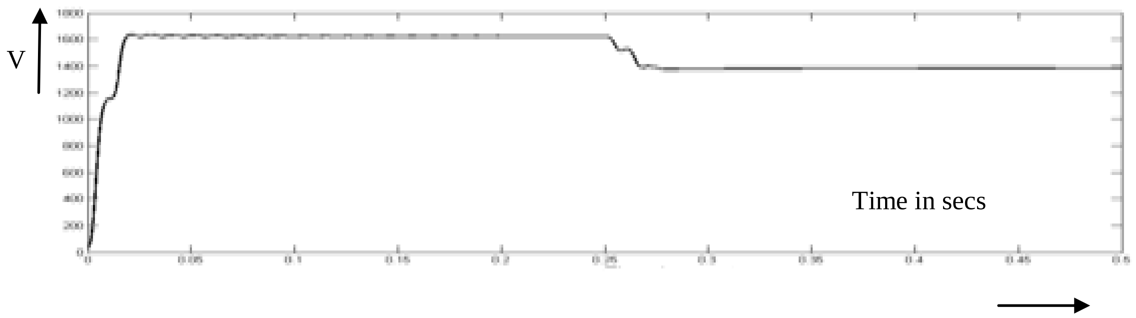

Fig. 7 Representation of RMS voltage of at bus-27

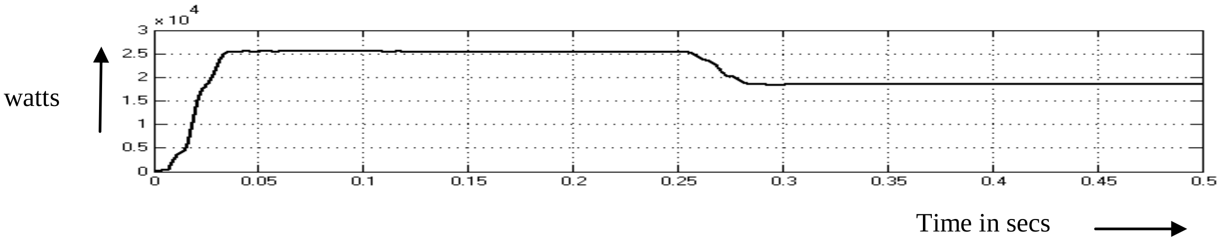

Fig. 8 Representation of Real power at bus-27

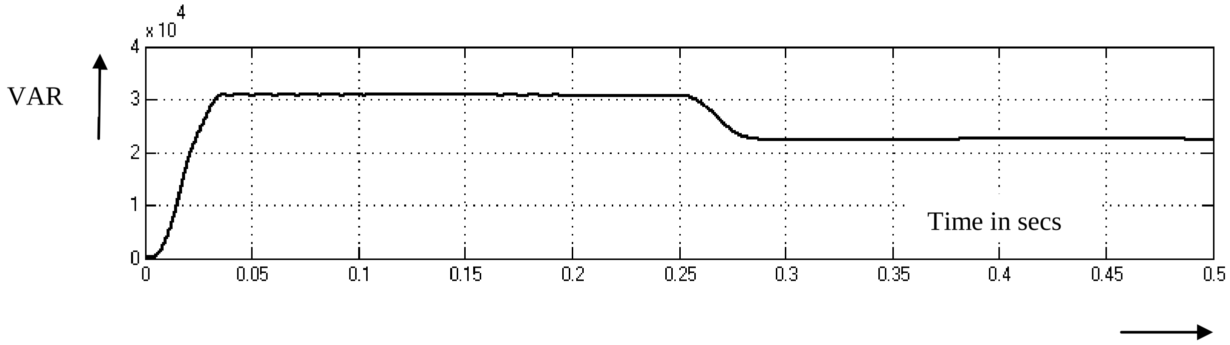

Fig. 9 Representation of Reactive power at bus-27

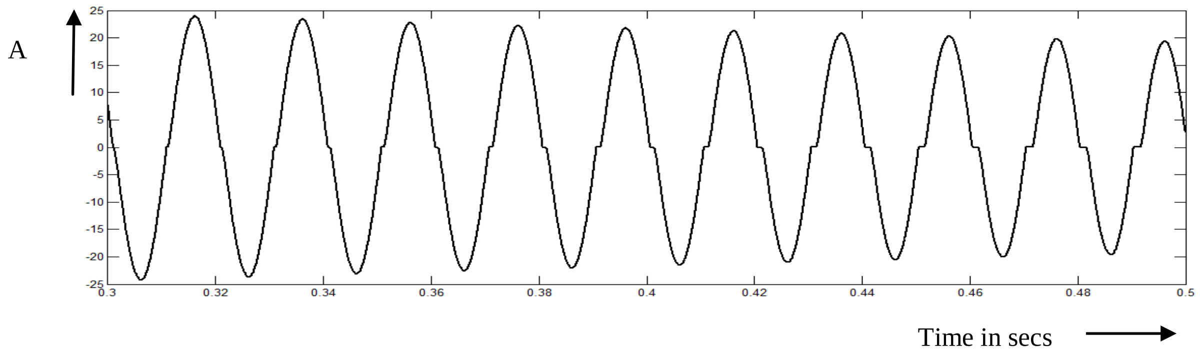

Fig. 10 Representation of current at bus-27

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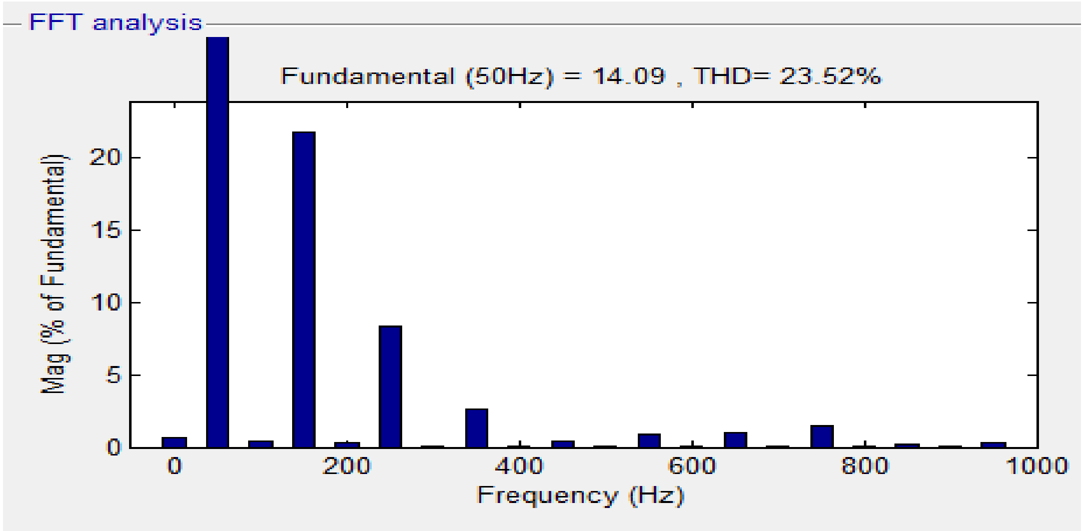

Fig. 11 Representation of current THD at bus-27

B. Closed loop IEEE 30 bus system with PI Controlled SAF

Closed loop thirty bus system with PI controller is appeared in Fig.12. Representation of voltage at bus 27 is appeared in Fig.13. and its value is 2000V. Representation of RMS voltage at bus 27 is appeared in Fig.14 and its value is 1540 V. Representation of Real power and Reactive power at bus 27 is appeared in Fig.15 and Fig.16 respectively and its corresponding value is 0.023MW and 0.027MVAR. Representation of current at bus 27 and THD is appeared in Fig.17 and Fig.18 respectively.

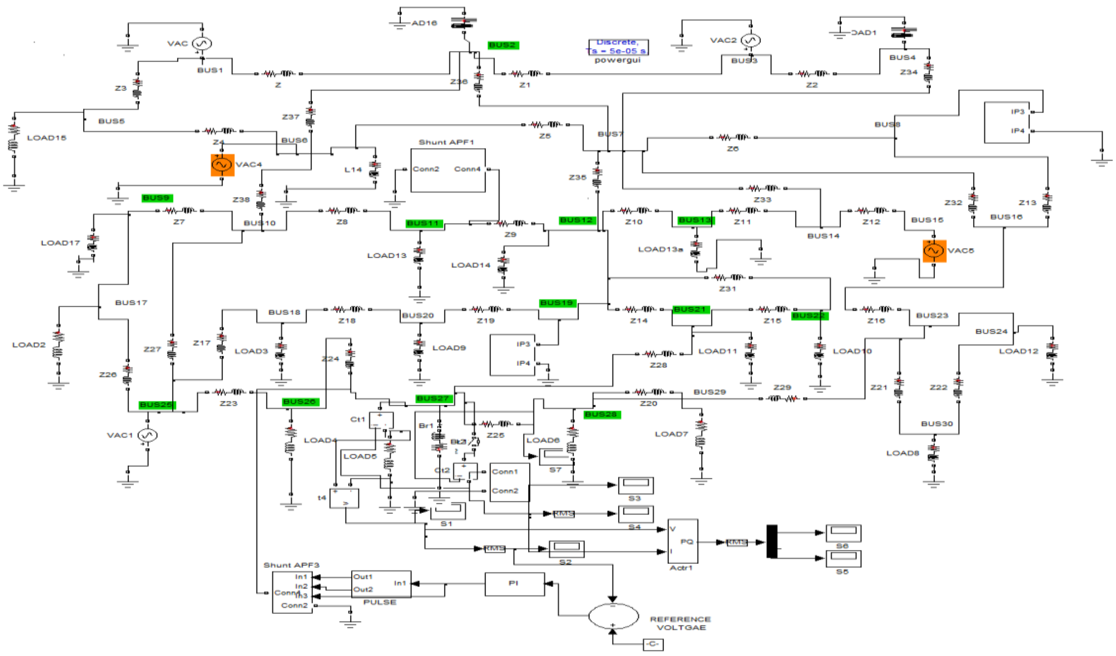

Fig. 12 Simlink of Closed loop thirty bus system with PI controller

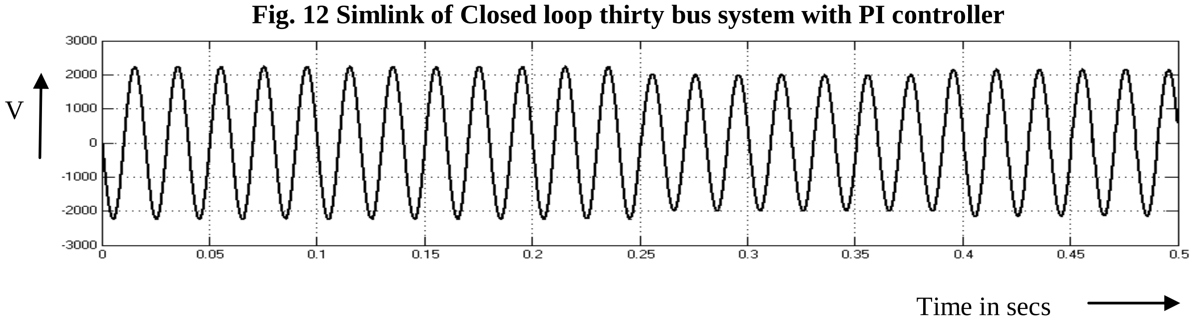

Fig. 13 Representation of voltage at bus-27

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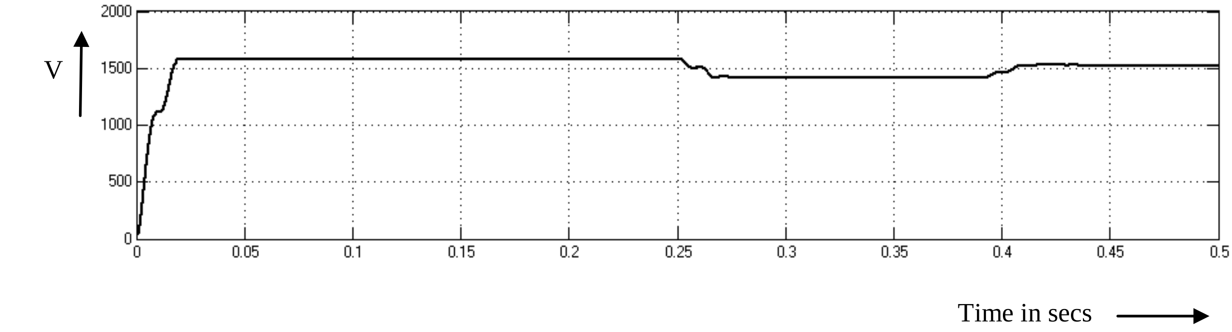

Fig. 14 Representation of RMS voltage of at bus-27

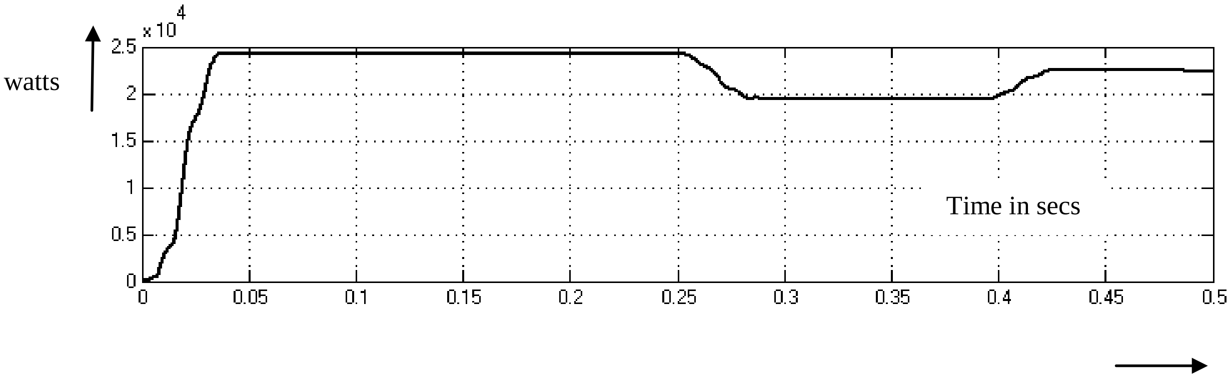

Fig. 15 Representation of Real power at bus-27

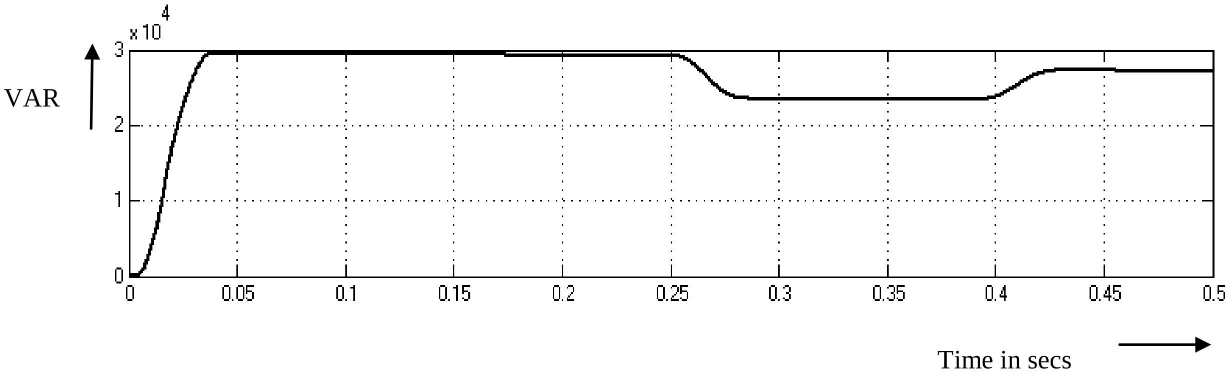

Fig. 16 Representation of Reactive power at bus-27

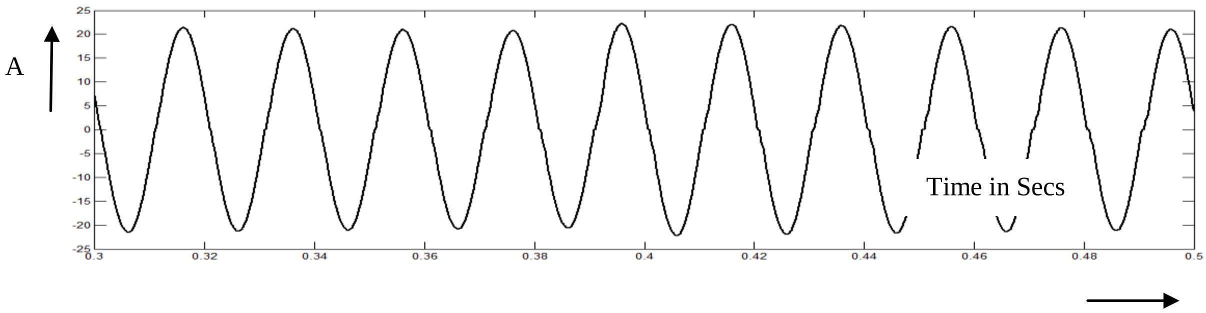

Fig. 17 Representation of current at bus-27

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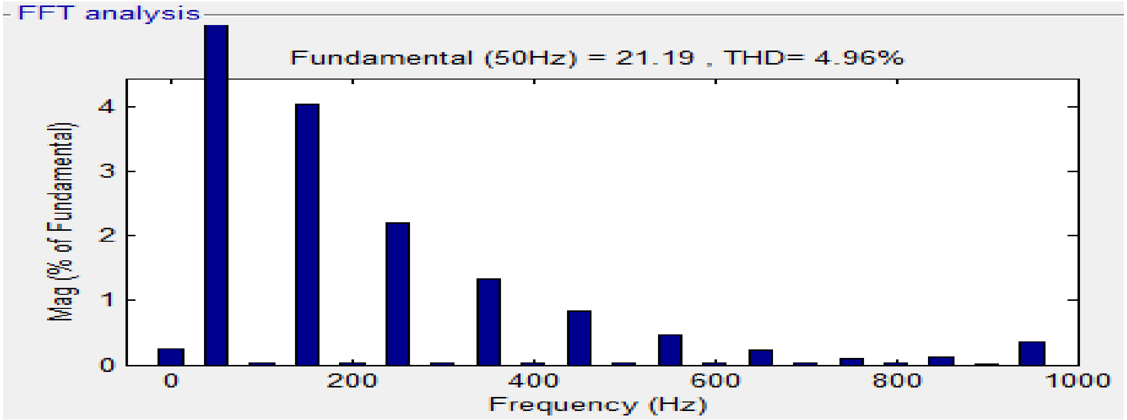

Fig. 18 Representation of Current THD at bus-27

C. Closed loop IEEE 30 bus system with SMC

Closed loop thirty bus system with SMC is appeared in Fig.19. Representation of voltage at bus 27 is appeared in Fig.20 and its value is 2000V. Representation of RMS voltage at bus 27 is appeared in Fig.21 and its value is 1550 V. Representation of Real power and Reactive power at bus 27 is appeared in Fig.22 and Fig.23 respectively and its corresponding value is 0.024M W and 0.028MVAR. Representation of current at bus 27 and THD is appeared in Fig.24 and Fig.25 respectively.

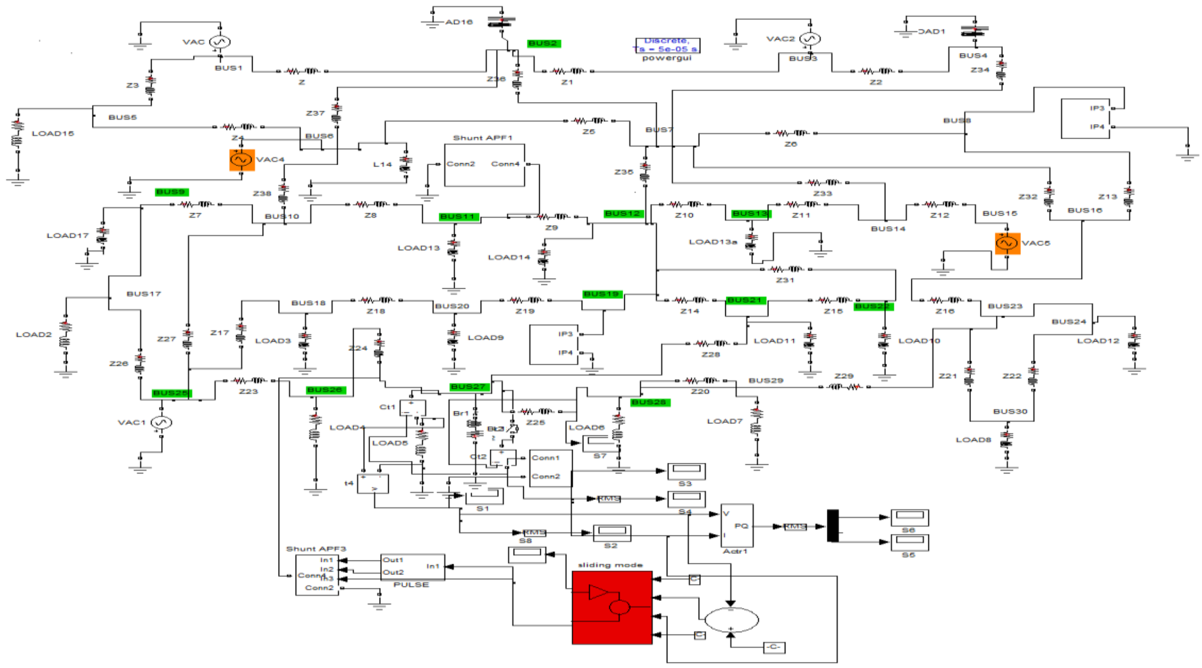

Fig. 19 Simlink of Closed loop thirty bus system with Sliding Mode Controller

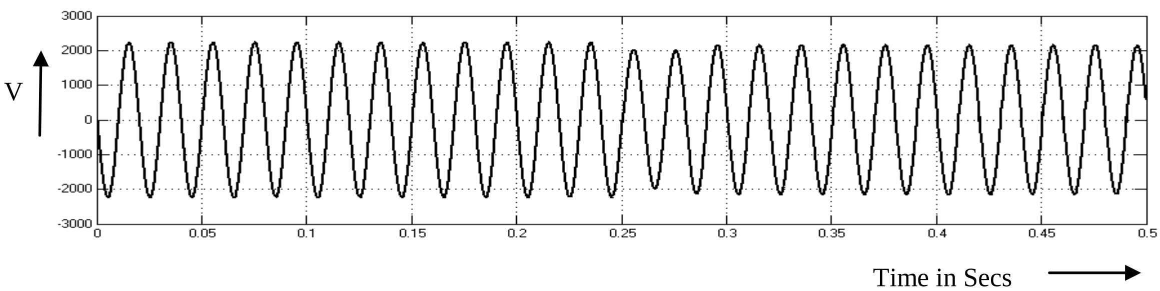

Fig. 20 Representation of voltage at bus-27

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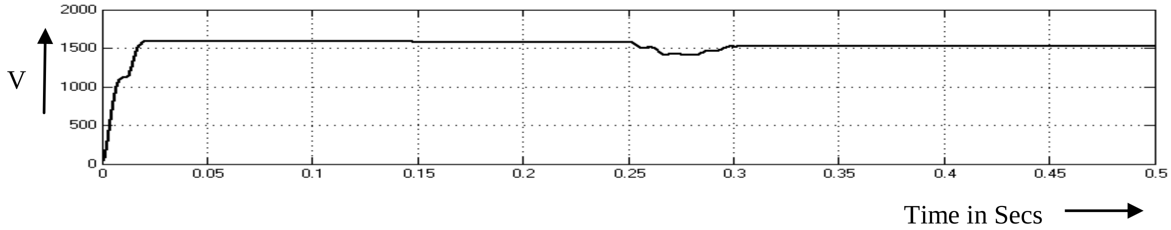

Fig. 21 Representation of RMS voltage at bus-27

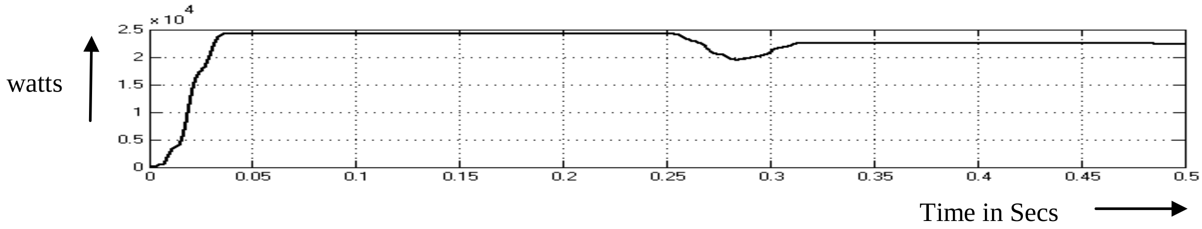

Fig. 22 Representation of Real power at bus-27

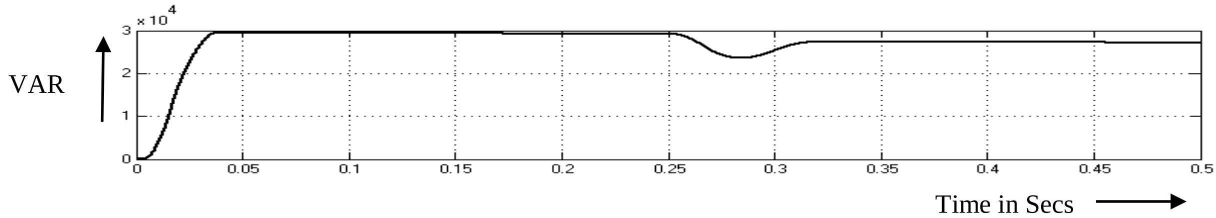

Fig. 23 Representation of Reactive power at bus-27

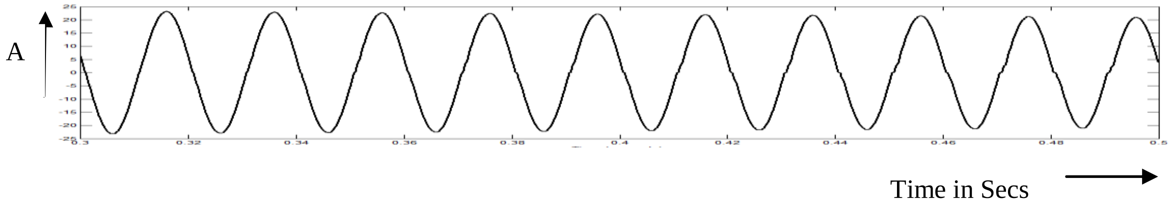

Fig. 24 Representation of current at bus-27

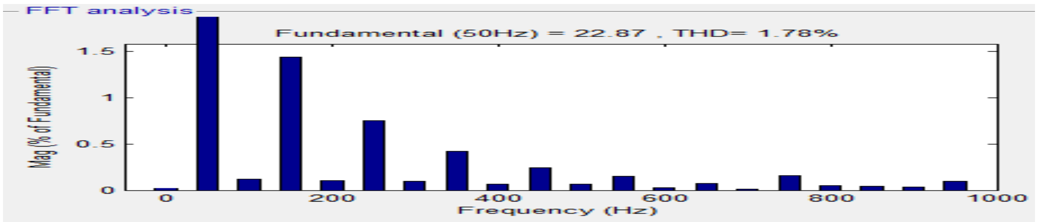

Fig. 25 Representation of current THD at bus-27

Table. 1 Comparison of time domain parameters for PI and SMC SAF

Controller	Rise time (s)	Peak time (s)	Settling time (s)	Steady state error (V)
PIC SAF	0.26	0.34	0.43	2.4
SMC SAF	0.25	0.25	0.26	1.1

Comparison of time domain parameters is appeared in table-1.By using SMC, rise time is reduced from 0.26 to 0.25 sec, peak time is reduced from 0.34 to 0.25 Sec, settling time is reduced from 0.43 to 0.26 Sec, Steady state error is reduced from 2.4 to 1.1 V. Comparison of current THD at bus 27 is appeared in table-2.By using SMC, THD is greatly reduced to 1.78% compared to PI controller based SAF. Hence, closed loop thirty bus system with SMC is superior to SAF with PI controller.

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Table. 2 Comparison of current THD at bus 27

Controller	Current THD
Open loop system without controller	23.52%
Closed loop thirty bus system with PI controlled SAF	4.96%
Closed loop thirty bus system with SMC controlled SAF	1.78%

APPENDIX-I LINE DATA AND LOAD DATA

BUS NO	VOLTAGE	LOAD IMPEDANCE		BUS NO	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

VII. CONCLUSION

In this paper closed loop IEEE thirty bus system with PI and Slide Mode Controller are simulated. The steady state error is reduced from 2.4 V to 1.1 V. Therefore SMC based active filter is alternative way of usuage for the existing controller. The reduction in settling time and steady state error is very high in the case of SMC system. The settling time is reduced from 0.43 seconds to 0.26 seconds.

This paper provides the performence evaluation of time domain parameters on IEEE thirty bus system in closed loop manner. The improvement of dynamic time response of IEEE Fifty seven bus system using SMCSAF will be accomplished in future.

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