COMPARATIVE ANALYSIS OF DIFFERENT SYSTEM TOPOLOGIES FOR A FUZZY CONTROLLED D-STATCOM FOR POWER FACTOR CORRECTION

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ABSTRACT: This paper presents three different topologies for D-STATCOM forimprovement of power factor in distribution network. Comparative analysis of different system topologies of D-STATCOM have been performed for power factor correction. The models are simulated in MATLAB for unbalanced and nonlinear load in a distribution system. The D-STATCOM is implemented with PWM current controlled six leg voltage source converter (IGBT based CSC) and switching patterns are generated through Synchronous Reference Frame Theory (SRFT).

Keywords:Distribution Static Compensator (D-STATCOM), Modeling, Fuzzy Logic controller, Synchronous Reference Frame Theory (SRFT).

INTRODUCTION

Most of the power quality problems in distribution system is due to unbalanced and non linearloads [1 2]. In most of applications the loads are nonlinear, such as converter,switch mode power supply (SMPS) ,arc furnace ,uninterruptable power supply (UPS),[3].Such type of loads introduce harmonic distortion and reactive power problems[4].the harmonic create undesirable issue as increase heat loss in transformer, low power factor,noise etc. The harmonic distortion problem is most common problem in distribution systemswhich is due to capacitor used for power factor correction and source impedance[5].there are technique which are used for power quality improvement in distribution system known as custom power devices[6]. These devices are useful for correction of power factor, harmonic compensation, voltage sag/swell compensation [7]. The Distribution Static Compensator is a shunt connected custom power device which is used for power factor correction on source side and THD improvement of source current [8]. D-STATCOM has a six leg voltage source converter with Insulated Gate Bipolar Transistor (IGBT) as a switching element. Different control strategies have been performed to evaluate the performance of D-STATCOM [9-15].Time domain simulation is used to perform these studies. This paper models and simulates three different topologies for distribution Static Compensator (D-STATCOM) using MATLAB/Simulink. These topologies are based on Synchronous Reference Frame [SRFT] control[16].

THREE DIFFERENT TOPOLOGY FOR D-STATCOM

Three different topologies which are used in this paper are

1. (Topology 1) D-STATCOM with supply side connected rectifier is shown in figure1
2. (Topology 2) D-STATCOM with load side connected rectifier is shown in figure2
3. (Topology 3) D-STATCOM with constant DC voltage is shown in figure3

Three phase unbalanced R-L load and diode rectifier as a nonlinear load is selected for these three topologies. A step transformer is used between D-STATCOM and distribution system.

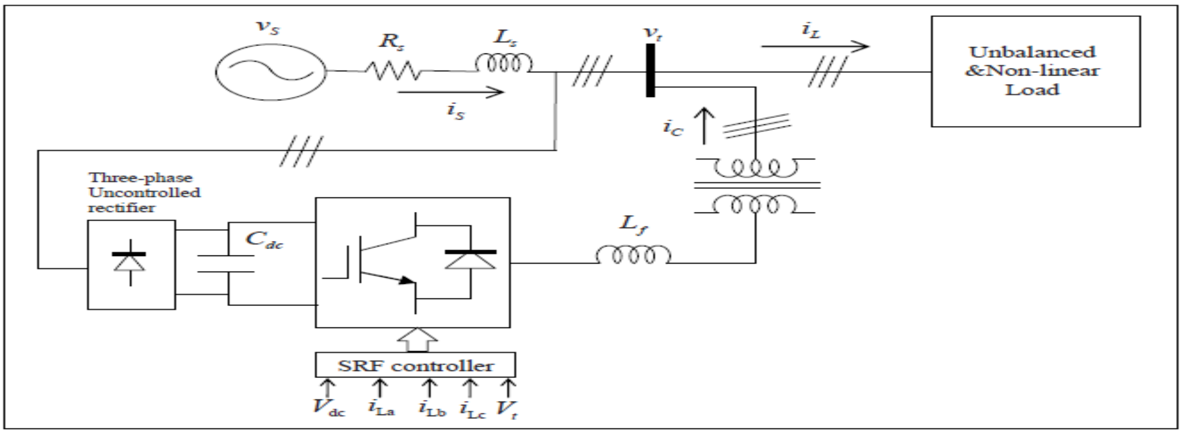


Figure1 D-STATCOM with supply side connected rectifier

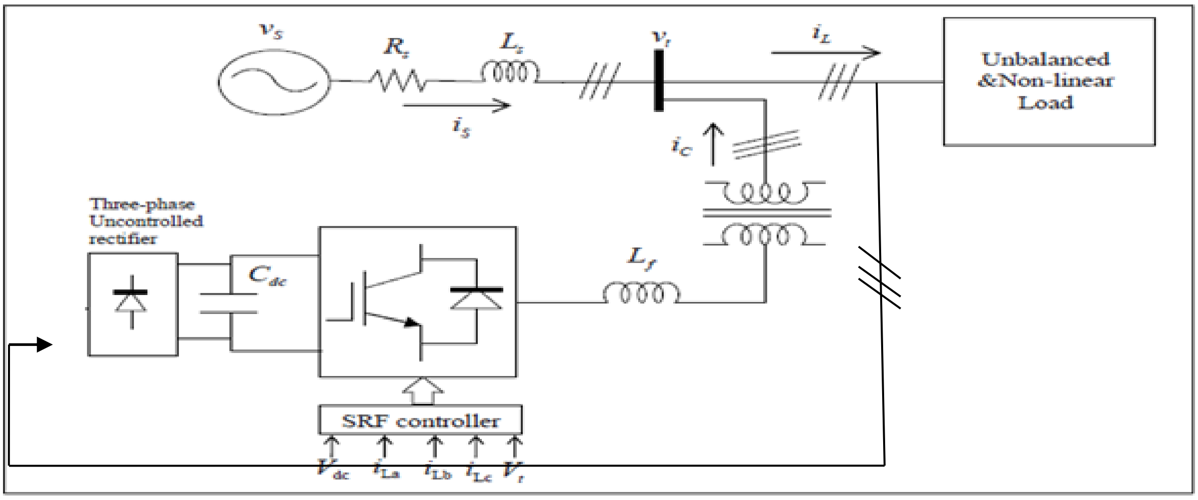


Figure2 D-STATCOM with load side connected rectifier

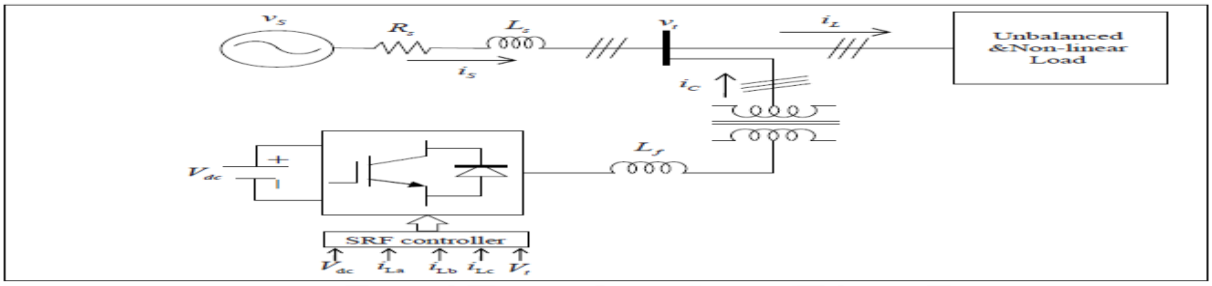


Figure3 D-STATCOM with constant DC supply voltage

CONTROL SCHEME

All topologies discussed above are controlled by Synchronous Reference Frame Theory (SRFT).It is shown in figure 4.Three phase load current in a-b-c frame are converted to two load current in d-q frame using following equation

$$id = \frac{2}{3}[i_{La}\sin\theta + i_{Lb}\sin(\theta-2\pi/3) + i_{Lc}\sin(\theta+2\pi/3)] \quad \ldots\ldots\ldots \quad (1)$$

$$iq = \frac{2}{3}[i_{La}\cos\theta + i_{Lb}\cos(\theta-2\pi/3) + i_{Lc}\cos(\theta+2\pi/3)] \quad \ldots\ldots\ldots \quad (2)$$

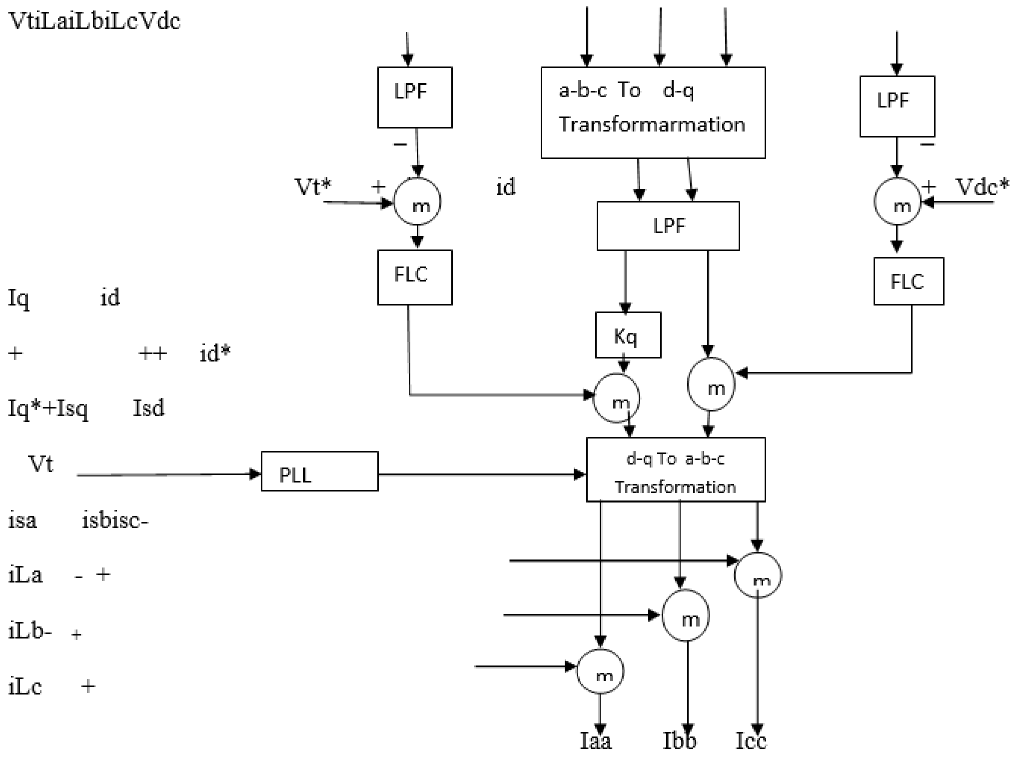


Figure4 Block diagram for Synchronous Reference Frame Control Scheme

The gain K_q is defined as ratio of Q_S^* to Q_L and its value will be zero for power factor improvement

The d-q component of reference source current are obtained as

$I_{Sd}=id+id^*$ ………… (3)

$I_{Sq}=K_q iq+iq^*$ ……….. (4)

The d-q component of reference source currents are converted to three phase a-b-c frame using following equation

$$isa = \frac{2}{3}[I_{Sd}\sin\theta + I_{Sq}\cos\theta] \quad \ldots\ldots\ldots \quad 5$$

$$isb = \frac{2}{3}[I_{Sd}\cos(\theta-2\pi/3) + I_{Sq}\sin(\theta-2\pi/3)] \quad \ldots\ldots\ldots \quad 6$$

$$isc = \frac{2}{3}[I_{Sd}\cos(\theta+2\pi/3) + I_{Sq}\sin(\theta+2\pi/3)] \quad \ldots\ldots\ldots \quad 7$$

The desired compensator current can be obtained as

$I_{ca} = i_{La} - isa$ ……… 8

$I_{cb} = i_{Lb} - isb$ ………. 9

$I_{cc} = i_{Lc} - isc$ ………. 10

FLC SECTION

The fuzzy Logic Controller (FLC) has been widely used in systems with complex structure as it does not require mathematical model of control system [17]. The FLC can be visualized as shown in figure 5. It consistsof four main component viz. Fuzzificationunits, Interference Engine, Rule Base and De fuzzification. Fuzzification is a process of transform the numeric into fuzzy sets. The interference engine is the heart of fuzzysystem. Itperforms all logical manipulation in a fuzzy system. Rule Base consist of IF-THEN rules and membership function that characterising the fuzzy sets. Output of interference unit represented by fuzzy sets, but the output of fuzzy sets should be numeric value. The transformation of fuzzy sets into numeric value is called De-fuzzification.The input, output scaling factor are needed to modify the universe of discourse.

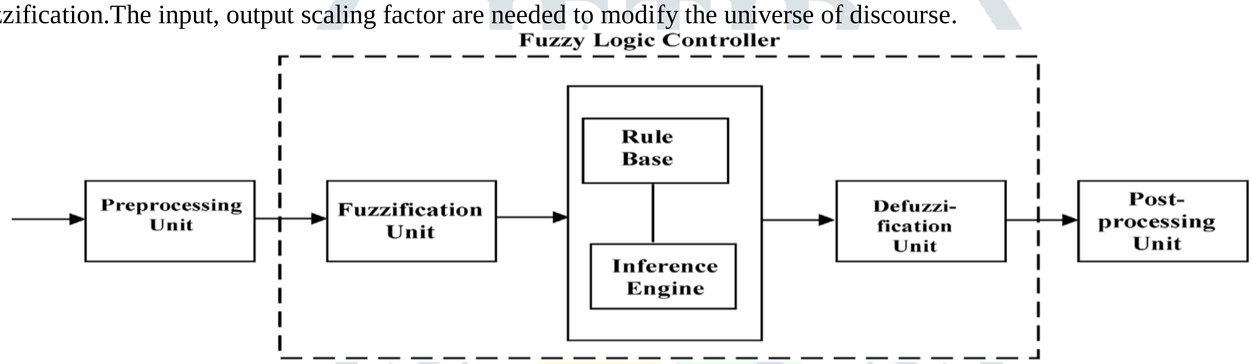


Figure 5 various parts of fuzzy logic controller

In synchronous Reference frame control two FLC block are used. One is used for error signal Id and other is used for error signal Iq. Both the controller has two inputs and one output.Simulink model of SRF controller using fuzzy controller is shown in figure 6.

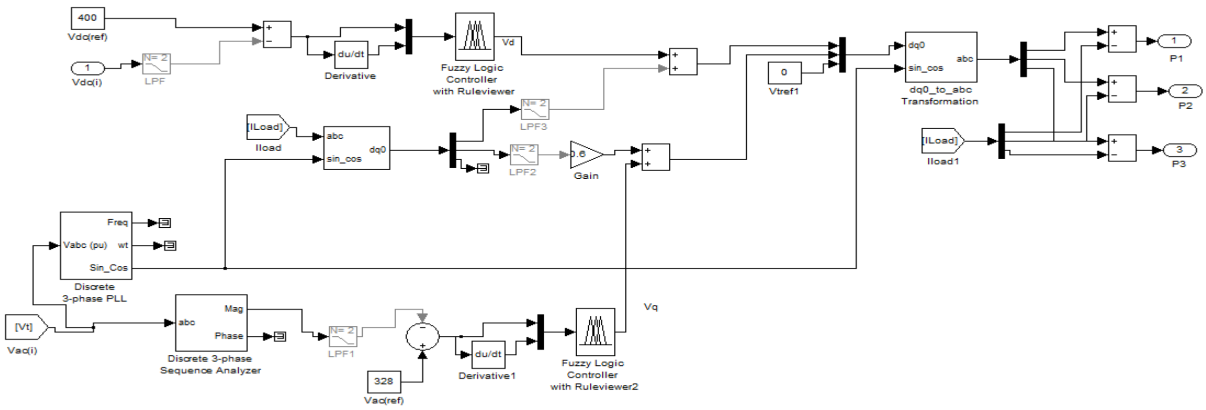


Figure 6 Simulink model of SRF controller using fuzzy controller

The input for direct axis FLC section is chosen as error in DC link voltage and change in DC link voltage can be represented as

$e(i) = V_{DC(ref)} - V_{DC(i)}$ …………………… (11)

$de(i) = e(i) - e(i-1)$ …………………… (12)

Wheree(i) is error and de(i) is change in error.$V_{DC(ref)}$ is DC reference voltage and V_{DC} is the DC link voltage.Theinput for second FLC is chosen as error in AC link voltage and changes in AC link voltage and can be represented as

$e(i) = V_{AC(ref)} - V_{AC(i)}$ …………………… (13)

$de(i) = e(i) - e(i-1)$ …………………… (14)

Where$V_{AC(ref)}$ is the reference AC voltage and $V_{AC(i)}$ is the AC link voltage.Five triangular membership functions are chosen for input variables and the output variable, namely: NB, NS, Z, PS and PB, representing negative big,negative small, zero and positive small and positive big, respectively, in the investigation implementedusing the membership function editor as depicted at Figure 7. A fuzzy inference systemfile named "AT2" is developed with the triangular membership functions as shown in Figure8.

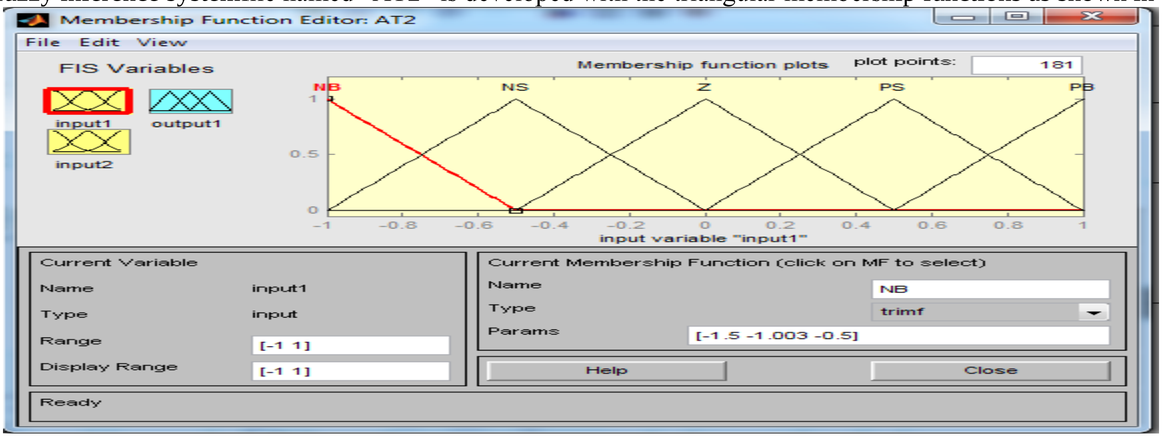


Figure 7 Membership Function for Fuzzy Logic Controller

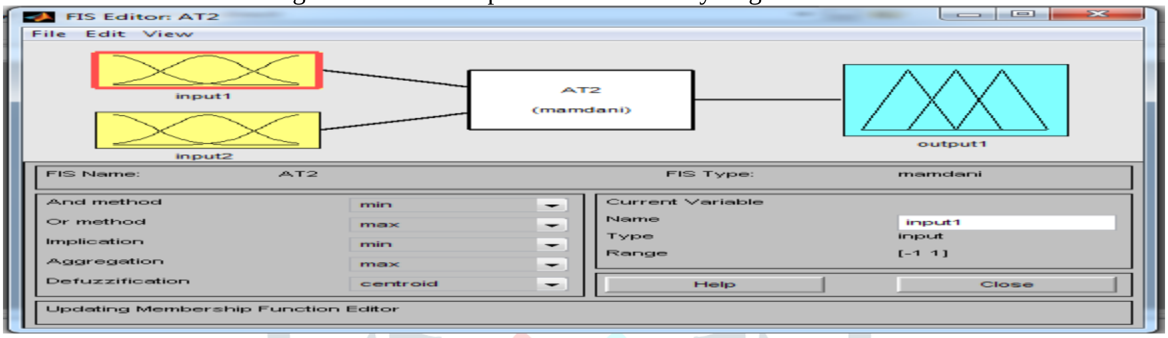


Figure 8 FIS file for Fuzzy Logic Controller

The 25 Fuzzy rules applied which are shown in Table 1. Thebasic rule of FLC gives the relationship between the input and output [18]. TheRule base characterizes the control goals and control policy of the domain experts by means of setlinguistic control rules.

Table1. Rule Base for Fuzzy Controller

e(i)	NB	NS	Z	PS	PB
de(i)					
NB	NB	NB	NS	NS	Z
NS	NB	NB	NS	Z	Z
Z	NS	NS	Z	PS	PS
PS	Z	PS	PS	PB	PB
PB	Z	Z	PS	PB	PB

Most of the FLCs are based on various methods. The widely used method inthe FLC design is the Mamdani method proposed by Mamdani and his associates who adopted amin–max compositional rule of inference based on an interpretation of a control rule as a conjunction of the antecedent and consequent and this method has been used in this work.

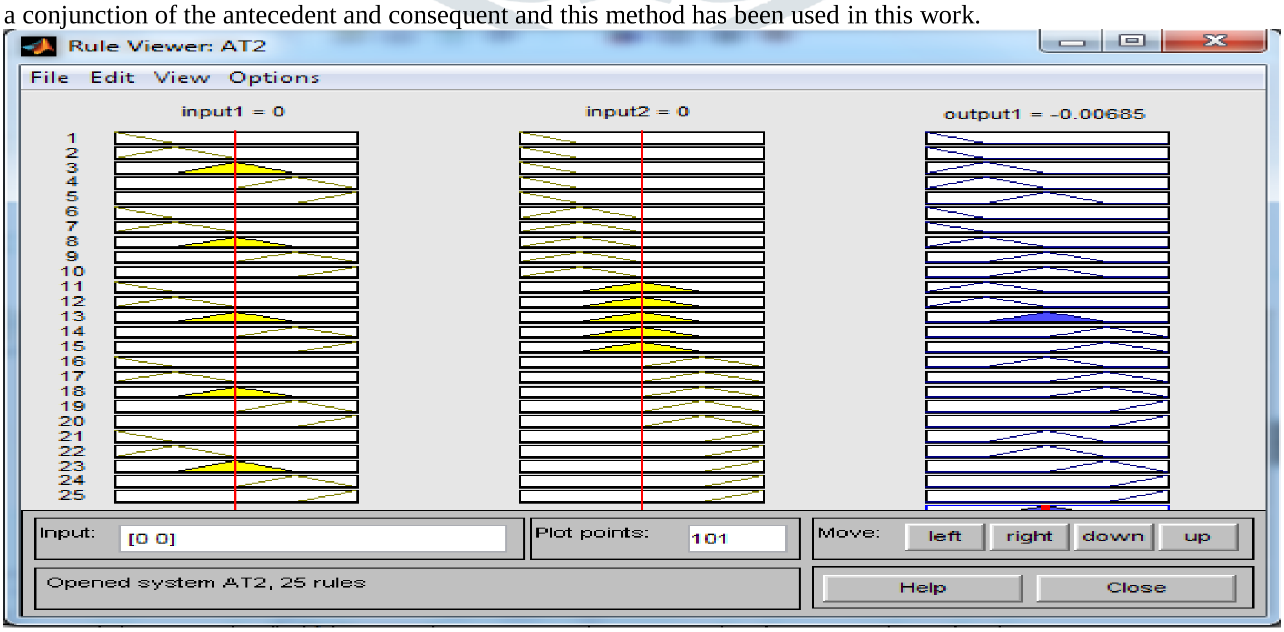


Figure9 Rule Viewer of Fuzzy Logic Controller

The ruleviewer and the surface viewers of the FLCs used in the model are shown Figures 9 and 10 respectively.The rule viewer is used for determining the approximate reasoning of the results of FLC andthe surface viewer is used to observe the pattern of decision-making based on the rules formulated.

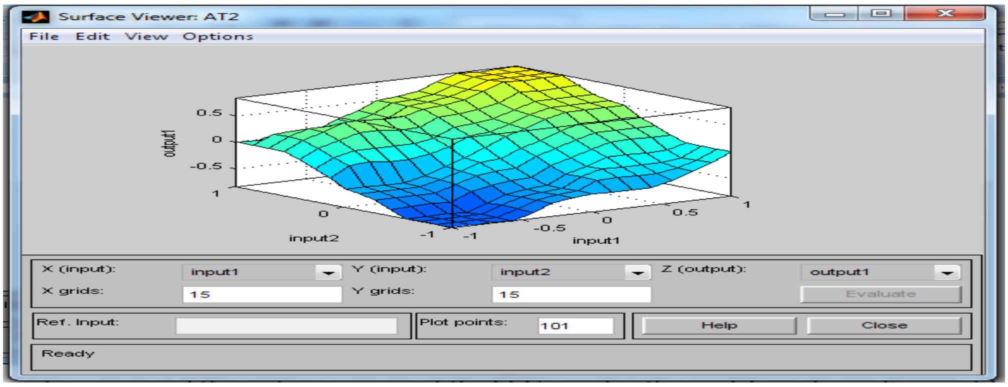


Figure10 Surface Viewer of Fuzzy Logic Controller

The basic fuzzy rules are framed using the rule editor available in the MATLAB environment. Aftercompiling the basic rules, the investigation is carried out in accordance with the rule and the surfaceviewers.

SIMULINK MODEL FOR DIFFERENT TOPOLOGIES

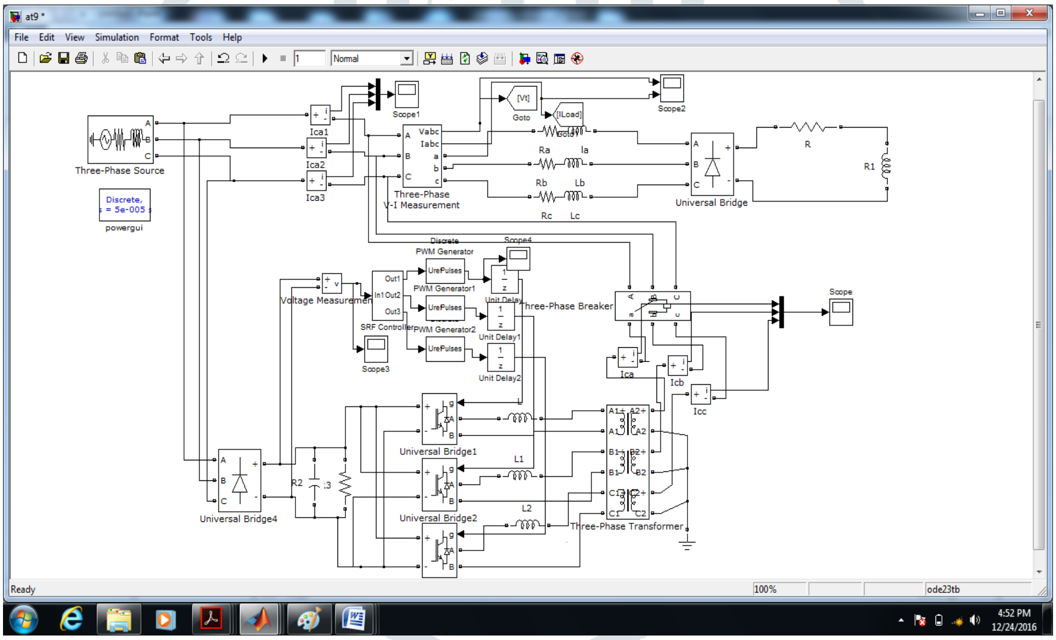


Figure 11 Simulink model of D-STATCOM with supply side connected rectifier

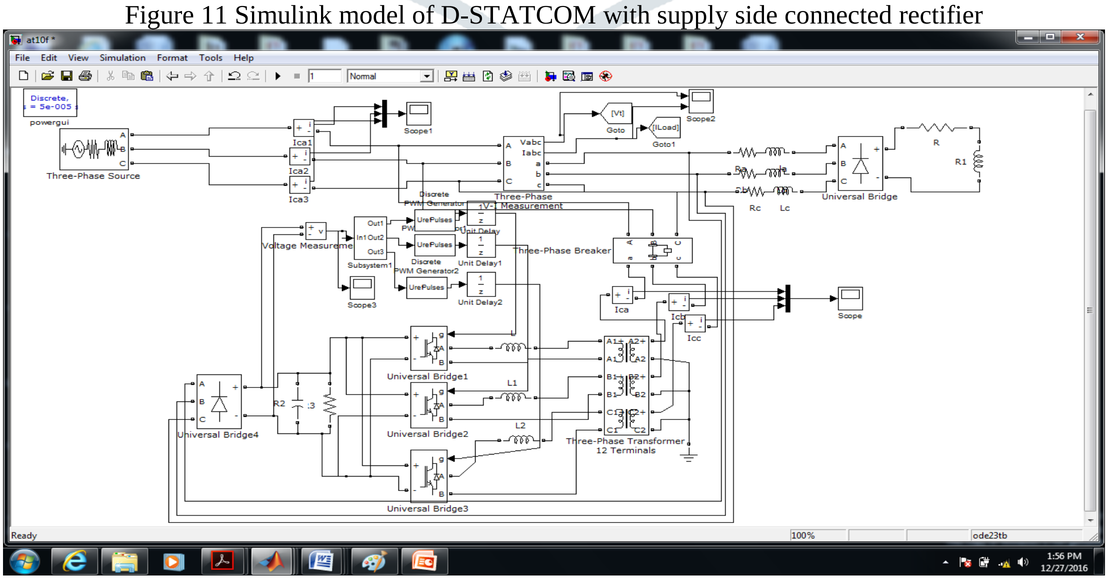


Figure 12 Simulink model of D-STATCOM with load side connected rectifier

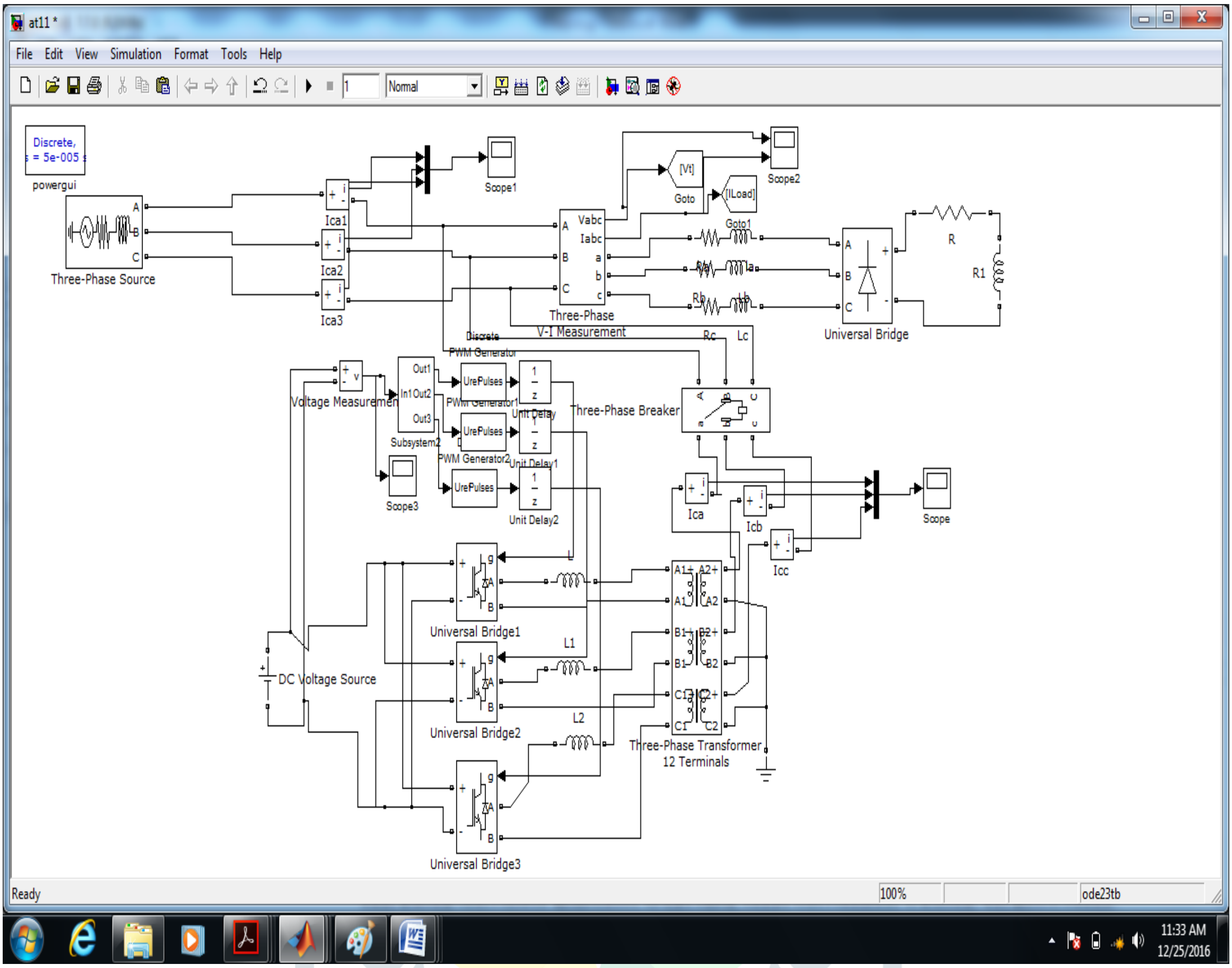


Figure 13 Simulink model of D-STATCOM with constant DC voltage supply

RESULT AND DISSCUSION

Three different topologies have been simulated for power factor improvement. Based on simulation following results can be analyzed.

Simulation results for Topology 1 is shown in figure 15 which shows the graph of source current, load current, compensator current, terminal voltage, and DC link voltage respectively. Load current is unbalanced and non-sinusoidal. Power Factor will be unity because the phase angle between the source currentand terminal voltage is zero. Power factor can be improved after the D-STATCOM is switched on. The DC link voltage increasescontinuously until the D-STATCOM is switched on and finally reaches to steady state value of 520V.

Simulation results for Topology 2 is shown in figure 16which shows the graph of source current, load current, source current,terminal voltage, and DC link voltage respectively. Load current magnitude is comparatively increased unbalanced.Power factor can be improved after the D-STATCOM is switched on. The DC link voltage increase exponentially until the D-STATCOM is switched on and finally reaches to steady state value of 270V.

Simulation results for system 3 is shown in figure 17 which shows the graph of source current, load current, compensator current,terminal voltage, and DC link voltage respectively. Power factor can be improved after the D-STATCOM is switched on. The DC link voltage is maintained constant at 500V before and after the D-STATCOM is switched on and allow the D-STATCOM to improve the power factor without any interruption in load current.

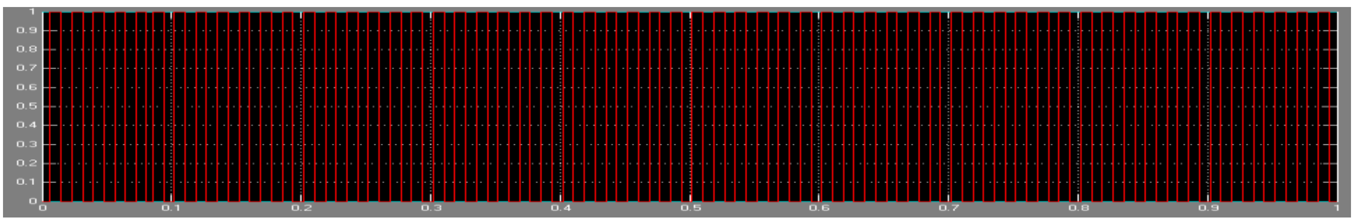


Figure14 PWM Pulses for IGBT

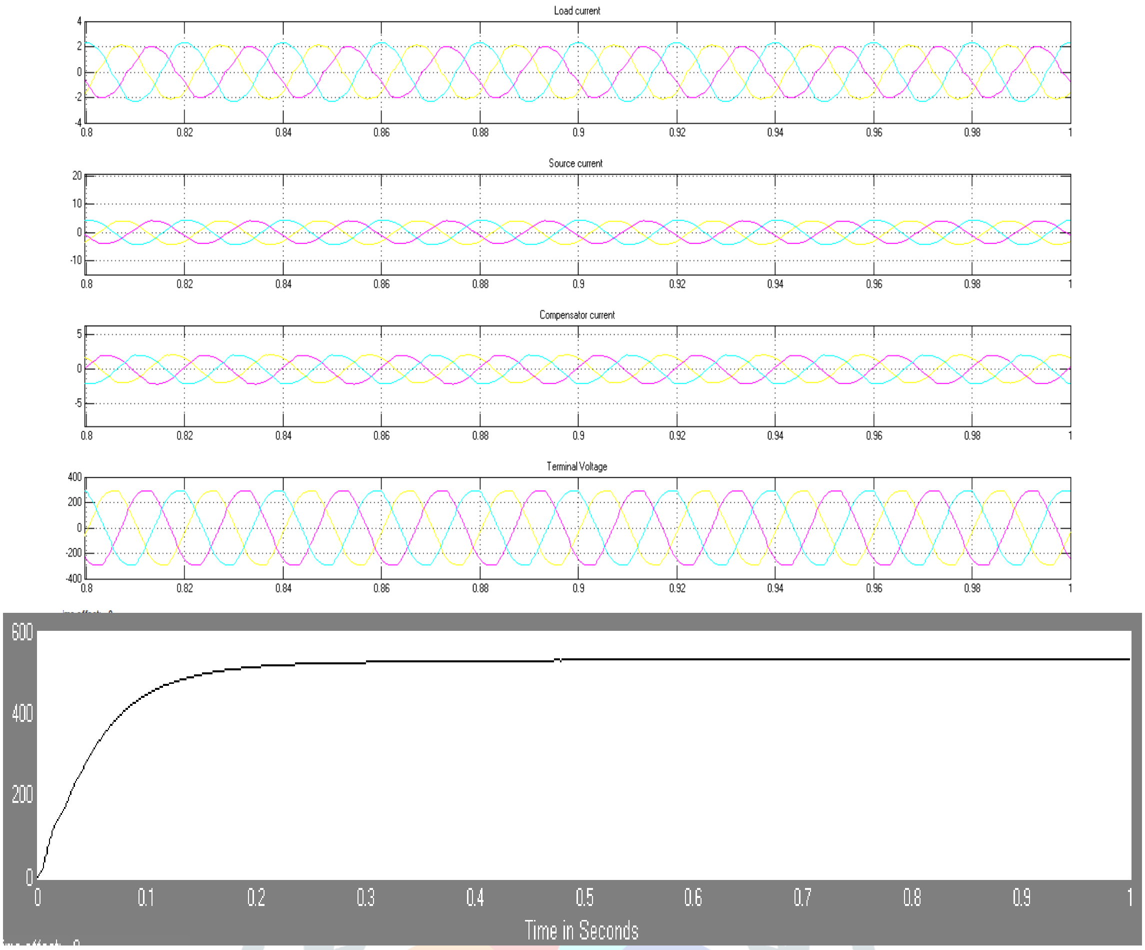
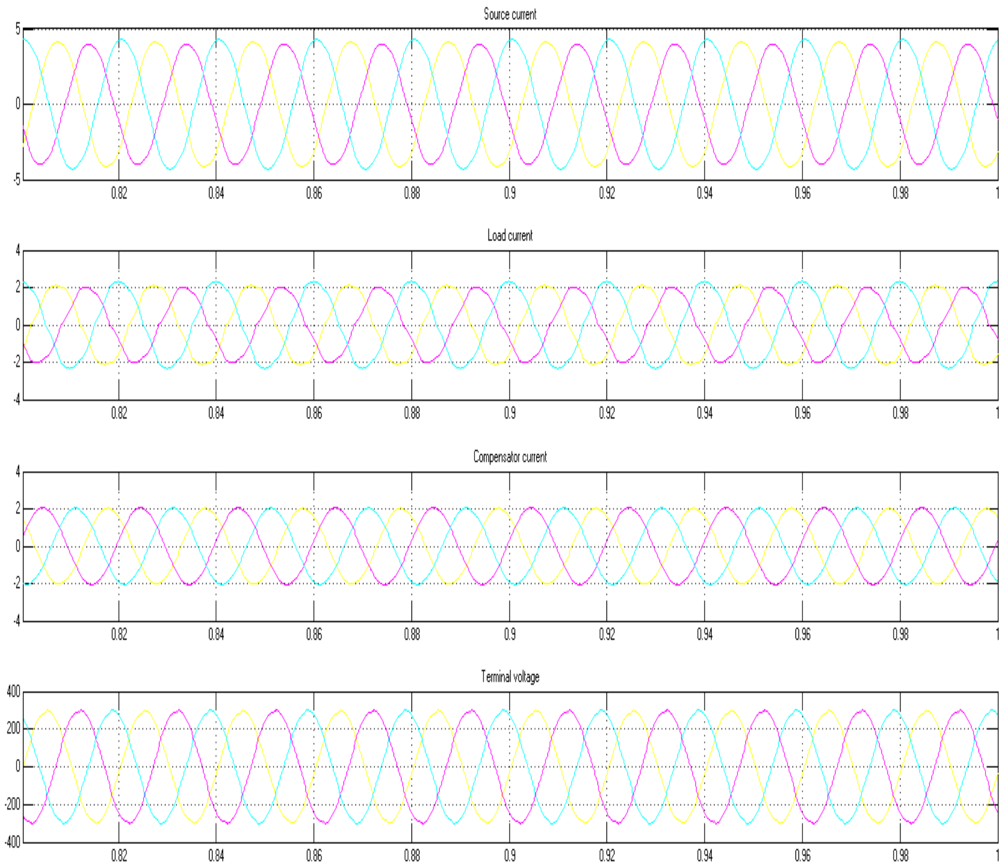


Figure 15 System responses with power Factor Improvement (Topology 1)



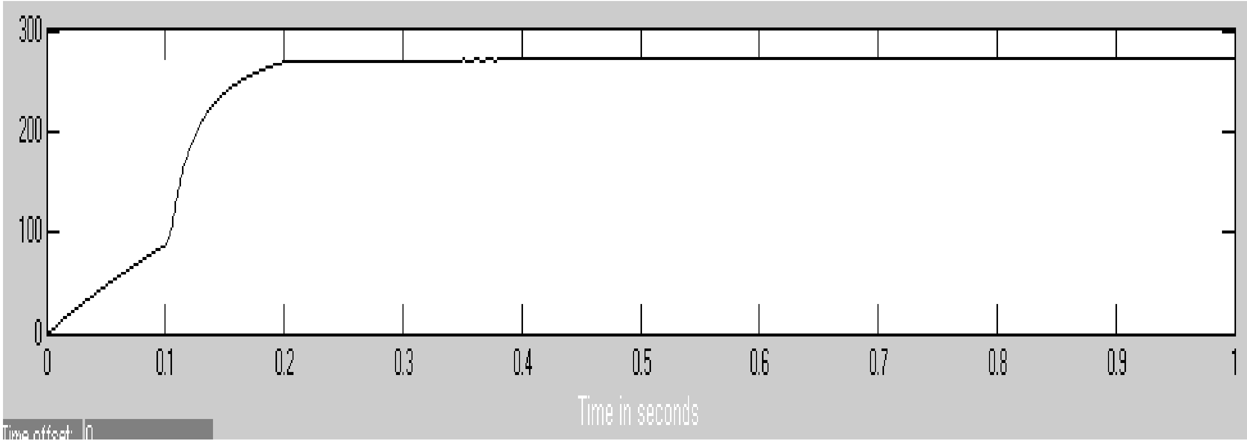


Figure 16 System responses with power Factor Improvement (topology 2)

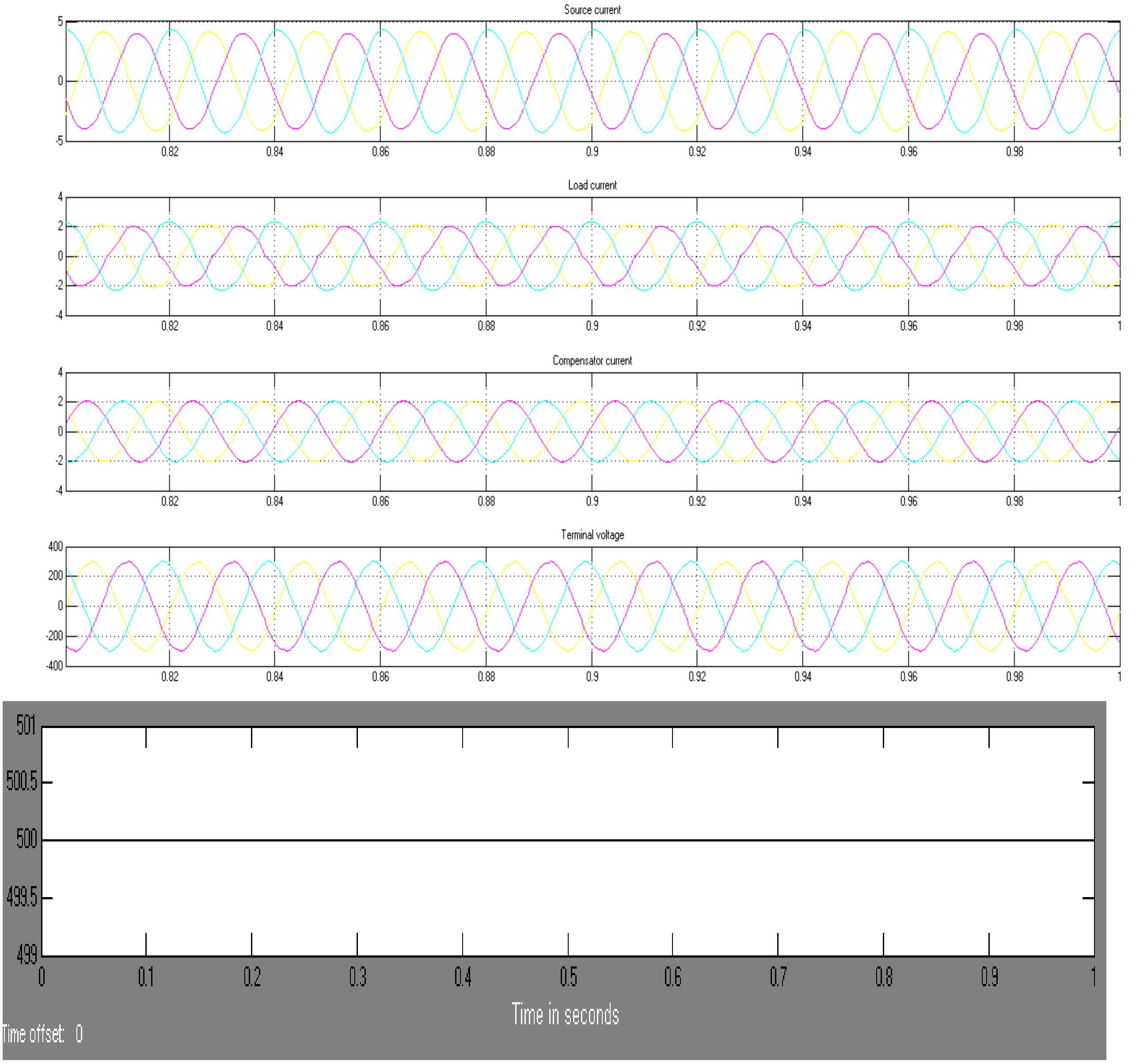


Figure 17 System responses with power Factor Improvement (Topology 3)

CONCLUSION

In this paper three different topologies of D-STATCOM have been analyzedfor power factor correction.The control of D-STATCOM system topologies is based on Synchronous Reference Frame Control. Time domain simulations have been used to verify the operation of the models.

In topology-1 the power factor is unity because the terminal voltage and source current are in phase. In topology-2 the factor in improved after the D-STATCOM is on. In topology-3before and after the D-STATCOM is switched on and allow the D-STATCOM to improve the power factor without any interruption in load current.

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