

A Fuzzy Controller based D-STATCOM for Induction Motor Drive Applications to Power Quality Improvement

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Abstract

In this article represent the development of fuzzy controller based DSTATCOM and placed at the load side in the EDS (Electrical distribution system), so in the load side which can be eliminate the power quality problems of input side (like voltage sags, swells and etc...). So improvement of power quality fuzzy controller based DSTATCOM will absorb along with supply reactive power to eliminate the voltage sags, swells and get better power factor in different circumstances. The main advantages of D-STATCOM designed for resolve power quality issues due to voltage sags, swells etc., have be recommended. The principle of fuzzy based D-STATCOM is to supply the better voltage regulation through the short period of the induction motor appliances starting as well as hence avoid the large voltage dips. So in this paper simulates a fuzzy based D-STATCOM for industrial induction applications and also check the performances of induction motor drives like speed, torque and stator currents by using MATLAB /SIMULINK software.

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I. INTRODUCTION

The FACTS (flexible AC transmission Systems) technology is an innovative explore region in Electrical engineering. It initiates the recent power electronic technology keen on conventional AC power transmission systems as well as extensively improves the power quality and relocate boundary. Flexible AC transmission Systems equipments are supply an improved variation to unreliable operational circumstances and get better the practice of previous mechanism. They include essential appliance such as power flow control, rising of transmission capacity, voltage control, reactive power compensation, stability development and

power quality improvement. The fuzzy based DSTATCOM-F is equipment of the flexible AC transmission Systems with it is stand on a VSI (voltage-source inverter) [5].

Improvement of the quality Power (flexible AC transmission) is the main important in the present world. It has turned into significant, frequently, through the preface of FACTS devices, whose presentation is extremely susceptible to the power quality supply. The quality of power issues is an incidence manifests as a voltage fluctuations levels, current or frequency those consequences in a breakdown of last part of the equipment. The main troubles deal at this point is the voltage sags,

sweels., etc. To eliminate this problem, custom power devices are used. One of those devices is the distribution static compensator DSTATCOM, which is the most efficient and beneficial modern custom power device used in the distribution system. Its appeal includes lower cost, smaller size, and fast response to the disturbance [1].

Voltage fluctuations (sags, swells, etc) are the most part happening power quality harms. Voltage sag is basis through a fault in the EDS, a fault contained by the consumer ability or a huge enhance of the load current, i.e., preliminary a motor or transformer stimulating. Designed for a manufacturing, voltage sags are happen further frequently as well as reason strict tribulations moreover inexpensive sufferers. Utilities frequently center on instability from customer equipment as the major power quality issues. There are dissimilar conducts toward moderate the power quality issues in Electrical transmission systems and Electrical distribution systems. In recent custom power devices, D-STATCOM is the most capable devices.

In the middle of these, the D-STATCOM is one of the most effective devices. The D-STATCOM saves from voltage fluctuations the efficacy electrical transmission systems or Electrical distribution system as of voltage flickers cause through fast unreliable reactive current require. In effectiveness application, a D-STATCOM supply covers reactive power to achieve scheme stability [2].

The D-STATCOM was offered support on the function of SVPWM in favor of 3- Φ VSC's as well as it is the normal PWM methods to use the DC-AC conversion as well as projected a fuzzy control scheme support on fuzzy variables which is a scale fault happening the among source of the D-STATCOM moreover its location for sag/swell rectification. [3] Also the significance of determine electrical energy sag difficulty apparent in voltage (or) current to facilitate effect in breakdown of customer power device. And headed for current representation of the CPD Devices are like D-

STATCOM along with fuzzy control function to moderate voltage sag problems, the new D-STATCOM equipment was develop by using MATLAB/Simulink tools, and the Simulation outcomes were accessible to reveal the voltage sags of the D-STATCOM[4]

Fuzzy logic Controller (FLC) is used as a controller of the proposed D-statcom represents qualitative information, as well as offers the interpretability toward method representation. Zadeh has reviewed FLC as a body of impression as well as procedures in favor of production with imprecision, in sequence granulation, estimated analysis as well as compute through terms fairly than numbers. In excess of the precedent two decades, the present incredible expansion in the employ of FLC'S in Electrical power systems as well as power conversion applications [6].

In paper explains the basic operation of Fuzzy controller based D-STATCOM for Induction Motor Drive Applications and in section II explains about DSTATCOM operation, section III explains the fuzzy controller operation section IV explains the Simulation Result Analysis, Section V explains the conclusion of the paper.

II. DSTATCOM

This main proposed method of the Distribution Static Compensator (DSTATCOM) with the both PI & fuzzy control methods. Commonly, the voltage Parameter is synchronized by a Proportional Integral (PI) controller while different controllers are use in favor of load compensation techniques. Throughout the load varies here is substantial difference in voltage which may have an effect on compensation. In the Present theory is a FLC (fuzzy logic controller) based technique is proposed controller to get better transitory performance of the dc link. The FLC based controller varies the proportional and integral gains of the PI controller throughout the

transient response instantaneously subsequent to a load vary.

Power quality is nothing but a have an effect on the voltage source, current source as well as frequency deviations of the power supply to the consumers. The stable voltage is the main condition of the consumer, if the voltage is worse than the acceptable limits it will reason over heating of the apparatus as well as a smaller amount illuminate power to the light loads. If it happens in higher than the boundary it may cause a fabric, insulation collapse, reduce the existence of light load, etc. Lightning of loads, over voltages caused by switching losses, short circuit faults, and short term faults are the major reasons of the voltage differences which may lead towards the enduring harm of the apparatus.

To control the Reactive power is a significant thought during improvement of the power quality in Electrical systems. To controlling of the Reactive power and the losses of the transmission systems is less, disgrace the transmission of power capacity as well as declines the regulation of voltage on the load side. In the conventional methods are Thyristor based Controlled Reactors (TCR) as well as Thyristor based Switched Capacitors be apply in favor of the reactive power reparation. In FACTS (flexible alternating current transmission systems) has been verified to the DSTATCOM is an apparatus able to resolve the power quality issues. If the power quality issues that constantly happen in the scheme is 3- $\emptyset$ faults which may reason by a short circuit in the scheme, mis-switching functions, preliminary large motors etc. This difficulty occurs in milli-seconds along with because the time restriction, it needs the D-STATCOM that has uninterrupted of the reactive power control through the quick response.

DSTATCOM is nothing but a shunt connected mechanism considered towards control the voltage also producing or spellbinding of the reactive power. The figure of a proposed CPD device D-STATCOM

has one DC capacitor, VSI, transformer as well as reactors.

In a D-STATCOM is the mainly capable and effectual recent CPD device is employed in Electrical Power system. Their requests contain lesser price, slighter size, as well as its quick response toward the interruption. DSTATCOM is having a one voltage source inverter (VSI), and DC power storage equipment, one transformer joined in shunt to the power system throughout a couple transformers. The VSI, which convert the DC voltage transversely the power storage device keen on a position of 3- ϕ AC output voltages. And the voltages are in phase and it's connected to the AC systems of transformer.

And the appropriate modification of the phase value as well as magnitude quantity of the D-STATCOM voltages allocate efficient control of the both active power as well as reactive power connections among the D-STATCOM along with the AC connected system. Such arrangements allow the apparatus to absorb otherwise generate convenient active power as well as reactive power as shown in the Figure 2

A D-STATCOM is able to compensate the bus voltage or line current. And D-STATCOM will be operates in two modes based on the restrictions which it regulate [9]. The two operation modes of DSTATCOM are classified as:

- Mode-1

In Voltage mode operation mode, it preserve create the bus voltage toward which it is coupled a sinusoidal form. This can be achieve irrespective of the disturb or deformation in the supply side voltage.

• Mode-2

In Current mode operation mode of process, the D-STATCOM is the source side current value toward the balanced condition of sinusoidal form irrespective of the load side current distortions.

The fundamental basic regulation of a D-STATCOM in voltage distortion is to control the bus voltage through produce or captivating the total reactive power. As a result, the proposed DSTATCOM operate any as an inductor or else like a capacitor mode is the magnitude value of the bus load voltage.

The expression for Reactive power by load part is

$$Q_L = Q_{s1} + Q_{sh} \quad (5)$$

Real power of the proposed D-STATCOM is

$$P_{STATCOM} = P_{sh} - P_{LOSS} \quad (6)$$

Reactive power of the proposed D-STATCOM-

$$Q_{STATCOM} = Q_{s1} + Q_{sh} \quad (7)$$

Where P_lossmodule of D-STATCOM commencing the schematic figure 1.

$$i_s = i_L(t) + i_{STATCOM}(t) \quad (8)$$

III. CONTROL METHODS

Proportional Integral (PI)

The main theme of the proposed control methods to implement the controlling of a D-STATCOM utilize for the voltage improvement is to manage the total of reactive power switch over among the STATCOM as well as the supply side of the bus. When the voltage of Point of Common Coupling (PCC) is having less than the Voltage reference worth followed by the D-SATACOM generate the reactive power along with the voltage of PCC is higher than the Voltage reference value next the D-SATACOM absorb the reactive power.

In the direction of attain the preferred characteristics, and then the pulses of firing angle in Pulse Width Modulation of VSI are controlled. The real bus voltage values is contrast through the reference voltage value as well as the error value is approved throughout a Proportional Integral (PI) regulator. The regulator generates a indicate which is particular as an input side toward the PWM generator. The generator to ending among generates trigger the pulses so that the value of the voltage is inequity correct. The controller diagram of the circuit as shown in the Figure 2.

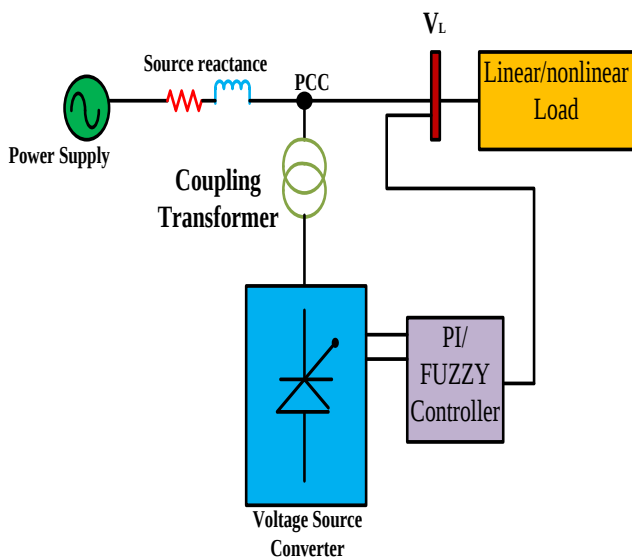


Figure.1: schematic diagram of Proposed D-STATCOM

The expression for the total instantaneous power release strained by a load is

$$P_L(t) = P_{s1}(t) + P_r(t) + P_{sh}(t) \quad (1)$$

And the power supplied from source is

$$P_s = P_{s1} \quad (2)$$

The expression for Reactive power by source part is

$$Q_s = 0 \quad (3)$$

So the Total Power is sum of source power and shunt power

$$P_L = P_{s1} + P_{sh} \quad (4)$$

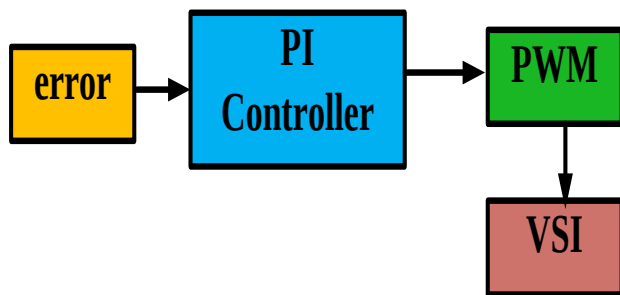


Figure 2: The diagram of the PI controller circuit of D-STATCOM

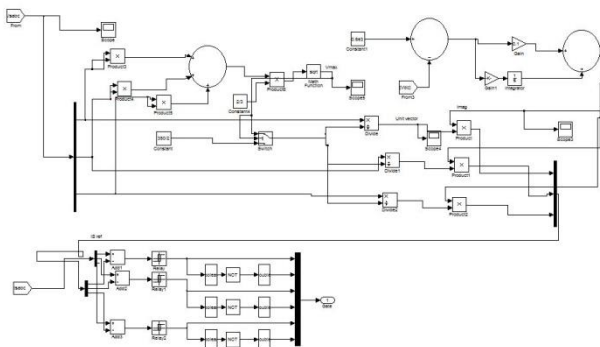


Figure 3: The Simulink diagram of diagram of the Proposed PI controller circuit of D-STATCOM

Fuzzy Logic Controller (FLC)

The term “fuzzy” in fuzzy logic Controller was first discovered in the year 1965 by Prof. Lofti Zadeh, He employ the word fuzzy locate toward explains the multiple value sets .The entire suitable world is complex; it is establish that the difficulty occur from improbability in the type of uncertainty.

According to the prof. Dr. Lotfi Zadeh, opinion of compatibility, the difficulty, as well as the indistinctness are connected along with ad, the nearer one appear by a valid world crisis, the fuzzy turn into the its resolution. The FLC apparatus be launched in the year of 1965,by Lotfi Zadeh, along the mathematical tool designed for commerce. It offers toward a soft computing corporation the significant idea of computing through terms. It

offers a method to compact through indistinctness as well as data.

And the block diagram of the fuzzy logic controller as shown in figure3.

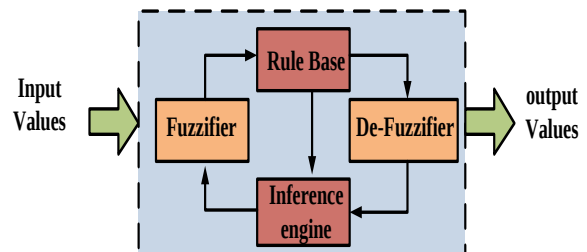


Figure 4 fuzzy logic controllers gure 2.5 Fuzzy Inference System (Ramnath, et. al., 2010)

Fuzzifier

The Fuzzifier procedure is executed throughout the run time as well as consists of conveying association degree linking 0 as well as 1 to the crisp inputs of running process record, floor space requisite (FSR), as well as the operative walking distance (OWD).

Rule Evaluation

The ruling assessment procedure consists of with the fuzzy crisp significance obtain throughout the fuzzifier as well as evaluate the ruling stand in classify to acquire a fuzzy crisp assessment for the amount produced. The rule evaluation tracks the type of if the condition is x along with the condition is y then the product is result z set of laws are well-designed. Essentially the exploit of the linguistic variable along with the fuzzy rule. The loop IF-THEN set of laws employ the lenience for indistinctness along with ambiguity impressionist the facility of the human being intelligence toward the recapitulate information along with focal point on decision-relevant data along with the produce commencing practiced information.

Inference Engine

The inference engine implements the fuzzy rule function through via fuzzifier information commencing fuzzifier through if-then rules.

Defuzzifier

The Defuzzification procedure consists of merge the fuzzy crisp values obtain commencing the rule valuation method along with the calculate the mutual in arrange to obtain the one crisp value

Output

The output values acquired while the product of Defuzzifier method is the output crisp value.

Operation of FIS

The estimated rule is originally generated by the beginning indicator, it verify the input side registers. If they are prepared, the valuations begin by opening to recover the regulations from the recollection step by step in command. Every rule is followed by translated along with prepared to be implementing. The implementation of a rule initial commence by transfer the sponsorship address towards the sponsorship recollection, which in revolve transmit the sponsorship utility of the flames might calculator unit. In addition to the calculator compute the flames strong point of every input value of that regulation and post it to the minimum (or) maximum assessor through a control indicator send to the law assessor representing the flames power is designed as well as prepared. The power of the output values of every law is too calculated as well as accessible towards the multiplier openly. The law assessors then send a control sign to the Minimum (or) Maximum assessor. The resultant fire power of the assessor is obtainable to together the multiplier along with the summer. Then the control sign representing the ending of the procedure estimate is produced. The fault estimation, the fault is intended commencing the differentiation connecting provide voltage information as well as the reference voltage

information. And the calculation of error rate is clear as:

$$\text{Error} = V_{\text{reference}} - V_{\text{source}} \quad (1)$$

$$\text{Error rate} = \text{error}(k) - \text{error}(k - 1) \quad (2)$$

Where $V_{\text{reference}}$ is the reference voltage and V_{source} is the source voltage.

The main goal of the fuzzy controller is to keep the voltage level at the point where a responsive load is linked below system turbulence. The voltage sag is formed at load side through a 3- ϕ fault is created. The over voltage troubles are sense individually with approved during the series analyzer. The Fuzzy controller of the common formation classically consists of a voltage rectification process which concludes the reference Vref introduced by a proposed D-STATCOM.

fuzzy controller have a total two inputs along with one output, the input are having total five parts in addition to output of the fuzzy values are having of 5 parts. The Range of the input values is defined as [-5 5], although the output of the range is defined as [-10 10]. A procedure intended for creating a fuzzy controller can be brief as follows:

Select the specified category of Fuzzy controller(Mamdani method/ Sugeno method)

choose the applicable input values as well as output values

Find out the amount of linguistic conditions connected through a every input & output variables

create a set of fuzzy controller if-then type of rules

And finally select the defuzzifier method

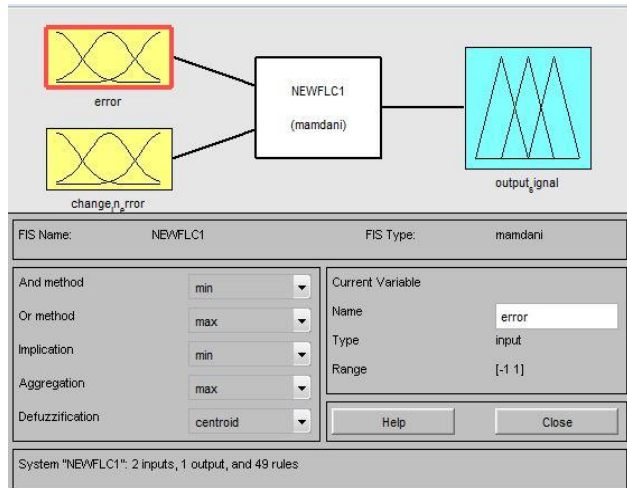


Fig 4 the output variables of the Fuzzy controller

Fuzzifier is a significant theory in the Fuzzy Interferer System theory. Fuzzifier is the procedure everywhere the crisp values of magnitudes are transformed to fuzzy variables. Thus Fuzzy procedure can occupy conveying sponsorship principles designed for the specified crisp magnitudes. This component changes the non-fuzzy input variable dimensions hooked on the fuzzy based sets named as linguistic variables to be a obviously define limit, lacking a crisp answer. In simulation revision, the error values along with error rate be clear by the linguistic variables named as

Negative big (NB)

Negative medium (NM)

Negative small (NS)

Zero (Z)

Positive small (PS)

Positive big (PB).

The fuzzy logic controller regulations for the error along with the rate of error are able to be shown in the table 1

Table 1

Table rules for error and change of error

Error/error rate	NB	NS	ZO	PS	PB
NB	NB	NB	NB	NS	ZO
NS	NB	NB	NS	ZO	PS
ZO	NB	NS	ZO	PS	PB
PS	NB	ZO	PS	PB	PB
PB	ZO	PB	PB	PB	PB

The CRISP Values sponsorship purpose for every rule is specified with the minimum operator. The Maximum operator is worn towards obtain the mutual Fuzzy crisp as of the position of output values of Minimum operator. The final output is formed by the controller is fuzzy positions along with the fuzzy logic procedures through assess the total rules.

VIII. SIMULATION RESULTS

The proposed D-statcom is designed in mat-lab simulink diagram then we will get the output voltages of the applied to load side.

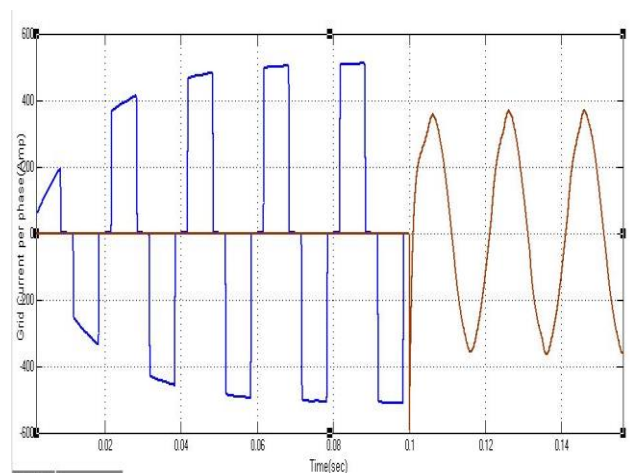


Fig.5. proposed D-statcom grid reference Voltage

The grid current of the proposed and reference current is shown in figure 5

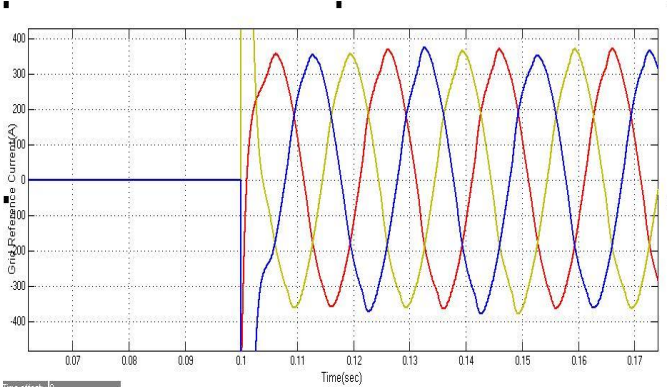


Fig.6. Proposed D-statcom of Grid reference current

The grid current of the proposed reference current is shown in figure 6

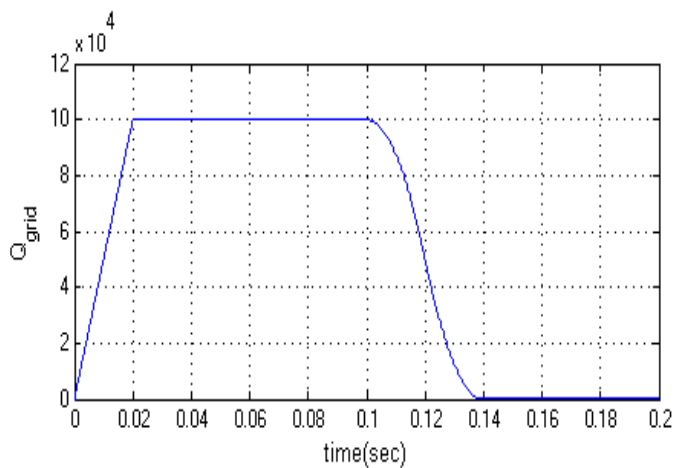


Fig.7. grid Reactive power of Proposed D-statcom

The grid Reactive power of Proposed D-statcom is 100K Watts is generated by the system.

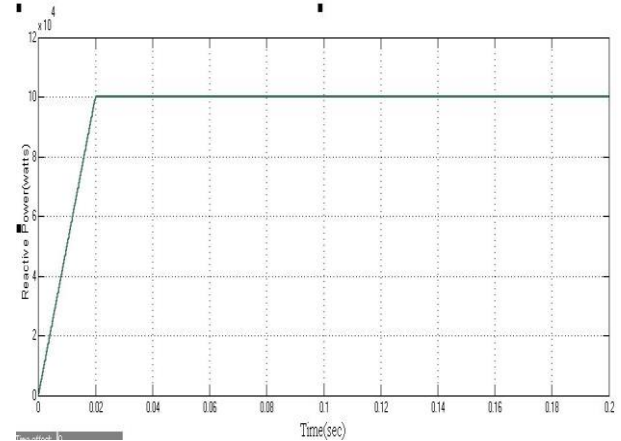


Fig.8. Simulation wave form of demanded load Reactive power

The grid Reactive power demanded by load of Proposed D-statcom is 100K Watts is generated by the system.

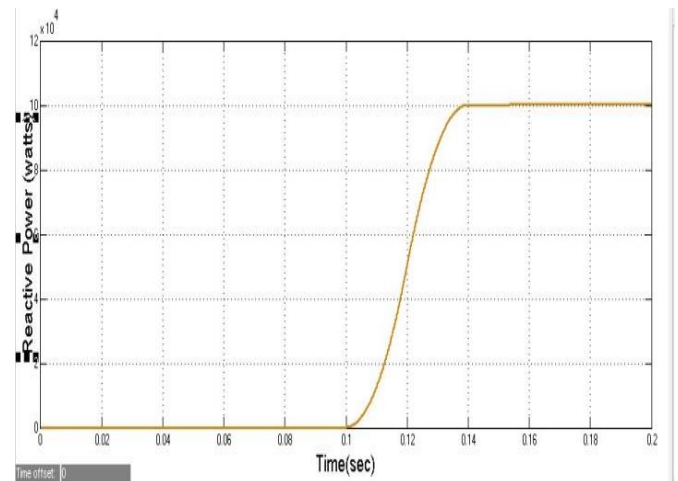


Fig.9. Simulation wave form of D-STATCOM Reactive power

The grid Reactive D-STATCOM Reactive power is 100K Watts is generated by the system.

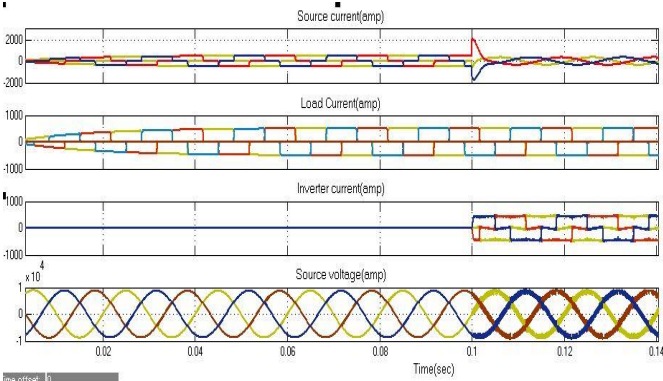


Fig.10. Simulation Wave form of the currents of load, source, inverter current and sag current

The grid Reactive D-STATCOM of the currents of load, source, inverter current and sag current are shown in figure 10.

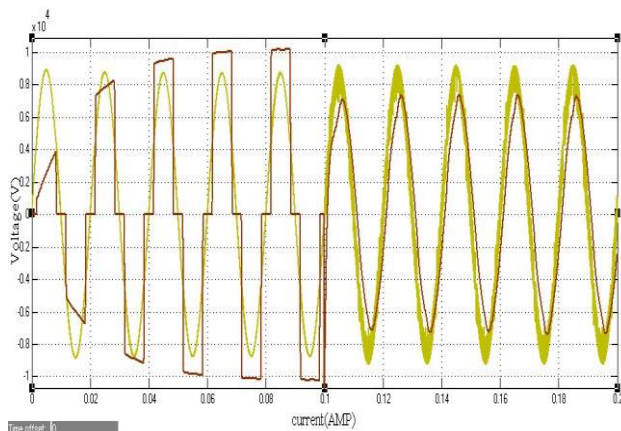


Fig.11. simulation Wave form of Power factor of the proposed D-statcom

The grid Reactive D-STATCOM simulation Wave form of Power factor of the proposed D-statcom are shown in figure 11.

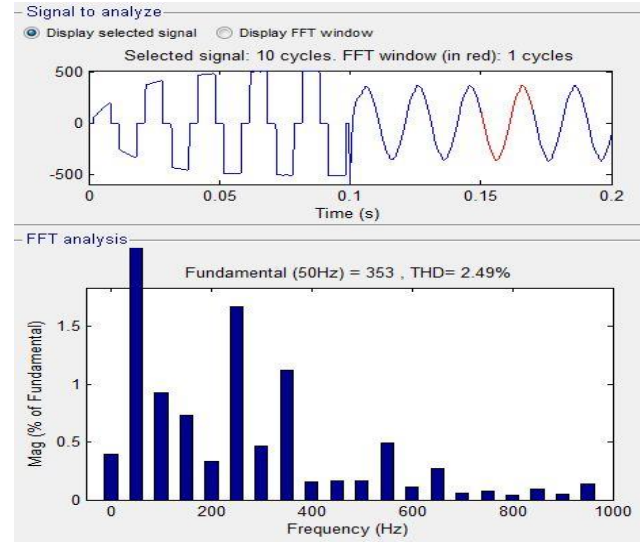


Fig.12 source current THD of PI controller based D-Statcom

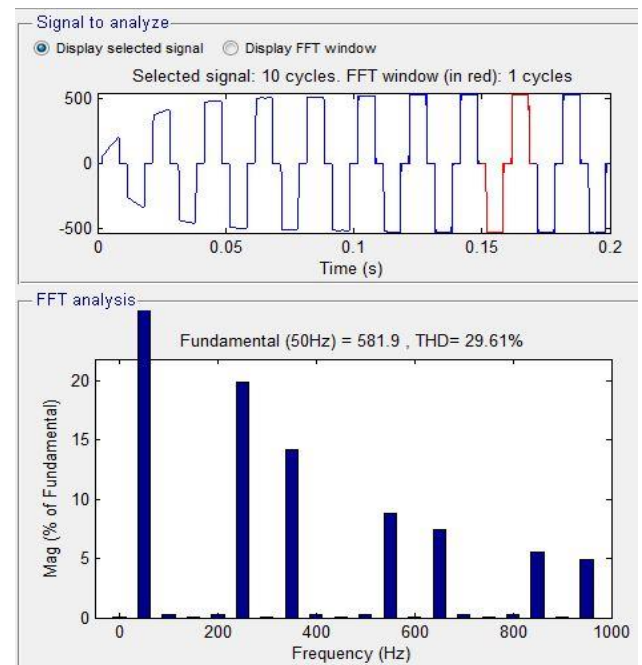


Fig.13. Load current THD of PI controller based D-Statcom

The grid Reactive D-STATCOM with PI Controller of source of the Total harmonic distortion is 2.49%, and the Load of the Total harmonic distortion is 29.61%

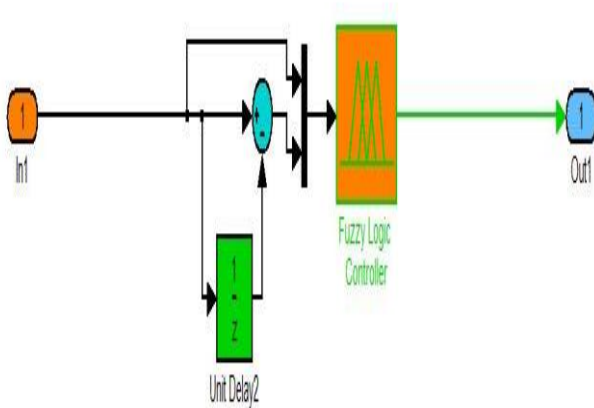


Fig 14 Simulink diagram of fuzzy logic controller design

The grid Reactive D-STATCOM of the fuzzy logic controller is as shown in figure 10.

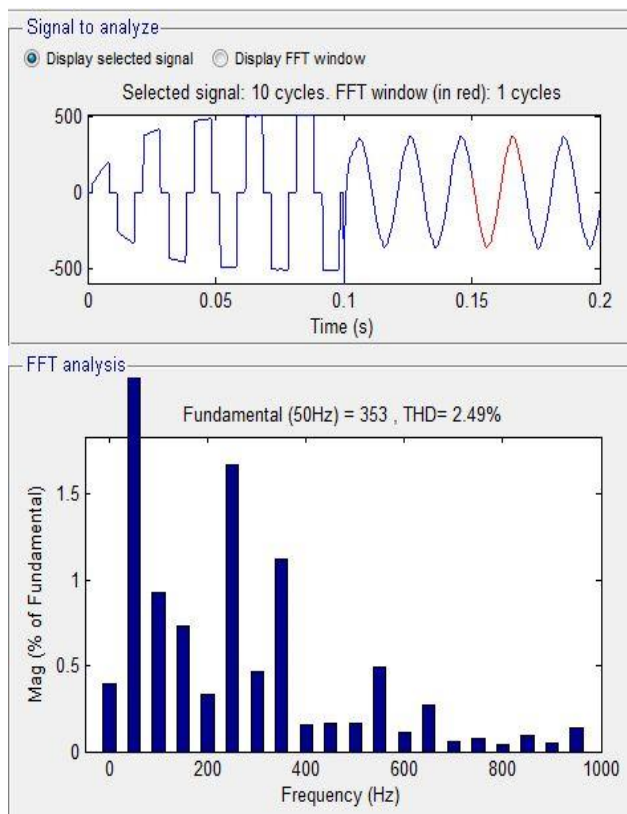


Fig.15 source current THD of fuzzy controller based D-Statcom

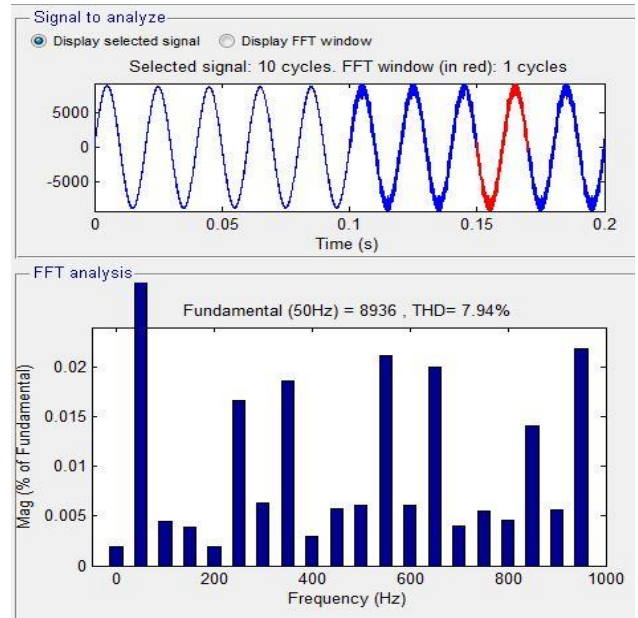


Fig.16. Load current THD of fuzzy controller based D-Statcom

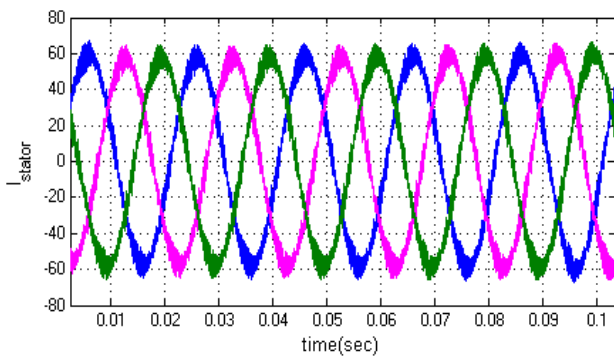
The grid Reactive D-STATCOM with fuzzy Controller of source of the Total harmonic distortion is 2.49%, and the Load of the Total harmonic distortion is 7.94%

Table 2 THD of the both PI & FUZZY Controllers

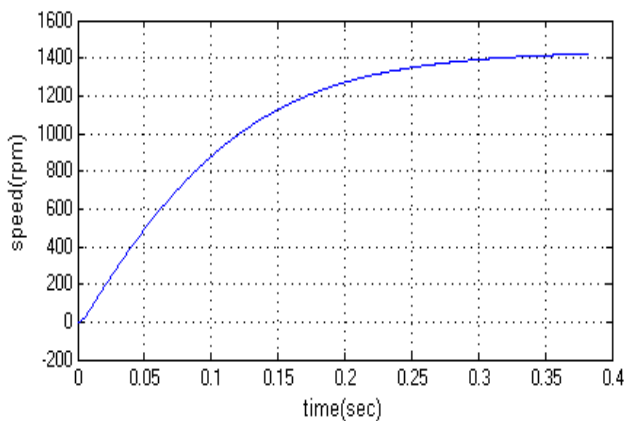
S.NO	PI Controller THD	Fuzzy Controller THD
1	Source Current=2.49%,	Source Current=2.49%,
2	Load Current=29.61%	Load Current=7.94%

Induction Motor Characteristics:

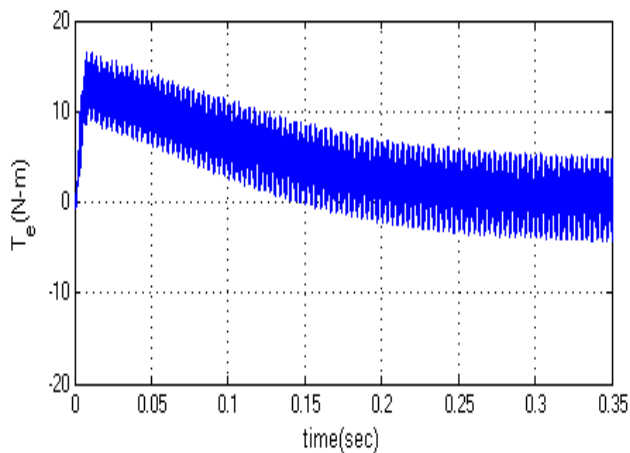
The Proposed D-statcom is applied to a induction motor drive then the characteristics of Stator current, speed and Torque are shown in the figure 17.



(a) Stator Current



(b) Speed



(c) Torque

Fig.17. Simulation waveforms for Induction motor Stator current, Speed and Torque

IX. CONCLUSION

The main aim of the proposed DSTATCOM with fuzzy controller is to learn the performance of the proposed D-statcom designed for extenuating voltage sag conditions, disruption, along with to get better the power quality in Electrical Distribution systems. The matlab output explains the presentation of fuzzy and PI based DSTATCOM scheme has be create to be suitable in favor of power quality improvement by the customer locations. The controllers of PI & Fuzzy of the DSTATCOM are gives better power quality along with it have be practical toward the able of correct power factor to be unity, reduce the THD values of in both supply and load terminals of the systems. It is too capable to control the voltage at PCC point. The control algorithm ofDSTATCOM has an inherent property to provide a self supportingDC bus of DSTATCOM. It has been found thatthe DSTATCOM system reduces THD in the supplycurrents for non-linear loads. The proposed D-STATCOM is further connected with induction motor drive is an application. In this work the motor stator current, speed and torque proved its good performance.

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