A Superlative Hybrid Fuzzy Contolled ZSI-DSTATCOM for PEV Charging Stations

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ABSTRACT

A ZSI supported DSTATCOM has been proposed for improving the power quality of a power system and PEV charging station by using the Instantaneous Symmetrical Component Theory (ISCT) control technique. The main objective is presented in this work, for decreasing harmonics on the supply signals and elimination of large currents in the system due to a fault in the power system and PEV charging station. The proposed ZSI acts as a multi converter and has a feature of buck/boost. The power quality aspects are governed by the various standards such as the IEEE-519-1992 standard. Additionally, regulation of DC capacitor voltage at a desired level using a PI controller is not suitable for enhanced PQ features. The proposed intelligent Fuzzy control schemes are highly used in several applications, in that Hybrid-Fuzzy controller has been greatly recognized due to enhanced performance over the classical PI and Fuzzy controllers. This work compares the performance of ZSI-DSTATCOM with classical PI and intelligent Fuzzy-Logic controller in PQ enhancement. The proposed hybrid-Fuzzy controlled ZSI-DSTATCOM provides compensates all current-related disturbances like current harmonics, reactive power control, power-factor correction, unbalanced current and reduction in Total Harmonic Distortion, so on.

Keyword: - *Power Quality, Plug-In Electric Vehicles, Z-Source Inverter, DSTATCOM, Total-Harmonic Distortions, Fuzzy-Logic Controller, Hybrid-Fuzzy Controllers.*

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1. INTRODUCTION

This has led to an increased interest in vehicle electrification, foremost electric vehicles (EVs) which can reduce fuel consumption compared to conventional vehicles, but also hybrid electric vehicles (HEVs). In EV's emission of pollution is not there and cost is less compare to conventional vehicles [1]. These EV have a major impact on the power gird & distribution networks due to the consequences of huge power demand to recharge their batteries. Large number of EV charging station when integrates with the utility grid, it produces harmonics, affect the current profile, finally affects the power quality. In this work, the impact of electric vehicle charging station on power grid and distribution networks is analyzed in terms of power demand, harmonics and unbalanced load conditions [2].

The distribution static compensator (DSTATCOM) gives quick control of active and reactive powers to permit load compensation, reduction of harmonics currents, voltage variations. The mitigation technique for reducing power quality disturbances is analyzed by using proposed Z-source supported DSTATCOM [3]. A ZSI supported DSTATCOM has been proposed for improving the power quality of a power system and PEV charging station by using the Instantaneous Symmetrical Component Theory (ISCT) control technique. The main objective is presented in this work, for decreasing harmonics on the supply signals and elimination of large currents in the system due to a fault in the power system and PEV charging station [4]-[6]. The proposed ZSI acts as a multi converter and has a feature of buck/boost. The power quality aspects are governed by the various standards such as the IEEE-519-1992 standard. Additionally, regulation of DC capacitor voltage at a desired level using a PI controller is not suitable for enhanced PQ features. But, this controller is unpopular due to tuning issues of current controller; the above-mentioned issues are regulated by using novel intelligent based Fuzzy-Logic controller achieving good performance features [7]-[9].

The proposed intelligent Fuzzy control schemes are highly used in several applications, in that Hybrid-Fuzzy controller has been greatly recognized due to enhanced performance over the classical PI and Fuzzy controllers. This work compares the performance of ZSI-DSTATCOM with classical PI and intelligent Fuzzy-Logic controller in PQ enhancement. The proposed hybrid-Fuzzy controlled ZSI-DSTATCOM provides compensates all current-related disturbances like current harmonics, reactive power control, power-factor correction, unbalanced current and reduction in Total Harmonic Distortion, so on. The performance of proposed ZSI-DSTATCOM is verified in both balanced and unbalanced loads by using classical PI and Intelligent Fuzzy, Hybrid-Fuzzy controller based ISCT for attaining good compensation features. The proposed system is verified by using Matlab/Simulink tool, results are presented with comparative analysis.

2. DESIGN OF THE PEV CHARGING STATION WITH ZSI SUPPORTED DSTATCOM

The DSTATCOM fundamentally structured with a three phase-four wire-controlled voltage source converter of Eight IGBTs, DC capacitor and filter (RL). DC capacitor acts for active filter energy storage. DSTATCOM is utilized to reduce current and voltage components of harmonics, reactive power on the supply side and accomplishing the supply side current absolutely sinusoidal and in phase with the supply voltage [10]-[14]. A modified topology ZSI based DSTATCOM is utilized as a compensator to reduce the power quality issues in PEV charging station and source side. This PEV charging station consists of a three phase four wire supply and EV Motor. Fig.1 represents the proposed ZSI based DSTATCOM. It is combined with the System at the PCC (point of common coupling) through interfacing impedance (Zc). The impedance (Zc) is filter values of DSTATCOM. The ZSI has an impedance network mix of two inductors (L1, L2) and two capacitors (C1, C2).It is looking like a shape of 'X'. The ZSI supported DSTATCOM IGBTs Switching signals pulses are developed by using the ISCT control technique. ISCT is a one of the best control theory for DSTATCOM.

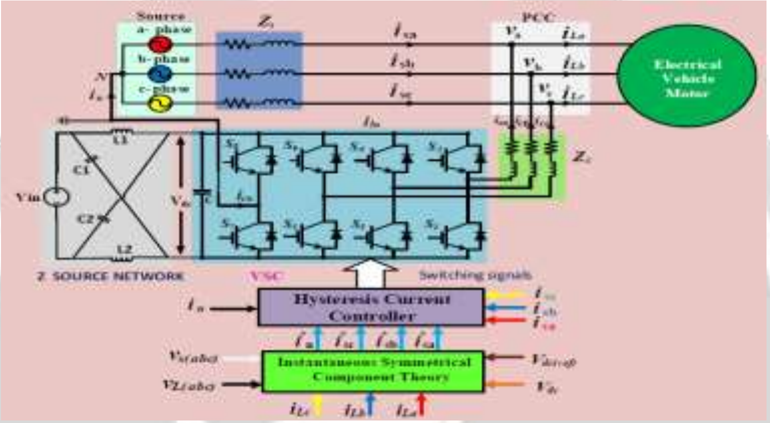


Fig.1 Design of the PEV charging station with ZSI supported DSTATCOM

The control technique block diagram is shown in Fig.2. The DSTATCOM is controlled by the reference of source currents (isa, isb, $iscand\ in$) and load currents (ila, ilb, $ilc\ and$, iln) are balanced and sinusoidal in phase with the individual terminal voltages (vsa, $vsb\ and\ vsc$). Furthermore, average load power ($plavg$)and losses ($ploss$) in the VSC are provided by the source. Since the source considered here is three-phase supply, the immediate use of terminal voltages to ascertain reference compensator currents will not provide better compensation. Hence, the principal positive sequence components of three-phase voltages are extricated to generate reference compensator currents (ica, icb, $iccandicn$) dependent on the PI-ISCT [15], [16].

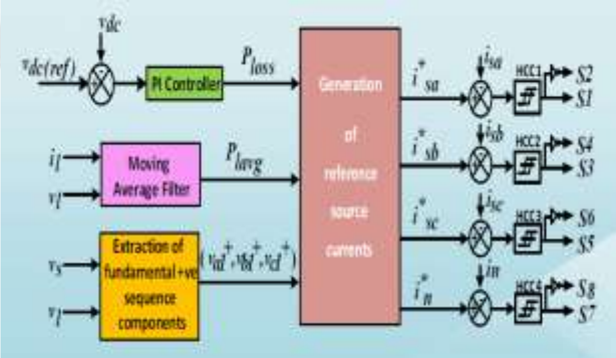


Fig.2: Generation of switching pulse using PI-ISCT control technique and HCC

These currents are given as follows:

$$i_{sa}^{*} = \frac{v_{a1}^{+}}{\Delta_1^{+}}\left(p_{lavg} + p_{loss}\right) \quad (1)$$

$$i_{sb}^{*} = \frac{v_{b1}^{+}}{\Delta_1^{+}}\left(p_{lavg} + p_{loss}\right) \quad (2)$$

$$i_{sc}^{*} = \frac{v_{c1}^{+}}{\Delta_1^{+}}\left(p_{lavg} + p_{loss}\right) \quad (3)$$

$$i_{n}^{*} = i_{sa}^{*} + i_{sb}^{*} + i_{sc}^{*} \quad (4)$$

Where $va1+$, $vb1+$and $vc1+$ are fundamental positive sequence voltages at the respective phase load terminal.

$$\Delta_1^{+} = (v_{a1}^{+})^2 + (v_{b1}^{+})^2 + (v_{c1}^{+})^2 \quad (5)$$

The terms $plavg$ and $ploss$ represent the average load power and the total losses in the VSC, respectively. At any subjective time$t1$, it is registered as follows:

$$p_{lavg} = \frac{1}{T}\int_{t_{1-T}}^{T} \left(v_a\, i_{la} + v_b i_{lb} + v_c i_{lc}\right) dt \quad (6)$$

The total losses in the DSTATCOM are figured utilizing a proportional–integral (PI) controller at the positive zero intersection of phase-a voltage and is given as

$$p_{loss} = k_p v_{dc(error)} + k_i \int v_{dc(error)}\, dt \quad (7)$$

Where kp and ki are the proportional gain and integral gain of the PI controller respectively. The compensator currents (ica, icb, $iccandicn$) are obtained by subtracting the actual load currents from the reference source currents. Then the compensator currents error is regulated around predefined hysteresis current controllers and IGBT Eight switching pulses are generated.

3. PROPOSED FUZZY LOGIC CONTROL SCHEME

The proposed fuzzy controller has been used extensively for many applications in control engineering, automation which is related to associate problems is designed easily. By utilizing the fuzzy evolution method which is relative functions of qualities work for designing the real time control objective. The fuzzy system in the process/plant is reflected by the control action of the design capabilities in both experience as well as intuitive specific functioning manner. It is mostly commanded for the control scheme of resembled on efficient mathematical plant model. The fuzzy control strategy uses the linguistic information which has many advantages may include the high robust performance, greater strength, model free, attain the universal approximation theorem with rule based algorithm has been selected.

The fuzzy logic controller has been distinctly characterized by the input data coming from the fuzzy scheme as depicted in Fig.3. Automatic translation of fuzzy from the overall fuzzification process, this fuzzy process is carried out by the effective control action. The creation of input information with the evaluation of the IF....THEN rules which are produced by the several linguistics logics. After the fuzzification process the rule processing stage reaches at the point of outcome summary, de-fuzzification process is started. The de-fuzzification process is carried during the final stage; the coming inferences are transformed to real data output by fuzzy enhancer. Hence, data is utilized as interfaced module for the need of processing.

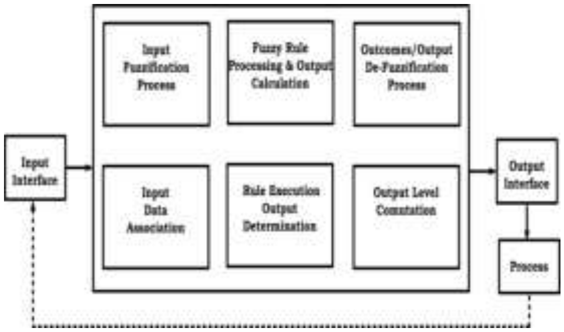


Fig.3 Block Diagram Representation of Fuzzy Control Logic

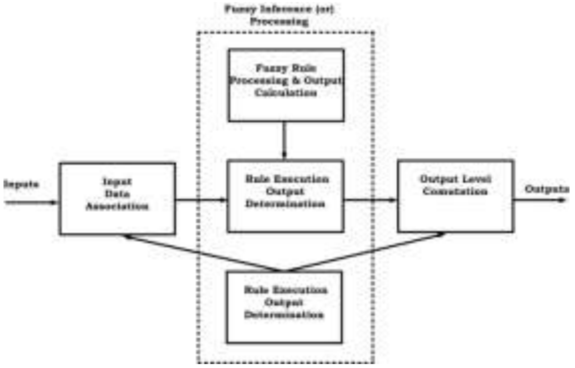


Fig.4 Configuration of Fuzzy Logic Inference Control Objective

The operational logics of the fuzzy logic control objective have been illustrated by linguistic nature is differentiated from the mathematical notations. In spite of linguistic terms delivers the derived methods that are most enhanced and feasible operational characteristics. This fuzzy logic control objective belongs to the symbolic nature control action that regards to a special class. The configuration of fuzzy logic inference control objective is depicted in Fig.4. The proposed fuzzy-logic controller membership functions are depicted in Fig.5 and the rule base is illustrated in Table.1. The block diagram of Proposed Fuzzy-Logic Controlled ISCT for ZSI-DSTATCOM is depicted in Fig.6.

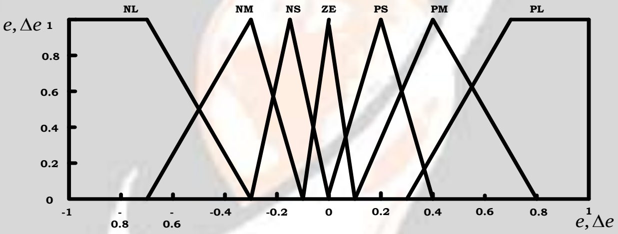


Fig.5 Fuzzy Logic Membership Functions

Table.1 Fuzzy Logic Rules

e Δe	**NB**	**NM**	**NS**	**ZE**	**PS**	**PM**	**PB**
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	NM	NS	ZE	PS	PM	PB

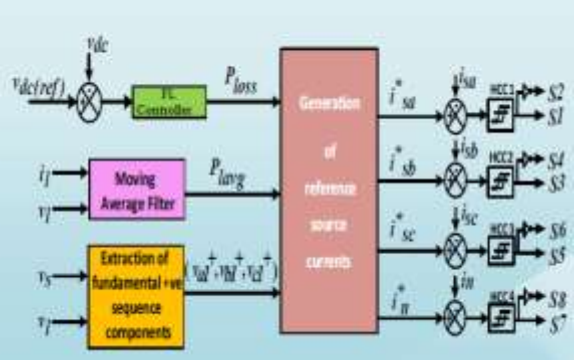


Fig.6 The block diagram of Proposed Fuzzy-Logic Controlled ISCT for ZSI-DSTATCOM

4. HYBRID FUZZY CONTROLLER

The objective of the hybrid controller is to utilize the best attributes of the PI and fuzzy logic controllers to provide a controller which will produce better response than either the PI or the fuzzy controller. There are two major differences between the tracking ability of the conventional PI controller and the fuzzy logic controller. Both the PI and fuzzy controller produce reasonably good tracking for steady-state or slowly varying operating conditions. However, when there is a step change in any of the operating conditions, such as may occur in the set point or load, the PI controller tends to exhibit some overshoot or oscillations. The fuzzy controller reduces both the overshoot and extent of oscillations under the same operating conditions.

Although the fuzzy controller has a slower response by itself, it reduces both the overshoot and extent of oscillations under the same operating conditions. The desire is that, by combining the two controllers, one can get the quick response of the PI controller while eliminating the overshoot possibly associated with it. Switching Control Strategy the switching between the two controllers needs a reliable basis for determining which controller would be more effective. The answer could be derived by looking at the advantages of each controller. Both controllers yield good responses to steady-state or slowly changing conditions. To take advantage of the rapid response of the PI controller, one needs to keep the system responding under the PI controller for a majority of the time, and use the fuzzy controller only when the system behaviour is oscillatory or tends to overshoot. Thus, after designing the best stand-alone PI and fuzzy controllers, one needs to develop a mechanism for switching from the PI to the fuzzy controllers, based on the following two conditions:

1) Switch when oscillations are detected;
2) Switch when overshoot is detected.

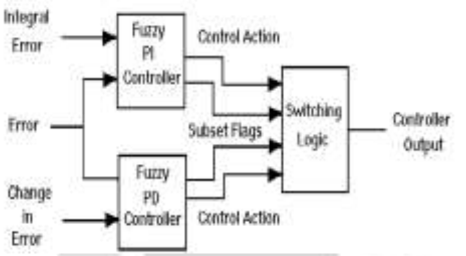


Fig.7 Block Diagram of Hybrid-Fuzzy Logic Controller

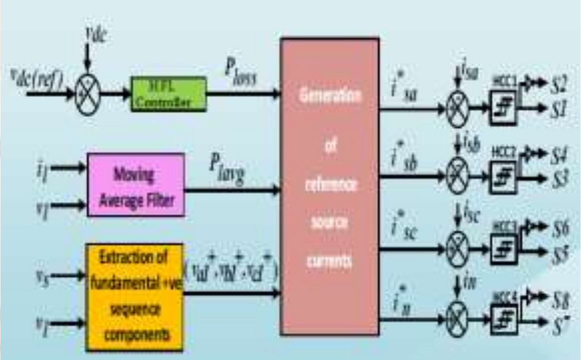


Fig.8 The block diagram of Proposed Hybrid Fuzzy-Logic Controlled ISCT for ZSI-DSTATCOM

The switching strategy is then simply based on the following conditions: IF the system has an oscillatory behaviour THEN fuzzy controller is activated, Otherwise PI controller is operated. IF the system has an overshoot THEN fuzzy controller is activated, Otherwise PI controller is operated. The system under study is considered as having an overshoot when the error is zero and the rate of change in error is any other value than zero. The system is considered oscillatory when the sum of the absolute values of the error taken over time does not equal the absolute values of the sum of the error over the same period of time. Since the system is expected to overshoot during oscillatory behavior, the only switching criterion that needs to be considered is overshoot. However, in practice, it is more convenient to directly implement the control signal according to the control actions delivered by the controller. Consequently, the fuzzy controller can be designed so that normal behavior (no oscillations or overshoot) results in a null fuzzy action. Accordingly, the switching between the two controllers reduces to using PI if the fuzzy has null value; otherwise, the fuzzy output is used. In particular, the fuzzy controller can be designed so that a normal behavior. The block diagram of proposed Hybrid-Fuzzy-Logic Controlled ISCT for ZSI-DSTATCOM is depicted in Fig.8.

5. MATLAB/SIMULINK RESULTS & ANALYSIS

The Matlab/Simulink modelling is carried based on various cases and the proposed models are developed by using described system specifications illustrated in Table.1.

Table.1 System Specifications

S.NO	**System Specifications**	**Values**
1	Source Voltage	Vrms-415V, Fs-50Hz
2	Source Inductance	L1-0.025mH,
3	DC-Link Capacitor	Vdc-800V, Cdc-1000 µF

4	ZSI Topology	L1=L2=1mH, C1=C2-1000 µF, Vdc-400V
5	Non-Linear Load Impedance	R_L-11Ω, L_L-8mH
6	Line Interfacing Inductive Filter	L-1mH
6	PI Controller	Kp-0.5, Ki-0.1

5.1 PEV CHARGING STATION WITHOUT DSTATCOM UNDER BALANCED NON-LINEAR LOAD

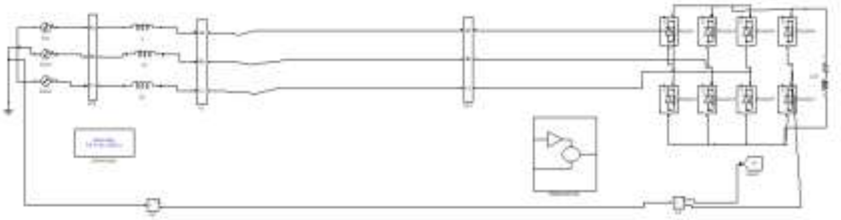
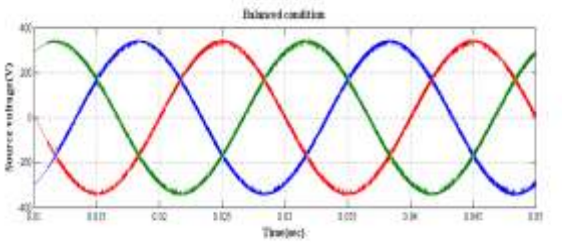
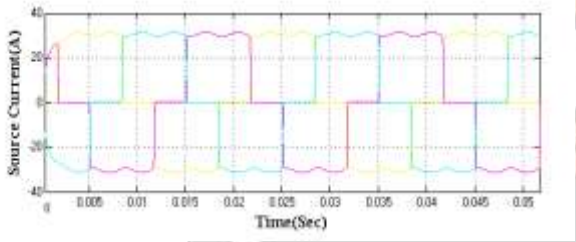


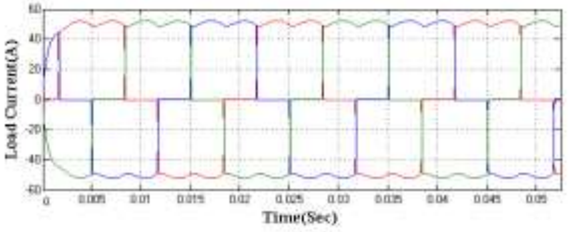
Fig.9 Matlab/Simulink Model of PEV Charging Station without DSTATCOM under Balanced Non-Linear Load



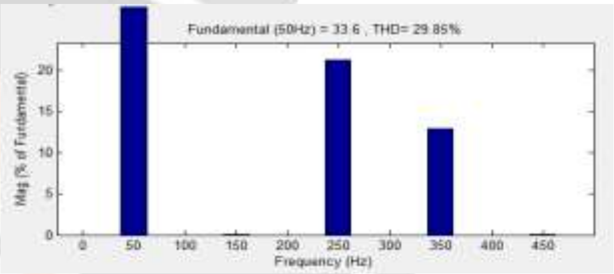
(a) Source Voltage



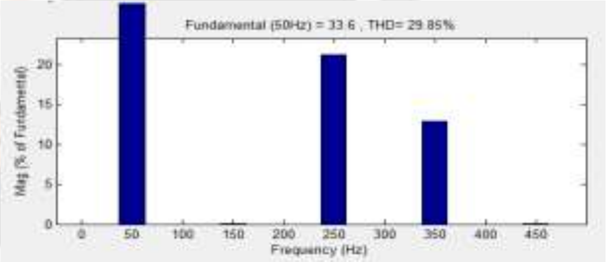
(b) Source Current



(c) Load Current



(d) THD of Source Current



(e) THD of Load Current

Fig.10 Simulation Result of PEV Charging Station without DSTATCOM under Balanced Non-Linear Load

The Matlab/Simulink Model of PEV Charging Station without DSTATCOM under Balanced Non-Linear Load is depicted in Fig.9.The Simulation Result of PEV Charging Station without DSTATCOM under Balanced Non-Linear Load is depicted in Fig.10. It includes, (a) Source Voltage, (b) Source Current, (c) Load Current, (d) THD of Source Current, (e) THD of Load Current, respectively. The non-linear loads in PEV charging station is powered by three-phase AC distribution system through three-phase Diode-Bridge rectifier with a value of 415V, 50Hz. Due to these non-linear devices in PEV charging station, the source or PCC current as harmonized and affecting the specifications in power distribution system. In this case, there is no presence of compensator; the source current is same as load current. The THD of source current and load current is measured with a value of 29.85%.

5.2 PEV CHARGING STATION WITHOUT DSTATCOM UNDER UNBALANCED NON-LINEAR LOAD

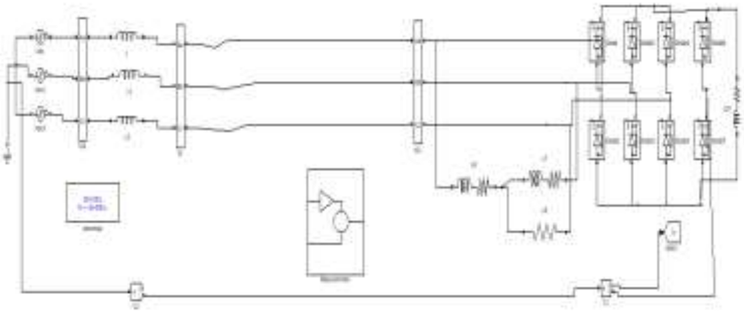
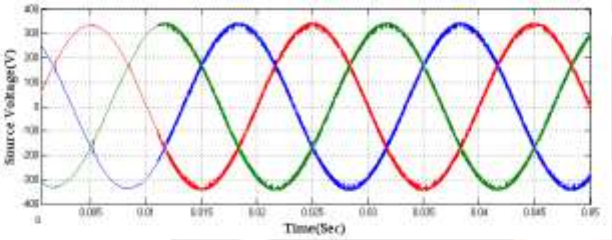
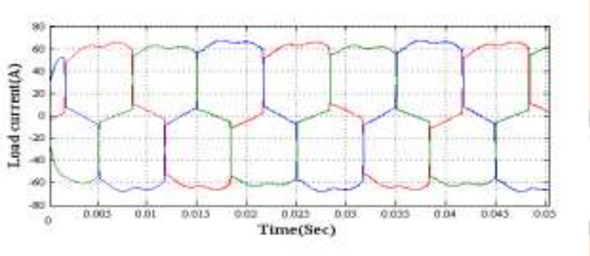


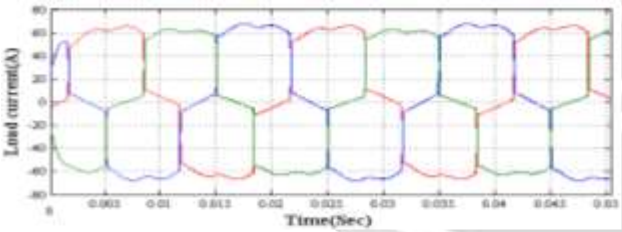
Fig.11 Matlab/Simulink Model of PEV Charging Station without DSTATCOM under Un-Balanced Non-Linear Load



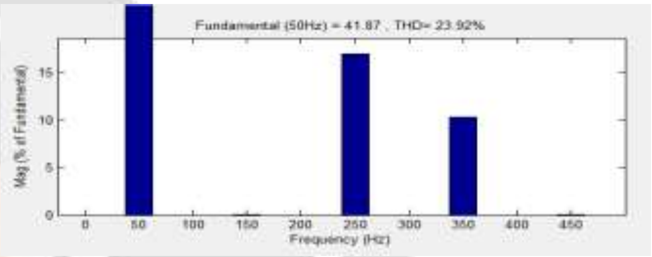
(a) Source Voltage



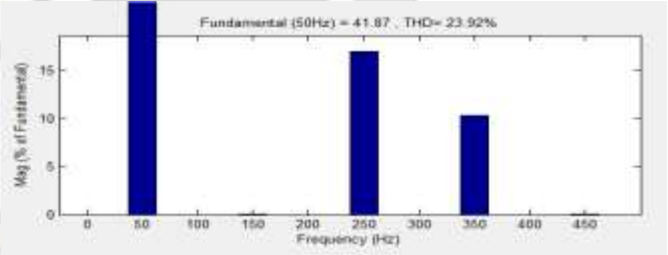
(b) Source Current



(c) Load Current



(d) THD of Source Current



(e) THD of Load Current

Fig.12 Simulation Result of PEV Charging Station without DSTATCOM under Un-Balanced Non-Linear Load

The Matlab/Simulink Model of PEV Charging Station without DSTATCOM under Un-Balanced Non-Linear Load is depicted in Fig.11.The Simulation Result of PEV Charging Station without DSTATCOM under Un-Balanced Non-Linear Load is depicted in Fig.12. It includes, (a) Source Voltage, (b) Source Current, (c) Load Current, (d) THD of Source Current, (e) THD of Load Current, respectively. The unbalanced non-linear loads in PEV charging station is powered by three-phase AC distribution system through three-phase Diode-Bridge rectifier with a value of 415V, 50Hz. Due to these unbalanced non-linear devices in PEV charging station, the source or PCC current as harmonized, unbalanced and affecting the specifications in power distribution system. In this case, there is no presence of compensator; the source current is same as load current. The THD of source current and load current is measured with a value of 23.92%.

5.3 DESIGN OF PROPOSED ZSI-DSTATCOM FOR PQ IMPROVEMENT IN DISTRIBUTION NETWORK USING PI-ISCT CONTROL SCHEME UNDER BALANCED LOAD

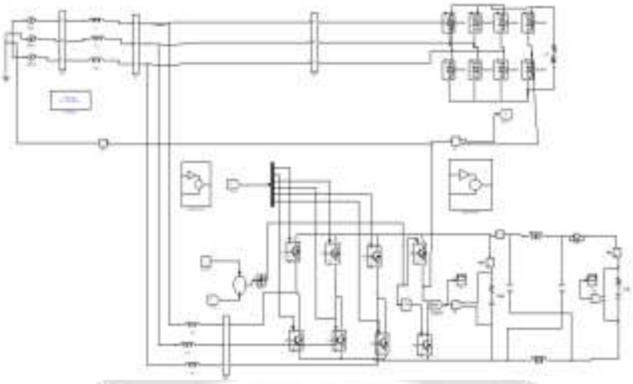
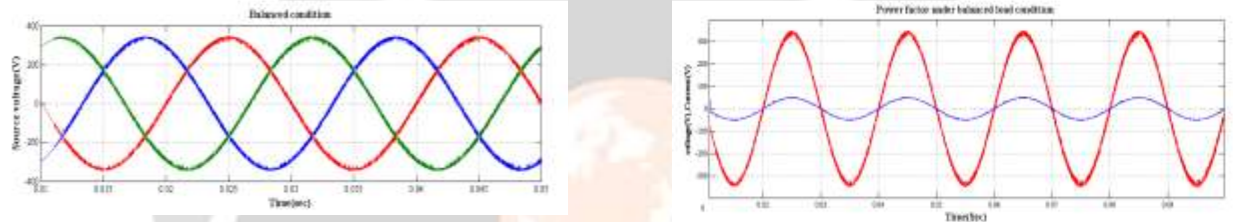
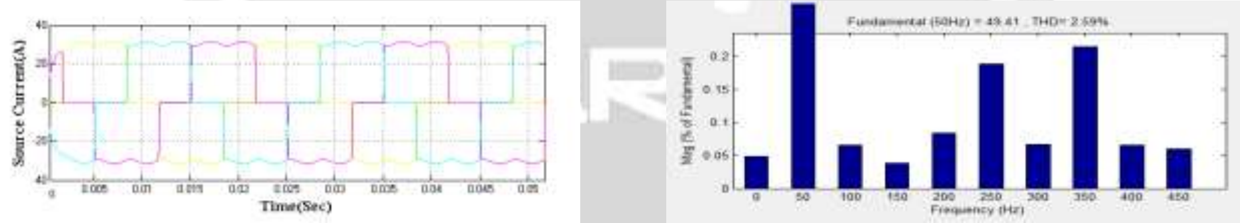


Fig.13 Matlab/Simulink Model of PEV Charging Station with ZSI-DSTATCOM under Balanced Non-Linear Load using PI-ISCT Control Scheme

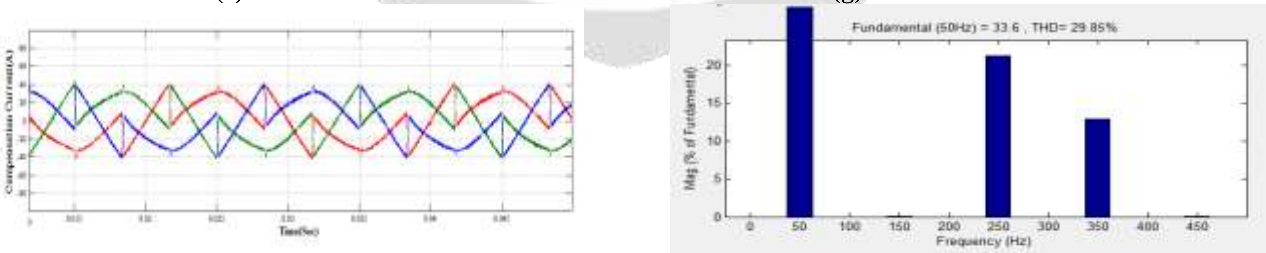


(a) Source Voltage (e) Source Voltage & Current-In Phase

(b) Source Current (f) DC-Link Voltage



(c) Load Current (g) THD of Source Current



(d) Compensation Current (h) THD of Load Current

Fig.14 Simulation Result of PEV Charging Station with ZSI-DSTATCOM under Balanced Non-Linear Load using PI-ISCT Control Scheme

The Matlab/Simulink Model of PEV Charging Station with ZSI-DSTATCOM under Balanced Non-Linear Load using PI-ISCT Control Scheme is depicted in Fig.13. The Simulation Result of PEV Charging Station with ZSI-DSTATCOM under Balanced Non-Linear Load using PI-ISCT Control Scheme is depicted in Fig.14. It includes, (a) Source Voltage, (b) Source Current, (c) Load Current, (d) Compensation Current, (e) Source Voltage & Current-In Phase, (f) DC-Link Voltage, (g) THD of Source Current, (h) THD of Load Current, respectively. The non-linear loads in PEV charging station is powered by three-phase AC distribution system through three-phase Diode-Bridge rectifier with a value of 415V, 50Hz. Due to these non-linear devices in PEV charging station, the source or PCC current is harmonized and affecting the specifications in power distribution system. In this case, PI-ISCT controlled ZSI-DSTATCOM is integrated to distribution for compensating the harmonic currents coming from non-linear PEV charging station and maintains source current as sinusoidal, balanced and linear nature. The DC-link capacitor value is reduced due to ZSI operation and maintains DC-link voltage as constant attains boost voltage. The THD of load current is measured with a value of 29.85% and the THD of source current is measured with a value of 2.59%, it is well within IEEE-519 standards.

5.4 DESIGN OF PROPOSED ZSI-DSTATCOM FOR PQ IMPROVEMENT IN DISTRIBUTION NETWORK USING PI-ISCT CONTROL SCHEME UNDER UNBALANCED LOAD

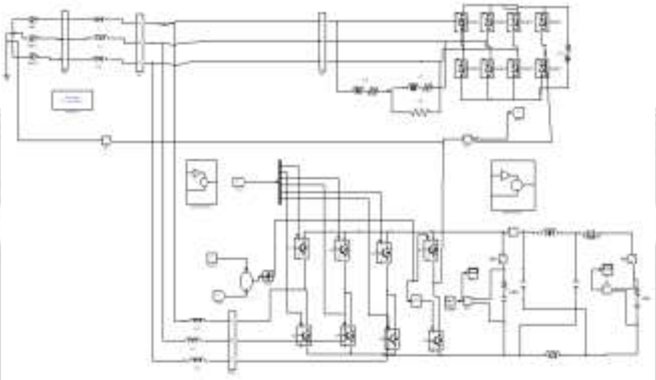
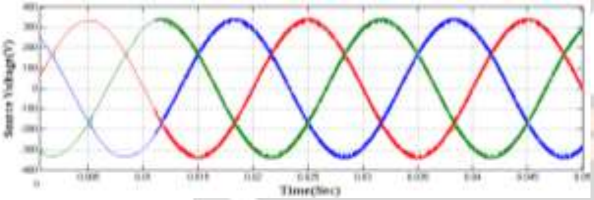
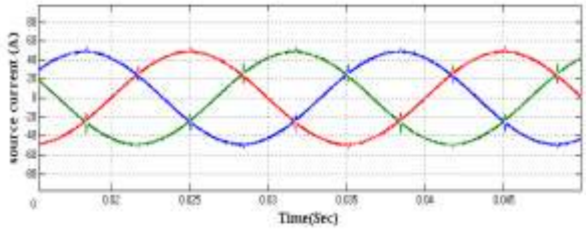


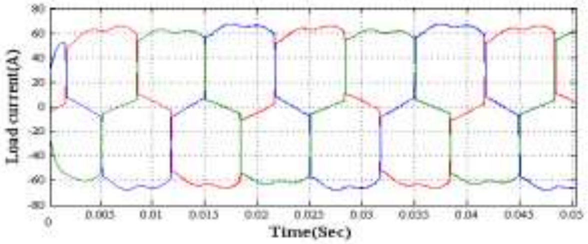
Fig.15 Matlab/Simulink Model of PEV Charging Station with ZSI-DSTATCOM under Un- Balanced Non-Linear Load using PI-ISCT Control Scheme



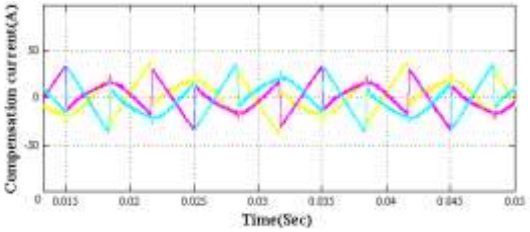
(a) Source Voltage



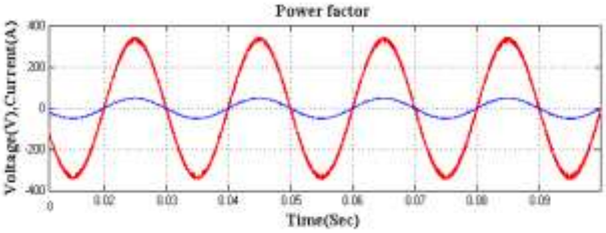
(b) Source Current



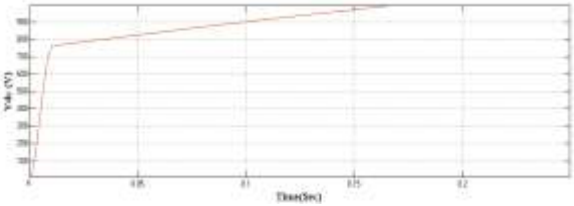
(c) Load Current



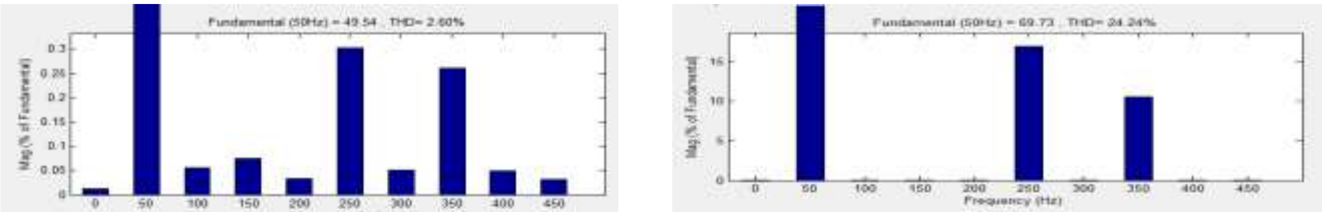
(d) Compensation Current



(e) Source Voltage & Current-In Phase



(f) DC-Link Voltage



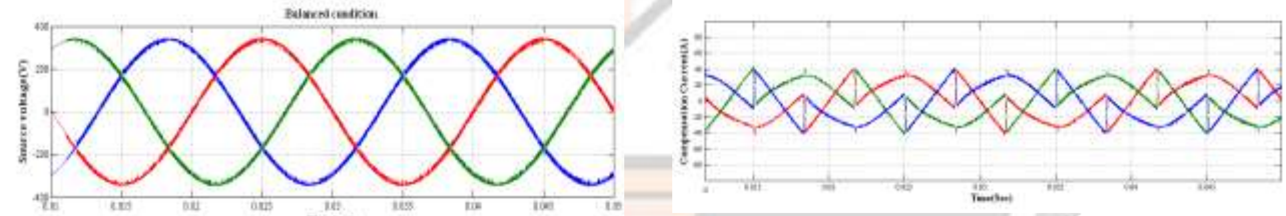
(g) THD of Source Current

(h) THD of Load Current

Fig.16 Simulation Result of PEV Charging Station with ZSI-DSTATCOM under Un-Balanced Non-Linear Load using PI-ISCT Control Scheme

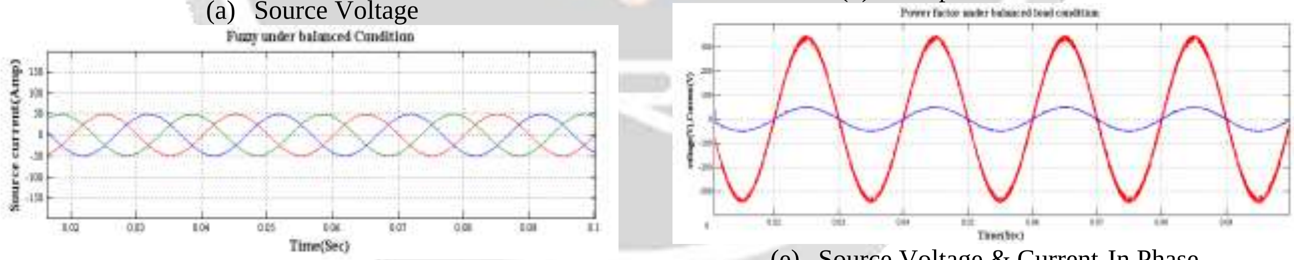
The Matlab/Simulink Model of PEV Charging Station with ZSI-DSTATCOM under Un-Balanced Non-Linear Load using PI-ISCT Control Scheme is depicted in Fig.15. The Simulation Result of PEV Charging Station with ZSI-DSTATCOM under Un-Balanced Non-Linear Load using PI-ISCT Control Scheme is depicted in Fig.16 The non-linear loads in PEV charging station is powered by three-phase AC distribution system through three-phase Diode-Bridge rectifier with a value of 415V, 50Hz. Due to these unbalanced non-linear devices in PEV charging station, the source or PCC current is unbalanced, harmonized and affecting the specifications in power distribution system. In this case, PI-ISCT controlled ZSI-DSTATCOM is integrated to distribution for compensating the unbalanced situation, harmonic currents coming from non-linear PEV charging station and maintains source current as sinusoidal, balanced and linear nature. The DC-link capacitor value is reduced due to ZSI operation and maintains DC-link voltage as constant attains boost voltage. The THD of load current is measured with a value of 24.24% and the THD of source current is measured with a value of 2.60%, it is well within IEEE-519 standards.

5.5 DESIGN OF PROPOSED ZSI-DSTATCOM FOR PQ IMPROVEMENT IN DISTRIBUTION NETWORK USING FUZZY-ISCT CONTROL SCHEME UNDER BALANCED LOAD



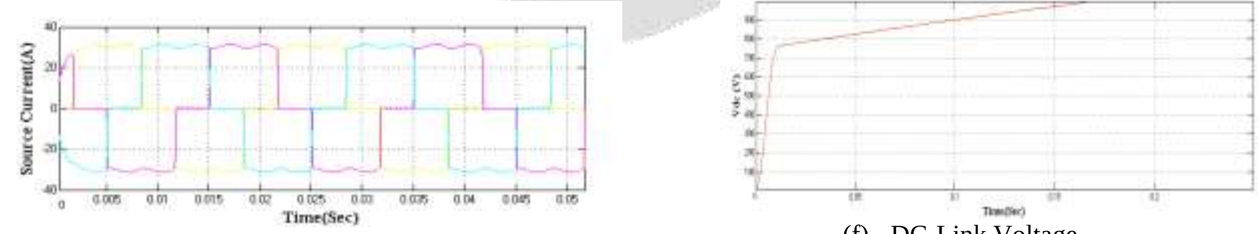
(a) Source Voltage

(d) Compensation Current



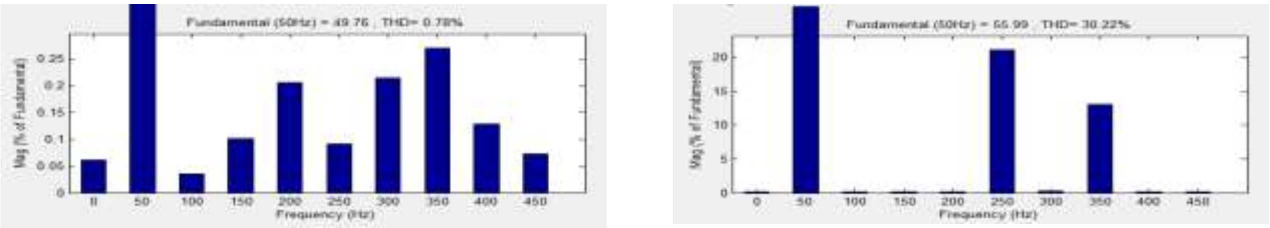
(b) Source Current

(e) Source Voltage & Current-In Phase



(c) Load Current

(f) DC-Link Voltage



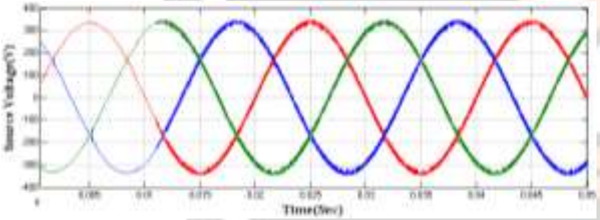
(g) THD of Source Current

(h) THD of Load Current

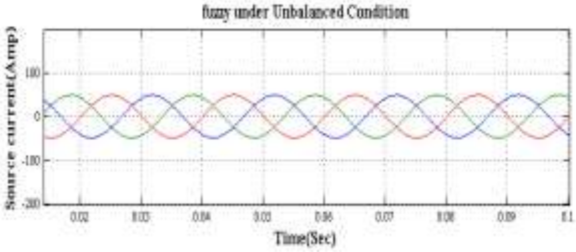
Fig.17 Simulation Result of PEV Charging Station with ZSI-DSTATCOM under Balanced Non-Linear Load using Fuzzy-ISCT Control Scheme

The Simulation Result of PEV Charging Station with ZSI-DSTATCOM under Balanced Non-Linear Load using Fuzzy-ISCT Control Scheme is depicted in Fig.17. It includes, (a) Source Voltage, (b) Source Current, (c) Load Current, (d) Compensation Current, (e) Source Voltage & Current-In Phase, (f) DC-Link Voltage, (g) THD of Source Current, (h) THD of Load Current, respectively. The non-linear loads in PEV charging station is powered by three-phase AC distribution system through three-phase Diode-Bridge rectifier with a value of 415V, 50Hz. Due to these non-linear devices in PEV charging station, the source or PCC current is harmonized and affecting the specifications in power distribution system. In this case, Fuzzy-ISCT controlled ZSI-DSTATCOM is integrated to distribution for compensating the harmonic currents coming from non-linear PEV charging station and maintains source current as sinusoidal, balanced and linear nature. The DC-link capacitor value is reduced due to ZSI operation and maintains DC-link voltage as constant attains boost voltage. The THD of load current is measured with a value of 30.22% and the THD of source current is measured with a value of 0.78%, it is well within IEEE-519 standards. The Fuzzy-ISCT controlled ZSI-DSTATCOM produces better compensation features over the classical PI-ISCT control scheme and enhances the PQ features in distribution system.

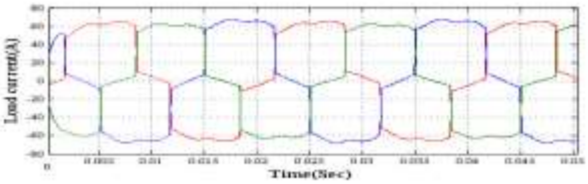
5.6 DESIGN OF PROPOSED ZSI-DSTATCOM FOR PQ IMPROVEMENT IN DISTRIBUTION NETWORK USING FUZZY-ISCT CONTROL SCHEME UNDER UNBALANCED LOAD



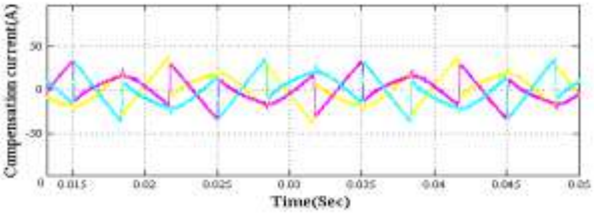
(a) Source Voltage



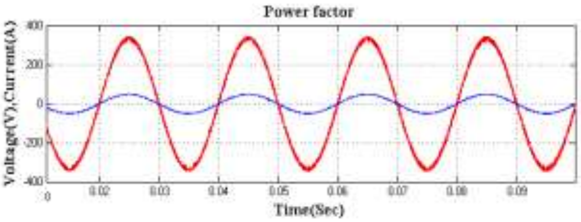
(b) Source Current



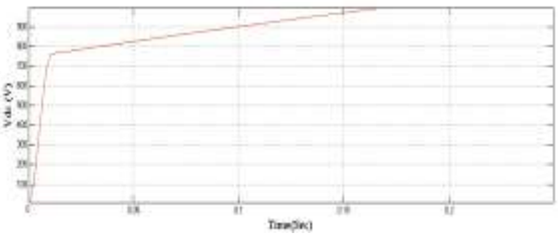
(c) Load Current



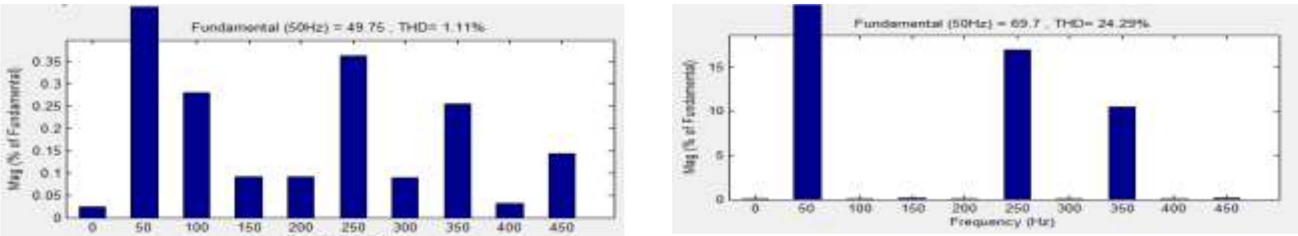
(d) Compensation Current



(e) Source Voltage & Current-In Phase



(f) DC-Link Voltage



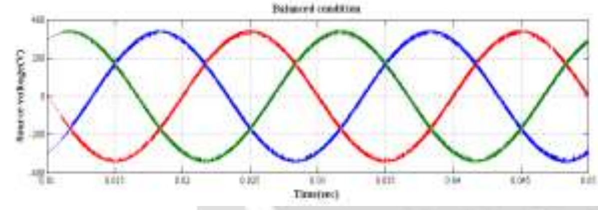
(g) THD of Source Current

(h) THD of Load Current

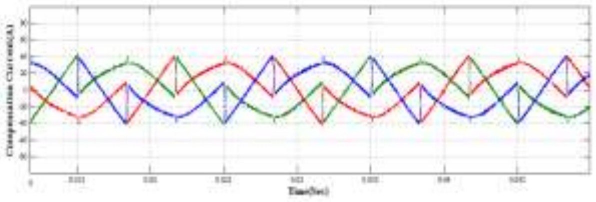
Fig.18 Simulation Result of PEV Charging Station with ZSI-DSTATCOM under Un-Balanced Non-Linear Load using Fuzzy-ISCT Control Scheme

The Simulation Result of PEV Charging Station with ZSI-DSTATCOM under Un-Balanced Non-Linear Load using Fuzzy-ISCT Control Scheme is depicted in Fig.18. It includes, (a) Source Voltage, (b) Source Current, (c) Load Current, (d) Compensation Current, (e) Source Voltage & Current-In Phase, (f) DC-Link Voltage, (g) THD of Source Current, (h) THD of Load Current, respectively. The unbalanced non-linear loads in PEV charging station is powered by three-phase AC distribution system through three-phase Diode-Bridge rectifier with a value of 415V, 50Hz. Due to these unbalanced non-linear devices in PEV charging station, the source or PCC current is unbalanced, harmonized and affecting the specifications in power distribution system. In this case, Fuzzy-ISCT controlled ZSI-DSTATCOM is integrated to distribution for compensating the unbalanced & harmonic currents coming from unbalanced non-linear PEV charging station and maintains source current as sinusoidal, balanced and linear nature. The DC-link capacitor value is reduced due to ZSI operation and maintains DC-link voltage as constant attains boost voltage. The THD of load current is measured with a value of 24.29% and the THD of source current is measured with a value of 1.1%, it is well within IEEE-519 standards. The Fuzzy-ISCT controlled ZSI-DSTATCOM produces better compensation features over the classical PI-ISCT control scheme and enhances the PQ features in distribution system.

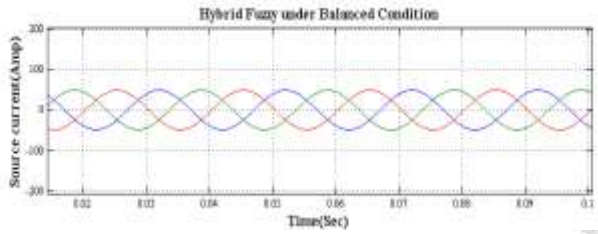
5.7 DESIGN OF PROPOSED ZSI-DSTATCOM FOR PQ IMPROVEMENT IN DISTRIBUTION NETWORK USING HYBRID FUZZY-ISCT CONTROL SCHEME UNDER BALANCED LOAD



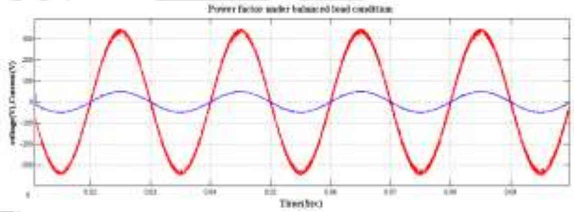
(a) Source Voltage



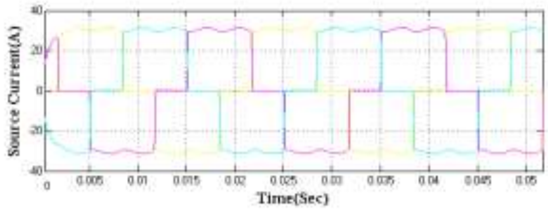
(d) Compensation Current



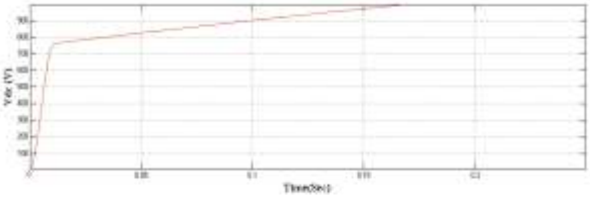
(b) Source Current



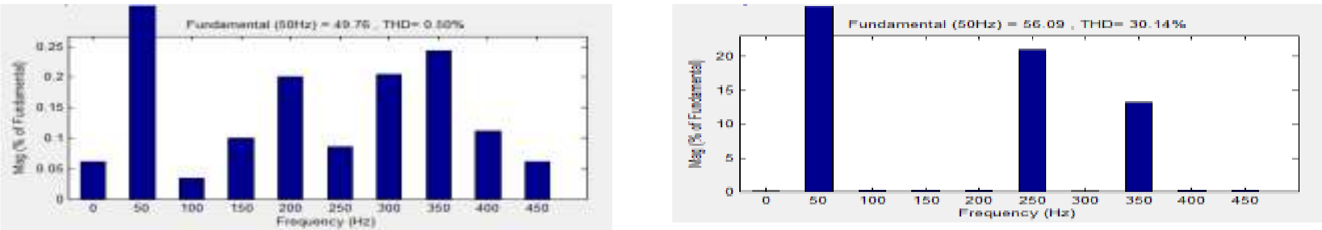
(e) Source Voltage & Current-In Phase



(c) Load Current



(f) DC-Link Voltage



(g) THD of Source Current

(h) THD of Load Current

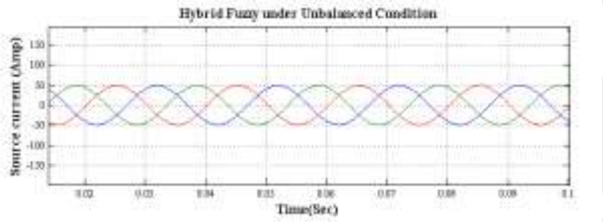
Fig.19 Simulation Result of PEV Charging Station with ZSI-DSTATCOM under Balanced Non-Linear Load using Hybrid Fuzzy-ISCT Control Scheme

The Simulation Result of PEV Charging Station with ZSI-DSTATCOM under Balanced Non-Linear Load using Hybrid Fuzzy-ISCT Control Scheme is depicted in Fig.19. It includes, (a) Source Voltage, (b) Source Current, (c) Load Current, (d) Compensation Current, (e) Source Voltage & Current-In Phase, (f) DC-Link Voltage, (g) THD of Source Current, (h) THD of Load Current, respectively. The non-linear loads in PEV charging station is powered by three-phase AC distribution system through three-phase Diode-Bridge rectifier with a value of 415V, 50Hz. Due to these non-linear devices in PEV charging station, the source or PCC current is harmonized and affecting the specifications in power distribution system. In this case, Fuzzy-ISCT controlled ZSI-DSTATCOM is integrated to distribution for compensating the harmonic currents coming from non-linear PEV charging station and maintains source current as sinusoidal, balanced and linear nature. The DC-link capacitor value is reduced due to ZSI operation and maintains DC-link voltage as constant attains boost voltage. The THD of load current is measured with a value of 30.14% and the THD of source current is measured with a value of 0.5%, it is well within IEEE-519 standards. The Hybrid Fuzzy-ISCT controlled ZSI-DSTATCOM produces better compensation features over the classical PI-ISCT and Fuzzy-ISCT control scheme and enhances the PQ features in distribution system.

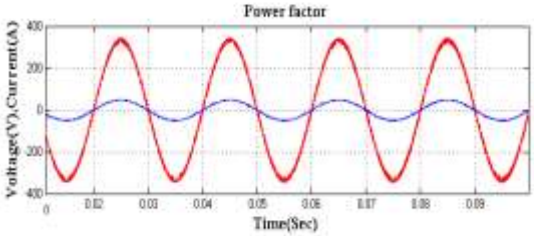
5.8 DESIGN OF PROPOSED ZSI-DSTATCOM FOR PQ IMPROVEMENT IN DISTRIBUTION NETWORK USING HYBRID FUZZY-ISCT CONTROL SCHEME UNDER UNBALANCED LOAD

(a) Source Voltage

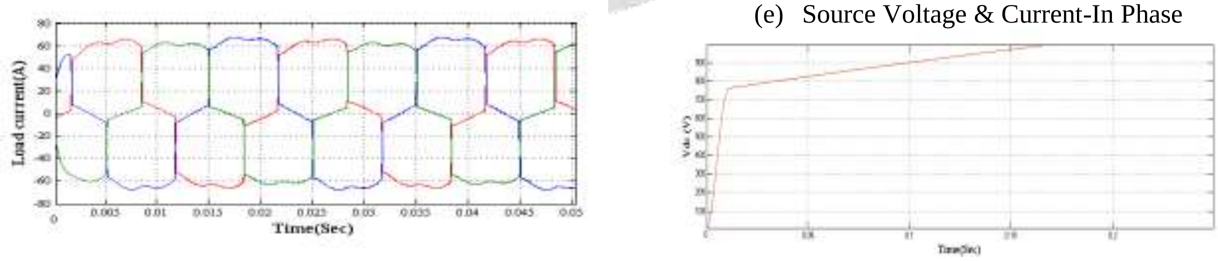
(d) Compensation Current



(b) Source Current

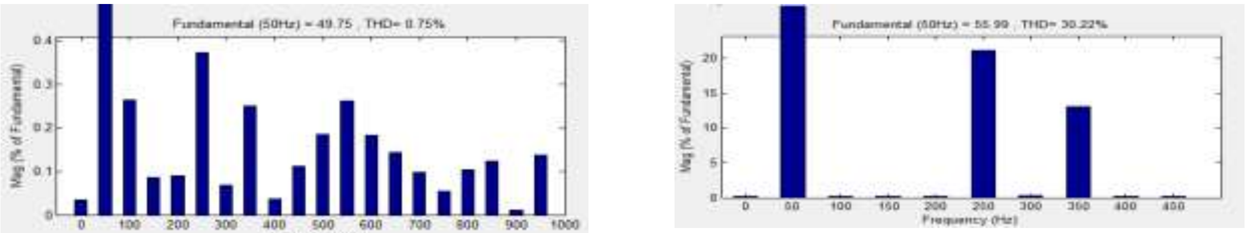


(e) Source Voltage & Current-In Phase



(c) Load Current

(f) DC-Link Voltage



(h) THD of Load Current

(g) THD of Source Current

Fig.20 Simulation Result of PEV Charging Station with ZSI-DSTATCOM under Un-Balanced Non-Linear Load using Hybrid Fuzzy-ISCT Control Scheme

The Simulation Result of PEV Charging Station with ZSI-DSTATCOM under Un-Balanced Non-Linear Load using Hybrid Fuzzy-ISCT Control Scheme is depicted in Fig.20. The unbalanced non-linear loads in PEV charging station is powered by three-phase AC distribution system through three-phase Diode-Bridge rectifier with a value of 415V, 50Hz. Due to these unbalanced non-linear devices in PEV charging station, the source or PCC current is unbalanced, harmonized and affecting the specifications in power distribution system. In this case, Fuzzy-ISCT controlled ZSI-DSTATCOM is integrated to distribution for compensating the unbalanced & harmonic currents coming from unbalanced non-linear PEV charging station and maintains source current as sinusoidal, balanced and linear nature. The DC-link capacitor value is reduced due to ZSI operation and maintains DC-link voltage as constant attains boost voltage. The THD of load current is measured with a value of 30.22% and the THD of source current is measured with a value of 0.75%, it is well within IEEE-519 standards. The Hybrid Fuzzy-ISCT controlled ZSI-DSTATCOM produces better compensation features over the classical PI-ISCT and Fuzzy-ISCT control scheme and enhances the PQ features in distribution system.

6. CONCLUSION

The Effect of Harmonics and large unbalanced currents occurs in the source side because of non-linear and unbalanced load switching in PEV charging stations. This work proposes the ZSI supported DSTATCOM for PEV charging station by using traditional & proposed intelligent control schemes. The performance evaluation of traditional PI and proposed intelligent controller based ISCT is verified under both balanced and un-balanced non-linear load condition. The Hybrid Fuzzy-ISCT controlled ZSI-DSTATCOM produces better compensation features over the classical PI-ISCT and Fuzzy-ISCT and maintains PCC/source as sinusoidal, balanced and linear nature. During both loads, the THD of source current is well within IEEE-519 standards which imply the enhanced PQ features in distribution network.

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