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Fuzzy Controlled Power Management and Power Quality Enhancement for Grid Integrated Renewable Energy sources with EV Fed UPQC

Alvala Mahesh Kumar [1], Sukhdeo Sao [2], E. Vidya Sagar [3]
[1] Research Scholler, Dept of Electrical Engineering, Osmania University, Telangana, India.
[2] Rtrd Professor, Dept of Electrical Engineering, Vasavi College of Engineering, Osmania University, Telangana, India.
[3] Professor, Dept of Electrical Engineering, Osmania University, Telangana, India

[1]maheshkumarphdou@gmail.com,[2]drssao53@gmail.com,[3]evsuceou@gmail.com

Abstract –Recently, the merging of Renewable Energy Sources (RES) and Electric Vehicles (EVs) has brought about significant changes in distribution systems. The main goal of this research is to effectively tackle power quality (PQ) concerns such as voltage fluctuations(sags and swells) and total harmonic distortion(THD) in a system connected to the grid .This system combines Solar Photovoltaic(SPV) and Wind Energy Systems(WES) and integrates a Battery Energy Storage System(BESS) and Electrical vehicles(EVs). To accomplish this, a versatile Unified Power Quality Conditioner (UPQC), referred to as U-SWEBEV, is employed. The control of power flow, encompassing the transfer from energy generation sources to consumer loads and among various sources, is efficiently managed through the application of a Fuzzy Interface System (FIS) regulation. This FIS system plays a key role in regulating power distribution. Additionally, a fuzzy Controller is implemented to enhance Maximum power Point Tracking (MPPT) from the SPV system. This combined approach , utilizing both Fuzzy Logic and the Unified power Quality Conditioner (UPQC), significantly contributes to the efficient and effective. utilization of power resources while successfully addressing power quality (PQ) concerns with different load combinations . The proposed method reduces the total harmonic distortion of load current and source voltage at linear nonlinear, nonlinear, Nonlinear and unbalanced linear loads with % THD 1.64 ,0.04,1.20,0.04 and 2.84,2.32 which are lower than the existing methods that are available in literature.

Keywords - Unified Power Quality Conditioner, Total Harmonic Distortion, Power Quality, fuzzy interface system, electric vehicle accumulator

1. Introduction

Recently, there has been a significant push towards integrating renewable energy sources like solar and wind into the distribution grid[1-3]. This integration not only helps to reduce the strain on converters and equipment ratings but also represents a notable development in the form of the solar -integrated UPQC. The inherent variability in Photovoltaic (PV) system introduces harmonic distribution into the grid, leading to distribution in load voltage and current. To counter these effects, Flexible AC Transmission Systems (FACTS) devices have been deployed. These devices, including the Unified power flow conditioner (UPFC), UPQC, Static var compensator (SVC), are widely employed to enhance power quality[4-6]. The integration of these FACTS devices not only address voltage stability concerns but also significantly improves the overall quality of power supplied by the grid.

The study delved into the utilization of UPQC in grid -tied SPV systems to uplift power quality(PQ)It also conducted a thorough examination of the roles and benefits of integrating EVs along with their charging strategies. The UPQC efficiently addressed a majority of the essential requirements, encompassing enhancements in voltage profiles, suppression of Total Harmonic Distortion THD, improvements in power factors, and an overall enhancement of PQ. Furthermore, introduced the incorporation of Battery Energy Storage Systems (BESS) with EVs, integrating a Fuzzy logic controller (FLC). This combined system significantly evaluated PQ and bolstered the overall reliability of the grid-connected system , which encompasses SPV-WES-BESS and EV’s in comparison to a basic grid setup[7-10].

The UPQC system integrated with solar energy was meticulously designed to tackle power quality (PQ) challenges[11]. It achieved this by finely tuning selection of PI controller parameters and filter parameters and using innovative soccer league optimization technique. For the UPQC system connected to wind batteries, a fuzzy controller was adopted to effectively address PQ issues related to voltage and current. To validate the system’s reliability, arrange of test

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scenarios were executed, each involving diverse load combinations. To efficiently reduce Total Hormonic Distortion (THD), a hybrid Fuzzy based controller was applied to the shunt active power filter within the wind-battery system[12].

While existing literature primarily revolves around UPQC applications in renewable energy sources like SPV and wind Energy systems(WES), often combined with battery Energy Storage Systems(BESS) and employing various control strategies , it overlooks the vital aspect of integrating Electrical Vehicle(EV's). This omission in particularly noteworthy because , during peak electricity demand periods, efficiently managing surplus power demand can be achieved by harnessing the capabilities of EVs[13-16]. The power flow from source to load and from one source to another source is controlled with the support of FLC EV power management system[17-19]. The UPQC improves the power quality under balanced and distorted load conditions[20].The FLC-MPPT provides better dynamic performance than conventional MPPT technique under change in voltage condition[21-22]

The contributions of this work are highlighted below

- Design of Electric vehicle accumulator for appropriate management in flow of power among EVs and RES Using Fuzzy controlling.
- Reduction of the source current and load voltage THD and elimination of grid voltage side issues like (disturbance, swell, sag) using U-SWEBEV.
- Integration of RES, EV and BESS for UPQC to reduce the stress and burden on SVC, supports to meet the load demand , maintain constant DC link's voltage during irradiation and load variations.

The paper is structured as follows: In Section 2, we delve the modeling of U-SWBEV and comprehensively covers the techniques employed in our research with Fuzzy technique. Section 3 provides results with discussions. Finally, in Section 4, ensure the conclusions from our work and outline potential future avenues for research in this field.

2. Design of proposed U-SWBEV

Figure 2.1 illustrates the structural configuration of the proposed system, which seamlessly integrates the grid with various elements, including Solar Photovoltaics (SPV), Wind Energy Systems (WES), Battery Energy Storage Systems (BESS), and Electric Vehicles (EVs). A phase inverter acts as the connecting link in this setup.The Unified Power Quality Conditioner (UPQC) assumes a central role, functioning as a pivotal device that amalgamates both shunt and series Voltage Source Converters (VSCs).The series filter takes on a critical role in mitigating voltage-related concerns on the grid side. It achieves this by supplying the necessary series voltage (V'se_abc) through an injecting transformer, facilitated by the series inductance . Similarly, the shunt filter establishes an electrical connection with the grid through the shunt inductance . The Shunt Active Power Filter (SHAPF) is entrusted with the task of rectifying existing waveform harmonics by introducing appropriate compensatory current and ensuring a consistent DC link voltage.

However, the main advantage of external renewable source support reduces the required ratings and stress of the converters. The SPV, WES, BESS, and EV parameters selected are listed in Table1. The dispersal of power is calculated by Eq. (2.1) and explanation is given in Table 1.

$$P_{GR} + P_{WE} + P_{SPV} + P_{BES} + P_{VH} = P_{LD} \quad (1)$$

Where, P_{SPV} denotes SPV output power
P_{WE} denotes WES output power
P_{BES} denotes energy storage battery output power
P_{VH} denotes output power of EV
P_{LD} denotes output power of Load
P_{GR} denotes output power

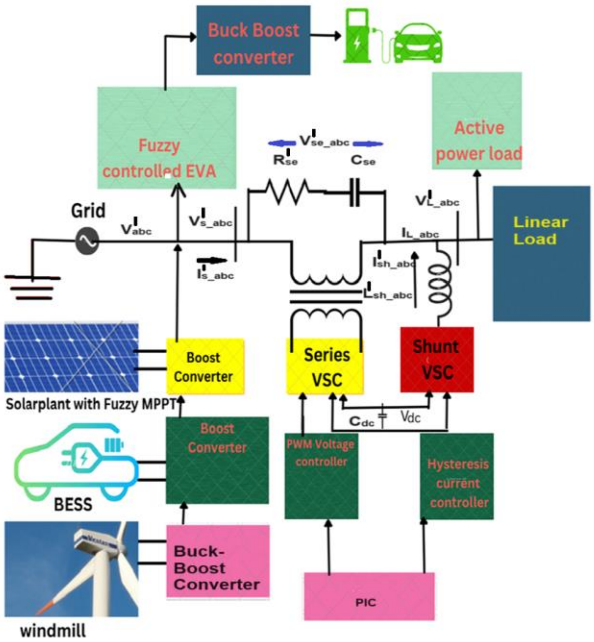


Figure 1: Proposed U-SWBEV configuration

Table 1: PV, Wind, BESS and EV selected ratings

Device	Configuration	Values
PV single panel (Sun power SPR-	PV cells connected in parallel, series	45, 10
	Rated Power	228.735W

215-WHT-U)	Short circuit current	8.18A
	Open circuit voltage	37.1V
	Under max power the voltage & current	29.9V /7.65A
Li-ion battery	Fully charge voltage	326.6V
	Rated Capacity of battery	400Ah
	Cut off voltage	225 V
	Normal Voltage	300V
	SOC	95%
Wind Turbine	Nominal turbine mechanical power	30 KW
	Maximum pitch angle	45deg.
	Base wind speed	15 m/sec
	Maximum rate of change of pitch angle	25deg./second
	Pitch angle K_i	5
	Pitch angle K_p	25

2.1. Design of Fuzzy Controller based MPPT for SPV System

The Solar Photovoltaic (SPV) systems convert sunlight into electricity, and this conversion process is influenced by the arrangement of PV modules. PV modules are connected in series to form a string, and then several of these strings are connected in parallel to generate the required voltage and current within each module, a single diode equivalent circuit represents each PV cell, as shown in Figure 2.

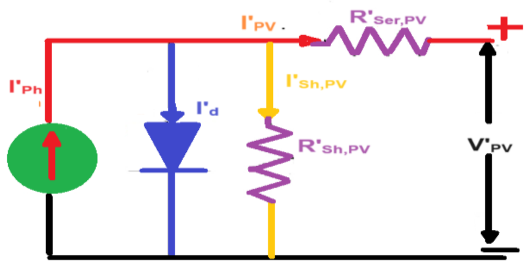


Figure 2 : PV cell single diode model

It comprises a photo current source (i'_p) with a forward diode (i'_d) conducting current, along with series and parallel resistances ($R'_{ser,PV}$ and $R'_{sh,PV}$) that carry currents (i'_{PV}, $i'_{sh,PV}$). The PV cell detects solar irradiation and transforms it into current. Using KCL, the PV cell's current at output (i'_{PV}) is determined as per Eq. (2).

$$i'_{PV} = i'_{ph} - i'_{d} - i'_{sh,PV} \qquad (2)$$

$$i'_{PV} = i'_p - i'_{sat}[exp(\frac{Q_C(V_{PV}+(i'_{PV}R_{S,PV}))}{\eta k T_C}) - 1] - \frac{V_{PV}+(i_{PV}R_{Ser,PV})}{(R'_{sh,PV})} \qquad (3)$$

In this context, i'_{sat} represents the reverse saturation current, Q_c stands for the charge of an electron, η represents the diode's ideal factor, k_b denotes Boltzmann's constant, and T_C represents the cell's temperature. Additionally, $V'_{PV,C}$ and $i'_{PV,C}$ refer to the voltage as well as current output of the cell. In the literature most of the conventional systems focuses mainly on P&O method is adopted.

A Solar Panel converts only 30 to 40 percentage of the incident solar irradiation into electrical Power. To improve the efficiency of the solar panel the maximum power point technique is applied

The power output of the Fuzzy based MPPT achieves its maximum when the source impedance aligns with the load impedance. The Fuzzy Logic-controlled Maximum Power Point Tracking (MPPT) system, where the input parameters consist of the photovoltaic current (I_{SPV}) and photovoltaic voltage (V_{SPV}). duty cycle is considered as output. The output power obtained from the solar system (P_{SPV}) is calculated by Eq. (4).

$$P_{SPV} = V_{SPV}.I_{SPV} \qquad (4)$$

To determine the number and shape of the membership functions for each fuzzy set, along with the selection of the fuzzy logic inference mechanism, was initially established through trial-and-error methods. This process entailed iteratively testing various configurations to ensure a thorough coverage of the region of interest by the input data. The guiding principle behind this selection process was intuitive: if the most recent adjustment in the control signal (D) resulted in an increase in power, the approach was to continue moving in the same direction. The MPPT system, utilizing Mamdani's FLC approach with the min-max operation fuzzy combination law, is structured to continuously adjust the operating point of the solar array[41]. The primary objective of this control task is to approach, as closely as possible, the MPP. Triangular and S shaped membership functions were employed in the fuzzification process. Two input variables namely error 'e' and change of error 'ec' and one output variable namely increment in duty cycle 'D' were considered. Which are defined in Eq. (5) ,(6) and Eq.(7) as

$$e(n) = \frac{P_{pv}(n) - P_{pv}(n-1)}{V_{pv}(n) - V_{pv}(n-1)} \quad (5)$$

$$ec(n) = e(n) - e(n-1) \quad (6)$$

$$D(n) = s_{\Delta D} * \Delta D(n-1) - D(n-1) \quad (7)$$

Where,
$P_{pv}(n)$ is the instant power of the PV generator, $V_{pv}(n)$ is the instant corresponding voltage

The fuzzy factor plays a pivotal role in regulating the duty cycle of the boost converter, facilitating the Maximum power point tracking (MPPT). In this configuration the boost converter dynamically adjusts the duty cycle based on the Fuzzy factor[47].

These inputs are chosen so that the instant value of e(n) shows if the load operation power point is located on the right or in the left compared to the Pmax actual position. While e(n) expresses the moving direction of this operation point.

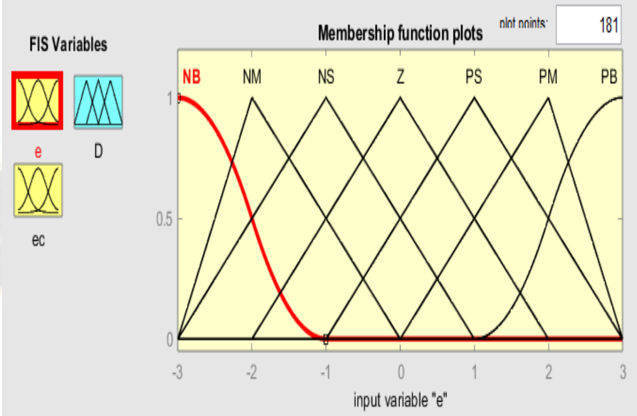
For each of these variables 7 membership functions were defined, representing linguistic variables: Negative big (NB), Negative Moderate (NM), Negative small (NS) , Zero (Z), Positive small (PS), Positive moderate(PM), Positive Big (PB). 49 rules are defined to map combinations of fuzzy input values to fuzzy output values. The graphical representation of the membership function illustrates the degree of membership function for each variable across the respective ranges. The triangular shapes convey how each linguistic variable associated with different regions within the input and output spaces, these membership functions serve as a crucial part of the fuzzy controller's desertion making process.

After applying the fuzzy rules, the output membership functions for 'P_{EVref}' have certain degree of membership. To obtain a crisp value for the Pulse Width Modulation (PWM) signal the Centroid method is employed. The centroid method calculates the center of mass of the fuzzy output membership functions. Each membership function contributes to the overall crisp output based on degree of membership. The crisp output as D_{crisp} and the membership functions as MF_i the formula for centroid defuzzification is expressed in Eq. (8)

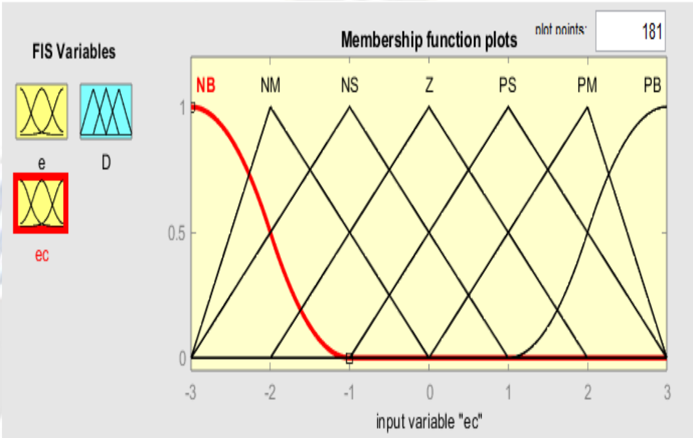
$$D_{crisp} = \Sigma_i(MF_i * Centroid_i)/\Sigma_i(MF_i) \quad (8)$$

Where $Centroid_i$ is the center of the i^{th} membership function MF_i is the degree of membership in the i^{th} membership function. The Input MSF for MPPT are illustrated in Fig 3.

The Fuzzy controller undergoes training to minimize the root mean square error between the obtained and desired output, with the objective of maximizing the output from the Solar Photovoltaic (SPV) system. Photocurrent and terminal voltage of the cell function as inputs to the Fuzzy controller, and the resulting duty cycle of the controller serves as the output for regulating the boost converter



(a) MSF for input1 "e"



(b) MSF for input1 "ec"

Figure 3: MSF for input of MPPT

The MSF for Output and Surface of Fuzzy controller are illustrated in Fig.4 and Fig. 4.8.

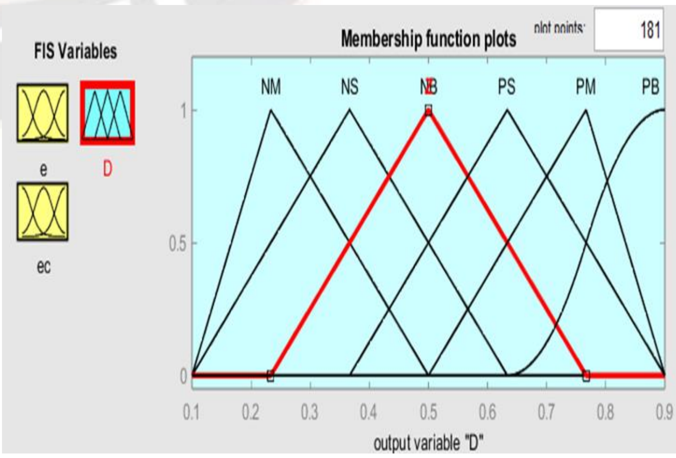


Figure 4.: MSF for Output Duty Ratio "D"

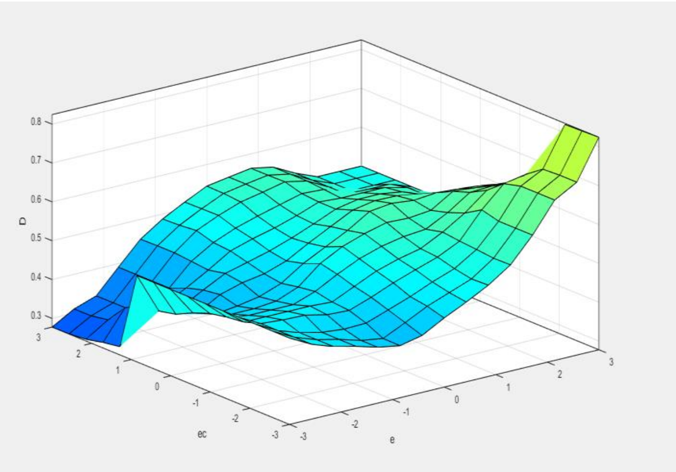


Figure 5: MPPT Fuzzy surface

A boost converter is employed alongside a solar panel to raise the output voltage. This increased voltage makes it suitable for various applications. By adjusting the duty cycle of the boost converter appropriately, we can align the source impedance with that of the load impedance. The System outputs of the duty ratio, as depicted in the accompanying in the Fig 6. The control system of PV and characteristics are illustrated in Fig. 7 respectively.

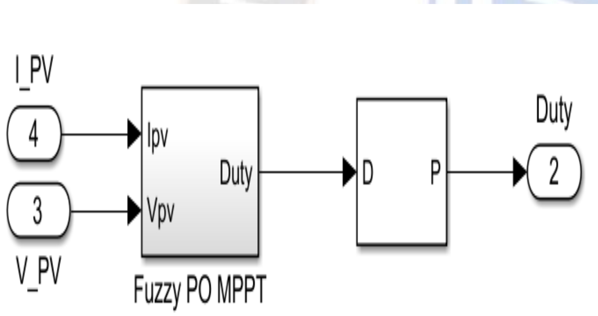


Figure 6: Fuzzy controlled MPPT.

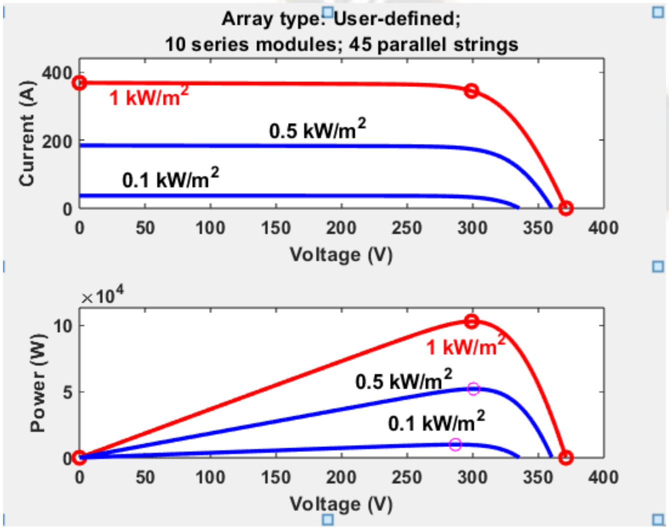


Figure 7: Variable irradiation constant temperature characteristics

The waveforms depicting the Duty Ratio and Output Voltage of the Boost Converter are provided in Figure 8.

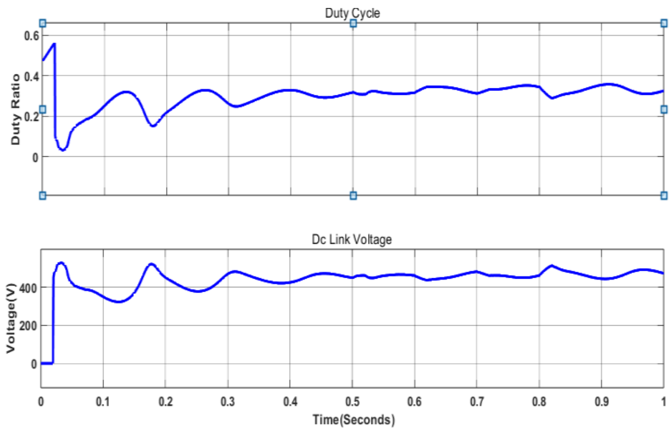


Figure 8: Duty ratio and voltage of DC to DC Boost Converter

The MATLAB model of Fuzzy controlled MPPT with SPV is given in Figure. 9 This boosted DC power is then fed into the grid-connected inverter. The grid-connected inverter, in this case, utilizes a three-level Neutral Point Clamped (NPC) topology. The NPC inverter is a type of multilevel inverter known for its ability to produce high-quality sinusoidal AC output with reduced harmonic distortion. Pulse Width Modulation (PWM) is employed to control the switching of the power devices in the inverter. By adjusting the width of the pulses in the inverter's output, the amplitude and frequency of the AC output waveform are regulated.

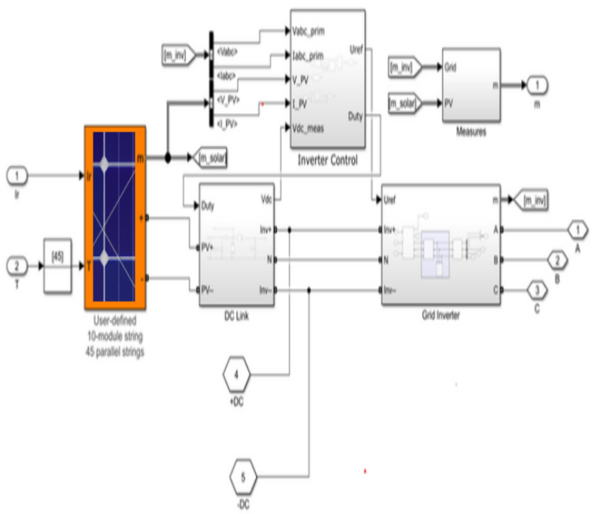


Figure 9: Solar PV Matlab/ simulink mode

2.2 Fuzzy Controlled EVA for Power Management

With the aid of RES's power generation forecasting system and load forecasting system, the EVA controller functions by overseeing the flow of power between EVs and the grid, facilitating power transfer either from EVs to the grid or from the grid to EV's.

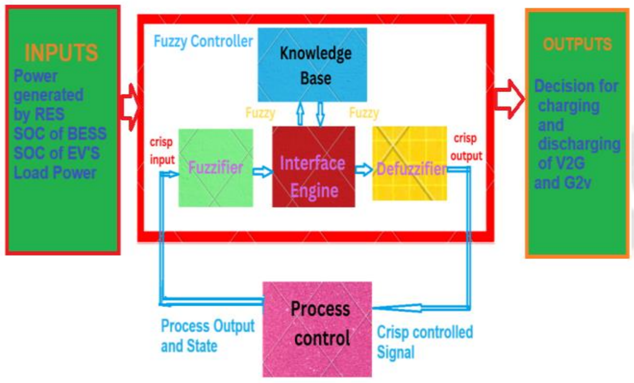


Figure 10: Fuzzy controlled EV System

The power management with the proposed technique is shown in Figure 10. EVA power management system is designed using a hybrid controller, sometimes referred to as an Fuzzy controller for performance analysis. Here, flow chart depicted in Figure 11. explains how the proposed fuzzy based EVA operates.

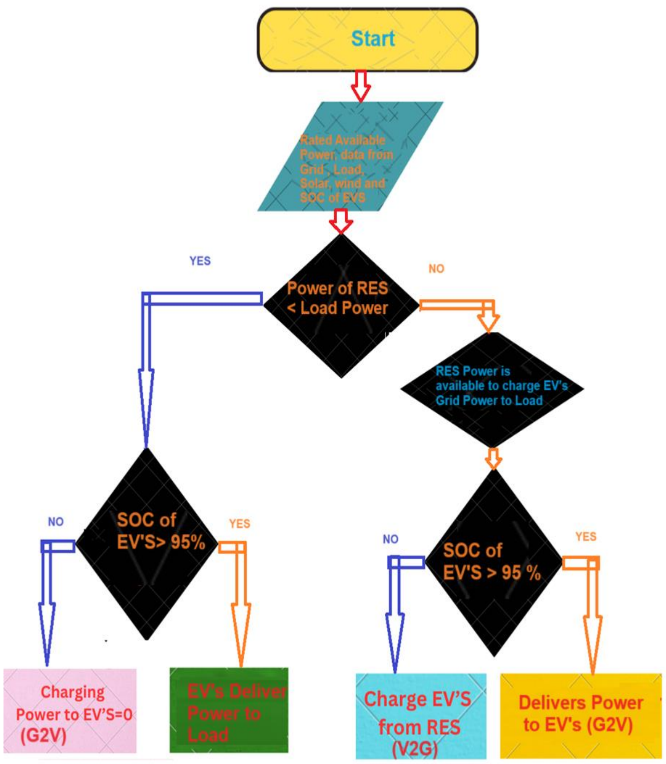


Figure 11: Flow chart for SOC control

Information is exchanged between the EVA controller and the grid, RESs, ESS, and charging stations (ST1, ST2, ST3, ST4). EV charging decisions are made with the assistance of EVA. If the EVs are not being driven, they stop at charging stations. During periods of high load, these EVs might be utilized as ESS. Because these are employed as ESS, for a period of time longer than the grid's peak load hour is lowered. The availability of EVs and their state of charge (SOC) determine how much power EVs can offer to the grid.

To meet load demands, BESS are vital for power management. Batteries, comprising cells connected in series or parallel arrangements, are employed to attain the required current or voltage levels. for power management Lead-Acid batteries were chosen due to their cost-effective maintenance characteristics, as available from the Simulink library. Eq. (9) outlines the charging and discharging model of Li-ion batteries.

$$V_{bry} = E'_{f1,2}(i'_t, i'_h, i'_b) - i'R' \qquad (9)$$

Where, $E'_{f1,2}(i'_t, i'_h, i'_b)$ is no load voltage, R' is the value of internal resistance, I'b battery current. The state of charge in battery (SOCBR) is expressed in Eq. (10).

$$SOCBR = 95(1 + \int i'_{BSS}\ dtQ') \qquad (10)$$

The SPG will decide whether, the battery to charge or discharge while satisfying the constraints given by Eq. (11). The discharge of battery is shown in Fig.12.

$$SOCBR_{min} \le SOCB \le SOCBR_{max} \qquad (11)$$

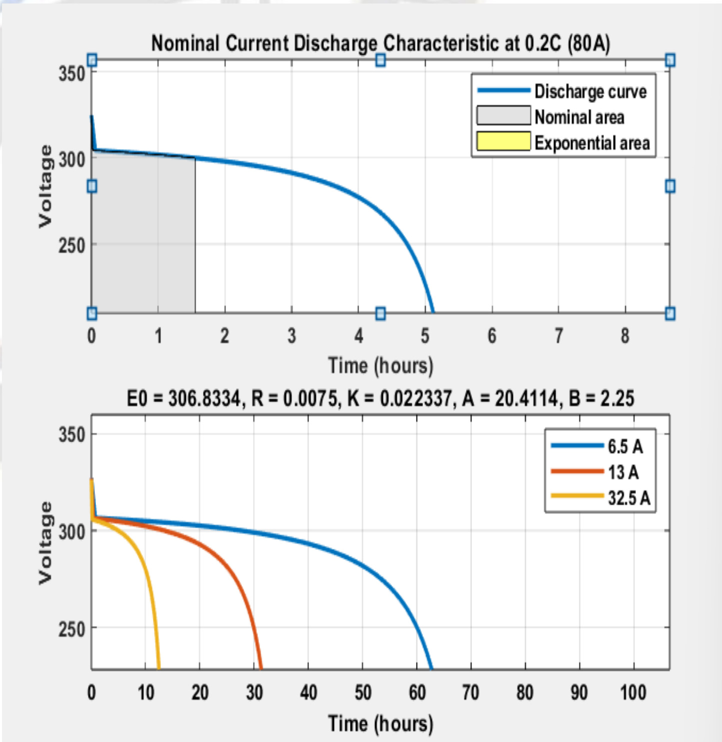
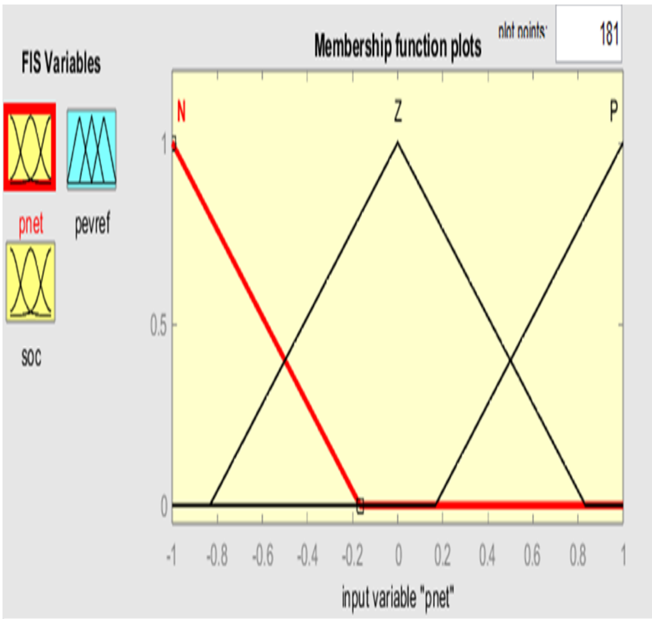


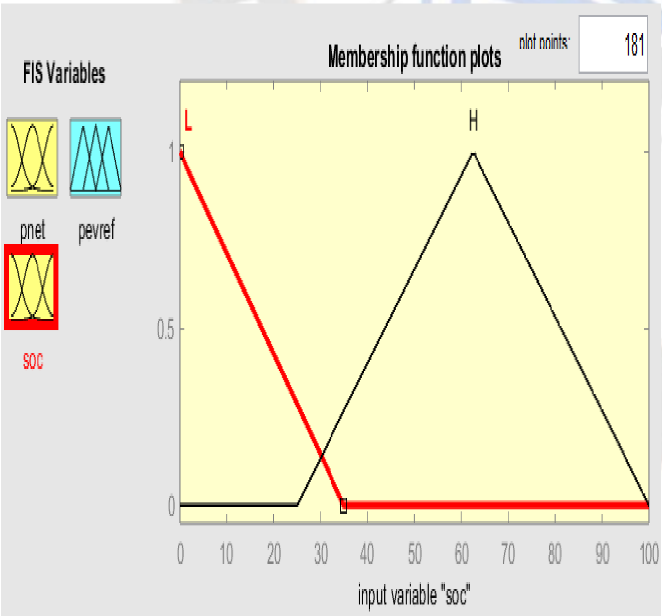
Figure 12: Battery discharge characteristics

Figure 13 The usage of Fuzzy system allows for the regulation of flow of power to load from various available

RES as well as from the BESS and EVs systems. a two-input, one-output system for controlling 'P_{EVref}' based on 'P_{net}' and 'SOC'. The fuzzy logic rules define how the inputs influence the output, and the membership functions define the fuzzy regions for each variable. However, the MSF of input and outputs are illustrated in Figure 14, Figure 15 respectively. The rule base and surface are given Figure16 and Figure 16 respectively.



(a) MSF for input1 "P_{net}"



(b) MSF for input2 "SOC"

Figure 13: MSF for input "P_{net}" and "SOC"

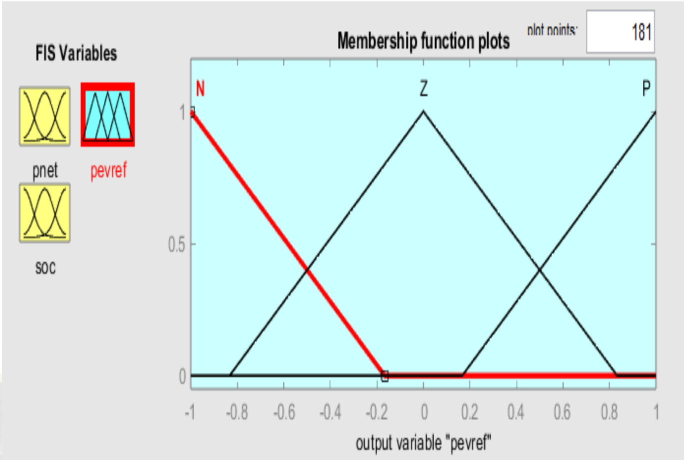


Figure 14: MSF Output of EVA P_{evref}

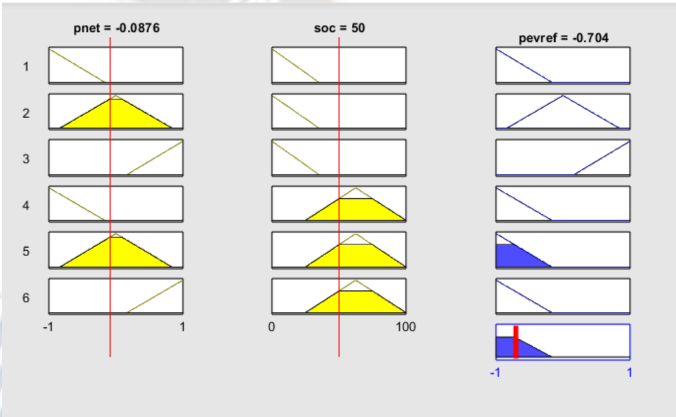


Figure 15:. EVA rule base

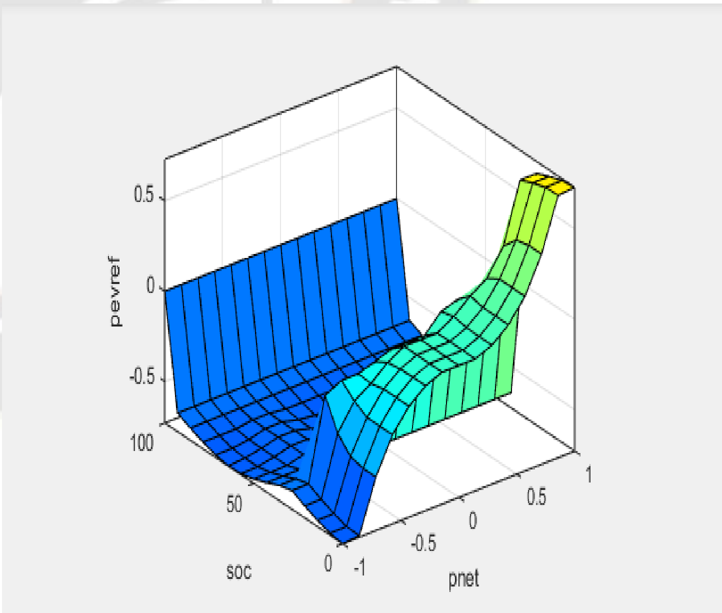


Figure 16. EVA Surface

2.3 UPQC Controller

To address the current harmonics and maintain DC-Link voltage stability, the SVC employes dual strategies . (i)

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Employing the dq0-abc and vise-versa shifting and (ii) incorporating a conventional PIC. Phase Locked Loop is integrated to extract Phase and frequency from the supply voltage, facilitating the transformation of the load current into the dq0 coordinate system. The PIC continuously monitors the DC bus voltage comparing it with a predetermined reference value. Upon detecting deviations from the reference, the PIC takes corrective measures to adjust the current ensuring that the voltage remains at the desired level. This voltage regulation is achieved by making precise adjustments to the reactive component to generate gate signals, a Hysteresis controller is adopted, as depicted in Figure 17. The voltage sag/swell $V_{sag/swell}$ is calculated by Eq (12) and the series compensated voltage of UPQC is given by Eq.(13).

$$V\frac{sag}{swell} = V_{ld} - V_s / V_{ld} \qquad (12)$$

$$V_{Ser} = V_{ld} - V_s \qquad (13)$$

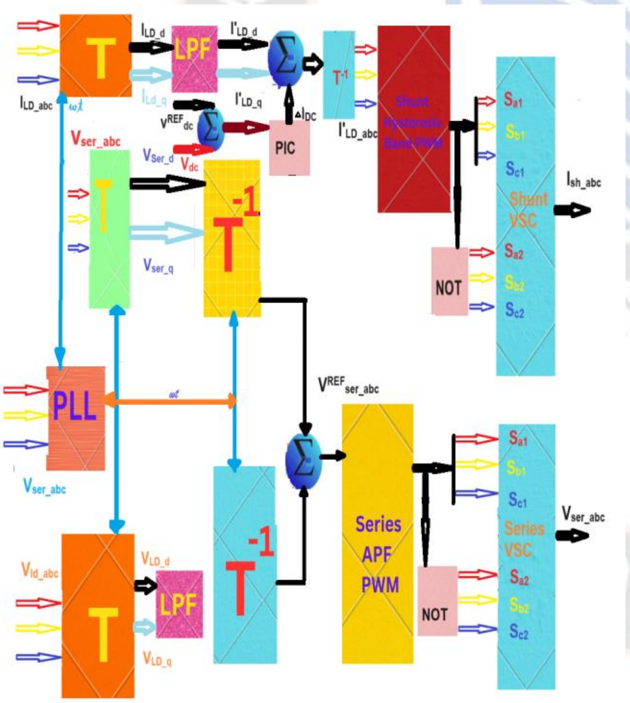

Figure 17: UPQC and series converter control syst

III. Results with Discussion

In this case study investigated with different scenarios characterized by voltage related challenges such as voltage sag, voltage swell with different loads such as nonlinear, combination of linear and nonlinear and combination of unbalanced linear and nonlinear loads impacted by inconsistent irradiation, all occurring under a constant temperature of 25ºC. The purpose of selecting these scenarios was to demonstrate how the enhanced voltage algorithm functions within the framework. Of U-SWEBEV. Additionally integrated the UPQC to enhance the power quality.

The THD is evaluated by Eq. (15).

$$THD = \frac{\sqrt{(I^2{}_2 + I^2{}_3 + ...I^2{}_n)}}{I_1} \qquad (15)$$

Where,

In= individual harmonic current distortion values in amps

I1= individual harmonic current distortion values in amps

I2= 2nd harmonic current distortion values in amps

Case1: Performance of proposed system under Constant irradiation (1000W/m2) and temperature of 250c with Loads 1& 2 (Linear and Non-Linear load)

In case1, from the Figure 18(a) it is observed that the proposed intelligent power management technique is working effectively for appropriate handling of EVSs depending on their SOCs. Here, the grid takes power while PV, WE and EV are providing their outputs. However, during this condition BESS charges and EVs discharges and supplies required amount of power to the load and maintains constant power to the load. In addition, Figure 18(b) provides the irradiation; the maximum output power from the SPV system by Fuzzy based MPPT to maintain DC Link voltage.

Similarly as illustrated in Figure 18(C) the performance of the series filter within the UPQC is its effective mitigation of voltage distortion between 0.3 to 0.4 seconds, the series filter adeptly eliminates harmonic distortion by injecting the necessary compensating voltage, thereby maintaining a constant load voltage .Furthermore, the UPQC demonstrates effective responsiveness in comparing for voltage related disturbances. Specially during the periods of 0.5 to 0.6 cycles (sag condition) it injects the voltage from coupling inductor to mitigate the sag while maintaining a constant voltage. From 0.7 to 0.8 second for voltage swell the excess voltage is appropriately absorbed by coupling inductor to maintain a stable voltage. The Load current , source current and compensated UPQC currents are illustrated in Figure 18(d).The THD of source current and load Voltage are 1.20 and 0.04 as given in Figure 19 respectively. Inductor

Case2: Performance of proposed system under Constant irradiation (1000W/m2) and temperature of 25^{0}c with Loads 1 (Nonlinear load)

In case 2 , from the Figure 20 (a) it is observed that the proposed intelligent power management technique is working effectively for appropriate handling of EVS depending on their

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SOCs. Here the grid takes power while PV, Wind , EV are providing their outpower to compensate grid power. However, during this condition EVs discharges and supplies required amount of power to the nonlinear load and maintains constant power to the load.

In addition, Figure 20(b) provides the irradiation, maximum output from solar PV. System by Fuzzy based MPPT to maintain DC link voltage. Similarly as illustrated in Figure 20 (c) the performance of the series filter within the UPQC in its effective mitigation of voltage distortion between 0.3 to 0.4 seconds by injecting the necessary compensating voltage , therefore maintaining a constant load voltage. Furthermore, the UPQC demonstrates effective responsiveness in compensating voltage related disturbances. Specially during the periods of 0.5 to 0.6 seconds (sag condition) it injects the voltage from coupling inductor to mitigate the sag while maintaining a constant voltage from 0.7 to 0.8 seconds for voltage swell the excess voltage is absorbed by coupling inductor.

The Load current, source current and compensated UPQC currents are illustrated in Figure 20(d). The THD of source current and load Voltage are 1.64 and 0.04 as given in Figure 21 respectively.

Test case 3: Performance of proposed system under Constant irradiation (1000W/m2) and temperature of 250c with Loads 1&2 (Nonlinear load and unbalanced linear load)

In case3, from the Fig 22(a) it is observed that the proposed intelligent power management technique is working effectively for appropriate handling of EVSs depending on their SOCs. Here, the grid takes power while PV,WE and EV are providing their outputs with Nonlinear and unbalanced linear load . However, during this condition BESS charges and EVs discharges and supplies required amount of power to the load and maintains constant power to the load. In addition, Fig 22(b) provides the irradiation; the maximum output power from the SPV system by Fuzzy based MPPT to maintain DC Link voltage.

Similarly as illustrated in Figure 22(C) the performance of the series filter within the UPQC in its effective mitigation of voltage distortion between 0.3 to 0.4 seconds, the series filter adeptly eliminates harmonic distortion by injecting the necessary compensating voltage, thereby maintaining a constant load voltage .Furthermore, the UPQC demonstrates effective responsiveness in comparing for voltage related disturbances. Specially during the periods of 0.5 to 0.6 cycles (sag condition) it injects the voltage from coupling inductor to mitigate the sag while maintaining a constant voltage. From 0.7 to 0.8 second for voltage swell the excess voltage is appropriately absorbed by coupling inductor to maintain a stable voltage.

The Load current , source current and compensated UPQC currents are illustrated in Figure 22(d). The THD of source current and load Voltage are 2.84 and 2.32 as given in Figure and Figure respectively.

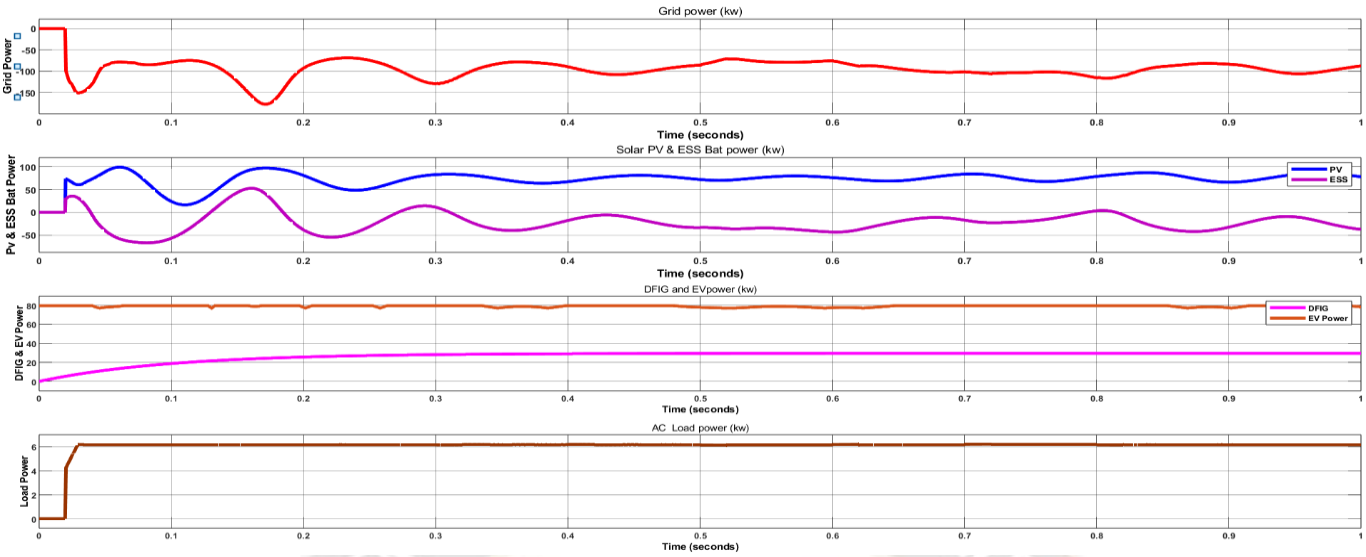
Table.3.1 shows the THD of the proposed method in all case studies. It exhibits that the proposed method has much lower THD at distortion, sag and swell within in the IEEE standards and compared with base paper results. However, Figure 24 represents the FFT analysis of case 3 source current of the proposed system. Table 3.2 shows the Source grid, DC link Capacitor and Load

Table 3.1: % THD comparison with literature

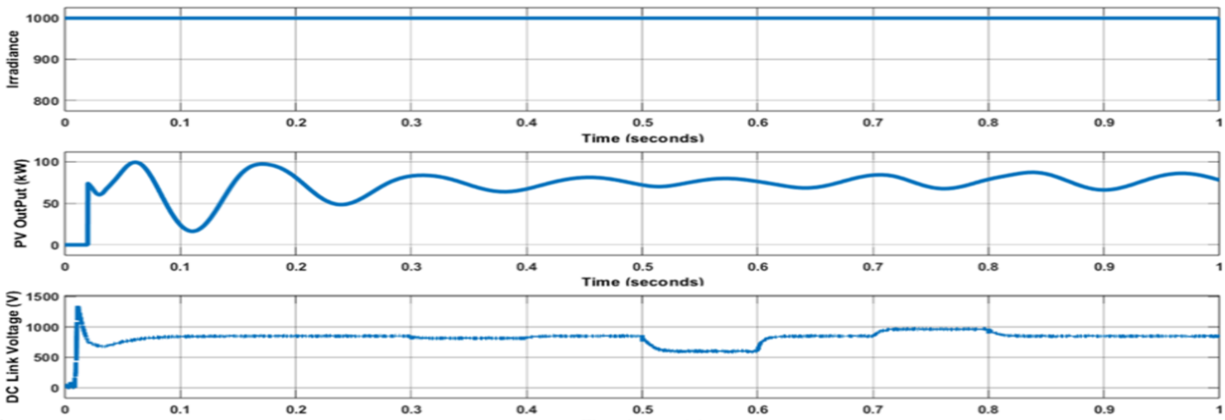
Controller for Reference	Type of Load	Load Voltage (V)	Source Current (A)
DM Fuzzy	Linear and Non-Linear Load	0.04	1.20
DM Fuzzy	Non-Linear Load	0.04	1.64
DM Fuzzy	Unbalanced Linear and Non-Linear Load	2.32	2.84
[14]	Linear Load	3.72	--
[15]	Linear Load	2.39	
[16]	Linear Load	2.40	--

Table 3.2: Grid system and UPQC parameters

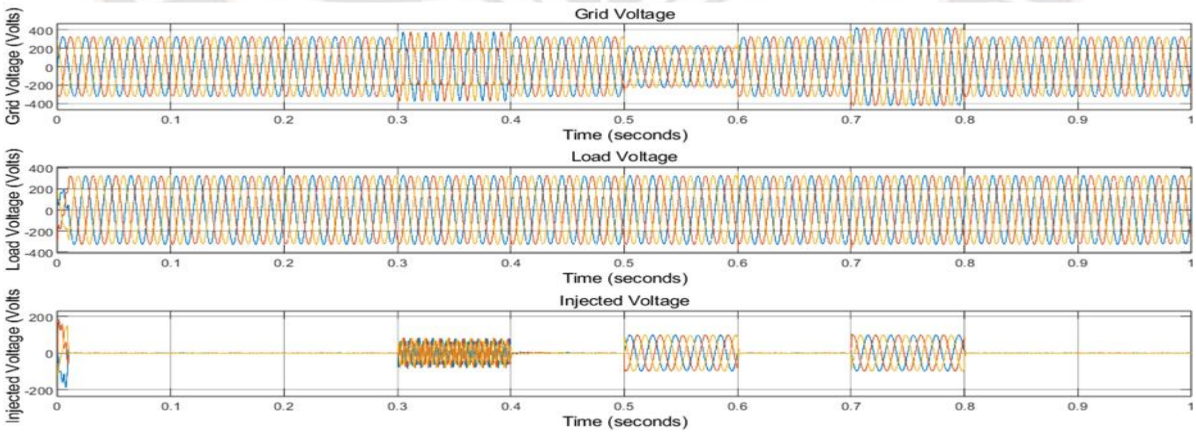
Source Grid	V_s : 415V, f : 50Hz
DC link capacitor &Coupling inductors	V_{dc}:470v, C_{dc}:100µF R_{se}=1ohm; C_{se}= 100µF, L_{sh}=10mH
Loads	1.Rectifier bridge load R= 60; L= 0.15e-3. 2. Active power load: P_{L1}=2kW 3. Un Balanced Active powers load: P_{L2}=10kW, 9kW, 11kW and Reactive powers (Positive Var) 100, 90,110



(a) Grid power, P_{PV}, P_{BESS}, P_w, P_{EV}, P_L



(b) G, P_{PV}, UPQC DC Link voltage



(c) Grid voltage, Load Voltage, Series filter compensated Voltage

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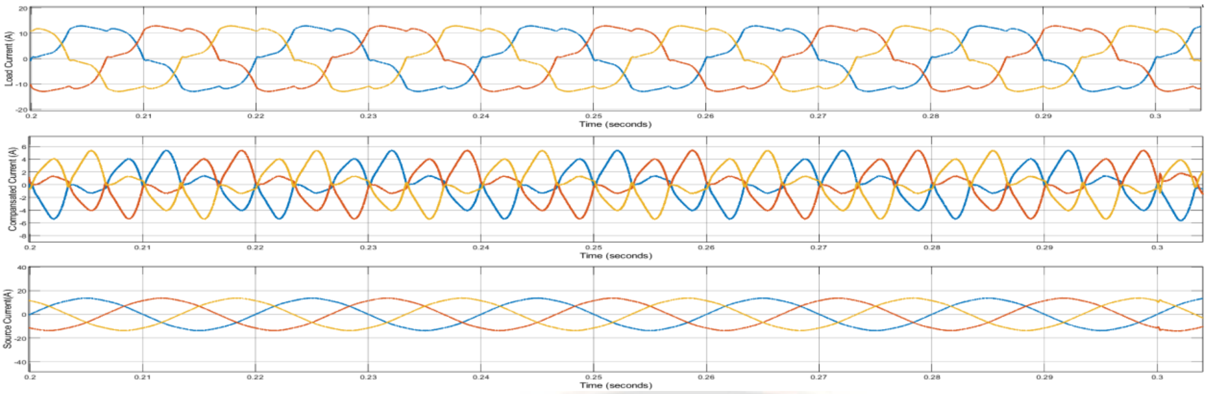


(d) Current at load, compensated current, Source current

Figure 18 Waveforms of the developed method for case-1

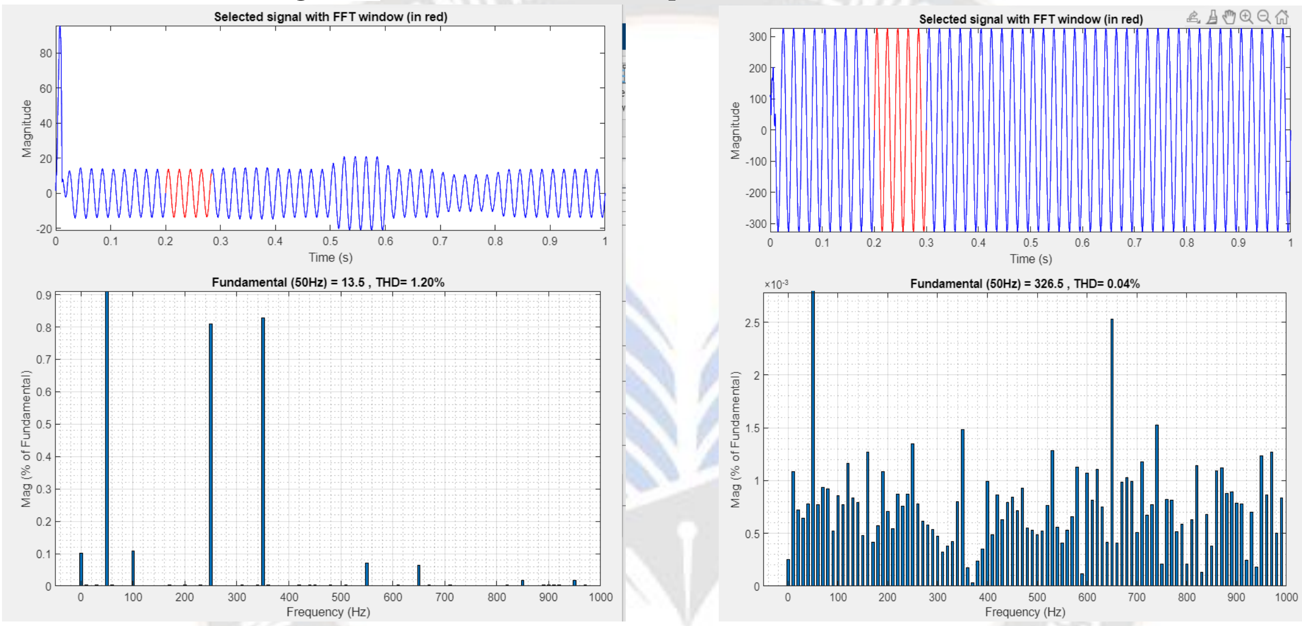
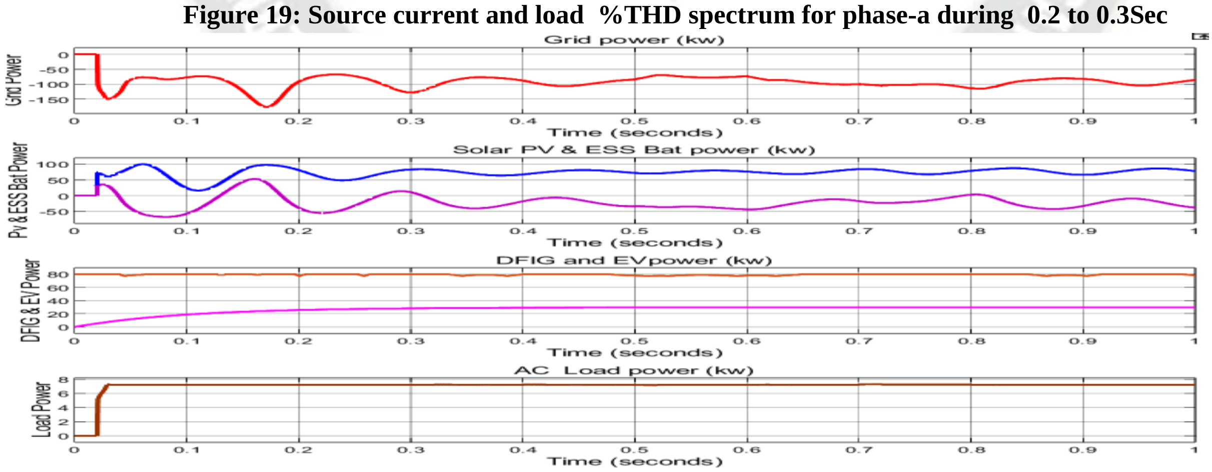


Figure 19: Source current and load %THD spectrum for phase-a during 0.2 to 0.3Sec



(a) Grid power, P_{PV}, P_{BESS}, P_w, P_{EV}, P_L

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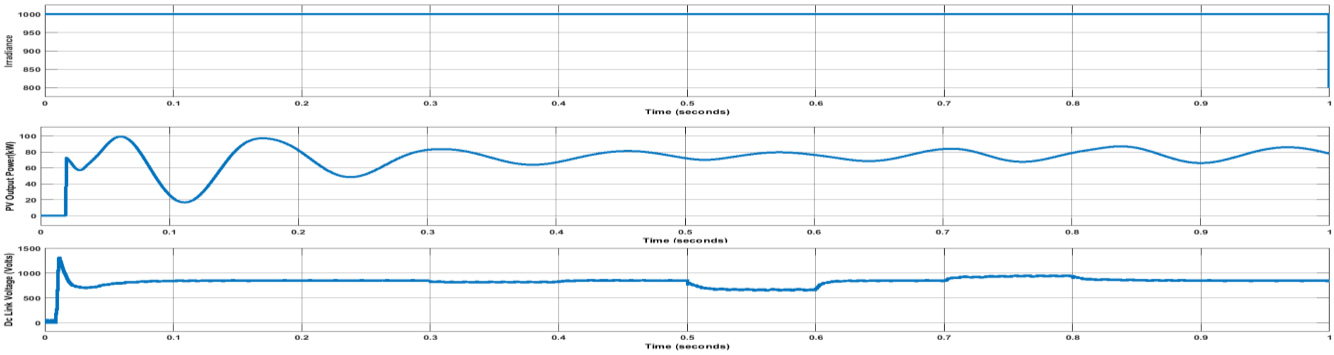
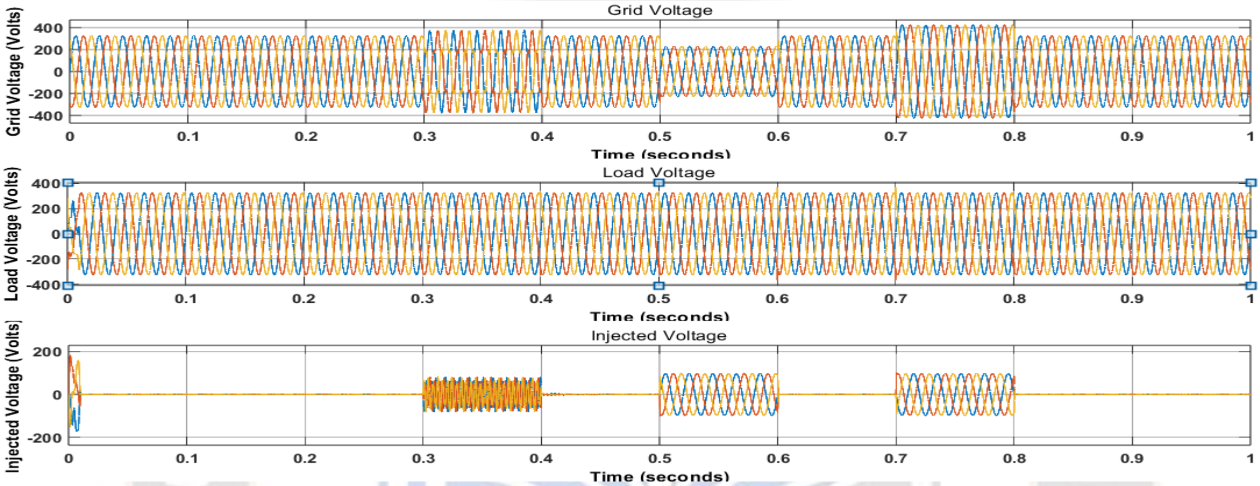
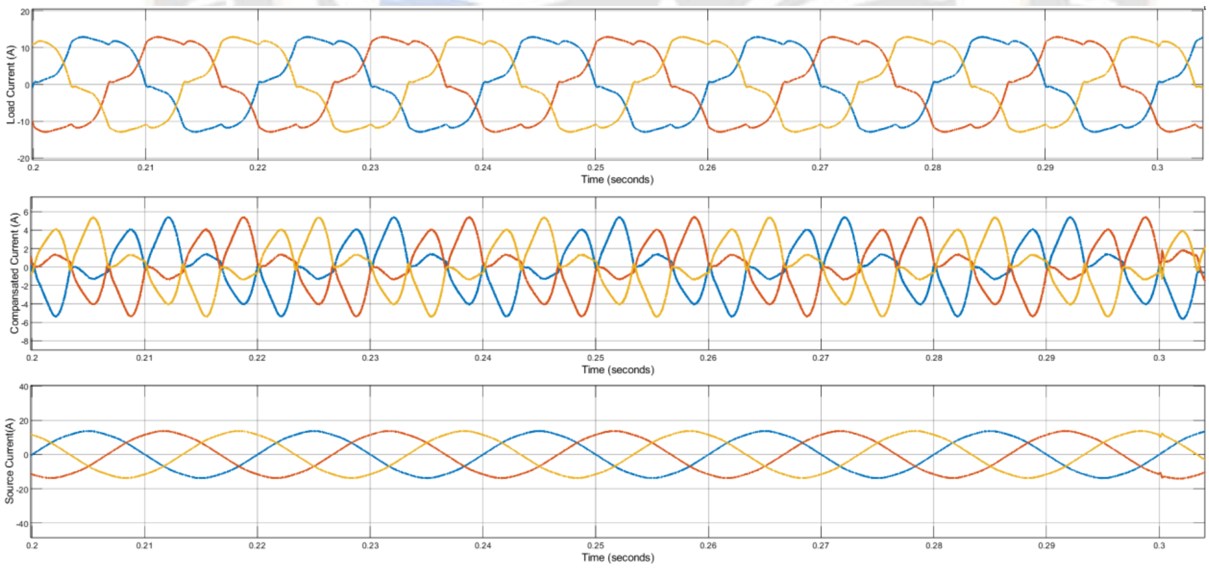


(b) G, P_{PV}, UPQC DC Link voltage



(c) Grid voltage, Load Voltage, Series filter compensated Voltage



(d) Current at load, compensated current, Source current

Figure 20: Waveforms of the developed method for case-2

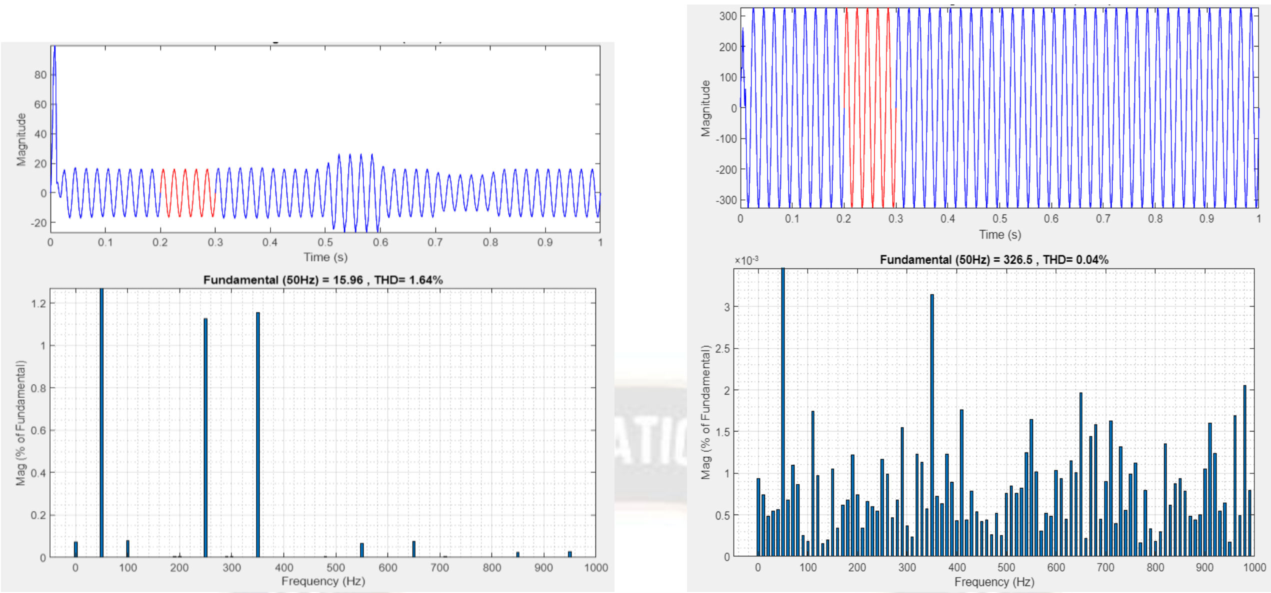
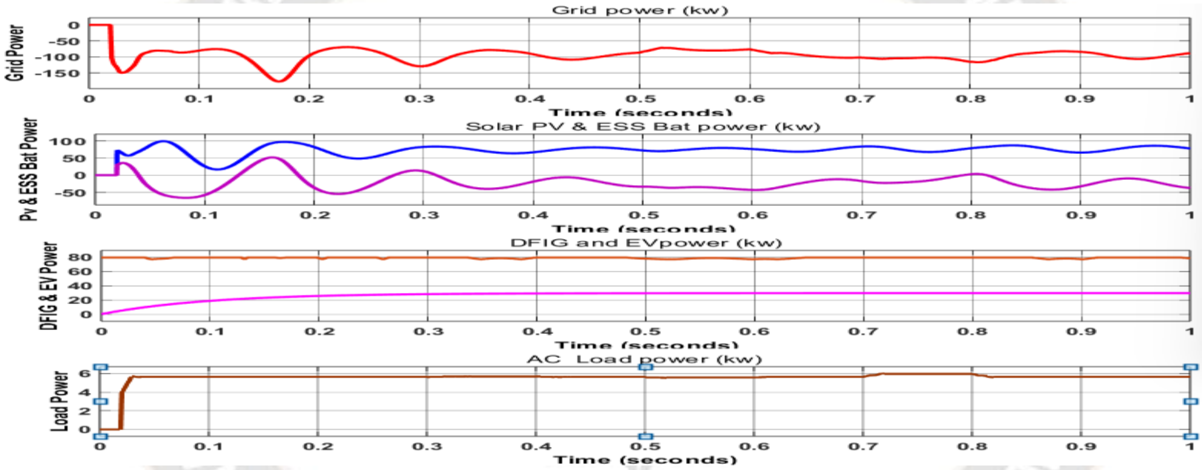
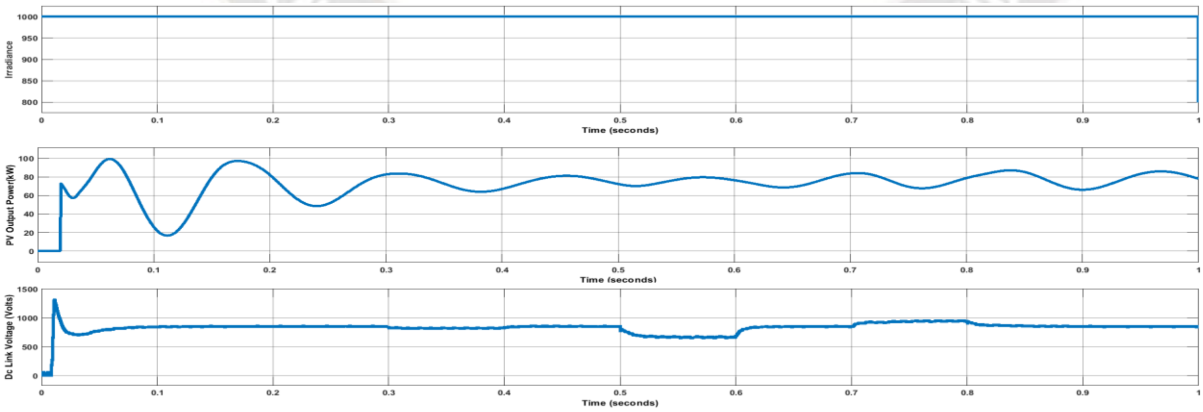


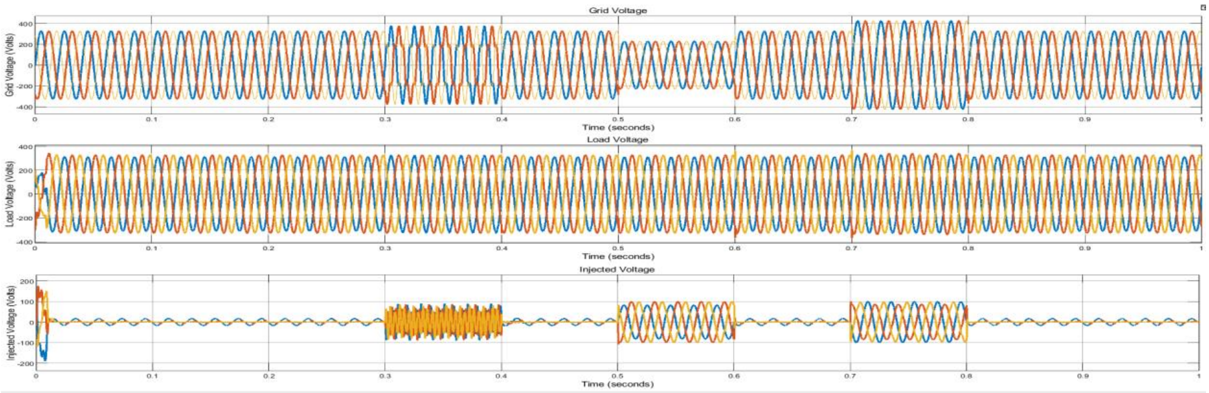
Figure 21: Source current and Load Voltage %THD spectrum for phase-a during 0.2 to 0.3Sec



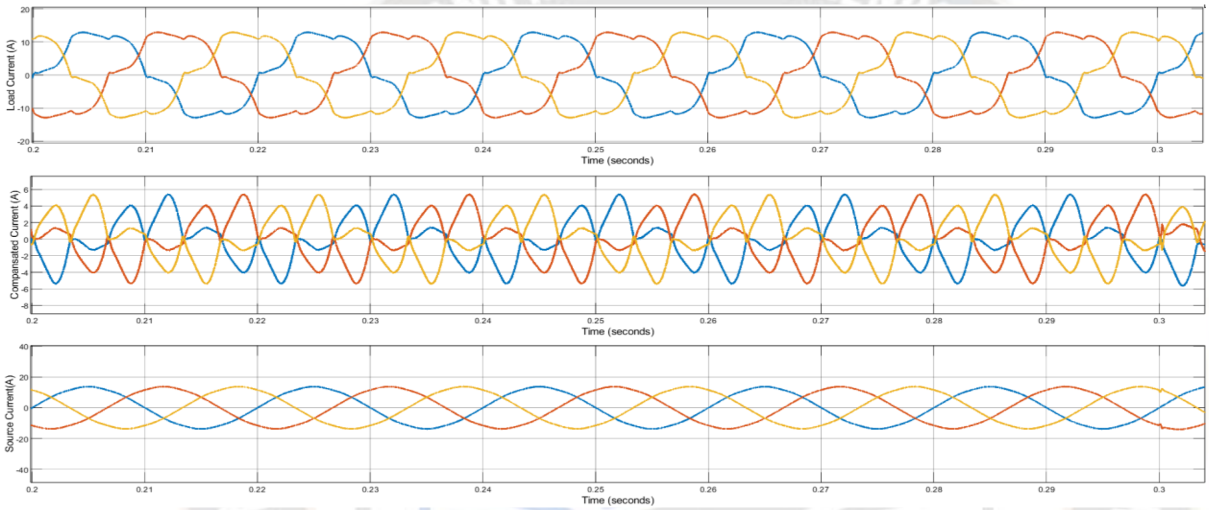
(a) Grid power, P_{PV}, P_{BESS}, P_w, P_{EV}, P_L



(b) G, P_{PV}, UPQC DC Link voltage



(C) Grid voltage, Load Voltage, Series filter compensated Voltage



(d) Current at load, compensated current, Source current

Figure 22: Designed system Waveforms for case-3

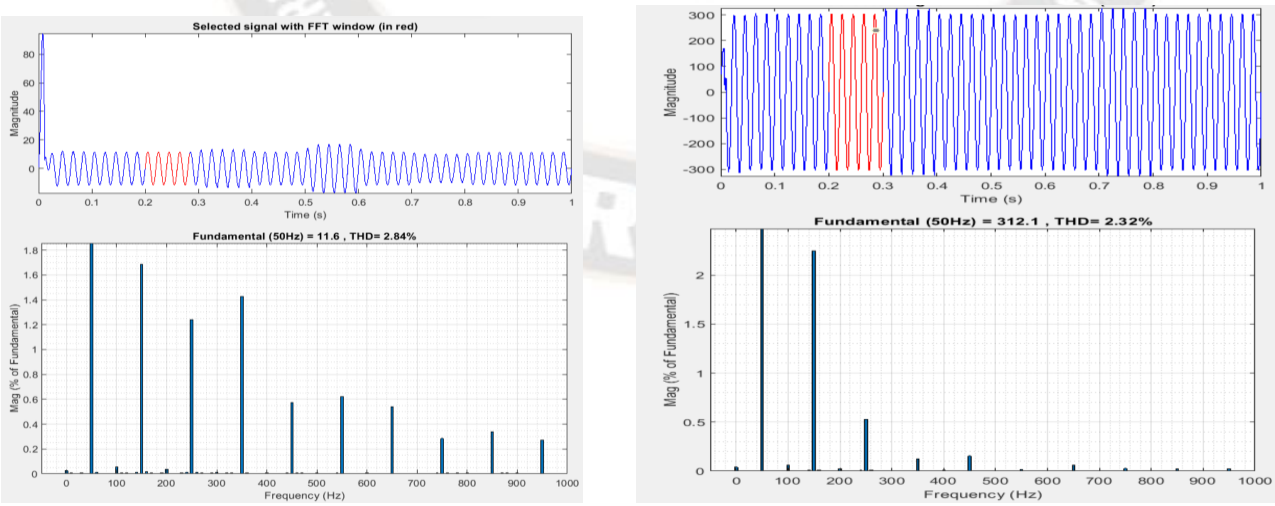


Figure 23: Source current and Load Voltage %THD spectrum for phase-a during 0.2 to 0.3Sec

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4. Conclusion

From this innovative approach introduced in this context is geared towards the intelligent SPV, WES, BESS, EVS. This Power management facilitated by a Fuzzy control based Electrical Vehicle with consideration of SOC characteristics of the battery with dynamic load conditions. More over the Fuzzy control base MPPT designed to extract maximum Power and control DC Boost converter duty cycle .This system effectively addresses concerns related by PQ by injecting voltage and current compensation to mitigate sag, swell , Distortion effectively with different loads such as nonlinear, combination of linear and nonlinear and combination of unbalanced linear and nonlinear loads. The UPQC plays a pivotal role in regulating DC link particularly under varying load conditions.

The proposed system not only ensures efficient power management but also enhance power quality by seamlessly integrating EV into the grid. The systems excels in mitigating voltage disturbances such as sags, swells and disturbances, while also rectifying imperfections in current waveforms. This approach also worked for Comprehensive measurements indicate the THD levels for both voltages and currents are below 5% using this developed approach. The findings of this research provide a solid foundation for future initiatives ,which may explore the implementation of metaheuristic algorithms to further enhance the capabilities of the EVA system.

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