Power Quality Diagnosis Due to Integration of Renewable Energy Source at Utility Grid

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Abstract. Article outlines hybrid energy sources for fulfil supply demand through proposed approach. The hybrid renewable energy sources generation capacity of 6 kW as solar power and 50 kW power as solid oxide fuel cell plant with storage system are interfaced to the DC bus in proposed paper for performance diagnosis on the basis of power demand as per utility load application by conversion of DC power to AC power and power quality of grid/load parameters collected on PCC, which affected by RE source integration at utility bus in terms of power quality parameters as per event ON/OFF grid mode. For this study design a two-bus test system, first bus is DC bus for integration of solar PV plant and solid oxide fuel cell power plant to generate hybrid DC power which convert to AC power by using inverter technology and deliver to the second bus of utility load bus in proposed test system for application of utility load as well as utility grid as per event proposed. A low pass LC filter is modeled to remove high frequency harmonics from the inverter output which is fed to grid as well as test system of utility network.

Keywords - Hybrid power system (HPS), Solar PV Plant (SPVP), THD, Solid oxide fuel cell power plant (SOFCPP), Integration of renewable energy sources (IRES), PCC.

1. Introduction

Owing to improvements in PV panel efficiency and the ongoing depletion of non-renewable energy sources, commercialising hybrid energy in large-scale installations will become more widespread. power outages, grid instability, power quality degradation, power reliability, etc. may all be readily resolved by integrating hybrid renewable energy source as SPP, SOFCPP and battery storage system (BSS) with the grid as reported in [1]. A DC-DC converter and a three-phase inverter are required for connecting HRES to the grid. Because SPVP and SOFCPP are expensive, it is best to utilise a dc-dc boost converter to increase the voltage rather than a lot more of HPS [2,3]. Using a second boost converter has the advantage of

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allowing for independent control of the PV panels' Maximum Power Point and the inverter's ability to regulate the current fed into the grid. Because to its inherent simplicity, the incremental conductance approach is utilised as the MPPT to extract the most power possible from the solar panels. A voltage source inverter is used to convert the boost converter's output's dc power to ac (VSI). Here, synchronous reference frame control, or d-q frame control, is employed with pulse width modulation (PWM) technology to control the amount of current injected to the grid. The output of the inverter should also be coordinated with the grid. Hence, the Phase Locked Loop (PLL) approach is used to match the grid frequency and phase. A transformer and an LC filter should both be used after an inverter to provide galvanic isolation and eliminate high frequency harmonics [4,5].

2. Proposed Test Architecture

Proposed test architecture (PTA) is used for the performance analysis of hybrid renewable energy sources (HRES) and load/grid parameters on the basis of power flow and evaluation of total harmonics distortions (THDs) which diagnosis of power quality of proposed HPS. The performance was recorded at point of common coupling (PCC) on utility load bus which is depicted in fig 1 in the presence of HRES penetration with and without utility grid. To diagnosis the power disturbance index ((PDI) of load/grid parameters by ON grid mode and OFF grid mode when switching the load is occur in the distribution network load system is detailed in this section.

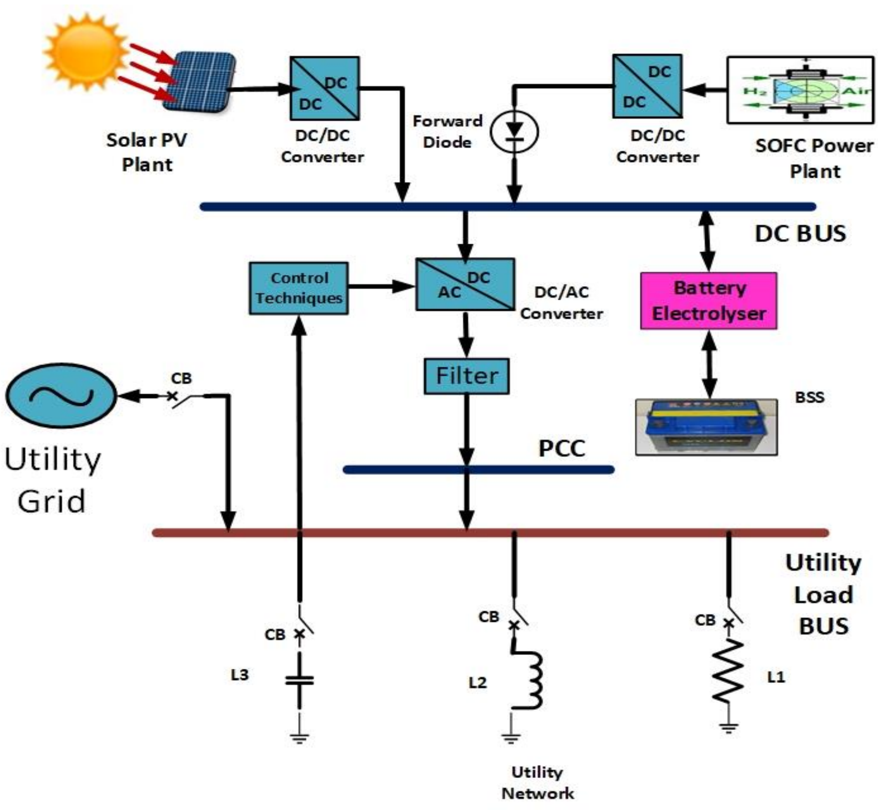


Fig.1. Proposed test architecture for study of research work

2.1 Proposed Test System

Proposed test system for the analysis the performance of HRES penetration at utility grid to drive a utility loads resistive, inductive, capacitive with penetration of energy storage system supported by BESS is illustrated in fig 1 as reported in [6]. The conventional infinite grid is connected to the utility load bus directly for deliver power to the load as per requirement of PTS. All events have changed the values of load as per case study proposed in test system of matlab simulink model. The simulation of SPVP with the SOFCPP for power generation is synchronize by help of boost converter to boost the voltage of the HRES, a VSI to convert dc to ac, and lastly the grid. The Perturbe & observation algorithm is utilized to operate the HRES at its maximum power, and the system also functions in a variety of changing environmental circumstances. Reference frame control is used to adjust inverter output in relation to the grid. Three phase PLL is used to lock grid frequency & phase with respect to inverter output. A low pass LC filter is modeled to remove high frequency harmonics from the inverter output which is fed to grid as well as test system of utility network. All the simulations are carried out in Simulink.

2.1.1 Solar PV Plant

The solar power conversion system that will be used for the proposed study is made up of parts such a 6kW solar generator that is inter connected to the proposed test system on a dc bus using a converter technology. For solar PV generation up to 12 kW with gain, the technical specification is employed, whereas for power production up to 6 kW without gain in [7]. With the aid of the maximum power tracking point (MPTP), the solar photovoltaic generator produces a DC voltage of 672 V, which is then raised to 814 V DC using a chopper circuit. The DC bus receives the voltage produced by the dc to dc converter. Table 1, provides information about the technical attribute utilized in the test network.

Table 1. SPECIFICATION OF SOLAR PV PLANT

S. No.	Parameter of SPVP	Value
1	Current	7.605 A
2	Short circuit current	8.305 A
3	Capacity of power before gain	6 kW
4	Open circuit voltage	406 V
5	Voltage at point of maximum power	336 V
6	Insolation to current gain	0.008
7	Solar radiation	1000
8	Resistance for series branch	0.605 Ω
9	Parallel resistance	545.5 Ω

2.1.2 Solid Oxide Fuel Cell Power Plant

A SOFCPP uses hydrogen and water to transform chemical energy into electrical power. H2 and O2 react in the SOFCPP generator to produce the electrical power. According to [8–10], the authors describe how a solid oxide fuel cell (SOFC) power conversion system connects to PTS on a dc bus using forward diodes to convert dc to dc and generates power up to 50 kW. The suggested study made use of the solid oxide fuel cell plant's technical specifications, which are displayed in Table 2.

Table 2. SPECIFICATIONS OF SOFCPP

S. No.	**Parameter of SOFCPP**	**Value**
1	Absolute temperature in kelv.	1273 (K)
2	Initial current	100 (A)
3	Faraday's constant	$96.487e^{-6}$ (C/K Mol)
4	Ideal standard potential	1.2 (V)
5	Number of cells in series	450
6	Ohmic loss per cell	$3.2813e^{-0.04}$ (Ω)
7	Electrical response time	0.8 (s)
8	Fuel processor response time	5 (s)
9	Ratio of hydrogen to oxygen	1.15

2.1.3 Converter Topology

Hybrid renewable energy sources produce a voltage in the form of direct current (DC). But, alternating current AC voltage are required to feed the supply to the second network load bus as well as utility grid. The machinery used to convert DC to AC is known as an inverter [11]. The VSC maintains the power at desired output from solar plant while converting the 230 V AC as grid synchronize from output of boost converter voltage 814 V DC. The synchronous reference frame theory is used for getting signal to control of inverter by PWM techniques.

2.1.4 BESS

The BESS is a critical component of a hybrid RE power system because it provides continuous energy to the utility load while also storing energy when surplus power supplied by RE sources is not consumed by the load as [12,13]. Storage device with DC link is combined with battery electrolyzer and interfaced on prosed work's dc bus. Table 3 shows the ESD parameters for the planned work.

Table 3. SPECIFICATIONS OF BESS

S. No.	**Parameter of BESS**	**Value**
1	Nominal rated voltage	295.5 V
2	Nominal rated value	7 Ah
3	Initial state of charge	85 %
4	Response time of BESS	20 s
5	Types of BESS	NMH

2.1.5 Utility Grid

The infinite bus system is used as grid at AC bus in proposed test system for deliver the power whenever required to load as well as it will take the power from HPS when utility load is not required the power, it will support to grid and share the power when utility grid is required. The level of voltages 177 - 230 V, 60 HZ source is used for this proposed study.

2.1.6 Utility Load Bus

Load L1 is pure resistive value of 20 kW, value of load L2 10 kVAr is inductive and the value of load L3 10 kVAr is capacitive it very as per event condition of study for the analysis of performance evaluation are connected to AC bus of PTS. For implementation of proposed work by switching event as described in simulation study to measure the performance of proposed hybrid renewable energy source with ON grid mode and OFF grid mode with the help of circuit breaker.

3. Power Optimization Technique

In this section of paper, Optimize the RE sources power which contribution as hybrid power to the utility load of network by using converter technology in presence of ONGM as well as OFGM at different test condition are achieved by following procedure.

3.1 HRES Voltage Evaluation

The expression (1) aids in determining the magnitude of the root mean square RMS) of the hybrid generation of voltage represented by the proposed hybrid RE-source and then evaluating the performance of the generated hybrid voltage/load voltage using the MAT-LAB tool in terms of total harmonics distortion presence in the voltage signal via fast fourier transform (FFT).

$$V_{Lrms} = \frac{\mathrm{V}_{max}}{\sqrt{2}} \qquad (1)$$

Where, V_{max} is the maximum value of HRES system voltage.

3.2 HRES Current Evaluation

The Expression (2) analyzed the performance of the hybrid current signal in RMS mode generated by the proposed hybrid RE-source system, and then evaluate the performance of the generated hybrid current/load current using the MAT-LAB tool in terms of total harmonics distortion presence in the current signal via FFT.

$$I_{Lrms} = \frac{\mathrm{I}_{max}}{\sqrt{2}} \qquad (2)$$

Where, I_{max} is the maximum value of HRES system current, it is gated from connected HRE sources as well as PTS.

3.3 HRES Power Evaluation

The expression (3) is used to determine the hybrid power value which is generated by proposed system and then calculate the performance of generated hybrid power/consumed power by load by using the MAT-LAB tool via FFT.

$$P = \sqrt{3}\, V_L\, I_L \qquad (3)$$

Where, P is the hybrid RE source power obtained by renewable sources which is measured and verified by MATLAB simulink model proposed in study, V_L is RMS voltage of PTS & I_L is RMS magnitude of current of PTS.

4. Graphical Results Presentation

The graphical result of proposed test simulink model with their discussion on the basis of different case study of load switching conditions as switching impact resistive load (SIRL), switching impact of inductive load (SIIL) and switching impact of capacitive load (SICL) in proposed test model (PTM) for the performance analysis of HRES in ON grid mode (ONGM) as well as OFF grid mode (OFGM) with battery storage system (BSS). The case study events include switching ON/OFF of different resistive load, inductive load and capacitive load as per PTS for the study of power contribution for proposed network load and impact of switching event (ISE) on utility load voltage and current profile which help to diagnosis of power quality in terms of total harmonics distortions (THDs) are presents in this section.

4.1 Case1: SIRL in OFGM

This study provides the switching impact of resistive load (SIRL) by impose the value of 20 kW resistive load L1 for the duration 2.5s from 0.5s to 3s simulation time with the help of circuit breaker (CB) operation in OFF grid mode OFGM) on MATLAB platform through proposed test model (PTM). The performance diagnosis of HRES with OFGM on the basis of power flow contribution towards the demand of utility load, impact of switching event (ISE) on grid voltage and load current profile for the diagnosis of power quality in terms of THDs profile are also presents in this subsection.

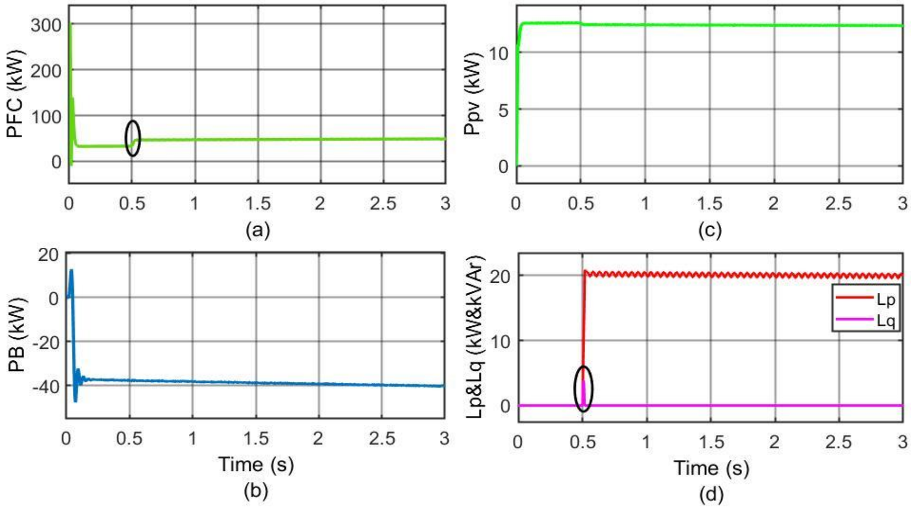
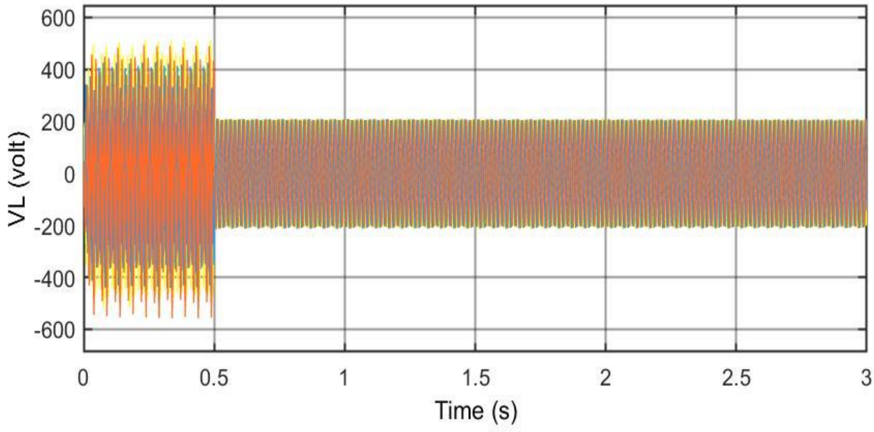
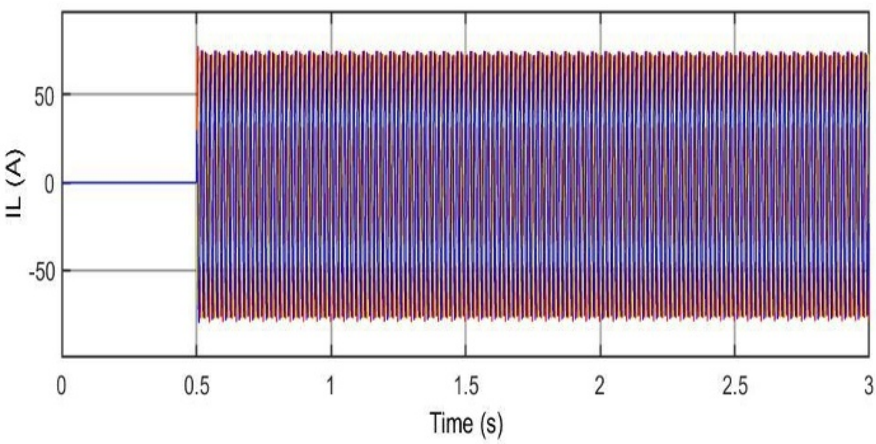


Fig.2. Profile of powers in OFGM (a) SOFCPP power (b) BSS Power (c) SPP power (d) Load power

Power generated by HRES and consume by load as per event condition of the proposed test model are depicted in fig 2. The observation from graphical result of simulation of fig. 2 (a) show the performance of power generated by SOFCPP at STC but impact of switching event (ISE) is also observed at the time of switching the load in PTS. The fig 2 (b) provide the BSS power contribution toward the load demand in PTS. Contribution of power generation of SPP is shown in fig 2 (c). The power consume by resistive load is observed by red line from 0.5s to 3s of simulation time because load L1 is active with the help of CB but there is no reactive power consume by load only small disturbance was observed at the time of load L1 switching in PTS as fig 2 (d), because only resistive load is imposed. It is showing the effectiveness of proposed work.



(a)

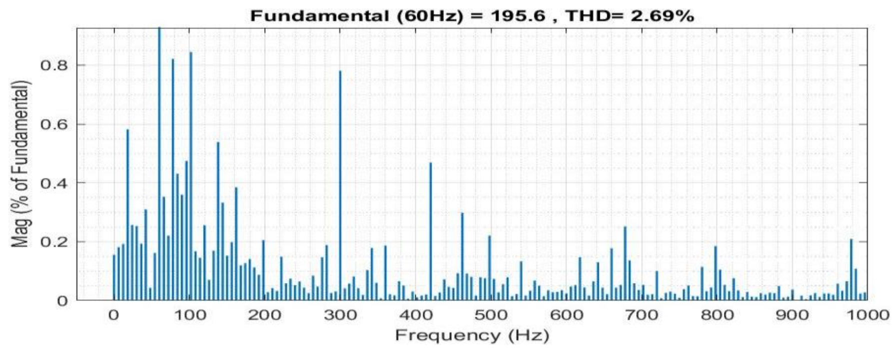


(b)

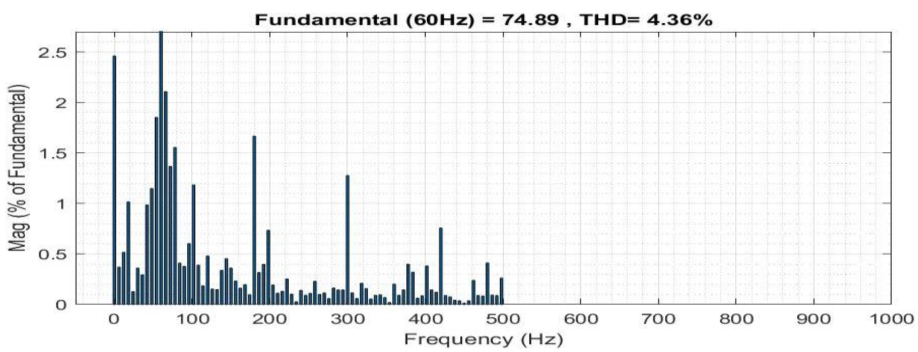
Fig.3. Utility load parameter performance in OFGM (a) Voltage signal profile (b) Current signal profile

The performance of utility load parameters voltage and current profile was recorded on PCC in PTM is depicted in fig 3 (a) & (b) when switching the resistive load (L1) 20 kW with the help of circuit breaker without on grid mode. It is showing the effectiveness of proposed test system.

Power quality performance was recorded in terms of THDs profile for 10 cycle of simulation time with the help of FFT tool, its presence in matlab simulink model by capturing of utility voltage and current profiles when switching ON the load (L1) with the help of circuit breaker in PTS which help to diagnosis the power quality index (PQI) is depicted in fig 4 (a) and (b).



(a)



(b)

Fig.4. Utility load parameters' THD performance (a) Voltage signal profile (b) Current signal profile

4.2 Case2: SIRL in ONGM

This study provides the switching impact of resistive load (SIRL) by impose the value of 20 kW resistive load L1 for the duration 2.5s from 0.5s to 3s simulation time with the help of circuit breaker operation in ON grid mode ONGM) on MATLAB platform through proposed test model (PTM).

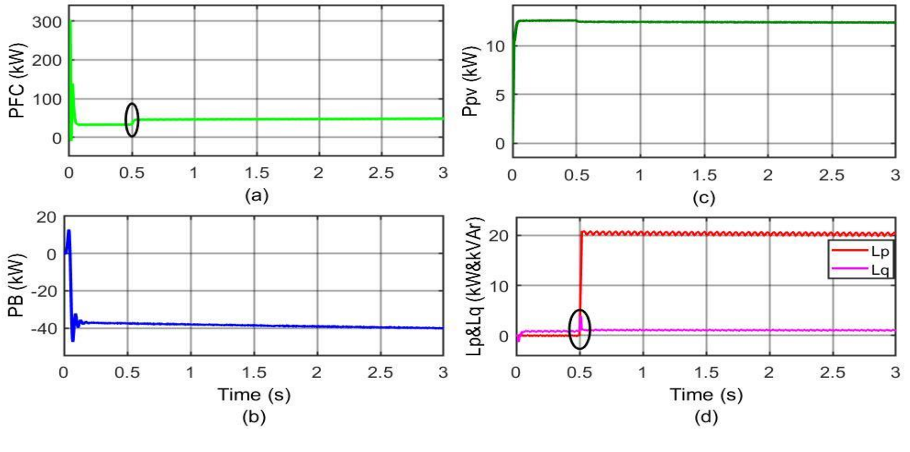
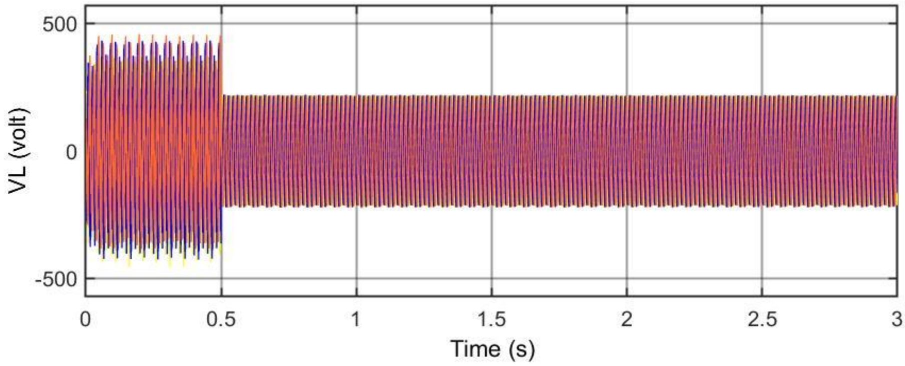


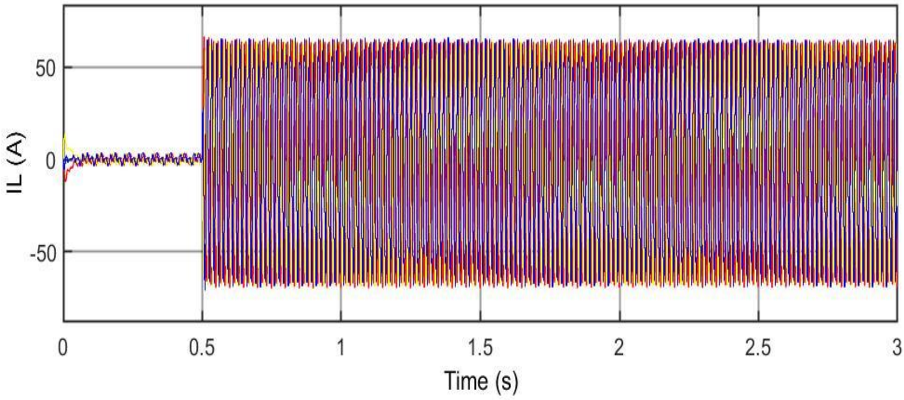
Fig.5. Profile of powers in ONGM (a) SOFCPP power (b) BSS Power (c) SPP power (d) Load power

The performance diagnosis of HRES with ONGM on the basis of power flow contribution towards the demand of utility load, impact of switching event (ISE) on grid voltage and load current profile for the diagnosis of power quality in terms of THDs profile are also presents in this subsection.

The power generated by HRES and consume by load as per event condition of the proposed test model are depicted in fig 5. The observation from graphical result of simulation of fig 5 (a) show the performance of power generated by SOFCPP at STC but impact of switching event (ISE) is also observed at the time of switching the load in PTS. The fig 5 (b) provide the BSS power contribution toward the load demand in PTS. Contribution of power generation of SPP is shown in fig 5 (c). There is no active reactive power consume by load but some disturbance was observed at the time of switching load L1 in PTS as fig 5 (d), because only resistive load is imposed.



(a)

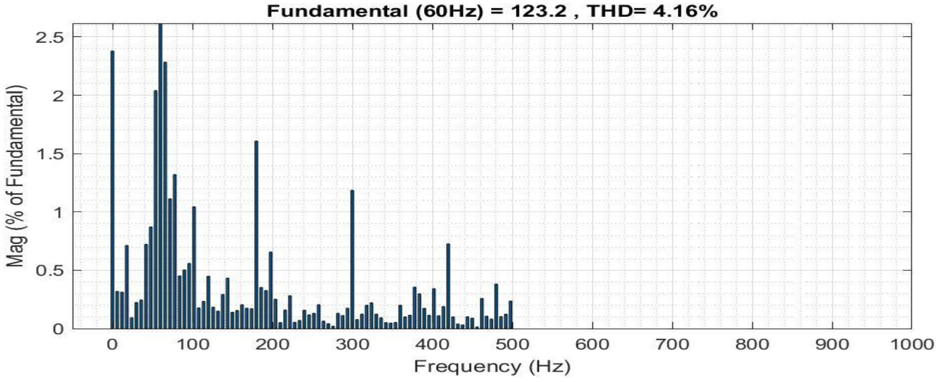


(b)

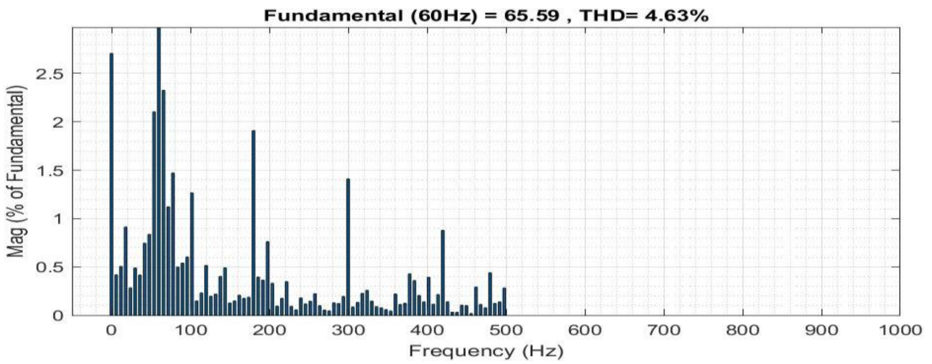
Fig.6. Utility load parameter performance in OFGM (a) Voltage signal profile (b) Current signal profile

The performance of utility load parameters voltage and current profile was recorded on PCC in PTM when switching ON the load L1 for the duration of 2.5s from 0.5s of simulation time in ONGM is depicted in fig 6 (a) & (b) for the diagnosis of power quality and switching impact of resistive load 20 kW with the help of circuit breaker in PTS. It is showing the effectiveness of proposed study work.

The power quality performance was recorded in terms of THDs profile for 10 cycle of simulation time with the help of FFT tool, its presence in matlab simulink model by capturing of utility voltage and current profiles when switching ON the load (L1) with the help of circuit breaker in PTM which help to diagnosis the percentage of power quality index (PQI) is depicted in fig 7 (a) and (b). It is observed that THDs presence in utility load parameters is increased from 2.69% to 4.16% and 4.36% to 4.63% as ONGM, HRES integration with grid leads to disturbance in power quality. It is showing the effectiveness of proposed study work.



(a)



(b)

Fig.7. Utility load parameters' THD performance (a) Voltage signal profile (b) Current signal profile

4.3 Case3: SIIL in OFGM

This study provides the switching impact of inductive load (SIIL) by impose load L2 value of 10 kVAr (+ve) with 20 kW resistive load L1 for the duration 2.5s from 0.5s to 3s simulation time with the help of circuit breaker operation in OFGM on MATLAB platform through PTM. The performance diagnosis of HRES with OFGM on the basis of power flow contribution towards the demand of utility load, impact of switching event (ISE) on utility voltage and load current profiles for the diagnosis of power quality in terms of THDs profile are also presents in this subsection.

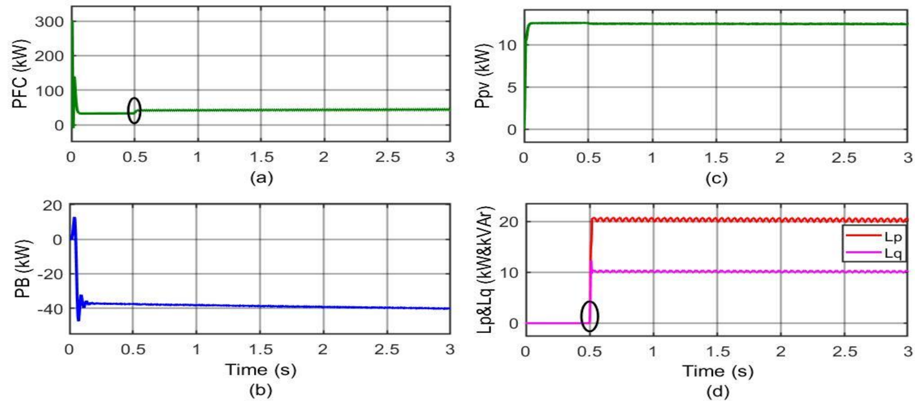
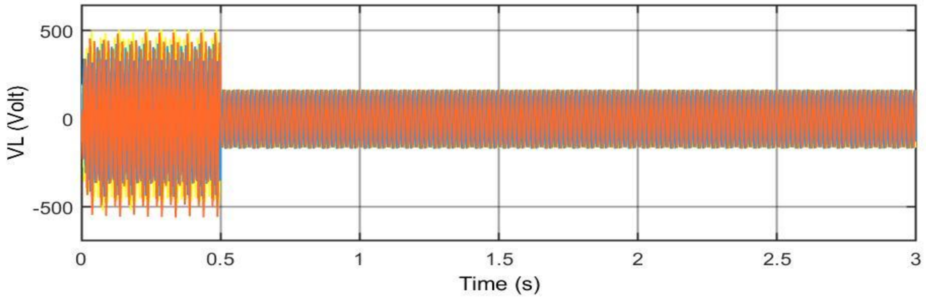
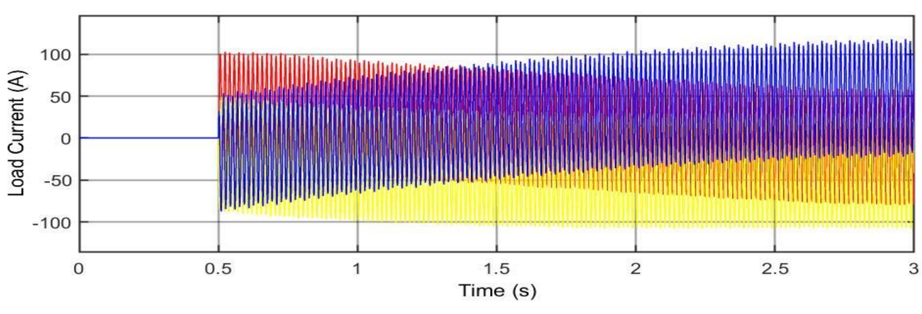


Fig.8. Profile of powers in OFGM (a) SOFCPP power (b) BSS Power (c) SPP power (d) Load power

Power generated by HRES and consume by load as per event condition of the proposed test model are depicted in fig 8. The observation from graphical result of simulation of fig. 8 (a) show the performance of power generated by SOFCPP at STC but impact of switching event (ISE) is also observed at the time of switching the load in PTS. The fig 8 (b) provide the BSS power contribution toward the load demand as well as store in PTS. Contribution of power generation of SPP is shown in fig 8 (c). The power consume by inductive load is observed by red and pink line from 0.5s to 3s of simulation time because load L1 & L2 is active with the help of CB was observed at the time switching in PTS as fig 8 (d). It is showing the effectiveness of proposed work.



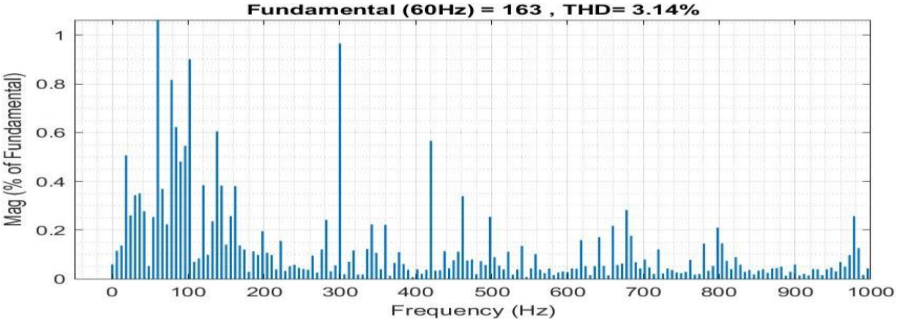
(a)



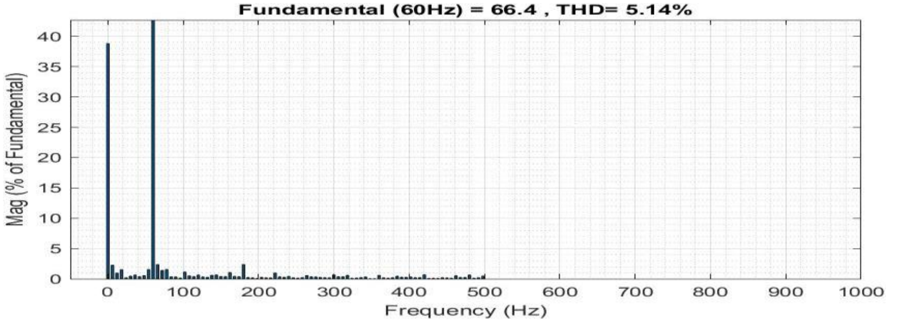
(b)

Fig.9. Utility load parameter performance in OFGM (a) Voltage signal profile (b) Current signal profile

The performance of utility load parameters voltage and current profiles was recorded on PCC in PTM is depicted in fig 9 (a) & (b) when switching the inductive load (L1 & L2) 20 kW & 10 kVAr (+ve) with the help of circuit breaker (CB) in OFGM. It is showing the effectiveness of proposed test system.



(a)



(b)

Fig.10. Utility load parameters' THD performance (a) Voltage signal profile (b) Current signal profile

The power quality performance was recorded in terms of THDs profile for 10 cycle of simulation time with the help of FFT tool, its presence in matlab simulink model by capturing of utility voltage and current profiles when switching ON the loads (L1 & L2) with the help of CB in PTM which help to diagnosis the percentage of power quality index (PQI) and is depicted in fig 10 (a) and (b). It is observed that THDs presence in utility load parameters as value 3.14% and 5.14% respectively in OFGM. It is showing the effectiveness of proposed study work.

4.4 Case 4: SIIL in ONGM

This study provides the switching impact of inductive load (SIIL) by impose load L2 value of 10 kVAr (+ve) with 20 kW resistive load L1 for the duration 2.5s from 0.5s to 3s simulation time with the help of circuit breaker operation in ONGM on MATLAB platform through PTM. The performance diagnosis of HRES with ONGM on the basis of power flow contribution towards the demand of utility load, impact of switching event (ISE) on utility voltage and load current profiles for the diagnosis of power quality in terms of THDs profile are also presents in this subsection.

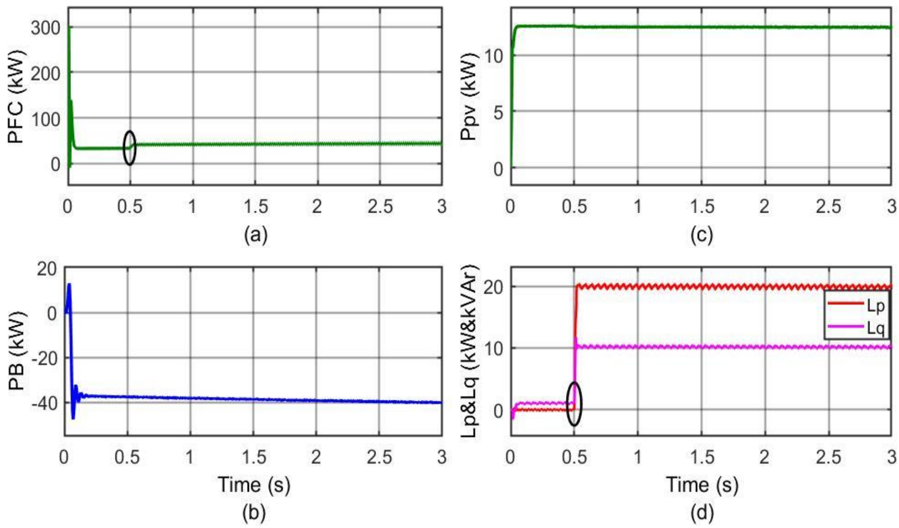
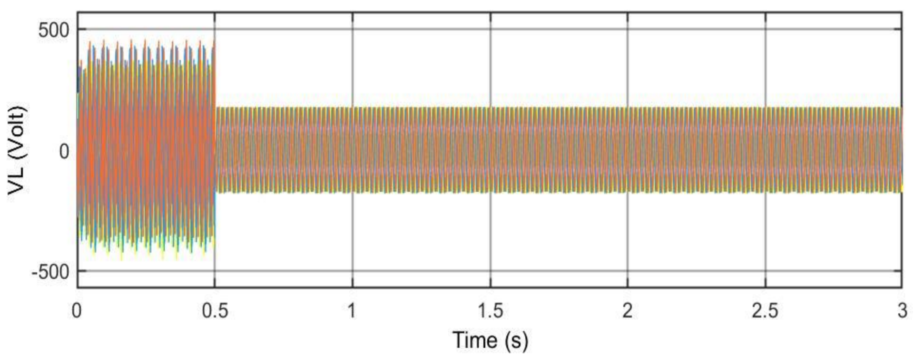
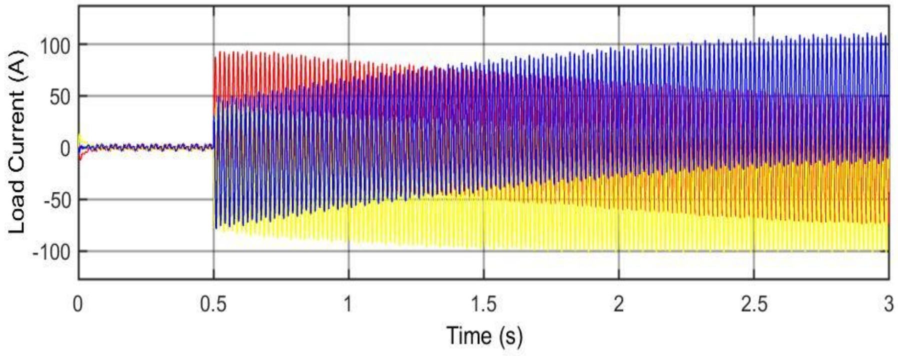


Fig.11. Profile of powers in ONGM (a) SOFCPP power (b) BSS Power (c) SPP power (d) Load power

The Power generated by HRES and consume by load as per event condition of the proposed test model are depicted in fig 11. The observation from graphical result of simulation of fig. 11 (a) show the performance of power generated by SOFCPP at STC but impact of switching event is also observed at the time of switching the load in PTS. The fig 11 (b) provide the BSS power contribution toward the load demand as well as store power in PTS. Contribution of power generation of SPP is shown in fig 11 (c). The power consume by inductive load is observed by red and pink line from 0.5s to 3s of simulation time because load L1 & L2 is active with the help of CB at the time of switching in PTS as fig 11 (d), but some reactive power is observed before switching the load because its presence in circuit model. It is showing the effectiveness of proposed work.



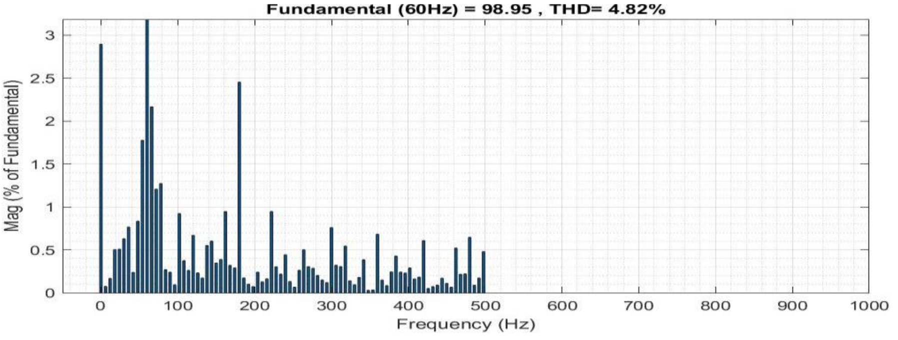
(a)



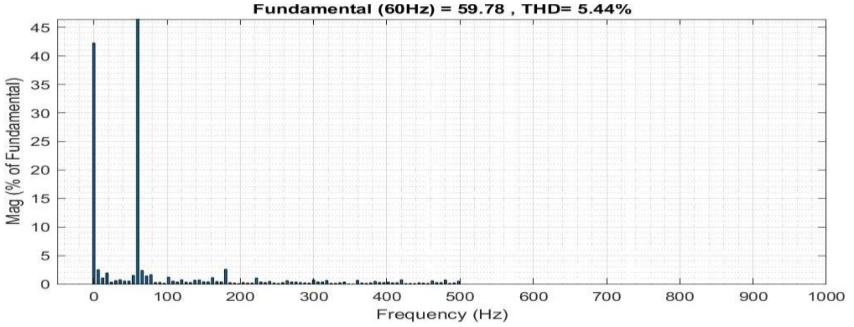
(b)

Fig.12. Utility load parameter performance in OFGM (a) Voltage signal profile (b) Current signal profile

The performance of utility load parameters voltage and current profiles was recorded on PCC in PTM is depicted in fig 12 (a) & (b) when switching ON the inductive load (L1 & L2) 20 kW & 10 kVAr (+ve) for the duration of 2.5s from 0.5s to 3s of simulation time with the help of circuit breaker (CB) in ONGM. It is showing the effectiveness of proposed study.



(a)



(b)

Fig.13. Utility load parameters' THD performance (a) Voltage signal profile (b) Current signal profile

The power quality performance was recorded in terms of THDs profile for 10 cycle of simulation time with the help of FFT tool, its presence in matlab simulink model by capturing of utility voltage and current profiles when switching ON the loads (L1 & L2) with the help of CB in PTM which help to diagnosis the percentage of power quality index (PQI) and is depicted in fig 13 (a) and (b). It is observed that THDs presence in utility load parameters are increased from 3.14% to 4.82% and 5.14% to 5.44% respectively in ONGM, it shows HRES integration with utility leads to disturbance in power quality. It is showing the effectiveness of proposed study work.

4.5 Case 5: SICL in OFGM

This study provides the switching impact of capacitive load (SICL) by impose load L3 value of 10 kVAr (-ve) with 20 kW resistive load L1 for the duration 2.5s from 0.5s to 3s simulation time with the help of circuit breaker operation in OFGM on MATLAB platform through PTM. The performance diagnosis of HRES with OFGM on the basis of power flow contribution towards the demand of utility load, impact of switching event (ISE) on utility voltage and load current profiles for the diagnosis of power quality in terms of THDs profile are also presents in this subsection.

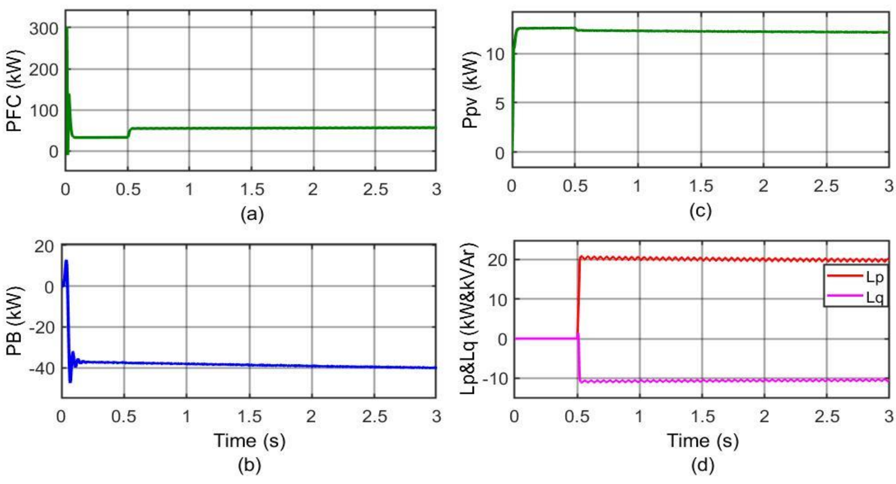
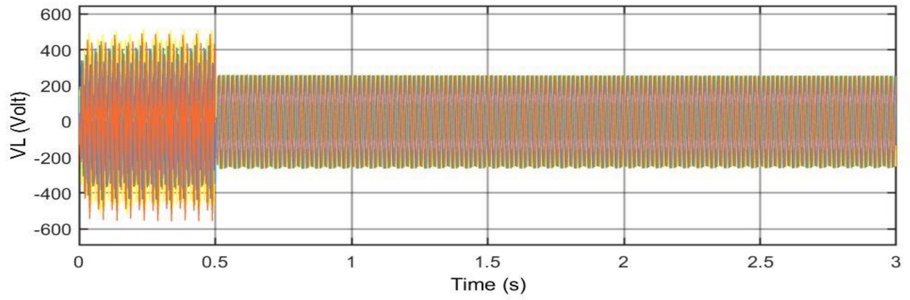


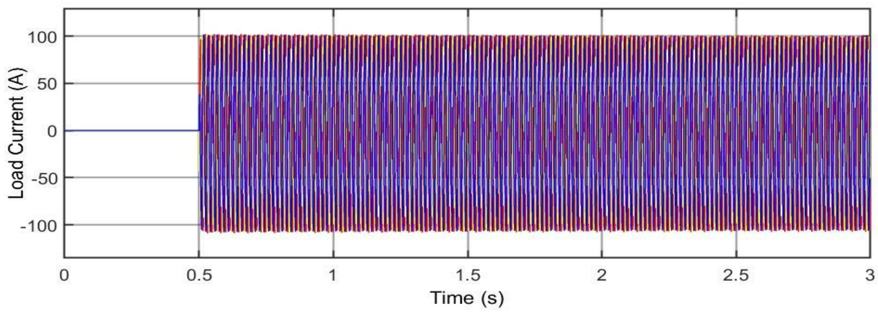
Fig.14. Profile of powers in OFGM (a) SOFCPP power (b) BSS Power (c) SPP power (d) Load power

The power generated by HRES and consume by load as per event condition of the proposed test model are depicted in fig 14. The observation from graphical result of simulation of fig. 14 (a) show the performance of power generated by SOFCPP at STC but impact of switching event (ISE) is also observed at the time of switching the load in PTS. The fig 14 (b) provide the BSS power contribution toward the load demand as well as store in PTS. Contribution of power generation of SPP is shown in fig 14 (c). The power consume by capacitive load is observed by red and pink line from 0.5s to 3s of simulation time because load L1 & L3 is active with the help of CB was observed at the time switching in PTS as fig 14 (d). It is showing the effectiveness of proposed work.

The performance of utility load parameters voltage and current profiles was recorded on PCC in PTM is depicted in fig 15 (a) & (b) when switching the capacitive load (L1 & L3) 20 kW & 10 kVAr (-ve) with the help of circuit breaker (CB) in OFGM. It is showing the effectiveness of proposed test system.



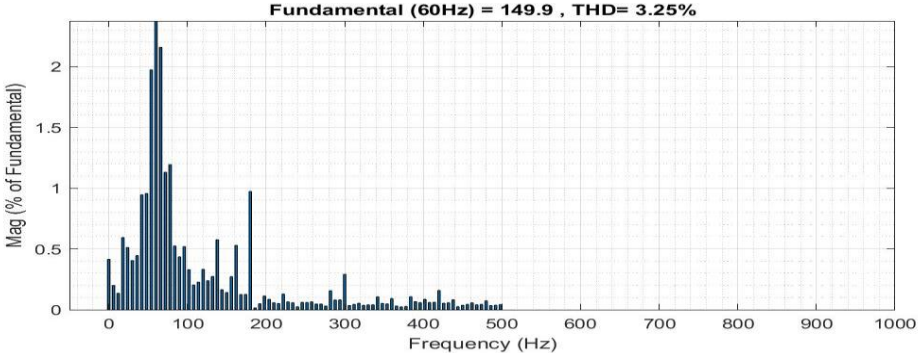
(a)



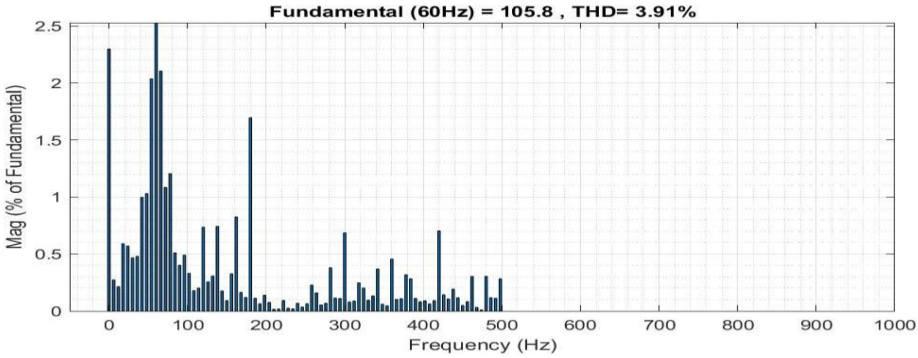
(b)

Fig.15. Utility load parameter performance in OFGM (a) Voltage signal profile (b) Current signal profile

The power quality performance was recorded in terms of THDs profile for 10 cycle of simulation time with the help of FFT tool, its presence in matlab simulink model by capturing of utility voltage and current profiles when switching ON the loads (L1 & L3) with the help of CB in PTM which help to diagnosis the percentage of power quality index (PQI) is depicted in fig 16 (a) and (b). It is observed that THDs presence in utility load parameters as value 3.14% and 5.14% respectively in OFGM. It is showing the effectiveness of proposed study work.



(a)



(b)

Fig.16. Utility load parameters' THD performance (a) Voltage signal profile (b) Current signal profile

4.6 Case 6: SICL in ONGM

This study provides the switching impact of capacitive load (SICL) by impose load L3 value of 10 kVAr (-ve) with 20 kW resistive load L1 for the duration 2.5s from 0.5s to 3s simulation time with the help of circuit breaker operation in ONGM on MATLAB platform as proposed in PTM. The performance diagnosis of HRES with ONGM on the basis of power flow contribution towards the demand of utility load, impact of switching event (ISE) on utility voltage and load current profiles for the diagnosis of power quality in terms of THDs profile are also presents in this subsection.

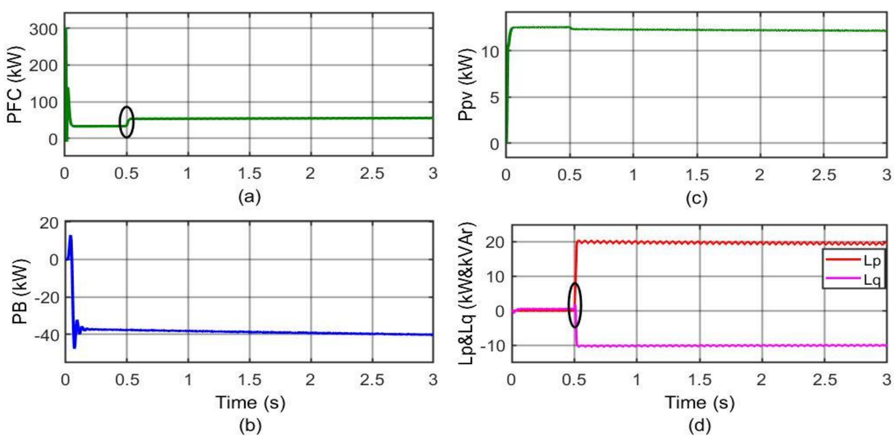
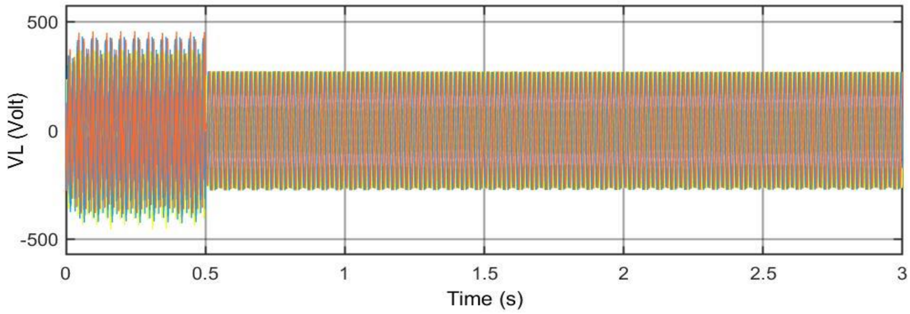
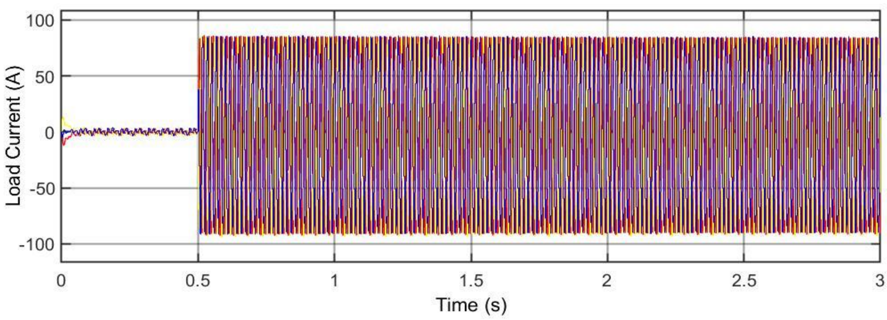


Fig.17. Profile of powers in ONGM (a) SOFCPP power (b) BSS Power (c) SPP power (d) Load power

The power generated by HRES and consume by load as per event condition of the proposed test model are depicted in fig 17. The observation from graphical result of simulation of fig. 17 (a) shows the performance of power generated by SOFCPP at STC but impact of switching event (ISE) is also observed at the time of switching the load in PTS. The fig 17 (b) provide the BSS power contribution toward the load demand as well as store in PTS. Contribution of power generation of SPP is shown in fig 17 (c). The power consume by capacitive load is observed by red and pink line from 0.5s to 3s of simulation time because load L1 & L3 is active with the help of CB was observed at the time of switching in PTS as fig 17 (d). It is showing the effectiveness of proposed work.



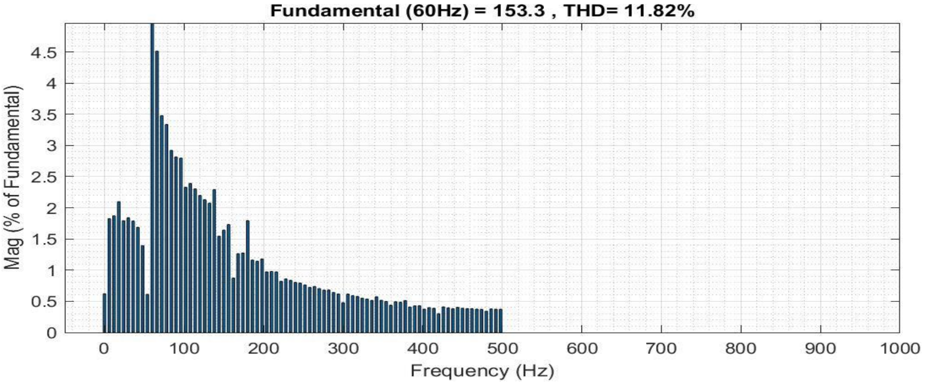
(a)



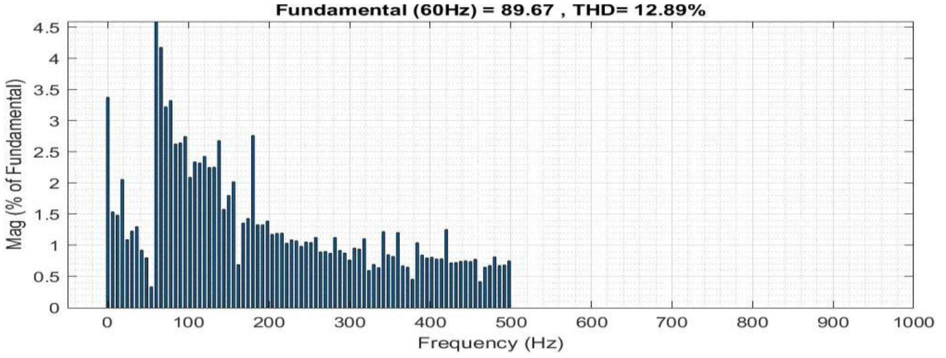
(b)

Fig.18. Utility load parameter performance in OFGM (a) Voltage signal profile (b) Current signal profile

The performance of utility load parameters voltage and current profiles was recorded on PCC in PTM is depicted in fig 18 (a) & (b) when switching ON the capacitive load (L1 & L3) 20 kW & 10 kVAr (-ve) for the duration of 2.5s from 0.5s to 3s of simulation time with the help of circuit breaker (CB) in ONGM. It is showing the effectiveness of proposed study.



(a)



(b)

Fig.19. Utility load parameters' THD performance (a) Voltage signal profile (b) Current signal profile

The power quality performance was recorded in terms of THDs profile for 10 cycle of simulation time with the help of FFT tool, its presence in matlab simulink model by capturing of utility voltage and current profiles when switching ON the loads (L1 & L3) with the help of CB in PTM which help to diagnosis the percentage of power quality index (PQI) is depicted in fig 19 (a) and (b). It is observed that THDs presence in utility load parameters are increased from 3.14% to 11.82% and 5.14% to 12.89% respectively in ONGM. It is showing the effectiveness of proposed study work.

5. COMPARATIVE DIAGNOSIS

MATLAB is used to assess the power quality of a hybrid SPV and FC power system with a battery storage system for a proposed utility network. The presence of total harmonic distortions in percentage is analyzed using simulink with OFGM and ONGM on voltage and current signals. Comparative power quality diagnosis index (PQDI) is evaluated using this expression (4) for validation of result as proposed existence vs alternative improvement.

$$PQDI = \frac{THDONGM - THDOFGM}{THDONGM} \times 100\% \qquad (4)$$

Where THDONGM is the THD when a grid is present and THDOFGM is the THD when a grid is absent. Only three events ON grid mode and OFF grid mode are depicted in the graphics due to page limits. However, this suggested strategy is put to use in numerous study instances, such as turning on and off domestic/industrial aspects with varying loads on the electricity grid. In Tables 4 and 5, the THD of utility load parameter signals is reported.

Table 4. THDs IN UTILITY VOLTAGE SIGNAL

Name of Events	THD (%)		PQDI (%)
	OFGM	ONGM	
Switching Resistive Load	2.69	4.16	35.33
Switching Inductive Load	3.14	4.82	34.85
Switching Capacitive Load	3.25	11.82	72.50

When the grid is interfaced with hybrid RE sources, THD created in the utility voltage waveform is increased. These operational tests include turning the circuit breaker on and off under event conditions. In all tests, the power quality diagnosis index (PQDI) values for THDs that are present in utility voltage signals as a result of IRES with grid are calculated to be greater than 35%, with the exception of capacitive loads, where they are calculated to be greater than 70%. It demonstrates how the utility grid's use along with IRES caused a decline in electricity quality.

Table 5. THDs in Utility Current Signal

Name of Events	THD (%)		PQDI (%)
	OFGM	ONGM	
Switching Resistive Load	4..36	4.63	5.83
Switching Inductive Load	5.14	5.44	5.51
Switching Capacitive Load	3.91	12.89	69.66

Additionally, operational experiments such as switching a circuit breaker on or off for an event situation and increasing THD produced in utility current waveforms by integrating hybrid RE sources into the grid are explored using table V's observations. The power quality diagnosis index (PQDI) values in terms of THDs which presence in utility current signal due to IRES with grid is evaluated to be greater than 5% in various test condition, exception in condition of capacitive load which is more than 69%. It shows the power quality deteriorated due to IRES with application of utility grid. It needs to improve the power quality by using appropriate method.

6. CONCLUSIONS

This research paper provide a performance on the basis of PQDI of HRES with and without grid application in terms of THDs presence in utility parameters voltage and current signal for improvement of the power quality with grid integration of hybrid renewable energy which is most consern to promote the green energy generation system as well as power contribution to the utility load which is demand by test condition those proposed in test system with the help of circuit breaker operation with and without grid mode. Also power quality diagnosis index is evaluated of the utility parameter with more than 35% and 5% respectively which shows the effectivenes of proposed research work in all physical test condition. This is the key point to improve power quality of grid connected HRE sources by reserchers in field of power system.

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