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RECONFIGURABLE INVERTER TOPOLOGY FOR A SOLAR POWERED HYBRID AC/DC HOME WITH FUZZY LOGIC CONTROLLER

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ABSTRACT
This project suggested a reconfigurable single phase inverter topology for a hybrid AC/DC solar powered home with FUZZY logic controller. This inverter possess a single phase single stage topology and the main advantage of this converter is that it can perform DC/DC, DC/AC and grid tie operation, thus reduces loss, cost, size of the converter. This hybrid AC/DC home has appliances of both AC and DC types. This type of system helps to reduce the power loss by avoiding unnecessary double stages of power conversion and improves the harmonic profile by isolating DC type loads to DC supply side and rest of AC side. Simulation is done in MATLAB/Simulink.

Key words: Fuzzy logic controller, Single phase single stage inverter, solar Photo Voltaic, Hybrid AC/DC Home, mitigation

I. INTRODUCTION
The current century has seen the uncommon advancement and development of sustainable power source around the world. There has been a considerable increment in the capacity and creation of every single inexhaustible innovation and furthermore development in supporting approaches. Between 2009-2013, solar PVs encountered the swiftest development rate to have included power capacity among all the renewables. Particularly, housetop solar PV areincreasing greater prevalence in conveyance system because of lessening in cost of solar board, Government strategies, for example, feed in levies to advance sustainable power source use, measured quality and less support and so forth. Be that as it may, irregular nature of the inexhaustible causes the noteworthy soundness and unwavering quality issues in the dissemination system. The rebuilding of the electric supply industry has incited the circumstance, where client is a basic business player. To relieve the vulnerability in solar PV age, stockpiling choices are presented, for example, battery system, Fuel cells and so on. Because of developing of nonlinear present day new advancements in

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houses, which expected to enhance efficiency and agreeableness, are fundamental wellspring of producing sounds current in appropriation feeder and that unfavorably influencing the power quality, power misfortunes alongside making a huge test for electrical designers. Current family unit loads have diverse qualities contrasted with loads show in prior stage. In any case, symphonious moderation and additionally its minimizations are enormous difficulties in appropriation system.

II. PROBLEM DESCRIPTION

Conventional grid connected inverter uses high dc link voltage, which will be the peak magnitude of the line-line grid voltage. For this particular purpose, two stage conversions are required to boost up the dc voltage and to invert it. However, this will increase the cost, size, and loss of the system. To improve the productivity and comfort ability, the modern household adds more and more nonlinear equipment, which are also main source of generating harmonics current in distribution feeder. This further adversely affects power quality, power losses and creating a significant challenge for electrical engineers. Modern household loads have different characteristics compared to loads present in earlier stage. However, harmonic mitigationand/or its minimizations are big challenges in distribution system.

III. OBJECTIVE OF THE PROJECT

The main objective of this project is to implement a single phase single-stage solar converter called reconfigurable solar converter (RSC) in the solar powered hybrid AC/DC residential building with energy storage devices.

The basic concept of the RSC is to use a single power conversion system to perform different operational modes such as solar PV to grid (Inverter operation, DC-AC), solar PV to battery/DC loads (DC-DC operation), battery to grid (DC-AC), battery/PV to grid (DC to AC) and Grid to battery (AC-DC) for solar PV systems with energy storage. This inverter is tested in a solar powered Hybrid AC/DC home which contains both AC and DC household loads. Individual appliances are selected according to the harmonic contributions they are injecting to the distribution grid from a typical modern house. Apart from the aforementioned, other additional contributions are as follow. The normal inductor only used for DC/DC operation. The variation in solar radiation is also considered and solar PV-Battery operation is verified. The circulation current is mitigated due to operation of the switches in the topology for DC/DC operation. The Fuzzy logic used in this project as a controller to reduce the total harmonic distortion and therefore the power quality will be improved.

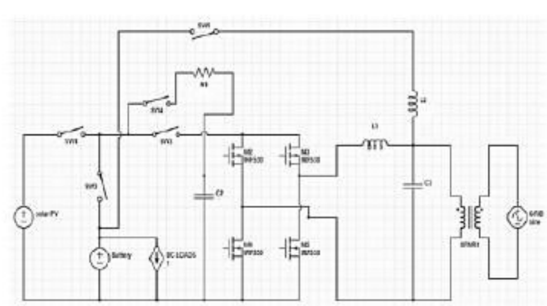

Fig.1Schematic of the proposed RSC circuit

IV. DESIGNING OF PV MODULE

A) Equivalent Circuit

Figure2 represents a single diode model which is widely used as compared to other PV module design. In this circuit, Rsh is

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shunt resistance, I is open circuit current of a solar cell, Io is diode saturation current, Iph is the light-generated current which depends upon solar radiation and cell temperature, Ish is shunt resistance current which flows through Rsh and flows between the n and p layers, Rse is series resistance which represents the losses due to flowing current across highly resistive emitter and contacts, Voc is terminal voltage of a solar cell, respectively.

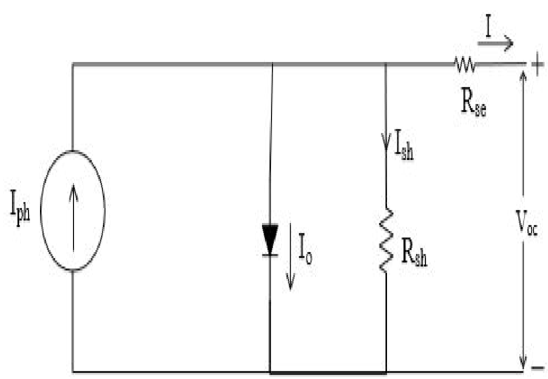

Fig. 2 Solar cell equivalent circuit

In this circuit the mathematical expression for cell current in single diode model is obtained by applying KCL,

I= Iph-Io-Ish (1) …….1

Where, Iph= [Isc+Ki (Tk-T)] *G/1000 …… 2

Iph is photocurrent under standard test conditions (STC), with reference solar radiation of 1000 W / m2 at solar spectrum of 1.5A and reference temperature of solar cell Tk of 25°C. T is instantaneous solar cell temperature, Ki is current temperature coefficient and G is an instantaneous solar radiation.

B) Module Reverse Saturation Current (I_{rs})

Module reverse saturation current, I_{rs}, is expressed as,

$I_{rs}= I_{sc}/ [exp (q*V_{oc}/Ns*k*A*T)-1]$ ………. 3

Where q is the electron charge (1.6 × 10í19 C), V_{oc} is Solar module open-circuit voltage (21.24V), Ns is the number of cells connected in series (6), A is the ideality factor (A=1.6). And k is the Boltzmann constant (k= 1.3805 × 10í23 J/K).

C) Module Saturation Current (I_0)

Variation of module saturation current I0takes place with respect to cell temperature. It is expressed as,

I_0=Irs [T/Tr] 3*exp $[q*E_{g0}/Ak*\{(1/T_r)-(1/T)\}]$ …..4

Where E_{g0} is the band gap energy of semiconductor (For polycrystalline Si at 25ħC, Eg0=1.1 eV). Simulation of equation (4) has been done and represented in Figure 4. Here, the inputs are module reverse saturation current, module operating temperature and reference temperature.

D) Module Output Current (IPV)

The PV module output current of single diode model is I_{PV} represented in Figure 5.1 is described by a basic equation and is expressed as,

$I_{pv}=N_p*I_{ph}-N_p*I_0$ [exp $\{q*(V_{pv}+I_{pv}*R_{se})*Ns*A*k*T1]$

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V. IV.TOPOLOGY OF RECONFIGURABLE SOLAR CONVERTER

The circuit diagram of reconfigurable solar inverter is given in the Fig. 3. Though it will reduce the no of power conversion stages but mechanical switches and cable requirement are more for this topology. The modes of operations of the proposed single phase single stage converter are given in Table 1. In addition, different operations modes are given in Figs. 3-6.

TABLE I MODES OF OPERATION

Modes of operation	ON switches	Off switches
PV-GRID	SW1 SW3 SW 4	SW2 SW 5
PV-BATTERY-GRID	SW1 SW2 SW3 SW4	SW5
PV- BATTERY	SW1 SW3 SW5	SW2 SW4
BATTERY-GRID	SW2 SW3	SW1 SW4 SW5

A) Mode-1

The mode of operation as shown in Fig.3 is directly connects PV to the Grid. MPPT controller is used to extract maximum power from the solar panel. Inverter controller is used to synchronize with grid and transfer active power to the grid.

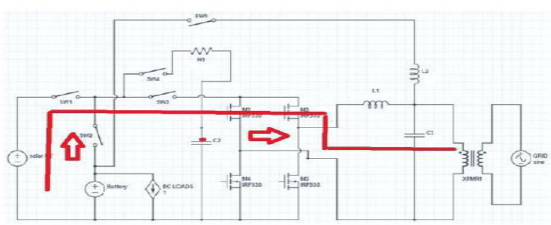

Fig 3PV to grid

B) Mode-2

In Fig. 4, the mode of operation is to supplying power to the grid from both solar PV and battery. This mode operates when there is a shortage of power from the solar PV due to external conditions, e.g., weather etc. One of the drawbacks of this connection is that the battery voltage and PV voltage should always be matching each other. Since battery voltage is stiff, MPPT controller cannot be used for this configuration.

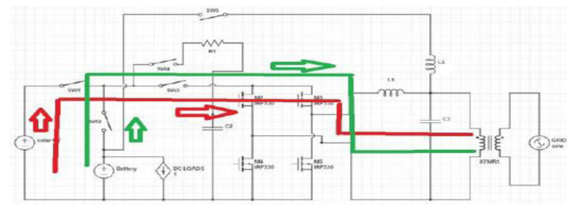

Fig 4.PV and Battery to grid

C) Mode-3

Figure.5 shows DC/DC operation of the proposed topology where battery is charged by a chopper action of the converter. The extra inductor is optional to reduce ripple in the charging current further. When there is an excess energy available, the battery is charged for the night time usage.

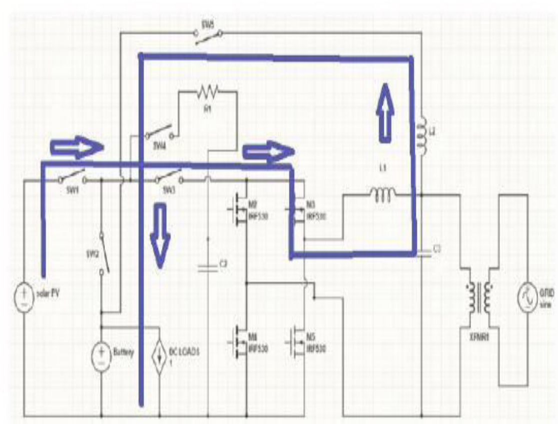

Fig.5 PV to Battery Charging

D) Mode-4

From Fig. 6, the energy stored in battery can be released to the appliances or grid during the night hours or when there is no solar radiation due to clouds or rainy conditions. Battery can supply stable power to the inverter. Thus, it can be very helpful in power quality improvement and ancillary services provision.

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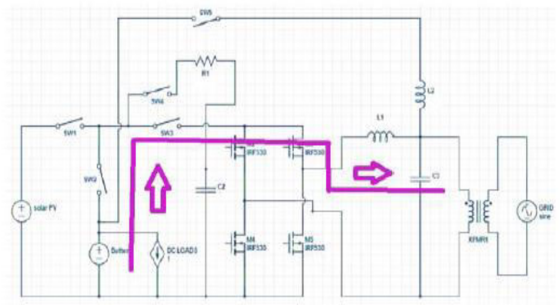

Fig 6.Battery to Grid

VI. PROPOSED FUZZY LOGIC CONTROLLER

The Fuzzy logic controller uses the fuzzy logics to make the decisions and to control the output of the controller. The main components in fuzzy logic based MPPT controller are fuzzification, rule-base, and inference and defuzzification as shown in figure 7.

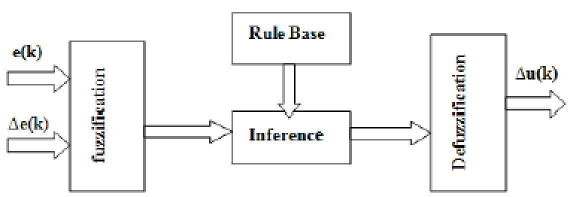

Fig 7. Fuzzy logic block diagram

Fuzzy logic is a dynamic control method. It is recognized by multivariable consideration and multi-rules-based resolution. Over the last decade Fuzzy MPPT is very much popular. Working with inaccurate inputs, the ability to handle non-linearity and not having a precise mathematical model are some of the advantages of fuzzy logic controllers. The Fuzzy MPPT flow chart is represented in Fig. and proposed Fuzzy MPPT Simulink model is represented in Fig. It consists of two inputs and one output. Error (E) and change of error (CE) are two FLC input variables. Duty cycle (D) is output variable. So fuzzy control algorithm have the ability to improve the tracking performance for both linear and nonlinear loads as compared with the classical methods. As fuzzy logic does not use complex mathematical equation therefore it is also appropriate for nonlinear control. Figure.10 represents the block diagram of fuzzy logic controller (FLC). The shape of membership functions of the rule base is one of the factor on which the behavior of a FLC depends.

Membership functions and rule base are designed with the help of Fuzzy Logic Tool Box in MATLAB. The membership function graphical view for error is represented by Fig.9 .Change of error is represented byFig.10 and fuzzy logic controller duty cycle is represented in Fig.11.

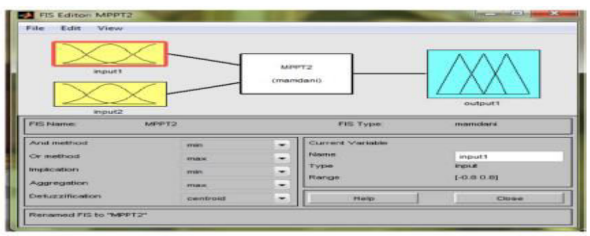

Fig. 8 Fuzzy logic Implementation in Simulation

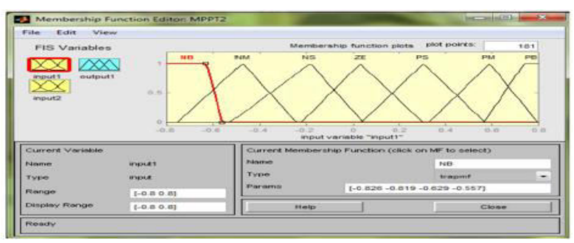

Fig.9 Fuzzy logic input Error (E)

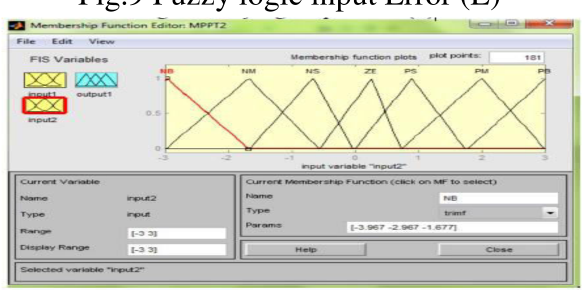

Fig.10 Fuzzy logic input change of Error (CE)

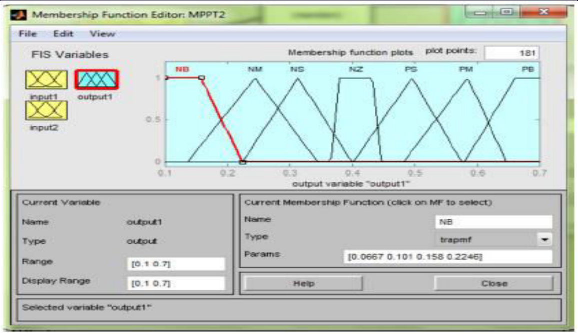

Fig.11 Fuzzy logic output (D)

Graphic view of the membership function for (a) error signal (b) change of error signal and (c) duty cycle. Different number of subsets has been used for rule settings of fuzzy logic MPPT. In this case, seven subsets based on forty- nine rules were used. The tuning of forty nine rules represents a better precision and dynamic response but it is time consuming.

VII. SIMULATION RESULTS

A) EXISITNG RESULTS

The simulation block diagram of reconfigurable solar converter is shown below fig 12. The simulation diagram contains PV, battery, inverter and grid .Fig 13 Simulink DC/DC chopper operation

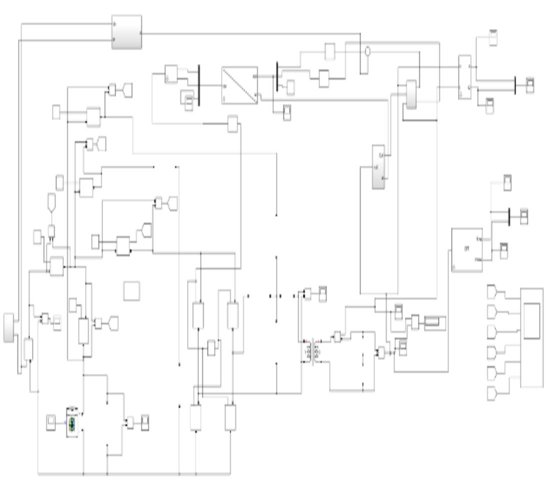

Fig.12 Simulation Block Diagram DC/AC inverter operation

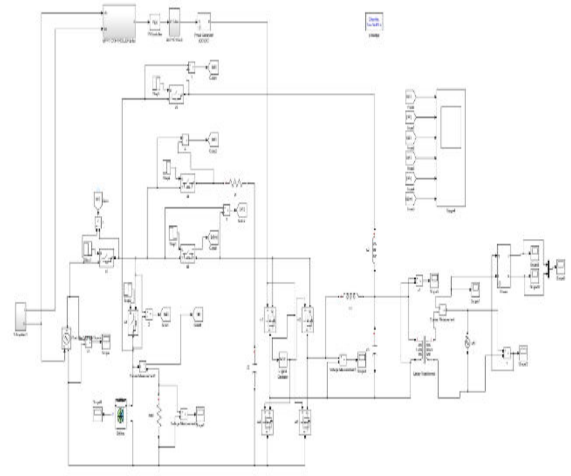

Fig.13 Simulink DC/DC chopper operation

The radiation is kept at maximum at 1000 W/m2. Inbuilt PLL and PWM pulse generator blocks in MATLAB/Simulink is used for controlling the inverter.

The design is done for 500 Watt inverter topology. The active and reactive power output for a load of 320 Watt and 80 VAr is simulated and shown in Fig.14In order to synchronize the solar inverter with grid, the magnitude and phase of the grid supply voltage must be known. Phase locked loop (PLL) is system which will track a signal with other signal system. PLL is actually a servo mechanism which will reduce the difference between phase and frequency of incoming signal to a reference signal. Active power transfer to the grid is possible if there is a difference between the Phase of the inverter and the grid supply system. PLL will capture the phase of the grid supply and required phase shift is generated using inverter controller for power transfer. The phasor diagram of inverter and grid supply during the power transfer is shown in Fig 15

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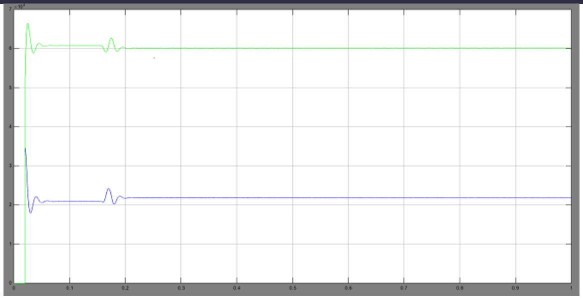

Fig 14.Active and reactive power

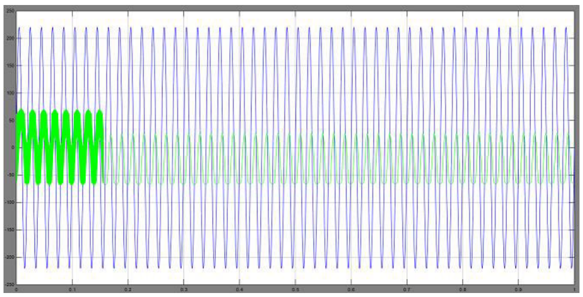

Fig. 15 Phases in radians (Grid supply and Inverter supply)

Battery charged through the proposed topology. Here constant voltage charging method is followed. Li-ion battery which is an inbuilt block ofMATLAB/Simulink is used as battery storage. The output voltage during the charging is given in Fig.16 Thus all operations of the converter are tested in simulation and results are analyzed. The control algorithm works perfectly in the simulation in MATLAB.

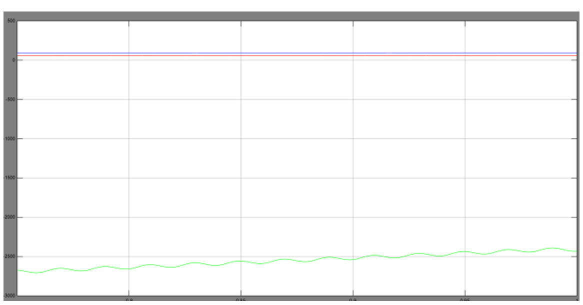

FIG 16. Battery voltage

B) EXTENSION RESULTS

Fig.17 shows the FUZZY controller subsystemfor the proposed system, fig.18 shows the Battery voltage, fig.19 shows grid voltage, fig.20 shows grid current,fig.21 shows active and reactive power, fig.22 shows Existing system Current THD 1.25%,and fig.23 shows Extension system Current THD 0.69%. Compared to extension system existing system THD is less.

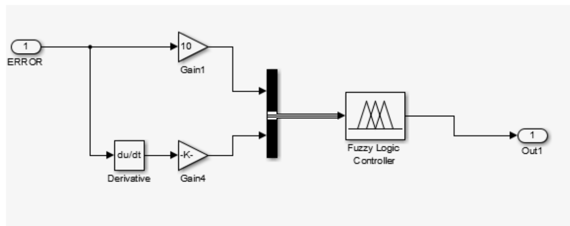

Fig 17.FUZZY controller subsystem

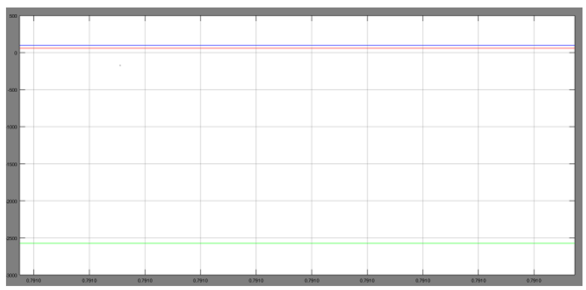

Fig 18.Battery voltage

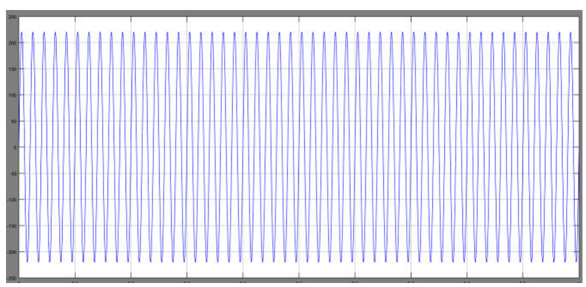

Fig 19.grid voltage

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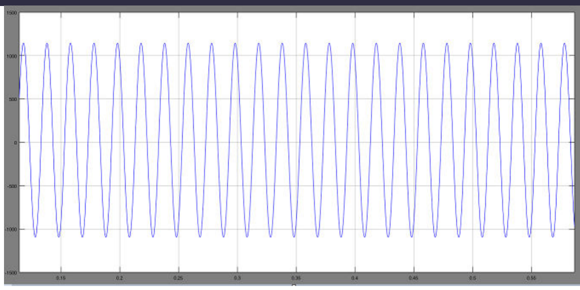

Fig 20.Grid current

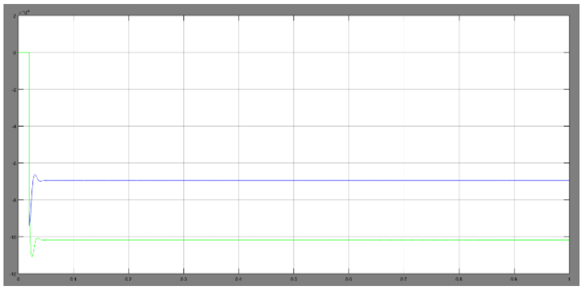

Fig 21. Active and reactive power

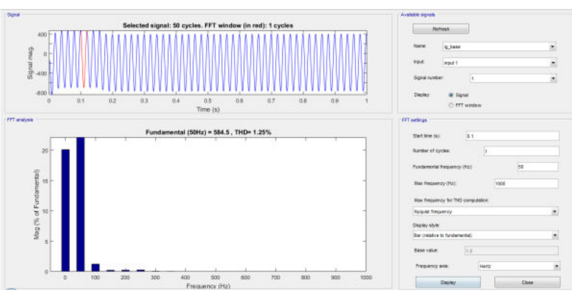

Fig 22. Existing system Current THD 1.25%

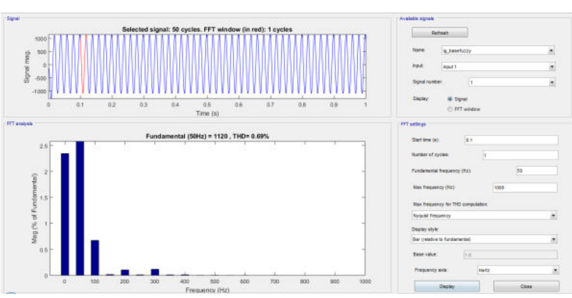

Fig 23. Extension system Current THD 0.69%

CONCLUSION

This project suggested a more suitable converter topology for a solar powered hybrid AC/DC home with FUZZY logic controller. The main concepts of this topology is that a single phase single conversion of AC power to DC and vice versa is employed, which improved the efficiency, reduces volume and enhances the reliability. The simulation implementation validates that the suggested converter topologies would be helpful to reduce significant amount of harmonics in the residential feeders of the future Smart Grid. Though, here only solar PV is considered as source of power, this topology could be equally applicable to wind, fuel cells etc.

FUTURE SCOPE

Solar powered home equipped with this new inverter topology could become a basic building block for future energy efficient smart grid and micro grid. By using Neuro fuzzy control we can further reduce THD of inverter voltage waveform.

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