ISSN 2394-3777 (Print)
ISSN 2394-3785 (Online)
Available online at www.ijartet.com

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 5, Special Issue 8, March 2018

ADAPTIVE FUZZY SLIDING MODE CONTROL OF AC-AC BOOST INVERTER

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Abstract: This project deals with adaptive fuzzy sliding mode control of AC-AC boost inverter (AFSMCBI). This project AC-AC boost inverter compared with conventional boost inverter. The boost inverter consists of two boost DC-DC converters, which provides sinusoidal AC output voltage. In this project a dual loop control method is applied to ensure pure sinusoidal output voltage with fast dynamic response and low input current ripple. The proposed adaptive fuzzy sliding mode control consists two control terms a fuzzy adaptive compensation control term, which solves the problem of parameter uncertainties and a sliding mode feedback control term which stabilizes the error dynamic of the system. It is proposed adaptive fuzzy sliding mode control of boost inverter can attain excellent voltage regulation features such as a fast dynamic response low total harmonic distortion (THD), and a small steady-state error under sudden load disturbances, non linear loads, and unbalanced loads in the existence of the parameter uncertainties. In this proposed method adaptive fuzzy sliding mode control of boost inverter (AFSMCBI) control scheme is designed for harmonic reduction & current control. The simulations are carried out using MATLAB / SIMULINK model and the results show that (AFSMCBI) is effective with the control strategy for balancing capacitor voltage.

***Keywords*—**AC-AC boost inverter, Adaptive fuzzy, Sliding mode, Pulse Width Modulation, Total harmonic distortion (THD).

I. INTRODUCTION

In order to protect the natural environment on the earth, the development of clean energy without pollution has the major representative role in the last decade. By accompanying the permission of Kyoto Protocol, clean energies, including fuel cell, photovoltaic, and wind energy, have been widely applied for distributed generation (DG) installations. More over, estimates by the World Bank state that as much as 40% of the world's population lives in villages not tied to any utility grid. However, the DG units often cannot directly support the electrical appliances with the same power qualities of the grid in terms of frequency and amplitude. Thus, a high performance inverter with the abilities of utility-grid connection is necessary to ensure efficient utilization of DG units. Developments in microelectronics and power devices have made the widespread applications of pulse width-modulation (PWM) inverters to industries. The basic mechanism of a PWM inverter is to convert the dc voltage to a sinusoidal ac output through the inverter–LC-filter blocks. The performance is evaluated by the total harmonic distortion (THD), the transient response, and the efficiency.

In the past decade, much attention has been paid to the closed-loop regulation of PWM inverters to achieve good dynamic response under different types of load, e.g., linear control, passivity-based control, and sliding-mode control (SMC). Recently, some research works have investigated advanced inverters for both stand-alone and grid-connected power supplies. Although both the functions of grid-connected power supplies can be achieved by various circuit frameworks or modern control schemes, the stability of the whole system cannot be proved in a more rigorous way, and newly designed circuit frameworks cannot be popularly adopted in commercial products. The motivation of this study is to design stable control strategies for a single inverter with a popular full bridge circuit framework addressing the issues of utility grid connection simultaneously. Synchronization is one of the most important issues if the PWM inverter is connected to the grid. In previous published literatures, the structure of a PLL control system has been proven to work well for the evaluation of the grid angle under different conditions. However, the analog PLL control framework will make the major circuit to be more complex and inflexible. Comparatively speaking, the digital PLL control scheme has superior performance, such as high robustness, low cost, easy implementation, and flexibility.

Implemented PLLs inside a higher level controller to estimate the grid-voltage phase angle and then manipulated the energy transfer between the power converter and the ac mains. In this study, a PLL control framework modified from the power-based PLL in is used to estimate the phase angle of the utility power for achieving the grid connection with a high power factor. SMC is one of the effective

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nonlinear robust control approaches since it provides system dynamics with an invariance property to uncertainties once the system dynamics are controlled in the sliding mode. The first step of SMC design is to select a sliding surface that models the desired closed-loop performance in state variable space. Then, design the control such that the system state trajectories are forced toward the sliding surface and to stay on it. The system state trajectory in the period of time before reaching the sliding surface is called the reaching phase. Once the system trajectory reaches the sliding surface, it stays on it and slides along it to the origin. The system trajectory sliding along the sliding surface to the origin is the sliding mode. The insensitivity of the controlled system to uncertainties exists in the sliding mode but not during the reaching phase, i.e., the system dynamic in the reaching phase is still influenced by uncertainties. Recently, some researchers have adopted the idea of total Fuzzy SMC (FTSMC). The process, so that the controlled system through the whole Control process is not influenced by uncertainties.

II. EXISTING SYSTEM

It is mostly applied for complex and high-dimensional problems and develop a systematic approach to generate fuzzy rules from a given input-output data set. The TSK model replaces the fuzzy consequent, of rule with the function of the input variables. A zero-order Sugeno fuzzy model can be viewed as a special case of the Mamdani fuzzy inference system in which each rule is specified by fuzzy singleton or a pre defuzzified consequent. the output of the single pv panel is approximately 50V. maximum power output of a single panel is 327W. the DC-DC step up converter raises the voltage from 100V to 360Vusing PI controller. It shows the voltage and current response of step up DC-DC converter. The experimental voltage and current response of the grid connected power supply mode with the proposed AFTSMC are shown, As the inverter current is synchronized with the utility voltage, the grid connected power factor. The AFTSMC controls the output voltage of the inverter with low THD. It shows the THD values of the grid connected current and it shows the voltage analysis of the grid connected power supply mode. The AFTSMC can manipulate the inverter current with high power factor and low THD% in the grid connected power supply mode. In this study, a PLL control framework modified from the power-based PLL in is used to estimate the phase angle of the utility power for achieving the grid connection with a high power factor.

A) Existing Circuit Diagram

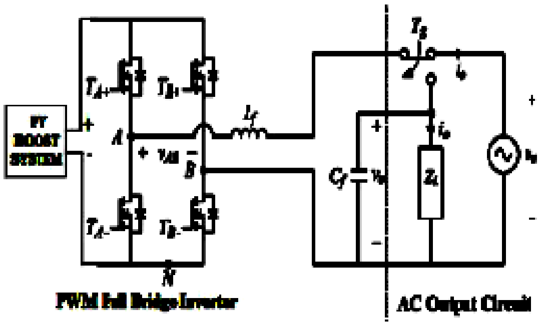

Fig 1.1 Circuit For Existing System

B) Efficiency Graph

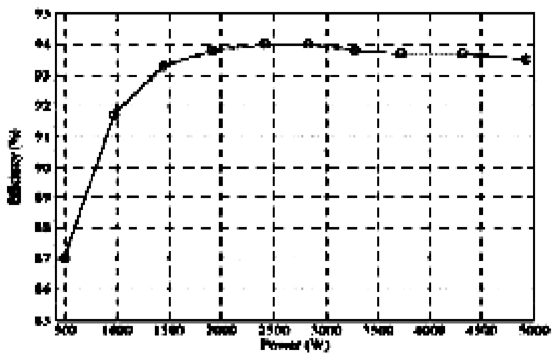

Fig 1.2 Efficiency Of Existing System

AFTSMC technique. Robust control performance, high stand-alone power supply quality, high grid connected power supply quality and automatic transformation between the stand-alone and grid connected power supply modes are the advantages of the DG inverter with the ATSMC scheme. The simulation results obtained using the MATLAB/SIMULINK and the software environment were incorporated to verify the effectiveness of the proposed system.

C) Existing Simulation Diagram

The Stable control strategies were designed for a single PWM inverter addressing the issues of both stand-alone and grid connected power supply modes. An Adaptive Fuzzy Total Sliding Mode Controller was used for voltage and current control of the DG inverter in stand-alone and grid connected power supply mode respectively. This lead to the minimization of THD in the output voltage and the improvement of power factor of the output current of the inverter.

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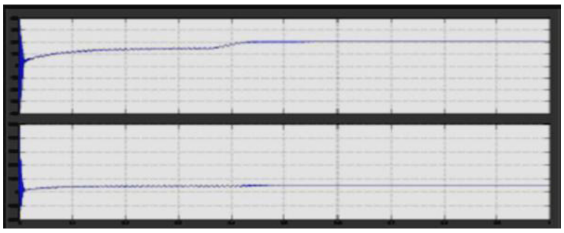
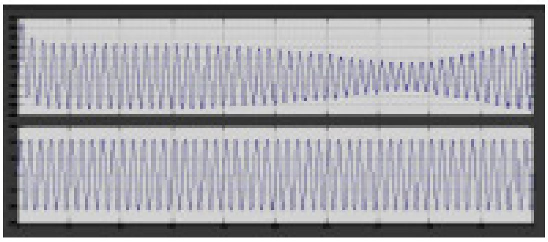


Fig.1.3 PV Panel Boost Converter Voltage



1.4 Grid Load Voltage And Current

The stand-alone and grid connected power supply modes are the advantages of the DG inverter with the ATSMC scheme. The simulation results obtained using the MATLAB/SIMULINK and the software environment were incorporated to verify the effectiveness of the proposed system

III. PROPOSED SYSTEM

a) Proposed Block Diagram

An alternative power generation systems. Alternative energy systems such as photovoltaic (PV), wind, fuel cell (FC), hydroelectric generators require converters to transform the voltage level and types to fulfil the application requirements. For instance, DC-DC converters are used control the DC voltage level and DC-AC converters also known as inverters are used to convert DC power into AC power.

Thus, cascading with boost DC-DC converter will increase the input voltage consequently the output voltage of the inverter. This structure is popular for its robustness, stability and easy implementation. However, the cascaded structure leads to high component count, bulkiness, low efficiency, high cost as well as big in size.

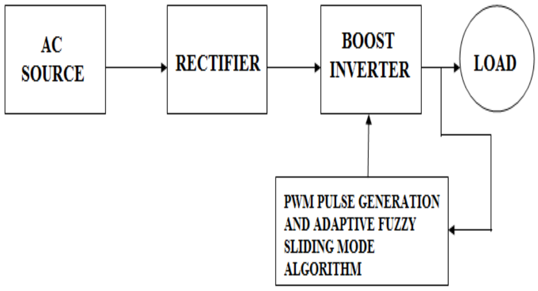


Fig 1.5 Block Diagram Of Proposed System

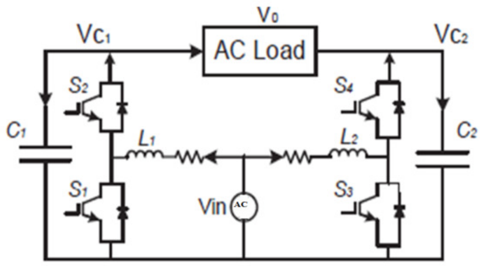


Fig.1.6 Circuit Diagram Of Proposed System

The boost inverter topology is chosen to process the output power of a 48 V proton exchange membrane fuel cell (PEMFC). The boost inverter configuration has advantages like simplicity in structure, higher efficiency and output filter is not required. The simplified structure requires lower number of switches thus, switching loss is less comparing to the multilevel inverters or other voltage source inverters (VSI).

The power supply is an electronic device that supplies electric energy to an electrical load. The primary function of a power supply is to convert one form of electrical energy to another. As a result, power supplies are sometimes referred to as electric power converters. H bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards or backwards. Most DC-to-AC converters (power inverters), most AC/AC converters, the DC-to-DC push–pull converter, most motor controllers, and many other kinds of power electronics use H bridges

b) Pulse Width Modulation

Pulse Width Modulation or PWM technology is used in Inverters to give a steady output voltage of 230 or 110 V

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AC irrespective of the load. The Inverters based on the PWM technology are more superior to the conventional inverters. The use of MOSFETs in the output stage and the PWM technology makes these inverters ideal for all types of loads. In addition to the pulse width modulation, the PWM Inverters have additional circuits for protection and voltage control.

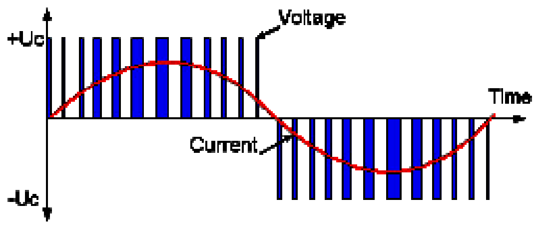


Fig 1.7 Wave Form For PWM Inverter

c) **Boost Inverter Topology**

The boost inverter concept evolves from the boost dc-dc converters. It is constructed using two bidirectional boost converters connected differentially with the load. Each boost converter is controlled to produce a dc biased ac output voltage exactly out of phase to each other. Thus, each converter only produces a unipolar voltage. Due to the exact 180 degree phase shift the resultant voltage across the load is twice of the ac voltage amplitude as the dc voltage eliminates each other.

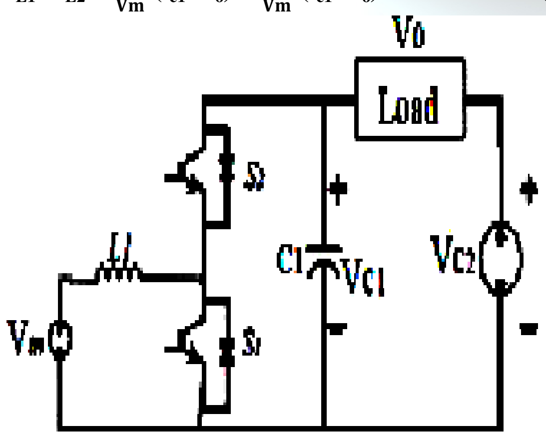
3.4 Equations

$$V_{c1} = V_{dc} + \frac{1}{2} A_{max} . \sin\theta \quad (1)$$

$$V_{c2} = V_{dc} + \frac{1}{2} A_{max} . \sin(\theta\text{-}180) \quad (2)$$

$$V_0 = V_{c1} - V_{c2} = A_{max} . \sin\theta \quad (3)$$

$$I_m = i_{L1} + i_{L2} = \frac{Vc1}{Vm}(i_{c1} + i_o) + \frac{Vc1}{Vm}(i_{c1} + i_o) \quad (4)$$



The duty cycle of the boost converters are,

$$\frac{Vo}{Vm} = \frac{1}{1-d1} - \frac{1}{1-d2} = \frac{2D-1}{D(1-D)} \quad (5)$$

$$L\frac{di}{dt} = V_{td} - (1 - d_j)\, V_{cl} \quad (6)$$

$$C\frac{dv}{dt} = (1 - d_j)\, i_{il} + (-1)^j\, i_o \quad (7)$$

$$L\frac{diL1}{dt} - \frac{diL2}{dt} = - V_{c1} + V_{c2} + d_1 V_{c1} - d_2 V_{c2} \quad (8)$$

$$C\frac{dvc1}{dt} - \frac{dvc2}{dt} = - i_{L1} - i_{L2} - d_1 i_{L1} + d_2 i_{L2} - 2i_0 \quad (9)$$

Here, *j* indicates the boost converter 1 or 2. For differential mode of operation the current, voltage and duty cycle parameters are defined

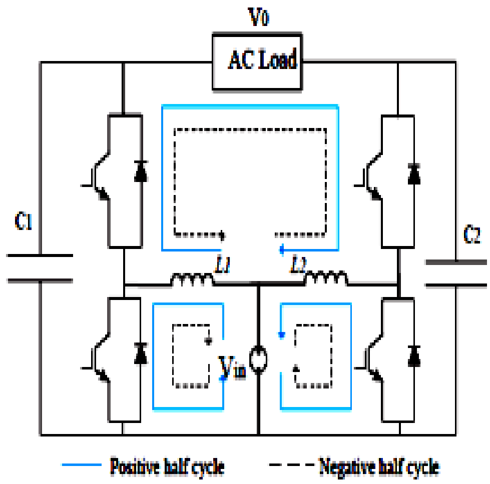


Fig 1.8 Circuit Diagram For Boost Inverter

$$L\frac{diDM}{dt} = -V_{DM} + \frac{D1Vc1-D2Vc2+d1Vc1-d2\,Vc2}{2} \quad (10)$$

$$C\frac{dvDM}{dt} - i_{DM} + \frac{D1iL1-D2iL2+d1IL1-d2\,IL2}{2} - \frac{Vdm}{R} \quad (11)$$

$$L\frac{di0}{dt} = (D\text{-}1)\, V_0 + dv_c \quad (12)$$

$$C\frac{dv0}{dt} = (1\text{-}D)\, i_0 - dI_L - \frac{V0}{R} \quad (13)$$

$$\frac{Io(s)}{d(s)} = \frac{CVcs+(1-D)IL+\frac{Vc}{R}}{LCs2+\frac{L}{Rs}+(1-D)2} \quad (14)$$

$$\frac{Vo(s)}{io(s)} = \frac{(1-D)Vc-LILs}{CVcs+(1-D)IL+\frac{Vc}{R}} \quad (15)$$

The equations (14) and (15) represent the transfer function of the boost inverter and they show that they are similar as the conventional boost converter. Thus similar control algorithms such as multiple loop control can be applied for this structure.

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d) Converter Parameters

TABLE-4.1

S.NO	PARAMETER	VALUES
1.	Input Voltage(average)	V_{in}=48V
2.	Output Voltage(rms)	V_{out}=110V
3.	Nominal Output Power(W)	P_o=5000W
4.	Output frequency	F=50H_Z
5.	Switching frequency	F_s=40000H_Z
6.	Boost Inductance(L_1,L_2)	L=2.1 Mh
7.	Output capacitor(C_1,C_2)	C=2.2mf
8.	Load Inductance	R_L=$1e^{-3}$
9.	Load Resistance	I_L=45ohms

e) Sliding Mode Control

The sliding-mode control is used in this approach to design a hysteresis-based Boost inverter that provides a regulated output voltage of 400-V DC from an input voltage in the range of 110- 220V DC. In this paper, the definition of a simple sliding surface for the regulation of the input inductor current yields the indirect control of the output voltage by forcing the mentioned current to reach a desired reference value in the equilibrium state.

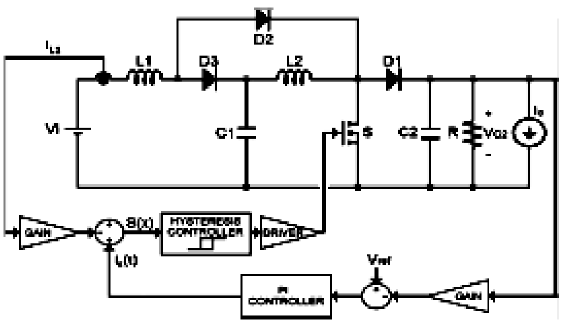


Fig 1.9 Boost Inverter With Sliding Mode Control

$$\frac{d_{L1}}{dt} = \frac{v_i}{L1} - \frac{v_{C1}}{L1}(1-u)$$
$$\frac{di_{L2}}{dt} = \frac{v_{C1}}{L2} - \frac{v_{C2}}{L2}(1-u)$$
$$\frac{dv_{C1}}{dt} = -\frac{i_{L2}}{C1} + \frac{i_{L2}}{C1}(1-u)$$
$$\frac{dv_{C2}}{dt} = -\frac{v_{C2}}{RC1} + \frac{i_{L2}}{C2}(1-u) - \frac{i_0}{C2}$$
$$M(D) = \left(\frac{v_{C1}}{v_i}\right)\left(\frac{v_{C2}}{v_{C2}}\right) = \frac{1}{(1-D)^2}$$

f) Adaptive Fuzzy Control

The adaptation of fuzzy controllers. First we will show a AFC (Adaptive Fuzzy Control), i.e., an adaptive control methodology requiring a minimal knowledge of the process to be coupled with, can be derived in a way very reminiscent of neurocontrol methods. Indeed a main point to be argued and illustrated in this chapter is the case to import methods and ideas emerging in the connectionist community for control applications as soon as the fuzzy controller is supplied with a gradient method for the automatic tuning of its parameters (such as the membership functions) akin to the well known back propagation for multilayer neural nets. Since fuzzy PID is one of the most popular fields of investigation in the fuzzy control community with researchers trying to understand better the kind of non-linear extrapolation the fuzzyfication of classical PID can provide.

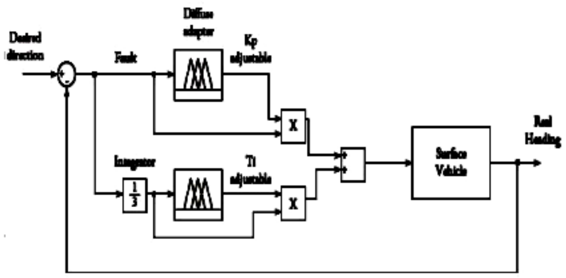
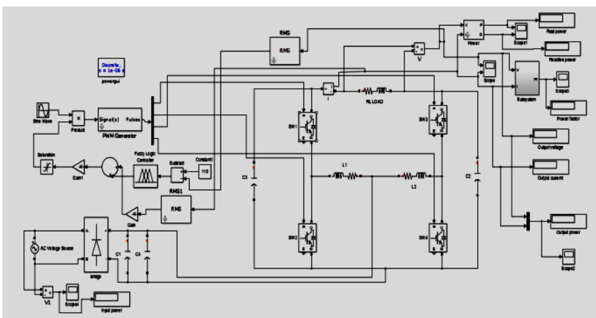


Fig 1.10 Circuit Diagram Of Adaptive Fuzzy Control

IV. SIMULATION DIAGRAM

This project presents an adaptive fuzzy sliding mode control of AC-AC boost inverter is specifically applied for application that needs a higher voltage than the input voltage level. A dual loop control strategy) integrated with adaptive fuzzy controller has been applied as the controller of the boost inverter. The controller enables the system to maintain a regulated output voltage under steady state and abrupt load change. In the simulation the total harmonic distortion (THD). This project validated the operation of the boost inverter through mathematics and simulation results, showing fast dynamic response, moderate THD and accurate output voltage. The proposed system using AFSM



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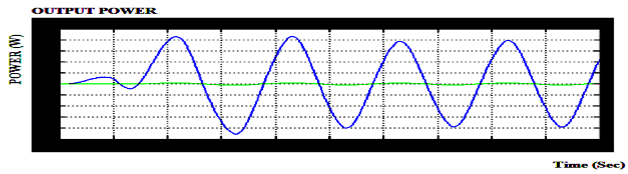
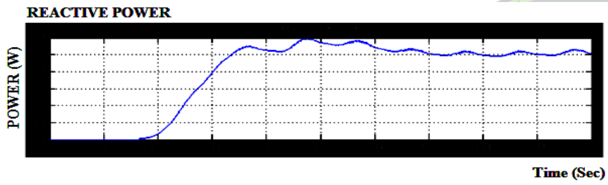
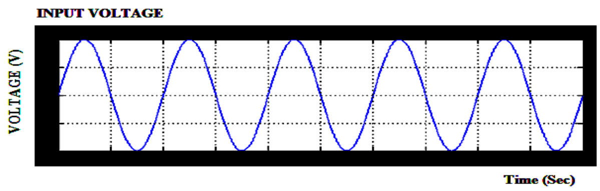
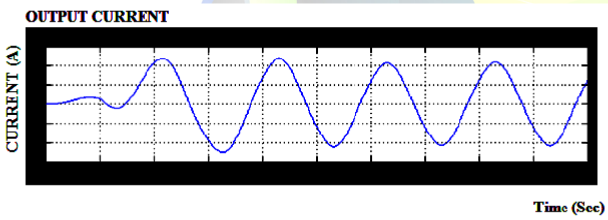
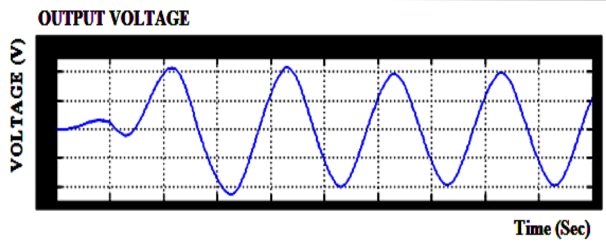
control can provide the maximum power generation and reduced harmonic contents in the output side. The adaptive fuzzy control of AC-AC boost inverter along with total sliding mode control technique using Boost inverter. The simulation is carried out using MATLAB / SIMULINK for control the balancing capacitor voltage.

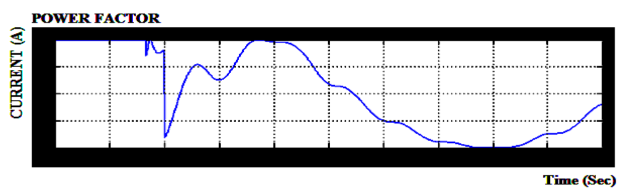




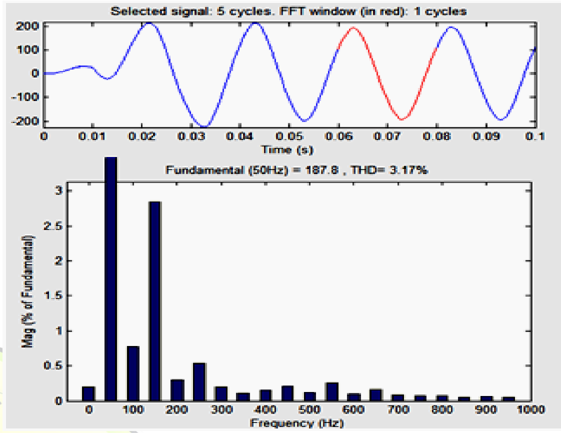








THD



V. COMPARE THE DIFFERENT VOLTAGE FOR THD

INPUT VOLTAGE (V)	OUTPUT VOLTAGE (V)	THD %
50	120	3.21
100	220	3.17
150	320	3.14
200	440	3.11
230	480	3.10

VI CONCLUSION

This project presents an adaptive fuzzy sliding mode control of AC-AC boost inverter is specifically applied for application that needs a higher voltage than the input voltage level. A dual loop control strategy) integrated with adaptive fuzzy controller has been applied as the controller of the boost inverter. The controller enables the system to maintain a regulated output voltage under steady state and abrupt load change. In the simulation the total harmonic distortion (THD). This project validated the operation of the boost inverter through mathematics and simulation results, showing fast dynamic response, moderate THD and accurate output voltage. The proposed system using AFSM control can provide the maximum power generation and reduced harmonic contents in the output side. The adaptive fuzzy control of AC-AC boost inverter along with total sliding mode control technique using Boost inverter. The

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