A Harmonic Detection for Grid Connected PV System under non linear load using cuk converter

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Abstract *— This paper proposes a Grid connected PV system using AI controlled CUK converter. Due to the presence of power electronics components in the converter and the inverter harmonics gets occurs in the devices. By using Cuk converter and different types of controller (PI, Fuzzy Logic Controller (FLC), FLC with PI and ANN controller) used in the inverter to reduce the harmonic occurs on the devices. In MATLAB simulink by using FFT analysis harmonics get detected and THD values are mentioned. Simulation results for grid connected PV system for various controllers are presented.Moreover, a Fast Fourier Transform (FFT) analysis is also included in harmonics detection control for injection of extracted solar PV power to the distribution system under grid connected mode and to improve the dynamic behaviour under climate changes. Simulation results of pv system based microgrid are presented under numerous operating states.*

Keywords *— cuk converter, fuzzy logic, voltage source converter*

I. INTRODUCTION

The use of power electronics in the renewable energy sources has significant effect on its reliability, efficiency, size, and life cycle.The usage of the grid-connected photovoltaic (PV) system has improved in order to meet the rising request of electrical energy.

The applications for PV energy are increased, and that need to improve the materials and methods used to harness this power source. Main factors that affect the efficiency of the collection process are PV efficiency, intensity of source radiation and storage techniques[2]. The efficiency of a PV is limited by materials used in PV manufacturing.

There are two major methodologies for maximizing power extraction in solar systems[3]. They are sun tracking, maximum power point (MPP) tracking or both. These methods need controllers which may be intelligent such as fuzzy logic controller or conventional controller such as Perturb & Observe method and Incremental Conductance method[13]. Hence, many complex systems can be controlled without knowing the exact mathematical model of the plant.

Besides seamless transition, microgrid provides harmonics current and reactive power demand of nonlinear loads to maintain the power factor of the utility close to unity under sudden change in insolation level and load variations. The total harmonics distortion (THD) of the grid current and voltage are preserved within the limits of an IEEE standard.

Moreover, the proposed micro grid shares the active power without any experience of transient in utility as well as in load under dynamic load variations. Moreover, if there is sudden reduction in the load power then grid current are smoothly increased to share the PV power, which is verified through simulation result.

II. CONTROL ALGORITHMS

A PV panel has a nonlinear characteristics and its output power depends mainly on the irradiance (amount of solar radiation) and the temperature. Moreover for the same temperature and irradiance the output power of a PV panel is function of its terminal voltage [15]. There is only one value for the terminal voltage that corresponding to maximum output power for each particular case. The procedure of searching for this voltage is called maximum power point tracking. Maximum power point tracking of a PV panel can be obtained either in a single stage or in a double stage. In the case of single stage, a DC/AC converter is utilized.

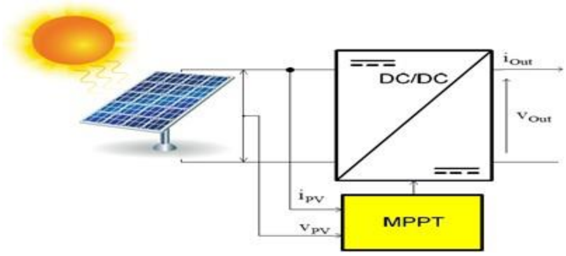

Fig 1:Maximum Power Point Tracker (MPPT) system as a block diagram.

There are two algorithms which are used in this paper for MPPT: (i) Hill Climbing methods, (ii) Fuzzy Based Algorithm

A. Hill ClimbingMethod

The hill climbing based techniques are so named because of the shape of the power-voltage (P-V) curve[16]. This technique is sub-categorized in two types:

Perturb and Observe method (P&O):

Perturb and Observe is a widely used method. It is common because of the simple feedback structure and the fewer control perimeters. The basic idea is to give a trial increment or decrement in the voltage, and if this result in an increase in the power, the subsequent perturbation is made in the same direction or vice versa. This method is easy enough to handle and manipulate.

Incremental Conductance method (ICT)

The incremental conductance method [17] is based on the fact that the slope of the PV array power curve is zero at the MPP, positive on the left of the MPP, and negative on the right,

$$\frac{dP}{dV} = 0 \; at\; MPP \qquad (1)$$

$$\frac{dP}{dV} > 0 \; Left\; of\; MPP \qquad (2)$$

$$\frac{dP}{dV} < 0 \; Right\; of\; MPP \qquad (3)$$

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} \approx I + V\frac{\Delta I}{\Delta V} \qquad (4)$$

$$\frac{\Delta I}{\Delta V} = -\frac{I}{V} \; at\; MPP \qquad (5)$$

$$\frac{\Delta I}{\Delta V} > -\frac{I}{V} \; at\; Left\; of\; MPP \qquad (6)$$

$$\frac{\Delta I}{\Delta V} < -\frac{I}{V} \; Right\; of\; MPP \qquad (7)$$

The Incremental Conductance Algorithm based tracking adjusts the duty cycle D of boost converter which adjusts the operating voltage of PV array to operate at MPP.

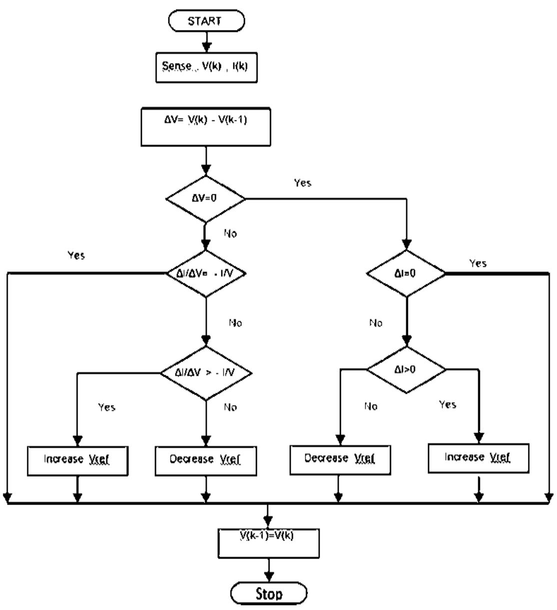

Fig 2:Flow Chart for maximum power point tracking for ICT Algorithm.

This method gives a very good and accurate performance under rapidly varying conditions. However, the drawback is that the actual algorithm is very complicated to handle. It requires sensors to carry out the computations and high power loss through the sensors.

III. DC-DC CONVERTERS

A. Cuk Converter

The **Cuk converter** is a type of DC/DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is essentially a boost converter followed by a buck converter with a capacitor to couple the energy.

The commonly used two type of cuk converter is

- Non isolated cuk converter
- Isolated cuk converter

A non-isolated Cuk converter comprises two inductors, two capacitors, a switch (usually a transistor), and a diode. It is an inverting converter, so the output voltage is negative with respect to the input voltage.

The capacitor C is used to transfer energy and is connected alternately to the input and to the output of the converter via the commutation of the transistor and the diode .

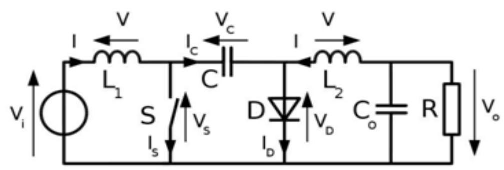

Fig 3:Non isolated cuk converter

The average output to input relations are similar to that of a buck-boost converter circuit. The output voltage is controlled by controlling the switch-duty cycle. The ratio of output voltage to input voltage is given by:

$$\frac{Vo}{Vin} = D.\frac{1}{1-D} = \frac{Iin}{Io} (8)$$

Where, V_o and V_{in} are the output and input voltages, respectively. The term I_o and $I_{in}$are the output and input currents, respectively.

B. Voltage Source Converter

The VSC is controlled in the rotating d-q frame to inject a controllable three phase AC current into the grid [21]. A phase locked loop (PLL) is used to lock on the grid frequency and provide a stable reference synchronization signal for the inverter control system, which works to minimize the error between the actual injected current and the reference current obtained from the DC link controller.

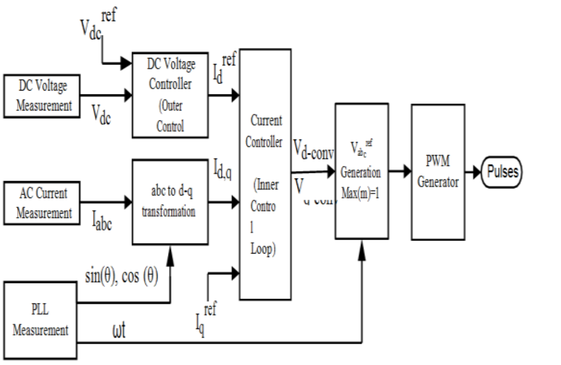

Fig 4:Functional control diagram of VSC using vector control.

The brief description of the controller component soft he vector control system is discussed below.

dqTransformation

dq transformation is the transformation of coordinates from the three-phase stationary coordinate system to the d-q rotating coordinate system. This transformation is made in two Steps:

- A transformation from the three-phase stationary coordinate system to the two-phase, α-β stationary coordinate system and
- A transformation from the α-β stationary coordinate system to the d-q rotating coordinate system.

Phase Locked Loop (PLL)

The Phase Locked Loop block [23] measures the system frequency and provides the phase synchronous angle θ (more precisely [sin (θ), cos (θ)]) for the d-q Transformations block. In steady state, sin (θ) is in phase with the fundamental (positive sequence) of the α component .

Fuzzy logic controller

Fuzzy control system is a control system based on fuzzy logic a mathematical system that analyses analog input values in terms of logical variables.The advantage of using Fuzzy that the solution to the problem can be cast in terms that human operators can understood.

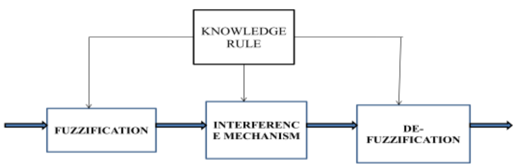

Fig 5 :Block diagram of fuzzy logic controller.

It can be divided into four main functional blocks namely Knowledge base, Fuzzification, Inference mechanism and Defuzzification. The knowledge base is composed of data-base and rule-base. The data-base, consisting of input and output membership functions, provides information for appropriate fuzzification operations, the inference mechanism and defuzzification. The rule-base consists of a set of linguistic rules relating the fuzzy input variables to the desired control actions. Fuzzification converts a crisp input signal, into fuzzified signals that can be identified by levelof membership in the fuzzy sets.

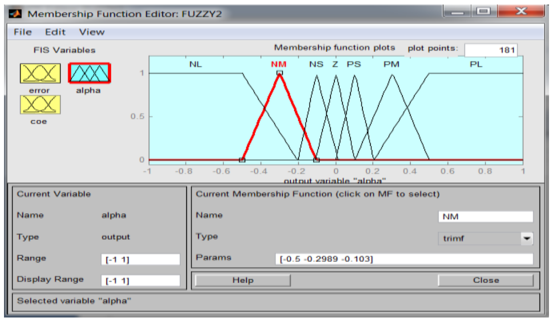

Fig 6 :Fuzzy membership output.

ANN(Artificial Neural Network)

Neural network (NN) has been employed in many applications in recent years. An NN is an interconnection of a number of artificial neurons that simulates a biological brain system.

Evolutionary Neural Network

Artificial Neural Networks offer an attractive paradigm for the design and analysis of adaptive, intelligent systems for applications in artificial intelligence and cognitive modelling.

ANN is a parallel distributed processing system handling a group of interconnected neurons designed to perform some intelligent task . This network attempts to minimize the energy function, which decreases monotonically with number of iterations.

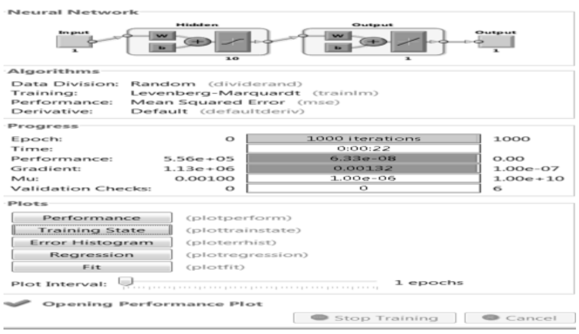

Fig.6: Neural network tools

Feedforward network

In a layered neural network the neuron are organized in the form of layers**.**

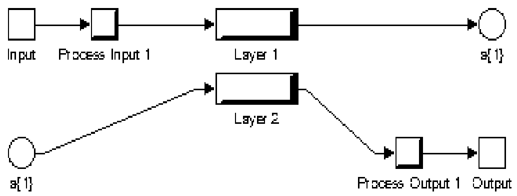

Fig.7: Feedforward network

In the simplest form of a layered network we have a input layer of source nodes that projects onto an output layer of neurons, but not vice versa. This network is strictly a Feedforward or acyclic type.

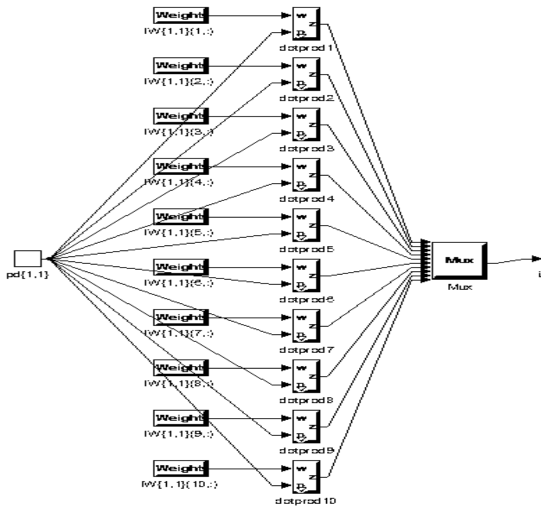

Fig.8: Feed forward network with hidden layer

DC-Voltage Controller

The dc voltage controller is discussed as the outer controller. Dimensioning of the dc link voltage controller is determined by the function between the current reference value to be given and the dc link voltage.

$$Id,ref = (Vdc - Vdc,ref) * \left[Kp + \frac{Ki}{s}\right] \qquad (9)$$

Sinusoidal pulse width modulation (spwm)

The DC-AC inverters usually operate on Pulse Width Modulation (PWM) technique. The PWM is a very useful technique in which width of the gate pulses are controlled by various mechanisms.As mentioned in , the advantages of using SPWM include low power consumption, high energy efficient up to 90%, high power handling capability, no temperature variation-and aging- caused drifting or degradation in linearity and SPWM is easy to implement and control.

PROPOSED BLOCK DIAGRAM

The complete system is to be simulated using the MATLAB/SIMULINK, and by varying the operating condition (solar irradiance and temperature), for the three different control algorithms, P&O algorithm, ICT algorithm .

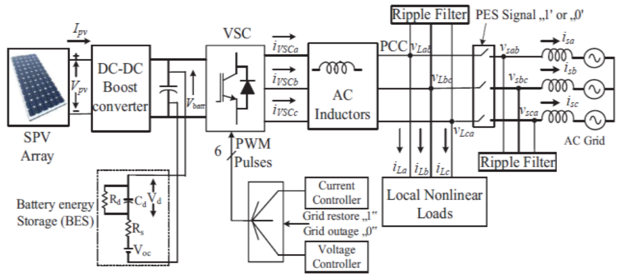

Fig. 9: Block diagram of the grid connected photovoltaic system.

IV. SIMULATION RESULTS

OUTPUT WAVEFORM FOR CONVERTERS

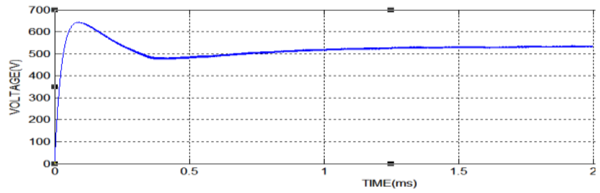

Fig .10: Output waveform for boost converter

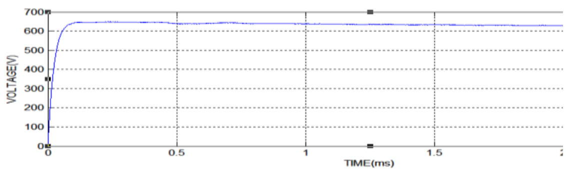

Fig.11:Output waveform for cukconverter

INPUT PULSE TO INVERTER WAVEFORM

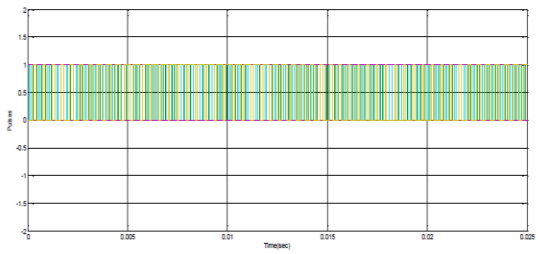

Fig.12:Waveform for Input Pulse to Inverter Circuit

OUTPUT WAVEFORM FOR PLL

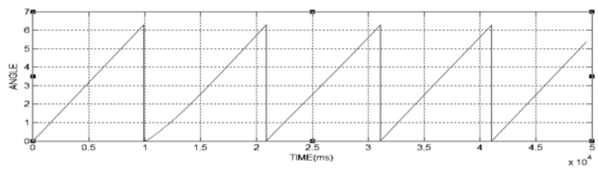

Fig .13:output waveform for PLL

OUTPUT WAVEFORM FOR INVERTER VOLTAGE AND CURRENT

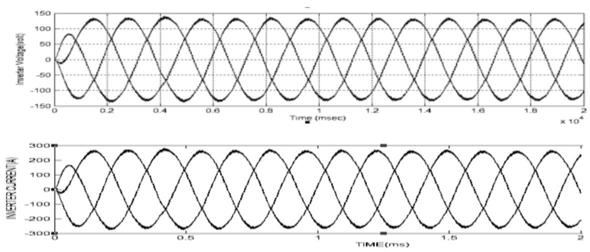

Fig.14:Output waveform for inverter voltage and current

OUTPUT WAVEFORM FOR GRID VOLTAGE AND CURRENT

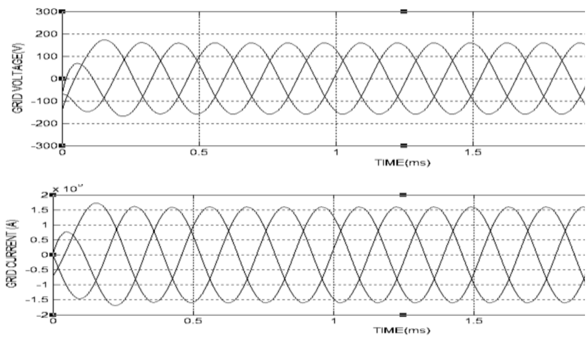

Fig.15:Waveform for grid voltage and current

COMPARISION OF INVERTER AND GRID VOLTAGE

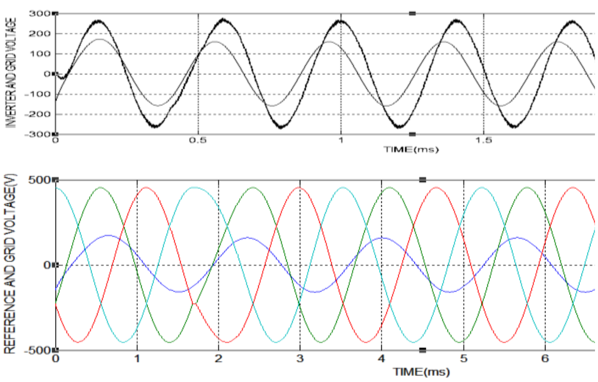

Fig.16:waveform for inverter and grid voltage.

FAULT ANALYSIS

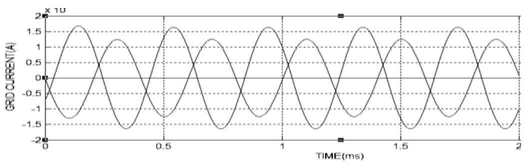

Fig.17:Grid voltage and current under L-G fault condition.

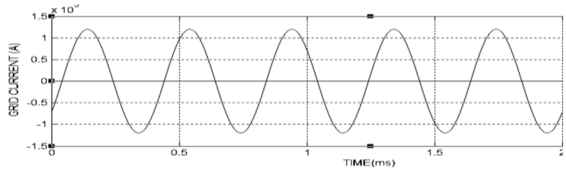

Fig.18:Grid voltage and current under LLG fault condition.

FFT ANALYSIS

The harmonics content in the grid current was reduced about 3.81% and the inverter current was reduced about 9.48%.

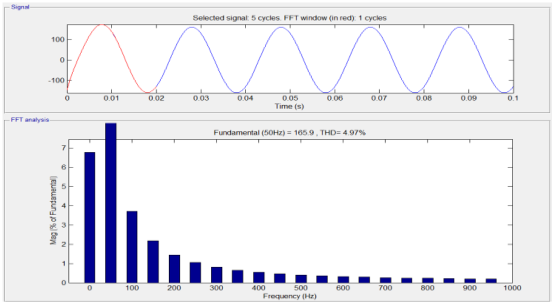

Fig.19:THD for grid voltage

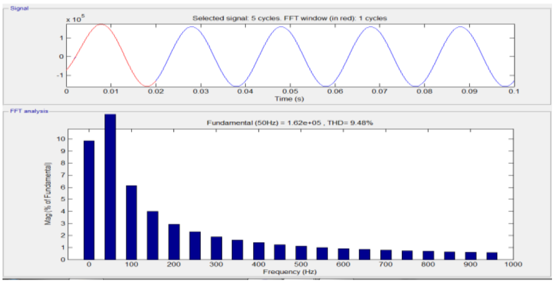

Fig.20:THD for inverter voltage

CONCLUSION

The proposed algorithm is by implementing a maximum power point tracker controlled by fuzzy logic controller and using Boost DC-to-DC converter to keep the PV output power at the maximum point all the time. Fuzzy logic controller was tested using Matlab/Simulink software, and the results were compared with a perturbation and observation controller and incremental conductance controller which were applied on the same system.

The simulation results under transient conditions show that, the output power injected to grid from PV array is approximately constant while utilizing the proposed FLC and the PV system can still connect to grid and deliver power to grid without any damage to the inverter switches.

The THD of grid current is maintained nearly 3.81% for and load current is nearly 9.48%. The obtained simulation have shown the satisfactory response of micro grid under various types of disturbances.

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