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IMPROVING THE RELIABILITY OF THREE PHASE INVERTER BASE ON CUK CONVERTER FOR PV APPLICATION

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Abstract — This paper present three phase inverter base on the cuk converter. The prime foredeal of this proposed theory is energy storage element like as inductors and capacitors can be reduced in order to reforms the system reliability and reduced total size alike total cost of system. The uncommon characteristics of cuk converter, when required ac voltage is depress or greater than dc side voltage but this quality is not found in conventional Current source inverter as well as voltage source inverter. Traditional method required any mathematical model but the fuzzy controller does not require any mathematical model and it's very simple to implement. The cuk converter is simulated for grid and their output voltage is settling at desired voltage. The performance of cuk converter simulated by using MATLAB/SIMULINK and contrast study is performed.

Index Terms— Cuk converter, PWM, Three phase inverter, Fuzzy logic controller, MATLAB/SIMULINK

INTRODUCTION

Recent year, use of renewable energy sources are more as compared to fossile fuel based energy sources. So new concepts towards the structured renewable system in which he lay the concepts of new power electronics equipment in generation and consumption for major efficiency improvement, as well as to minimize the system cost and improving reliability [1]. The methodology of DC to AC converter in terms of allay the size and numbers of passive component which is apply in inverter for emerging application of power electronics. And used the Moore's law [2] based integrated circuit and components which are smaller, efficient, faster, less costly and making possible developed speed to control the complex process. But the limitation is wide band gap in devices will not be practical for application [2]. The topology of voltage source inverter is suitable where the need of AC output voltages lower than the DC input voltage [3]. Normally in voltage source inverter, the ac voltage present at output side is lower than dc input. For this purposes dc-dc boost converter is used to change the voltage value of ac at output side [4].The auxiliary DC to DC boost converter which maximize the size, cost as well as it reduces the reliability [5]. For getting the output voltage lower and greater than input voltage to connecting load of system across DC to DC converter and modulating the converter voltage sinusoidally. In which the output voltage controlled by both converter and load voltage controlled indirectly with connecting large capacitors across the output side [6]. Hybrid Boost Inverter control system which is attractive by its quality of less power process stage and it economical compared to conventional system [7].

In [8], described the topology of Buck converter and boost converter and buck boost inverter which have merits of modularity, compactness and low cost. The boost inverter methodology which improve single phase single power fuel cell offering the vantage of low cost and synoptic [9]. In [10], the three phase AC - DC converter using as cuk rectifier as for DC distribution application. In that six converters fed with six rectifiers which designed two single switch cuk converters having for two rectifiers for one phase. This increases dynamic response of system but construction more complicated as well as costly.

In three phases PWM buck boost converter the voltage is step up and step down with bidirectional process operation. In which switching loss reduces, low order harmonics control but disadvantage is that its use only for low voltage application [11]. In [12], the novel technique regarding cuk converter is developed, which cuk converter is in between of solar panel and battery bus for DC to DC conversion process. This technique is increasing the efficiency of system as well as it is simple and elegant. The design of DC to DC converter using cuk converter, in which all converter transfer function is depend on duty ratio and converter function parameter. But in which the complexity is more as well as the time varying transfer functions which leads to current distortion [13]. The topology of three phase inverter based on cuk inverter, in which cuk converter are connected which have three bidirectional switches. The cuk converter with optimal dc link capacitor and this structure improving efficiency for industrial application [14].

It is essential to improve the performance of converter, there are copious topologies such as Buck converter and Boost converter, Buck Boost converter etc. are used as for conversion purpose. All these topologies have limitations regarding size and cost because numbers of elements are

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more, so it is essential to reduced it. In order to obtain authentic and more accurate performance it's necessary to change the control techniques of this cuk converter. The paper discusses the design of cuk converter at 50 Hz frequency fed by solar energy source as system input. Detail study of fuzzy controller design of cuk converter is carried out.

SYSTEM CONFIGURATION

Figure 1 shows system configuration, first stage is solar system is considered as system input. The second part is cuck converter which is fed by solar system output. And third stage is three phase inverter system.

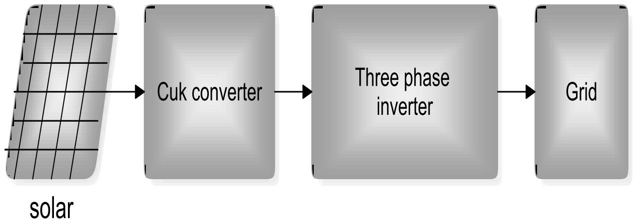

Fig 1: Proposed system configuration

The solar system output is variable due to the environmental conditions. For gain the constant output in system, use converter here. And output of this converter is fed to three phase inverter system. And again it will interface to the system grid.

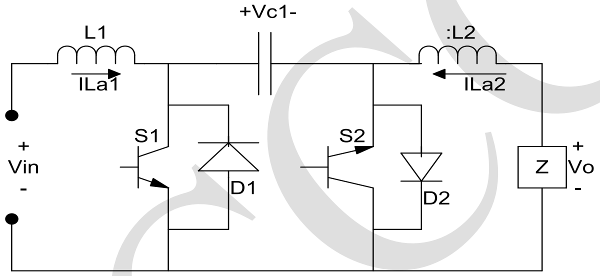

Fig 2: simplified operating modes in cuk converter

Figure 2 shows the cuk converter. In this proposed work the above type of cuk converter is used. This converter circuitry consists two switches S1 as well as S2, one capacitor that is C1 and two inductor are L1 and L2 and two antiparallel diodes D1 and D2. The energy is transfers between the voltage source and the load through capacitor C1. The energy is stored simultaneously in inductors L1 as well as L2. The rudimentary operation can be described merely, when switch S1 is off, then capacitor C1 is charge leading IL1 cause to decrease, where inductor L2 is discharge in the load causing IL2 which is to be increase.

Next switching period, when the switch S1 is on that time inductor L1 is charged and IL1 to be increase, where capacitor C1 is to be discharge and which causing IL2 to increasing. It can be speculated that IL1 and IL2 are interrelationship the energy transfer by capacitor C1.

A. Model Analysis

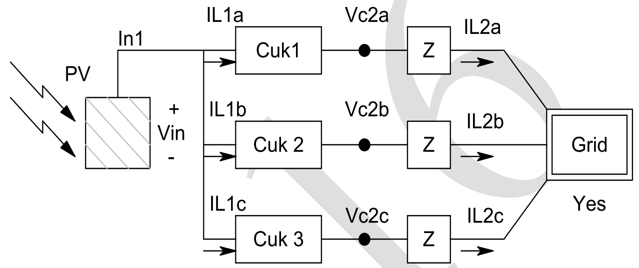

Fig 3: Power transfer in system.

The proposed three phase inverter base on Cuk converters is showed in Fig. 3. As a current sourc of this system configuration can be paralleled for power extension that which is for grid which is fed at end. Every cuk converter which in paralyzed in system are develops a sinusoidal output voltage wave, specifically current response with a dc offset. Assuming the dc voltage as well as ac voltage ratio between input as well as ouput are Hdc and Hac, respectively, and the relation between the input and output voltage .

$$V_{c2a} = H_a * V_{in}$$

$$H_a = H_{dc} + H_{ac} * \sin(\omega t + \theta) \quad (1)$$

$$V_{c2b} = H_b * V_{in}$$

$$H_b = H_{dc} + H_{ac} * \sin\left(\omega t - \frac{2\pi}{3} + \theta\right) \quad (2)$$

And

$$V_{c2c} = H_c * V_{in}$$

$$H_c = H_{dc} + H_{ac} * \sin\left(\omega t + \frac{2\pi}{3} + \theta\right) \quad (3)$$

So from the values of Ha, Hb and Hc. Now calculate the duty ratio for each that are δa , δb and δc as given following

$$\delta_a = \frac{H_a}{H_a + 1} \quad (4)$$

And

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$$\delta_b = \frac{H_b}{H_b + 1} \tag{5}$$

And

$$\delta_c = \frac{H_c}{H_c + 1} \tag{6}$$

From the voltage values that are Vc2a, Vc2b and Vc2c, can calculate the converter current IL2a, IL2b and IL2c.

So,

$$I_{L2a} = \frac{2}{3Z}V_{c2a} - \frac{1}{3Z}V_{c2b} - \frac{1}{3Z}V_{c2c}$$
$$I_{L2a} = I_0 \sin(\omega t + \gamma) \tag{7}$$

And

$$I_{L2b} = -\frac{1}{3Z}V_{c2a} + \frac{2}{3Z}V_{c2b} - \frac{1}{3Z}V_{c2c}$$
$$I_{L2b} = I_0 \sin\left(\omega t - \frac{2\pi}{3} + \gamma\right) \tag{8}$$

And

$$I_{L2c} = -\frac{1}{3Z}V_{c2a} - \frac{1}{3Z}V_{c2b} + \frac{2}{3Z}V_{c2c}$$
$$I_{L2c} = I_0 \sin\left(\omega t + \frac{2\pi}{3} + \gamma\right) \tag{9}$$

Therefore the balanced energy operation of respective three phase which is assumed that the dc offsets of every phase are cancel and the three-phase load which pure sinusoidal voltages as well as currents as prescribed in equation (5)

Controller design for system

Two methods used for controlling. First for to controlling the output voltage of cuk converter and second control system for the inverter are discussed in the paper in detail viz, fuzzy logic controller, pulse width modulation (dq0 theory)

1] Fuzzy logic controller:
The fuzzy logic controller is nothing but successful and it apply veracious applications of fuzzy set theory. Its major advantages are the use of linguistic variables instead of numerical variables, very simple and easy to implement no mathematical calculations necessary, provide faster transient response as well as reduce the overshoot as well as settling time of the converter. Fuzzy logic deals with hesitancy in engineering by attaching degrees of certainty to the answer of the logical question which is commercial as well as practical. Commercially, the fuzzy logic has been use with great success to control system machines and consumer products. In the way of applications fuzzy logic systems are simple to design, and can be understood alike implemented by no any specialists in control theory [15].

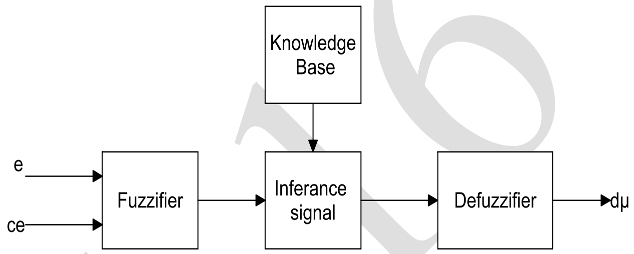

Fig.4.Basic structure of FLC

.The basic structure of the Fuzzy Logic Control is shown in Fig 4. As per Figure, a FLC is comprises four major components. The fuzzifier block this converts input data into the suitable linguistic values through using fuzzy variable sets. The fuzzy variables sets are introduced with membership function which are triangle, sigmoid or trapezoid. The knowledge base consists of a data base with the fundamental linguistic definitions and control rule set. The rule set of knowledge based compose of some fuzzy rule which define the relations between input and output. Actually, fuzzy rules can be defines in the form of 'IF THEN' fuzzy conditional statement:

$$R^i : IF = u_m = A_m^n \; and \; u_{m-1} = A_{m-1}^n \tag{10}$$
$$THEN v = Bi$$

Where, the um is the mth input variable, V is a output, A_m^n is the nth membership set and Bi is output membership set belongs to ith rule.

Inference engine simulate the human decision process. This unit denotes the fuzzy control action from the cognition of the control rules and the linguistic variable information. Hence, the knowledge base and the inference engine are in interconnection during the control process. Firstly active rules are unclosed by substituting fuzzified input variables into the rule base. Then these rules are blend by using one of the fuzzy reasoning methods. Maximum-Minimum and Maximum-Product are most common fuzzy reasoning methods.

The defuzzifier which converts the fuzzy control action that infers from inference engine to a no fuzzy control action. Different defuzzification methods are used as center of gravity, mean of maxima and minimum–maximum weighted

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average formula. Center of gravity is the most common defuzzification method and given in Equation (11)

$$Z^{*} = \frac{\sum \mu(z).z}{\sum \mu(z)} \qquad (11)$$

Where, the μ (z) is grade membership inference engine.

Z is the outputs of each rules

Z* is the defuzzified output

The first intrinsic step in the fuzzy controller definition is the choice of the input as well as output variables. In proposed study the output voltage error and rate of change are defined as input variables and change in duty cycle of controller output variable. The three variables of the Fuzzy Logic Controller, the error, change in error and change in duty cycle. The basic fuzzy logic sets of membership functions for the variables are as shown in the Figures. 5 and 6. The fuzzy variables are denoted by linguistic variables which are positive large that is (PL), positive medium that is (PM), positive small that is (PS), zero that is (Z), Negative small that is (NS), negative medium that is (NM), negative large that is (NL), for all three variables [15].

A rule in the rule base can be expressed in the form: If error is negative low (e is NL) and change in error is negative low (ce is NL), then change in duty cycle (cd is NL). The rules are set or define based upon to the knowledge of the system and the working of the system configuration. The rule base adjustment of the duty cycle for the Pulse Width Modulation (PWM) of the inverter according to the changes in the input of the Fuzzy Logic Controller. The number of rules can be set as it desired. The numbers of rules are forty-nine for the seven membership functions of the error as well as change in error (inputs of the Fuzzy Logic Controller).

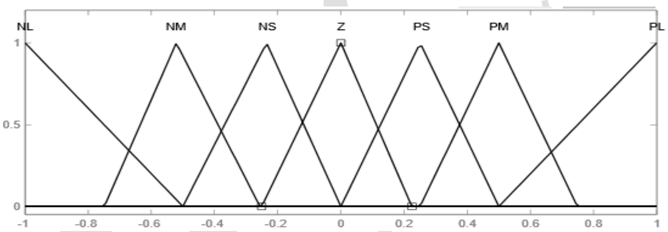

Fig. (5).Membership function for error

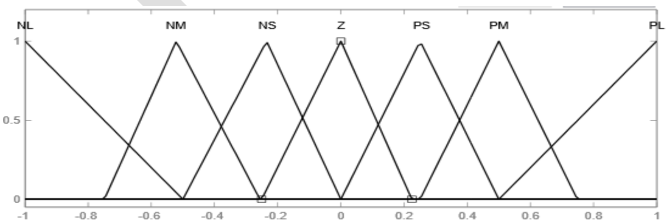

Fig. (6).Membership function for change in error

NL	NM	NS	Z	PS	PM	PL	e / ce
NL	NL	NL	NL	NM	NS	Z	NL
NL	NL	NL	NM	NS	Z	PS	NM
NL	NL	NM	NS	Z	PS	PM	NS
NL	NM	NS	Z	PS	PM	PL	Z
NM	NS	Z	PS	PM	PL	PL	PS
NS	Z	PS	PM	PL	PL	PL	PM
Z	PS	PM	PL	PL	PL	PL	PL

Fig. (7) Rule base FLC [15]

Therefore from the rule base fuzzy logic controller, developing total 49 rules, some as listed below-

(1) IF E (error) is NL (Negative Low) AND ΔE (Change in Error) is Negative Low (NL) THEN Output is Negative Low (NL)

(1) IF E (error) is NL (Negative Low) AND ΔE (Change in Error) is Negative Medium (NM) THEN Output is Negative Low (NL), so on

Therefore above rule strategy applied to all membership function and total 49 rules are developed.

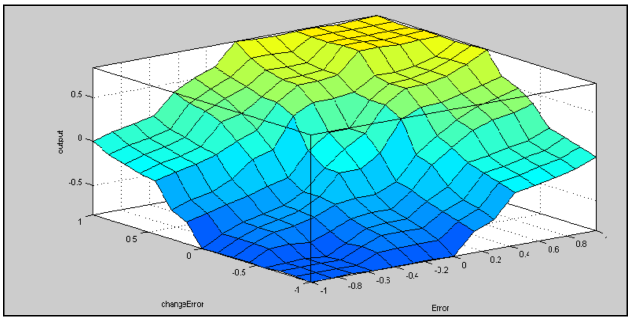

Fig. (8).Surface of FLC rules

2] Dq0 theory

In this experiment the dq0 controlling technique is used to controlling the output voltage of three phase inverter. In this dq0 control theory firstly the transformation of ABC to Dq0 is

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done. The high pass filter used for to remove the harmonics from output. And again that value convert into ABC form. This dqo transformation is done because to get the pure sinusoidal wave which will compared to PWM triangular wave and will get output signal. And then pulse giving to gate of MOSFET.

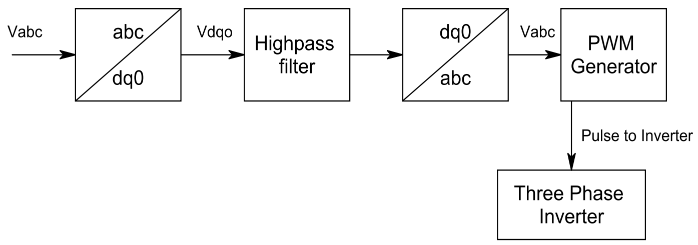
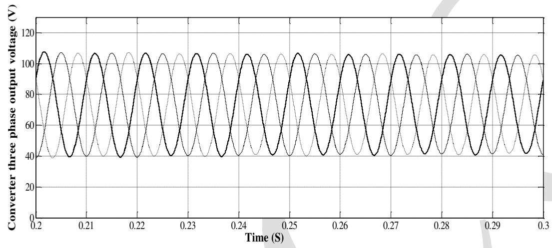


Fig. (9) dq0 control technique for inverter

Simulation results:

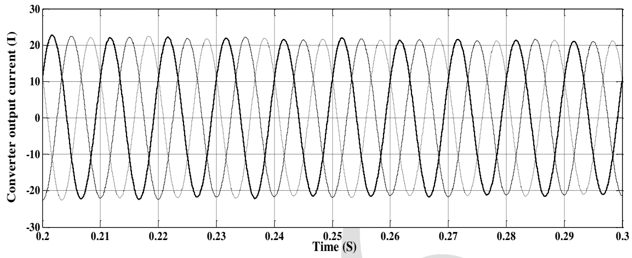
The proposed cuk converter is simulated by using MATLAB/SIMULINK with that selective parameter as well gain values. Figure no. (10) Shows the three phase converter output voltage. The reference values which are set to build three phases output voltage near about 110 volt peak to peak.



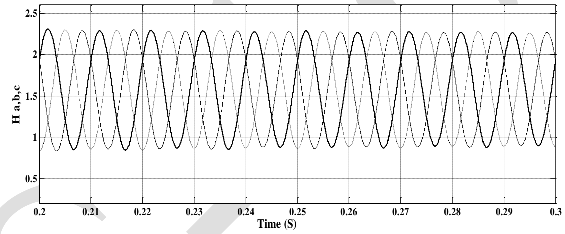
Fig, (10). Converter three phase output voltage

Figure no. (11) Shows the three phased converter current. The cuk converter current value set at 22 Amp peak to peak. The values of Ha, Hb, and Hc calculated in equation (1), (2) and (3). So the output waveform is shown in figure.(12). As well as the duty ratios that are δa, δb and δc are shown in the figure no. (13).

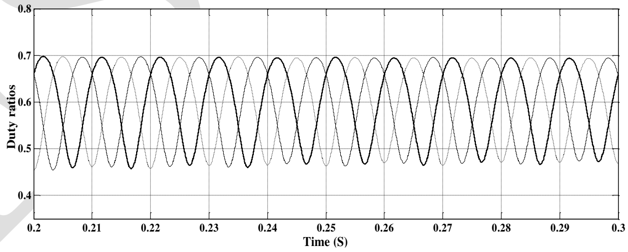
All duty ratios of each phase are set into the 0.7 peak to peak. These duty ratios of phases are calculated by an equation (4), (5) and (6).Figure no. (14) Shows the measurement of active reactive power when the system is implemented with using of fuzzy control technique. This topology makes the major difference in between the fuzzy technique and any mathematical calculation based control system.



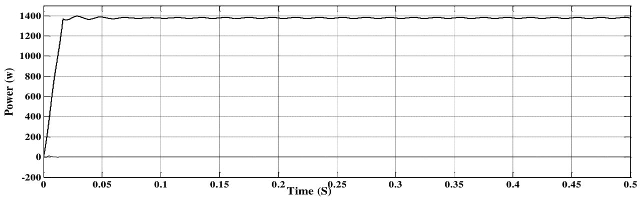
Fig, (11). Converter three phase output current



Fig, (12). H a,b,c



Fig, (13). Duty ratios



Fig, (14). Active and Reactive power measurement in system

Simulation Parameters:-

Switching device	MOSFET
Input voltage Vin	46v
Input current Vin	4.6A
Frequency	5KHz
Capacitor of cuk converter	20µF
Inductor of cuk converter	90mF
Grid Resistance	0.01Ω
Dc link capacitor	10mF

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CONCLUSION

The proposed Cuk converter base inverter introduces asunder advantages when employed at photovoltaic applications mostly because of low input current ripples, less switching loss, less conduction loss. Usually the high-order converters are avoided in use of inverter applications because of control complexity and disadvantages are regarding to leakage current losses, conductance losses, capacitance losses and magnetic losses etc. Barring, the Cuk converter's pristine nonlinearity properties therefore these all demerits can be dissolved. The fuzzy control method is applied to detect the number of error signal throughout in system. In futurity to fulfill the maximum requirement of grid the use of cuk converter is profitable. The satisfactory results in terms of the output currents as well voltages were obtained as well as verified through MATLAB/ SIMULINK software.

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