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LEAKAGE CURRENT ELIMINATION BY SINGLE PHASE TRANSFORMERLESS WITH CHARGE PUMP CIRCUIT FOR GRID TIED RENEWABLE APPLICATION

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ABSTRACT

This paper proposes a leakage current elimination by single phase transformerless inverter for grid tied pv systems. This topology is derived from a concept of a charge pump circuit in order to eliminate the leakage current. The neutral of a grid is directly connected to the negative polarity of the PV panel that creates a constant common mode voltage and zero leakage current. The charge pump circuit generates the negative output voltage of the proposed inverter during the negative cycle. A proportional resonant control strategy is used to control the injected current. The main The main benefits of a proposed inverter are: 1) the neutral of the grid is directly connected to the negative terminal of the PV panel, so the leakage current is eliminated; 2) its compact size; 3) low cost; 4) the used dc voltage of a proposed inverter is the same as the full-bridge inverter (unlike neutral point clamped (NPC), active NPC, and half-bridge inverters); 5) flexible grounding configuration; 6) capability of reactive power flow; and 7) high efficiency. A complete description of the operating principle and analysis of the proposed inverter are presented

Index Terms – Charge Pump Circuit,Leakage Current Elimination, Grid Tied Inverter, Transformerless Inverter

1.INTRODUCTION

Over a last two decades, renewable energy sources become very popular. In renewable energy sources Photovoltaic (PV) power system place a major role.because they generate a electricity with no moving parts and its operates quietly with no emission and it requires a little maintenance[1] [2]. Distributed grid-connected PVs are playing an very important role as the integral part of the electrical grid. However, due to the large stray capacitors between the PV panels and the ground, PV systems suffer from a high common mode (CM) current, which reduces the efficiency of the system and may cause a electric shock., transformers are commonly used to eliminate the leakage currents, in the PV system to provide galvanic isolation. However, it possesses undesirable properties including large size, high cost, and weight with additional losses [3]. Thus, removing the transformer is a great benefit for a further improvement to increase the efficiency of the system efficiency, reduce the size, and weight [4].

One of the important issues in the transformerless grid connected PV system is the galvanic connection of the grid and Photovoltaic system, which leads to a leakage current problems. For transformerless grid-connected inverters, full-bridge (FB) inverter, neutral point clamped (NPC), active NPC (ANPC) inverter [5], and many other topologies such as H5, H6, and highly efficient and reliable inverter concept (HERIC) were proposed to reduce a leakage current with disconnecting of the grid from the PV during the freewheeling modes [6]. However, these topologies are not totally free from leakage current or a Common mode current . The leakage current still exists due to the parasitic capacitor of the switch and stray capacitance between the PV panel and ground. So, some of these topologies require two or more filter inductors are used to reduce the leakage current, which leads to a rise in the volume and cost of the system. Photovoltaic (PV) ac modules may become a trend for the future PV systems because of their greater flexibility in distributed system expansion, easier installation due to their plug and play" nature, lower manufacturing cost from modular and a scalable production, and higher system-level energy harnessing capabilities under shaded or PV manufacturing mismatch conditions as compared to the single or multi- string inverter.

A number of inverter topologies for PV ac module applications had been reported so far with respect to the number of power stages, location of power-decoupling capacitors, use of a transformers, and types of grid interface. Unfortunately, these solutions are suffer from one or more of the following major drawbacks:

(1) The limited-lifetime issue of the electrolytic capacitors for a power decoupling;

(2) Limited input voltage range for a available panels in the market;

(3) high ground leakage current when the unipolar pulse-width- modulation(PWM) scheme is used in a transformer-less PV system;(4) Low system efficiency if an additional high-frequency bidirectional converter is employed

II SINGLE PHASE GRID TIED TRANSFORMERLESS INVERTER

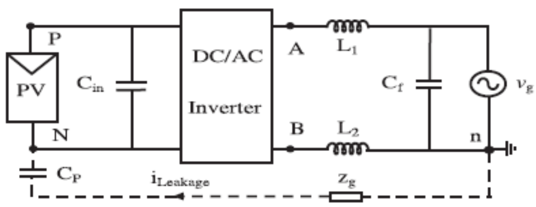

FIG 1:**Block diagram of a single phase grid connected transformerless inverter with leakage current path**

Fig.1:illustrates a single-phase grid tied transformerless inverter with Common mode current path, where P is positive terminal and N is negative terminals of the Photovoltaic, respectively.

In order to eliminate the leakage current, the Common mode voltage (CMV) (vcm)must be kept constant during all operation modes according to it. The V_{cm} with two inductor filiters (L1, L2) is calculated as follows

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$$V_{cm} = \frac{V_{An}+V_{Bn}}{2} + \frac{(V_{An}-V_{Bn})(L_2-L_1)}{2(L_2+L_1)} \quad (1)$$

Where V_{An} *and* V_{Bn} are the voltage difference between a midpoint A and B of the inverter to the dc bus minus terminal *N*, respectively.

If $L_1 \neq L_2$(asymmetrical inductor), V_{cm} is calculated according to (1) and the leakage current appears due to a varying Common mode voltage. If $L_1 = L_2$(symmetrical inductor), V_{cm} is simplified to

$$V_{cm} = \frac{V_{An}+V_{Bn}}{2} = \text{constant} \quad (2)$$

In this state, the CMV is constant and a leakage current is eliminated.

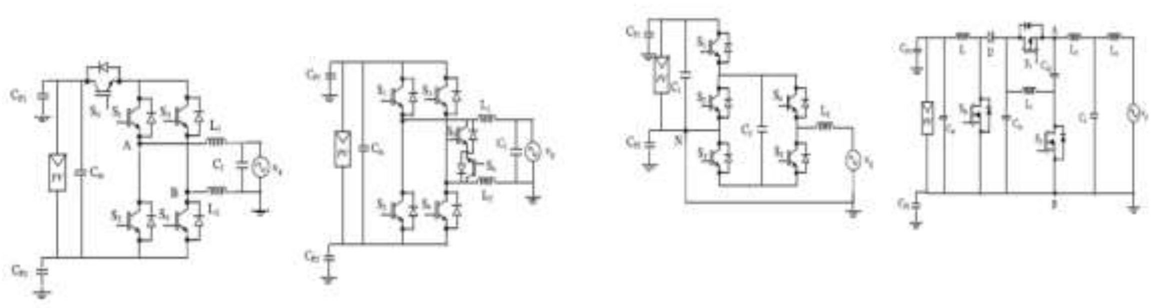
In some structures such as virtual dc-bus inverter and NPC inverter, one of the filter inductors is zero and only one filter inductor is used. In this state, after simplification of V_{cm} ,it will have a constant value according to (3) and the leakage current will be eliminated

$$V_{cm} = \frac{V_{An}+V_{Bn}}{2} + \frac{V_{An}-V_{Bn}}{2} = \text{constant} \quad (L_1 = 0)$$

$$V_{cm} = \frac{V_{An}+V_{Bn}}{2} - \frac{V_{An}-V_{Bn}}{2} = constant(L_2 = 0) \quad (3)$$

III INVERTER TOPOLOGIES

Inverters may have one or more stages according to a levels of power conversion. Generally single-phase systems are the most commonly used in the private sector or residential application. The majority of such PV systems can have be up to 5KW and are roof mounted with a fixed tilt and a southward orientation. Taking into consideration the presented scenario, highly efficient single-phase inverter topologies that will most likely reach a high level of efficiency at low cost are the ones established by a single-stage transformer less inverter. Fig(2) gives a detailed layout of the different transformer less inverter topologies



(A) (B) (C) (D)

Fig2 single –phase grid tied transformerless PV inverter topologies (A) H5inverter,[7](B) HERIC inverter,[8](C) virtual dc-bus inverter [9], and (D) CM inverter proposed in [10]

This paper introduces a new transformerless inverter based on charge pump circuit concept, which eliminates the leakage current of the grid-connected PV systems using a unipolar sinusoidal pulse width modulation (SPWM) technique. In this solution, the neutral of a grid is directly connected to a negative terminal of the charge pump circuit, so the voltage across the parasitic capacitor is connected to zero and the leakage current is eliminated. The charge pump circuit is implemented to generate negative output voltage.

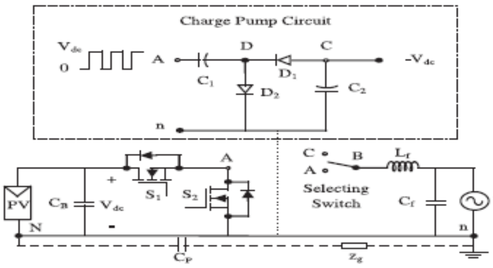


Fig 3 : Schematic diagram of the proposed inverter including the charge pump circuit

There is no any limitation on the modulation strategy of a proposed inverter because the leakage current is eliminated by the circuit topology. The proposed topology consists of four power switches, so the cost of a semiconductors is to be reduced and the power quality is improved by three-level output voltage in order to reduce the output current ripple. During operation of the proposed inverter the current flows through the two switches; thus, the conduction loss is also lower. The used dc voltage of a proposed inverter is same as the FB inverter (unlike NPC, ANPC, and half-bridge(HB) inverters). The proposed inverter is the capable of delivering reactive power into the grid too. Thus, it can be satisfy the requirement of a standard VDE-AR-N 4105.

4. PROPOSED TOPOLOGY AND MODULATION STRATEGY

A.Charge pump circuit concept:

The concept of a simple charge pump circuit to be used in a proposed topology to generate the inverter negative output voltage is shown in the Fig. 4. The circuit consists of two diodes (*D*1, *D*2) and the two capacitors (*C*1, *C*2). This charge pump circuit gives a negative dc output voltage at the point of *C and* equals to the voltage of point *A.* The capacitor *C*1 is used to couple the voltage point of *A* to the node *D*. Two Schottky diodes are used *D*1 and *D*2 to pump the output voltage.

When the diode *D*2 is forward biased, the capacitor *C*1 is charged by the diode *D*2 . The diode *D*1 is a reversed in this state. When a diode *D*1 conducts, capacitor *C*2 is charged through the capacitor *C*1 by using node *n* and switch *S*2.

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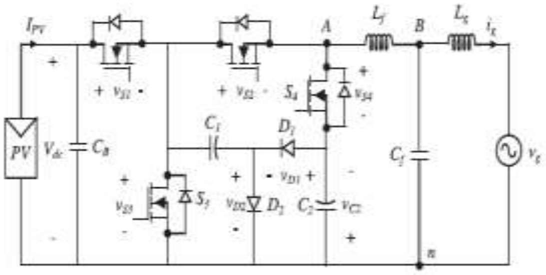

FIG4 proposed single-phase transformerless grid connected inverter.

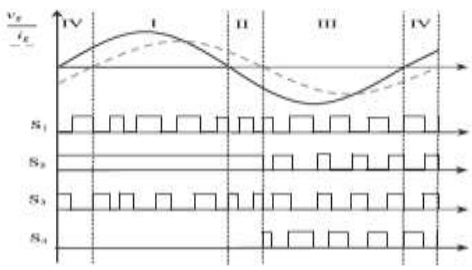

Fig5:Switching pattern of the proposed topology with reactive power flow

The above principle is to integrated into the proposed inverter by using the additional switching devices. The voltage difference between point *A* of a inverter to the point *n* is +*V*dc or zero, according to the switching state of the switch *S*1 and *S*2 , respectively.

The voltage of *C*1 and *C*2 must be kept constant during all the operation modes by selecting proper switching states. Point *B* must be connected to the points *A* or *C* with extra switches. This creates the three different voltages, namely +*V*dc, zero, and –*V*dc for the inverter operation.

In summary, the charge pump circuit in a transformer less inverter has the following characteristics for grid-tied applications.

1) This circuit has a common line with the negative terminal of a input dc voltage and the neutral point of the grid that causes the leakage current to be eliminated.

2) The charge pump circuit has no active device and it has a lower cost for grid-tied applications.

3) The capacitor of a proposed inverter charges every switching cycle, which will reduces the size of the required capacitor with the switching frequency.

4) The capacitor of the charge pump circuit charges with the switching cycle that eliminates the pulse duration sensitivity to generate the negative voltage.

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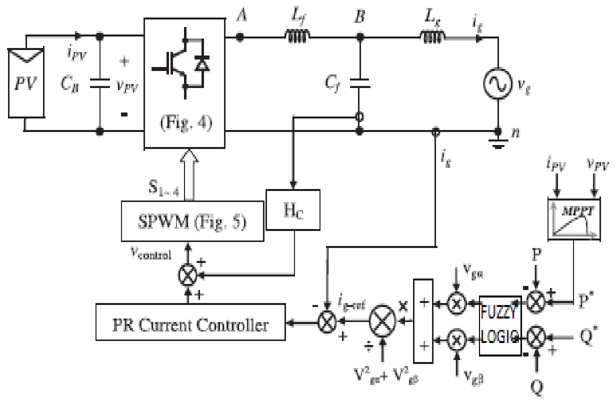


Fig 6. Control block diagram of the proposed single-phase grid-tiedinverter based on single-phase PQ theory

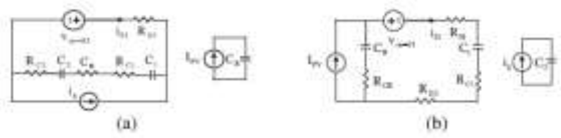


Fig 7: Equivalent circuit of the proposed converter during (a) zerostate and (b) negative state.

5.Control scheme

The control strategy of a proposed grid-tied single-phase inverter is shown in Fig. 7. It contains the two cascaded loops[11] the first loop is an inner control loop, which has to generate a sinusoidal current and the outer control loop is implemented for the current reference generation, where the power is controlled. A proportional resonant (PR) controller provide an infinite gain at a resonant frequency (*f*res) and can be eliminate the steady state error when tracking a sinusoidal signal, which is an index of the power quality. Due to these features, the PR controller is selected instead of the PI controller in the current control loop in this topology[12].The transfer function of this controller can be found as follows.

$$G_{PR}(S) = K_p + \frac{2K_r}{S^2+\omega^2} \quad (4)$$

Where K_p is the proportional gain K_r is the fundamental resonant gain, and ω is the resonant frequency.

The power control loop requires orthogonal signal generation systems to create quadrature components ($v_{g\alpha}$, $v_{g\beta}$ and $i_{g\alpha}$, $i_{g\beta}$) corresponding to the grid voltage v_g and grid current i_g , and then it generates a current reference, which is to be used in the inner current control loop. According to the single-phase *PQ* theory [13], [14], the current reference can be produced by regulating
the active and reactive powers. The active power (*P*) and reactive power (*Q*) for the proposed topology can be calculated by [15]

$$P = \frac{V_{g\alpha} i_{g\alpha} + V_{g\beta} i_{g\beta}}{2} \quad (5)$$

$$Q = \frac{V_{g\alpha} i_{g\alpha} - V_{g\beta} i_{g\beta}}{2} \quad (6)$$

Where, $V_{g\alpha}, i_{g\alpha}, V_{g\beta}, i_{g\beta}$ are the α *and* β components of grid voltage and grid current ,respectively. The active power and reactive power reference (P^* and Q^*) can be tuned by the operators{R-3} or in the control unit, When the MPPT control is activated.The current reference can be computed in th*e* $\alpha\beta$ –reference frame, which simplifies the overall control. Fuzzy logic ic connected in between MPPT and PR controller.fuzzy logic is used inorder to eliminate the leakage current.[16]

TABLE-1 PARAMETERVALUES:

PARAMERTER	VALUE	PARAMERTER	VALUE
Power rating (P)	500W	Capacitance (C1)	220μF,500V
Input volatge (Vdc)	400V	Capacitance (C2)	330μF,500V
Output voltage (V_{as})	220V(RMS)	L filter (Lf)	4mH
Input capacitor (C_a)	470μF,500V	C filter (Cf)	2.2μF
Power switches (S1-S4)	C2M0080120D,SIC MOSFET	L_g	2mH
Diodes (D1-D2)	C3D10060A schotty Diode	switching frequency (fs)	24KHz

TABLE-2 SPECIFICATIONS AND POWER DEVICES FOR EFFICIENCY

parameters	value
Input voltage	400v
Grid voltage/frequency	220v/50HZ
Rated power	500W
AC output current(RMS)	2.3A
switching frequency	24kHZ
Duty ratio (M)	0.78
MOSFET switches	C2M0080120D, R_{ds}=0.05
Diode (D1-D2)	C3D10060A, V_f=0.7v, R_{ak}=0.01

SIMULATION:

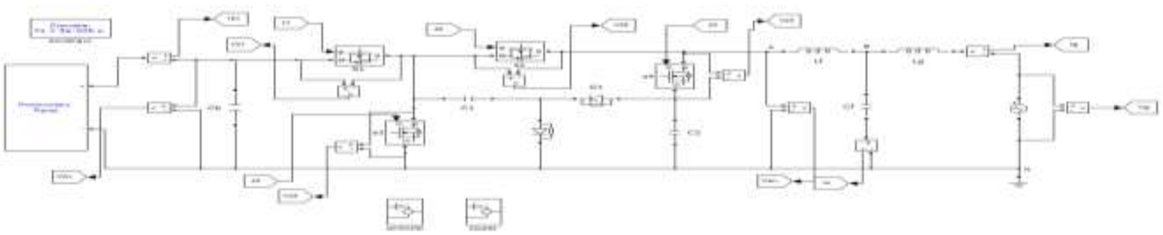


FIG 25: single phase grid tied inverter by using fuzzy logic control

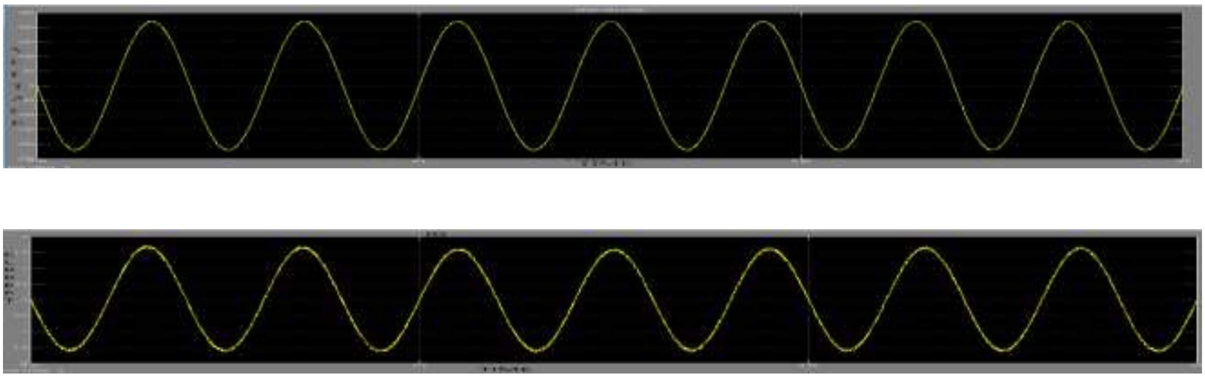


FIG 26.waveform of grid voltage and current by using fuzzy logic control

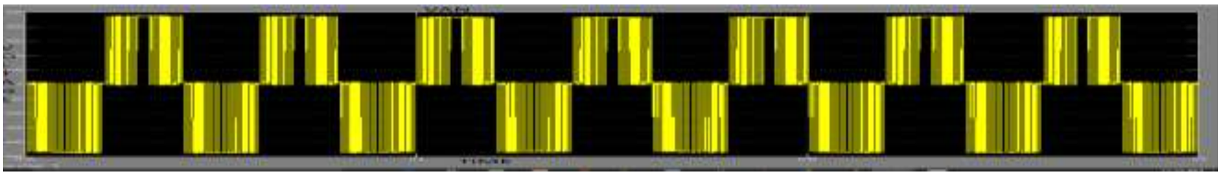
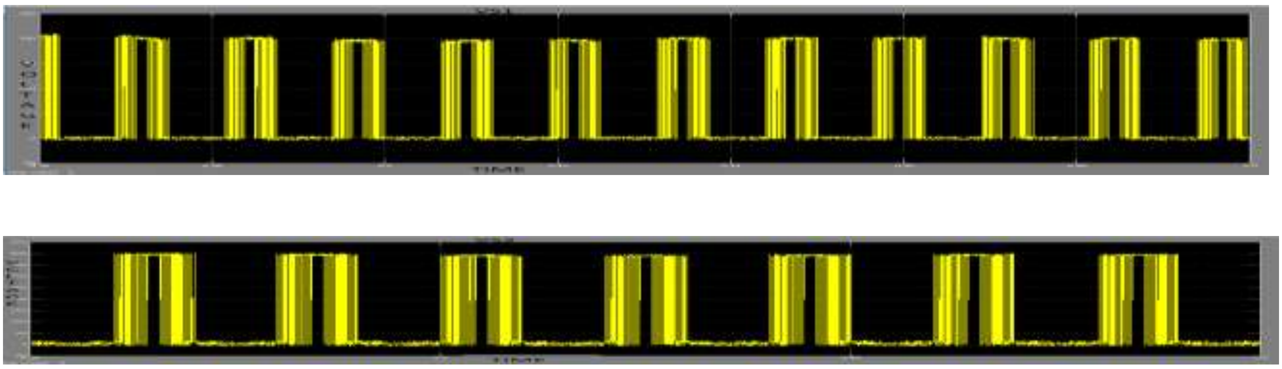


FIG 27: waveform of van



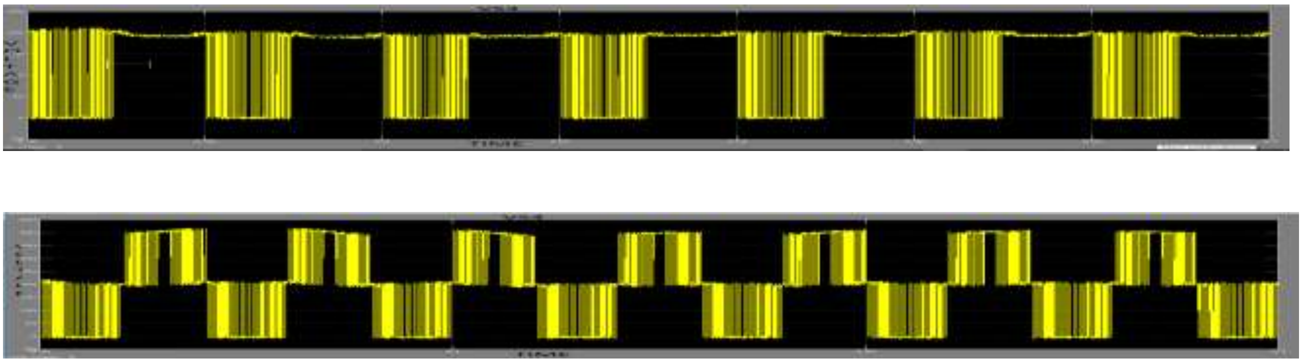


FIG 20: waveforms of drain source voltage of switches

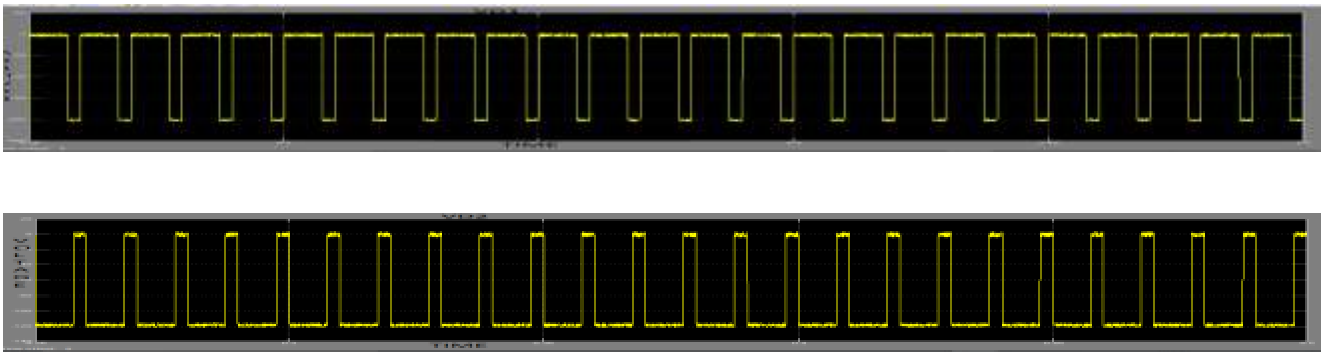


FIG 22: waveforms of diode voltage

CONCLUSION:

This paper proposed a new single-phase transformerless inverter for the grid-tied PV system using a charge pump circuit concept. The concept is proposed to generate the negative output voltage in the proposed inverter.. The proposed topology has also the ability to deliver reactive power into the grid. In addition, the proposed topology can be realized with a minimum number of components; hence, a higher power density can be achieved with the lower design cost. Compared to other existing transformerless topologies, the performance depicted by the proposed inverter is good. fuzzy logic control is used to eliminate the leakage currents.by using this fuzzy logic control leakage currents are eliminated.

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