Implementation of Single Phase Transformer less Inverter for Grid-Tied Photovoltaic System with Reactive Power Control

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***Abstract*- Now a day's Transformer less inverter has been an increasing interest due to its low cost, high efficiency and light weight. We proposed to convert the Solar PV DC voltage into AC voltage by using inverter and boost converter. The solar PV voltage is converted into pure DC and applied to boost converter which increases the solar PV's efficiency. Then the output of boost converter which is DC voltage is given to single phase inverter. Output of boost converter will convert the DC voltage into sinusoidal AC output voltage. Reactive power exists whenever voltage and current not in phase. Whenever there is variation in load, we can control reactive power by injecting or absorbing the power into the utility grid. All the devices are simulated in MATLAB and Hardware implemented by using AT89C52 Microcontroller.**

***Keywords*- Transformer less, High efficiency, Boost Converter, Solar PV system, Reactive power**

I. INTRODUCTION

Photovoltaic (PV) cells are made of special materials called semiconductors such as silicon, which is currently the most commonly used. Basically, when light strikes the cell, a certain portion of it is absorbed within the semiconductor material. PV cells have one or more electric fields that act to force electrons freed by light absorption to flow in a certain direction. This flow of electrons is a current, and by placing metal contacts on the top and bottom of the PV cell, we can draw that current off to use externally. Solar Panel Expose the cell to light and the energy from each photon (light particle) hitting the silicon, will liberate an electron and a corresponding hole. If this happens within range of the electric field's influence, the electrons will be sent to the N side and the holes to the P one, resulting in yet further disruption of electrical neutrality. This flow of electrons is a current; the electrical field in the cell causes a voltage and the product of these two is power. Boost converter is a step up chopper which is used for boosted the output. The inductor, a diode, & a high frequency switch are the important component of a boost converter. Boost converter also having a duty ratio, if the duty ratio is greater than 1 then only it is boost otherwise if the duty ratio is less than 1 then it is called as buck converter. Now it is necessary to increase the efficiency of solar PV DC voltage for that purpose, the MPPT technique is used to improve the system performance.

The main focus of the system to design the transformerless inverter to reduce the cost, more compact than inverter with transformer, lighter & inexpensive. For maintaining the voltage stability reactive power injection or absorption should be necessary. MOSFET is switches used having low conduction and switching losses. Voltage instability problem occurs during heavy loading condition. Whenever whole system working under active power control then voltage and current are in phase. On other hand system under reactive power control the current lead or lags voltage depending upon the loading conditions whether it may be inductive or capacitive The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to our proposed system and to many embedded control applications.

II. SYSTEM STRUCTURE

As shown in block diagram fig(1) involves solar PV having variable DC voltage which is to be boosted by boost converter i.e., step up chopper and then after it is to be converted into AC by inverter and getting appropriate AC output. For removing the unwanted harmonics it is necessary to connect a filter to inverter. Due to this the variable AC which is coming from the output of inverter is getting pure. After getting the AC sinusoidal waveform we transform that power by connecting transformer and feeding to load. All the system controlled by AT89S52 Microcontroller which required 5V DC power and Driver Circuit required 12V DC supply.

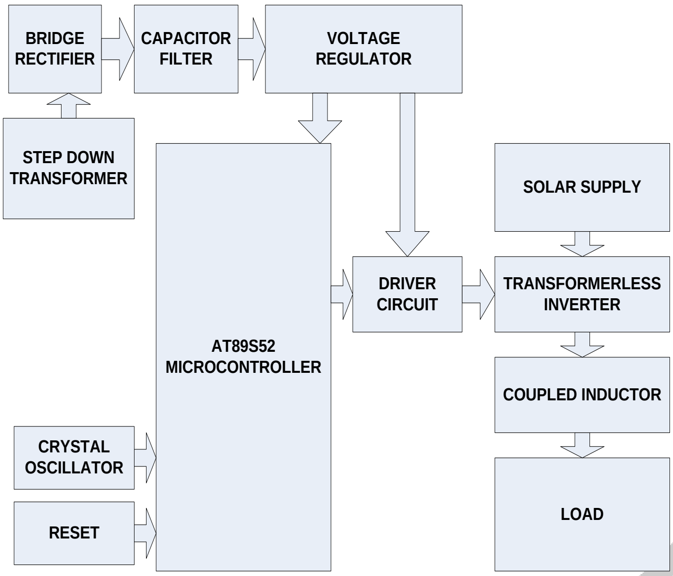

Figure1. Block Diagram

III. MICROCONTROLLER(AT89S52)

The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry.

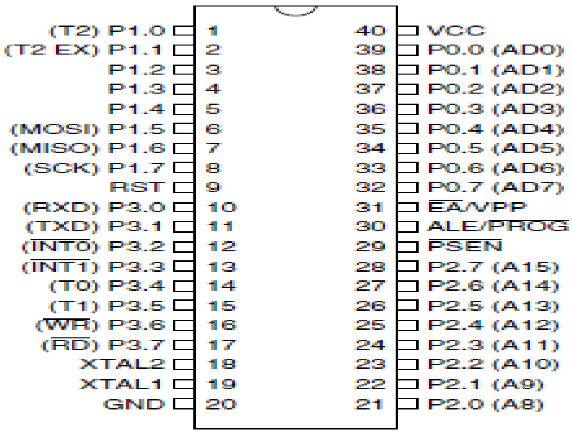

Figure2: Pin Diagrams of AT89S52 Microcontroller

A. Power Supply

To operate Microcontroller and Relay 5V DC and 12V DC power supply is needed respectively. The AC voltage is connected to Step down Transformer, which steps down AC voltage amplitude. To rectify signal a full wave bridge rectifier this gives pulsating DC. Capacitor filter connected in parallel with the load gives DC voltage which contains ripple in it. To get pure DC regulator IC (7805 for +5V, 7812 for +12V) is used.

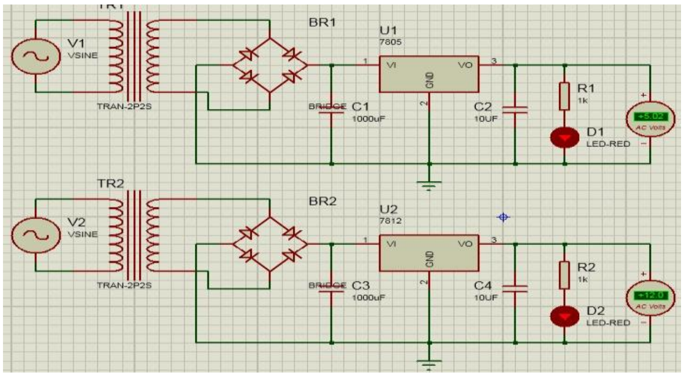

Figure 3: Circuit Diagram and Simulation of Power Supply Circuit

IV. SOLAR PHOTOVOLTAIC

A Photovoltaic cell getting the incident photon or light energy which is coming from sunlight and due to this, it creates the electrons holes and the PN junction which separates this charge carriers.

$$I = Iph - Ir \times e^{((q \times (V + I \times Rs)) / (A \times K \times T))} \quad (1)$$

$$Iph = [Isc + Ki \times (T - 298)] \times (G / 1000) \quad (2)$$

Where, Iph- PV current
q- Electron Charge
k- Boltzmann constant
A-Ideality factor
Ki- Short circuit Coefficient
Isc- Short circuit current
G- Irradiation
T- Temperature
Rs- Series resistance
Rsh- parallel resistance

A. Simulation of solar photovoltaic system

The simulation diagram of solar is shown in fig(4)by taking the idea from international journals and conferences simulation of solar has been done . By using the solar system as a source getting DC output depending upon the rating of solar PV.

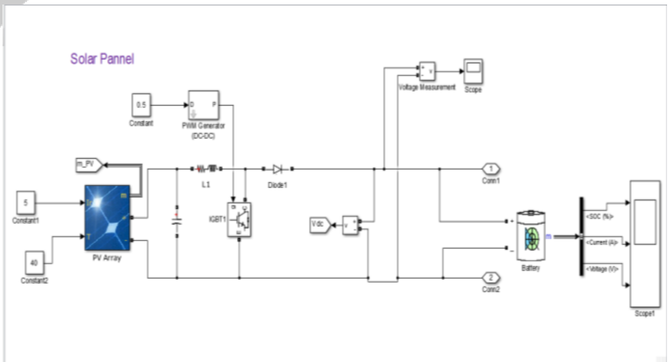

Figure 4:Simulation of solar photovoltaic

The Equation of Current of Single Solar PV Cell is,

$$I = w \times \{1 - t\, e^{((u-p)/(s \times r))} - 1\} + q \quad (3)$$

Where,

$$q = [(T - T_{ref} \times S)/\, S_{ref}] + [\,(S/\, S_{ref}) - 1] \quad (4)$$

Since,

$$Isc = [\,(S/S_{ref}) - 1] \quad (5)$$

From Equation (3), Where,

$$p = (T - T_{ref}) + q \quad (6)$$

$$s = ((Vm\ /Voc) - 1) \times (\,1/\,(\log(1 - (Im\ /\ Isc))) \quad (7)$$

$$t = (1 - Im\ /\ Isc) \times [(Vm\ /\ Voc - 1)\,(\,1/\,(\log(1 - (Im\ /\ Isc)))] \quad (8)$$

$$u = Vout \quad (9)$$

$$w = Isc \quad (10)$$

$$r = Voc \quad (11)$$

B. Boost Converter

From solar PV cell we getting the DC Voltage as output .By using the boost converter we can boost the output voltage. It will be converted to pure DC by using step-up chopper having the duty ratio is selected to in between 0.5 to 1.

V. SINGLE PHASE INVERTER

Inverter is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source.

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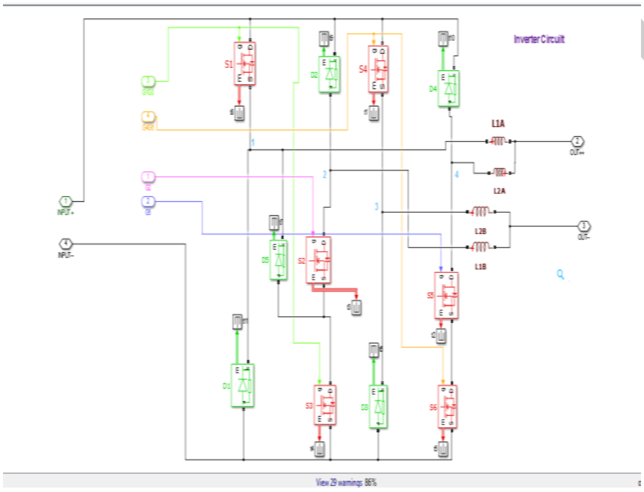


Figure5 Circuit Diagram and Simulation of Inverter Circuit

A.SWITCHING MODE OF INVERTER

There are many inverter topologies has been proposed, in this work Highly Efficient and Reliable Inverter Concept (HERIC) is used. It consist of six switches and six diodes G1, G2, G3, G4, G5, G6 &D1-D6 respectively.

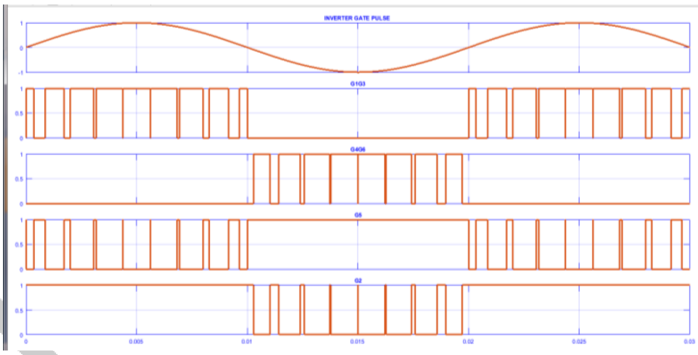


Figure 6:Switching pattern

VII .SIMULATION RESULT

A. SIMULATION OF OVERALL SYSTEM

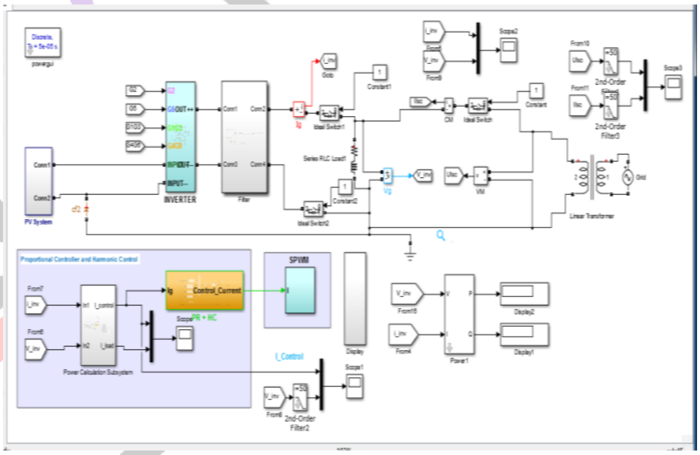
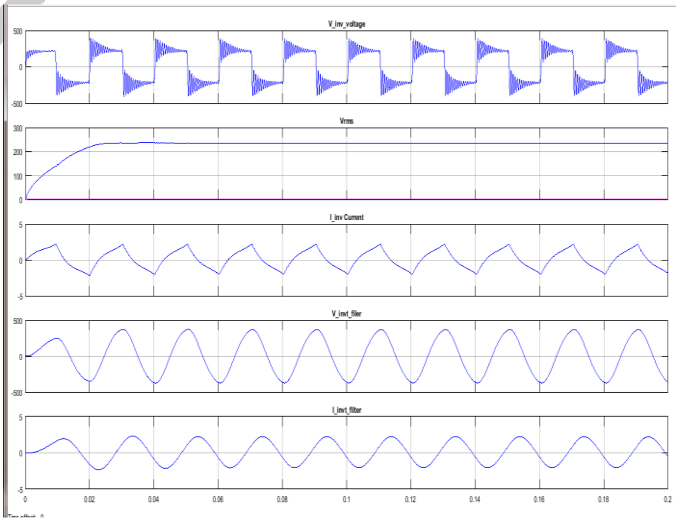


Figure 7 simulation of overall system

1. Inverter output



2.Active power control

In the refeance of the active power control grid current and voltage are in phase.This will be done by using PRcontroller.

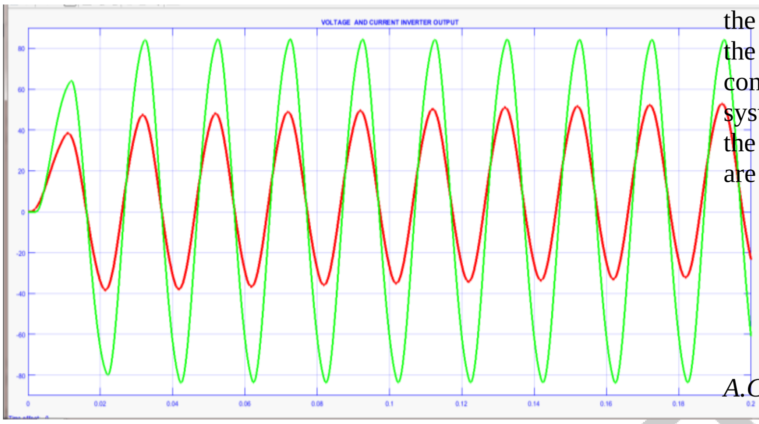


Figure 8: simulation result of active power

3. Reactive power Injection

The fig shows the reactive power injection in the utility grid .The grid current lags the voltage therefore we can say that there is injection of reactive power in the grid.

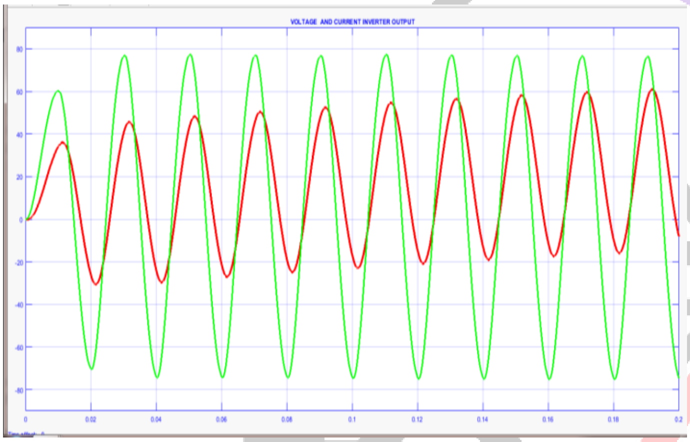


Figure 9: simulation result under reactive power injection

VIII. WORKING OF HARDWARE

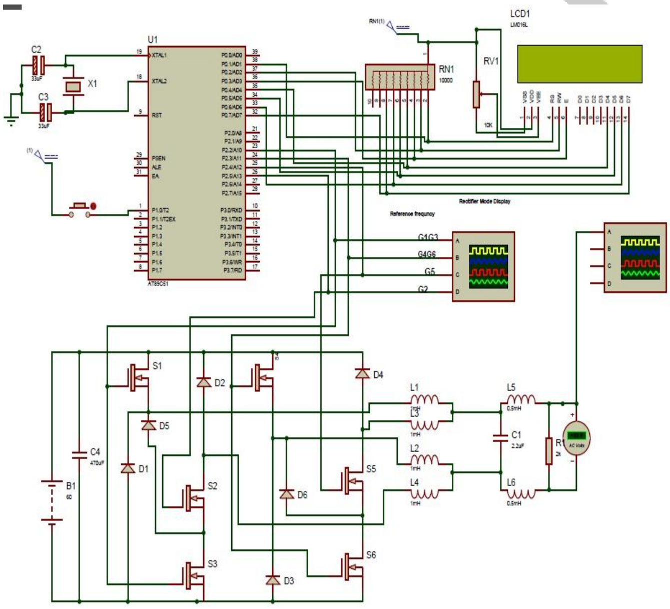


Figure 10: Overall System of hardware

The control strategy for whole circuit has been done by using microcontroller .For the inverter circuit we are using MOSFET.The gate pulse are given to the MOSFET by using microcontroller.When the solar supply is given to the circuit the solar output is connected to the boost converter to boost up the voltage.The boosted voltage is given to the inverter after connected the load.when we connect the load the whole system work under reactive power control.When disconnect the load the system work under active power .The both signal are given to the microcontroller and result display on LCD.

IX. HARDWARE RESULT

The results of hardware as shown in below

A.Complete hardware

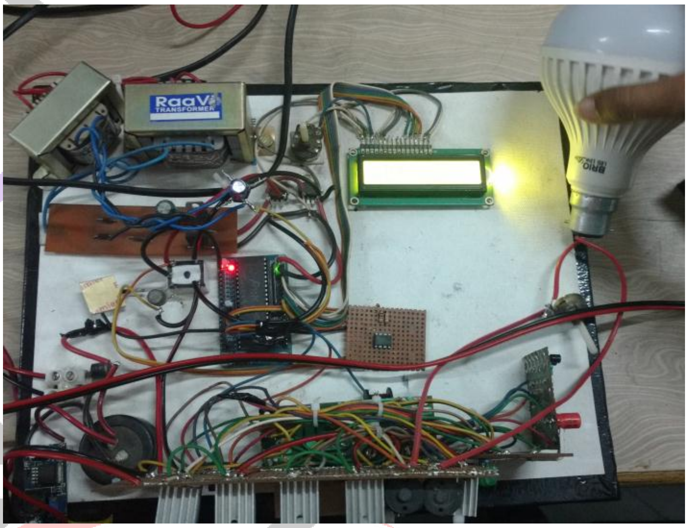


Figure11: Hardware Implementation of Proposed System

B. Solar System

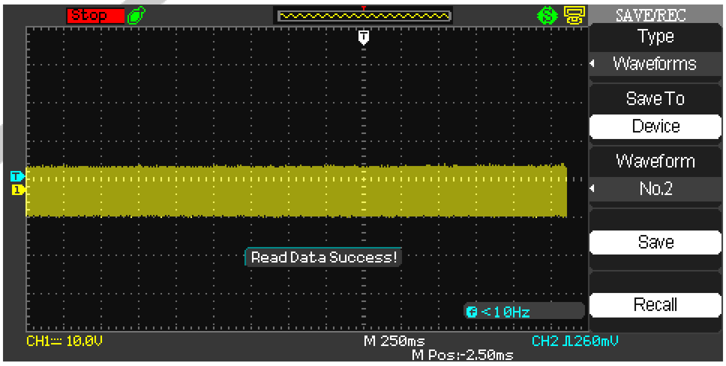


Figure 12:solar panel output

C.Inverter Output

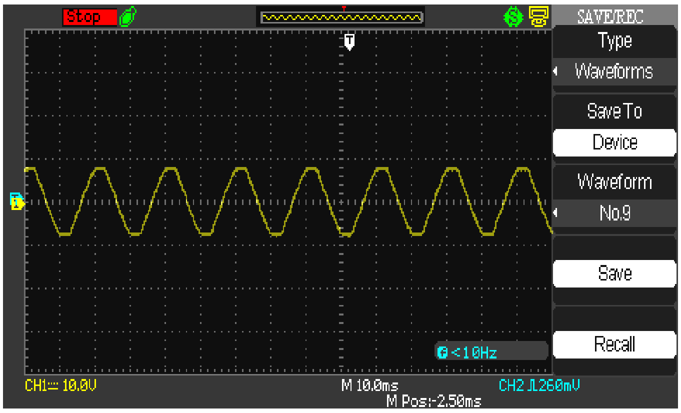


Figure 13:Inverter output waveform

X. CONCLUSION

A Single Phase Transformer less Inverter technique have been discussed, simulated, and tested in hardware. The proposed circuit has numerous benefits and reduced cost. Proposed system simulated in MATLAB and implemented using AT89S52 Microcontroller. In this way we achieve the result by using H-bridge inverter topology .We can reduce the cost, more compact less leakage current losses without using the transformer. We can get more efficient inverter overall efficiency get increased. Result shows that The solar PV output voltage is constant 50V DC and when synchronized with boost converter it get boosted up to 150V DC .

REFERENCES

[1] Monirul Islam, Nadia Afrin, and Saad Mekhilef, "Efficient Single Phase Transformerless Inverter for Grid-Tied PVG System With Reactive Power Control", IEEE TRANSACTIONS ON SUSTAINABLE ENERGY.

[2] I. Patrao, E. Figueres, F. González-Espín, and G. Garcerá, "Transformerless topologies for grid-connected single-phase photovoltaic inverters," Renew. Sustain. Energy Rev., vol. 15, pp. 3423–3431, 2011.

[3] M. Islam, S. Mekhilef, and M. Hasan, "Single phase transformerless inverter topologies for grid-tied photovoltaic system: A review," Renew. Sustain. Energy Rev., vol. 45, pp. 69–86, 2015.

[4] Y. Yang and F. Blaabjerg, "Low-voltage ride-through capability of a single-stage single-phase photovoltaic system connected to the low voltage grid," Int. J. Photoenergy, vol. 2013, pp. 1–9, 2013.

[5] S. B. Kjaer, J. K. Pedersen, and F. Blaabjerg, "A review of single-phase grid-connected inverters for photovoltaic modules," IEEE Trans. Ind. Appl., vol. 41, no. 5, pp. 1292–1306, Sep./Oct. 2005.

[6] X. Huafeng and X. Shaojun, "Leakage current analytical model and application in single-phase transformerless photovoltaic grid-connected inverter," IEEE Trans. Electromagn. Compat. vol. 52, no. 4, pp. 902–913, Nov. 2010.

[7] B. Farhangi, "Power Conditioning for Plug-In Hybrid Electric Vehicles," Texas A&M University, 2014.

[8] S. Wencong, H. Eichi, Z. Wente, and C. Mo-Yuen, "A Survey on the Electrification of Transportation in a Smart Grid Environment," Industrial Informatics, IEEE Transactions on, vol. 8, pp. 1-10, 2012.
.

[9] A. Ramezani, S. Farhangi, H. Iman-Eini, and B. Farhangi, "High efficiency wireless power transfer system design for circular magnetic structures," in Power Electronics and Drive Systems Technologies Conference (PEDSTC), 2016 7th, 2016, pp. 565-570.
.

[10] S. V. Araujo, P. Zacharias, and R. Mallwitz, "Highly efficient single-phase transformerless inverters for grid-connected photovoltaic systems," IEEE Trans. Ind. Electron., vol. 57, no. 9, pp. 3118–3128, Sep. 2010.