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An Intelligent Grid-Tied PV System with Dual-Charge Pump Circuits for Single-Phase Transformerless Inverters

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Abstract: Using a single-phase solar inverter without a transformer, we design a grid-connected photovoltaic system in this article. In order to stop the flow of water, we are creating a new topology that uses the electric pump concept. For control in this study, a fuzzy logic controller was employed. This paper describes a new transformer-less inverter that uses pulse width modulation

Keyword: Circuit charge by pumping (CPC), dual pumping system, transformer-less inverter.

I. INTRODUCTION

In the past twenty years, photovoltaic systems have become more and more common. However, they, are noisy, emit no pollutants or pollution, and need maintenance. On the other hand, the photovoltaic system will produce a form of current that will damage the system's operation and assure safety.

As a result, removing the transformer helps the system function more effectively overall and is smaller and lighter. This paper describes a new transformer-less inverter that uses pulse width modulation (SPWM) to reduce the current flow in the photovoltaic grid and is based on the idea of electric power charging.

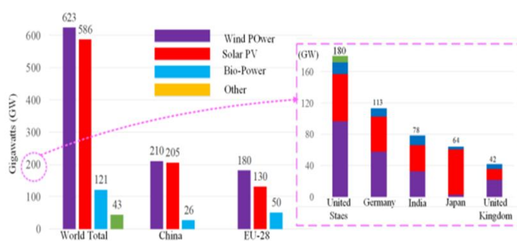


Fig 1.1 Solar, wind, and bio-power data of some biggest nations of the

Three-quarters of all global output is produced in Chine. China is the biggest renewable energy source are produced according to fig 1.1. One of the reasons of that is non-polluting.it is no harmful for nature. On the other hand, it reduce the loss of the current.

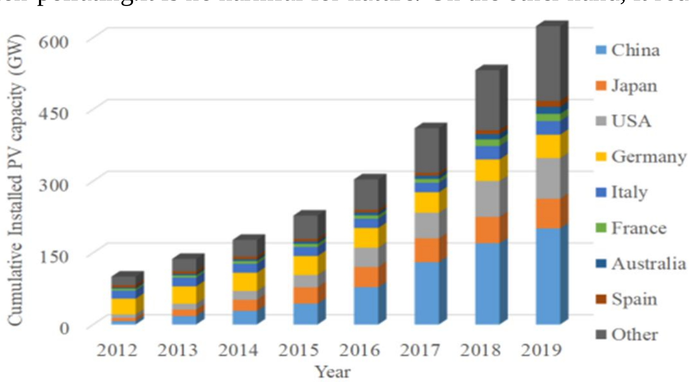


Fig 1.2 Yearly data of solar installation

This data shows how energy sources have become used more or more by early. This graph is increasing year by year. The price of solar energy is steadily declining.

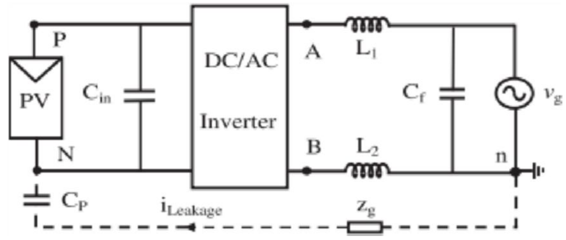


Fig 1.3 Illustration of loss of current in dc to ac inverter

The above fig 1.3 shows that the input is connected to the photovoltaic system to the inverter and the output is connected to the grid. L1 and L2 filter. Ig is the loss of current. V_{CM} is the voltage across the system and the base.

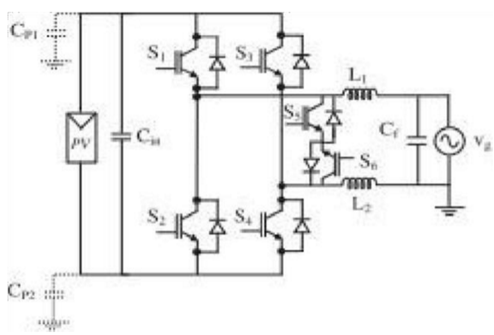
$$V_{cm} = \frac{V_{An}+V_{Bn}}{2} + \frac{(V_{An}-V_{Bn})(L_1-L_2)}{2(L_1+L_2)} \qquad (1)$$

$$V_{cm} = \frac{V_{An}+V_{Bn}}{2} = Constant \qquad (2)$$

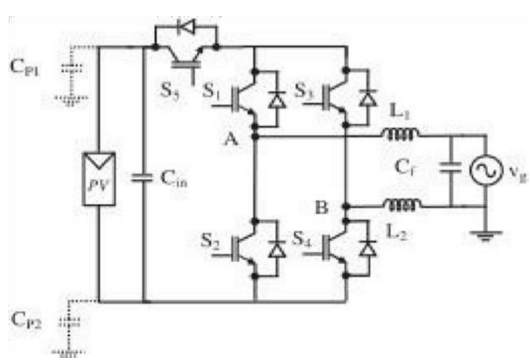
$$V_{cm} = \frac{V_{An}+V_{Bn}}{2} + \frac{(V_{An}-V_{Bn})}{2} = Constant(L_1=0)$$

Then,

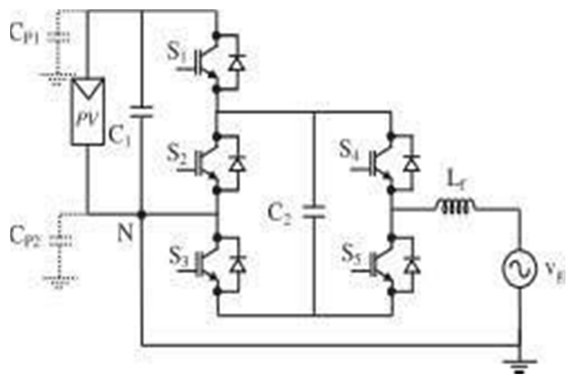
$$V_{cm} = \frac{V_{An}+V_{Bn}}{2} - \frac{(V_{An}-V_{Bn})}{2} = Constant(L_1=0) \quad (3)$$



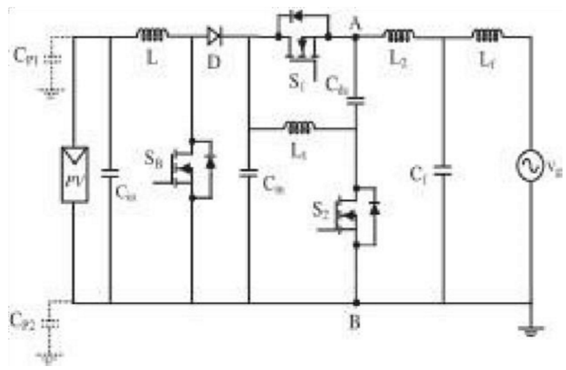
(a) H5 Inverter



(b) HERIC Inverter



(c) Dc bus Inverter



(d) Cm Inverter

This inverter is based on CPC (Charge Pump Circuit). The suggested configuration uses just 4 energy switches, cutting the price of electronic components and boosting the electrical performance through a 3-step voltage that decreases the current stream amplification. The research presented here proposes an innovative transformerless inverter designed around the CPC theory, which reduces the current loss of solar energy connected to the grid utilizing a sinusoidal pulse width modulation (SPWM) strategy.

II. TOPOLOGY AND MODULATION

A. CPC Structure

The CPC is the pump circuit. There is 2 diode, 2 capacitors interconnected to each other. Current flows through the positive to negative points.

$$V cm = -Vdc + V cut - in - D_1 + Vcut - in - D_2 \quad (4)$$

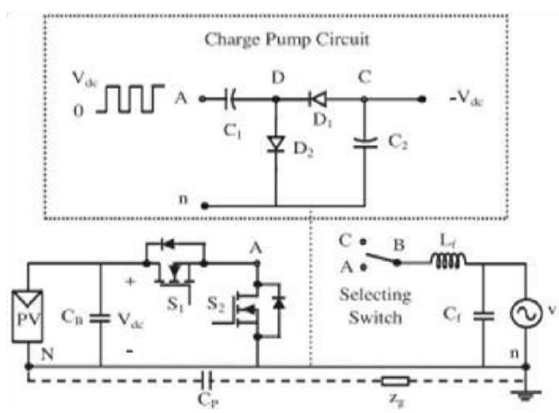


Fig 2.1 CPC with inverter

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B. Methodology

There is 4 switch circuit are represented. If D_1 is forward then C_2 is conduct and D_2 is reverse2.d then C_1 charges by $D_{1.}$

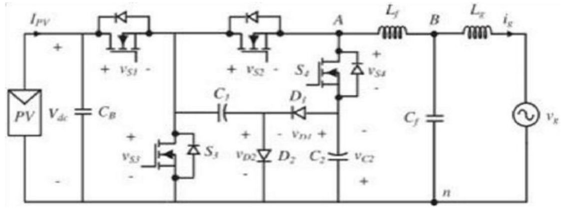

Fig 2.3 Transformerless inverter proposed

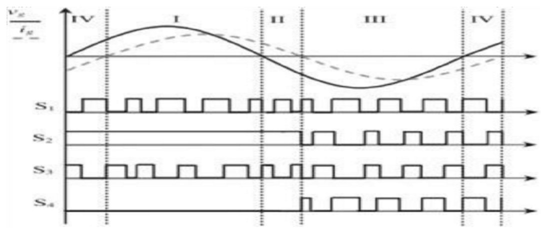

Fig 2.4 Switching pattern energy

Energy is flow from the inverter to the grid.

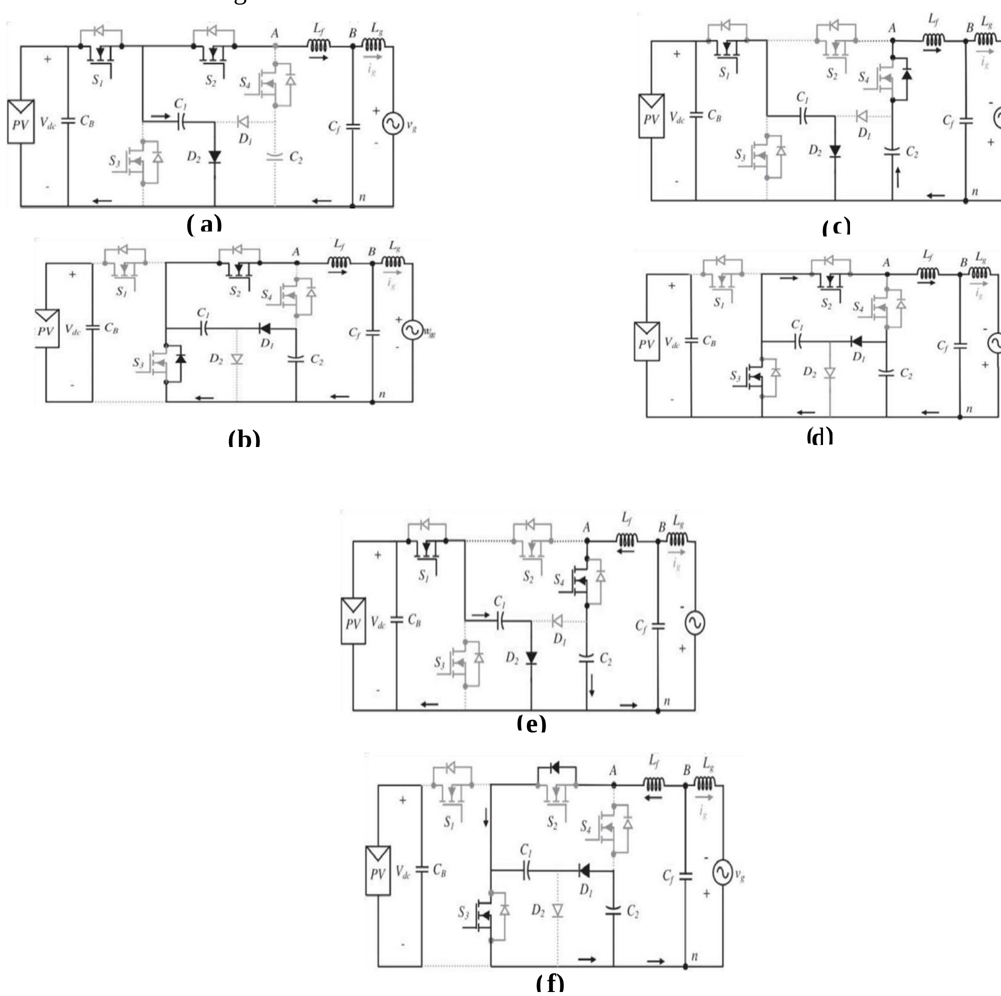

Fig 2.5 different inverter structure

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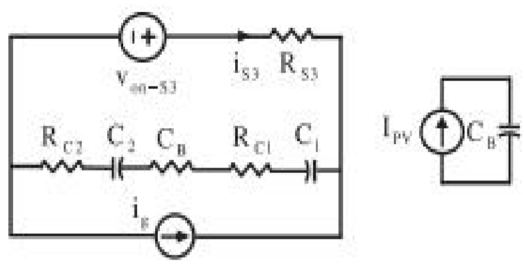
$$iCapacitors = Ce1 \frac{VC1 - VC2}{\tau C_2} \qquad (6)$$

$$\tau C2 = \mathrm{Re}\,1Ce1 \qquad (5)$$

Equation (6) and (5) there is very miner difference between them

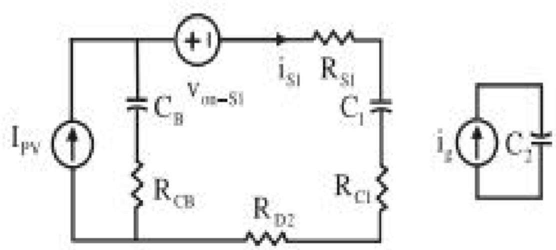
III. ANALYSIS OF TOPOLOGY



(a) Zero mode

$$\frac{dv_{diff,1}}{dt} = \frac{v_{diff,1} - R_{s3} i_g}{(R_{e1} + R_{s3}) C_{e1}} \qquad (7)$$

$$\frac{dv_{diff,2}}{dt} = \frac{I_{pv}}{C_B} - \frac{v_{diff,1} - R_{s3} i_g}{(R_{e1} + R_{s3}) C_1} \qquad (8)$$



(b) – ve mode

$$\frac{dv_{diff,1}}{dt} = \frac{R_{Cb} I_{pv} + dv_{diff,2}}{(R_{cb} + R_{e2}) C_1} + \frac{i_g}{C_2} \qquad (9)$$

$$\frac{dv_{diff,2}}{dt} = \frac{I_{pv}}{C_B} + \frac{R_{cb} I_{PV} - v_{diff,1}}{R_{e2} C_{e2}} \qquad (10)$$

$$R_{e2} = R_{D2} + R_{s1} + R_{C1} + R_{CB}, C_{e2} = \frac{C_1 C_B}{C_1 + C_B} \qquad (11)$$

Equation (11) is shows that the mathematical representation of the resistance and capacitor of the system

$$\frac{dv_{diff,1}}{dt} = (1+s(t))\frac{v_{diff,1} - R_{s3} i_g}{(R_{e1} + R_{e2}) C_{e1}} - s(t)\left(\frac{R_{CB} I_{PV} + v_{diff,2}}{(R_{CB} + R_{e2}) C_1} + i_g C_2\right) \frac{dv_{diff,2}}{dt} = (1+s(t))\left(\frac{I_{PV}}{C_B} - \frac{v_{diff,1} - R_{s3} i_g}{(R_{e1} + R_{e2}) C_1}\right) - s(t)\left(\frac{I_{PV}}{C_B} + \frac{R_{CB} I_{PV} + v_{diff,2}}{(R_{e2} + C_{e2})}\right) \qquad (12)$$

$$s(t) = \begin{cases} 1 \text{ when the circuit is at positive state} \\ 0 \text{ when the circuit is at zero state} \\ -1 \text{ when the circuit is at negative state} \end{cases}$$

$$\langle i_{s1,\max}\rangle T=\frac{1}{2}\left(\frac{C_1}{C_1+C_2}+1\right)\left(\frac{MI_m}{1-M}+\frac{T_s}{R_{e1}C_{e1}}\frac{1-M}{2}\right) \quad (15)$$

$$\langle i_{s3,\max}\rangle T=\frac{1}{2}\left(\frac{C_1}{C_1+C_B}+1\right)\left(\frac{MI_m}{1-M}+\frac{T_s}{R_{e2}C_{e2}}\frac{1-M}{2}\right) \quad (16)$$

$$i_c = C\frac{\Delta v_c}{\Delta t} \quad (17)$$

$$C_1 \text{ or B} = \frac{I_{C1} \text{ or B } (\max)}{\wedge (V_r V_n) f} \quad (18)$$

$$\text{MOSFET: } v_{Ds}(t) = i(t) R_{DS} \quad (19)$$

$$\text{Diode: } v_{AK}(t) = V_F + i(t) R_{AK} \quad (20)$$

Where,
V_{DS} = drain source voltage,
R_{DS} = drain source resistance,
V_{AK} = anode cathode voltage,
V_F = equivalent voltage

$$P_{MOSFET\_Cond} = \frac{1}{\pi}\int_0^{\pi} v_{DS}(t) i(t) d_{MOSFET}(t) d\omega t \quad (21)$$

$$P_{Diode\_Cond} = \frac{1}{\pi}\int_0^{\pi} v_{AK} i(t) d_{Diodes}(t) d\omega t$$
$$= \frac{1}{\pi}\int_0^{\pi} v_F i(t) R_{AK} i(t) d_{Diodes}(t) d\omega t \quad (22)$$

$$P_{MOSFET\_SW} = f_{SW} E_{OSS} V_F \quad (23)$$

$$P_{Total\_SW} = 4 f_{SW} E_{OSS} V_F = 3.46W \quad (24)$$

$$P_{CAP\_Cond\_1} = \frac{2(R_{C1}+R_{CB})}{\pi}\int_0^{\pi} d_c(t) i_{s1}^2(t) d\omega t \quad (25)$$

$$P_{CAP\_Cond\_2} = \frac{2(R_{C1}+R_{C2})}{\pi}\int_0^{\pi} d_c(t) i_{s3}^2(t) d\omega t \quad (26)$$

It shows that loses of the capacitor.

$$G_{PR(s)} = K_p + \frac{2K_r}{s^2+\omega^2} \quad (27)$$

$$P = \frac{v_{g\alpha} i_{g\alpha} + v_{g\beta} i_{g\beta}}{2}, Q = \frac{v_{g\alpha} i_{g\alpha} - v_{g\beta} i_{g\beta}}{2} \quad (28)$$

Equation (28) shows the value of the current and voltage components of the gird.

$$L_f = \frac{(v_{dc} - v_{An})\,(M \sin \omega t)}{f_{SW} \Delta i_L} \qquad (30)$$

$$v_{An} = M V_{dc} \sin \omega t \qquad (31)$$

$$L_f = \frac{(v_d)\,(RF)}{f_{SW} \Delta i_L} \qquad (32)$$

Equation 30,31 and 32 are observed and put value R_f form equation 33

$$RF = M \sin \omega t - M^2 \sin^2 \omega t \qquad (33)$$

C_f represents the f is frequency, V if the voltage of the system and P is the power. Equation (35) shows that the grid and inverter inductor are directly proportional to each other but the attenuation constant are present in between these two inductor.

$$C_{F,\max} = \frac{0.05 P_n}{2\pi f V_{rms}^2} \qquad (34)$$

$$L_g = rL_f \qquad (35)$$

IV. FUZZY LOGIC CONTROLLER

Fuzzy controller are basically used for the numerical value converted into logical value. This controller gives logical expression. It is true or false and 1 or 0. There are some basic rule present in this controller. There are three type of this controller. That is shown in fig 4.1

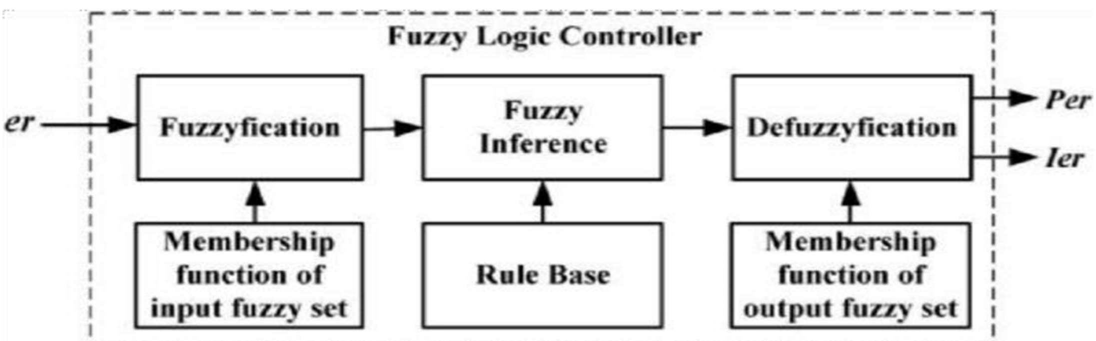


Fig 4.1 FLC

e / ė	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Fig 4.2 Rules

There is some rules shown in fig 4.2, which is the seven set of fuzzy input and fuzzy output, the "min" operation and each set are used as a triangular form.

$$E(k) = \frac{P\,ph\,(k) - Pph\,(k-1)}{Vph\,(k) - Vph\,(k-1)} \quad (36)$$

$$CE(k) = E(k) - E(k-1) \quad (37)$$

$$u = -[\,\alpha_{E} = (1-\alpha)*C] \quad (38)$$

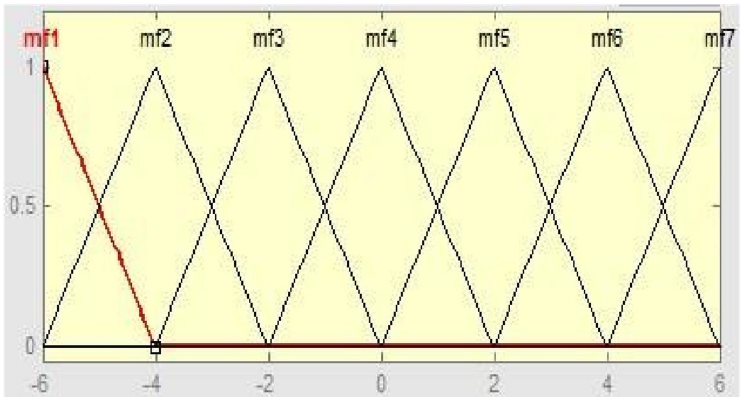


Fig. 8. input error as membership functions

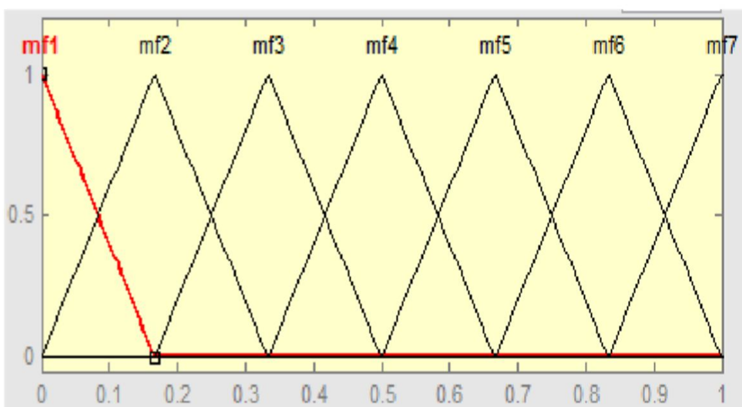


Fig. 9. Change as error membership functions

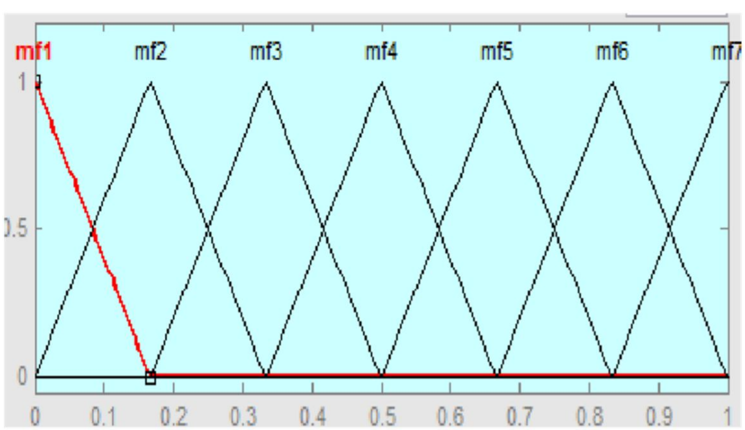


Fig. 10. Output variable membership functions

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Volume 11 Issue VIII Aug 2023- Available at www.ijraset.com

V. SIMULATION RESULTS

Table IV Parameters of the 500 W Prototype

Parameter	Value	Parameter	Value
Power rating (P)	500 W	Capacitance (C_1)	220 μF, 500 V
Input voltage (V_{dc})	400V	Capacitance (C_2)	330 μF, 500 V
Output voltage (v_{Bn})	220 V (RMS)	L filter (L_f)	4 mH
Input capacitor (C_B)	470 μF, 500 V	C filter (C_f)	2.2 μF
Power switches ($S_1 - S_4$)	C2M0080120D, SiC MOSFET	L_g	2 mH
Diodes (D_1, D_2)	C3D10060A Schottky Diode	Switching frequency (f_s)	24 kHz

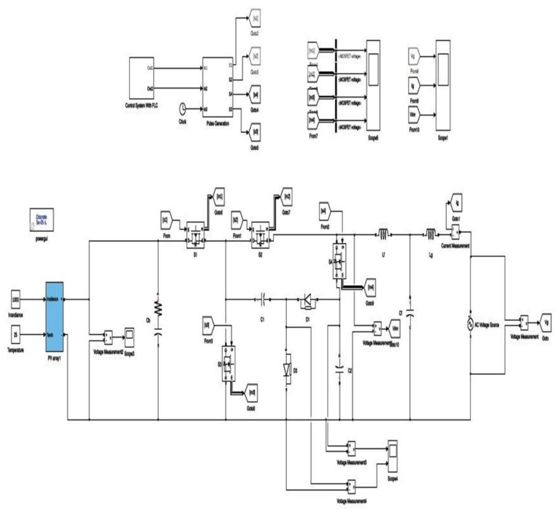

Fig 5.1 MATLAB Model

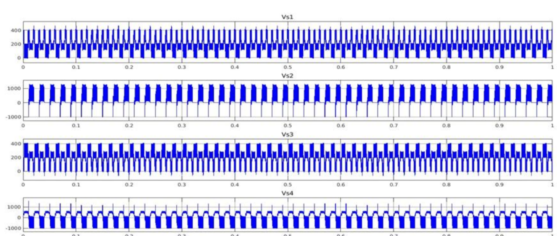

Fig 5.2 switches output

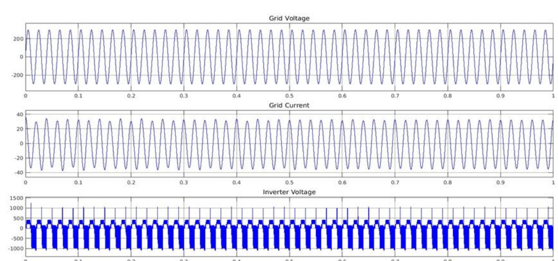

Fig 5.3 Voltage output

There is result shows that fig 5.2 and Fig 5.3,it conduct sinusoidal waves and low disturbances.

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VI. IMPLEMENTED WORK

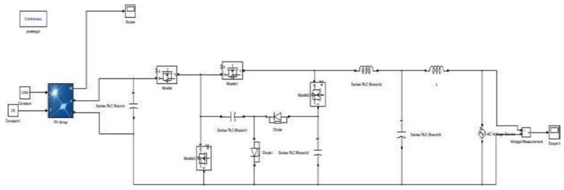

Fig 6.1 MATLAB inverter model

This model are built in MATLAB 2016.

Parameters: **-** For PV array:

- Power: 315W
- Temperature Range: 21 – 36^0 C
- Solar Panel : 15

For Inverter

- maximum input Power: 5.8KW
- maximum input Voltage: 600V
- maximum efficiency: 96.7 %

VII. CONCLUSION

This work is based on the CPC principle. To create the transformer-free inverter to use in solar. With the goal of getting higher reliability, manage algorithms. Fuzzy logic controllers are perfect for this theory. It gets better results for the system to support decisions for future purposes.

VIII. ACKNOWLEDGMENTS

I will be really thankful for my organization's contributions.

It will be very helpful for what I deserve. It will be a pleaser to contribute my own idea in that level to invent the transformerless inverter depending on the CPC. I express my profound gratitude to Prof. Radharaman Saha, Head of the Electrical Engineering Department at TGPCET in Nagpur, to contribute excellent direction, sage counsel. A great deal of gratitude for all of my professors, and sincere gratitude to my friends and family for their steadfast support and huge efforts of this journey.

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