TECHNO INTERNATIONAL NEW TOWN

NEW TOWN , RAJARHAT , KOLKATA – 700156

DEPARTMENT OF ELECTRICAL ENGINEERING

PROJECT REPORT

Three-Port Series-Resonant DC–DC Converter to Interface Renewable Energy Sources

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Supervisor: Monalisa Das

Date of Submission: 07/07/2020

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CERTIFICATE

This is to certify that the project entitled "**Three-Port Series-Resonant DC–DC Converter to Interface Renewable Energy Sources**", submitted in partial fulfillment of the requirement for the award of Bachelor of Technology(B.Tech) in Electrical Engineering of Maulana Abul Kalam Azad University of Technology, West Bengal , carried out by Roll No. 18701616116, Registration No. 161870110479 (of 2016 - 2020) under my guidance and supervision . The result presented in this project has not been submitted to any other University of Institution for any other degree.

Date:-___________________

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Supervisor: Mrs. Monalisa Das
Assistant Professor
Department of Electrical Engineering
Techno International, New Town

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Head of The department
Electrical Engineering
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CERTIFICATE OF APPROVAL

We hereby, have approved the project entitled " **Three-Port Series-Resonant DC–DC Converter to Interface Renewable Energy Sources** " under the guidance of Mrs.Monalisa Das, Assistant Professor, Techno International, New Town in partial fulfillment as the final year project of domain Electrical Engineering.

Date:_________________

Signature of Examiner(s):

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ACKNOWLEDGEMENT

Project of such comprehensive coverage cannot be realized without help from the numerous sources and people in the organization.

We would like to take this opportunity to show our gratitude towards our supervisor Mrs. Monalisa Das, Assistant Professor, Electrical department, TINT, who has helped us in bringing the project to its present form. She has been a sole motivator & a source of inspiration for us to carry out the necessary proceeding for the project. We are also highly obliged to all the respected faculty members for their constant help and encouragement. They have helped us a lot during this training period and thereby We could successfully complete our report.

Finally, We would like to take this opportunity to thank the college TINT for giving me an opportunity to acquire proper knowledge in our project.

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(Report Submitter)

ABSTRACT

In this project, a three-port converter with three active full bridges, two series-resonant tanks, and a three-winding transformer is proposed. It uses a single power conversion stage with high-frequency link to control power flow between batteries, load, and a renewable source such as PV cell. The converter has capabilities of bidirectional power flow in the battery and the load port. Use of series-resonance aids in high switching frequency operation with realizable component values when compared to existing three-port converters with only inductors. The converter has high efficiency due to soft-switching operation in all three bridges. Steady-state analysis of the converter is presented to determine the power flow equations, tank currents, and soft-switching region. Dynamic analysis is performed to design a closed-loop controller that will regulate the load-side port voltage and source-side port current. Design procedure for the three-port converter is explained and experimental results of a laboratory prototype are presented.

INTRODUCTION:

Future renewable energy systems will need to interface several energy sources such as fuel cells, photovoltaic (PV) arrays with the load along with battery backup. A three-port converter finds applications in such systems since it has advantages of reduced conversion stages, high-frequency ac-link, multi-winding transformer in a single core and centralized control. Some of the applications are in fuel-cell systems, automobiles, and stand-alone self-sufficient residential buildings.

A three-port bidirectional converter has been proposed for a fuel-cell and battery system to improve its transient response and also ensure constant power output from fuel-cell source. The circuit uses phase-shift control of three active bridges connected through a three-winding transformer and a network of inductors.

Since the power flow between ports is inversely proportional to the impedance offered by the leakage inductance and the external inductance, impedance has to be low at high power levels. To get realizable inductance values equal to or more than the leakage inductance of the transformer, the switching frequency has to be reduced. Hence, the selection of switching frequency is not independent of the value of inductance. A series-resonant converter has more freedom in choosing realizable inductance values and the switching frequency, independent of each other. Such a converter can operate at higher switching frequencies for medium and high-power converters. A three-port series-resonant converter operating at constant switching frequency and retaining all the advantages of a three-port structure is proposed. The phase shifts can be both positive and negative, and are extended to all bridges, including the load-side bridge along with bidirectional power flow.

In this project, a three-port bidirectional series-resonant converter is proposed with the following features.

1) All ports are bidirectional, including the load port for applications, such as motor loads with regenerative braking.

2) Centralized control of power flow by phase shifting the square wave outputs of the three bridges.

3) Higher switching frequencies with realizable component values when compared to three-port circuits with only inductors.
4) Reduced switching losses due to soft-switching operation.

5) Voltage gain increased by more than two times due to the phase-shifting between input and output bridges as opposed to a diode bridge at the load side

BI-DIRECTIONAL POWER FLOW:

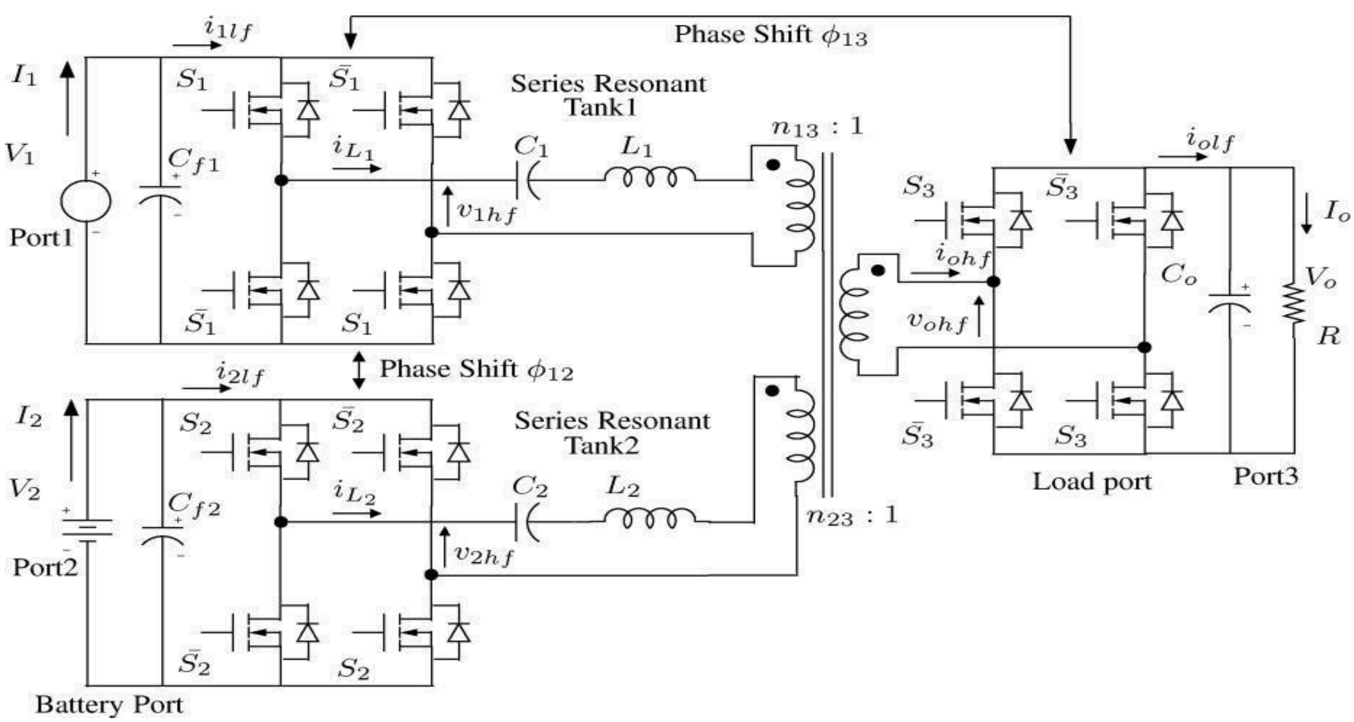
The main concept of our model revolves around what is known as bi-drectional power flow in a dc-dc converter. This phenomenon occurs when both the input and the output are capable of consuming power as well as generating it.In this system the inputs which are the pv array as well as the battery are capable of generation, while pv array might not consume power but if we use rechargeable cells (which can be charged by supplying power to them when circuit has opposite load flow) then we can charge them changing the load flow direction i.e, we can use it with a generator / dc shunt motors with regenerative braking we can charge the battery hence creating a system which is self sufficient and we can use this in many different types of application. During this flow we dis-connect the power from the pv array to ensure it is not harmed (as it a PN junction diode it might burn due to change in direction of the current flow through it).

We have incorporated this bi-directional power flow in our system to increase the number of applications of it. Every converter in this simulink model works as an active frontend converter that means they can act as both ACto DC rectifier or DC to AC inverter depending upon the output provided to them

OBJECTIVE:

The main objective of our project or the purpose of this project is to make a bi-directional dc-dc converter that can interface solar energy or any kind of renewable energy to obtain a safe and efficient source of power as well as to make sure that this type of converter can find applications in the places where there is a lack of conventional energy.

Here the choice of solar energy is mainly due to its availability and it is seen in the past years that solar energy is being studied as the best choice as the replacement of conventional energy production methods. Solar energy has found applications in street lights as well as in household lighting.

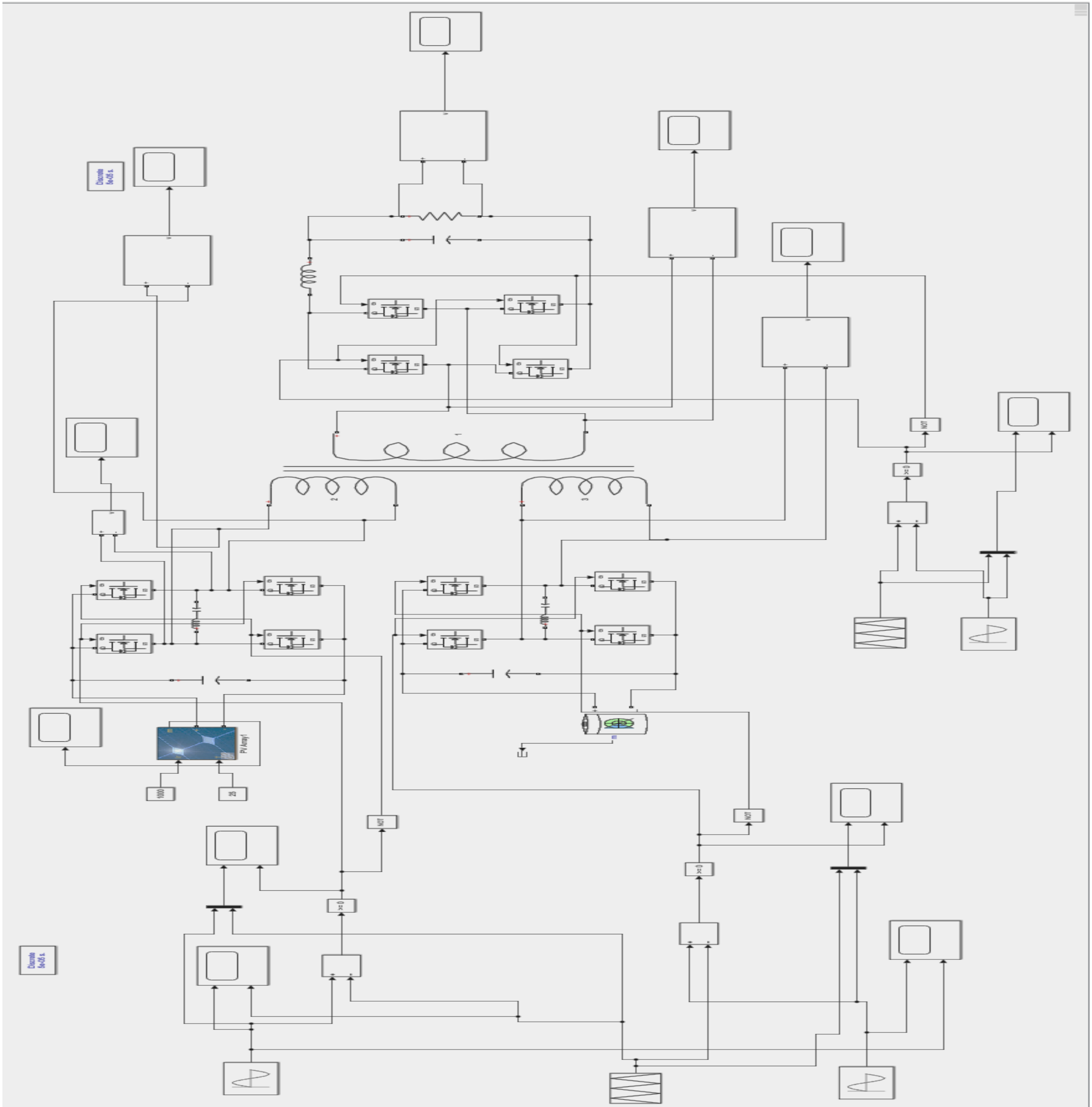


The proposed circuit is shown here. It has two series resonant tanks formed by $L1$ and $C1$, and $L2$ and $C2$, respectively. The input filter capacitors for port 1 and port 2 are $Cf1$ and $Cf2$, respectively. Two phase-shift control variables $\varphi 13$ and $\varphi 12$ are considered, as shown in Fig. 1. They control the phase shift between the square wave outputs of the active bridges. The phase shifts $\varphi 13$ and $\varphi 12$ are considered positive if $vohf$ lags $v1hf$, and $v2hf$ lags $v1hf$, respectively. The converter is operated at constant switching frequency above resonant frequency of both resonant tanks.

Converter Parameter	**Value**
Resonant Inductor L_1	$28.4\mu H$
Resonant Capacitor C_1	$0.1\mu F$
Resonant Inductor L_2	$14.7\mu H$
Resonant Capacitor C_2	$0.22\mu F$
Port1 Voltage V_1	$50V$
Port2 Voltage V_2	$36V$
Output Voltage V_o	$200V$
Turns ratio n_{13}	0.25
Turns ratio n_{23}	0.18

Here are the values of the parameters used in the circuit used for the experiment. The Simulink model is also provided with the parameters mentioned and the results obtained from the simulink model is attached to the project report and their analysis is also provided. The Simulink model is provided in the next page.

CIRCUIT SIMULINK MODEL:



EXPERIMENTATION AND OBSERVATION:

- **Working Principle:** In this experiment we have given the simulation some standard values(*mentioned in the table) and then run it by using gate pulse for the inverters.

As soon as the given pulse is provided the inverters begin to conduct and the circuit is turned on, here we have provided the PV array with a Temp of 100 unit and sunlight radiation of 50 unit and the battery voltage is taken as 12volts.

Now here a three winding linear transformer is being used in order provide an AC link and voltage regulation in between the load and the supply, as provided before another backup supply with DC battery is also provided and conducts as per requirement,i.e at night time when there is no availability of sunlight or at times when the power output from the given PV array is not good enough and also in the simulated version we have considered both of the inputs from the battery as well as the PV array is taken together.

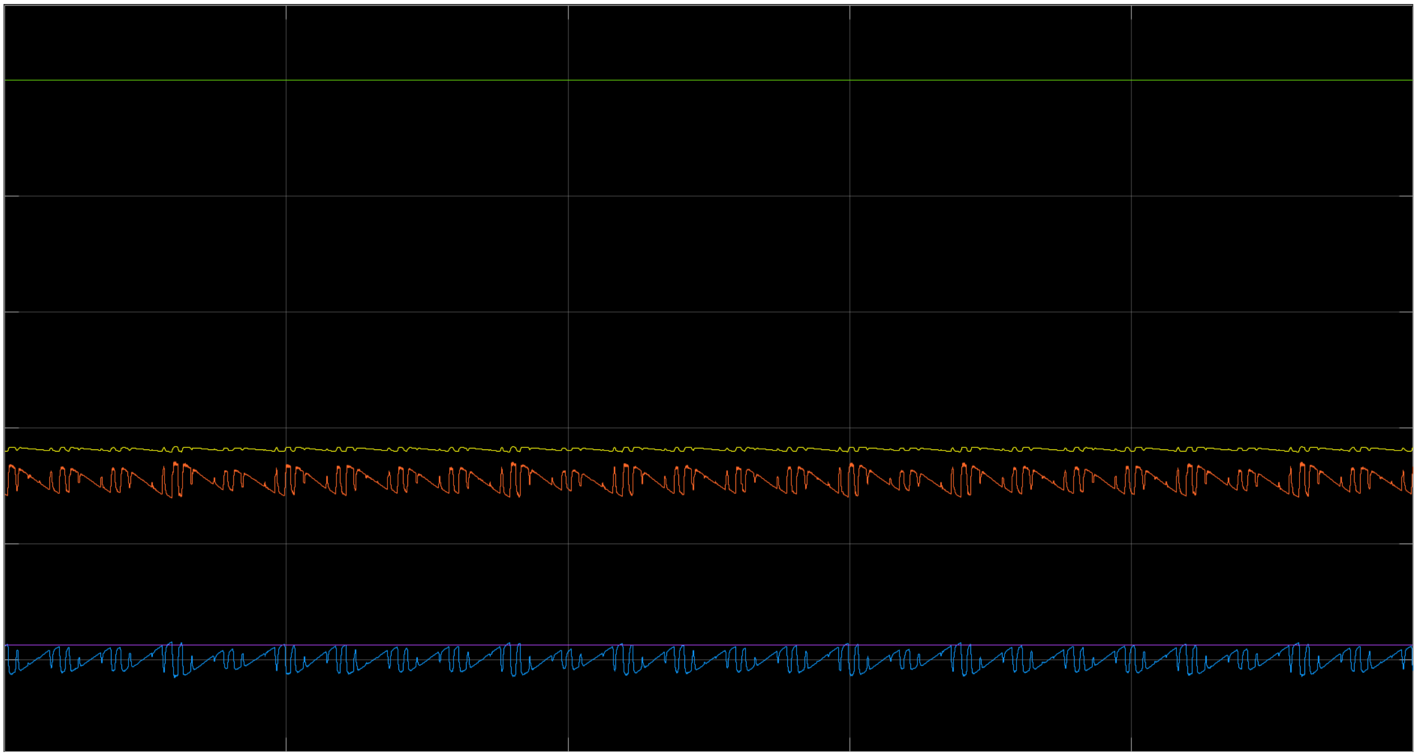
As seen from the given diagram there are also two tank circuits connected to the transformer windings such that the wave forms going to the generator are improved.

Once supply is provided then the generated outputs from the PV array and the battery is converted to their equivalent AC voltage with the help of the inverters, these o/p AC voltages will be regulated and transmitted to the load side and then the rectifier at the load side will convert in to their equivalent DC voltage and the results are shown.

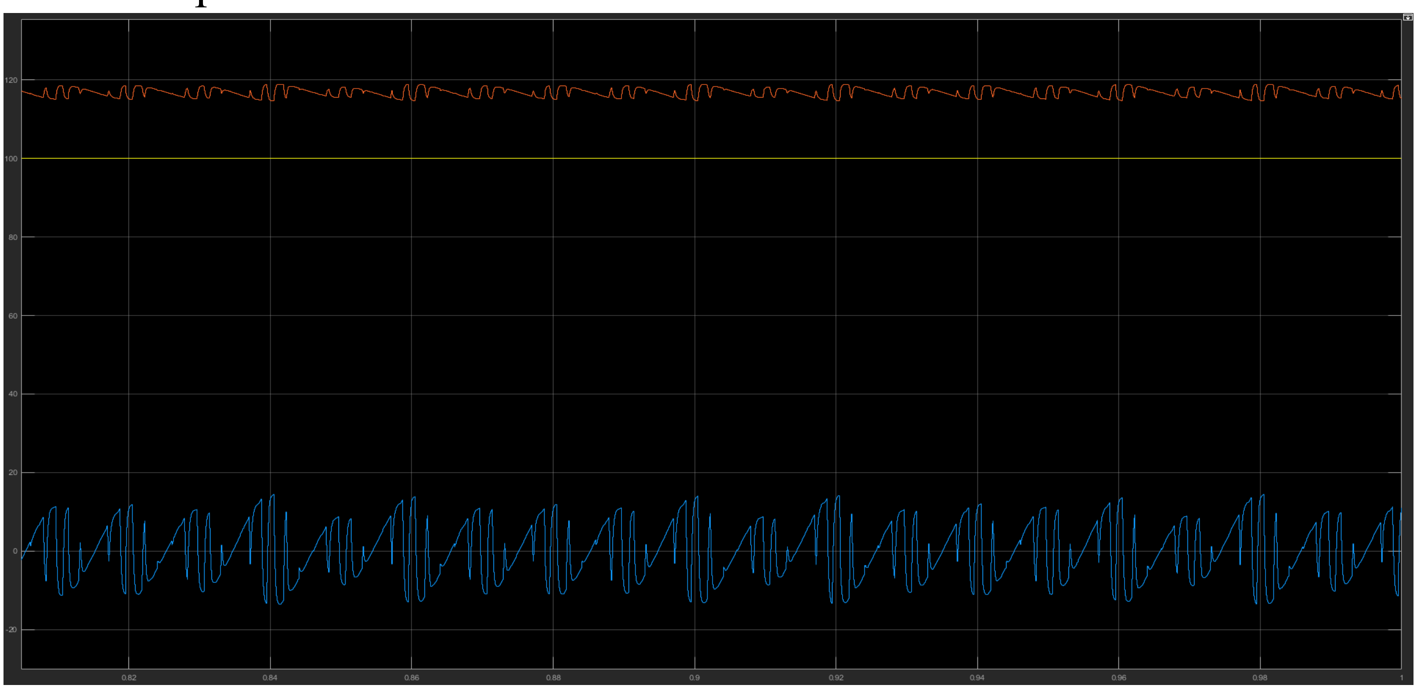
By referring from the circuit diagram we can say V0hf lags behind V1hf and V1hf lags behind Vh2f.

It is also to be noted that pulse width modulation (PWM) technique is used to provide gate pulses to the inverters. In this case the SINE wave is referenced with a TRIANGULAR wave in order to obtain our required gate pulse. The frequency of the TRIANGULAR wave is 100Hz and that of the SINE wave is 50Hz and by comparing these waves we have generated the gate pulse.

- **<u>INPUTS:</u>**
- Input from the PV array:



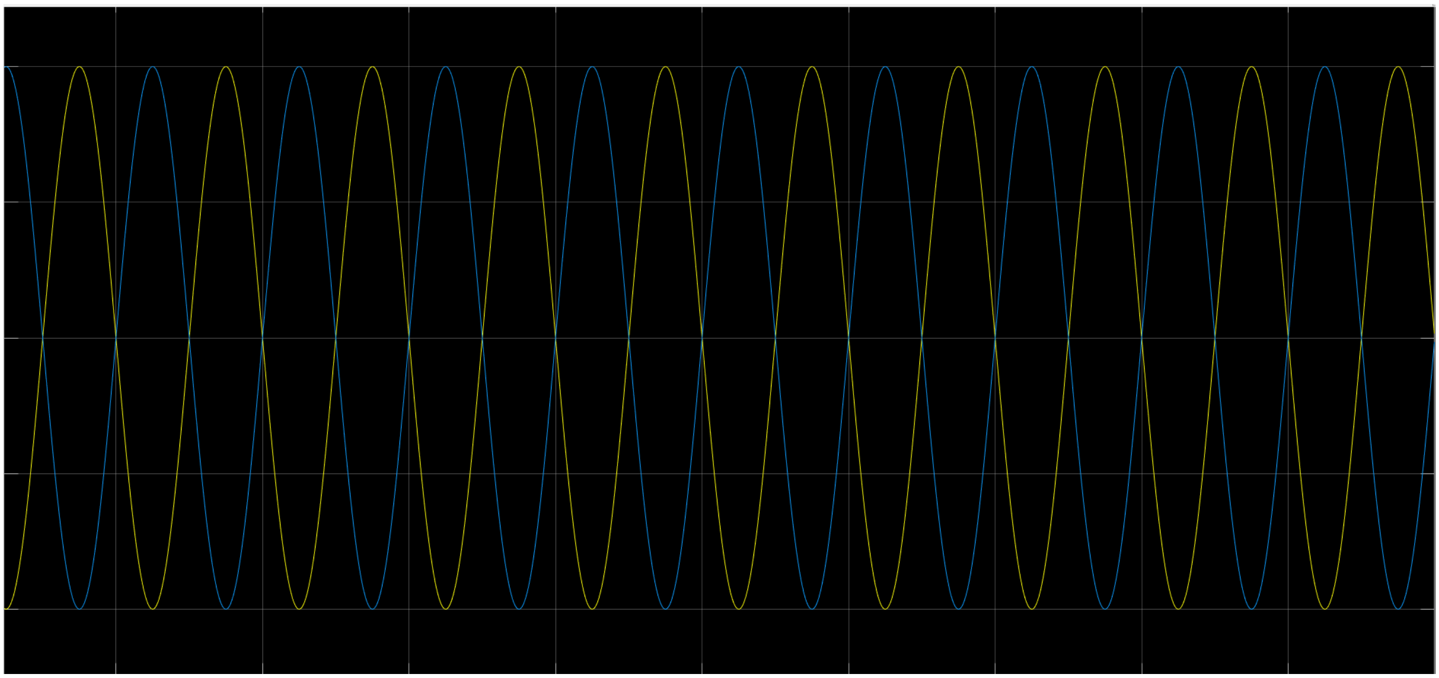
- Input from the DC cell:



GATE PULSES:

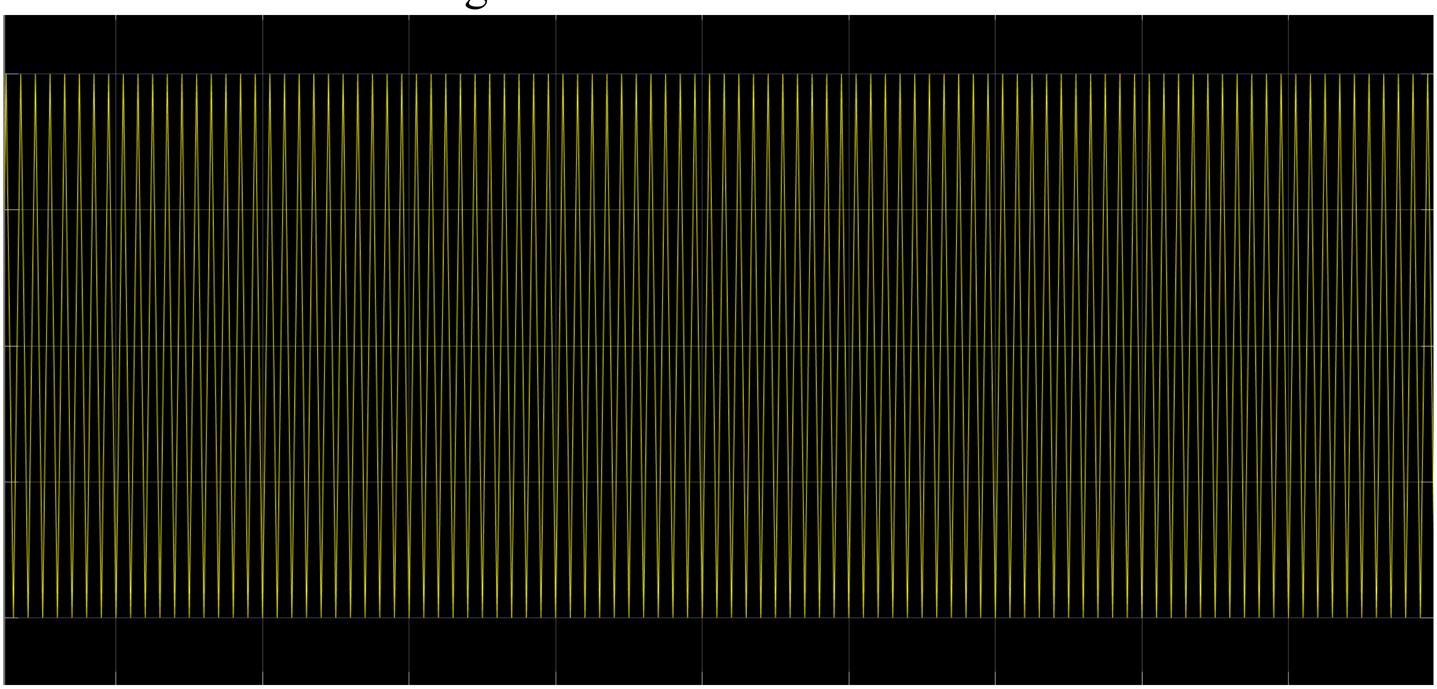
Input Side Inverters

- Sinusoidal waves:



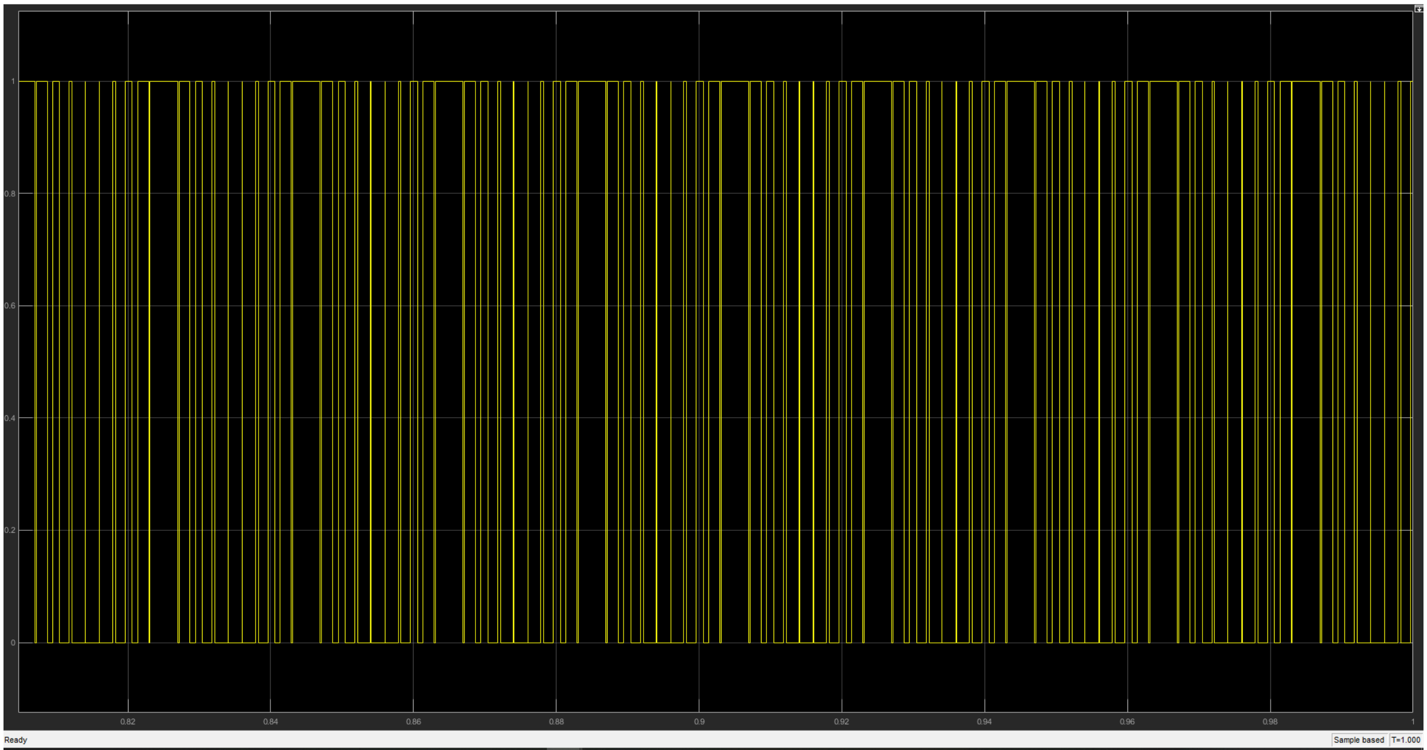
The blue wave is phase shifter by pi from the yellow wave, blue wave is used as the pulse for inverter 1(connected to the pv array) while the yellow wave is the pulse for inverter 2(connected to the dc battery).

- Reference Triangular wave:

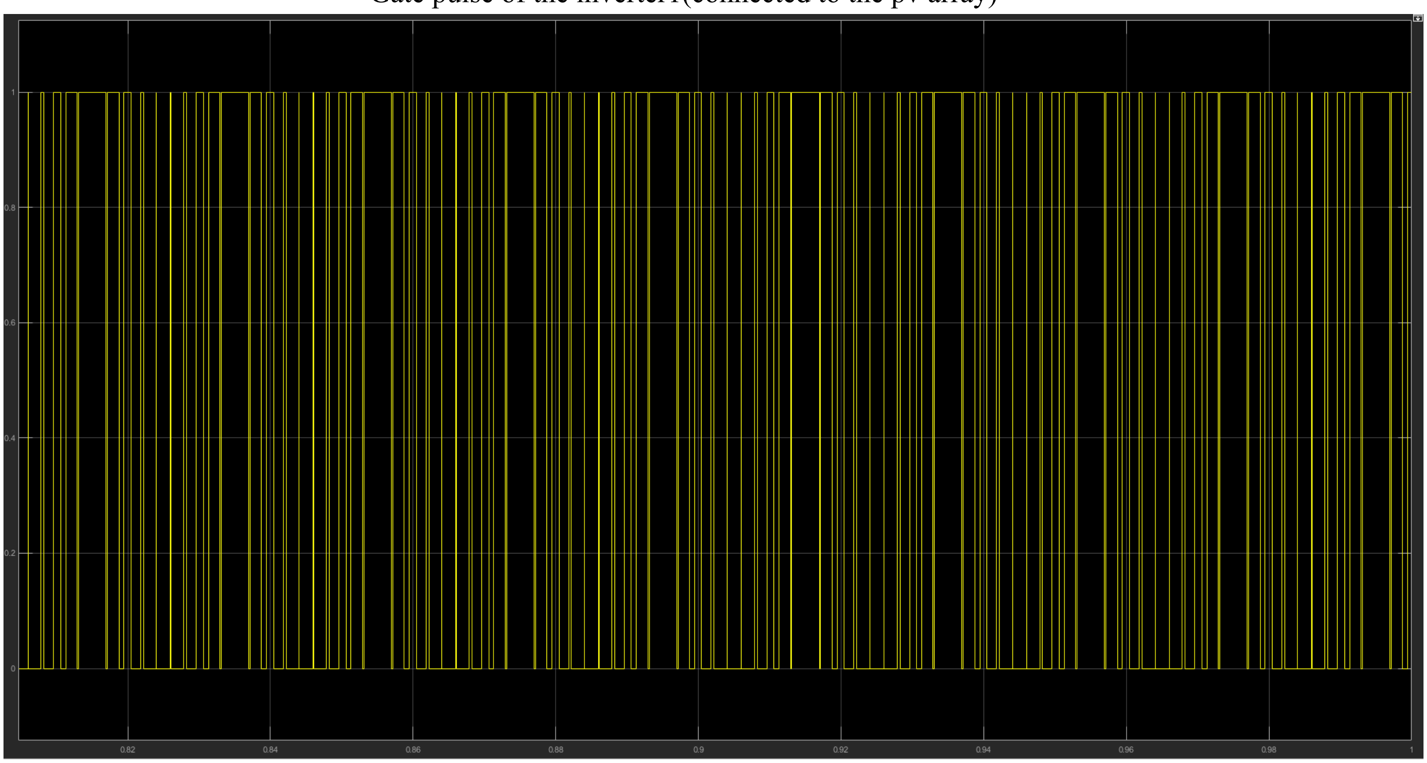


This wave is same for both output and input side

- Modulated Gate Pulses:



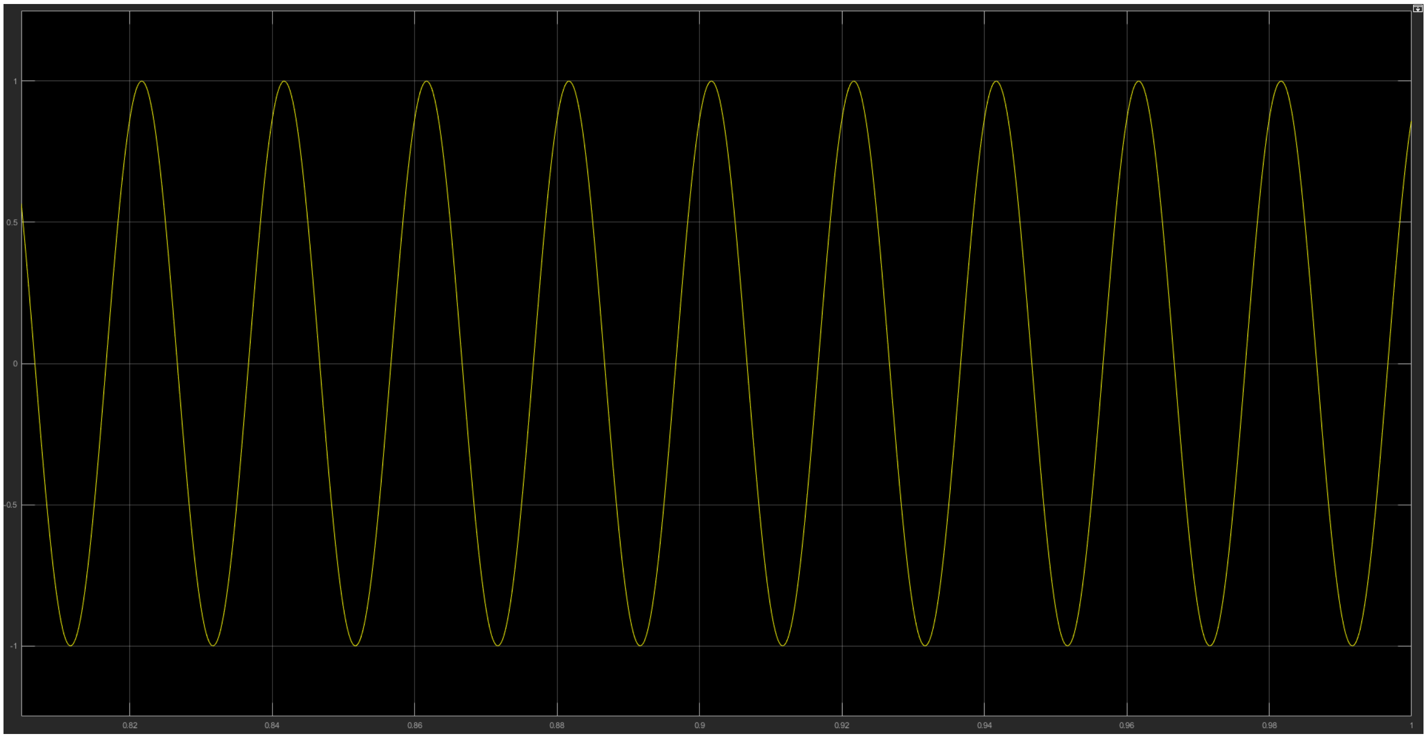
Gate pulse of the inverter1(connected to the pv array)



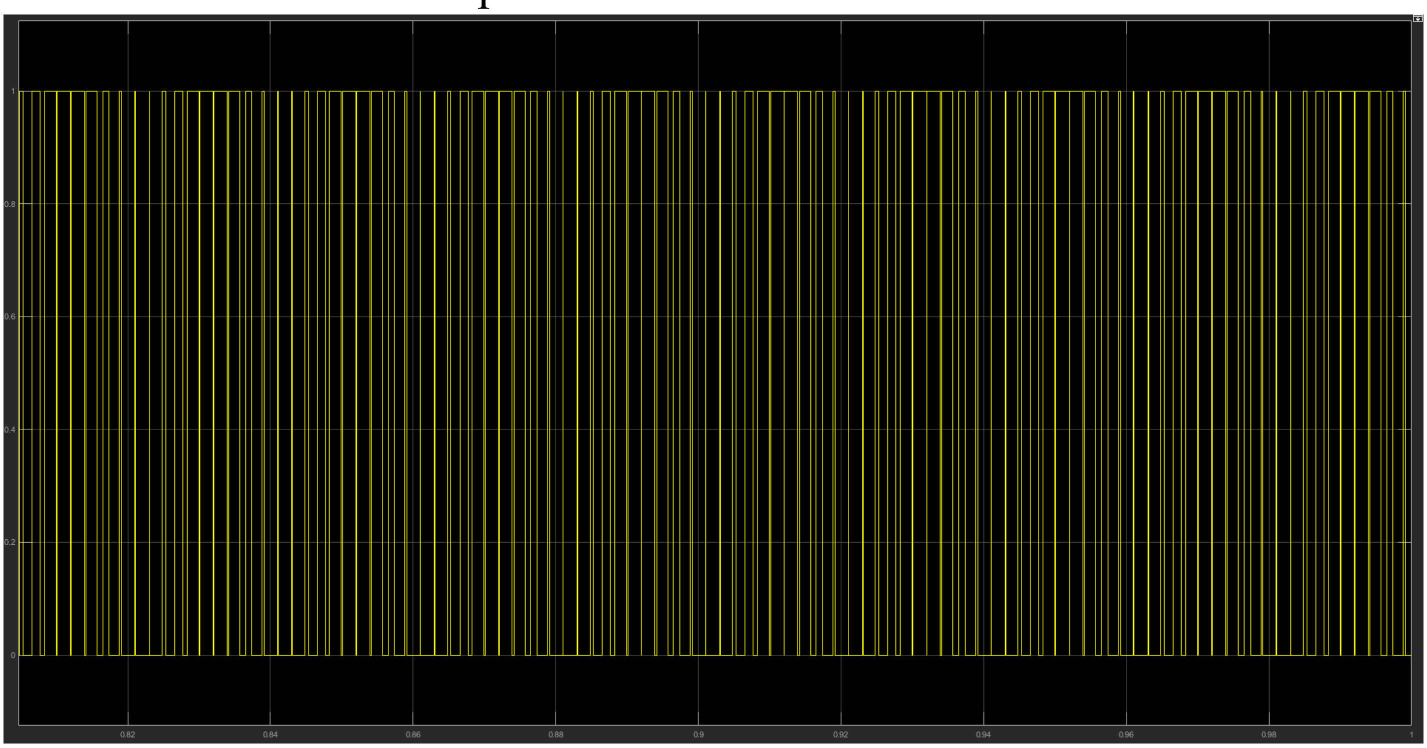
Gate pulse of the inverter2(connected to the dc battery)

Output Side Inverters

- Sinusoidal wave:



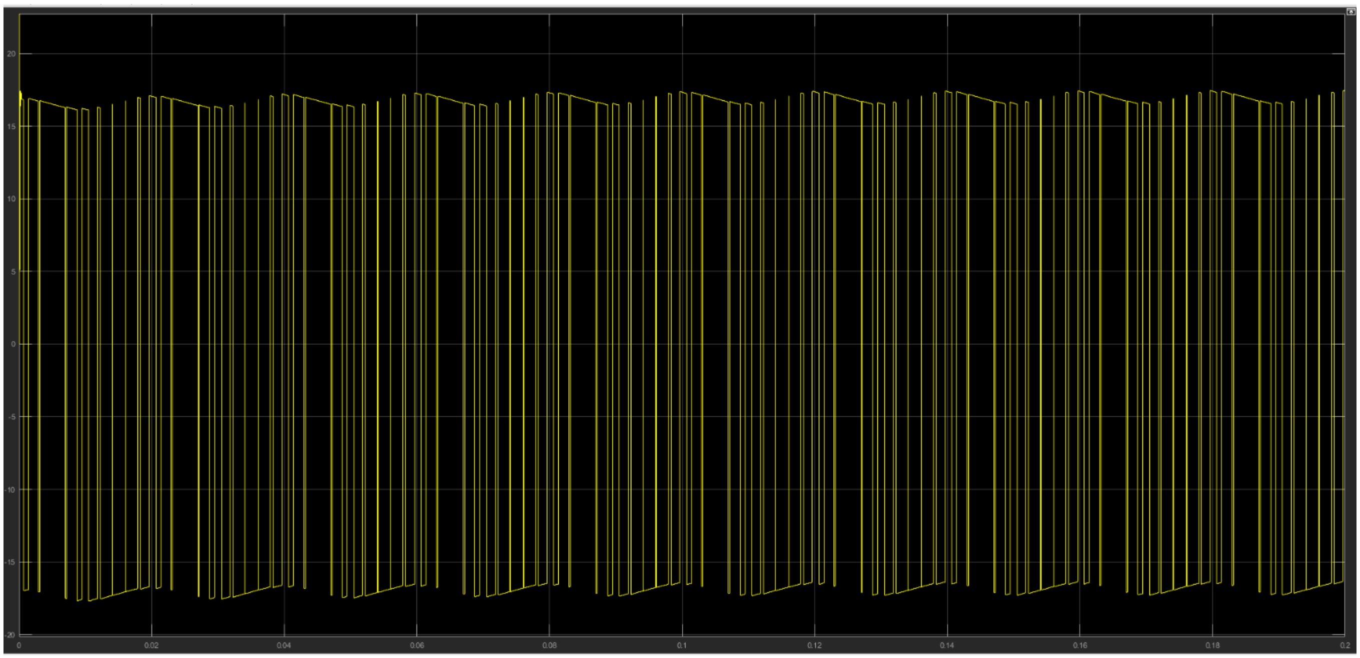
- Modulated Gate pulse:



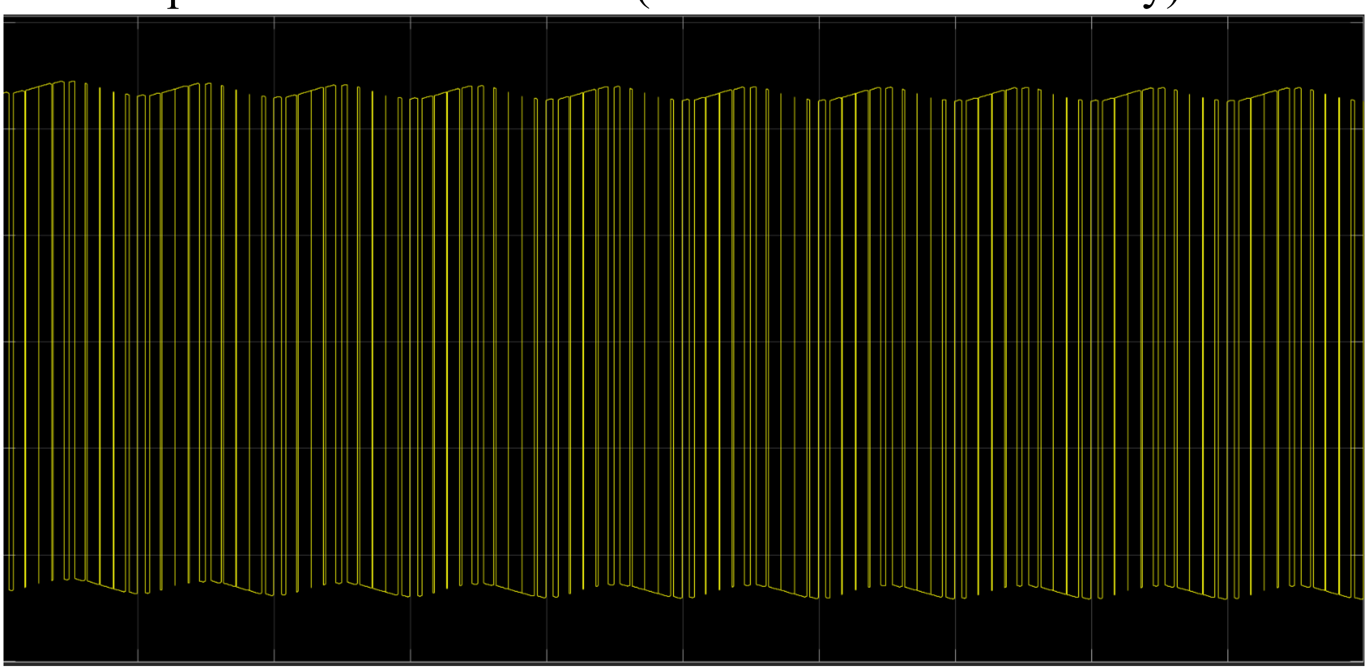
RESULTS:

Here the results are included with the same parameters and the time and their values are shown.

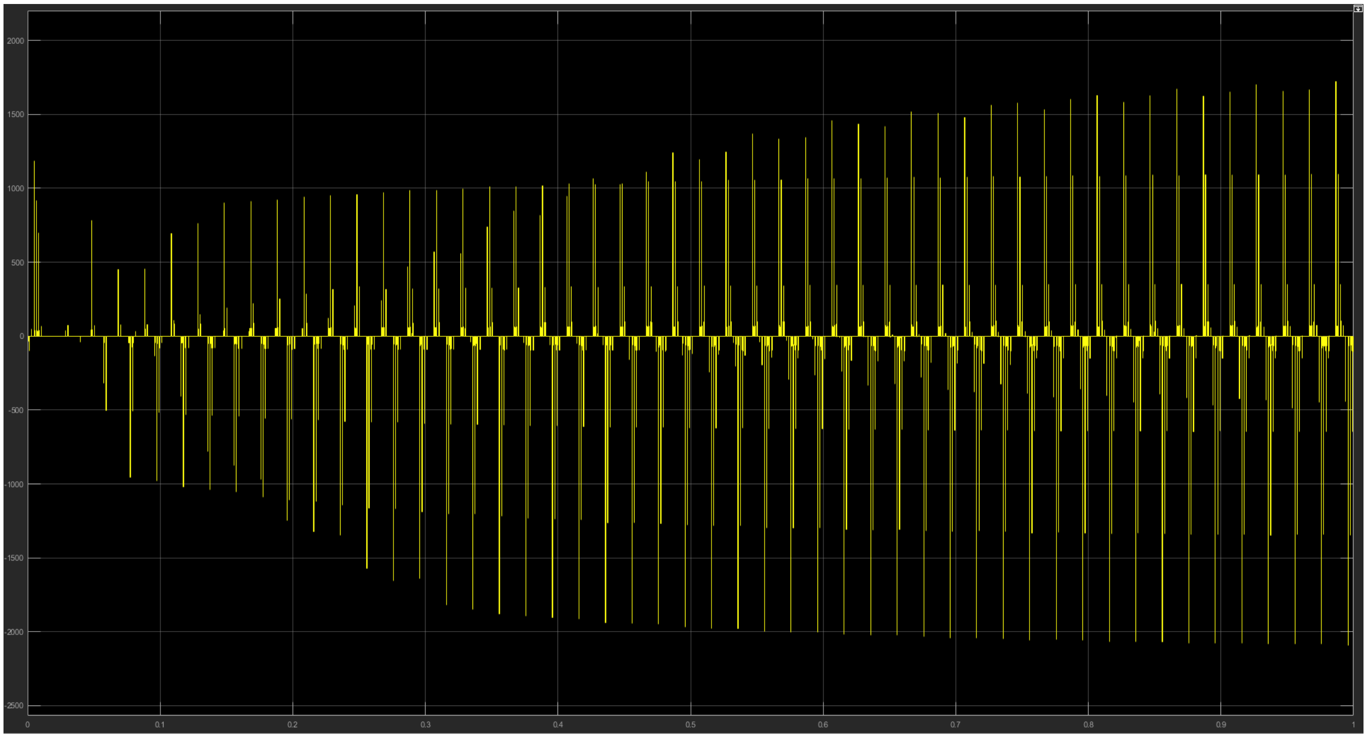
- Output from the converter 1(connected with the PV array)



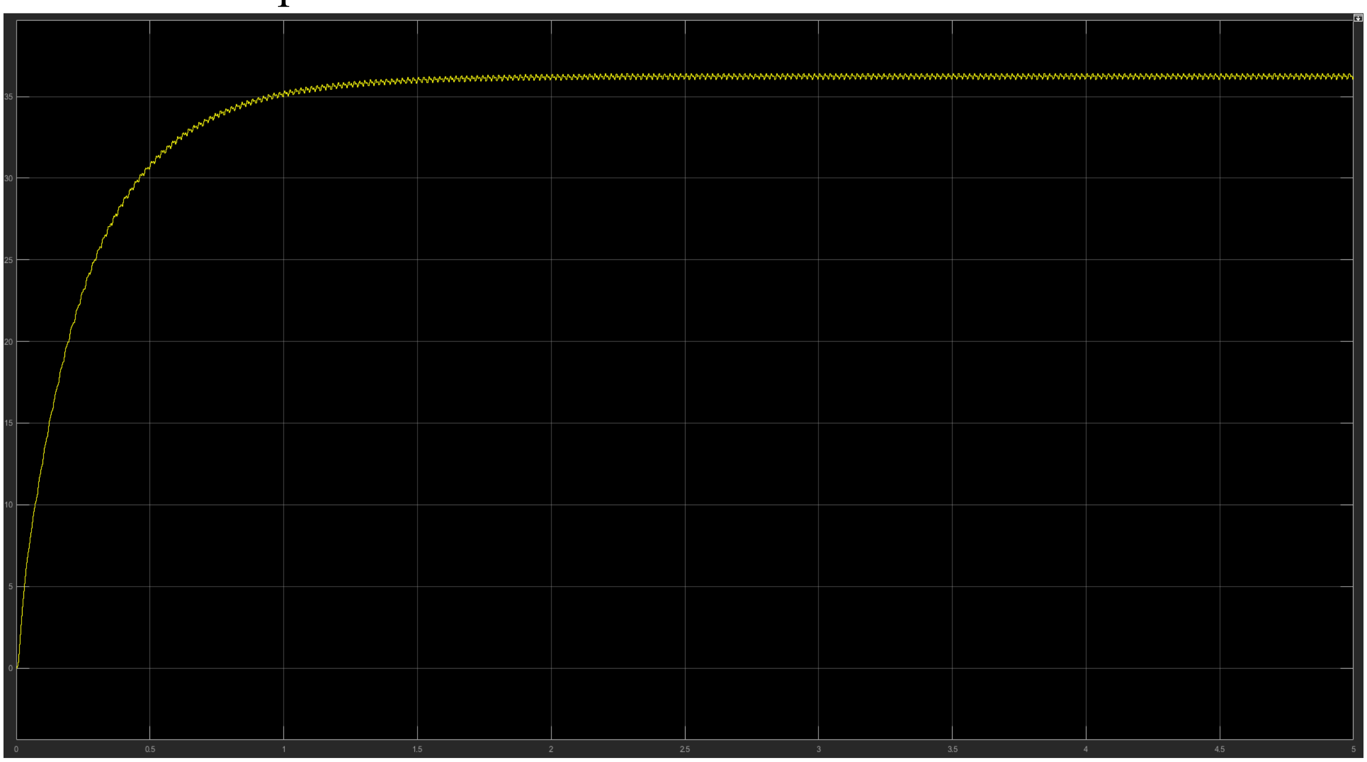
- Output from the converter 2(connected with the Battery)



- Output from converter 3(secondary side converter):



- Final Output:



APPLICATIONS:

1. This system can be used to generate electricity is any house-hold or small scale system where there is plenty of sun and also it can be used in systems where there is scarcity of conventional means of power.
2. It can be also used a alternate power supply system in those places where a huge amount of power is required
3. The most specific application of this system is with a DC shunt motor. where regenerative braking is possible utilizing the bi-directional power flow of the system.

CONCLUSION:

In this project, a three-port series resonant converter was introduced to interface renewable energy sources and the load, along with energy storage. It was proven by simulation and experimental results that power flow between ports can be controlled by series resonance and phase-shifting the square wave outputs of the three active bridges. The converter has bidirectional power flow and soft-switching operation capabilities in all ports. Dynamic model and controller design were presented for centralized control of the three-port converter. A design procedure with normalized variables, which can be used for various power and port voltage levels, was presented. Experimental results verify the functionality of the three-port converter.