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Grid Connected Multi-Energy Storage Device for PV array

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ABSTRACT: **:** Power can be generated by either renewable energy resource or non-renewable resource. The power which is obtained by using renewable energy resources is much cleaner but however the power obtained is not constant and varies depending on a number of factors: climatic conditions, time of the day etc. This project aims to compensate the difference in power which is generated and the demand. A new methodology for optimal design of transformer-less photovoltaic(PV) inverters targeting a cost-effective deployment of grid-connected PV systems is proposed in this project. The long term goal of our project is to decrease the dependency on non-renewable resources for power. We aim to achieve lower total manufacturing and maintenance cost and inject more energy into the grid.

KEYWORDS:PV array, MPPT, SEPIC converter, Solar energy, power generation, lead-acid battery, MATLAB Simulink

I.INTRODUCTION

Renewable energy is derived from renewable resources, which are recharged naturally over the years, such as solar radiation, rain, tides, waves, and geo thermal heat.

Usually renewable energy provides energy in four important sectors: power generation, air and water heating/cooling, transportation, and rural(off-grid) energy services.

Different sources of Renewable Energy are –

- Wind power :- Wind turbines can be used to obtain the energy available in airflows. Present day turbines have the range from low power to high power. The power output of the wind turbine is a function of the cube of the wind speed, as the wind velocity increases the power output significantly increases. Technological advancements and research have led to aero foil wind turbines, which have more efficiency due to a better aerodynamic structure.
- Solar power: Solar energy can be used in two main ways. Firstly, the captured heat can be used as solar thermal energy, with various applications like space heating. The second way is the conversion of incident solar radiation to electrical energy, which is the most used form of energy. This is achieved with the help of photovoltaic cells.
- Small hydropower :- Hydropower installations are considered as small hydropower and they are one of the forms of renewable energy resources. This involves the use of water turbines for converting the potential energy of water stored in dams into usable electrical energy. By this it aimed to utilize the kinetic energy of water without the need for building reservoirs or dams
- Biomass :- Biomass typically works as a natural battery where it stores the sun's energy and yields it on requirement. This is obtained when plants capture the energy of the sun through photosynthesis and on combustion, these plants release the trapped energy.
- Geothermal :- The thermal energy which is generated and stored within the layers of the Earth is called Geothermal energy The gradient which is hence developed conducts heat continuously from the core levels to the earth's surface. This gradient can be utilized to heat water to produce superheated steam and it can be utilised to operate steam turbines which in turn generate electricity. The main downside of this is that, it is usually restricted to regions near tectonic plate boundaries, although recent development has led to the diffusion of this technology.

Solar energy is available in abundance and hence it can be obtained in large quantities and converted it into required form of energy depending on the need of the application and it can utilized efficiently. The power which is hence obtained can either be connected to the grid or it can be an isolated or standalone power generation system which depends on utilisation, load area location and availability of nearby power grid. Solar energy can be used only in those areas where the availability of grid connection is very cost effective. The two major advantages of solar power are that it has zero fuel cost and the energy obtained is eco-friendly. Another upside of using this for small amounts of power generation is its portability.

In the recent years, the mechanisms for power conversion regarding solar energy has notably come in reduced sizes. The advances of research and technology in this field of power electronics and science have been of considerable help for engineers to develop a system that is significantly small but has high efficiency and systems that are capable of withstanding the supply of high electric power demand.
The growth of Photovoltaic energy has advanced at an average annual rate of 60% in the last 5 years and has excelled 1/3 of the progressive wind energy installed capacity, and is rapidly becoming a foremost part of the power systems. There has been a considerable reduction in the cost of PV modules. Due to this, it has to lead to the advancement of classic PV power converters from the conventional single-phase grid-tied inverters to more compound topologies to increase efficiency, power extraction from the sun, the reliability while at the same time not impacting the cost.

At the national level, at least 30 nations worldwide, are already contributing to more than 20 per cent of the energy through renewable energy production. National renewable energy markets are expected to grow continuously and immensely in the foreseeing future.

Solar photovoltaic (PV) energy conversion systems have had a large growth from a cumulative total power approximately equal to 1.2GW in the year of 1992 and it raised to 196GW in 2018 . This portent is possible because of various factors, all compiling together to increase the PV energy to achieve an important position today and potentially a very important stance shortly. Amongst several factors, the reduction in cost and improved efficiency, and the need for alternative clean energy resources, plus the supportive political rules from the government which establishes complementary feed-in tariffs designed to speed up the investment in renewable energy science.

The proposed methodology in this project works based on the principle that whenever the power generated is excess the additional power which is produced is used to charge the battery because in case of solar plants, the power generation is maximum at midday. Also the power generation is null at night, due to the absence of sunlight, this difference in power is fed from the batteries

II. LITERATURE SURVEY

A design example is presented, demonstrating that the PV inverters designed using the proposed optimization methodology exhibit lower total manufacturing and lifetime maintenance cost and inject more energy into the electric-grid and by that minimizing LCOE. The energy injected into the electric grid can be maximized by applying an effective maximum power point tracker (MPPT) control strategy [2].An intermediate dc-dc power stage is present between the PV modules and the grid-tied inverter. This is an optional stage used to decouple the PV system operating point from the PV inverter grid control . It can also boost the PV system dc output voltage if required, or provide galvanic isolation and perform the Maximum Power Point Tracking (MPPT) control.The high stray capacitance between the PV cells and the grounded metallic frame of every module and the high frequency harmonics caused by the modulation of the power converter results in leakage currents. Galvanic isolation can help to interrupt the leakage path, but the utilization of a transformer presents drawbacks such as higher cost and extra losses, resulting in reduced efficiency.[5]SEPIC converter and inverter is operated in closed loop, i.e, the control of converter is achieved by MPPT method whereas the control of an inverter is achieved by the use of Sinusoidal Pulse Width Modulation (SPWM) technique. P&O method of MPPT technique is employed here. The SEPIC converter was designed and simulated for a three phase load. In order to reduce the current ripples and voltage ripples at input and output side and also to reduce to filter size, the interleaving technique was used. By selecting proper power components this converter design can be applied to higher power applications.[6]

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III. PROPOSED METHODOLOGY & DISCUSSION

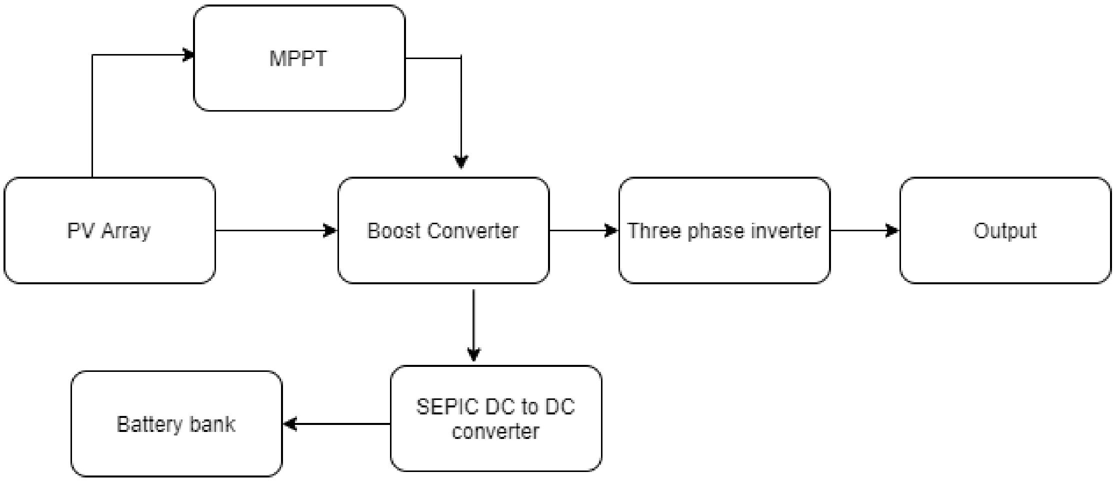

Figure 3.1: Block diagram of the system

The figure 3.1 shows the renewable energy system and energy storing device are connected to a grid which is represented by the output block. The energy storage system is integrated into a power grid to compensate the power fluctuation from the renewable energy system. The energy storing system consists of SEPIC DC-DC converter and energy storing device like battery. There are 6 main elements in the above Block Diagram. They are:-

1. Photo Voltaic array (PV array):-

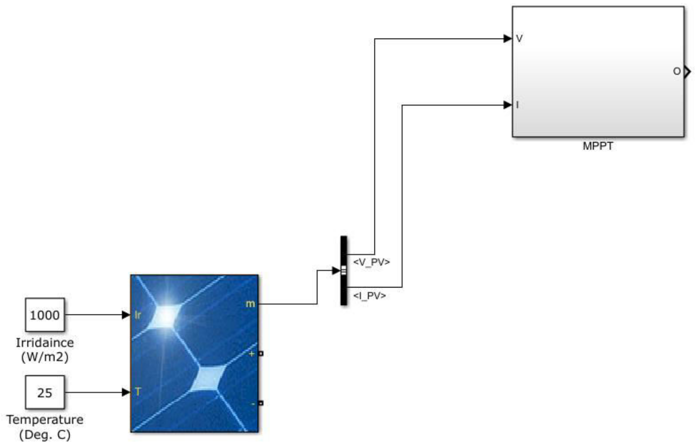

Figure 3.2: PV array along with MPPT

Photovoltaic array is by definition a linked collection of photovoltaic modules, which is shown in the figure 3.2 along with the block of MPPT. Each Photo Voltaic (PV) module is made of multiple interconnected PV cells. These multiple PV cells convert solar energy that falls on these panels in the form of light energy into direct current form of electricity. These PV modules are sometimes also referred to as solar panels, although that term better applies to solar-thermal water or air heating panels. Photovoltaic modules are distinguished from solar cells as they are conveniently sized and packaged in weather-resistant housings for easy installation and deployment in residential, commercial, and industrial applications.

These PV cells which are connected in the form of modules function via the photovoltaic effect which describes how the used materials can convert light energy from the sun falling on the PV cells into DC form electricity. The individual solar cells in these modules provide a relatively small amount of power but the overall electrical output can be significant when these cells are connected together in the form of modules. The cells, modules and arrays can be bridged in either series connection, parallel connection or typically a combination of both to create a voltage output which is desired.

2. Maximum Power Point Tracker (MPPT):-

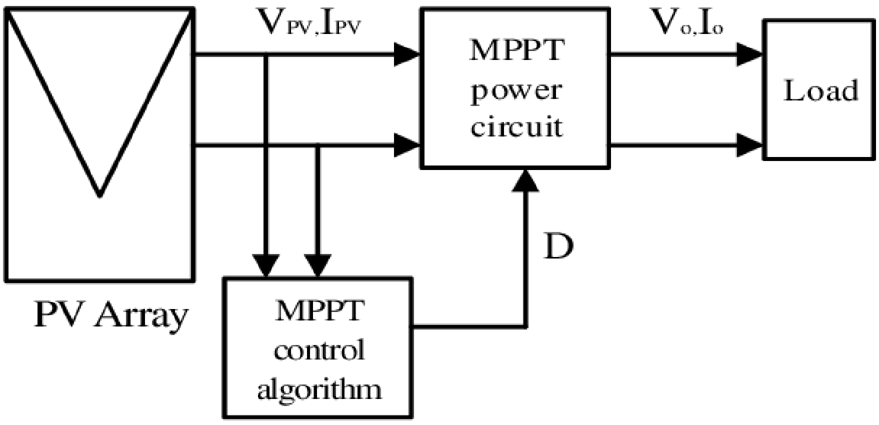

Figure 3.3: Block diagram of MPPT

Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic algorithmic system that allows the Photovoltaic array to produce maximum power that they are capable of producing throughout the day. MPPT is not a mechanical system that physically moves the PV panels with respect to time to make them point in the direction of the sun. It is a fully electronic algorithmic system that varies the electrical operating point of the PV cells which are interconnected as modules so that they deliver the maximum available power that is desired.

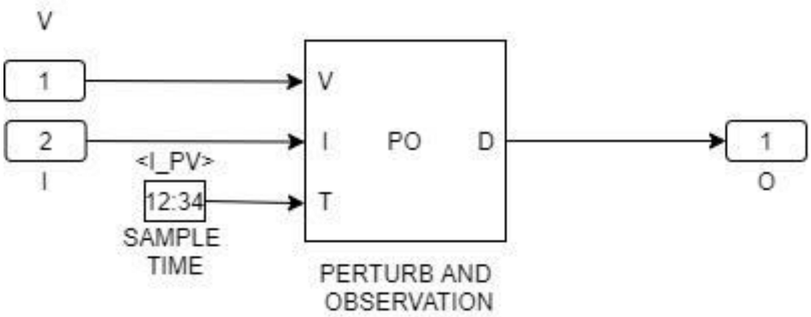

Figure 3.4: MPPT

A typical solar panel converts only 30 to 40% of the total incident solar irradiation into electrical energy as there are loses present due to shading and other factors. The main purpose of using Maximum power point tracking technique is to ensure the output power of the circuit is maximum when the load impedance is same as the impedance at the source side. MPPT is applied to a boost converter which is connected to the output of the PV array through a DC link in order to boost the output voltage to the desired value. By changing the duty cycle of the PWM signal given as the gate pulse to the control transistor which is MOSFET of the boost converter the source impedance is matched with that of the load impedance. There are various MPPT techniques presently used in the industry nowadays and we are using Perturb and Observe method as it has the following advantages over other techniques.

- Simplicity in algorithm
- Ease of implementation
- Low cost
- It is a very accurate method

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3. Boost converter:-

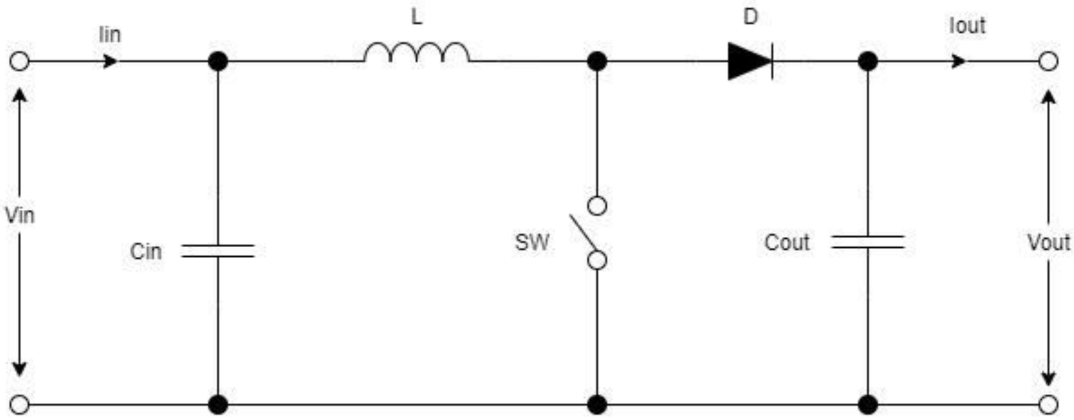

Figure 3.5: Boost converter

A boost converter also known as step-up converter is a DC-to-DC power converter that increases voltage while decreasing current from its input supply to its output load. It is a class of Switched-Mode Power Supply (SMPS) containing at least two semiconductors which in this case is a diode and a MOSFET and at least one energy storage element comprising of a capacitor, an inductor, or the combination of them. To decrease voltage ripple, filters made of capacitors sometimes in combination with inductors are normally added to a converter's output load-side filter and input supply-side filter.

4. Single Ended Primary Inductor Converter (SEPIC):-

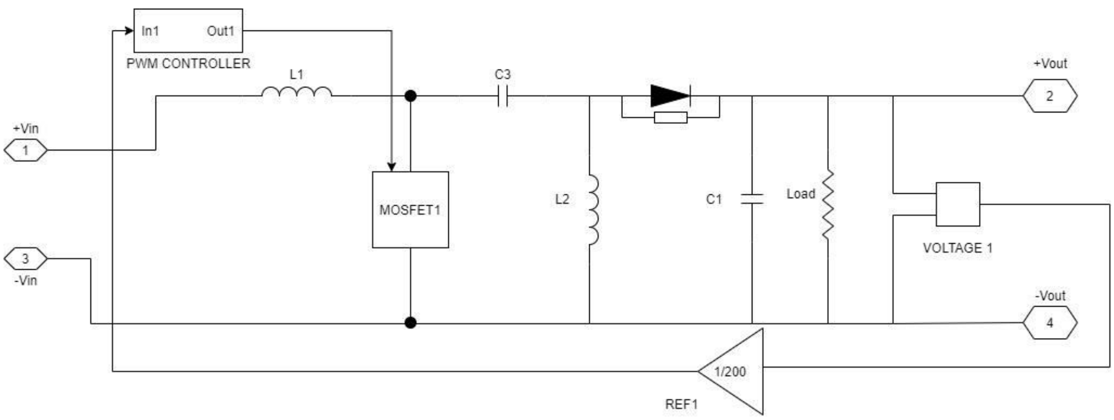

Figure 3.6 SEPIC DC-DC Converter

The Single Ended Primary Inductor Converter (SEPIC) is a type of DC to DC converter that allows the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input. The output of the SEPIC is controlled by the duty cycle of the MOSFET shown in the figure 3.6. SEPIC converter can work as buck converter as well as boost converter.

A SEPIC is essentially a boost converter followed by an inverted buck-boost converter, therefore it is similar to a traditional buck-boost converter, but has the advantages of having non-inverted output (the output having the same voltage polarity as the input), using a series capacitor to couple energy from the input to the output and thus can respond more gracefully to a short-circuit output. It is also capable of a true shutdown when the switch S1 is turned off the output voltage (V_0) drops to 0 V, following a fairly hefty transient dump of charge.

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5. Three Phase Inverter:-

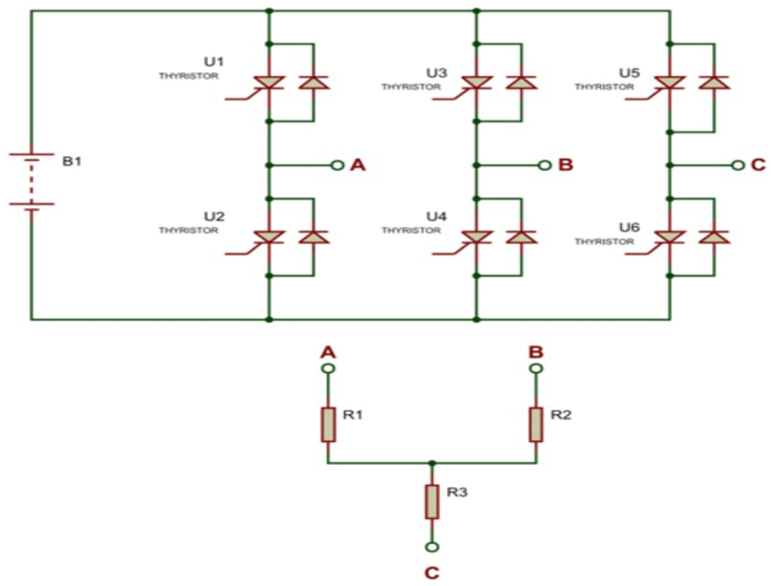

Figure 3.7: Schematic diagram of a Three level inverter

Inverter is a device which converts DC(direct current) to AC(alternating current). Three-level inverter is a high-efficiency power electronic inverter intended, in particular, for use with three-phase drives, as a grid-tie inverter for photovoltaic installations or wind turbines and in power supplies. In the figure 3.7, a schematic diagram of a three level inverter is seen designed using thyristors. A three-phase inverter converts a DC input into AC output. It has three arms which are normally delayed by an angle of 120° to generate a three-phase AC supply. The inverter switches each have a ratio of 50% and switching occurs after every $1/6^{th}$ of the time interval T at 60° angle interval. The switches of thyristors U1 and U2, the switches of thyristor U3 and U4 and the switches of thyristors U5 and U6 complement each other. There are two possible ways for triggering the switches to achieve the desired result, one is switches conduct for 120º which is used in our proposed project

6. Battery:-

Storage devices like batteries are used to smooth out the fluctuations of the PV output fed into electric grids, store energy for night time use for example, in zero energy buildings and residential homes or power arbitrage under time of use of electricity. A Lead acid battery based energy storage system is used. Lead-acid battery is the earliest type of rechargeable batteries despite having a very low energy-to-weight ratio and a low energy to volume ratio but has the ability to supply high surge currents which means that the cells have a relatively large power to weight ratio. Hence lead acid battery is the most appropriate battery to be used in our system.

WORKING PRINCIPLE

The basic working principle involved is that when sunlight falls on PV panel it converts the light energy into electrical energy which will be in direct current form. The output voltage of the PV array is stepped up to any desired higher value by applying the DC current across a boost converter . A Maximum Power Point Tracker (MPPT) employing P & O algorithm is used to control the duty cycle of pulses given to the switch of the DC-DC converter. The MPPT control algorithm takes the voltage and current readings of the PV panel as input and makes necessary changes in the PWM pulses given to the switch to ensure that the PV system is operating at its maximum power point. Once the voltage is boosted to the required value it is now given to the inverter and parallelly connected storage system consisting of a SEPIC converter integrated with the battery bank. The SEPIC converter takes the input from the boost converter and bucks the voltage as per the capacity of the battery bank. The output of boost converter can be fed to the load or grid by first converting it to AC using an inverter and then filtering it using an RLC filter to remove harmonics and a pure sine wave is obtained as the final output.

Operation of PV array and MPPT:

When sunlight hits the PV panels, the photons in the sunlight knocks the electrons out of the atoms in the PV cell and these free electrons lead to the generation of electricity in DC form. The PV system efficiency can be improved by operating it at its maximum power point. To achieve this various MPPT techniques are employed. Incremental conductance, Perturb and observation (P & O), short circuit current and open circuit voltage methods are a few examples. P & O algorithm being very simple and yet accurate was the perfect control algorithm for our project. Perturb typically means an alteration. In this method the operating voltage will be altered or perturbed slightly to analyze the change in power. The resulting power change decides the necessary control action that has to be taken to achieve system operation at maximum power point. A flowchart depicting the working of the P & O algorithm is shown below.

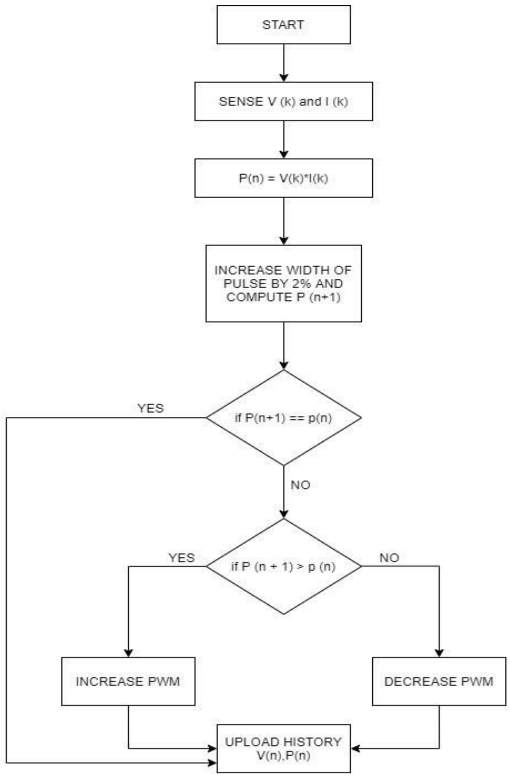

Figure 3.8: MPPT flowchart

The first step is to sense the current and voltage of the PV array and power has to be calculated at that voltage. In the next step, a slight perturbation is introduced in the voltage by increasing the PWM duty cycle by 2% and power is computed again. The next step is to analyze the change in power. If the newly computed power is same as the previously recorded power then no action is required. However if the new power is greater than the previously computed power then the operating point is towards the left side of the maximum power point and hence perturbation has to be continued in the same direction to reach MPP. Hence PWM duty cycle is increased further. Conversely, if the new power is less than the previously computed power then the operating point is towards the right side of the maximum power point and hence perturbation must be reversed in order to reach the MPP. Hence the PWM duty cycle is decreased to achieve this.

Operation of boost converter:

The output of the PV array is given as input to the boost converter. The PWM pulses of MPPT are used to control the switch of the boost converter. The switch used can be a MOSFET or an IGBT. We have used a MOSFET in our project. The other components in the boost converter are coupling capacitor, inductor and a diode arrangement. The coupling capacitor avoids the voltage fluctuations from the solar grid into converter circuit. The series diode is used to Prevent back flow of current. A parallel connection is taken out from the boost converter and given as input to the SEPIC type DC-DC converter. In order to convert the DC power to AC the output of boost converter is given to a three phase inverter.

Operation of SEPIC:

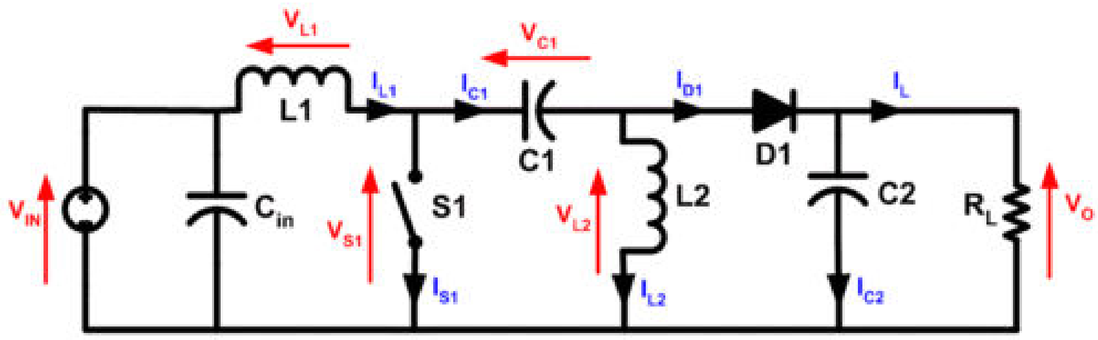

Figure 3.9: Schematic diagram of SEPIC

The schematic diagram for a basic SEPIC is shown in Figure 3.9.A single ended primary inductor capacitor is a DC-DC converter that converts voltage from one level to another by exchanging energy between capacitors and inductors. The switch S1 is used to control the amount of energy that can be exchanged between the inductor and capacitor. The switch used is usually a MOSFET. SEPICs are useful in applications in which unbalance voltage can be more or less than that of the intended output.

A SEPIC converter has 2 modes of operation:

- Continuous conduction mode – Here the current through L1 never falls to zero.
- Discontinuous conduction mode – Here the current through L1 is allowed to fall to zero.

The average voltage (V_{C1}) across the capacitor C_1 will be equal to the input voltage during steady state operation. As the capacitor blocks DC, the average current (Ic_1) through it will be zero hence the only source of DC load current is inductor L_2.Hence the average current through the inductor (L_2) will be equal to the average load current thus making it independent of the input voltage. Hence the following equation can be deduced from the above explanation:

$$V_{IN} = V_{L1} + V_{C1} + V_{L2}$$

Since the average voltage of V_{C1} is equal to V_{IN}, $V_{L1} = -V_{L2}$. Hence, the two inductors can be wound on the same core, This is similar to a fly-back converter. The voltages being equal in magnitude will have zero effect on mutual inductance, assuming the polarity of the windings is correct. Also, since the voltages are the same in magnitude, the ripple currents from the two inductors will be equal in magnitude.

The average currents can be calculated as follows (average capacitor currents must be zero):

$$I_{D1} = I_{L1} - I_{L2}$$

Initially when switch S1 is turned on, current I_{L1} increases and the current I_{L2} becomes more negative. The energy required to increase the current I_{L1} is obtained from the input source. When S1 closed, the instantaneous voltage V_{L1} is approximately equal to V_{IN} and the voltage V_{L2} is approximately equal to $-V_{C1}$. In order to increase the current I_{L2} , D_1 is opened and the capacitor C_1 supplies the energy to achieve this and this in turn increases the energy stored in L_2. I_L is supplied by C_2. This can be visualized by considering the bias voltages of the circuit in DC state and then close S1.

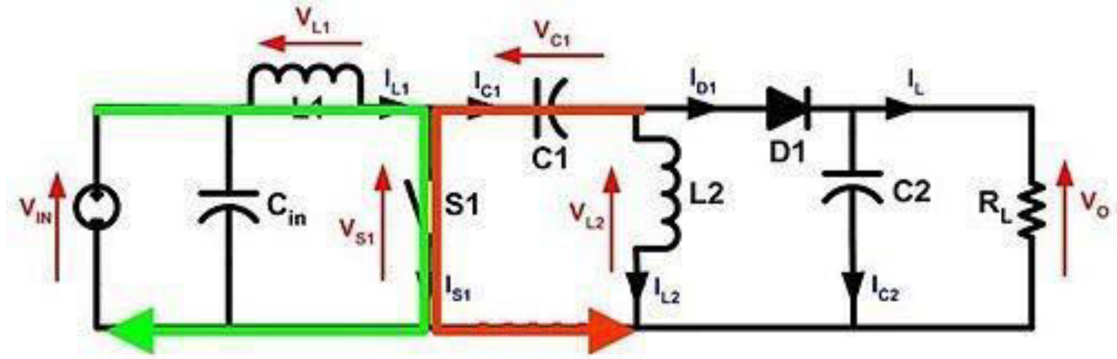

Figure 3.10: With S1 closed current increases through L_1 (green) and C_1 discharges increasing current in L_2 (red)

As inductors does not allow instantaneous change in current, when S1 is turned off, current I_{C1} becomes the same as the current I_{L1}.The current I_{L2} increases in negative direction itself. It is evident from the diagram that this negative current I_{L2} will add to the current I_{L1} to increase the current that is delivered to the load. Applying Kirchhoff's Current Law, we have $I_{D1} = I_{C1} - I_{L2}$Thus we can conclude that while S1 is off, the load receives power from both L_2 and L_1. C_1 gets charged by L_1 during this off cycle and this in turn is responsible for recharging L_2 during the following on cycle.

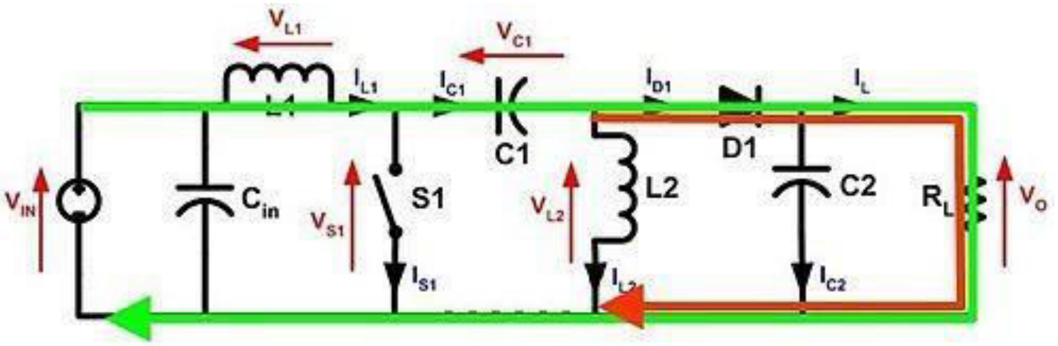

Figure 3.11: With S1 open current through L1 (green) and current through L2 (red)

From figure 3.11 they produce current through the load Because the voltage across capacitor C1 may reverse its direction every cycle and hence a non-polarized capacitor should be used. However, a polarized tantalum or electrolytic capacitor may be used in some cases because the potential across capacitor C1 will not change unless the switch is closed long enough for one half cycle of resonance with L2.

To reduce the effects of parasitic inductance and internal resistance of the power supply, the capacitor C_{IN} is employed in actual regulator circuits. However this doesn't have any effect on the analysis of the ideal circuit.

The capacitor C_1 and inductor L_2 are responsible for the buck/boost capabilities of the SEPIC converter. A standard boost converter, which generates a voltage (V_{S1}) that is higher than V_{IN} can be created by inductor L1 and switch S2. The magnitude of the output voltage is determined by the duty cycle of the switch S1. Since the average voltage across C_1 is equal to V_{IN}, the output voltage (V_O) is equal to V_{S1} - V_{IN} . Output voltage will be less than the input voltage when V_{S1} is less than double the V_{IN} . Consequently output voltage will be greater than the input voltage when V_{S1} is greater than double the V_{IN}. The output of the SEPIC converter is given to the battery until its charged upto 85% of its full capacity which can be used when required.

The output of the boost converter is given to the load through a three phase inverter and a filter.

Operation of three phase inverter:

The DC output from the boost converter is fed to the inverter to obtain a 3 Phase AC output. The 3 phase inverter consists of 3 arms with 2 switches in each arm as shown in the figure3.12.

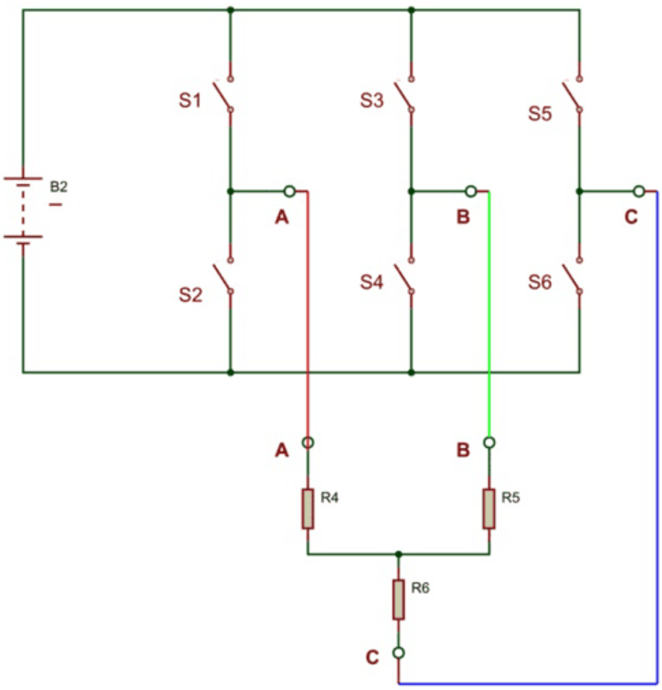

Figure 3.12: Three arm two switch inverter

120° conduction mode is the technique employed here. According to this technique each switch remains on continuously for 120°. The three arms of the inverter are also delayed by 120° from each other.The inverter switches each has a ratio of 50% and switching occurs after every T/6 of the time T i.e 60° angle interval. By following a proper switching sequence it is possible to accurately obtain a 3 phase output from a DC input.

At the beginning of the switching sequence S1 is closed and it conducts from 0° to 120°.Since one half cycle of the sinusoidal signal goes from 0 to 180º, for the remaining 60° S1 will be open and is represented by the grey area in the figure 3.13.

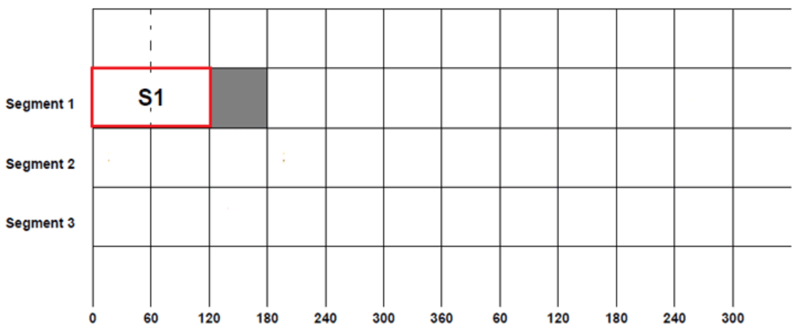

Figure 3.13: 1st stage of inverter

Now after 120º of the first phase, the second phase will also have a positive cycle as mentioned before, so switch S3 will be closed after closing S1. This S3 will also be kept closed for another 120º. So S3 will be closed from 120º to 240ºas shown in figure 3.14

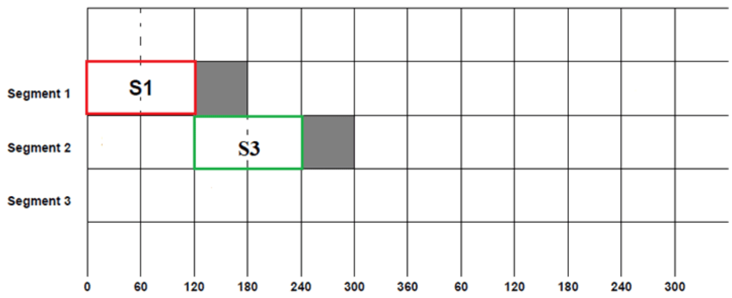

Figure 3.14: 2nd stage of inverter

Similarly, the third phase also has a positive cycle after 120º of the second phase positive cycle so the switch S5 will be closed after 120º of S3 closing. Once the switch is closed, it will be kept closed for the next 120º before being opened and with that, the switch S5 will be closed from 240º to 360º.

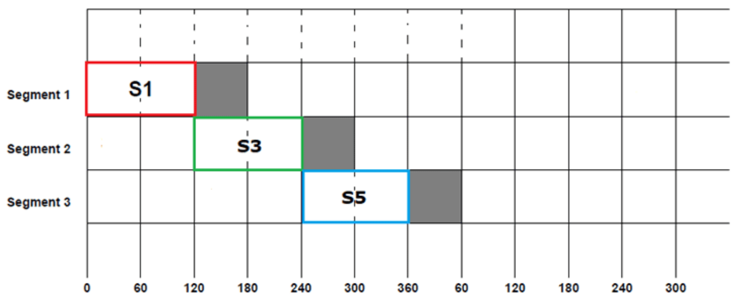

Figure 3.15: 3rd stage of inverter

The desired three-phase voltage can be obtained by continuing this switching pattern. If we fill in the beginning and ending switching sequence in the above table we will have a complete switching pattern for 120º conduction mode as shown in the figure 3.16

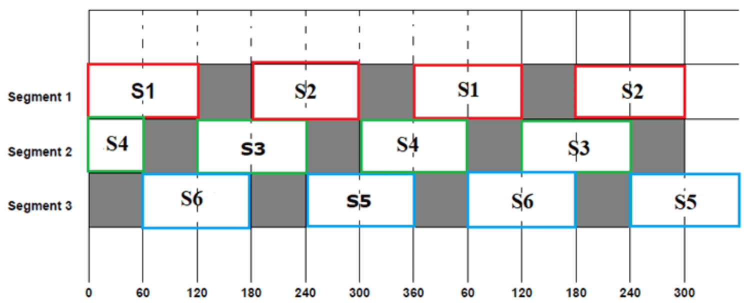

Figure 3.16: 4th stage of inverter

For every 60° interval any 2 switches will be on. From the figure 3.16 we will see that:

- From 0-60: S1&S4 are closed while remaining switches are opened.
- From 60-120: S1 &S6 are closed while remaining switches are opened.
- From 120-180: S3&S6 are closed while remaining switches are opened.
- From 180-240: S2&S3 are closed while remaining switches are opened.
- From 240-300: S2&S5 are closed while remaining switches are opened.
- From 300-360: S4&S5 are closed while remaining switches are opened.

The output of the inverter is given as the input to the filter. The filter is used for smoothening of the AC signal and to remove harmonics. The output of the filter is the desired output of the system

IV. CIRCUIT DIAGRAM AND DESIGN ASPECTS

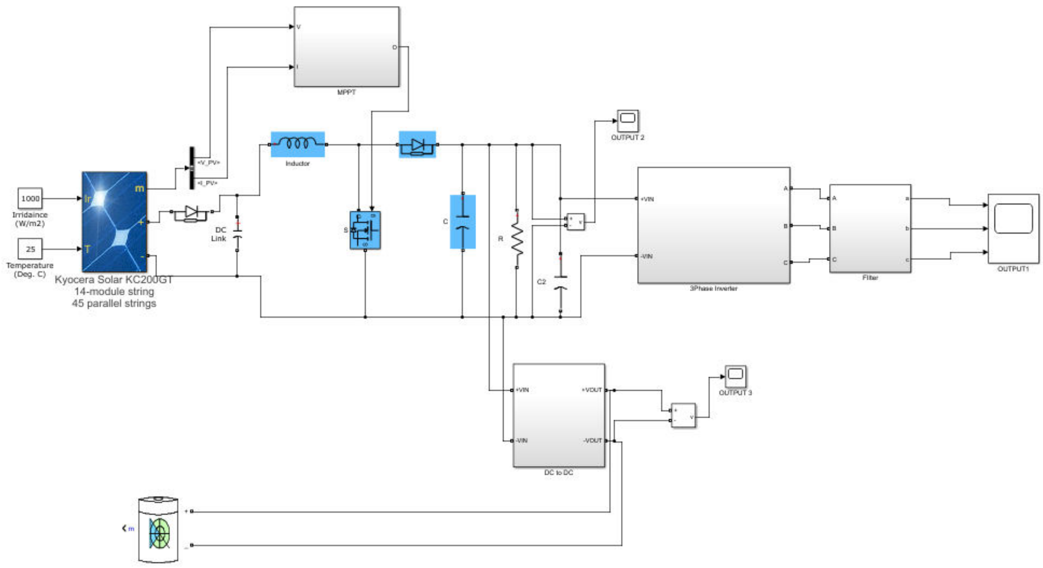

Figure 4.1: Circuit diagram of the system

Design aspects:

PV ARRAY:

MODULE – Kyocera200GT

• Open circuit voltage, V_{oc} = 32.9V

• Voltage at maximum Power point = 26.3V

• Short circuit current, I_{sc} = 8.21A

• Current at maximum power point = 7.61A

• Max power per string = 200.143W

• Number of series connected modules = 14

• Number of parallel strings = 45

• Maximum Power = No of series connected modules/string * No of parallel strings * Max power/string

= 14 * 45 * 200.143

= 126 kW

• Total output voltage of PV array= Number of series connected modules/string * voltage at maximum power point

= 14 * 26.3

= **368.2 V**

• Total output current of PV array = Number of parallel strings * current at maximum Power point

= 45 * 7.61

= **342.45 A**

BOOST CONVERTER:

• V_{in} = 370 V

• V_o = 410 V

Duty cycle: $D = 1 - (\frac{Vin(min)}{Vout} * n)$

$= 1 - \frac{370 * 0.8}{410}$

= 0.277 ≈ **0.3**

Input Ripple current: $\Delta IL = (0.2 \text{ to } 0.4) * I_{out} * \frac{Vout}{Vin}$

$= 0.2 * 738.8 * \frac{410}{370}$

= **163.72A**

Inductor: $L = \frac{(Vout - Vin) * Vin}{\Delta IL * fs * Vout}$

$= \frac{(410-370)370}{163.72*550*410}$

= **0.4 mH**

Capacitance: $\Delta V_{out} = ESR * (\frac{Iout(max)}{1-D} + \frac{\Delta IL}{2})$

$= 0.05 * (\frac{738.8}{1-0.3} + \frac{163.73}{2})$

= **56.86 V**

• C_{in} is taken from the datasheet.= **50 mF**

• $C_{out(min)} = \frac{Iout(max)*D}{fs * \Delta Vout}$

$= \frac{738.8*0.3}{550*56.86}$

= **7 mF**

SEPIC CONVERTER:

Since the values of SEPIC keep on changing due to the PWM signal, we have designed SEPIC for its open ended circuit values and implemented the same.

Parameters:

$V_s = 9V$

$V_o = 6V$

$\Delta Il1 = \Delta Il2 = 0.4$

$P_s = 12$

F = 100 KHz

Duty cycle : $D = \frac{Vo}{Vo+Vs} = 0.4$

Capacitance : $C1 = \frac{Vo}{D*F*\Delta Vc1} = 80\mu F$

$$C2 = \frac{Vo}{D*F*\Delta Vc2} = 80\mu F$$

Minimum and maximum inductance currents: $I_{L1max} = I_{L1} + \frac{\Delta i_{L1}}{2} = 1.33 + \frac{0.4}{2} = 1.53A$

$I_{L1min} = I_{L1} - \frac{\Delta i_{L1}}{2} = 1.33 - \frac{0.4}{2} = 1.13A$

$I_{L2max} = I_{L2} + \frac{\Delta i_{L2}}{2} = 2 + \frac{0.4}{2} = 2.2\ A$

$I_{L2min} = I_{L2} - \frac{\Delta i_{L2}}{2} = 2 - \frac{0.4}{2} = 1.8\ A$

Inductances : $L_1 = \frac{V_s D}{f\Delta i_{L1}} = 90\mu H = 100\mu H$

$L_2 = \frac{V_s D}{f\Delta i_{L2}} = 90\mu H = 100\mu H$

V. RESULT AND DISCUSSION

The figure 5.1 shows the boost converter output which is a plot of voltage vs simulation time. The theoretical expected output as show above in the design aspects section is 410V but in simulation we are getting a voltage of 414V which is shown in the figure 5.2.

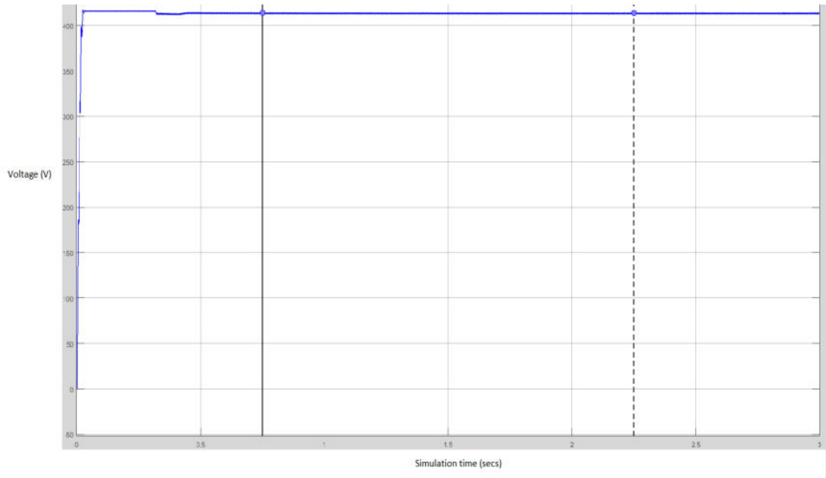

Figure 5.1: Plot of Voltage vs Simulation time of boost converter

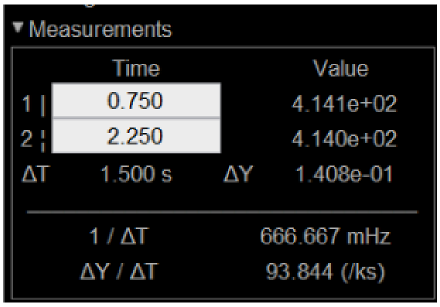

Figure 5.2: Measurement of the Boost converter output

Figure 5.3 shows the output of the SEPIC converter which is plot of voltage vs simulation time. The expected output from the theoretical calculations is supposed to be 180V but we are getting a voltage of 174V (RMS) which can be seen in the figure 5.4. This is due to losses in the switching of the MOSFET which is the control transistor in the SEPIC circuit.

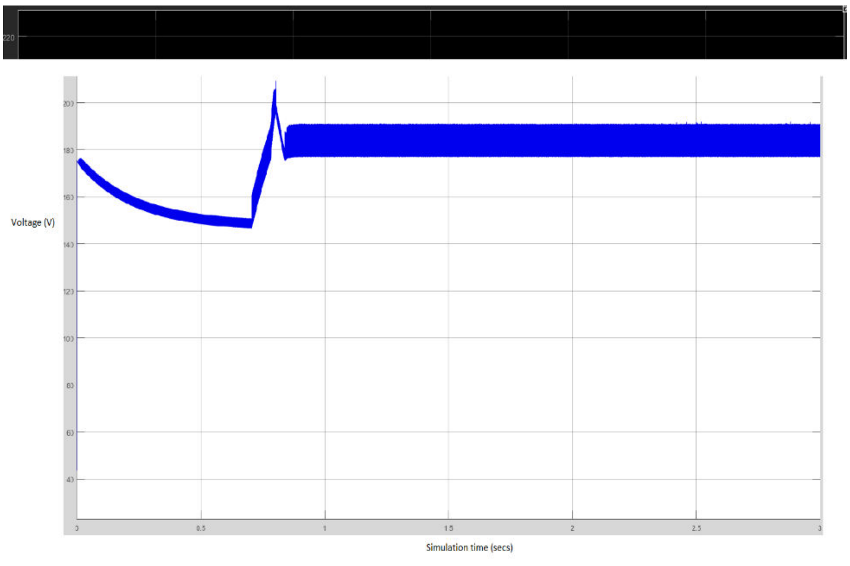

Figure 5.3: Plot of Voltage vs Simulation time of SEPIC

Signal Statistics

	Value	Time
Max	2.093e+02	0.803
Min	4.358e+01	0.000e+00
Peak to Peak	1.657e+02	
Mean	1.740e+02	
Median	1.775e+02	
RMS	1.744e+02	

Figure 5.4: Signal statistics of output of SEPIC

Figure 5.5 shows the final three phase output of the system. The phase voltage is 238V (RMS) and the line voltage is root 3 times of phase voltage which is 415V. The phase voltage of each phase is shown in the figures 5.6, 5.7 and 5.8 respectively.

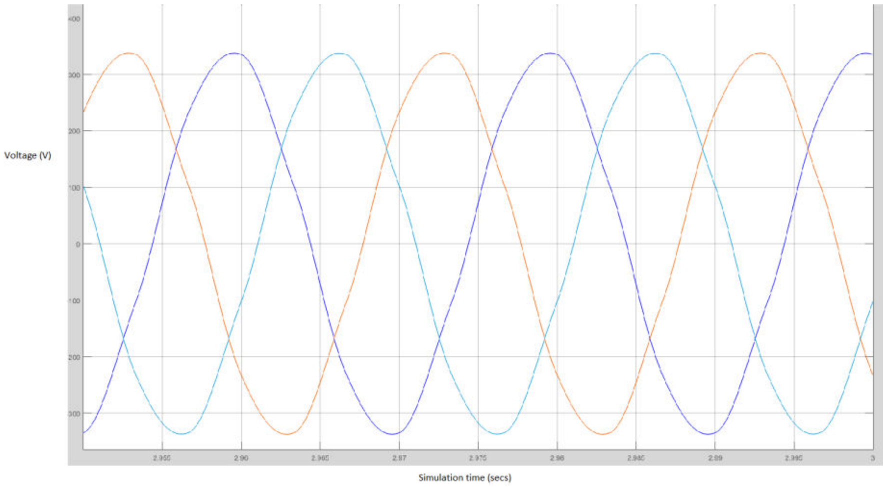

Figure 5.5: Final three phase output

Filter/1 — **Signal Statistics**

	Value	Time
Max	3.374e+02	2.980
Min	-3.374e+02	2.970
Peak to Peak	6.749e+02	
Mean	9.412e+00	
Median	1.442e+01	
RMS	2.389e+02	

Figure 5.6: Output of phase Y

Filter/2 — **Signal Statistics**

	Value	Time
Max	3.376e+02	2.993
Min	-3.376e+02	2.983
Peak to Peak	6.752e+02	
Mean	3.142e+01	
Median	5.987e+01	
RMS	2.391e+02	

Figure 5.7: Output of phase B

Filter/3 — **Signal Statistics**

	Value	Time
Max	3.372e+02	2.966
Min	-3.372e+02	2.956
Peak to Peak	6.743e+02	
Mean	-4.084e+01	
Median	-8.762e+01	
RMS	2.389e+02	

Figure 5.8: Output of phase R

VI.CONCLUSION

The demand for electrical power is going up day by day while the power generation from non-renewable resources is decreasing due to shortage of fossil fuels it is high time that we start using renewable energy resources for power generation. From this project we not only harness the energy obtained from the sun during the day but we store it and

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use it when there is need for additional power. This also shows a very cost effective way of achieving the same as there are no transformers involved and this project could be the solution for the future shortage of power that will be occurring inevitably. This project can be for distribution grids, large industries or even stand-alone systems.

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