

**SWITCHED INDUCTOR DOUBLE SWITCHED
DC-DC CONVERTER FOR SOLAR HOT PLATE
COOKING**

PHASE-2 PROJECT REPORT

submitted by

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**DEPARTMENT OF ELECTRICAL AND ELECTRONICS
ENGINEERING.**

T.K.M COLLEGE OF ENGINEERING, KOLLAM



CERTIFICATE

This is to certify that the report entitled '**SWITCHED INDUCTOR DOUBLE SWITCHED DC-DC CONVERTER FOR SOLAR HOT PLATE COOKING**' submitted by **JAYAKRISHNAN K** to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Electrical and Electronics Engineering is a bonafide record of the project work carried out by him under our guidance and supervision. This project report in any form has not been submitted to any other University or Institute for any purpose.

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ABSTRACT

Conventional DC/DC converters provide limited practical gains at high duty cycles and the passive elements required is higher which reduces the compactness, consequently, increases the cost of the system. Such trend is not suitable for various high gain applications. To overcome the above mentioned issue, a new switched inductor arrangement is proposed which is named as switched inductor double switch DC/DC converter (SL-DS-DC) and P&O MPPT technique will be implemented which provides better maximum power extraction and finally this circuit is used for solar hot plate cooking application. The major advantages of the proposed method is that it requires less number of passive elements eventually reduces the size. Another advantage of this converter is it provides lower voltage stress as compared to various other converters. The suggested high gain DC-DC converter, which can run a 240W solar hot plate cooking equipment, has been designed and simulated.

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Abbreviations and Notations

1. RES - Renewable Energy Sources
2. PV - Photovoltaic
3. MPPT - Maximum Power Point Tracking
4. ROI - Return On Investment
5. SL-DS-DC - Switched Inductance Double Switch DC-DC Converter
6. SCRB - Switched Capacitor Regenerative Boost Configuration

Chapter 1

Introduction

1.1 General Background

Renewable energy sources (RES), particularly photovoltaics (PV), are assuming a dominant role in power networks. The DC-DC boost converter functions as an integrator in these applications to control the voltage level. For renewable energy applications, high voltage gain DC-DC converters are essential. Although there are many DC-DC converters available to increase voltage gain, the necessity for passive parts is larger. Boost mode operation of DC-DC converter is reliant on input inductor current. The DC-DC step-up converter can operate in continuous current mode (CCM) and discontinuous current mode (DCM), depending on the inductor current profile. Due to its load independent voltage gain, less current ripple, and higher efficiency, the CCM is very well-liked. The need for high voltage gain can still be satisfied by a variety of topologies, but most of these require greater duty cycle variation ($0 \leq D \leq 1$). As a result, there is a possibility that the converter might reach inductor current saturation during duty cycle 0.5, drastically degrading its performance [1].

The emergence of power electronic converters in microgrid leads to more reliability concerned issues [2]. The use of renewable energy sources like solar, wind,

hydro, geothermal, and biomass is becoming more widespread. The average solar radiation received in India is $200\text{MW}/\text{km}^2$. Solar PV panels are being widely installed in the nation to take advantage of this. As of November 30, 2020, India had a total installed solar PV capacity of about 37GW. The use of solar panels to create power has several benefits, including the absence of noise and pollution, dependability, relatively cheap maintenance costs, and the free generation of electricity. Additionally, there are countless opportunities to obtain clean, environmental friendly energy from photovoltaic (PV) solar panels. Yet, people in Kerala right now are divided in their opinions, with some claiming that installing solar panels on roofs is not profitable while the other half claims that it is one of the most profitable business decisions and energy production strategies because it is a highly effective method of converting energy without leaving any carbon footprints and also when considering the ROI with a minimum of 3-6 years keeping into consideration of the overall life of panels i.e upto 25 years, the rest of the 19-22 years production is like bonus for the customers who took a decision on placing it on their homes in a long vision that when electric vehicles and all comes it will lessen the burden of grid if the abundant source of sun's light energy is extracted using various PV panels like monocrystalline, Polycrystalline etc. When it comes to using solar energy to cook meals, people and organisations in underdeveloped nations mainly rely on biomass to meet their energy needs. There are a number of harmful health and environmental effects associated with the unsustainable usage of biomass. Solar cooking offers a different approach because it uses clean energy. Despite having many advantages, solar cookers haven't become very successful. Strangely, there hasn't been much debate on this in academic circles.

In this project report, it is discuss the practicality of a novel autonomous solar cooker (hot plate) powered by clean photovoltaic (PV) energy. The equipment that is being offered is based on a PV system that has been scaled, designed, and built to meet the needs of users in both urban and rural settings. It is made up of PV panels, a high gain SL-DS-DC converter, thermal resistors, and a digital block for managing the system's electrical, thermal, and meteorological quantities (such as

lighting, PWM signals, currents, voltages, powers, efficiency, and temperatures).

1.2 Motivation

As its indicated before, the SL-DS-DC converter is designed with the fewest possible components in comparison to existing high gain networks. Additionally, the suggested converter has a better voltage gain than other high gain converters while using a less number of circuit components and a lower duty cycle that is below 0.3. As it previously mentioned, solar cooking offers a unique strategy because it makes use of renewable energy. Despite having a lot of benefits, solar cookers haven't been very popular. It's odd that there hasn't been much discussion about this in academia. So it is thereby combined to the high gain converter with a solar hot plate cooking system, taking use of its effective working mode with high gain at a low duty cycle.

1.3 Thesis Objective

Following study areas are defined based on thorough literature reviews on the subject, and efforts are made to integrate the Switched Inductor Double Switched DC-DC converter with a specific application, such as a solar hot plate cooking system. The following are the project's main objectives:

- Simulation of closed loop system of SL-DS-DC converter with PI controller, PO MPPT enabled PV boost circuit, battery with bidirectional converter circuit integrated with Hot Plate cooking setup.
- Design and simulation of Atmega 328P microcontroller prototype for master switching control of the overall setup in ARDUINO IDE software.
- Achieve high gain by the SL-DS-DC converter by reduced duty cycle to enable the working of Solar Hot Plate cooking setup.

1.4 Structure of Thesis

1.4.1 Chapter 1

This chapter's introductory portion highlights the use of the SL-DS-DC converter and how it could be combined with renewable applications, such as how it enables the working when connected to a solar hot plate cooking system. This also briefly addresses the thesis's motivation, objective and structure.

1.4.2 Chapter 2

The literature that was evaluated for the project's implementation is the subject of this chapter. The current literature on a variety of topics connected to the proposed system was thoroughly examined and analysed.

1.4.3 Chapter 3

This chapter addresses the modelling of the solar hot plate cooking system, which integrates an SL-DS-DC converter with the other circuits including the Lead acid battery, PV panels to produce a high gain at the load side. Here, the system's complete architecture is examined. In addition, it includes a simulation diagram of the various parts of the Hot Plate Solar Cooking Stove.

1.4.4 Chapter 4

Here in this section, the main emphasis is on the cost comparison, savings part and analysis of using liquefied petroleum gas and electricity generated by solar photovoltaic panels.

1.4.5 Chapter 5

This chapter deals with the scope, simulations, results and discussions. System is simulated in SIMULINK software. Results including the output power, current,

voltage, battery SOC during charging and discharging are also observed and analysed.

Chapter 2

Literature Survey

2.1 Introduction

This chapter provides an overview of the topics that supplied the ideas for this overall project. The following sections examine the previous works which have been done on the similar topics.

2.2 High step-up gain DC–DC converter with SC RB configuration for solar PV applications

According to this research, it is said as the transformer is one of the main burdens in grid-connected solar PV systems and lowers overall system efficiency because of its cost, size, and weight. In this study, a switched capacitor and regenerative boost (SCRB) configuration-based high step-up gain DC-DC converter is suggested as an alternative to using a transformer. The device stresses and losses connected with the converter are considerable in traditional boost type and derived converters, which leads to reduced efficiency. The switched capacitor and regenerative boost operations in the proposed converter are carried out simultaneously with the use of lossless passive components and a minimal number of semiconductor devices. As a result, efficiency is improved and the DC-voltage gain is dramatically increased. It

also prevails with less ripple content, which contributes to extending device lifespan and reducing electromagnetic interference. In-depth steady-state waveforms and different operating modes in the continuous conduction mode (CCM) and discontinuous conduction mode (DCM) are described in this work. Additionally, this study compares the proposed converter's features to those of traditional converters and details its performance.

2.3 An Impedance Network Boost Converter with a High-Voltage Gain

In this paper, a dc-dc boost converter with an impedance network is constructed. With fewer diodes and a lower duty cycle (less than 33% than a conventional boost converter), it can achieve higher voltage gains while avoiding instability brought on by the saturation of its inductors. In contrast, conventional boost converters achieve high voltage gains at rather high duty cycles (typically exceeding 50%), which leads to inductor saturation. Additionally, it is capable of meeting the demanding industrial standards, notably for renewable energy systems. In this study, a converter is developed, and continuous conduction modes are examined for various states of its constituent parts. The method for calculating its various two parameters is then demonstrated. The converter that is being proposed in this research work achieves a larger voltage gain while using fewer diodes and a lower duty cycle to prevent inductor saturation. On the other hand, this design uses 8 diodes and 4 inductors to achieve a high voltage ratio, which makes the converter circuit as a whole less compact and raises switching stress.

2.4 Switched capacitor/switched-inductor structures for getting transformer less hybrid DC to DC PWM converters

The simple switching structures produced by two capacitors and two to three diodes (C-switching) or two inductors and two to three diodes (L-switching) are discussed in this study. The two sorts of these structures are "step-down" and "step-up." Classical converters use the following building blocks: buck, boost, buck-boost, cuk, zeta, and sepic. The buck, buck-boost, Cuk, Zeta, and Sepic converters can be used with the "step-down" C- or L-switching structures to create a step-down function. The inductors in the L-switching blocks are charged in serially or the capacitors in the C-switching blocks are discharged parallely when the converter's active switch is ON. The inductors in the L-switching blocks discharges parallely, while the capacitors in the C-switching blocks charge in series, when the active switch is OFF. To create a "step-up" function, in the above mentioned converters are paired with C- or L-switching structures. The dc line-to-output voltage ratio of the new hybrid converters can be found by steady-state analysis. The gain formula demonstrates that the hybrid converters are more capable than the original, classical converters of lowering or raising the line voltage. The number of elements in the proposed hybrid converters in this study is equal to that of the quadratic converters. Their capabilities are contrasted with those of the available quadratic converters in terms of dc gain, voltage and current strains on the active switch and diodes, and currents through the inductors. The new hybrid converters' advantage is mostly attributable to their lower magnetic field energy, which results in smaller, less expensive inductors and lower current stresses in the switching parts, which reduce conduction losses. A unified approach for creating hybrid converters with a high step-down/up conversion voltage ratio was thus proposed for the entirety of this work. The dc gain's topologies and formulas have been deducted. The fundamental benefit of the work is that it results in reduced inductor size and cost, as well as reduced current stresses in the switching parts, which reduce conduction losses.

However, the circuit's high inductor and diodes produce EMI.

2.5 Solar Induction Cooker

This paper discusses an induction cooker that is powered by a renewable energy source, such as solar. Many people in developed nations struggle to cook with stoves that produce harmful fumes and contribute to the emission of greenhouse gases. Induction cooking is based on the electromagnetic induction principle and works by creating eddy currents in the coil that are excited in the ferromagnetic material to produce heating. The quickly accessible induction cooker employs AC as a source of input; doing so at times of high load takes a lot of current and affects utility service. Because of this, it's needed to find a quick answer, like a solar-powered induction cooker. Solar energy is used in the Solar Powered Induction Cooker. The total setup is carried out in two steps, the first of which is the conversion of boosted DC to high frequency DC. Because the output from solar panels is so low, a dc to dc converter is needed to boost activity. DC to high frequency AC, In order to achieve the high frequency requirement (20 kHz–100 kHz) for induction cooking, an ac conversion step is employed. The switching pulses are made via duty ratio control. The output of the converter is fed into an induction coil, which generates electrical energy that, thanks to the coil's resistance, is converted to heat and used to prepare food. Cookware made of specific materials with specific qualities is required in order for an induction hob to function. Heating won't be effective if the metal is too thin or doesn't offer much resistance to flow. Due to the magnetic field's inability to produce a focused current, the majority of induction tops will not heat copper or aluminium vessels. The operation of the cooker also requires DC-DC, DC-High frequency AC conversion, which raises the price, creates harmonics, etc.

2.6 Comparative Analysis of MPPT Techniques for PV applications

In this paper it is said that the use of photovoltaic (PV) systems is expanding globally as a result of the rising need for energy. Since PV systems are having non-linear characteristics, unique techniques are used to extract the most power possible. The PV module's non-linear IV curve has a single, distinct point of maximum output. Power electronic converters are employed in order for devices to function at that power point. MPPT approaches are algorithms used to manage these power electronic converters. The literature has a variety of original algorithms, each with unique benefits and disadvantages. In this paper, it is presenting a comparison of four commonly used MPPT techniques: 1) Fractional Short Circuit Current (FSCC), 2) Fractional Open Circuit Voltage (FOCV), 3) Perturb Observe (P&O), and 4) Incremental Conductance (IC) MPPTs. This is done with the understanding that an efficient tracking of Maximum Power Point (MPP) can increase the usability of a PV system by many folds. The comparative study lists the advantages and disadvantages of each MPPT when used with a ohmic load. The analysis focuses on the amount of time needed for each algorithm to monitor the system efficiency and maximum power.

One of the most used MPPT algorithms is the P&O approach. This method perturbs the voltage in one direction, and if the power output rises more, the algorithm continues to perturb in that direction. The new power will perturb in the opposite direction if it is smaller than the old power. However, after reaching the MPP, this algorithm continues to oscillate around the MPP. Additionally, under rapidly changing weather conditions, this algorithm frequently causes confusion. P&O is easy to implement in terms of both embedded software and hardware.

2.7 Conclusion

The results of the thorough investigation of the subjects pertaining to the suggested system are summarised in this part. This literature review assisted in identifying several strategies for putting into practise linked systems, as well as their methodology, benefits, and drawbacks.

Chapter 3

Methodology

3.1 Introduction

In addition to the SL-DS-DC high gain converter, battery arrangements, and accompanying solar PV MPPT system, this chapter covers several methodologies that were used in the Hot Plate Solar Stove configuration. The approaches include compiling data based on the current solar cooking systems and incorporating a High gain SL-DS-DC converter with a minor modifications in the circuit and finally the development of new idea to implementation level.

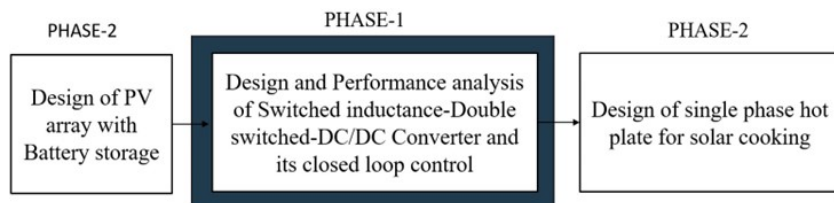


Fig. 3.1: Methodology Framework

3.2 Research on existing systems

Detailed literature survey is done on IEEE journals and conference papers dealing with similar topic the disadvantages of the systems were identified and is improved in the modified system.

3.3 Proposed system

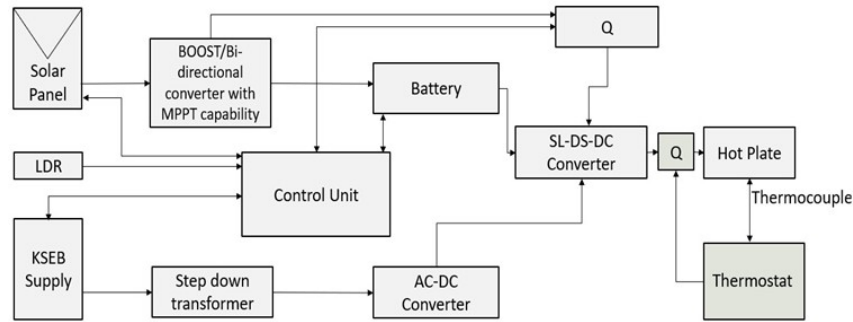


Fig. 3.2: Proposed Model

The project is proposing a Hot plate solar cooking stove set up of 240W power rating by integrating a high gain SL-DS-DC converter which can be related to the heart of this setup, there will be a master control unit coming which controls all the switching of Hot plate, MPPT charge controller etc.. according to various logics applied in the Atmega 328P microcontroller based ARDUINO UNO, here all the main conversions happens only in DC-DC mode (since our SL-DS high gain DC-DC converter is providing 200V output voltage from 40V input just by setting the duty cycle at 0.15 which is below 0.3 compared to conventional boost converter providing 2 times gain only at duty cycle range of 0.6-0.8 where the design specifications will be discussed in detail further) rather than converting AC-DC, DC to high frequency AC which happens in the case of AC induction cooking stove, where conventional cooking methods such as biomass, gas stoves as it is known that it emits large amount of precarious fumes and makes the working place messy. Cooking using electricity is one of the cleanest and efficient method of cooking as compared to biomass and other method of cooking. Use of DC system not only upsurge efficiency but also waive large and costly inverter that is required for cooking purpose using existing AC induction cooker.

In this work its been considered as a 240W heating load which is the solar hot plate system which works mainly on DC supply provided by the SL-DS-DC high gain converter i.e an output voltage of 200 V and 1.2 A output current. Considering the input energy source, it is considered a 1kW PV panel, battery capacity of 24V

40Ah Lead acid, Using a boost converter and P&O MPPT, the PV is connected to the bus. The bus voltage is always maintained at 40V which will be the input voltage to the SL-DS-DC high gain converter. According to the above mentioned PV and battery value the overall simulation is done which will be discussed detailed in the coming sections.

3.4 Design of Switched Inductance Double Switch DC-DC Converter

Fig. 3.3 depicts the suggested converter (SL-DS-DC). Two inductors, three capacitors, seven diodes, and two MOSFETs make up the SL-DS-DC. Since the inductor is constantly directly connected to the source, any current drawn from it will be continuous. The magnitude of both inductors in the proposed converter is the same. This is especially helpful for lessening the strain on the battery or power supply at present. Due to CCM's greater efficiency than DCM, the SL-DS-DC's functioning will only be described in that format. The two operating modes of the SL-DS-DC are depicted and figures 3.3 and 3.4 display the present flow path as blue lines.

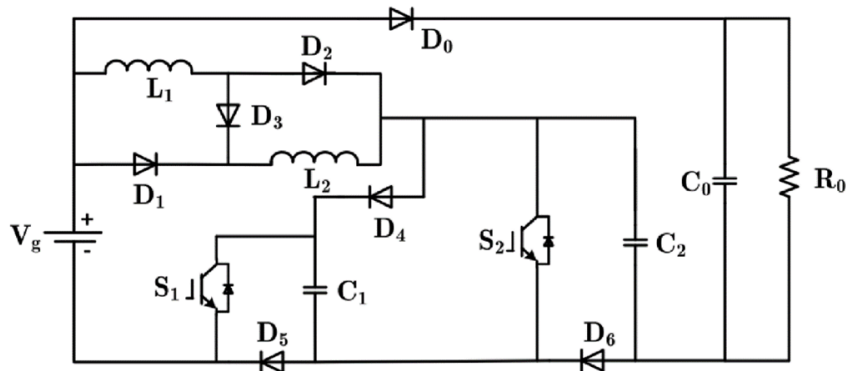


Fig. 3.3: Proposed SL-DS-DC high gain converter

3.4.1 Mode-1

Both switches S1 and S2 are turned ON when the system is in mode 1, ($0 \leq t \leq 1$). Due to the polarity of the inductors and voltage source, respectively, the diodes D_1 , D_2 and D_0 are in the forward state. In this mode, the sum of $V_g + V_{C1}$ charges

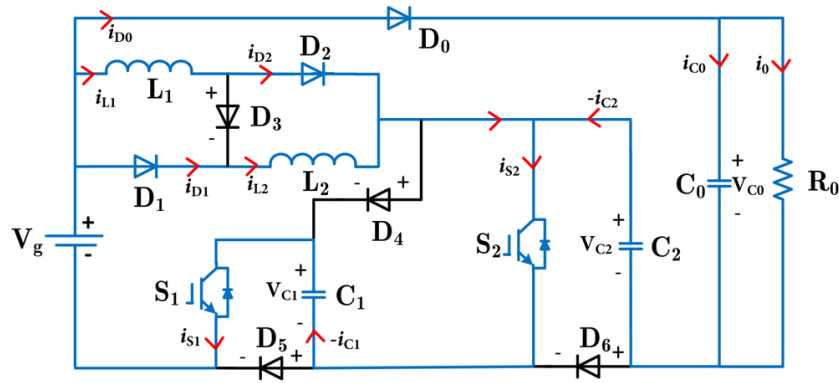


Fig. 3.4: Mode-1 Operation

the inductors L_1 and L_2 in parallel through S_2 , C_2 and S_1 . The voltage across the inductors is same since they are operating in parallel, or ($V_{L1} = V_{L2}$). During this time, the total of $V_g + V_{C1} + V_{C2}$ also supplies the load. According to Fig. 3.3, the steady state equations are as follows. (Assumption: $L_1 = L_2 = L$)

$$V_g - V_L + V_{C1} = 0 \quad (3.1)$$

$$-V_0 + V_{C2} + V_L = 0 \quad (3.2)$$

$$V_g - V_0 + V_{C2} + V_{C1} = 0 \quad (3.3)$$

Equation for current

$$i_{L1} + i_{L2} = i_{C1on} + i_{C2on} \quad (3.4)$$

$$i_{C2on} = -(i_{C0on} + i_0) \quad (3.5)$$

3.4.2 Mode-2

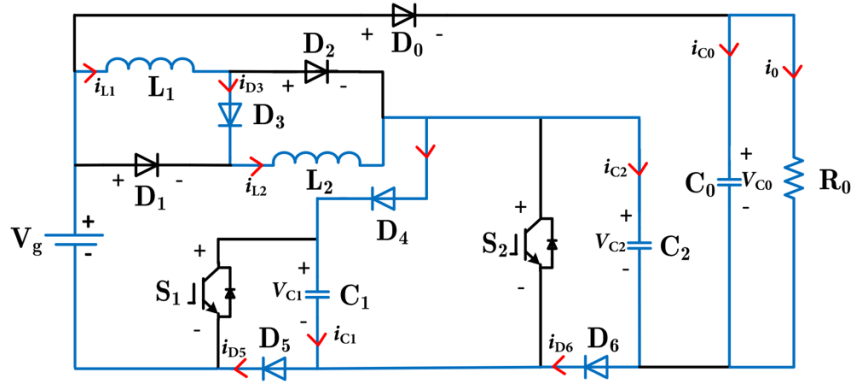


Fig. 3.5: Mode-2 Operation

The switches S1 and S2 are both in the OFF state in mode 2, which is represented by $(t_1 \leq t \leq t_2)$. Reverse bias is introduced into the diodes D1, D2 and D0. The forward biased diodes D3, D4, D5 and D6. The energy from the two inductors, which are connected in series, is distributed equally across the capacitors C1 and C2. The capacitor C0 is supplying the load at this time. The following are the steady state equations for this time period as shown in Fig. 3.5.

$$V_g - 2V_L - V_{C1} = 0 \quad (3.6)$$

$$V_{C2} = V_{C1} \quad (3.7)$$

Equation for current

$$i_{L1} = i_{L2} = i_{inoff} \quad (3.8)$$

$$i_{L1} = i_{L2} = i_{C1off} + i_{C2off} \quad (3.9)$$

$$i_{C0off} = i_0 \quad (3.10)$$

3.4.3 Voltage Gain Derivation

By taking average of voltage over a switching cycle across the inductor L,

$$\int_0^{DT_s} V_L dt + \int_{DT_s}^{T_s} V_L dt = 0 \quad (3.11)$$

Substituting the value of V_L

$$D(V_g + V_{C1} + (1 - D)(V_g - V_{C1})/2 = 0 \quad (3.12)$$

$$V_{C1} = \left(\frac{1 + D}{1 - 3D} \right) * V_g \quad (3.13)$$

As per the model $V_{C1}=V_{C2}$

$$V_{C2} = \left(\frac{1 + D}{1 - 3D} \right) * V_g \quad (3.14)$$

Substituting the values in eqn(3.3)

$$V_0 = \left(\frac{3 - D}{1 - 3D} \right) * V_g \quad (3.15)$$

Therefore the gain of SL-DC-DC is given as

$$G = \frac{3 - D}{1 - 3D} \quad (3.16)$$

3.5 Circuit Design

Considering the design for $V_g=40$ and $V_0=200$

3.5.1 Duty Cycle

From eqn(3.15) on substituting the values of V_g and V_0

$$200 = \left(\frac{3 - D}{1 - 3D} \right) * 40$$

$$D = 0.15$$

3.5.2 Inductor Design

$$L = \frac{V_s * D}{f_s * \Delta I_L} \quad (3.17)$$

Switching frequency f_s is taken as 50kHz. Here

$$\frac{L * \Delta I_s * f_s}{D} = V_g + V_{C1} \quad (3.18)$$

Using eqn(3.13) $V_{C1}=83.63V$ and $\Delta I_L=\%r * I_L$, where $\%r$ = ripple percentage.

According to the IEEE standars $\%r$ is taken as 9%.

$$I_L = \left(\frac{1}{1+D} \right) * \left(\left(\frac{V_0^2}{V_g * R_0} \right) - \left(\frac{DV_0}{R_0} \right) \right) \quad (3.19)$$

Since $P_o=P_i$, $R=200\Omega$.

Therefore $I_L=4.217mA$ On substituting these values in equation (3.17)

$$\boxed{L = 351\mu H}$$

3.5.3 Capacitor Design

$$C = \frac{I_{0max} * D}{f_s * \Delta V_c} \quad (3.20)$$

$$I_{0max} = 2I_L + I_0 \quad (3.21)$$

Therefore eqn(3.20) becomes

$$C = \frac{2I_L + I_0 * D}{f_s * \Delta V_{C1}} \quad (3.22)$$

Using $P_o=P_i$, $I_0=1A$

$$\Delta V_{C1} = \%r * V_{C1}$$

where the permissible range of $\%r$ is 0.005-2. Here taking it as 0.7%. On substituting these values C_1 becomes

$$\boxed{C_1 = 47\mu F}$$

Value of C_0 can be obtained using the below equation

$$C_0 = \frac{I_0 * (1 - D) * T_s}{\%r * V_0} \quad (3.23)$$

$$\boxed{C_0 = 100\mu F}$$

3.5.4 Circuit Specification of the Converter

Table 3.1: Circuit parameters and values

PARAMETER	PARAMETER VALUES
Input Voltage (V_g)	40V
Output Voltage (V_0)	200V
Output Current (I_0)	1A
Output Power (P_0)	200W
Inductors (L_1 and L_2)	350 μ H
Capacitor (C_1 and C_2)	47 μ F
Capacitor (C_0)	100 μ F
Resistor	200 Ω
Switching Frequency	50kHz

Values of L and C are designed using the equation given above. In the next section it includes the design criteria for solar PV and lead acid battery.

3.6 Design criteria for Solar PV and Lead acid battery

In this project a 5*213W i.e approximately 1kW panel of monocrystalline type with each panels $V_{oc}=36.3$ V , $I_{sc}=7.84$ A, $V_{mpp}=29$.

- Parallel strings=5
- Series connected modules per string =1
- Total power= 1kW
- Temperature=25 degree Celsius

The fundamental factors that must be taken into account when choosing a solar panel for the appropriate load and the design considerations when fixing the appropriate lead acid batteries for the backup purpose while taking the load into account

are-

- In industrial and solar applications, lead acid batteries are typically of the C10 and C5 types, where the C5,C10 (rapid discharge batteries) is actually the safest maximum charging/continuous discharge rate. For example, a 150Ah C20 battery, a medium discharge battery typically used in inverters and UPS systems, has a discharge rate of just 7.5A for 20 hours, whereas a 150Ah C10 lead acid battery has a discharge rate of 15A for 10 hours, which is theoretically conceivable but impractical.
- A 12V Lead acid is actually formed using six 2 volt single cells connected in series where the maximum charging voltage of the 12V battery is calculated by multiplying 6 with 2.2V(i.e 13.2V) where the 2.2V is the fully charged potential for a 2V single Lead acid battery where as the minimum discharge voltage for a 12V Lead acid battery is calculated as by multiplying 6 with 1.8V(i.e 10.8V) where the 1.8V is the fully discharged potential for a 2V single Lead acid battery.
- Another fact is here in the project two 12V 40Ah C10 lead acid batteries connected in series to obtain 24V in total and current rating is 40Ah as such because voltage will be added and the current will be not changing due to series connection. Here when it is considered the battery power it is $24V \times 40Ah = 960Whr$. That is to charge a battery of power 960 watt hour according to thumb rule its only needed $1/4^{th}$ of battery power which is 240W if a basic offgrid solar system is considered, but here in this project when during maximum irradiation condition the 240 watts heating load will be feeded directly without taking battery supply which works as a ongrid mode and if low irradiation condition happens only offgrid mode is considered where the battery supply is utilised to feed the heating load so it can work this system as a hybrid mode of working.
- In the proposed project for the design and selection of battery and for calculating the backup of lead acid battery to feed 240W load, The formulas taken

are

- Rating of the Battery selected for the project is 24V 40AH.
- Discharge Current of Battery= $\frac{240W}{24V}=10A$ which means in 1 hour 10 amps can be discharged but practically its not possible.
- Backup hours= $\frac{40Ah}{10A}=4Hrs$
- Backup time of the lead acid battery is calculated as $\frac{Battery(AH)*Batteryvoltage}{Load(W)}$
- Using the above equation backup is equal to $\frac{40Ah*24V}{240W}=4hrs$
- For any battery the efficiency is 70%(thumb rule) i.e , total backup that can be provided by the battery 24V 40AH for 240W running load= $4*0.7=2.8hrs$.

3.7 MPPT Control Design

Since PV systems are not linear in nature, unique techniques are used to extract the most power possible. The PV module's non-linear IV curve has a single, distinct point of maximum output. Power electronic converters are employed in order for devices to function at that power point. Maximum Power Point Tracking (MPPT) approaches are algorithms used to manage these power electronic converters. One of the most used MPPT algorithms is the P&O approach [3]. The flow chart in Fig.3.6 illustrates its mechanism. This method perturbs the voltage in one direction, and if the power output rises more, the algorithm continues to perturb in that direction. The new power will perturb in the opposite direction if it is smaller than the old power. However, after reaching the MPP, this algorithm continues to oscillate around the maximum power point. Additionally, under rapidly changing weather conditions, this algorithm frequently causes confusion.

The IV curve of solar PV module used is shown in fig. 3.7.

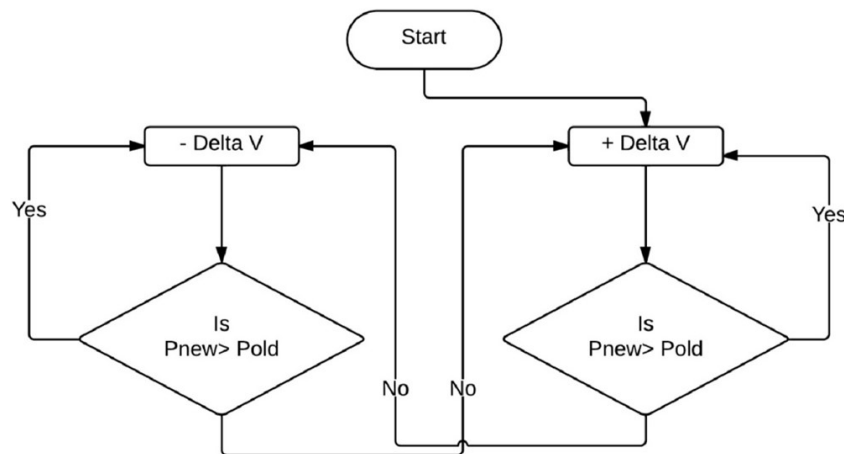


Fig. 3.6: Fundamental P&O MPPT algorithm

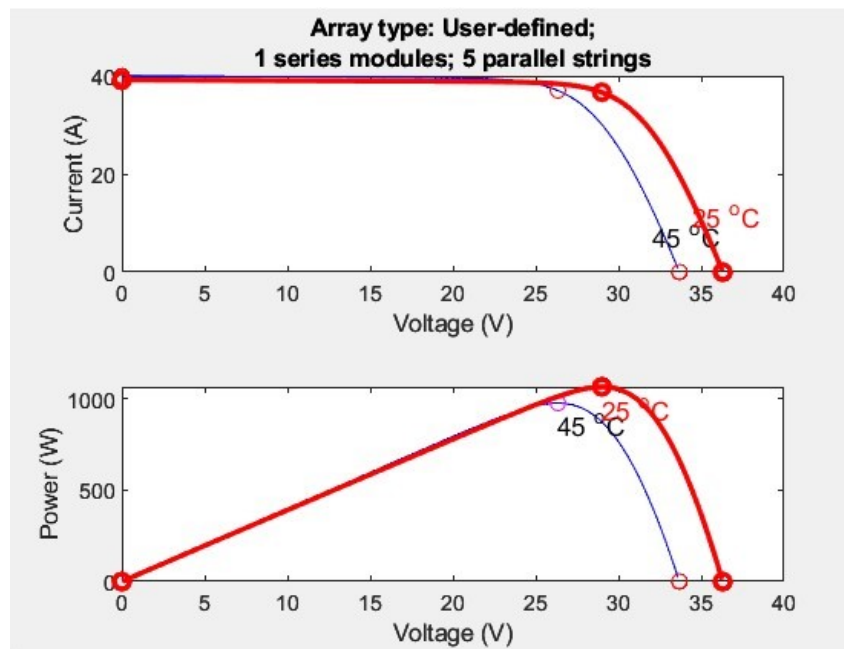


Fig. 3.7: PV characteristics

3.8 Design of the Master switching control using Atmega 328P based ARDUINO UNO CONTROLLER

The Arduino UNO is utilized as a central processor and master switching control for the implementation of the proposed Solar hot plate system. A microcontroller board called Arduino UNO is based on the ATmega328P. It contains 6 analogue

inputs, a 16 MHz ceramic resonator, 14 digital input/output pins (six of which can be used as PWM outputs), a USB port, a power jack, an ICSP header, and a reset button. It comes with everything needed to support the microcontroller; to get started, just plug in a USB cable, an AC-to-DC adapter, or a battery. It can be experimented with the UNO without being too concerned that it will make a mistake; in the worst case, it can replace the chip for a few rupees and start over.

When saying about its software and cloud capability, the following software tools allow to program the board both online and offline. Some of the simulation softwares used for simulating Arduino NANO, UNO and MEGA is Arduino IDE, Arduino CLI, Web Editor. In this project Arduino IDE is used for the simulation process of Arduino NANO.

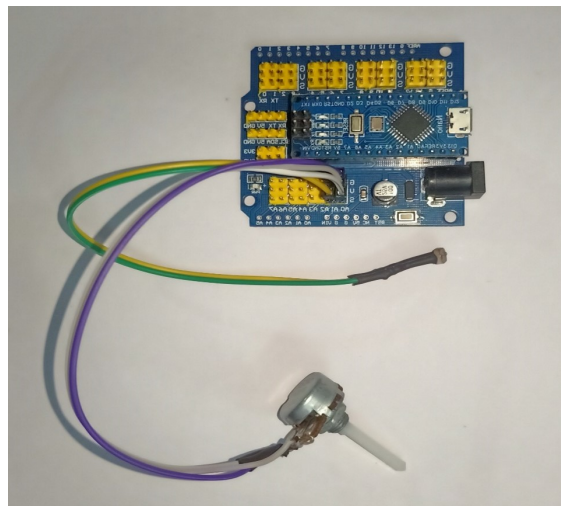


Fig. 3.8: Arduino NANO master control unit set up

In this proposed project Arduino NANO is used for master switching control i.e. a potentiometer is considered to simulate battery where the V_{cc} pin is connected to Analog 0 pin of NANO, LDR is used for checking the irradiation/light intensity level because it is economical since it can be avoided using costly irradiation measuring devices like Pyranometer, Solarimeter etc which cost upto 13500/- INR. These are the conditions which are considered for switching logics in Arduino NANO by considering the Solar light intensity level, Battery terminal voltage etc..

- DAY TIME WITH COOKING - BATTERY VOLTAGE = 13V IF LDR

VALUE > 60 - The Hot plate can be used from direct Solar Output in ongrid mode

- DAY TIME WITHOUT COOKING - BATTERY VOLTAGE > 13V LDR VALUE > 60
- NIGHT TIME WITH COOKING - $11.5 \leq \text{BATTERY VOLTAGE} \leq 13$ - The Hot plate can be used from direct battery supply which works in Offgrid mode.
- NIGHT TIME WITH NO SUFFICIENT BATTERY VOLTAGE i.e > 11.5V – Using Grid Supply

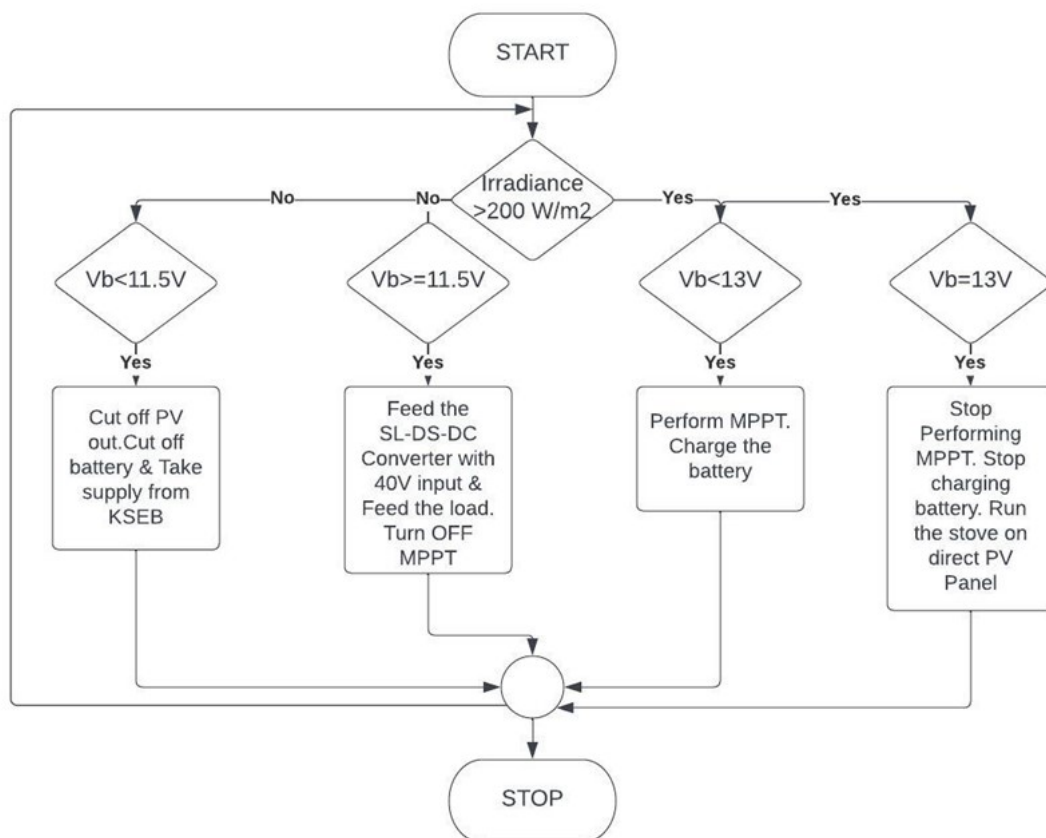


Fig. 3.9: Flowchart of master control unit for solar hot plate cooking system

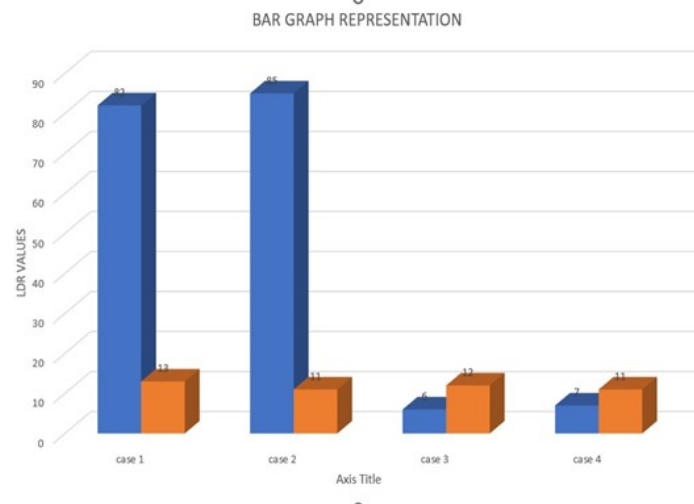


Fig. 3.10: Bar graph representation showing each cases of control strategies

3.8.1 Atmega 328P microcontroller based Arduino NANO programming in Arduino IDE Software

The IDE environment is mainly distributed into 3 sections

- Menu bar
- Text editor
- Output Panel

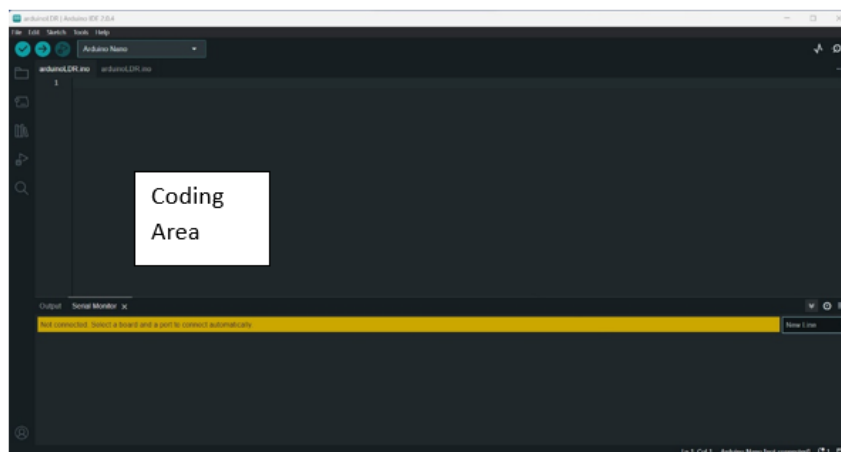


Fig. 3.11: Bar graph representation showing each cases of control strategies

The bar appearing on the top is called menu bar that comes with 5 different options as follows

- File- you can open a new window for writing the code over open an existing one.
- Edit-Used for copying and pasting the code with further modification for font.
- Sketch- For compiling and programming.
- Tools- mainly used for testing projects. The programmer section in this panel is used for burning a boot loader to the new microcontroller.
- Help- In case if it is feeling sceptical about software complete help is available from getting started to troubleshooting.

The 6 buttons appearing under the menu tab are connected with the running program as follows



Fig. 3.12: Bar graph representation showing each cases of control strategies

- The check mark appearing in the circular button is used to verify the code.
- The arrow key will upload and transfer the required code to the Arduino board.
- The 4th block represent which type of Arduino whether Arduino NANO, UNO or MEGA is connected to the Arduino IDE software.
- The button appearing on the top right corner is a serial monitor.

3.9 Conclusion

The complete proposed system design is initially individually developed and simulated and incorporated together to obtain the overall functioning of the respective Hot plate solar cooking setup.

Chapter 4

Simulation

4.1 Introduction

Matlab Simulink is used for simulation. A proprietary multi-paradigm programming language and numerical computing environment were created by MathWorks under the name MATLAB (short for "MATrix LABoratory"). Matlab offers matrix manipulation, function and data charting, algorithm implementation, user interface construction, and interface with other language-written programmes.

Although MATLAB is primarily designed for numeric computation, symbolic computation capabilities are accessible through an optional toolbox that uses the MuPAD symbolic engine. Graphical multi-domain simulation and model-based design for embedded and dynamic systems are added by the extra package Simulink. Additionally, Arduino IDE software is used to simulate the Atmega 328P microcontroller used in the Arduino NANO.

4.2 PV MPPT Boost Converter

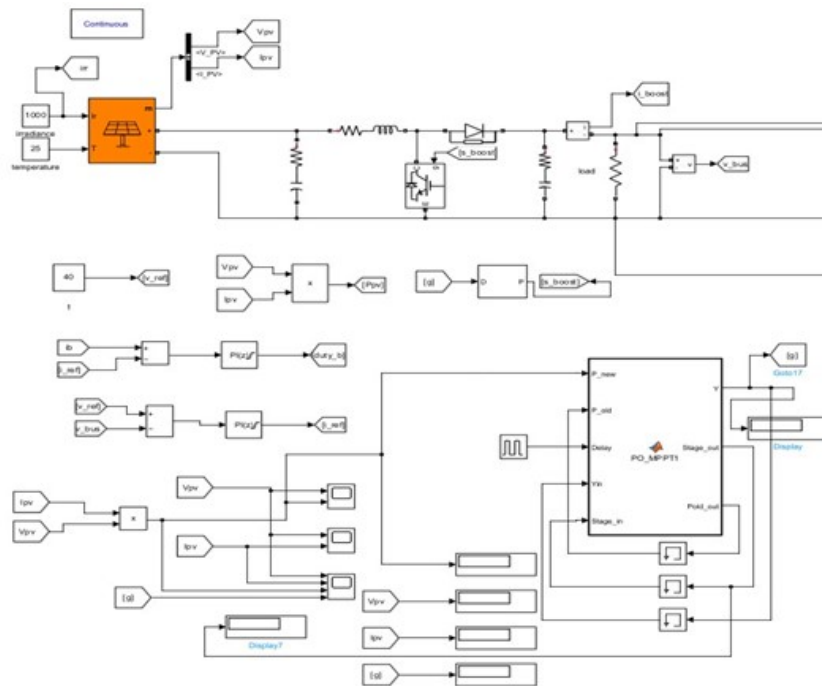


Fig. 4.1: PV MPPT Boost Converter

4.3 Battery bus with bidirectional converter

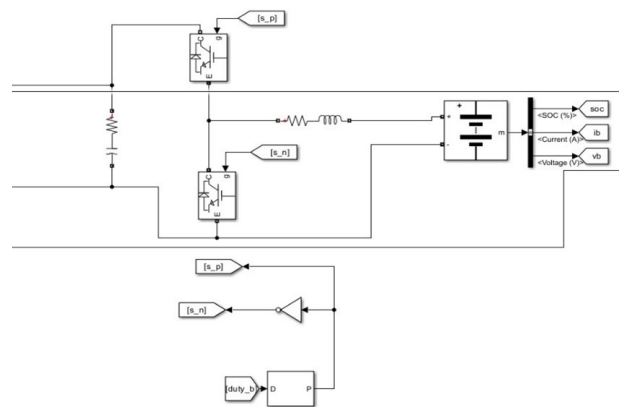


Fig. 4.2: Bidirectional Converter controller with Converter and battery

4.4 SL-DS-DC high gain converter open loop simulation

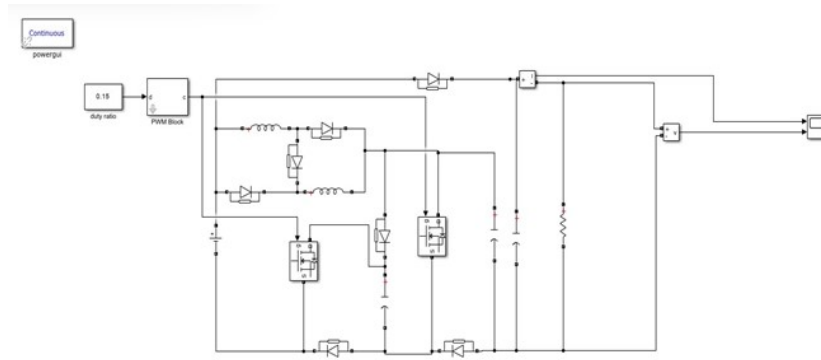


Fig. 4.3: Open loop simulation of the proposed high gain converter

4.5 SL-DS-DC high gain converter closed loop simulation with PI controller

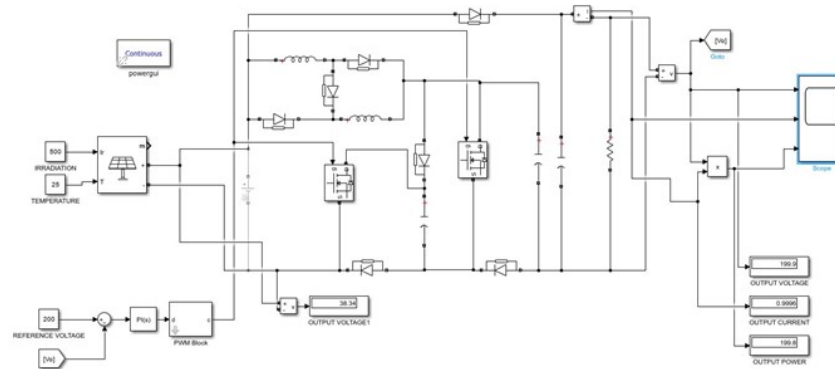


Fig. 4.4: Closed loop simulation with PI controller

4.6 Overall simulation of the solar Hot Plate set up

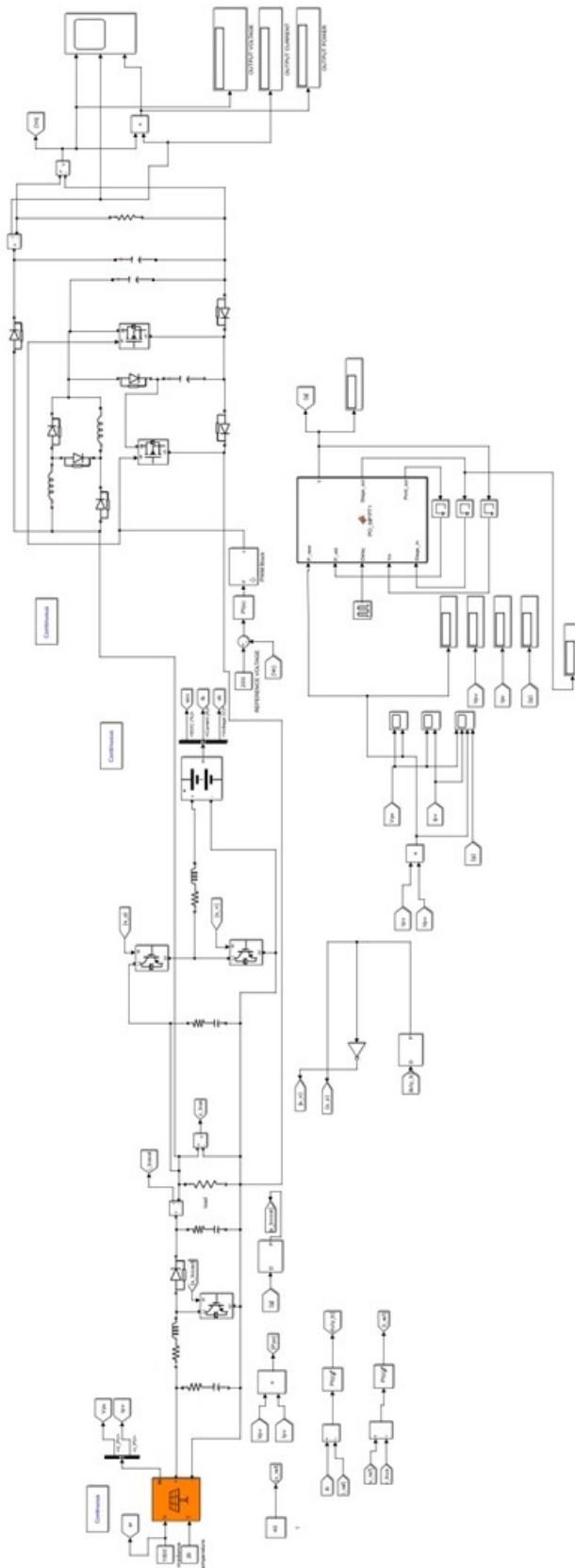
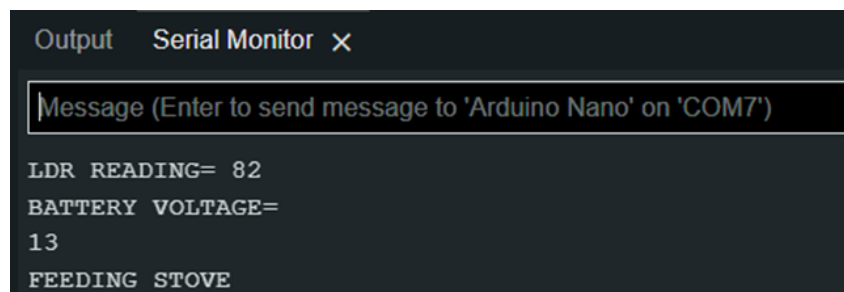


Fig. 4.5: Overall simulation of the Solar hot plate setup

4.7 Arduino NANO simulation in Arduino IDE software

Standard irradiation condition for a Solar Panel is 1000 watts/m² at 25 degree C. Here the irradiation is measured and mapped with LDR output values ranging from 0-100, Where values > 60 is taken as Peak solar irradiation condition (> 200watts/m²) values < 60 is taken a low irradiation condition (< 200watts/m²).

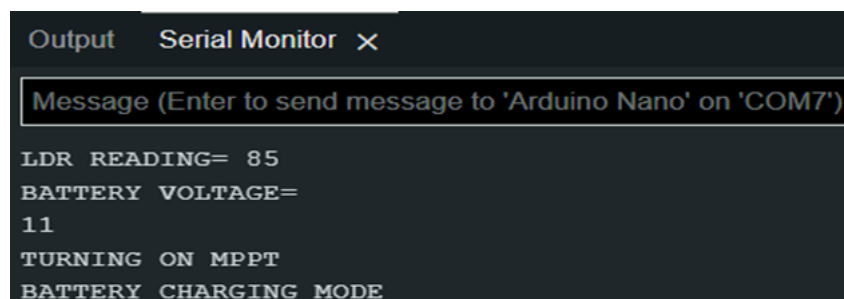


```

Output  Serial Monitor ✕
Message (Enter to send message to 'Arduino Nano' on 'COM7')
LDR READING= 82
BATTERY VOLTAGE=
13
FEEDING STOVE

```

Fig. 4.6: Output obtained from Arduino nano during peak solar irradiation condition (> 200watts/m²) when battery voltage =13V

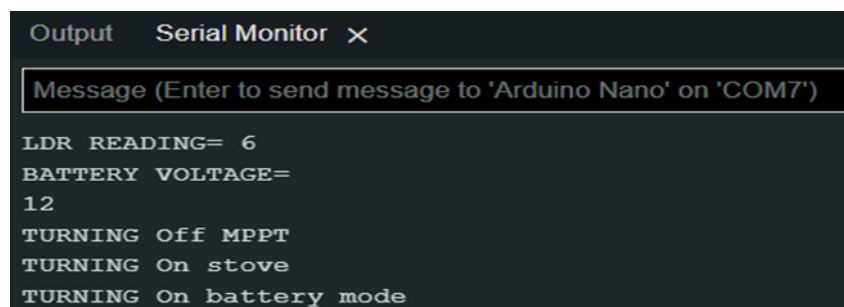


```

Output  Serial Monitor ✕
Message (Enter to send message to 'Arduino Nano' on 'COM7')
LDR READING= 85
BATTERY VOLTAGE=
11
TURNING ON MPPT
BATTERY CHARGING MODE

```

Fig. 4.7: Output obtained from Arduino nano during Peak solar irradiation condition 200watts/m² when battery voltage < 13V

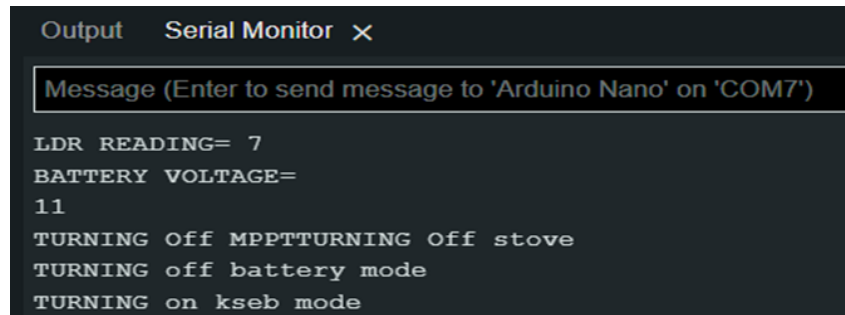


```

Output  Serial Monitor ✕
Message (Enter to send message to 'Arduino Nano' on 'COM7')
LDR READING= 6
BATTERY VOLTAGE=
12
TURNING Off MPPT
TURNING On stove
TURNING On battery mode

```

Fig. 4.8: Output obtained from Arduino nano during Low solar irradiation condition < 200watts/m² Battery voltage ≥11.5V

A screenshot of an Arduino IDE Serial Monitor window. The window title is "Output Serial Monitor" with a close button. Below the title bar is a text input field containing the placeholder text "Message (Enter to send message to 'Arduino Nano' on 'COM7')". The main area of the window displays the following text in a monospaced font:

```
LDR READING= 7  
BATTERY VOLTAGE=  
11  
TURNING Off MPPTTURNING Off stove  
TURNING off battery mode  
TURNING on kseb mode
```

Fig. 4.9: Output obtained from Arduino nano during Low irradiation condition $< 200\text{watts/m}^2$ battery Voltage $< 11.5\text{V}$

4.8 Conclusion

The simulation of the proposed system are carried out in matlab and the simulation of Arduino NANO is also simulated in Arduino IDE software.

Chapter 5

Cost Analysis Considering Solar cooking and cooking with LPG.

5.1 Introduction

One of the biggest advantages of solar cooking over cooking using LPG is the cost savings. Solar cooking requires no fuel, as it relies solely on the energy of the sun. This means that once a solar cooker is purchased, there are no ongoing costs associated with fuel or energy. In contrast, LPG cooking requires the purchase and ongoing replenishment of gas canisters or tanks, which can be a significant expense over time.

Solar cookers also have a longer lifespan than LPG stoves, which require maintenance and may need to be replaced more frequently. Additionally, solar cookers are often made from low-cost, durable materials, making them accessible and affordable to people in developing countries who may not have access to traditional cooking fuels. Overall, solar cooking can be a cost-effective and sustainable alternative to cooking with LPG, particularly in areas with abundant sunshine and limited access to traditional fuel sources. While the initial investment in a solar cooker may be higher than the cost of an LPG stove, the long-term savings and environmental

benefits can make it a worthwhile investment.

5.2 Cost Analysis

- Currently LPG gas rate in Kerala, for 14.2 Kg domestic cylinder = Rs 1,120/-
- If 1 kg of LPG burned it is equivalent to 5 units of electricity consumed. i.e For 1 kg gas ,the rate will be Rs. 78.8 approx. Rs 80/- for 5 units of electricity consumed costs around Rs 15.75/- (Rs 3.15/unit)
- Consider the case of a day where normally $\frac{1}{2}$ kg of LPG is burned for cooking it costs Rs. 40 and 500 Watts of electricity is used for 5 hours for cooking purpose i.e, 2.5 kWh or 2.5 units which costs only Rs 7.8/-. That is
 - For 1 day Rs.32.2/- can be saved
 - For 30 days Rs. 966/- can be saved
 - For 365 days Rs. 11,600/- can be saved
- So considering a 1000 Watts (5*213 Watts) Off grid Solar panel installation, Investment will be around 60,000 and if 30% subsidy is applied the cost of installation will be Rs. 42,000/-
- Hence 3 years and 7 months Return on investment(ROI).

5.3 Conclusion

It is understood and evident that cooking using solar is efficient and economic method than cooking using LPG from the cost analysis.

Chapter 6

Results and Discussion

6.1 Introduction

This chapter includes the results of the Switched inductor double switched DC-DC converter for solar hot plate cooking.

6.2 Results

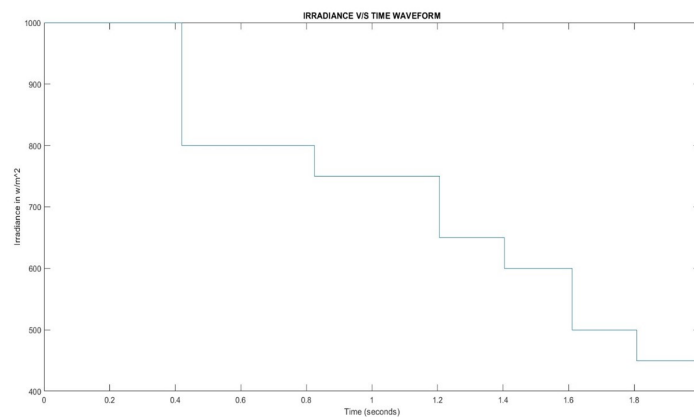


Fig. 6.1: Graph showing PV variable irradiation

From the Fig. 6.1 it is clear that a variable irradiation is given at each time intervals to study the performance of the MPPT technique. The energy can be maximised if the integrated load resistance matches that of the PV panel. The max-

imum power point tracking technique has a lot of potential for finding the best match between the PV and the load resistance.

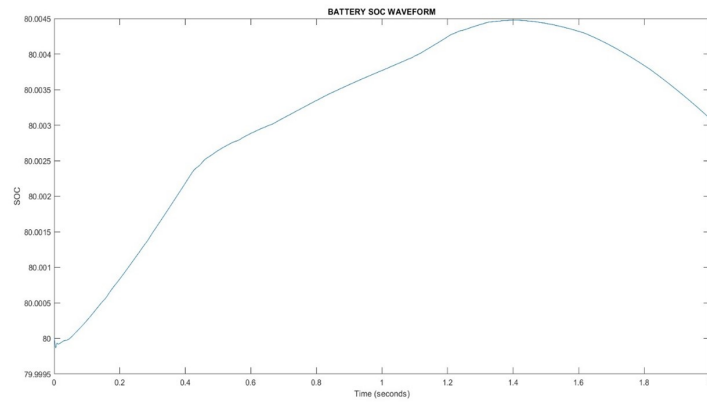


Fig. 6.2: Battery SOC during Charging and Discharging

Fig. 6.2. shows the battery State of charge during the charging and discharging time where it can be seen from the waveform that the SOC is set at 80% and from that particular set value of SOC the Lead acid battery is charged when maximum irradiation is available and starts discharging to the load at low irradiation condition.

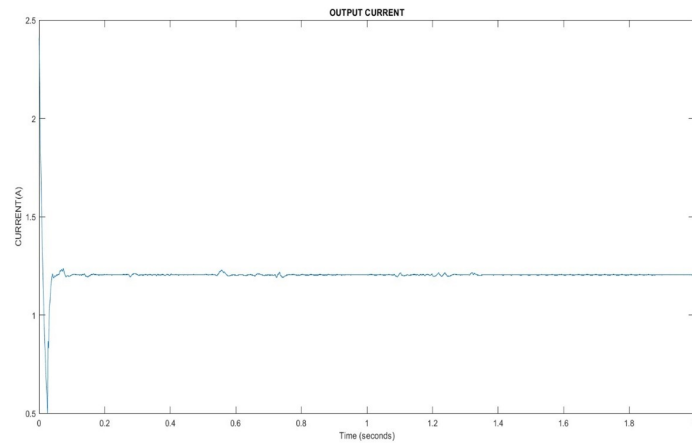


Fig. 6.3: Output current waveform

Fig. 6.3 shows the Output DC hot plate current waveform for 240W loading condition and the current is 1.2A.

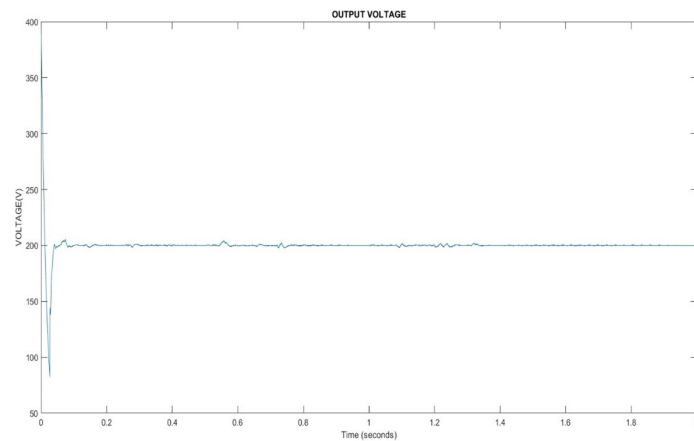


Fig. 6.4: Output voltage waveform

Fig. 6.4 shows the Output DC hot plate voltage waveform for 240W loading condition at the rated voltage and the voltage is 200V from the simulation which can be inferred from the above graph.

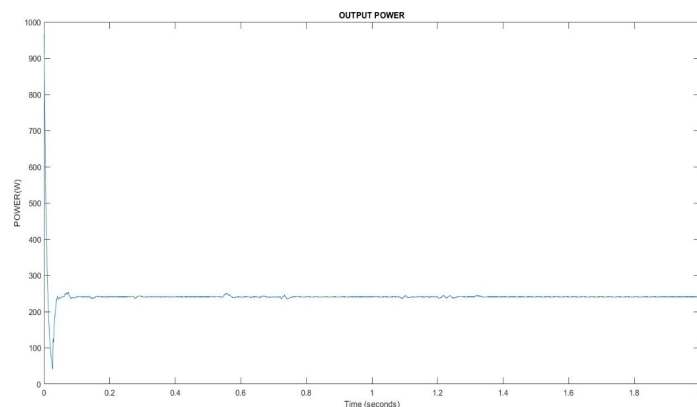


Fig. 6.5: Output power waveform

Fig. 6.5 shows the Output DC hot plate power waveform i.e in the design the power rating is considered as 240W at rated voltage and current. From the waveform it can be inferred that the required power is achieved from the simulation.

6.3 Conclusion

From these results it can be inferred that by using switched inductor double switched DC-DC converter can offer a huge gain at the load end with a lower duty cycle. Thus

it reduces the overall switching stresses. The hot plate method helps in reducing the cost of high frequency inverters. Since our requirement of the hot plate system is 240W. At the rated output voltage and rated output current obtained after simulation is 200V and 1.2A respectively. From the graph its evident that the requirement of 240 W is satisfied.

Chapter 7

Conclusion

Since the Conventional cooking methods such as biomass and gas stoves emit large amount of dicey fumes and makes the working place dirty. So, it is a better alternative that keeps the working place clean that is by using solar powered Hot plate cooking stove. The overall SL-DS-DC High gain Converter circuit along with PV and battery storage system suitable for solar hot plate cooking has been designed and simulated in this work. And it is understood that there will be a huge profit if this system is implemented in household applications, in water transport applications and one can carry this system in their vehicle if a flexible solar panel is used in case of flat type solar panels that makes the system very compact.

Also it is expecting a huge reduction in the overall cost much more than in this work its because our Central Government State Government is supporting by providing subsidies i.e upto 3kW it is given 40% subsidy and above 3kW for every increase in 1 kW upto 10kW its given 20% as the subsidy. After that a flat rate in case of subsidy is provided under SOURA PROJECT funded by Ministry of New And Renewable Energy Scheme(MNRE). And the rates of panels will reduces further because more companies have started producing panels in INDIA itself. Nowadays most of the cases are using imported panels from CHINA which increases the cost.

Chapter 8

Future scope

Nowadays there is a great scope of fixing Solar PV modules on the top of Fishing boats, House boat/passenger boats (seen mainly in Alapsee side) for its propulsion as well as in case of cooking applications where minimization of the green house gases emission and also the prevention of polluting the water bodies in a great extend.



Fig. 8.1: Solar PV installed in a fishing boat



Fig. 8.2: Flexible solar panel placed on top of Houseboats for Cooking process

It is seen that there is a great scope in case of placing PV modules in fishing boats, houseboats and passenger boats for cooking needs as well as can be used in propulsion cases too in some cases.

Appendix A

P&O MPPT Program

```
function [Y, Stage_out , Pold_out]=PO_MPPT1(P_new , P_old , Delay , Yin , Stage_in)
c=0.05;
Pold_out=P_old;
Y=Yin;
Stage_out=Stage_in;
if Delay==0
    if Stage_in==0

        if P_new>P_old
            Y=Yin+c;
            Pold_out=P_new;
        elseif P_new<P_old
            Y=Yin-c
            Stage_out=1;
            Pold_out=P_new;
        end
        Pold_out=P_new;
    end
    if Stage_in==1
```

```
    if P_new>P_old
        Y=Yin-c;
        Pold_out=P_new;
    elseif P_new<P_old
        Y=Yin+c
        Stage_out=0;
        Pold_out=P_new;
    end
    Pold_out=P_new;
end
end
```

Appendix B

Program of Arduino NANO

```
const int battery=A0;
const int ldr=A1;
const int relay=13;

int light_data;
int battery_volt;

void setup()
{
  pinMode(ldr ,INPUT_PULLUP);
  pinMode(battery ,INPUT);
  pinMode(relay ,OUTPUT);
  Serial.begin(9600);
}
void loop()
{
  light_data=analogRead(ldr);
  light_data = map( light_data , 0, 1023, 100, 0);
```

```
Serial.print("LDR READING= ");
Serial.println(light_data);

battery_volt=analogRead(battery);
battery_volt= map( battery_volt , 0, 1023, 0, 13);

Serial.println("BATTERY VOLTAGE= ");
Serial.println(battery_volt);
delay(7000);

if((light_data >60)&&(battery_volt >=13))
{ Serial.println("FEEDING STOVE");
  digitalWrite(relay ,HIGH);
  delay(7000);
}

else if((light_data >60)&&(battery_volt <=11.5))
{ Serial.println("TURNING ON MPPT");
  Serial.println("BATTERY CHARGING MODE");
  digitalWrite(relay ,LOW);
  delay(7000);
}

else if((light_data <20)&&(battery_volt >=11.5))
{ Serial.println("TURNING Off MPPT");
  Serial.println("TURNING On stove");
  Serial.println("TURNING On battery mode");
  digitalWrite(relay ,LOW);
delay(7000);
}
```

```
else if((light_data <20)&&(battery_volt <11.5))
{ Serial.print("TURNING Off MPPT");
  Serial.println("TURNING Off stove");
  Serial.println("TURNING off battery mode");
  Serial.println("TURNING on kseb mode");
  digitalWrite(relay ,LOW);
  delay(7000);
}
}
```

Bibliography

- [1] Danyang Bao, Avneet Kumar, Xuewei Pan, Xiaogang Xiong, Abdul R Beig and Santhosh Kumar Singh, "*Switched Inductor Double Switch High Gain DC-DC Converter for Renewable Applications*", IEEE Access, vol.9, pp. 14259 – 14270, January 2021.
- [2] W. Zhong, L. Wang, Z. Liu and S. Hou, "*Reliability Evaluation and Improvement of Islanded Microgrid Considering Operation Failures of Power Electronic Equipment*",in Journal of Modern Power Systems and Clean Energy, vol. 8, no. 1, pp. 111-123, January 2020.
- [3] Mehmet Ali Yildirim, Marzena Nowak-Oclon, "*Modified Maximum Power Point Tracking Algorithm under Time-Varying Solar Irradiation*",Energies 2020, 13, 6722; doi:10.3390/en13246722 www.mdpi.com/journal/energies , Dec. 2020.
- [4] Rayed Md. Muhaymin Hasan, Nahian Islam, Mehrab Azam Khan, Sams Shafiul Amin, A.K.M Abdul Malek Azad "*Improvement of Energy Efficiency and Effectiveness of Cooking in Solar Electric Slow Cooker for Tropical Countries*",2020 IEEE REGION 10 CONFERENCE(TENCON)
- [5] Immad Sham, Prashant Shrivastava, Kok Soon Tey "*Design and Implementation of Lithium-Ion Battery Based Smart Solar Powered Street Light System*",978-1-7281-5826-6/20/31.00,2020 IEEE explore
- [6] Debashish Mohapatra , Subhransu Padhee , Jhansirani Jena "*Design of Solar Powered Battery Charger: An Experimental Verification*",2018 IEEE Interna-

tional Students' Conference on Electrical, Electronics and Computer Science
(SCEECS)