DEPARTMENT OF ELECTRICAL ENGINEERING

**A**

**REPORT**

**ON**

**DP-1 Review**

# Cuk converter base electrical vehicle charger by using PV Array

M.Tech. 3rd Sem.

Prepared by: -

**Hareshkumar Sosa [190043008]**

Guided by: -

**Prof. Dhaval Raval**

# CERTIFICATE

This is to certify that the project entitled **Cuk converter base electrical vehicle charger by using PV array** is a benefited report of the work carried out by **Hareshkumar Sosa** under the guidance and supervision for the award of the degree of M.Tech Electrical Engineering at Atmiya University-Rajkot, Gujarat

To the best of my knowledge and belief, this work embodies the work of candidate himself, has duly been completed, fulfils the requirement of the ordinance relating to the M.Tech of the university and is up to the standard in respect of content, presentation and language for being referred to the examiner.

| | |
|---|---|
| **Signature** | **Signature** |
| Prof. Dr. D.J.Pandya | Dhaval Raval |
| H.O.D. | Assit.Prof. |

# ABSTRACT

This project represents the electrical vehicle charger. Which is consists of PV module with MPPT and DC-DC converter connected in cascaded form. Here DC-DC converter used is "INTERLEAVED CUK CONVERTER" due to its various advantages compare to conventional converters. The project takes irradiation from sun light from PV module which senses temperature change and irradiation and gives output according to input. After that this output is given to Battery for charging. Here, the analysis and the performance of the parameters are carried out by simulation in Matlab.

**Keywords:** CUK converter, PV module, MPPT, Perturb and Observe (P&O).

# ACKNOWLEDGEMENT

This is the time to express our deep sense of gratitude to our college, **Atmiya University, Rajkot** for giving us a great opportunity to prepare this report for my survey work.

We would like to thank our internal guide **Prof. Dhaval Raval, H. O. D**. **Of Electrical Engineering Department, Prof D.J.Pandya** for his precious help & guidance who always bears and motivate us with technical guidance throughout this semester period. Also, we would like to thank the other respected faculties of Electrical Engineering Department.

Most importantly, we would like to thank our Parents, for everything that they have done for us throughout our life and the joy they have brought to us for just having their support. Much of our success has been because of their love & encouragement.

# CONTENT

**CERTIFICATE** .......................................................................... I

**ABSTRACT** .......................................................................... II

**ACKNOWLEDGEMENT** .......................................................................... 1

**CONTENT** .......................................................................... 2

**LIST OF FIGURES** .......................................................................... 4

**LIST OF TABLES** .......................................................................... 4

**CHAPTER NO: -1** .......................................................................... 1

INTRODUCTION .......................................................................... 1

Literature Review .......................................................................... 2

**CHAPTER NO.2 CIRCUIT DIAGRAM** .......................................................................... 4

2.1 Basics of CUK converter .......................................................................... 4

2.2 Operating principle .......................................................................... 4

2.3 Basic of interleaved Cuk converter .......................................................................... 6

2.4 Operation modes of interleaved Cuk converter .......................................................................... 6

2.5 Calculation .......................................................................... 8

**CHAPTER-3 PV and MPPT** .......................................................................... 10

3.1 Renewable Energy Source for Power Generation .......................................................................... 10

3.2 Features of PV system .......................................................................... 11

3.3 PV Module Parameters and Characteristics .................................... 11
3.4 Behaviors of PV Module with Weather Conditions ........................... 13
3.5 Maximum Power Point Tracking ...................................................... 15
3.6 Modified P&O Algorithm ................................................................. 16

**Conclusion .......................................................................................... 18**

**Future Work ........................................................................................ 19**

**References .......................................................................................... 20**

## LIST OF FIGURES

FIGURE 1: CIRCUIT DIAGRAM OF CUK CONVERTER .................................................. 4
FIGURE 2:OUTPUT WAVEFORMS OF CUK CONVERTER ............................................... 5
FIGURE 3: BASIC CIRCUIT OF INTERLEAVED CUK CONVERTER ...................................... 6
FIGURE 4:S1 ON AND S2 OFF ........................................................................... 7
FIGURE 5: S1 OFF AND S2 OFF ........................................................................ 7
FIGURE 6:S1 OFF AND S2 ON ........................................................................... 8
FIGURE 7: TYPES OF RENEWABLE ENERGY GENERATION SOURCES ............................ 10
FIGURE 8:PV MODULE CHARACTERISTICS ............................................................ 12
FIGURE 9:EFFECT OF TEMPERATURE VARIATIONS ON PV MODULE BEHAVIOR............. 13
FIGURE 10:EFFECT OF TEMPERATURE VARIATIONS ON PV MODULE BEHAVIOR........... 14
FIGURE 11:WORKING OF MPPT ALGORITHMS ..................................................... 15
FIGURE 12: FLOWCHART OF MODIFIED P&O MPPT ALGORITHM ............................ 16

## LIST OF TABLES

TABLE 1: CHARGING AND DISCHARGING COMPONENTS IN DIFFERENT MODES ............. 6
TABLE 2: INSTALLED SOLAR CAPACITY OF GUJARAT .................................................. 11
TABLE 3: MODES OF MPPT ALGORITHM ...................................................................... 15
TABLE 4:CONTROL ACTIONS OF MODIFIED P&O.......................................................... 17

# CHAPTER NO: -1

## INTRODUCTION

- In today's scenario of growing energy needs and increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels were investigated.
- Global renewable energy capacity has been doubling since 2008. The solar and wind capacity installation in recent years is increased to about 25% today and it could reach 30% by 2022.
- Using PV panel the renewable energy from the sun is utilized. The efficiency of the PV system is low since it depends on irradiance and temperature variation.
- Therefore MPPT algorithm is employed to extract the maximum energy and to improve the efficiency of PV system.
- MPPT algorithms are of many types such as fractional open circuit voltage, fractional short circuit current, neural networks, fuzzy logic, and Incremental Conductance method and Perturb and Observe (P&O).
- P&O algorithm cannot determine the optimal operating point under varying atmospheric condition but in normal condition it is reliable.
- To overcome this, IC algorithm is used to track maximum power under varying atmospheric conditions. DC-DC converters are of many types such as buck, boost, CUK converter etc.., this paper deals with ICC since it reduces voltage and current ripple, improves efficiency, transient performance and also reduces switching losses.

## Literature Review

**[1] Syam M S, T. Sreejith Kailas "Grid Connected PV System using Cuk Converter" International Conference on Microelectronics, Communication and Renewable Energy (ICMiCR-2013)**

In this paper, the power loss in two stage grid connected system is less compared to the single stage system. Thus a comparative study of two, two stage GCPVS was done i.e.; using Boost Converter and Cuk Converter. Hence, MATLAB simulation of 3ϕ, two stage grid connected photovoltaic system was performed along with incremental conductance algorithm for MPPT. Cuk converter and boost converter although is able to maintain the output voltage, it is found that output current of Cuk converter is found to have less current ripples compared to the boost converter, and Cuk converter has better efficiency than Boost converter. Then the dc bus voltage algorithm was used for the DC-DC Converter control. Thus this paper presented an efficient means of two stage grid connected photovoltaic system using Cuk Converter. The simulation results can help engineers to choose a proper topology in PV system design.

**[2] T. Arun Srinivas a , G. Themozhi b S. "Current mode controlled fuzzy logic based inter leaved Cuk converter SVM DC-DC Converter fed induction motor drive system ",Received 30 September 2019 Revised 7 January2020Accepted 16 January 2020 Available online 21 January 2020**

Simulation studies were done for open and closed-loop ILC- CIMD systems with PI, PR and FL-controllers. These studies were carried out using the simulink-based models for Inter Leaved Cuk- converter DC-DC Converter fed induction-motor drive. By using FLC, the rise-time is decreased; the peak-time is de- creased; the settling-time is decreased and the steady-state error is decreased. The outcomes signify that the FL based ILCCIMD system gave an improved response as compared with PI and PR controlled ILCCIMD system. The present effort deals with closed-loop ILCCIMD systems with P-I, PR and FL controllers. Closed-loop ILCCIMD systems with SMC can be done in future.

**[3] Joseph K.D., Asha Elizabeth Daniel, Unnikrishnan A. "Interleaved Cuk Converter with Reduced Switch Current"**

In this paper Interleaved Cuk Converter (ICC) and Traditional Cuk Converter (TCC) is simulated and experimentally validated using XILINX FPGA controller. The phase shifted PWM technique used in this paper reduces the width of the gate pulses; it reduces the conduction period of switches. Simulation and experimental results yield that the peak current of switch is reduced compared to that of TCC. The switch rating is reduced, which reduces the size of heat sink and also size of series inductors. Also the transient performance of ICC is much better than interleaved boost converter; ICC provides an encouraging result of better efficiency above 90%. ICC improves the quality of source power by reducing ripples on source side and load side current in a large extent when it operates below 50% duty ratio compared that of TCC. The operation of ICC above 50% duty ratio creates ripple building issues on inductor and it can overcome by modifying the interleaved circuit.

**[4] ROHIT D. TAYADE & SHRIKANT S. MOPAR "COMPARATIVE ANALYSIS OF INTERLEAVED BOOST CONVERTER AND CUK CONVERTER FOR SOLAR POWERED BLDC MOTOR" International Journal of Electrical and Electronics Engineering (IJEEE),Vol. 6, Issue 4, Jun - Jul 2017, 1-12**

The selection of converter plays a considerable role in efficient utilization of the renewable energy. This paper discussed the principle of operation and various design parameters of IBC and CUK converter. Performance of IBC and CUK converter is analyzed in MATLAB with resistive and BLDC motor load. The simulation results obtained under various conditions illustrate that the IBC is more efficient than the CUK converter. The interleaved technique reduces the input ripple current and output voltage ripple. The transient and steady state response of BLDC motor is better with the IBC. The performance of converters with different irradiation level shows that Interleaved DC-DC Boost converter is a suitable choice for solar power..

**[5] Joseph K.D, Asha Elizabeth Daniel, A. Unnikrishnan "Interleaved Cuk converter with improved transient performance and reduced current ripple" Published in The Journal of Engineering; Received on 26th April 2017; Accepted on 13th June 2017**

In this paper the work reported here summaries the simulation and experimental validation of CCC and that of ICC. The results proved that the input current ripple reduced from 27 to 4.4% in the case of ICC. Also retaining an encouraging reduction of the output voltage ripple to 2.7%. Though the efficiency really matters when ripple reduction takes place, but the efficiency is not sacrificed and kept above 87% in the case of ICC. The settling time and overshoot for line and load transient performances for the ICC are much better than that of CCC.

# CHAPTER NO.2 CIRCUIT DIAGRAM

## 2.1 Basics of CUK converter

The Cuk converter is type of Buck-Boost converter with zero ripples current. Cuk converter can be seen as combination of Boost and Buck converter, which is heaving one switching device and mutual capacitor to couple the energy.

Similar to Buck-Boost converter with inverter topology output voltage of non isolated Cuk converter is typically inverted, with lower or higher vales with respect to input voltage. Usually in DC converters, the inductor is used as a main energy storage component. But in Cuk converter the main energy storage component is capacitor.

## 2.2 Operating principle

A non isolated Cuk converter is comprises of two inductors, two capacitors, switch and diode. Its circuit diagram is as shown in figure-1. It is an inverting converter. So the output voltage is negative with respect to input voltage.

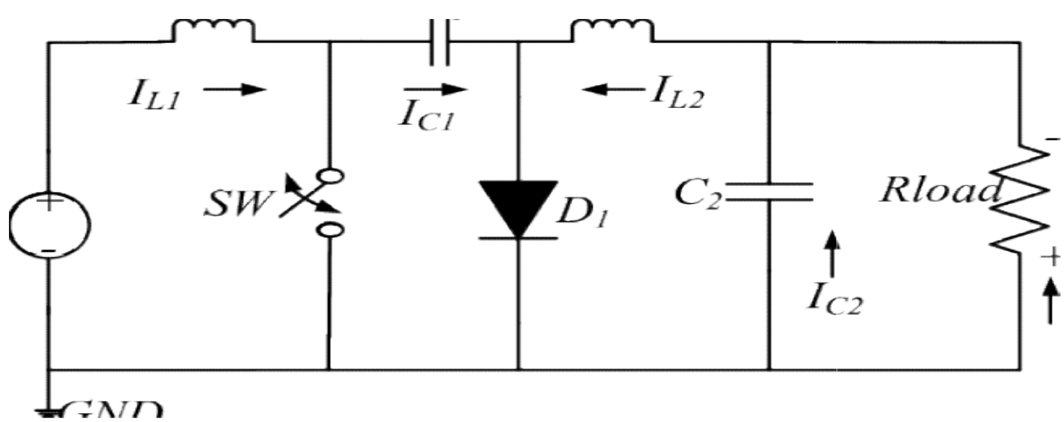


*Figure 1: Circuit diagram of Cuk converter*

The main advantage of this converter is the continuous currents at the input and output of the converter. The main disadvantage is the high current stress on the switch.

The capacitor C is used to transfer energy. It is connected alternatively to input and output of converter via commutation of transistor and diode.

The two inductor L1 and L2 are used to convert respectively input voltage source And output voltage source in to current source. At short time scale, inductor can be considered as a current source as it maintains a constant current. This conversion is necessary because if the capacitor were connected directly to voltage source, the current would be limited only by parasitic resistance, resulting in high energy loss. Charging a capacitor with a current source prevents resistive current limiting and its associated energy loss.

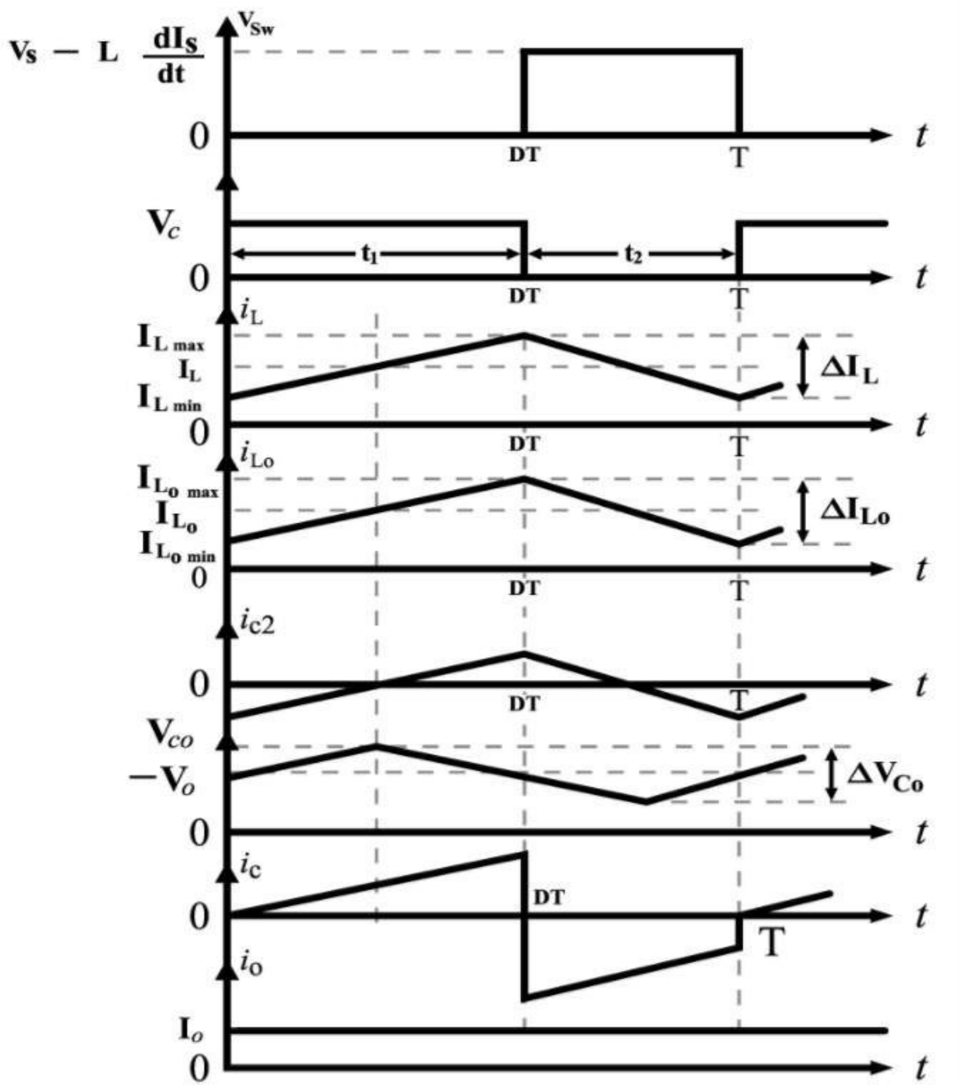


*Figure 2:Output waveforms of Cuk converter*

## 2.3 Basic of interleaved Cuk converter

Basic circuit diagram of interleaved Cuk converter is as shown in figure-3. Which is shares the source current into two inductors and reduces ripple on both input and output side. In this converter Capacitor C1 and C2 are used for energy transfer to output.

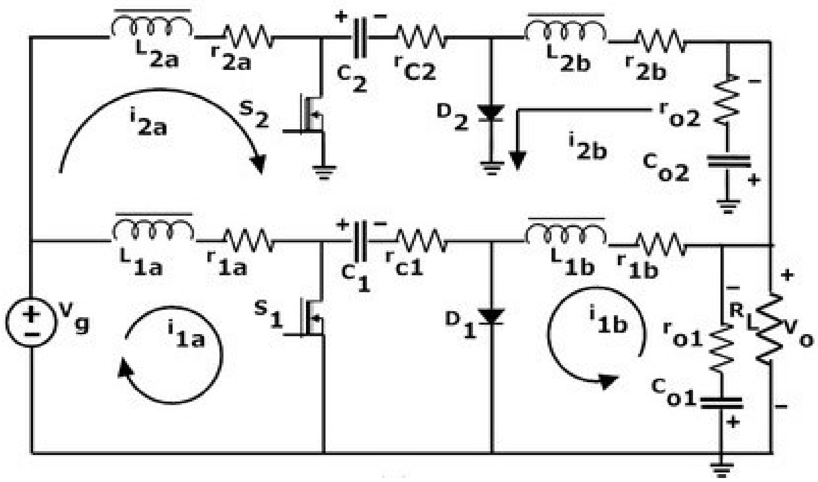


*Figure 3: Basic circuit of interleaved Cuk converter*

## 2.4 Operation modes of interleaved Cuk converter

### (1) Mode-1: S1 ON and S2 off(T0 to T1)

In this mode the switch S1 is close and S2 is opened as shown in figure-4. During this mode the charging and discharging of the passive element are shown in table-1.

*Table 1: CHARGING AND DISCHARGING COMPONENTS IN DIFFERENT MODES*

| Element | Status | | |
|---|---|---|---|
| Name | Mode-1 | Mode-2 | Mode-3 |
| L1a | Charging | Discharging | Discharging |
| L1b | Charging | Discharging | Discharging |
| L2a | Discharging | Discharging | Charging |
| L2b | Discharging | Discharging | Charging |
| C1 | Discharging | Charging | Charging |
| C2 | Charging | Charging | Discharging |
| Co1 | Discharging | Charging | Charging |
| Co2 | Charging | Charging | Discharging |

The inductor current i1a is increasing and i2a is decreasing. Hence the switch current Is1 through S1 is increasing as shown in figure-4. The switch is in series with inductors during charging; hence switch current is same as inductor current. The charging and discharging inductors in different modes reduce source current ripple.

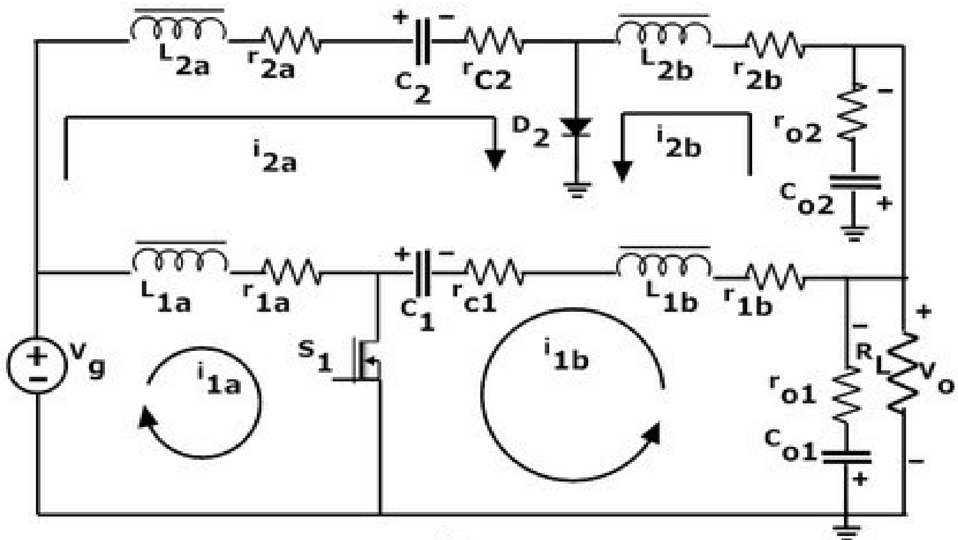


*Figure 4:S1 ON and S2 OFF*

## (2) Mode-2: S1 OFF and S2 OFF(T1 to T2)

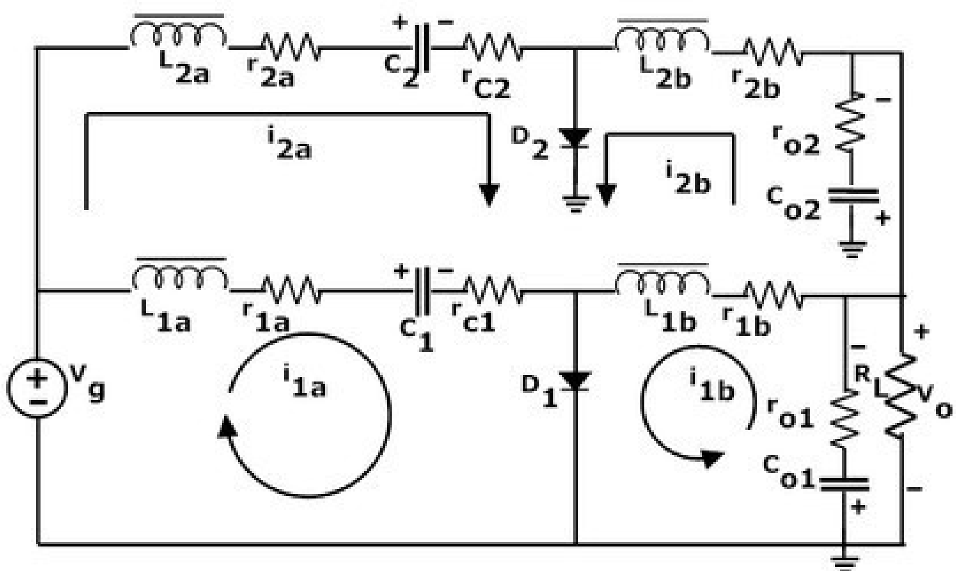


*Figure 5: S1 OFF and S2 OFF*

In this mode S1 and S2 are kept in OFF state as shown in Figure-5. During this mode all the inductors are discharging and capacitors are charging as shown in table-1.

## (3) Mode-2: S1 OFF and S2 ON(T2 to T3

In this mode switch S1 is kept OFF and S2 is turned ON as shown in figure- 6. During this mode the charging, discharging of the capacitor and inductor are as shown in table-1.

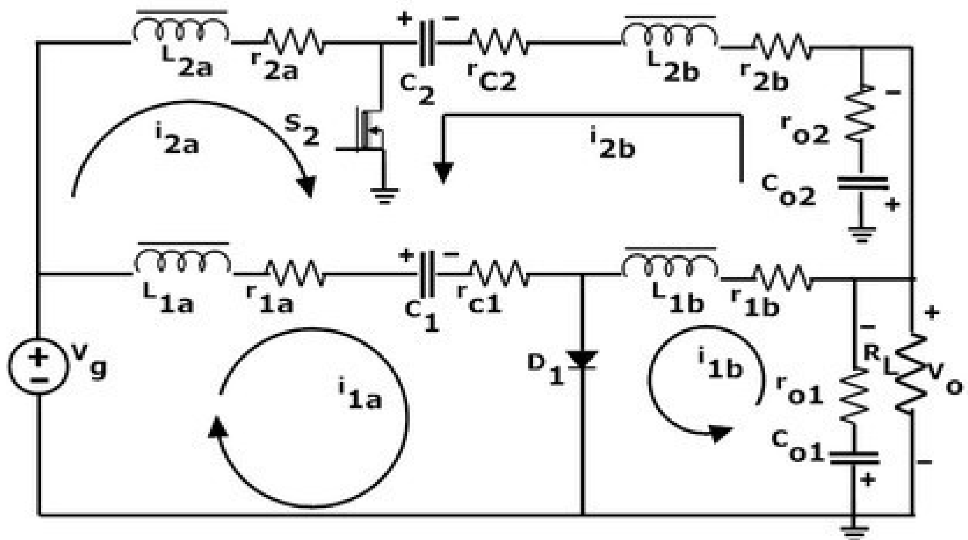


Figure 6:S1 OFF and S2 ON

## 2.5 Calculation

Design specification, $V_{\text{in}} = 20\ V$

$$V_{\text{out}} = 40\ V$$

$$R = 20\ \Omega$$

$$f = 20\ KHz$$

Voltage and Current ripple = 5 % of average value

Output and Input voltage relation:

$$V0 = \frac{DVin}{1 - D} = 60$$

Output and Input current relation:

$$I0 = \frac{DVin}{R} = 2\ A$$

$$Iin = \frac{DI0}{1 - D} = 4\ A$$

Input Inductor:

$$L1 = \frac{VinD}{f\Delta Il1} = 3.33\ mH$$

Output Inductor:

$$L2 = \frac{(1 - D)V0}{f\Delta Il2} = 6.66\ mH$$

Coupling Capacitor:

$$C1 = \frac{D^2 Vin}{f(1-D)\Delta Vc} = 22\ \mu F$$

Output Capacitor:

$$C2 = \frac{(1-D)V0}{8f^2 L_2 \Delta V_O} = 30\ \mu F$$

# CHAPTER-3  PV and MPPT

## 3.1 Renewable Energy Source for Power Generation

It is well known to us that fossil fuels are exponentially diminishing and this fact has been encouraging us to increase use of renewable energy sources for generation of electricity. Recent research works have proved some of the renewable energy sources as better options for practical use. These sources are depicted in Figure 7.

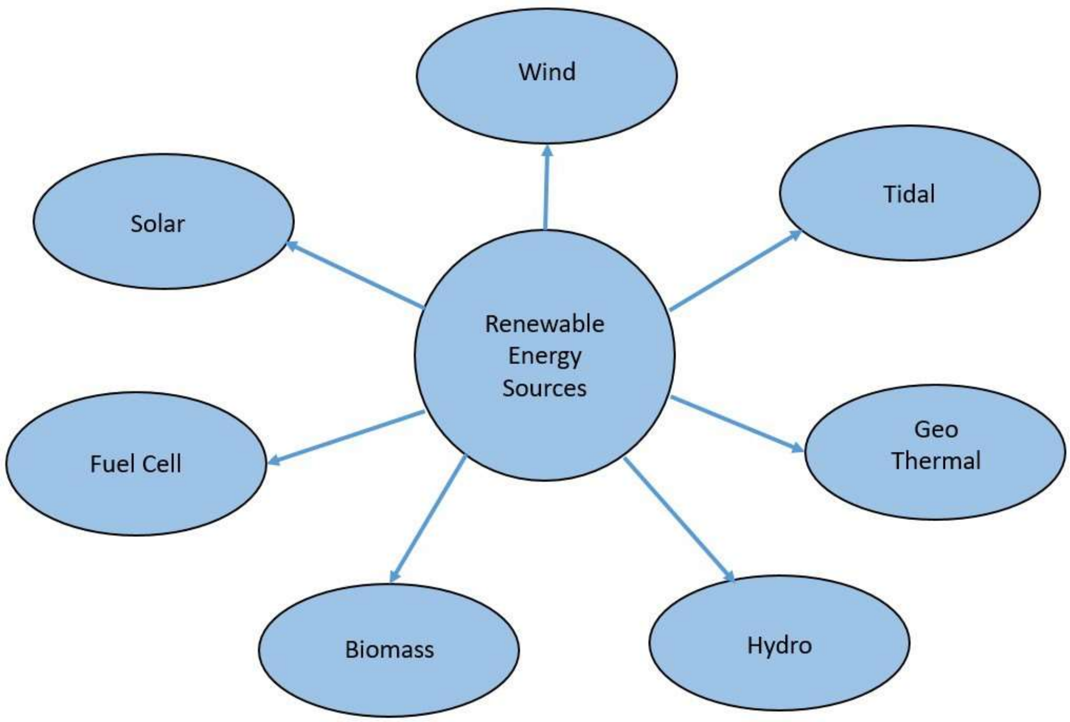


*Figure 7: Types of Renewable Energy Generation Sources*

Amidst all the sources listed above, solar, wind and hydro systems are installed on large scale all over the world. Hydro-plants and Wind-farms have stringent requirement of suitable site location with weather conditions. Moreover, they are generally preferred for bulk power generation. However, solar generation dominates because it can be used for bulk power generation as well as residential installations. Features of solar system are given in section.

Table 6-1 is statistical data taken from the official site of GEDA (Gujarat Energy Development Agency). It says that, day by day solar interest and installation is increasing exponentially.

*Table 2: Installed Solar Capacity of Gujarat*

| Year | Ground Mounted Installation Capacity - MW | Rooftop Installed Capacity - MW |
|---|---|---|
| **2010-11** | 5 | 0.020 |
| **2011-12** | 550.34 | 2.350 |
| **2012-13** | 296.97 | 5.600 |
| **2013-14** | 38.86 | 3.428 |
| **2014-15** | 104.67 | 4.117 |
| **2015-16** | 108 | 8.957 |
| **2016-17** | 125.74 | 12.681 |
| **2017-18** | 263.72 | 117.124 |
| **2018-19** | 620.17 | 172.232 |
| **2019-20** | 312.97 | 195.248 |
| **Total** | **2426.44** | **521.927** |

## 3.2 Features of PV system

- Sun is infinite source of energy
- There are no rotating parts in PV system which reduces conversion losses
- It is most simple to be installed
- It is pollution free generating system
- Requires less space compared to wind and hydro plants

Most suitable for both type of generation. Bulk power and individual use.

## 3.3 PV Module Parameters and Characteristics

PV module characteristics include relationship between PV module current and voltage ($\,_{\mathrm{pv}}\, vs\, V_{\mathrm{pv}}$) and between module power and voltage ($P_{\mathrm{pv}}\, vs\, V_{\mathrm{pv}}$). Characteristic curves are shown in Figure 8.

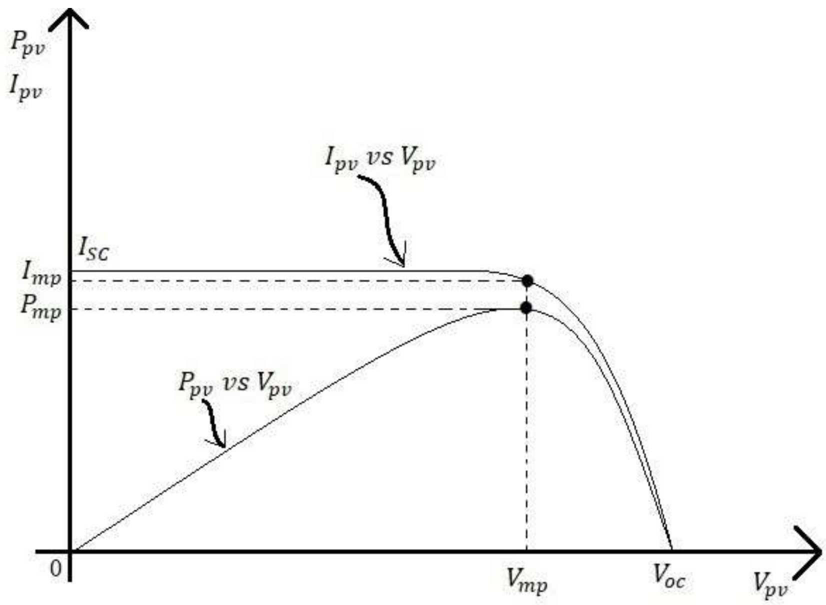


*Figure 8:PV Module Characteristics*

The characteristics define some important parameters of PV module, which are explained below.

1) **Maximum Power (W)**

   PV modules are generally selected based on their maximum power ratings. The point is shown in the P-V characteristic at the top of the curve. At this point PV module power output is maximum. It is preferred that module operates at its maximum power capability.

2) **Voltage at Maximum Power ($V_{mp}$)**

   It is the PV module voltage when operating at maximum power point.

3) **Current at Maximum Power ($I_{mp}$)**

   It is the PV module current when operating at maximum power point.

4) **Open Circuit Voltage ($V_{oc}$)**

   It is the terminal voltage when the terminals are open circuited. It is the maximum voltage value that PV can generate.

**(5) Short Circuit Current ($I_{sc}$)**

It is the current output of module when the terminal are short circuited. It is the maximum current value that PV can generate.

**5) Temperature Coefficient of $V_{oc}$**

It denotes the effect of temperature on PV module behavior. Variation in temperature affects more to the module voltage than current. It usually has negative value and is depicted with unit percentage per degree ($\%/°C$).

**6) Temperature Coefficient of $I_{sc}$**

It denotes the effect of temperature on PV module behavior. It usually has positive value and is depicted with unit percentage per degree ($\%/°C$).

## 3.4 Behaviors of PV Module with Weather Conditions

Behavior of PV module greatly depends upon solar irradiation and temperature conditions. Voltage and current of PV module changes with them and as a consequence power also changes. These effects are shown in the Figure 9.

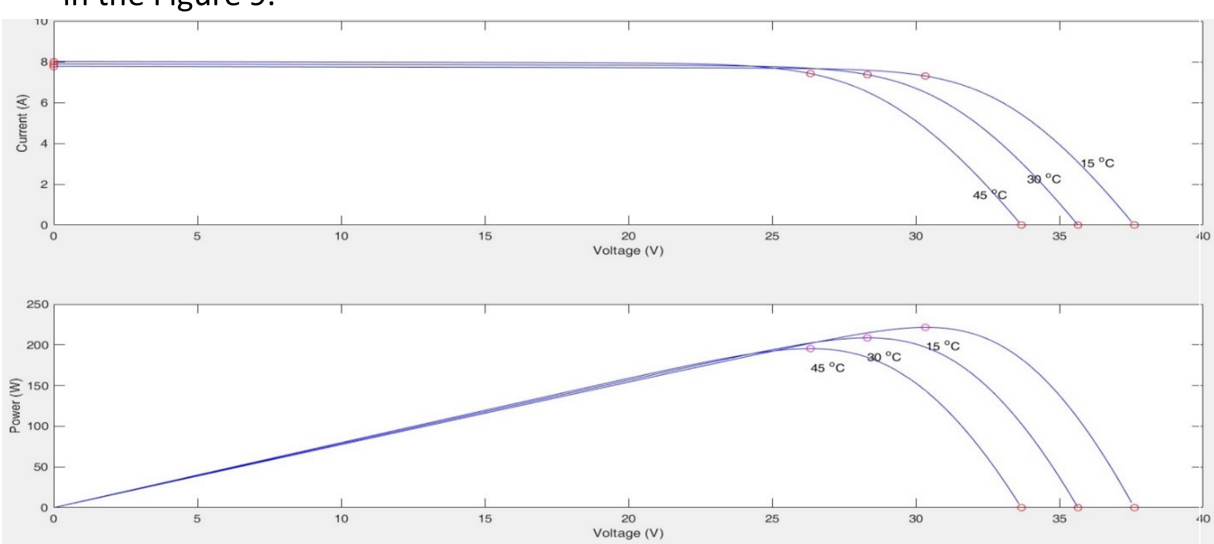


*Figure 9:Effect of Temperature Variations on PV Module Behavior*

It can be seen that effect of temperature in dominant over PV voltage than current. With change in temperature PV current remains more or less constant while PV voltage, both voltage at maximum power and open circuit voltage, decreases with increase in temperature. Thus, temperature coefficient of open circuit voltage has negative value.

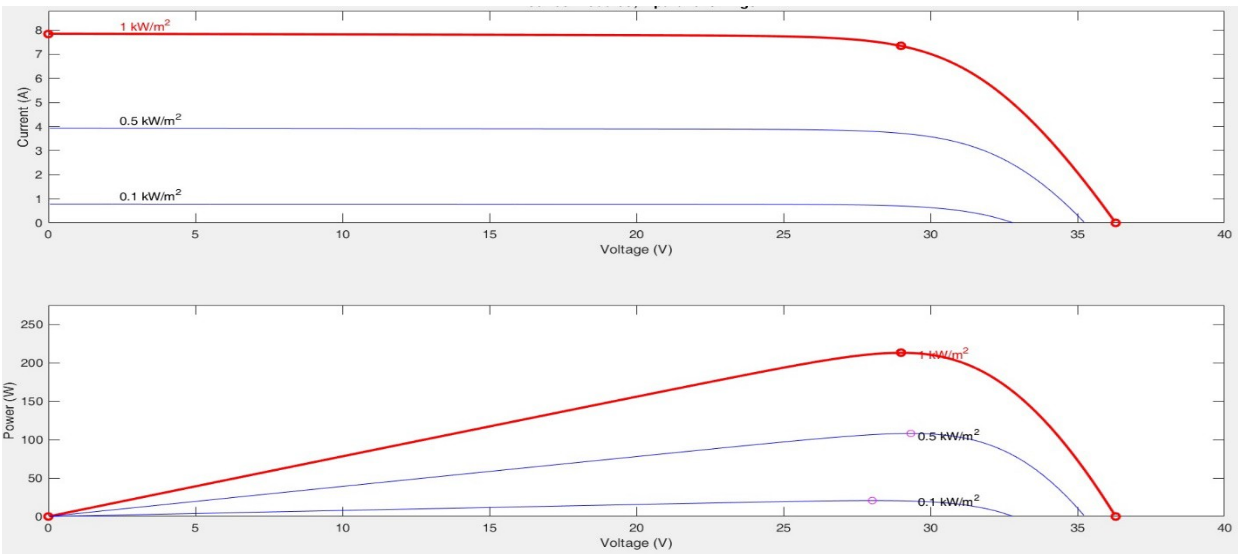


*Figure 10:Effect of Temperature Variations on PV Module Behavior*

Effect of solar irradiation on PV voltage and current is represented. Unlike effect of temperature, solar radiation greatly affects PV module current compared to voltage. Current increase and decrease in proportion to the solar irradiation input to the PV module.

It is because change in temperature affects the mobility of the ions present in the n-layer. As the temperature increases mobile ions generates more rapidly increasing value of current of the PV module.

## 3.5 Maximum Power Point Tracking

As shown in Figure 8, PV module power is maximum only at one point and that is the peak of the P-V curve. Therefore, it is recommended that the PV module operating point is near to the maximum power point and we can extract maximum energy from the PV module.

There are many methods available in order to approaching the maximum power point. These methods are called MPPT Algorithms. These algorithms generally use PV voltage and current and generate output in terms of duty cycle. This duty cycle is used to control the DC to DC converter to change the impedance of the converter in such a way that maximum power transfer takes place.

Basic understanding of how the MPPT algorithm works is illustrated in the Table 3.

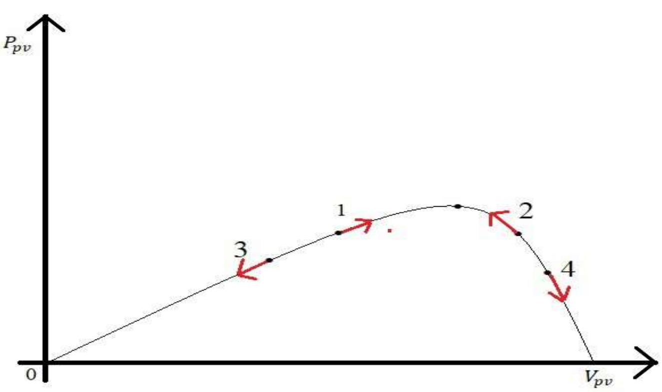


*Figure 11:Working of MPPT Algorithms*

*Table 3: Modes of MPPT Algorithm*

| **SR. NO.** | $\Delta V_{pv}$ | $\Delta P_{pv}$ | **Direction** | **Action** |
|---|---|---|---|---|
| 1 | + | + | Right | Increase PV Voltage |
| 2 | – | + | Right | Decrease PV Voltage |
| 3 | – | – | Wrong | Increase PV Voltage |
| 4 | + | – | Wrong | Decrease PV Voltage |

Basically, to get to the point of maximum power it is required to increase and decrease the PV module voltage. This can be achieved by use of DC to DC converters. In next section 6.6, Selection and use of DC to DC converter is discussed.

There are many MPPT algorithms are available. Their comparative study is given in [18]. Perturb and Observe (P&O) is usually used among them due to its simplicity in implementation. Working of P&O and its modifications are discussed at the end of this chapter.

## 3.6 Modified P&O Algorithm

P&O method is very common for MPPT because it is very easy to implement. It observes change in PV module voltage and power and accordingly changes the duty cycle of the DC converter with little perturbation. However, there are some drawbacks of conventional P&O method. First, it exhibits oscillations around maximum power point. Second, it has low accuracy when there is change in solar irradiation.

To overcome these drawbacks, modified P&O is proposed . Working of the modified P&O is illustrated in Figure 12 by flowchart.

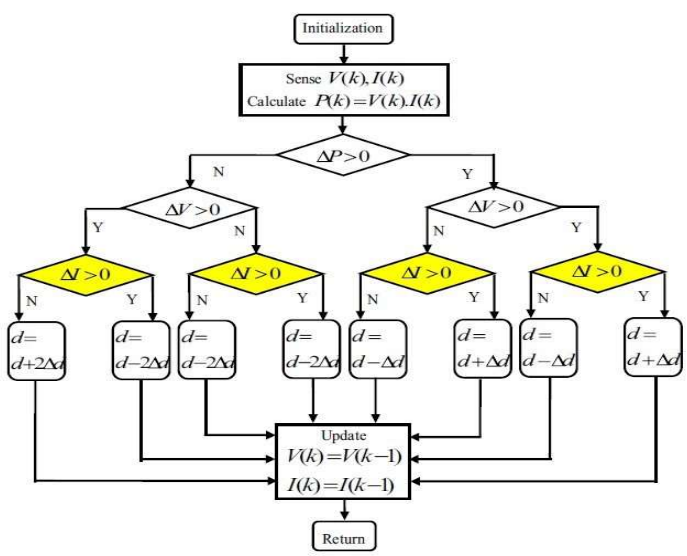


*Figure 12: Flowchart of Modified P&O MPPT Algorithm*

Modified P&O uses PV module voltage and current as the input like any other MPPT methods. Unlike, conventional P&O it observes change in voltage, current and power and accordingly changes the output in terms of duty cycle. Various models are described in the Table 4.

*Table 4:Control Actions of Modified P&O*

| Case | Δ V | Δ P | Δ I | Tracking Direction | D |
|---|---|---|---|---|---|
| **1** | + | + | + | Right | $D = D + \Delta D$ |
| **2** | + | + | - | Right | $D = D - \Delta D$ |
| **3** | + | - | + | Wrong | $D = D - 2\,\Delta D$ |
| **4** | + | - | - | Wrong | $D = D + 2\,\Delta D$ |
| **5** | - | + | + | Right | $D = D + \Delta D$ |
| **6** | - | + | - | Right | $D = D - \Delta D$ |
| **7** | - | - | + | Wrong | $D = D - 2\,\Delta D$ |
| **8** | - | - | - | Wrong | $D = D - 2\,\Delta D$ |

# Conclusion

- PV module-based charger is used to charge electrical vehicle.
- It has advantage over conventional charger is that it has low conversion process.
- It has disadvantage of slow charging compare to grid connected charger.
- Modified P&O method helps accurately in extracting maximum power from the PV modules.

# Future Work

- Analysis of Cuk converter base electrical charger using PV Array.
- Simulation of CUK converters circuit.

# References


1) Syam M S,T. Sreejith Kailas "GRID CONNECTED PV SYSTEM USING CUK CONVERTER" International Conference on Microelectronics, Communication and Renewable Energy (ICMiCR-2013)

2) Joseph K.D, Asha Elizabeth Daniel, A. Unnikrishnan, "INTERLEAVED CUK CONVERTER WITH IMPROVED TRANSISENT PERFORMANCE AND REDUCED CURRENT RIPPLE" Published in The Journal of Engineering; Received on 26th April 2017; Accepted on 13th June 2017

3) ROHIT D. TAYADE & SHRIKANT S. MOPAR"COMPARATIVE ANALYSIS OF INTERLEAVED BOOST CONVERTER AND CUK CONVERTER FOR SOLAR POWERED BLDC MOTOR" International Journal of Electrical and Electronics Engineering (IJEEE),Vol. 6, Issue 4, Jun - Jul 2017, 1-12

4) Joseph K.D., Asha Elizabeth Daniel, Unnikrishnan A."INTERLEAVED CUK CONVERTER WITH REDUCED SWITCHING CURRENT"

T. Arun Srinivas a , G. Themozhi b , S. Nagarajan "Current mode controlled fuzzy logic based inter leaved Cuk converter SVM DC- DC Converter fed induction motor drive system "Received 30 September 2019 Revised 7 January 2020 Accepted 16 January 2020 Available online 21 January 2020