Grid Tied Solar Micro-Converter with Optimizer Mode Operation for Weak-Grid Operation

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Abstract— This project proposes a dual mode flyback based hybrid converter that can support both a grid tied mode and islanded mode operation to extract maximum power from the solar PV source at all times. It is also designed to employ active power decoupling to draw constant input current with reduced filter size at the terminals of the PV panel in both AC and DC output power modes. The ability of the proposed converter to produce both DC and AC output allows flexibility of operation in environments where the grid may not be available for as high as 80% of sunlight hours while maintaining the advantages of micro-inverters. In advance the DC generated voltage is given to a CUK converter so that the proposed converter could be able to support both the AC grid and also the variable DC load both in positive and negative polarity.

Key words: Flyback; Photovoltaic; CUK Converter; PWM; Sunlight

I. INTRODUCTION

The objective of this project is firstly to review different MPPT algorithms. Then the most popular, perturb and observe (P&O), incremental conductance (InCond) and fuzzy logic control (FLC) are analysed in depth and tested according to the standard mentioned above. After that, improvements to the P&O and the InCond algorithms are suggested to succeed in the MPPT tracking under conditions of changing irradiance. To test the MPPT algorithms according to the irradiation profiles proposed in the standard, a simplified model was developed, because the simulation time required in some of the cases cannot be reached with the detailed switching model of a power converter in a normal desktop computer. The reason for that is that the computer runs out of memory after simulating only a few seconds with the complete model. Finally, the simplified model is verified by comparing its results with those obtained from a model containing a detailed model of an inverter.

II. POWER GENERATION IN SOLAR PANEL

Solar Photo voltaic System uses solar cells to convert light into electricity. A PV system consists of PV modules. Solar radiation is sufficient to generate required electricity. To run the elevator efficiently. The standard equivalent circuit of the PV cell is shown in FIGURE 1.

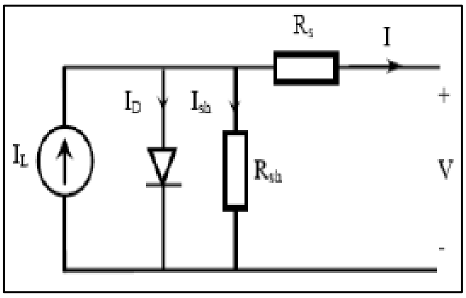

Fig. 1: Standard Equivalent Circuit of PV

The basic equation that describes the I-V Characteristics of the PV model is given by the following equation:

$$I = I_L - I_o\left(e^{\frac{q(V + IR_s)}{kT}} - 1\right) - \frac{V + IR_s}{R_{sh}}$$

Where:
I - Cell Current (A).
IL - Light Generated Current (A).
Io - Diode Saturation Current.
Q - Charge of Electron = 1.6x10-19 (Coul).
K - Boltzmann Constant (J/K)
V - Cell Output Voltage (V)
Rs, Rsh - Cell Series and Shunt Resistance (Ohms).

III. CUK CONVERTER

A. Analysis of CUK Converter

CUK converter is a type of DC/DC converter allowing the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input. The output of the CUK is controlled by the duty cycle of the control transistor.

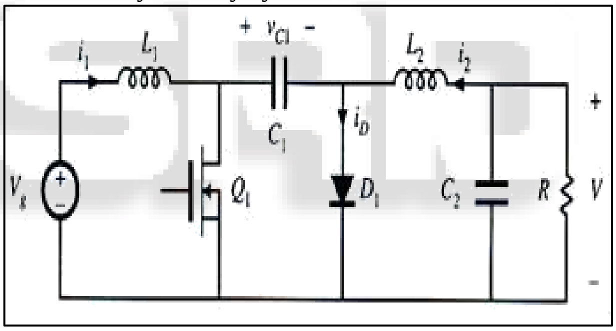

Fig. 2: Equivalent Circuit of CUK Converter with R Load

B. Operation of CUK Converter

All dc-dc converters operate by rapidly turning on and off a MOSFET, generally with a high frequency pulse. What the converter does as a result of this is what makes the CUK converter superior. For the CUK, when the pulse is high/the MOSFET is on, inductor 1 is charged by the input voltage and inductor 2 is charged by capacitor 1. The diode is off and the output is maintained by capacitor 2. When the pulse is low/the MOSFET is off, the inductors output through the diode to the load and the capacitors are charged.is shown below.

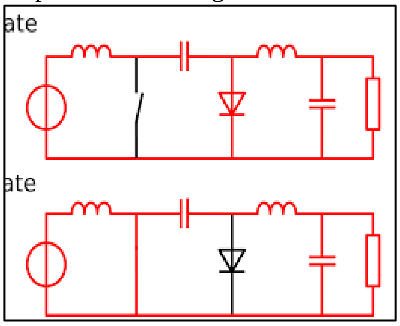

Fig. 3: CUK Converter Operation

C. *Duty Cycle Calculation*

The amount that the CUK converters step up or down the voltage depends primarily on the Duty Cycle and the parasitic elements in the circuit.

The output of an ideal CUK converter is,

$$V_o = \frac{D * V_i}{1 - D}$$

However, this does not account for losses due to parasitic elements such as the diode drop VD. These make the equation:

$$V_o + V_D = \frac{D * V_i}{1 - D}$$

This becomes,

$$D = \frac{V_o + V_D}{V_i + V_o + V_D}$$

IV. EXISITING SYSTEM

1) A limitation of the existing micro-inverter topologies is the need for a large energy buffering element such as a capacitor at the junction of the solar panel and inverter due to power pulsation at twice the line frequency that appears at the DC input reducing the efficiency of the PV generation.
2) Hence there is a need for power decoupling either active or passive to overcome the mismatch between the DC instantaneous input power and the AC instantaneous output power. Passive power decoupling either makes use of a bulky DC link capacitance or an LC resonant filters at the junction of the PV panel to absorb the power pulsation.
3) The use of bulky passive storage elements adds both to the cost and the size of the inverter while also diminishing its usability period as the lifetimes of electrolytic capacitors are shortened in high temperature conditions

A. *Existing Block Diagram*

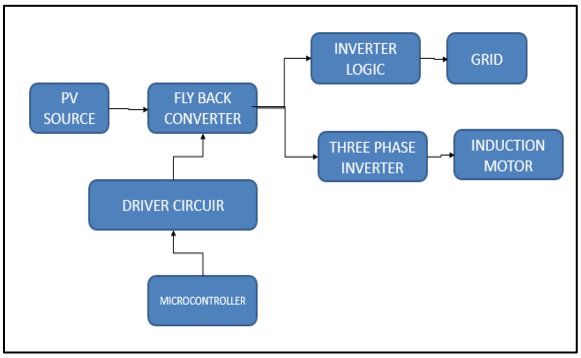

Fig. 4: Block Diagram of Existing System

B. *Disadvantages of Existing System*

1. Conduction Loss
2. High Efficiency
3. Total Harmonic Distortion

V. PROPOSED SYSTEM

1) The proposed system makes use of a single phase Fly back inverter with a center tap transformer operating in discontinuous conduction mode (DCM). It employs peak current control along with a decoupling circuit for APD as proposed for grid connected mode and is modified for our need to work as a DC converter during blackouts as the offline mode of operation.
2) When grid-tied the energy buffering in the converter, to achieve power pulsation at the output, is done using the decoupling capacitor CD and switch SD. During the offline mode the circuit is configured to produce output at a DC link, usually a battery or used to drive an elastic load in conjunction with critical load to extract power at MPP.
3) A CUK converter has been utilized here so that it can support variable output load with both positive polarity and negative polarity.
4) It's can support unstable load with constant current output. Headings, or heads, are organizational devices that guide the reader through your paper. There are two types: component heads and text heads.

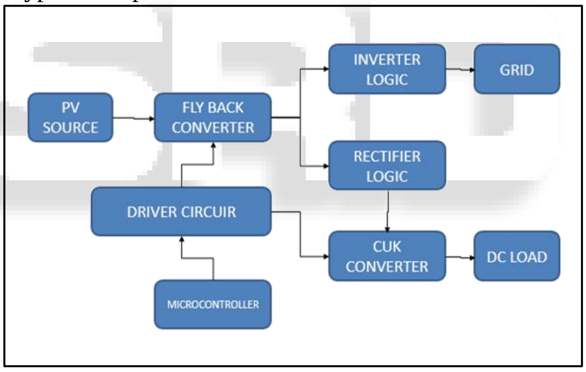

Fig. 5: Block Diagram of Proposed System

A. *Advantages of Proposed System*

a) High torque/current ratio
b) High power density
c) Higher efficiency
d) High voltage gain & efficiency
e) Simpler structure and control
f) Reduced size and weight
g) Provide a high voltage gain without extreme switch duty cycle.

B. *Solar Photovoltaic Systems*

Solar Photo voltaic System uses solar cells to convert light into electricity. A PV system consists of PV modules and balance of systems (BOS). Balance of systems includes module support structure, storage, wiring, power electronics, etc. DC (direct current) electricity is generated when solar radiation strikes the PV module. Power can be used in any DC load directly during this generation. But the generation exists during daytime. So, some storage device is needed to run the system at night or in low sunshine hour. Again this power cannot be used to run any AC (alternate current) load. Inverter has to be used to convert DC into AC.

Solar PV systems are categorized into following

a) Stand-alone PV systems (also called off-grid systems)
b) Grid connected PV systems (also called on-grid systems)
c) Hybrid systems

C. Stand-Alone PV Systems

Stand-alone systems are not connected with utility power lines and these are self-sufficient systems. These systems could either be used to charge the batteries that serve as an energy storage device or could work directly using the solar energy available in the day times. These systems consist of the following:

a) Solar panels mounted on the roof or in open spaces.
b) Photo voltaic module produces direct current (DC) electrical power.
c) Batteries to store DC energy generated by the solar panels.
d) Charge controller to prevent overcharging the battery.
e) Inverter to convert electricity produced by the system from DC to AC power.

The Figure 6 shows PV system powering AC loads with battery bank. DC loads can also be connected directly to the battery bank. It is also possible to power the AC load without battery, but in that case it would be confined only to daytime when solar radiation is sufficient to generate required electricity.

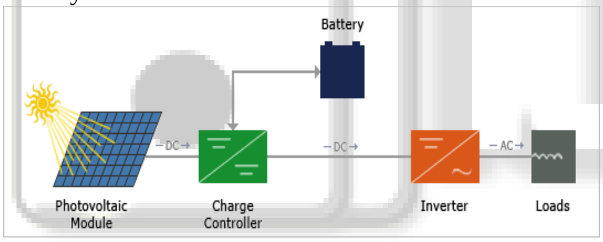

Fig. 6: PV System Powering AC Loads With Battery

VI. MPPT ALGORITHMS

A. Introduction

Photovoltaic (PV) systems have been used for many decades. Today, with the focus on greener sources of power, PV has become an important source of power for a wide range of applications. Improvements in converting light energy into electrical energy as well as the cost reductions have helped create this growth. Even with higher efficiency and lower cost, the goal remains to maximize the power from the PV system under various lighting conditions. Unfortunately, PV generation systems have two major problems: the conversion efficiency of electric power generation is very low (9・7%), especially under low irradiation conditions, and the amount of electric power generated by solar arrays changes continuously with weather conditions.

Moreover, the solar cell V-I characteristic is nonlinear and varies with irradiation and temperature. In general, there is a unique point on the V-I or V-P curve, called the Maximum Power Point (MPP), at which the entire PV system (array, converter, etc) operates with maximum efficiency and produces its maximum output power. The location of the MPP is not known, but can be located, either through calculation models or by search algorithms. Therefore Maximum Power Point Tracking (MPPT) techniques are needed to maintain the PV array's operating point at its MPP.

B. Maximum Power Point Tracking

Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Additional power harvested from the modules is then made available as increased battery charge current. MPPT can be used in conjunction with a mechanical tracking system, but the two systems are completely different.

C. Role of MPPT in SPV System

Photovoltaic systems normally use a maximum power point tracking (MPPT) technique to continuously deliver the highest possible power to the load when variations in the isolation and temperature occur, Photovoltaic (PV) generation is becoming increasingly important as a renewable source since it offers many advantages such as incurring no fuel costs, not being polluting, requiring little maintenance, and emitting no noise, among others. PV modules still have relatively low conversion efficiency; therefore, controlling maximum power point tracking (MPPT) for the solar array is essential in a PV system. The Maximum Power Point Tracking (MPPT) is a technique used in power electronic circuits to extract maximum energy from the Photovoltaic (PV) Systems.

In the recent days, PV power generation has gained more importance due its numerous advantages such as fuel free, requires very little maintenance and environmental benefits. To improve the energy efficiency, it is important to operate PV system always at its maximum power point. Many maximum power point Tracking (MPPT) techniques are available and proposed various methods for obtaining maximum power point. But, among the available techniques sufficient comparative study particularly with variable environmental conditions is not done. This paper is an attempt to study and evaluate s60e main types of MPPT techniques namely, Open-circuit voltage and Short-circuit current, P&O, IC etc. A solar cell basically is a p-n semiconductor junction. When exposed to light, a dc current is generated. The generated current varies linearly with the solar irradiance.

D. Incremental Conductance MPPT Algorithm

This method exploits the assumption of the ratio of change in output conductance is equal to the negative output Conductance Instantaneous conductance. We have,

$$P = V\,I$$

Applying the chain rule for the derivative of products yields to

$$\partial P/\partial V = [\partial (VI)]/\,\partial V$$

At MPP, as $\partial P/\partial V=0$

The above equation could be written in terms of array voltage V and array current I as

$$\partial I/\partial V = - I/V$$

The MPPT regulates the PWM control signal of the dc – to – dc boost converter until the condition: $(\partial I/\partial V) + (I/V) = 0$, is satisfied. In this method the peak power of the module lies at above 98% of its incremental conductance.

VII. INVERTER

In the world today there are currently two forms of electrical transmission, Direct Current (DC) and Alternating Current (AC), each with its own advantages and disadvantages. DC power is simply the application of a steady constant voltage across a circuit resulting in a constant current. A battery is the most common source of DC transmission as current flows from one end of a circuit to the other. Most digital circuitry today is run off of DC power as it carries the ability to provide either a constant high or constant low voltage, enabling digital logic to process code executions. Historically, electricity was first commercially transmitted by Thomas Edison, and was a DC power line. However, this electricity was low voltage, due to the inability to step up DC voltage at the time, and thus it was not capable of transmitting power over long distances.

$$V = IR$$

$$P = IV = I2R$$

As can be seen in the equations above, power loss can be derived from the electrical current squared and the resistance of a transmission line. When the voltage is increased, the current decreases and concurrently the power loss decreases exponentially; therefore high voltage transmission reduces power loss. For this reasoning electricity was generated at power stations and delivered to homes and businesses through AC power. Alternating current, unlike DC, oscillates between two voltage values at a specified frequency, and it's ever changing current and voltage makes it easy to step up or down the voltage. For high voltage and long distance transmission situations all that is needed to step up or down the voltage is a transformer. Developed in 1886 by William Stanley Jr., the transformer made long distance electrical transmission using AC power possible.

A. *Sinusoidal Pulse Width Modulation*

The switches in the voltage source inverter can be turned on and off as required. In the simplest approach, the top switch is turned on if turned on and off only once in each cycle, a square wave waveform results. However, if turned on several times in a cycle an improved harmonic profile may be achieved.

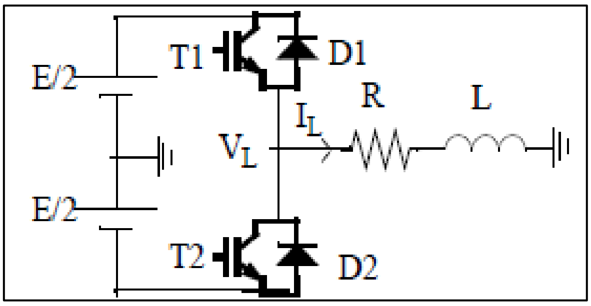

Fig. 7: Simple Voltage Source Inverter

In the most straightforward implementation, generation of the desired output voltage is achieved by comparing the desired reference waveform (modulating signal) with a high-frequency triangular 'carrier' wave as depicted schematically. Depending on whether the signal voltage is larger or smaller than the carrier waveform, either the positive or negative dc bus voltage is applied at the output. Note that over the period of one triangle wave, the average voltage applied to the load is proportional to the amplitude of the signal (assumed constant) during this period.

The resulting chopped square waveform contains a replica of the desired waveform in its low frequency components, with the higher frequency components being at frequencies of an close to the carrier frequency. Notice that the root mean square value of the ac voltage waveform is still equal to the dc bus voltage, and hence the total harmonic distortion is not affected by the PWM process. The harmonic components are merely shifted into the higher frequency range and are automatically filtered due to inductances in the ac system.

B. *SPWM Spectra*

Although the SPWM waveform has harmonics of several orders in the phase voltage waveform, the dominant ones other than the fundamental are of order n and n±2 where n = fc/fm. This is evident for the spectrum for n=15 and m = 0.8 shown in FIGURE 8. Note that if the other two phases are identically generated but 120o apart in phase, the line-line voltage will not have any triplen harmonics. Hence it is advisable to choose, as then the dominant harmonic will be eliminated.

Choosing a multiple of 3 is also convenient as then the same triangular waveform can be used as the carrier in all three phases, leading to some simplification in hardware. It is readily seen that as the where E is the dc bus voltage, that the rms value of the output voltage signal is unaffected by the PWM process. This is strictly true for the phase voltage as triplen harmonic orders are cancelled in the line voltage. However, the problematic harmonics are shifted to higher orders, thereby making filtering much easier. Often, the filtering is carried out via the natural high-impedance characteristic of the load.

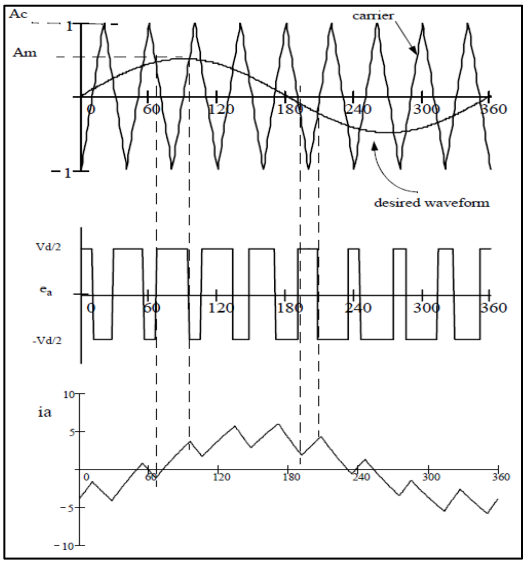

Fig. 8: Principle of Pulse Width Modulation

VIII. SIMULATION

A. *Introduction*

If you are new to MATLAB, you should start by reading Manipulating Matrices. The most important things to learn are how to enter matrices, how to use the: (colon) operator, and how to invoke functions. After you master the basics, you should read the rest of the sections below and run the demos. At the heart of MATLAB is a new language you must learn before you can fully exploit its power. You can learn the basics of MATLAB quickly, and mastery comes shortly after. You will be rewarded with high productivity, high-creativity computing power that will change the way you work.

B. *Typical Uses Includes*

a) Math and computation
b) Algorithm development
c) Modeling, simulation, and prototyping
d) Data analysis, exploration, and visualization
e) Scientific and engineering graphics
f) Application development, including graphical user interface building.

C. *MATLAB System*

The MATLAB system consists of five main parts:

1) *Development Environment*

This is the set of tools and facilities that help you use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, and browsers for viewing help, the workspace, files, and the search path.

2) *The Mathematical Function Library*

This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigenvalues, Bessel functions, and fast Fourier transforms.

3) *The MATLAB Language*

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create complete large and complex application programs.

4) *Handle Graphics*

This is the MATLAB graphics system. It includes high-level commands for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level commands that allow you to fully customize the appearance of graphics as well as to build complete graphical user interfaces on your MATLAB applications.

5) *The MATLAB Application Program Interface (API)*

This is a library that allows you to write C and FORTRAN programs that interact with MATLAB. It include facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

D. *Development Environment*

This chapter provides a brief introduction to starting and quitting MATLAB, and the tools and functions that help you to work with MATLAB variables and files. For more information about the topics covered here, see the corresponding topics under Development Environment in the MATLAB documentation, which is available online as well as in print.

IX. SIMULATION RESULT

A. *Conventional Circuit*

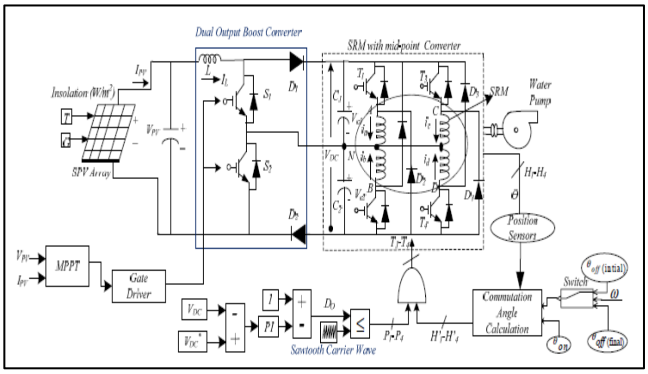

Fig. 9: Conventional Circuit

B. *Converter Output*

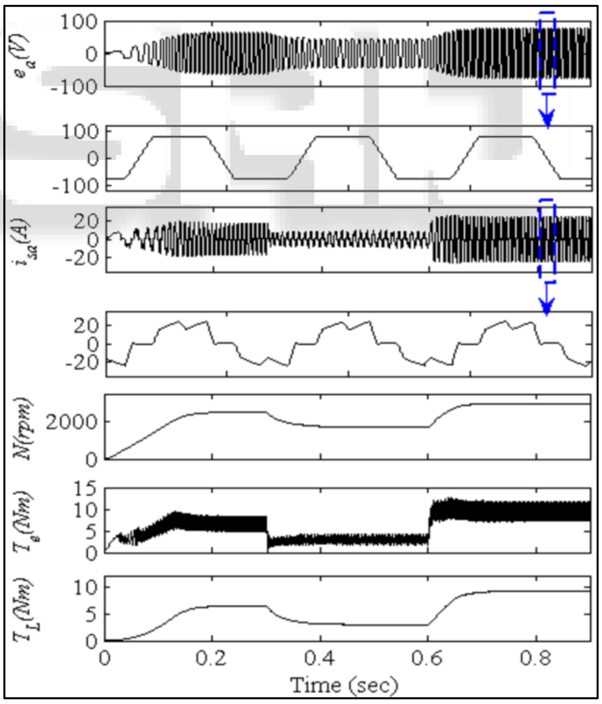

Fig. 9: Converter Output

Where ea(V) - Zeta converter voltage
I(sa) - Current from converter.
N - Speed of BLDC.
T - Torque of BLDC

C. Proposed Circuit Diagram and Its Outputs

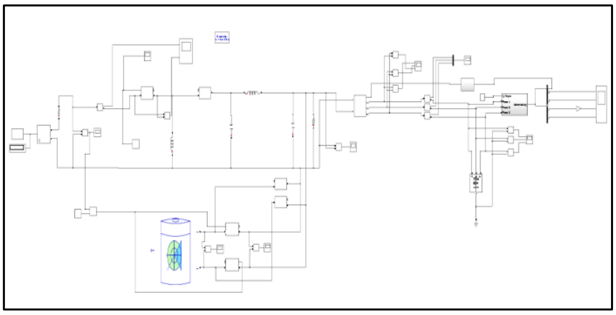

Fig. 10: Simulated Diagram of MATLAB Proposed System

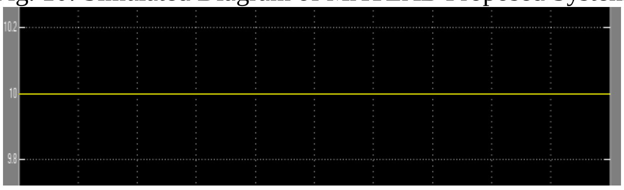

Fig. 11: DC Input Voltage

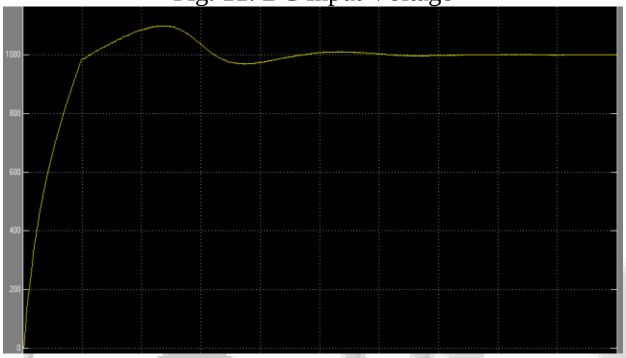

Fig. 12: Motor Speed 1000 Rpm

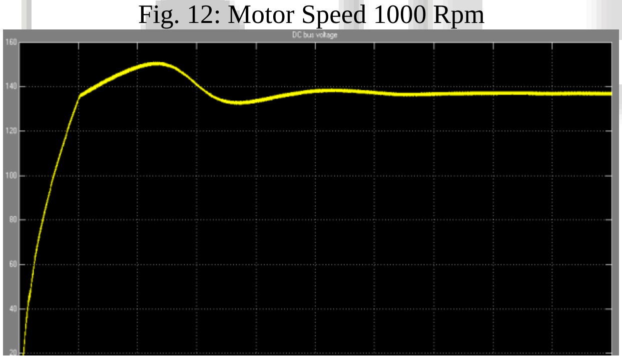

Fig. 13: Output from CUK Converter

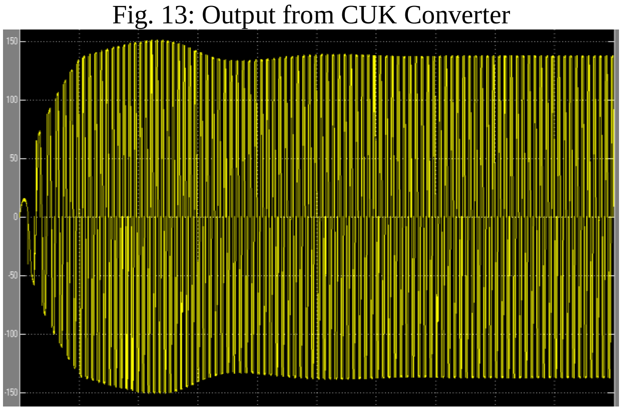

Fig. 14: AC Voltage from Inverter

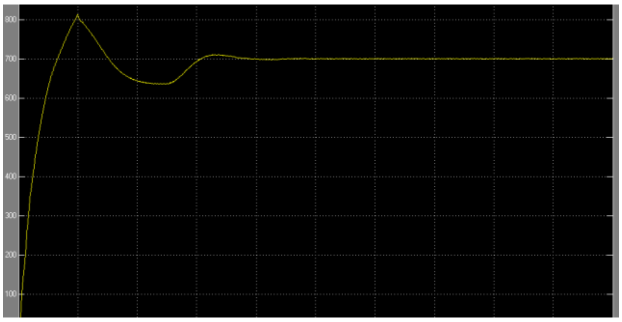

Fig. 15: For N=700 Rpm

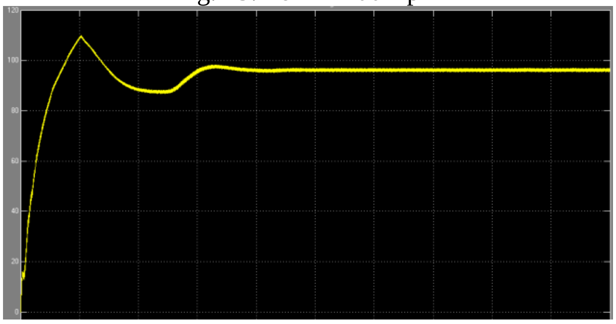

Fig. 16: Output of CUK

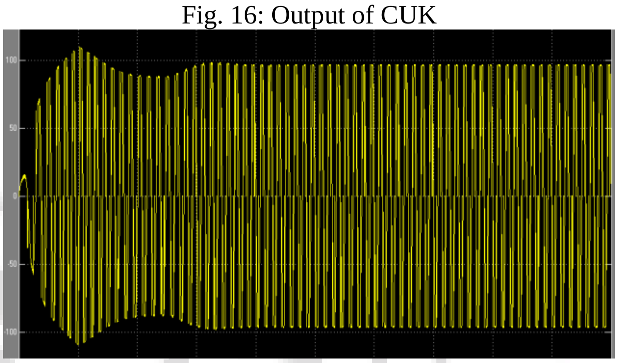

Fig. 17: AC Output Voltage

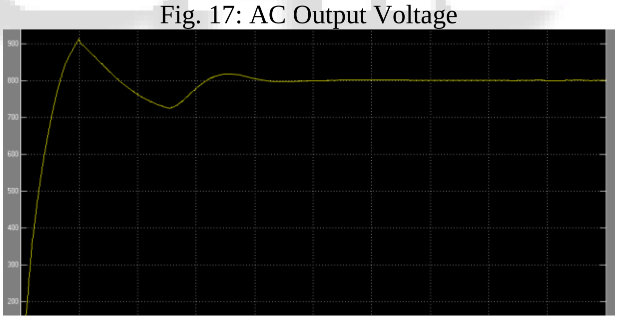

Fig. 18: For N=800 Rpm

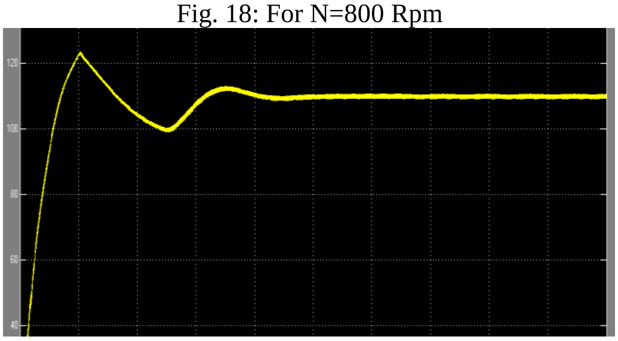

Fig. 19: Output Voltage of CUK

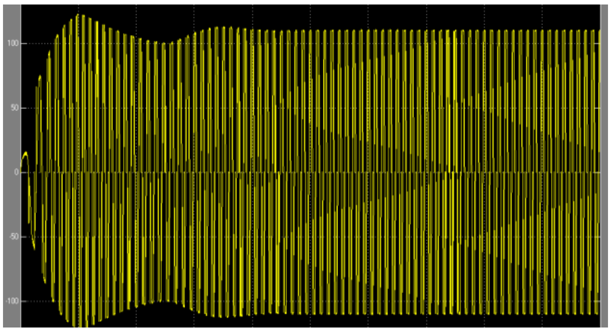
Fig. 20: AC Output Voltage from Inverter

D. THD (Total Harmonic Distortion)

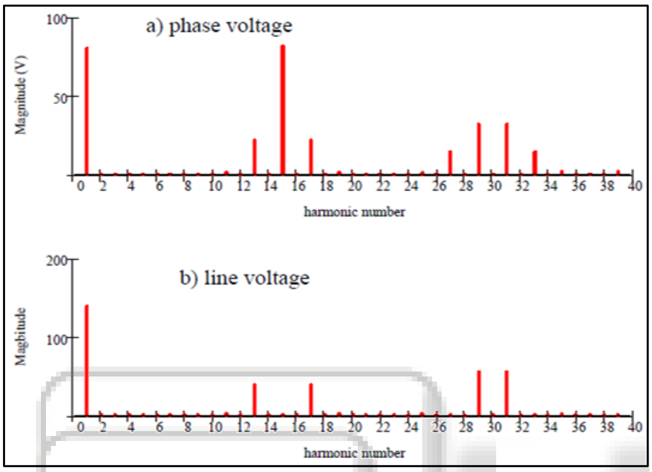

Figure 21.Harmonic Distortion

X. CONCLUSION

A new topology of solar pv array energized CUK converter based switched reluctance motor has been proposed and suitability of it has been authenticated by analyzing its various performance indices using MATLAB/simulink based study. A cost effective method for speed control of switched reluctance motor drive has been proposed, which has facilitated complete elimination of current sensors in the motor side. A trade-off between the MPPT achieving time and the perturbation duration has been reduced.

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