MICRO GRID SYSTEM CONFIGURATION OF INTERLEAVED FLYBACK CONVERTER FOR PHOTOVOLTAIC APPLICATION

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ABSTRACT—THIS PAPER PRESENTS THE MICRO GRID SYSTEM CONFIGURATION OF INTERLEAVED FLYBACK CONVERTER IN PV APPLICATIONS TOPOLOGY. IN TODAY'S PV APPLICATIONS THE USE OF FLYBACK CONVERTER IS PROMOTED AT MPPT AND SWITCHING CONTROL. THEREFORE THE PRIMARY OBJECTIVE OF THIS STUDY IS TO DESIGN A PV APPLICATION WITH INTERLEAVED FLYBACK CONVERTER TOPOLOGY AS A MICRO GRID SYSTEM WITH HIGH VOLTAGE BOOSTING WITH OPTIMIZED EFFICIENCY. THE CONCEPT OF EMBEDDED SYSTEM IS UTILIZED BY INTRODUCING A MICROCONTROLLER WHICH SERVES THE PURPOSE AND MOBILIZING THE PRIMARY SOURCE INTO CIRCUITRY COMPONENTS, FURTHER OPTIMIZING THE EFFECTIVE OUTPUT. THE SIMULATION AND EXPERIMENTAL RESULTS VERIFY THE EFFECTIVENESS OF THE PROPOSED MODELING.

Keywords—.Microgrid, interleaed flyback converter, grid interface, Photovoltaic Applications

1. INTRODUCTION

The flyback converter is a power supply topology that uses reciprocally coupled inductor, to store energy when current passes through and releasing the energy when the power is removed. The flyback converters are similar to the booster converters in architecture and performance. However, the primary winding of the transformer replaces inductor while the secondary provides the output. In the flyback configuration, the primary and secondary windings are utilized as two separate inductors. When the current flowing through an inductor is cut off, the energy stored in the magnetic field is released by a sudden reversal of the terminal voltage. If a diode is in place to conduct the stored energy somewhere useful, the diode is called a flyback diode. This only requires one winding on the inductor, so the inductor would be called a flyback transformer. This arrangement has the interesting property of transferring energy to the secondary side of the power supply only when the primary switch is off.

The basic flyback converter uses a relatively small number of components. A switching device chops the input DC voltage and the energy in the primary is transferred to the secondary through the switching transformer. A diode in the secondary rectifies the voltage while the capacitor smoothens the rectified voltage. In a practical circuit, a feedback circuit is used to monitor the output voltage and while a control circuit switching device.

2. LITERATURE REVIEW

1. B. Tamyurek and B. Kirimer, "An interleaved high-power flyback inverter for photovoltaic applications," IEEE Trans. Power Electron., vol. 30, no. 6, pp. 3228–3241, Jun. 2015.

This paper presents analysis, design, and implementation of an isolated grid-connected inverter for photovoltaic (PV) applications based on interleaved flyback converter topology operating in discontinuous current mode. In today's PV inverter technology, the simple and the low-cost advantage of the flyback topology is promoted only at very low power as micro-inverter. Therefore, the primary objective of this study is to design the flyback converter at high power and demonstrate its practicality with good performance as a central-type PV inverter. For this purpose, an inverter system rated at 2 kW is developed by interleaving of only three flyback cells with added benefit of reduced size of passive filtering elements. A simulation model is developed in the piecewise linear electrical circuit simulator. Then, the design is verified and optimized for the best performance based on the simulation results. Finally, a prototype at rated power is built and evaluated under the realistic conditions. The efficiency of the inverter, the total harmonic distortion of the grid current, and the power factor are measured as 90.16%, 4.42%, and 0.998, respectively. Consequently, it is demonstrated that the performance of the proposed system is comparable to the commercial isolated PV inverters in the market, but it may have some cost advantage

2.F. F. Edwin, W. Xiao, and V. Khadkikar, "Dynamic modeling and control of interleaved flyback module-integrated converter for PV power applications," IEEE Trans. Ind. Electron., vol. 61, no. 3, pp. 1377–1388,Mar. 2014.

For photovoltaic applications, the interleaved flyback module-integrated converters (MICs) (IFMICs) operating in continuous conduction mode (CCM) show the advantages of high power density, low voltage and current stresses, and low electromagnetic interference but demonstrate a difficult control problem compared to the discontinuous conduction mode. This paper concentrates on the control issues and presents detailed modeling, in-depth dynamic analysis, and a two-step controller design approach for IFMIC systems operating in CCM. The proposed modeling approach is based on the fourth-order system considering the dynamics of the output CL filter. This realistic fourth-order system modeling shows the presence of a resonant peak at a certain frequency, which can cause phase loss and constraints of system bandwidth. A decoupled two-step controller design approach is thus proposed to simplify the modeling and control synthesis in the IFMIC development. The decoupled controller consists of a proportional-integral controller (based on the simplified model), followed by a lag term for mitigating the effect of the resonant peak. A 200-W digitally controlled MIC prototype is constructed for evaluation purposes. The simulation and experimental results verify the effectiveness of the proposed modeling and control approaches.

3.N.Sukesh, M.Pahlevaninezhad, and P. K. Jain, "Analysis and implementation of a single-stage flyback PV microinverter with soft switching, "IEEE Trans. Ind. Electron., vol. 61, no. 4, pp. 1819–1833, Apr. 2014.

This paper presents a novel zero-voltage switching (ZVS) approach to a grid-connected single-stage flyback inverter. The soft-switching of the primary switch is achieved by allowing negative current from the grid side through bidirectional switches placed on the secondary side of the transformer. Basically, the negative current discharges the metal-oxide-semiconductor field-effect transistor's output capacitor, thereby allowing turn on of the primary switch under zero voltage. To optimize the amount of reactive current required to achieve ZVS, a variable-frequency control scheme is implemented over the line cycle. In addition, the bidirectional switches on the secondary side of the transformer have ZVS during the turn- on times. Therefore, the switching losses of the bidirectional switches are negligible. A 250-W prototype has been implemented to validate the proposed scheme. Experimental results confirm the feasibility and superior performance of the converter compared with the conventional flyback inverter.

4.F. Karbakhsh, M. Amiri and H. Abootorabi Zarchi, "Two-switch flyback inverter employing a current sensorless MPPT and scalar control for low cost solar powered pumps," in IET Renewable Power Generation, vol. 11, no. 5, pp. 669-677, 12 4 2017.

This study presents a two-switch flyback inverter followed by a low frequency unfolding bridge for fractional horse power water pumping systems. This topology mitigates the problem of high-voltage transients at switch turn off which commonly exists in single switch flyback inverters. The flyback converter is setup in a way to act as a two way switch which is the major modification as of this setup. Moreover, the proposed control strategy achieves an integration of a novel sensorless maximum power point tracking (MPPT) algorithm as well as a constant v / f control for the efficient utilization of both the PV panel and the motor. The proposed control algorithm minimizes the cost and simplifies the control strategy. The validity and capability of the proposed method are verified by both simulation and practical results of a DSP-based two-switch flyback solar micro inverter for a fractional horsepower water pumping system.

5.R.Za'im, J.Jamaludin and N. A. Rahim, "Photovoltaic Flyback Microinverter With Tertiary Winding Current Sensing," in IEEE Transactions on Power Electronics, vol. 34, no. 8, pp. 7588-7602, Aug. 2019.

This paper presents a new low cost, non-invasive, and isolated current sensing technique for the grid-tied photovoltaic (PV) flyback microinverter. This is accomplished by using the flyback transformer itself as a current sensor, achieved by introducing a tertiary winding to the flyback transformer. The mathematical integration of the tertiary winding's open circuit voltage through a ground-clamped-integrator results in the sensing of the magnetizing current. Since the magnetizing current is a combination of both primary and secondary current, control of both grid current and maximum power point tracking (MPPT) is implemented by sensing only the magnetizing current. This allows the PV, primary, secondary, and the grid current loops to be free of any invasive current sensors. Moreover, controlling the magnetizing current provides an alternative solution to an inherent problem with continuous conduction mode (CCM), the control complexity. Linear ramping and de-ramping of the magnetizing current allows for a set-reset hysteresis control to be implemented, resulting in CCM control simplicity that is akin to the boundary and discontinuous conduction mode. A grid-tied microinverter prototype is presented for verification, achieving the following experimental result: 1.9% grid current THD, 0.9988 power factor, above 99% static MPPT efficiency and dynamic efficiency of 98.50%.

3. EXISTING SYSTEM

A) TRANSFORMERLESS PV SYSTEMS AND ITS DRAWBACKS:

- The efficiency of the whole PV system can be increased with an extra 1%–2% in case the transformer is omitted.
- Transformer less inverters have higher efficiency and smaller weight and size than their counterparts with

galvanic separation.

- The ground leakage current is very high.
- In case the transformer is omitted, the generated common-mode behavior of the inverter topology greatly influences the ground leakage current through the parasitic capacitance of the PV.
- In order to minimize the ground leakage current through the parasitic capacitance of the PV array, several techniques have been used.

B)GALVANIC ISOLATION AND ITS DRAWBACKS:

- Galvanic isolation can be or on the grid side in the form of a big bulky ac transformer.
- Both of these solutions offer the safety and advantage of galvanic isolation, but the efficiency of the whole system is decreased due to power losses in these extra components.

C) FULL BRIDGE ISOLATED CONVERTER

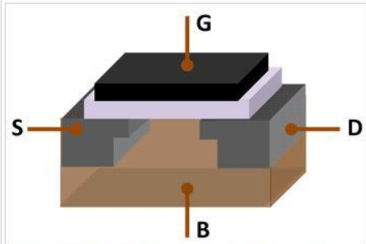
- The DC-DC converter to set up the voltage level using transformer. This converter that uses a transformer to increase or decrease the output voltage (depending on the transformer ratio).
- Snubber is needed, leakage inductance is more, filter value is high, number of switches, Losses due to transformer.

4. PROPOSED SYSTEM

In order to overcome the disadvantages of the conventional system an interleaved flyback converter is introduced in the proposed system. The flyback topology system is simple structure and easy power flow control with high power quality at the grid interface are the key motivations for this work. The flyback converter is recognized as the lowest cost converter among the isolated topologies since it need only the least number of components. This advantage comes from the ability of the flyback topology combining the energy storage inductor with the transformer. The combination of these two components in a flyback topology eliminates the bulky and costly energy storage inductor and therefore leads to a reduction in cost and size of the converter.

A. *Hardware Requiremnts*

*1) **MOSFET:*** The metal-oxide-semi-conductor field-effect transistor (MOSFET, MOS- FET, or MOS FET) is a type of field-effect transistor (FET), most commonly fabricated by the controlled oxidation of silicon. It has an insulated gate, whose voltage determines the conductivity of the device. This ability to change conductivity with the amount of applied voltage can be used for amplifying or switching electronic signals. The main advantage of a MOSFET is that it requires almost no input current to control the load current, when compared with bipolar transistors. In an enhancement mode MOSFET, voltage applied to the gate terminal increases the conductivity of the device. In depletion mode transistors, voltage applied at the gate reduced



MOSFET showing gate (G), body (B), source (S) and drain (D) terminals. The gate is separated from the body by an insulating layer (pink).

Fig V.1. MOSFET HardwareIlustration.

Application:

- Digital integrated circuits such as microprocessors and memory devices contain thousands to millions of integrated MOSFET transistors on each device, providing the basic switching functions required to implement logic gates and data storage.
- Discrete devices are widely used in applications such as switch mode power supplies, variable-frequency drives and other power electronics applications where each device may be switching thousands of watts.

2) **PIC16F84A:** This powerful (200 nanosecond instruction execution) yet easy-to-program (only 35 single word instructions) CMOS FLASH-based 8-bit microcontroller packs Microchip's powerful PIC® architecture into an 16-pin package and is upwards compatible with the PIC16C5X, PIC12CXXX and PIC16C7X devices. The PIC16F876A features 256 bytes of EEPROM data memory, self-programming, an ICD, 2 Comparators, 5 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I^2C™) bus and a Universal Asynchronous Receiver Transmitter (USART). All of these features make it ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications.

Fig V.2. Hardware Illustration of PIC16F84A

• **Specifications**

- 28-pin Low Power Microcontroller
- Flash Program Memory: 8192 bytes
- EEPROM Data Memory: 256 bytes
- SRAM Data Memory: 368 bytes
- I/O Pins: 22
- Timers: Two 8-bit / One 16-bit

• **Features:**

- Special Microcontroller Features
- Self-reprogrammable under software control
- CMOS Technology

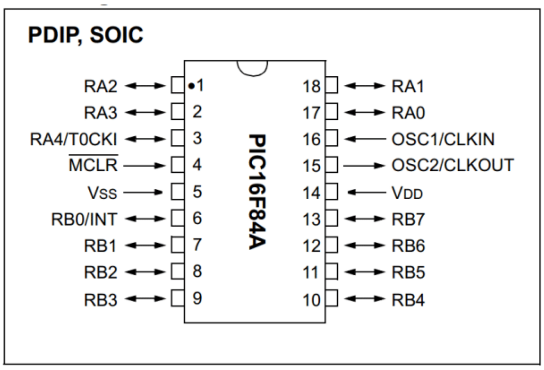


Fig V.3. Pinout Configuration of PIC16F84A

3) ***XTAL Crystal Oscillator:*** The **crystal oscillator** is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a precise frequency. This frequency is often used to keep track of time, as in quartz wristwatches, to provide a stable clock signal for digital integrated circuits, and to stabilize frequencies for radio transmitters and receivers. Therefore the quartz dielectric is the most common type of piezoelectric resonator use but other piezoelectric materials including polycrystalline ceramics are used in similar circuits

Fig V.4. Hardware Illustration of XTAL Crystal Oscillator

4) ***Gate Driver-FAN7392:*** FAN7392 is a monolithic high and low-side gate drive IC, that can drive high-speed MOSFETs and IGBTs that operate upto+600V. It has a buffered output stage with all NMOS transistors designed for high pulse current driving capability and minimum cross-conduction. Fairchild's high-voltage process and common-node noise can-ceiling techniques provide stable operation of the high-side driver under high dv/dt noise circumstances. An advanced level-shift circuit offers high-side gate driver operation upto Vs=9.8V for Vbs=15v. Logic inuts are compatible with standard CMOS or LSTTL output, down to 3.3V logic.

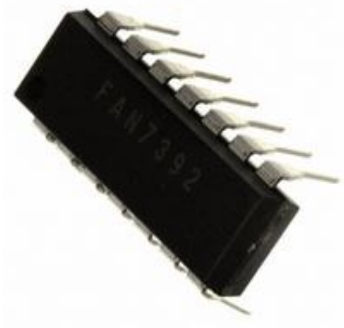


Fig V.5. Hardware Illustration of FAN7392

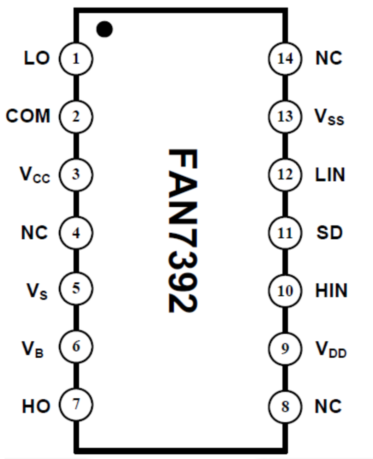
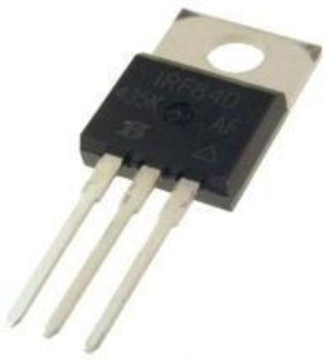


Fig V.6.Pinout Configuration of FAN7392

5) ***Power Mosfet IRF840:*** This N-Channel enhancement mode silicon gate power field effect transistor is an advanced power MOSFET designed, tested, and guaranteed to withstand a specified level of energy in the breakdown avalanche mode of operation.

All of these power MOSFETs are designed for applications such as switching regulators, switching converters, motor drivers, relay drivers, and drivers for high power bipolar switching transistors requiring high speed and low gate drive power.



IRF840

Fig V.7. Hardware Illustration of IRF840

*6) **Voltage Regulator-LM7805:*** LM7805 is a three terminal linear voltage regulator IC with a fixed output voltage of 5V which is useful in a wide range of applications. Voltage sources in a circuit may have fluctuations resulting in not providing fixed voltage outputs. A voltage regulator IC maintains the output voltage at a constant value. 7805 IC, a member of 78xx series of fixed linear voltage regulators used to maintain such fluctuations, is a popular voltage regulator integrated circuit (IC). The xx in 78xx indicates the output voltage it provides. 7805 IC provides +5 volts regulated power supply with provisions to add a heat sink.

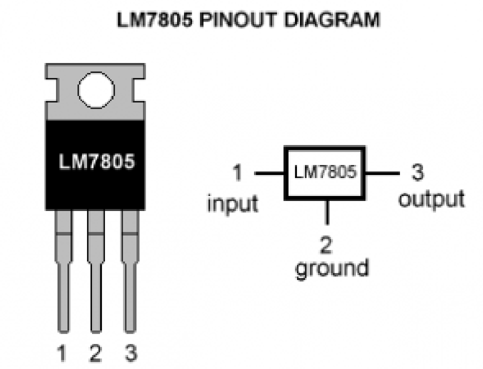


Fig V.8. Pinout Configuration of LM7805

*7) **Diode IN4007:*** 1N4007 is a PN junction diode. Diodes can be made by combining two different types of semiconductor e.g. P and N. PN junction is a junction formed between P and N types of semiconductors. **1N4007** is a PN junction rectifier diode. These types of diodes allow only the flow of electrical current in one direction only. 1N-4007 has different real life applications e.g. free wheeling diodes applications, general purpose rectification of power supplies, inverters, converters etc.

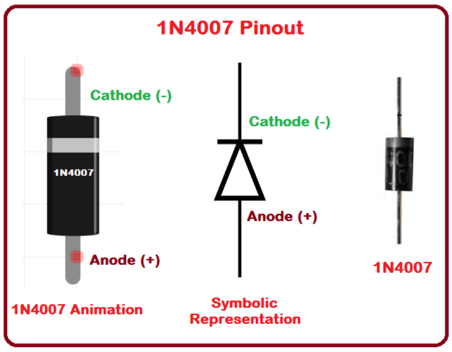


Fig V.9. Hardware and Pinout of 1N4007

*8) **Electrolytic Capacitor:*** An Electrolytic capacitor is a type of capacitor that uses an electrolyte to achieve a larger capacitance than other capacitor types. An electrolyte is a liquid or gel containing a high concentration of ions. Almost all electrolytic capacitors are polarized, which means that the voltage on the positive terminal must always be greater than the voltage on the negative terminal. The benefit of large capacitance in electrolytic capacitors comes with several drawbacks as well. Among these drawbacks are large leakage currents, value tolerances, equivalent series resistance and a limited lifetime. Electrolytic capacitors can be either wet-electrolyte or solid polymer. They are commonly made of tantalum or aluminum, although other materials may be used. Super capacitors are a special subtype of electrolytic capacitors, also called double-layer electrolytic capacitors, also it can be of capacitors with capacitances of hundreds and thousands of farads.

Fig V.10. Hardware Illustration of Electrolytic Capacitor

*9) **Ceramic Capacitor:*** A capacitor is an electrical device that stores energy in the form of an electric field. It consists of two metal plates separated by a dielectric or non-conducting substance. The capacitor types broadly divided based on fixed capacitance and variable capacitance. The most important is the fixed capacitance capacitors, but capacitors with variable capacitance also exist. These include rotary or trimmer capacitors. Capacitors with fixed capacitance are divided into film capacitors, ceramic capacitors, electrolytic, and superconductor capacitors. It uses a ceramic material as the dielectric. The ceramic capacitor is a non-polarity device, which means they do not have polarities.

Fig V.11. Hardware Illustration of Ceramic Capacitor

10) **Resistors(CFR):** The carbon film resistor is a type of fixed resistor that uses carbon film to restrict the electric current to certain level. These types of resistors are widely used in the electronic circuits. The carbon film resistor is made by placing the carbon film or carbon layer on a ceramic substrate. The carbon film acts as the resistive material to the electric current. Hence, the carbon film blocks some amount of electric current. The ceramic substrate acts as the insulating material to the heat or electricity. Hence, the ceramic substrate does not allow heat through them.

Fig V.12. Hardware Illustration of Resistors (CFR)

*B. **Software Requirements***

*1) **MATLAB System:*** Consists of five main parts: Desktop Tools and 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, an editor and debugger, a code analyser and other reports, and browsers for viewing help, the workspace, files, and the search path. 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 large and complex application programs.

*2) **Graphics:*** MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level functions that allow you to fully customize the appearance of graphics as well as to build complete graphical user interfaces on your MATLAB applications.

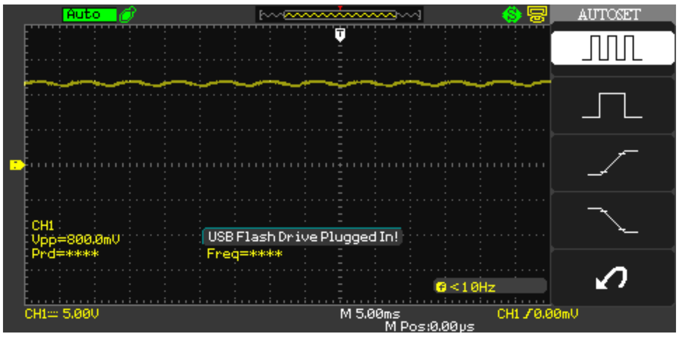
The MATLAB External Interfaces/API This is a library that allows you to write C and Fortran programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files

3) MATLAB Documentation: MATLAB provides extensive documentation, in both printed and online format, to help you learn about and use all of its features. If you are a new user, start with this Getting Started book. It covers all the primary MATLAB features at a high level, including many examples. The MATLAB online help provides task-oriented and reference information about MATLAB features. MATLAB documentation is also available in printed form and in PDF format. MATLAB Online Help to view the online documentation, select MATLAB Help from the Help menu in MATLAB. The MATLAB documentation is organized into these main topics.

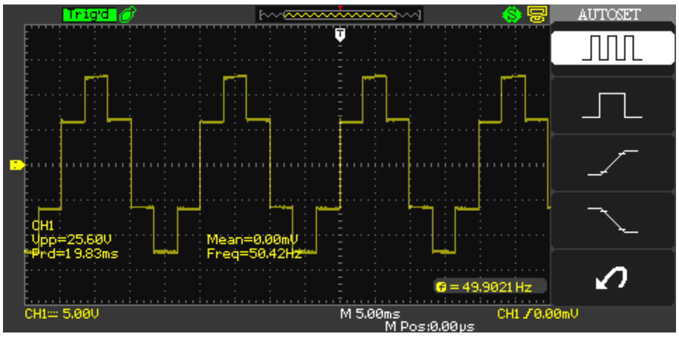
*4) **The Role of Simulation in Design**:* Electrical power systems are combinations of electrical circuits and electro mechanical devices like motors and generators. Engineers working in this discipline are constantly improving the performance of the systems. Requirements for drastically increased efficiency have forced power system designers to use power electronic devices and sophisticated control system concepts that tax traditional analysis tools and techniques. Further complicating the analyst's role is the fact that the system is often so nonlinear that the only way to understand it is through simulation. Land- based power generation from hydroelectric, steam, or other device is not the only use of power systems. A common attribute of these systems is their use of power electronics and control systems to achieve their performance objectives. Sim Power Systems is a modern design tool that allows scientists and engineers to rapidly and easily build models that simulate power systems. Sim Power Systems uses the Simulink environment, allowing you to build a model using simple click and drag procedures. Not only can you draw the circuit topology rapidly, but your analysis of the circuit can include its interactions with mechanical, thermal, control, and other disciplines. This is possible because all the electrical parts of the simulation interact with the extensive Simulink modelling library. Since Simulink uses MATLAB as its computational engine, designers can also use MATLAB toolboxes and Simulink block sets. SIM Power Systems and SIM Mechanics share a special Physical Modelling block and connection line interface.

C. *Experimental Results*

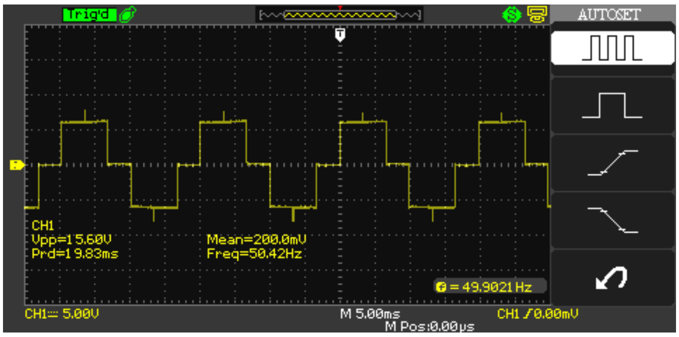
1) Output of Solar Panel



2) Three phase volatage output



3) Single Phase voltage output



5. CONCLUSION

The interleaved flyback converter with grid configuration approach is explained in this project. Thus by introducing interleaved flyback converter isolation between input and output section is achieved and the number of switches used is reduced thus reducing switching stress, the efficiency of the photovoltaic output is increased to a great extent.

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