

# Photovoltaic Management System in Residential Areas Using Power Line Communication

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**Abstract**— Energy consumption in residential areas is rising; residential areas have deployed a photovoltaic (PV) system to save energy cost and provide continuous power in the area. The PV system needs to be continuously monitored to maintain its performance. In addition, it is desirable to monitor each PV module because one abnormal PV module affects the whole PV system. Here Power line communication (PLCC) technology is used to monitor each PV module in order to check the performance of PV system. Power line communication (PLCC) carries data on a conductor that is also used simultaneously for AC electric power transmission. The parameters in PV module are monitored by PLC. The system architecture is composed of the following components: PLC modem, CUK Converter, and inverter connected with AC load. The PLC modems are deployed on each PV module for continuous monitoring. The CUK converter will provide constant voltage to the battery. The device retrieves the stored data in microcontroller unit and informs users about the status of the photovoltaic module. The device retrieves the stored data from the converter to inform users of the status of the PV system. Voltage, Current and Temperature are the parameters which are going to be noted in PV module. The output of the inverter circuit is given to the AC load by using resistive load. Users can browse and figure out the PV system performance in detail by using power line communication technology. The system is installed in the field. It is composed of sixteen PV modules with 960V; since each PV module provides 60V and a 1kW inverter. This scheme will maintain the performance of a PV system and can be used for industrial applications.

**Index Terms**— Power Line Communication, Photovoltaic Management System, CUK Converter ,Inverter and PV module .

## 1 INTRODUCTION

Recently, residential homes have deployed a photovoltaic (PV) system to generate electricity and reduce the energy cost. The PV system is the most popular renewable energy source in residential areas. Monitoring of the deployed PV system is important and essential for maintaining its high performance level. However, in many cases, residents can only check the generation data through the display of the inverter. Residents are difficult to figure out the performance degradation. Therefore, the PV system needs to provide users with an easy way of access to the status of the PV system. The more detailed data the PV system provides, the more properly users can manage the PV system. A normal PV system does not monitor the status of each PV module. A typical monitoring data is limited to the generation data from the inverter[13]. In a typical PV system structure, one abnormal PV module degrades the total performance of the PV system because it deteriorates the current flow of the whole PV system. The PV system is required to provide the status of each PV module as well as the generation data from the inverter. It helps users easily figure out the performance degradation and properly manage the PV system.

To monitor the status of each PV module requires a certain type of communication module that is attached on each PV module and a data aggregation device that gathers the status data from each communication module. This communication module and the data aggregation device communicate with each other based on the adopted communication technology. As a communication technology for monitoring, various technologies adopted in home network can be a candidate such as: ZigBee, WiFi, Bluetooth, RS-485, and power line communication (PLC). Additional installation of communication cables is very annoying because it causes high installation cost. As a result, ZigBee, WiFi, and PLC are considered as candidates for

communication technology because they do not need additional communication cables. ZigBee is the better choice than WiFi because WiFi consumes more energy than ZigBee. Several researches have adopted ZigBee technology to monitor the status of either the PV system or each PV module [5], [8]. However, because a WiFi access point (AP) is widely deployed in residential areas, frequency overlaps between ZigBee and WiFi can cause severe interference. The WiFi signal can corrupt any bit in a ZigBee packet because it is much stronger than the ZigBee signal. In residential areas, ZigBee can suffer from network impairment. As a result, the PLC technology can be considered as a better choice to monitor the status of each PV module. Numerous PLC-based PV monitoring systems have been proposed [9], [11]. However, they use nonstandard PLC technologies and do not provide an easy way of access to the status information of the deployed PV system. Therefore, the PV system is required to provide the communication based on standard PLC and an easy way of access to the status data.

## 2 PROPOSED SYSTEM

To maintain the solar panel power line communication is required to monitor the parameters of panel such as voltage, current and temperature. A solar panel is a set of solar photovoltaic modules electrically connected and mounted on a supporting structure. A photovoltaic module is a packaged, connected assembly of solar cells. The solar module can be used as a component of a larger photovoltaic system to generate and supply electricity in commercial and residential applications.

**2.1 Solar panel**

An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity. The solar panels are mainly made out of semiconductor material and silicon being the most abundantly used semiconductor. Solar cells are connected in series to increase the output voltage. [4] Similarly, the cells in parallel will yield a higher current. Series connected cells are called as PV modules and the interconnection series and parallel combination of solar cells is an array. The equivalent circuit of the general model which consists of a photo current, a diode, a parallel resistor expressing a leakage current, and a series resistor describing an internal resistance to the current flow.

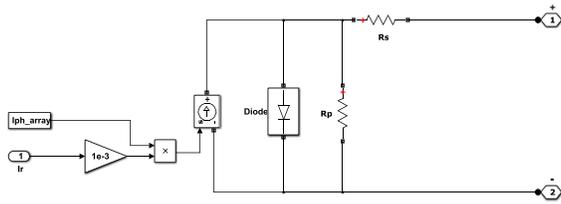


Fig1. Basic Diagram of PV cell

**2.2 CUK converter**

It consists of dc input voltage source  $V_S$ , input inductor  $L_1$ , controllable switch  $S$ , energy transfer capacitor  $C_1$ , diode  $D$ , filter inductor  $L_2$ , filter capacitor  $C$ , and load resistance  $R$ [14]. An important advantage of this topology is a continuous current at both the input and the output of the converter. Disadvantages of the Cuk converter include a high number of reactive components and high current stresses on the switch, the diode, and the capacitor  $C_1$ . Main waveforms in the converter are presented in Fig 2. To obtain the dc voltage transfer function of the converter, we shall use the principle that the average current through a capacitor is zero for steady-state operation.

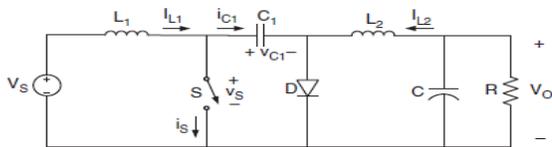


Fig2.Circuit Diagram of CUK Converter

When the switch is on, the diode is off and the capacitor  $C_1$  is discharged by the inductor  $L_2$  current. With the switch in the off state, the diode conducts currents of the inductors  $L_1$  and  $L_2$  whereas capacitor  $C_1$  is charged by the inductor  $L_1$  current. To obtain the dc voltage transfer function of the converter, we shall use the principle that the average current through a capacitor is zero for steady-state operation.

**2.3 Inverter**

An AC load can be powered from a DC source by using a converter to change DC to AC. This circuit is designed for taking 230V AC from the 12V DC input. An AC load can be powered from a DC source by using a converter to change DC to AC is shown in fig .3.0. This is efficiently done through above circuit with the use of two transistors  $Q_1$  &  $Q_2$  and one Transformer (T). The wattage of output depends on these three equipments[5].

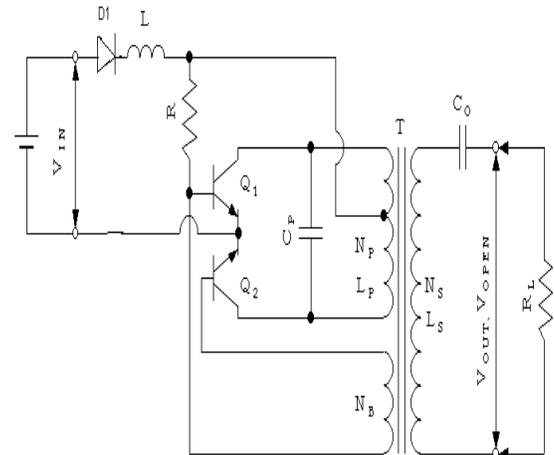


Fig3.Basic Circuit Diagram of Inverter

A DC-to-AC inverter energized from a 12-volt DC input signal uses a single stage inverter circuit to produce a quasi-sine wave output signal[23]. When we are giving 12V DC input to the circuit, initially it goes to diode  $D_1$  which is used to product reverse voltage. Then  $Q_1$  will conduct first, at that time we can get the positive cycle of 230V output in the output transformer side. It will prolong some seconds and gets saturated then  $Q_2$  will conduct this time. This switching makes the reverse polarity in the output side with constant 230V output. Then  $Q_2$  will conduct some seconds and gets saturated and  $Q_1$  will conduct. Likewise this switching makes alternating 230V output in the transformer output side [20]. This will continue up to the input given to the circuit, which makes constant 230V AC output in the transformer side.

**3 SIMULATION USING MAT LAB**

MAT LAB was written originally to provide easy access to matrix software developed by the LINPACK(linear system package) and EISPACK (eigen system package) projects.MAT LAB is high performance language for technical computing. It integrates computation, visualization, and programming environment. Furthermore, MAT LAB is a modern programming language environment : it has sophisticated data structures, contains built-in editing and debugging tools and supports object oriented programming. These factors make MAT LAB an excellent tool for teaching and research.MAT LAB has many advantages compared to conventional computer languages.(e.g., C FORTRAN) for solving

technical problems.

MAT LAB is a interactive system whose basic data element is an array that does not require dimensioning. The software package has been commercially available since 1984 and is now considered as a standard tool at most universities and industries world wide. It has powerful built-in routines that enable a very wide variety of computations. It also has easy to use graphic comments that make the visualization of result immediately available. Special applications are collected in packages referred to as tool box. There are tool boxes for signal processing, symbolic computations, control theory simulation, optimization and several other fields of applied science and engineering [21]. Uses of MAT LAB in a wide range of applications, including signal and image processing, communication, control design, test and measurements, financial modeling and analysis, and computational biology. Add-on tool boxes extend the MAT LAB environment to solve particular classes of problems in these application areas.

Simulink is an environment for multi-domain simulation and Model-Based Design for dynamic and embedded systems. It provides an interactive graphical environment and customizable set of block libraries that let you design, simulate, implement, and test a variety of time- varying systems, including communications, controls, signal processing, video processing, and image processing[2]. Simulink is integrated with MATLAB, which provides immediate access to an extensive range of tools that allows developing algorithms, analyzing and visualizing simulations, creating batch processing scripts, customizing the modeling environment, and defining signal, parameter, and test data.

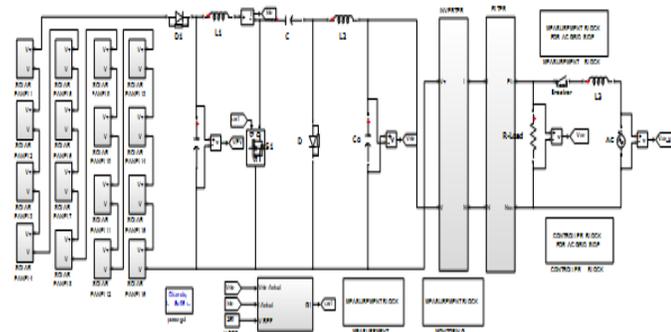


Fig4.Circuit used in the Simulation

The circuit consist of 16 solar panel which is connected in series, each panel output is of about 60V; therefore the output voltage of solar panel is 960V which is shown in fig 4. Here instead of boost or buck-boost converter CUK converter is used; since because in CUK converter the current ripple is less compared to the other two converter. The output of solar panel is given to the CUK converter which consist of two inductors in series and a parallel capacitor with MOSFET switch in between them has reduced to 250V which is DC link voltage. In order to convert DC to AC the inverter circuit is used. The inverter circuit converts 250V of DC into 250V AC and given to the filter. The purpose of filter is to reduce the ripples in the circuit which consist of both capacitor and inductor in it. And last it is given to the AC grid where the output is taken. The output produced is of about 230V 50Hz which can be used for AC

applications. Here it is given to the resistive load.

## 4RESULTS

### 4.1Output of DC Link Voltage

The waveform of DC link voltage of proposed system has increased to 250V by using CUK converter which is shown fig 5.0. The graph has scale 1cm = 1 sec in x-axis and 1cm = 50V in y-axis.

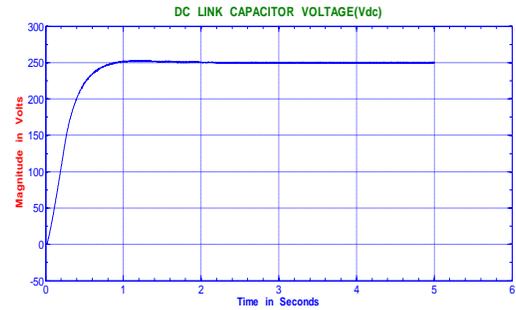


Fig5. DC Link capacitor voltage

### 4.2 Output of Solar Panel

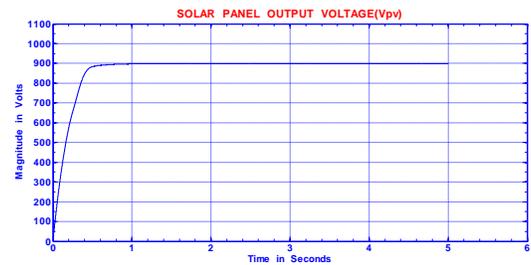


Fig 6. Proposed Output Voltage of Solar panel

The output of one panel is 60V here 16 panels are connected in series and hence output of solar panel is 960V which is represented in the waveform. In x axis 1cm = 1sec and y-axis 1cm = 100V .

### 4.3 AC grid Voltage

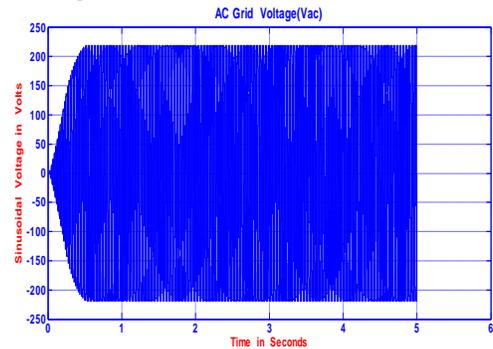


Fig7. AC grid Voltage

The above graph which is shown in fig 7 represents the output of AC voltage which is 230V. It has decreased from 250V to 230V by using inverter circuit and filter in order to reduce fluctuations. It can be used for AC load. x axis 1cm = 1sec and y axis 1cm = 50V.

#### 4.4 PV Module Voltage

The output of PV module is 60V which is represented in the waveform as shown in the below fig 8. The graph has time in x-axis 1cm = 1sec and y-axis 1cm = 10volts. The waveform indicates it is the output of individual PV module that is of about 60V.

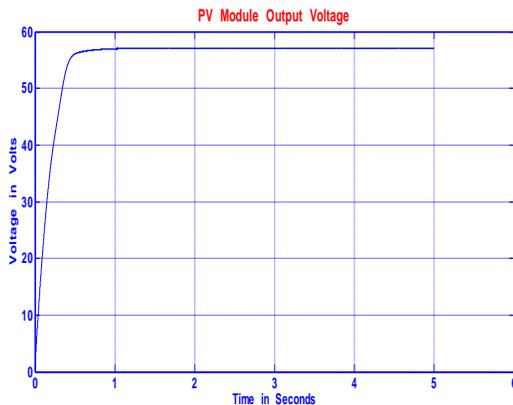


Fig8. PV Module Output Voltage

#### 6CONCLUSION

Monitoring of individual photovoltaic modules in a PV system and providing the monitored information through devices are necessary to effectively manage the PV system and efficiently maintain its performance in residential areas. The system introduces an identification mechanism of the proportional parameter to make the MPPT algorithm robust against disturbances such as shades and surface contamination on the PV panels. To achieve these needs, this paper adopts the power line communication technology. PLC has been proven to be a suitable solution and offers the possibility of carrying out a PV system predictive maintenance. The PLC modems and CUK Converter are developed and then deployed at the PV modules and the inverter, respectively. The status of each PV module from the PLC modems are monitored and given to converter to get constant output voltage of about 250V. The device enables users to access the status of each PV module as well as total PV system in detail, anywhere and anytime. MATLAB/Simulink simulations and experimental analyses were presented to demonstrate the performance of the photovoltaic system by using power line communication technology. The constant voltage maximum power point (MPP) algorithm presented is a simple method to continuously track the MPP of the solar cell array as the weather conditions vary, enhancing the PV system management and maintaining its performance. Monitoring PV modules and measuring will improve the PV systems behavior and reduce the losses in PV systems. With this scheme, users can precisely observe each PV module's performance and any abnormal status in the PV system. As a result,

it will enhance management in residential areas and can be used for industrial applications. It is an effective method for the energy consumption and hence has a promising future in the research oriented areas.

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