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Microcontroller based Bidirectional Energy Metering for Domestic User

Mallikarjun. G. Hudedmani[1], Vishwanath M. Soppimath[1], Chaitanya. K. Jambotkar[1], Digamber. S. Albur[2]

[1]Department of Electrical and Electronics Engineering, KLE Institute of Technology, Hubballi, Karnataka, India

[2]Department of Electronics and Communication Engineering, KLE Institute of Technology, Hubballi, Karnataka, India

E-mail: mallikarjunh@yahoo.com

Abstract

The present energy scenario is greatly alarming the energy consumers to conserve as fossil fuels are going to deplete shortly. In this regard the renewable energy systems are really gaining momentum. Solar and wind roof top fittings are becoming popular choice for the domestic user based on their financial affordability. Solar panels generate energy to power a building's electrical systems. In most cases, builders acknowledge that the solar panels installed on the roof will not always be sufficient for the building's electrical needs, so the building is also connected to the main utility grid. However, sometimes during clear days the solar panels generate surplus power beyond the needs of the building. At these times, the surplus power is exported into the main utility grid. Most utility companies offer credits to buildings that export power in this manner. "Bi-directional Meter" means a consumer meter for measuring, indicating and recording quanta of electricity flowing in opposite directions (export to the licensee's distribution system and import by the consumer from distribution system) in Kwh including any other quantity as per the requirement. Net metering / bidirectional metering record both import and export energy values giving prime focus on utilizing self produced electricity by renewable energy sources and excess or surplus to be sold to utilities or grid. It results into reduction of electricity bills. Solar photovoltaic system is used significantly in net metering. The design of microcontroller based bidirectional energy meter is low cost, affordable to consumer for domestic application and efficient. The current work focusses on the development of one of the type of bidirectional metering which accounts the net usage, export and the monetory exchange. The intelligent controller makes use of the measuring setup and controls all the major activities of the proposed work.

Keywords: *Energy scenario, solar root top, bidirectional meter, net meter, microcontroller*

INTRODUCTION

Electricity is one of the most vital requirement for the sustained development and comforts of the life. Currently, in the country in few of the regions generation is higher than the usage on the other side of it few not accessed the electricity till. The policy maker and the authorities are constantly and earnestly exploring different sources of clean energy to meet its increasing energy requirements diversify sources of energy and address potential climate change issues. The prevailing scenario of declining trend in solar tariff and increasing retail tariff across consumer categories like residential, commercial and industrial would encourage consumers to install roof top solar systems. Therefore, roof top solar is set to witness appreciable scaling of capacities in the years to come. As a developing country it is must for India to power those non electrified villages, for this it is best to go towards the Distributed

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Energy Resources like solar and implement these solar panels as the rooftop systems to avoid energy crisis. In this context this system will provide an easiest way for villagers to get powered by the natural resource which is abundantly available and monitor their usage and export using Net Energy Meter/bi directional meter.

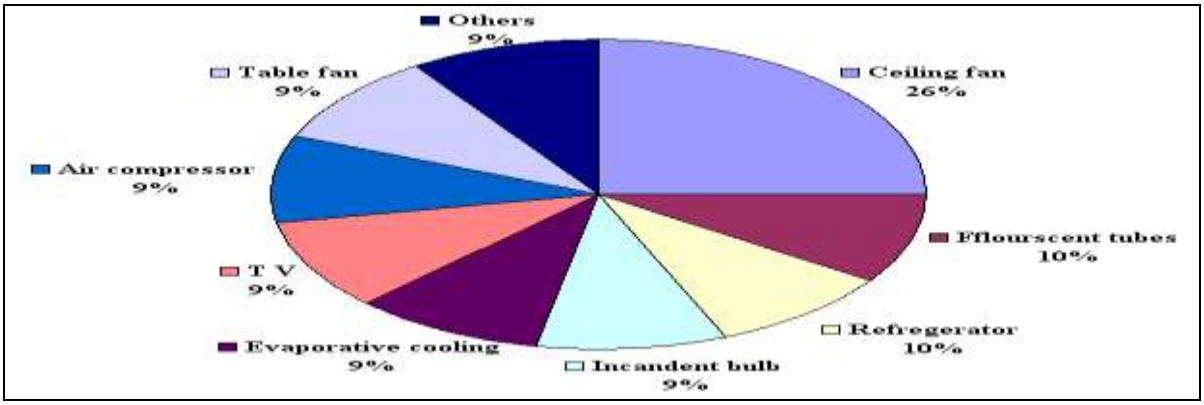


Fig. 1: *Domestic Energy Consumption.*

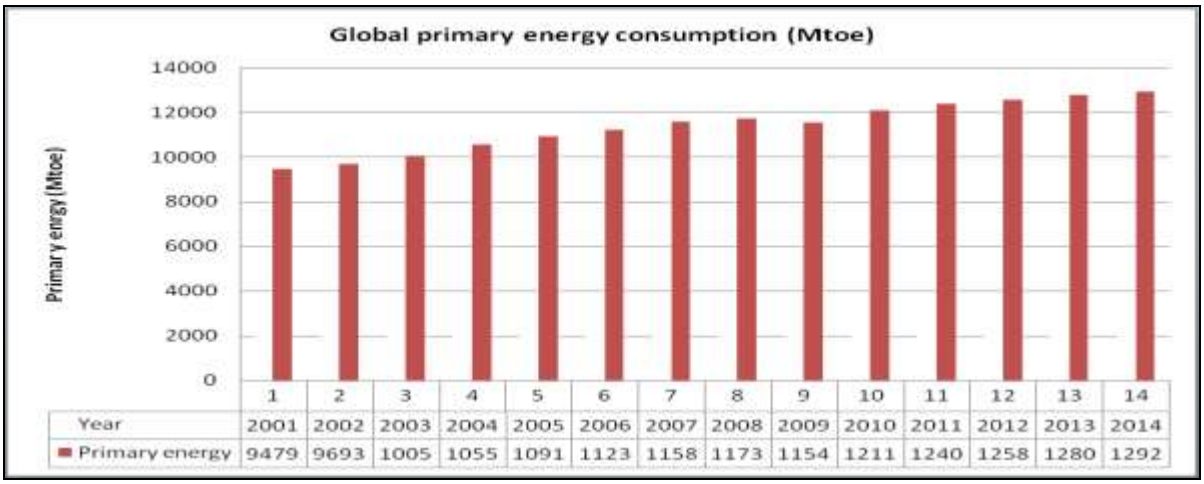


Fig. 2: *Global Primary Consumption (MToe).*

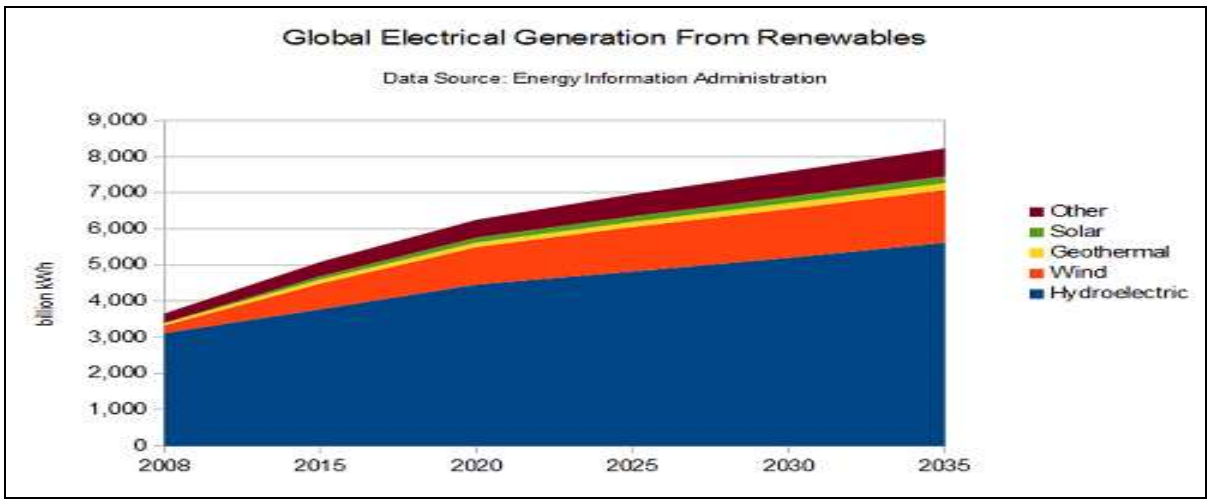


Fig. 3: *Global Electricity Generation from Renewable.*

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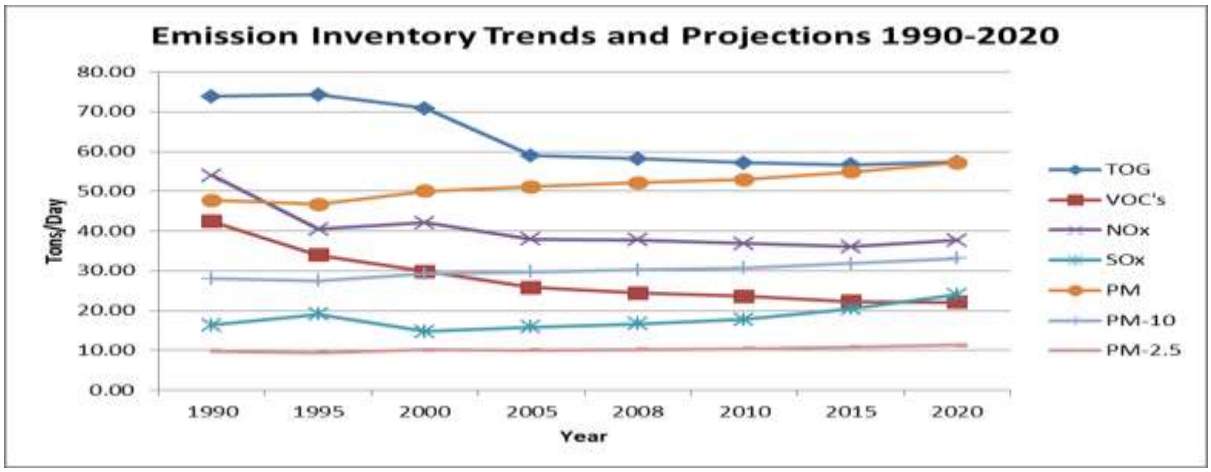


Fig. 4: *Gaseous Emission Trends.*

LITERATURE SURVEY

The energy consumption scenario clearly projects the rate with the need for the energy is changing and demand is increasing continuously. The search for new and renewable source is going on continuously and similarly rapid rise in emission into the atmosphere is also causing serious problems [1, 2]. The use of solar energy conversion systems is promising now a day due to the decline of prices and availability of material for the same in the recent years [3]. The technical publications in the chosen direction have clearly stated the mechanism and the probable cost of investment while developing the Net Energy Metering (NEM). The said instrument is capable of computing and displaying the energy usage statistics for the monetary calculations [4]. The simulation and analysis of NEM in MATLAB/SIMULINK justifies the choice before the implementation in the real field [5]. The usual difficulties and probable sources of errors are gradually minimized by the practice of automatic meter reading (AMR) and GSM based SMS handling [6–8]. Application of intelligent micro controller for the metering and communications in the electric system is slowly gaining momentum and becoming popular [9].

MICROCONTROLLER BASED BIDIRECTIONAL ENERGY METERING

The need for the design of low cost, efficient and compact bidirectional energy metering for the domestic users was worked out in the following sections.

PV SOLAR PANEL AND BASICS

In the proposed concept roof top solar PV panels play important role to obtain electricity by photovoltaic conversion and store the energy in battery. The output of the solar panel depends on the solar irradiation. To make the solar panel to give constant power output we need to make that solar panel to work at some constant voltage and to make this we need to use MPPT controller. Inverter of suitable capacity is able to meet the local load and export on excess generation. Solar or photovoltaic (PV) cells are made up of semiconducting materials that can convert solar insolation into electricity. When sunlight strikes the cells, it dislodges and liberates electrons within the material which then move to produce a direct electrical current (DC). This is done without any moving parts. PV cells are combined to make *modules* that are encased in glass or clear plastic. Modules can be aggregated together to make an array that is sized to the specific application Most commercial PV cells are

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made from silicon, and come in three general types namely, monocrystalline, multicrystalline and amorphous. Photovoltaic modules have been around for more than 50 years and have been mass produced since 1979. Due to improvements in manufacturing technology and economies of scale, the cost of PV has fallen by 90% since the early 1970s. Figures 4 and 5 gives the information about the choice and relationship of solar flux with time of day and efficiency of PV materials.

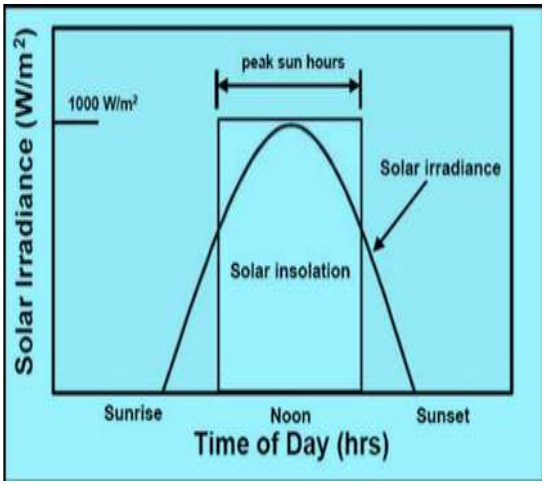
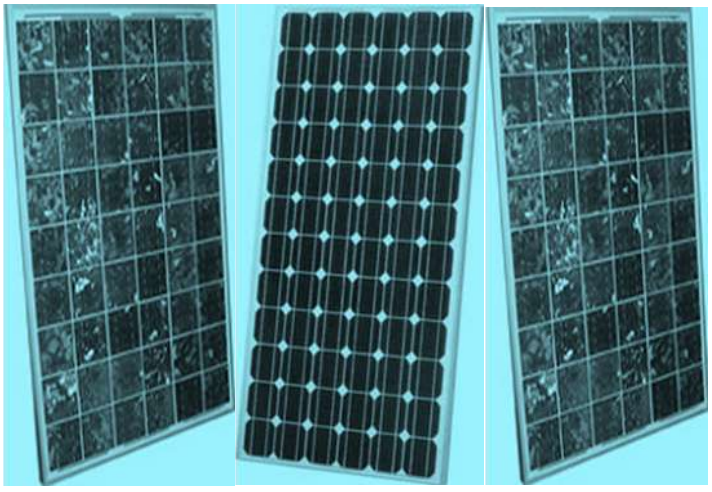


Fig. 5*: Solar Irradiance and Peak Sun Hours.*

PV cell material	Panel efficiency	Area needed for 1 kWp
Mono crystalline silicon	13-16%	7 m2 (75 sq.feet)
Polycrystalline silicon	12-14%	8 m2 (86 sq.feet)
Amorphous silicon	6-7%	15 m2 (161 sq.feet)

Fig. 6*: PV Solar Technology and Efficiency.*

PV modules are now readily available in a wide range of sizes from several well established companies. The reliability of PV is such that 20-25 year power warranties are typical, with life expectancies beyond 30 years. PV arrays are installed so that they maximize the amount of direct exposure to the sun. That usually means placement in an area clear of shading from buildings and trees in a southward direction and at an angle equal to the latitude of the location.



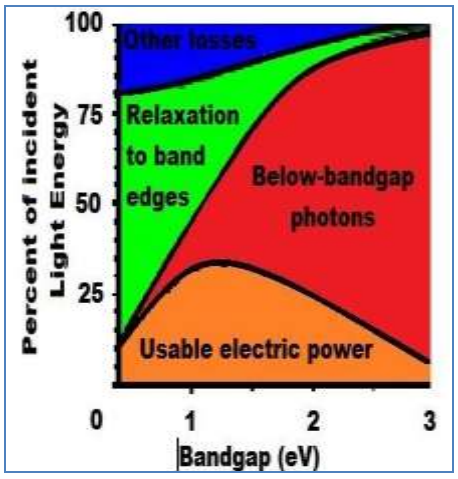


Fig. 7: *Different PV panels PV Solar Materials of*

Fig. 8: *Solar Incident Flux and Band Gap*

Examples of the Types of Commercially Available PV Modules are Amorphous (courtesy of Unisolar), Monocrystalline (courtesy of Sharp) and Polycrystalline (courtesy of Matrix) as shown above in Fig 7.

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SOLAR RADIATION

Solar radiation refers to the total energy from the sun that reaches the earth. It is commonly expressed in units of kilowatts per square meter (kW/m^2). The earth receives a nearly constant 1.36 kW/m^2 of solar radiation at its outer atmosphere. However, by the time this energy reaches the earth's surface the total amount of solar radiation is reduced to approximately 1 kW/m^2. The intensity of sunshine (i.e. solar radiation) varies with geographic location and also with the time of day.

SOLAR IRRADIANCE AND INSOLATION

Solar irradiance refers to the amount of solar energy received by or projected onto a specific surface. Solar irradiance is also expressed in units of kW/m^2 and is measured at the surface of the material. In the case of a PV-powered system, this surface is the solar panel. The amount of solar irradiance measured over a given period of time. It is typically quantified in peak sun hours, which are the equivalent number of hours per day when solar irradiance averages 1 kW/m^2. It is important to note that although the sun may be above the horizon for 14 hours in a given day, it may only generate energy equivalent to 6 peak sun hours.

METERING ARRANGEMENT

The use of two meters, one for the solar power generator and other to measure Import/Export with electric grid found necessary. The proposed concept deals with a single integrated instrument with necessary measurements to record the total solar generation in the consumer premises after the power conditioning unit and import to the premises or export. Figure 8 shows a generalized block diagram of grid connected solar PV roof top system.

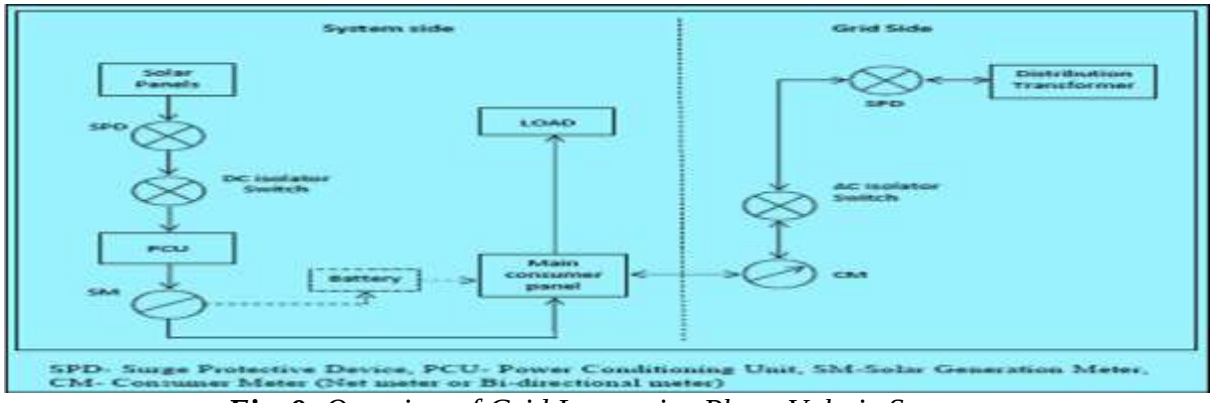


Fig. 9: *Overview of Grid Interactive Photo Voltaic System.*

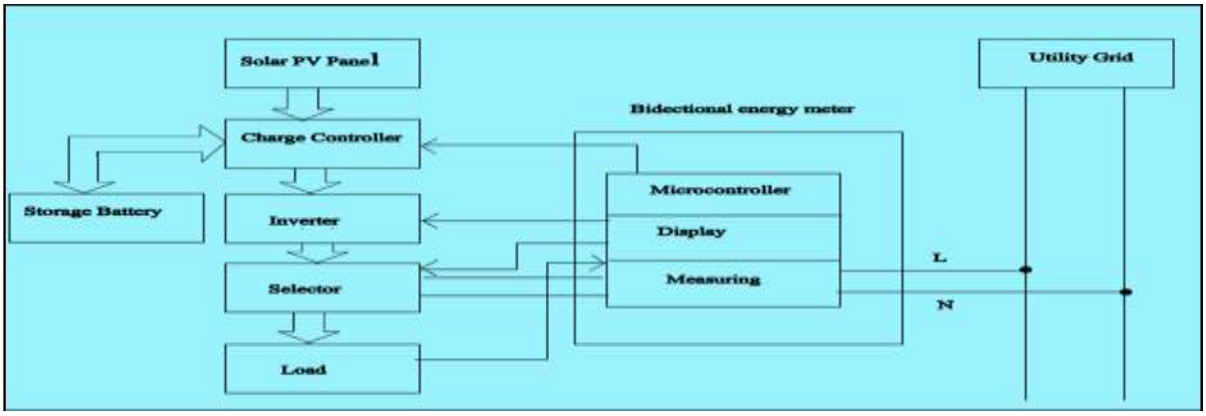


Fig. 10: *Block Diagram of Microcontroller based Bidirectional Energy Meter.*

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CHARGE CONTROLLER AND INVERTER

The charge controller is basically electrical and electronic circuit takes care of battery condition and charging. Inverter converts DC input in to AC so that it can be transmitted through the AC transmission line. Inverters are of two types one is single phase and another is three phase. Here in this system single phase inverter is proposed.

STORAGE BATTERY:

The battery bank is the storage mechanism with several batteries in series and parallel to meet string voltage and capacity considerations.

SELECTOR SWITCH

Selector switch is the controlled switching element to connect the utility grid with consumer load and consumer roof top generation inverter with the grid for the proper exchange of energy. This switch is controlled by the micro controller.

DOMESTIC LOAD

The net connected demand of the house is the total load of the system. The numbers of solar PV panels are chosen to match this requirement and excess for the safety factor.

UTILITYGRID

The utility grid is the national electric infrastructure providing support and means to deliver power supply to the different consumers like domestic, corporate and industrial etc. with their required specifications. This grid is the combination of various conventional and distributed energy resources that forms a complete energy system used to balance the captive supply and demand resources to maintain stability of service within specified boundary. When the electricity is fed to the grid the synchronization between the grid and the feeder is not required as it is a single phase.

MEASURING CIRCUITORY

The CS5460 is a highly integrated ΔΣ Analog-to-Digital Converter (ADC) which combines two ΔΣ ADCs, high speed power calculation functions, and a serial interface on a single chip. It is designed to accurately measure and calculate: Energy, Instantaneous Power, I_{RMS}, and
VRMS for single phase 2 or 3-wire power meter applications. The CS5460 interfaces to a low cost shunt or transformer to measure current and resistive divider or transformer to measure voltage. The CS5460 features a bi-directional serial interface for communication with a micro-controller and a fixed-width programmable frequency output that is proportional to energy. The product is initialized and fully functional upon power-up, and includes facilities for system-level calibration under control of the user program The CS5460 is a CMOS monolithic power measurement device with an energy computation engine which contains a programmable gain amplifier, two $\Delta\sum$ modulators, two high rate filters, system calibration, and power calculation functions to compute Energy, V- RMS, I-RMS and Instantaneous power. It is well suited for power meter applications and is optimized to interface to shunts or current transformers to measure current, and a resistive divider or transformer to measure voltage. A programmable gain amplifier (PGA) allows the user to measure either 150m V_{RMS} or 30m V_{RMS} signals. It includes two high-rate digital filters which output data at a (MCLK/K)/1024 output word rate (OWR). A High-pass filter in both channels can be enabled to remove the DC content from the input signal before the energy calculations are made. A simple three-wire serial interface makes it possible to communicate with a micro-controller. The CS5460 is designed to

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operate from a single +5V supply or dual ±2.5V supplies, to provide a 30m V_{RMS} or $_{150m}$ V_{RMS} range for the voltage channel. With single supply, the CS5460 is designed to accommodate common mode signals of -0.25V to VA+. Figure 4 illustrates the CS5460 connected to a service to measure power in a single – phase 2 –wire system. The CS5460 performs measurements of instantaneous current, instantaneous voltage, instantaneous power, energy, RMS current, and RMS voltage. These measurements are output as 24-bit signed and unsigned data formats as a percentage of full scale.

Features:

Energy Data Linearity: 0.1% of Reading over 1000:1 Dynamic Range

On-Chip Functions: Energy, I* V, I_{RMS} and V_{RMS}, Energy to Pulse-Rate Conversion

Complies with IEC 687/1036, JIS Power Consumption <12 mW, Interface Optimized for

Shunt Sensor Phase Compensation, Ground-Referenced Signals with Single Supply

System Calibration: On-chip 2.5 V Reference (60 ppm/°C drift), Simple Three-wire Serial Interface, Watch Dog Timer, Power Supply Monitor, Power Supply configurations

VA+ = +5 V; VA- = 0V; VD+ = +3 V to +5 V

VA+ = +2.5 V; VA- = -2.5 V; VD+ = +3 V

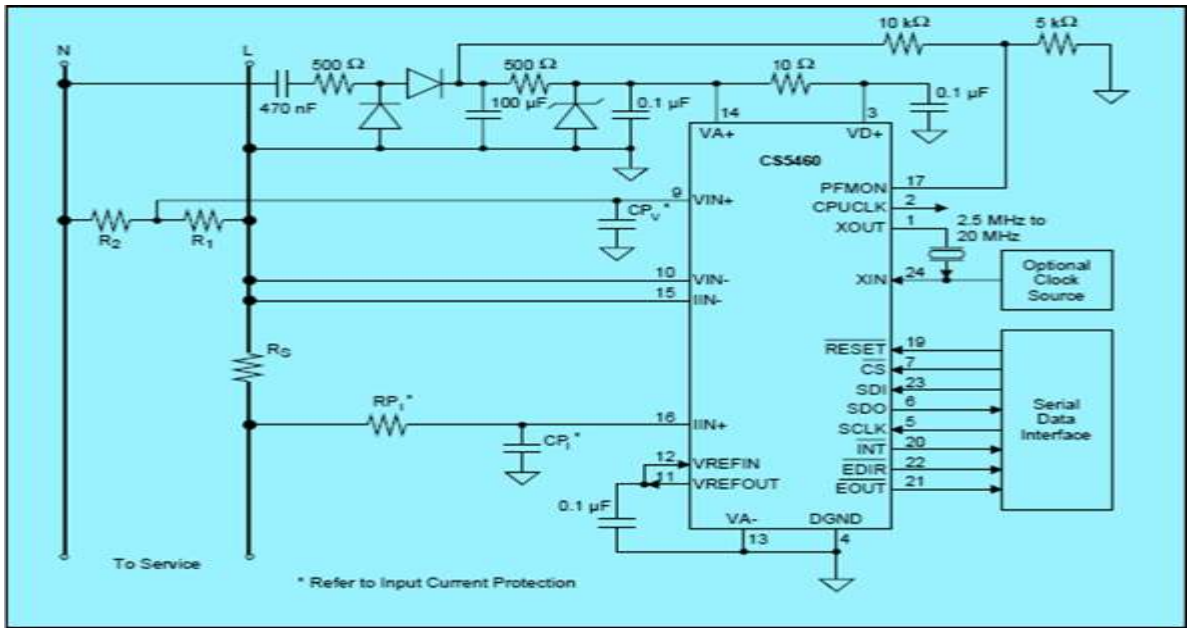


Fig. 11: *Typical Measuring Circuit Diagram (One –Phase-Wire).*

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Table 1: *Specification with MCLK = 4.096 MHz, K = 1, and N = 4000*

	Energy	Vrms	Irms
Range	1000:1	2:1	500:1
Max Input	See *Analog Characteristics*		
Linearity (After Calibration)	0.1% of reading	0.1% of reading	0.1% of reading
Output word	24-bits		

SAMPLE THEORATICAL COMPUTATION

The schematic shown below is a simple arrangement for the computation of net exchange between the consumer and the grid. The measurements V_A, VB, I_A, IB and power factor as shown lead the calculation.

$P_A = V_A * I_A * PF$ -------- Power received from AC mains

$P_B = V_B * I_B * PF$ -------- Power generated from roof top system

Net power=$P_A - P_B$

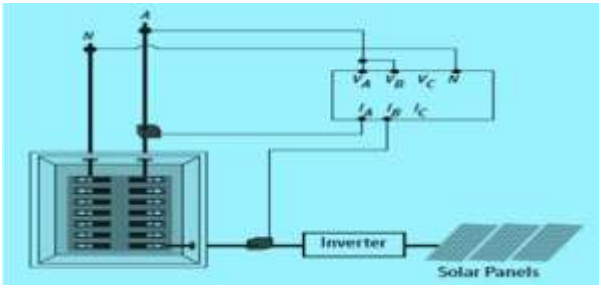


Fig. 12*: Typical Interconnection Diagram for the Net Power Calculation.*

ADVANTAGES, DISADVANTAGES AND APPLICATIONS

The following are the few important things about the solar roof top applications.

- Consumers need to install rooftop solar power plant and save roof covering cost
- Good life span of solar PV panel about 20- 25 years
- Good and short pay back of investments made
- Proper metering to account bidirectional power flow
- Transaction details of Excess power generated to sold to grid
- Investment and Incentives to motivate consumers to generate energy
- Proper periodic maintenance of solar PV panels
- Proper house keeping up of battery bank and terminals
- Occupies the nominal space for the accessories used in the system
- Noise due converting and inverting devices
- Challenge of cooling the components
- Probable natural disasters which damage the infrastructure
- Meet local load of the domestic installation and neighbor

CONCLUSION

As roof top solar PV systems are becoming affordable and realistic in the current days, the use and export of extra generated power to the grid need proper metering. The proposed microcontroller based bidirectional energy metering work could lead to an embedded meter capable of handling the energy information and transactions of energy of a domestic user. The existing digital energy meters with suitable additional circuits and measurements can clone the work proposed. As a scope for future, additional communications like GSM based

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implementations can ensure higher performance and security.

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