International Journal of Science & Technology Transactions
Vol. 1, Issue 1, pp: (13-20), Feb-2021

Solar Photovoltaic and Smart Energy Meter Based Intraday Load Forecasting using Arduino ATMEGA328P

Mayank Kumar
OIST, Bhopal, India
mayankumar3299@gmail.com

Monika Jain
SATI, Vidisha
chahatfeb2035@yahoo.co.in

Abstract: **The significant increases in energy consumption at user end create a huge power gap in demand and power supply. Thus creates stress in our existing power grid causing load shedding in different area. With the rapid development in renewable energy resources such as solar, this gap can be minimized. This project presents a noble approach of utilizing solar photovoltaic (SPV) generating system along with grid interface Arduino ATMEGA328p to connect and disconnect service line of a particular consumer. An SMS will send automatically to the consumer through GSM module whenever an unauthorized activity detected as well as it will disconnect the consumer from the utility grid but the consumer remain connected to SPV system throughout. This project also deals with different tariff plan and calculation in a month.**

Keyword*:* Solar photovoltaic (SPV), Arduino ATMEGA328p, GSM module, inverter, sensing unit.

I. INTRODUCTION

With the ever increasing energy demand and depleting conventional energy sources, renewable energy sources offer promotable alternative for fulfilling rapidly increasing gap between demand and supply. The renewable energy sources offer solution increasing global warning and also reduce the carbon footprint. Decreasing capital cost, minimal maintenance cost and zero operating cost have made SPV system the best possible alternative for clean energy generation [1]. In last few decades many research is going on SPV inverter based system which can directly connected with the home along with the main grid and continuously feeding the consumer [2].Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards or breadboards and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The microcontrollers are typically programmed using a programming languages C and C++ [3].

This project presents a noble approach of utilizing solar photovoltaic (SPV) generating system along with grid interface Arduino ATMEGA328p to connect and disconnect service line of a particular consumer. In this project four cases are considered:

- When consumer is connected to SPV system and tariff calculation during this period.
- When consumer is connected to grid and tariff calculation during this period..
- When consumer is connected to grid during peak hours.
- When consumer increase the load beyond its threshold limit and finally an SMS will be send automatically to the consumer through GSM module.

Further this project save the energy and it also help individual customer to gets updates of its daily unit consumption.

I. Existing Energy meter

Conventional System “Energy meters displays kilowatt-hour by continuously measuring the instantaneous voltage(volts) and current (amperes) to give energy used in joules’’ [4]. Drawbacks of the regular energy meter are:

- Highly depends on meter reader.
- Human error cannot be avoided for the manual meter reading.
- The consumer is not receiving updates of his regular usage of energy.
- The consumer may not receive his energy bill as per regular interval of the due date.
- No analysis of power during the peak hours.
- Consumer are not connected to renewable energy resources
- Theft of power by bypassing it

II. System Architecture

The system consist of a Solar PV array , Arduino uno (ATMEGA328P), GSM module , Relays, inverter and battery for storing energy. The block diagram and its circuit representation of proposed system is shown Fig.2 (a and b). The Photovoltaic modules (15 W) use light energy (photons) from the Sun to generate electricity through the photovoltaic effect. The majority of modules use wafer-based crystalline silicon cells or thin-film cells. Most modules are rigid, but semi-flexible ones based on thin-film cells are also available. The cells must be connected electrically in series, one to another depending upon system voltage and current requirement respectively. A lead acid battery (12 V, 2.5 A) of is connected to the system to store the energy from solar and used in meanwhile time when solar is available or not. The inverter is connected to the system which converts DC current to AC current. Finally the loads of 15 W, 40 W, 200W bulbs are connected to the system. Two current sensing devices are connected to Arduino, which generate the signal for relays at different conditions. In this project stand alone home is considered which consist of three different types of loads. Firstly, SPV system is supplying power to a 15 W load for defined period. As the load is increased from 15 W to 55 W, along with SPV unit and AC supply gets connected. During this process current sensing device monitor the excessive current and send signal to the Arduino to switch to AC main supply, without any delay. Further, load is increased to 200W, this is beyond the consumer household limit then again Arduino will send a signal to relay to trip the AC grid [5] from household with in 5sec and a warning SMS will sent to the consumer through GSM module sim 800A, but SPV system remains connected to household appliances. Fig. 3. represent the hardware implementation of the proposed project. The flow chart for the entire system is shown in Fig. 4.

IV. SYSTEM SPECIFICATION

The Proposed System consist of hardware which is easily available and their ease to use. In this model Microcontroller used is ATMEGA328P which is inbuilt in Arduino Board. The Arduino Board has 6 analog inputs and 14 digital input-output pins. The board consists of ATMEGA16U2 microcontroller IC/USB Controller and a power jack. The Arduino Board is powered by connecting it to computer via USB cable or AC-to-DC adapter or by using a battery (9V or Li-ion battery).

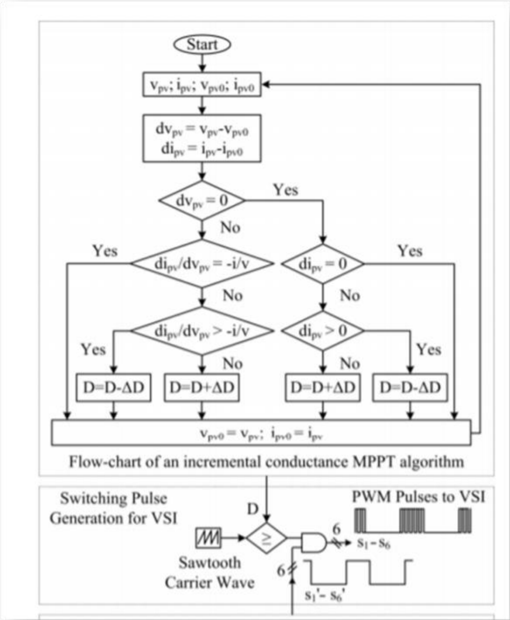
The Power source of proposed system is the Solar PV array [3] which is the combination of solar cells connected in series connection so as to produce the compatible voltage to charge the lead Acid battery of 12V. In stand-alone condition the PV cell generates a voltage in range of 0.5-0.6 volts.
In this system the Solar PV module has 28 cells connected in series is considered to make a PV array of the relevant size. Since a solar cell has an open circuit voltage in the range of 0.5 V-0.6 V at standard atmospheric condition .It is assumed that a module generates 28×0.55 = 12 V as its open circuit voltage. The voltage of a module at MPP is around 71%-78% of the open circuit voltage. Therefore, it is estimated as, 12×0.78 = 9.36 V.

Apart from this to boost the voltage level a DC-DC boost converter is used to enhance the voltage and current level. A **DC**-to-**DC converter** is an electronic circuit or electromechanical device that converts a source of direct current (**DC**) from one voltage level to another. It is a type of electric power **converter**. Power levels range from very low (small batteries) to very high (high-voltage power transmission).The Inverter circuit is used to convert the DC voltage [6] coming from the SPV System in to AC voltage to run the AC loads.

In order to to track the optimum operating point of Solar PV arrayINC-MPPT [4] approach is adopted ,The flow diagram of this algorithm is shown in Fig1. In Maximum Power Point Tracking the $V_{pv}$and I_{pv} are the present samples while V_{pv0} and I_{pv0} are the previous samples . The incremental change in voltage and current is given by $dV_{pv}$and $dI_{pv}$of PV module. In INC-MPPT the power slope of photovoltaic array becomes zero at MPP (ie: $dP_{pv}/ dV_{pv}= 0$). The Equation of MPP under incremental conductance is :

$$P_{pv} = V_{pv} \times I_{pv} \quad (1)$$

$$\frac{dPpv}{dVpv} = ipv + Vpv \times \frac{dipv}{dvpv} = 0 \tag{2}$$



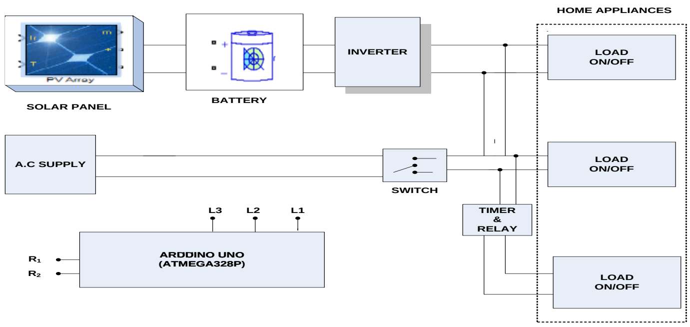


Fig. 2 (a). Proposed architecture of Smart Inverter Switching for Grid Interfaced Solar Photovoltaic System

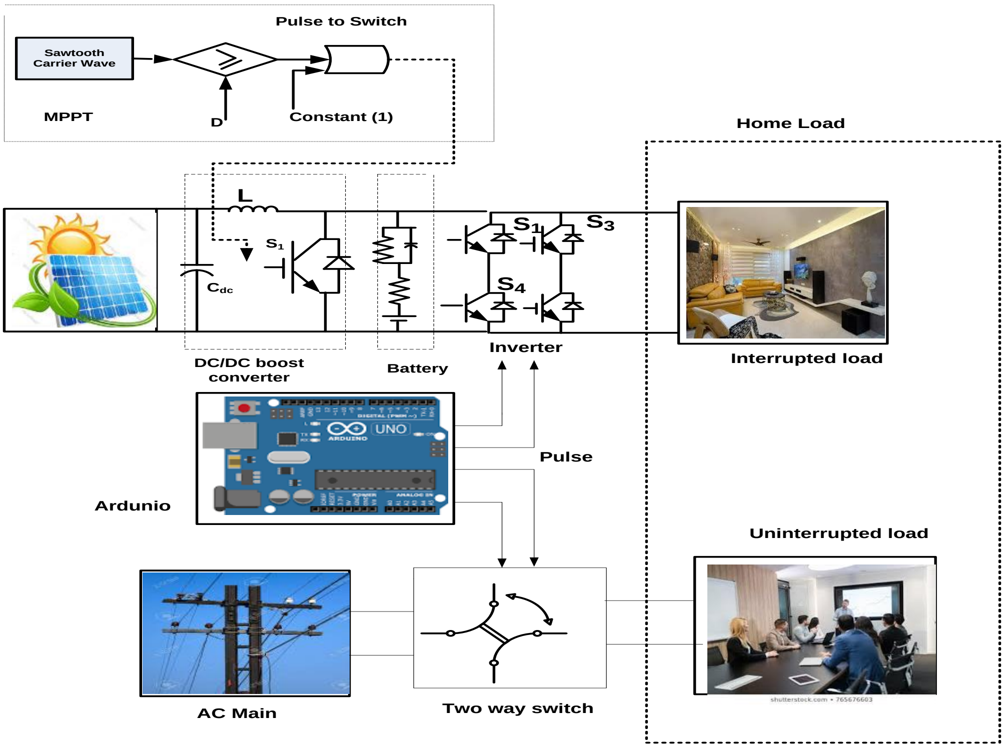


Fig. 2 (b). Proposed circuit diagram of Smart Inverter Switching for Grid Interfaced Solar Photovoltaic System

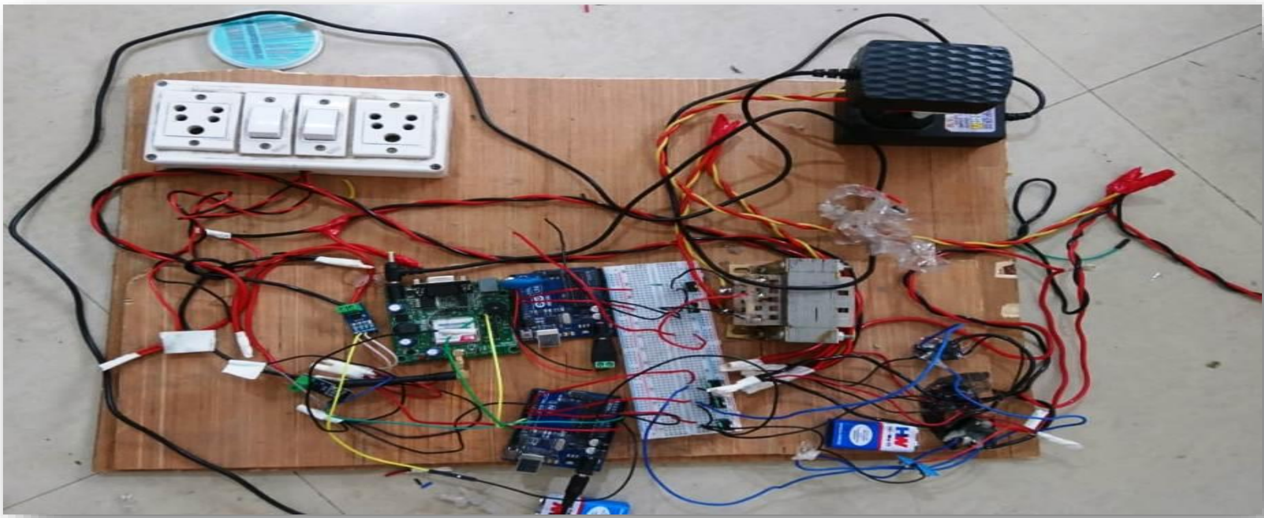


Fig.3 Hardware implementation of Smart Inverter Switching for Grid Interfaced Solar Photovoltaic System

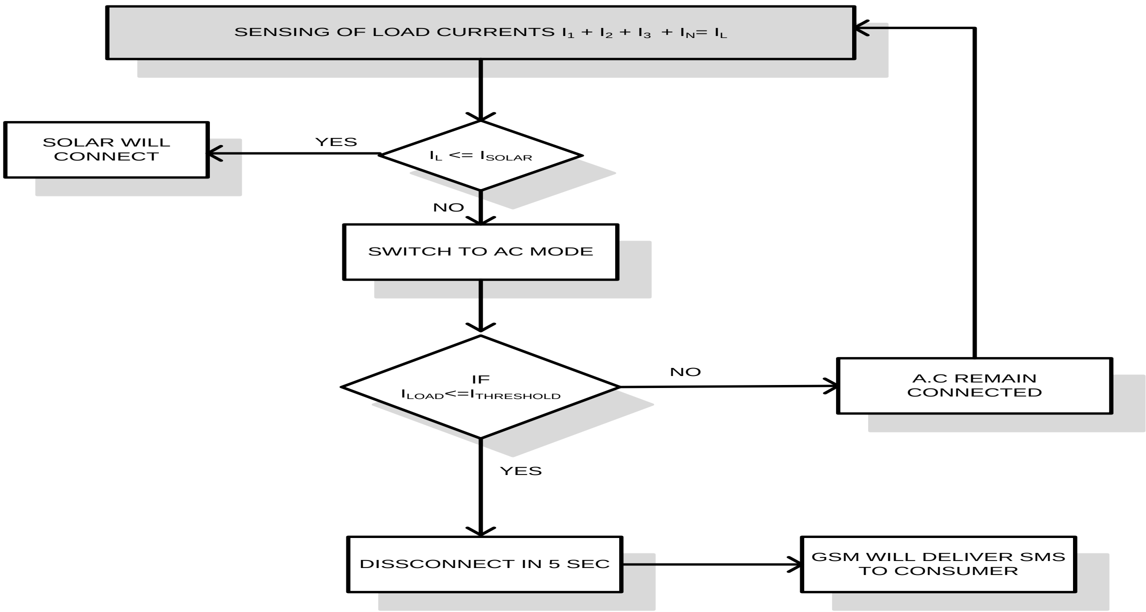


Fig. 4. Flow Chart of Smart Inverter Switching for Grid Interfaced Solar Photovoltaic System

V. RESULT AND DISCUSSION WITH TARIFF CALCULATION

The proposed model is tested during a day for single household applications. In this a day is divided into four time intervals, 00:00 hours to 6:00 hours, 6:00 hours to 12: 00hours, 12:hours to 18:00 hours, 18:00 to 24:00 hours. This system is practically tested for three different loads 15 W, 40 W and 200 W. The unit consumed during the précised interval of time is shown in table 1. The unit consumed by the above loads in a day is very less so a scale of 50 is used to uplift the unit and for better understanding the importance of proposed system. In this proposed model three cases are considered. The energy consumed in a day is shown in figure 4.

Table 1: Variation of loads during a day

S.NO	SOURCE	TIME (IN HRS)	CALCULATION Unit=hours× (watt/1000)	UNITS	Scaling Factor (10)
1.	GRID	12 AM-6 AM	6×(15/1000)	0.09 unit	0.9 unit
2.	GRID	6 AM-12 PM	6×(40/1000)	0.24 unit	2.4 unit
3.	GRID	12 PM-6 PM (peak hours)	6×(200/1000)	1.2 units	12 unit
4.	GRID	6 PM-12 AM	6×(40/1000)	0..24 units	2.4 unit
	TOTAL	**24 hours**		**0.435 Units**	**17.7 unit**

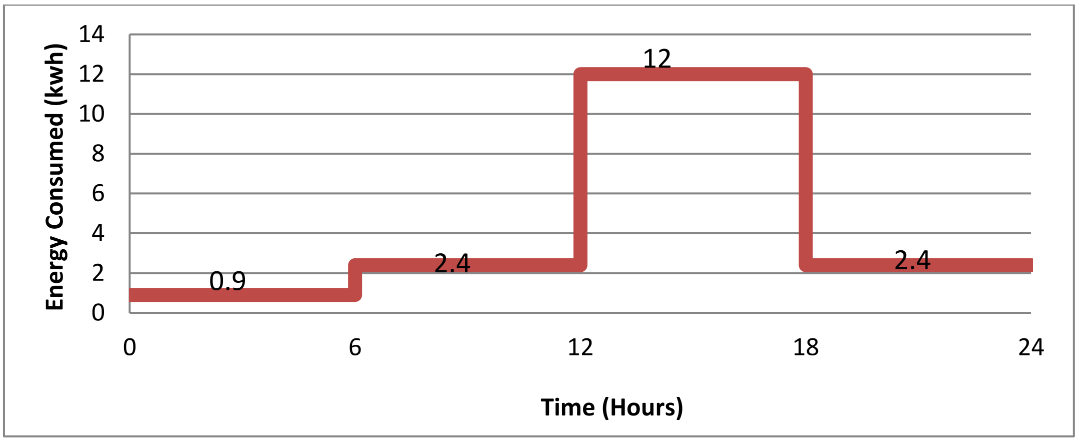


Fig. 4 Residential Load profile for 24 hours

Case I: In this case the household appliances are getting power from the grid and no other source is used, under fixed tariff of Rs 8/day. The per unit cost rate is assumed such that the consumer need to consumer power as per requirement. Fig.4 shows the assumed load of 17.7 units (0.9+2.4+12+2.4) consumed at the consumer side in a day. The load profile taken above is as per the proto type design for a residential load, with few appliances are in on state at time 24:00 to 6:00 Am, whereas during the time interval 6:00 to 12:00 Pm load increase. Further at time 12:00 to 6:00 Pm load demand increase to its peak resulting in congestion state for the transmission and generation lines. Fig 5. Shows the calculation of tariff based on fixed unit price which is taken as 8/- per unit. For the scheduled of 12:00 to 6:00 Pm the energy consumption is maximum around 96/- per day. The total cost on energy consumption during a day is approximately 160.8/- per day.

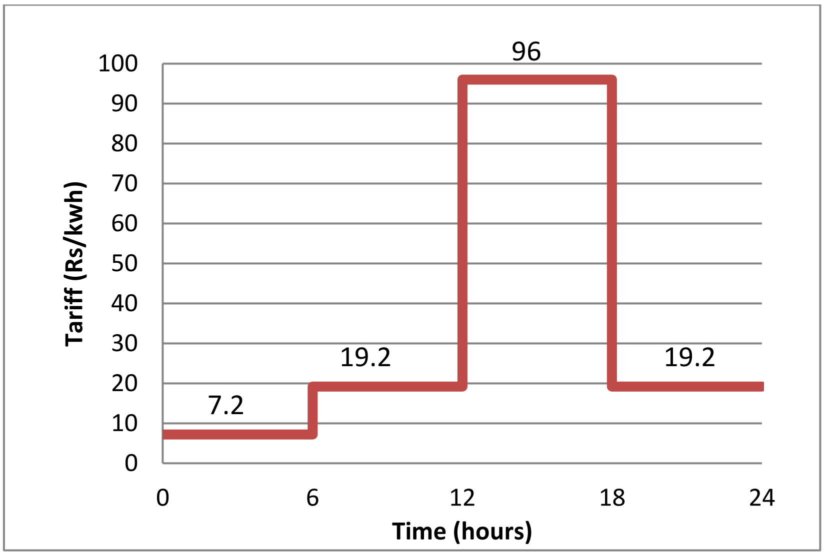


Fig.5 Calculated tariff for each period with fixed tariff rate

Case II: In this the load profile remains same as shown in the figure 4. In this variable tariff scheme is promoted during a day. In order to remove congestion in generation and transmission line, tariff during the peak hours increase in order to encourage the consumers to reduced the energy consumption during the peak other and shift their work load during the light loaded condition. The energy consumed during a day is around

193.2/- per day as shown in Fig. 7. Thus it is advisable to reduce the energy consumption during peak hours or to switch to another source of energy.

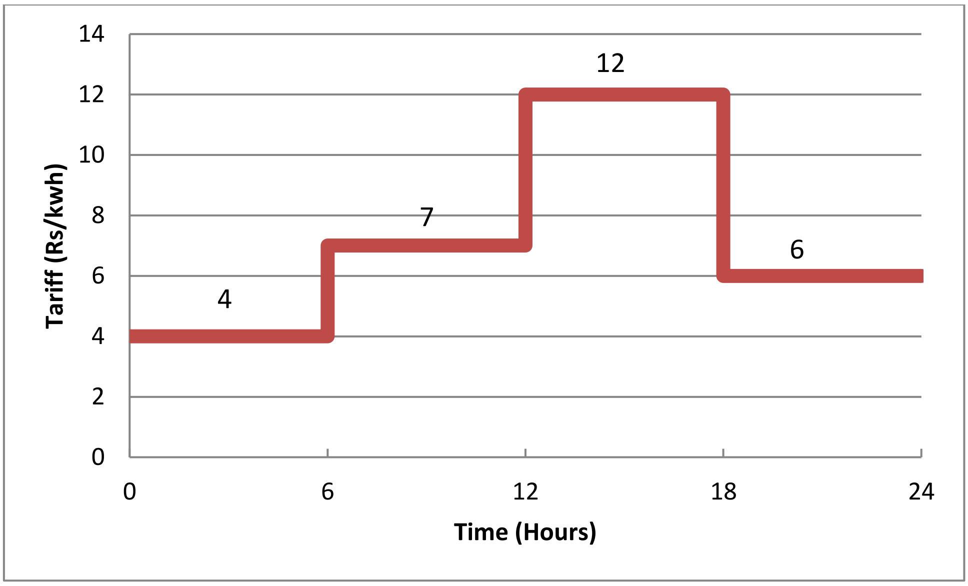


Fig. 6 Variable tariff rates for different time period

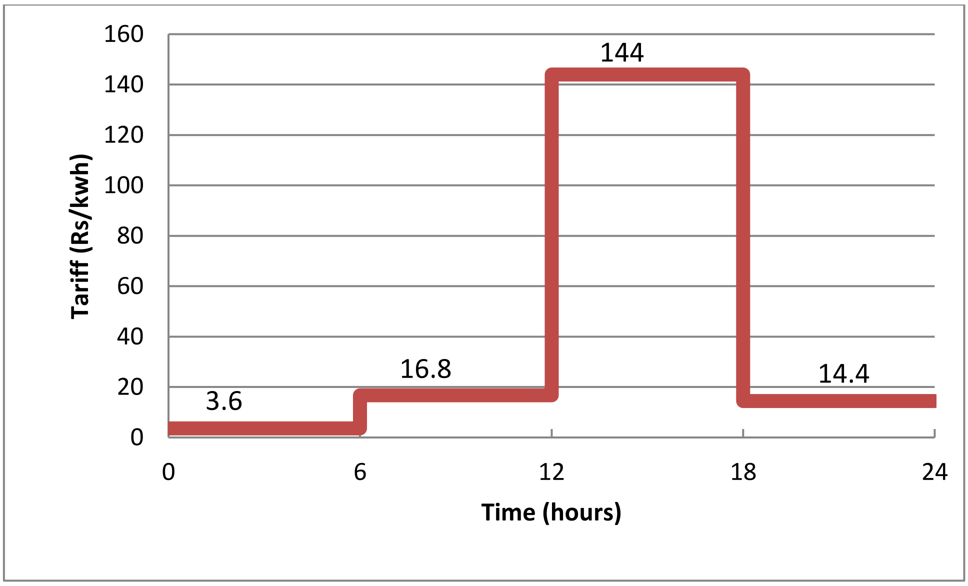


Fig. 7 Calculated tariff for each period with variable tariff rates

Case III: In this the load consumption remains same for a day. In this proposed system is introduced emphasis on the use of solar energy during the peak hours. So that the load on the line gets reduced as well as the tariff charge gets reduced during this period with variable tariff scheme. In the proposed system sun rays are easily available during peak hours thus with the use of PV modules along with inverter the energy can be easily withdrawn from solar, thus reducing load of the grid as well as saving cost also. Thus, by observing Fig 8 it is concluded that the total cost of consumption for a day using grid and renewable source of energy is around 34.8/- per day during 12:00 to 6:00 Pm when shifted to solar based PV system. Total cost of energy consumption in a month is around 1044/- (=34.8*30). The energy save by installing solar PV module in home is around 4752/- (193.2*30=5796, 5796-1044=4752).

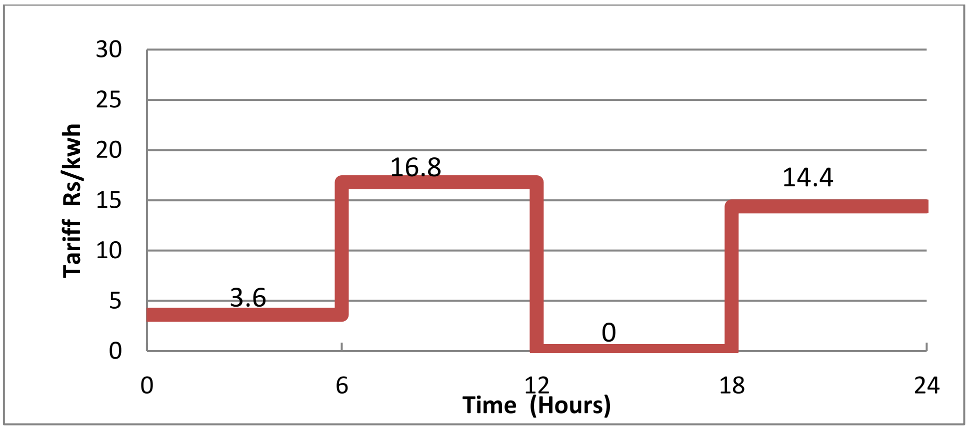


Fig. 8 Calculated tariff for each period with solar and variable tariff

VI. Conclusion

The proposed system consists of SPV unit along with grid interface Arduino ATMEGA328p to connect and disconnect service line of a particular consumer. This system can physically reduce the burden on our transmission line reduce the load shedding events and motivate the concept of renewable energy which is available throughout the year in country like India. As well as this project also restrict unlimited consumer load.

References

[1] Dineshkumar.K, "Development of ARM Processor based ElectricityTheft Control System using GSM Network", 2015 International Conference on Circuit, Power and Computing Technologies [ICCPCT].

[2] Md. Masudur Rahman; Noor-E-Jannat; Mohd. Ohidul Islam; Md.Serazus Salakin, "Arduino and GSM Based Smart Energy Meter for Advanced Metering and Billing System" 2nd Int'l Conf. on Electrical Engineering and Information & Communication Technology (ICEEICT) 2015 Jahangimagar University, Dhaka-I 342, Bangladesh, 21-23 May2015

[3] A. Zekry and A. Al-Mazroo, "A Distributed SPICE Model of a Solar Cell," IEEE Transactions on Electron Devices, Vol. 43, No. 5, May 1996, pp. 691-700.

[4] Deepak Verma, Savita Nema, A.M. Shandilya and Soubhagya K. Dash, "Maximum power point tracking (MPPT) techniques: Recapitulation in solar photovoltaic systems," Renewable Sustain. Energy Rev., vol. 54, pp. 1018-1034, February 2016.

[5]] A. K. Verma, B. Singh, D. T. Shahani, A. Chandra and K. Al-Haddad, "Combined operation of a VSC based grid interfaced solar photovoltaic power generation system with night time application," IEEE PES General Meeting Conf. & Expo., National Harbor, MD, 2014, pp. 1-5.

[6] A. A. A. Radwan and Y. A. R. I. Mohamed, "Power Synchronization Control for Grid-Connected Current-Source Inverter-Based Photovoltaic Systems," IEEE Trans. Energy Convers., vol. 31, no. 3, pp. 1023-1036, Sept. 2016.