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Solar Power Generation, Utilization and Monitoring Using Internet of Things

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Abstract - *Designing on-grid system with battery backup to cater the excess power to utility grid, post requirement. It is advantageous on grounds of providing credentials to electricity bills, establishing reliability and flexibility to system. Regular maintenance is required to ensure its uninterrupted operation. Seemingly, it's important to monitor solar setup to figure out optimum operation of solar system. This is achieved by incorporating IOT into the system. IOT provides information on energy consumption, generation, optimum energy and damage.*

Key Words: **on-grid battery backup, uninterrupted operation, credentials to electricity bills, IOT.**

1. INTRODUCTION

Solar energy is clean, abundant and easily available form of energy. In recent years, demand for energy is rising day by day with ever-growing increment of population. Developing countries still depend on non-renewable energy sources, such as coal, diesel and natural gas to meet enormous requirement of energy. But those non-renewable sources are confined and not favorable to the environment [1]. On the contrary, the solar energy has gained more popularity with advancement in technology and simultaneous reduction in cost. By incorporating modern techniques these sources of energy could possibly supersede conventional sources. According to the International Energy Agency (IEA), Renewable energy will be the fastest-growing source of electricity, in which wind and solar PV are technologically mature and economically affordable. But still there is increase in world's demand for energy. Adopting Renewable Energy technologies is one of the advance ways of reducing the environmental impact [2]. India is venturing very fast into renewable energy resources like wind and solar. Solar has great potential in India, with its average of 300 solar days per year. The Government is providing incentives for solar power generation and also various solar applications, and has set a goal that solar should contribute to 8% of India's total consumption of energy by 2022. With such high targets, solar is going to play a key role in shaping the future of India's power sector. According to status of 2017, solar grid-tied renewable energy contributed nearly 21% to India's cumulative renewable energy. [3]

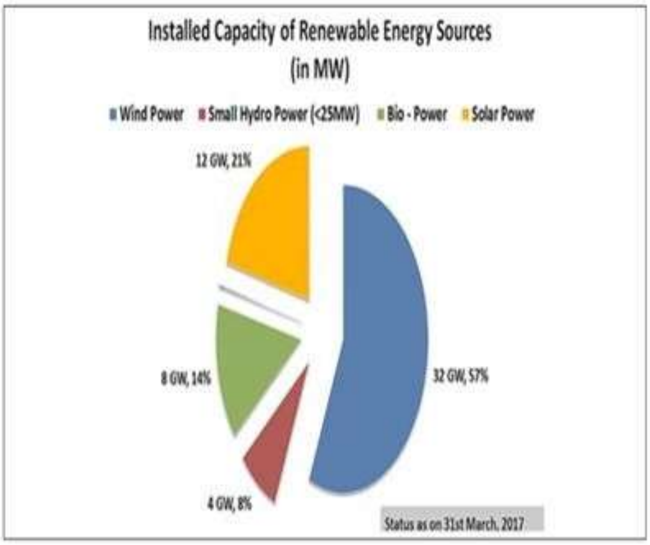


Figure 4: Installed capacity of renewable energy sources

This revelation along with worldwide trend of green energy, has led to an exponential growth of number of PV system installation [4]. India is having 330 million houses,166 million electrified houses,76 million houses use kerosene for lighting,

1.08 million houses are using solar for lighting, 140 million houses have proper roof (Concrete or Asbestos / metal sheet), 130 million houses are having more than 2 rooms. Average house can accommodate 1-3kWp of solar PV system. The large commercial roofs can accommodate larger capacities. As a conservative estimate, about 25000 MW capacity can be accommodated on roofs of buildings having more than 2 rooms alone if we consider 20% roofs.

In India, frequent power cut is very common and solar PV installations are sensitive to changes in weather conditions, temperature, solar coruscating etc. Due to this issue, it is important to use renewable energy and monitoring it. By monitoring the energy forecast, households and communities who are using solar power can utilize their energy production and consumption during good weather [2]. The Internet of Things (IoT) is a system of related computing devices, digital and mechanical machines, objects, people with unique identifiers and potential transfer of data over a network without human-to-human or human-to computer interaction. Physical objects those are no longer disconnected from the virtual world, but can be controlled remotely through Internet services [2]. This paper is being put forth to deal with on-grid system with battery backup which is monitored using Internet of Things (IOT). In order to achieve this attribution, future expansion is to merge the concepts of Cloud computing and the Internet of Things (IOT) with the system designed to maximize the output efficiently.

2. PROBLEMS IDENTIFIED

With advancement of technologies the cost of renewable energy equipment is going down globally encouraging large scale solar photovoltaic installations. This massive scale of solar photovoltaic deployment requires sophisticated systems for automation of the plant monitoring remotely. Need for preventive maintenance, fault detection, historical analysis of the plant in addition to real time monitoring is increasing [5].

Electrical energy or power is an important factor for human being survival now a day. Apart from these, automation in the energy distribution is necessary for enhancing people's needs. Now a day's human meter reading is providing insufficient to cope up with future residential need [6].

Power consumption of large population is becoming a huge issue in country. Due to the large gap between the supply and demand, there is cut in power supply frequently.

The utilization of sun as renewable source causes uncontrollable fluctuations in power generation. The use of Lead-acid batteries as energy buffers is problematic, since it is not possible to cover fast power fluctuations without dramatically reducing the batteries' lifetime [7].

In PV system, when alternating current is distributed to grid load there is a line loss increasing reactive power flow on the line, causing surge overvoltage [8].

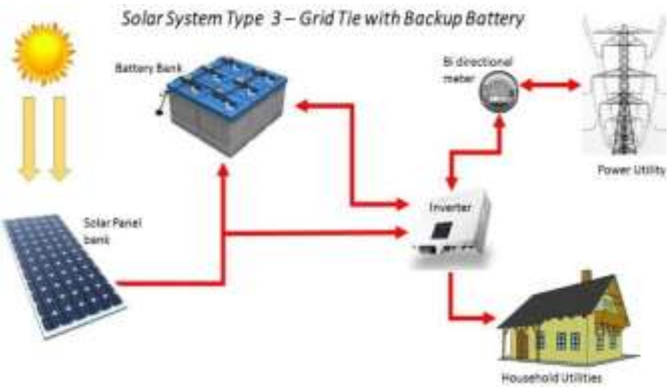
3. THE PROPOSAL

The ability to generate and use a limited amount of clean solar power during a blackout adds to the other advantages of going solar. In the long run, solar power is economical. Solar panels and installation involve high initial expenses, but this cost is soon offset by savings on energy bills. Solar can increase the value of your home. With a grid connection and net-metering rules, your solar power system can generate clean energy and share it with the grid. Federal tax credits can offset 30% of your investment. Solar energy systems are safe, reliable, and durable—the panels are warranted for 25 years [9]. With the growing presence of Wi-Fi and 4G-LTE wireless Internet access, the evolution towards omnipresent information and communication networks is already evident [10].

3.1 On-grid with battery back-up system

In this section we present the flow of the Energy generation in system.

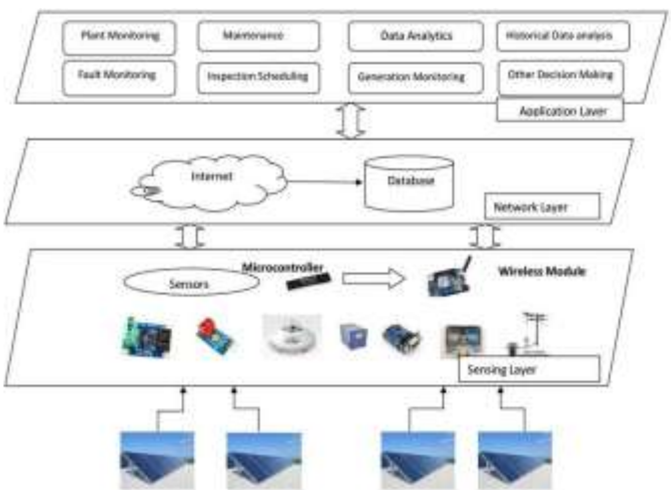
PV panels generate electrical energy by converting solar irradiance. Batteries act as storage house for uninterrupted power supply. Charge controllers aid to the amount of electric current added to or drawn from electric batteries thereby providing protection against over voltage and over charging, enhancing battery span. Inverter converts DC output from battery to alternating current to supply to the house load and excess power is sold to power company. In case of failure in solar power generation an option of drawing power from grid is also provided.



[11]

3.3 Monitoring system using IOT

The IOT allows objects to be sensed or controlled remotely over existing infrastructure creating opportunities for pure integration of the physical world into computer-based system and resulting in improved efficiency cum accuracy and economic benefit in addition to reduced human intervention [2]. Monitoring guides the user in analysis of renewable energy usage. This system is cost effective enabling the efficient use of renewable energy [2].



[12]

So, we propose an automated IOT based solar power system that allows for solar power monitoring from anywhere over the internet [13]. We use Arduino based system to monitor parameters and IOT think speak to transmit parameters over internet to IOT think speak server [11]. The monitored values obtained are helpful in predicting the future values of the parameters considered. The temperature sensor helps to analysis of fault detection [2].

In adherence to the above stated problems in section (2), the following rectifications are adopted. Using the Internet of Things Technology for supervising solar photovoltaic power generation can greatly enhance the performance, monitoring and maintenance of the plant. This will facilitate preventive maintenance, fault detection, historical analysis of the plant in addition to real time monitoring [5]. Low power consumption controller can solve the issues and increases the speed of performance. Demand is going to increase in rapid manner for Automatic Meter Reading (AMR) systems which measures power consumption readings electronically, and it is expanding at industrial, commercial with utility environment. AMR can be a further expansion to our current study and implementation. Supercapacitor is an electrochemical capacitor that has an unusually large amount of energy storage capability relative to its size, when compared to common capacitors. Super Capacitors have several advantages in relation to batteries - very high rates of charge and discharge, little degradation over hundreds of thousands of cycles, good reversibility, light weight, low toxicity of materials used and high cycle efficiency (95% or more).

Super Capacitors are applied to relieve fast changes in the battery storage system. Batteries are used to meet the energy requirements and Super Capacitors are used to meet the instantaneous power demand. At the end of this paper, a sizing method is proposed for the Super Capacitor system [7]. To resolve the issue of line loss thereby increasing reactive power flow on the line, power factor correction (PFC) technique using solid state switched capacitors and Arduino UNO controller.

4. THE BLOCK DIAGRAM

Energy generation in system is due to solar power. Generated power is being utilized as well as monitored. Block diagram explains the flow of energy from solar panels to load and also shows the system design for Solar energy monitoring using IOT. Power consumed by the loads can be monitored using the current and voltage value sensed by the Arduino. Addition implementation of super capacitors and power factor corrector improves overall efficiency of the system.

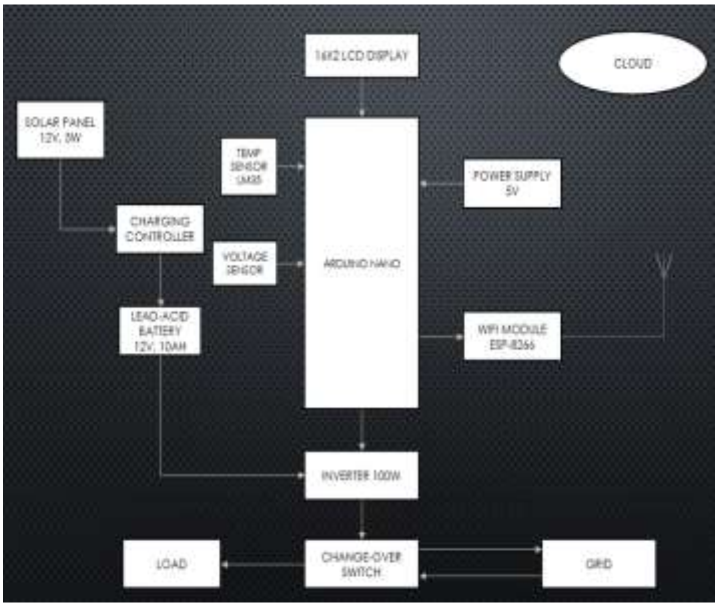


Fig.1 Block Diagram of Proposed scheme

Photovoltaic arrays produce DC, while the typical electricity grid is AC and most electrical devices operate on AC power. To ensure that the power produced by a PV array will flow into the grid, it is necessary for an inverter to convert the DC power produced by the PV array to AC power. As DC from panels is fluctuating it cannot be fed directly to inverter. DC charge controller is incorporated between panel and battery to boost voltage level so battery gets enough voltage for charging. Basic role of controller is to protect battery from over charging and over discharging. Traditionally all grid-interactive inverters incorporate transformers of varying types e.g., high or low frequency switching. High frequency transformers are more efficient and lighter than low-frequency transformers but are also more complicated to manufacture. Keeping in the mind the economic constraints and the simplicity of the system, Arduino Uno has been used which abates the programming complexity. Arduino sense the current and voltage value through analog pins. With the help of these values. Arduino programming calculates the power. The analog inputs of an Arduino can measure up to 5v. Two resistors from potential divider that helps to lower the voltage being measured to a level that the Arduino can read. The formula for calculating values in a potential divider is:

$$V_{out} = [R2/(R1+R2)] * Vin$$

For the measurement of current we have used current sensor ACS-712 which measures positive and negative 30A. In order to monitor the values a cloud is been setup. ThinkSpeak is an open source IOT application and API to store and retrieve data from things using the HTTP protocol over the internet or via a Local Area Network. ThinkSpeak enables the creation of sensor logging applications, location tracking applications such as social network of things with status updates.

5. THE IMPLEMENTATION

5.1 Work Flow

Fig.1 represents the process of proposed system from generation to monitoring system. The work flow of system is presented in form of step below.

Step 1: PV array produce DC power which is fed into battery via charge controller for discontinuous supply.

Step 2: DC power is inverted by grid tied transformer inverter.

Step 3: Power generated is utilized by house load and excess power is fed to grid to obtain credentials.

Step 4: Arduino display the power usage using sensed values through current sensor and voltage divider and sends to cloud

Step 5: Cloud will display the data in the form of graph, which is visible to the entire user.

5.2 Design

Panel design:

Assume load = 25Wh; Sunlight = 8h

Solar Panel = 25/8 = 3.125W ~= 5W (better to choose higher value as efficiency depends on irradiation).

As load is less; 5W, 12V panel is chosen which has specifications-

V_{oc}= 22.3v, I_{sc}=0.3A, $V_M@P_{max}$ = 17.8v, $I@P_{max}$ = 0.28A

Charge Controller design:

V_{in}= 8v to 16v; as panel o/p is fluctuating.

V_{out}=14v; due to potential difference for charge movement, V_{out} is 2v greater than battery voltage.

I_s = 0.416A

I_a=average load current = $I_s(1-k)$

To choose Duty Cycle (k): $V_{out} = V_{in}(1/(1-k))$ For V_{in} = 8v and V_{out}= 13.33v; K=40% Therefore = 0.4

I_a= 0.416 * (1-0.4) = 0.249A

For better efficiency; Oscillatory period should be 100 times switching time,

Therefore, F_s <= 33Khz We chose f_s as 25Khz

$L = V_{in} (V_{out} - V_{in}) / (F_s * \Delta I * V_{out})$ (ΔI = ripple current) To have $\Delta I \sim= 2 * I_a$

Assume L = 180μH

ΔI = 0.71A

ΔV_c = 0.4V (ripple voltage)

$C = (I_a * D) / (F_s * \Delta V_c)$ = 9.96μF ~= 10μF

Battery design:

12v, 10Ah battery is selected.

The battery can supply 0.416A current for 10Ah /0.416A = 24h. If load is 0.5W bulb for 2 hours= 0.5*2 = 1Wh

Lead Acid battery has 50% efficiency.

Therefore, 5Ah * 12v = 60Wh

Since load is 1Wh, it will draw 1W for an hour from the battery. Remaining power is stored in battery, and utilized upon requirement.

Inverter design:

$12V_{dc}$ to $12V_{ac}$ + Step-up transformer – 12v/220v $F = 1/(1.44 * (R_1 + 2*R_2) *C)$

F = 59.35 ~= 50Hz V_p = 12v; V_s = 220v;

N_p = 21 turns;

∴ N_s = 12/220 * N_p = 385 turns

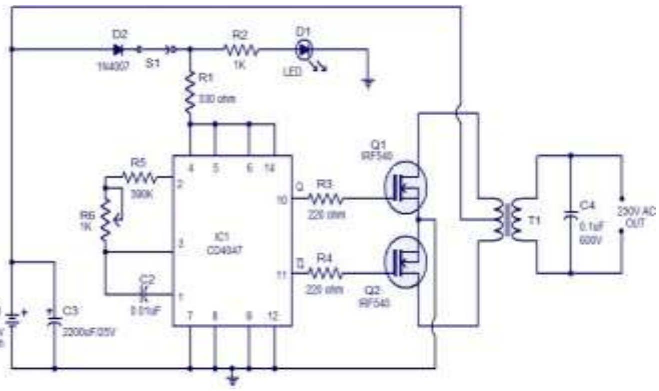


Fig.2 Inverter design

5.3 Hardware Results

Fig.3 Working of entire setup

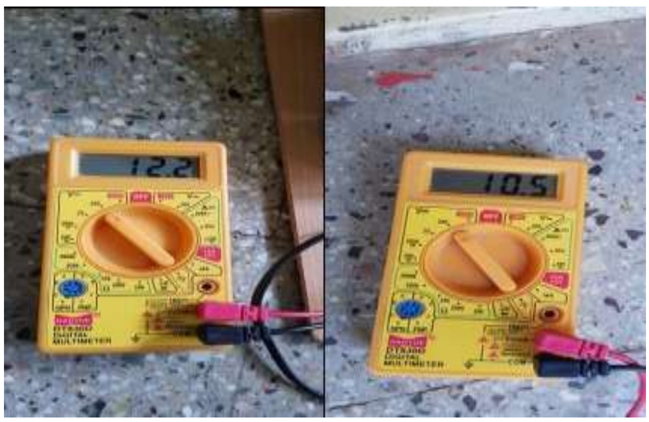


Fig.4 Output voltage of charge controller and Solar panel

Fig.5 Monitoring of power generated

6. THE CONCLUSION

The designing of this system is done in such a way that it is very flexible and user friendly. System parameters are being successfully sensed and a smart control system is developed making it more competent. Smart Monitoring displays daily usage of renewable energy. This helps the user to analysis of energy usage. Analysis impacts on the renewable energy usage and electricity issues [2]. This system also allows to monitor remotely and serves as an uninterrupted power supply. It provides energy independence by excluding power loss problems during door lockout. This type of setup has applicability in domestic, military and commercial installations, either rural or urban. Even though the output of the solar panel, is about 19%, we seek to harness the complete output, and ensure that no power is being wasted, by sending any unnecessary power to the grid. Additionally, based on how much power is sent to the grid and how much the house loads consume, the tariff amount will be much lesser than with only grid utility supply.

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