

A SIGNIFICANT SCHEME ON SMALL RENEWABLE HYBRID STAND-ALONE POWER GENERATION SYSTEM

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Abstract: This paper presents a schemeto design of a compact stand-alone hybrid power generation system using wind-solar resources. This system can be implemented in national highways, where huge amount of air can be collected due to the high speed motion of vehicles and at the same time the solar energy from the ambient will also be collected. Finally both energies will be acquired simultaneously for charging the batteries and is supplied for domestic and rural purposes. For the purpose of maximum uninterrupted power supply in industries and factories, a DC generator and power supply line are also connected to the system, but these two systems works in a priority order, only when the demand is not met by the Wind-Solar system. The main advantage of this system is that, it can be implemented as a standalone system and hence the renewable resources available in nature can be utilized to the maximum without much wastage.

Key words: Fuzzy Logic Controller (FLC), Pulse Width Modulation (PWM) Analog to Digital Converter (ADC) Complementary Metal Oxide Semiconductor (CMOS), Transistor Transistor Logic (TTL).

1. INTRODUCTION

Energy is one of the major factors for the economic welfare of any country. In case of developing countries, the increasing energy demand needs huge amount of investments to be met, which is of critical importance now. The continuous increase in human population in the world has created a number of problems regarding the need of power. One of them is global warming, occurring due the abundance of CO₂ available in the atmosphere, which is toxic gas produced due to burning of fossil fuels in the electrical plants. To reduce this emission into the atmosphere alternative sources of energy must be used. For the last twenty years solar energy and wind energy are alternate and renewable resources that is available in plenty. These energy resources are non-polluting and free in their

availability [2]. Due to the use of renewable resources in recent years advance materials, better manufacturing methods have decreased their capital costs making them more reliable and efficient[1]. In hybrid system, wind turbine and photovoltaic modules, offer greater reliability than using them separately, because the demand is not entirely based on one resource. For example, on a stormy day when solar energy generation is low there's likely enough wind energy available to compensate the lack in solar energy. In remote areas, where the grid connected power system does not exist, the stand-alone system can be used to satisfy the power demand.

2. DESCRIPTION OF THE PROPOSED SYSTEM

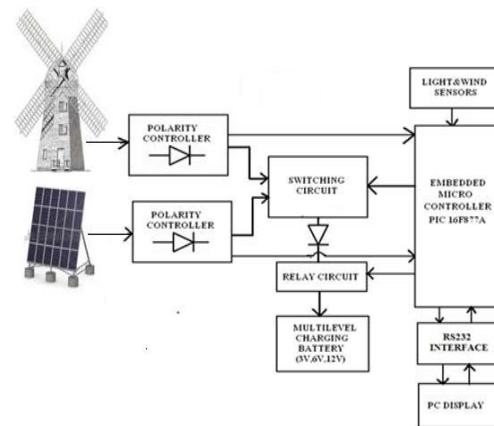


Fig.2.1 Block diagram of the hybrid stand-alone system

This forms the block diagram of our proposed system where the wind and solar energy is acquired from respective systems and sent through uni-directional polarity controllers to the switching circuit. The block diagram of the hybrid stand-alone

power generation system is shown in Fig. 2.1. The controller circuit is also connected to the switching circuit, which helps in charging the battery bank through relays.

A. Wind Turbine

To collect wind energy, we are using wind turbines made up of D.C generators with mechanical model. The wind turbine is capable of rotating for small amount of wind change from the ambient. The maximum output of the turbine will be 24W. This can further be enhanced to larger value for real time implementation [4]. The kinetic energy in the varying wind is converted into rotary mechanical energy by the wind turbine rotor. The rotor blades are made up of reinforced glass fiber, which is mounted on the steel shaft [5]. The turbine may be stall-regulated or pitch-regulated. For stall-regulated machines the pitch angle is fixed at the time of installation whereas in pitch-regulated machine it varies from various wind velocities to maintain the output power constant at rated value.

$$\text{Kinetic Energy} = 0.5 \rho A V * V^2 = 0.5 \rho A V^3 \dots \dots \dots (1)$$

$$\text{The output power of wind turbine is given by } P_w = 0.5 \rho C_p A V_w^3 \dots \dots \dots (2)$$

(2)

Where,

ρ - Air density (kg/m³)

A - Area swept by the turbine blades (m²)

V_w - Wind velocity (m/s)

C_p - A dimensionless power coefficient

C_p depends on the wind velocity and design factors of the turbine.

For the wind turbine used in this study, the following form approximated C_p as a function of λ known as the Tip-Speed Ratio (TSR). The output power circuit of the wind turbine, amplified and applied to the high frequency switching circuits is shown in the Fig.2.2.

B. Solar Panel

To acquire solar energy for this application, photo-voltaic cell made up of amorphous silicon module, which is very rigid with high thermal stability and can be utilized. The energy received in terms of power will be 12 W. The photo-voltaic cell will be installed below the wind turbine and works according to the quantity of light. The output power circuit of the photo-voltaic cell, amplified and applied to the high frequency switching circuits will be similar to the wind turbine output power circuit as shown in the Fig.2.2.

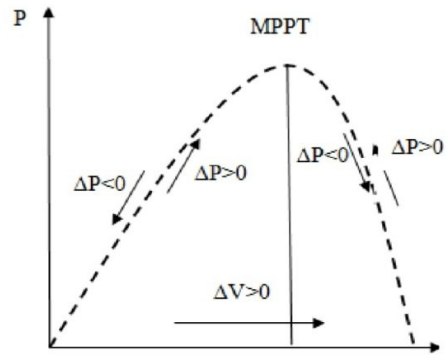


Fig.2.3 Power curve of the photo-voltaic cell

The output power of photo-voltaic cell can be mathematically expressed as:

$$P_i = \eta I_s \dots \dots \dots (3)$$

Where, η and I are energy conversion efficiency, generating power per 1 m² for 1 mJ/m², and isolation in kW/m². The output power of the photo-voltaic cell and the voltage characteristics will be as shown in Fig.2.3. The maximum power tracking point is achieved from this curve and its maximum depends on the maximum polarization of the solar cell module [6]. Normally, voltage output is based on solar irradiation and temperature of the cells. The fuzzy logic controller (FLC) is added to obtain the voltage for which the peak value of power achieved from photo-voltaic cells. ΔP and ΔV are used as seven input variables of the fuzzy controllers. The output

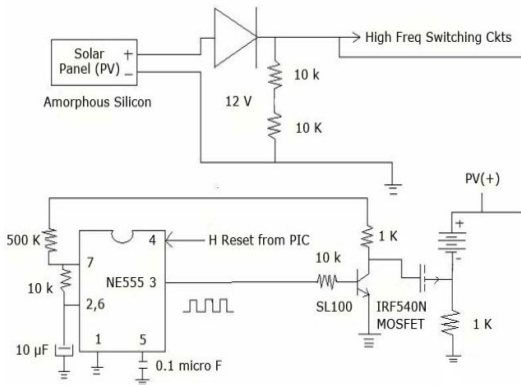


Fig.2.2 Circuit model of the wind turbine

variable is an increment value which increases or decreases the voltage reference of the photo-voltaic array. Then the PWM duty cycle of the boost converter connected to the DC-link.

C. Polarity Controller

Polarity controller is a diode with two electrodes called the anode and the cathode. Relative to the anode when the cathode is negatively charged at a voltage greater than the minimum level of voltage called forward breakdown voltage, then the current flows through the diode. If the cathode is positive with respect to the anode, or is negative by an amount less than the forward break over voltage, then the diode does not conduct current.

D. Signal Conditioner Circuit

Signal conditioners are essential to improve field received signals. Signal conditioner job starts from simple amplification to protection. For our circuit input will be 0V to 1000mV and must be amplified to 5V. For our project the output from thermistor is 20mV max for 50°C. We have to produce 5V for ADC for better accuracy we must amplify the 20mV to 5V.

$$A.F = \frac{\text{Output}}{\text{Input}} = \frac{5000}{20} = 250 \quad (4)$$

Net gain is split into two

$$A_1 \text{ gain} = 250/25 = 10 \quad (5)$$

$$A_2 \text{ gain} = 10 \quad (6)$$

For A_1 we have provided 10% adjustment by PR1

This serves two operations our circuit:

- Sign changer
- x 10 Amplifier

In our prior stage we have used 741 as an inverting amplifier whose output will be '-' always, which cannot be performed by ADC. By using A2 we do one more inversion to get '+' signal along with 10 times amplification. The signal condition unit is as shown in Fig.2.4.

$$\text{Gain of Inverting Amplifier} = R_f/R_{in} \quad (7)$$

Where,

$$R_{in} = 10k; R_f = 100k \quad (8)$$

$$\text{Gain} = -100/10 = -10 \quad (9)$$

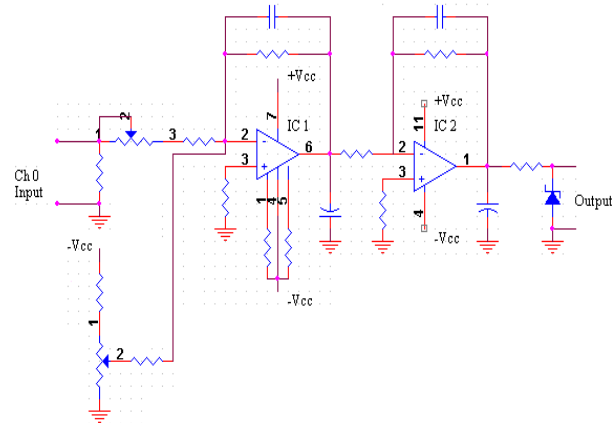


Fig.2.4 Circuit diagram of signal conditioning unit

3. CONTROL SYSTEM STRATEGY

From the circuit it can be seen that the reference analog supply after being regulated by the 9V regulator enters the zener diode through the resistance R4 where it is again regulated to 5V since the zener diode used here has a cut off of 5V. Thus we have a double regulated completely filtered analog reference source.

A. Controller unit

This means that the reference 5V can be used as it is or it can be made into a fraction of the 5V for example 1V so that readings in this range can be read with more precision. R6 is a potential divider used for setting the dynamic response range of the reference supply. This is because the ADC has 10 bit resolution which can be totally used for representing the 1V rather than 5V. The pins 2-5, 7-10, 35 and 36 are used as the 10 channels of the ADC. To these pins the analog inputs to be processed by the ADC are given. Y1 is the crystal oscillator used. It is of 10 MHz and gives a baud rate of 9600 bits/s. The capacitors C2 and C3 are used as decoupling capacitors to remove the high frequency noise signals. The capacitor C1 is in the off condition when power is switched off. The control circuit of the hybrid renewable system is shown in Fig.3.1. When the power is switched on or reset then this capacitor gets charged through the resistor R2 and then through R1 this appears at the MCLR pin of the PIC. This is the memory clear pin and thus the memory is cleared and is ready for use as soon as power is switched on. S1 is the synchronous switch which is also used for the same operation and for PC and PIC synchronous operation.

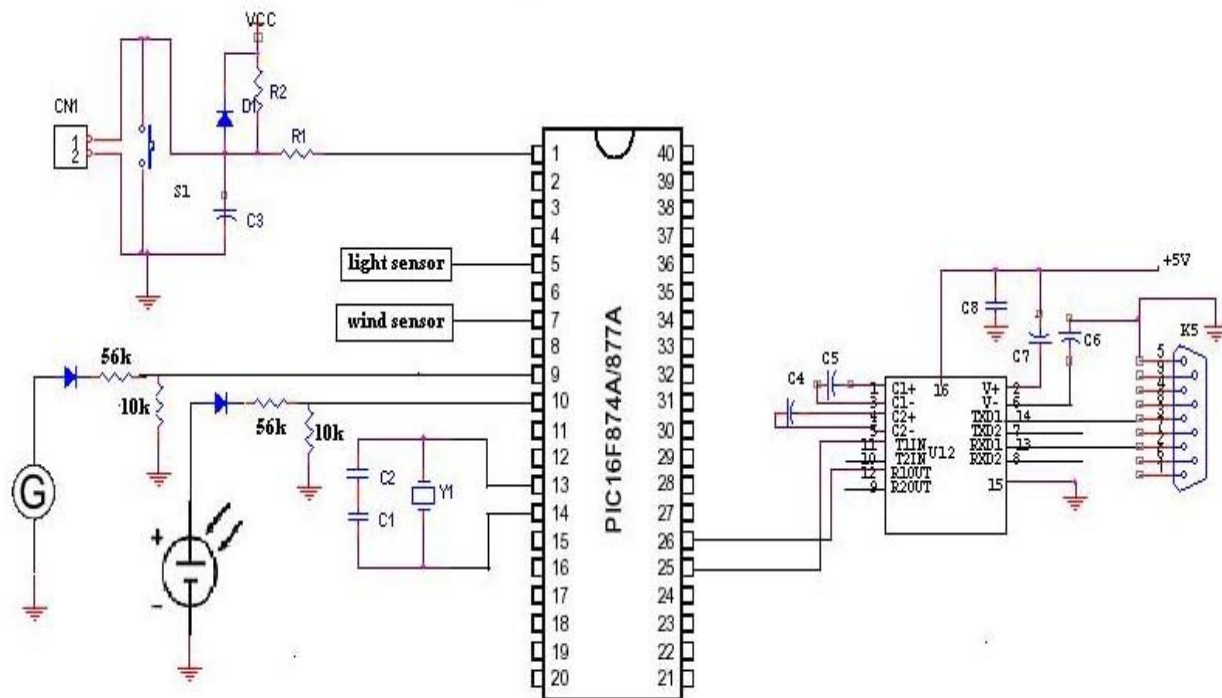


Fig.3.1 Control circuit of the proposed hybrid stand-alone hybrid system

B. Power supply section

The MAX232 power supply section has 2 charge pumps the first uses external capacitors C1 to double the +5V input to +10V with input impedance of approximately 200Ω. The second charge pump uses external capacitor to invert +10V to -10V with an overall output impedance of 45Ω. The best circuit uses 22μF capacitors for C1 and C4 but the value is not critical. Normally these capacitors are low cost aluminum electrolyte capacitors or tantalum if size is critical. Increasing the value of C1 and C2 to 47μF will lower the output impedance of +5V to +10V doublers by about 5Ω and +10V to -10V inverter by about 10Ω. Increasing the value of C3 and C4 lowers the ripple on the power supplies thereby lowering the 16 kHz ripple on the RS232 output. The value of C1 and C4 can be lowered to 1μF in systems where size is critical at the expense of an additional 20Ω impedance +10V output and additional 40Ω impedance at -10V input.

C. Transmitter section

Each of the two transmitters is a CMOS inverter powered by +10V internally generated supply. The input is TTL and CMOS compatible with a logic threshold of about 26% of V_{cc} . The input if an unused transmitter section can be left unconnected: an internal 400kΩ pull up resistor connected between the transistor input and V_{cc} will pull the input high forming the unused transistor output low. The open circuit output voltage swing is guaranteed to meet the RS232 specification +5V output swing under the worst of both transmitters driving the 3kΩ. Minimum load impedance, the V_{cc} input at 4.5V and maximum allowable ambient temperature typical voltage with 5kΩ and $V_{cc} = +0.9V$. The slow rate at output is limited to less than 30V/μs and the powered done output impedance will be minimum of 300Ω with +2V applied to the output with $V_{cc} = 0V$. The outputs are short circuit protected and can be short circuited to ground indefinitely.

D. Receiver Section

The two receivers fully conform to RS232 specifications. Their input impedance is between $3k\Omega$ either with or without 5V power applied and their switching threshold is within the +3V of RS232 specification. To ensure compatibility with either RS232 IIP or TTL/CMOS input. The MAX232 receivers have V_{IL} of 0.8V and V_{IH} of 2.4V the receivers have 0.5V of hysteresis to improve noise rejection. The TTL/CMOS compatible output of receiver will be low whenever the RS232 input is greater than 2.4V. The receiver output will be high when input is floating or driven between +0.8V and -30V.

E. Switching circuit

The technique used is pulse charging technique. This is Trickle method in boost charging system. A high end high frequency charging technique will be employed to charge the battery without loading the turbine and photovoltaic cell. This method reduces the charging time. For example if cell phones are charged using this way, then the cell phones will not get heated up. The switching circuit consists of the 555 timer and a MOSFET. The 555 timer works as the astable multivibrator which produces pulses of required frequency. IC 555 employed here as an astable multi vibrator to produce continuous square wave for charging [7].

IC 555 is the most versatile chip which can be used as a monostable, bistable and astable multivibrator by minimum change in the design. For a stable operation capacitor connected from pin No.2 to Ground and resistor connected from 7th pin to supply will decide output frequency whereas resistor connected between pin No. 6 & 7 will determine duty cycle of the pulse delivered. Pin No. 5 is the control voltage pin beyond that discharge will happen in the output. For healthy operation of the chip, pin No. 5 should be 75% of the applied voltage. Pin No. 4 is a reset which is connected to supply voltage for enabling the output. If pin No. 4 is connected to ground irrespective of any design output will be consistently zero (No frequency). Pin No. 3 is output pin where we get logical 0's and 1's. The output voltage may not be adequate for high current switching. So we need to amplify the signal using transistors. The output of the

transistor can drive subsequent MOSFET (or) IGBT's, which reproduces the frequency with offered voltage to it (photovoltaic output). In these circumstances, photovoltaic cell is connected between ground and drain of MOSFET through charging derives like battery. The photovoltaic output will be switched and charging the battery. The above operations will give long life to the photovoltaic because consumption of current is not constant so that terminal problems can be eliminated and loading of photovoltaic cells will be avoided. The switching circuit for the boost charging method is shown in Fig.3.2. The output of the MOSFET is connected to relay circuit, where an advanced logic is developed to select the battery based on receiving the light.

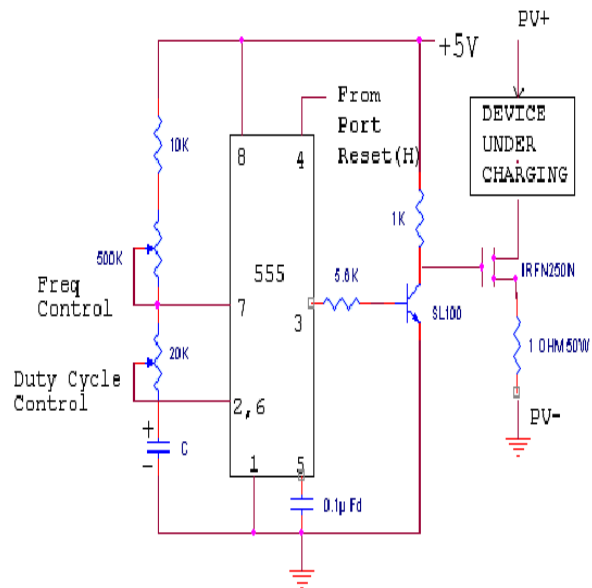


Fig.3.2 Switching circuit for the boost charging method

F. Multilevel charging

According to our scheme whatever the voltage we collect from photovoltaic and the dynamo that can be applied to a battery whose charging voltage equivalent to the collected voltage. Example: If we receive 4V, we can charge 3V battery. If we receive 7V, we can charge 6V battery respectively. To achieve this function we are measuring the output from both the solar panel and wind turbine using the embedded controller and generating various outputs to switch relays where batteries are connected.

4. RESULTS AND DISCUSSION

The results of the system in visual basic 6.0 software are as shown in Fig.4.1 and Fig.4.2. Due to the low energy demand and difficult access to isolated areas it is necessary to build a system that is reliable, efficient and presents enough flexibility to load increases. It was shown that these requirements can be fulfilled with parallel operation of inverters specially designed for these applications. The hybrid system output database sheet is shown in Fig. 4.3.

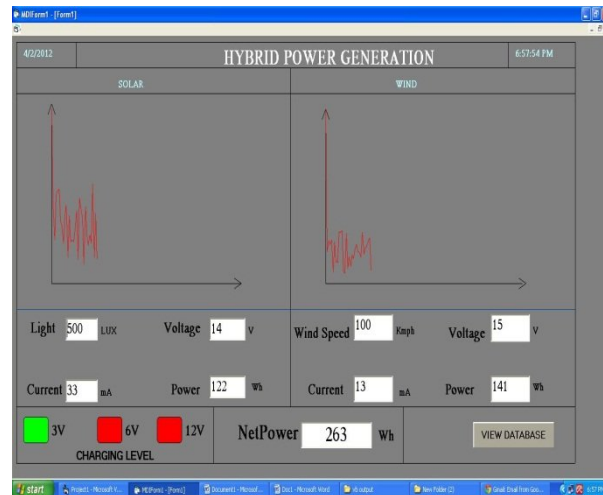


Fig.4.1 Visual basic output of power, voltage and current of hybrid power generation

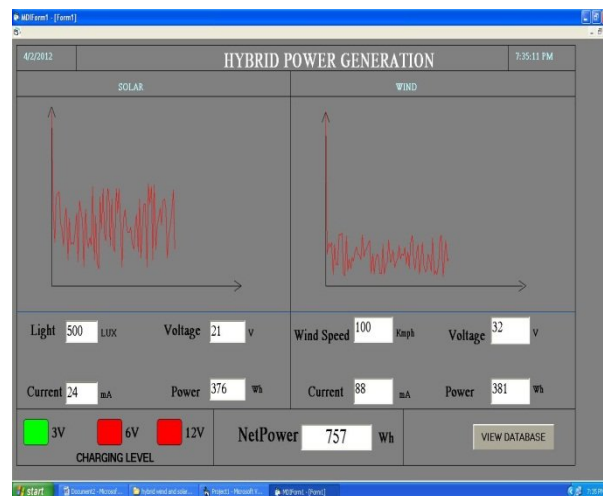
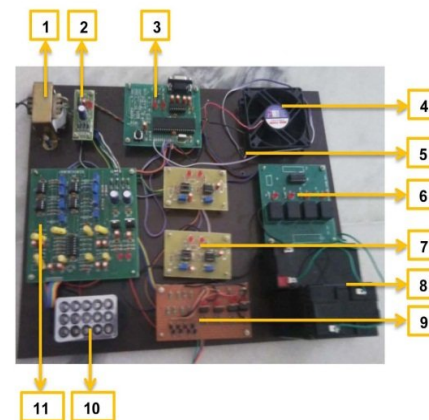


Fig.4.2 Visual basic output of hybrid power Generation

	S.VOLTAGE	S.CURRENT	S.LIGHT	S.POWER	W.VOLTAGE	W.CURRENT	W.SPEED	W.POWER
1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1
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98	1	1	1	1	1	1	1	1
99	1	1	1	1	1	1	1	1
100	1	1	1	1	1	1	1	1

Fig.4.3 Visual basic output of hybrid power log

The current model is as shown in the Fig.4.4.



- | | | |
|------|-----------------------|---------------------------------|
| S.No | Name | |
| 1. | Step Down Transformer | 7. Astable Circuit |
| 2. | Power Supply Circuit | 8. Battery |
| 3. | Embedded Circuit | 9. Switching Circuit |
| 4. | Wind Sensor | 10. Load Lamp |
| 5. | Solar Sensor | 11. Signal Conditioning Circuit |
| 6. | Relay Circuit | 12. Wind Mill |
| | | 13. Solar Panel |

Fig.4.4 Current prototype

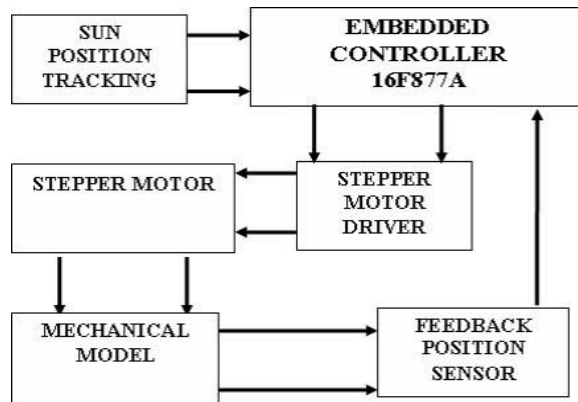


Fig.4.5 Enhanced circuit of solar cell in hybrid system

This project can be enhanced by moving the solar panel above the wind turbine and attaching stepper motor with light sensor to the solar panel for obtaining the maximum light intensity from the sun light. The enhanced circuit of solar cell hybrid system is shown in Fig. 4.5. Thus the efficiency of the system can be further increased.

5. CONCLUSION

This hybrid power generation project is to overcome the disadvantages of the existing model of solar panel and the wind turbine operating individually and also to avoid the disadvantages of the Paralleling method wherein the voltage of both sources has to be same so that they could be combined for storage, but here whatever the resource is available it's been utilized. This system by using the switching charge technique reduces the losses that occur due to the thermal effect caused in the storage system, which increases the life span of the batteries and also the wastage of power is reduced. The integration of both the solar power generation and the wind power generation as one will help us to increase the efficiency of the overall system, consistency of the power generation can be improved, and the interruption of the power flow could be avoided. As the systems are complementary, greater output can be obtained from the wind turbine during the winters and during the summers the solar panels would produce their peak outputs. Hybrid energy systems feature lowers fossil fuel emission and produces continuous power generation at all times thus being environmental friendly. This is a single time investment and this system is easy to install, operate and maintain.

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