Wind and Solar Hybrid Energy Generation

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***Abstract*— The main aim of this project is to design and develop a hybrid wind and solar energy generation which can increase the electrical energy's efficiency by using the wind turbine and solar panels. The implemented system aims at providing an amplified alternative source of renewable energy to cater for the already diminishing, pollutant and scarce traditional fuels such as oil, gas and coal. The implemented hybrid design consists of vertical axis wind turbine and two solar panels which are used to supplement the power generated especially during hot days when the wind speed is low. A permanent magnet synchronous generator redesigned from a recycled stepper motor and implemented with a total number of 9 copper wound coils for the stator and by using rare earth magnets for the rotor (shaft). The hybrid system implemented is able to generate maximum power of 75.05 W and minimum power of 18.2 W.**

***Index Terms*— Hybrid System, Electricity Generation, Permenent Magnet Synchronous Generation, Renewable Energy, Solar Energy, Solar Panel, Wind Energy, Wind Turbine**

1. Introduction

The ever-increasing demand for clean energy around the world arises from increasing global warming and power load demand in our society. The world has focus on environmental-friendly type of power generation to preserve the earth for the next coming generation. Numerous sources of clean and renewable energy have been explored over the times for power generation such as hydropower generation, wind energy, solar energy and wave energy. Innovative methods to harvest the energy more efficiently are rigorously explored as well. However, wind and solar energy have so far proved to have the biggest potential of meeting global energy demand in the present and future. (Marisarla & Kumar, 2013)

Solar energy is a type of energy that is gathered through the sun's radiation using solar panels that are placed in vast areas where the solar rays have the highest intensity to capture the maximum solar power. This energy is sustainable, abundant and continuous which makes it free to use for power generation. It has zero carbon emission, it is relatively cheaper and has low maintenance cost. However, there exists one limitation which is, the energy generated from solar cannot be fully utilized in cloudy, rainy or snowy weather condition.

Similarly, wind energy is a type of renewable energy which is extracted from environmental air or windy condition. A common method for wind energy extraction is the utilization of wind turbines which depends on the speed of the wind flowing in the atmosphere. It is cost effective and can be utilized to provide energy to users for 24-hours daily. (Ingole & Rakhonde, 2015). However, solar and wind energy harvesting come with various limitations in terms of articulating the behavior of energy sources produced in short and medium periods (Carli, Davide & Brunelli, 2011). Nonetheless, solar and wind energy harvesting is beneficial to area which is remote and away from power grid if they can be turned into electricity efficiently.

Due to the aforementioned limitations, a hybrid energy system to retrieve power from two sources of energy, viz. solar and wind was proposed to generate electricity simultaneously or complementary in a reliable and efficient manner. A prototype hybrid power generator was successfully developed and evaluated based on the local climate.

2. Materials and Methods

The prototype consists of 2 major components, viz. mechanical and electrical components. A schematic showing the connection of both the electronic and hardware connections is illustrated in Figure 1 and Table 1.

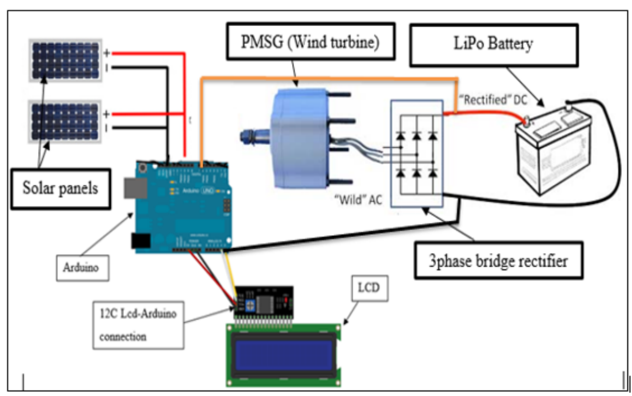

Figure 1: Hybrid system electronic construction

Table 1: Pin connection description for TEG

Component	Pin description	Arduino pin connection	Battery Charging
12C LCD connection	G_{nd}	G_{nd}	
	V_{cc}	+5v	
	SCL	2	
	SDA	3	
Rectifier (PMSG output)	Black	G_{nd}	Red(+12v)
	red	A0	Black (-12v)
Solar panels (series connection)	Black	G_{nd}	
	red	A1	

2.1. Mechanical Construction

The mechanical construction consists basically of the parts that were used to generate the initial/raw power and motion for the implemented hybrid system. The hybrid mechanical construction and part measurements are as shown in Figure 2 and Table 2.

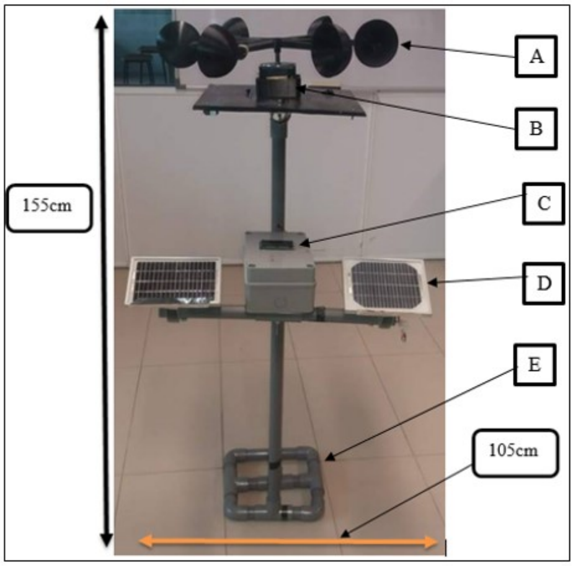

Figure 2: Hybrid system construction

Table 2: Hardware measurement

Part	Description	Size (L× *W*)
A	Cup turbine	19.5cm by 19.5cm
B	PMSG motor	11.5cm by 12.2cm
C	Circuit box	12.5cm by 15.6cm
D	Solar panel	18cm by 15cm
E	Stand	16.3cm by 15.8cm

2.1.1 Cup Shape Airfoil Wind Turbine

The cup shaped wind turbine consists of mainly 6 major arms that are spatially mounted on a vertical shaft consisting of cup shaped airfoils as shown in Figure 3. Snap fit connections were used to connect each arm onto the centralized vertical shaft for the sole purpose of attaching and removing each arm when the need arise. The cup shape blades were attached as vertical axis wind turbine (VAWT). The dimension of the cup shape turbine is listed in Table 3.

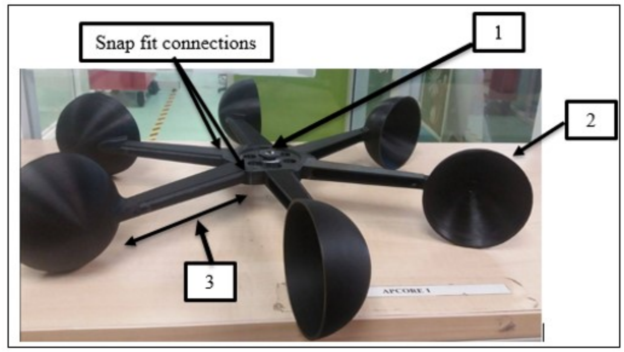

Figure 3: Cup shape wind turbine

Table 3: Construction dimensions

No.	Description	Dimensions
1	Shaft	Diameter (1.5cm)
2	Cup (Airfoils)	Diameter (9.5cm) & Length (7cm)
3	Arm	Length (12.5cm) & Thickness (1.2cm)

2.1.2 Generator Construction (PMSG)

A Low RPM Permanent Magnet Synchronous Generator (PMSG) as shown in Figure 4 was implemented in the hybrid system to help convert the kinetic energy harvested from the wind turbine to electrical energy. To achieve this a recycled stepper Motor was used to provide the necessary stator coils and housing for the shaft.

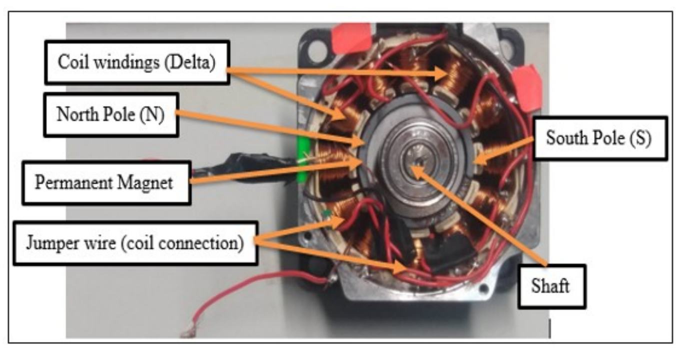

Figure 4: Low RPM permanent magnet synchronous generator

2.1.3 Solar Panel

The solar panels were basically used to harvest the solar energy from the sun and convert it to electrical energy for consumption. The implemented system consisted of two solar panels each with a power rating of 12V DC. Each solar panel measured 150 mm by 180 mm as shown in Figure 5.

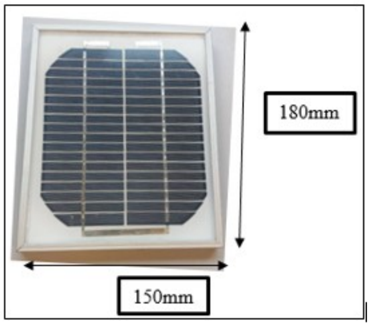

Figure 5: Solar panel

The solar panel implemented for the hybrid system has a maximum power rating of 2W and has the specifications illustrated in Table 4.

Table 4: Solar panel specifications (Model No. SW2)

Specifications	Value
P_{max}	2W
V_{mp}	17.5 V
I_{mp}	0.115A
V_{oc}	21V
Test condition	AM1.5, 25^0C, 1000W/m^2

2.2. Electrical Component

The project utilized multiple solar cells to achieve a single solar panel module in a series configuration as high performance single solar panel, while two solar panel were connected in parallel to achieve operation voltage of between 12V to 22.5V. Finally, solar-wind power generation was integrated to produce electricity by a micro electricity grid power supply. An inverter was used to change the DC voltage produced by micro grid into 240V AC for consumption purpose. Charge controller was used to connect battery and load to grid.
The voltage generated from the hybrid system was not constant and as the power kept on fluctuating. This was mainly attributed to the varying changes in the environmental conditions i.e. wind speed and solar power (light) intensity. Therefore, to achieve more stable output, a circuit consisting of a power converter was implemented with the sole purpose of converting the AC to DC using special solid-state semiconductors that operate at a specified frequency regardless of the system fluctuations. A filter consisting of 4000µF capacitors was used to smoothen the DC current produced from the rectifiers as shown in Figure 6.
A charge controller was also used to control the amount of charge stored in the battery. The charge controller played an important role after the conditioning of the circuit was done whereby it controlled the charging of the LiPo battery as well as providing the necessary power to drive the load (Led's) connected to the hybrid system. This was made possible by the short circuit protection circuit which was instrumental in varying the power generated with reference to the load demand.

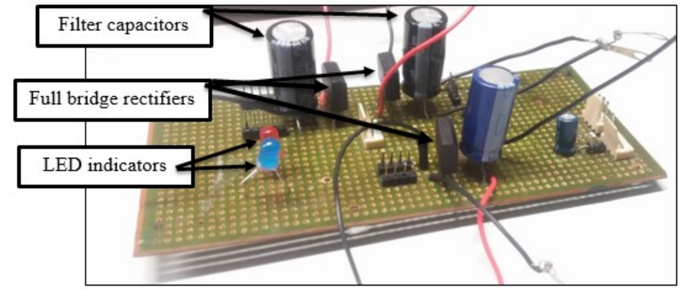

Figure 6: Power conditioning circuit

2.3 Working Principle

The hybrid power generation relied on power harvested from wind and solar energy using the combination of two solar panels and a wind turbine as shown in the flowchart in Figure 7. The power harvested from these two sources was led to a charge controller to regulate the rate of flow of current produced. The boost converter circuit was connected to the charge controller to step up the DC power generated. A lithium polymer ion battery (LiPo) and an inverter were then connected to the boost converter; whose work was to store the generated power and convert the DC power to AC respectively. The output of the inverter was connected to a conditioning circuitry consisting of a rectifier to direct the current to flow in one direction.

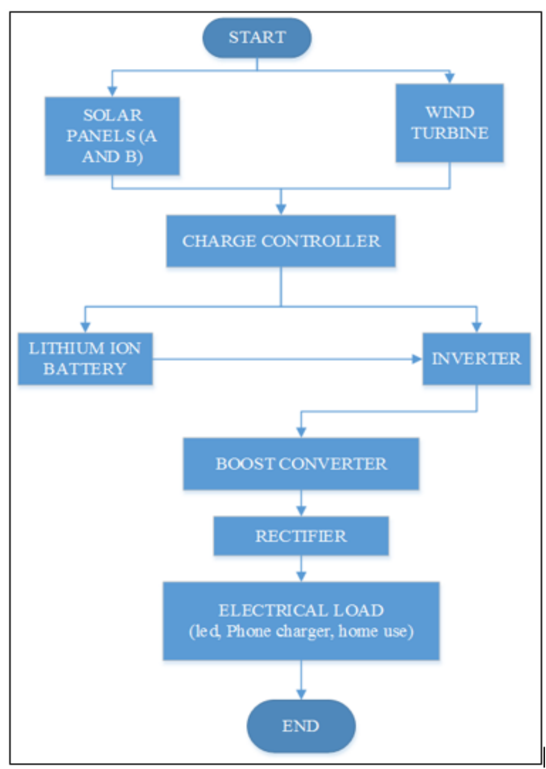

Figure 7: Hybrid system block diagram

3. Results and Discussion

The hybrid system was tested separately and then tested as hybrid system. The power output for the solar panels with the elevation angle of 24° is shown in Table 5.

Table 5: Power generated by solar panels

Date	Time	Voltage (v)	Current (A)	Power (V×I) (W)
Mon 3rd July 2017	7:00am	15.1	0.111	1.68
	8:00am	13.9	0.100	1.39
	9:00am	15.2	0.111	1.69
	10:00am	14.6	0.110	1.61
	11:00am	14.9	0.112	1.67
	12:00pm	13.6	0.109	1.48
	1:00pm	15.7	0.112	1.75
	2:00pm	14.2	0.110	1.58
	3:00pm	15.1	0.111	1.68
	4:00pm	14.2	0.109	1.55
	5:00pm	15.0	0.111	1.67
Total Power				17.75

The power output for the wind turbine with 6 cup blade is shown in Table 6.

Table 6: Power generated by Vertical Axis Wind Turbine

VAWT Type	Date	Time	Voltage (v)	Current (A)	Power (V×I) (W)
Cup Shaped	Tue 18th July 2017	7:00am	9.8	1.303	12.78
		8:00am	14.2	1.494	16.90
		9:00am	10.4	1.318	13.85
		10:00am	12.8	1.427	18.29
		11:00am	13.6	1.501	20.43
		12:00pm	12.8	1.429	12.05
		1:00pm	9.5	1.298	15.33
		2:00pm	10.8	1.319	13.32
		3:00pm	9.8	1.303	14.78
		4:00pm	10.1	1.319	13.32
Total Power					151.05

The overall power output of the hybrid system is shown in Table 7. During testing, the hybrid system was able to achieve a maximum power output of 75.05 watts when the VAWT and the two solar panels were combined together to give the overall output power. The maximum voltage generated by the system when solar and wind conditions were favorable, was 17.9V with a maximum peak current of 4.193A. However, the hybrid system would have produced more power under optimum conditions i.e. high wind velocity and maximum solar intensity. However, these optimum conditions are rare and hard to come by.

The implementation of a Permanent Synchronous Generator (PMSG) played a huge role in the increased power output of the hybrid system in comparison to those used by other researchers. The use of optimization techniques such as the use of the 9 coils configuration and the Neodymium earth magnets in the PMSG played a vital role in increasing the output of the system especially at low speeds.

Table 7: Power generated by the hybrid system

Date	Time	Voltage (v)	Current (A)	Power (V×I) (W)
Mon 14th Aug 2017	7:00am	8.3	2.193	18.2
	8:00am	9.6	2.219	21.3
	9:00am	10.9	3.214	35.03
	10:00am	14.5	3.319	48.13
	11:00am	17.9	4.193	75.05
	12:00pm	15.8	3.419	54.02
	1:00pm	14.6	3.902	68.67
	2:00pm	17.8	4.191	74.60
	3:00pm	15.6	3.209	50.06
	4:00pm	17.4	4.211	73.27
	5:00pm	17.6	4.205	74.01
	6:00pm	14.8	3.320	49.13
	7:00pm	9.2	2.198	20.22
Total Power				661.69

4. Conclusions

The conditioning circuit implemented consisted of a rectifier, boost inverter/converter was working well. The system developed was able to generate a maximum power of 20.43 W at peak condition for wind power and maximum 1.75 W at peak condition for solar power. When compared to the maximum output of the hybrid system of 75.05 W, the hybrid system has shown an increase of about 3.4 times the maximum power output of individual solar and wind power combined.

References

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