IMPLEMENTATION OF A REAL TIME SUPERVISORY CONTROLLER FOR AN ISOLATED HYBRID (WIND/ SOLAR/DIESEL) POWER SYSTEM

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Abstract

In most of the developing countries like India and South Africa, there exists still many remote places (isolated from the grid); where the electrification is unavailable due to the financial aspect related to establishing the infrastructure to distribute power over a long distance and consequent high transmission losses. Authors emphasize for an Autonomous Hybrid Power Systems (AHPS), which will eradicate the problems faced by the remote places. Integration of Wind/Solar/Diesel also ensures the prompt availability of power to primary health clinics, high way petrol bunks, schools and the basic communication networks located in remote places. In this scheme, DC power is generated by the wind turbine and solar and DC is connected to the load through an inverter. While doing so, the quality of the power as well as the variations in the environmental conditions does not disturb the loads connected. Therefore the reliability is also ensured in power generated with the AHPS. It is easy to construct the plant with 300W capacity on the roof top of the building; with a meager cost of around $1200.

Key-Words*:* Hybrid Power Systems, Isolated Power System, monitor and control, off-grid, Renewable Energy Sources, solar, Supervisory Controller, solar radiation, wind.

1 Introduction

The escalation in electrical energy costs associated with fossil and nuclear fuels, and enhanced public awareness of potential environmental impacts of conventional power generation has created an increased interest in the development and utilization of alternate energy sources [1]. Solar-PV and wind energy are being recognized as cost effective generation sources in small isolated power systems. Wind energy and solar energy are reliable energy sources but their output greatly depends on climatic conditions, including solar irradiance, wind speed, temperature, and so forth. The components and subsystems of a stand-alone power supply system based on renewable sources are inter connected to optimize the whole system.

Off-grid hybrid power systems can also incorporate energy storage in batteries to increase duration of energy autonomy. If some of the loads connected to a hybrid PV-wind system require permanent electric power supply, a backup diesel generator can be connected to the system to provide electric energy for peak loads which cannot be covered by the hybrid wind-solar combination [2]. Usually, most of hybrid systems are designed to supply electric power for lighting fixtures, radio/TV, domestic appliances etc. This is typical in isolated areas for rural households as well as of some public buildings such as schools, health clinics, cultural establishments, etc. For an average rural household it is necessary to provide the following services: indoor/outdoor lighting (5/6 points x 5 hours/day) and mobile charging/radio (4 hours/day). It is also necessary to ensure the minimum level of power for the functioning of the systems even during least unfavorable periods (at night, on cloudy and windless days). Electric energy for these periods is provided from energy storage batteries (their autonomy and capacity being determined on a case- to-case basis) [2]. For the above-mentioned requirements, the peak power level of the PV-wind electric generator can usually range from 200W to 300W. When combining the solar-PV, wind power generation with diesel generator, the instability of the output characteristic of each other was compensated and also offers a highly reliable source of power to the isolated customers.

1.1 Fundaments on Hybrid Systems

Stand-alone hybrid generation systems are usually used to supply isolated areas or locations interconnected to a weak grid. They combine several generation modules, typically incorporating different renewable energy sources. The application of these hybrid topologies reduces the probability of energy supply shortage and, with the incorporation of energy storage; it allows to eliminate the background diesel generator (which is commonly required in generation systems based on a single renewable energy source). In this context, many autonomous electric generation hybrid systems frequently combine solar and wind energy sources (taking advantage of their complementary nature) with a lead-acid battery bank (to overcome periods of scarce generation).

1.2 Proposed Hybrid Power System

The proposed hybrid (Wind/Solar/Diesel) power system is shown in Fig.1, which is constituted by a windmill, a permanent-magnet DC generator and a dc/dc converter to interface the generator with the dc bus. The converter commands the voltage on the PMDCG terminals, indirectly controlling the operation point of the wind turbine and, consequently, its power generation [4].

The solar module comprises PV module connected to the dc bus via a dc/dc converter. Similar to the wind subsystem, the converter controls the operation point of the PV module.

The dc bus collects the energy generated by both modules and delivers it to the dc loads connected in the DC bus and to the battery bank. Its voltage is imposed by the battery bank which comprises lead-acid batteries connected in a serial/parallel array. The load could be an AC load. In the case under analysis, it is assumed to be an AC load; therefore, a voltage inverter is required. The cost of the battery bank plays a fundamental role in the overall system cost.

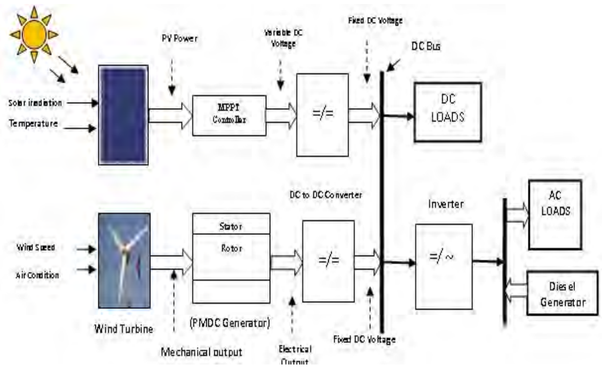

Fig.1. Proposed Hybrid Power System (HPS)

This is a critical reason to operate the battery bank carefully, with the objective of extending its operative life [5]. Many lead-acid battery manufacturers recommend specific recharge cycles to recover 100% of the charge capacity and also to protect the battery against dehydration.

2. Hardware Model of HPS

The Fig.2 shows the block diagram of a hybrid power system which includes solar PV module, wind turbine, battery and diesel generator. The input to the load is supplied through the inverter from the DC bus. The supervisory controller monitors and measures the voltages of the input sources and also controls the connectivity of each of the input source.

The controller monitors the voltage level of the battery, if it is overcharged, the wind and solar plant gets disconnected automatically. Similarly, the diesel engine connected to the load directly simultaneously charges the battery. Based on the charge condition monitored by the controller the diesel engine is disconnected. The inverter which is connected to the system converts fixed/variable DC input voltage to fixed AC output voltage. This system supply a load demand of 200W without any interruption.

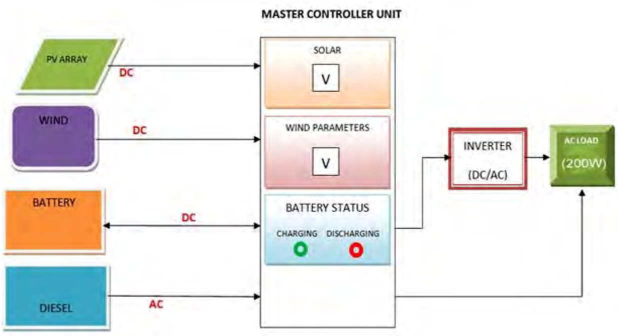

Fig.2 General Block Diagram of HPS

Table. 1 Specification of HAWT Blades

VOLTAGE	12 V
POWER	200 W
SPEED	1000 rpm
TYPE	PM13

Table. 2 Specification of PMDC Machine

DIAMETER	2.3 m
LENGTH	1 m
NUMBER OF BLADES	3
TYPE	H-TYPE

3. Project Site Geographical Information

The details of the project site are given below.

Location: SVS College of Engineering, Arasampalayam, Coimbatore, Tamil Nadu, India
Latitude 10.8484450 Longitude 77.0420541

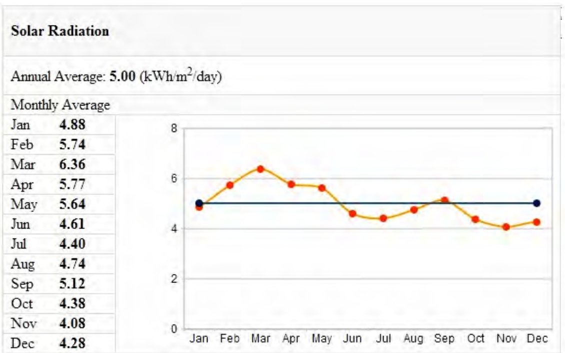

Fig.3 Solar Insolation for the year, 2012

Courtesy: NREL

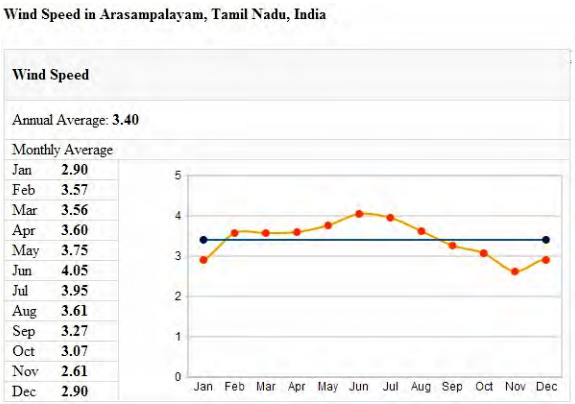

Fig.4 Average wind harnessed data, 2012

Courtesy: NREL

Table.3 Wind Data in the turbine installed location

Time (Hours)	Wind Speed (km/h)	Output Voltage (volts)	Current (A)	Power(W)
12:00 AM	8	7	6	42
1:00 AM	8	7	6	42
2:00 AM	8	7	6	42
3:00 AM	7	6	6	36
4:00 AM	7	6	6	36
5:00 AM	7	6	6	36
6:00 AM	8	7	7	49
7:00 AM	8	7	9	63
8:00 AM	9	8	12	96
9:00 AM	10	9	10	90
10:00 AM	12	11	9	99
11:00 AM	12	12	10	120
12:00 PM	11	12	10	120
1:00 PM	11	12	9	108
2:00 PM	11	12	9	108
3:00 PM	11	12	10	120
4:00 PM	10	11	11	121
5:00 PM	13	9	12	108
6:00 PM	12	7	12	84
7:00 PM	13	7	12	84
8:00 PM	12	6	14	84
9:00 PM	12	6	15	90
10:00 PM	11	6	13	78
11:00 PM	10	6	13	78

Courtesy: Tamil Nadu Agricultural University, Coimbatore

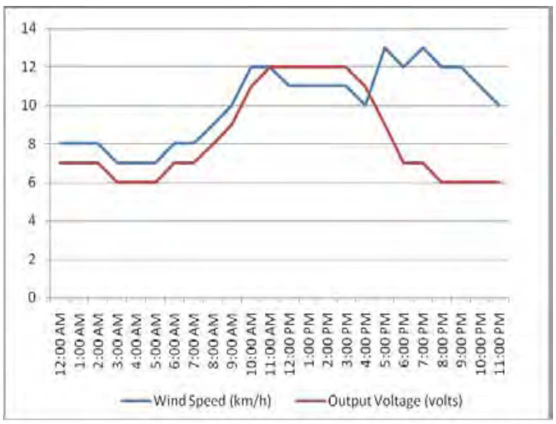

Fig.5 Wind Speed and Output Voltage Curve

Courtesy: Tamil Nadu Agricultural University, Coimbatore

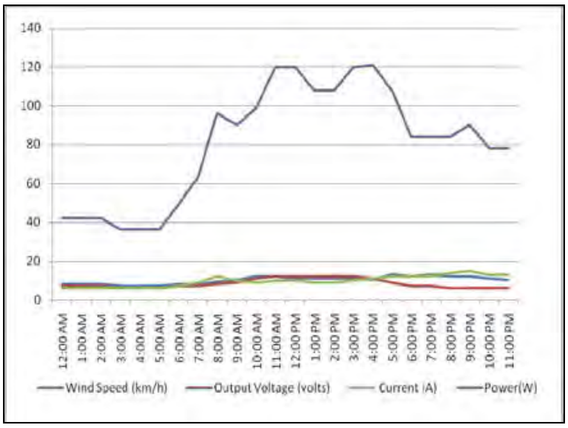

Fig.6 Wind Speed, Voltage, Current and Power Curve

Table.4 Solar Irradiance data

Time (Hours)	**Wind Speed (km/h)**	**Temp (°C)**	**Solar Radiation (kW/m2)**
12.00 Am	6	21	0
1:00 AM	6	21	0
2:00 AM	6	20	0
3:00 AM	5	22	0
4:00 AM	5	21	0
5:00 AM	5	21	0
6:00 AM	6	20	0
7:00 AM	6	20	0
8:00 AM	7	20	0.24
9:00 AM	8	21	0.36
10:00 AM	10	23	0.56
11:00 AM	11	25	0.7
12:00 PM	11	26	0.76
1:00 PM	11	28	0.84
2:00 PM	11	29	0.68
3:00 PM	11	29	0.5
4:00 PM	10	30	0.36
5:00 PM	8	29	0.16
6:00 PM	6	27	0.4
7:00 PM	6	26	0
8:00 PM	5	24	0
9:00 PM	5	23	0
10:00 PM	5	22	0
11:00 PM	5	22	0

Instant solar radiation and instant temperature data.
TMAX= 30°C, TMIN=20°C, HMAX=51 %,
HMIN=35 %, Sun Rise =05:14, Sun Set =06:53

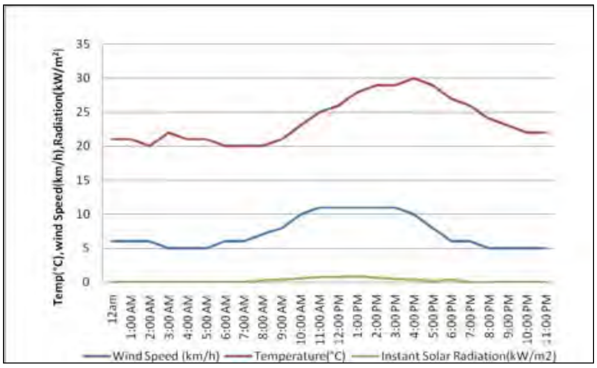

Fig.7 Wind Speed and Output Voltage Curve

4. Circuit Diagram with Supervisory Controller

The supervisory controller used in the system consists of a PIC 16F877A microcontroller with accessory units, which monitors the various parameters of the system and controls the subsystems. The controller unit acts as the intelligence of the entire unit and coordinates the autonomous HPS to maintain the stability, good operating system, good control of charge/discharge batteries and protection against overloading and deep discharge).This controller unit performs some operations they are:

- Monitors and controls the state of the system.
- Monitors and controls the battery voltage brings up the diesel generator when needed, and shuts off when not needed.
- Sheds low priority loads in accordance with the set priorities.

Wind and solar are both unpredictable and intermittent sources. These shortcomings can be greatly reduced by combining wind and solar in a single scheme, together with battery storage and a diesel generator [6].
This works on the following cases:

- When battery voltage = 14.5V, the battery will be fully charged, so the relay opens the solar and wind ensuring the overcharge of battery and switches from one battery to the parallel connected batteries through the relay control .
- When the battery voltage < 12.4V, the relay will again be closed and solar/wind charges the batteries based on the availability.
- When battery voltage is < 11.8V, the battery will be in critical stage due to the absence of both wind and solar. The controller turns on the diesel generator or AC mains.

The control circuit monitors the voltage level of the batteries and switches the charging mode to the next battery which is connected in parallel. Also while discharging, the control circuit automatically change-over the next battery based on the voltage level in each one of it.

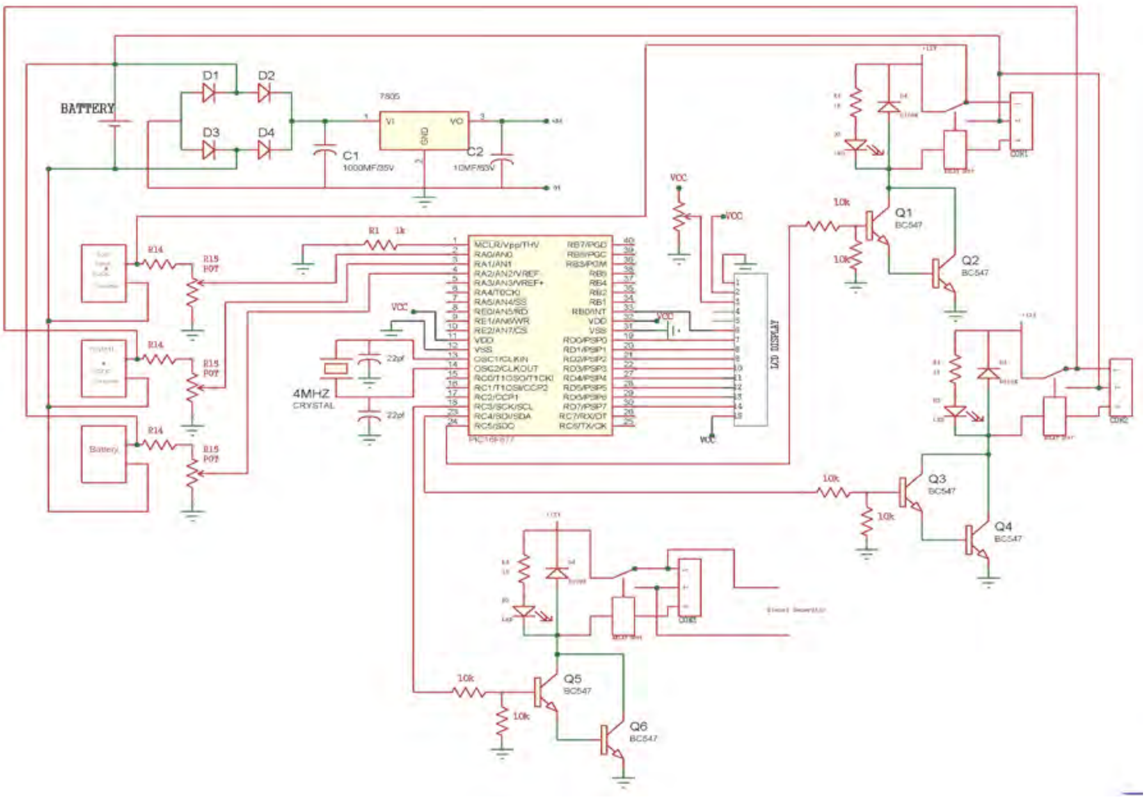

Fig. 8 Circuit Diagram of HPS with Supervisory Controller

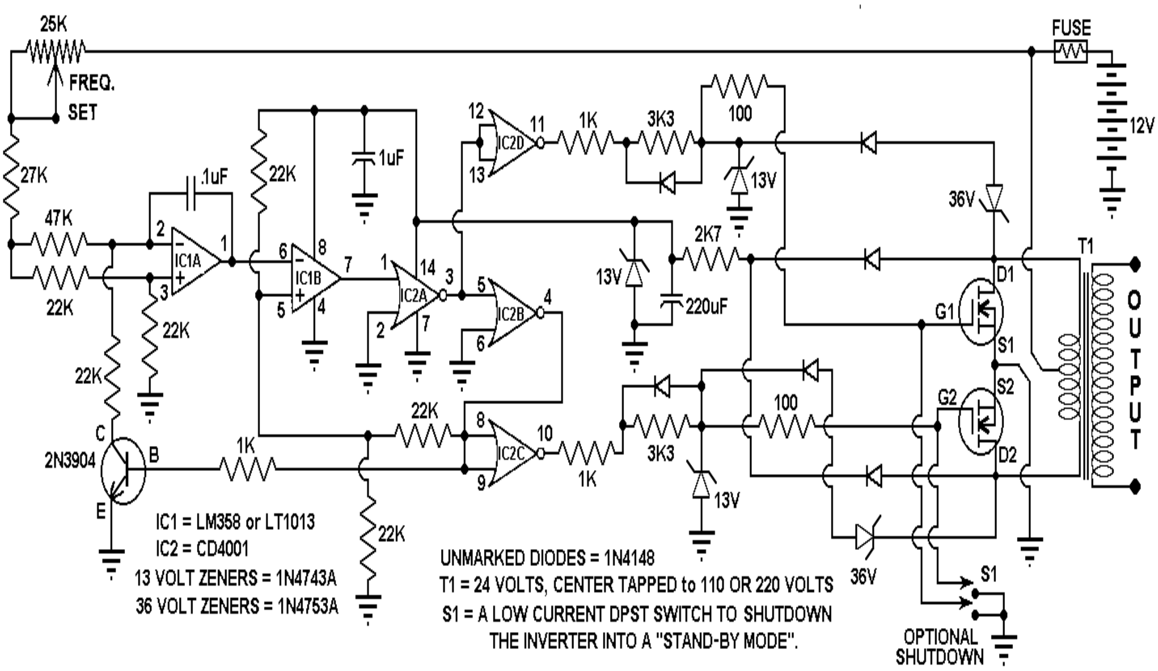

Fig.9 Circuit Diagram of the Inverter

5. Hybrid Power System Experimental Setup

Fig.10 Photograph showing the HPS

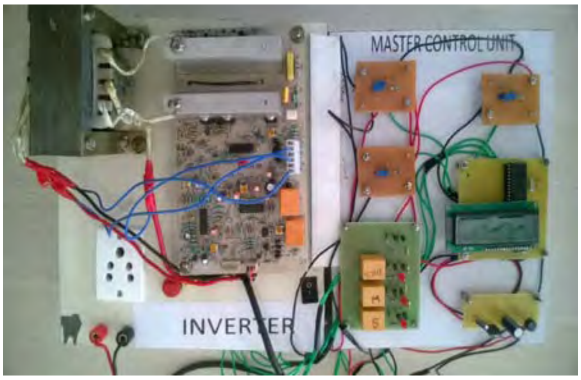

Fig.11 Photograph showing the Supervisory Controller

6. Conclusion

The wind- solar- diesel hybrid power plant with controller is essentially a foolproof method prioritization of charging of a battery from various renewable energy and non-renewable energy sources. The key factor is to enable the microcontroller to monitor the battery voltage and operate with all charging systems like the wind turbine or solar panels or mains/DG based on charge in the battery. This system has been successfully deployed to meet the small energy requirement of an office room in the educational institution. It also reduces the dependence on one single source of power and has increased the reliability. Thus, the hybrid power plant improves the efficiency of the system as compared with their individual mode of generation.

Acknowledgement

The authors would like to thank the Managements of SVS College of Engineering, Coimbatore and Sri Krishna College of Engineering and Technology, Coimbatore for their support.

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