Design and Implementation of a Domestic Solar-Wind Hybrid Energy System

Uğur FESLİ[1], Raif BAYIR[2], Mahmut ÖZER[3]

[1-3]Zonguldak Karaelmas University, Engineering Faculty, Department of Electrical and Electronics Engineering, 67100 Zonguldak, TURKEY ugurfesli@hotmail.com, mahmutozer2002@yahoo.com
[2]Karabük University, Faculty of Technical Education, Department of Electronic&Computer Education
100. Yıl Mah. 78050 Karabük, TURKEY
rbayir@karabuk.edu.tr

Abstract

In parallel to developing technology, demand for more energy makes us seek new energy sources. The most important application field of this search is renewable energy resources. Wind and solar energy have being popular ones owing to abundant, ease of availability and convertibility to the electric energy. This work covers realization of a hybrid renewable energy system for a domestic application, which runs under a microcontroller to utilize the solar and wind power. This project is implemented in accordance with available line-electricity. Batteries in the system are charged by either wind power via a small alternator or solar power via an MPPT Module. System control relies mainly on microcontroller. Power resources and loads in the system are monitored and controlled in real time.

1. Introduction

One of the driving forces for social and economic development and a basic demand of nations is energy. Most of the energy production methods are one-way, which requires change of form for the energy.

In parallel to developing technology, demand for more energy makes us seek new energy sources. Researches for renewable energies have been initiated first for wind power and then for solar power. Efficiency of solar power conversion systems is ca. 18%, whilst that of wind power is ca. 55%. These efficiencies could be increased by 50% with beam tracking, beam focusing and wind direction adaptive motion methods [1].

The aim of this work is design and implementation of a domestic solar-wind hybrid energy system under microcontroller. This work is expected to sustain some part of the daily domestic electricity consumption with an efficient utilization of solar and wind power.

2. Energy Resources

Since the invention of first engine in 17th century, energy consumption has been highlighted due to different causes, such as political, economic, world population based, requirements of new technologies in use.

Persistent increase in the energy demand has caused to seek new energy resources in the world. New alternative energy resources have been also utilized to minimize the energy deficit [2].

This deficit biased trend shows also how our country does depend on foreign energy suppliers. The World Energy Production/ Consumption Profile is show in Figure 1.

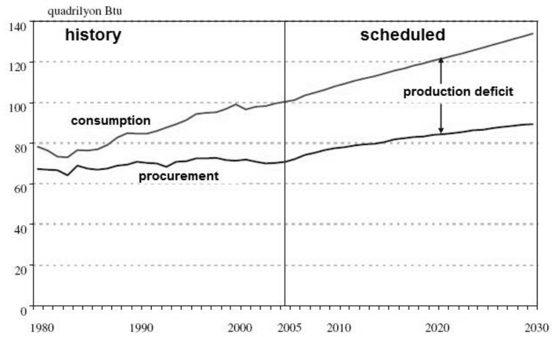

Fig. 1. World Energy Production/ Consumption profile [3]

Energy resources are classified into two groups: primary-unrenewable and secondary-renewable resources, with respect to change in quantitative.

2.1. Unrenewable Energy Resources

Unrenewable energy resources are the ones that decay partially or vanish with the time or needs decades for reuse, such as oil, coal and coal derivatives, natural gas, wood and radioactive atoms (uranium).

2.2. Renewable Energy Resources

Renewable energy resources are the ones that are persistently available and renewing itself with the time. Industrialization and increasing world population has remarked the use of renewable energy resources. Solar power, wind power, biomass, tide power, wave power, geothermal power is known ones.

2.2.1. Solar Power

Solar panels are the medium to convert solar power into the electrical power. Solar panels can convert the energy directly or heat the water with the induced energy. PV (Photo-voltaic) cells are made up from semiconductor structures as in the computer technologies. Sun beam is absorbed with this material and electrons are emitted from the atoms that they are bounded. This release activates a current. Photovoltaic is known as the process between beam absorbed and the electricity induced. With a common principle and individual components, solar power is converted into the electric power.

Solar batteries are produced by waffling p-n semi-conductors. A current-volt characteristic of the PV in the darkness is very similar to that of diot. Under beam, electron flow and current occurs. In closed-loop, PV current passes through the external load. While in open-loop, the current completes the circuit through the p-n diot structure [4].

Solar batteries can be represented with an equivalent circuit of a current source, a resistor and a diot in parallel, and an external load-resistor [5], as seen in Figure 3.

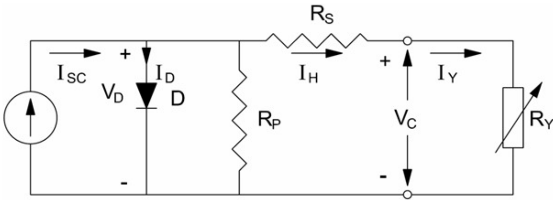

Fig. 3. Equivalent circuit of solar battery

It is possible to insert AC-DC converter, charger, accumulator, extra power source, and controller depending on the design differences in operational and functional specifications [6]. Solar system could be categorized into two types:

Line-independent systems: These are established in absence of line electricity to provide electricity. Since the current in these systems are DC and it must be also available overnight, energy is stored in accumulators, DC-Batteries. In case of AC-Supply requirements for the appliances, it is possible to use DC-AC invertor [6].

Line-dependent systems: These systems do not need DC-Batteries, since the energy is served to the demand with the help of an invertor. Line electricity is being switched in use in case of insufficient sun beam [6].

2.2.2. Wind Power

Wind turbines are used to convert the wind power into electric power. Electric generator inside the turbine converts the mechanical power into the electric power. Wind turbine systems are available ranging from 50W to 2-3 MW. The energy production by wind turbines depends on the wind velocity acting on the turbine. Wind power is used to feed both energy production and consumption demand, and transmission lines in the rural areas.

Wind turbines can be classified with respect to the physical features (dimensions, axes, number of blade), generated power and so on. For example, wind turbines with respect to axis structure: horizontal rotor plane located turbines, turbines with vertical or horizontal spinning directions with respect to the wind. Turbines with blade numbers: 3-blade, 2-blade and 1-blade turbines.

On the other hand, power production capacity based classification has four subclasses [7].

- Small Power Systems
- Moderate Power Systems
- Big Power Systems
- Megawatt Turbines

3. Design and Implementation of Domestic Solar-Wind Hybrid Energy System

Hybrid systems are the ones that use more than one energy resources. Integration of systems(wind and solar) has more influence in terms of electric power production. Such systems are called as “hybrid systems”.

Hybrid solar-wind applications are implemented in the field, where all-year energy is to be consumed without any chance for an interrupt. It is possible to have any combination of energy resources to supply the energy demand in the hybrid systems, such as oil, solar and wind. This project is similar with solar power panel and wind turbine power. Differently, it is only an add-on in the system.

Photovoltaic solar panels and small wind turbines depend on climate and weather conditions. Therefore, neither solar nor wind power is sufficient alone. A number of renewable energy expert claims to have a satisfactory hybrid energy resource if both wind and solar power are integrated within a unique body.

In the summer time, when sun beams are strong enough, wind velocity is relatively small. In the winter time, when sunny days are relatively shorter, wind velocity is high on the contrast. Efficiency of these renewable systems show also differences through the year. In other words, it is needed to support these two systems with each other to sustain the continuity of the energy production in the system.

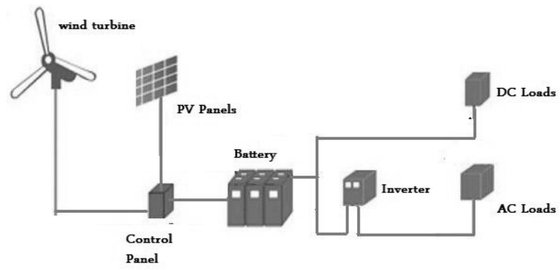

Fig. 4. Hybrid system

In the realized system, a portion of the required energy for an ordinary home has been obtained from electricity that is obtained from the wind and solar power. Experimental setup for the domestic hybrid system consists of a low power wind turbine and two PV panel. Depending on the environmental conditions, required energy for the system can be supplied either separately from the wind or solar systems or using these two resources at the same time is in show Figure 4. Control unit decides which source to use for charging the battery with respect to condition of the incoming energy as seen in Figure 5.

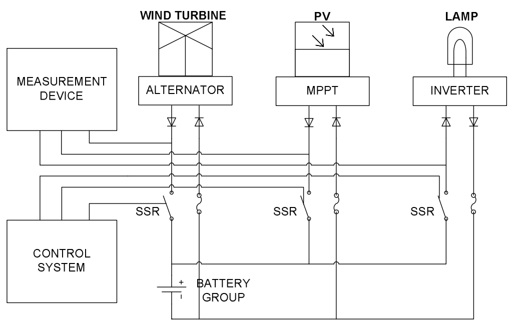

Fig. 5. System block diagram

Wind turbine first converts the kinetic energy to mechanical energy and then converts it to the electricity. The wind turbine in the system consists of tower, alternator, speed converters (gear box), and propeller. and a picture of the constructed hybrid system is show in Figure 8.

The kinetic energy of the wind is converted to the mechanical energy in the rotor. The rotor shaft speed, 1/18, is accelerated in the reduction gear and then transmitted to alternator. The electricity that comes from the alternator can be directly transmitted to DC receivers as well as it can be stored in the batteries.

The solar panels in the system convert the day light directly in to electricity. The properties of the PV module (PM 065, Solen Energy Corporation) in the system are given in the Table 1. below.

Table 1. PV module properties

PMAX (WP)	65
MPP Voltage (V)	16.5
MPP Current (A)	3.94
Open Circuit Voltage (V)	20
Short Circuit Current (I)	4.50

The solar panels can generate major amount of electricity even in the cloudy weathers.

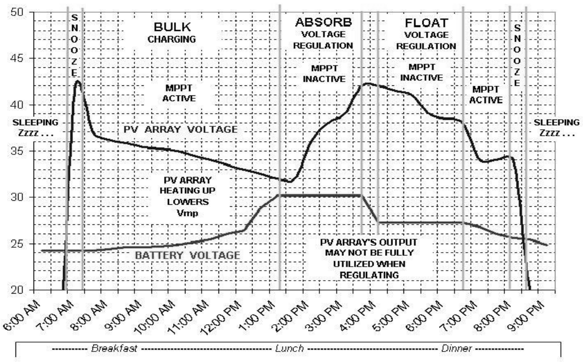

Fig. 6. Typical day in the Life of a MPPT controller charging Batteries[8]

MPPT regulates the energy coming from these panels and ensures a continuous high power generation. The current from the MPPT is used to charge the batter [8]. The system layout for MPPT charge controller (60 PV MPPT Charge Controller, OutBack) is shown in Figure 6.

Control card controls the microprocessor by processing the information coming from all the components in real time. Measurement card simultaneously measures the current and the voltage values of the wind, solar, and invertor systemsThey operate according to line-isolated Hall-Effect principle. In addition, these sensors have high precision (99.2 %), high linearity, high band width, and low response time features [8].

The current sensors used in the system are LTS-25 from LEM Company. They also operate according to Hall-Effect principle and have unipolar voltage feature. Measurement range is expanded. Solid state relays for switching the wind turbine, solar panels, and invertor system are capable of conducting high currents with low supply voltages [9].

The batteries in the system provide to store the electricity that is generated from the wind or the solar power. Any required capacity can be obtained by serial or parallel connections of the batteries. The battery that provides the most advantageous operation in the solar and wind power systems are maintenance free dry type and utilizes the special electrolytes. These batteries provide a perfect performance for long discharges.

The storage and usage of the electricity that is generated from the wind and solar power are controlled in the real time control system. In the domestic type hybrid system, the storage of the electricity from the wind turbine and solar panels is achieved by control card, measurement card and connection card is show in Figure 7.

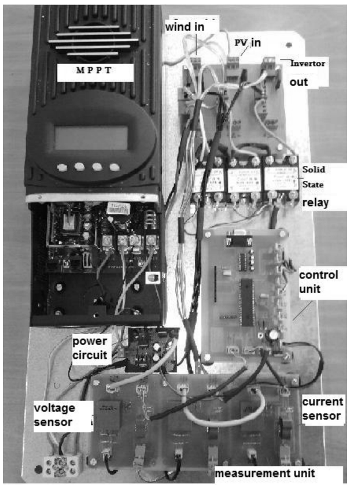

Fig. 7. Control system

Control card controls the microprocessor by processing the information coming from all the components in real time.

Measurement card simultaneously measures the current and the voltage values of the wind, solar, and invertor systems.

A semiconductor (tristor or transistor) with low operating power and low triggering voltage is connected to the input of the system and triggers another semiconductor with high operating power and low triggering voltage. Thus, the relay can switch on/off more quickly than the conventional relays. It is used because of the properties like spark free operation and long operation life.

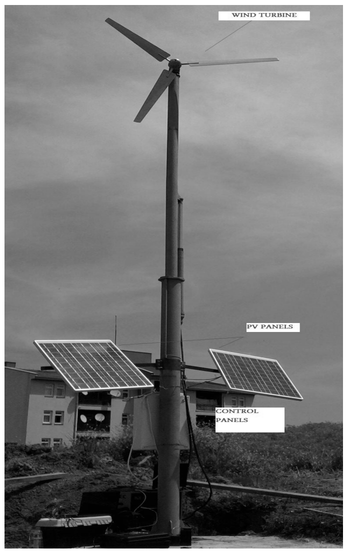

Fig. 8. A picture of the constructed hybrid system

Invertor in the system is used to convert the direct current to 220V alternative current. External invertors can use 12V and 24V direct current from the batteries and by converting it to 220V alternative current, they provide a safe operation for any electrical device. Depending on the output voltage, invertors have different output waves like square wave, modified sinusoidal wave and exact sinusoidal wave. Inentors with the exact sinusoidal wave output is used in the system. Linetech Cotek 300W exact sinusoidal invertors that can automatically turn off in case of the overload, overheating, and high-low battery voltage is used in the system. This inventor can operate to devices up to 300W and has a 400W surge rating.

4. Experimental Results

The current and voltage values from the wind turbine, solar panels, battery group, and load are measured in the implemented system. Production and consumption of power for each module are calculated. Picoscope 3423 measurement equipment used to perform measurements. In order to allow separate chassis, a laptop computer which is disconnected from the power line is used to record the measurement data of the operating system.

4.1. Wind Turbine Electrical Measurements

Measurements were carried on different time of day and different wind speeds for wind turbines. The results for variations in the rotation speed of the turbine blade due to the changing wind direction were recorded. Function of the control card was investigated by measurements for alternator output voltage and different output voltages.

The alternator provides a continuous output of 29V and 250ma for continuous wind blow. Minor disturbances in the direction of the wind cause little depressions in the voltage as shown in Figure 9. There are major decreases in the current value due to variations in the alternator speed. If the wind speed falls below the critical value, the alternator output voltage falls below 24V and the control system take out the wind turbine from the system.

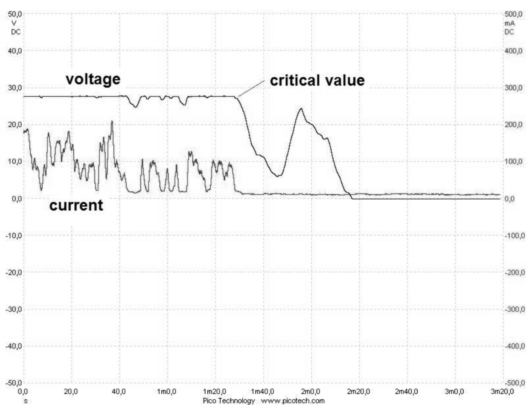

Fig. 9. Measurement values for wind turbine(18 May. 2009)

Special circumstances for variations in the wind force were defined in the control system. As shown in Figure 10, as long as the voltage value, which is depend on the variations in the wind speed, does not exceed the critical value, the system takes out the wind turbine and hence the transfer energy does not occur.

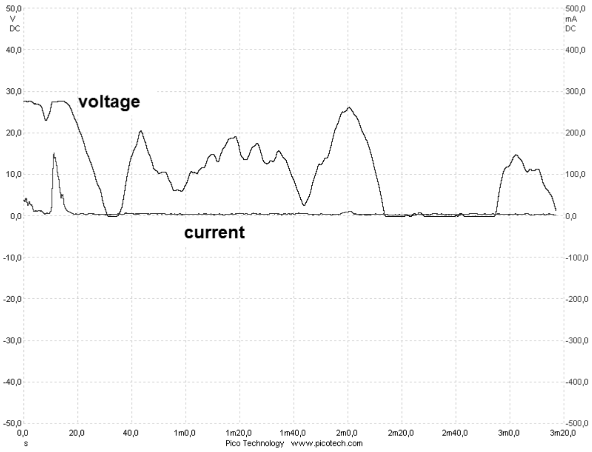

Fig. 10. Measurement values for wind turbine (19 May. 2009)

For the wind turbine to be taken into operation, as shown in Figure 11, the alternator output must remain above the critical level during a certain period of time. In the implemented system, this duration defined as 7 seconds. This value can be replaced by software in the system.

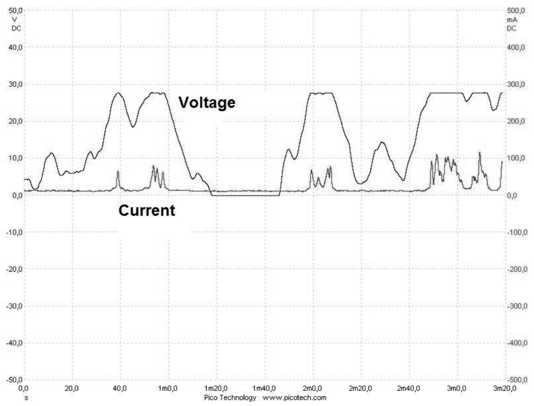

Fig. 11. Measurement values for wind turbine (18 May. 2009)

Fluctuations in the current value of wind turbine can be corrected by current filter of a high power turbine. There is no need any correction in the implemented system.

4.2. Electrical Measurements of Solar Panel

Solar panels were placed stationary. Therefore,measurements were carried out in different time of day since the incoming sunlight has different angles during the day. The input and output of MMPT, and function of control card investigated for output voltage of solar panels and different output voltages.

The measured current and voltage values from the solar panels for the daylight makes a peak, at 10:25am, are shown in Figure 12. MPPT is activated by the control system with switching on the solar panels and capture algorithm starts running to achieve the greatest power value. MPPT finds the peak point by search algorithm in 8 seconds and batteries are charged. In the measurements, it is seen that by deactivating the load, batteries charged at the maximum power point. The voltage value of these panels is 37V and the current value is 0.75A.

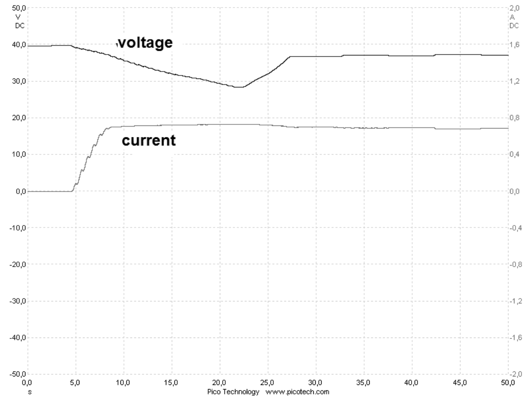

Fig. 12. Measurement values for solar panels (18 May. 2009)

Solar panels integrated to the system after 1.5 minutes when the batteries engaged to the system (Figure 13). To obtain the highest power output from the panel when the battery is being charged, if the load is engaged to the system when 1A current pulled out of the system, the current value in the system raises up to 3.2A. Meanwhile the voltage increases from 27V to 32V. The peak power point search algorithm causes large changes in current between the time interval of 2.5 minute and the 7.th minute.

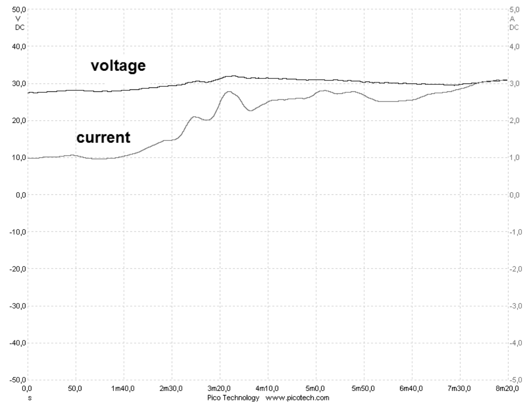

Fig. 13. Measurement values for solar panels (18 May. 2009)

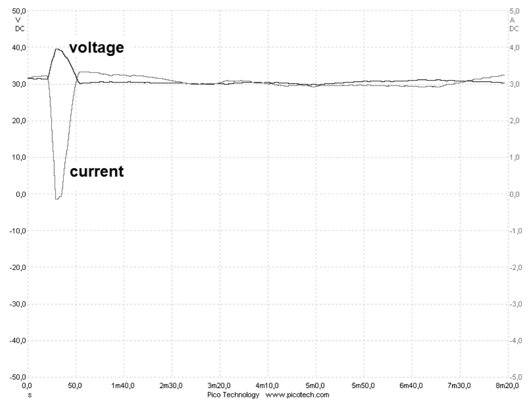

Fig. 14. Measurement values for solar panels (18 May. 2009)

When both the solar panels and the load are engaged to the system at the same time, MPPT continuously keep running the search algorithm as shown in Figure 14. If both the load and battery engaged to the system, this cause an increase in the current which is being pulling out from the system while the voltage values decreases. Measurements which were taken for 8 minutes at the highest sunshine hour, 01:30pm, show that the current changes 0.3A due to the load.

5. Conclusion

In this study, "A Domestic Type Solar-Wind Hybrid System Design and Application" was implemented. A portion of the energy requirement for a home has been supplied with the electricity generated from the wind and solar power. In the implemented system, control card in which the software was developed by experts, decides whether the energy generators would be engaged to the system or not. Real time control of the inputs and outputs was carried out by 3 current sensors and 3 voltage sensors in the system. Maximum power point tracking system used in the MPPT provided optimum benefit from the solar energy

6. References

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