

Control of the Energy Flow with PLC for Fuel Cell Supported Wind and Solar Hybrid Generation System

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ABSTRACT: This paper proposes to provide the energy continuity of a standalone distributed (off-grid) hybrid power system including solar power, wind power and fuel cell. The system has been applied to the lighting system of the laboratories of the Electrical and Electronic Engineering Department in the Afyon Kocatepe University. During the study, the lighting system of the laboratories has been comprised of 2X9 W powered LED. Regarding the components of the hybrid energy generating system, three pieces of 190W powered mono-crystal solar panel, 600W powered wind turbine with three phases have been used. Furthermore, 500 W powered proton exchange membrane fuel cell has been assembled to the system in order to store the energy surplus and to provide energy sustainability for the cases in which the system could not have generated energy from sun and wind. The energy generated in wind turbine and solar panels has been collected in 24 V stable DC bars by means of DC-DC convertors. Afterwards, stable DC voltage has been converted to AC by means of the inverter on the control unit and made ready for the operating voltage of the consumers. PLC (Programme Logic Controller) has been used in order to determine algorithms of the hybrid system. In addition, a Delphi program has been applied in order to create a system interface and to implement data process. Finally, the graphical and the numerical data received from the voltage and current sensors has been monitored.

KEYWORDS: Hybrid Power System, Energy Flow Control, Renewable Energy, Fuel Cell.

I. INTRODUCTION

It is necessary to generate and use energy in environmentally-conscious and climate friendly manner in order to be able to guarantee the life quality of future generations by decreasing the effects of global warming together with economic developments. For purpose of meeting the energy demand, the need for environmentally-conscious renewable energy sources that is considered as an important factor in decreasing of sera gas diffusion, one of the effects of the said global warming, increases further every passing day. With increasing technological innovations and gradually decreasing costs, it has been observed that concern on renewable energy sources increases further every passing day.

Especially, as a result of the concern on energy sources like sun, wind, biogas, geothermal and hydrogen, researches on these areas have become more important[1].

Utilization of the energy sources like sun, wind, biogas, etc that are known as renewable energy sources alone is not much useful in practice in terms of efficiency and effectiveness. For this reason, structures at which such systems are used together come into prominence today. So, studies concluded also demonstrate us this result [2].

The hybrid power generation system is an electric energy generation method constituted by different energy systems that come together and is mostly used with renewable energy systems [3].

The hybrid energy systems can be designed in a manner being operated in parallel with the electric distribution network or being operated fully independently from the network. In recent years, researches and studies made on this area have

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increased. Today, researchers have studied the possibility of hybrid energy systems to meet all the loads to supply the required power [4].

As it is known, though various studies have been made for storing of energy, more cost efficient method other than accumulator groups could not be found. However, as local generation of hydrogen is possible, hydrogen can be one of the most important energy sources in the future in terms of storing technology.

Besides, it is an energy source that can be transported easily and safely to everywhere, exposes to the least energy loss during transportation and can be benefited in every field from transportation vehicles to heating and industry to our kitchens. Though there are many techniques used in obtaining of hydrogen, the mostly known and used technique is the electrolysis of water.

The researchers, in using of hydrogen as an energy source, have focused on fuel cells that demonstrate the lowest environmental impact and the best performance. With this regard, hydrogen and fuel cells are a single technological element complementing each other [5].

The fuel cells are devices at which hydrogen is used as a fuel and with combination of hydrogen and oxygen, chemical reaction occurs and that gives electric, heat and water output as a result of transformation of chemical energy directly to electric energy. Rather than obtaining electric energy by transforming chemical energy to electric energy like accumulators, they are the systems that generate electric energy in every case the hydrogen can be provided [6].

The fuel cells that use hydrogen as a source have technologies that can easily meet the electricity need of houses and work places today. Besides, it can be used as a complementary and auxiliary power in transportation vehicles like car, plane, bus and pickup[7]. The fuel cells, also attractive for constant building applications, take attention with their features in terms of low emission, highelectrical efficiency, silent operation and using whenever it is desired [6].

In this study, by adding a proton exchange membrane fuel cell to the 1200 Watt wind-sun system installed for illumination of two laboratories of Afyon Kocatepe University, Technology Faculty, Electric-Electronic Engineering Department, a hybrid power generation system was designed. Besides, a programmable logic control-base control system was realized in order to be able use the generation and consumption power of the energy generation system that consists of wind-sun and fuel cell more efficiently and effectively.

II. COMPONENTS AND FEATURES OF THE HYBRID POWER GENERATION SYSTEM

In this study, the hybrid power generation system consists of 3 pieces of 24V mono crystal solar panels in power of 190W, a 600W and 3-phase wind turbine with permanent-magnet and synchronous generator that can rotate 360° depending on direction of wind and a 500W fuel cell with variable proton membrane. The fuel cell was used to store the consumption surplus electric energy or to ensure energy continuity in times there was no energy generation. The general view of the system is given in Figure 1.

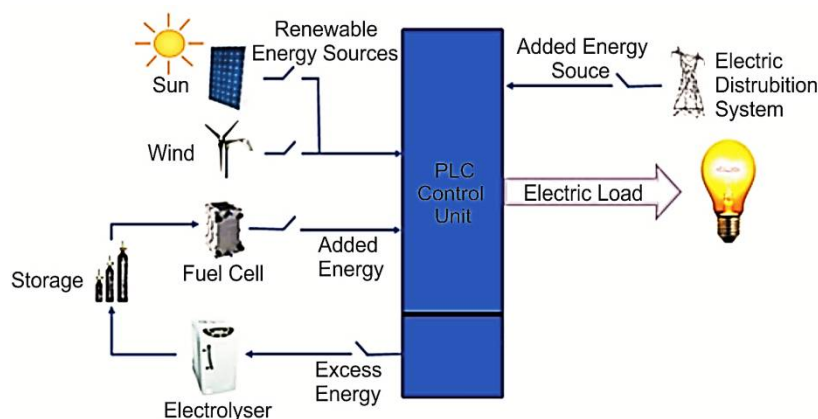


Fig. 1. General view of Hybrid Power Generation System

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III. ENERGY FLOW CONTROL IN HYBRID POWER GENERATION SYSTEM

In the hybrid power generation system, the energy obtained from wind turbine, solar panels and fuel cell was collected in a 24V stable DC voltage bar by means of DC-DC transformers. Then, by being transformed to AC voltage by means of an inverter via a stable DC voltage control unit, it was made suitable for use of consumers.

With the designed and applied PLC -base energy flow control system, the flow of energy data generated from solar panel, wind turbine and fuel cell were arranged. The power LED fluorescent lamps used for general illumination of laboratory were accepted as loads to be fed by the hybrid power generation system. In the hybrid power generation system, the wind turbine and solar panels were assessed as basic power sources.

The system algorithm was designed in a manner that the energy demanded by the load would firstly be met by the energy generated by wind turbine and solar panels. If the wind and/or sun energy systems can meet the energy demanded by load, the fuel cell system is not needed.

In the event that the energy generated by the wind turbine and solar panels cannot meet the energy needed by the load, the fuel cell will be activated actively according to the designed energy flow control system and supply the energy demanded by the load.

The surplus energy, in case the energy generated by the wind turbine and solar panels, one of the components of the hybrid energy generation system, is more than the energy needed by fluorescent lamps used for illumination of the laboratory, was used effectively. For this purpose, the surplus energy was used in obtaining of hydrogen gas by feeding the hydrogen generator. This obtained hydrogen gas was stored in the hydrogen tube and so, the surplus energy was not used unnecessarily.

The algorithm showing the activation order and logic of the generated and demanded power from hybrid power generation sources, depending on the size of power, is given in Figure 2. The control algorithm realized for effective and efficient use of energy is given in Figure 3.

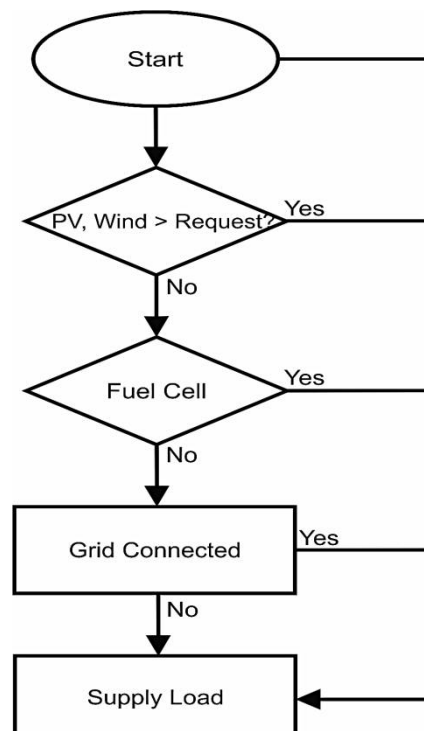


Fig. 2. The algorithm showing the activation order and logic of the generated and demanded power from hybrid power generation sources.

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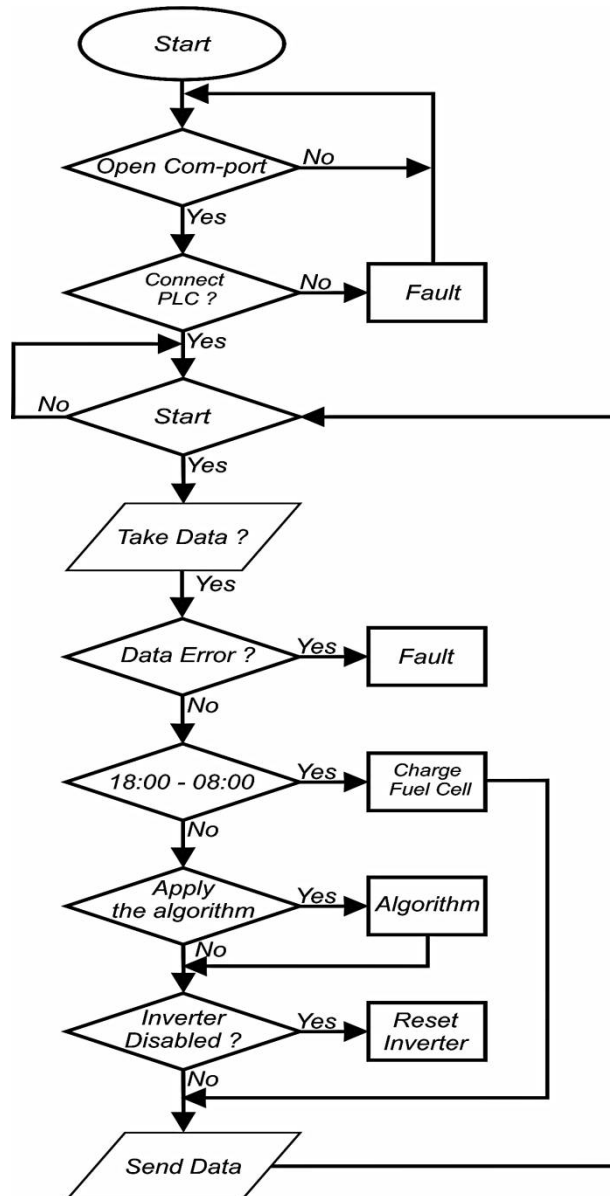


Fig. 3. The control algorithm realized for effective and efficient use of energy.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

In the realized study, firstly, ensuring of uninterrupted energy supply independently from network in the control system designed for the installed hybrid power generation system was studied.

When the energy generation performances of the sun, wind and fuel cell supported hybrid power generation systems independent from the network are considered from point of view that they are the basic energy sources of sun and wind energy generation systems, it is known that the power to be generated from such systems depend on meteorological conditions. For this reason, it is obligatory to establish energy management strategies to control the

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operation of elements constituting the system in the best manner and to use the generated energy effectively. The purpose of the energy control system is to provide the energy need of loads without interruption. While this process is being realized, the energy efficiency of fuel cell must be kept high and activation-deactivation frequency must be decreased. If the activation-deactivation frequency of the fuel cell that is a standby power unit at hybrid power generation system becomes lesser, it is thought that their operating life will be longer. The main factors that affect the energy flow management strategy at the hybrid power generation systems are amount of power obtained from renewable energy systems and fill rate of hydrogen tubes that provide energy to the fuel cell system.

In this study, the data about the energy generated by the hybrid power generation system and consumed energy were taken between dates of August 1, 2014- December 31, 2014. The data about the generation and consumption units were recorded in every 10 seconds until 18:00 in the computer environment starting from 08:00. After 18:00, the system was designed for hydrogen generation of hydrogen generator if it was needed. The energy data generated in monthly basis are shown separately as sun, wind and fuel cell in Table 1 below. Besides, generated energies are given graphically in Figure 4.

Table 1 Energy amounts generated in monthly basis.

| Months | Sun (Wh) | Wind (Wh) | Fuel Cell (Wh) |
|-----------|-----------|-----------|----------------|
| August | 61.054,80 | 1.595,00 | 5.618,00 |
| September | 55.300,00 | 620,60 | 4.494,40 |
| October | 58.503,00 | 2.534,60 | 4.868,93 |
| November | 43.758,50 | 2.517,20 | 3.745,33 |
| December | 33.097,26 | 4.860,80 | 5.992,54 |

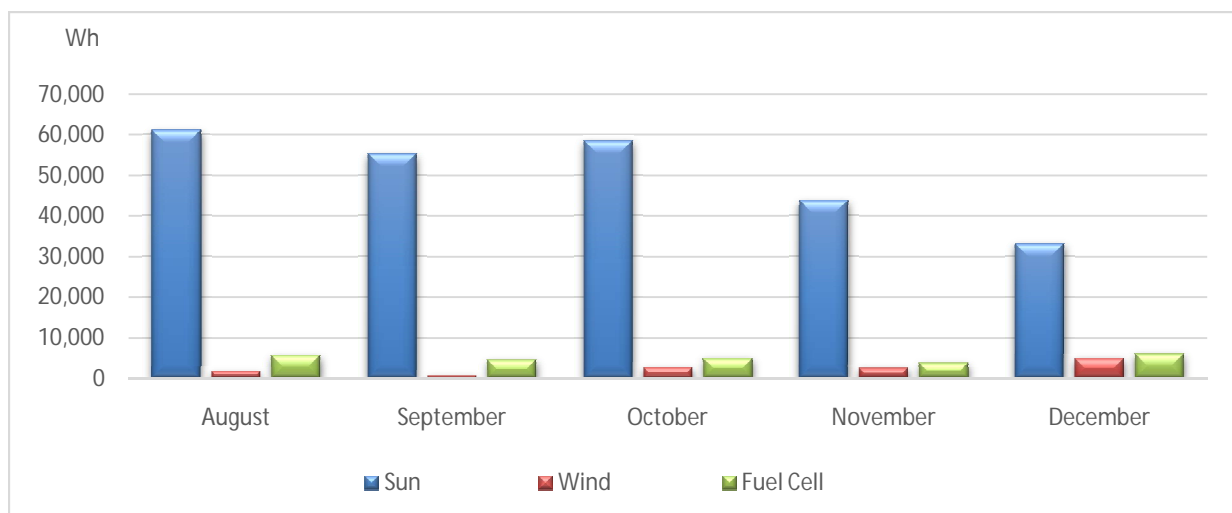


Fig. 4. Energy amounts generated in monthly basis in the hybrid power generation system

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In this study, wind exposing potential of the position and height of the wind turbine was low and this also reflected on the obtained power values. For this reason, on some days, no energy generation could be obtained from the wind turbine.

However, as the energy flow of the system was designed dynamic (according to the generated and consumed power), rapid activation and deactivation of energy generation sources became important. For this reason, for the switching systems on the control unit, initially 24V DC, 30A power relays that can react in 15ms were used. Then, this switching system was replaced with switching circuit having 1,5 μ s reaction time consisted of semiconductor circuit components mosfets to ensure energy continuity in the most suitable manner.

V. CONCLUSION

The main factors that affect the energy flow management strategy at the hybrid power generation systems are amount of power obtained from renewable energy systems and fill rate of hydrogen gas in hydrogen tubes for the fuel cell used under the scope of this study.

In this study, management strategies of a hybrid power generation system independent from network were studied. So, how uninterrupted energy flow in the energy demand system can be provided was emphasized. Besides, necessary studies to enable integration of the system with the electricity distribution network when necessary were made. Thanks to this, with the algorithm designed in case of operation together with the electricity network, it was considered to extend the life time of fuel cell by putting under control the activation conditions and frequency of the fuel cell. Besides, it was ensured to generate hydrogen from surplus electric energy generated from solar panels and wind turbine by means of electrolyser in order to be used in the fuel cell and be stored in tubes. With the used PLC system, changes such as activation orders, activation frequencies of energy sources were assessed depending on the situation.

VI. ACKNOWLEDGEMENTS

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