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Design and Implementation of Wind Speed/Solar Radiation Hybrid Energy Station Connected with the Network

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ABSTRACT

In this study, a new hybrid power plant is designed to convert solar and wind energy into electricity. Wind speed and solar radiation measurements were made in the different sections of Mersin Province. In the designed power plant, the energy obtained by tracing the direction of the sun and the wind is stored in accumulator groups. As soon as the accumulator groups are full, the generated energy is either transferred directly to the plateau houses or transferred to the network to produce a continuous energy production. This provides a continuous power flow between the power plant and the network. For this purpose, two boost converters were built to connect the electric power from the wind turbine and the solar panels. The boost converters are designed to operate parallel to each other and to keep the output power continuously at the maximum level. Both converters are controlled via a micro controller. It is demonstrated by this work how to make and select the location of high efficiency wind-solar hybrid power plant anywhere in the world. This designed and implemented power plant generated energy can be stored and energy surplus to the existing interconnection system can be transferred to obtain financial gain.

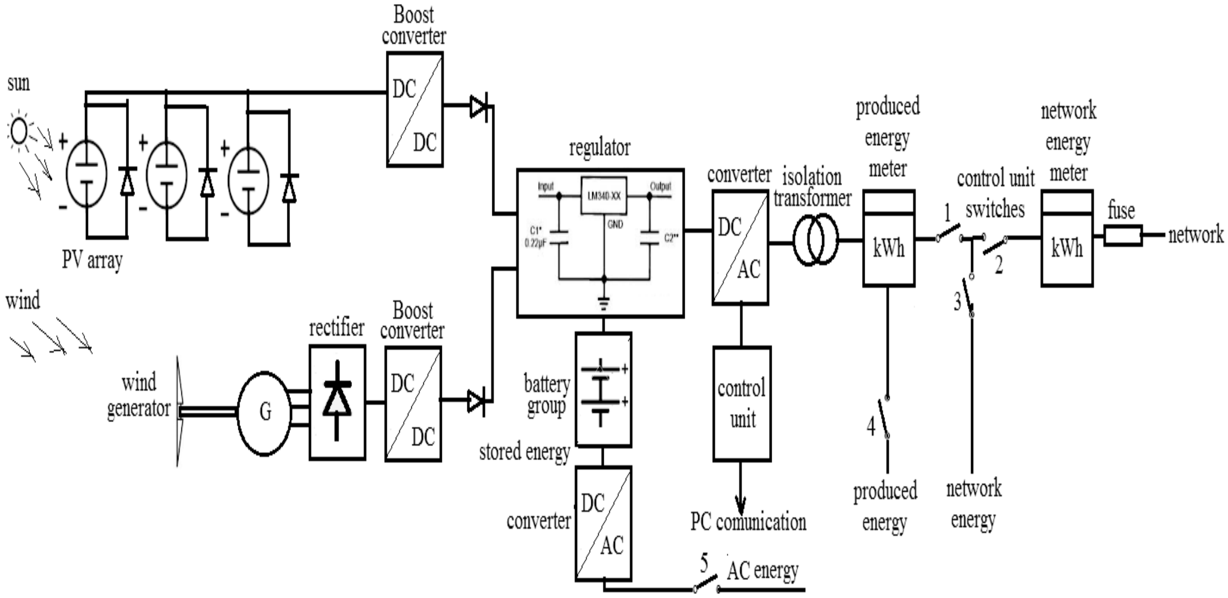
Keywords: Hybrid energy station; wind speed; solar radiation; renewable energy.

INTRODUCTION

Industrialization is increasing rapidly in Turkey. This has increased the amount of energy consumption per capital. Increasing the amount of energy consumption shows the importance of energy. When we look at Turkey's current energy potential, it is understood that nearly 72% of energy demand met from imported sources. Turkey's energy demand from domestic sources appears to provide a small amount. It is understood that renewable energy sources must be used effectively and efficiently. When the energy potential of Turkey is examined, it is seen after the coal to renewable energy sources. Turkey in terms of renewable energy sources, hydro, wind, solar, geothermal and biomass energy is significantly richer. The most important share of renewable energy is hydroelectric and biomass energy production in Turkey. Wind and solar energy are not utilized in sufficient quantities. Solar and wind energy is a clean, continuous source of energy that does not pollute the environment. Solar and wind energy has huge potential in Turkey. For these reasons solar and wind energy is very important in Turkey. One of the world's most important problems is the use of natural energy resources in a way that does not pollute the environment efficiently and efficiently (Razykov et al., 2011 & Shayani et al., 2011). Energy and environment are two factors that humanity cannot give up today. The environmental pollution as energy production and consumption increases. Both problems must be solved. In terms of sustainable environment, the use of clean energy sources is needed. Increasing use of renewable energy sources constitutes an important potential for our country in this respect. It can make a significant contribution to the country's economy and to the reduction of environmental pollution (Messenger et al., 2010, Coelho et al., 2012 & Rosell et al., 2006). Renewable energy sources as solar and wind energy are emerging and developing rapidly. Solar and wind energy systems are continuous and infinite energy sources with zero emissions. Coastline in terms of Turkey, regardless of geographic features such as mountain valley structure will be taken into consideration. It is understood that there is a significant potential of wind energy. In practice, systems in which more than one energy source is brought together are called hybrid systems (Carrero et al., 2010 & Katsanevakis et al., 2011). The goal in hybrid systems is to increase energy efficiency by providing energy sources together and to ensure that others are able to meet the energy needs of the system in the event that one of them fails or diminishes (Carrero et al., 2010 & Tomisa et al., 2011). Hybrid system components can be created by combining two or more sources. For example, there are hybrid energy system applications where energy sources such as sun, wind, fuel and hydrogen are put together. The most important factors that determine the number of sources and the type of source in such applications are the sufficiency of the source of energy to be produced and the sufficient level of technology to bring the system together in some types of energy (Pasicko et al., 2012 & Kaldellis et al., 2012).

MATERIALS AND METHODS

The wind speed and solar radiation potential for the purpose of energy production were determined and analyzed in the Gulnar district of Mersin province. First, potential identification studies were conducted with the data received and the results are analyzed according to the month. Solar and wind follow-up mechanisms have been used to increase the use of the solar and wind energy potential. In this study, a hybrid system was created in which the solar and wind energies were brought together. The aim of this study is to transfer the generated energy to the parallel energy network and battery pack if the energy is more than the energy consumed. However, if the energy produced does not meet the energy consumed, the necessary energy is supplied from the battery pack. In the districts of Mersin Province, a hybrid power plant will be designed which can convert solar energy and wind energy into electricity energy. For the place where the solar panels and wind rose will be established, researches will be done in the districts of Mersin province and data will be collected for the installation of the system. In this study, the hybrid power plant in which wind and solar energy were used jointly, was designed and applied. The block diagram of the applied system is given in Figure 1.



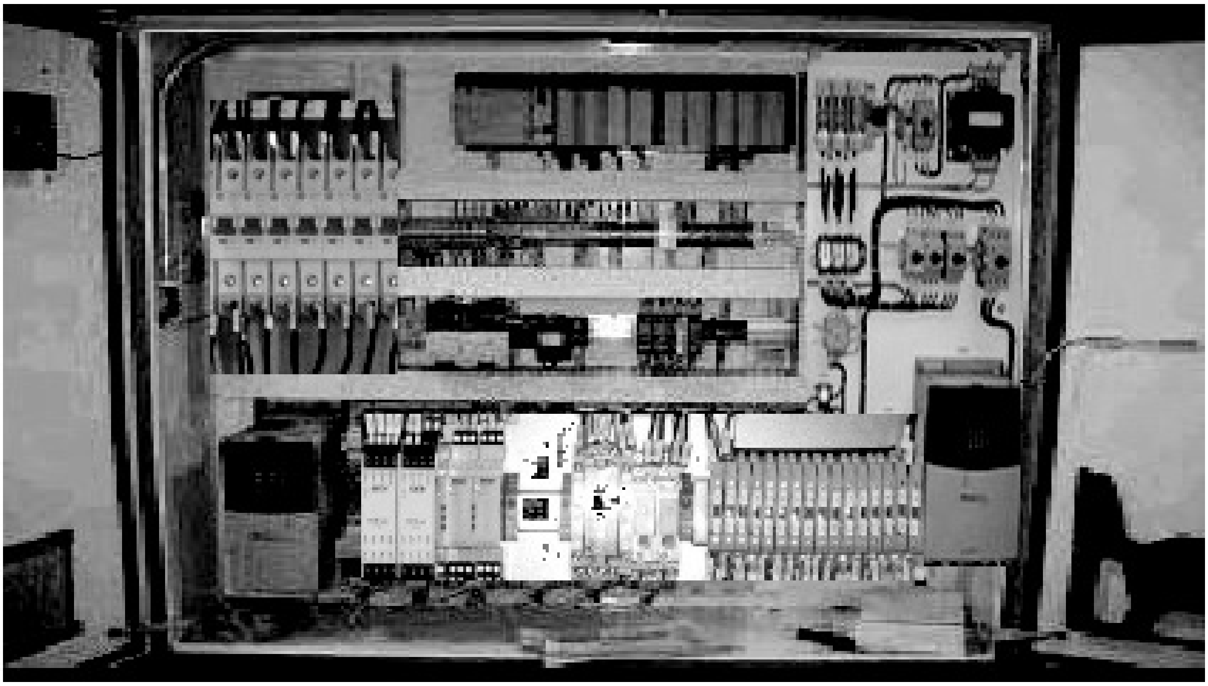


Figure 1. Block diagram of the designed and applied hybrid energy system.

The system consists of solar battery, wind turbine, battery group and electronic circuits that allow these units to work together in harmony. Solar tracking system has been used to maximize the use of solar energy. Power capacity of the created system is 7 kW. Direct current motor and strip led are used as DC load. Power capacity of the wind turbine used in the system is 5 kW. Its output voltage is 50 Volts. Its switching wind speed is 3 m/s. The solar panel used in the system has 0,5 kW power and the output voltage 32 volts. The system is formed by using accumulators, inverters, battery charge control devices and various electronic circuits. The solar panels and wind will be installed in the space where solar radiation and wind speed are the highest. Receiver connections will be implemented during the experiment. Solar and wind tracking system will be established from 14 sensors and servo motors. This will ensure that the energy from the sun and wind is at the highest level. The correct voltage from the solar panels will be transferred to the bar via the boost converter. Photovoltaic batteries are connected to each other in parallel to increase output power. Current, voltage and power information of these units will be recorded. DC bus voltage will be kept at constant value. The battery pack will be charged under the control of the microcontroller, with both the charger and the load connected to the charger. The energy from the battery bank or the boost converter will be converted to AC voltage by the help of the DC/AC inverter. Thus, the load will be supplied. Other components of the system, inverter and converter, battery charging unit, communication modules and other electronic circuits are combined. The amount of energy obtained during the operation will be recorded with the help of counters. It will be possible to obtain financial gain by transferring to the network with the help of switches by the control.

LOCATION DETERMINATION BY WIND SPEED/SOLAR RADIATION MEASUREMENTS

The geographical structure of the area where the solar measurement station is to be installed is important for determining potential and feasibility by measuring total and direct solar radiation, wind speed and direction, temperature, pressure, and humidity. When the solar radiation and wind speed measurement station are selected, the height of the solar measuring station and the height of the tree or rock closest to the installation site are taken into account (Shamsi et al., 2014 & Chen et al., 2007). It has been noted that the height of measuring station should be at least ten times the height of the elevations around it (Daraban et al., 2014 & Malla et al., 2014). It must be at least 5 degrees horizontally during sunrise and sunset (Tseng et al., 2013). So, it can receive the sun's rays and wind. Wind speed/solar radiation measuring station is shown in Figure 2.

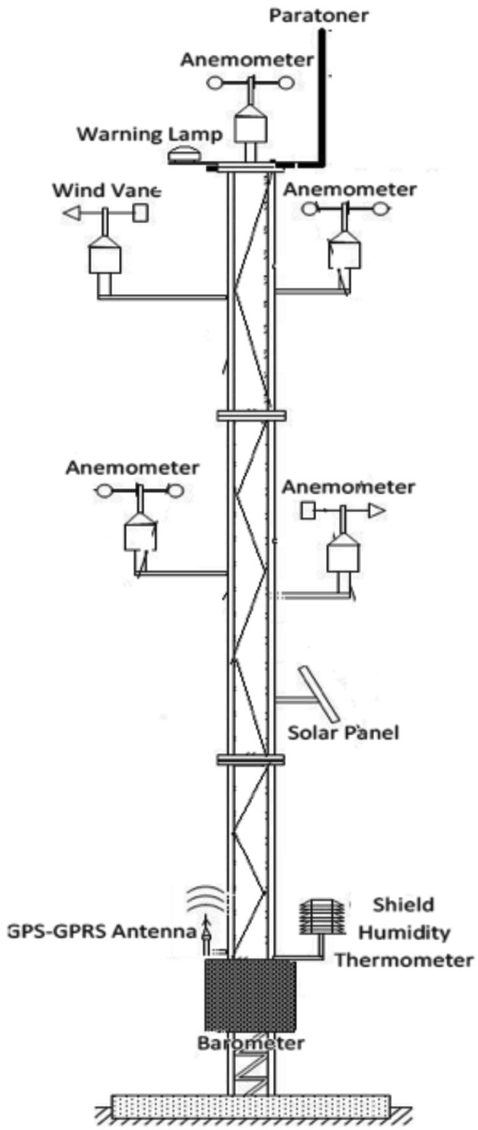


Figure 2. Wind speed/solar radiation measuring station.

The solar measuring station to be installed consists of pyranometer, solar tracker, pyrheliometer, anemometer, wind direction sensor, thermo-hygrometer, solar panel, charge regulator, data logger and measuring meter of 5 meters height. The total solar radiation is measured by devices such as pyramid, action graph or solar meter. Direct solar radiation intensity is measured by pyrheliometer. Diffuse solar radiation intensity is measured by piranha instruments using shadows or bands. Total solar radiation is calculated as the sum of direct, diffuse and reflected radiation from the inclined surface. Annual total solar energy potential measured in districts of Mersin Province is shown in Figure 3.

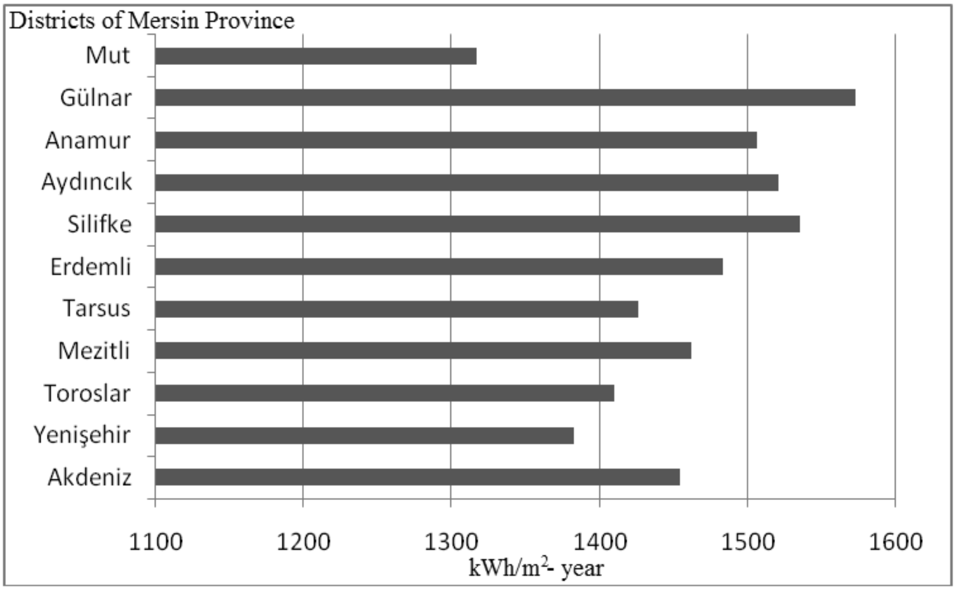


Figure 3. Annual total solar energy potential (kWh/m^2-year) measured in districts of Mersin Province.

Annual total sunrise time measured in districts of Mersin Province is shown in Figure 4. Annual wind speed average value measured in districts of Mersin Province is shown in Figure 5. When the measured radiation values in Mersin’s districts are examined, the least radiation area is Mut and Yenisehir region. These regions have both latitude and humidity. The excess water vapor in the atmosphere causes the radiation to shade.

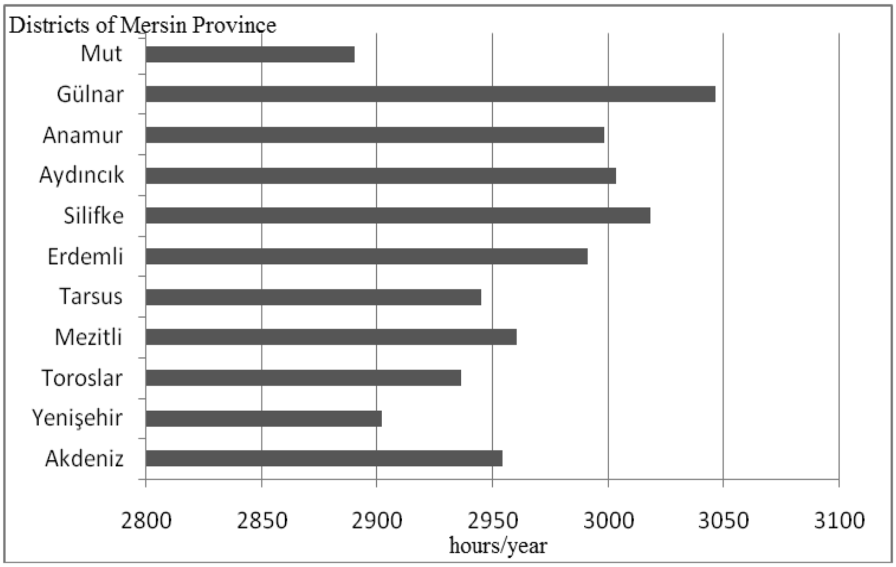


Figure 4. Annual total sunrise time (hours/year) measured in districts of Mersin Province.

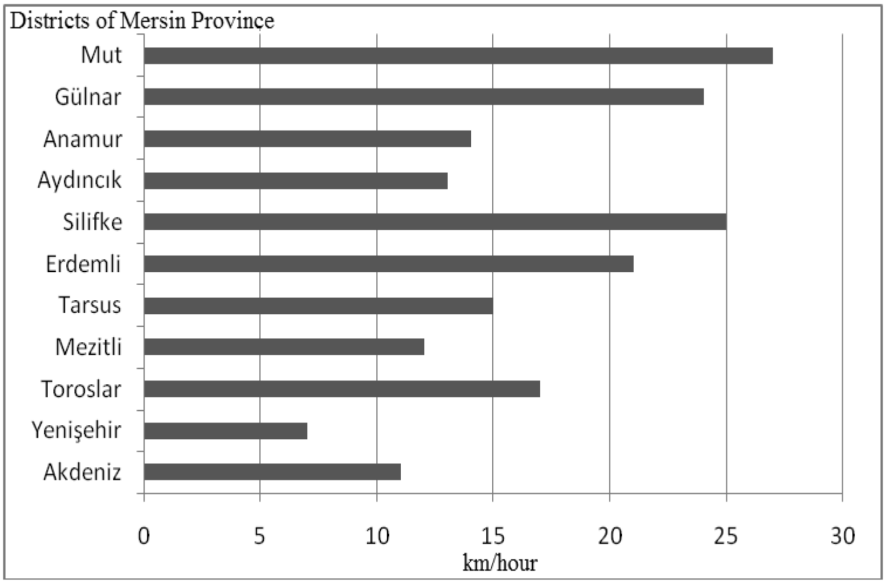


Figure 5. Annual wind speed average value (km/hour) measured in districts of Mersin Province.

Anamur, Aydincik and Erdemli region are slightly better than Mezitli, Akdeniz and Tarsus. Aydincik and Silifke receive moderate radiation. It is understood that Gulnar region has the best radiation values. Gulnar region is the place with the highest radiation in winter with cold climes according to other regions. The altitude is high. The water in the air cools in the form of steam, rain and snow, and the atmosphere is clearer and the beam curtain is the least. When the measured wind speed values in Mersin's provinces are examined, the least windy region is Yenisehir and the Mediterranean districts. Mut, Silifke and Gulnar region wind speeds are understood to be the best regions. The installation site of the hybrid power station is the best Gulnar region, which is the best solar radiation and one of the best three in wind speed.

TRACING THE DIRECTION OF THE SUN AND THE WIND

System diagrams of tracing the direction of the sun and the wind are shown in Figure 6.

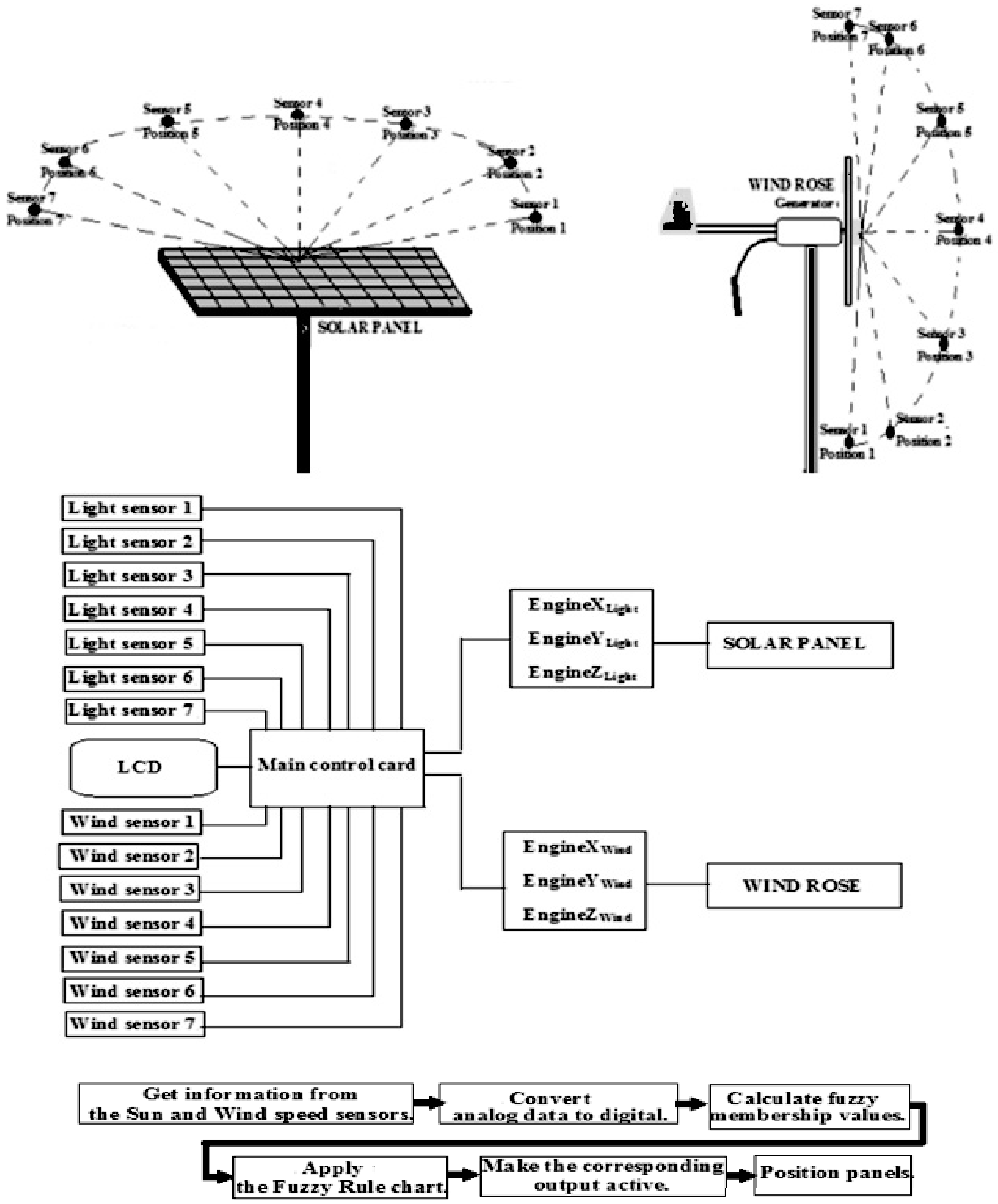


Figure 6. System diagrams of tracing the direction of the sun and the wind.

A solar and wind direction tracking system has been established in order to benefit from the solar panels and the wind rose with maximum efficiency. With the solar and wind tracking system created, it is ensured that the sun rays are directed perpendicularly to the photovoltaic surface and the wind motions are directed to the wind rose. The amount of energy obtained by this method is increased by 30-40%. Created fuzzy logic software for tracing the direction of the sun is shown in Figure 7.

- If LS1 is L and LS2 is L and LS3 is L and LS4 is L and LS5 is L and LS6 is L and LS7 is L then Output is P1
- If LS1 is N and LS2 is L and LS3 is L and LS4 is L and LS5 is L and LS6 is L and LS7 is L then Output is P1
- If LS1 is H and LS2 is L and LS3 is L and LS4 is L and LS5 is L and LS6 is L and LS7 is L then Output is P1
- If LS1 is L and LS2 is N and LS3 is L and LS4 is L and LS5 is L and LS6 is L and LS7 is L then Output is P2
- If LS1 is L and LS2 is H and LS3 is L and LS4 is L and LS5 is L and LS6 is L and LS7 is L then Output is P2
- If LS1 is L and LS2 is L and LS3 is N and LS4 is L and LS5 is L and LS6 is L and LS7 is L then Output is P3
- If LS1 is L and LS2 is L and LS3 is H and LS4 is L and LS5 is L and LS6 is L and LS7 is L then Output is P3
- If LS1 is L and LS2 is L and LS3 is L and LS4 is N and LS5 is L and LS6 is L and LS7 is L then Output is P4
- If LS1 is L and LS2 is L and LS3 is L and LS4 is H and LS5 is L and LS6 is L and LS7 is L then Output is P4
- If LS1 is L and LS2 is L and LS3 is L and LS4 is L and LS5 is N and LS6 is L and LS7 is L then Output is P5
- If LS1 is L and LS2 is L and LS3 is L and LS4 is L and LS5 is H and LS6 is N and LS7 is L then Output is P6
- If LS1 is L and LS2 is L and LS3 is L and LS4 is L and LS5 is L and LS6 is H and LS7 is L then Output is P6
- If LS1 is L and LS2 is L and LS3 is L and LS4 is L and LS5 is L and LS6 is L and LS7 is N then Output is P7
- If LS1 is L and LS2 is L and LS3 is L and LS4 is L and LS5 is L and LS6 is L and LS7 is H then Output is P7
- ……………………………………………
- ……………………………………………

Figure. 7 Created fuzzy logic software for tracing the direction of the sun.

Created fuzzy logic software for tracing the direction of the wind rose is shown in Figure 8.

- If W1 is L and W2 is L and W3 is L and W4 is L and W5 is L and W6 is L and W7 is L then Output is P1
- If W1 is N and W2 is L and W3 is L and W4 is L and W5 is L and W6 is L and W7 is L then Output is P1
- If W1 is H and W2 is L and W3 is L and W4 is L and W5 is L and W6 is L and W7 is L then Output is P1
- If W1 is L and W2 is N and W3 is L and W4 is L and W5 is L and W6 is L and W7 is L then Output is P2
- If W1 is L and W2 is H and W3 is L and W4 is L and W5 is L and W6 is L and W7 is L then Output is P2
- If W1 is L and W2 is L and W3 is N and W4 is L and W5 is L and W6 is L and W7 is L then Output is P3
- If W1 is L and W2 is L and W3 is H and W4 is L and W5 is L and W6 is L and W7 is L then Output is P3
- If W1 is L and W2 is L and W3 is L and W4 is N and W5 is L and W6 is L and W7 is L then Output is P4
- If W1 is L and W2 is L and W3 is L and W4 is H and W5 is L and W6 is L and W7 is L then Output is P4
- If W1 is L and W2 is L and W3 is L and W4 is L and W5 is N and W6 is L and W7 is L then Output is P5
- If W1 is L and W2 is L and W3 is L and W4 is L and W5 is H and W6 is N and W7 is L then Output is P6
- If W1 is L and W2 is L and W3 is L and W4 is L and W5 is L and W6 is H and W7 is L then Output is P6
- If W1 is L and W2 is L and W3 is L and W4 is L and W5 is L and W6 is L and W7 is N then Output is P7
- If W1 is L and W2 is L and W3 is L and W4 is L and W5 is L and W6 is L and W7 is H then Output is P7
- ……………………………………………
- ……………………………………………

Figure 8. Created fuzzy logic software for tracing the direction of the wind rose.

The boundaries of the membership linguistic values are L ‘low’, N ‘normal’ and H ‘high’. Linguistic position symbols are P1 ‘position 1’, P2 ‘position 2’, P3 ‘position 3’, P4 ‘position 4’, P5 ‘position 5’, P6 ‘position 6’ and P7 ‘position 7’. Linguistic light sensor symbols are LS1 ‘sensor 1’, LS2 ‘sensor 2’, LS3 ‘sensor 3’, LS4 ‘sensor 4’, LS5 ‘sensor 5’, LS6 ‘sensor 6’ and LS7 ‘sensor 7’. Linguistic wind rose sensor symbols are W1 ‘ sensor 1’, W2 ‘sensor 2’, W3 ‘ sensor 3’, W4 ‘sensor 4’, W5 ‘sensor 5’, W6 ‘sensor 6’ and W7 ‘sensor 7’. The primary purpose of our system is to maximize the benefit from the sun’s rays and the thrust of the wind as much as possible. The better our panel gets the sun’s rays and the windy thrust, the better is the system performance. The purpose of the study is to detect the location of the sun and the wind and to get the solar panels and the wind rose to the exact required position by ‘the seven light sensors and seven wind detectors’ used in created system. Solar panels and wind rose are used for energy production. There are six stepper motors to position the solar panel and the wind. The system uses the PIC16F877 control card for fuzzy logic control and the LCD display for status information of the system. In addition to the components of this equipment, there is also C sharp program embedded in the microcontroller that allows the system to function.

The logic of our program's algorithm is as follows; the membership grades and values of each sensor are determined according to the information from the sensors. The specified membership values are recorded in the relevant part of the database. The location information and values are saved in the database where it is separated from the database. These values are constant in each case. The program sections for each rule are passed. These sections include the conditions set out in the rules. The minimum sensor value determined in each rule section is multiplied by the position constant and stored in the relevant memory area as the rule result value. The rule result values and the rule minimum values that are found when all the rules are completed are collected separately and these sum values are saved in the relevant memory area. The total rule value found is divided by the total rule minimum value and the corresponding output port is activated according to the value obtained. The seven light sensors in the system were used to track the movement of the sun. The seven wind sensors were used to track the movement of the wind. The movement of the sun is taken as the axis of east-west axis. This axis is divided into four divisions of 45 degrees and seven different points of motion. The position of the panel and the wind rose is fixed to the movement regions determined by the information sent by the sensors to the control system.

DESIGN OF HYBRID ENERGY STATION CONNECTED WITH THE NETWORK

It is understood that the power obtained from the solar panels has changed depending on the angle of view of the sun, the duration of sunbathing and the temperature. The curves for the output characteristic behavior of the panel at various sun values are given in Figure 9.

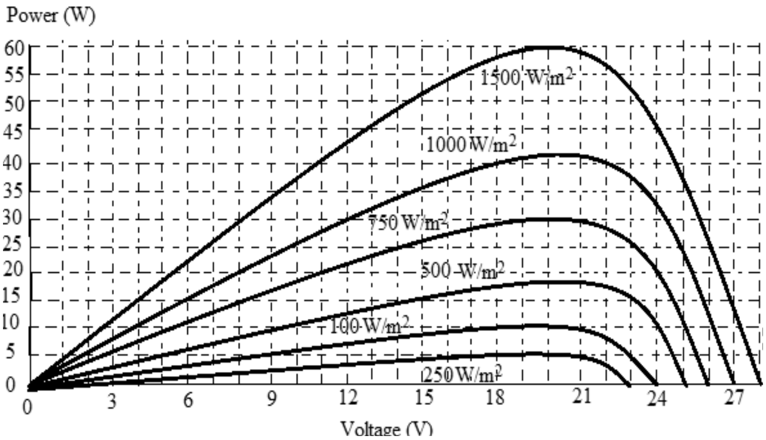


Figure 9. Voltage-power curve of 2 kW solar panels.

It is understood that as the amount of sunbathing in the unit area increases, the power value obtained from the panel increases as the relationship between the power and the voltage applied is increased. It is understood that the panel voltage and current values change when the solar panel changes the surface temperature. When the panel voltage and current values change, the generated power values change. 5 kW wind turbine was used in the system. The alternator speed is measured at various wind speeds. Curves were created to compare the output power obtained at different wind speeds. By using these generated curves, the maximum power points of the turbine have been determined. The settings in the generated hybrid system are arranged according to these curves. The velocity-output power curve obtained as a result of the measurements made is given in Figure 10.

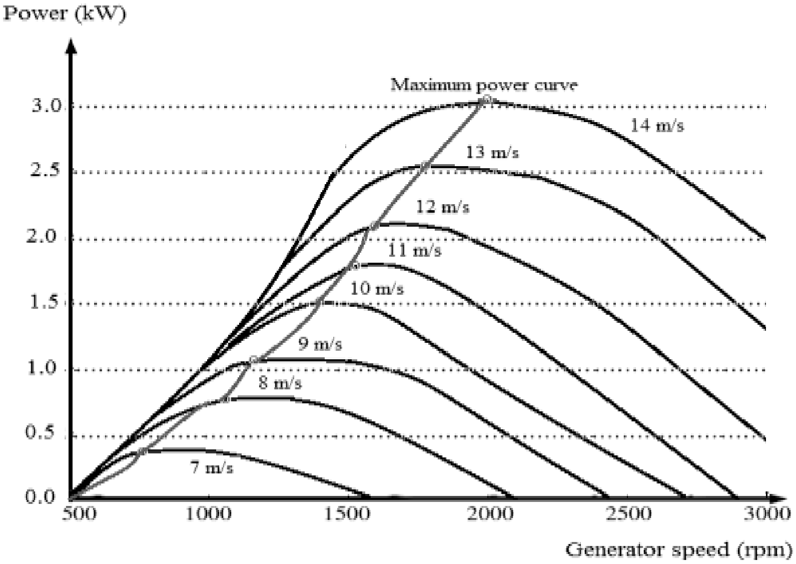


Figure 10. Speed-power curve of a 5 kW wind turbine.

In this system, the wind turbine and the electric energy obtained from the solar panels are combined in the same direct current copper bar. Two raised converters have been designed to be used for directing to the load with the aid of the inverter. The battery pack is charged with the converter output voltage to store the energy. More electricity is supplied to the network with the help of an inverter that can operate in parallel with the network. The system that is being designed works at the same time as an uninterruptible power supply. Thus, if the electricity energy is more than necessary, the user can make an economic contribution by selling excess energy to the network system. In the applied system, the electric power obtained from the wind turbine and solar panels is combined. The converters are able to operate in parallel with each other. The resulting output is designed to keep the power constantly at maximum level. Both converters are controlled via a micro controller.

Current and voltage information of the system are evaluated here. There is one control circuit for both and voltage information of the system is evaluated here. There is one control circuit for both systems in order to collect the energy produced in the solar panels and the wind turbine as data and to intervene with the systems via the computer. These control circuits are connected to computers via RS485 and RS232 lines. Interfaces were created in Visual C Language for computer system control. The system was run during the day during the follow-up, control, and recording phases. The interface card is designed to communicate between the parts of the system and the program of this card is written in PICC language. By this card, the voltage information from the solar panels and the battery group is evaluated when the charge unit is started and stopped. In addition, the charging voltage of the battery pack is sufficient when the battery is full. The voltage from the panel is transferred to the converter. Data collection was done for a period of about a month about the sun and the wind.

CONCLUSION

The solar radiation and wind speed capacity in the districts of Mersin were determined in the measurement station. The direction and speed of the wind, the quantity and duration of solar radiation, pressure, humidity and temperature were recorded in the data recorder in the measurement area. According to the data obtained, it was decided to install the hybrid energy production station in Gulnar district. In the hybrid energy production system established in Gulnar district, it is understood that the solar power of the hybrid power system depends on the environmental conditions and changes over time, as well as the fact that the wind changes during the day, making it difficult to maintain the uninterrupted power supply with these systems. Solar and wind tracking system is installed with stepper motors. The fuzzy logic software was created to control stepper motors. The maximum solar radiation and wind speed obtained by the created solar and wind tracking system have been converted into electrical energy. A total of 7 kW of electrical energy was obtained from 5 kW wind rose and from 2 kW solar panels. A highland house was supplied by using DC/AC converters. It is stored with the batteries used in the system during the periods when electricity energy is not consumed. By the parallel network system created, it is possible to transfer energy to the network during the time when the batteries are full. The created system is a prototype. In case of using more capacity wind rose and more solar panels, the desired capacity will be produced. The created hybrid energy generation systems are using places where power transmission is difficult and costly. It is possible to use this system in places far from the settlements where the electric network does not reach. Renewable energy investments in Turkey should be increased. Wind-solar exploitation of the potential will primarily reduce outsider dependent energy policies. In addition, the production of renewable energy systems in the development of the industry should be adopted as a state policy. Supporting the energy sector with incentives, development of domestic small wind turbines is important in business area and employment.

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تصميم وتنفيذ محطة طاقة هجينة تعمل بسرعة الرياح / والأشعة الشمسية المتصلة بالشبكة

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الخلاصة

في هذه الدراسة، تم إنشاء محطة جديدة للطاقة الهجينة لتحويل الطاقة الشمسية وطاقة الرياح إلى كهرباء. أُجريت قياسات لسرعة الرياح والأشعة الشمسية في قطاعات مختلفة من محافظة مرسين. تم تخزين الطاقة التي تم الحصول عليها عن طريق تتبع اتجاه الشمس والرياح في مجموعات مراكم في محطة الطاقة المُعدة لذلك. وبمجرد امتلاء مجموعات المراكم، يتم نقل الطاقة المُولَدة إما إلى منازل الهضبة مباشرةً أو إلى الشبكة لإنتاج طاقة مستمرة. ويوفر هذا تدفقاً مستمراً للطاقة بين محطة الطاقة والشبكة. ولهذا الغرض، تم بناء محولين تعزيز لتوصيل الطاقة الكهربائية من توربينات الرياح والألواح الشمسية. تم تصميم تلك المحولات للعمل بشكل متوازٍ مع بعضها البعض وللحفاظ على طاقة الخرج عند أقصى مستوى بشكل مستمر، ويتم التحكم في كل من المحولين عن طريق وحدة تحكم صغيرة. يتضح من خلال هذا العمل كيفية صنع واختيار موقع محطة توليد كهرباء هجينة عالية الكفاءة تعمل بالرياح والطاقة الشمسية في أي مكان في العالم. يمكن تخزين ونقل فائض الطاقة المولدة من محطة توليد الطاقة المعنية إلى نظام الربط البيني الحالي للحصول على مكاسب مالية.