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Alternative Approach to Charging Stations: Hybrid Renewable Energy System Design

Samet Yavuz[1], Selim Sayın[1], Emre Çakır[1], Kübra Keser[1,*]

[1] *Kutahya Dumlupinar University, Simav Technical Faculty, Department of Electrical and Electronics Engineering, 43500 Simav/Kutahya, Turkey*

ABSTRACT

Solar and wind energy are among the renewable energy sources and are green energy types that do not create polluting waste. Integrating renewable energy into power systems is one of the most popular approaches today. By combining the two types of energy, the effects of energy sources can be understood, a safe and economical system can be created. Hybrid renewable energy systems can provide energy sustainability. The aim of this study is to present an innovative system that feeds Arduino and creates a mini mobile phone charging station by using the voltage values obtained from solar panels and wind turbines together. The system optimizes the supply and demand balance by synchronizing both energy sources. Thanks to the system, the energy produced by the solar panel and wind turbine is collected and combined with an energy management system. Arduino is integrated with the energy management system to monitor energy, control the charging process and provide a user interface. The most important features of the study are to contribute to the use of renewable energy sources with the developed method and to increase environmental awareness, as well as to provide awareness and skills in electronics and energy systems. The study provides the user with a practical and environmentally friendly charging solution, while serving as an example to demonstrate the potential of renewable energy sources.

Keywords: *Solar panel, Wind turbine, Green energy, Arduino, Renewable energy*

Şarj İstasyonlarına Alternatif Yaklaşım: Hibrit Yenilenebilir Enerji Sistemi Tasarımı

ÖZET

Güneş ve rüzgâr enerjisi yenilenebilir enerji kaynakları arasında yer almakta olup, kirletici atık oluşturmayan yeşil enerji türüdür. Yenilenebilir enerjiyi güç sistemlerine entegre etmek günümüzde en popüler yaklaşımlardan biridir. İki enerji türünü birleştirerek enerji kaynaklarının etkisi anlaşılabilir, güvenli ve ekonomik bir sistem oluşturulabilir. Hibrit yenilenebilir enerji sistemleri enerji sürdürülebilirliğini sağlayabilir. Bu çalışmanın amacı, güneş panellerinden ve rüzgâr türbinlerinden elde edilen voltaj değerlerini birlikte kullanarak Arduino'yu besleyen ve mini bir cep telefonu şarj istasyonu oluşturan yenilikçi bir sistem sunmaktır. Sistem, her iki enerji kaynağını senkronize ederek arz ve talep dengesini optimize eder. Sistem sayesinde güneş paneli ve rüzgâr türbini tarafından üretilen enerji toplanır ve bir enerji yönetim sistemi ile birleştirilir. Arduino, enerjiyi izlemek, şarj sürecini kontrol etmek ve bir kullanıcı arayüzü sağlamak için enerji yönetim sistemi ile entegre edilmiştir. Çalışmanın en önemli özellikleri, geliştirilen yöntemle yenilenebilir enerji kaynaklarının kullanımına katkıda bulunmak ve çevre bilincini artırmak, ayrıca elektronik ve enerji sistemleri konusunda farkındalık ve beceri kazandırmaktır. Çalışma kullanıcıya pratik ve çevre dostu bir şarj çözümü sunarken, yenilenebilir enerji kaynaklarının potansiyelini göstermek için bir örnek teşkil etmektedir.

Anahtar Kelimeler*: Güneş paneli, Rüzgâr türbini, Yeşil enerji, Arduino, Yenilenebilir enerji*

1. INTRODUCTION

Fossil fuel resources are used to meet energy needs in Turkey and the world. While these resources are among the exhaustible energy resources, they have increased the need for alternative energy resources due to their harm to human health [1-3] and the environment (soil, water, air pollution, etc.) [4,5]. Clean, reliable, sustainable energy that will overcome negativities, reduce dependency on other countries, and make maximum use of energy produced with renewable resources is of great importance here.

Solar energy is a type of energy with high potential for widespread use due to its advantages such as being environmentally friendly, renewable, the cleanest and inexhaustible energy source, and reducing carbon dioxide emissions in the atmosphere [6,7]. Solar energy can be used in three ways: photovoltaic (PV), photothermal and photocatalytic [7]. PV panels convert sunlight directly into electricity, while thermal

*Corresponding author, e-mail: mgunay@karabuk.edu.tr

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systems are used to heat water or air using solar energy [6]. Solar energy is converted into electrical energy in PV panels, where monocrystalline and polycrystalline silicon materials are commonly used. This panel structure has a built-in electric field. When photons with an energy greater than the band gap energy of the semiconductor material of the panels come from the sun, if these photons are absorbed, electrons move towards the conduction band. DC power is generated by the flow of this electron-hole structure in opposite directions [8]. In addition to the increasing interest in PV cells worldwide, the increasing trend in installed capacity, their ease of installation, not causing waste, not affecting living things and lower costs make them preferred [9,10]. Wind energy stands out with its development in the last decade, its low energy costs, its high-power generation capacity, its sustainable clean energy source, and its public health protection due to the fact that it does not produce gas that will cause environmental and air pollution [11,12]. In addition, although the annual cumulative wind energy capacity is constantly increasing, it is stated in various studies that generating power from wind energy reduces greenhouse gas (GHG) emissions by 330-590 tons of CO2 per Gigawatt (GW) hour [12].

Both types of energy are green energy types as they are among the renewable energy sources and do not create waste that pollutes the environment. However, the use of renewable energy sources separately increases the capital cost due to the variability and intermittency of some energies and decreases the system reliability [13]. In this case, hybrid renewable energy systems, where energy is produced by bringing at least two energy sources together, are one of the most popular approaches.

PV-wind energy systems are among the examples that can be given to different types of hybrid renewable energy systems. Although the sun's rays decrease towards the end of the day, there is more intense solar radiation in certain seasons. Wind, on the other hand, blows continuously, although it has different speeds. Bringing these two energies together can bring about a hybrid system that complements each other [13]. Turkey has much more advantage than many countries in terms of both solar energy and wind energy potential due to its location in the middle belt with its geographical location.

When looking at the literature, it is seen that there is a review of the final dimensioning methodologies of hybrid renewable energy systems [13], where information is presented and evaluations are made about different types of hybrid renewable energy systems, as well as another comprehensive review that aims to present a review of the latest developments in the field of optimization of different hybrid renewable energy systems (HRES) using various optimization techniques based on classical methods, artificial intelligence (AI), hybrid algorithms and software-based optimization tools [14]. In a study where solar energy is used for battery charging systems, it is reported that an Arduino-based solar battery charging system is designed and implemented, and it is stated that the system consists of a solar panel, Arduino microcontroller and battery [15]. In the study, where it is aimed to propose the preliminary design of a small Arduino-based wind energy production system, it is stated that the data can be used for further analysis to determine the wind energy potential in the field [16]. Another study, titled A review of hybrid renewable energy systems: Solar and wind-powered solutions: Challenges, opportunities, and policy implications, addresses key challenges such as system optimization, energy storage, and seamless power management, as well as discussing technological innovations such as machine learning algorithms and advanced inverters that have the potential to overcome these hurdles. It also emphasizes that the study's results show that hybrid renewable energy systems have the potential to not only meet but also exceed future energy demands in a sustainable manner [17]. Another study examining the latest studies published in hybrid renewable energy systems focuses on the four basic categories of hybrid energy systems: dimensioning, optimization, control and energy management. The advantages and disadvantages of these methods are discussed comparatively [18]. In a study where a grid-connected solar-wind hybrid system was presented to meet the electrical load demand of a small shopping complex and an electric vehicle charging station was included in the grid, it was stated that a cost-effective and reliable system could be designed by appropriately managing renewable power generation and load demands. In this study, a solar-wind hybrid system is proposed, the working methodology, mathematical model, objective function and constraints of the system as well as various optimization algorithms are included [19]. In the study titled Techno-economic analysis of a hybrid solar wind electric vehicle charging station in highway roads, it is stated that 17 electric vehicles can be charged during the day from 6:00 in the morning to 6:00 in the evening with the designed system [20].

When these studies are examined, it is seen that there are generally studies on the dimensioning, optimization, modeling and examination of hybrid renewable energy systems; review articles presenting information on different hybrid renewable energy systems; and studies on hybrid energy systems for electric vehicles. In the study on Arduino-based systems, it is seen that solar or wind energy is included separately, and most of them do not aim to charge electronic devices such as phones.

Based on all these shortcomings, this study aims to design and develop an Arduino-based charging station to charge mobile phones using solar and wind energy together. PV-wind hybrid systems were considered and focused on obtaining higher power, and an innovative system was presented that uses the voltage values obtained from solar panels and wind turbines together to power the Arduino and create a mini charging station.

With the created system, both energy sources are synchronized and the supply and demand balance is optimized. Thanks to the system, the energy produced by the solar panel and wind turbine is collected and combined with an energy management system. Arduino is integrated with the energy management system to monitor the energy, control the charging process and provide the user interface. A wind energy system consisting of a wind turbine, charge controller and batteries is added. The wind turbine produces electricity from the blowing wind and this electricity is processed by the charge controller and stored in the battery.

The developed method contributes to the use of renewable energy sources and the increase of environmental awareness, while also raising awareness about electronics and energy systems. The original and special aspect of the study is the ability to charge portable devices such as mobile phones without being dependent on the electrical grid and the provision of a clean and reliable hybrid renewable energy source to power small electronic devices. Another unique aspect is that devices can be charged even when there is little or no sunlight. This study can be developed and used more widely in larger power systems in the future.

2. MATERIAL AND METHOD

2.1. Materials

Solar panels, wind turbine, Arduino microcontroller, DC-DC charging module, voltage regulator, 3 diodes (1N4007), 6 resistors, 2 coils (750 nH), 4 capacitors (2350 uF/1410 uF) were used in the creation of the system. The basic features of the elements used are given in Table 1.

Table 1. Basic properties of the elements used

Element used	Basic properties
Solar panels	12 V, 300 mA, 5 W; dimension: 110 cmx220 cm; 30° inclined (for optimal light reception)
Wind turbine	16 V, 310 mA, 5W, horizontal vertical axis, hard plastic
Arduino microcontroller	5 V, uno, 14 digital I/O pins and 6 analog inputs
DC-DC charging module	Input voltage 6-24V, output current 3A
Voltage regulator	LM2596 adjustable DC-DC regulator, 4-35V input voltage, 1-30V output voltage

2.2. System Design

In order to equalize the frequencies of the voltage values coming from the wind turbine and solar panel, to ensure synchronous operation and to prevent possible frequency fluctuations from damaging the Arduino and other electronic materials to be used, a rectifier circuit was installed and connected to the outputs of each energy source. In order to prevent feedback to the outputs of the motor used in the wind turbine, 2 diode connections were made, one for input and one for output. The output of these diodes was connected to the positive and negative ends of the 2350 μF capacitor, and then the LM2596 adjustable DC-DC regulator was connected to the ends of the 1410 μF capacitor. The same process was applied to the solar panel. The positive and negative poles of the solar panel were connected as inputs by the 2350 μF capacitor of the second circuit we created from the capacitors and coils, and the LM2596 adjustable DC-DC regulator was connected to the ends of the 1410 μF capacitor as outputs. In order to increase the current value of the circuit, the outputs of the LM2596 adjustable DC-DC regulators were connected in parallel.

The rotor blades of the wind turbine are made of lightweight materials and are designed to start rotating even at low wind speeds, then mounted to capture maximum wind (Figure 1.a). For the turbine's electricity production efficiency, the turbine outputs are regularly monitored and necessary adjustments are made.

Solar panels, which are one of the energy types in the system and are used in solar energy production, are mounted to receive the sun's rays at the steepest angle in order to obtain the highest energy efficiency (Figure 1.b). After the panel connections were made in parallel and series configurations to provide the voltage and

current values obtained in the simulation program and required for the operation of the system, the voltage measurements were verified using digital multimeters.

After the installation of solar panels and wind turbine is completed, the DC motor used in the wind turbine must be able to reach the desired speed with the help of the wing connected to the motor. For this, calculations were made and a gearbox design was created that would allow the motor to make 25 turns with one turn of the wing due to the effect of the wind. The spur gears to be used in the gearbox design phase were drawn in the AutoCAD program and printed on a 3D printer. The assembly of these printed spur gears was compressed between two transparent plexiglas and the gearbox design was completed. In order to minimize the wear of the gears in the wind turbine mechanism, the gear sizes were kept thick and the minimum wearable material was used (Figure 1.c-e).

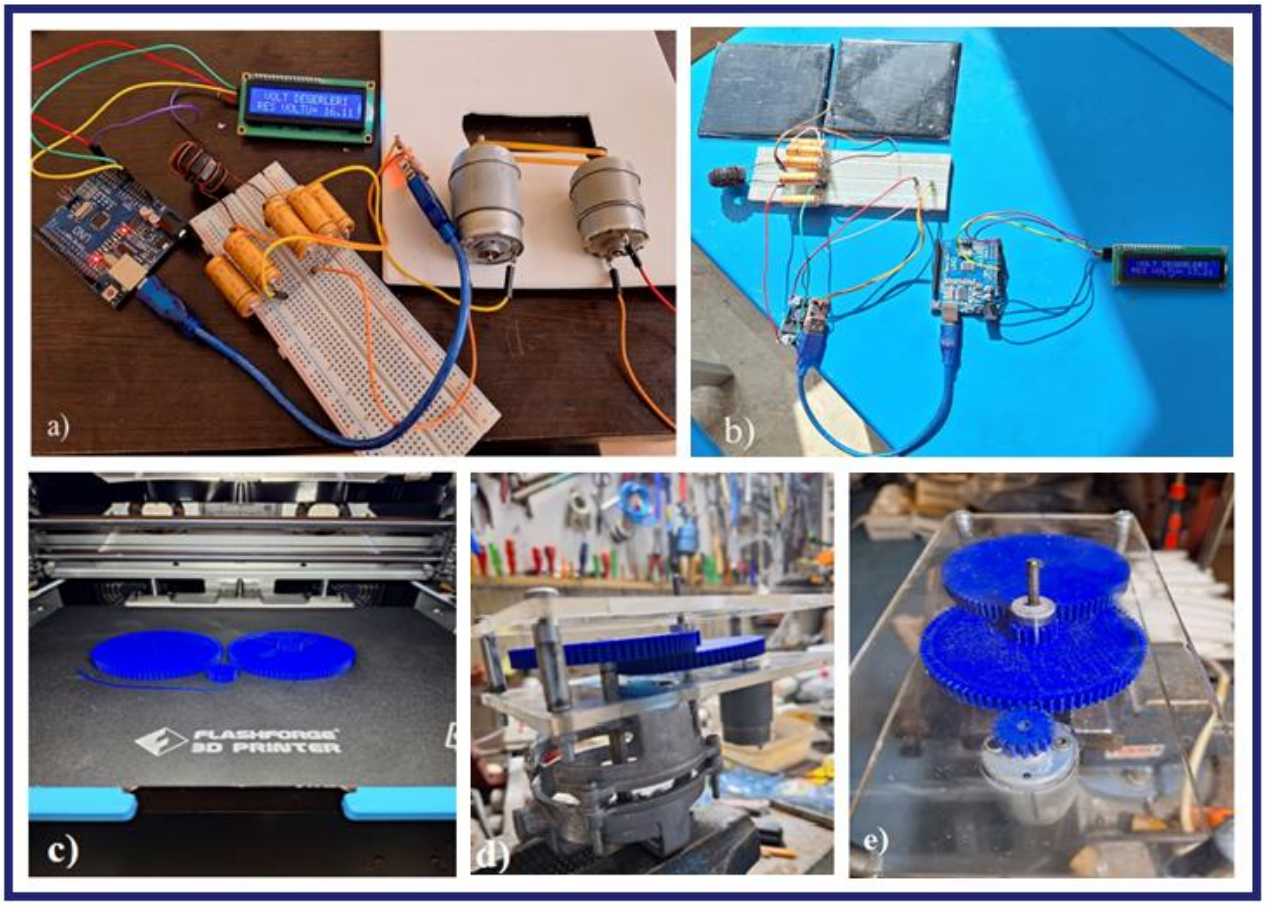

Figure 1. Design of hybrid renewable energy system a) Wind energy system circuit b) Solar energy system circuit c-e) Gear box

In the next stage, the Arduino was properly connected to the microcontroller and the analog pins were used for the connections of the loads (phone charger). The connection diagram was drawn in detail and tested on the breadboard.

By integrating Arduino with the energy management system, it is possible to monitor energy, control the charging process and stop the solar panel and wind turbine if necessary. Following this process, an interface software was developed that will monitor energy levels, manage the charging process and provide information to the user.

In order to feed the Arduino, the parallel connected outputs of the LM2596 adjustable DC-DC regulators were connected to the DC-DC charging module and the Arduino was fed from the output of this module. In addition, a second DC-DC charging module to be used for phone charging was connected in parallel to this DC-DC charging module.

A circuit design was made on the perforated plate so that the voltage values produced by the power sources could be displayed on the LCD screen via the Arduino. The terminals coming from the output of the rectifier circuit consisting of the capacitors and coils connected to the output of the solar panel with the 10K and 1K resistors connected in series were connected ((+) terminal to the 10K resistor, (-) terminal to the 1K

resistor). Then, the connection was made from the serially connected terminals of the 1K and 10K resistors to the A1 analog pin on the Arduino.

In order to measure the voltage value generated in the wind turbine, a simple circuit consisting of a series connection of a separate 10 K and 1 K resistor was connected to the plus and minus poles coming from the output of the rectifier circuit consisting of a capacitor and a coil ((+) end to the 10 K resistor, (-) end to the 1 K resistor). Afterwards, the DC motor used in the wind turbine was associated with these circuit connections and a connection was made from the series-connected ends of the two resistors to the A2 analog pin on the Arduino.

In order to measure the output voltage of the parallel connection of the LM2596 adjustable DC-DC regulators, the series connection of the 10K and 1K resistors was connected to the ends, the (+) of the parallel connection was connected to the 10K resistor and the (-) to the 1K resistor, and then this series resistor structure was connected to the analog A0 pin on the Arduino.

For the LCD screen connection, the SCL pin on the LCM1602 module outputs connected to the LCD screen is connected to the Arduino's analog A5 pin; the SDA pin is connected to the Arduino's analog A4 pin, while the VCC pin is connected to the Arduino's 5 Volt pin and the GND pin is connected to the Arduino's GND pin (Figure 2).

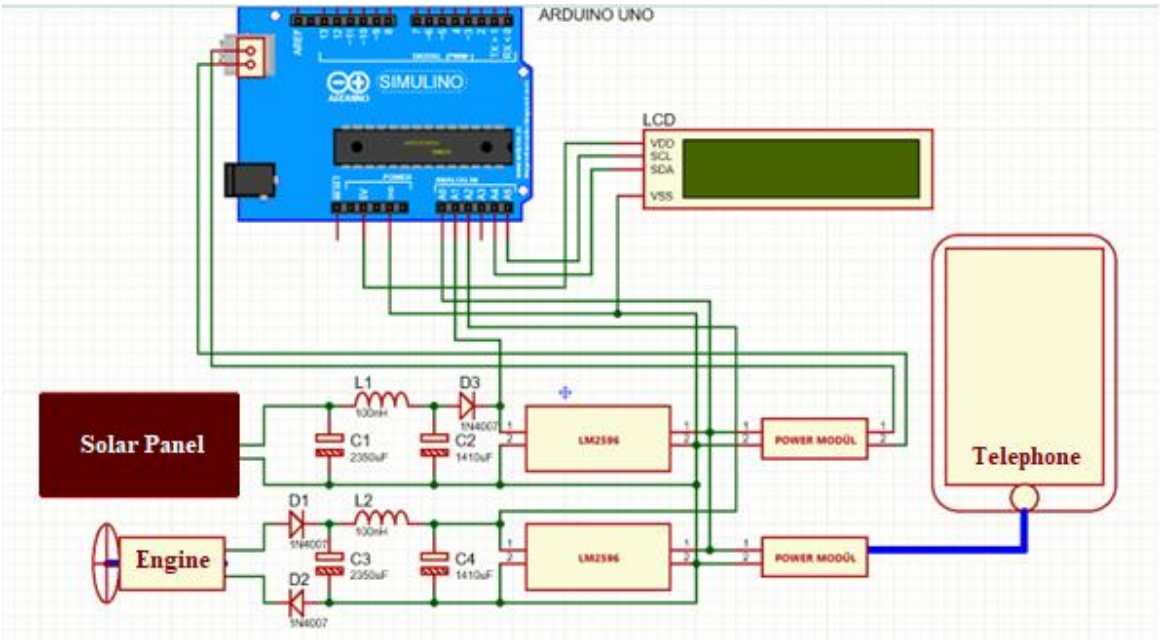

Figure 2. Proteus circuit simulation of hybrid system (for single voltmeter)

2.3. System Testing and Calibration

After the system design was completed, the power data obtained from the solar panel and wind turbine were tested in various weather conditions. Charge and discharge performances were monitored and the overall efficiency of the system was evaluated. Percentage error values were calculated from the data obtained by using the equation in Equation 1.

$$\text{Percentage Error} = [(\text{Observed value} - \text{True value})/(\text{True value})]\text{x}100 \quad (1)$$

3. EXPERIMENT AND OPTIMIZATION RESULTS

In addition to the importance of the separate design of circuits in hybrid renewable energy systems, another of the most important issues is that the installed systems can be operated without problems when they are integrated. In the final stage of this study, a power box was created in which the solar panel and wind turbine, which were designed separately, were brought together. The power box view of the created hybrid renewable energy system is given in Figure 3.

Separate buttons were placed on the box to cut the energy of the LCD screen, wind turbine and solar panel, and a separate button was installed to cut the energy of the modules used for Arduino supply and phone charging.

Figure 3. Electronic hardware of the designed hybrid system

The structure where the solar panel is placed on the wing, DC motor and gearbox is connected to the wooden floor via an aluminum pipe.

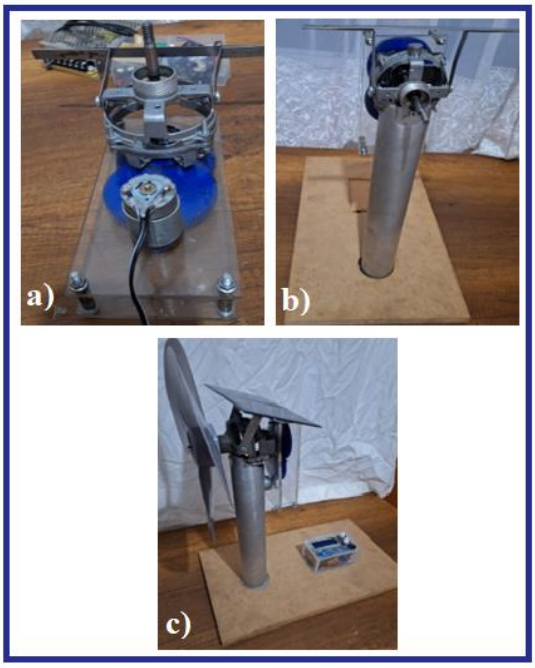

Figure 4. Combining wind and solar energy systems

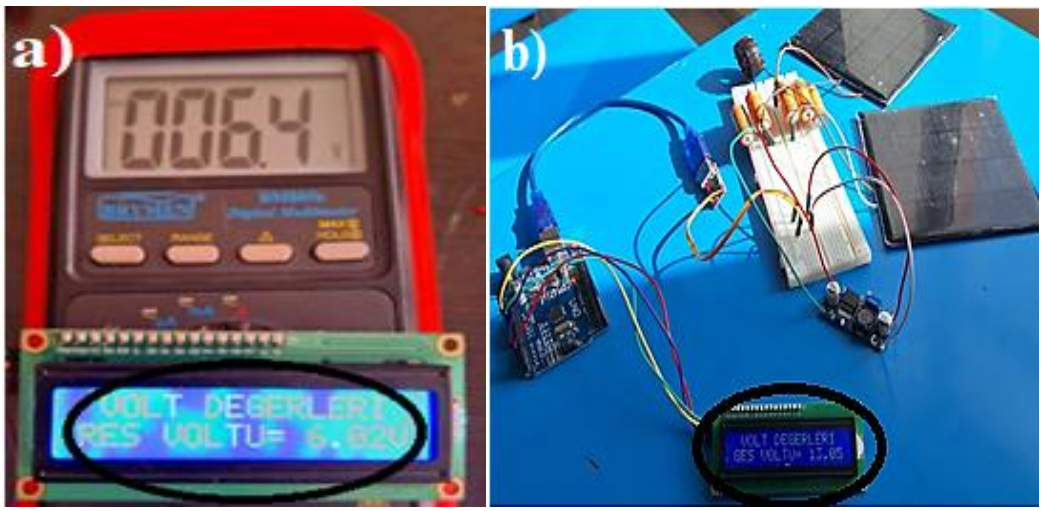

Figure 5. Obtained test results a) Wind energy system result b) Solar energy system result

When looking at Figure 5.a, it is seen that the voltage value obtained from the system created with the wind energy system is 6.4 V when read with a voltmeter, while it is 6.02 V when read from the LCD screen on the power box. When looking at Figure 5.b, the voltage value read on the LCD screen in the system created with the solar energy system is 13.02 V.

When these data are evaluated, it is confirmed that measurements can be made with a 6% error with the wind energy system with RES, that synchronous measurements can be made, and that the energy produced by the solar panel and wind turbine is collected and used correctly.

In addition, the voltage measurements of all modules were calibrated by testing whether energy management was done properly. After this stage, the study was concluded when it was seen that Arduino controlled the feeding process correctly and the phone charging process could be done successfully and without any problems.

4. CONCLUSIONS

In this study, an innovative system that feeds Arduino and creates a mini charging station using the voltage values obtained from a hybrid renewable energy system where solar panels and wind turbines are used together, which has not been used in other studies in the literature, is presented.

With the work presented,

- Having a structure that optimizes the supply and demand balance by synchronizing both energy sources and combining them with an energy management system,
- In addition to being able to make synchronous measurements, measurements can be made with a 6% error with the wind energy system,
- Verifying that the energy produced by the solar panel and wind turbine is collected and used correctly are the most important outputs presented.

It has been tested in the experimental stages that the phone charges successfully with the designed system, but studies need to be done on increasing the charging efficiency and shortening the charging time.

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