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ISTANBUL AYDIN UNIVERSITY
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OPTIMAL DESIGN OF A ROOFTOP WIND-PV HYBRID SYSTEM TO MEET ENERGY DEMAND FOR A TYPICAL RESIDENTIAL HOME

MASTER SCIENCE THESIS

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Danışman	Prof. Dr.	Nedim TUTKUN	İstanbul Aydın Üniversitesi	
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ONAY

Prof. Dr. Ragıp Kutay KARACA
Enstitü Müdürü

DEDICATION

I hereby declare with respect that the study, which I submitted as a Master thesis in this document, has been obtained and presented in accordance with academic rules and ethical conduct, and I referenced the works and material that I have benefited.

Aussama ALKHESHA

FOREWORD

After thanks to Allah our creator, I would like to thank my mother and my father who raised me to become a good person. My family, my wife and two daughters, thank you very much. My wife, thank you very much for your support in my life and during my master’s period. I am truly thankful for having you in my life. I hope I can make you happy and return even some of what you gave.

I would like to thank my thesis advisor Dr. Nedim TUTKUN for his guidance, support, and help during my work in the thesis. I thank him for everything I learned from him.

I thank all my teachers starting from my school time until today as they had great influence on me and made me love education and I hope I can become one day a good teacher as they were.

December 2019 Aussama ALKHESHA

OPTIMAL DESIGN OF A ROOFTOP WIND-PV HYBRID SYSTEM TO MEET ENERGY DEMAND FOR A TYPICAL RESIDENTIAL HOME

ABSTRACT

Energy price gradually increases all over the world every year due to population and economic growths. The primary sources of electricity are usually fossil fuels and major part of them is imported. It is a typical indication of the foreign energy dependency although many countries in the world have renewable energy potential. This potential can be seized on using on-grid or off-grid renewable systems in particular wind-PV systems ranging from power ratings of 1 to 10 kW in remote areas.

To make such systems economic, power balance between generation and consumption should be maintained at hourly time slots in the day.

One way to do that is to solve a discrete optimization problem and the solution can be achieved by a mathematical model satisfying the given constraints in a certain location. Unit sizing of a low power off-grid renewable system to meet power demand for a typical residential home in a location is achieved, in the design process the genetics algorithm is encoded in MATLAB environment for simplicity and robustness, and the outcomes are meaningful and encouraging for widening renewable energy applications worldwide.

Keywords: Rooftop wind-PV hybrid system, Optimal design, Metaheuristic techniques, Renewable energy applications.

TIPIK BIR KONUTUN ENERJI TALEBINI KARŞILAMAK İÇIN ÇATI-ÜSTÜ RÜZGAR VE FV HIBRIT SISTEMININ OPTIMAL TASARIMI

ÖZET

Enerji fiyatı, her yıl nüfus ve ekonomik büyümeler nedeniyle tüm dünyada giderek artmaktadır. Birincil elektrik kaynakları genellikle fosil yakıtlardır ve bunların büyük bir kısmı ithal edilmektedir. Dünyadaki birçok ülkenin yenilenebilir enerji potansiyeline sahip olmasına rağmen, yabancı enerji bağımlılığının tipik bir göstergesidir. Bu potansiyel, şebeke içi veya şebeke dışı yenilenebilir sistemler, özellikle uzak bölgelerde 1 ila 10 kW güç sınıfları arasında değişen rüzgar-FV sistemleri kullanılarak ele alınabilir.

Bu sistemleri ekonomik hale getirmek için, üretim ve tüketim arasındaki güç dengesi günün saatlik zaman aralıklarında tutulmalıdır.

Bunu yapmanın bir yolu, ayrı bir optimizasyon problemini çözmektir ve çözüm, belirli bir konumda verilen kısıtlamaları karşılayan bir matematiksel model ile elde edilebilir. Bir lokasyonda tipik bir konut için güç talebini karşılamak için düşük güçlü bir şebekeden bağımsız yenilenebilir sistemin birim boyutlandırması elde edilir, tasarım sürecinde genetik algoritma basitlik ve sağlamlık için MATLAB ortamında kodlanır ve sonuçlar anlamlı ve cesaret vericidir. dünya çapında yenilenebilir enerji uygulamalarını genişletmek için.

Anahtar Kelimeler: Çatı üstü rüzgar-FV hibrid sistemi, Optimal tasarım, Meta-sezgisel teknikler, Yenilenebilir enerji uygulamaları.

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I. INTRODUCTION

A. Overview

Energy is a key issue in the social and socio-economic development of a society. The energy parameter is at the top of the country's development indicators. Especially in developing countries like our country, the demand for energy is increasing. This has increased interest in renewable energy sources. Although renewable energy has advantages, renewable energy sources have significant disadvantages, such as production discontinuity due to weather conditions. Therefore, hybrid systems are used consisting of different renewable energy sources, such as wind, photovoltaic and hydraulic (Lu, Zeng, et all. 2013).

The traditional optimization techniques available for electrical power systems to size the hybrid system are linear programming, dynamic programming and analytical methods. Furthermore, evolutionary techniques such as genetic algorithms, simulated annealing and flock flux optimization have been applied to design the hybrid system. Growing concerns about global warming have urged interest in reducing greenhouse gas emissions, including those emitted during electricity generation from conventional sources such as coal, oil and natural gas etc. In addition, energy security concerns have prompted nations to look for sustainable energy sources to replace fossil fuels that are running out. Renewable energy sources (RES) like wind power and solar power offer sustainable and ecological alternatives for energy production. However, some technical and economic challenges must be resolved before these sources can replace current power generation resources. First of all, these RES are intermittent, unpredictable and uncontrollable, which means that they cannot be used exclusively to meet load demand reliably. Furthermore, renewable energy generation technologies are generally more expensive than conventional generators of comparable size, especially if used together with energy storage devices to improve their reliability. As a result, they cannot supply energy at a competitive price. Finally, its distributed nature and its dependence on location cause difficulties with respect to its integration into the centralized architecture of power generation and contemporary delivery systems.

The energy generation system with renewable energy sources can be built by a single system (photovoltaic only, only wind) or a hybrid system with other sources or generators of renewable energy (photovoltaic / wind, photovoltaic / diesel). Furthermore, these systems can be connected to the network or be independent of the network. Despite the unpredictable nature of resources in the independent renewable energy generation systems of the network, it is important for the continuity of the power generation system designed as a hybrid due to its variable spacing and intermittent nature. The most used systems are solar and wind energy systems due to their modularity. The integration of various types of conventional and / or renewable energy generation technologies into a single energy system, with the possibility of integrating them with energy storage devices, can be a viable solution to some of these challenges. In particular, exploiting the difference in seasonal and daily supply profiles of some types of RES as wind and solar to complement each other can significantly improve reliability and reduce the cost of energy for such systems. This type of integrated system is generally known as hybrid power systems. The energy conversion technologies that are generally used in them include: photovoltaic, wind turbines, micro-hydroelectric and combined heat and power units. Furthermore, energy storage technologies on a network scale are rapidly improving and could soon become an integral part of any hybrid energy system to address the intermittency problem and drive the integration of distributed generation powered by renewable energy sources in energy systems (Tutkun, Ungören, & Alpagut, 2017).

The generation of energy through standalone renewable energy systems is more expensive than the energy generation systems with fossil fuels. It is therefore important to optimally design such systems in many aspects, such as low cost operation and maintenance, optimal size and location. Recently few researchers have been using meta-heuristic algorithms to accomplish these goals by solving complex problems derived from system modeling in design process and preliminary outcomes of using these techniques exhibit better performance compared to other deterministic techniques. In order to design a wind-PV hybrid system to meet energy demand for a typical residential home, deterministic optimization techniques such as linear programming, dynamic programming and analytical methods are one of alternatives.

However, in some cases the objective function obtained from modeling may be complex due to linear and nonlinear constraints so that they are mostly incapable of solving it. Thus metaheuristic techniques such as the simulated annealing, particle swarm optimization, the shuffled frog-leaping algorithm, gravitational search optimization etc. can be one option to solve for optimal values. Few investigations on this problem are discussed as follows (Tutkun, 2019).

B. Literature Review

Tutkun et al presented a micro-hybrid energy system with low power wind turbines, several photovoltaic panels, a few storage batteries and controllable and uncontrollable electrical loads to generate low-cost electricity in residential homes or similar places. The operation cost of this system was reduced to an acceptable amount of cost for a fair competition with grid cost. The Shuffled Frog-Leaping Algorithm (SFLA) software was designed to find the minimum daily operating cost for wind-PV hybrid system installed in the residential house. With a time interval of one hour, the operation cost of the unscheduled load profile was ₺ 8.12 per day. The designed software was used to optimally program the energy demand to minimize operating costs. Once the optimization process was completed, the operating cost was reduced to ₺ 7.07 for one day, to be precise, the operation cost was improved by around 13% (Tutkun, Can, & San, 2015).

Jaszczur et al, presented a hybrid system for renewable energies for residential use that is based on two different optimization criteria. The system presented uses photovoltaic modules, wind generators and batteries as energy stores. The analyzes were carried out on the basis of experimental measurements regarding electrical charge, local solar radiation, wind speed and other environmental parameters. The optimization process was carried out from two economic and ecological points of view, whereby the optimization process showed that low wind energy affects the system, while photovoltaic modules show better alternatives, whereby this study focused more on the environmental aspect, which eliminated the idea of a diesel generator and there were no effective ones Mechanisms to control daily loads (Jaszczur, Hassan & Palej, 2019).

Antonio et al, carried out a high-resolution analysis with which a hybrid bank of batteries for photovoltaic wind turbines can be dimensioned. The analysis aims to minimize the annual cost of the systems by meeting two reliability constraints. The solution was obtained numerically using an iterative technique. The decision variables are the photovoltaic area, the wind generator radius and the battery capacity. Based on the fuzzy logic inference system, a high-resolution model was developed to evaluate the number of active residents and the electricity consumption in the household. To enable a more precise dimensioning of the system, a new reliability parameter called seasonal load loss index was defined, which takes into account the seasonality of the data. In the iterative process, in addition to the most common probability of a load loss, the probability ratio of a seasonal load loss was used. In comparison to conventional methods, the results obtained show that the introduction of the new parameter into the iterative process results in a significant improvement in the reliability of the system and a slight increase in its costs. In my view, the study was almost complete. since it was important to analyze the stresses in two hot and cold seasons and in the cold season there is a possibility of energy loss (Giallanza, Porretto, Puma & Marannano, 2018).

Hemeida et al, wanted to present a realistic solution for the energy requirements in Makadi Bay, Red Sea, Hurghada, Egypt, of the battery storage (BE S). TORSCHE's linear optimization technology was used to achieve an optimal solution for the proposed renewable cross-energy system. The optimal size of the hybrid renewable energy system was examined based on the actual weather and load data collected. The individual configuration of PVS and WES in the presence of BES was examined and compared with the PV / WT hybrid. In addition, the economic analysis was presented to show the best economic system. The final results that obtained showed that the installation of this hybrid system consisting of WES, PVS and BES is cheaper than the individual installation. In my opinion, the study was based on a comparison of the feasibility of setting up a hybrid system on the one hand or creating separate systems on the other, which can be evident in many cases, particularly in the regions of the Mediterranean (Hemeida, El-Ahmar, et all. 2019).

Nurunnabi et al presented a feasibility and sensitivity analysis of microgrids connected to the network and outside the network based on renewable energies and examined the potential of wind and solar energy in various areas. A special neural network algorithm was used to track wind speed and solar radiation in two prominent regions throughout the year, and promising results were analyzed to decide whether the data is reliable for the forecast or not. Four different model types, including PV-Grid, Wind-Grid, Wind-PV-Grid and hybrid renewable energy sources outside the network, are developed using HOMER Pro software (Hybrid Optimization of Multiple Energy Resources). Consideration of the key factors: net electricity costs, energy costs, share of renewable energies, local load demand, availability of renewable energy sources, system economics and greenhouse gas emissions, optimal hybrid system for renewable energies (HRES), lot. The results showed that the optimal solutions are significantly influenced by the uncertainty of the key variables , for the fixed configuration of the system, e.g. the wind PV grid system, a sensitivity analysis with six uncertain input variables (such as the nominal discount rate, the price of the network energy, the runtime of the wind turbine) is carried out, the average wind speed, the solar radiation and the average electrical charge show how sensitive the current total net costs are to each type of uncertain variable. The final results of analysis showed the total net costs are more sensitive to the nominal discount rate and average wind speed than the other four variables. I think information can help a system designer prioritize efforts to reduce wind speed. Uncertainty the results also show that the optimal configuration and size of the system vary significantly with the reduction of the nominal discount rate by 1% (Nurunnabi, Hossain & Pota, 2019).

Moghaddam et al, they presented the design of an optimal hybrid photovoltaic / wind / battery energy system for the load requirement, taking into account the actual data on annual solar radiation and wind speed in Zanjan, Iran. The optimal capacity of the hybrid system component is determined to minimize the NPCS of current net costs and improve the likelihood of hourly blackouts from the Reliability Index Deficit using the new improved crow search algorithm (ICSA). The optimal capacity of the hybrid system components is shown in different combinations and in different amounts of the DPHIP restriction. The simulation results showed that the PV / Batt hybrid system is cheaper and more reliable for the city of Zanjan compared to the other combination in terms of NPCS and DPHIP. The results also showed that the construction costs of the WT / Batt system are higher for Zanjan than for the other combinations, and it is not cheap that one of the important reasons is the weak wind potential in the city of Zanjan and the dependency of this combination on the Way to the high-bay warehouse for freight delivery. In addition, when designing the hybrid system according to the ICSA method, the impact of important technical factors is assessed, including changes in the efficiency of the inverter and the investment costs of the storage system and changes in the load. The results showed that higher inverter efficiency lowers NPCS and improves reliability, so increasing the cost of storage investments increases NPCS and degrades reliability. NPCS also increase with increasing demand (Moghaddam, Bigdeli, et all. 2019).

Madziga et al, wanted to present an optimal hybrid energy system to reliably and sustainably cover the electricity needs of a remote village without a grid connection, Gwakwani, South Africa. Three off-grid systems have been proposed: (i) photovoltaic systems with a diesel generator; (ii) photovoltaic systems and battery storage; and (iii) photovoltaic systems with a diesel generator and battery storage. based on three main goals: (i) meeting energy needs; (ii) system costs; and (iii) pollution based on three main objectives: (i) meeting energy needs; (ii) system costs; and (iii) the contamination for this analysis was tested different sizes of photovoltaic panels and the optimal size selected in each scenario. A general comparison was made between the two optimal systems when using the diesel generator and when using the battery. Both scenarios are able to meet the demand adequately without any significant interruption, but there are differences in costs and technical optimization. The result is: The three scenarios of the model system can be used for electrification and for combining the energy requirements at a considerable price. However, the optimal solution guarantees a more reliable system in terms of costs, as shown in scenario (1). The cost of adopting scenario (3) is not economical for a small village. In my opinion, the study did not show a final solution, just a general comparison of all options (Madziga, Rahil & Mansoor, 2018).

Dong et al, conducted a simulation experiment to demonstrate the advantages of the hybrid system with the data obtained from the island of Zhoushan, Zhejiang province, China. In their study, they aimed to optimize the size of grid independent photovoltaic (FV), wind turbine (RT), battery and hydrogen system (storage source battery and hydrogen based hybrid system) reliably and economically. They used the Ant Colony Algorithm to optimize the hybrid system's size optimization to maximize system reliability (probability of power supply loss-LPSP) and minimum annual system costs to size the hybrid system with an efficient energy storage to meet basic load demand. They found that there was a paradoxical relationship between reduced system cost and increased system reliability in simulations using CCA, which reduced search time to achieve the goal. The battery-only hybrid system, the hydrogen-only hybrid system, and the three systems, both of which are compared. They concluded that the battery and hydrogen-based system are more economical than other systems (Dong, & Xiang, 2016).

Hadidian et al, proposed the size optimization method of grid independent photovoltaic / wind turbine / battery power energy system using Gray Wolf Optimization algorithm formulated in Matlab software. The main objective of optimization is to minimize the total annual cost of the hybrid system by determining the most appropriate wind turbine, photovoltaic panel and battery number by considering reliability (LPSP). In this method, they have determined the most suitable hybrid system to meet the load as wind turbine and battery. In their studies comparing 90%, 95% and 100% usability of the components of the hybrid power generation system, they concluded that the reliability of the devices decreased as the usability decreased. The results obtained from the optimization have found that Gray Wolf Optimization algorithm can easily find the optimum hybrid power energy system quickly and at lower cost compared with the methods well known in the literature. They suggested that consideration of the reliability method could have a significant impact on optimization (Hadidian-Moghaddam, Arabi-Nowdeh, & Bigdeli, 2016).

Sanajaoba et al, presented the optimization of the hybrid energy system by taking into account the usability of photovoltaic panels and the power interruption rates of wind turbines (accepted as 0.05) in their study with data obtained from Almora region of India. For the optimization of the hybrid energy system, a new meta-heuristic algorithm called Cuckoo Bird search algorithm has been implemented in MATLAB programming environment. They also investigated the sensitivity of various input parameters such as solar radiation, wind resources and cost of capital to the unit energy cost. The results of the Cuckoo Bird search algorithm are compared with Genetic Algorithms and Particle Swarm Optimization algorithms and it is concluded that the calculation times are decreased by 20.1% and 17.8% respectively (Sanajaoba Singh & Fernandez, 2018).

Sangeetha et al, modeled the hybrid system consisting of photovoltaic panel, wind turbine and battery group using Simulink program and estimated size optimization by using heuristic optimization techniques in Matlab program. They aimed to maximize power supply reliability and minimize power generation costs in the size optimization of the hybrid system. In this study, they compared the results with Genetic Algorithm and Flower Pollination Algorithm for size optimization. They have proven that the genetic algorithm also provides good results in optimization, but the Flower Pollination Algorithm has achieved better results than the Genetic Algorithm by taking into account the energy production and energy costs that meet the installed power (Sangeetha, & Suja, 2017).

Zhang et al. Aimed to develop a new effective methodology for modeling and optimization of the hybrid system for renewable energy by considering two hydrogen and battery-based energy storage devices. They proposed a hybrid Chaotic Search and Harmonia Search based Simulated Annealing algorithm for optimization. The proposed algorithm performance compared with the Simulated Annealing and Harmonic Search based Simulated Annealing algorithms. Algorithms have been developed in Matlab program to obtain the minimum life cycle cost of the hybrid system by supplying the electricity load of the housing in a remote region in Kerman Province of Iran with renewable energy sources independent from the network. The optimization results of the six hybrid systems consisting of wind turbine / hydrogen, photovoltaic panel / hydrogen, wind turbine / photovoltaic panel / hydrogen, wind turbine / battery, photovoltaic panel / battery and wind turbine / photovoltaic panel / battery were compared. According to the optimization results, they concluded that battery-based hybrid systems provide lower cost and reliable energy than hydrogen-based hybrid systems. They stated that the most suitable and economical hybrid system is wind turbine / battery, the ratio of wind turbine, battery and converter to total life cycle costs are 67%, 5% and 28% respectively. 50 independent studies have been conducted for the comparison of the performance of the algorithms and the robustness of the algorithms and they have concluded that the proposed hybrid Chaotic Search and Harmonia Search based Simulated Annealing algorithm is superior to the others (Zhang, Maleki, Rosen, & Liu, 2018).

C. Purpose of the Thesis

The main objective of this thesis is to create optimally design a rooftop hybrid wind-PV power generation system to partly meet power demand for a residential home with controllable and uncontrollable appliances using the binary-code genetic algorithm, which is mostly widely used metaheuristic technique for home energy management in a wind-PV hybrid system consisting of a number of wind turbine, PV panels and batteries. In this hybrid system, total annual net operation and maintenance cost and determination of the number of components are estimated. In the design process the genetics algorithm is encoded in MATLAB environment for simplicity and robustness. The simulation results have shown that the proposed method worked well for the problem under consideration.

II. SYSTEM ARCHITECTURE AND DESCRIPTION

A. Introduction

An off-grid hybrid wind-PV system is designed to meet the energy needs of a small residential building. In terms of benefits and costs, this system differ significantly from each other. The off-grid system optionally requires an emergency generator, or some loads may be shut down when the energy demand is greater than the generated and stored electricity. If the generated excess energy is available at any time interval, it must be dissipated into a controllable discharge load (usually a purely resistive load) to maintain voltage and frequency stability in the AC bus. In some applications, a discharge charge may be an electric water heating system. In a system connected to the network, surplus power is expected to be supplied to the network, reducing operating costs. The energy system considered here consists of three main parts: wind turbine, photovoltaic cells, and battery. The two previous units generate power corresponding to the local wind and solar energy sources to deliver freight. The battery bank is the energy storage system that can feed the load in case of a power failure and store excess energy when the generated energy exceeds the charge. The energy storage system is important to cover the lack of the unpredictable and fluctuating nature of renewable energy, but its existence creates difficulties with the sizing problem. The system works as follows:

PV modules and wind turbines generate electricity when the irradiation and wind speed during the day reach sufficient levels. The fact is that the amount of photovoltaic energy production depends strongly on the speed and the temperature of the solar radiation as well as on the energy efficiency of the modules and therefore changes strongly with an interval of one hour. Similarly, wind turbines may begin to produce energy at wind speeds greater than 3 m / s and stop at wind speeds greater than 25 m/s. If the energy generated in a period of time is greater than the energy required, this excess energy is used to fully charge the batteries; then it will be transferred to an electric water heating system or similar system if energy is still being generated.

There are two types of busbar in the system: direct current (DC) and alternating current (AC).

The direct current (DC) power of the photovoltaic modules is used to charge the batteries via the DC-DC converter. Even the alternative current (AC) power of the wind turbines is converted to the appropriate voltage by the AC to DC converter to charge the batteries as well. The DC energy stored in the batteries is converted into AC energy by the DC-AC converter and transferred to the AC busbar to supply the AC loads. In this case, the DC loads from the DC bus are fed to the voltage level of the battery pack and the AC loads supplied by the AC power bus at a certain voltage and frequency. To be sure our system is working properly, the battery management system controls the charging and discharging of the battery. The block diagram and the open scheme of the hybrid system are shown in Figure 1.

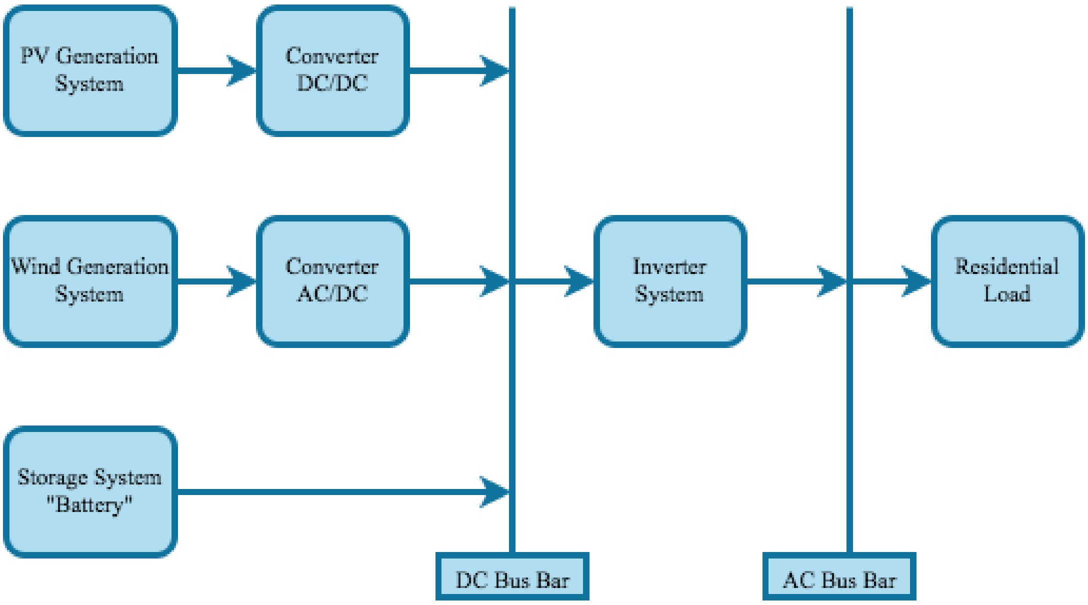

Figure 1 Hybrid System Block Diagram

Table 1 System Components Costs and Ratings

Component	Ratings	Costs $
Wind Turbine	48 V, 1 kW	1688
Pure Sine Inverter	48/220 V, 3.5 kW	512
Mono Crystalline PV Panel	0.25 kWp	250
Deep Cycle Gel Battery	12 V, 200 Ah	325

B. Wind Turbine

1. Power Generation from Wind Energy

Wind is a natural phenomenon caused by air movement due to air pressure gradients. The wind flows from high pressure areas to low pressure areas. The higher the atmospheric pressure gradient, the higher the wind speed and hence the wind energy that can be detected by the wind through wind power conversion machines.

The use of wind energy goes back thousands of years. Ancient human history has shown that wind energy is independently discovered and used in different parts of the world. Windmills have been used in various agricultural sectors, such as pumping water or grinding grain.

Wind turbines need a certain wind speed to generate energy. Start (cut in) and (cut out) can generate energy between wind speeds. The limit is the lower limit, as a rule the system stops below this limit. In modern turbines, the intervention value is between 2 and 4 m/s. The energy gained by the turbine increases with increasing wind speed. At a given wind speed for wind turbines, the system-related power reaches its maximum value. The maximum speed reached is called the rated speed and the maximum power is the rated speed. As soon as the wind speed will exceed the rated speed, the system-related power equals the rated power. In modern turbines, the rated speed is generally between 10 and 15 m/s. The system must stop to prevent damage to the system at higher wind speeds. The point of maximum speed to stop the system is called a disconnect. In modern turbines, this value is usually between 25 and 35 m/s.

2. Wind turbine elements

The main turbine components are shown in Figure 2 and consist of an extruded aluminum shaft, an aluminum die-cast nacelle and integrated electronic components, carbon fiber reinforced epoxy resin blades / diffuser and aluminum fins. An inverter is required to network the turbine.

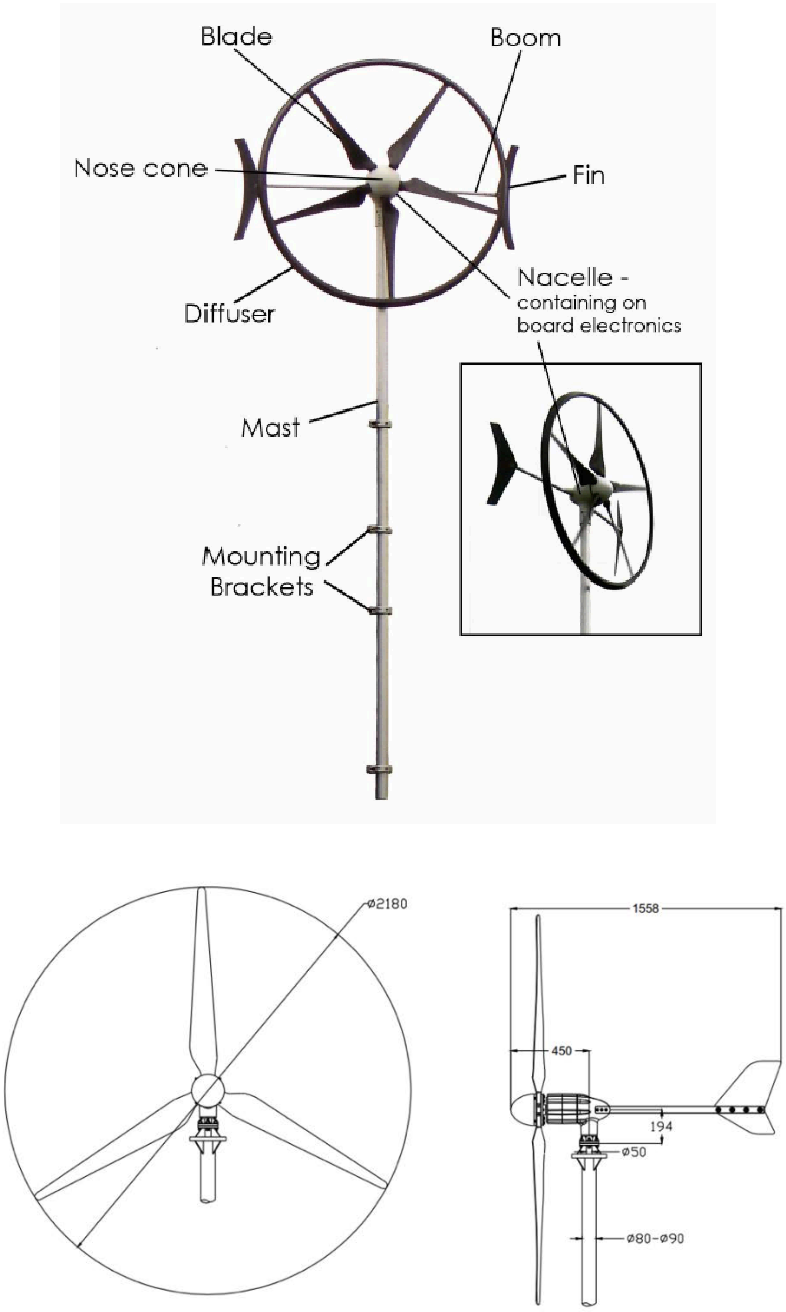

Figure 2 Structure of rooftop wind turbine

Source: (Babu,., Kiran, & Rajendra, 2017).

In wind turbines, the vanes and the hub are defined as rotors, and also the tilt rotation system called tilt control is included in this part. The housing (nacelle) is the part that is connected to the rotor and placed on the tower to accommodate the transmission, the high and low-speed shaft, the control unit, and the generator parts. (Anonymous. 2014).

The transmission transmits the high torque formed in the blades at low speed to the generator by converting the low torque at high speed. The generator is converted into electrical energy with a longer or smaller torque. The tower is made of steel and durable material that carries the rotors, the body, and the blades of the wind turbine. The anemometer is the measurement device of wind speed caused by the temperature difference between the wind and the cables that are under the wind.

Wind turbines are advertised with a nominal output. Roof turbines generally have an output of 400 W to 1 kW. With a quick mental calculation, the 1 kW turbine would generate 24 kWh of energy every day (1 kW x 24 hours). Well, it would be true if the wind blows constantly at the nominal wind speed. The fact is, however, that none of these conditions can occur on a roof, Table 2. shows our wind turbine parameters rated values.

Table 2 Wind Turbine Parameters Rating Values

Properties	**Rated Values**
Output Power	1000W
Max Output Power	1200W
Rotor Diameter	2.18m
Swept Area	3.73 sq.m.
Number of blades	3
Output Voltage	DC24V / 48V
Rotate speed	500 rpm
Cut in wind speed	3m/s
Wind speed	11m/s

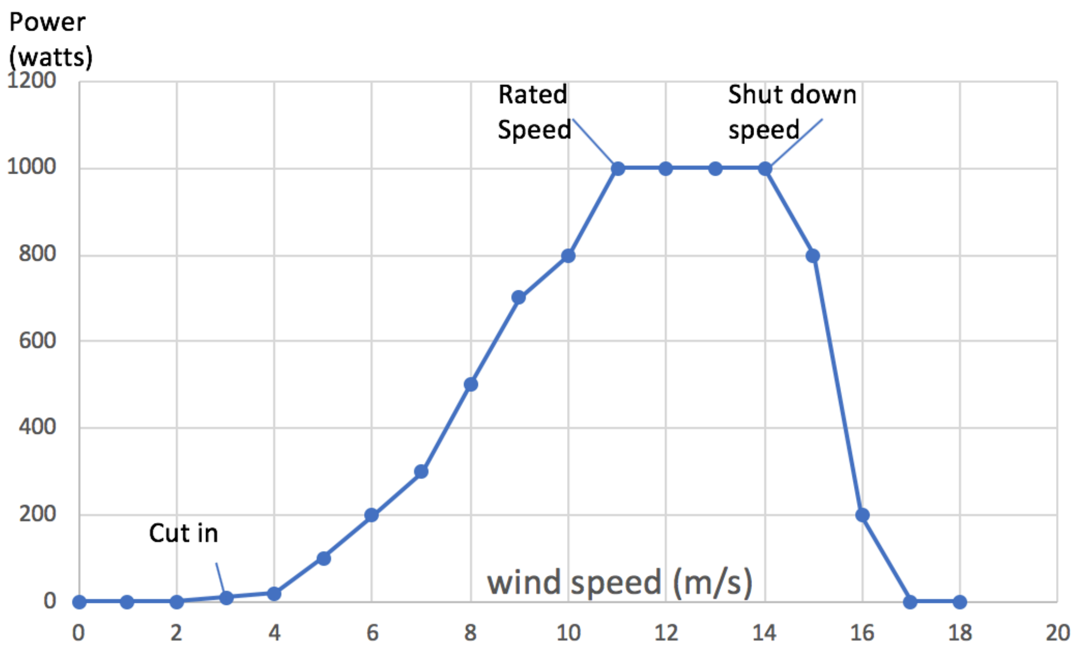

Figure 3 Structure of rooftop wind turbine

The curve shows in Figure 3 that the turbine produces electricity at approximately 3 m/s, the cutting speed. The slower winds do not have enough power to turn the rotor. When the wind speed increases, the power increases rapidly, but the power only reaches 1 kW (the nominal power) when the wind speed is about 11 m/s. To put it in perspective: Winds are more likely to occur in the range of 3 to 5 m/s, which means that a 1 kW turbine generally produces less than a tenth of its nominal value.

The shutdown speed is the speed at which the turbine applies a braking mechanism to avoid damage. A typical shutdown speed is only a few m/s higher than the nominal speed, so that the "weak point", the area in which the turbine generates its nominal power, is quite small.

3. Wind Turbine modeling

A wind turbine generates power Pw when the wind speed V is greater than the cutting in speed Vci and turns off when V is greater than the shutdown (cutting out) speed Vco.

If Vr <V <Vco (Vr is the nominal wind speed), the wind turbine generates the nominal power Pr.

If Vci <V <Vr, the output power of the wind turbine varies according to the Cube Act. The Equation 1 are used to model the wind turbine:

$$\mathrm{P}_w = \begin{cases} P_r.\left(\frac{V^3 - V_{ci}^3}{V_r^3 - V_{ci}^3}\right), V_{ci} \leq V \leq V_r \\ P_r\,,\ V_r \leq V \leq V_{co} \\ 0\,,\ V_{co} \leq V \text{ or } V \leq V_{ci} \end{cases} \qquad \text{(Equation 1)}$$

where

$$P_r = \frac{1}{2}\, C_p \rho_{air} A_w V_r^3 \qquad \text{(Equation 2)}$$

Where $C_{p\ \mathrm{is}}$ the power factor, ρ_{air} is the air mass density shown in Equation 3, and Aw is the cross section of the wind rotor.

In the Equation 2 the values affecting the power available in the wind flow are air density, wind rotor size and wind speed. The main factors affecting air density are ambient temperature, atmospheric pressure, altitude and air components and others. If the altitude and temperature values are known, the air density can be calculated by Equation 3, and the wind speed value measured by the meteorological station is reduced to the location where the renewable system is installed by the Equation 4.

$$\rho_{air} = \frac{353{,}49}{T}\ .\, e^{\left(\frac{-Z}{30\,T}\right)} \qquad \text{(Equation 3)}$$

$$V = V_o.\left(\frac{H}{H_0}\right)^{\alpha} \qquad \text{(Equation 4)}$$

Where *T* is the temperature at the site where the wind turbine is installed measured in (°C).

H is the height at the site where the wind turbine is installed, H_0 height at the original location (statutory conditions or factor value), measured in meter (m).

V is the increased wind speed at the height of the cube H, V_o is the wind speed at the original location (statutory conditions or factor value).

C. Photovoltaic

1. Electricity generation from Photovoltaic

Although solar energy technologies differ from methods and techniques, they are generally studied under two major titles. The first of these are solar thermal technologies. In these systems, heat energy is first obtained, so that the recovered heat can be used directly or converted into electrical energy. The second are photovoltaic systems. Thanks to the solar cells used in these systems, sunlight is converted directly into electricity.

Photovoltaic energy come through the photovoltaic effect, which describes how some materials can convert sunlight into electricity. They absorb some of the solar energy and allow the current to flow between two opposing layers. Individual solar cells provide a relatively small amount of energy, but electrical energy may be important in interconnecting. The cells, modules and matrices may be switched in series or in parallel or in combination generally to produce the desired peak voltage output.

2. Photovoltaic cell

A photovoltaic cell (PV cell) is an energy-sensing technology that converts solar energy into useful electricity through a process called a photovoltaic effect. It uses semiconductors to interact with photons coming from the sun and generate an electric current. (Xu, Zhang, et all 2019).

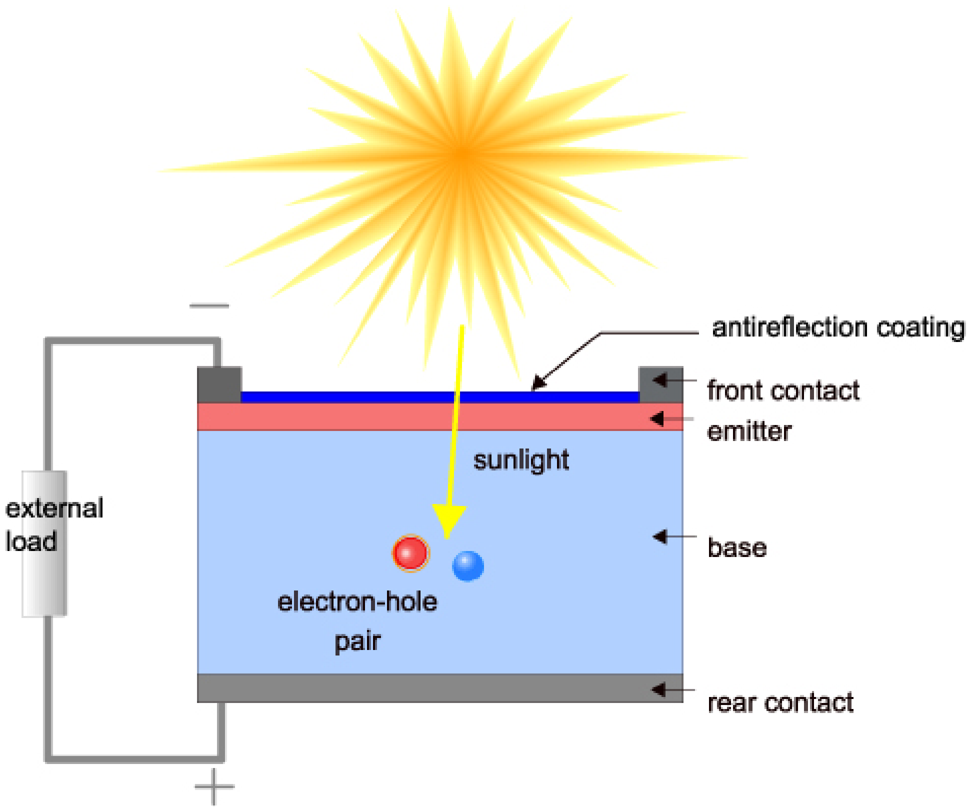

Figure 4 Basic Operation of PV Cell

Source (Asif-Uzzaman, 2015).

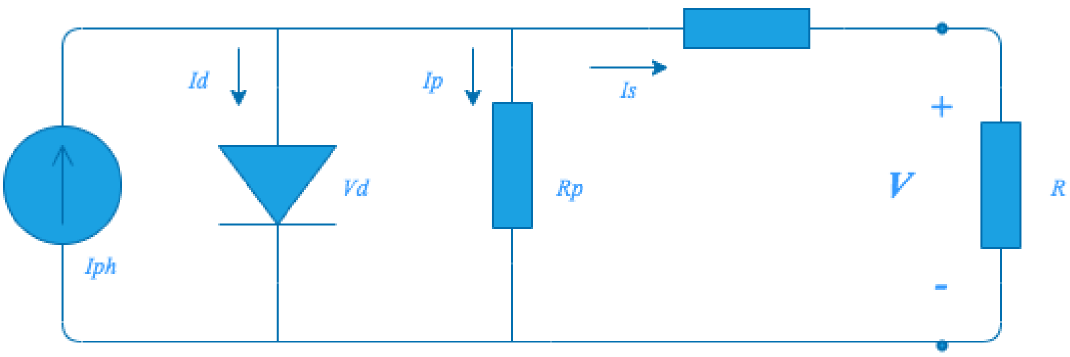

Figure 5 Single Equivalent Circuit Model of PV Cell

3. PV Module

A single solar cell cannot deliver the required net output. In order to increase the output power of a photovoltaic system, it is therefore necessary to connect the number of these photovoltaic solar cells. A solar panel is normally connected in series with a sufficient number of solar cells to provide the required standard voltage and output. A solar module can be designed from 3 watts to 300 watts. Solar modules or photovoltaic modules are basic components available on the market for a solar power generation plant.

In reality, a single photovoltaic solar cell produces a very small amount that varies between about 0.1 watts and 2 watts. However, it is not practical to use a low power device as part of a system. The required number of such cells is combined to form a commercial solar system, which is referred to as a solar module or photovoltaic module.

In a solar module, solar cells such as battery cell units are connected in a battery system. This means that the positive terminals of a cell, which is connected to the negative terminal voltage of the solar module, the simple sum of the voltage of the individual cells, which are connected in series in the module.

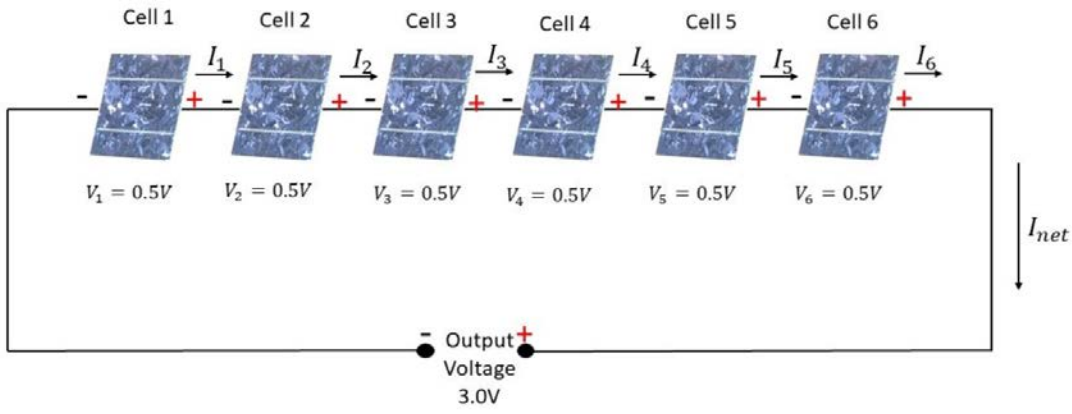

Figure 6 PV module Connected Series

The normal output voltage of a solar cell is about 0.5 V, so if 6 of these cells are connected in series, the output voltage of the cell would be 0.5 × 6 = 3 volts.

The performance of a solar module depends on certain conditions, such as the ambient temperature and the intensity of the incident light. Therefore, the evaluation of a solar module must be determined under such conditions. It is a common practice to express the rating of the photovoltaic or solar module at a temperature of 25 ° C and a light radiation of 1000 W / m2. Solar modules are classified according to open circuit output voltage (Voc), short circuit current (Isc) and maximum output (Wp).

This means that these three parameters (Voc, Isc and Wp) can be measured by a solar module at 25 ° C and a solar radiation of 1000 W / m2.

These conditions, namely the temperature of 25 ° C and the solar radiation of 1000 W / m2, are collectively referred to as standard test conditions. (Hiendro, Yusuf, et all, 2018).

The site where the solar modules are installed. This is because the sunlight and the temperature vary with time and place.

a) Characteristics of PV Module

If we plot a diagram in which the X-axis is represented as a voltage axis and the Y-axis as a solar module, then the diagram represents the V-I characteristic of a solar module.

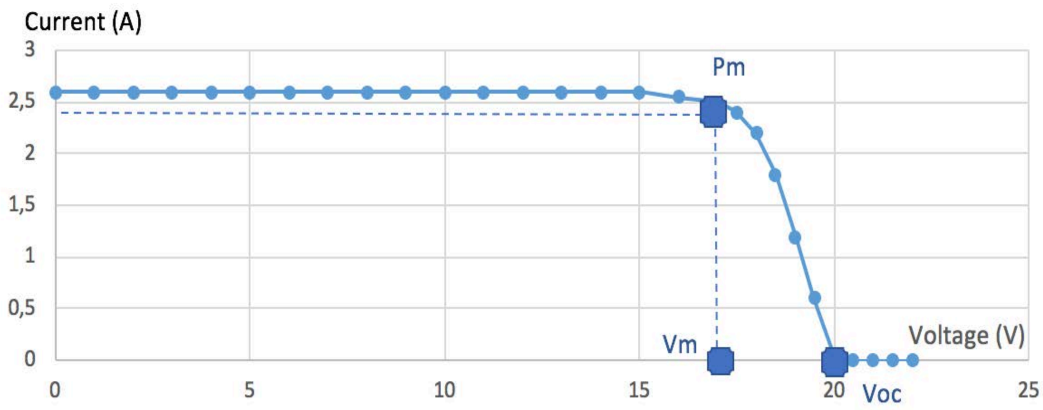

Figure 7 Characteristics of PV Module

The I-V curve of an illuminated solar cell has the shape shown in Figure 7. Many cell performance parameters can be obtained from this curve:

- Short Circuit Current, Isc
- Open Circuit Voltage, Voc
- Theoretical Power, Pth
- Maximum Power, PMax

4. PV Arrays

A photovoltaic array is a coherent collection of photovoltaic modules as shown in the Figure 8. Each photovoltaic module (PV module) consists of several interconnected photovoltaic cells. Cells convert solar energy into direct current. Photovoltaic modules are sometimes referred to as solar modules, although this term is best used for solar thermal modules or air heaters. Photovoltaic modules differ from solar cells in that they are the right size and packaged in weatherproof enclosures for easy installation and installation in residential, commercial and industrial applications. The application and investigation of photovoltaic devices is called photovoltaics.

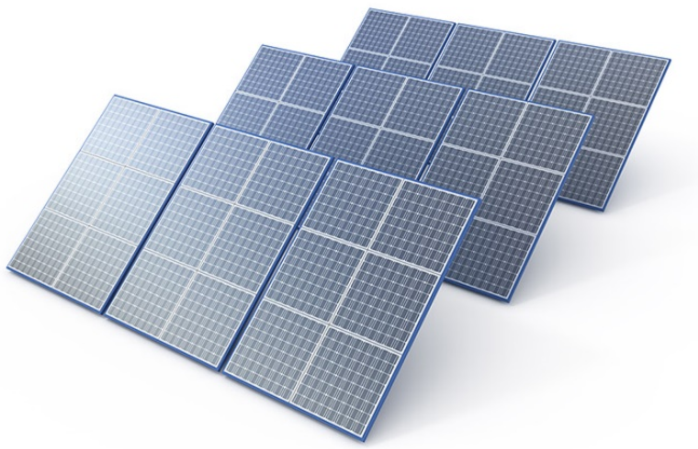

Figure 8 PV Arrays General Shape

a) PV Arrays Modeling

For a photovoltaic system with η_{PV} efficiency and A_{PV} area (m2), the P_{PV} output power (kW), if it is subject to the available solar radiation R (kW / m2) on the inclined surface, results from Equation 5:

$$P_{PV} = R \,.\, A_{PV} \,.\, \eta_{PV} \qquad \text{(Equation 5)}$$

5. Photovoltaic systems summary

Photovoltaic systems are also used as renewable energy sources and solar thermal energy technologies.

Photovoltaic (PV) technology converts direct solar energy into electricity according to the photoelectric principle. The photovoltaic technology is therefore suitable for areas with low and high direct radiation.

The surfaces of photovoltaic systems may vary in square, circular or rectangular. Its thickness is about 0.2 mm or 0.4 mm and its area can vary up to 100 m2. It is known that the intensity of solar radiation at sea level on a sunny day is 1000 W / m2. Depending on the region, the amount of energy per 1 m2 varies between 800 and 2600 kW / h per year.

Photovoltaic technology uses solar collectors made from various types of photovoltaic materials to produce electricity. The most commonly used materials include mono- and polycrystalline silicon triple-fused solar cells, cadmium tellurite (CdTe), gallium arsenide (GaAs), and indium gallium phosphite (InGaP).

A solar cell is generally a small power generator. To generate electricity on a large scale, solar cells form a multicellular module. These modules are mounted in a photovoltaic field with a length of up to several meters.

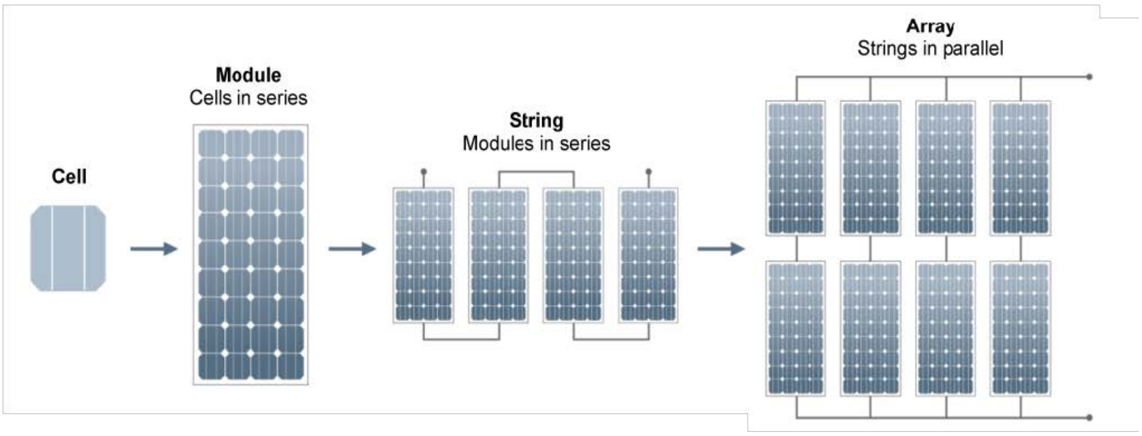

Figure 9 PV System General Layout

Table 3 PV Parameters Rating Values

Parameter Name	**Value**
Maximum Power	250 W
Short Circuit Current	8,42 A
Open Circuit Voltage	37,3 V
Maximum Power Voltage	30,4 V
Maximum Power Current	7,74 A
Cells No.	60
Short Circuit Current Temperature Coefficient	0,04%/ ºC
Maximum Power Temperature Coefficient	-0,44%/ ºC
Open Circuit Voltage Temperature Coefficient	-0,35%/ ºC
Normal Operating Condition Temperature	45±2 ºC

D. Battery Bank

The battery storage serves to store the additional energy generated by PV and WT and to compensate for the energy deficit when renewable energies cannot meet the charging requirement. The battery charging process begins when the total output power of the wind and photovoltaic generator is greater than the charging demand, while the battery bank is discharged when the power generated by the wind and photovoltaic generator is less than the demand charging The proposed deterministic approach becomes the uncertainties of solar radiation which takes into account wind speed and load demand when taking into account the uncertainty factor determined from the average forecast error with the PV / WT generation models.

1. Battery Bank Modelling

At every hour t; the battery state of charge [SOC (t)] is linked to the state of the previous charge [SOC (t - 1)] and the situation of the production and energy consumption of the system during the period t - 1 to t. During the charging process when the charge of the (PB battery) flows to the battery (i.e. PB> 0), the state of charge of the battery available at time t can be described by:

$$SOC_{(t)} = SOC_{(t-1)} + \frac{P_B(t).\Delta t}{1000\, C_b} \quad \text{(Equation 6)}$$

Δt is the simulation step time (which is set to 1 hour) and *Cb* is the total nominal capacity of the battery in kilowatt hours. On the other hand, when the battery charge leaks from the battery (i.e., PB <0), the battery is discharged. Therefore, the state of charge of the battery that is available at time t can be expressed as:

$$SOC_{(t)} = SOC_{(t-1)} - \frac{P_B(t).\Delta t}{1000\, C_b} \quad \text{(Equation 7)}$$

To extend the life of the battery, the battery must not be discharged or overcharged. This means that the *SOC* battery must be subject to the following restriction at all times:

$$(1 - DOD_{max}) \leq SOC_{(t)} \leq SOC_{(max)} \quad \text{(Equation 8)}$$

Where *DODmax* and *SOCmax* are the maximum permissible discharge depth of the battery and the *SOC*.

E. Load profile

Residential load can generally be divided into two main categories, based on their ability to reschedule. These categories are:

1. **Uncontrollable load.**

2. **Controllable load.**

The non-controllable load consists of non-controllable devices and accounts for 20% of the total load such as lighting, television, computers and refrigerators. The power supply must be available when consumers use the first category device.

Controllable charging or intelligent charging uses new technologies, such as intelligent devices, and is divided into two subcategories: not delayed and delayed. Non-controllable appliances are those that are thermostatically controlled, such as the air conditioning, heating and automatic water heater, and account for 50% of the total load. Non time delay devices can be controlled when heat storage is installed to reduce the energy shortage. The devices that can be undone are those that are not controlled by a thermostat, such as a thermostat clothes washer / dryer and dishwasher, iron, kettle and vacuum cleaner. Deferred devices account for 30% of the total load. The residents are flexible to change their use at low price periods.

Due to the controllable load, the request response strategy can be used efficiently, e.g. B. Load reduction and load transfer. During the request to answer the question, the program participants therefore reduce the energy consumption of the network and program it in another time interval in which the energy price is low. In times of low activity, the participants can consume energy in the networks to simplify this.

The load profile and working hours in our typical house are given in the table 4:

Table 4 Typical Residential Loads and Operation Hours

No	Load	Power (kW)	Operating Range (h)	Duration (h)
1	Dishwasher	2.1	9-21	1.5
2	Washing Machine	1.5	8-21	0.75
3	Smoothing Iron	2.4	8-21	0.75
4	Oven	1.7	10-19	0.5
5	Fridge	0.2	1-24	12
6	Toast Machine	2.4	7-19	0.25
7	Dryer	2.2	9-22	1
8	TV	0.1	8-24	17
9	PC	0.2	9-20	4
10	Combi Heater	0.15	1-24	12
11	Vacuum Cleaner	2	9-19	1
12	Mini Oven	1.4	8-11	0.5
13	Water Kettle	2.2	8-11	0.5
14	Indoor Lightning	0.2	7-24	9
15	Outdoor Lightning	0.2	1-24	13

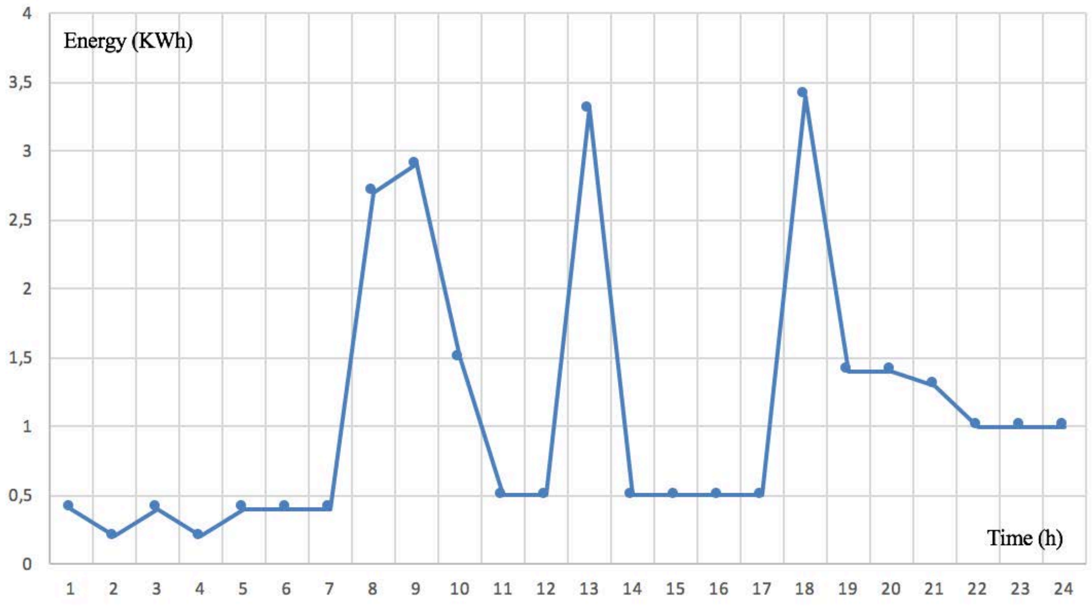

Figure 10 Load Profile for Typical Residential Home Load

III. PROBLM FORMULATION AND SYSTEM OPTIMIZATION

A. Introduction

Optimization is the sum of the mathematical principles and methods for solving numerical problems in many disciplines such as physics, biology, engineering, business and trade. In engineering, optimization is the most efficient use of resources (labor, time, capital, processes, raw materials, capacities, equipment, etc.) in a system for specific purposes (cost reduction, maximizing profits, maximizing) the use and maximizing efficiency). It is defined as a method that enables access (Touré, Addouche, et all, 2019).

Optimization is the process of doing something better. During optimization, the inputs are adjusted to determine the minimum or maximum result or the maximum output. It depends on a device, a math operation, or an experiment. As shown in the following figure, the entries consist of variables. The process or function is referred to as a cost function, target function, fitness functions and the result as costs and fitness. (Tutkun, Moses, 2014), (Tutkun, Moses, 2014).

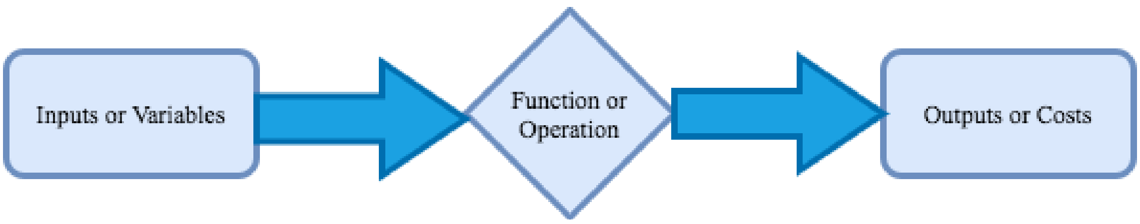

Figure 11**:** General Optimization process Diagram

Mathematically, optimization can be defined as finding the best solution to a function with one or more arguments with certain restrictions. Optimization is the largest and smallest process that spans many disciplines, from economy to business, from production to design. It is an optimization process to get the maximum benefit or the lowest cost in the company, to manufacture the device in the most ideal dimensions in the design, to design the devices that use less energy or to the harmful gases emitted by the engine to minimize (Mekontso, Abubakar, et all, 2019).

Optimization problems are the selection of the best system components from a search field or a range of possible solutions.

B. Construction of Objective Function

Optimization methods can be divided into two categories as conventional and next generation methods. Conventional methods are the graphical structure method, the iterative method, the probability method and the exchange method. Conventional methods follow a strict procedure and also show little flexibility, low convergence speeds, longer calculation times and no dynamic changes. Nowadays, these techniques are rarely used due to their inconvenience. On the other hand, next generation approaches are faster, more flexible than traditional approaches, with higher convergence speeds and effective global search solutions. This trend shows that the new generation of algorithms (evolutionary heuristics) has been widely accepted and used in the literature in recent years. The next generation methods are taboo search based on artificial intelligence, genetic annealing, simulated annealing, harmony search, optimization based on biogeography, ant colony optimization, cuckoo bird, Firefly algorithms as heuristic algorithms inspired by nature. (Ndukwe, Iqbal, Liang, & Khan, 2019).

Renewable energy systems rely heavily on system components. Correctly modeling each component therefore provides tools to better understand system performance and reliability, and to optimize the system. The researchers use various optimization techniques such as the graphic method, the probabilistic approach, the iterative technique, artificial intelligence (intuitive), dynamic programming, linear programming, multi-purpose design and software to optimize the hybrid photovoltaic system. / wind (Oviroh, & Jen, 2018).

The main concern in designing the proposed PV wind hybrid system is to determine the size of each component involved in the system so that the load can be met in an economical and reliable manner. System components are therefore subject to:

1. Minimize the total cost of the system.

2. Make sure that the load is delivered according to certain reliability criteria.

In order to minimize the cost in the hybrid system, the power difference between the generated and consumed powers must be reduced as much as possible. In this case the difference power can be expressed by Equation 8.

$$\sum_{k=1}^{24} \left(\Delta P(k) = P_g(k) - P_d(k) \right) = 0 \quad \text{(Equation 8)}$$

Where k is the consecutive integers 1 to 24, *Pg (k)* and *Pd (k)* are the forces produced and consumed respectively in the hourly time period.

The energy generated and demanded in total in each 24 hour period can be expressed in Equation 9 and Equation 10.

$$W_g = \Delta t \sum_{k=1}^{24} \{ N_w \times P_w(k) + N_p \times P_p(k) \} \quad \text{(Equation 9)}$$

$$W_d = \Delta t \sum_{k=1}^{24} P_d(k) \quad \text{(Equation 10)}$$

Here, Δt is the time interval, *Pw (k), Pp (k), Np* and *Nw* respectively, the wind turbine in the k-hour period, the forces generated by the panels, the number of PV panels and the number of wind turbines (Kharrich, Akherraz, & Sayouti, 2017).

To achieve the balance between daily generated and consumed forces, the average 24-hour energy difference must be zero. When the hourly change of power difference is considered, it is seen that it has positive and negative values. The positive and negative values of the power difference indicate excess power and lack of power, respectively. The integration of the power difference over time gives the total daily energy difference and is expressed in Equation 11.

$$\Delta W = W_g - W_d = \Delta t \sum_{k=1}^{24} \Delta(k) \quad \text{(Equation 11)}$$

To determine the amount of batteries to be stored we use the difference between the positive and negative peak values of the energy change over an average day.

Gel batteries have a life cycle of 1500 cycles, and this cycle should not exceed 80% charge and less than 20% discharge for good performance. Accordingly, the number of batteries required for storage capacity can be calculated by Equation 12.

$$N_b \geq \frac{\Delta W_{max} - \Delta W_{min}}{0.8 W_b} \quad \text{(Equation 12)}$$

Where, ΔW_{max}, ΔW_{min} and Wb are the maximum and minimum energy values of the energy difference and the largest amount the battery can store.

To determine the number of PV panels and wind turbines required in the hybrid system needed to feed electrical loads in a typical house, the following procedures should be followed:

1. The unit prices and average life of commercially available 1 kW wind turbines, 0.25 kW PV panels and 200 Ah gel batteries are determined.
2. If the wind turbine power exceeds a single PV panel power rating, the number of PV panels is gradually increased to maintain power balance.
3. Annual cost is calculated for each combination and the lowest cost hybrid system combination is found.
4. Choose the best combination with the lowest cost.

Taking these steps into consideration, the most suitable combination of WIND-PV-Battery components to be used to meet the energy requirements of a residence in the Turkish south boarder area of Kilis was chosen. (Tutkun, Can, Afandi, 2017)

Pricing of each component of the system is given and this combination is determined to minimize installation, maintenance and operation costs.

Based on the data of Table 1 for 20 years of system life only wind turbine, only PV and hybrid WIND-PV system combinations are calculated with the total cost (TC) of Equation 13.

$$TC = (N_{WT} \times C_{WT} \times F_{WT} \times P_{WT} + N_{PV} \times C_{PV} \times F_{PV} + 5 \times N_B \times C_B \times F_B) \times C_{IR} + \left(N_{WT} \times B_{WT} \times E_{WT} + N_{PV} \times B_{PV} \times E_{PV} + \sum_{k=1}^{24} \left\{ \left(\sum_{i=1,j=1}^{N_{WT},N_{PV}} c_{WTi} P_{WTi}(k) + c_{PVj} P_{PVj}(k) \right) - c_c P_c(k) + c_d P_d(k)\, c_m P_m(k) - c_e P_e(k) \right\} \right) \times 365 \quad \text{(Equation 13)}$$

Depending on the following constraints:

$$\sum_{k=1}^{24}\left\{\sum_{i=1,j=1}^{M,N}\left(P_{WTi}(k)+P_{PVj}(k)\right)-P_c(k)+P_d(k)+P_e(k)-P_f(k)-P_l(k)\right\}$$

(Equation 14)

$$0 \leq P_{WTi}(k) \leq P_{WTimax}$$

$$0 \leq P_{PVj}(k) \leq P_{PVjmax}$$

$$0 \leq W_d(k) \leq 2{,}4\ kWh$$

$$0 \leq W_c(k) \leq 2{,}4\ kWh$$

$$W_d(k) - W_c(k-1) \leq 0$$

$$W_d(0) = W_0 = 1{,}2\ kWh$$

Where N_{WT} number of wind turbines (WT), C_{WT} unit generation cost coefficient, F_{WT} price of each WT, P_{WT} rated power of WT, N_{PV} PV panel number, C_{PV} PV installation cost coefficient, F_{PV} PV panel price, N_B number of batteries, C_B battery installation cost coefficient, F_B battery price, C_{IR} combined interest rate, B_{WT} WT maintenance cost per kWh, E_{WT} amount of energy produced by kWh in kWh per year, B_{PV} PV maintenance cost per kWh, E_{PV} PV panels is the amount of energy produced in kWh in one year.

The maintenance costs per kWh for WT and PV panels are taken as 0,85 and 0,42 cents respectively.

P_{WT} power generated by WT, P_{PV} power generated by PV, P_l power demand, P_c charging power to the batteries, P_d discharging power from the batteries, P_m missing power, P_e extra power generated, W_c the amount of energy stored in the batteries, W_0 the amount of energy initially charged in the batteries.

c_{WT} the unit costs of WT power = 0.03 $, c_{PV} the unit costs of PV power = 0.03 $, c_c the unit costs of charge power = 0.04 $, c_d the unit costs of discharge power = 0.03 $, c_m the unit costs of missing power = 0.11 $, c_e the unit costs of extra generated power = 0.03 $.

In the scale WT-PV hybrid system shown in Figure 1, PV panels and WT are used for basic electricity production and batteries are used for storage. In the area where the system is installed, electricity production with PV panels and WT is mainly dependent on radiation and wind speed, respectively. The maximum energy to be obtained from each device is usually given by the manufacturer as a datasheet, as given in Table 3, but the radiation level, wind speed and temperature, and so on. elements may change momentarily according to the conditions of the environment at any moment. (Tutkun, 2014)

The energy generated by each subsystem can be estimated by a small calculation by looking at their respective power curves. It produces 0.25 kW and 1 kW electrical energy with a monocrystalline PV panel and a horizontal axis WT sequence. The gel batteries used in the hybrid system have a storage capacity of 2.4 kWh and are suitable for deep cycle use. A 3 kW closed loop full sine converter is required to convert the DC power stored in the batteries to AC power in order to supply AC loads in the settlement. The maximum energy to be obtained from PV panels at any time is provided by maximum power point tracking system and the maximum energy to be obtained from WT is determined mechanically by wind direction. Thus, once the power to be produced with PV panels and WT is determined, the energy demand is met by methods such as load shifting, valley filling, hill trimming according to the changing time during the day. In order to reduce the energy, installation, operation and maintenance costs of the small-scale system, it is necessary to balance the energy produced and consumed in each time frame. (Tutkun, Çelebi, 2014)

C. Binary-Coded Genetic Algorithms

Genetic algorithms play an important role in many areas such as artificial intelligence, engineering, robotics, etc., for example in research techniques for managing complex spaces. Genetic algorithms are based on the underlying genetic process in biological organisms and on the principles of the natural evolution of populations. These algorithms process a population of chromosomes that represent

spatial research solutions with three operations: selection, crossing, and mutation. In their original formulation, search space solutions are encoded using the binary alphabet. However, the good properties of these algorithms do not result from the use of this alphabet. Other types of encoding have been considered for the rendering problem, such as real encoding, which appears particularly natural when addressing parameter optimization problems with variables in continuous domains (Babu,., Kiran, & Rajendra, 2017).

In order to solve this optimization problem, genetic algorithm (GA) is proposed, in which the code of the genetic algorithm with the MATLAB software is used in this work to solve the previous optimization problem, GA contains the elitist approach.

This means that a solution cannot be degraded from one generation to the next, but that the best individual from one generation is copied to the next generation without changes. (Tutkun, Moses, 2014)

The GA used is based on the use of the flow chart in the following figure to obtain the optimal solution. Initially, GA picks random individuals from the current population as parents and uses them to father children for the next generation using the three main operations of selection, crossing, and mutation operations. Therefore, you can change a population of individual solutions repeatedly, with the population developing into an optimal solution in later generations. It should be noted that the different configurations used in the GA 100 individuals for the population size, the stochastic uniformity function for the selection operation, the scatter cross function (with a crossing probability of 80%) for the cross operation, possible adaptive mutation function (with a probability of 1%) for mutation surgery and an elite person. It should be noted that the three additional limits of the last equation can be entered directly into the specific positions of the GA. (Kömürcü, Tutkun, Özölçer, Akpınar, 2008).

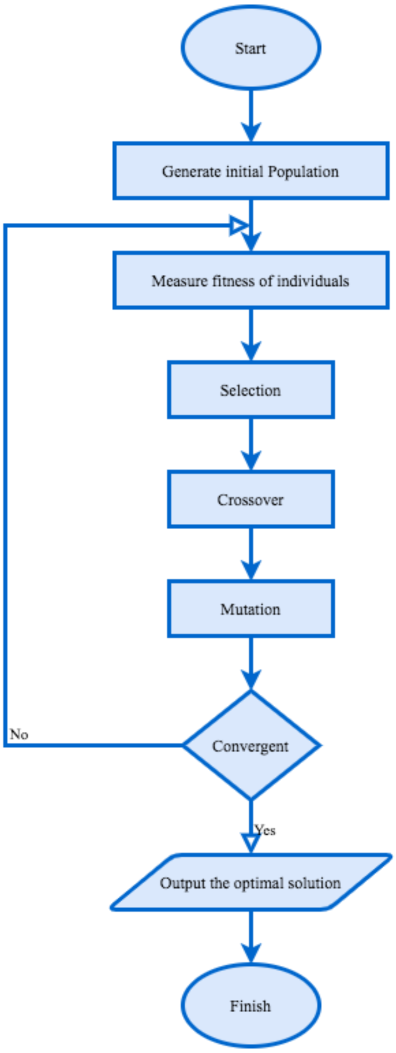

Figure 12 Genetic Algorithm Flowchart

D. Methodology

We will assume to design a 5 kW wind-PV system for 20 year lifetime and we have to feed constant 5 kW load residential home.

There are loads have rated power value and operating at different hours as I mentioned previously, as washing machine is operated 0,75 hour and rated power value is 1.5 kW.

So, the main objective is to design a low-cost wind-PV hybrid system in terms of investment and operation and maintenance costs.

To make this we have to optimize wind-PV system using the real coded system in terms of number of PV panels, wind turbines, batteries.

Wind speed and insolation rate data used in the calculation of the estimated power are obtained as the annual average of each hour of the day. The average wind speed and sunbathing data for 2015, 2016 and 2017 were obtained from the local weather station and adapted to the specified location.

Figure 14 and Figure 13 show the hourly variation of average wind speed and radiation level during the day on an hourly basis corresponding to each hour of each day of the three years. The average wind speed and radiation level during the day were calculated as 6.36 m/s and 0.21 kW/m2, respectively. The typical load profile and working hours rated power values are given in Table 4.

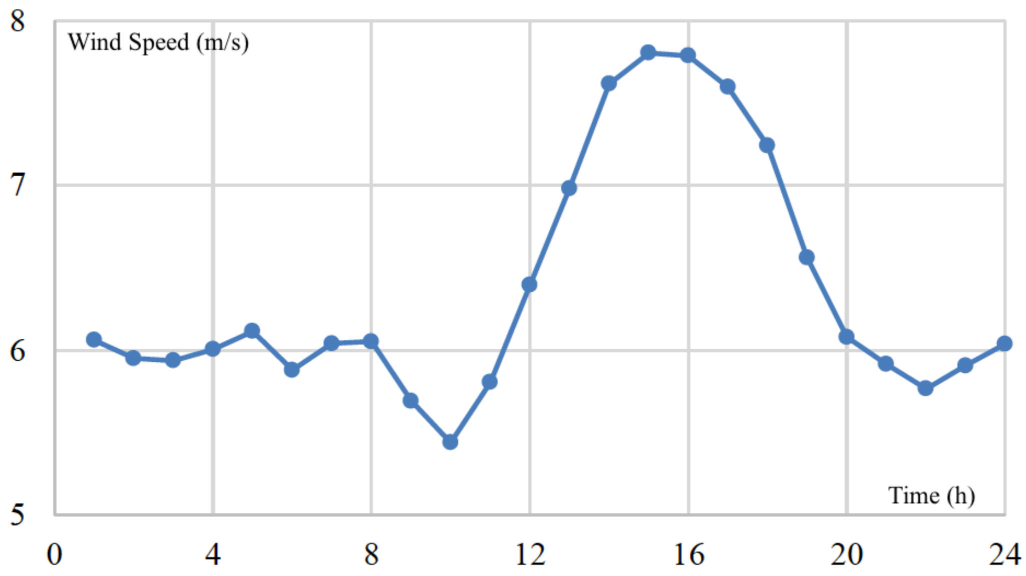

Figure 13 Hourly Change of 3-Year Average Wind Speed

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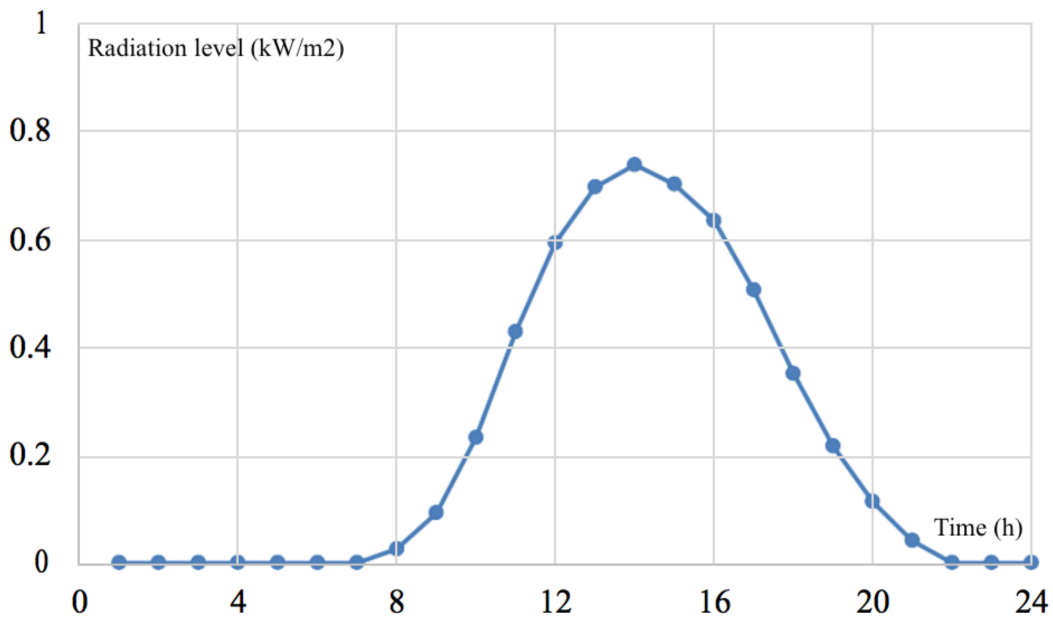

Figure 14 Hourly Change of 3-Year Average Radiation Level

In the scale WT-PV hybrid system shown in Figure 1, PV panels and WT are used for basic electricity production and batteries are used for storage. In the area where the system is installed, electricity production with PV panels and WT is mainly dependent on radiation and wind speed, respectively. The maximum energy to be obtained from each device is usually given by the manufacturer as a datasheet, as given in Table 3, but the radiation level, wind speed and temperature, and so on elements may change momentarily according to the conditions of the environment at any moment.

The energy generated by each subsystem can be estimated by a small calculation by looking at their respective power curves. It produces 0.25 kW and 1 kW electrical energy with a monocrystalline PV panel and a horizontal axis WT sequence. The gel batteries used in the hybrid system have a storage capacity of 2.4 kWh and are suitable for deep cycle use. A 3 kW closed loop full sine converter is required to convert the DC power stored in the batteries to AC power in order to supply AC loads in the settlement. The maximum energy to be obtained from PV panels at any time is provided by maximum power point tracking system and the maximum energy to be obtained from WT is determined mechanically by wind direction. Thus, once the power to be produced with PV panels and WT is determined, the energy demand is met by methods such as load shifting, valley filling, hill trimming according to the changing time during the day. In order to reduce the energy, installation, operation and maintenance costs of the small-scale system, it is necessary to balance the energy produced and consumed in each time frame.

The Figure 15 shows the proposed optimization procedure of the PV-Wind hybrid system based on high resolution solar irradiance including the cost analysis.

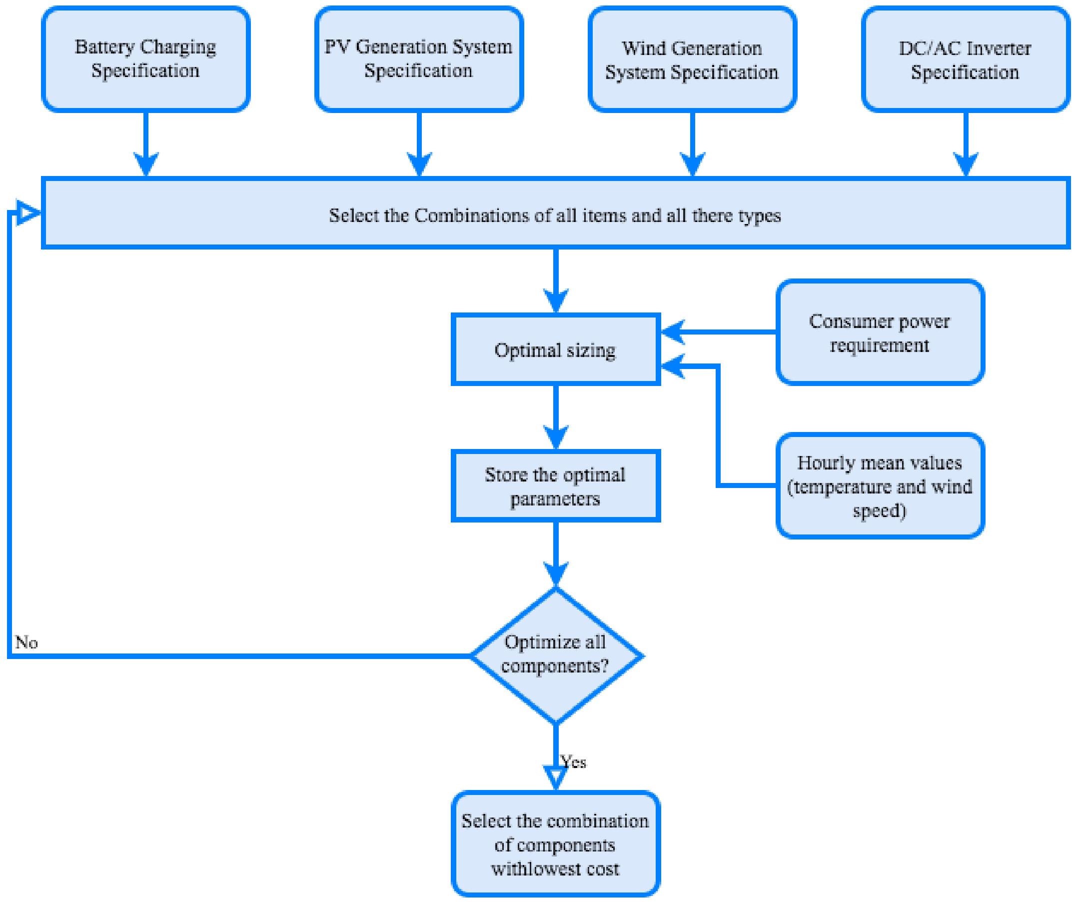

Figure 15 proposed optimization methodology Flowchart

IV. RESULTS

A lot of studies have been conducted to select the most appropriate number and properties of the components of the WT-PV-Battery system that can typically meet the energy needs at the lowest cost in terms of installation, production and maintenance costs of a house in the province of Kilis and the following results have been achieved. The average annual load profile of Kilis per hour is shown in the following figure: This is a good example of the electricity needs of households with an average income level in the region. The specific wind speed of the region and the radiation values were taken from the Directorate General for Renewable Energies.

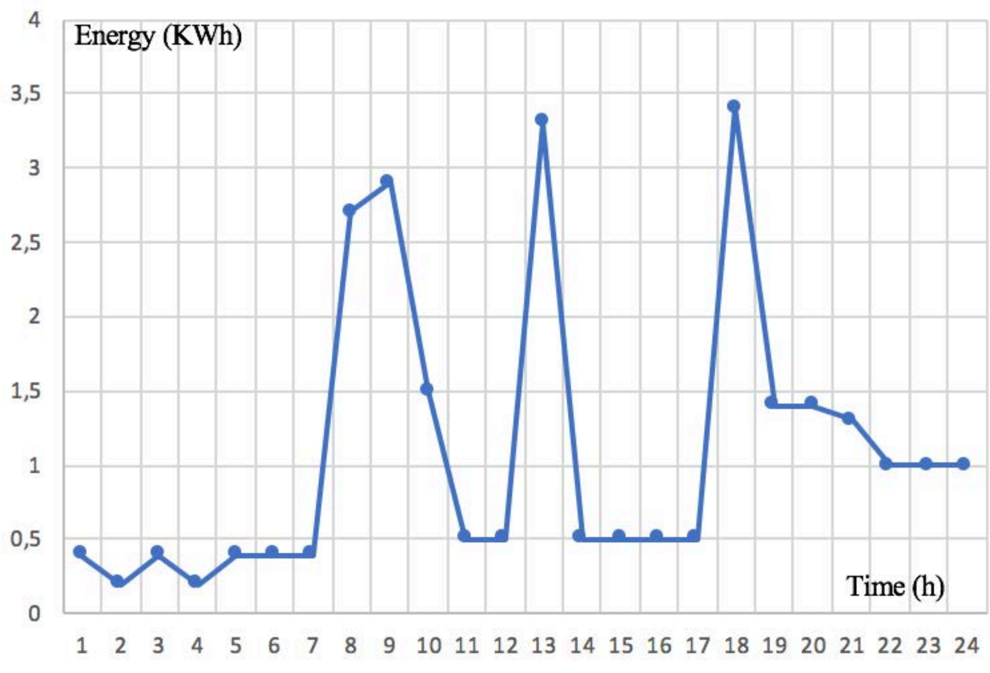

Figure 16 Load Profile

In Figure 16, daily energy demand varied from 0.2 to 3.3 kWh per hour. The total amount of energy required for such a load profile in one day is calculated as 26.63 kWh and the average energy amount is calculated as 1.05 kWh.

The changes in the amount of power converted from the current wind speed and solar radiation during the day are given in Figure 17 and Figure 18.

Figure 17 shows the variation of the power values produced by wind turbine with 1, 1.5 and 2 m wing lengths during the day. In the standard 1 kW wind turbine power curve modeling, the power coefficient is calculated as 0.45 and the wing length is assumed to reach 1 m and maximum power at speeds of 9-10 m / s. Since the average speed in Kilis province is 50% less than this rated speed, the primary way to increase the power is to increase the wing lengths considerably. In this study, wind turbine, which has a pole length of 10 m and wing length of 2 m, can be easily installed in the vicinity of a typical house.

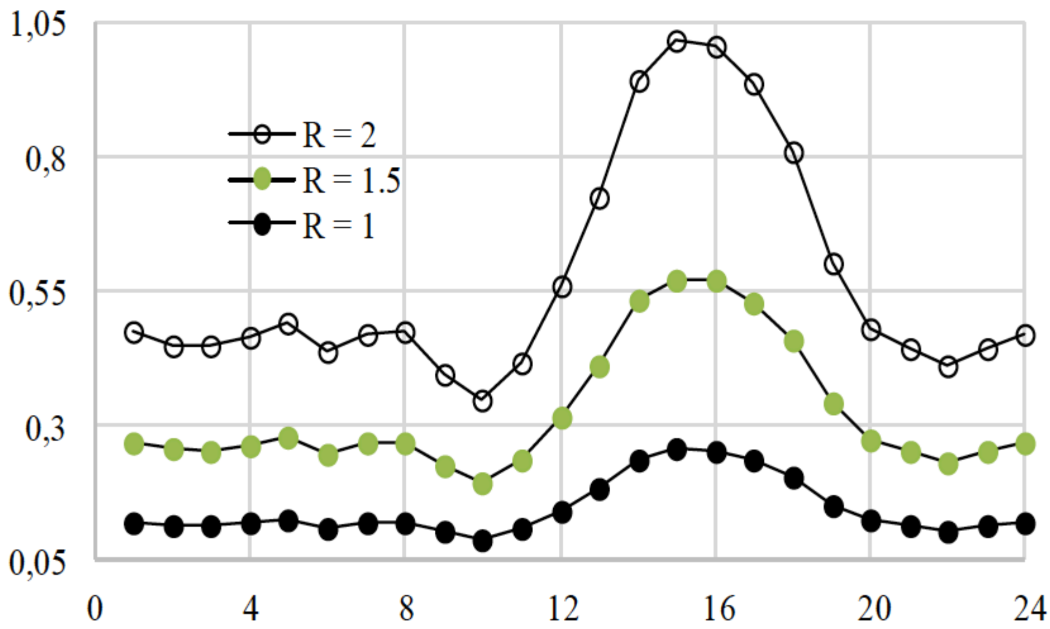

Figure 17 Variation of Power Generated at Different Wing Lengths

The daily change of power produced by the mono-crystalline PV panel used in energy production with the PV system or Wind -PV system in Kilis province is given in Figure 18. The area of the planar panel is 1.6 m2 and its efficiency is taken as 15%. The highest value of the power produced from the said PV panel is 0,18 kW and this value occurs in the 13th time of day.

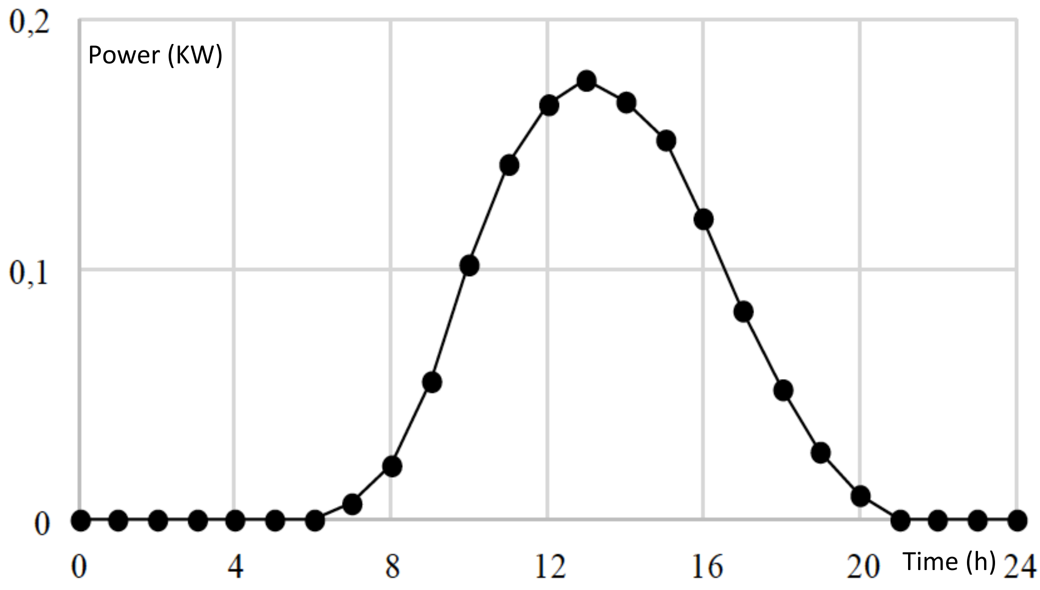

Figure 18 Daily Power Change of PV Panel

The first proposed combination consists of pure PV panels, batteries and a full sine converter. According to the calculations made with Equation 13, 19 units of 0.25 kWp planar PV panels, 3.5 kW full sine grid connection inverters, using the data available in the diesel generator network disconnected system needed to meet the energy of a typical house in Kilis province from pure PV panels, 4 200 Ah gel battery is required. Additional costs of 25% of the total cost are required for this system. Accordingly, the current price of a single panel, inverter, battery and diesel generator is changed every 4 years by adding additional costs for a 20-year operating life of 250 $, 512 $, 325 $, 2000 $.

System components and prices for combinations formed in 3 different formats are given in Table 5. In the 3 prescribed combinations, the diesel generator will be used to supply insufficient energy if the wind and radiation levels are insufficient and the energy stored in the batteries is insufficient. In order to calculate the annual operating, maintenance and investment costs in the system combinations thus formed, 10% annual difference, 0.14 cent per kWh for PV panels, 0,27 cent maintenance cost for WTs and 2000 $ 1.5 kVA of diesel generator is taken into calculation.

Table 5 Hybrid System Component's Ratings and Costs with Backup Generator

Component	Ratings	Price $
Wind Turbine	48 V, 1 kW	1688
Pure Sine Inverter	48/220 V, 3.5 kW	512
Mono Crystalline PV Panel	0.25 kWp	250
Deep Cycle Gel Battery	12 V, 200 Ah	325
Diesel generator	220 V; 1,5 kVA	2000

A. Unplanted Load Status

The electrical loads in a typical house are routinely distributed and the annual installation, maintenance and operating costs are calculated for pure PV, pure Wind and hybrid Wind-PV systems. As it is known, since wind and solar are momentary changeable renewable energy sources, the distribution of the load during the day in accordance with minute or hourly changes may reduce the costs relatively to the current situation. In order to see this clearly in this study, the total installation, maintenance and operating costs of the three systems were calculated according to the unplanned load distribution given in Table 6 and the results obtained are given below.

1. Pure PV System

In this system, there are 19 PV panels, 4 gel batteries, 1 inverter and 1 diesel generator and the annual cost is 1423.16 $ Figure 19 shows the energy produced by PV panels on a daily basis in the pure PV system, the demanded energy and the difference energy changes. The difference between the energies produced and demanded here is 3.09 kWh, it occurs in the 14th time zone, -2,71 kWh and in the 19th and 20th time zones. The positive energy difference indicates the excess production and the negative energy difference indicates the energy deficit. The difference between these two values is expressed in Equation 12 and is used to determine the number of batteries. As expected, PV power reaches the highest values at midday hours. That is, the 11th, 12th, 13th, 14th, 15th time zones are the values in which the generated energy reaches considerable quantities. Figure 20 shows the charge and discharge status of the batteries used in this combination. Initially, 1.2 kWh of energy was stored before the battery group consisting of 4 batteries was started. In Figure 15, the battery group is discharged in the 1st, 2nd, 3rd, 10th, 11th, 18th, and 19th time periods. The largest and smallest discharges occur in the 18th and 10th periods, which are 0.15 and 1.81 kWh, respectively. The battery group is charged with 0.61 and 2.35 kWh during the 9th and 12th periods and no other charge occurs. When the current charge state of the battery is examined, it is seen that the charge status is zero between 3-8 and 19-24 slices, the charge is full between 12-17 and it reaches 2.4 kWh.

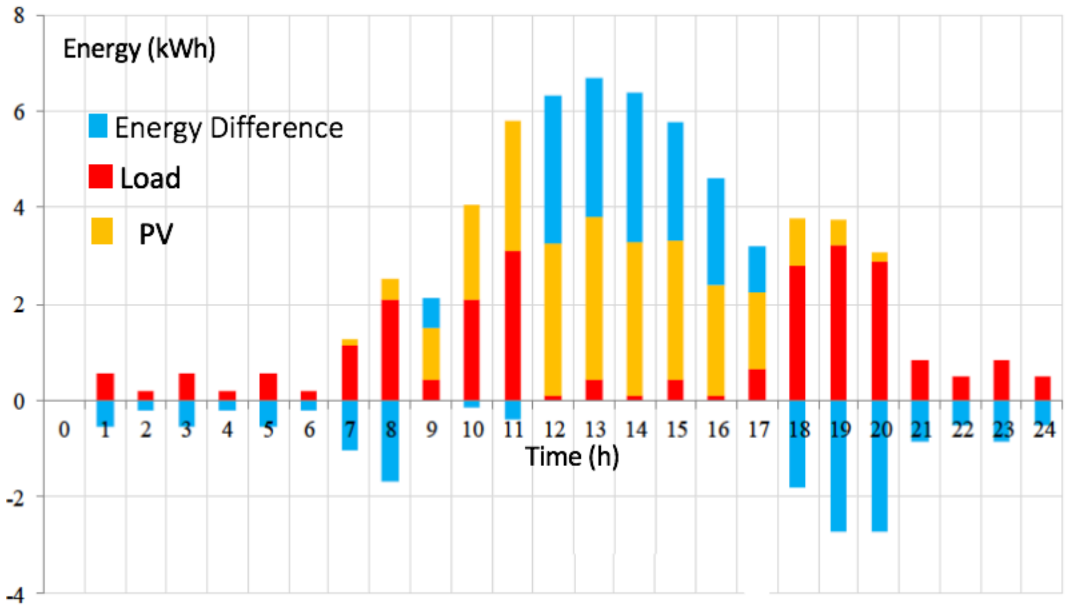

Figure 19 Daily basis of total power generation and consumption in the optimally designed PV system

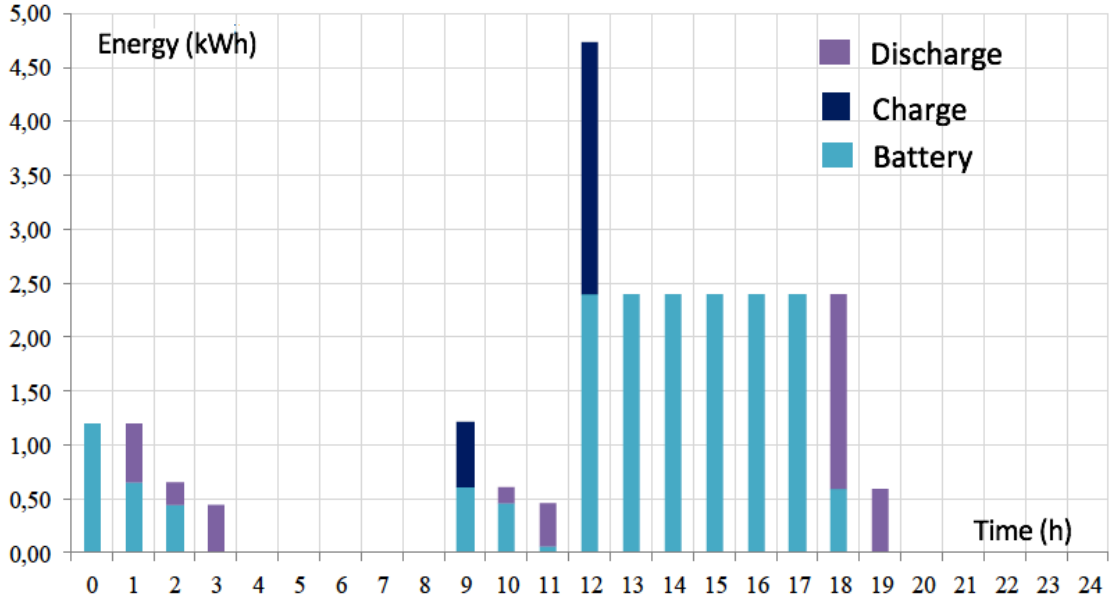

Figure 20 Daily Change of Battery Charge and Discharge Status in Pure PV System

Figure 21 shows the variation of the over- and under-generated forces during the day in the PV system alone. The use of diesel generators or gasoline generators is generally preferred in order to meet the missing power and to ensure the continuity of energy in case of insufficient power to supply the loads in this system.

As seen in Figure 21, it is seen that sufficient energy cannot be produced in 3-8 and 19-24 time periods, and that the system generates excess energy in 12-17 time periods. diesel generator provides minimum energy with 0.1 kWh in 3rd time zone and maximum energy with 2.71 kWh in 20th time zone. In this system combination, it can be seen that the diesel generator operates for a total of 12 hours, resulting in additional fuel costs. In addition, the PV system produces the smallest energy at 0.72 kWh in the 12th time zone and the largest amount of surplus energy at 3.09 kWh in the 14th time zone.

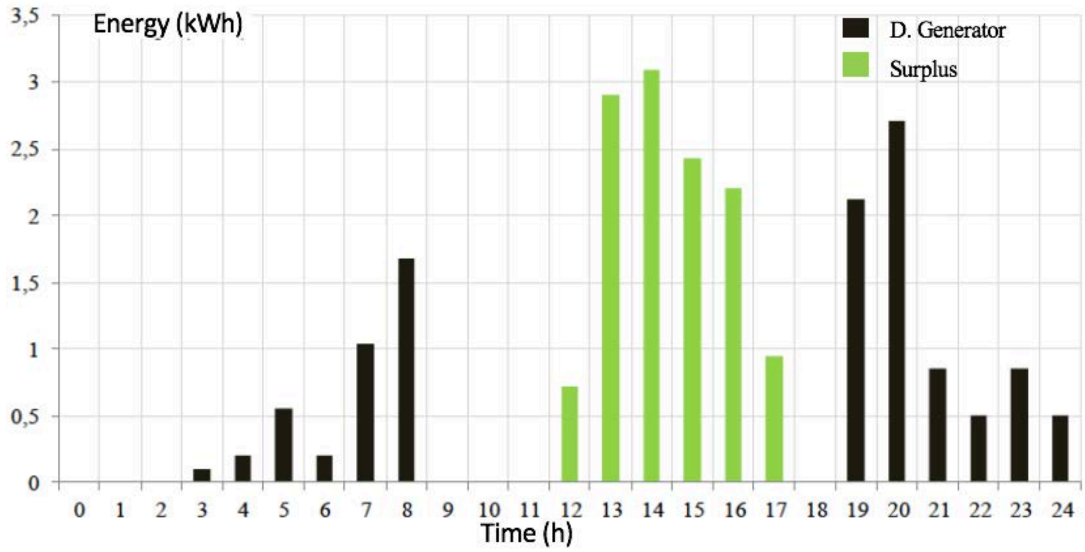

Figure 21 Time slots of a diesel generator use in the optimally designed PV system

2. Wind turbine only System

The proposed system consists of two 2 m blade length 1 kW horizontal axis wind turbines, batteries, full sine inverter and diesel generator. According to the calculations made with wind turbine, 3.5 kW full sine grid disconnect inverter, 3 200 Ah gel batteries are required. There is an additional cost of 25% of the total cost for this system. Accordingly, a 10-year maturity difference to calculate one-year operating, maintenance and investment costs in a system combination created by adding additional costs for a 20-year service life, 0.14 and 0,27 cent maintenance for PV panels and wind turbines per kWh respectively and the cost of the diesel generator is 1278,5 $. Figure 22 shows the power produced, demanded and the difference between the two 1 kW pure wind turbines produced during 1 hour period during the day. The power produced reaches its maximum value with 2.03 in the 15-hour period and the lowest value with 0.69 kW in the 10-hour period. It is seen that the demanded power is greater than the power values produced in the 7th, 8th, 10th, 11th, 18th, 19th, and 20th hour time frames, whereas the power values produced in the other time periods are greater than the demanded power values.

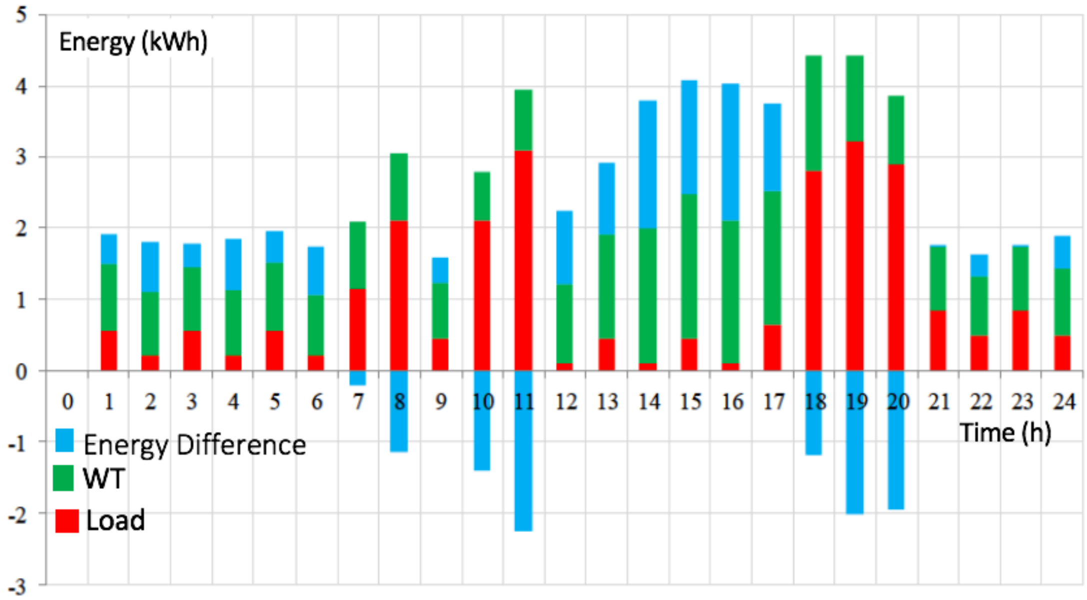

Figure 22 Daily Change of Energy Produced and Demanded with 2 pieces 1 kW wind turbine

Figure 23 shows the daily change of charge and discharge status of the battery group in two 1 kW wind turbines. Figure 23 shows that the battery charge status is zero in the 10th, 11th, 19th and 20th time zones and that the required power is met by the Diesel generator in these time zones. When the battery group is charged in the 1st, 2nd, 3rd, 9th, 12th, 13th, 14th, 21st, 22nd, 23rd and 24th time periods, the largest charged energy value is 1,02 kWh in the 12th hour period.

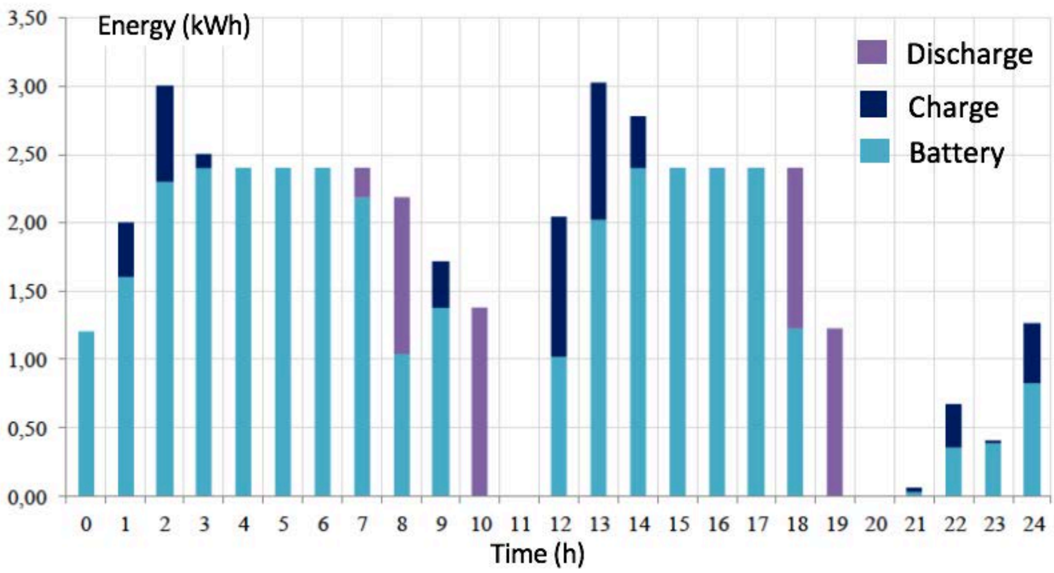

Figure 23 Daily Change of Battery Charge and Discharge Status in 2 pieces 1kW Wind Turbine Powered System

Figure 24 shows the excess power and the daily variation of the power generated by the diesel generator in the pure wind turbine system. In this system, the Diesel generator is used to meet the required power in cases where no power is generated in each time zone. As can be seen in Figure 24, it is seen that it is not possible to produce enough energy in the tenth, eleventh, nineteenth and twentieth periods and that the diesel generator satisfies the energy required in these periods of time. The diesel generator provides minimum energy with 0.03 kWh in the tenth time zone and maximum energy with 2.25 kWh in the eleventh time zone. In addition, with this system, it is seen that excess energy occurs in time zones between 3-6 and 14-17, the smallest energy with 0.24 kWh in the third time zone and the largest surplus of energy with 1.92 kWh in the 16 the time zone is observed.

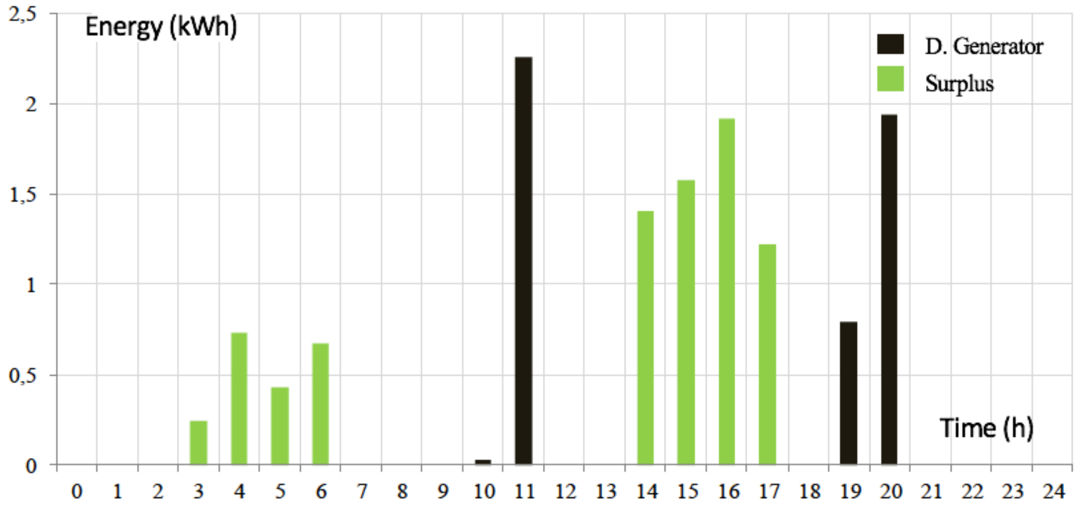

Figure 24 Daily Change of Energy Generated by Extra and Diesel Generators in Pure Wind Turbine System

3. WIND-PV System

The third proposed combination consists of a 1 kW horizontal axis wind turbine with a 2 m blade length, a planar PV panel, batteries, a full sine converter and a diesel generator. In order to meet the energy of a typical house in Kilis with the WIND-PV hybrid system, one 1 kW horizontal axis wind turbine, nine PV panels, 3.5 kW full sine grid connection according to the calculations made with Equation 13. converter, four 200 Ah gel batteries are required. The total cost for this system Up to 25% additional costs are required.

Accordingly, in the system combination created by adding additional costs for a 20-year working life, one-year operation, maintenance and investment cost, 10% annual difference, an annual maintenance cost of 0.14 and 0,27 cents for PV panels and wind turbines per kWh, respectively. and when the diesel generator is taken into account, it is 1.393,08 $.

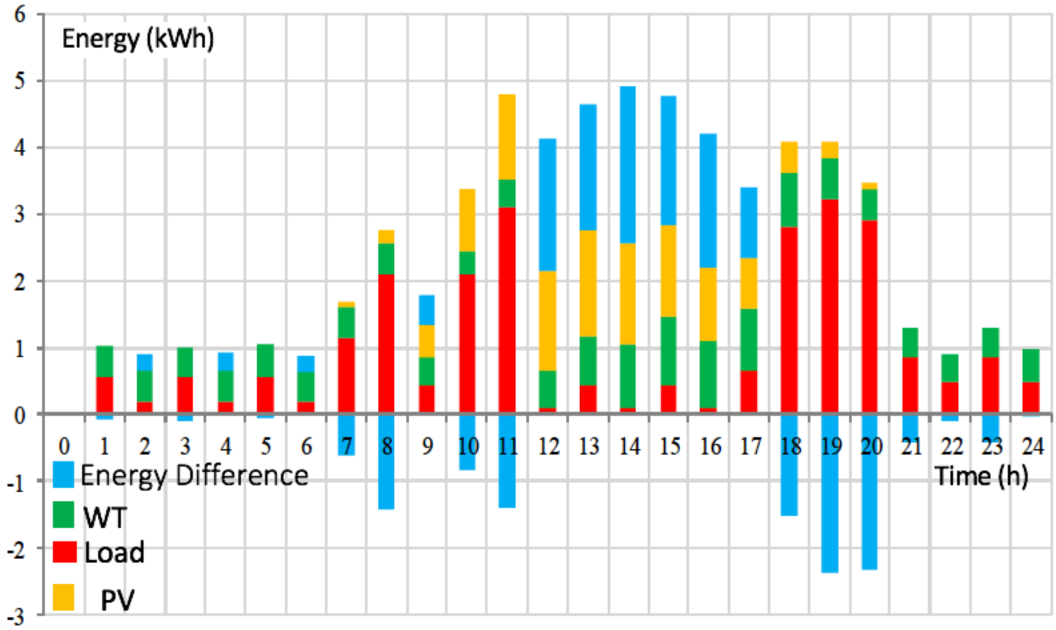

Figure 25 Daily Variation of Generated, Demanded and Difference Energy Amounts in Wind-PV Hybrid System

The minimum and maximum values of the power values produced from wind turbine and PV panels are 0.34 to 1.02 kW and 0.06 to 1.59 kW, respectively. It is determined that the energy difference between the produced and consumed power is 2.02 to -1.41 kWh. The time zones in which the energy difference is negative are determined as 1, 3, 5, 7, 8, 10, 11, 18, 19, 20, 21, 22, 23 and 24. In other time periods, the energy difference is positive.

The most disadvantageous situation of this system compared to the other two systems is that the energy difference is negative in more time periods. This is the increase in operating costs as the diesel generator is used more and fuel costs increase. Figure 25 shows the forces produced and requested in the WIND-PV hybrid system and the daily variation of the difference between them.

Figure 26 shows the daily change of charge and discharge status of the battery group in the WIND-PV hybrid system. As shown in Figure 26, WIND-PV hybrid system 8-

11. and 19-24. the battery charge status is zero in time zones. Since there is no amount of stored energy in these periods, the required energy is supplied from the diesel generator. It is seen that the battery group is charged in the 2nd, 4th, 6th, 12th, 13th, 14th, 15th and 16th periods and the biggest charged energy value is 0.84 kWh in the 14th period. Similarly, the energy discharged from the battery group occurred in the 1st, 3rd, 5th, 7th, 8th, 18th and 19th time periods, and the largest discharged energy amount was 1.99 kWh in the 18th period.

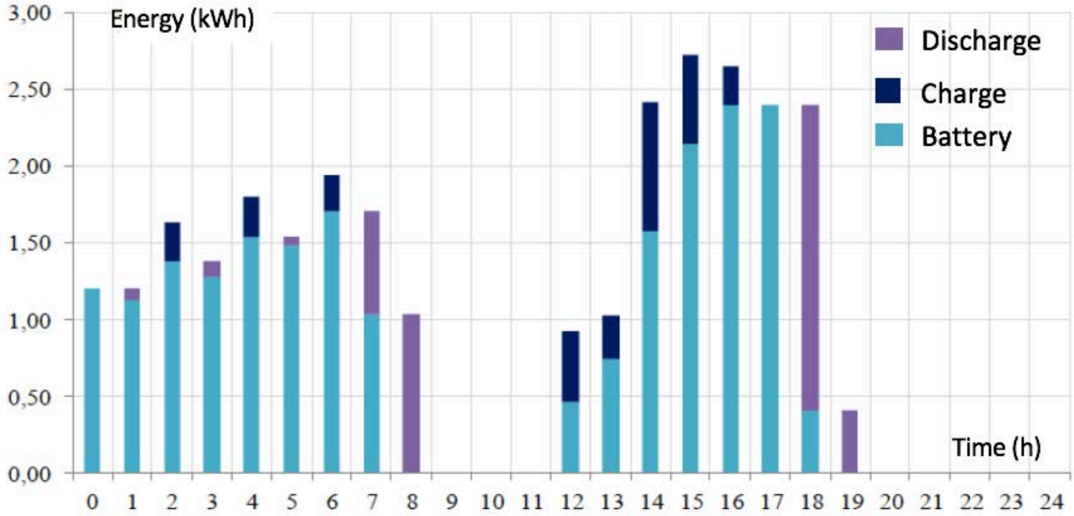

Figure 26 Daily Change of Battery Charge and Discharge Status in WIND-PV Hybrid System

The surplus of the WIND-PV hybrid system and the daily change of energy generated by the diesel generator are shown in Figure 27. The diesel generator is activated in order to fully meet the demanded power in the required time period and generates the required energy. As can be seen from Figure 27, 8, 9, 10, 11, 19, 20, 21, 22, 23, and 24 can not be produced enough energy in the time periods, the energy needed in these time periods Diesel generator is met by. Diesel generator provides minimum energy with 0.03 kWh in 24th time zone and maximum energy with 2.68 kWh in 11th time zone. In addition, this system generates excess energy in the 16th and 17th time zones. In the 17th time zone, the smallest amount of energy is produced with 0.29 kWh and in the 16th time zone, with the largest amount of 0.66 kWh.

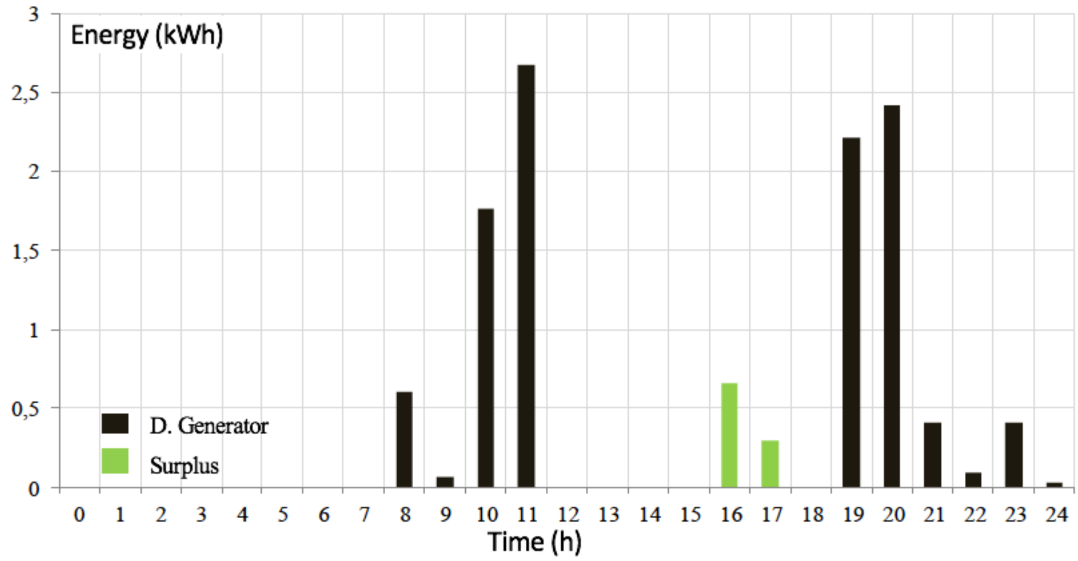

Figure 27 Daily Change in Excess and Diesel Generators Produced in Wind-PV Hybrid System

Table 6 Unplanned Load Distribution

Device	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
The dishwasher																		2	1,1					
Washing machine																			1,1					
Iron								2																
Oven											0,9													
A refrigerator	0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2	
Toaster							0,6																	
Dryer																				2				
Television								0	0,1	0	0,1	0	0,1	0	0,1	0	0,1	0	0,1	0	0,1	0	0,1	0
Computer																	0,2	0	0,2	0				
Combi Engine	0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2	
Vacuum cleaner										2														
Mini Oven											0,7													
Boiler											1,1													
Interior Lighting							0,2	0										0	0,2	0	0,2	0	0,2	0
Outdoor Lighting	0,2	0	0,2	0	0,2	0												0	0,2	0	0,2	0	0,2	0

B. PLANNED LOAD STATUS

In the results given above, the electrical loads in a typical house are routinely distributed and annual installation, maintenance and operation costs are calculated for pure PV, pure wind turbine and hybrid WIND-PV systems. As it is known, since wind and solar are momentary changeable renewable energy sources, the distribution of the load during the day in accordance with minute or hourly changes can reduce the costs relatively to the current situation. The basic rule here is to feed as much load as possible during the hours when power is produced more. This is generally accomplished through production and demand management. In this study, the power balance in hourly zones is based on demand management consisting of six strategies. Load shifting strategy is known as the most used strategy among these strategies and it has been chosen in this study for optimal distribution of loads. Optimal distribution of loads can be achieved by combinatorial optimization based on the genetic algorithm method. Table 7, 8 and 9, the most appropriate load distribution by finding the above-mentioned three systems, the sum of the installation, maintenance and operating costs are calculated, and the results are given below.

1. Pure PV System

The daily variation of the energy quantities produced, demanded and difference according to the optimally distributed load condition by genetic algorithm in the pure PV system described above is given in Figure 28. As shown in Figure 28, the load distribution throughout the day is more appropriately distributed than the routine load situation. Such that in this system, the power difference is 17 times negative in the case of routine load and the same size is negative 15 times in the case of planned load. In addition, it is seen that the amplitude of the power difference occurring in the case of the appropriate distributed load is less. Figure 29 shows the charge status and charge-discharge quantities of the battery group. When the charge state of the battery group is considered, it is seen that the battery is charged more in the planned load state and the charge level is better than the routine distributed load state. In the case of a planned load, there are more charges and more discharges. Figure 30 shows the variation of the power produced in this system and demanded from the diesel generator during the day. In Figure 30, when the energy amount of excess power and the use of Diesel generators are considered, it is seen that less generators are used in case of planned load. In addition, the excess energy was found to be smaller. This shows that there is a relative improvement in battery management in the event of a planned load.

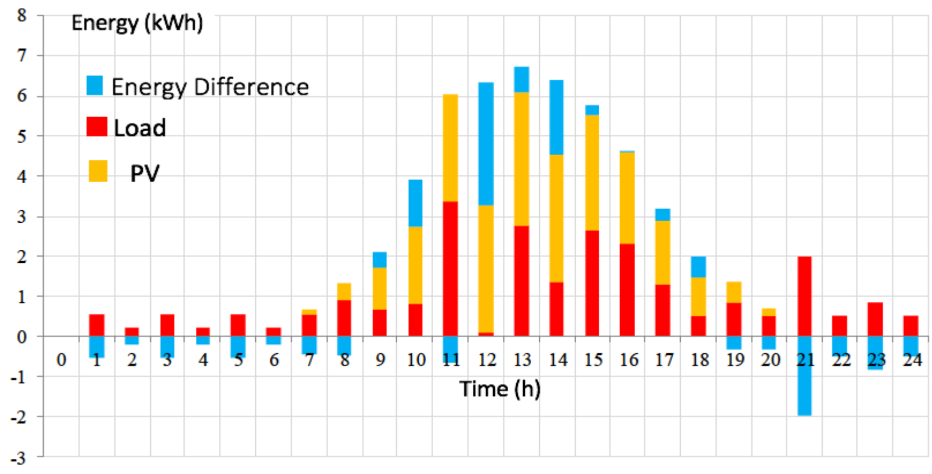

Figure 28 Daily Variation of Produced, Demanded and Difference Energy Quantities According to the Load Distributed State in Optimally Distributed PV System

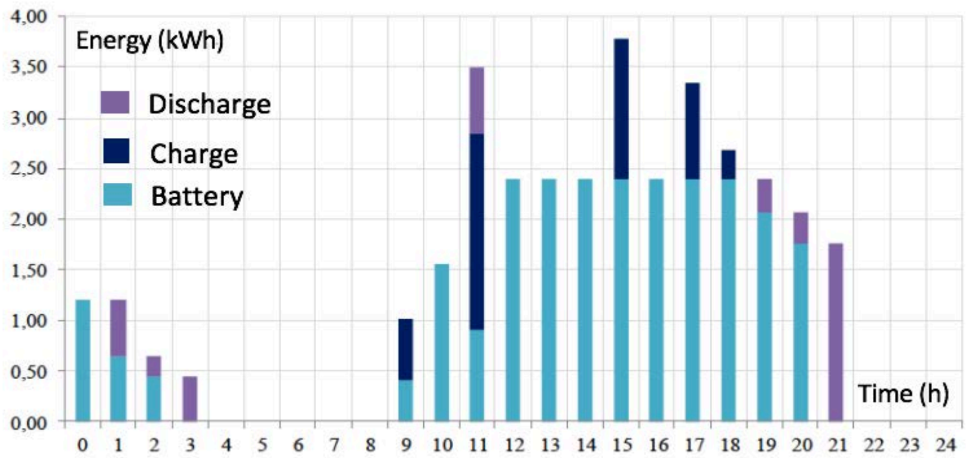

Figure 29 Daily Change of Battery Charge and Discharge Status in Optimally Distributed Load Status in Pure PV System

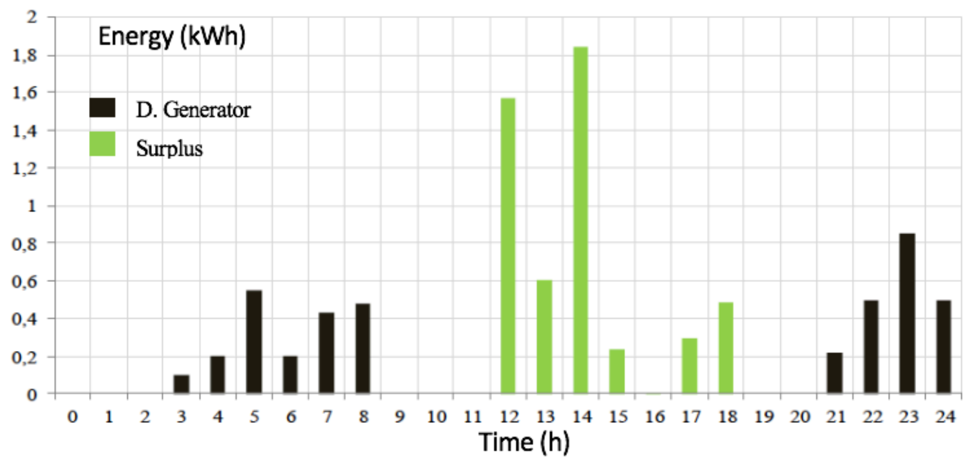

Figure 30 Surplus Based on Optimally Distributed Load Status in Pure PV System and Diesel Generator Produced By Daily Exchange

2. Wind turbine pure System

Similarly, the genetic variation for the purely wind turbine system described above is produced according to the optimally distributed load situation, the demand and the daily change of the difference energy amounts are given in Figure 31. As seen in Figure 31, it is seen that the negative energy difference occurring during the day is less than the unplanned load situation of the same system. It can be said that the improvement made here is mostly to reduce the amount of negative energy difference further. This is an indication that the power balance in the case of a planned load is relatively improved in accordance with the present conditions. When the battery charge status given in Figure 32 is considered in the wind turbine system alone, it is seen that the charge and discharge numbers are higher in the planned load situation. It was also found that the battery charge rate is larger and more balanced as expected. The largest charge and discharge amount occurred in the case of planned load and both values were determined as 1.93 kWh. In the same system, when the amount of over-generated energy and the use of generators shown in Figure 33 are considered, it is seen that less generators are used and less energy is produced in case of planned load. In the case of a planned load, a generator is used in two time periods and in this usage, 0.64 to 0.20 kWh of energy is produced. However, in case of unplanned load 3 times the generator is used, 2.26, 1.94 and 0.80 kWh'e energy is produced. In terms of energy surplus, the maximum amount of energy produced in the planned load case was 0.78 kWh, whereas in unplanned load this amount was found to be 1.92 kWh.

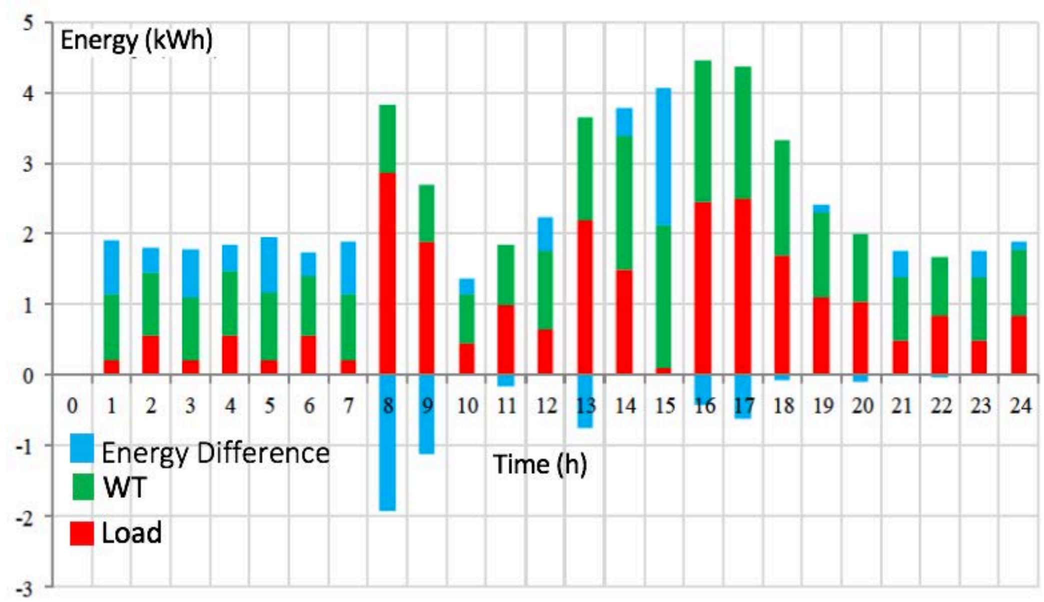

Figure 31 Daily Change of the Energy Difference Produced and Demanded According to the Load Distributed in the Optimally Distributed Load Condition in 2 Piece 1 kW wind turbine System

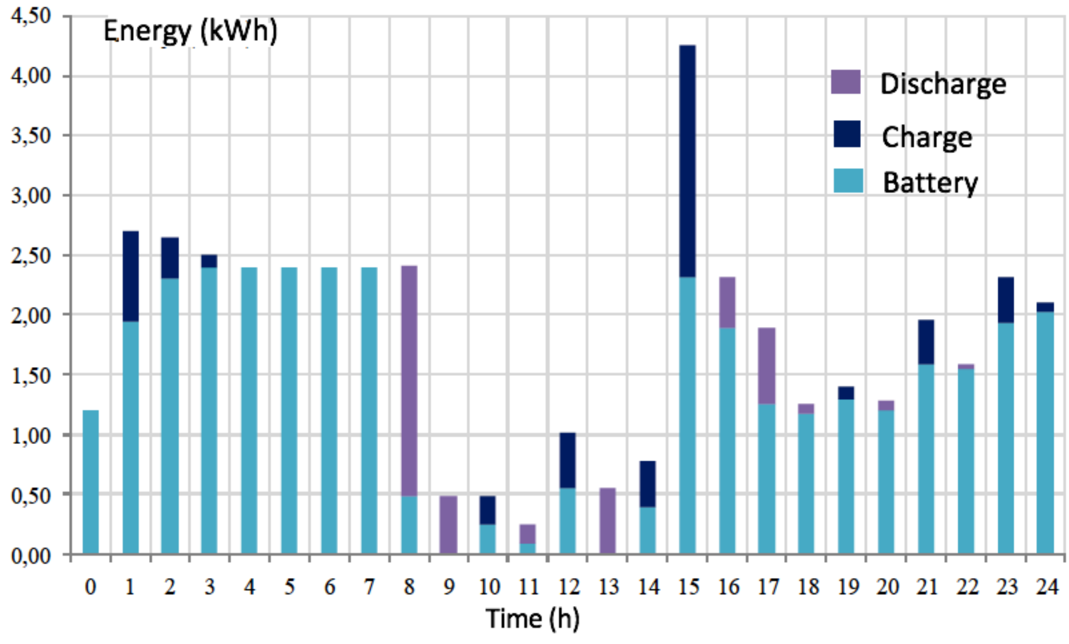

Figure 32 Daily Change of Battery Charge and Discharge Status According to the Load Distribution in the Most Optimally Distributed State in 2 pcs 1 kW wind turbine System

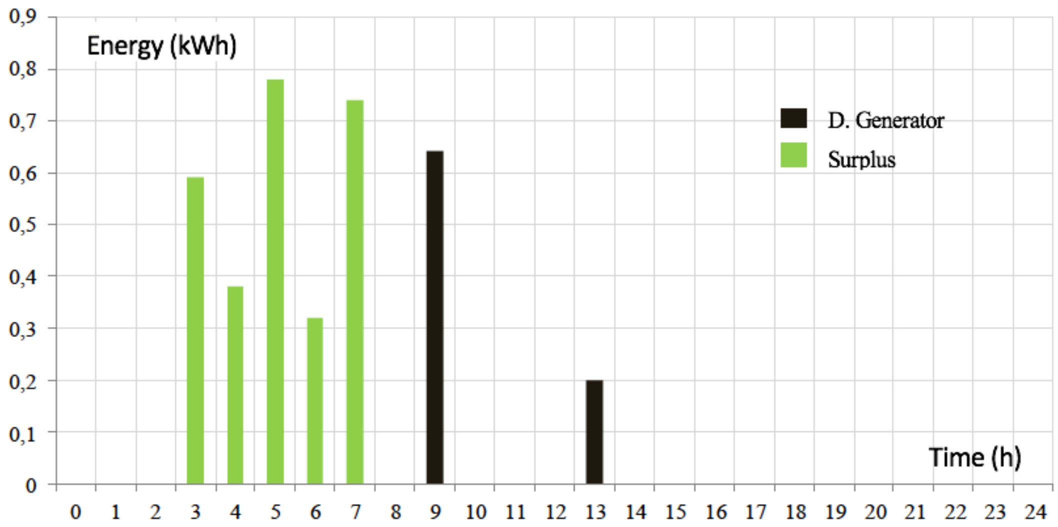

Figure 33 Daily Change of Energy Produced by 2 pieces of 1 kW wind turbine and Diesel Generators according to the most appropriately distributed load status

3. WIND-PV System

Compared to the planned and unplanned load conditions in the WIND-PV hybrid system, it is seen in Figure 34 that the negative energy difference is less in number and quantity in the case of planned load.

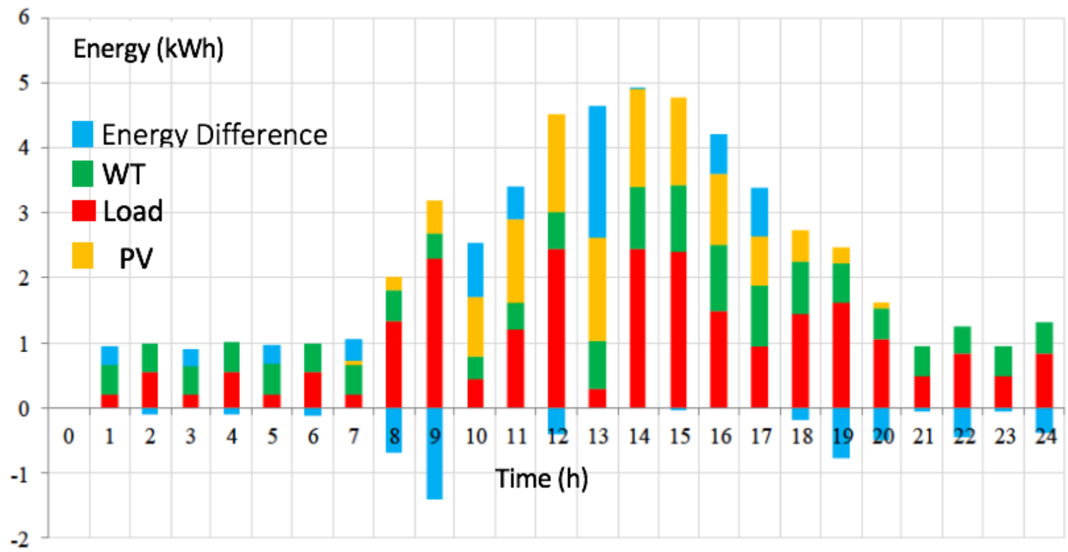

Figure 34 Daily Change of Energy and Energy Difference Produced and Demanded According to the Optimally Distributed Load Condition in 9 PV Panels and 1 kW wind turbine System

For example, in the case of unplanned load, the negative energy difference reaches -2.38 kWh, and in the case of planned load this value is -1.41 kWh. When the battery charge status shown in Figure 35 is considered, it is seen that the battery charge rate shows a more balanced change in the planned load situation compared to the unplanned load status. For example, in case of unplanned load, the battery charge state is zero in the 10th time zone, while in the case of planned load the charge state is zero in the 9th and 24th time zones. In addition, the average discharge amount in case of planned load is lower. In Figure 36, it is seen that only one generator is used in case of planned load and more power is generated in 3 hours.

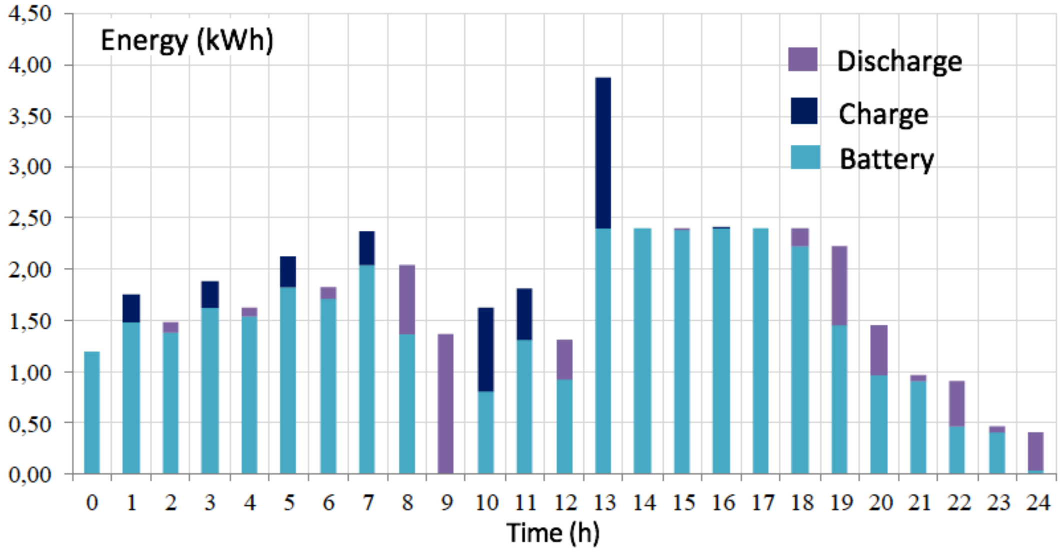

Figure 35 Daily Change of Battery Charge and Discharge Status According to Optimally Distributed Load Status in 9 PV Panels and 1 kW wind turbine System

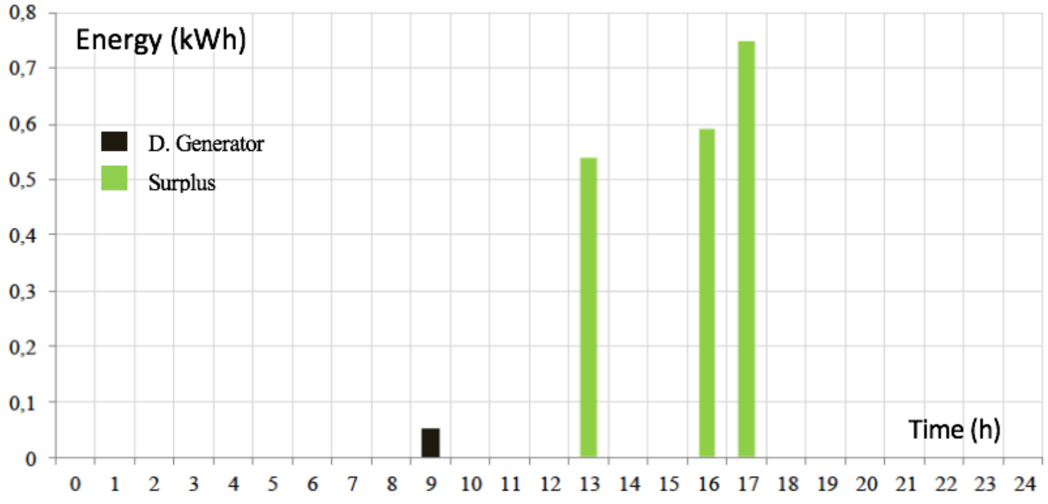

Figure 36**:** Daily Change of Energy Generated by Extra Diesel Generators and 9 PV Panels and 1 kW wind turbine System According to the Load Distribution

Table 7 Planned Load Distribution with Pure PV System

Device	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
The dishwasher													2,1	1										
Washing machine																					1,1			
Iron											1,8													
Oven																	0,9							
A refrigerator	0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2	
Toaster								1																
Dryer																2								
Television								0	0,1	0	0,1	0	0,1	0	0,1	0	0,1	0	0,1	0	0,1	0	0,1	0
Computer									0,2				0,2	0	0,2									
Combi Engine	0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2	
Vacuum cleaner															2									
Mini Oven										1														
Boiler											1,1													
Interior Lighting							0,2	0										0	0,2	0	0,2	0	0,2	0
Outdoor Lighting	0,2	0	0,2	0	0,2	0												0	0,2	0	0,2	0	0,2	0

Table 8 Planned Load Distribution with pure wind turbine system

Device	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
The dishwasher													2,1	1,05										
Washing machine								1,13																
Iron									1,8															
Oven																		0,85						
A refrigerator		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2
Toaster																			0,6					
Dryer																	2,2							
Television								0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Computer											0,2	0,2					0,2			0,2				
Combi Engine		0,15		0,15		0,15		0,15		0,15		0,15		0,15		0,15		0,15		0,15		0,15		0,15
Vacuum cleaner																2								
Mini Oven											0,7													
Boiler								1,1																
Interior Lighting							0,2	0,2										0,2	0,2	0,2	0,2	0,2	0,2	0,2
Outdoor Lighting	0,2	0,2	0,2	0,2	0,2	0,2												0,2	0,2	0,2	0,2	0,2	0,2	0,2

Table 9 Planned Load Distribution with Wind-PV System

Device	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
The dishwasher												2,1	1,05											
Washing machine																1,13								
Iron											1,8													
Oven																		0,85						
A refrigerator	0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2		0,2	
Toaster								0,6																
Dryer														2,2										
Television								0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Computer									0,2				0,2	0,2	0,2									
Combi Engine	0,15		0,15		0,15		0,15		0,15		0,15		0,15		0,15		0,15		0,15		0,15		0,15	
Vacuum cleaner																	2							
Mini Oven										0,7														
Boiler								1,1																
Interior Lighting							0,2	0,2										0,2	0,2	0,2	0,2	0,2	0,2	0,2
Outdoor Lighting	0,2	0,2	0,2	0,2	0,2	0,2												0,2	0,2	0,2	0,2	0,2	0,2	0,2

C. Controlled and Uncontrolled Load Status

Some of the electric loads in a typical home are controllable and are used to find the optimal load distribution. However, since the operating hours of some of these loads are fixed, they cannot be controlled. For example, internal and external lighting, television and computer are not treated as controlled loads to find an optimal distribution of loads in some applications of such systems. This section emphasizes the changes in energy consumption of controlled and uncontrolled loads during the day in the planned and unplanned load distribution. Figure 37, Figure 38 and Figure 39, pure photovoltaic systems, pure wind turbines and WIND-PV hybrid systems are visible in controlled and uncontrolled load variations during the day.

Looking at the planned and unplanned controlled load variations in Figure 37, we see that there is a different variation between the two. For example, unplanned controlled loads were 1.9 and 0.5 kWh in the eighth and thirteenth time zones, respectively, and 0.7 and 2.8 kWh in the same time zones, respectively. Similarly, the same situations are seen in Figure 38 and Figure 39.

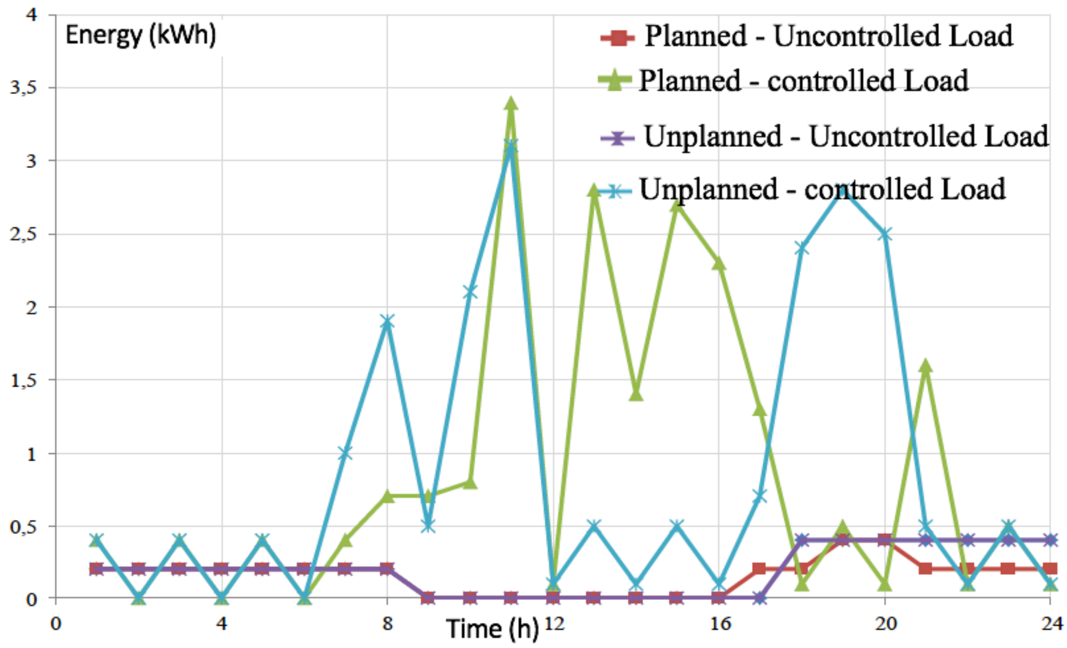

Figure 37 Daily Change of Energy Consumption of Controlled and Uncontrolled Loads in Planned-Unplanned Load Distribution in Pure PV System

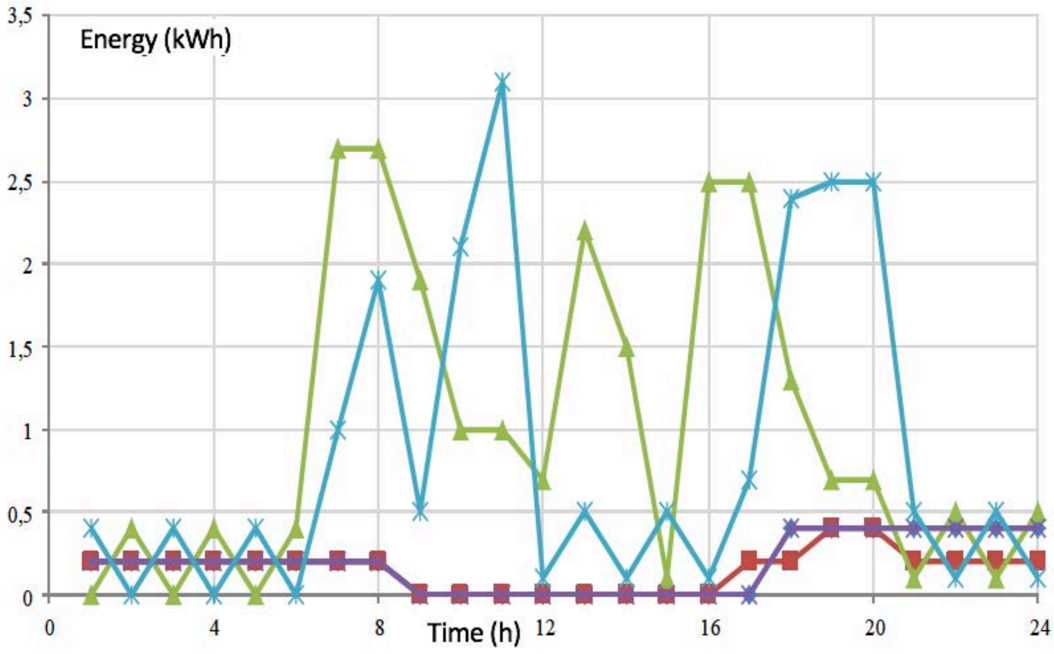

Figure 38 Daily Change of Energy Consumption of Controlled and Uncontrolled Loads in Planned-Unplanned Load Distribution in Pure wind turbine System

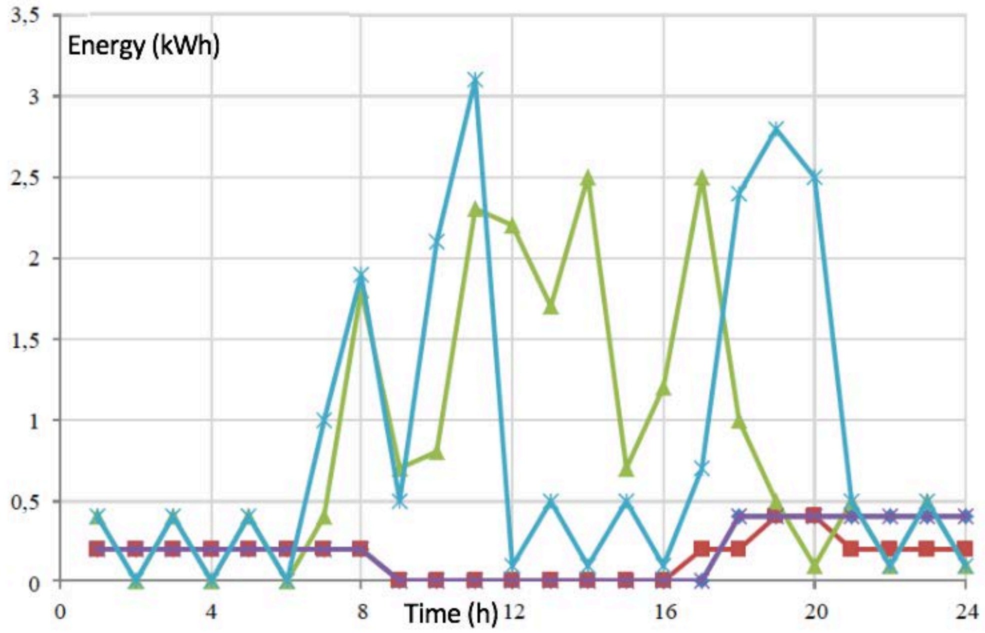

Figure 39 Daily Change of Energy Consumption of Controlled and Uncontrolled Loads in Planned-Unplanned Load Distribution in Wind-PV System

D. Performance Analysis of Genetic Algorithms

The combinatorial optimization used in this study was performed with genetic algorithm and the performance results obtained are shown in Figure 40 and Figure 41. As shown in Figure 40, the best fit value obtained in each generation was obtained for all three systems, significant improvement in compliance values up to the 10th generation, limited improvement was achieved from generation 10 to generation 50. After the 50th generation, no improvement was achieved in the best fit value for all three systems. Similarly, when the convergence error is considered, it can easily be seen from Figure 41 that for all three systems, this error is very close to zero after the 50th generation.

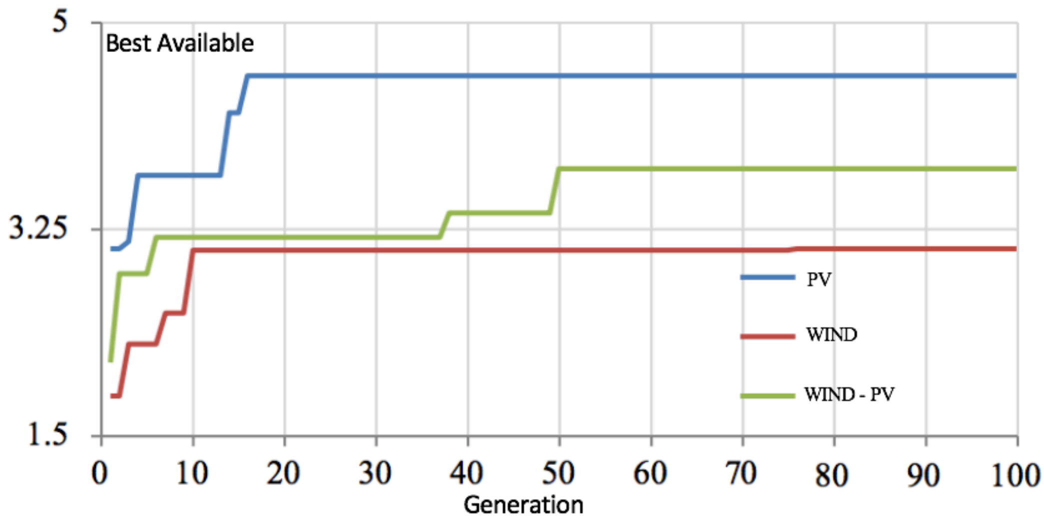

Figure 40 Variation of Maximum Conformity Value with Generation to Obtain Planned Load Distribution

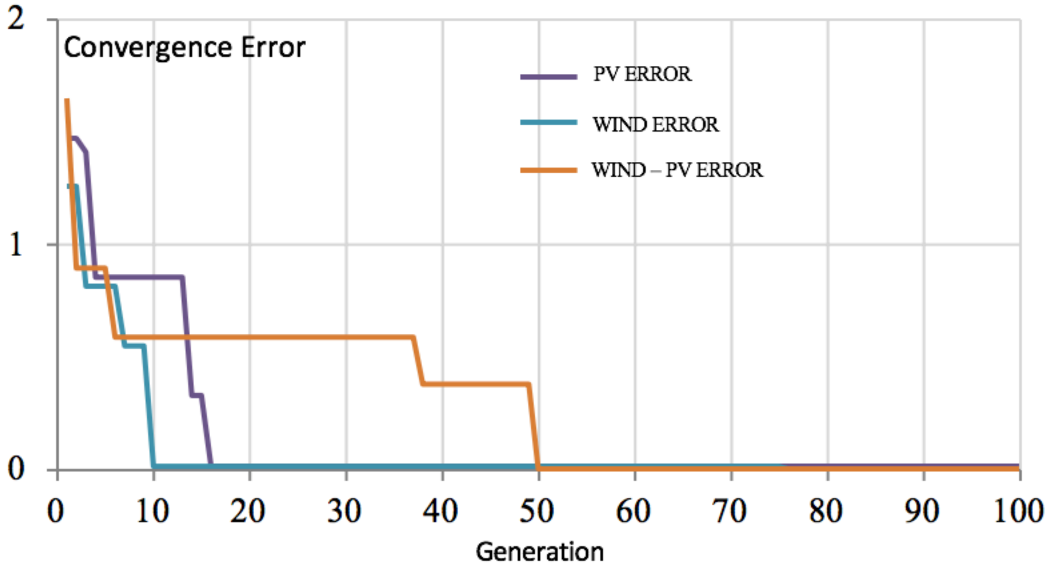

Figure 41 Variation of Convergence Error with Generation to Obtain Planned Load Distribution

E. Analysis of Individual Loads

A few of the loads given in the table of the residential loads have been selected in order to see how there is a change in the working hours of the individual loads which can be controlled and cannot be controlled in case of planned and unplanned loads. Figure 42 shows the working hours of the dishwasher during the day. As can be seen from this graph, in case of unplanned load, the dishwasher operates in the 18th and 19th time zones, while in the case of planned load the operating hours of the dishwasher are shifted to the 12th, 13th and 14th time zones. Similarly, the washing machine was shifted to the 8th, 16th and 21st time zones for each system in the planned load state while in the unplanned state, as shown in Figure 43.

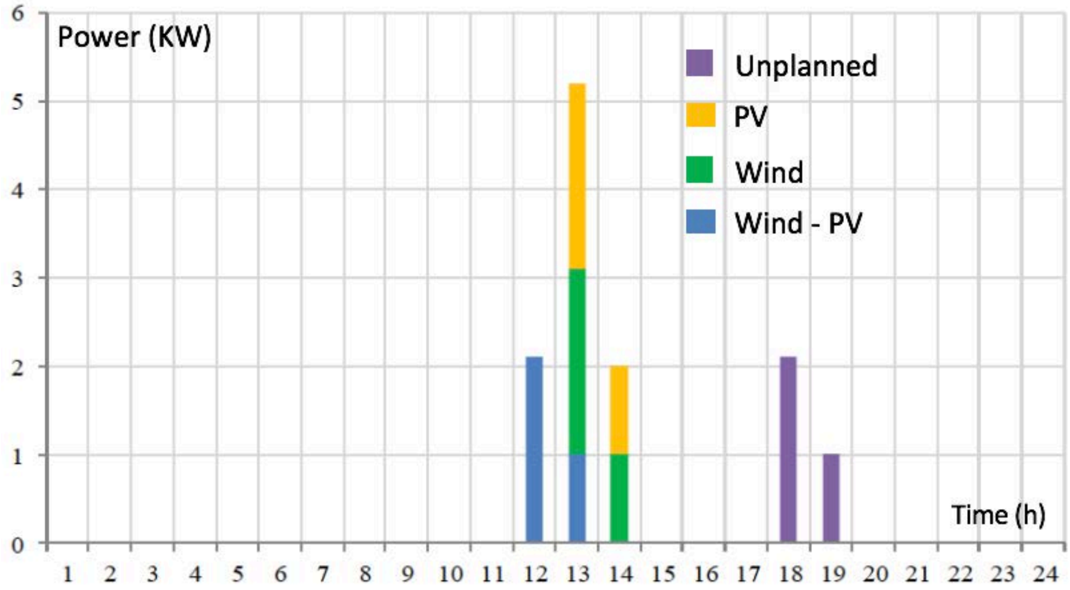

Figure 42 Unplanned and planned determination of working hours of the dishwasher during the day

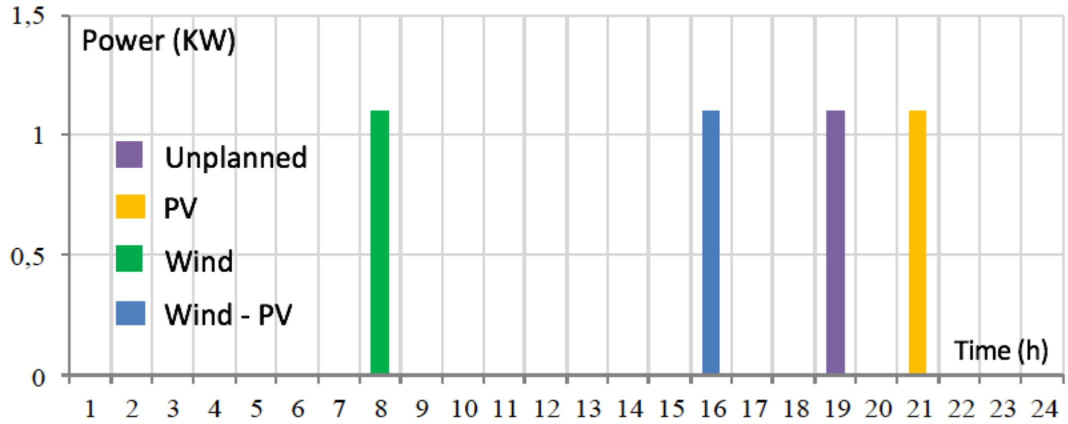

Figure 43**:** Unplanned and planned determination of working hours of washing machine during the day

V. CONCLUSION AND FUTURE WORKS

In this thesis, some inferences were obtained in order to benefit from solar and wind potential at the lowest cost in Kilis province. These are given in the following items.

- Considering the 20-year working life of systems consisting of wind turbines, pure PV panels and WT panels to meet the electrical energy requirements of a typical house, the most economical system was found to be 1 kW horizontal axis WT systems. However, since the wind speed in the region is in the range of 5-6 m/s, it is necessary to change the wing lengths outside the standard design, ie to increase the wing lengths by 50% in order to obtain more power than the existing wind potential.
- With wind turbines, electricity production varies cubically with wind speed, which leads to a large loss of power. For this reason, as the wind turbine-only system has such a disadvantage, it is important to reinforce it with PV panels for energy continuity. In terms of one-year economic cost, the transition from a pure wind turbine system to a mixed system, namely the WT-PV system, results in a cost increase of only 9%. Therefore, it is seen that the most suitable system to meet the energy requirement in the houses under Kilis conditions is the mixed WT-PV system.
- It is necessary to use an additional generator to ensure continuity in the energy produced in systems where the network is available but not connected to the network. For this, it can be said that it is a more correct approach to prefer Diesel generator, which generally has less fuel consumption. However, this is not required in the grid-connected system and the energy requirement is met from the grid when needed. In addition, extra energy is transferred to the grid. When connected to this network with a bidirectional counter, it provides a relative reduction in total cost.
- In order to achieve a reduction in total cost, at least one of the cost components must be reduced, with the other remaining constant. In order to reduce the cost of

installation, the number of devices selected and their characteristics and location should be selected in the most appropriate way. In order to minimize operating and maintenance costs, the power generated by the existing system must be increased and maintenance costs reduced. Reducing operating costs is often possible with load demand management, while lowering maintenance costs by reducing prices per kWh. This is possible with the use of appropriate optimization techniques, where the realization of demand management with real-coded GA software is demonstrated.

- It is important to use effective forecasting methods for the day after at the location of the system. That is, the wind speed and the amount of instant radiation must be calculated with the least error. For this purpose, it is too important to use appropriate methods like artificial neural networks and support vector machines.
- As a blueprint for future business and research, the system should be expanded to cover a neighbourhood or village. In parallel, improvement tools must be developed, and other renewable energy sources included so that we can dispense with the standby generator.

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RESUME

Name Surname: Aussama ALKHESHA

Date of birth: 26-03-1988

Contact:

aussama.alkhesha@gmail.com

Education:

- **Bachelor:** 2010, Damascus University in Damascus – Syria. Power Electrical Engineering

- **Masters:** ISTANBUL AYDIN UNIVERSITY in Istanbul – Turkey. Electronics Engineering (Thesis 2 Semester).

Experiences:

- Project Management Professional – PMP.
- Electrical Power Systems Analysing.
- Electrical Power Systems Protection Relays Selectivity Studying.
- Electrical Power Plants and Substations Protection and Control Schematics Drawings Studying and Drawing.
- Electrical Power Plants and Substations Erection, Commissioning and Operating.
- Electrical Power Plants and Substations High Voltage Equipment's Erection and Testing.