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Original Research

Energy Management in Stadiums by Using Hybrid Renewable Energy Systems

Vajiheh Javani[1*], Elshan Davarn Hagh[2]

1. *Department of Sport Management, Faculty of Physical Education and Sport Sciences, University of Tabriz, Tabriz, Iran*
2. *Department of Electrical Engineering, Shabestar Branch, Islamic Azad University, Shabestar, Iran*

ABSTRACT

Non-renewable energy sources generate severe problems for the environment and human health problems. In recent years, hybrid renewable systems that use more than one energy source to supply the power demands have attracted attention. This study set out to verify using a hybrid system to supply electricity demand in a considered stadium based on the data in northeastern Iran with an average wind speed and daily solar radiation. Furthermore, the feasibility of adding renewable energy sources to gain an economical and environmental power supply to secure the electricity demand of the considered area was discussed. The HOMER was used in this study to analyze and optimize hybrid power systems. This work focuses on energy supply via hybrid diesel, photovoltaic array, wind, battery, and converters. If proposed hybrid systems are used to supply energy-demanding, they would have low expenses and help significantly rise in utilizing the renewable energy system, providing economic and clean energy systems.

Keywords: Hybrid system, renewable energy, energy cost, stadium

Corresponding Author: Vajiheh Javani, Assistant Professor, Department of Sport Management, Faculty of Physical Education and Sport Sciences, University of Tabriz, Email: v.javani@tabrizu.ac.ir, Tel: +989144097284

INTRODUCTION

The phenomenon of sport is attracted millions of people around the world. Therefore, there are several mega and large sport events with mass audiences attendance (1). Therefore, the stadiums are the best places to gather fans and spectators. Over 11,000 stadiums of different sizes are used for sport and non-sport events worldwide (2). So, providing the energy of a multi-functional stadium is a critical issue. Nowadays, the possibilities of controlling energy usage vary considering energy-saving measures and renewable energy technologies, which could also be utilized for sport stadiums (3). Whereas, Renewable energy plays a considerable role in reducing demands for the production of electricity from coal and reducing global warming (4). However, implementing energy-saving measures and renewable technologies could significantly impact sports stadiums regarding the energy costs. For example, energy performance upgrade of sports facilities according to hydrogen technologies was studied in a sports centre in Dubai (5).

Additionally, scholars focused on investigating and evaluating alternative passive and active technologies for athletic swimming pools heating (6-7). However, the optimum mixture of the most feasible available technologies on energy performance upgrade of stadiums is affected by several parameters, including the geographical location, the available Renewable Energy Sources (R.E.S.) potential and the prevailing climate conditions, as well as the size of the stadium and the current total energy needs (8). Nevertheless, using and producing renewable energy is not well known because of the lack of research about this subject. Therefore, this research aims to supply potentials of available energy-saving measures and renewable energy technologies for sport stadiums based on designing and analyzing, and optimization hybrid power systems that contain a mixture of conventional generators, renewable energy systems like wind turbine and solar photovoltaic arrays, batteries, electric power converters, and other inputs by utilizing HOMER.

Power supply installation in every area should consider several options. Considering increasing fuel prices, energy demands, the growth of society's concerns with noise and air pollution, and greenhouse gas emissions, renewable energy sources are rapidly growing worldwide. In addition, non-renewable energy sources cause severe environmental and human health problems and have high maintenance and operation costs (4).

The term hybrid energy systems are used to explain a power system with more than one type of generator; usually, a typical generator powered by a gas or diesel engine and a renewable energy source such as wind turbines, photovoltaic arrays (P.V.), batteries for saving energy and converters for the convention of voltage or current energy direction type.

The use of hybrid renewable systems to supply remote areas' energy demands has attracted some researchers' attention (9-12). In (13), the design, operation, and control of the PV-solar and wind hybrid energy systems with conventional generating sources were analyzed. Also, developments and potential of these systems in economic subjects and acceptance of them by users were mentioned. In (14) electric requirement of the most significant island of Turkey was analyzed, and how renewable energy systems could be supplied with these electrical demands were discussed. Hybrid energy systems consisting of solar panels, wind turbines, batteries, and grid connection or diesel generators for backup power were modeled (14). The pre-feasibility of adding wind turbines into an existing diesel generator at the village in Saudi Arabia was shown in (15) and (16) to optimize hybrid renewable energy systems.

A hybrid energy system parallel with hydrogen energy storage is a solution for stand-alone power generation. In (17), a review of the optimal planning of hybrid renewable energy systems using HOMER was described. In (18), a pre-feasibility study of adding hybrid energy systems with hydrogen as a carrier of energy in new-found land, Canada, was described. Because of lower costs and higher reliability of stand-alone hybrid renewable energy systems, in (19), simulation and design of these systems for electricity generation was revised.

The techno-economic feasibility of hybrid PV-diesel battery power systems to extend the energy-demanding of remote areas of Saudi Arabia in off-grid applications was explained in (20). Also, similar work on the grey wolf optimizer for the optimal design of hybrid renewable energy system PV-Diesel Generator-Battery in a city of Algeria was reported (21). In (22), the initial cost, net percent cost, and electricity cost were obtained by HOMER software in rural regions in southern Iraq with P.V. renewable solar system to power a health clinic in the area. In Bangladesh, a study that quantifies power generation with wind and solar systems was done (23). Estimating the potential of solar energy and wind energy using a hybrid system optimization model for electric renewable (HOMER) was studied (24). The HOMER software has also been used to design optimal hybrid renewable energy systems in the Maldives (25).

An off-grid generation has been simulated for remote villages in Cameron in (26), and HOMER simulated energy cost for hybrid systems. A hybrid photovoltaic (P.V.) /diesel energy system was used in a remote area in Malaysia (27). Performance analysis of the techno-economic feasibility was shown by HOMMER software. The pilot project's technical and cost characteristics in an environmental protection area in Brazil were studied (28). Moreover, the importance of a grid-connected P.V. system was explained in (29). This paper showed a good performance and high efficiency and power factor of the P.V. grid connection. Also, the reduction of cost, size, and weight from using P.V. systems was studied. An analysis of the technical and financial of a renewable energy system for a large-scale hotel was presented in (30). HOMER obtained optimization modeling of hybrid configuration. In other research papers (31-33), hybrid renewable energy sources were used to optimize models and generate sustainable electricity systems. However, it is necessary to study each region based on influential local factors for designing its specific energy system. Therefore, the present research focused on using a hybrid system in northwestern Iran to provide a hybrid renewable energy system for a sports stadium. Thus, the study aims to provide a renewable energy system to supply electricity demand in a remote area with an average wind speed of 6.82 m/s at 40 m height and an average daily solar radiation of 4.79 kw/m^2 per day. In a second step, we investigated the feasibility of adding renewable energy sources to the current diesel generating system to achieve an economical and environmental energy system.

MATERIAL AND METHODS

This section describes the theories and techniques for analyzing the HOMER software about the area's potential and the electrical load of the study case. The HOMER (hybrid optimization model for electric renewables) is a computer modelling program used in this study. It is a powerful software for designing, analyzing, and optimizing hybrid energy systems containing a mixture of conventional generators, renewable energy systems like wind turbines and solar photovoltaic arrays, batteries, electric power converters, and other inputs. Analysis with HOMER needs input on load data and all resources, types of components, costs, financial information, efficiency levels, lifetime. The program is mainly used for hybrid systems optimization (34). Economic and pollution concerns about energy supply are also included in sports complexes and stadiums. Sport stadiums worldwide are used for sports events, concerts, museums, and business meetings or conferences. Thus, the stadiums are multi-functional places that attract many people. Stadiums are known for various functions, high energy usage, noise and air pollution, and environmental side effects. Nowadays, there are many possibilities to control energy usage with energy-saving measures and renewable energy technologies. This paper used HOMER as the simulator software to provide a hybrid energy system in the remote area focused on sports stadiums. This study is based on the data of northeastern Iran with an average wind speed of 6.82 m/s at 40 m height and an average daily solar radiation of 4.79 kw/m^2 per day. So with the aid of HOMER, we can recognize which hybrid energy system is the most efficient to net present cost (N.P.C.) and which hybrid renewable energy source is more efficient to consider such places?

Analyzing the power situation in the considered area, HOMER was used to make economic analysis and the feasible systems suggested by N.P.C. The N.P.C. method measures the costs and benefits of the system for a particular period. Also, the system may have higher investment costs, but it can be more economical in its lifetime cost. HOMER simulated the specific configurations of all the feasible stand-alone systems for the study case in this section. Grid extension and the costs of connections were essential factors for constructing renewable energy sources into an exciting electricity network. The operational costs of grid extension by medium voltage lines in Iran are $200 \$/year * km$. The average grid power price in Iran is $0.1 \$/kwh$ (35).

Diesel generator

A diesel generator with a capacity of 15 kw was selected for a peak load of 13.4 kw. Ten percent of the hourly load was considered for the operating reserve. The initial capacity costs of the diesel generators were supported $by\ 1000 \$/kw$, replacement costs assumed $900 \$/kw$ and operational costs supported $0.02 \$/kw$. At last operating lifetime was considered 15000 hr.

Photovoltaic array

Installation and replacement costs of a 1 kw solar energy system were considered \$ 6000 and \$ 5000, respectively. Five different sizes of P.V. array were analyzed in this study. Their lifetime was taken as 25 years.

Wind energy conversion system (WECS)

The wind turbine in this study is a B.W.C. excel-s model (36), with a capacity of 10 kw and an A.C. output of 220 V. This type of wind turbine is connected to the A.C. bus with excellent advantages in energy efficiency. At the same time, the generated electricity can directly supply the load without diverting through the D.C. bus and storage components. The cost of one unit was assumed to be \$ 30000. Replacement and maintenance costs were taken \$ 26000 and $150 \$/year$, respectively. Three options were fed into the HOMER for analysis and to find an optimum solution with no turbines, one turbine, and two turbines-lifetime was considered 15 years for a turbine.

Battery

For energy storage, lead-acid batteries were considered in this study. Commercially available battery models were used, such as the Surrette 6CS25P model (6V,1156Ah, 9645KWh) (37). The cost of one battery with replacement and operation and maintenance was assumed \$ 1100, \$ 1000 and $10 \$/year$ respectively. The battery bank was considered to contain any number of 0,10,20,30, 50 batteries to find an optimum configuration.

Power converter

A power electronic converter is essential to maintain energy flow between the A.C. and D.C. buses. Therefore, the installation and replacement costs were \$ 900 and \$ 800 for a 1 kw system. According to the definition of the above components, the energy flow diagram of the system simulated by HOMER is shown in Figure 1.

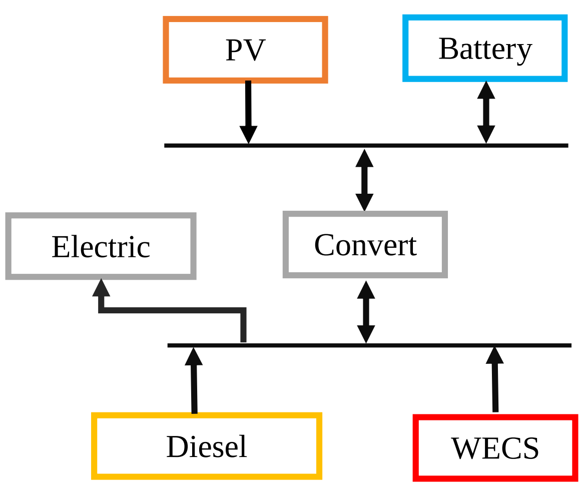

Figure 1. Energy flow diagram of the system.

Information of the considered area

Load profile

HOMER calculates the system's operation by calculating the energy balance for every 8760 hrs in a year. However, the hourly load profile of the area was not available for a whole year, so HOMER is used to synthesize the load profile with randomness by using the values for a typical day. The monthly load profile is shown in Figure 2 by the synthesizing process of HOMER. The average annual electricity is 145 kwh/d and the peak load demand is 13.4 kw, which the power system should be met them.

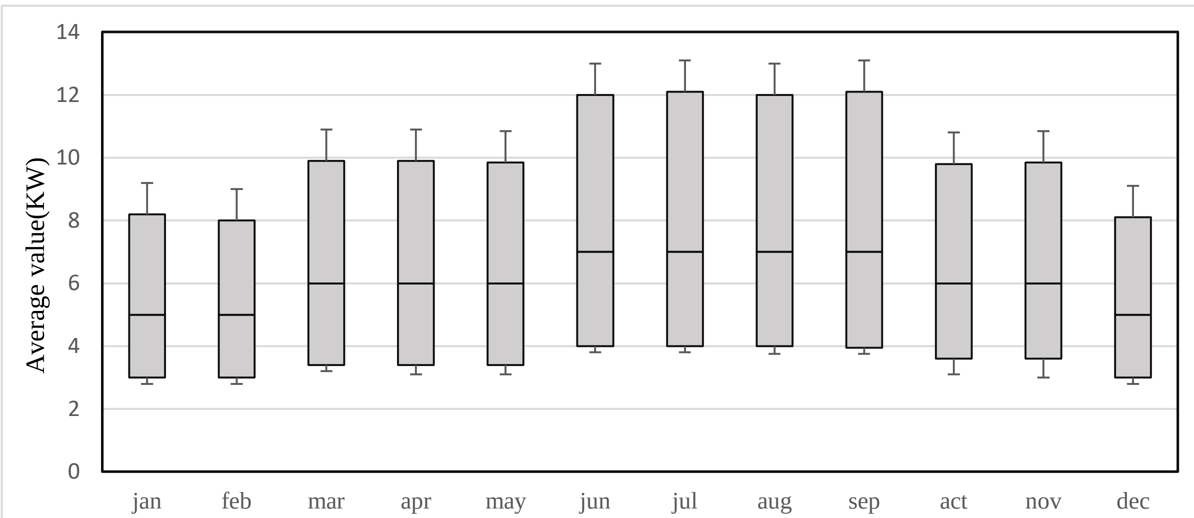

Figure 2. Monthly load profile

Achievable renewable energy sources

Monthly average values of solar radiation data related to the considered area are shown in Figure 3. The area's minimum and maximum solar radiation are in December and June, respectively. The average of daily radiation is 4.79 $kwh/m^2 * day$ during the year.

The average wind speed of the considered site is 6.82 m/s at 40 m height, that is a suitable situation for installing wind turbines. The average wind speed at 30 m height is 6.43 m/s and the lowest and the highest monthly wind speed is in January and July, respectively. Thus, it is possible to use wind turbines when the average wind blowing in the area is acceptable; if it does not blow consistently enough, the system may be uneconomic.

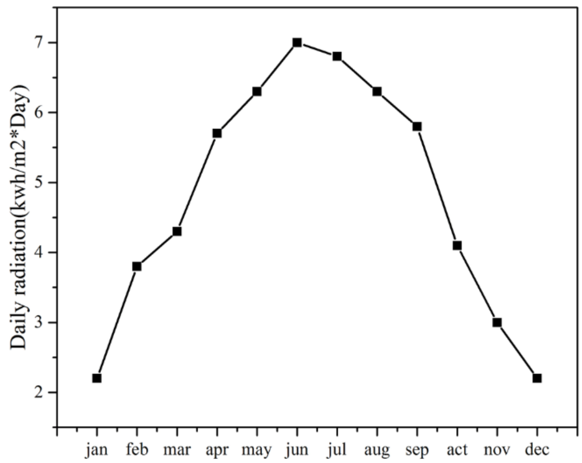

Figure 3. Average solar radiation data of case study location.

RESULTS

The most economical system in each category was taken as the indicator of that category. Finally, the selected systems from all categories were ranked to the least economical. A summary of the results of these processes is shown in Table 1.

Table 1. Categorized optimization results.

PV (KW)	WECS (number)	Conv. (K.W.)	Initial capital ($)	Operation cost ($/Year)	Total N.P.C. ($)	C.O.E. ($/KWh)	Renewable fraction	Emission of co_2
0	0	0	0	5391	47985	0.120	0.00	34568
0	1	0	32	4158	67456	0.139	0.278	23545
5	0	10	42	4757	83278	0.168	0.187	28795
5	1	10	71	3695	103784	0.225	0.468	16897

Diesel only:
According to optimization results perfumed by HOMER for the defined parameters in section 3, the first economically viable system is diesel.
Wind-diesel-battery:
According to Table 1, the second economically viable system, which is the most affordable among the feasible hybrid energy systems, is the wind-diesel-battery design that contains one B.W.C. excels wind turbine, a 15 kw diesel generator, ten batteries, one 10 kw power converter, with a total net present cost of $196.361 and a cost of energy of $ $0.409/KWh$.
According to observations, this system brought a renewable fraction of 31% while the system motived a growth rate of just 11% in total net present cost compared to a diesel-only system with an excellent wind regime in the considered area.
PV-Diesel-battery:
As noticed in Table 1, the fourth economically feasible system, which is the second most affordable one between the feasible hybrid renewable energy systems, is PV-wind-diesel-battery sketch that contains a 15 kw diesel generator, 10 batteries, and a 10 kw power converter, with a total net present cost of $ 202.905 and a cost of energy of $ $0.422/KWh$, such a system brought a renewable fraction of 45%.

Discussion

In this study, findings could be utilized in real-life stadiums to show if it is possible to create stadiums with fewer energy demands that run on primarily renewable energy. As mentioned, economic and pollution concerns about electricity demand are also related to sports complexes and stadiums. Sport stadiums worldwide are used for sports events and shopping, concerts, museums, events, and business meetings or conferences (38). Stadiums are getting larger and have more and more other functions that increase energy use, noise and air pollution (3-5). Therefore, It is needed to find possibilities for applying energy-saving measures and renewable energy technologies. This study proposes hybrid energy systems to supply sport stadiums energy demand. In that case, it will supply low expenses and could help achieve a significant rise in using the renewable energy system that provides less pollution (7-8). Simulation results of proposed systems refer to wind turbines that can reduce carbon dioxide emissions. Eventually, the results showed that in terms of economic and environmental concerns, hybrid renewable energy sources should be seriously considered in designing power systems, with the issue of energy convention.

Conclusion

The current study has suggested a hybrid system to supply electricity demand in a considered stadium to achieve the renewable energy system, providing economic and clean energy systems of sports stadiums. It is shown that the suggested hybrid system can decrease energy consumption and pollution.

The proposed hybrid system that contains a mixture of conventional generators, renewable energy systems including wind turbine and solar photovoltaic arrays, batteries, and electric power converters can be used to supply potentials of available energy-saving measures and renewable energy technologies for sport stadiums located a the studied area with a certain average wind speed and an average daily solar radiation. In a second step, we investigated the feasibility of adding renewable energy sources to the current system to achieve an economical and environmental power supply for the electricity demand.

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مدیریت انرژی در استادیوم‌ها با استفاده از سیستم‌های انرژی‌های تجدیدپذیر هیبریدی

وجیهه جوانی*[1]، الشن داوران حق[2]

۱-گروه مدیریت ورزشی، دانشکده تربیت بدنی و علوم ورزشی، دانشگاه تبریز، تبریز، ایران

۲-گروه مهندسی برق، واحد شبستر، دانشگاه آزاد اسلامی، شبستر، ایران.

منابع انرژی تجدیدناپذیر علاوه‌بر هزینه‌های بالای نگهداری و عملیاتی، مشکلات جدی برای محیط زیست و سلامت انسان ایجاد می‌کنند. در سال‌های اخیر، سیستم‌های تجدیدپذیر هیبریدی که از بیش از یک نوع انرژی برای تامین نیاز برق استفاده می‌کنند، توجهات را به خود جلب کرده‌اند. این مطالعه با استفاده از یک سیستم هیبریدی به‌منظور تامین تقاضای برق برای استادیوم در منطقه مورد نظر، بر اساس داده‌های شمال شرق ایران با میانگین سرعت باد و تابش روزانه خورشید انجام شد. علاوه‌بر این، امکان افزودن منابع انرژی تجدیدپذیر برای به‌دست آوردن یک منبع انرژی اقتصادی و زیست محیطی برای تامین نیاز برق منطقه مورد نظر استفاده شد. در این مطالعه، هومر برای تجزیه و تحلیل و بهینه‌سازی سیستم‌های انرژی هیبریدی استفاده شد. این کار بر تامین انرژی از طریق دیزل هیبریدی، آرایه فتوولتائیک، باد، باتری و مبدل‌ها تمرکز داشت. اگر سیستم‌های هیبریدی پیشنهادی برای تامین انرژی مورد نیاز مورد استفاده قرار گیرند، هزینه‌های پایینی داشته و به‌صورت قابل توجهی در افزایش استفاده از سیستم انرژی تجدیدپذیر، ارائه سیستم‌های انرژی پاک و اقتصادی کمک می‌کنند.

واژه های کلیدی: سیستم هیبریدی، انرژی‌های تجدیدپذیر، هزینه انرژی، استادیوم