Design and Management of Hybrid Renewable Energy System using RETscreen Software: A Case Study

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Abstract: - This research clarified a complete design for a renewable microgrid for Al-aroub technical college in Palestine. It consists of various renewable energy systems, including the photovoltaic system, biogas as a primary energy source, a fuel cell generator and a hydrogen storage unit, which can provide electricity to developing economies. As the photoelectric generator and the methane generator provide sufficient electrical energy during the day that covers the requirements of the different loads on the farm, while the excess energy is transferred to the electrolyzer for hydrogen production and storage, and when the load needs more energy, the electric fuel cells are turned on where the hydrogen is obtained from the energy storage unit. An energy management strategy was also proposed in this study as the newly developed network control and management system, and Matlab was chosen to undertake this task. Moreover, the RETscreen Expert software that enables to determine the optimum size that meets the potential demand along with the most feasible economic values and guarantees the highest system reliability. Therefore, three scenarios were proposed and tested, the first being the basic model which was a solar system with traditional batteries, the second a solar system, biogas with batteries, and finally, solar energy, biogas, and fuel cell with hydrogen energy storage unit. Technical analysis of the combined generation was also performed using Power world simulator to obtain constant frequency and voltage (stability conditions). The simulation results clearly show that the hybrid renewable energy system (HRES) consist of PV, bioenergy and small-scale fuel cell generator is a more economical configuration than single renewable energy systems with battery which has a total net cost of $ 473570, levelized cost of energy (LCOE) of 0.157 $/kWh and the lowest CO2 emission model that was 2.1 tons per year.

Key-Words: - Hybrid renewable energy system, Fuel cell generator, Photoelectric generator, Photovoltaic, RETscreen software, Levelized cost of energy.

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1 Introduction

There has been a growing interest in hybrid microgrids in recent years, as evidenced by the increasing number of research papers and publications on the topic. A literature survey of hybrid microgrids reveals that a number of different technologies and approaches are being developed and implemented around the world [1].

One of the key areas of research is the optimization of hybrid microgrids. This includes the development of new control algorithms and energy management systems that can optimize the use of energy resources and minimize costs. Another area of research is the development of new technologies for hybrid microgrids, such as energy storage devices and smart inverters [2]-[3].

Hybrid microgrids offer a number of advantages over traditional power systems, including increased reliability, reduced emissions, increased efficiency, and improved resilience. Hybrid microgrids can be used in a wide range of applications, including rural electrification, disaster relief, remote communities, and commercial and industrial facilities [4]-[6].

Small hybrid microgrid systems (HMGS), which are a promising answer to the supply of energy on the one hand and cut costs on the other, are the result of thinking about the supply of remote and isolated locations located far from the main grid. These microgrids are created as low- to medium-voltage systems using a variety of parallel-connected resources that can produce power and meet demand. A straightforward structural example of HMGS is illustrated in Figures 1 [7]-[9].

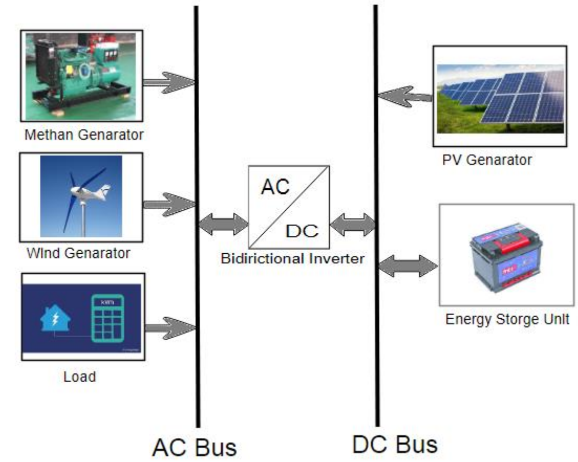

Fig.1: A simple structural example of (HMGS).

While hybrid microgrids offer a number of advantages, there are also some challenges that need to be addressed, including: the initial cost of installing a hybrid microgrid can be high. However, the long-term savings on energy costs can offset the initial investment, hybrid microgrids are complex systems that require careful integration of different energy sources and technologies, there is a lack of skilled workers who have the expertise to design, install, and operate hybrid microgrids [10]-[12].

There are a number of different methods that can be used to size RESs for a microgrid. One common method is to use a simulation software package, such as HOMER or SAM. These software packages can be used to model the performance of different microgrid configurations and to optimize the sizing of the RESs. Another method for sizing RESs is to use a rule-of-thumb approach. One common rule-of-thumb is to size the RESs to meet 100% of the peak load demand. However, this rule-of-thumb may not be appropriate for all microgrids. For example, microgrids that are connected to the main power grid may not need to size their RESs to meet 100% of the peak load demand. The best approach for sizing RESs for a microgrid is to use a combination of simulation software and rule-of-thumb methods. This will ensure that the microgrid is designed to meet the specific needs of the community [13]-[16].

In this study, the hybrid renewable energy system has been designed to meet Al-arroub technical college's peak and average power demand, as well as its energy demand. The system has been sized to ensure that the college has a reliable and sustainable source of electricity.

The proposed hybrid renewable energy system would be beneficial for Al-arroub technical college in a number of ways. The system would reduce the college's reliance on the grid, save money on energy costs, and improve the reliability of the college's electricity supply. The system would also be a good example of renewable energy technology for the college's students and faculty.

Three different scenarios have been presented for the case study: the baseline scenario, a PV system with battery energy storage; the second scenario based on the availability of renewable energy sources (solar PV, bioenergy, battery storage); and the third scenario using a combination of technologies (solar, bioenergy, and fuel cell with ESS).

2 Problem Formulation

Al-arroub technical college is located in Hebron city in Palestine. The geographical coordinates of it are 31°6′N 35°13′E, at an elevation of 930 meters above sea level. The annual average solar radiation is calculated as of 5.94 kWh/m^2/day. The average solar radiation for the college is shown in Figure 2 as well as the wind speed at the college site is shown in Figure 3.

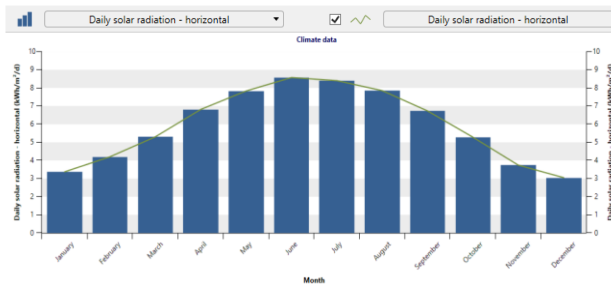

Fig. 2: Monthly average solar radiation with daily average radiation.

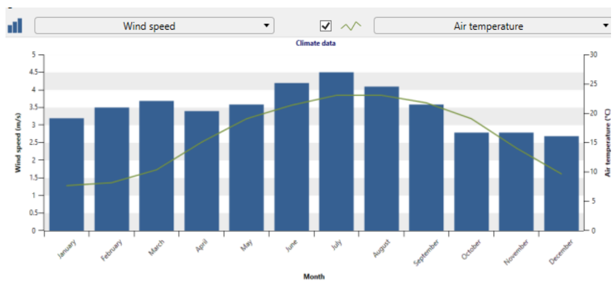

Fig. 3: Monthly wind speed with air temperature

The best tilt angle for PV system installation is about 30^{o} as shown in Figure 4.

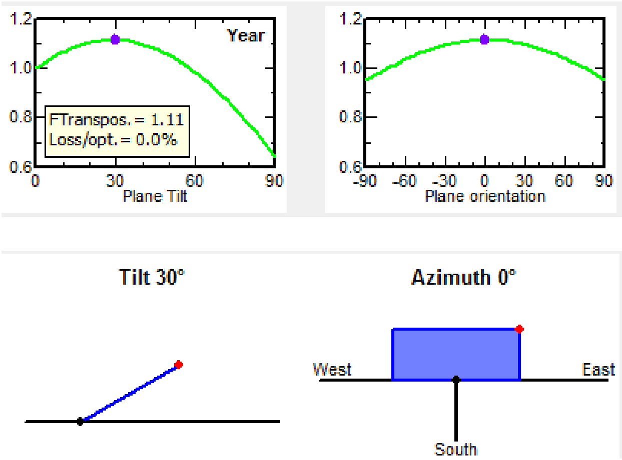

Fig. 4: The PV plane tilt angle and orientation.

The bioenergy system design depends on many factors, the predicted manure and amount, the needed power production, and finally the max capacitive of the line. Beside that the available manures in the area. The design of the proposed system has included two digesters; one as main digester and the other as post digesters as shown in Figure 5. The gas engines with the capacity of 6kW for each one. Combined heat and power (CHP) type has used in this study.

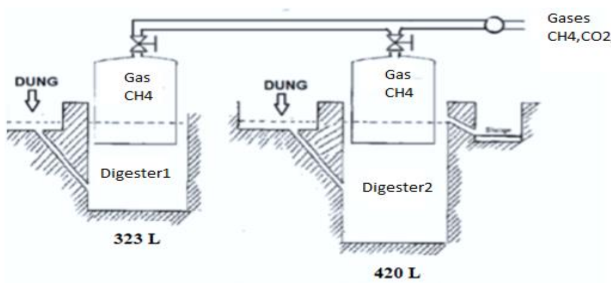

Fig. 5: The proposed design of digesters

3 Power Management Strategy

For control side, power management strategy has built and satisfied the following conditions:

If $P_{net} > P_{load}$, then the electrolyzer will work and use this energy to get hydrogen and store it.

If $P_{net} < P_{load}$, then FC will work and use hydrogen from energy storage.

The base RE sources will be solar system and biogas generator, at on peak time of the demand, fuel cell will work. power management strategy is shown in Figure 6.

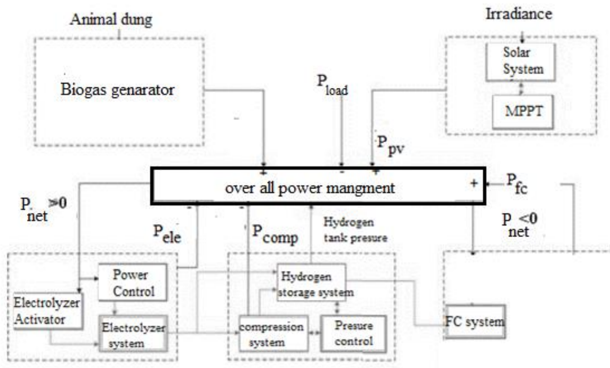

Fig. 6: The proposed power management strategy.

Where:
$P_{net} = P_{pv} + P_{methan}$
P_{ele}: power for electrolyzer
P_{fc}: Fuel Cell Power
P_{comp}: compression system power.

4 Results and Discussions

In this study, three scenarios are considered; the first scenario: (Base model), solar PV System with battery energy storage, the second scenario: solar PV, bioenergy, battery storage, and the third scenario: solar PV, bioenergy, fuel cell with ESS.

4.1 Scenario 1: Base model, PV System with batteries energy storage

In this scenario, solar PV with battery energy storage (off grid system) has been proposed to cover all load requirements without need of Israel Electric Corporation (IEC) company. The net present value (NPV) is 0.371859M$ and that good indicator that this model is good but not enough. So, the other factor LCOE is 0.7 $ /kWh and this value had been assumed as high cost that's due using battery storage system about 25% of demand. Also, the environment sense has been mentioned in this study. The carbon dioxide emission was the other indicator, it is 117.5 ton/year and that because using battery as energy storage system. The Figure 7 shows the results of optimization for each hour a long year (i.e., 8760 hour) as well as the output of the PV for all hours during the year.

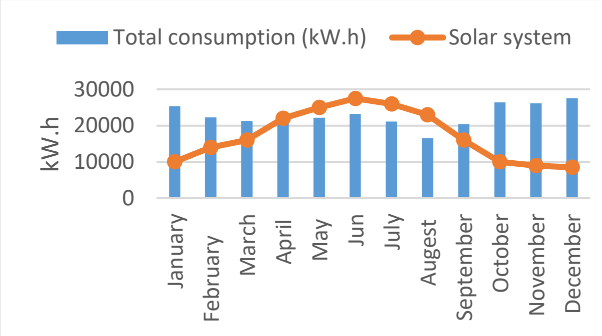

Fig. 7: Output energy of the PV and battery for a year

The proposed solar system with a capacity of 188 kWp able to generate 207,000 kWh/y; that can cover 75% of the energy demand and the battery covered the rest. The cost configurations are divided into four sections, capital costs, replacement costs, operating cost, and salvage over 25 years. Figure 8 shows the cost components for this model. Whereas Figure 9 and Figure 10 show the net and cumulative cash flow of the PV system with battery, respectively.

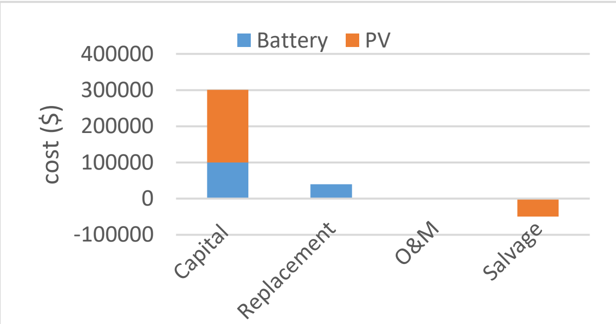

Fig. 8: The cost components for scenario 1.

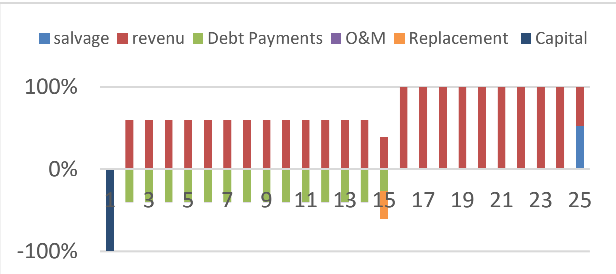

Fig. 9: Cash flow for scenario 1.

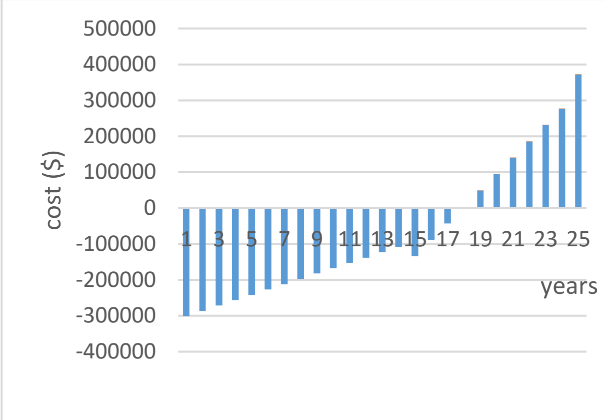

Fig. 10: Cumulative cash flow for scenario 1

4.2 Scenario 2: solar PV, bioenergy, batteries storage

In this scenario, solar PV with bioenergy system and batteries for energy storage have been proposed. The results show the NPV is -0. 403796M$ and this value is a bad indicator, thus this model not good for the investment. The Figure 11 presents the output of the PV, biogas and battery for all hours during the year.

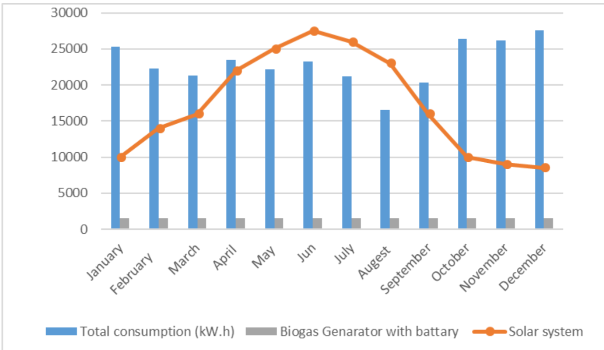

Fig. 11: Output of the PV, biogas and battery for a year.

The Cost configurations are divided into four sections, capital costs, replacement costs, operating cost, and salvage over 25 years. Figure 12 which represents the cost components for this model. Figures 13 and 14 show the net and cumulative cash flow of the PV-bio system with battery, respectively.

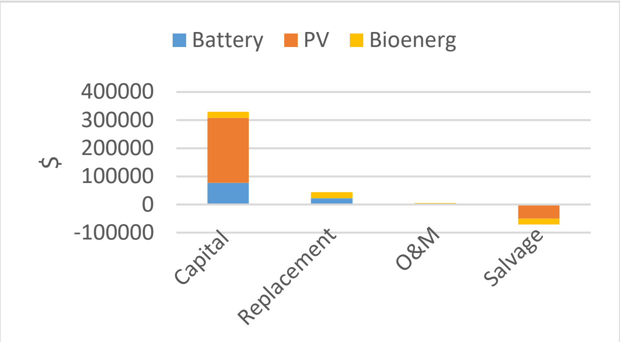

Fig. 12: The cost components for scenario 2

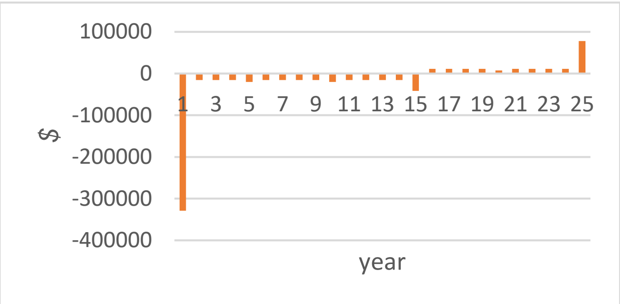

Fig. 13: The cash flow for scenario 2

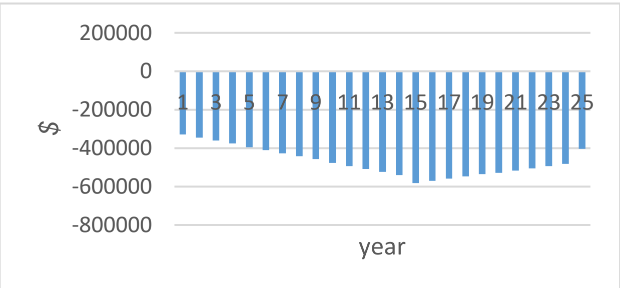

Fig. 14: Cumulative cash flow for scenario 2

4.3 scenario 3: solar PV, bioenergy, and fuel cell with ESS 10kW

In this scenario, the solar PV with bioenergy system and fuel cell energy storage units have been used. The results of this scenario show that; The NPV is $ 473570 which is a good indicator for a good investment. The average load consumption and embedded generation is illustrated in Figure 15, so when the load is more than embedded generation the fuel cells work and generate electricity at on peak time as stand by generator. On the other hand, when the embedded generation is more than load electrolyzer uses this exceed energy to analysis water and store hydrogen as fuels for fuel cells.

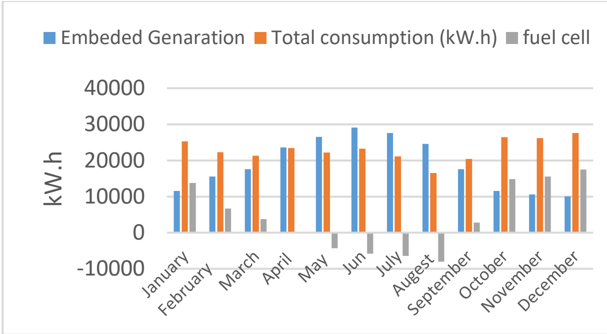

Fig. 15: The average load consumption and embedded generation

Solar system with a capacity of 188 kWp able to generate 207,000 kWh/y; an output that can cover 75% of demand and the FC with biogas generator covered the rest. The cost configurations are divided into four sections, capital costs, replacement costs, operating cost, and salvage over 25 years. Figure 16 which represents the cost components for this model. Bioenergy generator had replacement cost about 4330$ each 5 years and fuel cells every 15 years with salvage value that make FC with hydrogen storage system better than traditional battery. Figures 17 and 18 show the net and cumulative cash flow of the PV-bio system with FC and ESS, respectively.

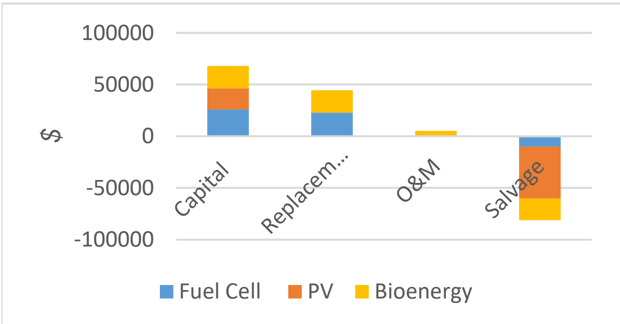

Fig. 16: The cost components for scenario 3

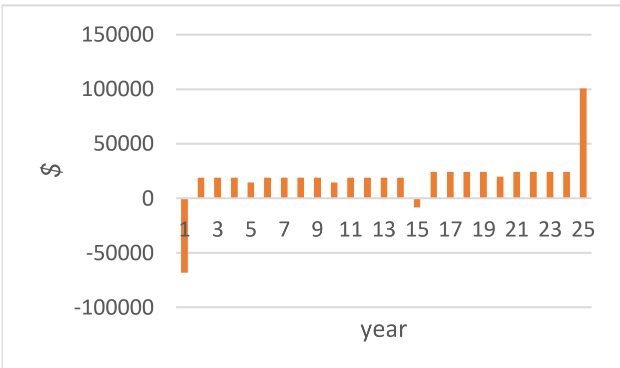

Fig. 17: The cash flow for scenario 3

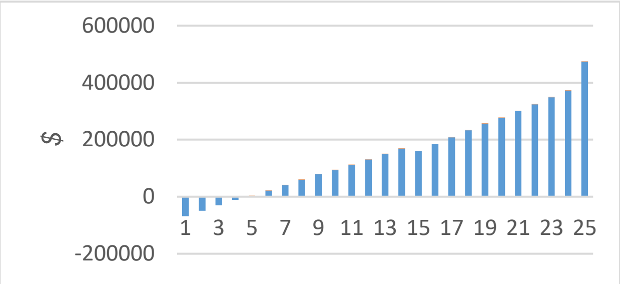

Fig. 18: The cumulative cash flow for scenario 3

4 Conclusion

In this study, a hybrid renewable energy system has been designed to supply electricity for Al-aroub technical college in Hebron city in Palestine. The power management strategy and optimization models have been introduced. Photovoltaic (PV) and methane power system have a higher capability to deliver continuous power with reduced energy storage so the results is better utilization factor of control equipment and power conversion than single sources. Power load management in microgrid PV-methane generation systems have been proposed in this study. the proposed system could be work on grid system or off-grid system. The system uses hybrid renewable sources biogas and solar energy with FC and ESS.

Three different scenarios have been studied in this work using RETScreen expert; the first scenario base model, PV System with battery energy storage, the second scenario depending on RE sources model; solar PV, bioenergy, battery storage, and in the third scenario has used solar, bioenergy, fuel cell with ESS. The most suitable scenario is the third one according to the result with ratios 75% solar and 25 %bioenergy with fuel cell and ESS. LCOE of 0.157$/kWh with the payback of investment during about 5 years.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.