ECONOMIC ANALYSIS OF A HYBRID ENERGY SYSTEM FOR RURAL ELECTRIFICATION IN THE HASIK AREA, OMAN

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Introduction

Oman like other countries has some remote communities that are not connected to the main grid system but are supplied mainly using diesel generators through islanded modes. One such example of a remote community in the Sultanate of Oman is Hasik, an area located in the Wilayat of Saadha in the Dhofar Governorate. Hasik is located approximately 950 km from Muscat, the country's capital. The area has untapped economic opportunities, including tourism; however, having adequate and affordable energy is necessary for its development. Providing reliable, cost-effective electrical power to such communities like Hasik that are located far from the main networks and are sparsely populated is very expensive. Moreover, this endeavor requires building significant infrastructure, such as towers and connecting electric lines for long distances, as well as managing difficult geographic areas, which make installation and supply of electricity through the grid financially unviable or practically infeasible. In this case, resorting to diesel generators simply to avoid connecting rural areas to the main network is very common, yet it is still costly due to diesel fuel costs and its transportation and storage. One solution to supply such areas with electrical energy is islanded power generation systems that use available renewable energy resources (RERs) and different power generation units to form what is called a hybrid system (HS).

The hybrid system is a combination of two or more power sources, such as a solar-diesel system or a solar-wind-diesel-battery system.[1] A hybrid system has many benefits as reliance on a single system could result in system oversizing, thus increasing the total capital investment. On the other hand, dependence on renewable energy resources lacks reliability as RERs are affected by weather conditions of either wind speed fluctuation, in case of the wind turbines, or solar radiation fluctuations, in case of solar-based system.[2] Hybrid systems of RERs and diesel generators are applicable for rural areas that are supplied mainly by diesel generators. Furthermore, the research in this field is also driven by the depletion of fossil fuel reserves and their environmental effects, which can be mitigated by the usage of eco-friendly RERs. With the presence of various generating units in the HS as well as energy storage units, it is necessary to evaluate the economic feasibility of such a system. The options of the HS can be limited as hybrid power resources are affected by many factors including site topography, RER availability, energy storage costs, and load demand.[3]

Different hybrid systems are discussed in the literature, including different combinations of photovoltaic (PV) systems, wind turbines, storage, and diesel generators. For instance, J. Kumari et al. concluded that, among three different HS combinations, their research found the most economical to be a PV-biodiesel generator-battery system.[4] The renewable energy fraction of the proposed system is 91% and the cost of energy (CoE) is USD $0.23/kWh.

In the research by R. Rajbongshi et al. various options of hybrid systems were discussed, including biomass, PV, diesel generators, and a battery system for off-grid application.[5] For 19 kW peak load, the biomass-battery hybrid system was found optimal, but it depends on the biomass cost as the optimality moves to PV-biomass-battery hybrid system when the biomass cost increases. The authors also analyzed different peak loads and found the optimal hybrid system is affected by various factors such as load factor, peak load, and cost of RE resources. Moreover, this study illustrated that for a peak load of 19 kW, the off-grid hybrid system is still the optimum choice for a village that is 6.53 km away from the grid. However, this breakeven distance depends on the village load. A techno-economic study carried out by S. Salisu et al. for a hybrid system to supply a peak load of 17.08 kW in a remote community in Nigeria concluded that a PV-biomass-battery hybrid system is an optimal solution with CoE of USD $0.031/kWh, which is almost half the CoE from the grid without HS.[6]

M. Shafik et al. presented the results obtained from the use of a hybrid system in Sohag, Egypt, using HOMER Pro software, in addition to the simulation program (NEPALN).[7] Furthermore, it was managed using C++ based on an online optimizer, for a network consisting of 48 busbars with a peak consumption of 6,154 kW and 3,271 kVar. The proposed hybrid system consists of diesel generators, PV, wind turbines, and electric grid. Different scenarios were analyzed to reach the lowest CoE and minimum net present cost (NPC), considering reduced carbon emissions and reduced energy losses. The optimal combination was 2,000 kW PV, 35 wind turbines of 100 kW each, and 700 kW diesel generator, in the presence of the electric grid. The cost of energy (CoE) was USD $0.117/kWh. Moreover, the HS led to a 57% power loss reduction in the network.

In the research by U. Akram et al. two types of algorithms were used to reach the optimal design for a hybrid system consisting of wind turbines, PV, and a battery storage system for a system connected to the electrical grid.[8] The first algorithm was used to determine the optimal sizing of renewable energy generators, while the second algorithm was used to determine the optimal capacity of the battery storage system in order to reach the lowest cost and highest reliability. In the second algorithm, 1,000 different combination possibilities of the hybrid system were selected, and the capacity was determined for each option of the hybrid mix. The optimal solution, which takes into account the highest reliability at the lowest cost, was determined to be a combination of 57 MW PV, 187 MW wind turbines, and 63 MWh battery storage system. The CoE for this combination was estimated to be USD $0.1873/kWh.

O. Krishan and S. Suhag used HOMER to study the feasibility of a hybrid system including wind, PV, and battery systems for a residential and agricultural peak load of 30.5 kW.[9] It was found that PV, wind, and battery systems are the most economical configuration with CoE of USD $0.288/kWh. Moreover, MATLAB/Simulink was used for further technical analysis to maintain the power balance. A techno-economic feasibility study was demonstrated by J. Li et al. for an off-grid hybrid power system that includes solar, wind, and biomass in West China.[10] The system consisted of 78.62 kW peak primary load and 40 kW peak deferrable load. Using HOMER, a combination of wind, PV, biomass, and battery were found to be feasible configurations of the HS with a CoE of USD $0.201/kWh.

J. Ahmad et al., in their case study of Kallar Kahar in Pakistan, proposed a 50 MW wind, PV, and biomass grid-tied hybrid system for an area of 73.6 MW peak.[11] As the system was proposed for an on-grid application, the surplus power was assumed to be sold with the same CoE of USD $0.0574/kWh. Furthermore, the proposed system has contributed to emission reductions as the renewable penetration reached 87.7%.

S. Hoseinzadeh and D. Garcia studied the economic and technical use of PV, wind, fuel cells, electrolyzer, and hydrogen tanks for a load of 2 MW for Italy.[12] Since the study was intended for an off-grid application, hydrogen storage and electrolysis are proposed to balance the energy. Using HOMER optimization, the system levelized CoE reached USD $0.80/kWh. Moreover, the emissions were very low compared to the previous mentioned systems; for instance, carbon dioxide emissions did not exceed 13 kg/year.

The potential use of wind, PV, and battery HS to supply a peak load of 125 kW was studied by M. Ramli et al. for the case of Western Coastal Saudi Arabia.[13] The best combination was optimized using both HOMER and MATLAB, taking into consideration the unmet load and excess electricity. Moreover, the authors observed that PV has higher efficiency at this location than other resources; however, the inclusion of wind and battery as an optimal configuration had an important addition to meet load demand during night hours. The CoE for this system was USD $0.329/kWh. Table 1 summarizes different hybrid systems with their cost of energy found in some literature.

The objective of this paper is to determine the optimum size of an isolated PV diesel system to provide the energy requirements in the Hasik area, which is a remote site located in the southern part of Oman. The National Renewable Energy Laboratory (NREL)'s HOMER Pro version 3.14.5 software was used to perform the feasibility study.[14] The software performs economic analysis and ranks the systems according to their net present cost. It needs information about wind and solar resources, control methods, energy storage medium, and economic constraints. The paper is organized as follows: in the next section we describe the existing system, then we discuss the modeling of the proposed system, followed by an explanation of how to build the system using Helioscope, an overview of our results, and, in the final section, we offer the paper's conclusions.

Table 1
LITERATURE REVIEW OF HYBRID SYSTEMS SUMMARY

Reference	Peak Load	Software	Hybrid System	Location	Renewable Energy Factor	Cost of Energy (USD $/kWh)
J. Kumari et al. (2017)	2.2 kW	HOMER	PV, biodiesel generator, battery	Perumal Kovilpathy, Coimbatore, India	91%	0.23
R. Rajbongshi et al. (2017)	19 kW 25 kW 41 kW	HOMER	PV, biomass-battery	Jhawani, Tezpur, India	100%	0.119 0.116 0.100
M. Shahzad et al. (2017)	17.08 kWh	HOMER	PV, biomass-battery	Karor Lal Eason, Layyah, Pakistan	100%	0.031
M. Shafik et al. (2020)	6154 kw	HOMER, NEPALN	diesel generators, PV, wind	Sohag, Egypt	–	0.117
U. Akram et al. (2019)	100 MW	MATLAB	wind turbines, PV, and a battery storage system, grid	Dammam, Saudi Arabia	–	0.187
O. Krishan and S. Suhag (2019)	30.5 kW	HOMER, MATLAB	PV, wind, battery system	Yamunanagar, Haryana, India	100%	0.288
J. Li et al. (2020)	118.62 kW	HOMER	wind, PV, biomass, battery	Leopard Beach Village, West China, China	100%	0.201
J. Ahmad et al. (2019)	73.6 MW	HOMER	wind, PV, biomass	Kallar Kahar, Punjab Province, Pakistan	87.7%	0.057

(continued)

Table 1 (continued)
LITERATURE REVIEW OF HYBRID SYSTEMS SUMMARY

Reference	Peak Load	Software	Hybrid System	Location	Renewable Energy Factor	Cost of Energy (USD $/kWh)
S. Hoseinzadeh and D. Garcia (2022)	2 MW	HOMER	PV, wind, fuel cells, electrolyzer, hydrogen tanks	Catania City, Sicily Island, Italy	100%	0.80
M. Ramli et al. (2016)	125 kW	HOMER, MATLAB	PV, wind, battery	Yanbu Industrial City, Saudi Arabia	100%	0.149

References: J. Kumari, P. Subathra, J. E. Moses, and D. Shruthi, "Economic Analysis of Hybrid Energy System for Rural Electrification Using HOMER," 2017 in Proceedings from the International Conference on Innovations in Electrical, Electronics, Instrumentation and Media Technology (ICEEIMT), Coimbatore, India, February, 3-4, 2017, pp. 151–56; R. Rajbongshi, D. Borgohain, and S. Mahapatra, "Optimization of PV-Biomass-Diesel and Grid Base Hybrid Energy Systems for Rural Electrification by using HOMER," *Energy*, vol. 126 (2017), pp. 461–74; M. Shahzad, A. Zahid, T. Rashid, M. Rehan, M. Ali, and M. Ahmad, "Techno-Economic Feasibility Analysis of a Solar-Biomass Off Grid System for the Electrification of Remote Rural Areas in Pakistan Using HOMER Software," *Renewable Energy*, vol. 106 (2017), pp. 264–73; M. Shafik, G. Rashed, and H. Chen, "Optimizing Energy Savings and Operation of Active Distribution Networks Utilizing Hybrid Energy Resources and Soft Open Points: Case Study in Sohag, Egypt," *IEEE Access*, vol. 8 (2020), pp. 28704–8717; U. Akram, M. Khalid, and S. Shafiq, "Optimal Sizing of a Wind/Solar/Battery Hybrid Grid-Connected Microgrid System," *IET Renewable Power Generation*, vol. 12, no. 1 (2019), pp. 72–80; O. Krishan and S. Suhag, "Techno-Economic Analysis of a Hybrid Renewable Energy System for an Energy Poor Rural Community," *Journal of Energy Storage*, vol. 23 (2019), pp. 305–19; J. Li, P. Liu, and Z. Li, "Optimal Design and Techno-Economic Analysis of a Solar-Wind-Biomass Off-Grid Hybrid Power System for Remote Rural Electrification: A Case Study of West China," *Energy*, vol. 208, issue C (2020); J. Ahmad, M. Imran, A. Khalid, W. Iqbal, S. R. Ashraf, M. Adnan, S. F. Ali, and K. S. Khokhar, "Techno Economic Analysis of a Wind-Photovoltaic-Biomass Hybrid Renewable Energy System for Rural Electrification: A Case Study of Kallar Kahar," *Energy*, vol. 148, issue C (2018) , pp. 208–34; S. Hoseinzadeh and D. Astiaso Garcia, "Techno-Economic Assessment of Hybrid Energy Flexibility Systems for Islands' Decarbonization: A Case Study in Italy," *Sustainable Energy Technologies and Assessments*, vol. 51, no. 8 (2022); and M. Ramli, A. Hiendro, and Y. Al-Turki, "Techno-Economic Energy Analysis of Wind/Solar Hybrid System: Case Study for Western Coastal Area of Saudi Arabia," *Renewable Energy*, vol. 91, issue C (2016), pp. 374–85.

Existing System

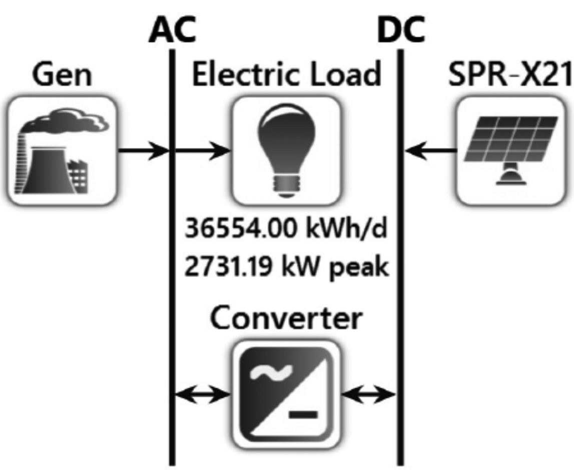
The small diesel power station at Hasik is managed by Tanweer company[15] and consists of five units each of 1 MW. The system voltage at Hasik is 11 kV and 415 V for distribution and service voltage levels, respectively.[16] The load at Hasik is mainly residential with a total installed capacity of 5 MW serving 394 customers as per Tanweer's latest Capability Statement.[17] The available capacity is 3.2 MW, and the actual peak demand in 2020 was 2.8 MW. However, the forecasted peak demand by 2023 is 3.2 MW.

Modeling of the Proposed System

In this study, a techno-economic analysis is carried out using HOMER to determine the optimal sizing of a hybrid system at Hasik. Real data about Hasik's electric network are utilized in the hybrid system model. A PV system will be integrated as a renewable resource in the existing Hasik distribution network. Figure 1 shows the configuration of the hybrid system at Hasik designed in HOMER. The real load data for 2020 was used in HOMER. The hybrid system was designed based on the following parameters: the load profile of Hasik network, meteorological data, generators' characteristics, economic data, and PV and converter technical data. These data will be explained in the following subsections.

Meteorological Data: The Solar Global Horizontal Irradiation (GHI) was downloaded from NASA Prediction Worldwide Energy resource (power) data base as presented in figure 2.[18] HOMER used these data to calculate the output power of the PV system.

Figure 1
SCHEMATIC OF A HYBRID SYSTEM AT HASIK IN HOMER



Load Profile of Hasik Power Network: The load profile is the most important part for the simulation and optimization. HOMER was fed with an average hourly load (kW) of the Hasik network for the year 2020 as shown in figure 3. The maximum and minimum demand were recorded in June 2020 of around 2.6 MW and January 2020 of around 493 kW, respectively. The load for the Hasik area is mainly residential load and the change of load is very limited. Figure 4 presents the total energy generated at the Hasik power station for a four-year period, which was almost constant during this period.[19]

PV Modular and Converter: The Sun power X21-335-BLK PV modular was selected from the HOMER PV's list. It has a 20% efficiency with a lifetime of 25 years. The operation temperature of this type of PV is 45°C. The converter data inputs were selected to comply with the characteristics of ABB PVI 100 kW inverter, which has a 15-year lifetime and 98% output efficiency.

Diesel Generators: The diesel generator was placed in the auto sizing option in the HOMER software. However, the results of the generator optimal sizing will be compared later with actual diesel generators available capacity at the Hasik network. The diesel generator's fuel price was provided in a monthly basis from Tanweer Company and then was considered to be an average of USD $0.67/L.[20]

Economic Data and Constraints: The economic data are mostly related to the costs, which are highly considered in the simulation and optimization calculations of HOMER. Each component in the hybrid system has the following cost inputs: capital cost, replacement cost, and operation and maintenance cost as presented in table 2. Additionally, the inflation and discount rates were taken as 3.35% and 7.5%, respectively.[21] The cost for PVs and inverters are based on the current price provided by Nafath Renewable Energy company in Oman.[22] For a diesel unit, the initial cost was taken from USP&E Global.[23] The project lifetime was considered to be 25 years.

Figure 2
HASIK AREA: SOLAR GLOBAL HORIZONTAL IRRADIATION (GHI)

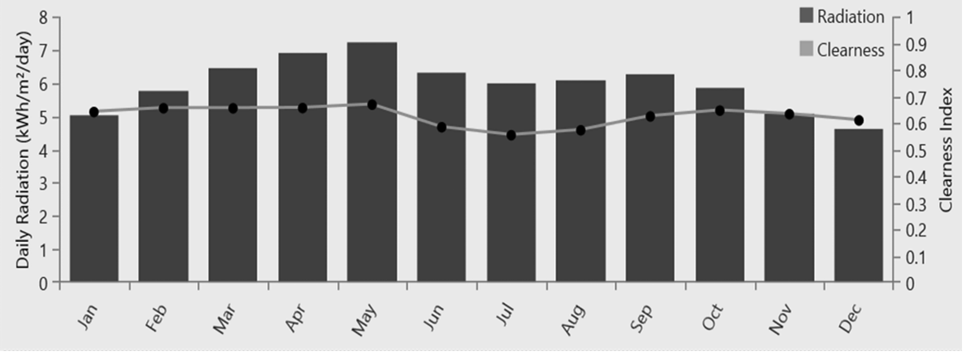
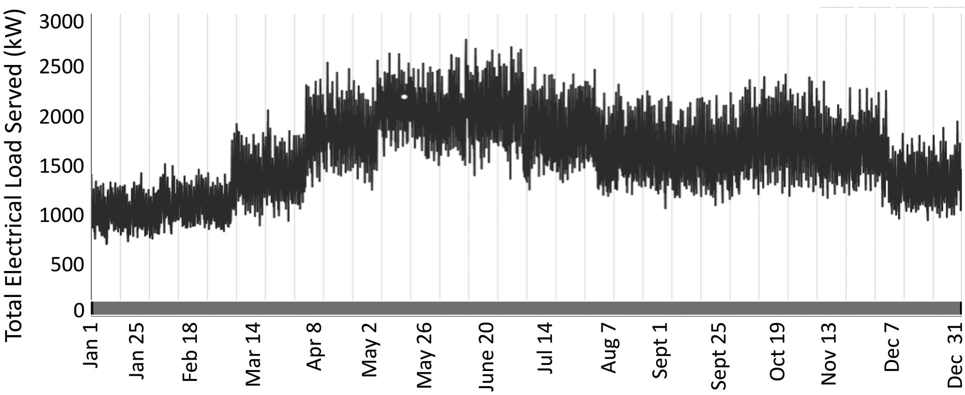


Figure 3
HASIK HOURLY LOAD FOR YEAR 2020



Discussion of Results

Figure 5 shows the monthly production of the PV system and diesel generator for one year. The total electrical production for the whole year is 14,852,448 kWh/y, of which 30.9% comes from the PV system. The renewable penetration of the system is shown in figure 6. The highest penetration was detected between January to

Figure 4
TOTAL ENERGY PRODUCTION IN HASIK AREA

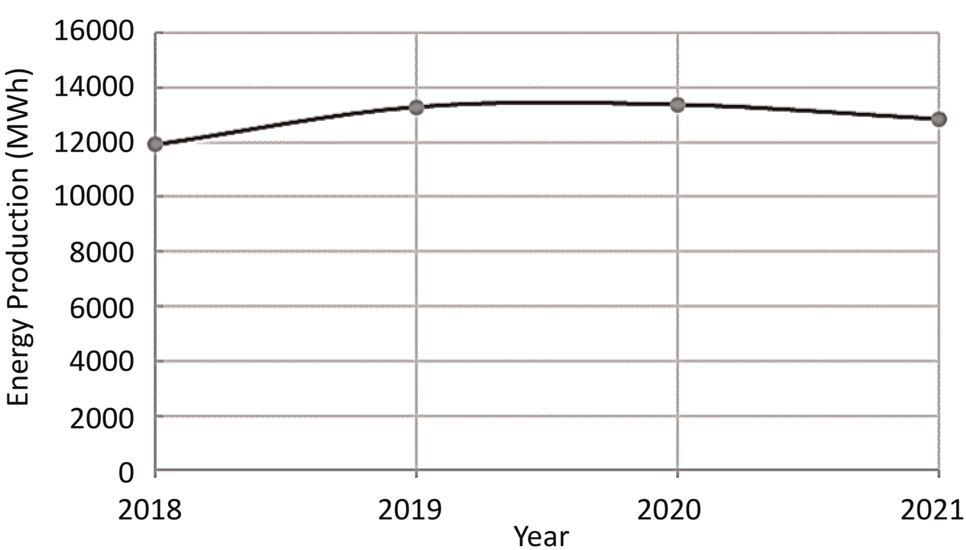


Table 2
COST OF HYBRID SYSTEM COMPONENTS

Description	Data
PV	
Capital cost	USD $1,000/kW
Lifetime	25 years
Operation and maintenance cost	USD $10/year
Inverter	
Capital cost	USD $500/kW
Lifetime	25 years
Operation and maintenance cost	USD $0/year
Diesel Unit	
Each unit	USD $250/kW
Operation and maintenance cost	USD $0.67/Liter
Interest Rate	
Discount rate	7.5%
Inflation Rate	3.35%

the beginning of March where the demand is low during high solar production. The capacity factor of the renewable source is 21% with total production of 4,591,631 kWh/y.

Energy Cost for the Optimal System: HOMER simulation selected an integration between a 2,500 kW PV system and a 3,100 kW diesel generator as the winning system architecture. Table 3 highlights the main features of the HOMER Pro results, which consist of net present cost (NPC), operation cost, fuel cost, cost of energy (CoE), and CO_2 emissions.

Figure 5
THE MONTHLY PRODUCTION OF THE PV SYSTEM AND DIESEL GENERATOR

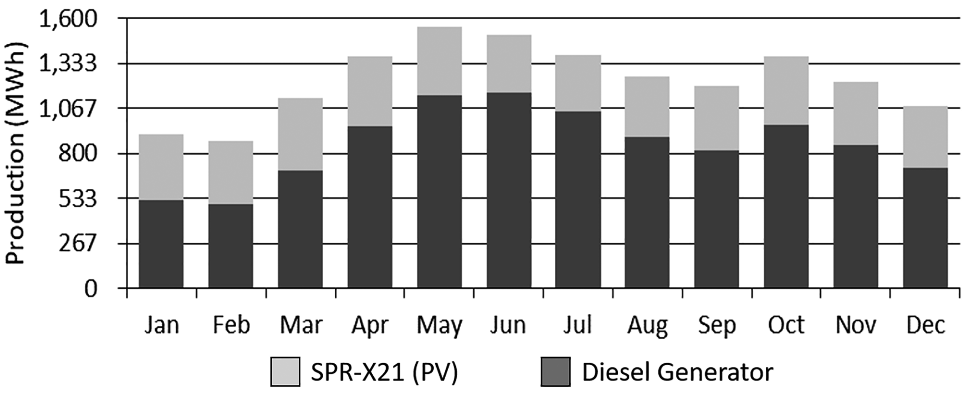
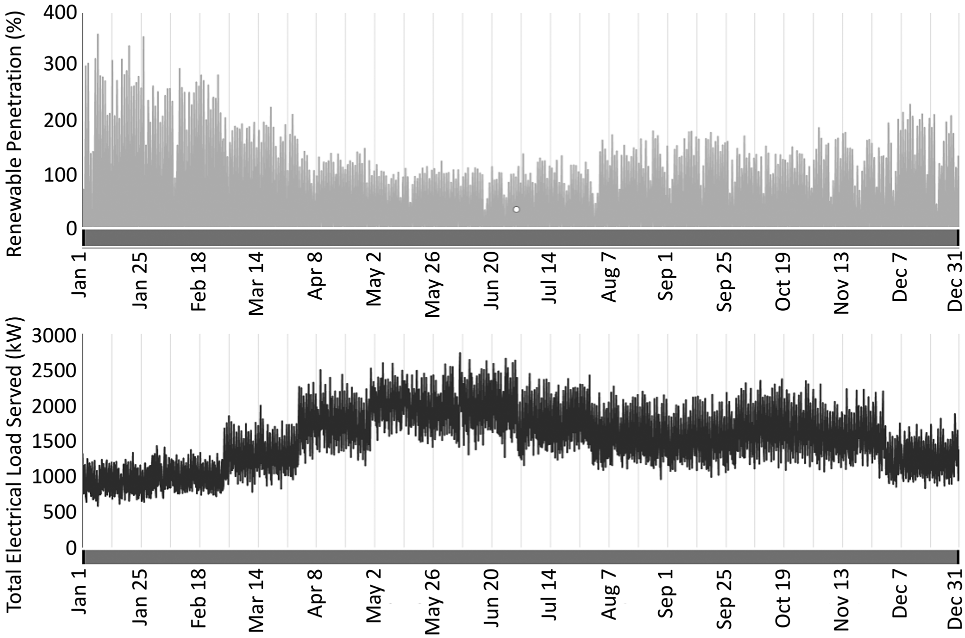


Figure 6
RENEWABLE PENETRATION



The cost of energy for the winning scenario drops from USD $0.245/kWh to USD $0.214/kWh, which is around 13%. Furthermore, the winning case will have a reduction in the net present cost (NPC) by 13%, a reduction in fuel cost, and operation cost. The payback period of this investment is 4.3 years with an internal rate of return (IRR) of 23%.

CO_2 Emissions and Carbon Taxes: The PV production's contribution to the penetration level is 30.9% of the total power generation in this hybrid system. This value has a direct impact on the reduction of CO_2 emissions. This was confirmed by a reduction in CO_2 emissions by 22% from the base case of 9,288,445 Kg/year to 7,245,367 Kg/year.

Table 3
COMPARISON BETWEEN SOME ECONOMIC FEATURES OF HOMER PRO CASES

	Net Present Cost (in US$)	Operation Cost (in US$)	Fuel Cost (in US$)	Cost of Energy (CoE) (in US$)	CO_2 Emissions (in KG/year)
Base	$50.9 M	$3.21 M	$2.39 M	$0.245	9,288,445
Proposed	$44.5 M ↓	$2.58 M ↓	$1.864 M ↓	$0.214 ↓	7,246,367 ↓

Figure 7
HASIK 37-BUS SYSTEM

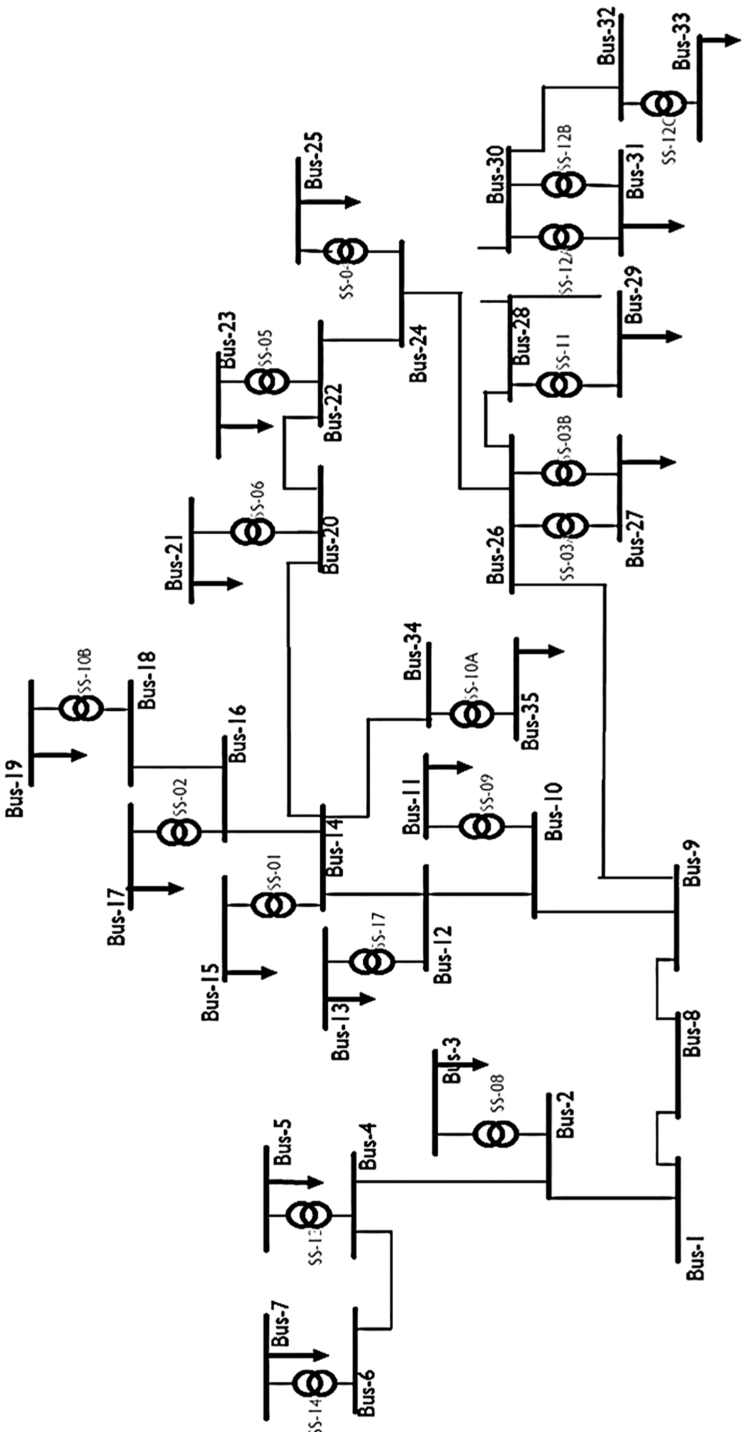


Table 4
TRANSFORMER SIZING[a]

TX-NO	TX.KVA	TX-NO	TX.KVA
1	1000	9	500
2	500	10-A	100
3-A	1000	10-B	1000
3-B	1000	11	500
4	1000	12A	1000
5	1000	12B	1000
6	1000	12C	1000
7	500	13	1000
8	500	14	1000

[a]TX-NO = Transformer number and TX.KVA = Transformer size.

Table 5
TRANSFORMER'S RATING

Size (MVA)	X/R Ratio	%Z	%X	%R
1	5.57	4.75	4.68	0.84
0.5	5.1	4.75	4.66	0.91

PV Optimization Using MATLAB: We used the MATLAB load flow tool to model and simulate the Hasik power network. The target was to investigate the solar energy system effects on the network operation, mainly the system voltage at different buses, which are the nodes where a line or several lines are connected and may also include several components such as loads and generators in a power system, with respect to the PV connection at the optimum location. The optimum location of the PV was assumed to be at the most loaded buses. The optimal sizing system was found using HOMER, yet the MATLAB Genetic Algorithm (GA) is

Table 6
CONDUCTOR DATA[a]

Conductor Type	Size (mm2)	R(Ω/km)	X(Ω/km)	B(S/km)
3/C XLPE Cable	70	0.387	0.107	–
3/C XLPE Cable	185	0.128	0.112	0.0001351
3/C XLPE Cable	240	0.098	0.109	0.0001495
WOLF ACSR OHL	150	0.1828	0.221	0

[a]R = Resistance, Ω/km = Ohm per kilometer, X = Reactance, B = Susceptance, and S/km = Siemens per kilometer.

Table 7
MATLAB SIMULATION SUMMARY[a]

	Real Power "P" (in MW)	Reactive Power "Q" (in MVAR)
Generation	2.559	1.795
Demand	2.539	1.89
Losses	0.02	−0.096

[a]MW = Megawatts and MVAR = Megavolt-Ampere Reactive.

used here to determine the optimal PV sizing based on minimizing the power losses.

Modeling of the System: The Hasik network consists of an 11 kV diesel power station and three main feeders that have a total of 37 buses as shown in figure 7. The network consists of 18 step-down transformers (11/0.415 kV). Table 4 and table 5 provide the transformer sizes and transformer ratings of the system, respectively. Table 6 shows the conductor parameters that are used in the Hasik network. The load data were provided by Tanweer company based on 2020 peak load condition.

Power Flow: The power flow model of Hasik was built with an actual data of the network, loads, and generations. The power flow was solved using Newton-Raphson method iterative techniques, which is commonly used for nonlinear equations.[24] Hence, the voltage at different buses, current, and power losses were calculated for different cases.

Model Verification: The power flow simulation results are summarized in table 7.

The voltage profile of the system buses is shown in figure 7 (base value). The voltage profile should be within ±6% of the nominal value in distribution networks (11 kV and 415 V) based on the Oman Distribution Code.[25] It was found that almost all voltages at buses are close to unity voltage because Hasik has a very small network and low demand compared to the network capacity.

PV System Optimal Sizing: The PV system could be connected near the diesel power station. However, that location would not be the optimal one which is

Table 8
OPTIMAL PV SIZING AND TOTAL SYSTEM LOSSES IN TWO SCENARIOS[a]

	Base Case	Scenario 1 (PV @ Bus-14)	Scenario 2 (PV @ Bus-26)
Optimal PV sizing (MW)	No PV System	1.34	2.31
Network total losses (MW)	.02	0.017	0.014

[a]MW = Megawatts.

Figure 8
VOLTAGE PROFILE AT PEAK DEMAND FOR DIFFERENT SCENARIOS

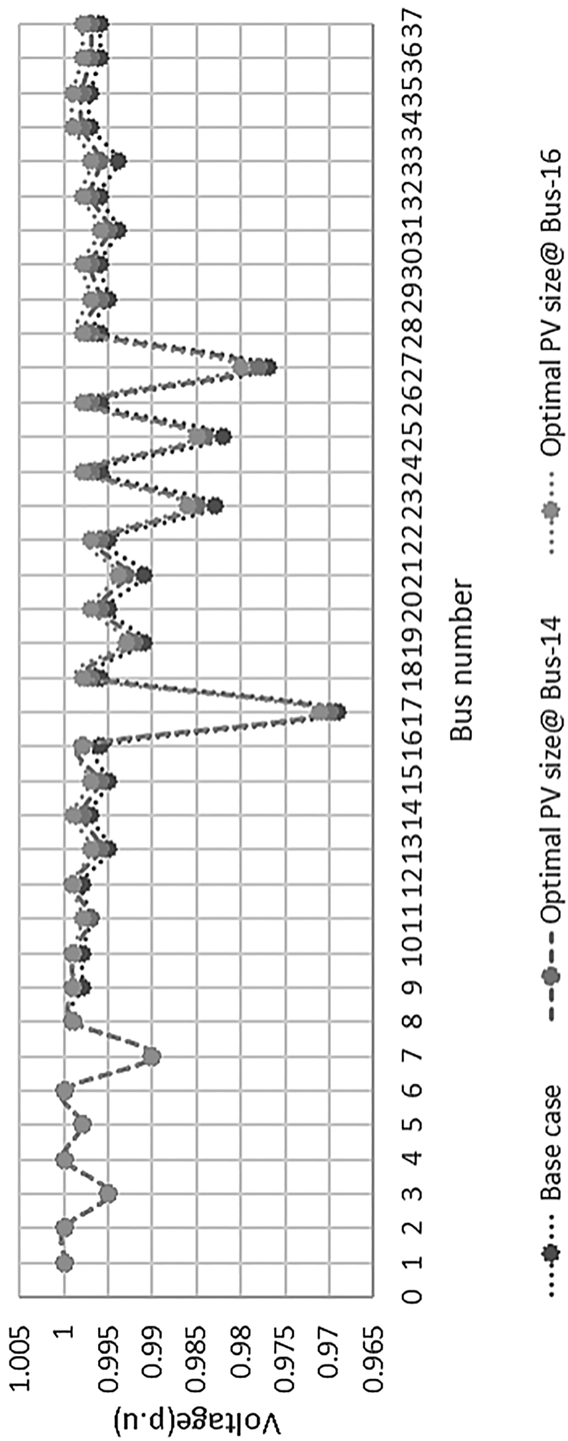
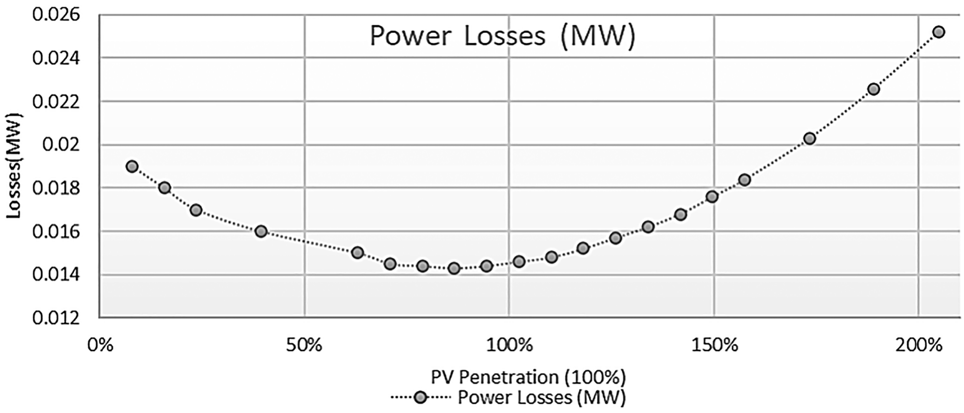


Figure 9
CHANGES IN SYSTEM LOSSES WITH PV SYSTEM SIZE AT BUS-26



supposed to reduce the system power losses and improve the system voltage profile. Thus, to find the optimum size of the PV based on minimizing power losses, a Genetic Algorithm (GA) was used. For the optimum location, the most loaded buses in the system were selected for the PV connection. For the Hasik area, the PV were connected to substation 1 (SS-01) and substation 3 (SS-03) (see figure 6), which are the most loaded buses in the power system network. The MATALB GA calling function applies to two scenarios. Scenario 1 is to find the optimal sizing and the voltage profile in (SS-01) whereas scenario 2 finds the same in (SS-03). Table 8 compares the optimal results of the two scenarios whereas figure 7 shows the voltage profile for the two scenarios compared with the base case (without PV).

The first observation that can be seen from table 8 is the reduction in overall network losses when an optimal PV size is applied. The second observation is that selecting the location of the PV system also has an impact on the amount of losses; connecting the optimal PV system to Bus-26 and Bus-14 reduces the losses by 30% and 15%. respectively. The third observation is the enhancement in voltage profile as shown in figure 8.

Total Losses as a Function of PV Sizing: A case study of the distribution network power losses as a function of the size of the PV system installed at Bus-26 is presented in figure 9. Simulation results show that power losses are reduced from 0.02 MW with no PV system installed to 0.014 MW with a 2.31 MW PV system connected to Bus-26. Increasing the PV system capacity beyond this value results in higher power system losses.

Conclusions

This study was conducted to investigate the technical and financial evaluation for implementation of a hybrid PV-diesel system at Oman's Hasik area using HOMER and MATLAB software. It was found that the hybrid system is feasible as the PV system investment can be recovered in a very short period compared to other investments with a payback period of 4.3 years.

The Genetic Algorithm optimization technique was used to find out the optimal PV system sizing that will be connected to most loaded buses. Using the optimal PV sizing resulted in a 30% losses reduction in Bus-26 as well as improving the voltage profiles along different feeders.

Based on the optimization result, it can be summarized that using a PV system along with the existing diesel generator in the Hasik network is a feasible project. The capital investment of PV with an inverter system is USD $4.2M with NPC of USD $44.5M. This will result in a 22% reduction in diesel consumption annually, as well as a reduction in greenhouse gases emissions (GHG). Moreover, the cost of energy will drop from USD $0.245/kWh to USD $0.214US/kWh.

This study has implications for other remote communities in Oman and other countries seeking to expand hybrid energy systems for rural electrification. In particular, those nations that can best optimize renewable energies due to their geography could benefit from more in-depth economic analyses. While this research focused on the Hasik Area in Oman, there are certainly many other opportunities for further studies to be conducted on the economic analysis of hybrid energy systems and how that could potentially serve as a solution to reduce costs and emissions.

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