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Technical and economic feasibility of solar PV systems supported by energy storage in hospitals in KSA

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Abstract. The ambitious KSA 2030 Vision has among others targeted the deployment of renewable energies to meet KSA's primary electric load in the residential, commercial, and industrial sectors. Within this framework, the authors have evaluated the economic and technical feasibility of using a combination of solar PV systems and central energy storage systems in the health sectors. The combination of the two sources means reducing gas emissions, and increasing the instantaneous power from renewable energy sources while using energy storage to counterattack the intermittency of solar PV energy that is known to cause stability issues for the grid. In addition, it reduces the dependency on standby diesel generators that emit high pollution levels. The paper addresses the available energy storage devices and the design of a hybrid solar PV system combined with battery-stored energy. Through the study, it was found that up to 15 percent of the electric consumption can be provided by the solar PV system. It was found that the cost of energy competes with conventional electricity. In addition, the cost of storage devices has a significant impact on the cost of energy. Moreover, low payback periods were obtained for some systems.

Introduction

Batteries have been around since the early 1800s, and hydropower with pumped storage has been employed in the US since the 1920s. However, there has been a noticeable increase in the construction of new energy storage projects as well as the creation of advanced and improved energy storage technologies as a result of the desire for a more dynamic and cleaner grid. One of the projects and technologies revolves around solar energy.

In terms of solar energy potential, Saudi Arabia is one of the richest nations in the world. The nation has installed more than 3 GW of photovoltaic (PV) capacity in just six years. This will supply energy to more than 600,000 dwellings. By installing an additional 7.2 GW of PV capacity by 2022, Saudi Arabia is on pace, according to a new estimate from Bloomberg New Energy Finance (BNEF). The installed capacity would then increase to 10.2 GW. [1]

There are several reasons that contribute to the Saudi Solar Market's rapid growth. For example, solar panels are now more reasonably priced for customers thanks to a recent sharp decline in their cost. Second, the Saudi government has made significant investments in solar and other renewable energy sources. Also, solar will play a role in achieving the government's objective of having 9.5GW of renewable energy capacity by 2023. And finally but not least, people are becoming more and more conscious of solar energy's advantages for the environment. People are looking for solutions to lower their carbon footprint as their worry over climate change grows.

Community Solar, Storage, and Microgrids

A community solar project is a sizable solar power plant in the center of town whose electricity is used by numerous properties. A single community solar project can power hundreds or even thousands of houses because it is measured in megawatts, whereas residential solar installations are measured in kilowatts. Other names for community solar include shared solar, solar gardens, and roofless solar. Participants in community solar projects lock in monthly savings on their electricity bills, which is one of the two main advantages of community-shared solar. Community solar also enables more people to access the advantages of solar power. Community solar also benefits utility companies by allowing them to build projects in their regions.

What is the community microgrid?

The local bulk (i.e., high-voltage) transmission system, commonly referred to as the "microgrid," is a relatively small, controllable power system that is made up of one or more generation units connected to nearby users. Microgrids fall under the category of distributed generation because the energy (power and heat) is produced close to where they are needed. In the past, combined heat and power (CHP) systems powered by fossil fuels and generators with reciprocating engines were used to power microgrids. Today, projects are utilizing more environmentally friendly resources, such as solar energy and energy storage. When developing technologies like fuel cells and even tiny modular nuclear reactors become commercially viable, microgrids may be powered by renewable energy sources, combustion turbines powered by natural gas, or other sources. Microgrid demand has increased in the Saudi Arabian market due to the rising demand for reliable power supply and rapid infrastructure development. The need for microgrids is rising in the healthcare and military sectors, and there are many chances for growth in the microgrid industry. The development of renewable energy-based microgrid technology has also been boosted by several government strategies and technological developments.

System Design

The research team have planned to use solar PV to feed a local hospital equipped with energy storage banks so that this energy usage can be shifted during the day. Moreover, energy exchange with the local grid company where excess energy is sold back to the grid at an agreed upon tariff.

HOMER software is used in order to simulate the power system design. HOMER is capable of calculating the optimized cost for the system. It requires input data such as daily load demand, peak load, load factor, and renewable resources. Meanwhile, fuel costs, conventional generation units, maintenance costs, and storage devices characteristics are also considered in the optimization process.

Figure 1 shows how HOMER operation principles, the required input data, and optimal generation configuration.

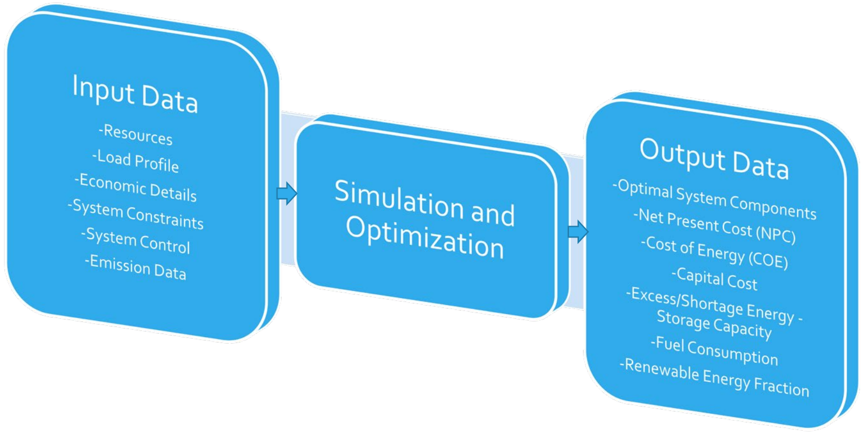

Figure 1: HOMER operation principles

System Location

The authors chose one of the most important and respected hospitals in Saudi Arabia. Figure 2 shows the layout of the hospital and potential areas for installing a rooftop solar PV system. There are 8 areas marked in red.

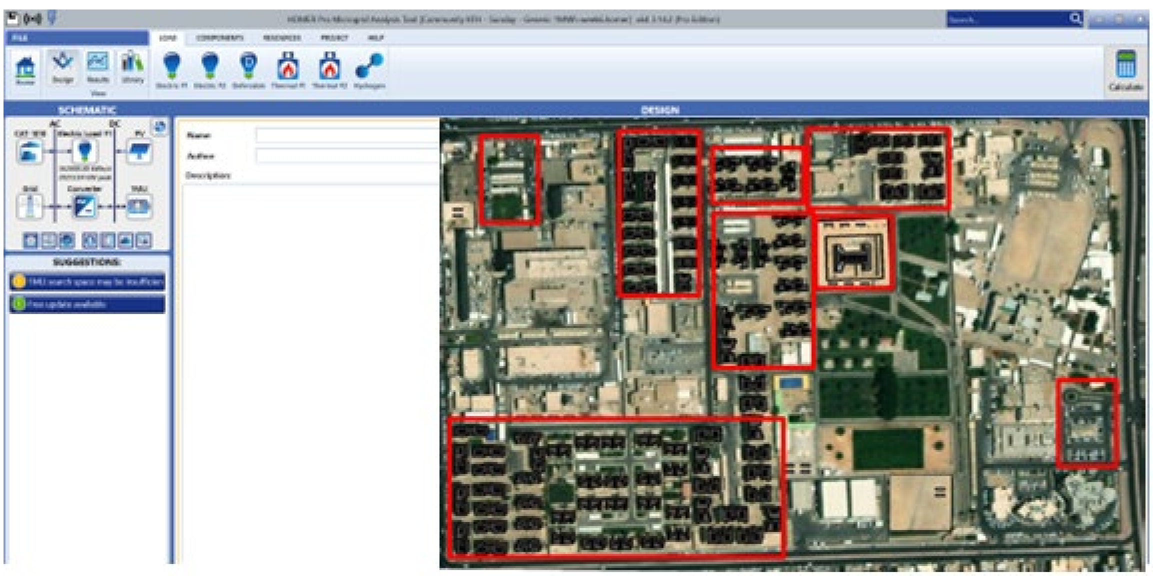

Figure 2: The layout of the public hospital under study

System Components

Figure 2 displays the various components of the proposed power system for the hospital on the top left. Table 1 displays the generation specifications and hospital electric demand.

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Table 1: ***Generation and Load Constraints***

Item	Description		Notes
Load	Peak load Load factor Daily energy	30 MW 52% 362 MWh	
Grid	Cost of Energy (purchase/sale)	0.64 SAR/kWh	Capacity constraint 19 MW
Storage Unit	Lifetime Capital cost O&M cost Replacement cost	5 years 300,000 SAR/MWh 3,000 SAR 30,000 SAR	Minimum storage 1 MWh Maximum storage 6 MWh
Solar PV	Lifetime Capital cost O&M cost Replacement cost	25 years 4,000 SAR/kW 110 SAR 400 SAR	Minimum capacity 1000 kW Maximum capacity 15000 kW
Converters	Lifetime Capital cost O&M cost Replacement cost	15 years 330 SAR / 1kW 100 SAR 330 SAR	Capacity 100 kVA-5000 kVA
Diesel Generators	Lifetime Capital cost O&M cost Replacement cost	50,000 Hours 154,000 SAR / Unit 318,000 SAR 100,000 SAR	Size 500kVA/1000kVA (already installed and manually scheduled)

To find the optimal generation mix for the hospital, the Homer software was run using the above generation and load constraints found in Table 1. The search domain was extended to include additional options such as wind turbines and hydro storage and the results are included in Figure 5. However, considering that the KSA vision requires the installation of as much PV as possible, the authors selected option One which is pointed with the arrow below. The performance and the economic analysis of the selected option are discussed below. Table 2, the cost summary is found of the selected optimal system.

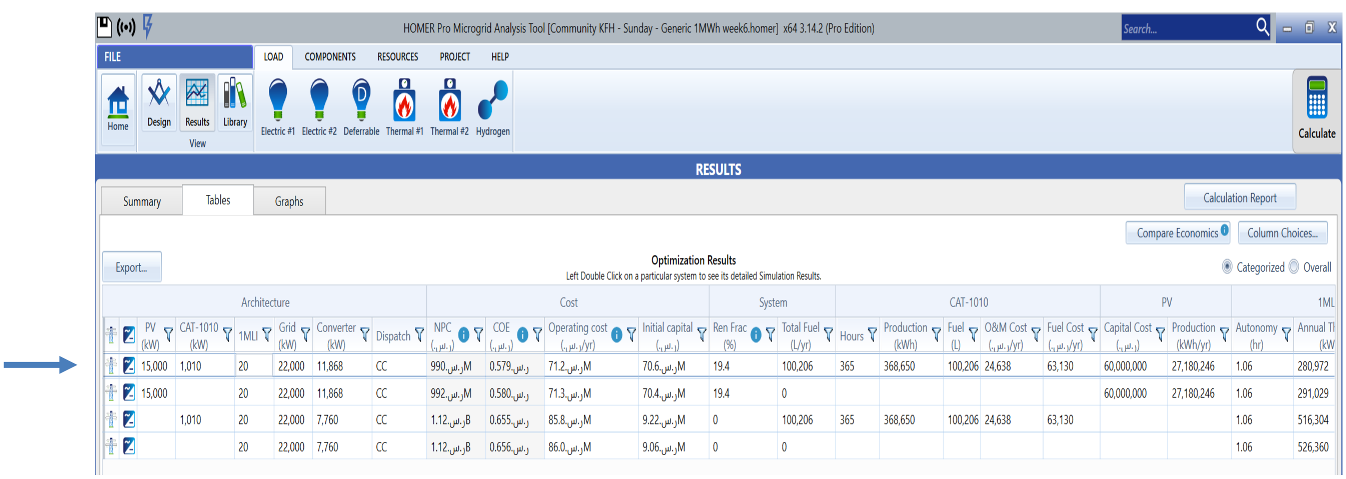

Figure 5: The Optimal Generation Mix Scenarios for the Hospital.

Figure 6 lists the project summary for the proposed solar PV and storage power system versus the existing system. In particular, the operating cost is reduced by approximately 14.88 MSAR and an annual saving of 14.8 MSAR. The designed system performance, economic analysis, and generation breakdown are shown in Table 2.

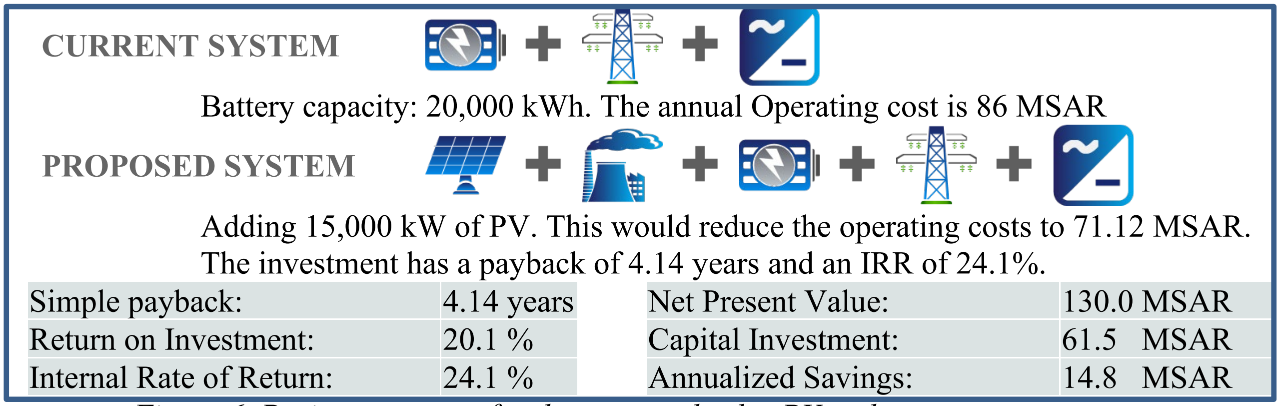

Figure 6. Project summary for the proposed solar PV and storage power system.

Table 2: Performance, economic analysis, and generation breakdown

Solar PV System		
Rated Capacity	15,000	*kW*
Capital Cost	60	*MSAR*
Specific Yield	1,812	*kWh/kW*
PV Penetration	20.6	*%*
Total Production	27,180,246	*kWh*
Maintenance Cost	1,650,000	*SAR*
LCOE	0.231	*SAR/kWh*
Storage System		
Rated Capacity	20,000 kWh	*kWh*
Annual Throughput	280,972	*kWh/yr*
Maintenance Cost	60,000	*SAR*
Autonomy	1.06	*Hour*
Expected Life	15.0	*Year*
Capital Costs	6.0	*MSAR*
Losses	29,574	*kWh/yr*

Figure 7 displays the cumulative cash flow over the 25-year project lifetime. The cash flows for the current and the proposed systems are compared. It is observed that the proposed system would have a higher initial cost compared with the reference case. The hospital energy consumption is shown in Figure 8. The hospital requires 362 MWh/day and has a peak of 29.12 MW.

Finally, the annual energy purchased from the grid is approximately 106 GWh and the annual energy sold to the grid is 116 MWh. Table 3 displays the energy interchange with the grid and total charges. The annual energy purchased from the grid and that sold to the grid are 106.20 GWh and 116.13 MWh, respectively.

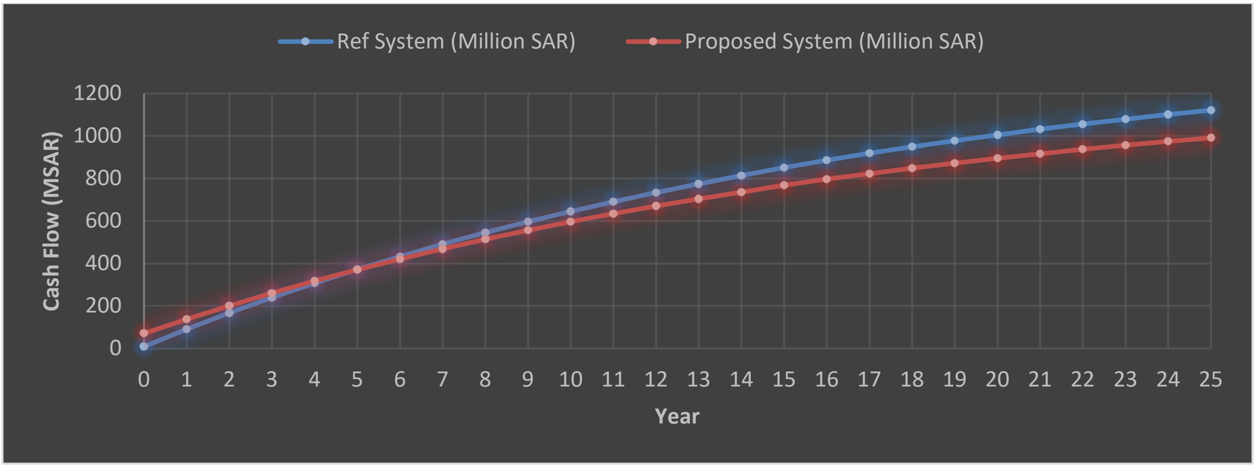

Figure 7 Cumulative Cash Flow over Project Lifetime

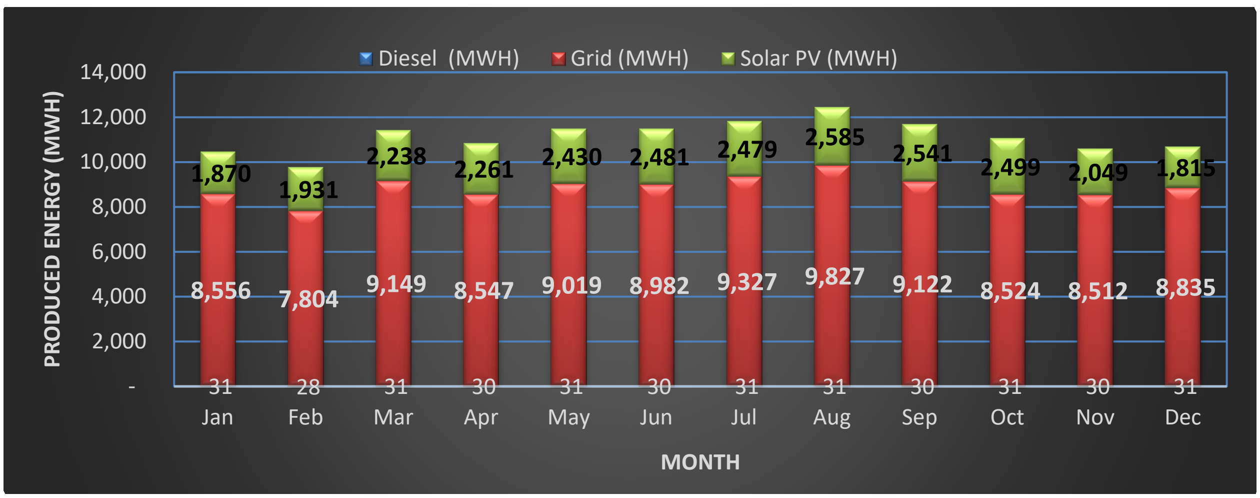

Figure 8. Monthly Grid, Solar PV and diesel Energy

Table 3 Energy Production, exchange, and charges.

Month	Solar PV Energy (GWh)	Energy Purchased (MWh)	Energy Sold (MWh)	Net Energy Purchased (MWh)	Energy Charge (MSAR)	Total Charges (MSAR)
Jan	1.870	8,556	8,524	8.524	5.460	5.465
Feb	1.931	7,804	7,796	7.796	4.990	4.995
Mar	2.238	9,149	9,138	9.138	5.850	5.855
Apr	2.261	8,547	8,536	8.536	5.460	5.465
May	2.430	9,019	9,008	9.008	5.770	5.775
Jun	2.481	8,982	8,977	8.977	5.750	5.755
Jul	2.479	9,327	9,321	9.321	5.970	5.975
Aug	2.585	9,827	9,823	9.823	6.290	6.295
Sep	2.541	9,122	9,118	9.118	5.840	5.845
Oct	2.499	8,524	8,511	8.511	5.450	5.455
Nov	2.049	8,512	8,508	8.508	5.450	5.455
Dec	1.815	8,835	8,827	8.827	5.650	5.655
Annual	27.18	106,205	106,089	106.089	67.930	67.989

Conclusion and Future Work

In this study, the optimal hybrid hospital power supply mix is obtained. It will achieve a cost of energy of 0.57 SAR/kWh and the payback is 4.14 years. Furthermore, the PV energy will reach

27.18 GWh with more than a 20% PV penetration level. Such a high penetration level is achieved in other parts of the kingdom due to the significant solar resources. On the other hand, the emission savings of CO_2 for the case without PV energy will reach 83,602 tons/yr. However, for the case that includes PV energy, it will reach 67,000 tons/yr.

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