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Impacts Of Replacing Conventional Generating Units with PV Sources in Power Plants

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Abstract

It has become economically feasible in the so-called energy mix to add a share of renewable energy known as photovoltaic (PV) as a percentage of the total power plant capabilities to work with conventional fossil fuel-powered generating units. The purpose of renewable energy sharing is to support and strengthen the power plant's reserve so that it can respond efficiently and ably to the growth of present and future loads with reduced operational costs. The action necessary to achieve this target is in the appropriate location for these types of power plants, considering climatic and environmental impacts such as temperature, altitude, and average solar radiation. Therefore, this study selected the ideal location for the power plant to be in one of the prosperous cities in the eastern region of the Kingdom. In this research, the process of comparing the addition of photovoltaic to cope with maximum loads was carried out in several cases where photovoltaic power was added from the time of sunrise to sunset with conventional generation to see the effect of renewable energy before and after replacement. To accomplish this task, this research project adopted the use of one of the most popular and pronounced economic and technical simulation programs known as "System Advisor Model, SAM". SAM will assess the reliability of performance and rationalization in operation cost. The outcome will offer a sound decision-making that takes those technical, economic and performance aspects between renewable energy sources and power generating units. In this thesis, three different cases of the penetration of PV interconnected and disconnected with the grid have been

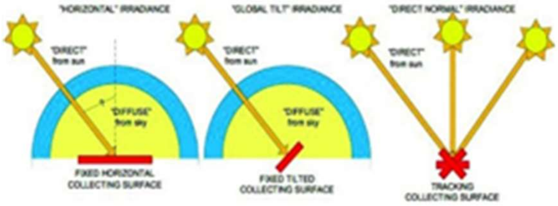
covered; Case 1: use the PV from sunrise to sunset, it will first prioritize PV and then it will take remaining units from the grid. Case 2: deals with peak load only, it will follow BAU at non-peak hours, at the time of peak, it will first prioritize PV and then it will take remaining units from the grid. Case 3: use only the grid without PV. The monthly bill for Cases 1, 2 and 3 (BAU) is 82,237(SR), 90,562(SR) and 98,437(SR) respectively. As case three is BAU, that is typical rate of the grid applied right now, our strategies of case 1 and case 2 cuts off the bill to 19.6% and 8.69%.

*** Introduction**

Renewable energy is one of the most important projects in the 2030 vision in the kingdom of Saudi Arabia, NEOM will build a 100% renewable energy system and establish a world-class customer experience. The energy can be classified into two types: renewable and non-renewable. Nonrenewable energy utilizes fuel or gas as source to deliver energy. it creates colossal sum of energy in brief period, but it does not final until the end of time and its extraction taken a toll is so costly in expansion to its fetched it annihilates the nature environment. Those drawbacks driven to consider another source of energy. Renewable energy utilizes sun and wind to deliver energy. It is accessible for each one and its clean and never run out, sun powered energy is the foremost successful source in Center East locale since it is one of the foremost locales having concentrated daylight within the world close to the clear climate it has. The solar energy is the radiation energy emitted from the sun and received to the earth, the sum of energy transmitted by the sun is 3.84x1026 J/S and the amount of energy receives from the sun is 9x1016 J/S.In later a long time, building energy utilization has been consistently expanding with the improvement of the economy and the advancement of living guidelines in Saudi Arabia. It possesses 30% of the entire energy utilization in Saudi Arabia, 50–60% of which is devoured by air conditioning in buildings in sizzling summer. The Gulf Cooperation Council (GCC) for the Arab countries see in their future in renewable energy markets at the chances for renewable energy sending in their economies and offers proposals for more noteworthy integration of renewables into the territorial vitality blend. This investigation from the International Renewable Energy Agency (IRENA) highlights the finest homes in policymaking, extend improvement and financing that have started clearing the way for more economical energy frameworks.

Renewable energy sources, such as sun, wind, and hydrogen, among others, employ neutral to generate energy. The best source of energy is solar in the Middle East area since it is one of the locations with the most concentrated sunshine in the world; in addition to the clear weather, it has. Global Horizontal Irradiance (GHI) is the quantity of shortwave radiation received by the earth's surface horizontal to the ground and is the total of Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DHI). The DHI is the amount of radiation received per unit area by a surface (free from any shade or shadow) that does not travel directly from the sun but is instead evenly distributed from all directions due to atmospheric molecules and particles. The GHI is the total amount of shortwave radiation that a surface horizontal to the ground receives from above. This value is of particular interest to photovoltaic installations and includes both DNI and DHI.

Global Horizontal (GHI) = Direct Normal (DNI) X cos(θ) + Diffuse Horizontal (DHI)



Solar energy is primarily created by two technologies: PV and CSP. Solar energy is immediately transformed into electricity in a PV system via the photoelectric effect. PV is one of the most popular renewable energy sources, with costs falling by 80% globally. Certain aspects, including the placement of the PV system and how to reduce the system's cost, must be addressed while choosing a site for PV system installations.

The globe today consumes a total of 18 TW (18 terawatts) of energy annually, which comes from all fossil fuels combined (oil, gas, and coal), as well as nuclear and hydro (hydroelectric) power, and a pitiful portion of the rest from renewable sources. Table 1 provides a breakdown of these varied contributions. Almost two-fifths of all energy is produced by crude oil, with coal and natural gas contributing roughly a quarter of that amount. Nuclear and hydropower each make up about 6% of the total, while renewable energy sources including wind, wave, geothermal, wood, and sun make up less than 1%

Fuel Type	Average power (TW)	Energy/Year (EJ)
Oil	5.6	180
Gas	3.5	110
Coal	3.8	120
Hydroelectric	0.9	30
Nuclear	0.9	30
Geothermal, wind, solar, wood	0.13	4

Table 1: Fuel type and average power

Solar energy is an abundant energy that can be obtained from the sun. The process of turning sunlight into electricity is known as solar power. It require a lot of electricity because it is essential to daily living. Since sunlight is both free and clean, solar power may be produced from it. In essence, a solar power plant is a system that provides electricity to large areas. The solar power tower system uses numerous sun tracking mirrors to guide sunlight toward a central receiver. In the solar thermal power system, the sun's energy raises the temperature of the thermal oil flowing through the receivers to 400 degrees Celsius, enabling the production of steam by the downstream heat exchanger.

The turbine that powers the generator is then pressured by the stream. As a result, the heat that the receiver collects is converted into electricity and used for a variety of tasks and objectives. Solar-powered facilities, which have been operating for a while, aid in supplying electricity. They serve as an entirely clean and environmentally favorable source of electricity. Solar thermal plants were the type of conventional solar power plants utilized in the past. However, because they are comprised of commonly available materials, solar power plants may be built extremely easily in a brief period. These solar power facilities need to move quickly since they are so large. Deserts and other desolate, uninhabited places would therefore make the ideal location for their establishment. In addition to solar power plants that use tracking mirrors, photovoltaic cells also aid in directly converting sunlight into electricity. These cells are composed of crystalline silicon semiconductors, which are both affordable and efficient. Despite the high installation costs, solar power facilities are being erected across the board in developing nations.

Solar energy or sun energy can be used in two diverse ways to generate electricity. First, photovoltaic electricity can be used to generate it, and then solar thermal electricity. To generate electricity, photovoltaic cells are used as part of the process. Solar cells are what the photovoltaic cells are made of. On the other hand, solar thermal power uses a solar collector that contains a mirror for reflecting sunlight into the receiver, which heats the liquid and causes it to produce steam, which is then utilized to generate electricity.

*** Methodology**

A large-scale solar 500 kW PV power plant design is the focus of this title. To complete a project of this nature, a methodology of calculations is conducted. Consequently, the various boundaries got are contrasted and boundaries acquired in writing and with the parameters got through specific PV software System Advisor Model (SAM). The design and simulation of a large-scale PV solar power plant is the driving force behind this venture. We will involve utility inverters for this project because the benefits of utility inverters are dependability and swiftness as compared to other inverters. The enlarged mismatch losses and MPPT shortage for each string of the array associated are, however, the principal downsides of this innovation.

1- Design the PV: It is necessary to select the PV modules and inverters that will be used throughout the computation process before commencing the estimations of the PV plant plan. Furthermore, because these sections' specialized details will be used during estimations, it is critical to obtain them.

The following are the modules and inverters that were chosen for the PV plant configuration: -

Trina Solar is a Chinese solar panel manufacturer with operations in the United States and Europe. With a total of 3.66 GW of installed capacity in 2014, this company became the largest PV module supplier. TALLMAX modules from Trina Solar allow commercial and utility-scale solar projects to save money on their systems. Trina Solar oversees the quality of our PV systems across the whole supply chain as a vertically integrated firm, reducing risk and increasing ROI. In Fig.1 and Fig. 2 the Module Characteristics and Physical Characteristics for Trina solar as it can see the nominal efficiency is 19.71%, maximum power for one panel is 400.314W and the martial is Mono-crystalline.

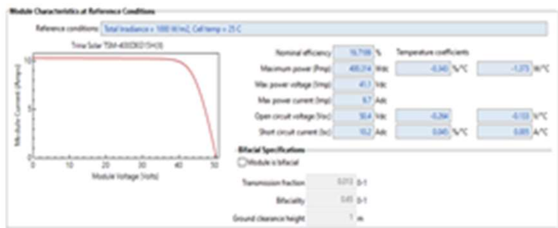


Figure 1: Module Characteristics

Figure 2: Physical Characteristics

SMA is a German firm that manufactures photovoltaic solar inverters ranging in size from 500 kW to several megawatts for self-consumption of solar energy as well as feeding the utility grid.

SMA has been developing and marketing high-quality PV inverters and unique technology for intelligent energy management for 40 years as a system technology specialist.

It is technology and service solutions for all photovoltaic applications let consumers meet their energy needs more efficiently and independently.

In Fig. 3 the Inverter Characteristics for SMA Inverter as we can see the Maximum Ac power is 514 kW, it is higher than our design 500 kW.

Figure 3: Inverter Characteristics

The tilt angle photovoltaic (PV) modules are the main consideration influencing how much solar radiation falls on the board surface. The ideal tilt angle relies upon the place of the sun, scope, and neighborhood topographical attributes. For simulation purposes, horizontal solar radiation information for the review of urban communities was gotten from NASA. MATLAB programming was utilized to upgrade tilt angle by boosting solar radiation. An ideal tilt angle of 23° is best for Saudi Arabia and for our site.

The optimum azimuth angle for installations in northern hemisphere is 180 (facing south).

*** Results and Discussion**

The overall number of PV panels required in the system depends on the module technology chosen for the PV plant; in our example, the selected PV module power rating is 400.314 W, and the power plant design capacity is 500 kW.

formula:

$$\text{Total Number of PV Panels} = \frac{\text{Total Power Plant Design Capacity}}{\text{PV Module Power Rating}} \quad (4.1)$$

$$= \frac{500000}{400.314}$$

So, we need 1249 solar panels for the 500 kW power plant.

It is especially important in a PV system to make an optimum series-parallel combination of panels because wrong combinations can affect the efficiency of the inverter and overall system. For making the best combination, we will check the module power current, voltage, and inverter MPPT DC voltages and DC current.

These are the optimum number of modules, which we can put in one string or connect them in series. But for our design we selected 18 modules in series or in one string.

The maximum number of modules that we can connect in parallel are 103 and in our design, it connected 70 modules in parallel.

Net metering was shown to cut the annual energy expense by more than 50% at a capital cost of 4.425 SR per watt.

*** Results**

Figure 15 shows complete picture of the total demand, the priority to fulfill the needs of this community is solar PV generation, as it is cheap and environment friendly. PV generation fulfills the energy needs of community at priority basis and then units from the Utility are used. Figure 15 depicts total units generated from PV and remaining brought from the main grid. This process lowers down the peak at peak hours when sun is out.

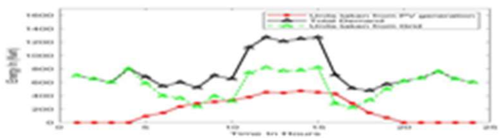


Figure 15: Case 1 (Generation / Demand)

Figure 16 demonstrates the cut down in per hour pricing on per day basis. Integration of PV with the conventional grid lowers down the cost of unit specially at peak hours. A per hour chart of the pricing tells a clear picture of how PV integration can lower down the per hour electricity rate of a community.

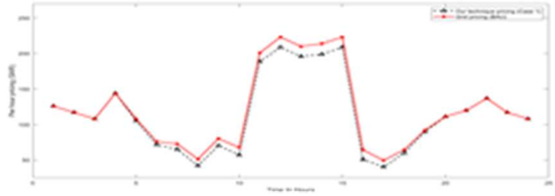


Figure 16: Case 1 Pricing

Case 2 deals with peak load only, it will follow BAU at non-peak hours, at the time of peak, it will first prioritize PV and then it will take remaining units from the grid. In this way, the peak is normalized. In the remaining hours, PV can be used to charge batteries, EVs can be sold to any other grid that can be considered in our future work as shown in Figure 17 from 11am to 3pm, PV generation is being used as priority and then remaining deficit units are taken from the grid generation.

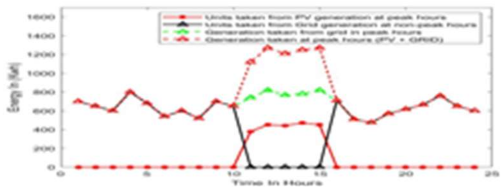


Figure 17: Case 2 Generation / Demand

In figure 18, non-peak hours follow the same price schedule as BAU. But at time 11am – 3pm a lower price signal is observed; it is because at that time PV unit price is considered which is lower that the peak price as mentioned in the tables above. The time when PV is not used, it can be sold back to the grid, or it can be used to charge EVs or batteries in such a way that generated units can be consumed in a better way.

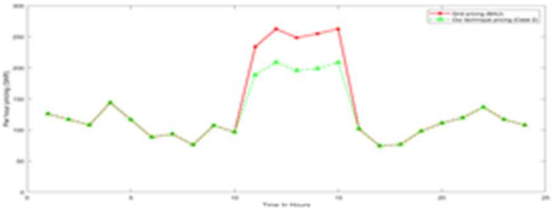


Figure 1: Case 2 Pricing

Figure 19 demonstrates a per hour comparison between case 1, case 2 and BAU prices. It is easily noticeable change in price. According to the situations that can arise due to peak and non-peak signals

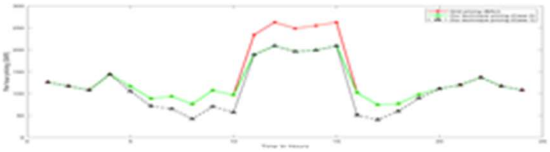


Figure 2: Comparison of per hour pricing between cases

Figure 20 shows the monthly break down in the bill of the community, our cases cut down the monthly bill when PV is used efficiently at peak hours period. The monthly bill for Cases 1, 2 and 3 (BAU) is 82,237(SR), 90,562(SR) and 98,437(SR) respectively. As case three is BAU, that is typical rate of the grid applied right now, our strategies of case 1 and case 2 cuts off the bill to 19.6% and 8.69%.

Figure 20: Comparison of monthly pricing between cases

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