SSURJET

Sir Syed University Research Journal of Engineering & Technology
2022, Vol. 12, No. 1,
https://doi.org/10.33317/ssurj.313

Technical and Economical Evaluation of Solar PV System for Domestic Load in Pakistan: An Overlook Contributor to High Tariff and Load Shedding

Shoaib Ahmed Shaikh[1], Abdul Majeed Shaikh[1], Muhammad Fawad Shaikh[1], Shakil Ahmed Jiskani[1], and Qasir Ali Memon[1]

[1]*Department of Electrical Engineering, Sukkur IBA University, Sukkur, Sindh, Pakistan*

Correspondence Author: Shoaib Ahmed Shaikh (shoaibahmed@iba-suk.edu.pk)

Received April 20, 2021; Revised February 03, 2022; Accepted February 09, 2022

Abstract

Despite the addition of generation sources to the installed capacity, Pakistan is facing frequent load-shedding, electricity interception, and a high tariff rate. Focusing on the said issues, an investigation has been completed of all the Distribution Companies (DISCOs) along with statistics like yearly losses, recovery, and tariff are reviewed to analyze the power network. It is a clear scenario that there is still a gap between supply and demand, and the generation major part is from fossil fuels which result in the high tariff due to unvarying fuel prices and environmental issues. This in fact has become uneconomical for the domestic users to utilize electricity from the power companies. Apart from this, Pakistan is blessed with a high potential for renewable energy resources, which is a good indication from an economic and environmental point of view but unfortunately, its usage is less. Keeping in view all statistics and key issues, this article focusses on the economic and technical evaluation on different cases like load running on Water and Power Development Authority (WAPDA), load on Solar PV system with backup, load on Solar PV system without backup, and Utility with a generator backup. Various economic techniques are used as Net Present Value (NPV), Payback Period (PBP), and Internal Rate of Return (IRR) to analyze and select the cost-effective solution. From the analysis, utilization of load from the Utility company and PV systems were compared. The PV system is the most economical and reliable system when compared with other cases.

Index Terms: *Generation, T and D Losses, High Tariff, Load Shedding, Pay Back Period.*

I. INTRODUCTION

Presently, the shortfall of electricity in Pakistan has left a lot of influence on its economy. According to studies, the total power generated from all types of sources is about 24838 MW, while the shortage of power is 4500 MW. This enhances the load shedding in rural as well as urban areas. Load shedding time in rural areas is up to 20 hours whereas 8 to 10 hours is observed in urban areas. The electricity demand is increased due to the rapid growth of the population [1] and [2]. Almost, 52 million peoples are unable to get electricity in remote areas of the country which is about 27.5% of the population [3].

With every passing year, electric power demands have increased but generation does not show any such proportional increase since the last two decades. Many power plants are operated behind the design capacity because of some reasons like shortage of gas and oil reservoirs, recovery and return from electric utilities, and procrastination in the upgrading and the replacement. It was also suggested to do the regular maintenance of power plant machinery after a required period but does not happen. This leads to the ultimate deterioration of the system, resulting in the overall inefficiency of the power plants [4] and [5]. The more utilization of fossil fuels has left an adverse impact on the environment. Though, the country is producing more power through conventional sources. These conventional sources utilize fossil fuels which have variable prices resulting in high tariffs. This is quite unbearable for both economic and environmental conditions [6] and climate change is also one of the critical issues due to the utilization of fossil fuels [7].

Renewable energy resources are the best alternative solution to reduce the greenhouse effect and decrease the import of fossil fuels to boost the economy. This also reduces the transmission and distribution cost of electricity in remote areas. Integration of solar technology in remote areas also produces employment opportunities [8]. Pakistan is bestowed with natural renewable sources and solar energy is one of them. The country is among the richest countries in the world that receive much amount of solar irradiance. Studies entail, Pakistan receives 5.3 Kwh/m^2 solar irradiance per day. Thus, net power production via solar energy is 2500 MW, which is about 10% and this will increase up to 6500 MW by 2030. The usage of renewable energy is increased and this will boom

the economy of the country [9] and [10]. Many Researchers also proposed to utilize cost-effective and efficient lights [11-13]. This will decline energy consumption and save energy expenses. In this way, saved energy can be utilized for commercial purposes to meet energy shortfall. Solar energy has become a contributing factor to the world's energy source with a contribution of 5.95 GW of photovoltaic energy provided in 2008, which will attain 11% by 2050 [14]. One of the biggest issues in Pakistan is the continuous supply of energy which is also termed energy security. Wind energy is also another option, but PV is dominant over the wind. This is due to the fact that solar irradiance is available for more time as compared to the wind [15].

In this paper, the most suitable scheme from an economic and environmental point of view has been discussed. Section II contains a background study including the power generation profile, transmission and distribution losses, recovery, and circular debt. Section III highlights the key problems. Section IV represents the total potential of solar in Pakistan. Section V contains the cost-competitive evaluation of the PV system comprised of several indicators like energy consumption, Net Present Value (NPV), Internal Rate of Return (IRR), and Simple Payback Period (SPBP), which are essential to investigate. Section VI explains the results and discussion on the solar system with and without backup, utility connection and generator backup, and utility connection and solar backup. Meanwhile, the conclusion is discussed in Section VII.

II. BACKGROUND STUDY

Energy keeps an important role in developing contemporary economies. It is a fundamental part of the economic order of Pakistan due to the strong bonding between energy demand and economic development share [5] and [16]. The country is unsuccessful if there is a lack of proper utilization of energy because human life is dependent on it, due to its utilization in domestic, education, commercial, industries, hospitals, agriculture, municipal, and irrigations. Pakistan is in a developing phase; however, the population is increasing with a high ratio.

A. Power Generation Profile of Pakistan

The installed capacity from different sources in different provinces of Pakistan is depicted in Figure 1 [17]. It is shown that there is a high share of power generation through thermal, then hydel, nuclear, wind, solar, and bagasse. It is important to note that there is a very low share of renewable energy sources. Nevertheless, province-wise, high-power generation contributes to Punjab, then Sindh, KPK, Baluchistan, and AJK provinces.

With the growing era of technology, Pakistan is traveling toward environmental issues in the energy sector. Since fossil fuels are not eco-friendly, though they emit a high amount of carbon and are the main reason for global warming, even the waste of these things is totally hazardous to our environment and the health of living beings. Fossil fuel which includes coal, natural gas, and oil are rock-like resources that are burned to generate power. They are also used in our daily life chores, like transportation, cooking, and so on. They are at top of global warming sources and world pollution. There is a clear hierarchy amongst fossil fuels in the environmental destruction they wreak. Knowing all these impacts leads us for evaluating the true cost of fossil fuel and knowing the future choice of electricity production source. They are not proven to become a green source of electricity. As a result, it can be said that fossil fuels are unsafe, and the accident happens [13] and [2].

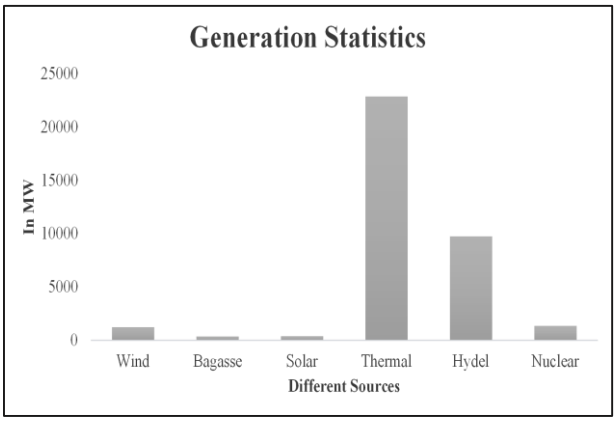

Figure 1: Generation Sources in Pakistan [17]

B. Transmission and Distribution (T&D) Losses

Power losses are always tended to when power is delivered from power sources to consumer points. Such losses are due to Joule's effect in the distribution network which can be higher as 13% of the energy generated. These non-zero losses have generated financial problems and distribution utility performance issues which have decreased the overall efficiency. So, methods or techniques used for loss reduction are important to be implemented for achieving distribution companies' targets. Two types of losses that occur in transmission and distribution networks are technical and non-technical losses. Technical losses are reliant on the material and its properties, and its resistance due to electric current which flows is in the form of heat dissipation. Non-technical losses are due to covert connections, deficiencies in the energy measurement processes and diversity of readings, pseudo in meters, and the bulk of these losses are triggered by electricity theft, poor maintenance, bill calculation, and accounting mistakes [18] and [19]. Causes that may result in the increased rate of technical and non-technical losses include low standard of service to consumers, high cost due to unnecessary expenditures, and sales reduction resulting in cash problems with all assuring implications.

It is important to remember that goals have been taken into account on an extensive scale, while the goal rates during the first nine months of 2017-18 vary from the subsequent three months. Over the last several years through ongoing efforts, K-Electric has become successful by taking steps to reduce the line losses and by improving the recovery ratio in several areas of Karachi showing the losses are decreased from 25.3% to 20.4% in four years. The utility remains focused on further improving the situation through unceasing process enhancements and numerous trial projects are under exploration [2]. Figure 2 represents the overall statistics of T and D losses from FY-15 to FY-19.

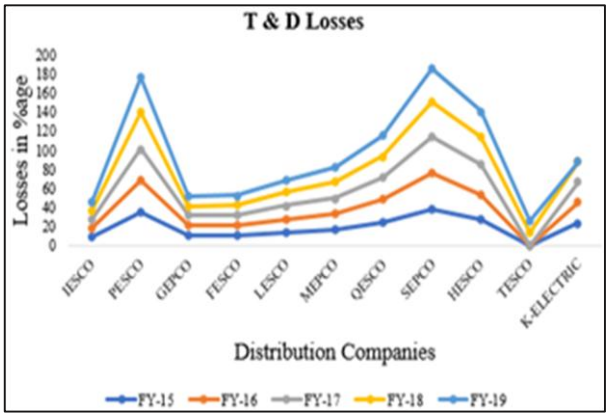

Figure 2: T and D Losses

C. Recovery

A contrast of recovered ratios of all supply firms throughout the last two years is specified in Figure 3. It is indicated that PESCO reported a 0.69% decrease in its recovery position as according to the performance of the subsequent year, while TESCO's recovery ratio decreased by 16.29 % as per the study for 2016-17. In addition, the IESCO, LESCO, and MEPCO improvement figures have worsened over the past year. Likewise, in respective recovery ratios, HESCO, SEPCO, and QESCO often see dramatic declines. Correspondingly, in respective recovery ratios, HESCO, SEPCO, and QESCO have observed a significant drop. GEPCO and FESCO have really shown an insignificant increase; yet, the cumulative recovery percentage has revealed a decrease of a further 4% because of the adverse results of all other distribution companies consistently. K-Electric recovery ratio was increased during FY-18 rather than FY-17. This is repeated that greater T and D deficits and poor recovery rates have essentially deteriorated revenue below reasonable standards, and despite regulatory directives to DISCOs and recommendations to the governing council, no significant effort or change has been noted [20] and [21].

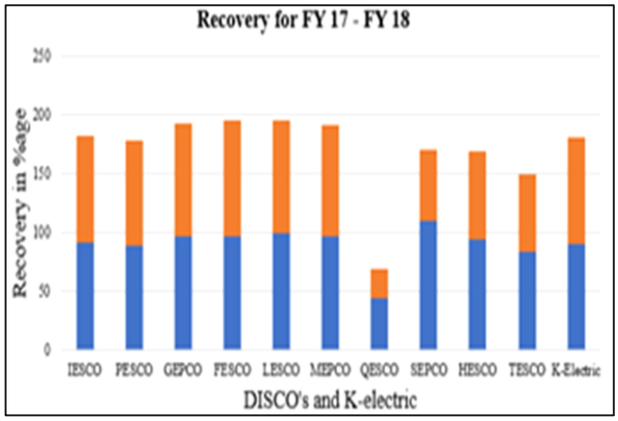

Figure 3: Recovery of all Distribution Companies (FY 17- FY 18)

The recovery position (%) of each DISCO against the billed amount during FY 2020-21 and its comparison with FY 2019-20 are shown in Figure 4.

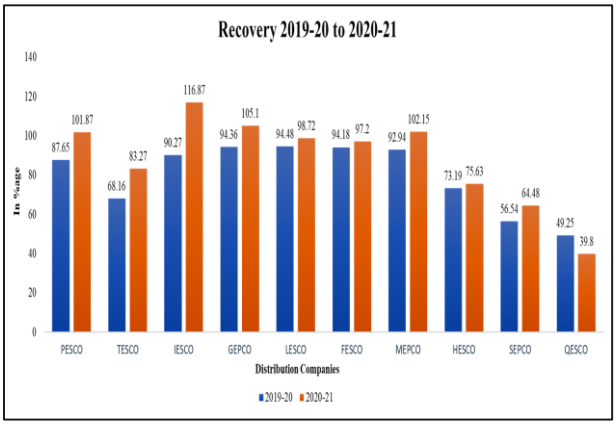

Figure 4: Recovery of all Distribution Companies (2019-20 TO 2020-21)

DISCOs have been given a target of 100% recovery against the billed amount. However, against the target of 100%, the combined recovery of all DISCOs during FY 2020-21 remained 97.30% i.e., short by 2.70%. The recovery of all DISCOs except QESCO showed improvement during FY 2020-21 over the last year. The short recovery of billed amounts results in an increase in circular debt [22].

The major reasons for poor recovery in Pakistan are the high cost of electricity. Again, the high cost is due to the use of fossil fuels. As fuel price is varying due to import and export. Tariff reports of recent years inculcate these issues properly. It is noticed that from 2013-14 and onward there is a continuous increase in the tariff rate. This is because of many reasons like losses in transmission and distribution, less recovery, and theft. Almost, fuel is imported hence, fuel prices are gradually increasing so our tariff is also increasing continuously.

D. Circular Debt

Circular debt is a serious problem facing the electricity market. High T and D deficits in distribution companies are among the precipitators to the budget deficit. Refusal of distribution companies to demonstrate some change in their depreciation level chiefly the authority's approved goal culminated in an annual loss of nearly Rs. 46 billion relying on the rate that persisted and reported during the period under analysis, i.e., FY 2017-18. It is important to note that the estimated cumulative total of transmission and dispatch losses figure only for FY 2017-18 was 15.92%, while DISCOs conveyed real losses stayed about 18.32% for the identical duration. Less recovery ratio is one of the major concerns of distribution companies. The regulator deems the 100% retention rate when determining the customer's tariffs for DISCOs. Conversely, during the year 2017-18, the recorded improvement figure of distribution companies stuck at approximately 87%. The consequence of reduced returns, including the 100 percent framework provided by the Authorities, contributed to an annual deficit of about Rs. 147 billion [21].

III. KEY PROBLEMS

From the above explanation and data, we have come to illustrate the status of all the categories of the power system network. In the generation network, the high share is of thermal using fossil fuels (64-65%) and a very low share of renewable energy resources (5-6%). Fossil fuels cause

water pollution, land degradation, global warming pollution, emissions, and ocean acidification. Moreover, there is a major issue of import and increasing price of crude oil which has created economic and financial loss issues resulting in high tariff rate.

The distribution network reported major problems like high transmission and distribution losses (technical and non-technical), increasing tariff rate a poor recovery. Some distribution companies like K-Electric and others have shown good results by improving their network performance. Furthermore. Consumers keep a vital role in utilizing electrical appliances. Not all consumers are using efficient and cost-effective appliances.

It is evident from the above technical issues that Pakistan lacks behind in the utilization of sustainable energy resources. Although the country is blessed with a high potential for renewable energy resources. Other countries are highly involved in producing electricity from renewable sources. There are some leading countries for installed renewable energy as per 2019-year statistics.

The potential of solar is high enough to utilize for domestic consumers and others.

IV. SOLAR POTENTIAL IN PAKISTAN

Solar energy has become the most capable and advantageous renewable. It is not significantly susceptible to seasonal weather pattern changes and is reliable. Pakistan is having 2900 GW of immense solar energy capacity [23]. Each year Country collects approximately solar irradiance of 15.5x1014 kWh with most areas receiving about 8-10 sunlight hours/day [24].

Solar power can be produced on demand in both rural and urban areas. Solar thermal and solar photovoltaic (PV) are mainly two technologies that exploit solar energy for different applications. Solar thermal technologies use Sun's heat energy for different purposes while solar Photovoltaic technology makes it possible to transform sunlight directly into electricity by using semiconductor devices so-called solar photovoltaic modules [25].

Overall, 5-7 kWh/m^2/day solar global insolation [26] occurs in the country concluded more than 95% of its surface area, with a persistence factor of more than 85% meaning that daily sun energy of 18-25 MJ/m^2/day is available as a natural input energy resource for photovoltaic or solar thermal generation applications [27]. Keeping in view the available solar energy, Pakistan has 1900-2200 kWh/m^2 an annual global irradiance value which is among the finest countries across the world [28] and [29]. Apart from this, the demand for solar PV is rising like other technologies at a rate of 30% to 40% due to the reduced cost of solar modules. Solar photovoltaics has become the major contributor to the supply of energy to the world [30-33].

V. METHODS AND MATERIALS

Pakistan has good potential for renewable energy resources suffering from various issues like high tariff rates, electricity shortage, load shedding, and environmental issues. In this regard, the solution to overcome these issues is deliberately discussed. In order to take a cost-competitive evaluation of the PV system, there are several indicators that are essential to investigate. This detailed investigation is applied to the domestic load which is considered as 5 kW. The most common investigations are calculations of Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PBP). These calculations are for the supply from the utility, from solar without back-up, and solar with back-up. Apparently, this will help us to investigate economic feasibility.

A. Energy Consumption

Electric energy consumption is the form of energy consumption that uses electric energy. It is a product of Power (kW) and Time (Hours).

$$Energy\ Consumption = P * T\ (kWh) \quad (1)$$

B. Net Present Value (NPV)

The Net Present Value or NPV is basically used to figure out the profitability of the project. NPV is the difference of net cash inflow to net cash outflow over a period and a positive value from the calculation is always a feasible option [34].

$$Net\ Present\ Value = \sum_{n=1}^{n} \frac{X_n}{(1+i)^n} - X_0 \quad (2)$$

C. Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) is also used to calculate the profitability of the project, but the only difference is that it is the discount rate that makes the NPV all flows equal to zero [34].

$$0 = \sum_{n=1}^{n} \frac{X_n}{(1+IRR)^n} - X_0 \quad (3)$$

D. Simple Pay Back Period (SPBP)

For the Simple Payback Period (SPBP) it is necessary to find annual Statement of Cash Flows (SCF), which is equal to the cash inflow – cash outflow as shown in the equation below [34]:

$$SCF_y = Cash\ inflow_y - Cash\ outflow_y \quad (4)$$

Now for SPBP, it is the amount required to repay in a given amount of time.

$$Simple\ Payback\ Period = \frac{Initial\ Investment}{Annual\ Saving}(years) \quad (5)$$

VI. RESULTS ANALYSIS AND DISCUSSION

In this section, calculations are carried out with suitable options to evaluate the best suitable system. In the summer season number of units consumed are always more than in any other season. In Table 1, the annual bill of 5 kW load with the tariff rate of Rs. 18/unit is assessed. With the help of this data, the calculation of NPV, IRR, and PBP is shown in Table 2. Furthermore, the cost of the solar system for a year is also calculated. It is noted that the life cycle year of each device is more than one year. Hence, first, the cost of all required devices for 25 years has been calculated at the first stage, and then with that data calculations for NPV, IRR and PBP are also achieved. It is mandatory to remember that on-grid system storage solar system can provide one-third of power while grid will supply two-thirds of power without any storage system. In these

circumstances, calculations for NPV, IRR, and PBP are performed which has become more than that of standalone economically as well as environmentally. The last case is that of the generator, for this current price of a generator as well as fuel used in the generator is collected. So, based on these evaluations of all the parameters maintenance cost is also calculated.

A. Supply from WAPDA

In this case, supply from utility to the load is considered. So, the annual energy cost consumption of any house can be easily calculated, but Table 1 of the total load in a regular house is important to work on. Average unit consumption of different appliances with distinct quantity and their operating time during the summer and winter seasons is mentioned in Table 1.

In Table 1 total load and the average hours according to the utilization of different appliances in a single house along with the wattage rating are mentioned in detail. It is also distinguished that there are different hours of usage for different appliances in summer as well as winter, to get the exact consumption of load, unit consumption per day of each appliance is calculated accordingly. After this step, the monthly bill according to NEPRA's tariff rates has been calculated with respect to the consumption of various appliances. Calculations of monthly bills are depicted in Table 2.

Table 1: Average Unit Consumption of Different Appliances

Appliances	**Quantity**	**Watt/Piece**	**Total Load**	**Average Hours of Operation**		**Average Units Consumption (kWh)**					
				Summer	***Winter***	***Summer***	***Winter***	***summer***	***winter***	***Summer***	***Winter***
				Summer	***Winter***	***Per Day***	***Per Day***	***Per Month***	***Per Month***	***6 Months***	***6 Months***
Induction Motor	1	746	746	2	2	1.492	1.492	44.76	44.76	268.56	268.56
LED Bulb	10	13	130	10	10	1.3	1.3	39	39	234	234
Refrigerator	1	200	200	20	15	4	3	120	90	720	540
Fans	3	38	114	12	0	1.368	0	41.04	0	246.24	0
AC	1	2000	2000	10	0	20	0	600	0	3600	0
Iron	1	1000	1000	1.5	1.5	1.5	1.5	45	45	270	270
Wash: Machine	1	500	500	1.5	1.5	0.75	0.75	22.5	22.5	135	135
Laptop	3	20	60	8	8	0.48	0.48	14.4	14.4	86.4	86.4
Mobile Charger	3	5	15	2	2	0.03	0.03	0.9	0.9	5.4	5.4
Total Load			4765	67	40	30.92	8.552	927.6	256.56	5565.6	1539.36

Table 2: Average Monthly Bill for Summer and Winter Season

Average Monthly Bill for Summer		**Average Monthly Bill for Winter**	
Details	**PKR Amount (Rs.)**	**Details**	**PKR Amount (Rs.)**
30.92 kWh = 30.92 Units/Day 30.92*30 days = 927.6 Units/Month	-	8.552 kWh = 8.552 Units/Day 8.552*30 days = 256.56 Units /Month	-
0 ~ 100 = 100 * 18.80= 1880	1880	0 ~ 100 = 100 * 18.80 = 1880	1880
101 ~ 200 = 100 * 20.45 = 2045	2045	101 ~ 200 = 100 * 20.45 = 2045	2045
201~300 = 100 * 21.85= 2185	2185	201-300 = 56.56*21.85 = 1234.8	1235.8
301~700 = 400 *23.10 = 9240	9240	301~700 = 0 *19.81= 0	0
Above 700 = 227.6*24.75= 5633.1	5633.1	Above 700 = 0*20.75= 0	0
QTR TARRIF ADJ/DMC @1.65	0	QTR TARRIF ADJ/DMC @1.65	590
Electricity Duty @1.5 /kWh	45	Electricity Duty @1.5 /kWh	70
GST	177.57	GST	855
FC Surcharge @ Rs. 0.43/kWh	60.58	FC Surcharge @ Rs. 0.43/kWh	153.76
NJ Surcharge @Rs.0.10/kWh	14.9	NJ Surcharge @Rs.0.10/kWh	41.55
PTV Fees	35	PTV Fees	35
Total Bill per Month	21316.15	**Total Bill per Month**	6906.1

Table 2 shows the average monthly bill of both seasons. In Pakistan, extreme summer is observed, so the annual period in equal halves is divided, respectively. Calculations for the annual bill are specified in Table 3. It becomes evident from Table 3 that the total annual cost for energy consumption is Rs. 169333.56/-. These calculations will help to find out the PBP of the solar system and NPV and other values as well.

B. Supply from Solar System With and Without Backup

In this case, specifications and costs of the solar system are conferred with and without backup. Tall tubular batteries are being used as a backup in this study, these batteries will provide backup for 12 hours from sunset to sunrise. This type of system with backup is useful for homes as well as restaurants. The details of equipment with specifications, price, lifetime, and cost of the solar system with backup that is focused on in this research are briefed in Table 4. Furthermore, Table 4 entails the total initial investment and per year cost of PV solar system with backup and without a backup for 5 kW home system. PV system without battery backup can be useful for shops and places that are open from 9 AM-6 PM, as direct sunlight is present in this time periods so there is no need for battery backup, but to face the cloudy and cold weather one battery can be added which will sustain the load when direct sunlight is not available during the daylight. To use this type of system in shops it is important to change the loads and usage as well. Since the only difference in both types of PV systems are batteries. It is clear from Table 4, the amount difference between a system with backup and a system without backup is Rs.21000/- for one year. The system without backup will provide electricity only when direct sunlight is reaching the solar lights, batteries could be added according to the requirement of backup needed. The simple payback period of a system with backup is 12 years whereas that of a system without backup is 9.43 years.

Table 3: Annual Bill Calculation

Annual Bill Calculation	
Average Summer Bill *6	Rs.127896.9/-
Average Winter Bill *6	Rs.41436.66/-
Average Annual Bill	Rs.169333.56/-

Table 4: Investment in Solar with and without Backup

Equipment	**Rating**	**Quantity**	**Life Cycle Per Year**	**Cost Per Piece**	**Cumulative Cost**	**Per Year Cost**	**Maintenance Cost**
Solar Panels	360W	14	25	16500	231000	9240	2000
Batteries	12V,185Ah	4	10	21000	84000	21000	1000
Inverter	32kW	1	10	90000	90000	9000	2000
Miscellaneous Cost = Rs.10000/-							
Total Investment on Solar Installation for One Year With-Backup = Rs.44240/-							
Total Investment on Solar Installation for One Year Without-Backup = Rs.23240/-							

C. Supply from Utility and Generator Backup

In this case, a petrol generator is considered to provide electricity to a regular home having a load of around 5 kW. For this motive, the 'Homage' generator having a maximum load rating of 6 KVA which is enough for the load supposed, is used in this research. This generator has 25 liters' tank capacity with a digital meter, double muffler, and lead-acid battery. The fuel consumption of this generator is 3.1 liter/hour. Generators are not designed to run 24 hours continuously and their tanks cannot be filled while it is running, the heated engine can ignite the fuel and cause fire/explosion.

The load shedding time in urban areas of Pakistan is about 6 to 8 hours while it varies from area to area. So, the operating time of the generator is supposed to be 8 hours per day. The lifetime of this generator is expected to be about 30000 hours, this number may vary because it depends upon the usage time, load, and preventive and creative maintenance. The approximate time is about 10.27 years, let us round off and say the running life of the generator is 10 years. Running cost per year with different resource charges is explained in Table 5.

From Table 5 it can be seen that the price of this generator is Rs.85499/-, the maintenance cost per year is assumed Rs.5000/-, so the running cost of the generator is calculated. This generator consumes 3.1 liter/hour on full load approximately. Assuming that generator runs 8 hours a day for one year, the total hourly usage per year will be 2920 hours. The current price of petrol is Rs.105/- hence, the generator will consume 9,052 liters/year and it will cost Rs.9, 42,440/-.

Table 5: Running Cost of Generator

Item	**Unit Price**	**Per Year Cost**
Generator	85,499	8549.9
Petrol Charges	105	9,37,440
Maintenance	-	5000
Cost Per Year		9,42,440

D. Supply from Utility and Solar System

It is unlikely to run a house with only a connection from WAPDA due to load shedding and high tariff problems in Pakistan. This system is a realistic system to work with the load shedding problem in our country, solar system will be designed with backup to minimize electricity consumption during the daytime and provide backup during the load shedding period. This is the most preferred system utilized by people these days as it has two backup systems. It can be utilized in place of grid electricity during the daytime and as a solution to the load shedding problem as well. In this system, we will have these parameters like NPV, PBP, and IRR. Calculations of this study are carried out with reference to the yearly electricity bill calculation provided. The tariff rate increases every year so, an increment of 6% every year in the bill has been done in order to have realistic results. Calculations of NPV, IRR, and SPBP with an 11% discount rate are mentioned in Table 6.

Table 6: Calculated Values of NPV, IRR, and SPBP

Entity	PV System With-Backup	PV System With-Utility	PV System Without-Backup
NPV	60210.67	27257.17	8802
IRR	55%	50%	24%
SPBP	5.08 Months	5.37 Months	8.7 Months

The results from that table show that the supply from WAPDA and solar systems is a feasible solution for domestic consumers. Utilizing a solar system in the day and from the grid at night is preferred as cost-effective and reliable for average consumers.

VII. CONCLUSION

To avail electricity in urban and remote areas, the study of various factors is carried out such as transmission and distribution losses, recovery, circular debt, tariff details. It becomes evident that electricity generated from fossils will be quite expensive. As there are huge losses during transmission and distribution. Though, Distribution Companies (DISCOs) are also unable to get rid of the transmission and distribution losses, so solar energy from renewable sources is considered in this research. Furthermore, technical, and economic analysis is performed by calculating the regular load of the home taking different appliances into account during the summer and winter seasons. According to the tariff, bills are calculated for both the summer and winter seasons. For the summer and winter season it is Rs.127896.9/- and Rs.41436.66/-, respectively. However, the total annual cost for energy consumption is Rs.41801.28/-. First, the total initial investment of PV solar system with backup and without a backup for 5 kW home system is calculated. The amount of difference observed without backup is Rs.21000/-. The SPBP of the system with backup is 12 years whereas that of the system without backup is 9.43 years. Secondly, in the case of generator backup, the cost per year calculated for the 5 KW load is Rs.942440/-. Third, a PV system with WAPDA for a home that has a 5 kW load is assumed for calculations in this study. In the end, the distinct NPV in rupees, PBP in years, IRR in percentage, and Discounted Payback Period (DPP) in years is also analyzed for PV with-backup, PV without-back up and gird along with PV system. After analysis and results, it is concluded that gird along with PV system is more desirable to implement for reducing the economic expenses.

Acknowledgement

I would like to thanks almighty Allah first and then all the co-authors for their full support, hard work and dedication we have completed this research study successfully.

Authors Contributions

Shoaib Ahmed Shaikh contribution to this study was the concept, technical implementation and correspondence. The methodology/framework to conduct this research work was proposed by Abdul Majeed Shaikh. Muhammad Fawad Shaikh performed, data collection and helped in supervision. Shakil Ahmed Jiskani, and Qasir Ali Memon jointly performed the data compilation and validation, project administration, and paper writing.

Conflict of Interest

There is no conflict of interest among all the authors.

Data Availability Statement

The testing data is available in this paper.

Funding

This research received no external funding.

References

[1] Shirazi, S. A., & Kazmi, S. J. H. (2020). Analysis of population growth and urban development in Lahore-Pakistan using geospatial techniques: Suggesting some future options. *South Asian Studies*, *29*(1).

[2] Shaikh, S., Katyara, S., Majeed, A., Khand, Z. H., Staszewski, L., Shah, M., ... & Akhtar, F. (2020). Holistic and Scientific Perspectives of Energy Sector in Pakistan: Progression, Challenges, and Opportunities. *IEEE Access*, *8*, 227232-227246.

[3] Latif, A., & Ramzan, N. (2014). A review of renewable energy resources in Pakistan. *J. Glob. Innov. Agric. Soc. Sci*, *2*(3), 127-132.

[4] Mirza, U. K., Ahmad, N., Majeed, T., & Harijan, K. (2007). Wind energy development in Pakistan. *Renewable and Sustainable Energy Reviews*, *11*(9), 2179-2190.

[5] Khan, D. I. (2015). Impact of energy crisis on economic growth of Pakistan. *International Journal of African and Asian Studies*, 33-42.

[6] Bhan, V., Shaikh, S. A., Khand, Z. H., Ahmed, T., Khan, L. A., Chachar, F. A., & Shaikh, A. M. (2021). Performance Evaluation of Perturb and Observe Algorithm for MPPT with Buck–Boost Charge Controller in Photovoltaic Systems. *Journal of Control, Automation and Electrical Systems*, *32*(6), 1652-1662.

[7] Owusu, P. A., & Asumadu-Sarkodie, S. (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. *Cogent Engineering*, *3*(1), 1167990.

[8] Asumadu-Sarkodie, S., & Owusu, P. A. (2016). A review of Ghana's solar energy potential. *Aims Energy*, *4*(5), 675-696.

[9] Chermat, F., Khemliche, M., Badoud, A. E., & Latreche, S. (2018). Techno-Economic Feasibility Study of Investigation of Renewable Energy System for Rural Electrification in South Algeria. *Engineering, Technology & Applied Science Research*, *8*(5), 3421-3426.

[10] Al-Ammar, E. A., Malik, N. H., & Usman, M. (2011). Application of using hybrid renewable energy in Saudi Arabia. *Engineering, Technology & Applied Science Research*, *1*(4), 84-89.

[11] Shaikh, S., Soomro, N., Razaque, F., Soomro, S., Shaikh, N., & Abid, G. (2018, August). Analysis of Illumination Lamp's Performance by Retrofit at University Building. In *International Conference for Emerging Technologies in Computing* (pp. 137-152). Springer, Cham.

[12] Shaikh, S. A. (2018). Comparative Analysis of Different Commercial Lights. *Sukkur IBA Journal of Emerging Technologies*, *1*(1), 34-44.

[13] Belkadi, A., Mezghani, D., & Mami, A. (2019). Energy Design and Optimization of a Greenhouse. *Engineering, Technology & Applied Science Research*, *9*(3), 4235-4242.

[14] Østergaard, P. A., Duic, N., Noorollahi, Y., Mikulcic, H., & Kalogirou, S. (2020). Sustainable development using renewable energy technology. *Renewable Energy*, *146*, 2430-2437.

[15] Shah, S. B., Harijan, K., Tunio, M. M., Abro, R., Shaikh, P. H., Kumar, L., ... & Mubarak, N. M. (2018). Economic viability of photovoltaic power plant for Sukkur–Pakistan. *Eurasian Journal of Analytical Chemistry*, *13*(5), em46.

[16] Subrahmanyam, J. B. V., Alluvada, P., Bhanupriya, K., & Shashidhar, C. (2012). Renewable energy systems: Development and perspectives of a hybrid solar-wind system. *Engineering, Technology & Applied Science Research*, *2*(1), 177-181.

[17] Nepra . (2020, Apr. 11). *NEPRA Annual Report 2018-19*. Retrieved from; https://nepra.org.pk/publications/Annual Reports/Annual Report 2018-19.pdf

[18] Razaque, F., Soomro, N., Samo, J. A., Dharejo, H., & Shaikh, S. (2017). Analysis of Home Energy Consumption by K-Mean. *Annals of Emerging Technologies in Computing (AETiC), Print ISSN*, 2516-0281.

[19] Hussain, Z., Memon, S., Dhomeja, L., & Abbasi, S. (2017). Analysis of non-technical electrical power losses and their economic impact on Pakistan. *Sindh University Research Journal-SURJ (Science Series)*, *49*(2).

[20] Dos Santos, C. M. (2006, August). Determination of electric power losses in distribution systems. In *2006 IEEE/PES Transmission & Distribution Conference and Exposition: Latin America* (pp.. 1-5). IEEE

[21] Nepra. (2020, Apr. 10). *State of Industry Report 2018*. Retrieved from https://nepra.org.pk/publications/State of Industry Reports/State of Industry Report 2018.pdf

[22] Nepra. (2021). *State of Industry Report 2021*. Retrieved from; https://nepra.org.pk/publications/State%20of%20Industry%20Reports

[23] Harijan, K., Uqaili, M. A., & Mirza, U. K. (2015). Assessment of solar PV power generation potential in Pakistan. *Journal of Clean Energy Technologies*, *3*(1), 54-56.

[24] Farooqui, S. Z. (2014). Prospects of renewables penetration in the energy mix of Pakistan. *Renewable and Sustainable Energy Reviews*, *29*, 693-700.

[25] Memon, Q. A., Rahimoon, A. Q., Ali, K., Shaikh, M. F., & Shaikh, S. A. (2021). Determining Optimum Tilt Angle for 1 MW Photovoltaic System at Sukkur, Pakistan. *International Journal of Photoenergy*, *2021*.

[26] Mirza, U. K., Maroto-Valer, M. M., & Ahmad, N. (2003). Status and outlook of solar energy use in Pakistan. *Renewable and Sustainable Energy Reviews*, *7*(6), 501-514.

[27] Sheikh, M. A. (2009). Renewable energy resource potential in Pakistan. *Renewable and Sustainable Energy Reviews*, *13*(9), 2696-2702.

[28] Asif, M. (2009). Sustainable energy options for Pakistan. *Renewable and Sustainable Energy Reviews*, *13*(4), 903-909.

[29] Adnan, S., Hayat Khan, A., Haider, S., & Mahmood, R. (2012). Solar energy potential in Pakistan. *Journal of Renewable and Sustainable Energy*, *4*(3), 032701.

[30] Abdullah, M., & Naqvi, A. H. (2019). Techno-economic Study for Water Pumping by Solar Power Driven Three Phase Induction Motor. *Sir Syed University Research Journal of Engineering & Technology*, *9*(1).

[31] Faryal, S., Ali, A., & Memon, A. H. (2019). Lifespan and Decomposition Effects of 1st and 3 rd Generation Silicon Solar Cell with respect to Environment and Health. *Sir Syed University Research Journal of Engineering & Technology*, *9*(1).

[32] Uddin Ahmed, S., Memon, A. H., & Kamboh, A. A. (2019). Regional renewable energy resource potential in Pakistan. *Sir Syed University Research Journal of Engineering & Technology*, *9*(2).

[33] Javed, H., & Muqeet, H. A. (2021). Design, Model & Planning of Prosumer Microgrid for MNSUET Multan Campus. *Sir Syed University Research Journal of Engineering & Technology*, *11*(2), 1-7.

[34] Rodrigues, S., Torabikalaki, R., Faria, F., Cafôfo, N., Chen, X., Ivaki, A. R., ... & Morgado-Dias, F. J. S. E. (2016). Economic feasibility analysis of small scale PV systems in different countries. *Solar Energy*, *131*, 81-95.