Reduction of Utility Bill through Hybrid Solar System and Net Metering

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Abstract

In this research proposal we introduce with novel approach the net metering through solar hybrid system integrated with grid. As we know the demand of electricity increases as the use of modern electronic devices has increased manifold in household. The main purpose of this research is to develop knowledge about the residential generating station from solar photovoltaic cell near to consumer site. This study has been pursuit to assure if solar energy is cost beneficial over a 25 years period for residential, commercial and agricultural sector. The results show it will be also a great business and helpful to all the consumer to earn profit and earn back their capital through net metering.

In Pakistan, in 2015 the net metering incentive has introduced by National Electric Power Regulatory Authority (NEPRA), which allows wind and photovoltaic (PV) distributed generation systems from 1kWp up-to 1MWp to sell surplus units of electricity to the grid and net them off against the units which are consumed from the grid. This paper presents a detailed conduct economic analysis of prosumers of Sukkur Electric Power Company (SEPCO) Pakistan, having net metering systems of 7kW and 10kW solar distributed generation (DG). Detailed economic analysis has been simulated by using HOMER Pro®, a micro grid optimization software. Economic analysis gives result of the (NPC) net present cost, (LCOE) levelized cost of electricity, (IRR) internal rate of return, (ROI) return on investment and calculate payback period of the system. Results illustrate that as DG generation capacity is increased, the payback period and LCOE decrease.

Keywords — *Net metering; Distributed Generation; Photovoltaic; LCOE; NPC; IRR; ROI.*

I. INTRODUCTION

A. Renewable Energy around world.

Many countries are working out to develop different useful polices for production of electrical power due to lack of conventional sources and high level of air pollution Environmental effects. Solar energy has great potential to produce green energy. Fig. 1 shows Renewable capacity growth between 2019 and 2024 has been made by technology at renewable energy sector and the world is moving towards renewable energy sources. Between 2019 and 2024 renewable power capacity led by solar PV is set to expand by 50% [1].

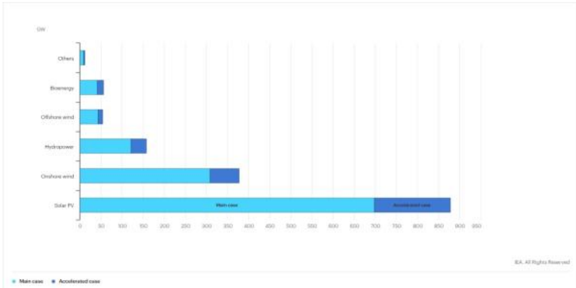

Figure 1: Renewable Capacity Growth

B. Solar Potential in Pakistan.

Pakistan is one of those countries having the maximum solar irradiance. Pakistan's solar irradiance map indicates that many regions in the Pakistan have high solar irradiance averaging 5 to 7 kWh/m2 per day [2]. The sun shines 7 to 8 hours in many areas of Pakistan with solar energy of 2300- 2400 hours/annum for more than 300 days [3]. Pakistan's average solar irradiance is 2400kWh/m2 [4].

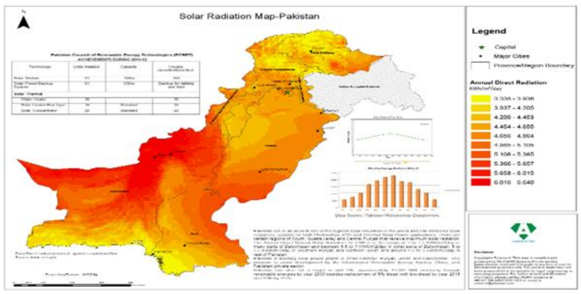

Figure 2: Solar Irradiance Map of Pakistan

C. Net Metering In Pakistan

The government of Pakistan is promoting the solar PV market, including loans for PV modules, rooftop PV setups and solar PV grid-connected utilization, to escalate the use of the renewable energy in the country. Introducing net-metering in, NEPRA issued its regulations for net-metering on 1st September 2015 allowing the distribution companies (DISCOs) in the country to purchase excess electricity units produced by the consumers through solar power (1

KWp up-to 1 MWp). Which can not only help to mitigate the energy shortage problem but also help in the reduction in electricity bills [5]. Net metering policy allows utility customers to produce electricity from PV systems. A bi-directional smart meter is used in net metering that can record the both directions flow of energy. The meter spins forward when customer is importing from grid (i.e. using more electrical power than DG generate) and spins backward when energy is being exported to the grid (i.e. using less electrical power than DG generates). At given month end, the customer pays for the net electricity [6].

Net metering policy has been implemented at all the distribution companies, but its installation has been finite to some of the DISCOs. On 26th January 2019 Sukkur Electric Power Company (SEPCO) has installed first net metering system at SIBA University Sukkur and license is issued by NEPRA on 8th October 2018 to SIBA formerly known as IBA Sukkur [7]. In these net metering systems, 98 percent of DG systems are solar PV based.

II. METHODOLOGY

In this research, the focus has been on the 'prosumers' of SEPCO. Consumers with generation facility are also called 'prosumers' because they can sell to and consume grid energy. In this research, residential consumers with 7kW and 10kW solar PV DG systems has been studied because the consumers with that capacity are most in SEPCO. Economic analysis is explained below.

A. Economic Analysis.

Extensive economic analysis includes these following costs.

a) Lifecycle cost (LCC):

Lifecycle cost is defined as system cost of the system installation, replacement, operation and maintenance for given time minus the salvage cost. It is represented by Eq. 1 below.

$$LCC = C_{int} + C_{rep} + C_{OM} - C_{salvage} \qquad (1)$$

Where C_{int} is the system installation cost, consisting of installation of PV, inverter, etc. C_{rep} is system equipment replacement cost. C_{OM} is system operation and maintenance cost which is considered as 1% of the system initial capital [8]. $C_{salvage}$ is the cost of a project during its end. The lifetime of PV panels is taken as 25 years where as inverter is taken as 15 years.

b) Payback Period:

The payback period is time require for the capital investment recovery from profit or saving. It is shown by Eq. 2 below [8].

$$T_{payback} = C_{int}/(C_{bill} - C_{net_{bill}} \qquad (2)$$

In the above equation, $T_{(payback)}$ is the period of payback in years, C_{int} is total initial cost, C_{bill} is electricity bill cost without net metering and $C_{netbill}$ is the electricity bill cost with net metering system.

c) Levelized Cost of Electricity (LCOE):

Levelized cost of electricity is defined as the amount of life cycle cost over energy generated in a year. LCOE is determined by Eq. 3 [8].

$$LCOE = \frac{LCC}{\sum_1^n E_{ann}} \qquad (3)$$

Where E_{ann} is the total electrical energy produced per year and n is the total number of years.

d) Net Present Cost (NPC):

The present amount of all the individual costs of the system spent over the lifetime, minus the present amount of all the revenue it earns in its life time is the net present cost (NPC) of system. In HOMER Pro®, NPC is determined by Eq. 4 [9].

$$NPC = \sum_{t-1}^{T} \frac{C_t}{(1+r)^t} - C_o \qquad (4)$$

Where C_t is net cash inflow during the period t, Co is the total initial investment cost, 'r' is the discount rate, and 't' is time period.

e) Internal Rate of Return (IRR):

Internal rate of return is a mathematical tool used to find out the profitability of potential investments in the capital budgeting [10]. Internal rate of return is found out from the equation as of NPC as below.

$$NPC = \sum_{t-1}^{T} C_t/(1+r)^t - C_o \qquad (5)$$

From the above Eq. 5, the value of 'r', which is the discount rate, will be the IRR of that project.

f) Return on Investment (ROI):

ROI is a performance indicator, used in evaluation of the efficiency of a given investment or to compare many different investments. The result can be expressed in terms of a percentage or a ratio. The return on investment is determined from the Eq. 6 [10].

$$ROI = \frac{G_i - C_i}{C_i} \qquad (6)$$

Where G_i is investment gain and C_i is investment cost .

B. Simulation Software.

HOMER (Hybrid Optimization of Multiple Electric Renewables), helps to evaluate design of both power systems off-grid and on-grid. It provides analysis of sensitivity and shows optimize cost system configuration. HOMER simulates energy systems and gives sensitivity analysis with optimize cost. It uses variable components like, energy resources, solar radiation, wind speed, temperature data cost variation which helps in evaluation of many possible cost optimize system configurations. Optimize system consists on project NPC (Net Present Cost). In Homer results can be displayed in graph and export the data table sheet to evaluate and analyse the economic and technical merits. In this paper all results of the simulated system design have been taken from HOMER Pro, a micro-grid software by HOMER Energy.

C. System Design Configuration.

In this research, extensive analysis of the residential ‘prosumers’ of SEPCO, having 7 KW and 10 KW solar PV net metering DG systems with facility have been performed. Load profiles of the prosumers are calculated from the electricity bill, and the average load has been fed in to HOMER Pro® for analysis.

a) Sukkur’s solar radiation and temperature:

Daily solar radiation and the temperature for the PV system of Sukkur city have been acquired through HOMER Pro® as shown in Fig. 3 and 4. Annual average solar radiation in Fig. 3 is 5.35 KWh/m²/day. The annual average temperature in fig 4 is 26.14 °C in Sukkur.

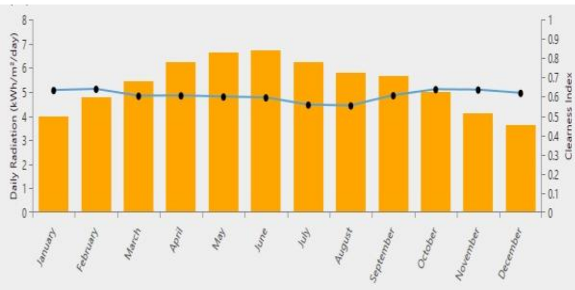

Figure 3: Daily Solar Radiation in Sukkur

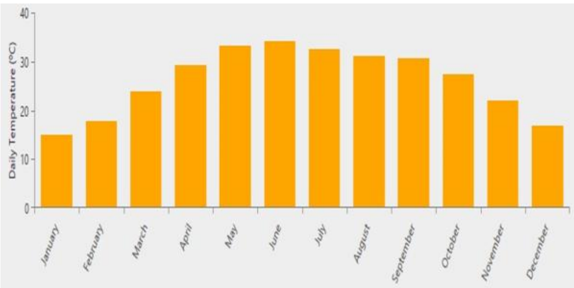

Figure 4: Daily Temperature in Sukkur

b) Tariff Rates:

In the electrical bill tariff rates play a vital role in the net metering billing system and the economic analysis of DG systems. Table I shows the peak load and off-peak load timings and cost of electricity (COE) for the residential consumers of SEPCO [11]

Table I: Input Parameters of all DG Systems

Season	Peak Load Hours (24 Hours)	Off Peak Load Hours (24 Hours)
April to October	18:30 to 22:30	00:00 to 18:30 & 22:30 to 24:00
November to March	18:00 to 22:00	00:00 to 18:00 & 22:00 to 24:00
Residential tariff		
COE (Rs/KWh)	20.70	14.38

c) System Design:

All the input parameters have been specified for the system economic analysis is in table 1 and table 2. Derating factor in Table II is a scaling factor of HOMER Pro which considers for output of PV modules to include the variations of output in the real-world conditions, as compared to the conditions in which was PV module rated [12].

Table II: Input Parameters of DG Systems

1	Project life time (years)		25	
2	Nominal discount rate (%)		6	
3	Fixed O&M cost (Cost/year)		1% of capital cost	
4	Expected Inflation rate of the project (%)		5	
	Components	**Efficiency (%)**	**Derating Factor (%)**	**Lifetime**
(I)	Inverter	95	N/A	15 years
(II)	Solar Panels	N/A	80	25 years

Table III: Different Cost for Different DG Systems

System	PV Cost (PKR)	Inverter Cost (PKR)	O&M Cost/ year (PKR)	Civil Cost (PKR)	Install Cost (PKR)
7 KW	385000	120000	5620	25000	28000
10 KW	550000	180000	8181	40000	40000

In Table III, the Grade-1 PV module cost has been considered as PKR 55/watt same as general market rates in Pakistan of 21 January 2020. The cost of mounting structure also includes in civil cost for PV structure. The amount charged by vendors for installing PV system is PKR 4/watt.

d) Design Scheme

The schematic designs in HOMER PRO simulator.

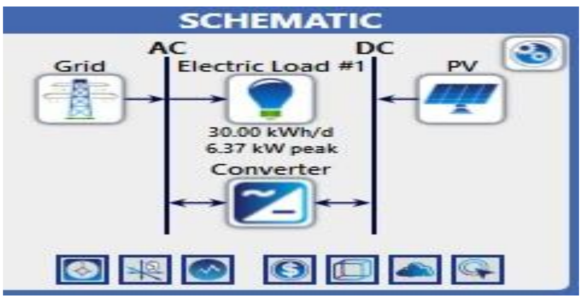

Figure 5: Schematic for 7 KW

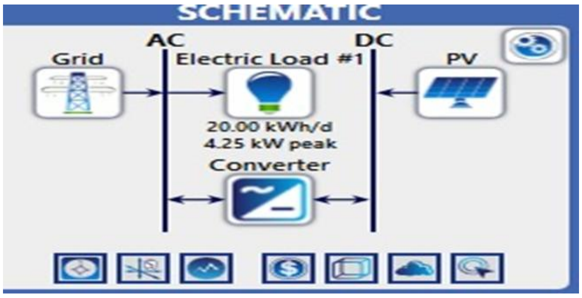

Figure 6: Schematic for 10 KW

A 7 KW DG system, 7 KW PV and 3-phase 7 KW GW inverter are connected to the grid as shown in Fig. 5. An average residential load of 20 KWh/d and 4.25 KW peak hour load is connected in this simulated system. Also, 10 KW DG system,10 kW PV and 3-phase 10 kW GW inverter are connected to the grid as shown in Fig. 6. A residential load of 30 KWh/d and 6.37 KW peak hour load is connected in this simulated system.

III.RESULTS AND ANALYSIS

A. 7 KW DG System.

Figure 7: Monthly average electric production by 7kW DG system

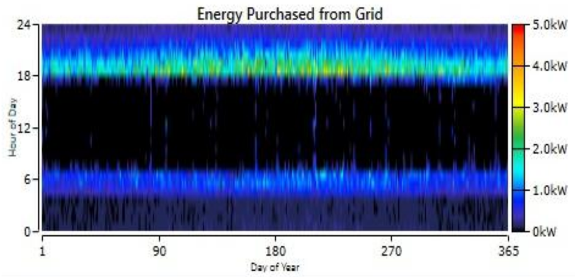

Figure 8: Energy Purchased from Grid

Fig. 7 shows monthly average electric production by 7 KW DG system. The PV production is 12004 KWh/yr. Grid purchases are 3874 kWh/yr.

Fig 8 show the energy purchased from the grid and the results show the highest amount of energy Purchased 396 KWh in the month of August and the peak demand was maximum in the month of July with 4 KWh.

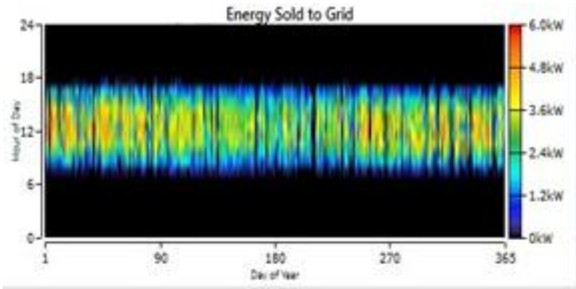

Figure 9: Energy Sold to Grid

Fig 9 show the energy sold from the grid and the results show the highest amount of energy sold 740 KWh in the month of march.

B. 10 KW DG System.

Figure 10: Monthly average electric production by 10kW DG system

Fig. 10 shows monthly average electric production by 10 KW DG system. The generic flat plate PV production is 17720 KWh/yr. Grid purchases are 5821 KWh/yr. In this case, energy purchases are maximum as because the consumed energy was less than the generation of 10 KW PV system is installed.

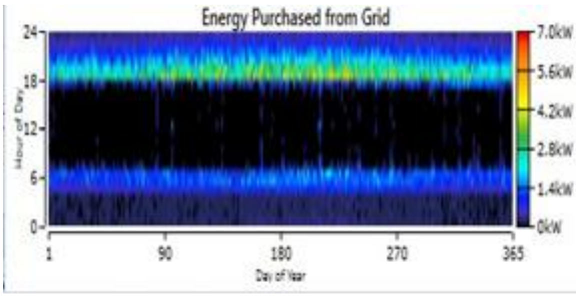

Figure 11: Energy Purchased from Grid

Fig 11 show the energy purchased from the grid and the results show the highest amount of energy Purchased 596 KWh in the month of August and the peak demand was maximum in the month of July with 6 KWh.

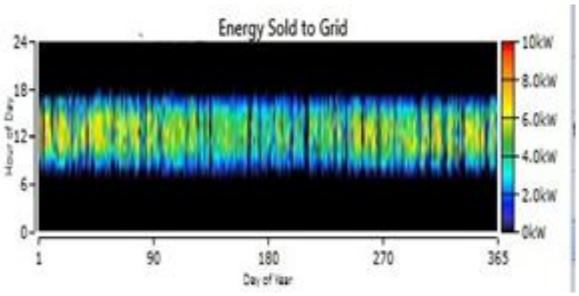

Figure 12: Energy Sold to Grid

Fig 12 show the energy sold from the grid and the results show the highest amount of energy sold 1086 KWh in the month of march.

C. Cost Summary

Table IV: Cost Summary

Metric	System	
	7kw	10 kw
Total NPC	Rs 0.86 M	Rs 1.07 M
Levelized COE	Rs 4.44	Rs 3.70
Internal rate of return (%)	37.60%	38.10%
Return on Investment (%)	33.60%	34.10%
Simple payback(year)	Rs 2.66	2.62
System without Net Metering		
Total NPC	Rs 2.32 M	Rs 3.93 M
Levelized COE	Rs 24.89	Rs 28.14

The results in Table IV shows that ROI, IRR increase as DG system capacity increase. The increase of ROI is a positive and proportion of return (benefit) is more. Therefore, investor benefit increases as increase in capacity. Higher rate of IRR points out that project is more feasible. The reduction of LCOE shows consumer will pay less amount of utility bill which also reduce the payback time. As the results in Table 4 reduction in the LCOE indicated, for 7 KW DG system net-metering consumer will have to pay Rs 4.44 per unit cost with, and Rs 24.89 per unit without net metering. Moreover, other benefits associated with net metering and PV DG systems like strengthening the distribution grid, increasing the stability of the grid and reducing the frequency of maintenance, troubleshooting the fault and enhance the power distribution grid, PV module system strengthens the distribution grid to overcome the voltage drop when the load is high because when the load is high the voltage drop causes breaker trip and sometime blackout occurs" [13].

IV. CONCLUSIONS AND FUTURE RECOMMENDATIONS

Net metering is a beneficial policy introduced by NEPRA in Pakistan for escalation of DG systems. Net metering can help to mitigate energy crisis of Pakistan and promote green energy. Moreover, economic analysis is evident that the net metering is an appealing policy which greatly reduce electricity prices for prosumer. Net metering also improves the grid and overcome the voltage drop problem like load-shedding and power outages etc. Moreover, explicit analysis of DG net metering systems can be a great help to earn profit for prosumer. To find the effect of different PV module and inverters in DG systems technical analysis can be performed.

NOMENCLATURE

DG: Distributed generation.
NEPRA: National electric power regulatory authority.
DISCOs: Distribution companies.
SEPCO: Sukkur Electric Power Company.
KWp: Kilowatt peak.
PV: Photovoltaic.
KWh: Kilowatt hour.
MWp: Megawatt peak.
NPC: Net present cost.
LCC: Life cycle cost.
LCOE: Levelized cost of electricity.
IRR: Internal rate of return.
ROI: Return on investment.
O&M: Operation and maintenance.
COE: Cost of electricity.
GW: Good We inverter.
PKR(Rs): Pakistani rupee.

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