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ORIGINAL PAPER

Techno-Economic Feasibility Analysis of 100 MW Solar Photovoltaic Power Plant in Pakistan

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Abstract

In this era of adaptation of renewable energy resources at huge level, Pakistan still depends upon the fossil fuels to generate electricity which are harmful for the environment and depleting day by day. This article presents feasibility analysis of 100 MW_p solar photovoltaic (PV) power plant in Pakistan. The purpose of this study is to present the techno-economic feasibility of the 100 MW_p grid connected solar (PV) power plant. The calculations have been done using mathematical model PV*SOL computer software algorithms and results have been presented. This paper briefly describes the process flow, timelines, and steps involved in initiating the project through an issuance of letter of interest (LOI) application up till the commissioning of the plant. A summary of financial feasibility to set a 100 MW_p solar PV project including revenue, operations & maintenance, interest payment on project loan, net profit and payback is presented. The economic analyses are performed for a period of 25 years and the results of simulation show that the proposed plant can supply 180,000 GWh/year (Gega watt hour per year) of electricity by reducing 90,225 tons/year of CO_2 emission. Provided that land is supplied by the government, payback period was calculated as 3.125 years. As this research is a complete techno-economic analysis of 100MWp solar power plant, it attracts sponsor, company or government itself for installing a new plant that may be a good business plan.

Keywords Energy mix · Feasibility · Inverter · Photovoltaic · Solar Power Plant

Introduction

Man has been trying to harness solar power for lightning, cooking, energy and military needs since antediluvian times. Ancient Greeks and Egyptians and later Muslim have been attempting to design sun machines to focus solar energy on enemy warships [1]. Energy drifts occurring on the earth are empowered by solar radiations to drive the life and energy cycles. Sun is 93 million miles away from the earth and generates energy by a giant thermonuclear fusion reaction. Temperatures of sun photosphere and core are in the range of 5500 °C to 20,000,000 °C. At sun core about 657 million tons of hydrogen isotopes are converted into 653 million-tons of helium during each second [2]. The residual mass of 5 million tons mass is converted to energy. Applying Einstein's equation

$$Power = {}^{energy/second} = (4*10^9)(3*10^8)^2 = 3.6*10^{26}\ 360\ YW \quad (1)$$

To imagine the energy converted to 360 YW power, consider a giant gasoline reservoir filled in about 3.5 million years at flow rate of 5 billion gallons per hour. If that huge quantity of gasoline reservoir is burnt in one second, the energy released would give above 360YW power that sun has continuously been releasing since last 4–5 billion years. The sun sends to the earth surface a billionth fraction of its total energy, 30% of which is reflected back to space or absorbed by the atmosphere. If harvested adequately, the radiant energy reaching earth's surface in 40 min can meet all global annual energy needs. Solar energy flux reaching earth's surface is about 220 W/m^2.

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In Pakistan utilities are responsible for supplying electricity throughout the country, but due to shortage of supply and load shedding, it is unable to provide continuous electricity to the consumers. There are number of solutions available to overcome the problem of load shedding. One of the potential solutions is that homes, banks, educational institutions, industrial sector and independent units may be able to produce their onsite electricity. Those who are producing electricity are dependent on conventional energy resources like petrol, gas and diesel. These conventional sources are expensive, harmful for nature, and also the resources are being depleted from earth's crust. When it is desired to opt for the self-generating solution; moving towards renewable energy sources for electricity generation like solar, wind, water, tidal is promising solution. Renewable sources have an intermittent supply of energy. Solar is easily accessible and economical available source of electricity generation. The solar has number of benefits like environment friendly, lower maintenance cost, long life cycle [1, 2]. By considering technical factors for Pakistan, the solar as a source to produce electricity seems the best alternative [3, 4].

Pakistan is mainly depending upon the imported oil and natural gas for generation of electricity. This imported oil has deteriorating effects on environment and also affecting the economy of the country. The air pollution and global warming are rising day by day due to the utilization of the fossil fuels in the thermal power plants. Pakistan has vast renewable energy potential for the production of electricity. These alternative energy sources offer more benefits towards sustainable future as compared to fossil fuels and have fewer impacts on economy of the country [5]. Environmental threats have also become extra serious globally than ever before due to the rise in the demand for energy. The greenhouse gases (GHGs) and carbon emissions are contributing to ozone depletion and global warming [6]. The problems relating to energy crisis and possible solutions are illustrated in the Fig. 1.

PV cell is an efficient device that converts incident solar insolation into electrical energy. It is suitable alternate to conventional sources for electricity generation being safe, noiseless, non-polluting and having a lifetime between 20 to 30 years [7, 8]. In grid-tied solar PV power plant, the solar panel produces the DC power, which is subsequently converted into AC power and supplied to the grid for distribution and utilization. It may achieve maximum power from the PV system during daytime, as solar radiation is available at its peak [9, 10]. A typical 6-8kWh$_{solar}$/m^2 results in 90-100W$_e$/m^2 or 10W$_e$/ft^2 electric power using 12% efficiency PV Systems. It means 98.950% of the incident solar light flux is wasted in air. By combining the PV system with thermal systems then hybrid system works at 50–60% efficiency to produce electricity as well as heat for room heating or power production.

This research presents the techno-economic analysis of 100 MW$_p$ solar PV system in meteorological conditions of Pakistan. The significance of this paper is that it briefly describes the process flow, timelines, and steps involved in initiating the project through issuance of letter of interest (LOI) application until the commissioning of the plant. Furthermore, this work summarizes the financial feasibility to set a 100 MW$_p$ solar PV power plant project including revenue, operations & maintenance, interest payment on project loan, net profit and payback components. This feasibility has debt-to-equity ratio of 80/20, but if the investors have more equity and less debt, then they can earn more revenue.

Background and Review of Literature

The gap between the Pakistan's energy demand and supply is flaring owing to exponentially growing population, modern way of life, and cheaper information technology (IT) gadgets. The present energy mix of Pakistan shows a major portion is supplied by fossil fuels (23.8%), hydel (32.7%), gas (11.9%) [11] presented in Figs. 2 and 3. The existing energy

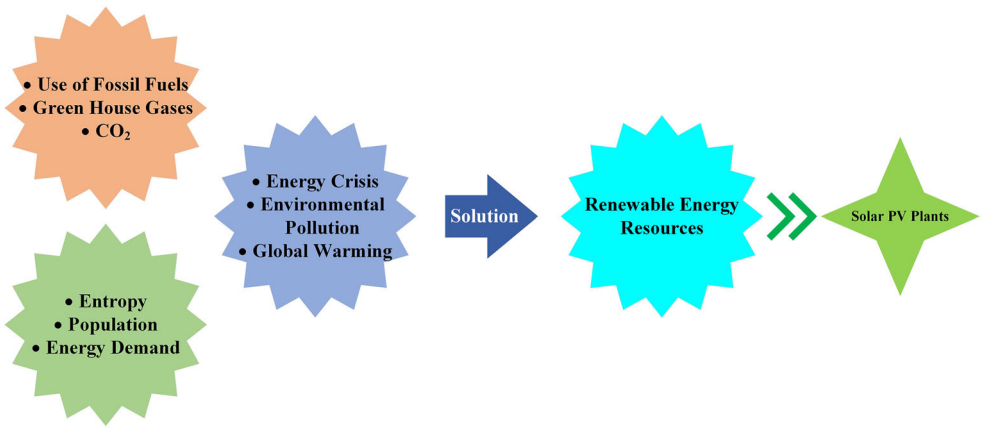

Fig. 1 Problems and proposed solution in the present energy scenario

mix relies mainly on burning of furnace and diesel oil, liquefied petroleum gas (LPG) and coal which has very high CO_2 emission rate.

Pakistan has vast potential for various renewable energy sources. Solar has a potential of 2,900,000 MW, biogas 3000 MW, waste materials energy has 1000 MW, wind 34,600 MW and small hydel power has 2000 MW. Currently, most of the electric power is produced from conventional sources and less than 1% energy is being generated from renewable resources [13].

Previously, various techno-economic studies have been performed for the feasibility analysis of renewable energy driven plants as reported in the literature. However due to growing fossil fuel prices and their nuisance effects, the policy makers are now inclined to use DG-PV power plants. Being signatory of Montreal protocol (1987) and Paris accord (2015), the global community is compelling Pakistan to increase renewable energy share in future energy-mix. Ozcan et al. used PVsyst program to calculate annual production for different cities. For financial analysis of the project, complete costs, payback period and return on investment were calculated. The comparative analysis for three cities was done in terms of financial performance, annual production rate and rate of return calculations. Payback period has been calculated 7.03, 6.7 and 13.6 years for the investments done in Izmir, Ankara and Istanbul locations respectively [16]. Bishoyi proposed a 100 MW solar power plant having 21% efficiency and annual production of 285GWh of electricity. The thermal performance and design have been evaluated on the System Advisor Model (SAM). Rajasthan in India site was chosen for the hypothetical solar power plant and technical feasibility and performance analysis of this study are proposed to be promising for the stated region [17]. The off-grid PV systems may be of interest and profitable as envisaged by Diantari [18]. For the optimal installation of PV panels to obtain maximum achieveable efficiency at particular angle, proposed design utilizes 50 m_2 roof area with electric output of 6 kWp. PV panels were installed at an angle of 6° and is capable of producing 10 MWh/year. Chen calculated the maximum savings for nine sites in USA by the optimum PV system sizing. Selection of inverter design has been optimized and it was concluded that optimal size is dependent upon economic as well weather parameters [19]. Sahin et al. performed economic analysis for PV solar panels to produce electrical energy required for different sites in Saudi Arabia and India for pumping underground water. A comparative analysis has been done among the sites for maximum & minimum generation, economic analysis for payback period and amount of total water pumped [20]. Studies on controller design for a hybrid renewable energy system based on artificial neural network have been performed for power management system. It was proposed that to overcome intermittent nature of renewable resources, a controller with maximum power generation capability should be used [21]. Another study of controller-based power quality enhancement of renewable energy systems proposes reduction of total harmonics distortion. The proposed design of the system has reduced harmonic value to less than 5% in accordance with IEEE standard 1547 [22]. Abbas and co-authors simulated a 100 MW concentric solar thermal power plant in National Renewable Energy Laboratory's solar advisor model software at three sites of Algeria to perform techno-economic analysis. The evaluation of monthly generation of energy, annual output and levelized cost of energy (LCOE) is performed in this study [23].

An energy management system for multiple PV systems with storage backup has been developed for smart grid connection. Lifetime analysis and economic advantages have been analyzed through iterations. Results of the simulation showed that the presented methodology may efficiently lessen

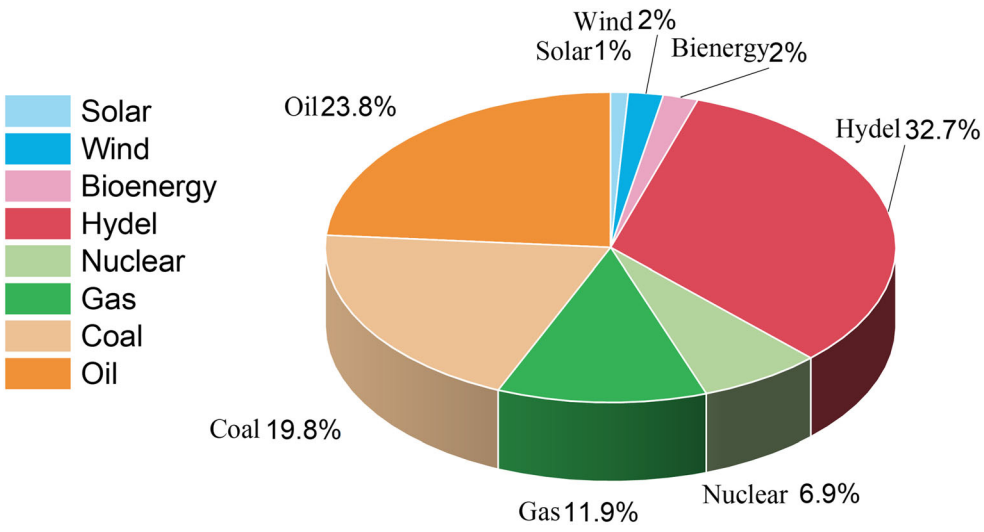

Fig. 2 Present established electricity production capacity of Pakistan

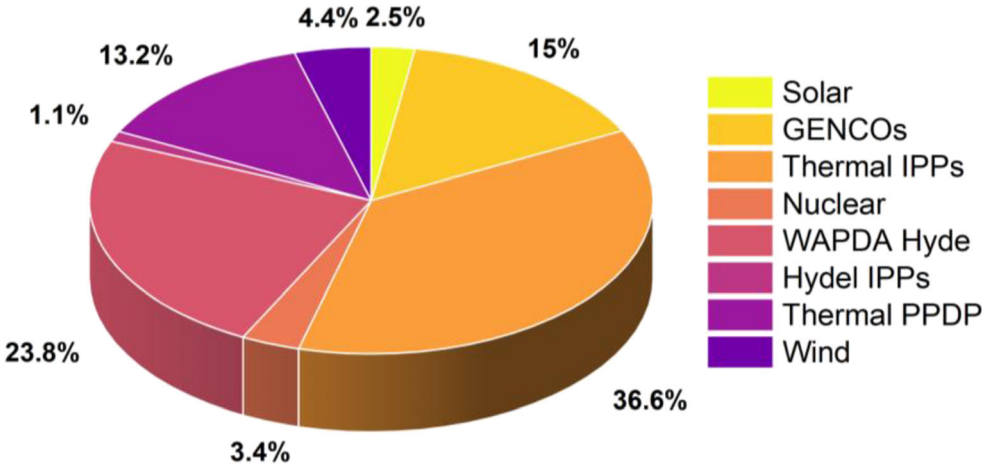

Fig. 3 Energy mix scenario during year 2017-2018

voltage regulation problems [24]. A feasibility study for electric supply viability analysis has been performed by considering off-grid PV, on grid PV and on-ground PV systems as alternative options. Parameters selected for analysis are net present value, energy cost, environment and social factors. The system proposed is deigned and simulated in computer simulation software. Results of the study have shown highest feasibility for floating off grid system [25]. Applying PV systems for supplying electric power to communication system, a study to analyze feasibility of PV powered remote telecom network performance has been studied. DC/DC converters are a viable option for remote area systems driven by solar PV systems [26]. Harmonics issues associated with PV powered system need to be addressed properly for the improved power quality of the system. In this context, considering boundaries of IEEE 519–1992 standard and applying Newton-Raphson algorithm for harmonic analysis has been performed [27].

System Design and Components

Solar PV power plants are divided into four major categories including standalone, grid-tied PV with and without battery bank, and hybrid systems [28]. Public offices in Pakistan operate between 09 AM to 04 PM which is best time for utilization of solar energy for electricity production. Due to intermittent nature of solar energy and varying demand, authors chose grid-tied without battery bank system. In Pakistan, the government offer a very favorable policy of electricity trade between customer and utility with the help of bi-directional energy meter. Presently, two public sector educational institutes are partially supplying their electrical needs on public-private joint venture. These projects were initiated by Punjab Energy Efficiency and Conservation Agency (PEECA) to meet local demand by local production. The schematic of proposed system is shown in Fig. 4.

A part of incident solar radiations is directly converted into electrical energy by PV cells that is supplied to inverter. The most common types of solar cells are thin films and mono or poly crystalline silicon. Both mono and polycrystalline are in commercial use due to large range of acceptance of solar radiations [29]. The proposed 100MWp will supply electrical energy to meet the campus demand on day time, while in absence of solar energy at night the electrical grid will provide the electric power. During weekends (Saturday and Sunday), the campus merely needs 20% of its own power produced. The surplus power produced will be exported to national grid. The educational campus usually observes 30 days summer vacations, 10 days winter vacations, 10 days semester break,

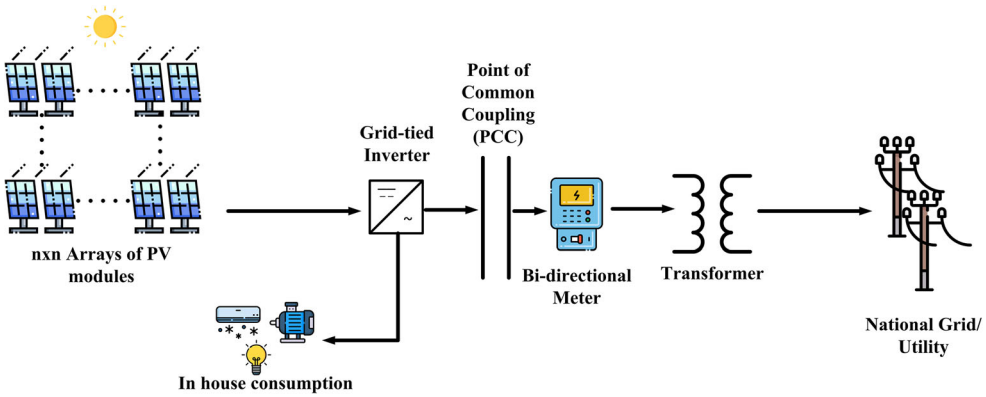

Fig. 4 Schematic of proposed grid tied PV power plant

22 national holidays. During this period the solar power plant shall feed the national grid and exported units will be augmented. These accumulated units will be used as tradeoff for the units consumed at night time [31

System Design and Methodology

Site Details

Pakistan has an area of 796,096 km^2 with the abundance of wind, water and solar energy potential. From previous five years the capability of generating electricity from solar system has raised up to 55% worldwide [32]. Average solar radiation varies from 1500 to 2750 W/m^2/day for 10 h a day, mainly in Baluchistan, Sindh, and southern Punjab. Electrical power capacity in the range of 45-83 MW in the area of 100m^2 per month in the stated locations [33]. The proposed system has capacity to produce 100 MW$_p$ electrical energy in the weather conditions of Lahore, Pakistan having coordinates 31.5204° N, 74.3587° E. The calculations have been done with a mathematical model of software PV*SOL algorithms and results have been presented.

PV System Calculations

Units Production Calculations

1 MW peak capacity PV system provides 150,000 units in a month.

$$1MW = 150^{MWh}/month \tag{2}$$

Now calculating electric power produced by the 1 MW system throughout the year. For the year's round, the system will produce:

$$1MW = 1800^{Wh}/year \tag{3}$$

Power produced by 100 MW system will be;

$$100MW = 180000000^{kWh}/_{year} \tag{4}$$

$$100MW = 180^{GWh}/year \tag{5}$$

Area Calculations

Considering area and power production of a single PV panel can be extended to all plant. Size of a single half-cut cell mono-perc solar PV panel of 500Wp capacity is 7.5*3.5ft. Converting this value to square meter area will be as;

$$1PVpanelsizeof 2.44m^2 = 0.5kW_e \tag{6}$$

$$48.8m^2 = 10kW_e \tag{7}$$

By tilting PV panels at 27°, area required will be:

$$43.34m^2 = 10kW_e \tag{8}$$

As per Fig. 5 of right-angled triangle, it is required to find the base value, and by tilting the PV panel (hypotenuse) at 27°.

$$Base = hypotenuse*\cos(\theta) \tag{9}$$

By tilting PV panels at 27°, area required will be:

$$43.34m^2 = 10kW_e \tag{10}$$

By adding 11m^2 spacing between two arrays of 10 kW to avoid shading and to provide spacing for personnel to work;

$$54.34m^2 = 10kW_e \tag{11}$$

Extending same calculation for 100 MW proposed system area required will be

$$543400m^2 = 100MW_e \tag{12}$$

Number of PV Panels Calculations

By using 500W$_e$ each panel, total panels required will be:

$$500W = 1\ Panel \tag{13}$$

$$100MW = 200,000\ Panel \tag{14}$$

Number of Inverters Calculations

By using transformer less 500 kW Huawei inverter, total number of inverters required will be:

$$500kW = 1\ inverter \tag{15}$$

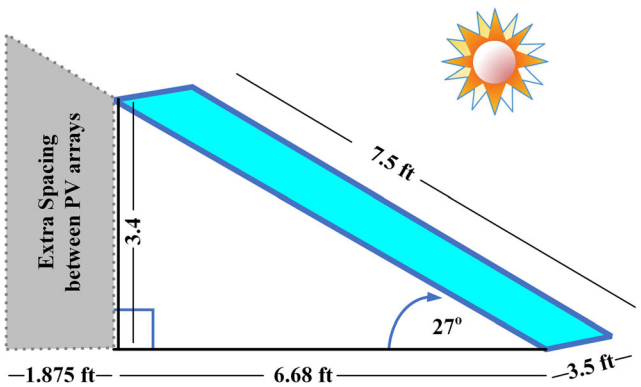

Fig. 5 Right-angled triangle for PV area calculation

$$100\text{MW} = 200 \text{ inverters} \quad (16)$$

Cost Calculation

For the calculation of costing of PV system, each Watt costs 90PKR. Based on this value

$$1MW = 90,000,000\ PKR \quad (17)$$

$$100\ MW = 9,000,000,000\ PKR = 9Billion\ PKR \quad (18)$$

Converting these values to USD units (@ 176.25 PKR/USD):

$$100MW = 510.63829\ \ MillionUSD \quad (19)$$

Calculations for Rate of Return (ROR)

Total units produced by 100 MW system will provide electricity cost per year (@16PKR/unit export rate)

$$180000000\ units*16 = 2880000000\ PKR = 2.88\ B \quad (20)$$

And total system cost is 9B PKR, so calculating ROR will be:

$$ROR\ (year) = \frac{Total\ cost\ of\ the\ system}{Total\ price\ of\ exported\ units\ in\ a\ year} \quad (21)$$

$$ROR\ (year) = \frac{9\ Billion\ PKR}{2.88\ Billion\ PKR} = 3.125 \quad (22)$$

So, the cost of PV system installed will be recovered in 37.5 months.

Technical Analysis of Solar Photovoltaic Power Plant

The selection of PV module depends upon cost, performance in low light, power output, warranty time and degradation rate. Total number of modules required in this project is 200,000 of 500 Wp each and total PV generator surface area required is 543,400m^2. Total 200 inverters are required to convert this DC supply into three phase AC, which is further provided to the transformer to step up the voltage level for supplying the power to the national grid.

e technical specifications of the system are described in Table 1.

The solar PV system produces the electrical energy when the photons from the sun rays strike on the PV modules. As the solar irradiation changes throughout the year, output results of the plant vary accordingly. Horizons of the PV array are shown accordingly in Fig. 6 as obtained from simulation results. The horizon of a PV panel is simply a line overlaid on path of sun map having multiple numbers of azimuthal points. Horizon allows shading to model automatically in correspondence with terrain adjacent to the desired site. This helps precise assessment of shading and enhances production of PV power.

The simulation result of month wise production of energy forecast of the system is shown in Fig. 7.

The designed system produces 180Wh/year. The output of the modules and the existing system decreases yearly. The performance output of PV modules and entire system will decrease by 20% after 25 years. Degradation in the efficiency of the PV modules and electric power produced are presented in Figs. 8 and 9 respectively.

Setup Process of PV Power Plant

For new solar power plants the following process should be followed by the organization.

- Governing Bodies
- Issuance of Letter of Interest (LOI)
- Feasibility Study
- Power Generation License
- Selection of Law Firm
- Tariff Application
- Issuance of Letter of Support

Sponsors who wish to undertake a Solar-PV power project at a raw site in Pakistan need to apply Alternative Energy Development Board (AEDB) or Punjab Power Development Board (PPDB) for the license issuance. Issuance of LOI (Letter of Interest) is based on the acceptance of the application/proposal from either of the two bodies.

A detailed proposal needs to be submitted that should include the following minimum requirements as per the set guidelines in the RE Policy of AEDB [34].

Table 1 Technical specifications of system

Parameter	Value
PV generator surface	543,400 m^2
No. of PV modules	200,000 (@500 W each)
No. of inverters	200 (@500kW each)
No. of phases	3
Main voltages (1-phase)	230 V
Displacement power factor (cosφ)	± 1
CO_2 emission avoided	90,225tons/year
Output power produced	180GWh/year

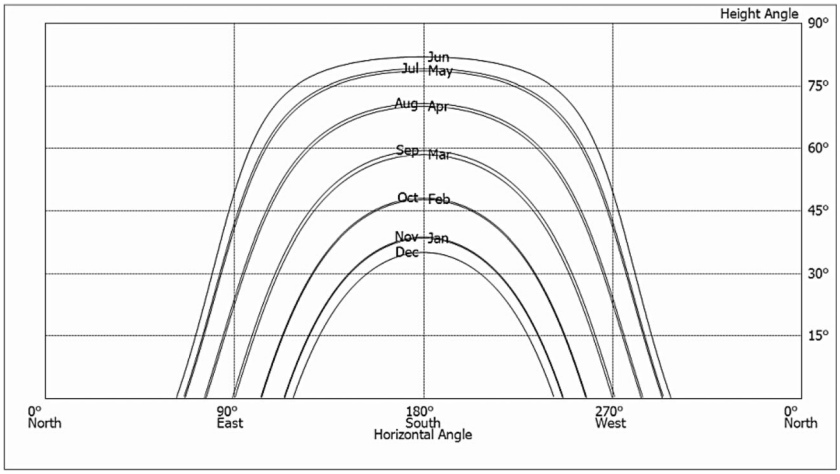

Fig. 6 Horizon of PV module area

- Report of qualification of project sponsors, listing relevant corporate personnel, experience and fiscal capacity
- The name of project and renewable energy technology (RET) categorization (wind/solar/hydro).
- The location of project.
- Proposed installed capacity (MW) and estimated annual output of energy (MWh)
- Basic sketch of plant and structures
- Summary of implementing plan, committing highlights for project groundwork, implementation and completion date
- Expected distance from 132 kV or 11 kV line or the grid station

LOI is usually issued with a maximum timeline of 18 months upon which the sponsor will submit a bank guarantee and fee depending upon plant capacity. During the timeline the following milestones need to be achieved by the sponsor

- Pre-feasibility surveys (Geotechnical/Topographic, Grid-Interconnection, Environmental Impact Assessment)
- Site earmarking and plant location finalization
- Site climate data collection
- Feasibility study

Feasibility Study

A feasibility study is conducted by a consultant preferably having expertise in this particular domain. Typical data initially required by the consultant includes location, topographic details, grid

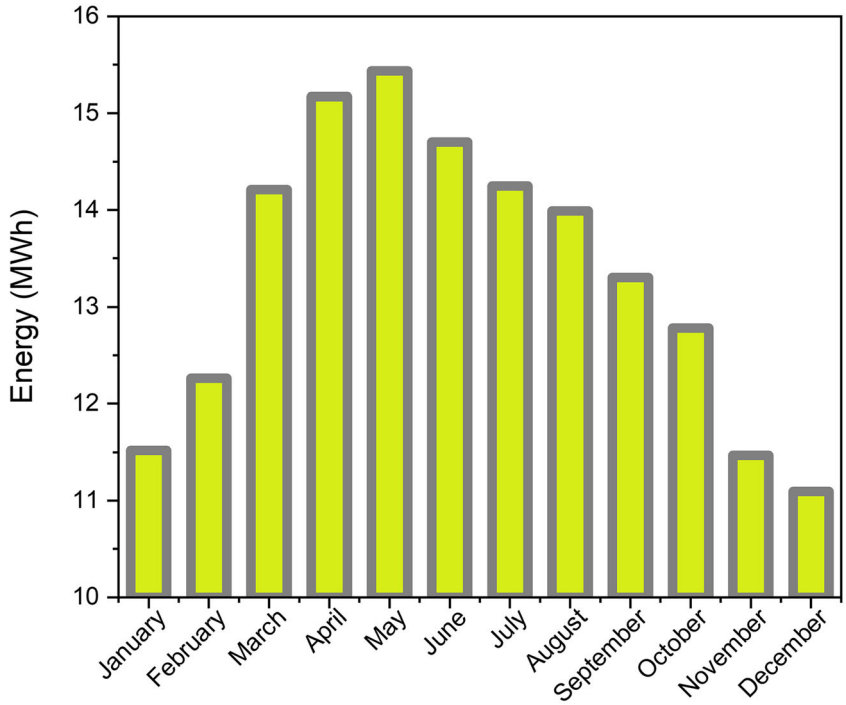

Fig. 7 Month wise electric power production forecast

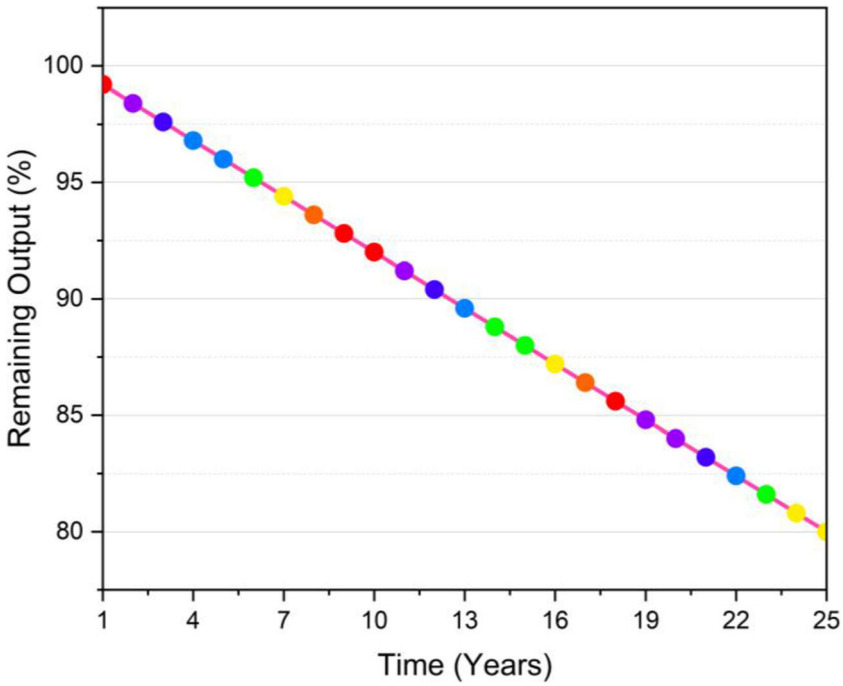

Fig. 8 Curve of output degradation of modules

interconnection details, financial inputs and project financial resources. Feasibility study deliverable includes a fully-fledged feasibility study report that is submitted to the respective department along with other LOI Milestones.

Power Generation License

After the completion of the LOI milestones, the complete set of documents along with their approvals is submitted to AEDB/PPDB. In this phase, the feasibility Report is verified by a third-party consultant for which the sponsor is required to pay an amount depending upon the plant capacity. Sponsor can apply for power generation license after approval of feasibility study to National Electric Power Regulatory Authority (NEPRA).

Selection of Law Firm

Law firm will be hired by sponsor for the complete project or on the basis of task. Typical scope for the law firm is corporate and regulatory matters.

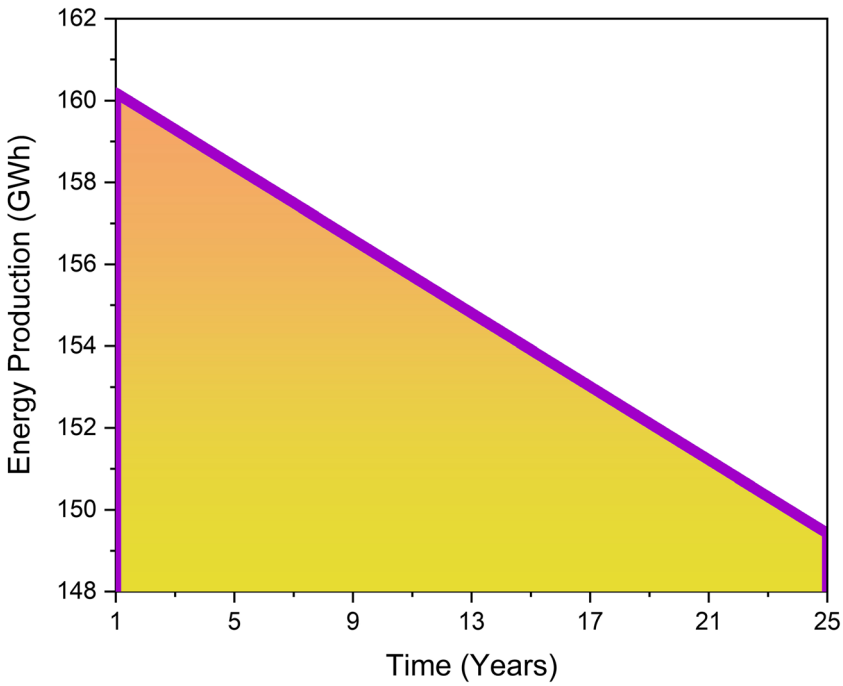

Fig. 9 Total energy production degradation curve

Table 2 Baseline data for financial evaluation

Parameter	Value
Power Plant Capacity	100 MW
Total Annual Energy Production (First Year)	180GWh
Energy Degradation	0.7%
Debt/Equity Ratio	80/20
Service Life of Project	25 Years
Debt Servicing	10 Years
Rate of Financing	12.5%
Tariff (1–10 Years)	0.1718 (USD/kWh)
Tariff (11–25 Years)	0.0780 (USD/kWh)
Project Cost	Milion USD 158

Tariff Application

After obtaining generation license, the tariff application is submitted to NEPRA. Sponsor can opt for upfront tariff as decided by NEPRA or can come up with its own tariff (cost plus) that will further be evaluated through committee hearings. Opting for upfront tariff will not require any justification. Upon approval of tariff the sponsor will submit a performance guarantee to AEDB/PPDB (based on Plant capacity), and pay a Project Facilitation Fee to AEDB/PPDB (Based on Plant Capacity). Land Approval is obtained from PPDB based on the approval of tariff. Land is allocated on lease basis. Applicants for allocation of land are accommodated on first come-first serve basis. Letter of Support (LOS) will be issued by AEDB/PPDB after submission of guarantee. Sponsor will be required to achieve financial close during this timeframe.

Issuance of Letter of Support (LOS)

After the issuance of LOS, the sponsor would be required to sign the agreements of implementation, certified emission reduction and power acquisition with the relevant power procurer. Sponsor will attain fiscal close, carry out and commission the project in accordance with major highlights established in the letter of support. The flow chart

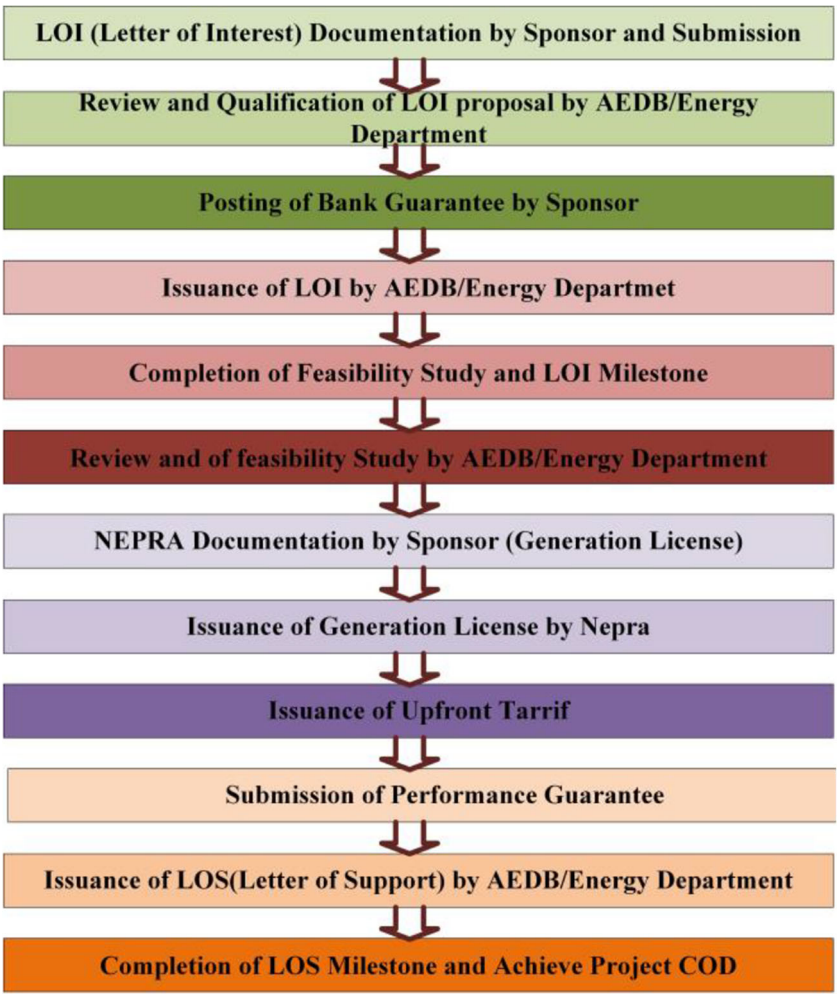

Fig. 10 Flow chart of major activities to start a new solar power plant

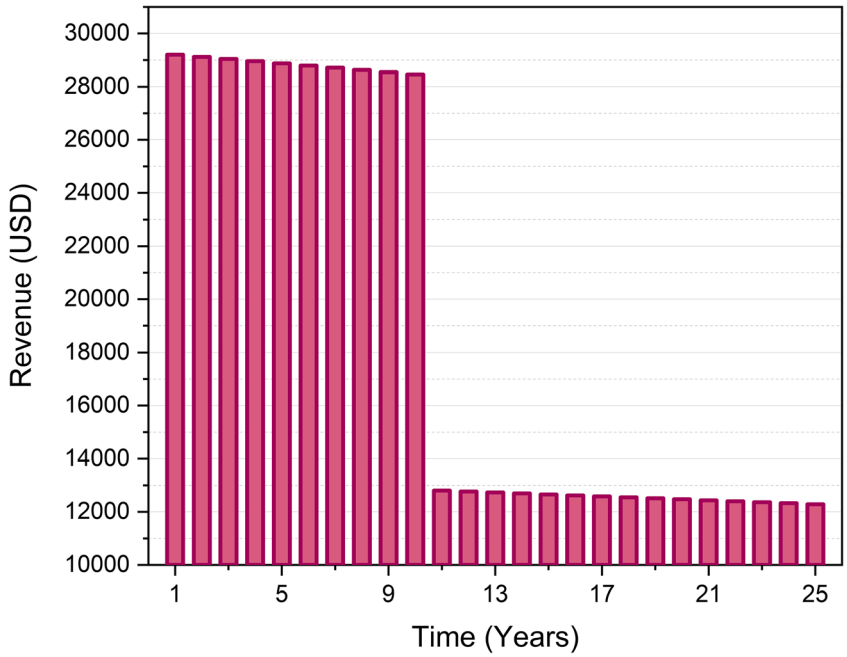

Fig. 11 Graph of the revenue produced by the plant

explaining all the steps involved in the process of initiating power plant is shown in Fig. 10.

Economic Analysis of the Power Plant

The baseline data considered for financial evaluation of the project is shown in Table 2.

Revenue

The revenue remains sufficiently consistent in the 1–10 year and 11–25 year periods, in line with the tariff that applies to the time periods. The slight decrease in revenue is reflected due to 0.7% degradation of plant as per NEPRA guidelines. The total Revenue over the period of 25 Years is 476.549 Million USD as described in Fig. 11.

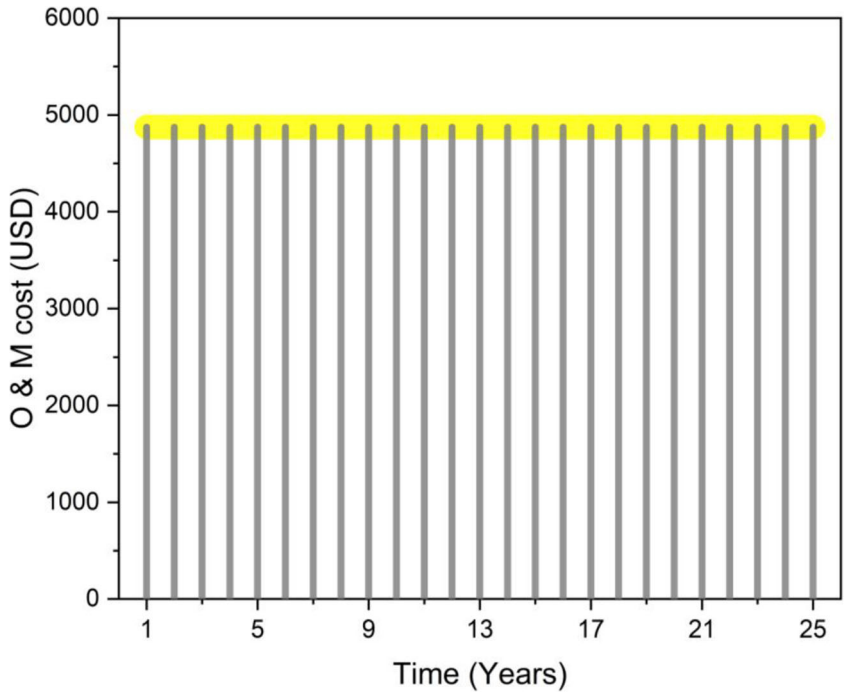

Fig. 12 Operations & maintenance cost of the plant over analysis time

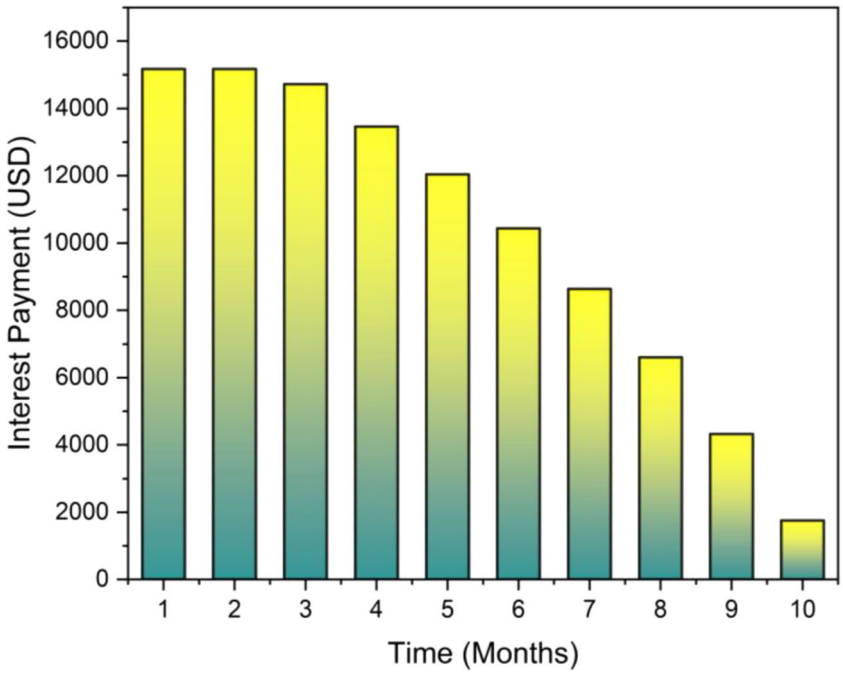

Fig. 13 Interest payment on project loan

Operations & Maintenance Cost (O&M)

The O&M component of the project cost includes human resources, cost of materials, company asset replacement, insurance during operations, and fixed O&M cost for the plant as per NEPRA Guidelines. The O&M expenditure over a period of 25 Years is 121.885 Million USD as shown in Fig. 12.

Interest Payment on Project Loan

The interest payments for equity and debt are as per the rate of financing mentioned earlier. The total amount of interest to be paid is 102.319 Million USD. Principal repayment is being made from the 3rd Year. Figure 13 shows the interest payment of the project over ten years.

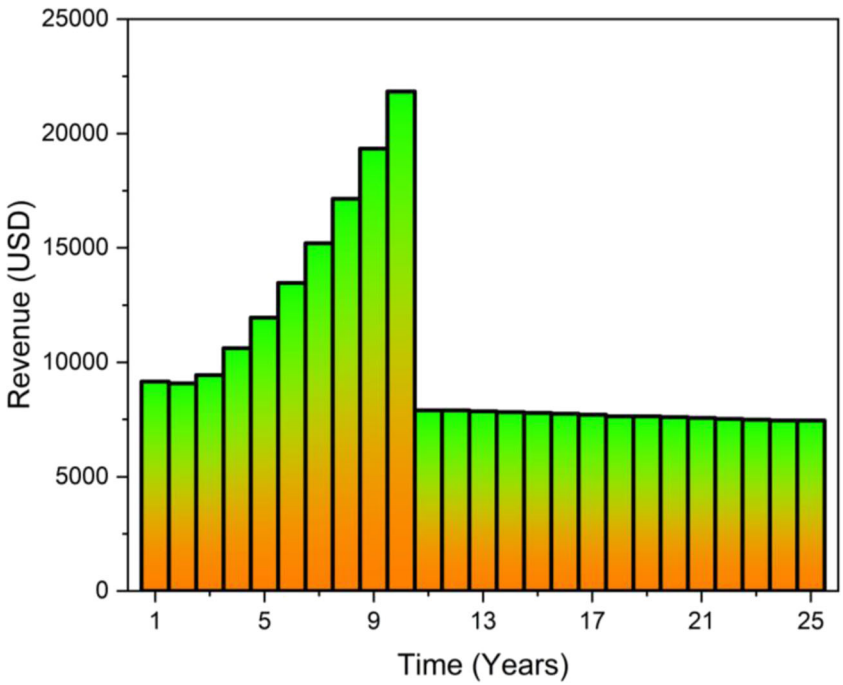

Fig. 14 Graph of net profit of project

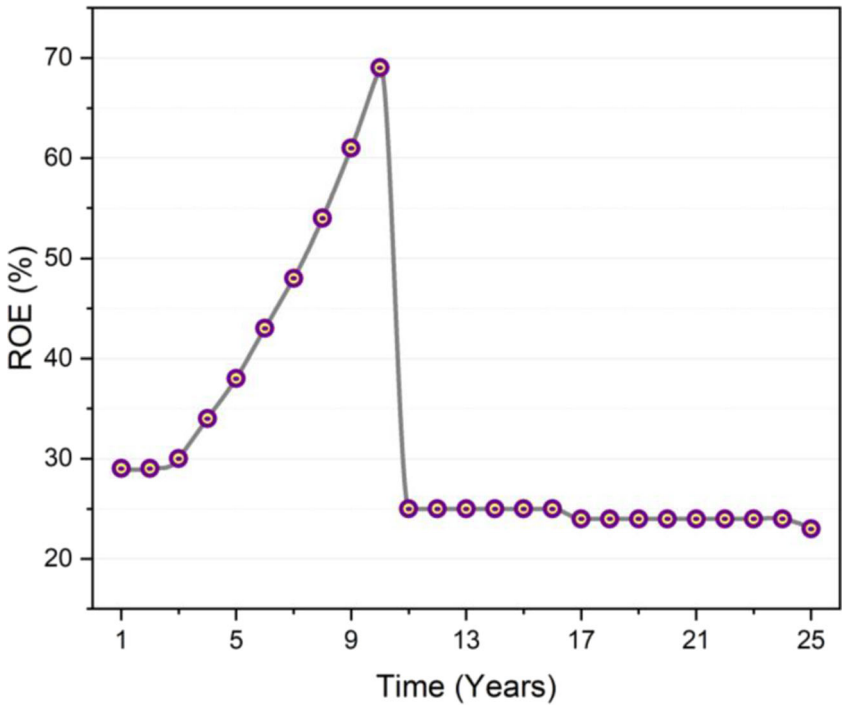

Fig. 15 Graph for Return on equity

Net Profit

Net profit over the life of the project is depicted in Fig. 14. The increase in net profit is attributed to a high tariff during the debt servicing period in the first 10 years with a corresponding annual decrease in the debt (principal + markup) expense as the debt is reduced and reaches maturity. In the 11th Year, the upfront tariff is reduced and the debt completely paid off, resulting in a lower but steady cash flow and income.

Return on Equity ROE

The ROE is graphically represented in the graph. The increase in ROE is directly attributed to the higher net profit, which is associated with lower debt expense incurred for financing per annual as the debt reaches maturity. Subsequently, lower tariff after the debt servicing period yields a consistent return as shown in Fig. 15.

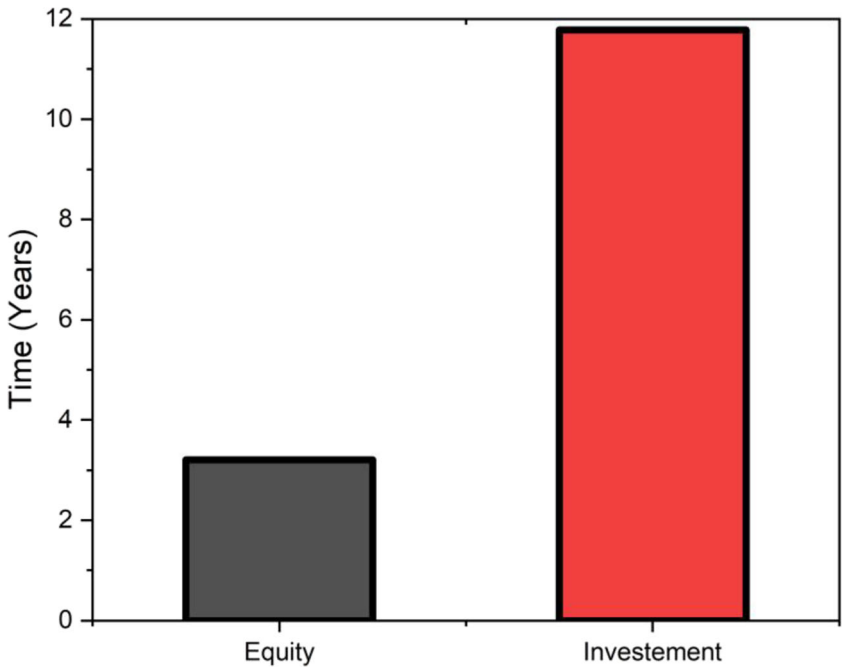

Fig. 16 Graph of payback (equity & investment)

Table 3 Summary of Financial analysis

Parameter	Values (Million USD)
Total Project Cost	158
Total Project Revenue	476.549
Total O&M	121.885
Total Interest Charges	102.319
Net Profit	94.334

Payback (Equity & Investment)

Payback period for equity is 3.2 years based on 20% equity estimated to be USD 32 Million. Payback period for total project investment is 11.89 Years based on total project cost of 158 Million USD as shown in Fig. 16.

Losses

One of the problems to install a solar power plant is the losses of the system should be considered. These losses include particular losses, inverters losses and transformer losses. The total annual loss factor for proposed system is 22.2%. The losses must have a bad impact on the efficiency. Table 3 provides the summary of the financial analysis over a period of 25 Years.

Comparative Analysis

The proposed solar PV power plant is producing 180 GWh per year of electricity. Considering conventional steam fuel oil fired, gas turbine diesel oil fired and combined cycle natural gas fired 100 MWp instead of PV have installation time duration 4, 5 and 5 years respectively, but solar power plant will be constructed in 1 year almost. Their fuel cost will be ($/MMBtu) 5.61, 16.17 and 15.10 respectively while in case of solar power plant fuel cost will be 0. The heat Rate will be 7050, 13,100 and 10,850 (Btu/KWh) but in case of solar power plant this value will be zero [35]. Here is a comparative table of the different power plants of same capacity discussed as shown in Table 4.

Conclusions

Electric power generation from solar power plant is suitable alternative to power the people in next decades for sustainable and green future. Pakistan has a huge potential for solar energy to meet the energy crisis in the country. A techno-economic analysis of 100 MW_p solar power plant has been simulated in PV-SOL software. Mathematical equations-based model for the calculation of system design for PV system is presented. The proposed solar PV power plant is capable of producing 180GWh per year of electricity and reducing 90,225 tons/year of CO_2 emissions. The estimated life of this power plant is 25 years. This project has an estimated cost of 158 Million USD with payback period of 11.89 years and total profit 94. MillionUSD. This analysis covers all the technical, legal and financial considerations for the commissioning of a PV plant in Pakistan including revenue, operations & maintenance, interest payment on project loan, net profit and payback. Cost of installation of PV has payback period of 3.125 years which represents high feasibility of PV system in the stated area. PV powered grid-tied solar energy systems have high potential for on-site electric power generation for government institutes and educational buildings.

Table 4 Comparison of PV power with other resources

System Parameters	Technology			
	Conventional steam fuel oil fired	Gas turbine (GT) diesel oil fired	Combined cycle (CC) natural gas fired	Solar power plant
Installed capacity (MW)	100	100	100	100
Installed life (Years)	4	5	5	1
Fuel Cost ($/MMBtu)	5.61	16.17	15.10	0
Heat Rate (Btu/kWh)	7050	13,100	10,850	0
Generation Hours per Years	8760	8760	8760	8760
Plant Life (Years)	30	30	30	25

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