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Original article

# Performance indices evaluation and techno economic analysis of photovoltaic power plant for the application of isolated India's island

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ABSTRACT

The usage of PV technology based electricity generation is much more popular nowadays and is being adopted by many countries as an alternative option for fossil fuel power generations. The present paper focuses on normalized performance indices and techno-economic based feasibility analysis of PV plant in an Indian isolated island, Andaman and Nicobar island where grid supply is not feasible. The estimated normalized indices range obtained for the aforementioned island are 3.0–5.10 h/d for array yield, 2.70–4.59 h/d for final yield, 1.10–1.95 h/d for array capture losses, 0.3–0.51 for system losses and 68.55–80.22% for performance ratio. The island annual global solar radiation is found to be 5.29 kWh/m$^2$/day with clearness index lies within 0.42–0.68. The techno-economic analysis is performed by using HOMER simulation software to obtained optimal size by assuming typical seasonal load profile for a single household. The obtained optimal PV configuration contains 2.5 kW PV array, 12 numbers of battery and converter size of 2.0 kW with cost of energy is found to be $0.398, net present cost of $9637, 224 $/year operating cost, 9.3 years as battery life, initial capital cost of $6773 and renewable fraction of 1.
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## Introduction

Over past decades, the increasing consumption and cost concern related to power generation from available conventional resources in worldwide is a serious issue for the developing and developed countries. Globally, the major power generation from conventional resources is, basically, based on fossil fuel. An emerging by-product of using conventional resources evolves serious impact towards the eco system in terms of green house gas emissions and global warming. The necessity in today's world is the use of renewable energy resources (RESs) such as the wind, solar and hydro [1–3] for power generation in order to reduce the emission and without affecting the environment. Among all RESs, electricity generation through photovoltaic (PV) systems are widely accepted across the world [4] and considered to be clean and eco-friendly RESs as it produces no by-product such as CO2 emissions. The PV array is an ensemble of PV modules which converts solar energy directly to the dc electrical energy when sufficient solar radiation fall on it [5]. Moreover, PV system now turns out to be one of the foremost future sources of electricity generation in terms of cost reduction and efficiency [6]. The significant benefit of using PV system is that it requires less maintenance and size may be increased to meet emergent energy needs [7]. In the current scenario, most of the developing countries have very low electrification rate [8] which have an effect on the development and standard of living. In the context of developing nation, such as India, total commercial energy consumption is 65% which includes 55% from coal, followed by oil at 31%, 11% from natural gas, 3% from hydro energy and 30% from non-commercial energy source over the total energy consumption [9–10]. Although India is at the third position in the world on the stage of prevalent energy, end-user with general electrification rate is 64.5% but still 35.5% populace live without access to power [11]. Therefore, there is, constantly, emerging need to generate energy to accumulate both access and demand challenges. In remote isolated area where grid extension is major issues in terms of economic and also because of geographic location (constrain such as islands which is far located from mainland), the use of standalone PV systems can play important role for the local inhabitant for generation of electricity and can mitigate the energy security and country electrification quandary within Indian province and can be considered as a 'local energy resources' [12]. The economic viability of using PV technology for power generation has been previously conducted by several researchers of different countries. Based on economic viability aspect, the net

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**Nomenclature**

| | |
|---|---|
| $P_{ac}$ | actual AC power output (kW) |
| $E_{prim}$ | AC primary load (kWh/year) |
| $E_{ac}$ | alternating current (AC) energy generated (kWh) |
| $E_{AC,daily}$ | alternating current (AC) daily energy generated (kWh) |
| $T_{a,NOCT}$ | ambient temperature at which NOCT is 20 °C |
| $T_a$ | ambient temperature °C |
| $E_{AC,annual}$ | annual alternating current (AC) energy generated (kWh) |
| $L_C$ | array capture losses $(h/d)$ |
| $Y_{Array}$ | array yield $(h/d)$ |
| $CF$ | capacity factor (%) |
| $CRF(\cdot)$ | capital recovery factor |
| $K_T$ | clearness index |
| $U_L$ | coefficient of heat transfer to the surroundings in (kW/m$^2$/°C) |
| $R_{comp}$ | component lifetime (year) |
| $\eta$ | conversion efficiency of the DC/AC converter (%) |
| $COE$ | cost of energy ($) |
| $Y_{Array,daily}$ | daily array yield $(h/d)$ |
| $Y_{Final,daily}$ | daily final yield $(h/d)$ |
| $E_{def}$ | deferrable load served (kWh/year) |
| $E_{DC}$ | direct current (DC) energy generated (kWh) |
| $E_{DC,daily}$ | direct current (DC) daily energy generated (kWh) |
| $\eta_c$ | electrical conversion efficiency of the PV array (%) |
| $\overline{H}_{E,av}$ | extraterrestrial horizontal solar radiation at the top of the earth's atmosphere (kWh/m$^2$/day) |
| $Y_{Final}$ | final yield $(h/d)$ |
| FC | fuel cost ($) |
| $H_{t,daily}$ | global in plane horizontal insolation (kWh/m$^2$) |
| $\overline{G}_{T,STC}$ | Incident radiation at standard test condition having value equal to 1 kW/m$^2$ |
| ICC | Initial capital cost ($) |
| $INT(.)$ | Integer function, returning the integer portion of real value |
| $Y_{Array,monthly}$ | monthly average daily array yields $(h/d)$ |
| $Y_{Final,monthly}$ | Monthly average daily final yield$(h/d)$ |
| $\overline{H}_{av}$ | monthly average solar radiation on the horizontal surface of the earth (kWh/m$^2$/day) |
| $C_{NPC}$ | net present cost ($) |
| $T_{c,NOCT}$ | nominal operating cell temperature (°C) |
| $N$ | number of years |
| OM cost | operating and maintaining cost ($) |
| $PR$ | performance ratio (%) |
| $R_{proj}$ | project lifetime (year) |
| $f_{PV}$ | PV derating factor (%) |
| $T_c$ | PV cell temperature (°C) |
| $T_{c,STC}$ | PV cell temperature under standard test condition which is equal to 25 °C |
| $Y_{PV}$ | rated capacity of PV array (kW) under standard test conditions |
| $P_{dc,STC}$ | rated DC power under standard test conditions (kW) |
| $P_{PV,rated}$ | rated PV array power (kW) |
| $i$ | real interest rate (%) |
| $Y_{Reference}$ | reference yield $(h/d)$ |
| $R_{rem}$ | remaining life of the component at the end of the project lifetime (year) |
| $C_{rep}$ | replacement cost ($) |
| RC | replacement cost of component ($) |
| $S$ | salvage value |
| $\alpha$ | solar absorptance of PV array (%) |
| $G_{T,NOCT}$ | solar radiation at which NOCT is defined *i.e.* 0.8 kW/m$^2$ |
| $\overline{G}_T$ | solar radiation incident on the PV array (kW/m$^2$) |
| $\tau$ | solar transmittance over the PV array (%) |
| $L_S$ | system losses $(h/d)$ |
| $\alpha_P$ | temperature coefficient of power %°C |
| $C_{ann,tot}$ | total annualized cost of the system ($/year) |
| LCC | total cost of installing and operating a component over a specific time span |

present value (NPV), internal rate of return (IRR), benefit cost ratio (BCR) and payback period (PBP) methods have been evaluated for Farafenni town, Gambia by Sowe et al. [17] in which technical and economic viability assessment were discussed and evaluated for 1 MW PV power plants using crystalline Si (c-Si) and thin film CdTe (CdTe) modules. By using HOMER simulation software, Missoum et al. [18] have discussed the energy performance of grid-connected PV system under the climatic conditions of Chlef district located at north-western of Algeria. Weniger et al. [19] have carried out the simulation-based sensitivity analysis along with the economic assessment of a residential PV-battery system by varying PV and battery size to get the optimal system configuration. Ali and Emziane [20] have presented results based on simulated performance monitoring of seven different roofs mounted PV systems in Abu Dhabi, UAE. With the help of the mathematical model, Sharaf Eldin et al. [21] have investigated the output of PV panels' feasibility by considering different solar tracking systems in hot and cold regions. Essah et al. [22] have investigated the normalized performance indices such as performance ratio, array yield and reference yield for silicon PV modules located in the engineering building of The University of Reading, UK. In literature [23], performance ratio, final yield and capacity factor for PV system using different types of PV modules located in Abu Dhabi, were evaluated and compared with the PV system operated in different countries. Various normalized performance parameters are also evaluated for different types of PV module.

A performance study on 200 kWp grid connected PV system has been conducted at Jean University by Drif [24]. Bianchini et al. [25] have analyzed the PV plant performances with different technology under different environmental conditions and have evaluated the PV technology investments through the application of the Levelized cost of energy (LCOE) and the net present value (NPV) methods. Adaramola [12] has performed a techno-economic analysis and has presented the monthly and annual performance indices of a 1.2 kW rooftop PV-grid-tied system installed on a laboratory building in Norwegian University of Life Sciences, Norway. An attempt has been made by Sundaram and Babu [26] to validate the annual performance analysis with the monitored results from a 5 MWp grid-connected PV plant located in India at Sivagangai district of Tamilnadu. According to IEC guideline 61724 [27], Padmavathi and Daniel [28] have evaluated the performance of 3 MWp grid connected solar PV plant located in Karnataka state, India and have also analyzed the effect of solar radiation and PV cell temperature on system losses. By using PVsyst software, Sharma and Chandel [29] have validated the obtained results from 190 kWp PV plant and have carried out a performance analysis. The performance evaluation analysis of a 5.28 kW isolated grid PV power plant has been carried out by Rehman and El-Amin [30] which is installed at King Fahd University of Petroleum and Minerals, Dhahran Saudi Arabia. The results show that DC performance ratio and daily energy yield indicates a decreasing trend with increasing PV panel surface temperature. In order to examine the behaviour of grid-connected PV systems in the climatic conditions of Southern Spain, Sidrach-de-Cardona and Mora Lo'pez [31] have evaluated the essential performance parameters (known as final yield and performance ratio) of a 2.0 kWp power system

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