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# *Enhancement Energy Saving and CO2 Emissions Reducing through PV Systems*

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***Abstract*—The growing energy demand in developing nations has triggered the issue of energy security. Exploiting renewable energy sources for electricity production has been extensively investigated over recent years, and many countries especially Egypt have been working to promote the use of renewable energy to decrease energy consumption and $CO_2$ emissions. Egypt has a climate, which is characterized by hot dry summers and mild winters. Most of the country enjoys many hours of sunshine and high levels of illumination. This has given birth to the widespread use of solar water heaters, but as yet there has been little development of domestic electricity generation using photovoltaic (PV) panels.**

**Grid connected PV systems have become the best alternatives in solar energy application, fast solution and economical. Performance analysis of this grid connected prototype could help in designing, operating and maintenance of new grid connected systems.**

**A 5.5 kW photovoltaic grid connected prototype is installed on the roof of Benha faculty of engineering, Benha, Egypt. The site receives a good average solar radiation about 6.2 kWh/m$^2$/day and annual average temperature of about 21.9 ºC. The plant is designed to operate with a fixed tilt angle. In this study the solar PV plant design aspects along with its annual performance is investigated.**

**The various types of power losses (temperature, internal network, power electronics, grid connected etc.) and performance ratio are also calculated. The performance results of the plant are also compared with other simulated results obtained from PV-syst software.**

***Keywords—Solar energy; Photovoltaic; PV syst software; PV-Performance; Energy efficiency.***

## I. INTRODUCTION

The objective of the present study is to provide technical and economical analyses of a grid-connected PV system for a small power demand required as houses government building to saving energy and $CO_2$ emission.

There are different methods of reducing energy load and protecting the environment, such as behavioral changes [1, 2], demand side management [3, 4], and renewable energy application.

Energy conservation through behavioral changes can be done, for example, by encouraging hotel guests to reuse linens and towels [5] or by changing light bulbs with energy efficient ones and uses photocell to control the electrical equipment. Demand side management is usually applied by utilities when demand shifts from peak hours to off peak hours are expected.

Recently, the installation of small-scale PV system has been accelerated as the interest of eco-friendly alternative energy continues to increase in domestic and international [6].

As the installation of PV system is continuously increasing [7], the need for management such as monitoring system from such plants is importance. A vital point in achieving this is adequate monitoring of the performance and safety of the system. Huge PV plants can afford to have delicate PV monitoring systems as well as trained personnel available on site for continuous monitoring and maintenance [8].

Compared to huge PV plants, small-scale PV plants such as residential or commercial installations are often insufficiently monitored after installation. In this case faults can go unnoticed for long periods of time until they are detected and proper

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maintenance actions can be performed, causing significant power loss of up to 18% as was reported for some cases [9].

Faults and degradation affecting the PV generator inherently leads to a decrease in the energy harvesting of the plant. There can be many factors that impact performance of a PV plant, such as front surface soiling [10], partial shading [9], increased series losses in the electrical components or the PV generator [10], potential induced degradation [11], etc. Most of the degradation modes can be detected by performing current-voltage (*I-V*) curve measurements [12-14] or even simply by monitoring the production of the PV arrays and the circumjacent conditions [14, 15].

Nowadays, commercial inverter manufacturers improve or combine monitoring functions in their products capable of measuring a wide range of system operation data. However, small-scale PV is generally not provided a monitoring system as a high cost.

Therefore, this work proposes that the small-scale PV plant provides with low cost monitoring system.

## II. System Description

The current work introduces a real-time remote-monitoring system for small-scale solar PV power plant. The system installed up the roof of Benha faculty of engineering, Benha, Egypt. It provides the status information of PV systems such as voltage, current, power, power factor, environment information and saving $CO_2$ emission to users through a data logger connected with network in a real time. Fig. 1 shows the component of a grid connected PV system. The small-scale PV plant is made up of solar panel, DC cables, DC switch, 3-phase on-grid inverter, AC cables, AC switch, meter, and monitoring systems (MS) connected with web LAN.

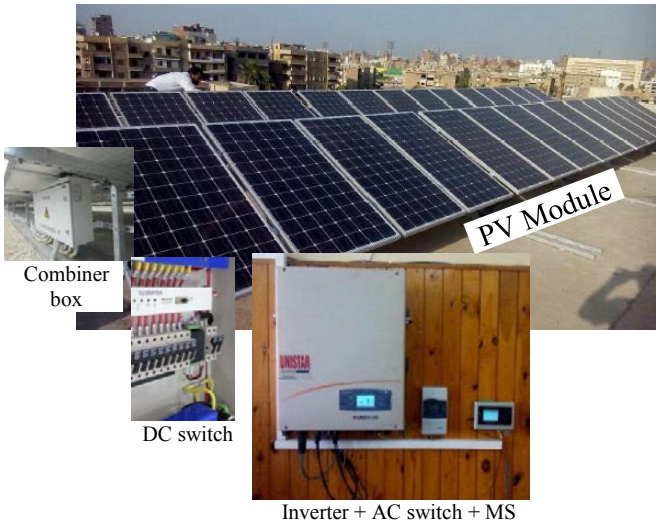


Fig. 1. Components of a grid-connected PV system

### A. PV- panels

PV modules convert directly daylight into electricity. A number of modules are connected together in order to increase the electrical power that can be generated. The entire bank of modules may be referred to as PV array.

### B. Power Conditioning Unit

A power conditioning unit (PCU) is employed to convert DC power into AC using inverter. It is also used to regulate the DC voltage and tracking the maximum power point (MPP).

Other electrical equipment such as combiner box, fuses board, PV plant meter, etc. can make the system complete and ensure the performance. Table I shows the characteristic performance of grid-connected inverter.

TABLE I MAIN PCU CHARACTERISATION

| Item | | Spec |
|---|---|---|
| Size & Weight | System Capacity | 8kWp |
| | Dimensions | 535*710*220mm |
| | Weight | 36kg |
| Input side (DC) | No. of MPPTs | 2 |
| | Max. number of PV strings per MPPT | 3/1 |
| | Max. number of PV current | 33A(22A/11) |
| Output side (AC) | Max. AC output current | 11.6 A |
| | Nominal AC voltage | 3/N/PE, 230/240 Vac |
| | AC voltage range | 310~480Vac |
| Communication | RS485 | 2 (RJ45 connector) |
| | Digital inputs | 4 |
| | Digital outputs | 2 |
| | Display | Graphic LCD |

The above table shows wide MPPT voltage range, wide DC input voltage up to 1000V, integrated convergence futures, max. efficiency at 98% and MPPT efficiency up to 99.9%. Also, the inverter provides a fail-safe link between the solar generator and the mains electricity network.

### C. Monitoring Systems (MS)

The MS is communication module that it's connected to the serial communication cable. The MS receives the operating information and fault information of the PV plant through an inverter, and it transmits them to the storage card. The MS Photograph is shown in Fig. 2. The MS is designed by Sungrow. It consisted of micro SD-card, WLAN, RS485 port, LED display, power 3W as shown. A performance specification of MS is like a table II.

Suninfo monitoring system can enable to the following; obtaining the data of generated & saved energy all day long; getting other data, such as your daily contribution in respect of carbon emission; being aware of the appropriate time to cleanse your system; and knowing about the breakdown of the system in time.

In addition, it is easy for the system fault diagnosis and anomalies to maintain small-scale solar photovoltaic system by MS device. For the future, we can suggest customized installation criterion such as angle of solar panels, solar tracking system about facility expansion of photovoltaic by mining the accumulated data.

Fig. 2. MS photograph

TABLE II MS SPECIFICATIONS

| Item | Spec |
|---|---|
| Inverter communication | RS485*1 |
| PC communication | 10/100Mbit Ethernet/ USB/ RS232/ RS485 |
| Power consumption | Typ.3W/max.10W |
| Ambient temperature | -20~60℃ |
| Internal Memory<br>External Memory | 4 MB circulating memory<br>2GB |

### *D. On-gride PV meter*

The on-grid PV meter accurately counts the number of units of electricity generated by the PV system. The counts of electricity generated by the PV system are important for the measurement of the feed-In tariff revenue. There are two types of on-grid meter, one way meter, two way meter as shown below in Fig. 3.

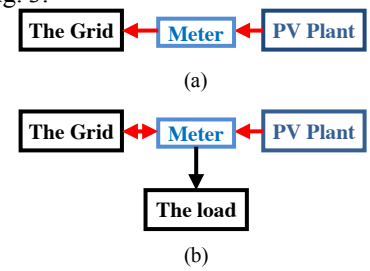


Fig. 3. Typs of on-grid PV meter, (a) one way meter (b) two way meter.

## III. $CO_2$ EMISSION MITIGATION AND CARBON CREDIT POTENTIAL FROM PROPOSED PV SYSTEM

### *A. $CO_2$ emission mitigation from proposed PV system*

PV system is considered as one of the more reliable, environment friendly and sustainable renewable energy technology. The grid electricity has been used in base case; hence there is $CO_2$ emission which is saved by electricity production through renewable energy systems which have been proposed in this case study. It also gives the effective carbon credits in terms of money which may be sold.

The average intensity of $CO_2$ emission from a coal fired power plant in India is 1.57 kg/kWh [16, 17] as similarly Egypt. Based on this the total $CO_2$ emission mitigation from the proposed PV system can be calculated using (1).

$$CO_2 \text{ emission mitigated (kg)} = 1.57 \text{ (kg/kWh)} \times Ec \text{ (kWh/year)} \times \text{life of system (year)} \quad (1)$$

### *B. Carbon credit potential from proposed PV system*

The value for mitigating 1 ton of $CO_2$ emission is one carbon credit. The market value for 1 carbon credit is ` 1706/ton [18]. The total carbon credited from the proposed PV system can be calculated from (2).

$$\text{Carbon credit earned (Rs)} = Rs\ 1706/\text{ton} \times CO_2 \text{ emission mitigated from PV system (tons)} \quad (2)$$

## IV. EXPERIMENTAL RESULTS AND DISCUSSION

### *A. Ideal, Fluctuated and Failure characteristics*

The PV plant and monitoring system has been running for seven months on three real cases and the obtained results are presented in the following figures. The first case (Fig. 4) shows the ideal and smooth graph of the output PV power during sunny day whereas the second one (Fig. 5) represents a fluctuated graph of PV output power during cloudy day. The last case (Fig. 6) represents the PV output power in case of a system failure. The failure may be occur due to the probability of the network failure and failure of the power conditioning unit. In that case, the analysis of the resulting data for seven months, the communication is likely impaired. If PCU fails, the waveform is unstable. On the other hand, when the communication failure, the wave breaks.

The power generated by PV system during 24 hours in a typical days (summer solstice, autumnal equinox and winter solstice) are presented in Fig. 7.

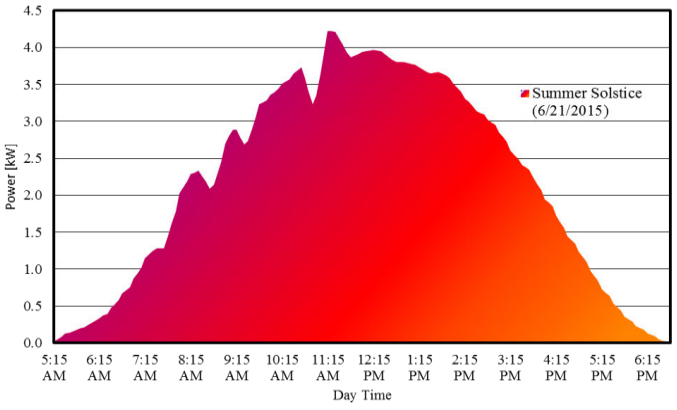


Fig. 4. Graph of sunny day

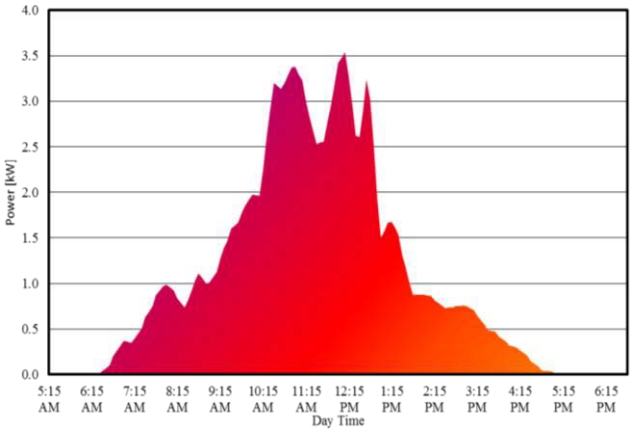


Fig. 5. Graph of cloudy day

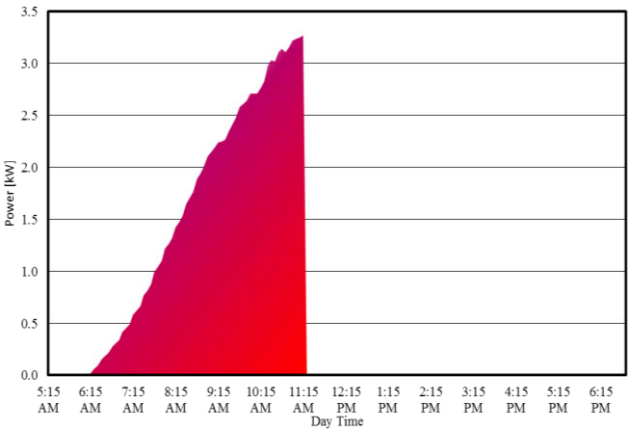


Fig. 6. Graph of failure

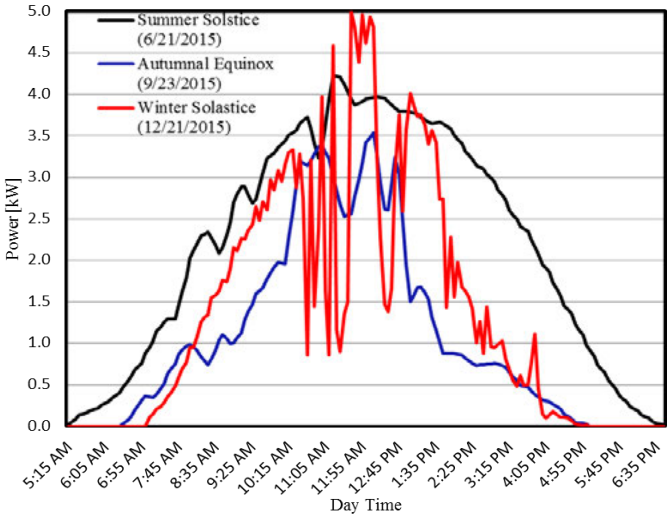


Fig. 7. Powers evolutions during 24 hours for diff. solstice and equinox.

*B. comparison of PV syst and actual montly energy production*

Simulation is carried out by taking Si-mono based solar module (GPM200-A-72), considering the availability of the solar module in the market currently in Egypt, and for economic and less complexity installation, it is assumed that a fixed mounted system is the most suitable for limited application. The PV system has no tracking system and is designed to be tilted toward south with angle equal to the latitude angle of the site under study in order to capture the most year round solar energy

The monthly energy production for a year and its performance ratio of a 5.5 kWp Si-mono based solar module is presented in Fig. 8. From Fig. 8 one can see that during September the actual generated PV energy is less than the PV energy simulated by PV syst software program. That energy reduction due to the collected dust above the PV array.

*C. $CO_2$ saving*

The energy consumed by the load and corresponding $CO_2$ emission mitigated per year was calculated as 10.25 MWh/year and 16.0925 tons/year from (1). Hence, the total $CO_2$ emission mitigated by proposed PV system in 25 years life time was calculated using (2) as 402.31 tons. This reduction in $CO_2$ by renewable energy systems can also provide carbon credits as intensives, subsequently; the carbon credit from this PV system was `686340.86.

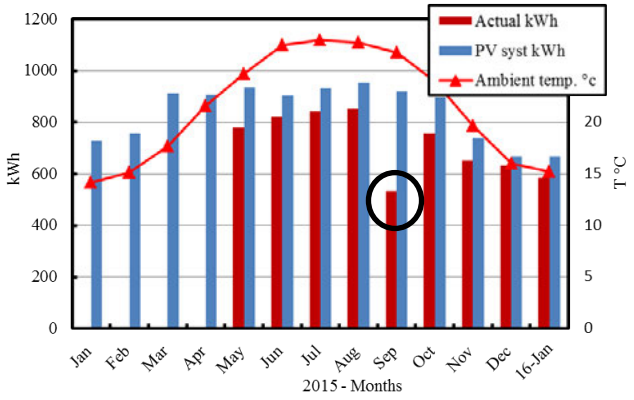


Fig. 8. Monthly energy production and its ambient temp. of a 5.5 kWp Si-mono based solar module.

## V. CONCLUSION

In this paper a small-scale PV monitoring system have been described about the architecture, together with the system implementation. The main advantages of the proposed monitoring system are the low cost/kWp, real-time monitoring.

A simulation using PV syst software model to size and assess solar potential the performance a PV installation in Benha, Egypt has been carried out.

It also reduces the $CO_2$ emission which make clean environment. In addition to this, it makes carbon credits which may be sold for making the incentives. The concept of grid

connected renewable energy systems is well suited for the location where the local network are near and power failures are common. It fulfils the requirement and excess/deficit electricity can be managed by grid. The payback period of the systems is low which increase the adoptability of the systems. It also acts as a demonstration of the solar PV technology for students and public awareness.

In the future, add a temperature and humidity, ambient light sensor or pyranometers to the PV plant, and to apply to the fault diagnosis system.

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