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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

Benha Faculty of Engineering, Benha University 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.

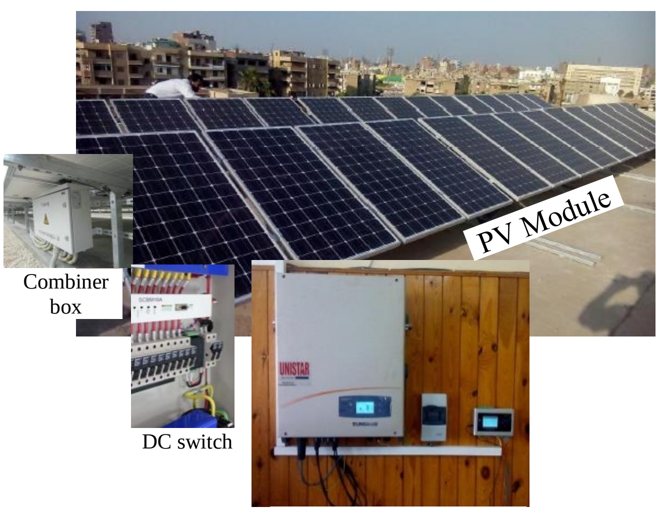

Fig. 1. Components of a grid-connected PV system

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 External Memory	4 MB circulating memory 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.

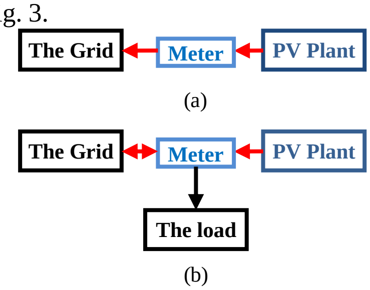

Fig. 3. Typs of on-grid PV meter, (a) one way meter (b) two way meter.

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).

$$\textit{CO}_2 \textit{ emission mitigated (kg)} = 1.57 \text{ (kg/kWh) x } \textit{Ec (kWh/year)} \text{ x } \textit{life of system (year)} \quad (1)$$

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).

$$\textit{Carbon credit earned (Rs)} = \textit{Rs } 1706\text{/ton x } \textit{CO}_2 \textit{ emission mitigated from PV system (tons)} \quad (2)$$

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.

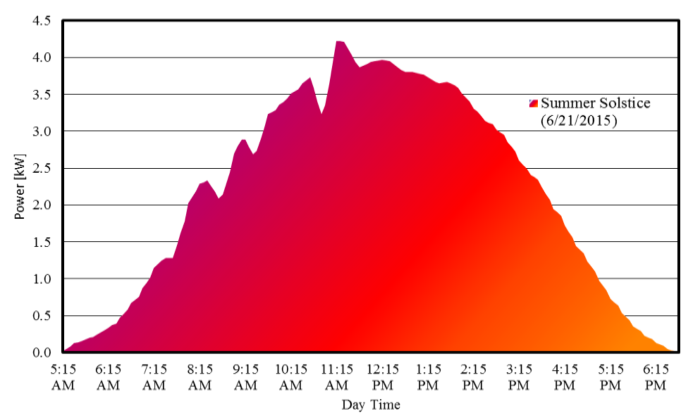

Fig. 4. Graph of sunny day

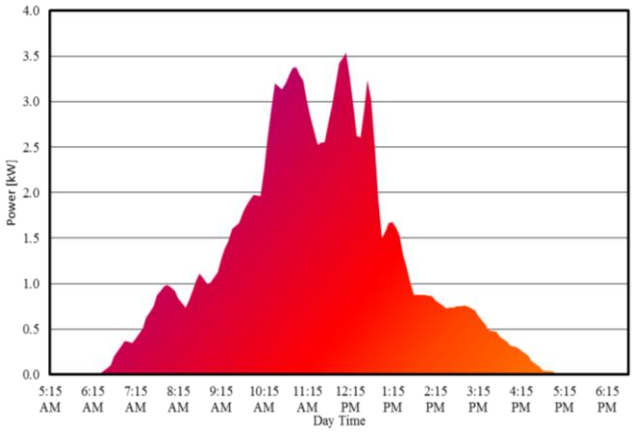

Fig. 5. Graph of cloudy day

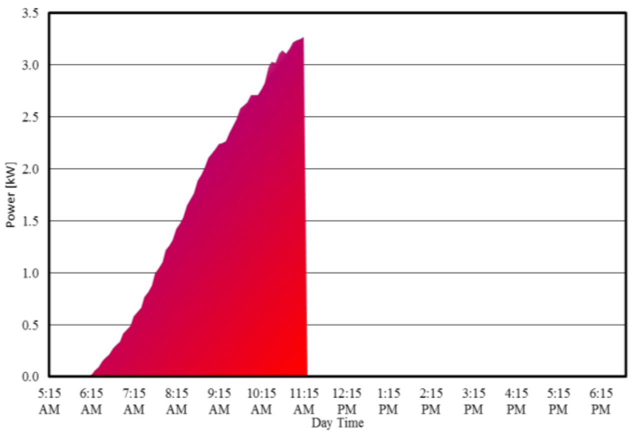

Fig. 6. Graph of failure

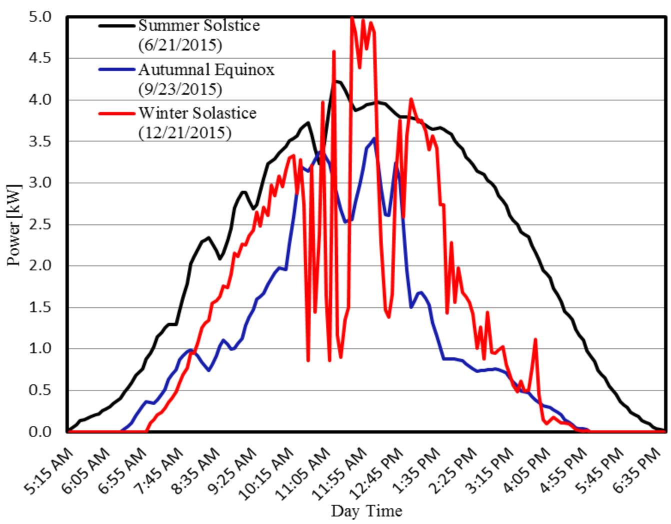

Fig. 7. Powers evolutions during 24 hours for diff. solstice and equinox.

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.

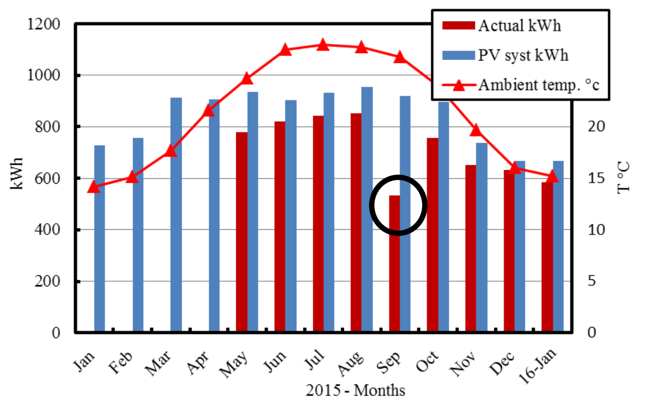

Fig. 8. Monthly energy production and its ambient temp. of a 5.5 kWp Si-mono based solar module.

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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REFFERENCES

[1] L. Steg, and C. Vlek, "Encouraging proenvironmental behaviour: An integrative review and research agenda," Journal of Environmental Psychology. 29(3),pp. 309-317, 2009.

[2] C.J. Midden, F.G. Kaiser, , L.T. McCalley, "Technology's four roles in understanding individuals' conservation of natural resources," Journal of Social Issues. 63(1),pp. 155-174, 2007.

[3] C. W.Gellings, "The concept of demand-side management for electric utilities," Proceedings of the IEEE. 7310,pp.1468-1470, 1985.

[4] M.F. Fels, and K.M. Keating, "Measurement of energy savings from demand-side management programs in us electric utilities," Annual Review of Energy and the Environment. 18(1),pp.57-88, 1993.

[5] W.G. Santika, D.M.S. Antara, and A.A.N. Harmini, "Memotivasi perilaku hemat energy dan ramah lingkungan di sebuah hotel," Bumi Lestari Journal of Environment, 13(2),pp.374-383, 2013.

[6] C. Joon Kim, J. Ki Kim*, K. Sik Jang, "HAENERGY : A Realtime Remote-Monitoring System for Small-Scale Solar Photovoltaic Power Plant," The 30th International Technical Conference on Circuits/Systems, Computers and Communications, 2015.

[7] EPIA, "Global Market Outlook for Photovoltaics 2013-2017," European Photovoltaic Industry Association, Brussels,2013.

[8] C. Kopacz, S. Spataru, D. Sera, T. Kerekes, "Remote and Centralized Monitoring of PV Power Plants," in Optimization of Electrical and Electronic Equipment, International Conference on,pp.721-728, 2014.

[9] S. K. Firth, K. J. Lomas, and S. J. Rees, "A simple model of PV system performance and its use in fault detection," Solar Energy, vol. 84, pp.624-635, 2010.

[10] E. L. Meyer and E. E. van Dyk, "Assessing the reliability and degradation of photovoltaic module performance parameters," IEEE Transactions on Reliability, vol. 53, pp. 83-92,2004.

[11] S. Pingel, O. Frank, M. Winkler, S. Daryan, T. Geipel, H. Hoehne, et al., "Potential induced degradation of solar cells and panels," in 35th IEEE Photovoltaic Specialists Conference, Honolulu, Hawaii, pp. 2817-2822, 2010.

[12] A. J. Aristizabal, C. A. Arredondo, J. Hernandez, and G. Gordillo, "Development of Equipment for Monitoring PV Power Plants, using Virtual Instrumentation," in Photovoltaic Energy Conversion, Conference Record of the 2006 IEEE 4th World Conference , pp. 2367-2370, 2006.

[13] D. Sera, S. Spataru, L. Mathe, T. Kerekes, and R. Teodorescu, "Sensorless PV Array Diagnostic Method for Residential PV Systems," presented at the 26th European Photovoltaic Solar Energy Conference and Exhibition, Hamburg, Germany, 2011.

[14] S. Spataru, D. Sera, T. Kerekes, and R. Teodorescu, "Detection of increased series losses in PV arrays using Fuzzy Inference Systems," presented at the Photovoltaic Specialists Conference (PVSC), 38th IEEE, Austin, Texas, 2012.

[15] A. Chouder and S. Silvestre, "Automatic supervision and fault detection of PV systems based on power losses analysis," Energy Conversion and Management, vol. 51, pp. 1929-1937, 2010.

[16] A. Chel, G.N. Tiwari, A. Chandra, "Sizing and cost estimation methodology for stand-alone residential PV power system," International Journal of Agile Systems and Management 4, pp. 21–40, 2009.

[17] A. Chel, G.N. Tiwari, "Thermal performance and embodied energy analysis of a passive house—case study of vault roof mud-house in India," Applied Energy 86, pp.1956–1969,2009.

[18] A. Chel, G.N. Tiwari, A. Chandra, "A model for estimation of daylight factor for skylight: an experimental validation using pyramid shape skylight over vault roof mud-house in New Delhi (India) ," Applied Energy 86, pp.2507–2519,2009.