Integrated Grid-Connected PV Monitoring System

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Abstract

This paper presents the development of integrated grid-connected PV system design tool and monitoring system. The development and deployment of photovoltaic system need a strategy in order to get the maximum performance result. Designing a PV system is not conceptually difficult, yet many PV projects fail to achieve their objective because of improper installation, essential variables are not monitored, mismatch system's component, not cost effective. The performance of a PV system depends on the environmental factors such as irradiation, environment temperature and other weather condition. For this purpose, solar radiation, temperature and wind speed are utilized as the input information in real condition. The output is to predict maximum performance of PV system power generation under the real condition by those environmental factors. The final result of the developed system will be a complete model design of PV system including the performance of the proposed system, cost analysis and deployment strategy for the selected area.

Keywords:

PV System, Grid-connected, Expert System, Life Cycle Cost

Introduction

Malaysia lies entirely in the equatorial region. The monthly average daily solar radiation in Malaysia is 4000 – 5000 Whr/m^2, with the monthly average sunshine duration ranging from 4 to 8 hours [4]. Malaysia has a very high potential for utilizing electricity from photovoltaic system but currently the development still in the early stage. A solar photovoltaic installation in Malaysia would produce energy of about 900-1400 kWh/kWp a year depending on the locations [2].

As is true with any means of producing power, a variety of performance, technical, reliability, safety, environmental, legal, cost and practical consideration heavily influence the design of a photovoltaic (PV) system. Some concerns are site-specific while others are more generic. Sunlight is a fluctuating energy resource with about 1000 W/m^2 as a maximum, which occurs only at certain times of the day and year and never at certain locations. Sunlight has regular seasonal cycles interrupted bv various irregular weather conditions. Latitude and si ... cloudiness, shading, raining ... clearness factor are the primary determinants of total annual sunlight at a given location.

The major PV subsystem component, and at this time by far the most costly, is the PV module itself. Modules are now commercially available in various sizes, power rating and voltage levels. Module reliability and durability are important concerns since the economic justification for choosing a PV system requires long-term use. In tropical countries like Malaysia, solar energy has a big potential to be utilized in wide range of applications of remote and urban areas. However, it is not fully utilized until recently. The main problems limiting solar utilization are the use of costly equipment and the selection of wrong peak sunshine data that result the wrong sizing of equipment for solar energy system. It s therefore very important to form proper design procedures and solar energy component sizing for the solar power production before opting any actual implementation of solar power energy system. The problem involved in right sizing and using the right data are the key success to solar energy applications, improve its performances and reduces unnecessary costs. For these reason, a design tool for grid-connected PV system has been developed in order to evaluate and design the proper system of solar energy. This program has capability to evaluate under the real condition such as PV module performance monitoring and resources availability. This solar monitoring system is running almost in real time and data is download at a given interval time. The final result will propose a complete model of PV system that proper to the location which can maximize the performance and minimize the cost of development.

Approach and Methods

System architecture is the hardware and software platform that is used. The hardware platform is defined by specifying the microsystem unit. The software platform is defined by specifying the user interface for system monitoring and project design unit. The task here is not only limited to collecting data for a data collection, but the system also has capability to analyze and estimate the performance of photovoltaic module system. The implementation of microsystem unit allowing intelligent management of many sensors and parameters on the system.

System Design Architecture

The basic configuration of the system is shown in block diagram in Figure 1. In hardware part, all the data are collected by the microsystem before send to the monitoring pc. The microsystem of data acquisition as related to photovoltaic systems gives comprehensive support to the design of a PV system for general users. The data are collected from PV module where all the output from PV module such voltage, current and power are recorded. These two major parameters (weather condition and PV module monitoring) will be analyzed by the system to evaluate the best PV system model for a particular location.

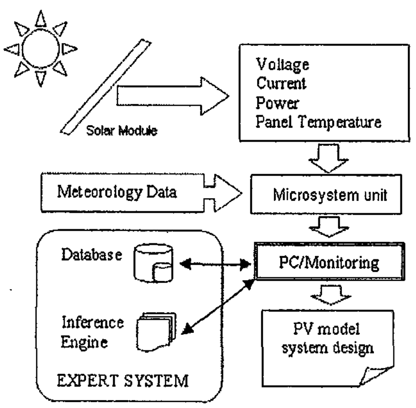

Figure 1- System's block diagram

In software section, the tool uses a structured navigating path to enable user to specify about the location in detail and energy demand for that location. Figure 2 shows the main window of the system.

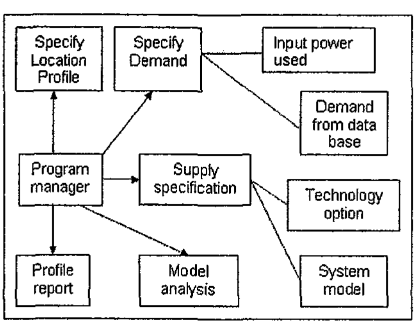

Figure 2- Components of software development

As to make a user friendly, the tool has been designed as simple as possible for the user to put the data. For evaluation and analysis of the performance of the proposed PV system model, the user has two choices to do, either for step by step analysis or let the auto design solution to find the best way for PV design strategy. So, this tool makes easier for the user especially for those who do not know much about PV design and sizing. This program consist more than 100 type of solar panels and inverters technologies which available in market. These technologies come with complete specification including the price and manufactures as can be seen in Figure 3. All the solar panel technologies available in market are stored in database and can be updated or modified.

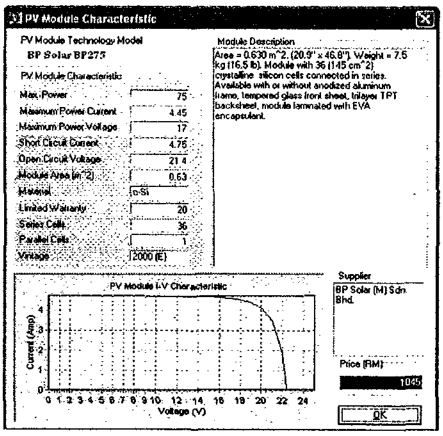

Figure 3 – PV module technology and its specification

Expert System

In order to help the user in designing solar power system, this tool comes with a small expert system as an advisor or decision maker. It will guide the user to find the proper and match PV system component. If the PV modules size is not match with the inverter, so it will give the warning and the tips to the best solution. Figure 4 shows a sample code used in the expert system for module operating voltage greater than inverter voltage.

```
//R17=57
 if( Pa>(Pi-(0.1*Pi)) && Pa<(Pi+(0.1*Pi)) && TVmpp>Vix )
 {
  Label6->Caption ="The array power is match with the inverter power BUT \n Array Mpp
  operating voltage greater than inverter maximum operating voltage";
  Label6->Font->Color = clMaroon;
  String text;
  text="R17=57-> Please decrease the quantity of series array ";
  Memo1->Clear() ;
  Memo1->Lines->Add(text);
 }
```

Figure 4 – Sample code for expert system

This tool also considered the economic factor for the whole system including pay-back period when using solar compared to conventional supply. This tool will help the end user estimate the size and cost of a PV system. This program will automatically perform the mathematical calculations required for system sizing, greatly reducing the time required to size PV systems. The final model will give the complete design of PV system with the right number of PV modules and configuration, number of series and parallel connection for a PV system. Doing a life cycle cost analysis (LCC) gives the total cost of the PV system. There are two reasons to do an LCC analysis i.e. to compare different power supply options and determine the most cost effective system design. So, in the PV system design, the final result output will show the total cost benefit of the system and its pay back period to recover the investment.

Result

This tool is used for PV systems design with different technologies of PV modules and inverter that available in today's market. User has many choices in designing the PV system. More than 100 types of PV module and inverter technologies available in the database with complete specifications. To start design PV system, the user has to enter the PV System Design windows. The main windows of PV system design can be seen in Figure 5.

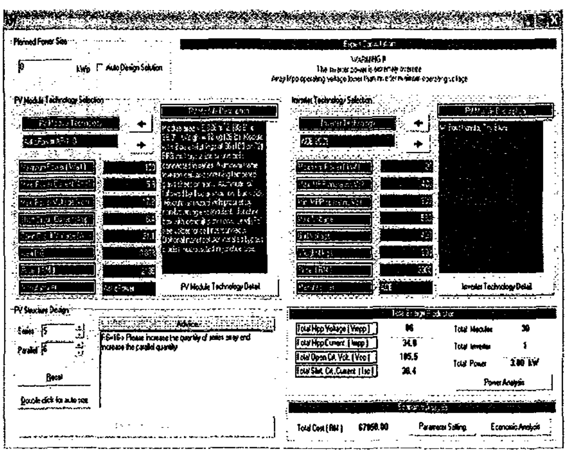

Figure 5 - The main windows of PV system design

This design tools will help the user find the best technology selection and give the proper design solution. The improper design will be warn by the system for example if the module size is bigger than inverter size, the system will show the warning signal and reason like "The inverter power is extremely undersize and array MPP operating voltage lower than inverter minimum operating voltage". Then advice will be given in order to get the proper design and match each other.

Grid-connected Solar PV Project Design

The design was made according to a case study at Taman Sri Acheh, near Nibong Tebal, Penang. This location is a housing area. The household in Malaysia is simple and does not required a large quantities of electrical energy used for lighting and electrical appliances. The hourly average electrical load data for a single house in Taman Sri Acheh are given in Figure 6. This residential area currently is using electricity from TNB. The peak demand is about 980 Wh and the total energy consumed is about 8.430 kWh a day.

The monthly average daily global radiation on the horizontal and monthly average daily temperature at Taman Sri Acheh can be seen in Table 1. Both data are measured in degree Celsius and mega joule per square meter respectively.

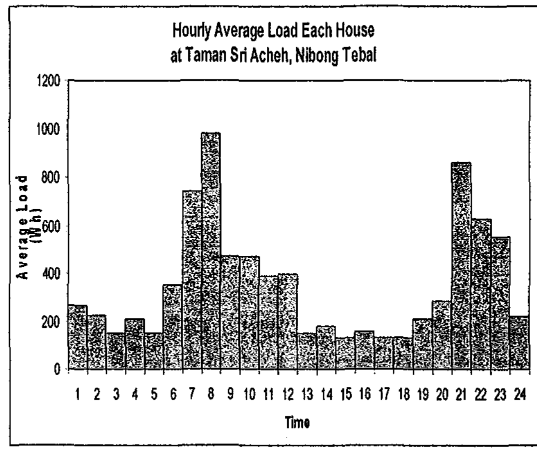

Figure 6 - Hourly Average Load Each House at Taman Sri Acheh, Nibong Tebal, Penang

Table 1 – Meteorology data at Taman Sri Acheh in 2004

Month	Temp (°C)	Radiation (MJm^{-2})
Jan	28.0	19.13
Feb	27.9	20.01
Mar	28.6	19.61
Apr	28.3	19.50
May	28.6	19.31
Jun	27.7	16.96
Jul	27.5	18.31
Aug	27.5	17.46
Sep	27.3	18.64
Oct	27.0	16.60
Nov	27.3	18.51
Dec	28.0	15.90

System Design Specification

All the collected data are inserted in the data input form before start the simulation process. The next step is the design selection of PV system component and technology. The system were designed using BP275 model from BP Solar and SUNstring 1200-L inverter from Aixcon technology. The simulation result is shown in the project report windows in Figure 7.

Economic Analysis

From the economical point of view, the photovoltaic system is differ from conventional energy system because it has high initial cost and low investment for PV system is an important factors in this analysis. The components include in the investment cost are the prices of PV modules, inverter and other auxiliary cost. Life cycle cost of the system will be considered for 30 years life span. In this case, interest rate and escalation rate are considered 8% and 4% respectively. The final result of economic analysis and payback period of the whole system is shown in Figure 8.

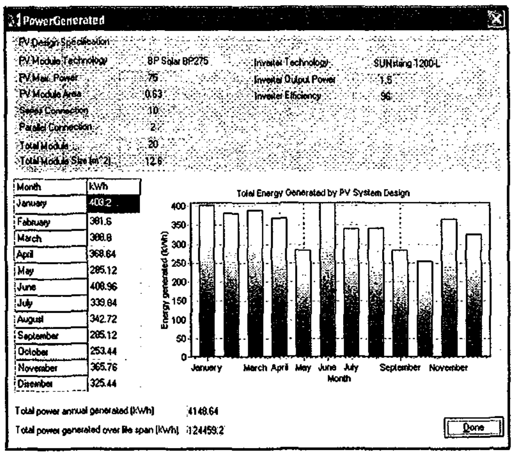

Figure 7 - PV system design for a house at Taman Sri Acheh

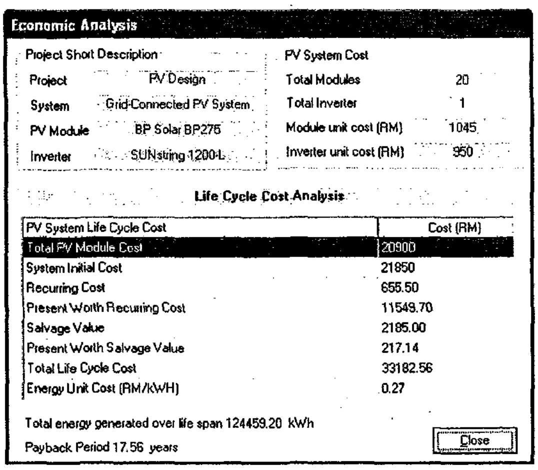

Figure 8 - Economic analysis and payback period of the whole system

In this life cycle cost analysis, it is found that the LCC of PV power generation system is RM 0.27/kWh. The selected PV modules' technology where it was used in the design has a price about RM 14.00 /W_P. Thus, the simple payback time for PV system is 17.56 years.

PV Modules Monitoring System

As to evaluate the performance of the photovoltaic system, the monitoring system will collect the data at a particular location. These performance data are very important in order to see the PV system characteristic at that site. Figure 9 shows the sample data captured from October 15, 2004 until October 19, 2004.

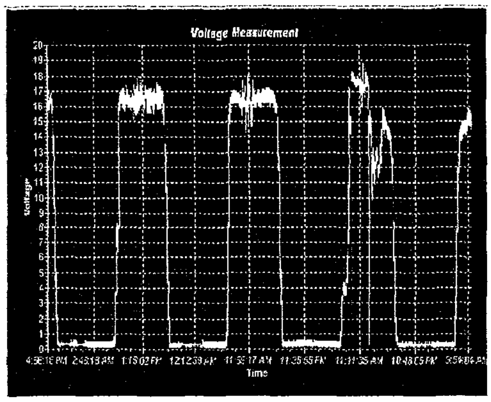

Figure 9 - Sample result of voltage measurement captured from October 15, 2004 until October 19, 2004

Discussion

PV system applications are among the cost-effective renewable energy application in many developed country. In Malaysia, however, PV technology has been left out as viable renewable energy application alternative due to its high cost. This is the main reason that PV system is not the main choice for the electricity user. By using this tool, user can evaluate the performance and cost benefit of the proposed system.

Conclusion

The development of integrated grid-connected PV system design tool and monitoring system has described in this paper. The system developed, using the latest technology in the field of data acquisition and conditioning, leads to significant improvement in the efficiency of PV system. It also enables users to have a more comprehensive diagnostic of the PV system under different operating conditions. Furthermore, the system is very easily connected and implement. The effectiveness of the tools is confirmed through by several design examples. Using photovoltaic power supply replace conventional electricity supply have many advantages for long period of time either for large scale of photovoltaic power supply or for a single building or house. This project allows energy managers, planners and designers to appraise the potential for PV system deployment at an early stage in the design process of solar power supply. Besides that, this evaluation tool also will increase public awareness about the benefit of photovoltaic power generation. The propose system designed by this tools will make the user realize how much valuable if they prefer to use renewable energy instead of using conventional energy supply. So the user can measure the values of the actual systems.

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References

[1] Fanney, A.H, Dougherty, B.P. and Davis, M.W. 2001. Measured Performance of Building Integrated Photovoltaic Panels. Forum Solar Energy: The Power to Choose.

[2] Alamsyah, T.M.I, Sopain, K. and Shahrir, A., 2004. Predicting Average energy conversion of Photovoltaic System in Malaysia using simplified method. Renewable Energy, 29/3 pp. 403-411.

[3] Sopian, K and Othman, M.Y. 1992. Estimate of Monthly Average Daily Global Solar Radiation in Malaysia. Renewable Energy, Vol2 (3). Pp 319-325.

[4] M. Shawal and S. Taib.2003. Development of Expert System as an Evaluation Tool for Photovoltaic Power Supply. In Proceedings PECon 2003, National Power Energy Conf., Bangi, Malaysia.

[5] Benghanem, M. and Maafi, A.1997. Real time supervision of photovoltaic system by a microcontroller. in Proceeding of MEPCON'97, Fifth Int. Middle East Power Conf., Alexandria, Egypt, Jan. 4-6, 1997, Vol. 2. pp. 645-648.

[6] King, D.L. 2002. Photovoltaic module and Array Performance Characterization method for all System Operating Conditions. In Proceedings of NREL/SNL Photovoltaic Program Review Meeting.

[7] Fanney, A. H., Dougherty, B. P. and Davis, M. W. 2001 Measured Performance of Building Integrated Photovoltaic Panels. Forum Solar Energy: The Power to Choose.

[8] Archer, M.D. and Hill, R. 2001.Clean Electricity from Photovoltaic. Imperial College Press, London.

[9] Omar, A. 2003. Software development for energy Auditing practice", In Proceeding of SCOReD.

[10]Alsema, E. A., Frankl, P. and Kato, K. 1998. Energy Pay-Back Time of Photovoltaic Energy System: Present Status and Prospects. In 2nd World Conference on Photovoltaic Solar Energy Conversion

[11]Ahmed, M. M. and Sulaiman, M. 2003. Design and Proper Sizing of Solar Energy Schemes for Electricity Production in Malaysia. In PECon 2003 Proceedings.