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Application of LabVIEW and Compact Data Acquisition to Study the Behavior of the Photovoltaic Stand-Alone Energy System

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ABSTRACT

The aim of this research is to develop a software and hardware to measure and monitor the behavior and the power flow of the laboratory-scaled of photovoltaic stand-alone energy system. The software is developed by using LabVIEW. The features of the software are that it is able to display real-time data and is able to interface with the NI Compact DAQ hardware. The results show that LabVIEW-based software is able to measure and record various electrical parameters from the solar panels, energy reservoir, inverters, load and a pyranometer that measure solar irradiance. The monitoring program is useful for the studies of the real time behavior from the AC part and the DC part of the PV-stand-alone energy system. Moreover, this system should be applied to monitor the grid-connected PV system without the addition of hardware and software. There is also a possibility to be used in demonstrations for the training program of technician or engineers up to and including the students of engineering program in the country.

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INTRODUCTION

The photovoltaic stand-alone energy system was designed for the remote areas where there are no electricity distribution networks. The working principle is divided into two periods (i) during the day, solar panels will absorb the sunlight and will produce electricity and supply to the load as well as charge the excess electricity to batteries simultaneously (ii) during the night, there is no sunlight. Solar panels cannot generate electricity. Therefore, energy from the battery that was charged during the day will be supplied to the load. (Anuphapharadorn *et al.*, 2014) In some application, it is able to supply AC electricity to the remote equipment such as outdoor refrigerator or any weather station in remote area. (Tina *et al.*, 2014) The photovoltaic energy system consists of the four main parts. There are (i) solar panels that convert the energy from solar irradiance (W/m²) to be an electrical energy (DC power). (ii) The inverter that convert direct current (DC) power to be an alternating current (AC) power. (iii) Solar charger that will charge the DC power from solar panels to be stored in the batteries. (iv) The battery could store energy and supply to the load via an inverter. Solar

Energy Research and Technology Transfer Center (SERTT), of Rajamangala University of Technology Suvarnabhumi Thailand have a mission to studies and research in topics of solar electricity and applications. The research output can be applied to the user by way of training and knowledge transfer.

The way that students can understand the real behavior of the system includes some question such as: How does the equipment of the photovoltaic stand-alone energy system work? How and when the energy flow in this system? These question need to be solved and clearly explained to the students which in turn will let them understand and discuss about the advantage and disadvantage of the photovoltaic stand-alone energy system. From these questions, the measurement and monitoring system are necessary in this application. The LabVIEW-based monitoring system with a DAQ interfacing (Data acquisition interface) are used (Liao *et al.*, 2011) to study the performance and dynamic behavior of photovoltaic energy systems by using LabVIEW real-time interface system. The developed software tool integrates several types of instruments into a single system which is able to offer online measurements from all data sources and compare simulated results

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with monitored data in real-time. (Chouder *et al.*, 2013) (Morris *et al.*, 2012)

The data acquisitions system could store data in micro-second sampling with high accuracy and can develop software to suite different users. In LabVIEW environment the author can display monitored data in numerical, graph, and data table. This conforms to the study of (Koutroulis and Kalaitzakis, 2003) that used LabVIEW with DAQ system to measure and monitor the renewable energy power plant, and the study of (Mingle *et al.*, 2012) that present the control and measurement of the Fiber Spinning Machine by using LabVIEW, and interface with serial port. Also the study of (Chouder *et al.*, 2013) which is about the studies of the performance and behavior of the PV energy system by using the real time interface based on LabVIEW. (Mahjoubi *et al.*, 2012) studied about the data acquisition system with available components and the feasibility of different existing methodologies linked to the field's data acquisition from remote photovoltaic (PV) water pumping systems in Tunisia. According to the study of (Wang *et al.*, 2012), the technique of visual instrument and the characteristic of solar absorption refrigerator, using National Instrument's product LabVIEW, to develop an effective data acquisition (DAQ) system. This DAQ system can realize the real-time data acquisition as well as data transmission, processing, and display, in addition to that, provides users with historic data inquiry. From details above, it is obvious that the LabVIEW based environment is very popular to be applied for the

control, measurement and monitoring of real time data in any system. DAQ system have many type for example Compact DAQ, Compact RIO, USB type, industrial type and embedded type. The NI Compact DAQ is a portable, rugged data acquisition platform that integrates connectivity and signal conditioning into modular I/O for directly interfacing to any sensor or signal. Use NI Compact DAQ with NI LabVIEW software to customize how you acquire, analyze, present, and manage the measurement data to validation, NI provides programmable software, high-accuracy measurements.

The author is an engineering teacher and need to have a very good equipment to practice the students and let them analyze, think and summary there lesson. Author has a motivation to develop the LabVIEW monitoring program with the National Instrument's industrial type hardware. There is compact DAQ and will be applied to the measurement of the result and monitoring the behavior and the power flow of the laboratory-scaled of photovoltaic stand-alone energy system. This project is used in the laboratory of faculty of engineering and architecture of Rajamangala University of Technology Suvarnabhumi, Thailand. This development could be beneficial to be applied with the engineering students and for training the peoples that is interested in the photovoltaic energy system.

Method:

To design the hardware.

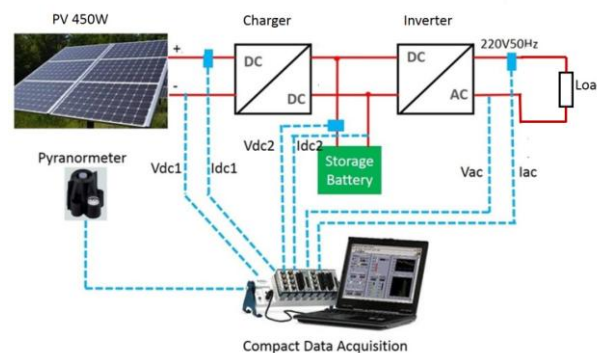


Fig. 1: The photovoltaic stand-alone system with interfacing module diagram.

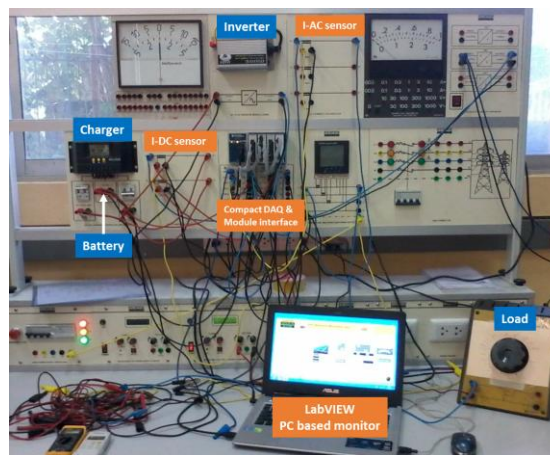
The concept to design hardware is to use the industrial product, that can match with the LabVIEW environments. The photovoltaic stand-alone system that the author design are as follow: (i) System input voltage is 24 V_{DC} (ii) Output voltage is 220V_{AC} 50Hz. (iii) Solar panels is two of 225W_p, V_{mp}=29.2V, I_{mp}=7.71A. (iv) Solar charger is 24V 20A with mppt control. (v) Battery is two of 80Ah 12V connected in parallel. (vi) The inverter is 160W 220V 50 Hz. (vii) Resistive load as variable load from 0 to 400 Ω. (viii)

The pyranometer is the photovoltaic stand-alone system diagram as shown in figure 1.

There are other hardware that is required in this research such as DC current sensor, AC current sensor and chassis NI DAQ including the data acquisitions module. The author needs to choose the DAQ module, for example analog input module for the interface with voltage and current sensor. The AC voltage interface module and the AC current interface module are shown in table 1. All of them are industrial products.

Table 1: The match of hardware between the photovoltaic stand-alone energy system with the Compact DAQ hardware based on LabVIEW.

The system hardware				
PV stand alone system		Data Acquisition system		Remark
PV	Poly crystalline 450Wp			
	Vmp= 29.2V	NI 9229	input AI1	4-Channel, ± 60 V/ ± 10 V, 24-Bit , Analog Input Modules
	I _{mp} = 7.71A	NI 9215	input AI1	4-Channel, ± 10 V, 16-Bit ,Analog Input Module
DC current sensor	DK 20 C10 U convert 0-15 A to 0-10 VDC			LEM
Charger	24V / 20A			
Battery	24V / 160Ah	NI 9229	input AI2	National Instruments
		NI 9215	input AI2	National Instruments
DC current sensor	DK 20 C10 U convert 0-15 A to 0-10 VDC			LEM
Inverter	24Vdc / 220Vac / 150 W	NI 9225	input AI0	300 Vrms, Analog Input, 50 kS/s, 3 Ch Module
		NI 9203	input AI0	8-Channel, ± 20 mA, 16-Bit Analog Input Module
AC current sensor	AK 5 B420L convert 0-5 A to 0-20 mA			LEM
Load	R = 0-400 Ω / 2A / 220V			
Pyranometer	input 0-1500 W/m ² output 4-20 mA			Davis Instruments
		NI 9203	input AI1	National Instruments
Chassis NI DAQ		CDAQ 9174	NI cDAQ™-9174 NI CompactDAQ Four-Slot USB Chassis	

**Fig. 2:** The experimental setup in the laboratory.

To design the software

The software was developed by LabVIEW in order to calculate and store data to the MySQL database, communicate with sensors, DAQ module and laptop computer. The sampling time that was setup to acquire the data can be adjusted at the default set to be 10 second. The flowchart of the monitor program is shown in figure 3. The sequence of the software operating as follows: (i) Acquire to interface compact DAQ and acquire solar irradiation from a pyranometer. (ii) Acquire data from DC power. The program will read the DC voltage and current from V-I current sensor that measure on the

DC part of the system including data from PV and battery. These data are used to calculate to DC power. (iii) Acquire data from AC power. System will read the AC voltage and current from V-I current sensor that measure on the AC part (load). These data are used to calculate the AC power (watt) and energy production (kWh). (iv) Scale data from sensor. Any data will be scale by this VI-blog with a calibration factor that depending on each sensors. (v) Display and measure information on the computer screen. (vi) Save data to the database. (vii) Wait until the loop cycle is finished or for the user's command.

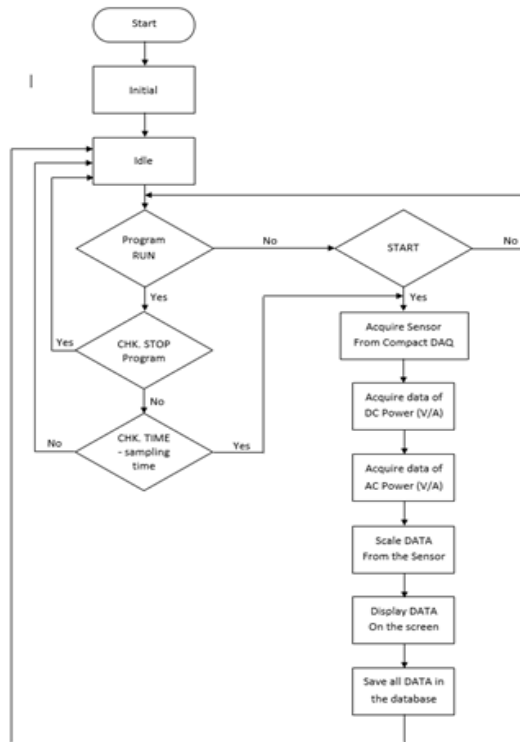


Fig. 3: Flowchart on the monitor program.

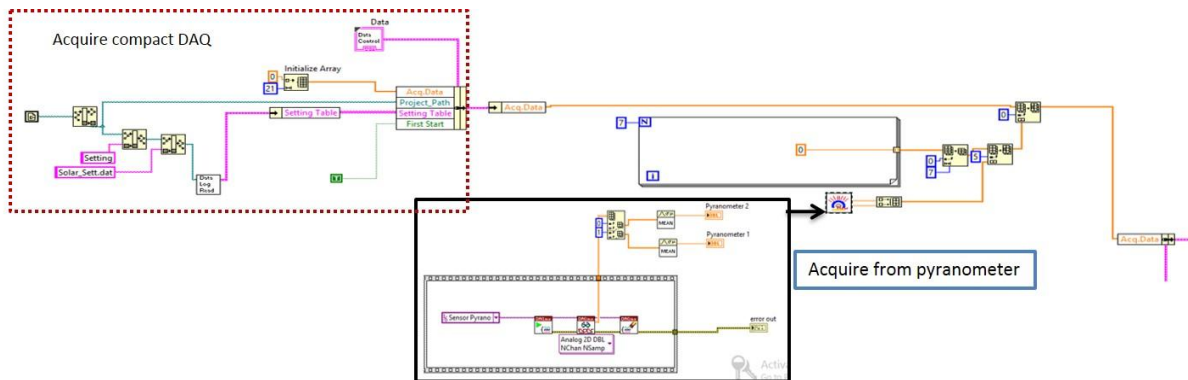


Fig. 4: The VI of an acquire sensor from cDAQ

The author could show some of VI block that develop from LabVIEW. For example the VI that show how can acquire data of solar irradiance from pyranometer. This VI is shown in figure 4. The VI will show you the acquire data from pyranometer with the block of the hardware interface. The data output will be corrected onto the Acquire data array. Next is the VI block of Acquire data from the PV (photovoltaic panel) as shown in figure 5.

The last example is to display all data on the screen. This VI is shown in figure 6. It shows the big four group of data there are Acq.Data, PV 400W, Storage, and Inverter. Acq.Data will show the irradiance data from pyranometer as indicator and

numerical. Data from PV, storage battery and inverter will display separate in the DC part and AC part of the PV energy system. The AC power, DC power and energy should calculate and display.

Results:

The results of the hardware development especially the measurement module such as: NI 9229 for DC voltage measurement, NI 9215 for DC current measurement, NI 9225 for AC voltage measurement, NI 9203 for AC current and irradiance measurement, and cDAQ 9174 as a 4 slots chassis with power supply are shown in figure 2 and figure 7.

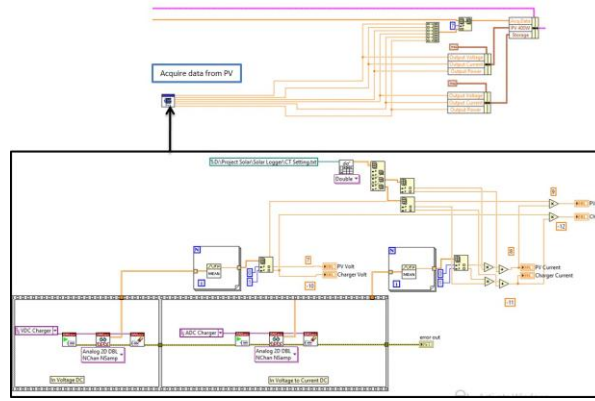


Fig. 5: The VI of an acquire data from PV

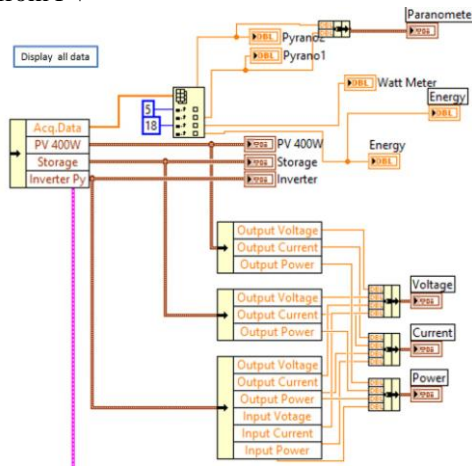


Fig. 6: The VI of display all data.



Fig. 7: The Compact DAQ with interfacing modules.

The software developments are as shown in figure 8. This software can measure the solar irradiance, DC voltage, DC current from solar panels and from battery storage as well as calculate the power and energy and display to the monitor. They can measure and display the real time data

measurements of AC voltage, AC current, load power, load energy. This means that the hardware that the author chose for this system works very well. It supports the software that the author developed to measure and display as well.

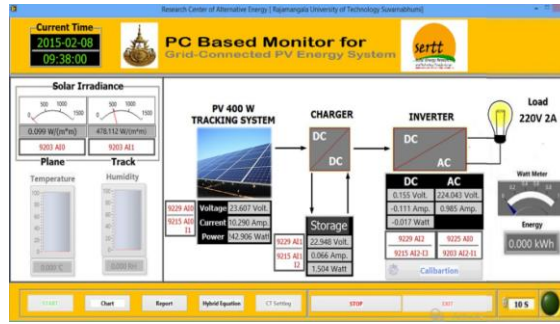


Fig. 8: The front page of the Monitor program that develop by LabVIEW.

Figure 9 shows that the measurement results of the voltage current and power from photovoltaic panel in day time. The PV voltage slipped a bit from 25 to 27V, the graph of current and power from PV panels are the same. The power peak at 9.48.21 a.m. is about 196.57W, peak current is 6.55 A at that time. Also figure 10 shows the voltage current and power

at resistive load staying constant depending on the load resistance. If the load resistance is around 70Ω, the load power is 181.65 W and load current is about 0.55A. If the author changes the load resistance, the monitor program will be display the different value of AC load current immediately as shown in figure 10.

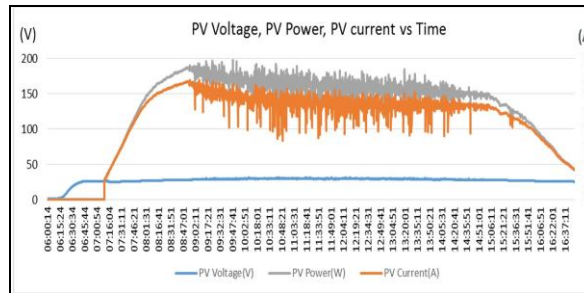


Fig. 9: Measurement results of the voltage current and power from photovoltaic panel. On 10 February 2015

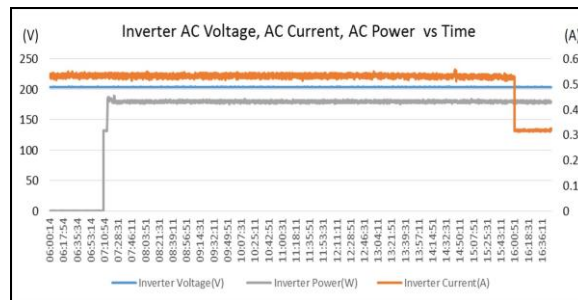


Fig. 10: Measurement results of the voltage current and power at load on 10 February 2015

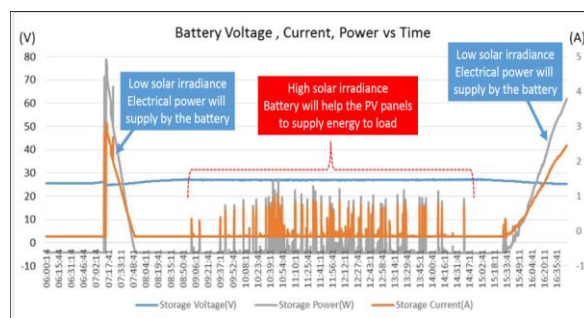


Fig. 11: Measurement results of the voltage current and power of the battery storage On 10 February 2015

From figure 11, the monitor system can show the behavior of the PV stand-alone energy system. In this case, in early morning the solar irradiance should be low the energy from the PV panels is too small. Most of energy input will be supplied from the battery until the solar irradiance is concentrated, the energy input will be fed from the PV panels to the inverter and also to the load as shown in figure 9. If the solar panels cannot supply enough energy for the load, the energy will be discharged from the battery like a second DC power supply. In the evening the battery will feed the electrical power to the load alone. Because of the energy from the sun is not enough for the PV panels to produce energy.

Conclusion:

The output of this research brings the authors to the application of LabVIEW to measure and monitor the behavior of photovoltaic stand-alone energy system. This application is very suitable to study the behavior of the photovoltaic stand-alone system, and help us to understand the operating of every equipment in the PV stand-alone system easily. This system has a high accuracy of measurement, and software that can generate any information. There is a guideline to design the protection system and the way to choose the right equipment for the photovoltaic stand-alone system and also to develop the data acquisition system for the other applications. This system is suitable for training and teaching in order to teach the engineering students and others. Nowadays, Thailand has a renewable energy policy. This project can support the policy in the term of technician development. Moreover, this system should apply to monitor the grid-connected PV system by do not need the addition hardware and software.

Future work, the author has an idea to develop the feature of the monitoring software to be able to measure and monitor for the multi sources and multi load system.

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