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Design of solar power plant and real-time voltage quality monitoring system using LabVIEW

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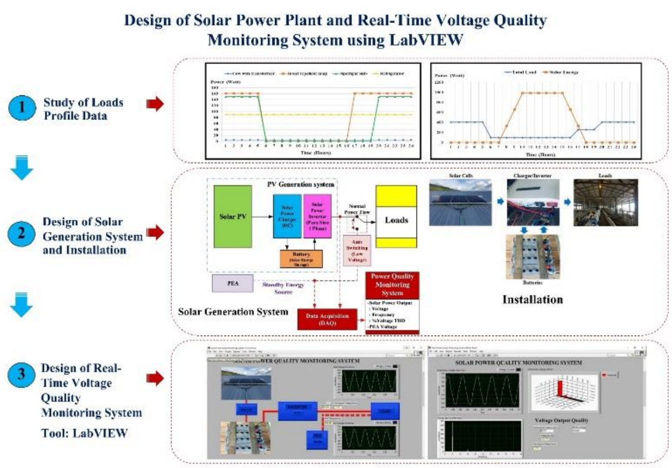
Abstract

This research presented the design of a solar power generation system in combination with an energy storage unit. The objective of this research was to apply renewable energy production technology to reduce the use of external energy. This research aimed to design a solar power generation system for the beef cattle breeding group in the Na Yom sub-district, Mueang District, Phetchabun Province. The solar power generation system is designed to be installed on a roof. In addition, this research and the development of innovative prototypes for real-time solar voltage quality monitoring systems used the LabVIEW program. The study results showed that this solar power generation system, in combination with an energy storage unit, can supply the load covering the energy consumption of the beef cowshed, which can reduce the use of external electricity by 23.10%. Further, the solar voltage quality monitoring system can display the results for the monitoring of the solar power generation system in conjunction with real-time voltage quality, which is recorded during the night; voltage reading accuracy compared to standard equipment was -0.65%. In addition to the objectives of this solar power generation system, it can be developed to further the innovation of renewable energy generation. If a group of farmers build a widespread power generation system, including electricity generation from other types of renewable energy, it can be developed into a microgrid system for energy security.



Keywords: Solar power; Energy storage unit; Real time; Voltage quality; LabVIEW

Introduction

Currently, electrical power plays a highly important role in the development of agriculture and livestock systems used to improve and increase productivity. This is especially true if the power generation system is environmentally friendly. Therefore, photovoltaic power generation is a suitable alternative for agriculture and livestock systems in remote areas or for systems that need to reduce external power consumption [1, 2]. However, installing a solar photovoltaic power generation system requires significant investment and maintenance costs. Therefore, the installation design determines the appropriate size, whether it is the capacity, number of solar panels, and the size of the energy storage unit. These things contribute to the cost of production; if it is very large, it costs money, and if it is too small, it is not enough.

This research study aimed to determine the appropriate size for a prototype of a voltage quality monitoring system. The research study focused on a design for livestock, namely a group of beef cattle in Mueang District, Phetchabun Province. The solar power generation system is the type installed on a roof. Finding the optimal size between the size of the solar panel's capacity and the size of the energy storage unit is important, and the first fundamental factor in the design is to determine how much is appropriate [3, 4]. Therefore, the design must consider and be in accordance with the variation of the energy consumption of the load in that area. The energy storage unit must be able to support the load during the absence of sunlight. This information is very important in the design. Solar panel performance monitoring [5] was designed for the real-time monitoring and control of solar panels using LabVIEW, which can show graphics and tracks the voltage, current and light intensity of solar panels. In addition, [6] designed the real-time data monitoring of PV solar cells using LabVIEW, which can show and monitor the current of solar panels and light intensity.

This research also examined the creation of a prototype real-time system to measure and display the system voltage quality by focusing on voltage level (Vrms), voltage frequency and %voltage harmonics (%THD_V) [7, 8]. This research assessed the pattern of the solar power generation process and the energy storage process and studied the patterns of changes as well as the amount of electricity demand every hour of the day. This information is used in the study for design purposes to determine the production capacity, the number of solar panels, and the appropriate energy storage unit. In addition, if a group of farmers builds a solar power generation system extensively or builds a power generation system from other types of renewable energy, it can also be developed to create a microgrid for farmers' energy security [9, 10].

Materials and Methods

In the research process of designing a solar power generation system with an energy storage unit and a prototype real-time voltage quality monitoring system, the target group in the study was the beef cattle breeding group in Na Yom sub-district, Mueang District, Phetchabun Province. The methodology for conducting research was established as follows: The study of the model of the solar power generation process with the power reserve unit, the study of the load type, and the variation of the average daily power demand by the beef farm. The study designed the amount of power generation and energy storage that is suitable for the load during the off-solar period as well as for the electricity generated. The study of the design of the voltage quality monitoring system of the solar power generation system used the LabVIEW Program in conjunction with Data Acquisition (DAQ) to test the efficiency of use and record the results [5, 6].

Results and Discussions

The results of research on the design of solar power plant and real-time voltage quality monitoring system using LabVIEW can be explained as follows:

Results of a study on the model for the solar power generation process

The solar power generation process model and voltage quality monitoring system in this research can be illustrated as shown in Fig. 1.

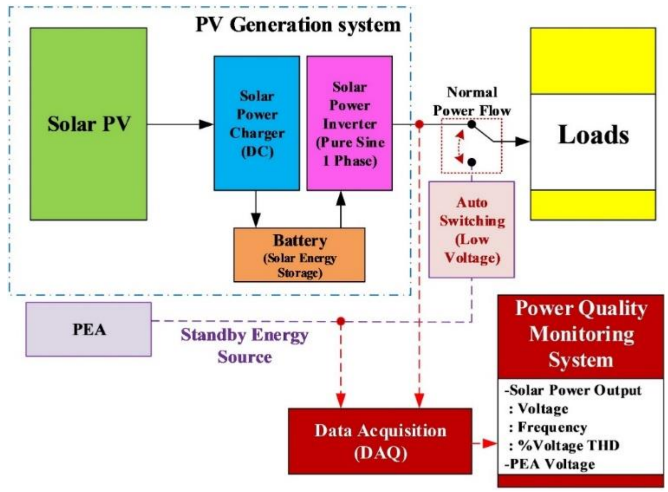


Fig. 1 Solar power plant and voltage quality monitoring system.

As shown in Fig. 1, the electrical power generated by the solar cell is charged to the energy storage unit **[**11, 12**]** to store energy through a charge controller; if power is applied, the system will supply electricity from the battery through the inverter to convert the DC to AC power and ensure stable power supply to the load. The solar power generation system that has been designed will draw power from the provincial electricity authority (PEA) system to supply the load instead if the voltage in the system is insufficient. In the design, a prototype for a solar power plant output voltage monitoring system was developed for real-time voltage quality monitoring.

Results of the study of load volume and load operating time

The study of load volume and load operating time were considered based on the power electric factor and the actual consumption in the beef farm, which can be subdivided into three parts. The first part, beef cattle shed 1, uses the area for raising beef cattle, and the second part is the beef cattle shed 2, which is the part where the farm is being renovated to be used to raise cows and store hay and feed for beef cattle. The third part is the officer's accommodation area. It was found that the farms consumed an average of 25,417 Wh of electricity over 24 h. In the study, energy consumption reductions were emphasized. The first part was to reduce energy consumption in the farm area and beef stable 1 with an overall load of 406 W or 5,873 Wh, which is estimated to be 23.10% of the total electricity used in beef cattle farms. The study of the working pattern for the load group in beef stable 1 and the change in the load during 1 day can be shown in Fig. 2, while the photovoltaic power model and overall load are shown in Fig.3.

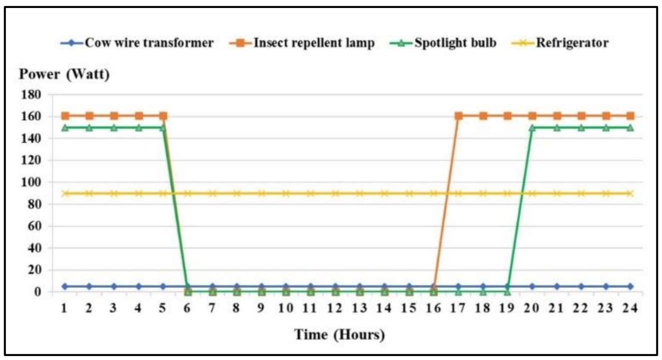


Fig. 2 Electrical load profile in one day.

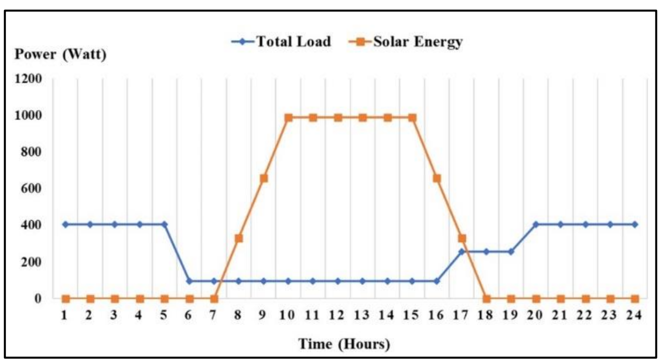


Fig. 3 Solar power and overall load in one day.

Results of calculating the amount of electrical power in Watt-Hours (Wh)

This research focuses on the design of a photovoltaic power generation system to support the load in a beef cattle shed with an overall load of 406 W and energy consumption of 5,873 Wh. In the calculations, the efficiency of the inverter must be taken into account, which is usually around 90 – 95%. In this study, the efficiency of the MPPT inverter was considered, which was roughly 95%. Therefore, considering the calculated load of approximately 5,873 Wh, the calculation can be shown in Eq. (1).

$$\text{Total Loads} = \frac{5{,}873}{0.65} = 6{,}182\ \text{Wh} \tag{1}$$

Results of calculating the size of battery capacity

In designing the battery size, determination is made from the total electricity consumption of 6,182 Wh and the required system voltage, which in this research was designed at 24 Vdc. Thus, the current value can be calculated as in Eq. (2).

$$I = \frac{P}{V} = \frac{6{,}182}{24} = 257.58\ \text{Ah} \tag{2}$$

The required capacity of the battery is 257.58 Ah. In general, the power supplies of a battery are an important factor to consider in terms of the percentage of energy stored by the battery, called depth of discharge (DOD).

The design is intended to discharge the battery at a depth of 60% to extend its life. Therefore, calculating the battery size can be expressed in Eq. (3).

$$\text{Battery capacity} = \frac{\text{Battery (Ah)}}{\text{DOD (\%)}} = \frac{257.58}{0.6} = 429.3\ \text{Ah} \tag{3}$$

The battery capacity is 429.30 Ah at 24 Vdc, but considering the available battery data in the market, it can be concluded by choosing a battery size of 12 V 120 Ah. Four pieces are connected in series with two sets of batteries and then connected in parallel; the total capacity of the battery is 480 Ah 12 Vdc.

Results of calculating the size of the inverter

In the calculations to determine the inverter size, it is calculated from the overall load in the calculations to determine the size of the inverter. The total load is calculated that adds an allowance for the changed load with the load to be supplied by setting the allowance at 25% of the load, as shown in Eq. (4).

$$\frac{\text{Total Loads (W)} \times 25}{100} + \text{Total Loads (W)} \tag{4}$$

$$= \frac{406 \times 25}{100} + 406 = 507.50\ \text{W}$$

In selecting the inverter size, the size must be higher than the calculated value when comparing the sizes of inverters available in the market. Therefore, a 750 W inverter was used in the study.

Results of calculating the size and number of solar cells

In calculating the size and number of solar cells relative to the type of charger to be used, charging hours per day are taken into account by considering the daily amount of sunlight. Typically, 5 – 6 h are considered. In this study, 6 h of charging time was taken into account (9:30 – 15:30), with calculations shown in Eq. (5).

$$\text{PV Capacity} = \frac{\text{Totalload (Wh)}}{\text{Charging Time}} = \frac{5{,}873}{6} = 978.83\ \text{W} \quad (5)$$

Therefore, the capacity of the solar cell is 978.83 W and the size of each panel affects how many are needed; if you choose to use a 330 W panel, you will get the number of panels. This can be shown in Eq. (6), but the actual implementation selects an integer to round up, so 330 W are used for three panels each.

$$\text{PV Quantity} = \frac{\text{Total PV Capacity}}{\text{PV Capacity (Selected)}} = \frac{978.83}{330} = 2.96\ \text{Panels} \quad (6)$$

Results of calculating the size of the charger

Calculating the size of the charger can be determined from Eq. (7), in the design. An allowance of 25% must be taken into account to prevent the charger from being damaged due to overload using the calculation shown in Eq. (7).

$$\text{Charger Capacity} = \text{Total PV Capacity} \times 1.25 = 990 \times 1.25 = 1{,}238\ \text{W} \quad (7)$$

Considering the size of the selected charger must be higher than the calculated value and the voltage of the panel set to be connected to the inverter, which must be able to withstand the voltage from the solar panel set. In the market, the charger that is sold is 1,500 W with a high input voltage of 150 Vdc. It can charge a maximum current of 62 A at an output voltage of 24 Vdc.

From the results of the design of the photovoltaic system for electric load in a farm area and a beef cowshed, the load amount is 507.5 W, including an allowance of 25%. The energy used in 1 day is 5,873 Wh, which can be summarized as follows:

Three 330 W panel sizes and 990 W power output, 750 W inverter, 1,500 W charger (24 Vdc, 62 A), 12 V battery 120 Ah of 4 units connected to a 24 V system, the current value of 480 Ah by installing a solar panel power generation and energy storage unit can be seen in Fig. 4.

Fig. 4 Installation of a solar power generation and energy storage unit.

Results of the voltage quality monitoring system

In the design of the solar power generation and voltage quality monitoring system, the LabVIEW program and data acquisition (DAQ) were used. In the design of the system, it is intended to be able to measure the voltage quality of solar power plant output as well as measure the voltage of the Provincial Electricity Authority (PEA). The solar voltage quality measurement can be seen in Fig. 5, and the block diagram of solar voltage quality monitoring can be seen in Fig. 61. The LabVIEW front panels in the design and study results can be seen in Fig. 7 and 8, respectively, which are displayed only on a computer and recorded during the night. In Fig. 7, the voltage monitoring unit is shown with voltage waveform and voltage values designed to show real-time monitoring results. In addition, the design has also devised a monitoring system for checking the voltage level of external agencies, which here is the voltage level of the PEA and whether or not the system is ready to supply electricity. It is designed to display the AC voltage on the display screen. The voltage reading accuracy compared to standard equipment is -0.65 percent as compared with a LuZino multimeter 7000728 model. The output voltage from the inverter is shown in Fig. 8. In the solar voltage quality monitoring system, the inverter output voltage was measured and analyzed by designing the voltage total harmonic distortion (%THD), fundamental harmonics and voltage frequency. The measurement results showed that the frequency of the voltage being supplied is 49.97 Hz, with the fundamental frequency being close to the Thai standard frequency, which is 50 Hz. The %THD of voltage is 8.65%

and the average output voltage is 237.76 Vac (Vrms). PEA standby power voltage is 208.60 Vac (Vrms).

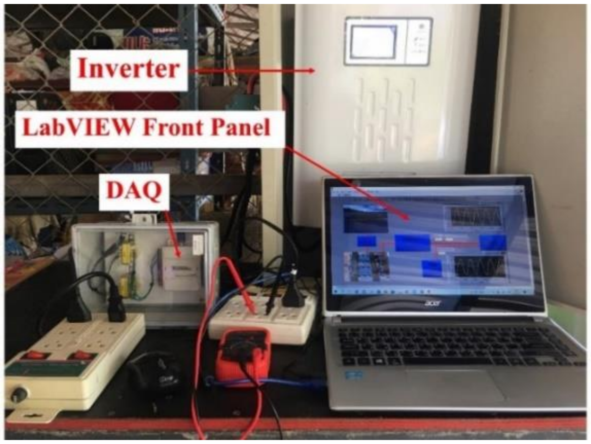


Fig. 5 Solar voltage quality measurement.

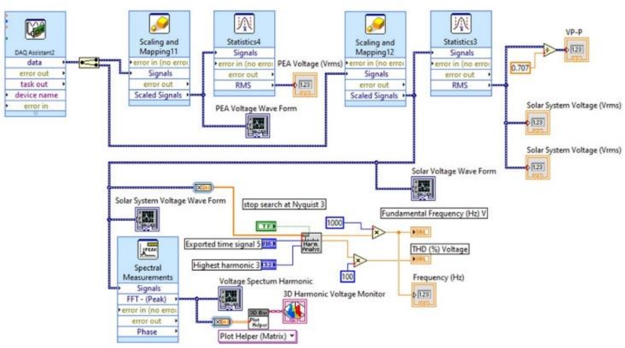


Fig. 6 Block diagram of solar voltage quality monitoring.

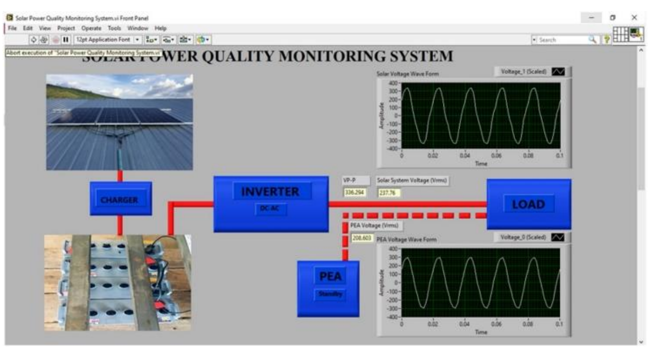


Fig. 7 The LabVIEW front panel of the solar voltage monitoring system.

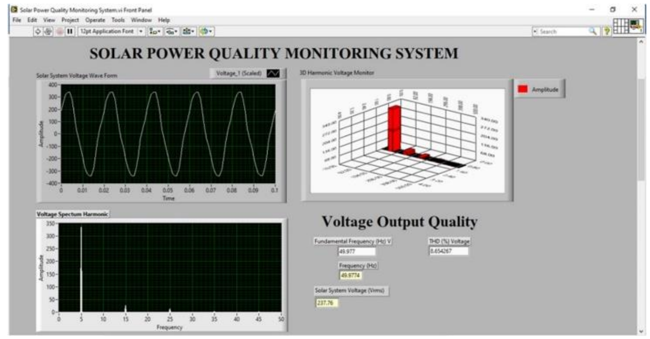


Fig. 8 The LabVIEW front panel of the solar output voltage quality monitoring system.

Conclusion

The results for the design of the solar power generation system, together with the energy storage kit, were designed for the beef cattle breeding group, Na Yom Sub-district, Mueang District, Phetchabun Province. A beef cowshed with a load of 507.50 W includes an allowance of 25%. The energy used each day is 5,873 Wh. The design of the power generation system can be summarized as follows: The solar panel uses three 330 W panels with a power output of 990 W, a 750 W inverter, a 1500 W charger (24 Vdc, 62 A), and four 12 V 120 Ah batteries. A 24 V system was connected to a current of 480 Ah. In the design and construction of the prototype for a power quality monitoring system, the LabVIEW program was used. The voltage quality monitoring system can be divided into the output voltage level, THD%, fundamental harmonics and voltage frequency. A sample of the measurement results found that the frequency of the voltage being supplied was 49.97 Hz by the fundamental frequency, which is close to the Thai standard frequency of 50 Hz; THD% of the voltage is 8.65% and the average supply voltage is 237.76 Vac (Vrms).

Suggestions

This prototype focuses only on the voltage quality of solar power generation systems. However, the development of innovative instrumentation is essential for more comprehensive power quality monitoring, which can add additional monitoring functions such as reactive power, THD_i, PF, voltage fluctuation, phase angle, etc.

In addition to the application of solar power generation technology in beef cattle production, it can help increase productivity in beef cattle production by reducing the cost of electricity. This photovoltaic power generation system can then be developed into a microgrid system to create energy strength in communities if a group of beef cattle farmers are interested in applying solar cell power generation technology extensively. Further, cattle raisers for technology used to monitor the performance of solar power generation systems can be developed to measure energy consumption in cattle houses for energy planning and energy conservation, which is another way to reduce the cost of using energy and increase productivity in beef cattle production.

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