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The integration of renewable energy sources and IoT devices as a future sustainable energy solution

TY Bunly, and CHEY Chan Oeurn*
Graduate School of Science, Royal University of Phnom Penh, Russian Federation Boulevard, Toul Kork, Phnom Penh, Cambodia
*Corresponding Author: CHEY Chan Oeurn (chanoeurn@rupp.edu.kh)

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សង្ខិត្តន័យ

បច្ចុប្បន្ននេះ ការផ្គត់ផ្គង់ថាមពលអគ្គិសនីនៅប្រទេសកម្ពុជានៅមានការខ្វះខាតនៅឡើយ។ ការខ្វះខាតនេះបណ្តាលមកពីការផលិតថាមពលមិនទាន់គ្រប់គ្រាន់ និងការប្រើប្រាស់ថាមពលអគ្គិសនីមិនទាន់មានប្រសិទ្ធភាពខ្ពស់នៅឡើយ។ ការស្រាវជ្រាវនេះមានគោលបំណងដោះស្រាយបញ្ហានេះតាមរយៈការរៀបចំប្រព័ន្ធអគ្គិសនីតាមផ្ទះនិងតាមអាគារនានាដោយប្រើបន្ទះសូឡាដែលមានកុងតាក់អាចគ្រប់គ្រងការប្រើប្រាស់ថាមពលអគ្គិសនីពីចំងាយដើម្បីសន្សំថាមពល។ ប្រព័ន្ធថ្មីនេះរួមមានបន្ទះសូឡា on-grid បណ្តាញអគ្គិសនីដែលមានតាមផ្ទះស្រាប់ ប្រព័ន្ធនានាសម្រាប់ប្រមូលទិន្នន័យ និងប្រព័ន្ធកុងតាក់ online។ លទ្ធផលពិសោធបានបង្ហាញថា បន្ទះសូឡា 130-watts មានសមត្ថភាពផលិតថាមពលអគ្គិសនីបាន ១៧៦.៩៦kWh ក្នុងមួយឆ្នាំ ដែលសមាមាត្រទៅនឹងថវិកាប្រមាណ១៣២,៧២០.00រៀល ហើយប្រសិនបើឧបករណ៍ IoT ត្រូវបានប្រើសម្រាប់គ្រប់គ្រងការប្រើប្រាស់ថាមពលអគ្គិសនី វានឹងអាចជួយសន្សំថាមពលបានមួយកម្រិត

ទៀត។ របៀបថ្មីនេះផ្ដល់នូវភាពងាយស្រួលក្នុងការប្រើប្រាស់ថាមពលស្អាត និងនាំមកនូវអត្ថប្រយោជន៍នានាផ្នែកសេដ្ឋកិច្ច បរិស្ថាន និងសង្គមទៀតផង។

Abstract

Cambodia still faces significant constraints in supplying adequate electricity to its citizens. Currently, energy shortages tend to derive from both limited energy generation and inefficient energy consumption. This research explores alternatives to this situation via the use of innovative technologies. It seeks to integrate solar panels with energy grids in buildings, equipped with online switches for controlling these systems, to save energy. The proposed system uses a combination of on-grid solar systems, the existing grid, systems for data collection, as well as online switches. An experimental model was used to demonstrate that a 130-watt solar panel has the capacity to generate 176.96 kWh per annum, equivalent to 132,720 KHR; if used with IoT devices to collect data to efficiently control the system. This innovative approach enables easy access to clean energy, leading to benefits for the economy, environment and society.

Keywords: on-grid solar systems, SMART grids, online switches

Introduction

Energy consumption in Cambodia is increasing due to population growth and economic development. Current electricity shortages affect economic activities, social development and wellbeing. Sufficient electricity is required to support the development of many industries, including small to medium enterprises (SMEs) in the textile and agricultural sectors. According to Cambodia Basic Energy Plan, 2019, the electricity demand increased by 18% per year and the power generation increased by 19% per year between 2010 and 2016. The Cambodia Energy Outlook also reports that its electricity demand will increase by 7.5 times between 2015 and 2040. To maintain affordability and security, the Basic Energy Plan of Cambodia recommends that the power generation mix in 2030 should be 35%, 55%, and 10% of coal, hydropower and renewable energy, respectively (ERIA, 2019).

Even though, energy demand in Cambodia has gradually increased with economic development, this has negatively impacted the environment. Moreover, between April and May 2018, Cambodia faced significant energy shortages as a result of low dam levels, with existing hydropower stations producing only 30% of their regular output (CDC, 2019). Additionally, there was increased energy consumption in households via greater use of electrical appliances. In response, the Ministry of Mines and Energy (MME) planned the delivery of a range of infrastructure projects by 2020; including a 20 MW solar system in Kampong Speu, a 30 MW system in Pursat, a 60 MW system in Battambang, a 30 MW in Banteay Meanchey; as well as a 400 MW coal-fired power station (CDC, 2019).

Electricity shortages affect the living conditions and livelihoods of Cambodian people. This problem is partially linked to inefficient energy consumption. For instance, many household users do not switch off circuit breakers when they leave buildings. Moreover, renewable energy sources, such as solar-voltaic systems may be capable of meeting some of the unmet demand in Cambodia; but they are expensive and require an improved capacity in the country to implement them. Advanced technologies such as SMART meters, which gather energy consumption data, connected to on-grid systems may result in further benefits, such as reduced CO_2 emissions.

This research examines how solar on grid systems may take advantage of the weather conditions in Cambodia more effectively by using the combination of solar on grid and smart controlling online switches. It proposes the measurement of consumption data to develop strategies for saving energy. Specific objectives include: (1) integrating solar energy with a centralised grid; and (2) the collection of data using IoT smart devices for controlling electricity use via online. It is assumed that this system will improve access to clean energy for the benefit of the economy and society.

Literature Review

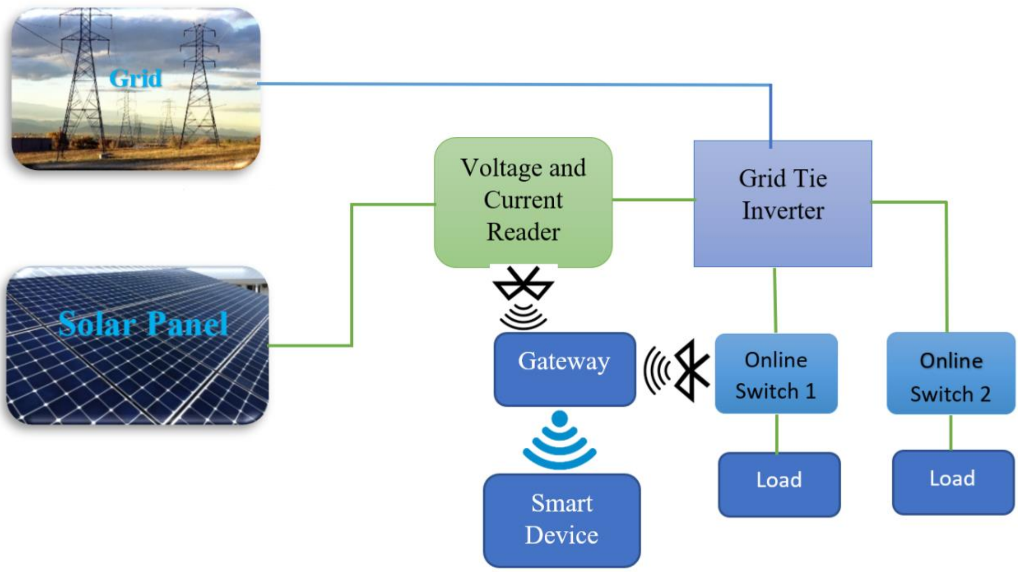
New technologies are required to respond to needs for electricity in every sector in Cambodia. Photo-voltaic systems have the potential to be quite useful and powerful, as other energy sources have a significant environmental impact. Enhancing the efficiency of energy consumption with IoT devices has the potential to make solar equipment more effective and improve the quality of life of people in Cambodia. Among IoT applications, smart homes are expected to have the most significant potential in the near future (Shuhaiber, 2018). Over the past few years, cloud computing initiatives have been used to collect data to be used for intelligently managing energy consumption in buildings (Khan et al., 2017). Technology upgrades, such as smart home appliances have been used to help facilitate this, using mobile phones to remotely control energy consumption.

The use of big data and cloud computing to monitoring energy consumption through sensor management, IoT devices, and smart phones has become increasingly significant (Plageras et al, 2018) among researchers and policy makers. Although a number of IoT systems have been proposed for use with smart buildings, on-grid solar systems with the capacity to collect data and alter the distribution of loads are a priority. Using smart devices to lower energy consumption is a key factor in the development of sustainable energy solutions, however, the feasibility of integrating these systems into the design of buildings has not yet been tested.

Research Methodology and Process

Figure 1. illustrates IoT devices used in sustainable energy system. The system under examination has been designed to include three major components including an on-grid solar system, a data collection capacity and an online control switch. The on-grid system comprises solar panels, an inverter, and the grid. A data collector sits between the solar panels and the inverter; and online switches are set up between the inverter and the grid. The system utilizes two energy sources to supply electricity and an inverter is used when electricity is required from the grid, or another AC source.

Figure 1. IoT devices used in sustainable energy system



To manage the system, a data collector is added to enable the online switch to control the inverter. Energy produced by the solar system may be used to supply electricity when there is radiation from the sun. This is combined with electricity from the grid if this is not sufficient for consumption. If surplus energy is produced by the solar system, it is transferred to the grid. The connection of this type of system needs to be approved by the electric authority and is limited to a maximum capacity of 40% of the total supply in Cambodia. However, in reality, electricity production and consumption are not always stable; with oversupply a common occurrence. It wastes money if it is not permitted to be supplied to the grid. There are several key points to be noted when designing such a system. First, an analysis of the load and the energy source needs to be conducted to size the system correctly. Second, the on-grids and load connections need to be controlled with an online switch to enable the system to operate.

Online functionality. Many functions have been developed for use on the internet. Data is received and used to control switches. This is applicable in many sectors and is designed to produce energy consumption data, as well as to control the switches. The data may be downloaded to an Excel file for further analysis.

Working example of a solar on-grid system. Photo-voltaic systems depend on both light intensity and the incident angle of the light. Good conditions occur when light intensity is high, with an incident angle that is perpendicular with the surface of panels. In Cambodia, the solar system may work for between 10 and 11 hours daily, however the production energy is not stable over this time. The efficiency of systems using stand fixed panels and sun trackers is different.

The design of data collection. The collection of data from the photo-voltaic system are specific to the design of each system. To access this data, a voltage and current meters are required. This information is transferred via Bluetooth over short distances or via wireless for long distances.

Online Switch. Switches are used to turn the electricity on or off. There are several categories of switches that are commonly used including manual, remote and online types. Online switches may be controlled remotely by smart phone or computer. To enable this control, it is often required for these switches to be linked via both Wireless and Bluetooth.

Experimental Process. There were three main components used in the experiment including grid, data collection and online switch systems. The details of each component are provided in Appendix 1.

Prior to the experiment, a site selection process was a priority task to ensure sufficient light intensity would be achievable, with respect to sun light and a suitable temperature. For this experiment, the system was installed on the top of the Solar Green Energy Cambodia (SOGE) building. The Solar on grid system used in this experiment comprised two 65W solar panels connected in in parallel, a grid connected micro-inverter, a current and voltage meter and online switches (Figure 2).

The configuration of this system is shown in Figure 3. Two solar panels were installed and connected to an inverter to convert DC electricity into AC electricity, which was then combined with electricity from the grid to supply power to the building. During the daytime, when the solar panels could produce sufficient power, it was supplied by solar panels. At other times, power was distributed from the grid. If the inverter was oversupplied, extra electricity was distributed to the grid automatically.

Figure 2. Configuration of the Proposed-On Grid System

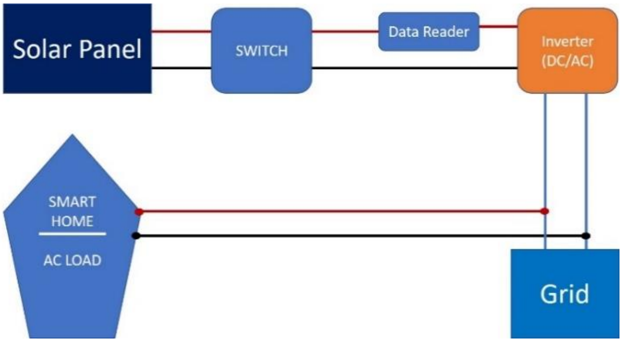
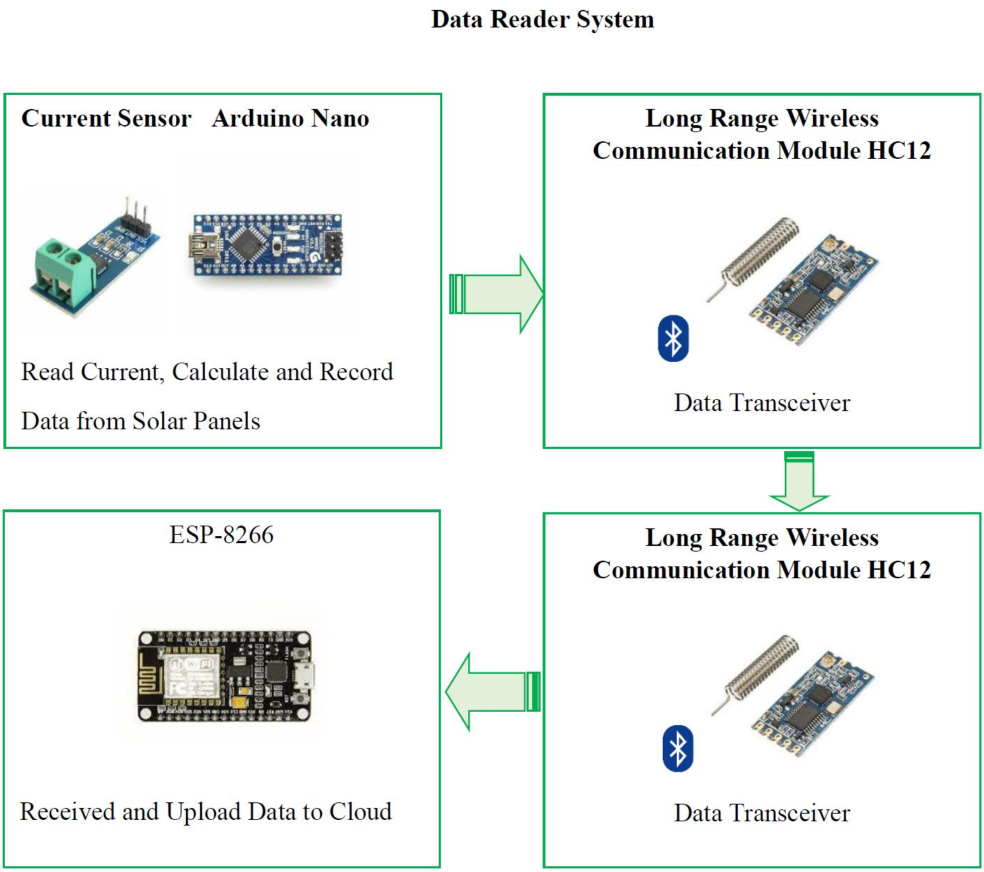


Figure 3. Configuration of the data reader or gateway and switch



To record the amount of energy generated from the solar panels, a data reader system, or gateway, was used. The reader calculated and uploaded data to a web-based cloud, where the information was stored. It measured current, voltage and power generated from the solar panels before transferring this information via a long-range wireless communication module (HC-12 system and ESP-8266).

Results and Discussion

Electricity generated by the solar system

Table 2 displays the results for the electricity generated from the solar system. It was operated from 6:30 am till 5:00 pm. Energy production increased with light intensity as the injection angle of the light became more perpendicular to the surface of the panels. As the panels were fixed, the injection angle changed with the position of the sun. This meant that the energy produced varied over time. When radiation from the sun was perpendicular to the surface of the panel, light was at its highest and a maximum amount of energy was produced. An average electrical energy of 176.96 kWh per year was recorded from the data reader.

Table 2. Electrical energy generated from the 130 W solar system

Average output power (kW)	**Average energy generated per day (kWh)**
42.16×10^{-3}	484.84×10^{-3}
Average electricity from solar panels per year (kWh)	
176966.60×10^{-3}	

The data reader also recorded the average energy generated from one solar panel over various periods between 6:30 am and 5:00 pm, as shown in Table 3.

Table 3. Average electrical power and energy record by Data Reader

Average energy (kWh)	Time	Average power (kW)
55.41×10^{-3}	6:30 am - 9:00 am	15.83×10^{-3}
337.75×10^{-3}	9:00 am - 2:00 pm	67.55×10^{-3}
129.27×10^{-3}	2:00 pm - 5:00 pm	43.09×10^{-3}
	6:30 am – 5:00 pm	42.16×10^{-3}

Online switch control by smart phone

To control the switches remotely, a smart phone or laptop with internet access was required. This enabled it to be seen whether the load was switched on or off. These smart devices were able to control the switches remotely. The signal from the smart devices was transmitted to the gateway online and continued to the switch via a wireless connection. Using the HC-12 short range transmitter and receiver to send information to and from the gateway may help facilitating control in places where WIFI access is limited. They enable data to be sent over a distance of 30 meters.

The use of this experimental model produced knowledge about how this innovative system may help to solve energy issues related to both energy generation and the energy efficiency of buildings. This proposed system demonstrates how the control system, saves time and energy, reducing environmental impact. This experiment shows that an IoT device may be used to detect unusually high levels of energy consumption and manage them from a distance. This model may help to observe and control electrical systems more effectively.

The environmental benefits of energy conservation

To generate electricity, most power plants burn coal, crude oil or other fossil fuels. Although this method of creating energy is relatively inexpensive, there are many environmental impacts. Carbon dioxide, sulfur dioxide and nitrogen oxides are just a few of the byproducts that result from these traditional methods of power generation. Reducing energy consumption reduces the amount of electricity that power plants have to produce, reducing the amount of fossil fuels that are combusted each day. If the experimental system is installed at scale, a large reduction in the volume of CO_2 emissions generated would result. This is a major cause of air pollution and global warming, which are major global environmental issues. It is expected that this system may play a role in addressing some of these issues in the near future.

Conclusion

An innovative system of efficiently integrating renewable energy sources with the grid in Cambodia was tested in terms of the economic and environment benefits it may provide. This was found to be an efficient, effective, and financially viable approach. This means that the proposed system may quickly achieve energy reduction targets by making buildings more energy efficient. The total cost of the control system is approximately 65 USD (current and voltage meters, three Arduino Nano systems, four HC-12, ESP-8266 and relay switches). This is affordable with a short payback period. It is recommended that people who live in the city that require large amounts of electricity to power their houses and buildings use this system to reduce costs and energy consumption. The integration of renewable energy sources into existing grids is an effective approach to solve problems such as the poor energy efficiency, high costs, and limited function of existing systems. It may reduce the need to import energy from neighboring countries importing and reduce Cambodia's volume of CO_2 emissions, with immediate benefits for the country.

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Biography of Authors

Ty Bunly received BSc. in Physics from Royal University of Phnom Penh (RUPP) in 2016 and is currently pursuing his MSc. in Physics at the same institution. He has worked as solar system designer and installer for Solar Green Energy (Cambodia) since 2016.

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Appendix 1. Experimental specifications

Equipment	**Quantity**	**Specification**
On grid system		
Solar panel	2	• 65W
On grid inverter	1	• Grid-tied micro-inverter • Model: 3L2 • Input: 12-28VDC 20A MAX • Output: 180-260VAC 50Hz • Output power: 250 WP, 12V DC 230V AC
Grid	ECD	• Single phase
Data collection		
Voltage and current meter	1	• DC voltage meter • Max voltage: 30V • Current meter • Max current: 30A • HC-12, Arduino Nano
Gateway system	1	• HC-12, ESP 8266
Laptop	1	• Asus
Wireless network and cloud technology	1 set	• Cloud technology
Online switch		
Smart phone	1	• Redmi
Switch	2	• HC-12, Arduino Nano, Relay, MOSFET 1404