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Integration of Kouprey-Inspired Optimization Algorithms with Smart Energy Nodes for Sustainable Energy Management of Agricultural Orchards

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Abstract: Energy expenditures are now the main cost for two businesses that generate huge incomes each year for Thailand, which are agribusiness and community tourism. As entrepreneurs have to share a portion of their income as energy utility bills each month. This is a factor which results in them getting a low net return. Recognizing the need for energy management for sustainable use in agriculture focusing on durian cultivation in Kantharalak district and community tourism in Sisaket province, this research used a newly developed optimization algorithm called Kouprey-inspired optimization (KIO) to assist energy management in smart agriculture to support community-based tourism. This was initiated with a smart energy node to reduce the energy and labor costs for volcanic durian planting and accommodation in community-based tourist attractions in Sisaket province. The results showed that the combination of the KIO algorithm and smart energy node allowed for efficient management of the volcanic durian orchards and the use of clean energy in combination with traditional electric power for volcanic durian cultivation and community-based tourism. As the research area in Sisaket province had eight hours of solar power per day, this was sufficient for smart agriculture and community-based tourism in the daytime and in the evening. Furthermore, this allowed operators in both the agricultural and tourism sectors to reduce the labor costs of the durian orchard business and community-based tourism by about 30%, and in the energy sector, the costs could be reduced by 50%. As a consequence, this prototype would lead to the expansion and trial in durian orchards in the Eastern Economic Corridor area, which is an important economic area producing durian for export of the country.

Keywords: kouprey-inspired optimization; smart energy node; agricultural orchard; Internet of Things; sustainable energy management

1. Introduction

In the digital disruption world with rapid changes, the advances in information technology and engineering surrounded by inexpensive mass production of sensor nodes and the Internet of Things (IoT)technology have demonstrated research and developmental interests in numerous fields like communication, agriculture, industry, smart health, monitoring, business, and tourism [1]. Furthermore, the capability of IoT technology has permitted the operation and collaboration of many devices with different communication and computing capabilities; such as, sensors, actuators, smartphones, and others via a wireless sensor network (WSN), as well as various other smart communication technologies [2]. Simultaneously, the combination of a huge number of interconnected sensor nodes without using wires could form a WSN. Nodes in WSNs are distributed randomly and deployed in areas that are usually not accessible to individuals. Therefore, the topology of the network must be dynamic. The capability of IoT technology has also been used with regularity in agriculture, especially the smart agriculture orchard concept by applying IoT with the sensor nodes to operate independently and construct a network infrastructure in an ad-hoc manner [1,2]. In the aspect of research regarding smart agriculture production, an IoT-based WSN has been used to observe the condition of the yields and automate precision agriculture by using various sensors. Nevertheless, the sensors were deployed in a smart agricultural eco-system to improve production yields through intelligent farming decisions and obtain information regarding crops, plants, temperature measurement, humidity, and irrigation systems. However, the sensors have had limited resources concerning processing, energy, transmitting, and memory capabilities that could negatively impact agricultural production [1–3]. Autonomous wireless sensors represent the core of the WSN, which must deliver data with high reliability, exhibit high energetic performance, as well as provide autonomy. Therefore, the current technology would allow for the development of a large spectrum of sensor-based applications in various fields [1,3].

Figure 1 shows the scenario for a smart agriculture orchard based on various sensors, sink notes, base station (BS), Internet, and PH, temperature, fertilizer, water, heat, and humidity. Nevertheless, a smart agriculture orchard that would rely on seasonal climate in the field has been impacted by climate change with heavy rain, droughts, floods, and unexpected weather conditions that have affected the agricultural ecosystem [1,4,5]. Currently, the WSN has been applied worldwide because of the low cost, easy deployment, and cost-effective environment [1,6,7].

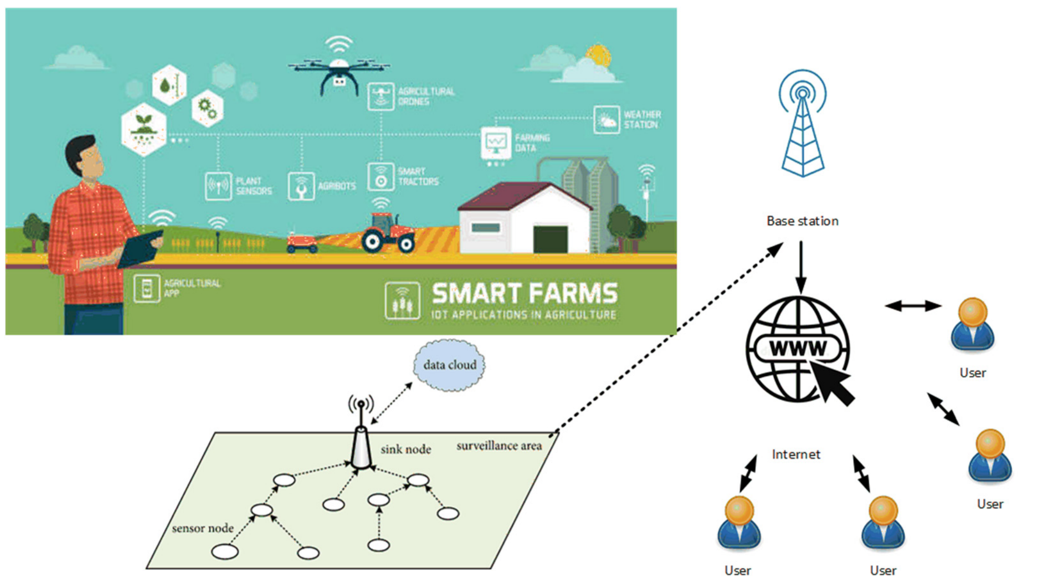

Figure 1. A smart agriculture orchard based on a wireless sensor network (WSN).

Recently, the field of a smart agriculture orchard has performed a vital role in the improvement of the economic growth of many countries; therefore, agriculture should be further developed with modern technologies; such as, an IoT based WSN and integrated with optimization algorithms to reduce time, energy, and human effort leading to increasing the agricultural throughput in the quality of life [1,8–10]. Moreover, sensors could be used for determining the soil, weather, moisture, and temperature conditions. A WSN has also been utilized by many researchers in the domain of agriculture to improve its performance and reduce the agriculturist's burden [1,11,12].

Apart from smart agriculture orchards, a WSN is becoming popular in Thailand, where most Thai people work as agriculturists as the backbone of the country. This has been associated with using energy; such as, oil, gas, and water for the agriculture orchard in their daily life. As the situation about the energy crisis has become a significant issue, management through sustainability is very necessary because energy is a very important factor in Thailand's industry and business sectors. The unexpected rapid increase in energy prices has had a huge impact on the rising costs of agribusiness and tourism [13]. This situation has resulted in entrepreneurs experiencing financial problems and increased the economic risks of different countries. The stability of the energy prices therefore would play a very important role in economic development. However, the situation would be easier if a country had its own natural energy sources including oil and electric power, especially Thailand that is located in an area with abundant natural energy [13,14].

The research area in this research was the Sisaket province of Thailand, where the population was low-income. However, only this area is suitable for volcanic durian cultivation for Thailand, which can generate income for the people in the local community that is becoming widely known as an agro-tourism destination. Due to the uniqueness of volcanic durian that cannot be grown in other areas, there are more agricultural crops in Sisaket province. From an interview and field investigation, it was found that although the volcano durian plantation generated up to 4–5 million Thai Baht per year in income for the owners, the energy, labor, and fertilizer costs were also up to 2–3 million Thai Baht per year. Moreover, the costs of the volcanic durian plantation comprising energy, labor, fertilizer, and water were costs that had never previously been collected and presented. Thus, reducing energy and labor costs using solar energy and Internet of Things (IoT)technology would be an important option to increase the profit for the plantation owners. Therefore, to bridge the gap in the research, the aim of this paper was to improve the energy management for both types of businesses in conjunction with natural energy efficiency to reduce the energy costs with an optimized algorithm consistent with the concept of Roslan et al. [15] and Reddy et al. [16]. Hence, the researchers proposed the Kouprey-inspired optimization (KIO) algorithm for this study because it was simple and fast for establishing a behavioral algorithm. The main process works in three steps: initialized, creating alternatives for solutions, and choosing the most appropriate answer in each round.

2. Literature Review

2.1. Sustainable Energy Management

To make the country drive and develop sustainable business operations in various sectors would require the introduction of new technologies to assist in the management. At present, the problem of energy costs has resulted in less net income from the agricultural and tourism sectors. As a result, people in countries that practice both agriculture and tourism are still impoverished. A tangible way to reduce the costs of the agricultural and tourism businesses would be through sustainable energy management. Sustainable energy is energy that does not affect the environment and people, and the energy itself can be used for a long period of time with a limited budget. This includes solar energy, wind energy, marine energy, biomass energy, or geothermal energy [1,17].

To solve environmental problems effectively, the transition from traditional energy systems to sustainable energy systems would be essential [17]. Achieving a successful energy transition would require the people to change their energy habits and take more sustainable actions in a wide variety of areas. In particular, they would need to exhibit attenuation behavior (e.g., turn down the heater), efficiency behavior (e.g., adopt energy-saving devices), adopt sustainable energy sources; such as, wind or solar, and change when using energy at a sustainable production time with the existing energy [18]. One way to encourage people to adopt sustainable energy behavior is to develop and implement policies to promote this behavior, which would be essential for the policies to be successful in a democratic society. Public acceptance of the policies would be important. This is because low publicly accepted energy policies may be delayed, canceled, or even have repercussions [19].

Moreover, the energy management of the IOT/WSN nodes was presented as a new energy-saving centroid routing protocol (EECRP) to manage the power of the WSN-assisted IoT by solving the spacing-dependent clustering problem. From the power center [20], this also offered an optimization algorithm based on the number of idle nodes and the number of cluster head nodes. Based on the simulation results, when the BS was in the network location, the EECRP could transmit large amounts of data at very low power dissipation. Simultaneously, the network lifetime of the EECRP was longer than that of the LEACH, LEACH-C, and GEEC. Future work would attempt to improve the protocol by routing the multi-hop paths from the CH to BS nodes. Using the CH node to transmit the data packets, it is hoped that their future protocols would be able to do so when the BS is out of the network [21]. In addition, Zhang et al. [22] presented the IEA EHWSN global platform, which provided an optimal power management mechanism for intermittent operation. At a minimal level in an environment without energy harvesting, this could measure the power levels with accuracy of 99.89%, consume only 157 μW, and support strong EH WSN. As for the node performance and cost, the IEA platform used the COT components, so the IEA was not only an experimental platform for the EH-WSN, but also a cost-effective tool to use [23].

2.2. Smart Agriculture for Supporting Community-Based Tourism to Sustainability

Smart agriculture orchards and smart farming are the applications of computer technology; such as, sensors and artificial intelligence (AI) and communication systems like the Internet to be used to aid farming and to ensure accurate management, save labor, and reduce costs in various fields. This could also create a point of interest for the community in terms of creating new learning attractions.

According to the 'Agriculture 2050′ program, the Food and Agriculture Organization of the United Nations (FAO)has projected that the global population would reach approximately 10 billion by the end of 2050 [24]. Therefore, food production should increase approximately by at least 70% to support this population growth [25]. As such, there is an urgent need to improve crop yields, so precision farming and smart farming are very important in today's world. In this regard, technologies related to smart agriculture that include robotics, AI, information and communication technology (ICT), unmanned aerial vehicles (UAV), deep learning (DL), IoT, and big data analytics could effectively address the challenges involved. This would have a positive effect in terms of reducing food scarcity and resource loss [26].

2.3. Research Areas for Smart Agriculture Orchards to Support Community-Based Tourism (CBT)

For this study, the research team selected the area in Kantharalak district, Sisaket province, Thailand. This is located in the Northeastern region of Thailand, and was selected as the research area because it is a district where most of the population is engaged in agriculture. There is an environment suitable for orchards, while there are natural attractions and historical landmarks, which support both agriculture and natural tourism. In this regard, the famous fruit of Kantharalak district and Sisaket province is "volcanic durian"(Figure 2). and this is the only place in the world where this species of the fruit can be found.

However, even though durian is an important fruit of Kantharalak district, Sisaket province that can generate income of several million Thai Baht per year for agriculturists, it is a fruit that requires close care such as, regular watering, fertilizing at the right time, including the control of soil acidity and alkalinity. The fruit has just the right amount of sweetness and a crisp, oily texture [27].

In 2019, the price of volcanic durian in Sisaket province increased to 1200 Thai Baht per kilogram, which was a very high price. Although volcanic durian is highly rewarding for the agriculturists in Sisaket, due to the cost of irrigating and fertilizing, the energy costs for watering and fertilizing the durian orchards are also high, thus causing farmers in some years to suffer losses and labor shortages in providing water and fertilizer to the durian trees. These issues established the research team to realize the importance of energy management used in the durian orchard business for sustainability and solve the economic problems for the agriculturists in Kantharalak district, Sisaket province and become a 'model of development' that could be expanded to other durian orchards in Thailand [28].

Figure 2. Volcanic durian in Kantharak district Sisaket province.

3. Materials and Methods

3.1. Smart Energy Node

The smart energy node in this research was a component of a sustainable energy system developed by the researchers based on the same principles as a smart grid. The general definition of a "smart grid" is a smart system that integrates various technologies. It covers the smart application of those technologies throughout the power system chain from power generation, transmission, and distribution to the consumer sector, including the ability to communicate to collect data and to control the supply and use of energy on its own [29].

A smart grid is an electrical network that transmits electricity in a controlled manner. It also provides several benefits; such as, the growth and efficient management of renewable energy sources. A smart grid generally refers to intelligent technologies related to photovoltaic (PV) systems, storage, buildings, and the environment. In the framework of PV/smart applications, factors like PV promotion/integrated building smart grid configuration and systems assessment in different countries/markets play an important role in the storage of parameters; such as, recycling and non-connected spaces. In addition, the development of smart grids/intelligent systems in the building sector involves zero-energy buildings, indoor and environmental control generation, policy, etc. With regard to the environment, various studies have addressed common environmental issues (e.g., CO_2 emissions and energy efficiency) and no environmental life cycle assessment (E-LCA). There are also several methods for assessing life cycle impacts and environmental indicators. In terms of the above problems, it could be seen that the smart grid/smart system poses several challenges: flexibility and user engagement promotion of renewable energy systems (offshore wind power plant integrated with a solar system in buildings, etc.), energy transfer, etc. [30].

The research to develop to make smart grid devices to be more intelligent has been conducted continuously. Wang et al. [31] proposed blockchain-based architecture for optimal scheduling of deliverable units in a smart grid. Taking into account the increase in the high levels of renewable energy sources, the proposed method leveraged blockchain technology to secure the data exchange between agents in the smart grid and avoided unauthorized access to the real system data. This considered the flexibility that came from optimal switching in the smart grid, which optimized all the operations and reliability index using the honeybee mating (HBM) algorithm.

3.2. Kouprey Inspired Optimization Algorithm

The KIO algorithm was developed by a research team [32]. The KIO was inspired by the kouprey, a type of wild bovine that was once found in Sisaket province. In order to obtain a suitable model of finding an optimal answer, the researchers studied the migration patterns of the kouprey herd, which were written as the migration patterns and directions.

The reason for using KIO was that it was more suitable than other algorithms because the population of the cows in the Kouprey herd was usually around 20, which corresponded to the number of smart energy nodes. Then, candidate solutions were created from only three cows to compete with the best cows based on a mere three-way splitting behavior to shake (perturb) the best value and to find the values that had a chance to be more appropriate. This enabled the exploration features to be achieved with very little processing time. This was based on the Equations (1)–(3) of creating the candidate solutions to compete with the best.

$$\text{x\_new1} = \text{x\_best} + \sin(135), \tag{1}$$

$$\text{x\_new2} = \text{x\_best} + \sin(315), \tag{2}$$

$$\text{x\_new3} = \text{x\_best} + \sin(90), \tag{3}$$

From Equations (1)–(3) for creating the three best competitor solutions, when converted to the Matlab code and timed with the tictoc function, it was found that the processing time was very fast.

This was a computational feature that was suitable for the tasks that needed to be consistent with the changes in the sunlight and time to avoid breakdowns in the electrical equipment due to changing the power sources. Compared to algorithms like particle swarm optimization (pso), it was found that updating the position of the population in the pso was more complicated to calculate.

$$v_i = Wv_i + c_1 r_1 (P_{best,i} - x_i) + c_2 r_2 (g_{best} - x_i), \tag{4}$$

$$x_i = x_i + v_i, \tag{5}$$

The research results found that the problem of choosing multiple power sources to reduce energy costs was a major issue. Furthermore, the importance of this problem was recognized to be consistent with the findings of Warkozek et al. [33], who defined and analyzed optimal energy management in multisource systems. An overview of the research model of the selection of the power source is shown in Figure 3. Based on Figure 3, the research team adapted the linear formula of our optimization problem according to Equation (1) of Warkozek et al. [34].

However, Warkozek et al.'s study [33] was not used as a benchmark, but their model was adapted to more advanced technologies like the Internet of Things (IoT) and optimization to be suitable for the situation of the research area in Thailand. Hence, this issue focused on processing the speed, ease of implementation, and knowledge transfer. Since many people in both the agricultural and tourism sectors in the research area were not very knowledgeable and did not have much capital for investment, the KIO algorithms were suitable for this research study's implementation.

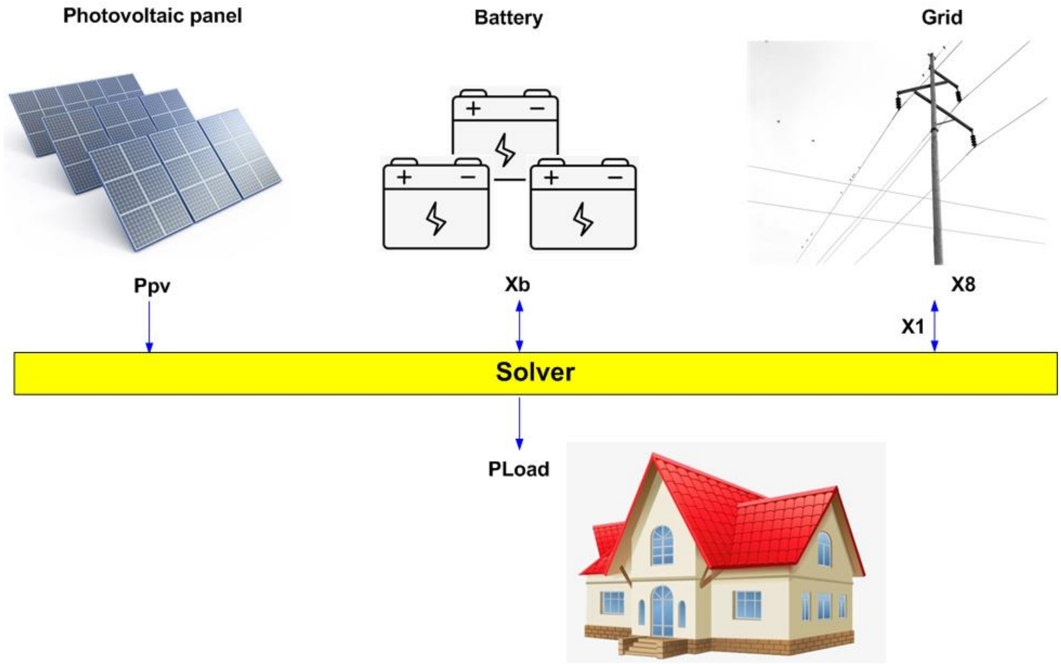

Figure 3. Overview of a multi-source system.

Based on Equation (6), this was an overview of the energy management system that aimed to achieve a value close to 0 when the solar cell was used and subtracted from the normal power, which was consistent with Warkozek et al.'s [29]. concept. However, the true equations to change the power source were Equations (6) and (7).

$$E_{selecttion} = \left(\sum_{i=1}^{N} Smart\_Energy\_Nodes \right) > Traditional\_power\_source, \quad (6)$$

where

$E_{selecttion}$ stands for selected power source.

$\sum_{i=1}^{N} Smart\_Energy\_Nodes$ refers to the sum of energy from all Smart Energy Nodes in the system.

$Traditional\_power\_source$ refers to the traditional power source.

$$e_{Total} = obj(V_{node1}) + obj(V_{node2}) + obj(V_{node3}) + \ldots\ obj(V_{node\_n}), \quad (7)$$

where

e_{Total} stands for the energy value of all nodes.

$obj(V_{node})$ refers to the objective function obtained by reading the battery power in the node using the Voltage Sensor.

V_{node} refers to energy of each node.

$$x_1^{(t)} + x_2^{(t)} - x_3^{(t)} = 0 \quad (8)$$

where

$x_1^{(t)}$ stands for power required from conventional energy source at t: time step.

$x_2^{(t)}$ refers to amount of energy exchanged with the storage system in the battery (kWh) at t: time step.

$x_3^{(t)}$ refers to the surplus energy from smart energy source at *t*: time step.

From the above equation, the least power from the conventional energy source at the time step *t* was needed. This was a result of the use of power from the battery of the system, and the excess energy that the system produced and supplied to the Smart Energy System, which was sufficient to meet the load requirements at time step *t*.

This research used KIO because it was faster than a classic algorithm such as the genetic algorithm because KIO only had three steps as mentioned above, which were faster than that of the selection, crossover, and mutation process in the genetic algorithm [3]. Since the change between normal power and photovoltaic power had to be done quickly, this required a simple and fast establishing algorithm like KIO.

This algorithm was more suitable for managing the power between two sources than other classical algorithms. Due to the faster response of the finding of the answers, there was a real time that corresponded to the change in the amount of sunlight. There was also a simple processing procedure, which was easy to understand and modify than that of the classical algorithms.

In this research, all the wild bulls or koupreys (Figures 4 and 5) could be transformed into the best in every cycle with the best foraging cows being promoted to the "Best". There was also a new herd leader, where all the cows would follow the leader to the food source. In this case, the cow's food source was the amount of electricity generated from the energy. Solar energy from smart energy nodes was read by the input voltage sensor coming to the ESP32 microcontroller board attached to each smart energy node, and passing the HTTP protocol to the system server to determine the source selection between the smart energy nodes or conventional energy source.

Figure 4. Areas where the presence of kouprey herds on the border of Thailand, Cambodia, and Lao PDR. have been found.

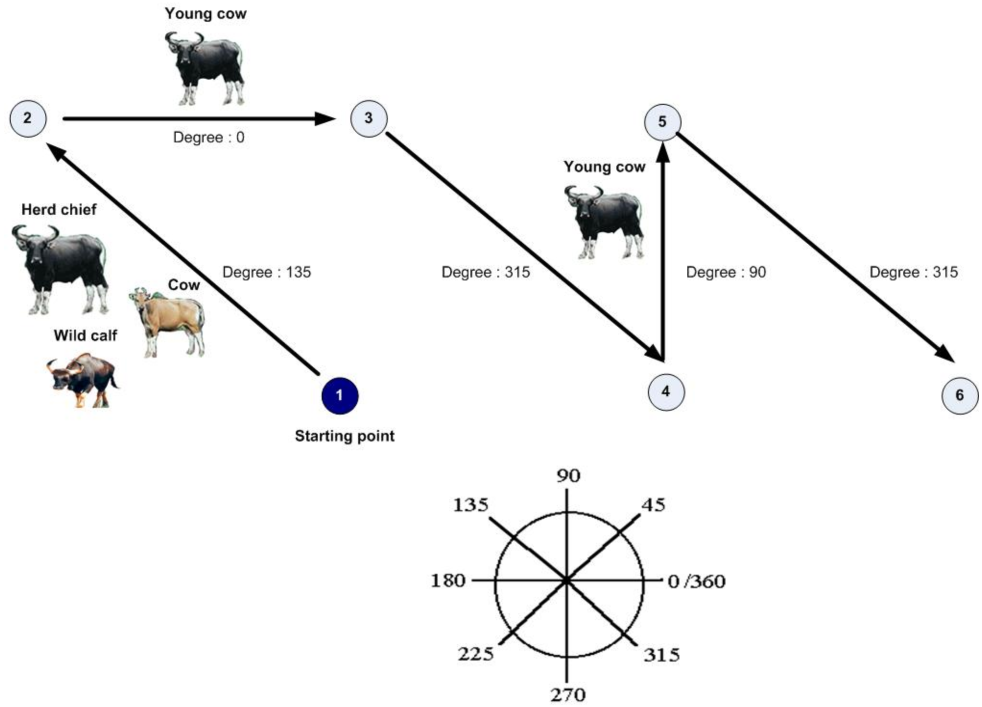

Figure 5. The behavior of the kouprey herd over the years reveals the pattern and direction of the herd's migration.

From the study of the Kouprey and the migratory pattern of the herd (Show in Algorithm 1), the research team designed an optimization algorithm named KIO, which has the following processing steps:

Algorithm 1

Initialization:
Obj. function: $\boldsymbol{f(x) = (x_1, x_2, x_3, \ldots x_n)}$
Generate Kouprey herd randomly
Generate run group around Herd Chief ($\boldsymbol{x_{best}}$)
Generate run direction vector
For every iteration **do**
Compute the herd center
Compute the candidate x_{new}(young cow) with
$\boldsymbol{x_{old} + sin(135), x_{old} + sin(315),\ or\ x_{old} + sin(90)}$
For young cow ($\boldsymbol{x_{new}}$) **do**
Compare $\boldsymbol{x_{new}}$with $\boldsymbol{x_{old}}$
$\boldsymbol{if(x_{new}) > f(x_{old})}$ then move to $\boldsymbol{x_{new}}$
End
Compute the newer herd cheif
$\boldsymbol{f(x_{new}) > f(x_{best})}$ then $\boldsymbol{x_{best} = x_{new}}$
Sort Kouprey herd
End

To create a default Kouprey group, the number of Dimensions, Upper Bound, and Lower Bound are used to generate a random number as shown in Equation (9)

$$x = rand(1, dim) \times (Upperbound - Lowerbound) + Lowerbound, \quad (9)$$

where

x stands for initial population of Kouprey.
dim refers to the dimensions of problem.

Meanwhile, creating an alternative population of Kouprey $\boldsymbol{x_{new}}$ for each cycle to create a new solution uses the perturbation of $\boldsymbol{x_{old}}$ with Equations (10)–(12).

$$\boldsymbol{x_{new}} = \boldsymbol{x_{old}} + \boldsymbol{sin}(\mathbf{135}), \quad (10)$$

$$\boldsymbol{x_{new}} = \boldsymbol{x_{old}} + \boldsymbol{sin}(\mathbf{315}), \quad (11)$$

$$\boldsymbol{x_{new}} = \boldsymbol{x_{old}} + \boldsymbol{sin}(\mathbf{90}), \quad (12)$$

where

$\boldsymbol{x_{new}}$ stands for new $\boldsymbol{x}$.

$\boldsymbol{sin}(\mathbf{135})$, $\boldsymbol{sin}(\mathbf{315})$, $\boldsymbol{sin}(\mathbf{90})$ refers to the perturbation of $\boldsymbol{x_{old}}$ which corresponds to the migration of the Kouprey herd.

In order to manage the energy of the smart energy node together with the traditional electric power of the agribusiness and tourism entrepreneurs in Sisaket province to be efficient and sustainable, the researcher carried out the following research procedures: (1) Conducted relevant research studies; (2) designed the system's architectural design; (3) implemented the development of the platform; (4) collected data to create a valued algorithm model; (5)practiced the operation of the algorithm; (6) tested the operation of the algorithm and equipment for energy management; and (7)performed an evaluation of the system performance.

Figure 6 shows that the smart energy nodes generated electricity for use both in the durian plantation and for supply to the tourist homes. It selected the power supply based on the power level and took into account the time conditions to maximize the extraction of solar power from the normal power, especially during the day. Moreover, in this research not only were smart energy nodes used to generate and control the distribution of electricity to use in the durian plantation activities, but also they would be used as a power source to supply to the information source in community-based tourism and homestays near the durian plantation area. When a guest entered a villa in the vicinity of the smart energy node, the electricity would be supplied by selecting the most energy-efficient power source, and during the day, the power supply to the villa would be selected from the battery. The smart energy node would use a light sensor to act as a switch.

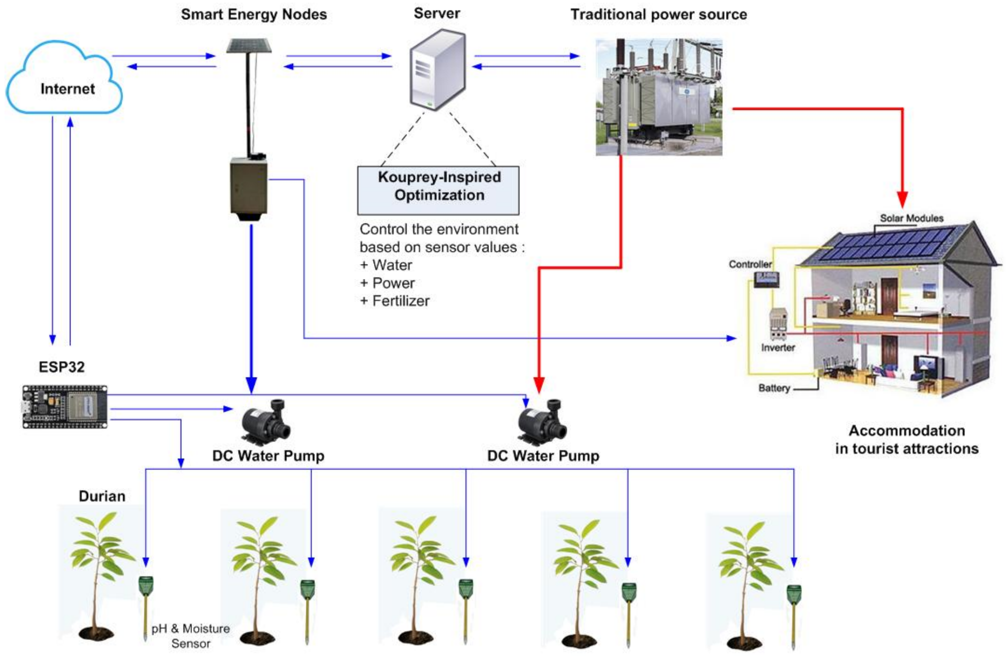

Figure 6. Theoretical framework.

As shown in Figure 6, the power levels from each smart energy node were measured with a voltage sensor and fed to the ESP32 microcontroller board within each smart energy node in the system. It was then transmitted from each smart energy node to the server at the center of the system via the HTTP protocol. At the host computer of the system equipped with the KIO algorithm, the energy generated from each smart energy node was inputted into the optimization equation to decide whether to supply electricity from the smart energy nodes from the conventional energy source to the durian plantation and homestays.

In this research, a PV controller was continued to be used to control the charge from the solar panels to the batteries that were distributed in different smart nodes, and charge it to its battery. Therefore, the ESP32 board was used to connect to each battery voltage sensor and transmit the data from the smart energy node distributed via the HTTP protocol to the system center with the server and process the KIO algorithm to choose between the power sources from the smart energy nodes or conventional energy sources.

In this study, important information; such as, the power level obtained from each smart energy node was transmitted to the system's servers via the HTTP protocol, which was the standard protocol for communicating over the Internet. This was because in this research, the smart energy node was not just a power generator, but also functioned as a small web server. The system was the communication between the server and the server itself. When the data of each node were gathered in the center of the system running the KIO algorithm inside the system's main server, it was just a normal internal computer process.

After conducting the relevant research studies, the research team designed the architecture of an intelligent energy management system between the solar energy and traditional electricity systems used in the durian orchards and community-based tourism in Kantharalak district, Sisaket province. The system used sensors to measure the environment in the durian orchards, including the soil moisture and pH, to send to the smart energy node to control the distribution of water and fertilizer to the durian trees using solar energy. In addition, the energy from the smart energy node was considered in conjunction with the traditional electric power for the selection of the energy sources that would be used to power accommodation in the tourist attractions and community's accommodation.

In this research, the selection of energy sources to supply the smart durian orchards and accommodation in community-based tourist attractions in Kantharalak district, Sisaket Province can be seen in Equation (13).

$$E_{selecttion} = \left(\sum_{i=1}^{N} Smart\_Energy\_Nodes \right) > Traditional\_power\_source, \qquad (13)$$

where

$E_{selecttion}$ stands forselected power source.

$\sum_{i=1}^{N} Smart\_Energy\_Nodes$ refers to the sum of energy from all Smart Energy Nodes in the system.

$Traditional\_power\_source$ refers to the traditional power source.

Equation (6) shows the conditions for selecting power supply for smart durian plantation and community accommodation in Kantharalak District, Sisaket Province. It selects the power source from smart energy nodes when the sum of all smart energy nodes is greater than that of the energy from the original power source.

Meanwhile, the total energy value from all smart energy nodes is obtained by measuring the voltage value of each smart energy nodes with Equation (14).

$$e_{Total} = obj(V_{node1}) + obj(V_{node2}) + obj(V_{node3}) + \ldots obj(V_{node_n}), \qquad (14)$$

where

e_{Total} stands for the energy value of all nodes.

$obj(V_{node})$ refers to the objective function obtained by reading the battery power in the node using the Voltage Sensor.
V_{node} refers to energy of each node.

From the literature review, it was found that the duration of intense solar radiation and the energy required by humans had increased as noted by Warkozek et al. [29]. This was consistent with the concept of this current research. Solar power generation efficiency increased during the solar radiation period after 12.00 h., when the experiment was performed and the results were compiled (Table 1), which was consistent with the findings of Warkozek et al. [32] in Figure 3. This time in Thailand is a period of rising temperatures that make homes and households need more energy. Therefore, the use of electricity from the smart energy nodes during this period would greatly reduce the cost of electricity in the orchards, houses, and homestays.

Table 1. Shows the cost of electricity that can be reduced by using energy from the Smart Energy Node.

	Solar Panel Power Generation			
	1.5 kW	**3 kW**	**5 kW**	**10 kW**
Lower electricity bill	850–1000 Baht	1700–2000 Baht	2550–3000 Baht	5100–6000 Baht

4. Results

In addition, the research results demonstrated that durian agriculturists and community-based tour operators in the research area could manage the energy consumption by using a smart power node integrated with a KIO algorithm to transfer between normal use and photovoltaic power efficiently and sustainably. This was the result of testing in a control environment and real environment (Figures 7–10).

Figure 7. Testing to determine when solar power could be generated.

In the system proposed in the current research, both the smart energy node and the KIO at the center of the system worked together as one framework. This was designed as such because if the KIO algorithms were deployed directly to each smart energy node, it would cost more to supply a higher priced controller board to each node, which was not ideal. In addition, deploying the KIO algorithm into every smart energy node would make it difficult to develop a new communication protocol and make the implementation of this framework to be undertaken step-by-step, including requiring a large number of experts to deploy the system.

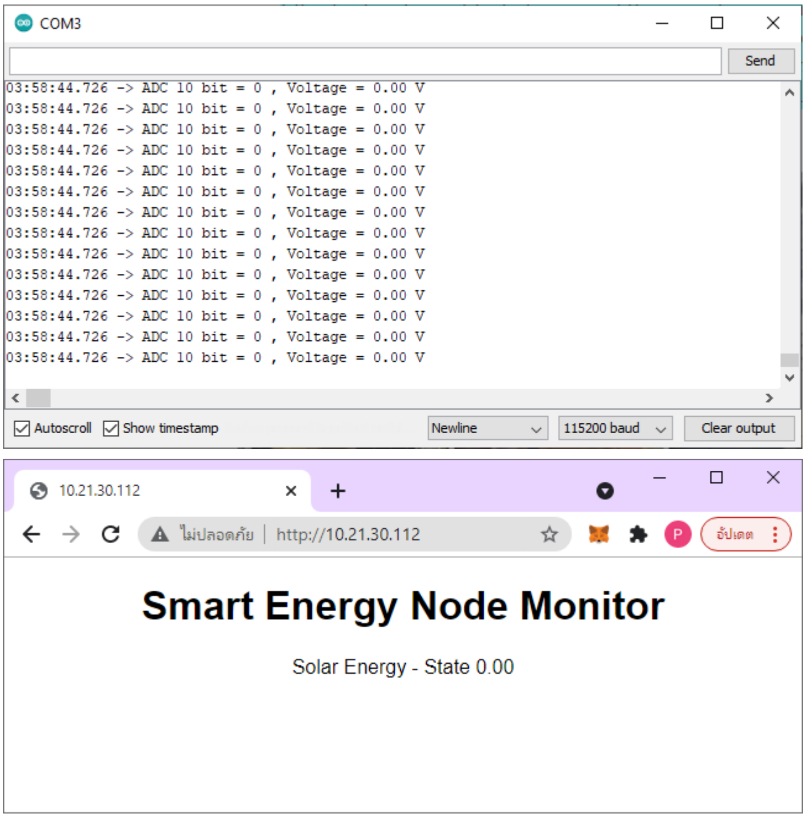

Figure 8. Monitoring of the smart energy node can be done over the Internet using the HTTP protocol, which is the result of applying the ESP32 microcontroller to this research.

(**A**) (**B**)

Figure 9. (**A**): Smart energy node.(**B**): The interior of the smart energy node prototype.

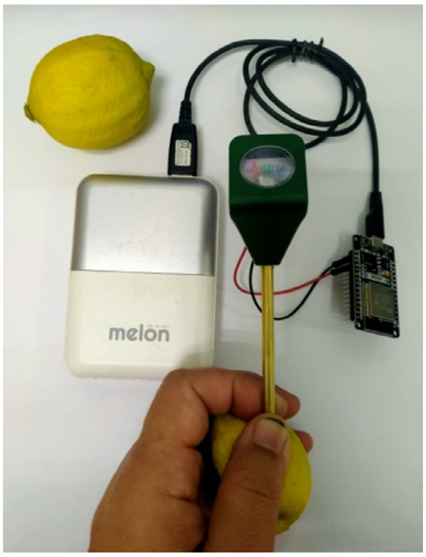

Figure 10. Testing of pH measurements with a proposed device when working with small uninterruptible power supplies.

Figure 7 shows the test to assess the potential of generating electricity from solar cells in the research area. The researchers found that in research area, electricity could be generated from solar cells for up to eight hours a day starting from 08:00 h., to 17:00 h., which made it easy to decide how it could be utilized. The power from the solar cells was combined with traditional electric power in this research.

In order to be able to receive the values from the smart energy nodes and sensors that were scattered in different areas, in this study, the researchers chose an ESP32 microcontroller board as the controller for each smart energy node, as it was equipped with a built-in Wi-Fi module and could be set to operate in web server mode.

Figure 8 shows the ability of the system to monitor the energy levels in the smart energy node via a web browser.

As shown in Figure 9, the interior of the smart energy node was connected to a special set of sensors buried in the soil beneath the durian trees that the researchers had developed specifically to enable accurate and robust measurements. This was more weather resistant than prefabricated sensors available today. After connecting the special sensor to the ESP32 board, the researchers tested the pH values of a lemon (Figure 10).

A functional test of the prototype device was used to measure the acidity, alkalinity, and soil moisture conditions of the durian trees by relying on energy from a power source that could move like a power bank. In Figure 10, the soil pH measurement from the original human measurement was converted to a common measurement device that had been adapted to the ESP32 microcontroller board to reduce the consumption of human labor.

In Table 2, the results of the readings from the smart sensor developed by the researchers were sent to the smart energy nodes for processing before ordering the power to be switched between the smart energy node's storage and traditional home electricity.

Table 2. Shows the power level that one solar panel could produce in three different time periods, and the angle of installation.

	Angle of the Solar Panel Placement		
Period	**15**	**45**	**90**
08:00 h.	21.5 Volts	21.2 Volts	19.0 Volts
13:00 h.	21.8 Volts	21.0 Volts	20.0 Volts
17:00 h.	17.6 Volts	17.3 Volts	16.0 Volts

Table 3 shows the power levels that a single unit (18 volts, 20 watts) of solar panel could produce over three different time periods, and different panel mounting angles.

Table 3. The values that the smart energy node read from the sensors in this study.

Sensor Values	Average
1. Voltage	21.8
2. Soil moisture level	38%
3. pH values	6.0

The duration of the solar panel power generation and the angle of the panel were important details that durian agriculturists and community-based tourism entrepreneurs could apply to their own businesses to achieve sustainable management of energy consumption and control their business expenditure.

In terms of user satisfaction in both the agricultural and local community tourism business, the research team gathered data from 30 users on six issues: 1. benefit of the system, 2. system design, 3. content, 4. easy to use, 5. the functionality of the system, and 6. overall satisfaction and effectiveness. It was found (Table 4) that the average satisfaction level was 4.21 with a standard deviation of 0.64. It was classified as a mean satisfaction in terms of the benefit of the system at 4.24. The average system design satisfaction was 4.23, and the content satisfaction average was 4.07. Moreover, the average satisfaction for easy to use was 4.31, the average satisfaction for the functionality of the system was 4.12, while the average overall satisfaction and effectiveness was 4.17, respectively.

Table 4. Evaluation of the smart energy node.

Variable	$\acute{x}$	S.D.
1. Benefit of the system		
1.1 The system is important for searching for information to support their travel planning.	4.17	0.54
1.2 The system is easy to access information.	4.31	0.47
1.3 The system is a useful tool/	4.24	0.64
2. System's design		
2.1 The color use is appropriate.	4.21	0.82
2.2 The size of the font is easy to read.	4.17	0.85
2.3 The buttons in the application are easy to use.	4.21	0.68
2.4 The used images are clear and beautiful.	4.31	0.81
3. Content		
3.1 The content is easy to understand.	4.00	0.60
3.2 The content has the appropriate amount of data.	4.14	0.69
4. Easy to use		
4.1 The system is easy to use.	4.28	0.59
4.2 The system is a quick process.	4.45	0.51
4.3 The buttons in the application are properly placed and easy to use.	4.31	0.49
4.4 The links are accessible.	4.21	0.67
5. The functionality of the system		
5.1 The system can be easily installed.	4.10	0.77
5.2 The system is stable.	4.14	0.52
6. Overall satisfaction and effectiveness		
6.1 The system should be recommended.	4.21	0.62
6.2 The system is beneficial to the user.	4.26	0.57
6.3 The system has effectiveness.	4.00	0.60
6.4 Overall satisfaction.	4.20	0.63

5. Discussion and Conclusions

The research contributed to the integration of KIO algorithms with smart energy nodes for sustainable management for durian plantations and supported the community-based tourism of Kantharalak district, Sisaket province, Thailand. As a result of implementing a system that helped agriculturists and tourism entrepreneurs to increase their profit after deducting the expenses by using sensors in a smart energy node system, this could reduce the cost of caring for the durian trees, whether it was labor, water, and fertilizer. In terms of utilizing energy from the smart energy node for local community-based tourism, this could reduce the energy costs from using a solar power grid by up to 50%. Additionally, the results of this research reflected that the KIO algorithm was an appropriate choice for efficient energy management between renewable energy and conventional electricity. The findings of this research were also consistent with previous studies by Borza et al. [3], Haseeb et al. [1], Suanpang and Jamtuntr [2] Xu et al. [33], Saadaoui et al. [34], and Suanpang et al. [30]. Furthermore, the platform that was offered could contribute to the adoption of natural renewable energy [35,36] in other businesses in Thailand. The idea of implementing an energy management system using solar power to increase the profit in the agricultural sector presented by the research team in this paper was consistent with the idea of using renewable energy and an optimization algorithm to increase profits to dairy farms [37].

In addition to assessing the efficiency and potential of managing alternative energy in conjunction with conventional electricity, in this research, the researchers assessed the satisfaction of two user groups; namely, a group of durian agriculturists and a group of community-based tourism operators in Kantharalak district, Sisaket province. The average user satisfaction was 4.21 with a standard deviation of 0.64, which indicated that the users of both groups were most satisfied with the developed system.

In further studies, the research team plans to make the sustainable energy management platform to have greater efficiency by combining quantum computing and new blockchain technologies.

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