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Faculty of Administrative Science and Policy Studies

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INTEGRATED SOLAR-IoT MONITORING AND PREDICTIVE MAINTENANCE SYSTEMS FOR IRRIGATION (S-IoTP)

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ABSTRACT
S-IoTP is an integrated prototype system of Internet-of-Things (IoT) with auto-tracking solar panel for irrigation. It consists of an auto-track-developed solar panel to power water pump with IoT hardware and software and mobile user interface. The solar panel moves based on the sunlight direction to harvest maximum solar output. With IoT software, real-time data of the solar power output was monitored. The predictive analysis for forecasting solar power output based on model-based algorithm using Python to ensure sustainable power for electricity, optimise the irrigation process and water consumption. **S-IoTP** provides a consumer-oriented solar system with affordable cost and energy saving device that fits consumer needs. With **S-IoTP**, the irrigation cost can be reduced to ±93%, which, the total cost per year for this whole system is RM 1020 only, compared to the traditional process of irrigation which costs RM 16200 per year. To date, the technology readiness level of the S-IoTP is TRL 5, which is in the stage of development and it is validated in relevant environment.

Keywords: solar energy, auto-track, internet-of-things, irrigation, ARIMA model, prediction

INTRODUCTION

The context of this innovation is based on the digitalisation of agriculture, from Industry 4.0 (IR4.0) to Agriculture 4.0. IR4.0 is based on Internet of Things (IoT) technology which has transformed the production infrastructures such as connected farms, connected tractors and machines. It enables an increase in productivity, quality, and environmental protection. Agriculture 4.0 is about connectivity which is the ability to remotely collect, use, exchange data and publish information on the production processes. Sensor deployments and connectivity enable the users to track the operation, detect early a loss of performance and offer preventive maintenance operations. Additionally, the collected data helps the users to better understand the needs and usages to improve its line of process. A wave of IR4.0 will change global production in the near future. Future workers need to be highly trained in these emerging technologies. Hence, the current education system needs to adapt to the demands of IR4.0 in preparing the students for the future careers. Tomorrow's industry leaders and managers must possess new skill sets to adapt, manage, and take advantage of Industry 4.0. They must be able to see beyond what the technology can offer and the implications for the society. Business leaders, educators and governments all need to be proactive in up-skilling and retraining people so everyone can benefit from the Fourth Industrial Revolution (Alex Gray, 2016).

PROBLEM STATEMENT & OBJECTIVE

The conventional farmer uses electricity to power the water pump for irrigation. It is indeed costly, and the farm is usually located very far from the source of electricity. The restrictions on the movement during COVID-19 pandemic also halt the farm operation since the workers are unable to go and monitor the farm. For the case of manual monitoring, after growth of crops, water reaches the basins in disproportionate quantity that thereby causing wastage of water. Besides, it is labour and time intensive operation. There is a complete IoT system for irrigation that is available in the market, but the price is still considerably expensive for most modern farmers. Although the system may provide an automatic control operation for 24/7 like other IoT monitoring systems however, it is unable to provide the solar power output prediction. Without the prediction on the energy performance, it is impossible to manage the back-up electricity especially during the rainy season. There are 2 main objectives of the project which are, to design, build and test smart auto-tracking solar panels equipped with Internet-of-Thing (IoT) system for irrigation at very low operation cost. Secondly, to forecast the solar power generation based on previous data in order to ensure the back-up electricity during the rainy season.

PRODUCT DEVELOPMENT

Based on Figure 1, **S-IoTP** consists of auto-track-developed solar panel (1) to power pump for irrigation with IoT hardware (sensors) (2), software (3) and user interface via mobile (4). With IoT sensors, the solar panel moves following the sunlight direction in order to harvest maximum solar energy output. While, with IoT software, real-time (vpv) and current (ipv) data of the panel voltage of the solar panel was monitored. The predictive analysis was conducted to predict solar energy generation based on specific model-based algorithm using the Python tool.

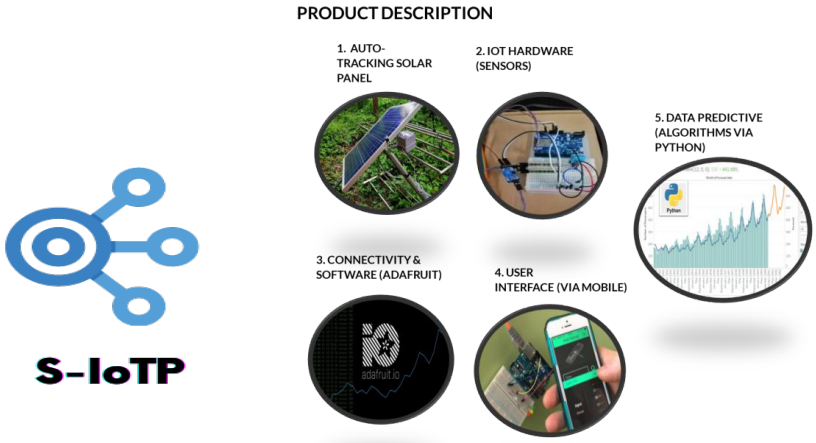

Figure 1. S-IoTP system

SYSTEM PERFORMANCE

The highest solar output was recorded at 12.00–2.00 pm (61% performance efficiency) (Figure 2) and it can reach up to 309W (±45.6% p.e) at ±30.9 ºC. The obtained solar power output was used to power 2V water pump for the irrigation twice daily and for energy backup for 3 days. Higher power generation of auto-tracking solar panel (125.6W, 45.9%) was found compared to fitted-solar panel (104.1W, 37.9%); an increase of 8%. ARIMA (4, 2, 8) model was used for prediction analysis (Figure 3) and the results was found with ±68% accuracy.

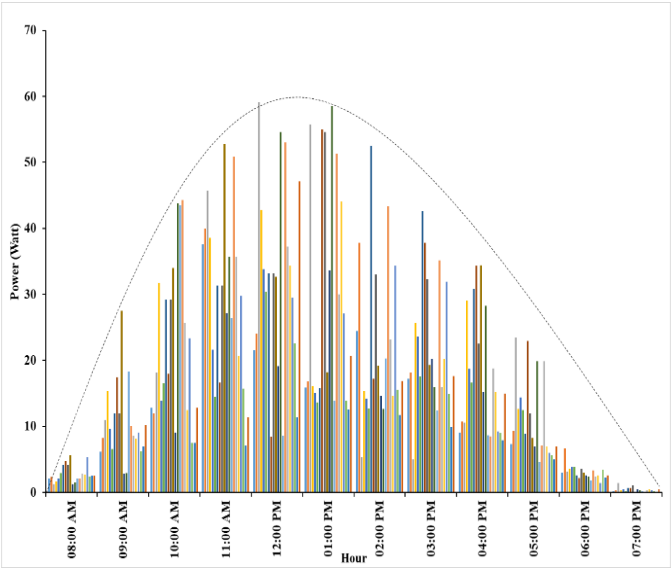

Figure 2. The solar power generated daily from 0800 hours until 1900 hours.

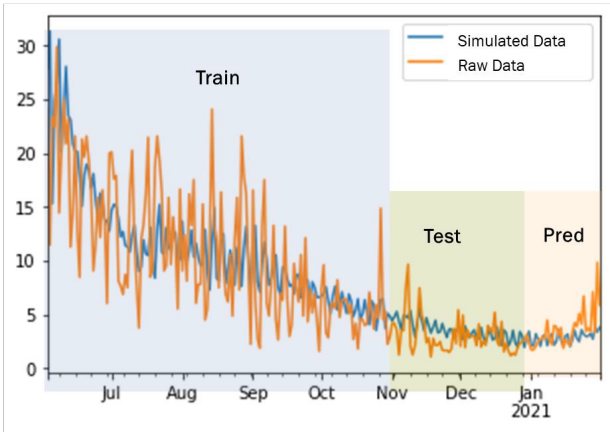

Figure 3. Around 32% of Mean Absolute Percentage Error (MAPE) implies the model is about 68% in predicting the next month from actual data (p-value: 5.3 e-11).

ADVANTAGES

S-IoTP has an integrated system of solar energy as green energy to replace fossil fuels that are now facing depletion. With an auto-track solar panel, high efficiency of solar energy can be captured with improved monitoring performance and maintenance of solar farm via IoT system (Ku Hussin et al., 2021). With **S-IoTP** concept, students can be exposed to prototype-level of IoT-based technology with the usage of various sensors that fits any application. From there, the students can explore other IoT-based applications to be able to see beyond when the concept turns to prototype that can benefit humankind. As the COVID-19 pandemic has triggered an unprecedented crisis in almost every sector globally, current technologies play a crucial role in keeping the society functional during lockdowns and quarantines. With **S-IoTP**, the users can monitor the farm remotely 24/7, keep the farm under surveillance and reduce the need for human workers. Whilst, with data predictive, it can ensure sustainable power for electricity, optimise the irrigation process and water consumption. **S-IoTP** provides consumer-oriented solar system with affordable cost and energy saving device that fit consumer needs. With **S-IoTP**, the irrigation cost can be reduced to ±93%, where the total cost per year for this whole system is RM 1020 only (from custom solar system design, IoT systems and water bill for RM 60, 120 and 840 respectively), compared to the traditional process of irrigation which costs RM 16200 per year (from electricity cost, worker wage and water bill for RM 300, 900 and 150 respectively).

NOVELTY/INVENTIVENESS

S-IoTP may highlight on the novelty of following points, such as the auto-tracking solar panel which integrated with IoT monitoring system to access real-time data 24/7 and the user can acquire fast alert if something is wrong with the irrigation. Besides, the system is a consumer-oriented solar system where 93% of the cost is reduced compared to the cost of manual irrigation. The element of predictive analysis also highlights the novelty of the system which is important for continuous operation (energy sustain), back-up electricity and early-detection if it is the rainy season or cloudy weather that causes a drop of solar power output.

With the prediction, back-up energy can be ensured upon the event occurance.

COMMERCIALISATION

To date, the technology readiness level of the S-IoTP is TRL 5, which is in the stage of development and it is validated in relevant environment. **S-IoTP** has a great potential to be commercialised in future from TRL 5 to TRL 7.

ACHIEVEMENT

To date, the finding based on this prototype was published at international level (scopus) and another 2 papers are under review.

Ku Hussin, K.A., Mohd Adenam, N., Mat Yunin, Y.A., Wan Salihin Wong, K.N.S, Mohd Hashim, S.Z. & Adli, H.K. (2021). Monitoring and optimizing solar power generation of flat-fixed and auto-tracking solar panels with IoT system. IOP Conference Series: Materials Science and Engineering, 1-8. https://doi.org/10.1088/1757-899X/1062/1/012011 (Scopus)

The previous version of **S-IoTP** received the Silver Award from the Carnival of Research and Innovation 2020 (CRI 2020 UMK). There are 3 industries which have shown interest in **S-IoTP** which are:
1) Kampus Satelit CIAST – Institut Latihan Perindustrian (ILP) Kota Bharu
2) Oriejelly Food & Agro Industries (003271859-P)
3) Kuwa Trading (KT0259174-P)

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