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Towards the Development of an Intelligent Control for LED lighting with Solar Energy and Energy Storage for a Jogging Track in the Countryside

Jorge Solis, *Senior Member, IEEE*, Sebastian Arnesson, Isac M. Andersson, Magnus Nilsson, Johan Rahm and Su-Ping Burman

***Abstract*— Our research aims to develop an intelligent control system for optimizing the operation of lighting systems for a jogging track in the countryside by using adaptive control methods, and optimization of built-in lighting control. Through this, lighting systems will be optimized, energy consumption will be minimized and the lighting system will be adapted to be able to handle a larger amount of local renewable energy production. Due to the level of complexity, in this paper, we have focused to integrate a commercial lighting control system and the solar energy system with energy storage. In particular, their respective components were selected and integrated by means of a distributed control architecture. An API was developed by using the design science research methodology aiming at bridging proprietary systems for sustainable lighting solutions.**

I. Introduction

The world is fast becoming a global village due to the increasing daily requirement of energy by all population across the world while the earth in its form cannot change. The need for energy and its related services to satisfy human social and economic development, welfare and health is increasing [1]. In particular, nowadays there are about 1 700 illuminated jogging tracks in Sweden where most of them use mercury-based lamps which are harmful to the environment [2]. By 2025 many of these lamps will be prohibited to manufacture, import or export in accordance with the EU Regulation - 2017/852 - EN - EUR-Lex, 2017.

However, the system integration of jogging tracks to renewable energy with energy storage has been scarcely studied. Therefore, the authors proposed to integrate and test a modular, safe and smart energy system that enables sport associations to get a good lighting quality in their facilities, while at the same time, they can save energy and get income from the excess of renewable energy produced during the sunny periods of the year.

In this paper, we present our research approach to integrate a lighting control system with a solar energy system with battery energy storage for a jogging track in the countryside of Värmland in Sweden. As a first approach, we proposed the implementation of a distributed control architecture as well as the development and evaluation of an application programming interface (API) for adapting the lighting and power management parameters of the proposed system.

II. System Integration of the Lighting Control System for a Jogging Track and the PV System

A. *Distributed Control Architecture*

The lighting system is composed of 81 LED-fixtures from PrismaTibro (Prisma Light Elton). In order to collect and modify the light control parameters, the *Citygrid Dashboard* was used. By using the software from the company, it is possible to control the following parameters: activation and deactivation times, number of fixtures to be activated upon detection, etc. On the other hand, the solar energy system is composed by 72 solar panels each of 280 W, a LiFePO4 battery from FerroAmp with a charging capacity of 14.2 kWh and the EnergyHub with a rated power of 21kW. In order to collect and modify the power management parameters, the *EnergyCloud* has been used. By using the software from the company, it is possible to specify the battery control parameters, the charging limits, etc. Due to the complexity of the proposed system, as a first approach, a distributed control architecture has been proposed. As it is shown in Fig. 1, a mini-PC has been installed in the battery building in order to communicate with both the PrismaTimbro and Energyhub.

B. *Application Programming Interface*

In order to develop the application programming interface, the design science research (DSR) approach has been proposed [3]. DSR is a research method where an artifact is created and evaluated to solve an identified problem, and thus making contribution to the intended research community. In this context an artifact is an object which has been designed in conjunction with research contributions. This could be a physical object or as abstract as a theoretical model.

Since both systems are controlled by digital software, the logical conclusion is that the solution is a software as well. This means that the solution will be in the form of an application that integrates with other applications that can fetch and input necessary data from each system and relay it to where it is needed. One of the systems already has this option in the form

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Jorge Solis is with the Department of Engineering and Physics, Karlstad University, Universitetsgatan 2, 651 88, Karlstad, Sweden (+46 54 700 1953; e-mail: solis@ieee.org).

Sebastian Anderson is with the Karlstad Business School, Karlstad University, Universitetsgatan 2, 651 88, Karlstad, Sweden

Johan Rahm is with the Department of Architecture and Built Environment, Lund University, Box 118. 221 00 Lund, Sweden(e-mail: johan.rahm@abm.lth.se).

Isac M. Andersson, Magnus Nilsson and Su-Ping Burman are with Glava Energy Center, Hillringsberg, 770 20, Glava, Sweden

of an API, but the other (the lighting system) does not. The solution needed to handle fetched data and through optimizing calculations send the optimal settings for each system. The 19 lighting-system only supports export of data through API and all input can either be done through the web portal or through a smartphone app with a special Bluetooth tool that communicates individually with the lighting armatures on site.

Figure 1. Proposed distributed control system

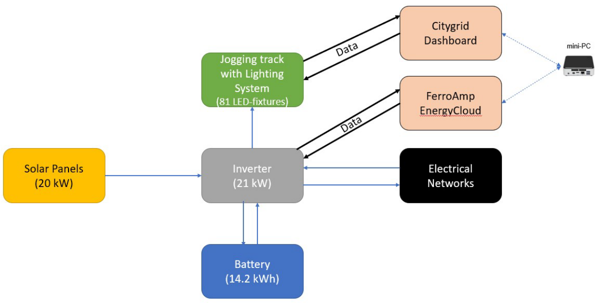


Figure 2. Optimization calculation flowchart (economic mode)

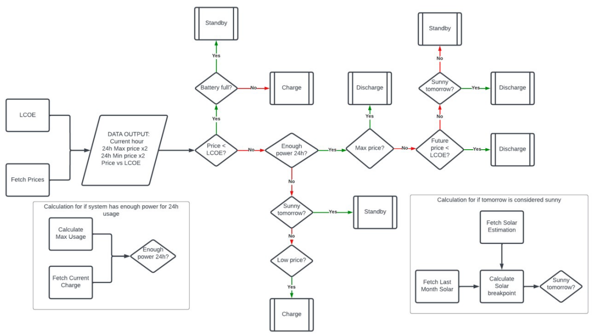
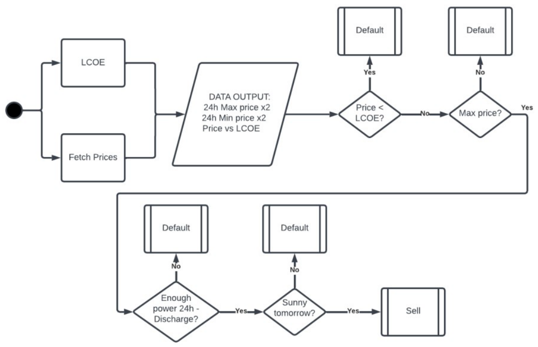


Figure 3. Optimization calculation flowchart (enviromental mode)



Therefore, the only practical solution for automated interaction with the lighting system would be using web automation since the other alternatives would include reverse-engineering the gateway firmware which would be extremely difficult and probably breach the term of service. After searching for different ways to perform web automation Selenium was chosen due to its widespread community. Python was then chosen as the language because of its compatibility with Selenium, familiarity with the author and its real-time interpretation meaning it is ideal for rapid prototyping. The IDE chosen was Visual Studio Code (VSCode) because its ability to smoothly integrate with GitHub which is the de facto standard version control for coding projects. After the web automation was completed, analysis began to discover which data would be needed for the optimization algorithm This started with the creation of charts showing the potential inputs needed as well as desired outputs (Fig. 2 and 3). During the development of the proposed API, it has been noticed that the levelized cost of electricity (LCOE) is an important value, as it determines at what price generated power is considered more expensive due to installation and maintenance cost. This meant that the system should always try charge when the electricity price with tax is lower than the calculated LCOE value if set to economic mode.

III. Experiments & Results

In order to evaluate the proposed API, seven days' worth of data was used. All data available was exported and was put together with the average daily spot-price for the current region. With this the cost of imported and gain of exported energy was then added to show the cost or gain of the day. A simulation script was created to simulate the optimization on a daily basis following the optimization charts seen in Figure 2 and Fig. 4. The information about solar production, consumption and price was manually fed into the script which then calculated hourly to either charge, discharge or do nothing with the battery. The result of the decision was then output as cost or gain for the day in SEK. The result for both the original and optimized control was then input into another spreadsheet and the difference was calculated in SEK/day and an average delta was calculated as shown in Figure 4.

Figure 4. Cost comparison between original and optimized controls

Date	Original control expence - SEK	Optimized expence - SEK	Delta
04/04/2024	-1.99	0	1.99
05/04/2024	0.74	0	-0.74
08/04/2024	-1.32	4.89504	6.21504
09/04/2024	-1.62	0	1.62
10/04/2024	-3.96	0	3.96
12/04/2024	-4.98	2.3464	7.3264
14/04/2024	-3.09	1.92	5.01
Average delta:	3.62592		

IV. Conclusion

In this paper, the authors proposed the system integration for the lighting control of a jogging track with a high proportion of local renewable energy. A distributed control architecture was proposed and an API was developed to analyze environmental data to control the lighting and energy usage through an optimization algorithm. Based on the preliminary experiments, the feasibility of the proposed approach was verified.

References

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