Power Optimization of Electric Developments in Diesel Power Plant for the Electrical Energy Sources using Dynamic Programming Algorithm

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Abstract

The electricity need in the G4 Building at the State University of Malang was more than 85 kVA. All electrical devices could be activated; but when the energy source was inactive, all electricity requirements were transferred to the diesel power plant (DPP). However, the electrical capacity of DPP was only 20 kVA; therefore, it was necessary to optimize the electrical power load so that the DPP energy could be absorbed optimally using the room scheduling and electrical devices priority systems. The Dynamic Programming Algorithm was embedded in the power optimization system to help optimize the work. The power optimization prototype was used to simulate the 1st floor of the G4 Building's condition. The system consisted of a controller, a central controller, and a user interface. the controller comprised of a current sensor, microcontroller, and a relay. The central controller consisted of Raspberry Pi 3 hardware that was installed as the server to answer the HTTP request from the controller and user interface. The user interface was displayed in a dynamic web to ease the user in managing the electrical devices and entering the room usage schedule. The power optimization system managed the electrical energy from DPP by turning on the electrical devices according to the priority value. The power optimization system tests were divided into six problems, of which each stage had an error value of 0%.

1. Introduction

State Electricity Company as a state-owned enterprise that manages and supplies the electric system in Indonesia is responsible for meeting the electricity demand and avoiding the electricity deficit. To further avoid the matter, there needs a formulation such as developing various power plants and periodically maintain the devices [1]–[3]. The applied solution not always resulted in a continuous electricity supply because the distribution always creates power outages due to network trouble or system maintenance [4]–[6]. Electricity supply is required in the education sector to turn the electrical devices on and support the teaching and learning process.

The electricity need in the G4 Building at the State University of Malang was more than 85 kVA. Moreover, as an effort to avoid disturbing the learning process during the power outage, PLN advised the consumers to use a backup electricity source such as Diesel Power Plant (DPP) or generator set [5]. The capacity of DPP in the G4 Building was 20 kVA; therefore, it requires power management to optimize the correct absorption of electricity.

The power optimization system uses room scheduling and electrical devices priority system. A good room scheduling system is an indicator of daily distributed learning in an education institution [7], [8]. In a priority scale, the usage of electrical devices should be divided following the requirement level in the learning process. The Dynamic Programming Algorithm will be embedded in the optimization power to optimize the system.

2. Method

The amount of controlled electrical devices through a system caused several troubles such as in the dynamic programming algorithm that should be integrated with the devices [9]. Therefore, there needed a problem separation system that connects. The system should have three parts: the electrical devices controller in each room called the controller device, the central controller, and the user interface. The development also required a prototype to simulate the real electrical situation inside the building.

A. System design

   a. *Controller Design*

The controller was used to observe and control each electrical device in each room. The controller functioned as the current reader in each electrical device using the ZMCT103C current sensor. The controller device had processing hardware, the ESP32 microcontroller, with a wifi module that acted as the mediator between the controller and the central controller. The ESP32 microcontroller would send the data on electrical devices condition that in turn would be sent to the central controller [10]–[12]. The microcontroller also functioned as an order receiver that was given by the central controller after the computation process. There was a relay that acted as a switch to connect and disconnect the current based on the received order.

   b. *Central Controller Design*

The central controller was also called the server. As the central controller of the electrical devices, the central controller should be able to serve any electrical devices. Therefore, this research used the Raspberry Pi 3 hardware.

   c. *Interface Design*

To facilitate the user in long-distance observation and controlling, there needed an interactive and dynamic interface consisted of:

   1. Login page
   2. Main page
   3. Device database page, and
   4. Device controlling page
   5. Room scheduling management page

B. Implementation

The implementation stage covered the implementation of (1) controller part, (2) central controller part, (3) user interface part, and (4) pre-designed prototype part.

C. Testing

The test consisted of four developed systems: (1) controller test, (2) central controller test, (3) user interface test, and (4) prototype test. The testing stage covered the test for each subsystem to find the performance of each subsystem following the set specification. The failure level in each software was high; thus, need test in each subsystem.

D. Evaluation

The evaluation process could also be called system maintenance. This process was performed to improve system failure and perfecting the research. Changes in the system or devices are possible after evaluation and continuous periodic maintenance to keep the excellent performance of the power optimization system.

E. Design Test

The test method in this research was a functionality test in each part of the system. They were room scheduling and priority scale in the electrical device. There were 16 rooms in the prototype with six problems in the testing.

3. Result

A. Designing the Power Optimization System

The power optimization system would become active when there was a blackout from searching which devices need activation following the room schedule and priority scale as set by the user. The power optimization system would activate the prioritized device and deactivated the devices out of the priority. The design of the dynamic programming algorithm in this power optimization would search the devices through four steps.

B. Power Optimization Prototype Controller device

The input in the controller design was ZMCT103C's current sensor. The sensor was used as the media to obtain the actual current data in the electrical device. The ZMCT103C is a current transformer that could detect the current between 0–5 A. The 5 A current resulted in a 5 mA output current from the sensor. Figure 1 displays the controller circuit.
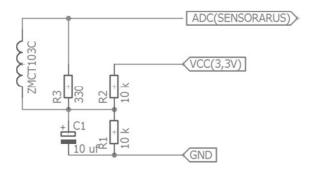
Figure 1. Controller Input Circuit

The processing media in this research was ESP32 microcontroller with wifi module as the communication media between the ESP32 with the server. Each controller had one processing media as the communicator between the electrical device and the system. Figure 2 presents the controller processing circuit.
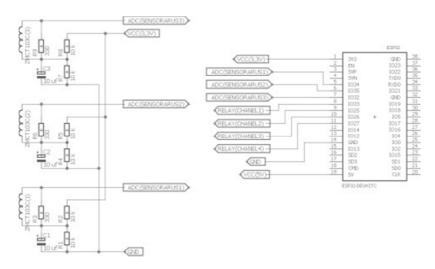

Figure 2. Control Device Processing Circuit

The output was in the form of a relay. It was an electronic switch that could control the current to each device and this research used 4 channel relay modules. Figure 3 shows the controller output circuit.
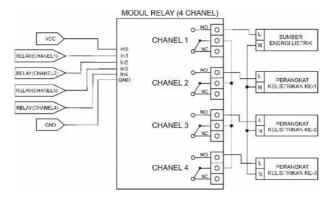

Figure 3. Control Device Output Circuit

C. Central Controller

This research used Raspberry Pi 3 hardware that was installed as the server. To became the server, Raspberry Pi 3 was installed in the Linux-base operation system OS Raspbian series. This research also used Apache 2.4 software and PHP 7.7 framework as a dynamic web program. MySQL 5 database system was used as the data storage on the electrical devices, room scheduling, etc.

D. User interface

This research had three primary users: administrator, lecturer, and student. The interface design had five main menus: main menu, device menu, controller menu, priority menu, and timing menu. Figure 9 shows the main menu page; Figure 10 displays the device menu page. Figure 6 presents the controller menu page; Figure 12 shows the priority menu page, and Figure 4 displays the timing menu page.
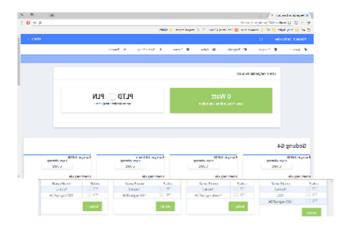
1. Main Menu

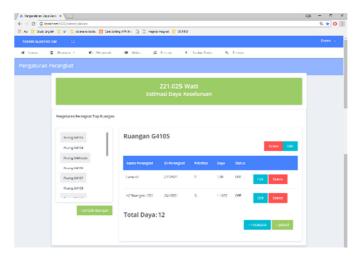Figure 4. Main Menu Page

2. Device Menu
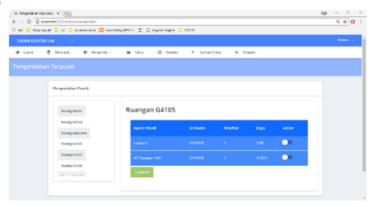

Figure 5. Device Menu Page

3. Controller Menu

Figure 6. Controller Menu Page
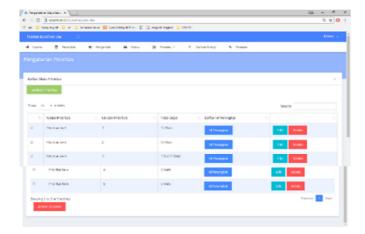
4. Priority Menu

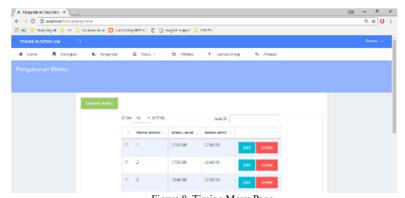Figure 7. Priority Menu Page

5. Timing Menu

Figure 8. Timing Menu Page

E. Test Results

Based on the background and advanced features, the tests were divided into six problems. In each problem, the power optimization performed well with the error value of 0%

4. Conclusion

The power optimization was built using the dynamic programming algorithm/method. The problems in this optimization were divided into four: a) electrical device ID analysis, b) searching room scheduling system, c) searching the priority scale system, and d) optimization result. The power optimization system prototype consisted of three main parts: a) controller device to detect the condition of the electrical device and send the data to the central controller and received order to connect or disconnect the electricity with the help of a relay, b) central controller device to process the system, and c) user interface to ease the user in simulating the electrical energy capacity from the DPP and data management. The overall optimization system was distributed into six problems, with the result of each test had an error value of 0%.

References

[1] F. S. Abu-Mouti and M. E. El-Hawary, "Optimal Distributed Generation Allocation and Sizing in Distribution Systems via Artificial Bee Colony Algorithm," *IEEE Trans. Power Deliv.*, vol. 26, no. 4, pp. 2090–2101, Oct. 2011, doi: 10.1109/TPWRD.2011.2158246.

[2] K. Chandram, N. Subrahmanyam, and M. Sydulu, "Equal embedded algorithm for economic load dispatch problem with transmission losses," *Int. J. Electr. Power Energy Syst.*, vol. 33, no. 3, pp. 500–507, Mar. 2011, doi: 10.1016/j.ijepes.2010.12.002.

[3] İ. Erozan, "A fuzzy decision support system for managing maintenance activities of critical components in manufacturing systems," *J. Manuf. Syst.*, vol. 52, pp. 110–120, Jul. 2019, doi: 10.1016/j.jmsy.2019.06.002.

[4] E. Shayesteh, J. Yu, and P. Hilber, "Maintenance optimization of power systems with renewable energy sources integrated," *Energy*, vol. 149, pp. 577–586, Apr. 2018, doi: 10.1016/j.energy.2018.02.066.

[5] M. C. Carnero and A. Gómez, "Maintenance strategy selection in electric power distribution systems," *Energy*, vol. 129, pp. 255–272, Jun. 2017, doi: 10.1016/j.energy.2017.04.100.

[6] H. Mo, G. Sansavini, and M. Xie, "Performance-based maintenance of gas turbines for reliable control of degraded power systems," *Mech. Syst. Signal Process.*, vol. 103, pp. 398–412, Mar. 2018, doi: 10.1016/j.ymssp.2017.10.021.

[7] A. Medjber, A. Guessoum, H. Belmili, and A. Mellit, "New neural network and fuzzy logic controllers to monitor maximum power for wind energy conversion system," *Energy*, vol. 106, pp. 137–146, Jul. 2016, doi: 10.1016/j.energy.2016.03.026.

[8] E. F. Ferreira and J. D. Barros, "Faults Monitoring System in the Electric Power Grid of Medium Voltage," *Procedia Comput. Sci.*, vol. 130, pp. 696–703, 2018, doi: 10.1016/j.procs.2018.04.123.

[9] T. S. Prasanna and P. Somasundaram, "Fuzzy mutated evolutionary programming based algorithm for combined economic and emission dispatch," in *TENCON 2008 - 2008 IEEE Region 10 Conference*, Hyderabad, India, 2008, pp. 1–5, doi: 10.1109/TENCON.2008.4766769.

[10] P. M. García-Vite, B. L. Reyes-García, C. L. Valdez-Hernández, and A. L. Martínez-Salazar, "Microcontroller-based emulation of a PEM fuel cell," *Int. J. Hydrog. Energy*, p. S0360319919337735, Nov. 2019, doi: 10.1016/j.ijhydene.2019.10.034.

[11] M. M. Al-Kofahi, M. Y. Al-Shorman, and O. M. Al-Kofahi, "Toward energy efficient microcontrollers and Internet-of-Things systems," *Comput. Electr. Eng.*, vol. 79, p. 106457, Oct. 2019, doi: 10.1016/j.compeleceng.2019.106457.

[12] J. R. Raj, S. M. K. Rahman, and S. Anand, "Microcontroller USB interfacing with MATLAB GUI for low cost medical ultrasound scanners," *Eng. Sci. Technol. Int. J.*, vol. 19, no. 2, pp. 964–969, Jun. 2016, doi: 10.1016/j.jestch.2016.01.008.