Energy Efficiency On Smart Street Lighting Using Raspberry Pi Based On Scada And Internet Of Things (IoT)

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Abstract. One of the criteria of a city categorized as Smart city is the ability to manage infrastructure, property and human resources intelligently. A reliable, sustainable and customizable electric energy source is an absolute requirement for a smart city. However, the management of electrical energy must be economically so that it does not burden the local government budget. From a number of infrastructures that consume a lot of electrical energy under the authority of the responsibility of the local government, namely Public Street Lighting (PSL). Lighting from PLS that emits too much light when unnecessary is useless. At present, conventional PLS systems are synonymous with energy waste. Monitors and controls only do locally without having the ability to monitor and control remotely so that if there is damage or theft, it is slow to handle. The solution is to build a smart PSL system and its management. This paper presents a real-world proven solution that relies on a Raspberry Pi, SCADA, and Internet of Things (IoT). This system provides an energy efficiency. Smart PSL will work intelligently in accordance with their environmental conditions. Lighting and illumination are arranged based on the presence of people and vehicles so that they can avoid over lighting and glare. SCADA and IoT technologies are used for work process monitoring systems and data viewers that are carried out continuously and in real time. The result is the smart PLS mode is 43% more efficient than conventional PLS modes.

1. Introduction

Public Street Lighting (PSL) is one of the infrastructures in smart cities that consume a lot of electricity. This is because PSL lighting emits too much light when and where it is not needed. Waste of energy has enormous economic and environmental consequences. Examples of cases in the United States, in one year the average outdoor lighting uses about 120 hours of energy, mostly to illuminate the road and parking lot. Whereas, that energy enough to fill New York City’s total electricity needs for two years. An estimated 30 percent of all PSL energy in the US is wasted (http://www.darksky.org). In addition, the use of quality PSL lamps will increase air pollution in the form of carbon dioxide release.

This also happens in Indonesia, which still uses conventional PSL systems. With operating hours from 5pm to 6am, it continues without stopping even if no person or vehicle passes, causing waste of energy. In terms of security, PSL is often the object of vandalism and theft. In short, the conventional PSL system is synonymous with energy waste. Monitoring and controlling PSL only local without
having the ability to be done remotely, slow to handle if there is damage due to multiple malfunction systems or due to criminal actions. The existence of a smart PSL system that is able to cover system shortages conventional becomes urgent.

At present, smart PSL system consist of LED lights to saving energy [1], [2], [3], [4], [5], various sensors, display monitored[6] and integration of multimedia communication to transfer data [7], [8], [9],[10], [2],[11],[12]. However, management of PSL based on IoT[13], [14], [15], [16]is still in the early and wide-open stage to be developed.

This paper presents a real-world proven solution that relies on a Raspberry Pi, SCADA, and IoT. Management of PSL arrange by an IoT-based SCADA system to produce measurable, holistic and efficient solutions. Any disruption in the PSL system monitored through monitoring and mobile device centers, whether internet-based or not. This system produce energy saving solution.

2. Methodology
The specific objective of this research is to build a smart PSL system that can work automatically and can be monitored (work processes and electrical parameters) remotely through SCADA and IoT. The capability of this smart PSL will contribute to the efficiency of energy consumption and ease of maintenance. A general description of the PSL smart system is in Figure 1.

![Figure 1. A general description of the PSL smart system](image)

The form of this research is a miniature PSL consisting of five LED lights. Each lamp is fitted with current, voltage, PIR, infrared and LDR sensors. All sensors are integrated to read environmental conditions. Data from sensors displayed on SCADA, smartphone and IoT through a Wi-Fi / wireless connection. The system block diagram is in Figure 2.
To find out energy efficiency, we simulate the miniature PSL in two modes, namely
1. Conventional mode (12-hour mode), where the PSL starts to light up at 6:00 a.m. and off at 6:00 a.m.
2. Smart mode, where PSL starts to turn on if the LDR sensor has not detected sunlight. If the PIR sensor detects something, the sensor will give a signal to the PSL to light up 100% while the other lights turn dim. The intensity of light will increase along with the vehicle journey.

3. Result and Discussion
3.1 Miniature of PSL
PSL smart system is applied in miniature form. Miniature size refers to SNI 7391: 2008 concerning Specifications for Street Lighting in Urban Areas. It is assumed that the position of PSL is in the traffic lane (artery) in the residential area. In accordance with SNI, light intensity is 11 Lux, pole height is 10 m, Distance per pole is 30 m and road width is 4 m. Therefore, the miniature scale is 1:100, as shown in figure 3.
3.2 Wiring Sensor Diagram

Each sensor is connected to the controller according to the addressing as in Table 1. One example of a sensor-wiring diagram is in Figure 4.

Table 1. Address miniature PSL

| No | TAG NAME     | MODBUS ADDRESS | WEB IOT |
|----|--------------|----------------|---------|
|    |              | HMI Droid | SCADA | DATA TYPE |         |
| 1  | LDR          | 0         | 00000 | DIGITAL | GPIO17  |
| 2  | PROXIMITY_1  | 1         | 00001 | DIGITAL | GPIO18  |
| 3  | PROXIMITY_2  | 2         | 00002 | DIGITAL | GPIO27  |
| 4  | PROXIMITY_3  | 3         | 00003 | DIGITAL | GPIO22  |
| 5  | PROXIMITY_4  | 4         | 00004 | DIGITAL | GPIO23  |
| 6  | PROXIMITY_5  | 5         | 00005 | DIGITAL | GPIO24  |
| 7  | PIR_1        | 6         | 00006 | DIGITAL | GPIO25  |
| 8  | PIR_2        | 7         | 00007 | DIGITAL | GPIO5   |
| 9  | PIR_3        | 8         | 00008 | DIGITAL | GPIO6   |
| 10 | PIR_4        | 9         | 00009 | DIGITAL | GPIO13  |
| 11 | PIR_5        | 10        | 00010 | DIGITAL | GPIO19  |
| 12 | LED_1        | 11        | 00011 | DIGITAL | GPIO12  |
| 13 | LED_2        | 12        | 00012 | DIGITAL | GPIO16  |
| 14 | LED_3        | 13        | 00013 | DIGITAL | GPIO20  |
| 15 | LED_4        | 14        | 00014 | DIGITAL | GPIO26  |
| 16 | LED_5        | 15        | 00015 | DIGITAL | GPIO21  |
| 17 | INDIKA_PIR   | -         | 00016 | DIGITAL | -       |
| 18 | INDIKA_PROXIMITY | -     | 00017 | DIGITAL | -       |
| 19 | INDIKA_LDR   | -         | 00018 | DIGITAL | -       |
| 20 | INDIKA_SAVPO | -         | 00019 | DIGITAL | -       |
| 21 | STSP_12H     | 20        | 00020 | DIGITAL | -       |
| 22 | STSP_Smart   | 21        | 00021 | DIGITAL | -       |
| 23 | STSP_LDR     | 22        | 00022 | DIGITAL | -       |
| 24 | ShutDown     | 23        | 00023 | DIGITAL | -       |
| 25 | Reboot       | 24        | 00024 | DIGITAL | -       |
| 26 | RECORD       | -         | 00025 | DIGITAL | -       |
| 27 | VOL_INA1     | 0         | 40000 | INTEGER | -       |
| 28 | AMP_INA1     | 1         | 40001 | INTEGER | -       |
| 29 | VOL_INA2     | 2         | 40002 | INTEGER | -       |
| 30 | AMP_INA2     | 3         | 40003 | INTEGER | -       |
| 31 | VOL_INA3     | 4         | 40004 | INTEGER | -       |
| 32 | AMP_INA3     | 5         | 40005 | INTEGER | -       |
| 33 | VOL_INA4     | 6         | 40006 | INTEGER | -       |
**Table:**

| No | TAG NAME | MODIFY ADDRESS | SCADA | DATA TYPE | WEB IOT |
|----|----------|----------------|-------|-----------|---------|
| 34 | AMP_INA4 | 7              | 40007 | INTEGER   | -       |
| 35 | VOL_INA5 | 8              | 40008 | INTEGER   | -       |
| 37 | AMP_INA5 | 9              | 40009 | INTEGER   | -       |
| 38 | ON_JAM   | 10             | 40010 | INTEGER   | -       |
| 39 | ON_MNT   | 11             | 40011 | INTEGER   | -       |
| 40 | OFF_JAM  | 12             | 40012 | INTEGER   | -       |
| 41 | OFF_MNT  | 13             | 40013 | INTEGER   | -       |

**Figure 4.** Wiring Sensor LDR diagram

### 3.3 Display Of SCADA, Smartphone, And Web IoT

To turn on the PSL, you must first select the mode manually through the SCADA or Smartphone screen, as shown in Figure 5. After selecting the mode, a display will appear like Figure 6 on the SCADA screen and smartphone.
For display on the IoT website, use two web platforms, namely Cayyane, (Figure 7) for sensor indicators and Thingspeak, (Figure 8) to display data in graphical form.

URL IoT website:
- https://cayenne.mydevices.com/cayenne/dashboard/project/c71d6aa8-8257-46b1-af0e-6b409970fdd0
- https://thingspeak.com/channels/539095

Figure 5. Display application for selecting PSL mode on SCADA and smartphone

Figure 6. Display of PSL applications on SCADA and smartphones
3.4 System Testing

Testing of PSL miniature systems consist of two setting modes:

- Conventional mode (12 hours)
  The test was carried out for 30 minutes starting at 7:00 p.m. until 7:30 p.m. WIB. The controller per 2 seconds sends data to the Thingspeak data logger. The results of reading data shown in Table 2. Miniature images of PSL when on and off can be seen in Figures 9 and 10.
Table 2. Data Logger Testing Results for the 12-hour mode

| Time            | Logger Thingspeak Mode 12 hour |
|-----------------|---------------------------------|
|                 | (KWh | Current (A) | Voltage (V) | Power (W) |
| 06/08/2018 19:01| 2.52  | 0.165        | 195.8       | 29.4      |
| 06/08/2018 19:03| 2.521 | 0.17         | 202.2       | 31.4      |
| 06/08/2018 19:05| 2.523 | 0.17         | 199.7       | 30.7      |
| 06/08/2018 19:07| 2.523 | 0.169        | 197.2       | 30.1      |
| 06/08/2018 19:09| 2.524 | 0.175        | 202.2       | 31.1      |
| 06/08/2018 19:11| 2.528 | 0.166        | 200.1       | 29.3      |
| 06/08/2018 19:13| 2.529 | 0.156        | 201.8       | 29.1      |
| 06/08/2018 19:15| 2.529 | 0.169        | 202.2       | 29.5      |
| 06/08/2018 19:17| 2.53  | 0.166        | 201.2       | 29.6      |
| 06/08/2018 19:19| 2.53  | 0.163        | 201.7       | 29.7      |
| 06/08/2018 19:21| 2.53  | 0.166        | 203.1       | 29.8      |
| 06/08/2018 19:23| 2.531 | 0.167        | 204.2       | 30.2      |
| 06/08/2018 19:25| 2.532 | 0.219        | 203.2       | 43.1      |
| 06/08/2018 19:27| 2.533 | 0.218        | 202.7       | 42.9      |
| 06/08/2018 19:29| 2.533 | 0.219        | 204.2       | 43.5      |

Figure 9. PSL Condition Off
Figure 10. PSL Condition On

- **Smart Mode**
The test start at 8:00 p.m. until 08.28 WIB. The simulation of the existence of objects / people is assumed to occur only eight times in the period of testing. The controller per 2 seconds sends data to the Thingspeak data logger. The results of reading the data shown in Table 3. A miniature image of PSL when the PIR sensor detects that a vehicle is passing shown in Figures 11 and 12.

| Time          | Logger KWh  | Thingspeak Current (A) | Voltage (V) | Power (W) |
|---------------|-------------|-------------------------|-------------|-----------|
| 06/08/2018 20:00 | 2,524       | 0.153                   | 187.2        | 25.9      |
| 06/08/2018 20:02 | 2,526       | 0.16                    | 188.0        | 25.1      |
| 06/08/2018 20:04 | 2,528       | 0.16                    | 189.9        | 25.7      |
| 06/08/2018 20:06 | 2,528       | 0.151                   | 188.5        | 25.2      |
| 06/08/2018 20:08 | 2,539       | 0.158                   | 189.3        | 25.5      |
| 06/08/2018 20:10 | 2,539       | 0.158                   | 190.3        | 25.8      |
| 06/08/2018 20:12 | 2,535       | 0.155                   | 190.5        | 25.6      |
| 06/08/2018 20:14 | 2,535       | 0.159                   | 190.3        | 25.6      |
| 06/08/2018 20:16 | 2,543       | 0.162                   | 192.7        | 27.5      |
| 06/08/2018 20:18 | 2,548       | 0.165                   | 193.5        | 28.0      |
| 06/08/2018 20:20 | 2,549       | 0.166                   | 192.6        | 27.8      |
| 06/08/2018 20:22 | 2,550       | 0.172                   | 192.9        | 29.0      |
| 06/08/2018 20:24 | 2,553       | 0.163                   | 191.0        | 26.8      |
| 06/08/2018 20:26 | 2,555       | 0.158                   | 191.1        | 27.2      |
| 06/08/2018 20:28 | 2,555       | 0.166                   | 191.5        | 27.1      |
From these two modes, the smart mode is more efficient in energy consumption. Within 30 minutes, conventional mode consumes an average of 32.67 W, while in smart mode consumes an average of 24.70 W.

3.5 Connectivity Testing

Based on the tests to determine the speed of data transfer, the results is in Table 4. Data transfer times have delays or delays from Real data transfer times, on SCADA, HMI Droid, Cayanne and ThingspeakIoT.
Table 4. Result of Connectivity Testing

| Mode     | Time Delay Monitoring (ms) |
|----------|----------------------------|
|          | Real          | SCADA | HMI Droid | IoT Cayanne | IoT Thingspeak |
| Conventional | ±0         | ±1    | ±1        | ±2          | ±2            |
| Smart    | ±0          | ±1    | ±1        | ±2          | ±2            |

4. Conclusion

The intelligent PSL system in miniature form operates according to the desired description. Monitoring of sensor indicators and parameter data proven that shown through SCADA, mobile and IoT websites. Although there is still a delay when displaying data for 2 seconds for IoT websites, and one second for smartphones and SCADA. When viewed from energy efficiency, during a 30-minute trial, smart mode proved to be more economical in energy consumption when compared to conventional mode by 43%.

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