Determination system for solar cell layout in traffic light network using dominating set

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Abstract. Graph Theory is one of the fields in Mathematics that solves discrete problems. In daily life, the applications of Graph Theory are used to solve various problems. One of the topics in the Graph Theory that is used to solve the problem is the dominating set. The concept of dominating set is used, for example, to locate some objects systematically. In this study, the dominating set are used to determine the dominating points for solar panels, where the vertex represents the traffic light point and the edge represents the connection between the points of the traffic light. To search the dominating points for solar panels using the greedy algorithm. This algorithm is used to determine the location of solar panel. This research produced applications that can determine the location of solar panels with optimal results, that is, the minimum dominating points.

1. Introduction

Energy plays a very important role in human life. Any activity from homework to office work requires energy resources. The utilization of energy resources in infrastructure development and facilities is needed. The energy sources that are mostly used are non-renewable energy sources (conventional). In fact, that energy sources are starting to decrease and not sustainable. To overcome this problem, the utilization of new energy and renewable energy sources is an alternative that must be developed and improved as a source of energy in the future.

Law of the Republic of Indonesia Number 30 Year 2007 on Energy Article 20 Verse (4) states that the provision of new energy and renewable energy shall be enhanced by the Government and the regional government according to their respective authority. Furthermore, Verse (5) states that any business entity, permanent business establishment and individual that provide energy from new energy sources and renewable energy sources may obtain facilities and/or incentives from the Government and/or the regional government according to their respective authority for a certain period until the economic value is reached [1].

The energy source that can be utilized is solar light by using solar panels as a power plant. Solar panels have the advantage of being a practical energy source, because they can be installed modularly in every location as required. Ones that can utilize this energy source are traffic lights. The determination of solar panels at traffic light points requires the right strategy. In this case it should pay attention to several aspects such as, the efficiency of the number of solar panels used, so that any solar panels placed at one traffic point can distribute electrical power to at least one nearest red light point. A mathematical approach that can be used to minimize the number of solar panels is by Graph Theory. The essence of applying graph is how to model the problem, and then defines which will be the vertices of the graph. Once the vertices have been obtained, it will be easy to build a graph by providing edges to connect the vertices accordingly [2].

The efficiency factor is used in the determination of the location of solar panels, so that any solar panels placed at one traffic point can supply power to at least one traffic light point. The distribution of electrical power from the solar panels to the traffic light points using the power cord. Solar panels have the advantage of being a practical and eco-friendly energy source considering it does not require...
transmission like a conventional power grid, as it can be installed modularly in any location that requires [3]. There are various types of solar panels, some are called Poly-crystal, Mono-crystal, Morpheus and Compound [4]. But now there are two kinds of popular solar panels, namely poly-crystalline and mono-crystalline. Poly-crystalline is a solar panel that has a random crystal arrangement. This type requires a larger surface area compared with the mono-crystal type to produce the same electrical power, but can generate electricity during clouding. Mono-crystalline is the most efficient panels, producing the highest electrical power unity. It has an efficiency of up to 15%. The disadvantage of this type of panel is that it will not work well in areas with less sunlight (shade) so that the efficiency will drop dramatically in cloudy weather.

The problem is that how to determine the location of solar panels on the traffic light network. These problems can be solved using the dominating set of a graph. A dominating set provides a way of vertices determination on a graph as a dominating set that can reach all vertices in the graph [2]. A dominating set in a graph \( G \) is a set \( S \) of vertices of \( G \) such that every vertex in \( V(G) \setminus S \) is adjacent to at least one vertex in \( S \). The domination number of \( G \) is the minimum cardinality of a dominating set of \( G \). For more details about the notion of domination in graphs, see [5].

In this paper, we develop an information system to determine the location of solar panels that will be placed on traffic light network using dominating set. To implement the system, we choose the traffic light networks in the city area of Banyuwangi as a case study although it can be used for any traffic light networks providing the graph as its representation.

2. Methods

This research used System Development Life Cycle (SDLC) methods with Waterfall model. The Waterfall model is a systematic and linear sequential design approach through some phases in SDLC to develop a system or an application. This model is suitable to develop a medium scale application that involves limited human resources. The illustration of phases in Waterfall model is shown in Figure 1.

![Figure 1. Phases in Waterfall model resource: Sommerville, 2010](image)

3. Result and Discussion

The determination of the location of solar panels that will be placed on traffic light network makes use the concept of dominating set of Graph Theory. Consequently, we require an algorithm to find an optimal solution on determining the dominating set of a graph that represents the traffic light network.

There are two algorithms that can be selected to support the concept of the dominating set. The first algorithm is the Greedy algorithm. The Greedy algorithm is based on the transfer of edges per edge and at every step taken no thought to the future consequences. Greedy algorithm does not operate thoroughly against all alternative solutions and some problems do not always succeed in providing a truly optimum but definitely provide a solution that approaches the optimum value [6]. The second algorithm is the Breadth-First Search algorithm. The advantages of the Breadth-First Search algorithm
is that it will not find a dead end, because all nodes will be checked thoroughly at each level and if there is one solution then Breadth-First Search will find it, and if there is more than one solution then the minimum solution will be found. However, Breadth-First Search takes much longer execution time than Greedy algorithm [7]. Thus, the Greedy algorithm is used to find an optimal solution in this research.

This study begins by representing the traffic light networks as vertices and edges in a graph. The vertices in the represented graph are sorted by the greatest degree. The next stage is to determine the dominating vertex based on the list of vertices owned. If the vertex list has not been dominated by another vertex, then that vertex becomes the dominating vertex. Mark the vertex with red which is a vertex that has been covered by another vertex that becomes dominator. At the next stage, the remaining search is done. The result of the selection of the remaining vertex can be seen in Table 1. The vertex with yellow color is a vertex that has not been covered by the dominating vertex. The next stage is to find the dominating vertex for the remaining vertices that have not been dominated. The result of selection of dominating vertices can be seen in Table 2. It can be seen that the dominating vertex is traffic light 2. Traffic lights 1, 3, 4 and 5 are the vertices that has been covered by traffic light 2. The next step is to combine the vertices that becomes dominating vertices into the domination set. The results obtained from the search dominating vertices using the Greedy algorithm is 3 vertices. The result of domination set can be seen in Figure 2.

The domination set of traffic lights which become the sources of solar cell consists of 3 traffic lights, namely, 2, 7, and 14. This result is optimal because it satisfies the lower and upper bounds, that is, \(2 \leq 3 \leq 8\) [8]. This means that the determination of solar panel point by using Greedy algorithm has been optimized because approaching the minimum domination set.

| Traffic Light | Number of Degree | List            | Information          |
|---------------|------------------|-----------------|----------------------|
| 7             | 6                | 4,6,8,9,10,11   | Dominator           |
| 4             | 5                | 1,2,3,5,7       | Not Dominator       |
| 2             | 4                | 1,3,4,5         | Not Dominator       |
| 5             | 4                | 1,4,5,8         | Not Dominator       |
| 10            | 4                | 7,9,11,13       | Not Dominator       |
| 1             | 3                | 2,4,5           | Not Dominator       |
| 3             | 3                | 2,4,6           | Not Dominator       |
| 6             | 3                | 3,7,9           | Not Dominator       |
| 8             | 3                | 5,7,12          | Not Dominator       |
| 9             | 3                | 6,7,10          | Not Dominator       |
| 11            | 3                | 7,10,12         | Not Dominator       |
| 12            | 3                | 8,11,14         | Not Dominator       |
| 13            | 2                | 10,14           | Not Dominator       |
| 14            | 2                | 12,13           | Dominator           |

| Traffic Light | Number of Degree | List    | Information          |
|---------------|------------------|---------|----------------------|
| 2             | 3                | 1,3,4,5 | Dominator           |
| 5             | 2                | 1,4,5,8 | Not Dominator       |
| 1             | 2                | 2,4,5   | Not Dominator       |
| 3             | 1                | 2,4,6   | Not Dominator       |
Figure 2. The determination of solar cell location at the traffic light network

Figure 3. Homepage of the web based system for determination of solar cell location at the traffic light network using dominating set
Figure 4. The results of solar cells determination in the system

Figure 3 shows the homepage of the web based system for determination of solar cell location at the traffic light network using dominating set. When this application is running, the system will look for dominating vertices by using Greedy algorithm. If the desired result is optimized based on the concept of dominating set, then the application will display the result as shown in Figure 4.

The data used to compare cost efficiency between conventional and renewable energy sources is which obtained from the results of interviews with the Office of Transportation (DLLAJ) Banyuwangi and manual calculations. The results obtained from the interviews are as follows:

1. each traffic light point that utilizes the energy source of PLN is charged a monthly electrical charge of Rp 300,000 and the required power of 860 wh; and
2. procurement of solar panels for power source of any traffic light point of Rp 80,000,000 and generate power of 1500 wh.

The calculation results from the simulation of the above electrical load usage shows that PLN’s electricity load for the fourteen traffic lights for 10 years is Rp 504,000,000. In order to meet the needs of the traffic lights, the required solar panels are three sets of solar panels with the amount of power generated at 4500W. The cost of procurement for the three sets of solar panels is Rp 240,000,000. Calculation of the cost of electricity for 10 years, solar panels far more efficient than conventional energy. This simulation does not include repair and battery replacement.

4. Conclusions

The information system is developed to provide the determination of solar cell location by using Greedy algorithm. The determination of solar cell location using Greedy algorithm in this research is conducted in 5 stages. The first step is to sort the data of traffic light points by the number of degrees from big to small. The second stage is to find the dominating point by considering the list point, in this process produces 2 dominator point. The third stage is to find the point that has not been covered, at this stage produces 4 remaining points. The fourth stage is to find the dominating vertex from the rest of vertices which produces 1 dominating vertex. The last stage is to combine the whole dominating vertices which produces 3 dominating vertices. The solar cell determination result of this system increases the efficiency of electricity costs compared to the use of conventional power within the next 10 years.
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