INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH
M. Z. Rahman et al., Vol.4, No.4, 2014

Modeling Components of Solar Street Light

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Received: 29.09.2014 Accepted: 07.11.2014

Abstract- The analytical, numerical or hypothetical modeling of a system goes easy when the system could possibly be described by means of mathematical equations. Unfortunately, there were no such equations exist for solar street lighting in the literature. We took the endeavor to construct the equations that might help to describe and calculate the exact amount of components when it comes as a matter of solar street light design. These equations are very first of its kind. We had checked and justified the validity of the equations for real world data. They were amazingly fit and showed the expected results.

Keywords—solar energy, street light, pole.

1. Introduction

Solar energy already has proved its position as a green energy solution for a sustainable and pollution free future [1-4]. The solar energy has found its common uses in running the home appliances and home lighting to a greater extent. To take off the burden from conventional fossil fuel based electricity driven street lighting, many countries already have taken measures to light the street powered by solar energy [5]. A solar street light generally consists of a pole, solar panel mounted on the pole, a rechargeable battery, a charge controller and a bulb (usually LED bulb). A schematic diagram of solar street lighting is shown in figure 1.

The material flow analysis and cost calculation of investment is very crucial for any large system (for example, solar street lighting) design and implementation. The material flow analysis ensures the timely and exact requirements of necessary components for the desire system. The cost analysis helps to figure out the feasibility, profit and loss of the system to be implemented. A theoretical study eventually comes out as very handy for such analysis. Unfortunately, there is no such theoretical study exist in the literature solely for street lighting. This study hence has focused on the exclusive theoretical formulation of the

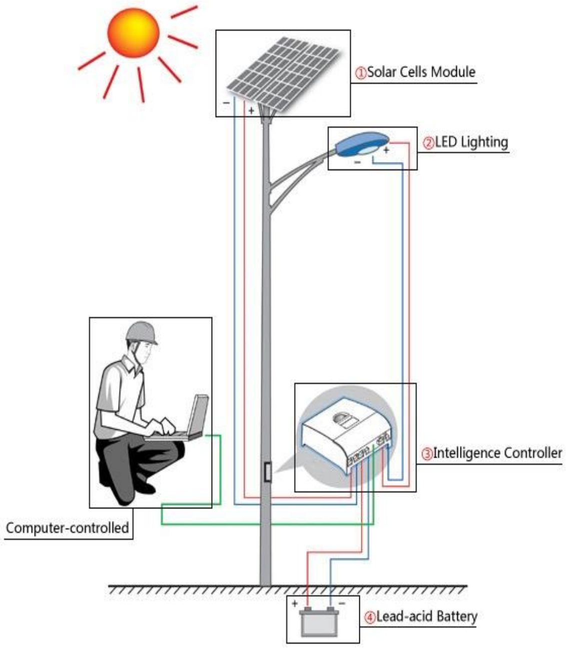

Figure 1. A schametic model of a Solar Street Light [6].

components of a solar assisted street light for any arbitrary shape of the road.

2. Background of Theoretical Formulation

Solar street lights are raised light sources which are powered by photovoltaic panels generally mounted on the lighting structure. The photovoltaic panel charges a rechargeable battery, which powers a fluorescent or LED lamp during the night. Most solar panels turn on and turn off automatically by sensing outdoor light using a light source. Solar streetlights are designed to work throughout the night. Many can stay lit for more than one night if the sun is not available for a couple of days. Older models included lamps that were not fluorescent or LED. Solar lights installed in windy regions are generally equipped with flat panels to better cope with the winds.

Lumen is the quantity of light that leaves the lamp, measured in lumens (lm). Lamps are rated in both initial and mean lumens. Initial lumens indicate how much light is produced once the lamp has stabilized. The lumen of a light depends on the height of a pole. The height of a pole stimulates the intensity of the particular light. It resolves the capacity of the light & its efficiency. Another quantity that has to be taken into consideration is viewing angle of the light. The viewing angle is the maximum angle at which a display can be viewed with acceptable visual performance. In a technical context, this angular range is called viewing cone defined by a multitude of viewing directions[7].The viewing angles for an LED light are measured horizontally and vertically, and indicate over what amount of lights are fully visible or how bright the things are shown[5]. It is obvious that maximum illumination coverage of an area by solar street light mainly depends on the height of pole, lumen of light & viewing angles. We have conceptualized mathematical formula to calculate the number of pole as a function of length of the road, height of the pole, viewing angle and distance between poles for three different shapes of roads, such as straight road, circular road & triangular road.

3. No. of Pole Calculation

We have devised equation 1 to 3 to calculate the no. of poles for straight, triangular and circular roads. The validity of the equations is justified in terms of real data for different parameters of the equations, and the calculation showed a good agreement.

$$P_{SR} = \frac{L}{2h\tan\theta + d}$$

$$P_{CR} = \frac{2\pi r}{2h\tan\theta + d}$$

$$P_{TR} = \begin{cases} 3(P_{SR} - 1) \rightarrow equal\ length\ sides \\ \sum_{k=1}^{3} P_{SR_k} - 3 \rightarrow unequal\ length\ sides \end{cases}$$

here, P_{SR}, P_{CR}, P_{TR} are the no. of poles for straight, circular and triangular road, respectively; L is the length of the road, h is the height of the pole, d is the distance between two successive poles, r is the radius of the circular road, and Θ is the viewing angle. All the units are in MKS units.

4. Justification and Validation of the Formula

In the following paragraph, the validity of the derived equations have justified with practical data. The calculation shows that equations are amazingly fit to get the desired values.

Table 1. Calculation of no. of poles for straight road as per equation 1 for varying length of the road.

L(m)	Ø(°)	θ(°)	h(m)	d(m)	P_{SR}(pieces)
1000	60	30	8	10	**52**
2000	60	30	8	10	**104**
3000	60	30	8	10	**156**
4000	60	30	8	10	**208**
5000	60	30	8	10	**260**

Using standard value for different parameters value, the calculation for no. of poles for a straight road as per equation 1 has shown in table 1 and 2. The simulated figures that have shown in figure 2 and 3 depict the nature of the equation 1. From the simulated curve of figure 3, it is quite obvious that the requirement of the no. of poles is linearly proportional to the length of the road as it is also expected for real case. The figure 3 shows the opposite relation of that of figure 2 as expected. So, the equation 1 is fully justified.

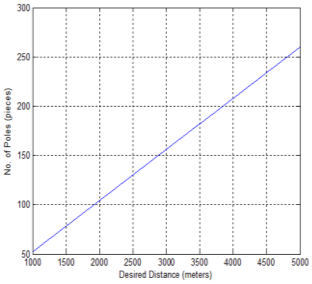

Fig. 2. Relation between the no. of poles and varying length of a straight road.

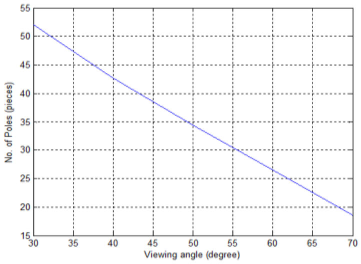

Fig. 3. Relation between the no. of poles of a straight road and varying viewing angle of a light.

Table 2. Calculation of no. of poles for straight road as per equation 1 for varying viewing angle.

L(m)	Ø(º)	Θ(º)	h(m)	d(m)	P_{SR}(pieces)
1000	60	30	8	10	**52**
1000	80	40	8	10	**43**
1000	100	50	8	10	**34**
1000	120	60	8	10	**27**
1000	140	70	8	10	**19**

Table 3. Calculation of no. of poles for circular road as per equation 2 for varying length of the radius.

r(m)	PI	Θ(º)	h(m)	d(m)	P_{CR}(pieces)
160	3.14	30	8	10	**52**
319	3.14	30	8	10	**104**
478	3.14	30	8	10	**156**
637	3.14	30	8	10	**208**
795	3.14	30	8	10	**260**

When it comes about circular road, the no. of poles are calculated around the circumference of the road. The radius of the circle now appears as very important parameter. Hence in equation 1, if we replace the length with the circumference we eventually get the equation 2.

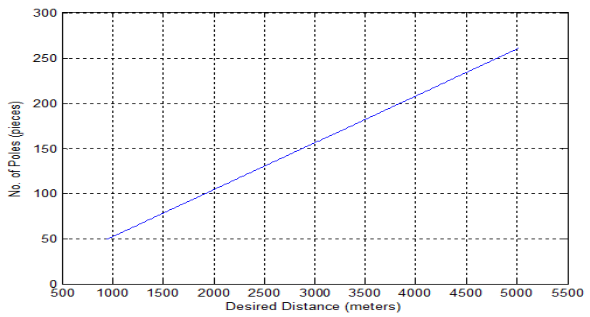

Fig. 4. Relation between the no. of poles and varying length of the radius of a circular road.

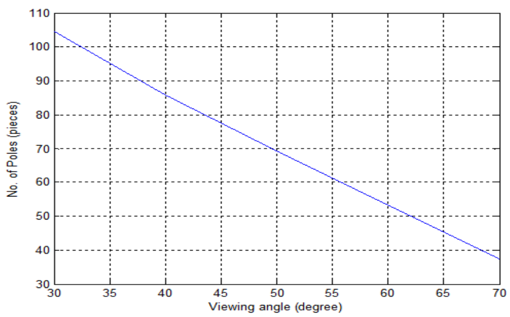

Fig. 5. Relation between the no. of poles and varying viewing angle of a circular road.

The no. of poles for a circular road as per equation 2 is shown in table 3 and 4. The simulated curves are shown in figure 4 and 5. Both the calculated and simulated data produce the expected results for a circular road, and the equation is justified as well.

Table 4. Calculation of no. of poles for circular road as per equation 2 for varying viewing angle of the light.

r(m)	PI	Θ (º)	h(m)	d(m)	P_{CR}(pieces)
320	3.14	**30**	8	10	**104**
320	3.14	**40**	8	10	**86**
320	**3.14**	**50**	**8**	**10**	**69**
320	3.14	**60**	8	10	**53**
320	3.14	**70**	8	10	**37**

For a triangular shape road, equation 1 can be adopted to calculate the total no. of poles for any of the side of the triangle. As there are three common points in a triangular shape, while calculating the total no. of poles, common point poles must be deducted to get the actual no. of poles. Hence, in equation 3 a minus 3 term has evolved.

Table5. Calculation of no. of poles for triangular road as per equation 3 for equal length of the side of the road.

L(m)	Θ(º)	h(m)	d(m)	P_{TR}(pieces)
1000	30	8	10	**154**
2000	30	8	10	**310**
3000	30	8	10	**466**
4000	30	8	10	**622**
5000	30	8	10	**778**

Table 6. Calculation of no. of poles for triangular road as per equation 3 for varying viewing angle of the light.

L(m)	Θ(º)	h(m)	d(m)	P_{TR} (pieces)
2000	**30**	8	10	**310**
2000	**40**	8	10	**254**
2000	**50**	8	10	**204**
2000	**60**	8	10	**157**
2000	**70**	8	10	**109**

The data that are shown in table 5 and 6 are calculated based on the equation 3 for equal length of the sides of the triangle. For an unequal length of triangular road, the no. of poles calculated as per equation 3 have shown in table 7 and 8. The simulated curves in figure 6 and 7 show a good agreement with the expected results and it justified the equation 3 indeed.

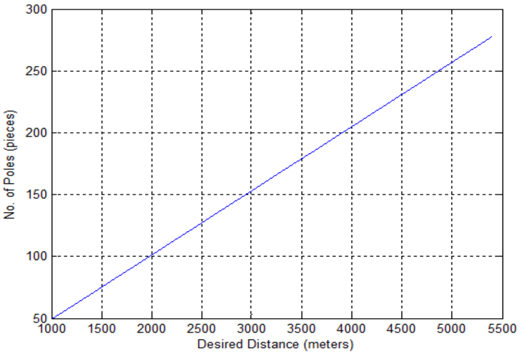

Fig. 6. Relation between the no. of poles and varying length of the equal (unequal) sides a triangular road.

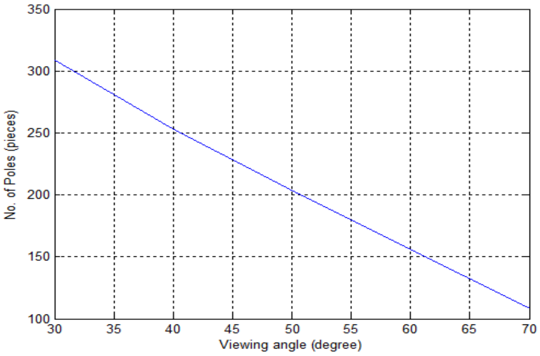

Fig. 7. Relation between the no. of poles and varying viewing angle length of the equal (unequal) sides triangular road..

Table7. Calculation of no. of poles for triangular road as per equation 3 for unequal length of the side of the road.

L_1(m)	L_2 (m)	L_3(m)	Θ(°)	h(m)	d(m)	P_{TR}(pieces)
1000	1200	1350	30	8	10	**183**
2000	1300	1400	30	8	10	**242**
3000	1350	1500	30	8	10	**302**
4000	1400	1600	30	8	10	**362**
5000	1450	1700	30	8	10	**422**

Table 8. Calculation of no. of poles for unequal triangular road as per equation 3 for varying viewing angle of the light.

L_1(m)	L_2 (m)	L_3(m)	Θ(°)	h(m)	d(m)	P_{TR} (pieces)
1000	1200	1350	**30**	8	10	**183**
1000	1200	1350	**40**	8	10	**150**
1000	1200	1350	**50**	8	10	**120**
1000	1200	1350	**60**	8	10	**92**
1000	1200	1350	**70**	8	10	**64**

5. Calculation of Components of SSL

A solar street light (SSL) basically consists of a pole, lights, PV module, battery and charge controller. For a particular shape and length of a road, if we could calculate the exact amount of poles required, we can then calculate the total no. of others component as well. If every single component needs one piece at a time to construct a complete solar street light, then the total no. of components may ask for are exactly the five times of the no. of poles calculated so far.

6. Conclusion

Solar Street lighting system is an ideal lighting system for the illumination of streets, squares and cross roads located in areas that are not connected to the power grid. We have developed few unique equations to model the components of solar street light. The equations are justified and validated with real world data to observe if they can produce the expected results. These equations have proved its 100% accuracy in this purpose. It is now possible to take a theoretical approach to model, design and cost analysis of a solar street lighting.

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