International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 09 | Sep 2019 www.irjet.net p-ISSN: 2395-0072

A Review on Design and Fabrication of a Solar Roadways

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Abstract - *The Solar roadways is a series of structurally-engineered solar panels that are driven upon. The idea is to replace all current petroleum-based asphalt roads, parking lots and driveways with solar road panels that collect energy to be used by homes and businesses. The renewable energy created by solar road panels will replace the current need for fossil fuel which is used for generation of electricity in turn reduces greenhouse gases. An intelligent highway infrastructure and a self-healing decentralized power grid that will eliminate our need for fossil fuels. Additionally, it can be used for traffic detection, illuminated roadways and on the go charging of electric vehicles using inductive charging.*

***Key Words*: solar, renewable energy, fossil fuels, greenhouse gases, electric vehicles.**

1. INTRODUCTION

The solar roadways are a series of structurally engineered solar panels that are driven upon. The idea is to replace all current petroleum-based asphalt and concrete roads, parking lots and drive ways with solar road panels that collect energy to be used by our homes and businesses. The ultimate goal is to store excess energy in or alongside the solar roadways. This renewable energy replaces the need for the current fossil fuel use for the generation of electricity. This, in term, reduces the greenhouse gases to half. The Solar roadways system would might, at present, cost about 3 times what it costs to install and asphalt road but would be more durable, more easily replaced in modular fashion and is able to pay for itself by generating more electricity than our economy can consume. At just 15% efficiency, far below what is expected, 100% solar roadways at enabled driving infrastructure would produce 3 times total electricity demand. There are additional benefits as well, which is a built-in smart grid, major new investment and job creation. The economic benefits inherent in global leadership in build in the most advanced clean energy infrastructure. Every dollar invested in renewable sources ultimately generates return because the resource is not burnt and lost. The roadways can also communicate with drivers, altering drivers with visual message to caution about the road ahead, help in traffic management, illuminate roads, at night for better visibility of the roads and lane markings. By integrating wireless inductive charging in the solar roads, we can also charge electric vehicles on the go.

They can make the emerging electric vehicle economy far more affordable and easier to manage. They can help us to eliminate 100s of billions of dollars per year, or more in externalized costs of burning fossil fuels. Perhaps the most important element of solar roadways technology is that its power generation capacity demonstrates the base load viability of renewable energy sources. Clean energy technology existence can power the entire countries economy and more.

1.1 Mean Daily Global Isolation

Insolation (also known as solar irradiation) is a measure of the solar radiation received by a given area over a given period of time. The unit used for insolation is either MJ/m2 or kWh/m2. The mean daily global insolation will give a measure of total solar energy available in each part of India. In order to calculate the amount of electricity that can be produced by the solar panels, the solar insolation data for each area are required, so that the calculated amounts of electricity that can be produced by the solar panels are closer to the actual electricity that will be produced under real environmental conditions. The mean daily global insolation values given in map for the purpose of evaluating the mean daily global insolation, the following factors have been taken into consideration:

- Solar panel orientation is treated as horizontal for this case, as they are going to be placed on roads.
- Period for which the mean daily global insolation is considered is annual. This consideration is made as we require data for calculation purposes only. The period can also be considered on a monthly or daily basis instead of annual, for more accurate calculations.
- Maximum and minimum available mean daily global insolation value as depicted in map are taken into consideration, so that an upper and lower bound estimate of the amount of electricity that may be produced by the Solar Roadways system can be predicted.

The Average Mean Insolation received in India is around 5 kWh/m2/day which is around 1825kWh/m2 per year.

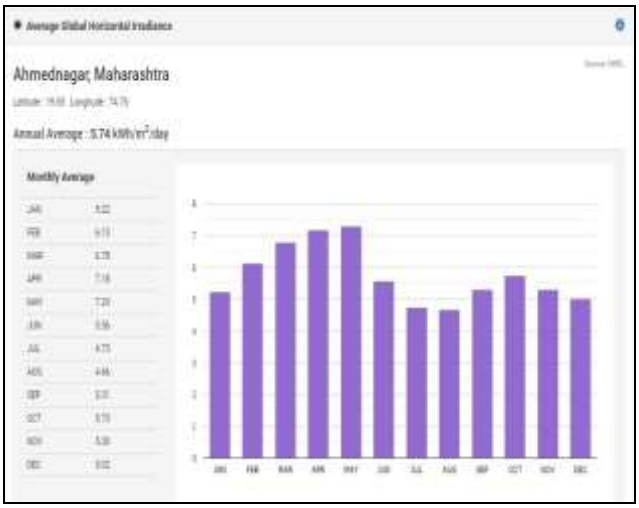

Photo – 1: Direct Horizontal Radiance in India

2. PROBLEM STATEMENT

The population of the world is on rise. It is hard to keep in line with electricity demands of the population. Thus, in developing countries like India, we still have to depend on load shading as an option to meet with the electricity supply of the country.

In India, 76.5% of electricity is generated with coal. Coal is a nonrenewable resource of energy and will exhaust in few years. Power generation with coal powered Thermal Power Plants pollute the environment and is the major cause of global warming.

Thus, to tackle with this problem, we need to implement the use of solar energy as it is free, nonpolluting and never-ending source of energy.

Our roads and highways receive plenty of sunlight during the day time. If only we were able to harness this solar energy, we would be able to meet up with the ever-growing requirement of electricity.

Solar energy is a clean and renewable source of energy. The operating cost of the solar energy generation is negligible. Thus, it also helps in reducing the cost of energy to the consumers.

3. OBJECTIVES

- India receives plenty of the solar insolation with an annual average of 5.44 kwh/m^2/day, which is quite high. Thus, making India one of the most suitable countries for solar power utilization.
- The total length of operational express ways in India is about 1581 Km. with around 800 Km. under construction. This is a total of 2381 Km. of roads which are just absorbing the suns energy. As the world is shifting towards the use of renewable energy for production of electricity, one cannot miss on solar energy. Solar roadways will eliminate the need for extra land for energy production as our existing road network can be used for generation of energy.
- In this paper, we find out the feasibility of solar roadways in India, if it covers all our roads with smart solar road panels which generates electricity, illuminates road, wireless charging of EVs and much more.

4. SYSTEM COMPONENTS

i. Solar panel

Table – 1: Types of solar panels and specifications

Solar Cell Type	Efficiency -Rate	Advantages	Disadvantages
Monocrystalline Solar Panels (Mono-SI)	~20%	High efficiency rate; optimised for commercial use; high life-time value	Expensive
Polycrystalline Solar Panels (p-Si)	~15%	Lower price	Sensitive to high temperatures; lower lifespan & slightly less space efficiency
Thin-Film: Amorphous Silicon Solar Panels (A-SI)	~7-10%	Relatively low costs; easy to produce & flexible	shorter warranties & lifespan
Concentrated PV Cell (CVP)	~41%	Very high performance & efficiency rate	Solar tracker & cooling system needed (to reach high efficiency rate)

Table – 2: Specification Of Solar Panel

Maximum Power	10W
Tolerance of Maximum Power	± 3%
Open Circuit Voltage	21 V
Maximum Power Voltage	100VDC
Maximum Power Current	9.63A
Module Efficiency	19%
Type of Cells	Polycrystalline Silicon

Cell Configurations	72 in Series
Dimensions (L x B x H)	338 × 258 × 16 mm

ii. Base layer

Generally, the base layer is made up of the recyclable materials used in construction work. These materials are as follows

- Fly ash
- Micro silica
- Crushed Air-Cooled Blast Furnace Slag (Aggregate)
- Ground Granulated Blast Furnace Slag (GGBFS)
- Demolition Waste (MALWA)
- Reclaimed Bitumen/Asphalt Pavement (RAP)
- Plywood sheets

iii. Battery Bank
iv. LEDs
v. Transformer
vi. PIC Controller
vii. Relay
viii. LCD Display (16x2)
ix. IR Sensor
x. Wireless charging Kit
xi. Power Supply
xii. Glass

5. DESIGN & CONSTRUCTION

5.1 List of Materials

Table – 3: List of Materials

SR. NO.	NAME OF THE PARTS	MATERIAL/ MODEL	SPECIFICATIONS	QTY.
1	Solar Panels	Monocrystalline (Solar India)	10W	1
2	Base Layer	Plywood	-	1
3	Battery Bank	-	12V	1
4	LED	4 stripes of 3 LEDs each and 2 Individual LEDs	-	12
5	Transformer	-	-	2
6	Pic Controller	PIC16F877A	40 pins	1
7	Relay	Sun hold RAS-1210 Relay	-	1
8	LCD Display	-	16x2	1
9	IR Sensor	-	2cm Range	2
10	Wireless Charging Kit	Copper Windings (Coils)	4 coils	4
11	Power Supply	-	-	1

5.2 Schematic Diagram

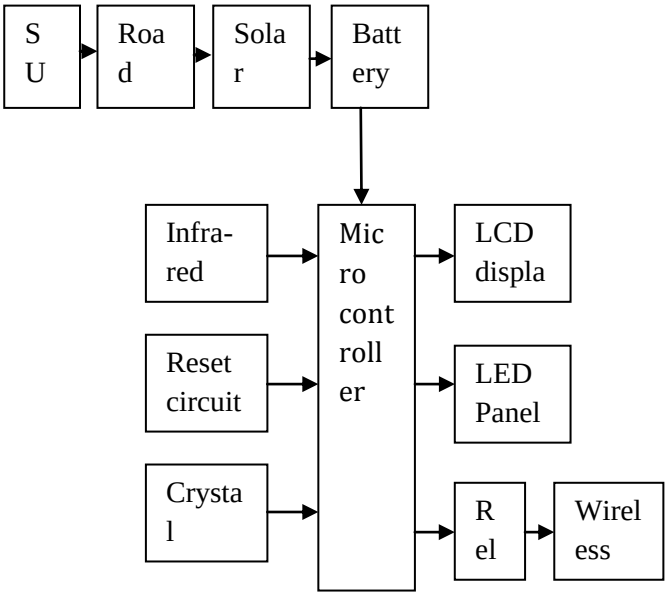

Figure – 1: Schematic Diagram

5.3 Model

The project design and modelling are done on Catia V.5, the assembly design and exploded view is as below:

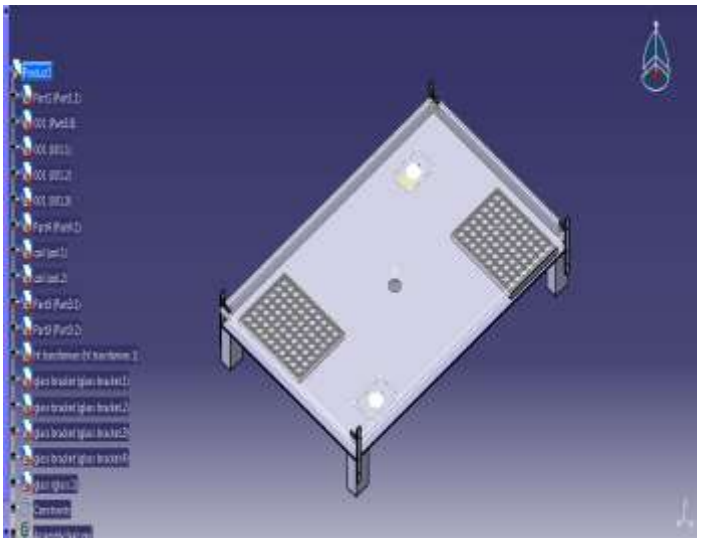

Photo – 2: Assembled (Isometric) View

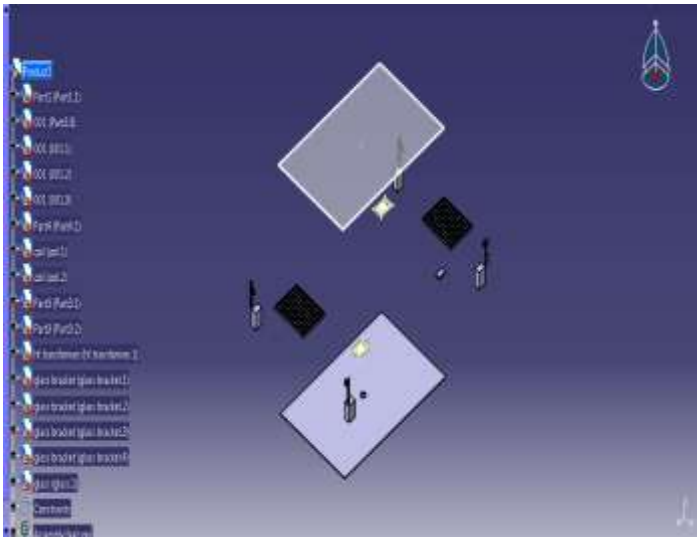

Photo – 3: Exploded View

5.4Energy Produced In Each Area Based On Selected Parameters

Based on the available length and width of road for each area total area available forconverting into Solar Roadways is calculated.

Total Length of Expressway Roads = 1581.4 km
Considering road of 4 lanes. Width of 1 lane is 3.75m.
Width of 4 lanes = 15m

Therefore, the total Area of Solar Roadways = Length of Road x Width of Lanes
Hence, Area = 1581.4x103 x 15 = 2, 37, 21,000 sq. m.
Then based on the average daily sun peak hours (i.e. number of hours in a day a location will have solar irradiation of 1000 watts per square meter), total sun peak hours available for a year in each area is calculated. Finally, based on the calculated area, total yearly sun peak hours in each province and using the data form the selected solar panel, the energy that can be produced in each province by solar roadways is calculated. The global formula to estimate the electricity generated in output of a photovoltaic system is:

E=A x r x H x PR
E =Energy (kWh)
A =Total Solar Panel Area (m2) = 2, 37, 21,000 sq. m
r = Solar Panel Yield or Efficiency (%) = 19% = 0.19
H = Annual Average Solar Radiation (shadings not included) = 1825 sq. m
PR = Performance ratio, coefficient for losses (range between 0.5 and 0.9, default value= 0.75) = 0.75
Therefore,
E= 2, 37, 21,000 x 0.19 x 1825 x 0.75
Hence, annual solar energy output of a photovoltaic system
E=6, 16, 89, 42,562.5 kWh
Or
E= 61, 68,942.5625 MWh
E=6168.9425 GWh

5.5 Cost of Solar Roadways

The solar roadways panel consists of the following parts liste d below

i. Solar Panels
ii. Pre-casted concrete housing
iii. LEDs
iv. Induction Charging
v. Electronic Circuit Board
vi. Piezo-electric Sensor
vii. Tempered Glass Surface
viii. Battery Bank

5.5.1 Solar Panels

We have selected solar panel manufactured by Vikram Solar Technologies which has an efficiency of 19.0% which is highest available in India. SOMERA Grand 1500V SERIES poly solar panel is selected. The cost of the above Solar Panel model is INR 13, 00,000/-

The dimensions of the Solar Panel are 1956 × 992 × 36 mm. Thus, total surface area of the solar panel is 1.94 m2. Approx. 2 m2
Thus, total solar panels needed to cover 1 km of length and 15m width (4 lanes) is, Surface Area of 1 km road is = 1000 x 15 = 15,000 m2.
Therefore, Total number of Solar Panels needed to cover 1 km is = Surface Area of Road / Surface Area of Solar Panel = 15,000 / 2 = 7500. Therefore, for 1 km of Road, we require, 7500 Solar Panels.
Cost of Solar Panels for 1 km is 7500 x 13,000 = INR 9, 75, 00,000/-

5.5.2 Cost of Tempered Glass

Tempered Toughened Glass of 30mm thickness is used. The Cost of toughened glass is INR 350 /sq. ft.

Thus, to cover a single solar Panel of $2m^2$ surface area,
The cost of covering a single unit of Solar Panel is,
$2m^2$ = 21.5278 sq. ft. x 350 = 7534.73 INR approx. INR 7500/-

Hence, to cover road of 1 Km length = No. of Solar Road Panels X Cost of covering a
Single unit = 7500 x 7500 = INR 5, 62, 50,000/-
Hence, Cost of Covering the Surface with Tempered Glass is INR 5, 62,500/-

5.5.3 Cost of Pre-Casted Concrete Housing

Cost of Pre-cast Concrete is about INR 2000 per sq. ft.
Hence, for a single unit, the cost of concrete housing is 21.5278 x 2000 = INR 43055.6
Approx. INR 43,000 per solar roadway unit.

Hence, to cover the road of 1 Km length, total 7500 units of S olar Panels are used.
Hence, the cost of Pre-Cast concrete for 7500 units is INR 32, 25, 00,000.
Cost of PreCast Concrete for 1 km length is INR 32,25,00,000

5.5.5 Cost of LEDs

The Cost of a RGB LED Strip is INR 100 per meter length.
Considering laying LEDs onthe perimeter and in the middle, hence total length in 8m.
Hence, cost of covering each panel is INR 800.
For, 1 Km road, Cost of LEDs are 800 x 7500 = INR 60,00,000

5.5.6 Cost of Piezoelectric Modules.

Cost of Piezoelectric Generator is around INR 5000 for a sing le Panel.
Hence, cost of piezoelectric generator for Road Length of 1 K m is 5000 x 7500 =3,75,00,000.
Cost of Piezoelectric Module is INR 3,75,00,000/-

5.5.7 Cost of Induction Charging Module

Basic Cost of a copper wire is INR 75 per meter. The inductio n charger is of diameter0.8m and 36 turns. Hence, cost of tot al copper wire used is ΠD x no. of turns x cost
Hence, cost is π x 0.8 x 36 x 75 = INR 2160 for a single unit of Solar Roadways.
Cost for 7500 units which cover 1 Km length of road is INR 1,62,00,000
Cost of Induction Charging Module is INR 1,62,00,000/-

5.5.8 Cost of Electronics

The electronic circuit board consists of LED Control Module, Communication Module, Sensor Settings, Wireless Induction Charging control, etc. The electronic circuit board controls the operation of the Solar Roadway Unit.
Considering the cost of Electronics about INR 10,000 for each unit, and thus for covering a length of 1 Km road which has 7500 modules = 10,000 x 7500 = 7,50,00,000
Cost of Electronics is INR 7,50,000/-

5.5.9 Total Cost of Solar Roadways.

Cost per unit = INR 86,460/-
Cost of 1 Km length of 15 m width = INR 64,84,50,000/-

6. RESULTS & DISCUSSIONS

6.1 Result

The following outputs have been measured during the daylight conditions at Different elevation,

Table – 4: Daylight Condition at different Elevation

Height	In	Out	Time
0	20.2V	18.5V	6 Sec
5mm	13.43	14.75V	6 Sec
1cm	9.8V	10.33V	6 Sec
2cm	6.10V	6.94V	6 Sec
3cm	3.76V	4.54V	6 Sec
4cm	2.60V	2.84V	6 Sec
5cm	1.83V	1.89V	6 Sec

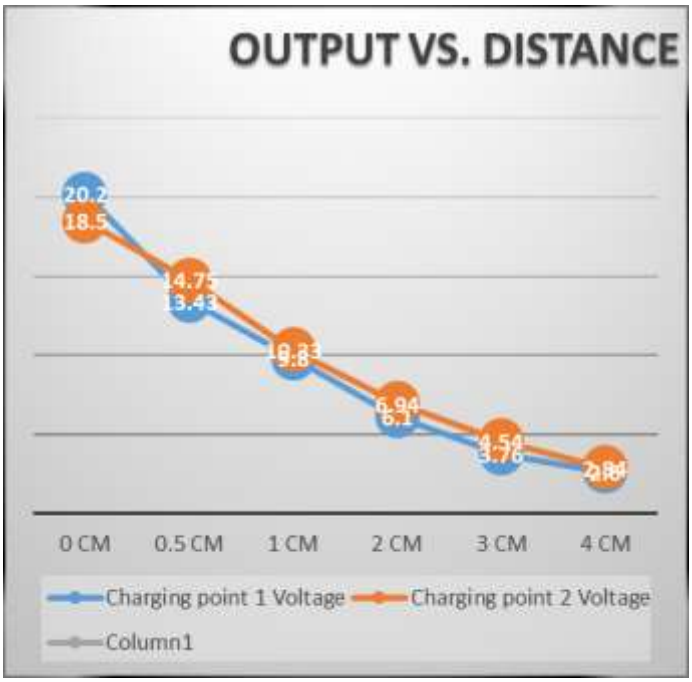

Chart - 1: Graph of Output Vs Distance

6.2 Advantages

1. Renewability and lifespan the main advantage of the Solar Roadway concept is that it utilizes a renewable source of energy to produce electricity. It has the potential to reduce our dependence on conventional sources of energy such as coal, petroleum, and other fossil fuels. Also, the life span of the solar panels is around 3040 years, much greater than normal asphalt roads, which only last 7-12 years.

2. No requirements to develop environmentally sensitive lands another advantage of the Solar Roadway is that it does not require the development of unused and potentially, environmentally sensitive lands. But since the roads are already there, this is not an issue. Also, unlike large photovoltaic installations, new transmission corridors - across environmentally sensitive land- would not be required to bring power to consumers in urban areas. Transmission lines could simply be run along already established roadways.

3. On-the-go charging with induction plating embedded inside these roads, all electric cars can be recharged while in motion on top of these roads. This would reduce the costs, and the time inconvenience to wait at a charging station.

6.3 Disadvantages

In spite of these advantages, initially, the startup and maintenance costs of building roadways and parking lots may be extremely high. (However, advances in this technology will (hopefully) cause the costs to fall.) Another issue to deal with is the efficiency of solar panels. The average efficiency is currently a matter of concern. Another disadvantage is that it cannot be constructed in the poorest developing nations due to the high initial start-up costs. Road surfaces also accumulate rubber, salt, etc., which block sunlight. Salt might be easy to wash off, but not rubber. It would also be quite costly. Solar roadways may not be feasible and economical as it initial and installation cost may be three times more compared to our convectional roads, but if this, evaluated as a long-term investment this may prove to be much more economical as it pays us back.

7. CONCLUSIONS

• If the government sanctions it in the step by step like firstly going with the small expressways which will make money supplying the power to grid, or small industries nearby.
• But Solar Roadways at present is not feasible to be implemented on a large scale. Mostly, because of the very low efficiency, of the solar panel and the very high initial cost. The efficiency of the solar panel also fluctuates throughout the day, if we are able to increase, the efficiency of the solar panel and the lower cost at the same time, solar roadways will be a very good alternative for both electricity generation and smart roads.
• As for India, India enjoys high solar Insolation throughout the year. Hence, Solar based power generation will be a very good option the only drawback is the high temperature, in our country as the efficiency of the solar panel drops with increase in temperature.

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