A Path to the Future: Solar Roads

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Abstract - *There have always been issues in the Indian power industry in meeting the power generation goals. Conventional sources of energy, especially coal, have not been able to keep up with demand. The idea of implementing Solar Roads in India isn't a new one. The New Delhi Municipal Council (NDMC) planned on implementing a solar road in New Delhi, and even presented it as a pilot project in their 2018 budget, But the trial of the project failed. Through this paper, we intend to present a better plan for construction of smart solar roads in India. One of the biggest advantages of Solar Roads is that, once installed, it can solve maximum road issues and problems using one of the inexhaustible sources of solar energy, the sun. Through the research conducted by us for this paper, we found out that solar roads will be able to produce almost three times the electricity generated currently in the country.*

Key Words: **Solar Roads, Solar Energy, Construction, Electricity Generation, Smart Road.**

1. INTRODUCTION

Solar Roads consist of structurally engineered solar panels which are interlinked with each other to form a road on which we can drive. A solar road is a paved surface that generates electricity by using embedded solar power photovoltaic cells which will replace the existing asphalt-based highway system with an intelligent road, which will generate large amounts of electricity. The panels will be constructed of specially formulated tempered glass that will be resistant to heavy vehicles and have an asphalt-like surface. Photovoltaic cells are used in making the solar panels along with electrical wiring and LED lights. When connected between highways, villages, parking lots and rest stops; this system creates a vast, power-collecting network. They provide a decentralized, secure, intelligent power grid which pays for itself.

As we know, the electricity is available to many places, yet there are towns in India where electricity is scarce and moreover the cost of bringing electricity to remote areas only increases the cost on the company as well as the customers. This is where solar road comes into the picture, it helps people staying in remote areas to get a cheaper and convenient source of electricity. The land that is taken in for construction of solar roads provides more accessible roads for traveling which encourages tourism and is also a cheaper source for electricity.

The goal is to store the excess energy generated by the Solar Roadways. The use of fossil fuels for the generation of electricity can also be reduced by using renewable solar energy, which in turn also reduces the greenhouse gases by almost 50%. The Solar Roadways system at present costs about three times than what it costs to put down an asphalt road, but over time it would be durable, easier to replace in an exceedingly modular fashion, and ready to generate more electricity than our economy can consume.

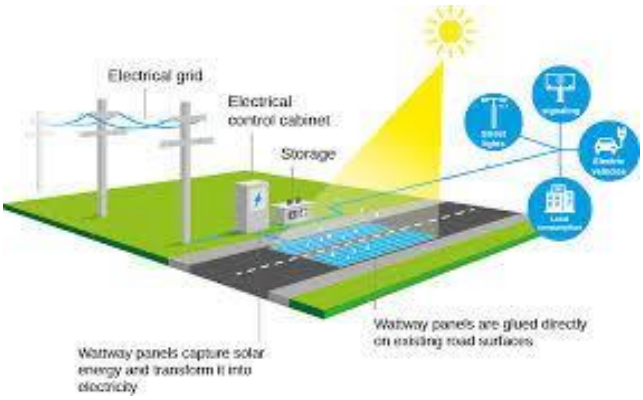

Figure 1.1 Working of Solar Cells

At just 20% efficiency, a 100% Solar Roadway infrastructure would produce thrice the total electricity demand. There are additional benefits, such as a built-in smart grid, major investment, job creation, the economic benefits in global leadership by building the foremost advanced clean energy infrastructure and every rupee invested will ultimately generates returns, because the resource isn't burned and lost.

2. LITERATURE REVIEW

This section helps in reviewing and understanding the contents of the preceding papers and research conducted in this field.

In paper [1] a comparative study was conducted between rigid and flexible solar panels. From this paper we learnt that currently solar cells are producing only around 1% of the earth's energy every year and hence our paper is an

attempt to increase the use of the vast and untapped potential energy in the form of solar power. This paper concluded that flexible cells will be used worldwide, where sunlight is abundant and land use is less. Paper [2] gives a brief study of solar roads and their workings and what is the necessity of solar roads. The comparison between asphalt and solar roads based on safety and costs tells us that solar roads are much more reliable and also help in generating electricity.

Paper [3] consisted of the perfect combination of piezoelectric and solar energy that can be used to generate electricity and make travelling safer and cost effective, highlighting the operation and advantages of solar panel roadway. The paper ends with a discussion of how these solar roads are much better and efficient. In paper [4] the advantages and disadvantages of the solar roads and their implementation in the upcoming future were discussed. This paper also gives a brief overview of the challenges faced during the practical implementation of solar roads and ends with the future scope of these roadways.

Paper[5] presents a case study of the different solar roadways already built by exploring their various features. This paper concluded that solar roadways could help in reducing the country's greenhouse gas emission by 50% and will also help in the prevention of accidents. In paper[6], a study investigating the possibility of solar roads all over the world is presented. The overview of construction and cost calculation is also given in this paper. Finally, the paper ends with a discussion of how solar roadways would prove to be beneficial for India.

After a thorough understanding of the previous work done in this field, we proceed further to present our study and findings on this topic.

3. PROPOSED TECHNIQUE

3.1. SOLAR ROADS

The Solar Road is a series of interconnected, mechanically powered Solar Road panels. These Solar Road panels will capture and store solar energy to be used by our homes and businesses. This energy from renewable sources eliminates the need for the existing fossil fuels used to produce electricity. In fact, this practically cuts greenhouse gases in half.

The initial targets for these solar roads are highways, petrol pumps and parking lots. Through the initial studies conducted, it is estimated that the solar roads will produce more than thrice the electricity currently produced and used nationwide, based on an earlier analysis of the electricity which will be produced by solar roads.

The panels can support heavy vehicles since they are made of specially formulated tempered glass which has a surface with properties like asphalt. The solar road panels consist of heating elements (Snowmelt System), microprocessors, motion sensors and LED lights.

3.2. WORKING AND DESIGN

The basic design of a solar road panel is shown in the figure below:

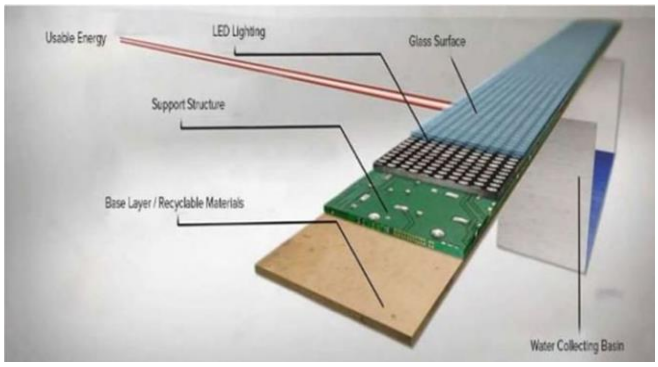

Figure 3.1 Basic Design of a Solar Road Panel

The solar road panels will have 4 layers:

- The first layer will be the special tempered glass layer which can support heavy vehicles.
- The second layer consists of the solar cells integrated with the LED lights.
- The third layer is the electronics layer which will consist of the motion sensors, microprocessors, the snowmelt system, and cables.
- The fourth layer will be the base plate layer which will distribute the power collected to the electric grid where all the power is stored and will also protect and insulate the electronics layer above.

The LEDs will help in illuminating the roads thus, saving the cost of road signs. They can indicate if there is a blockage in the road ahead or if there is a freer route available.

Figure 3.2 LED Smart Road with SLOW Sign

3.3. MATERIALS

Table 3.3 Materials and Hardness for solar roads.

Hardness (Moh scale)	Material
1.0	Graphite
1.3	Asphalt
3.5	Brass
5 - 5.5	Knife plate
5.5 - 6.0	Plate glass
9.0	Tempered glass

3.4. SMART ROADS

The solar roads can communicate with drivers by alerting them with visual messages to the presence of pedestrians in a crosswalk. The microprocessors will be used to collect data and will help the solar road panels to communicate with each other and with a central control station.

The motion sensors will detect motion in light and dark conditions which will be useful in conserving the energy used by the lampposts along the highway when a particular stretch of the road hasn't been used for some time and to check the speeds of the vehicles driving on these roads. These sensors will help by detecting suspicious movement thus, providing security. The third-generation solar cells having a guaranteed efficiency of 30% or more efficient and are also cheaper as compared to the first and second generation of solar cells.

Solar cells will be placed in a way to absorb the maximum amount of sunlight that leads to the photovoltaic effect to take place. The photovoltaic effect causes the separation of charged particles creating an electric field. The electricity generated due to the potential difference will flow to the end of the solar cell into a conducting wire. The wire will transport the electricity to the inverter where the DC is converted to AC which can be used in households.

An extensive analysis can be done by performing experiments and researching on this project to find out the voltage output of each solar cell. With extensive resources being put into the research and the project, rigid equations have already been implied when considering the equations such as annual output average, early power and energy equations of no loss systems, loss leverage early power and the list goes on.

4. PREVIOUS WORKS

Everywhere you look, there is an attempt to use renewable energy as the main energy source, and one of the most interesting is solar roads. From American start-ups to French prototypes and beyond, solar roads have gone through their trials and tribulations. Where's the technology at? Will we be seeing them soon? Let's get into the details about their previous developments in the world, and if they were worth it.

4.1. SOLAR ROADS IN THE UNITED STATES

The Solar Roadways Route 66 experiment isn't offering good number of benefits to justify paving the entire United States in solar road tiles. Although these roads provide other features, but all are irrelevant to the main point: These roads are not practical due the safety issues along with high cost of maintenance, So the solar roads are not a feasible solution in the United States.

4.2. THE SHANDONG PROJECT IN CHINA

China opened a one-kilometer-long solar road as a trial for future developments in the field, to observe and study the benefits of solar roads. China's data suggests that it's not a viable plan. Having a cost of over $450 USD equivalent per square foot, it is not a reasonable investment by any government: They don't generate enough electricity to be worth it. While solar energy being a renewable source could power an entire country but due to the lack of resources and no results to show for it, we are still a long away from implementing solar roads on a large-scale.

Figure 4.1 Shandong Project Solar Road

4.3. THE FRENCH WATTWAY

Dubbed by ARS Technical as the "World's first solar road". In 2014, in the village of Tourouvre au Perche in Normandy this road was strategically placed. The initial goal was to redirect all solar power generated from the road to the streetlights in the village. The conclusion of the Wattway was that solar roads are currently far too expensive to implement.

4.4. THE DUTCH SOLAR BICYCLE PATH

As a slightly different approach, designed for cyclists instead of automobiles, the Dutch created a solar pathway. The results proved to be far more favorable in terms of durability, after replacing the top layer with a more durable material since the top layer of the road came off in its first year, this issue gave them insight for improvement.

Figure 4.2 Dutch Solar Bike Path

5. COMPARISON WITH PREVIOUS WORKS

Some countries have experimented with solar roads with transparent concrete/asphalt being employed rather than tempered glass. However, due to the staggering prices, such experiments have limited to only a few tiny stretches of roads. Cost accounting around Rs15 Lakh, the New Delhi Municipal Council (NDMC) had also started a test on solar roads in a public-private partnership (PPP) model in 2018. The test trial was conducted on a 380-square meter stretch within the NDMC headquarters, with 704 solar panels put beneath glass-paved roads. But India's first solar roadway in Delhi was scrapped because of insufficient research. A major problem being faced with solar roads is safety as the experiments show that the cars are skidding off the solar road surface. The panels also have issues of leakage of water and dirt and muck sticking under them, which if not cleaned, will not generate energy.

Due to all the previous unsuccessful attempts to generate maximum energy through solar roads, we have used third generation solar cells which combine the best features of the first- and second-generation solar cells to generate maximum amount of energy. These solar cells are much cheaper, more efficient, and much more practical than previous generation solar cells, which would help in reducing the overall cost of the project. We have selected the hexagonal shape of these panels after careful deliberation so that any force from vehicles is distributed to multiple surrounding panels thus reducing the amount of damage done to the solar roads and strong, specially tempered glass is used to improve longevity and safety. So given proper funding, resources and support we will do proper research to overcome the limitations that came up the 1st time around. To assure increased durability of solar roadways, we will also be using motion sensors to track the speed of vehicles moving on the roads to ensure that they don't damage the solar road panels.

6. LIMITATIONS

Talking about the limitations, solar roads are much costlier as compared to the asphalt roads on the initial stages i.e., when we must replace the asphalt roads to the solar roads. The cost of the solar cells required is one of the main reasons that this technology has a slow growth. Also, the storage required for storing this solar energy is expensive. The top layer of panels is made up of glass, so there would be a chance of the glass to break due to heavy weight. In regions where there are snow falls, this project is impractical because the roads may be covered with the snow and there would be no direct sunlight available.

During the time of maintenance or a repair is needed the cost may be higher as compared to the asphalt roads. The durability and the damage controllability may affect the traffic and power. Depending on solar throughout the year maybe difficult in some areas that may not have sun during some seasons. The creators are seeking funding and more research to make this more affordable and to increase the efficiency.

7. CONCLUSION

India has the second-largest road network in the world and receives about 300 days of sunny weather. The Government of India is convinced about the potential of solar power, which can be seen by the announcement of its goal to increase India's solar power capacity to 100 gigawatts by the year 2022. The downside of the current scenario in the Indian power industry is that India has always faced issues in meeting its power generation goals and thus, does not have enough electricity to power all its cities, towns, and villages. In this context, the idea of solar-powered roads that provide electricity to homes and businesses throughout the country does sound like a good idea. Solar Roads, once installed, can solve maximum road issues and problems too using one of the inexhaustible sources of energy, the sun.

Solar roads currently have a few drawbacks like high cost, durability, and unfavorable weather conditions. However, we tend to believe that with the proper resources, funding, and support, we will be able to design solar roads in such a way that we will be ready to overcome those limitations and thus, solar roads will provide energy with much more efficiency.

We would like to inaugurate this technology in India by proposing a project to design, develop, properly test and implement solar roads in India. The designing and development of solar roads will be done in such a way that it will best suit the transportation needs and topography of the country. The solar road panels and therefore, the smart roads that accompany them, will create significant environmental and similarly social differences. Compared

to conventional asphalt and concrete roads, these roads will have safer driving conditions, will provide a major supply of unpolluted and clean energy, and will help in the conservation of energy. These roads are a giant investment initially. However, they are going to, without a doubt, pay off in the long run not only financially but also environmentally.

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