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DESIGN OF SOLAR BASED E-VEHICLE CHARGING SYSTEM

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ABSTRACT:

Charging electric vehicles (EV) from photovoltaic (PV) panels provides a sustainable mode of transportation. In order to reduce the net costs of charging EV from PV and the grid, the PV generation and/or the EV charging can be controlled based on the energy prices in the grid. The traditional approach to designing the solar system for EV charging is to maximize the energy yield. In this paper, an alternate approach to PV system design is proposed by which the PV panels are orientated so as to maximize the PV revenue. This technique is compared with that of reducing the net costs by smart charging of the EV based on energy prices. Two case studies for Netherlands and Texas are done to compare the PV energy generated and the net cost of EV charging from PV based on the two techniques.

1. INTRODUCTION:

Road transport is undoubtedly the most common and affordable form of commute for people around the world. However, recently, it has faced much criticism due to its dependence on fossil fuels and its relatively low operational inefficiency. This has opened the doors for the electric mobility industry, and the world has witnessed a drastic surge in the acceptability of EVs.

As India aims to decrease its carbon footprint like other nations and step into the world of sustainability, the government is consistently introducing transport sector reforms that aim at the electrification of all effective forms of commute. As a result, according to a study conducted between 2020–2027, the average annual growth rate for the EV sector in India is estimated to be around 44%.

Articles published by various research scholars and authorities mainly focus on the importance of shifting towards EVs, the technical aspects of charging stations, and the governments' policies to develop the necessary infrastructure for EVs. Topics such as the need for India to move away from its crude oil imports, fighting climate change to reduce its carbon footprints, and reducing pollution have been discussed in detail, and conclusions regarding India moving into the EV space following its global peers have been made. Moreover, new energy storage and transfer technologies that can be used to implement the charging infrastructure have been studied according to the necessary requirements.

It is essential to differentiate between what 'looks sustainable' and what 'is sustainable' to implement sustainability. EVs are a formidable example of decreasing instantaneous emissions, but they shift the energy demand from crude oil to electricity. This ultimately increases the pressure on the grid infrastructure that is already facing an energy deficit. In India, nearly 61% of the grid electricity is from coal-based thermal power plants

Upon considering three categories of vehicles, EVs running on electricity from the grid, internal combustion engine-based vehicles (ICEVs), and EVs running on electricity from solar photo voltaics (PV), and calculating their well-to-wheel CO2 emissions, EVs running on electricity from solar PV turned out to be the least polluting. Such an EV would lead to only 0.6 kg of CO2 emission per 100 km travelled. In contrast, a 5-seater gasoline-based ICEV would produce about 13 kg of CO2 in covering the same distance, and an EV running on grid electricity would cause 10 kg of CO2 emissions per 100 km travelled (considering a similar share of the different sources, as listed above). The unavailability of charging stations at regular intervals is another matter of concern, and nearly all of the available ones are grid-tied. Hence, grid availability becomes a crucial point while deciding the location of a charging station.

2.BLOCK DIAGRAM:

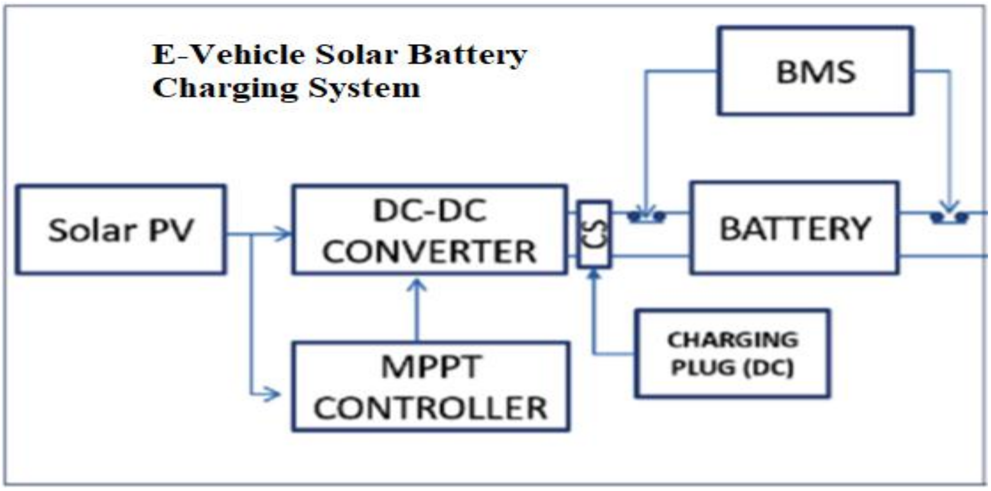

Fig.1 E-Vehicle Solar Battery Charging System

Solar Panel: Solar panel consists of PV cell which converts suns energy directly into electric energy. Solar panels are made up of silicon. They consist of 72 or 60 solar cells, they are electrically interconnected in series and parallel and sand witched between glass and plastics. There are 3 types of solar panels they are, mono crystalline, polycrystalline and amorphous. The most efficient solar panel is mono crystalline can reach over 20% efficiency where as poly crystalline can reach only 15 to 17% efficiency.

MPPT: MPPT (Maximum Power Point Tracker) is algorithm that includes charge controllers used for extracting maximum available power from solar module under certain conditions. The voltage at which solar module can produce maximum power is called maximum power point. MPPT check output of solar panel, compares it to battery voltage then fixes what is the best power that solar panel can produce to charge and to get maximum current into battery.

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DC-DC Converter: An electronic DC-DC converter helps in converting the high power generated from solar panels to required EV battery voltage. These DC-DC converters use MPPT to support the PV panels to operate at maximum power. The DC-DC converter offers an interfacing between the PV panel and the load to achieve maximum power transfer without loss.DC-DC converters are widely used to efficiently produce a regulated voltage from a source that may or may not be well controlled to a load that may or may not be constant.

Battery: The batteries are made up of unit cells containing the stored chemical energy that can be converted into electrical energy. Lead acid battery is a type of rechargeable battery. It is the first type of rechargeable battery ever created. Compared to modern rechargeable batteries, lead-acid batteries have relatively low energy density.

Battery Management System: The purpose of a battery management system is to keep the battery safe and secure for long hours from over charging and discharging. This restrict the energy supplied to the battery from the solar panel when the battery reached full charge and disconnect the electrical loads from battery when the battery reaches to minimum level. This automatically connects and disconnects through BMS using ON state/ OFF state switches.

3.TYPES OF CHARGING METHODS:

CONDUCTIVE CHARGING-AC AND DC:

This is the most common charging method right now it has 2 categories: ac and dc charging.

- **AC charging:**
- The battery can be recharged anywhere using the ac grid and the onboard EV charger.
- The EV charger can easily communicate with the battery management system (BMS) and no additional power electronic converters are needed in the EV charger. This leads to higher performance and lower cost.
- **DC charging:**
- It can be designed with either a high a low a charging rate, and is not limited in its weight and size.
- Dc charging with high power requires a low charging time.

INDUCTIVE CHARGING –STATIC AND DYNAMIC:

- **Static charging:**
  - The main idea behind inductive charging is the use of two electro magnetically linked coils.
  - The primary coil is placed on the road surface in a pad-like construction linked with to the electricity network.
  - The secondary coil is placed on bottom or top of the vehicle.
  - The 50Hz AC power from the grid is rectified to DC and is then converted to a high-frequency AC power within the off board charger station. Then this high-frequency power is transferred to the EV side by electromagnetic induction. The coils on the car convert this high-frequency AC power back to DC to charge the EV using the onboard charger.
- **Dynamic charging:**
- The other way to charge a car wirelessly is called dynamic charging the coils are connected to electric cables which used to provide the power and are buried in the road.

- The coils emit an electromagnetic field that is picked up by the vehicles driving over them and converted into electricity to charge the vehicles.

BATTERY SWAP CHARGING:

- The third method of EV charging is a battery swap. It works on the basis of switching out the depleted battery and replacing the same with a full battery.
- The process involves driving into a battery switching bay and an automated process will position the vehicle, switch out the current battery, and replace it with a fully charged battery. The depleted batteries are charged in the station for later deployment.
- The system works on the business concept that the EV user owns the vehicle and not the battery. Battery swap requires a foolproof way to estimate the batteries' state of health to check for its usage pattern and to ensure that only authorized vehicles and charging stations can charge it.

4. PROBLEM IDENTIFICATION:

- Electric vehicle which uses 100% electric power, use electric motors instead of an internal Combustion engine to produce motive force.
- Solar powered vehicles (SPVs) use photovoltaic (PV) cells to convert sunlight into electricity.
- The electricity goes either directly to an electric motor powering the vehicle, or to a special battery.
- PV cells produce electricity only when the sun is shining. Without sunlight, a solar powered car depends on electricity stored in its batteries.
- Since the invention of petrol diesel, it has been consumed recklessly for the source of energy without considering the harmful effects caused by it to the environment.
- At this level of consumption petrol diesel is going to extinct by 2050. But the need for energy resources increasing is 105 times faster than the nature can create.
- Most of cities in developing countries are highly polluted. The main reasons are the air and noise pollution caused by transport vehicles, especially petrol- powered two and three wheelers.
- For example, in India are close to 18 million petrol powered two wheelers and about 1.5 million petrol and diesel powered three wheelers.
- Their population is growing at a healthy rate of about 15% per annum being a major hazard to people ’health’.
- These machines are guzzling huge amount of petrol and diesel for which the country has to pay dearly in foreign exchange out flow.
- In fact, it is a common sight in developing countries that during traffic jams in congested areas of cities these vehicles produce tremendous pollution.

5.SIMULATION:

The e-Rickshaw battery charging system is analyzed at different insulations and temperature. The irradiance on PV system is varied to 500W/m2 from 1000W/m2 at 250C temperature, for which PV array output power changed from 701W to 346.5W. Similarly, output voltage at its MPP is changed from 92V to 87.5V. The

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Fig.4.3.1 and Fig.4.3.2 presents the PV output power and voltage with change in time. When irradiance kept as fixed and it is observed that the SOC of the battery is increased linearly. For a small charging time i.e. 10s the SOC of the battery is changed from 30.000% to 30.023%, it is seen from the Fig 4.3.3.

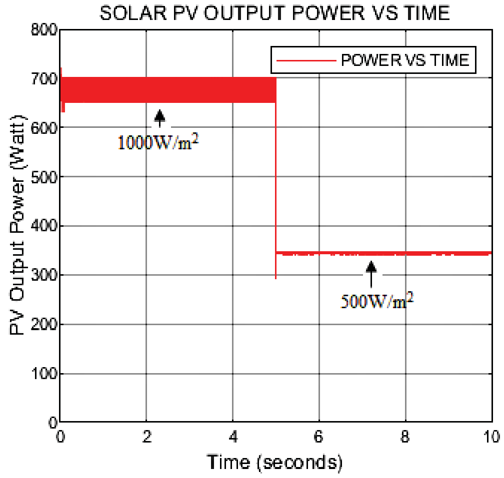

Fig 4.3.1 PV output Power vs. Time at 1000W/m2 and at 500W/m2

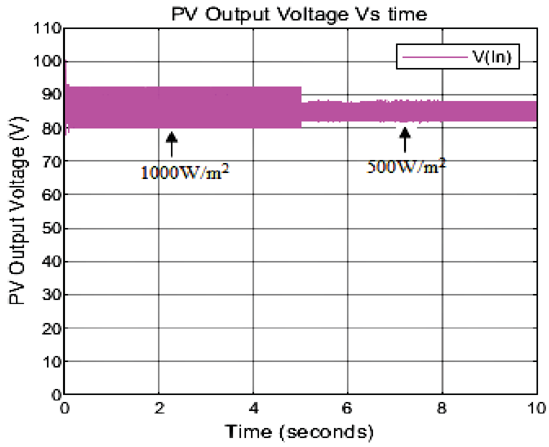

Fig 4.3.2 PV output voltage vs. time at 1000W/m2and at 500W/m2.

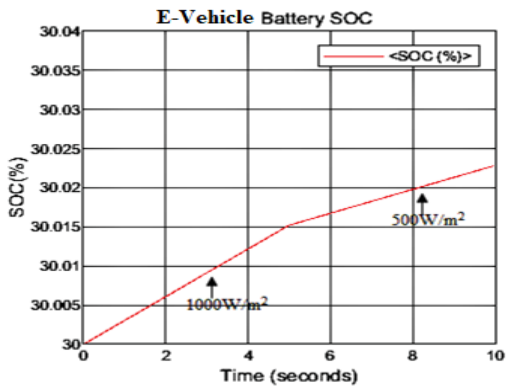

Fig 4.3.3 Change in SOC (%) vs. time 1000W/m2

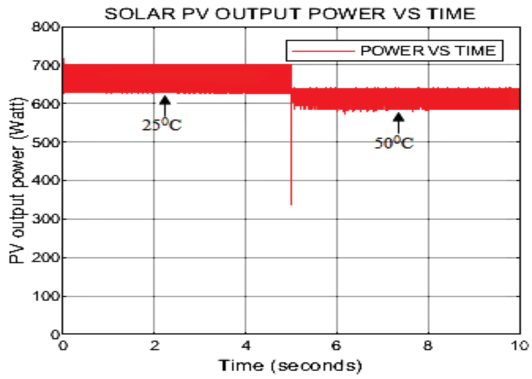

Fig 4.3.4. PV output power vs. time at 250C and 500C and at 1000W/m2 and at 500W/m2.

Further, this is analyzed by changing the temperature of Photovoltaic cell from 250C to 500C. The PV output power and voltage changed from 701W to 640W and 92V to 83V and which is presented in Fig.4.3.4 and Fig.4.3.5 respectively. Similarly, at fixed irradiance the rate of change of SOC in 10s of charging is from 30.000% to 30.026%, which can be observed in Fig.4.3.6.

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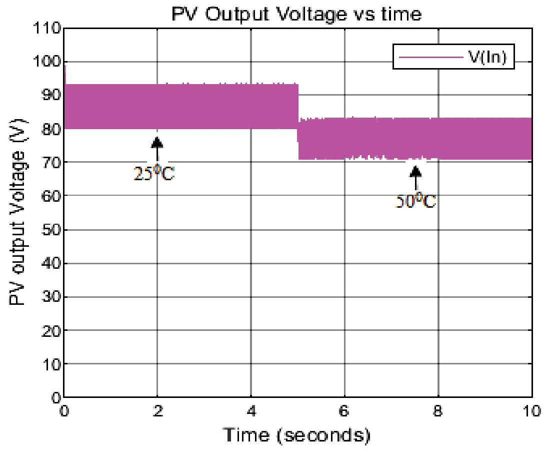


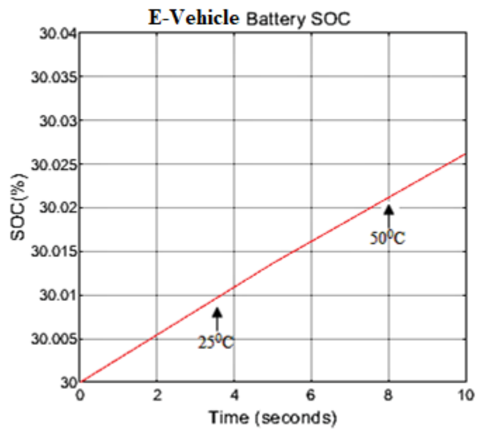
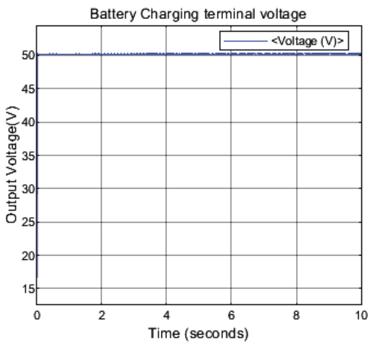


Fig.4.3.5. PV output voltage vs. Time 250C and 500C and 1000W/m2.

Fig.4.3.6. Change in SOC (%) vs. time at at 250C and 500C and 1000W/m2.

However, the charging voltage of the battery charger in the e-Rickshaw is regulated at its rated voltage (50.25V) through MPPT charge controller and is depicted in Fig.4.3.7. Moreover, the battery is analyzed from over charge flow and depth of discharge by using BMS. The Fig.4.3.8 can be observed that battery is started charging from 80% of SOC and after full charged i.e. 100% the battery disconnected from charging. Similarly, battery is protected from deep discharging.



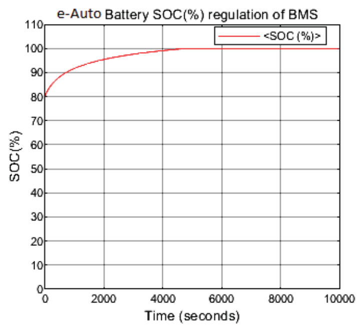


Fig 4.3.7. Charging voltage vs. time.

Fig 4.3.8. E-Vehicle battery protecting from overcharging by BMS.

Solar Hybrid E-Vehicle is simulated with Li-ion battery pack and the variations of Motor Current, battery pack Voltage, battery pack Current and State of Charge (SOC) are observed as shown in Figures 4.3.9 & 4.3.10.

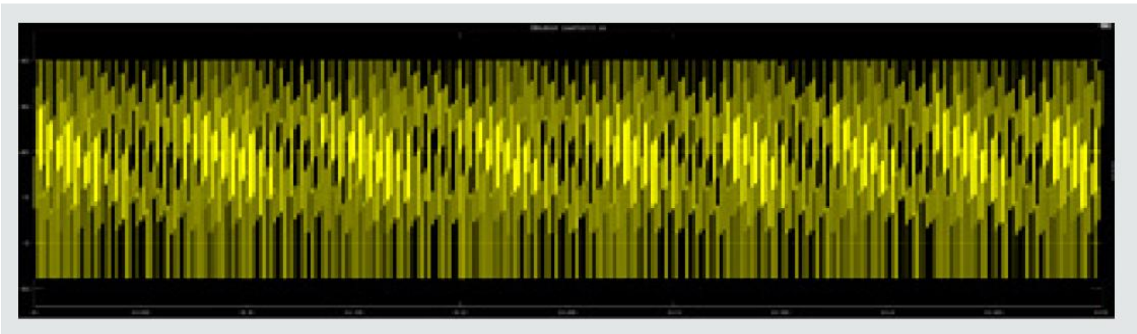


Fig 4.3.9:Li-ion battery pack Voltage, Current and State of Charge (SOC in %).

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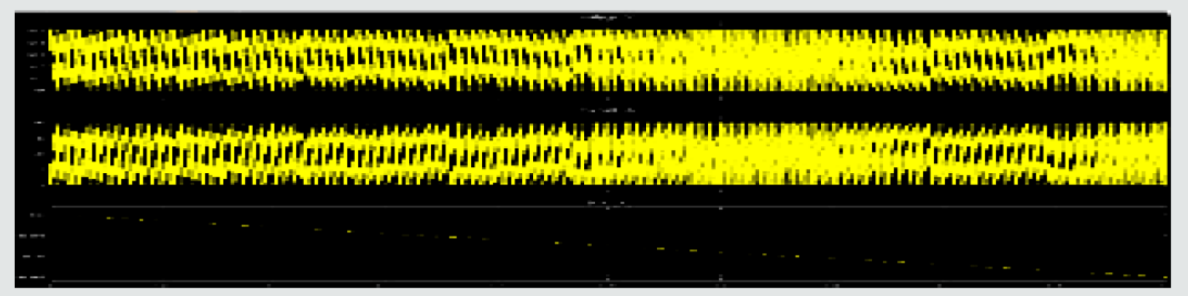

Fig4.3.10. BLDC Stator Current.

Results for Solar Hybrid E-Vehicle Simulation with Simultaneous Heterogeneous Battery Packs. In this part the solar hybrid E-rickshaw is simulated with both Li-ion and lead acid battery packs. The variations of Battery pack State of Charge (SOC), voltage and current are observed as shown in Figures 4.3.11 & 4.3.12. The energy sharing for the simulation of solar hybrid E-Vehicle with heterogeneous batteries shows that that Li-ion battery shares higher energy during transient operating conditions.

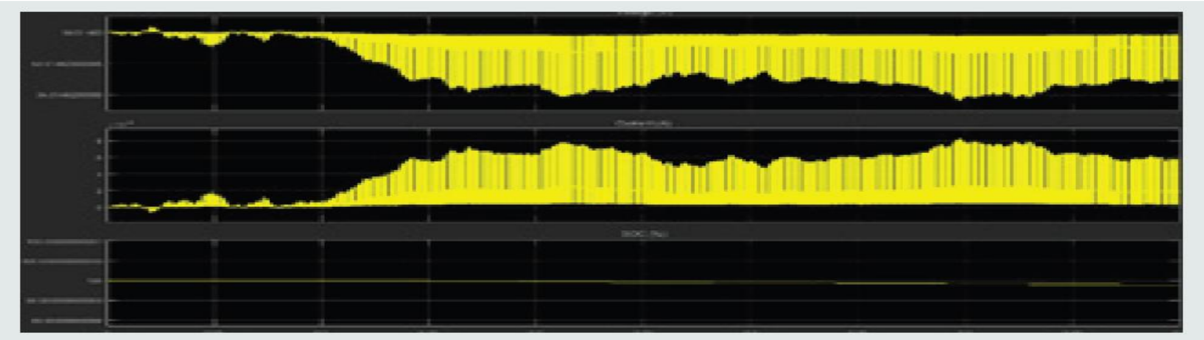

Fig 4.3.11: Li-ion battery pack Voltage, Current and State of Charge (SOC in %).

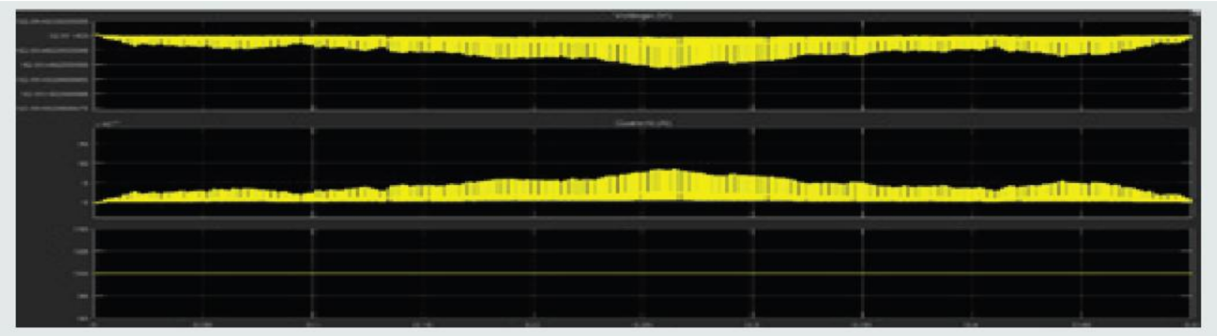

Fig 4.3.12. Lead Acid battery pack Voltage, Current and State of Charge (SOC in %).

6.CONCLUSION:

Workplace charging of EV from solar energy provides a sustainable gateway for transportation in the future. It provides a direct utilization of the PV power during the day and exploits the solar potential rooftops of buildings. In this paper, the PV system design and dynamic charging for a solar energy powered EV charging station for Netherlands is investigated. Using data from KNMI, it was seen that the optimal tilt for PV panels in the Netherlands to get maximum yield is 28.The annual yield of a 10 kW PV system using Sun power modules was

10,890 kW h. Using a 2-axis solar tracker increases the yield by 17%, but this gain is concentrated in summer. Solar tracking was thus found to be ineffective in increasing the winter yield, which is the bottleneck of the system. The average daily PV energy production exhibits a difference of five times between summer and winter. This necessitates a grid connection for the EV–PV charger to supply power in winter and to absorb the excess PV power in summer. Since high intensity insolation occurs rarely in the Netherlands,the PV power converter can be undersized with respect to the PV array by 30%, resulting in a loss of only 3.2% of the energy. Such a technique can be used for different metrological conditions in the world for optimally sizing the power converter with respect to the peak power array for the array. Dynamic charging of EV facilitates the variation of EV charging power so as to closely follow the solar generation. Since solar generation exhibits a Gaussian variation with time over a 24 h period, Gaussian EV charging profile with a peak at 1200 h and a peak lesser than the installed peak power of the solar panels would be most ideal. The exact value of the Gaussian peak and width are location dependent. EV charging using Gaussian charging profile G3 and G4 with peak power of 5 kW and 4 kW were found to closely follow the PV generation curve of Netherlands.

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