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Output Prediction (Reading and drawing conclusions)

The following document aims to develop a starting equation for predicting solar panel power outputs. It will be organized as follows: paper summaries (of the existing literature) with subsequent commentary of each, thoughts on an initial formula structure, work on said structure, and then testable variations.

Resource 1: Real-time prediction models for output power and efficiency of grid-connected solar photovoltaic systems

Key terms:

Solar irradiance – Power per unit area produced by the sun in electromagnetic radiation. This is measured as watt per square meter (W/m2). It should be noted that solar irradiance is most intense in places where directly facing the sun (ie. The equator).

\*I think it should also be noted that the panel observed was placed in Macau, China, which is near Beijing, which has slightly-less-than-average solar potential.

Installed capacity – the max. capacity that a system is able to run at. This is found by multiplying the amount of modules by their max. power output.

Summary: The paper appears to make equations to cover yearly and monthly output power for solar systems, fitting a measured value of about R2 (whatever that means). The researchers account for multiple incarnations of efficiency and solar irradiance along with the fitted values of each. The experiment implements the Gaussian model to find joint distribution of efficiency (that could be useful).

The researchers gathered data by monitoring an array of cells over the course of 12 months (with the data being recorded in real-time). Using real-time data, the researchers procured graphs of linear fit and drew conclusions as to what the key determinants were. The researchers sought to find formulas for both power output in the yearly/monthly criteria and power efficiencies in the yearly/monthly criteria.

The power output of the panels, as expected, fluctuated in steady bell curves, with the peak of power output close to noon and no power output during the night hours. This bell curve had predictable tendencies, but the size of each curve was heavily influenced by overcast. While analyzing power output averages over the course of a month, the researchers confirmed that summer months outputted more power on average and for longer times in any given day.

The writers address the three main models for predicting solar output, which are physical, time series, and neural network (NN) models, and explain how their model deviates from these three. Unlike the three main models, the writers’ model makes use of Gaussian equations and focuses more on real-time data (as opposed to historical data or statistical data).

My thoughts: Let me give a rundown of the potentially useful equations I’m seeing within this study…

-yearly average minutely output power

-monthly average minutely output power, which is effectively the same equation but with more detailed data points (and because of this I ought to use it for the application).

-yearly/monthly averages of solar irradiance over the course of a day

-yearly/monthly efficiencies of a solar panel

I think most of what I’m seeing can be implemented into my equation, but I need to think about how the data that I can collect can be accurately implemented into these formulas. One of the new things about solar panels that I learned from this article is that solar panels tend to be more *efficient* during the winter, because the cells at this time aren’t as hot and can absorb more energy.

One of the things lacking from this article is patterns pertaining to shading caused by the weather. While it is obvious that clear skies allow for a perfect power output curve, it does not say how one can predict power output given overcast on a certain day. One thing I would have also had liked to know about was the total output (in kWh) per month & year the solar panel outputted. Since the number wasn’t given to me, I am attempting to ascertain an estimate given the formulas they provide in their equation (and that doesn’t include the interference of weather).

A bit of explanation on behalf of the part of power output and the charts presented. Fig 1. Of section 3 shows the power output of watts per meters squared per minute. This means that the total system’s output is that number times the surface area of the panel arrangement (15.325 m2). Using the noon hour of March 4 as an example, we see that the average output is about 90 W/m2, so the total output of the system during that minute is:

**90 x 15.325 = 1379.25 Watts 🡪 1.37925 kW**

The installed capacity of the solar arrangement is 2.1 kW, meaning that the arrangement is never used to its full capacity (and I would suppose this is due to the less-than average solar irradiance in China, where the experiment was conducted. Had it been set up here in Arizona, I think we would see higher efficiencies). The writers express the panel’s efficiency ratio as:

**Efficiency ratio (t) = (power outputted at time t) / (solar irradiance at time t)**

Looking back on the efficiencies section, I’m thinking that this issue might be better addressed after I can predict the power output. Most solar panel products already give you an estimated efficiency, so it seems I could use this as a way to find output. In other words:

**Power Output = [(Avg. solar irradiance in a region) \* (Efficiency ratio of the PV panel)] \* Time**

…and of course, this does not factor in the weather for the given amount of time. Another thing the above equation would need to look at is how the solar irradiance changes over time. Being able to figure this issue out, one would have the power output of a PV system under perfect conditions over period of time (t). As of right now, finding an API or formula for solar irradiance is the next step for the broader equation.

Resource 2: Calculation of Solar Insolation

Key Terms:

-Solar Insolation: Just another term for solar irradiance.

-air mass: path that the light particles take through the atmosphere to get to a certain point on the earth’s surface.

Summary: This info page features a small interactive graph to show daily solar insolation given latitude and day of the year. There’s a trove of equations I can use to develop the graph into my own code. Couple this with the efficiency of a given panel, and I think we have the “best case” power output.

Commentary: