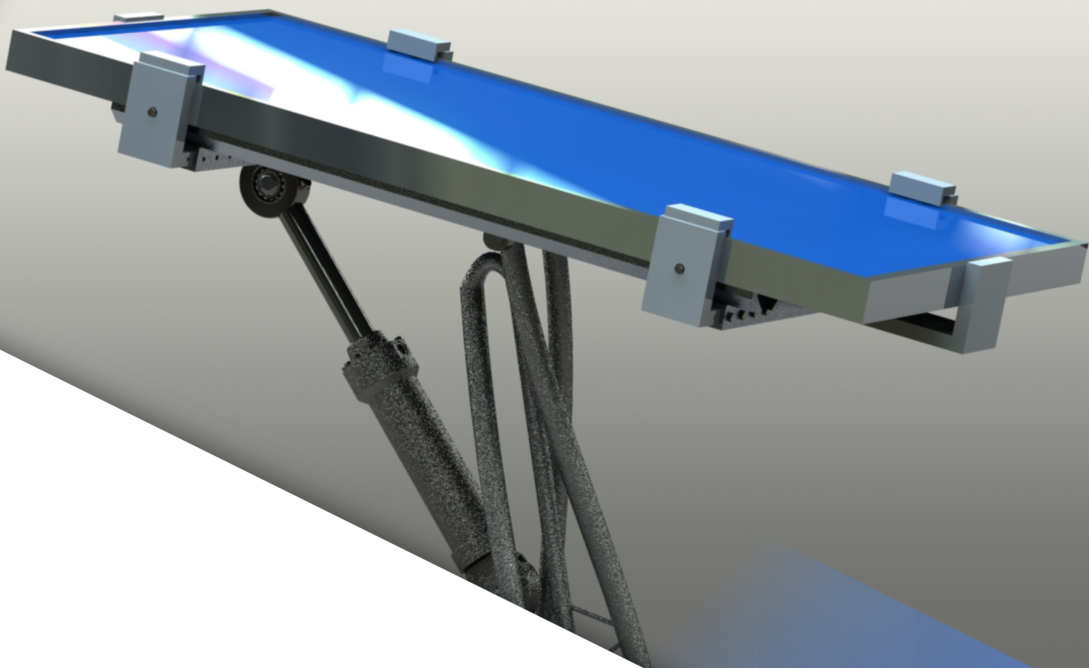

HELIONEX

Case Study

Analysis of Tracking Technology on PV Systems

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Purpose and Disclaimer

This case study is meant to compare the benefit of tracking solar energy systems to traditional static panels. The report does not examine a particular concept of implementing solar panels, rather it shows a spectrum of potential benefits and shortcomings. As a result, specific analysis of performance (section 2) and limitations (section 4) are widely generalized, and an economical analysis (section 3) is solely written to show potential cost impacts without any figures.

HELIONEX actively works on prototypes to innovate solar technology and will provide data-based analysis on the respective methods, some of which are seen in section 5. Until then, the reader can educate themselves on the potential drawbacks and benefits that a dynamic system will have over a static one.

1 General Motivation

Reliance on transitory energy, such as fossil fuels, expedites depletion of international resources. Non-renewable energy accounts for nearly 85% of all energy consumption and as a result, is expected to deplete its finite resources within the century if no alternative is found.

Low-resource requirements deem solar energy as the leading renewable source available. Although it lacks residential consumption compared to traditional energy, its market share grows alongside its research opportunity. Photovoltaic research and development grow at an exponential rate, leading to discoveries such as perovskite-silicon tandem solar cells which increase efficiency and power generation [6].

Developing a dynamic system that works alongside PV research will result in multiplied energy generation. The outcome of this technology can optimize efficiency to play on par with non-renewable sources of energy, hence preventing an energy crisis while maintaining resistant qualities that prevent obsolescence.

2 Anticipated Performance

We can simplify analysis based on our *ideal conditions*[1]. Our first step is to determine the *solar irradiance*[2] variation throughout the day [7], and apply a restriction dependant on the max conversion available with today's technology.

In figure 1, the red function represents the solar energy generated from the dynamic system, assuming it uses 20% of available solar irradiance [1] available throughout a day. This data is obtained from a day in summer. The cyan function shows the energy generation of a static solar panel. It is adjusted to obtain the maximum amount of energy at solar noon in summer, also known as our optimal solar angle. Conversely, the dark blue curve is there to represent how a static panel that is most optimized for capturing energy during solar noon in winter would behave throughout a day in summer.

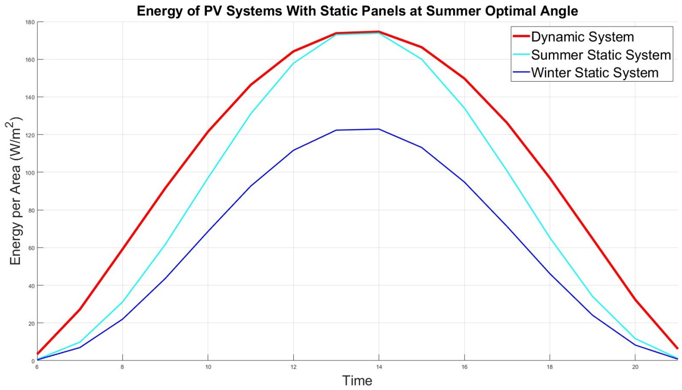

Figure 1: Solar radiation variation throughout the Day in Summer for Calgary, assuming ideal conditions

As a consequence, the curves shown in the figure do not represent specific real-world data.. However, it is good at presenting the upper and lower limits of the performance increase with adding dynamic systems. As it happens, we can actually predict the benefit of tracking technology by creating a function that is dependent on how far we deviate from the most optimal summer angle. Recall, a summer angle is the angle at which a static panel faces to obtain the highest amount of energy generation during solar noon at a given day in summer. Any deviation from this angle results in lower efficiency. Indeed, the greater the deviation from the summer angle, the greater the benefit of upgrading to a dynamic system. The function is plotted in figure 2.

Accordingly, many dynamic systems are optimized to benefit from both winter and summer. The light blue section in figure 2 shows where most systems would fall in; between 20% and 50%.

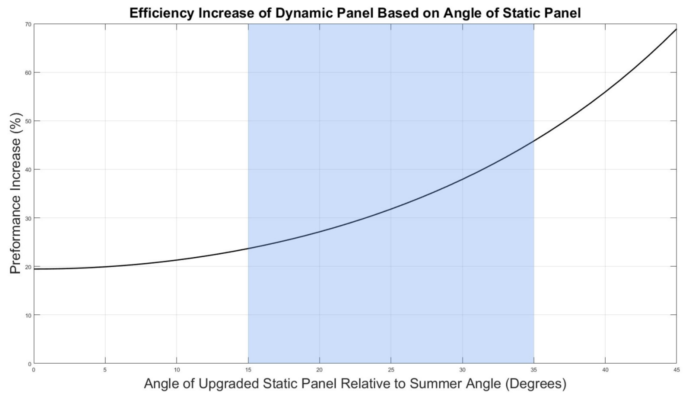

Figure 2: Efficiency increase, dependent on the variation of summer angle.

3 Economical Viability

The cost of operation is a major factor in determining if upgrades into dynamic systems are worth it. If an increase in performance in greater than an increase in price, there is some a point that exists that we can squeeze out the most efficiency at an optimal price. This is one area of research that is still developing; cutting costs in manufacturing and

[1] Our ideal condition neglects weather effects and sun variation, and assumes the systems are in the same location. We limit our scope to one day and one season to control how many sun hours we obtain. This differs from STC conditions.

[2] Solar Irradiance – Power per unit area that the sun radiates to earth. This value varies based on geographical location, weather, etc.

research to drive PV systems down. This section covers some points that may be important to think about when discussing economic viability.

Cost-Benefit Analysis

For tracking technology to be viable, it should be able to compete with a similar lifespan compared to static systems. However due to the potential complications of dynamic application, the maintenance period or cost will increase. Compared to a static panel these factors are more costly in the long term. However, a benefit of an upgraded system presenting even 50% more energy can incorporate net metering[3] technology into panels. This will significantly offset costs for consumers and develop a more financially stable structure for long-term usage, despite having higher upfront and maintenance costs.

ROI and Efficiency Gains

The return on investment for consumers is measured in the excess power of the panels (along with the credit due to net metering) as well as the overall increase in energy production through a fixed cost with annual maintenance rather than a monthly bill based on the electricity consumption of the household. Because dynamic solar panels are more effective than standard energy systems, longer usage of a dynamic pane results in exponential benefit gain compared to a traditional system. This is not only in terms of just the net metering credit but also overall energy production.

As an example, if a household's usage for a given period is 35kWh with a solar panel grid that generates 45kWh, they have an excess of 10kWh which is sent back to the grid. With the implementation of a dynamic system, let's assume a 30% increase in efficiency which results in a generation of 58.5 kWh. Because of the unchanged usage there is an excess 23.5kWh sent to the grid, a 135% increase in net metering. For this given scenario, every 10% increase in efficiency leads to nearly a 20% increase in net metering income. This is shown in figure 3.

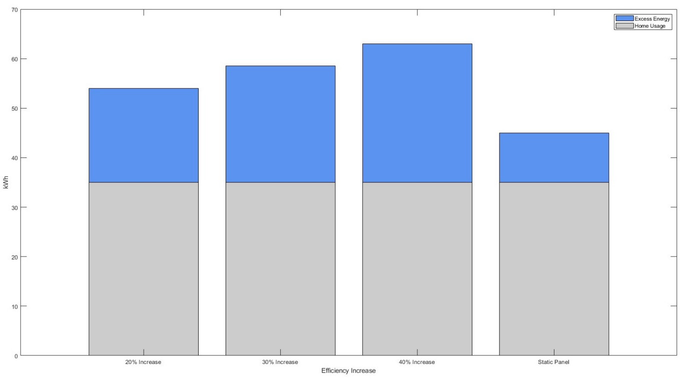

Figure 3: The increase in net metering compared to an increase in energy generation.

Costs of Solar Cells

The typical solar panel is a standalone monocrystalline residential solar panel containing around 60 solar cells that generate around 1.75 - 2.80 kilowatt-hours (kWh) of energy per day. The power output is enough to power all sorts of small home appliances like microwaves or coffee makers and can go all the way up to powering a home's AC system. Monocrystalline panels are panels made with a single piece of silicon containing pyramid cell patterns, therefore making it much easier for electricity to flow through and covering a larger surface to collect more solar energy, giving it an efficiency rating of 18%-22%. The cost of solar panels will dictate the overall cost of a dynamic system, so it is important for this technology to become more feasible and efficient to drive costs down.

4 Limitations

Limitations of modern tracking technology on solar panels could be seen mainly when monitoring the solar panel efficiency for commercial uses as compared to more urban and home-owner-friendly ones. The following section outlines some tracking panel usage limitations that may not drastically improve upon static systems or may even reduce viability.

Environmental Conditions

A common and less preventable limitation is the environmental conditions. For example, short winters and snowy days in Canada limit static and dynamic systems' exposure to sunlight. However, dynamic panels could prevail in this limitation with techniques to melt snow off panels, discussed further in Michigan Tech's research [2].

Another issue would be overheating, for countries near the equator. It turns out that even though solar panels want sun, they drop 0.5% points in efficiency for every degree Celsius above their recommended temperature requirements [3]. This limitation can impact both static and tracking panels as certain areas around the world, such as those faced with easterly winds and polar winds, can influence their maintenance requirements for mechanics and general electrical efficiency.

Spatial Requirements

The size of solar panels greatly affects their performance and ability to track effectively. The costs of larger solar panels, generally, are greater by over 25% [4]. Some studies suggest that consumers would rather purchase smaller, and multiple, short-celled solar panels for lower prices rather than larger cell arrangements as their prices seem more favourable [5] (despite pricing being nearly the same). Larger solar panels are beneficial as they contain a larger surface area, generating more energy. In contrast, smaller solar panels take longer to generate the same amount of energy, assuming they are exposed to the same conditions.

[3]Net Metering - electric grid stores any excess energy to credit back to you

When discussing dynamics, smaller sizes translate to less power required for actuation, whereas larger solar panels will need more power to move.

Resources

The availability of natural resources impacts the manufacturing and production of solar panels. High-efficiency solar panels, such as those equipped with tracking technology, require higher-costing resources. This creates a dilemma for companies seeking to produce and distribute solar panels, considering both time and quantity. A primary influence is a company's ability to gather resources (based on financial availability). The resource limitation affects tracking panels more, as tracking technology is more resource-demanding. Static panels are restricted to a simple mount, whereas dynamic systems require unique mounts and actuation technology.

5 Implementation

The conditions in which a solar panel functions can vary greatly from nation to nation. It is essential to consider the geographical challenges that solar panels face, which has an impact on metrics such as performance and structural integrity. We are able to consider a variety of systems and designs that could work depending on the factors we wish to fulfill.

Single and Dual Axis Systems

Single axis systems would restrict solar panel movement to a single axis. Though limiting movement, less energy is spent aligning the solar panel, and therefore more useful energy is conserved for other functions such as household/industrial use. On the other hand, dual axis systems could be more useful with more precise alignment on maximum energy generation. However, dual-axis systems impose an additional degree of freedom which can greatly complicate our system with cost and design. This in return can impose larger size requirements and increase energy consumption. Applying an efficient technique to choose which system works for a given scenario is a difficult task that affects the long-term benefit for a consumer.

Fully Off-Grid Systems

A major implementation which has been less pursued but holds great potential is the applications of off-grid solar systems, such as remote vacation rentals. These solar panels run independently and are able to combat the challenges of sensor accuracies through self-sufficient optimization tools. Off-grid systems follow a conversion cycle that ensures they function independently of external influence such as powerline transmission controlled by municipalities. Although an off-grid system isn't fully reliant on dynamic panels, we can still consider how much more independent an off-grid system can become through more optimized energy generation techniques. Systems exist today that rely solely on static systems,

Sensor and Sensor-less Designs

Sensor designs are useful in collecting data and precisely predicting the environmental conditions for a dynamic panel to adjust accordingly. However, this design adds a level of complexity to our build. As an alternative, we are able to use a "brainless" design. Chemicals can be placed as a thin layer inside a solar panel (nearest the external environment) and react to the sun's direct exposure as it varies throughout the day. This system allows for an effective alternative to tracking sensors and can be implemented on static panels. The thin layer of chemical acts as a 'guide' for the solar panel, and evaporation can create lower pressure areas of the solar panel which could result in re-orientation.

Methods of Actuation

The dynamics of a system depend on how we can actually move the solar panel around. Some factors to consider include maintenance, lifespan, and complexity. If we choose hydraulic pistons, we only require one piston per degree of freedom. These mechanisms alone can last for a decade, but require general maintenance to prevent any fluid leakage. We can also consider motors, which can move the mechanism for a degree of freedom, but require more complex parts such as power transmissions. With more dependent parts, frequent maintenance is required. However, the lifespan of these mechanics can exceed over a decade.

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