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Estimating Material Cost for a Ground-Mounted PV Tracker Plant

How a Solar Tracker's Material Cost is Affected by Wind, Snow, and Seismic Loads for a Given Terrain

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Introduction

It is well known that one of the best locations for a Photovoltaic Solar Plant is where solar radiation is greatest. In general, these locations are in the southwestern US as shown in figure 1. Other sunny locations include Hawaii and southern Florida. What may not be so apparent is how a solar plant's material cost may be affected by geographical location. Depending on the terrain, forces on the structure created by wind, snow, and seismic events affect the required size of the structural members which in turn affects overall system weight. For instance, in Arizona, design wind speeds are 90mph, but in southern Florida, design wind speeds can reach 150mph. In most situations, wind loading is typically the primary consideration when designing a single axis solar tracking system. As the wind passes over the top of the photovoltaic panels, in certain cases, it applies a torque or moment to the supporting structure (figure 2.) This torsional load is then reacted by the supporting structure, and eventually, if designed properly, finds its way to ground.

Another type of loading occurs in mountainous or higher elevations where snow loading is a consideration. Building codes such as ASCE 7-05, ANSI/AISC 360-10, 360-05 require these type of structures to simultaneously support snow and wind loads. In areas of heavy snow fall, this becomes a driver of material cost.

Finally, the 3rd most common consideration for the structural design of a solar plant is seismic loading. Similar to how a bobblehead doll on a vehicle's dashboard reacts to road conditions, seismic events shake the solar tracking system in various directions, thus stressing the members the same as the bobblehead's spring would be stressed.

In this study, we investigate how the cost of steel for a basic, 10 megawatt, single-axis flat panel PV tracker plant is affected by terrain. We'll investigate how the weight of the steel structure will be affected if located in different locations of the United States such as Arizona, Colorado, Hawaii, California, and Southern Florida. Each of these states is chosen because of their unique weather or seismicity.

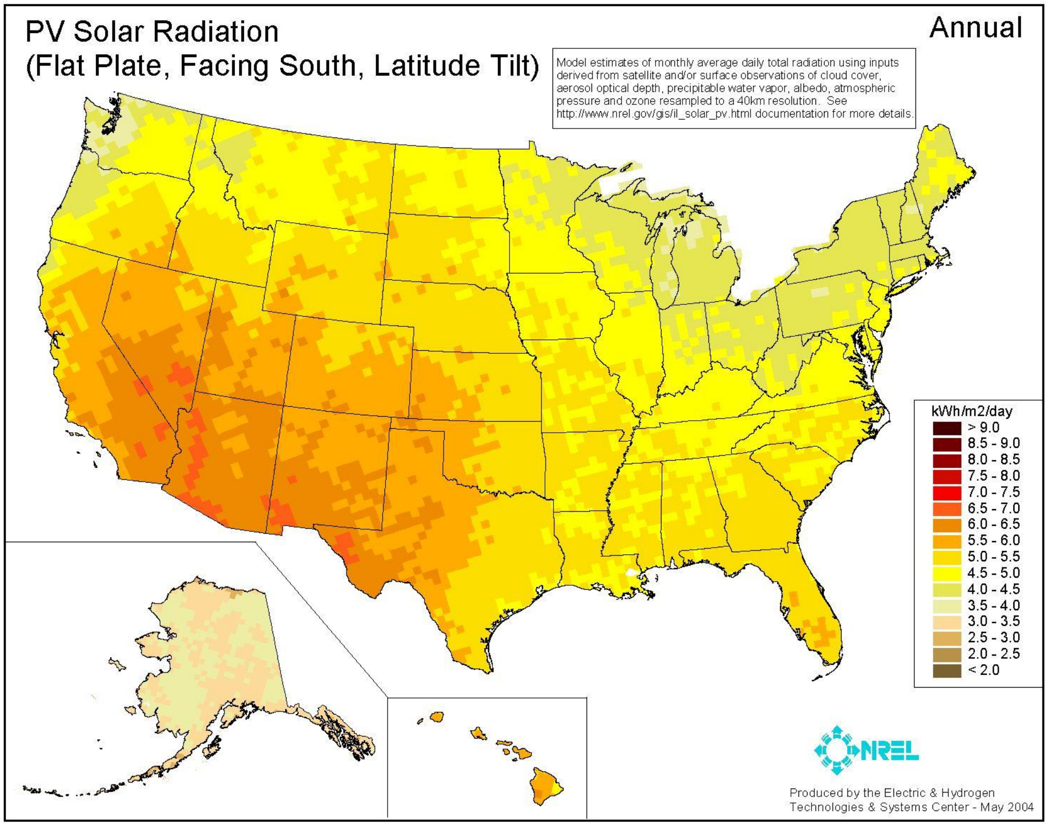

Figure 1 Solar radiation map for the United States. Produced by NREL for the United States

Figure 2 North Elevation of a single-axis tracker row. Wind torque resulting from unbalanced (non-uniform) wind pressure

Finite Element Analysis Model (FEA)

When designing any solar tracking plant, it is helpful to design the system in a 3D modeling package such as Solidworks or Autodesk Inventor. At the same time, an FEA structural model may be created in software designed specifically to check members to building code requirements. Additional tools that may be developed in-house can be used to check each of the structural connections. Likewise, structural software with connection checking functionality may also be used.
The system under consideration is shown in figures 2 through 4. It consists of a single-axis tracking array that is replicated x number of times to achieve a 10 megawatt (10MW) solar plant.

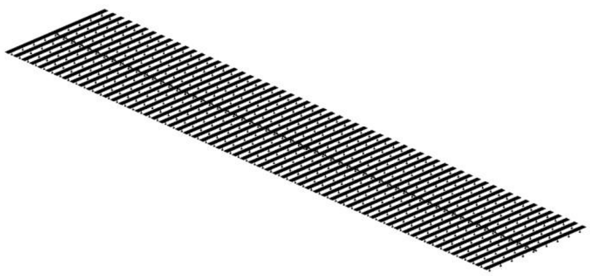

Figure 3 Single tracking array of a 10MW plant

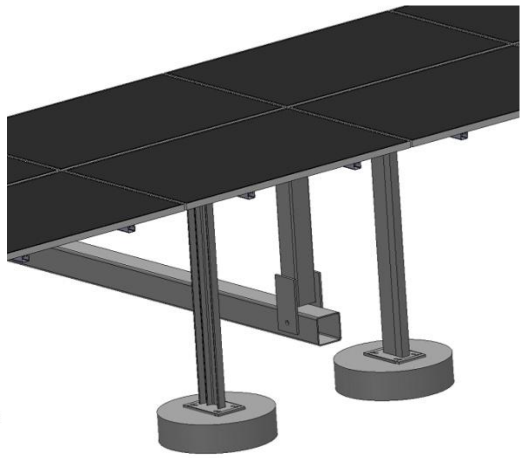

Figure 4 Single axis tracker common construction

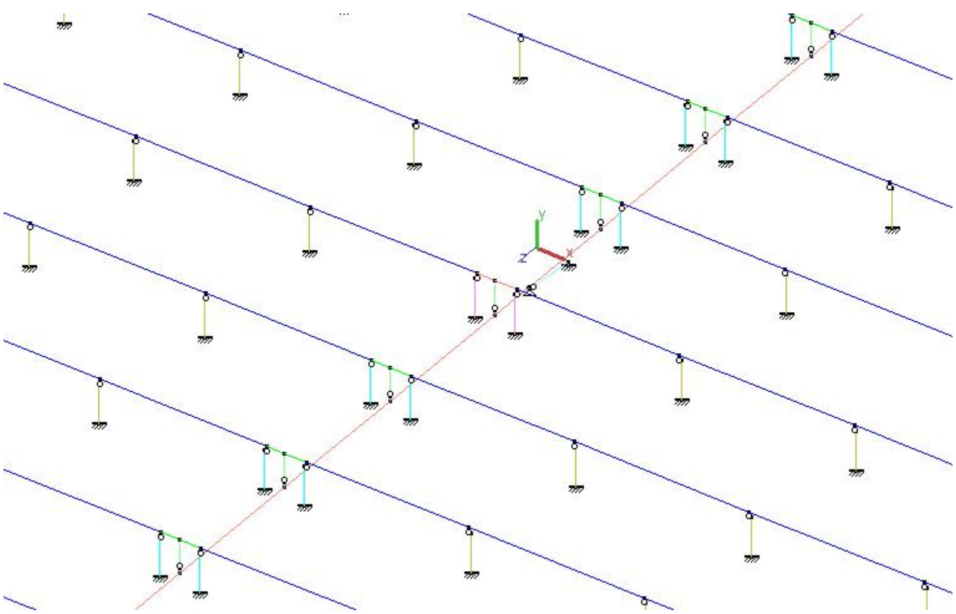

Figure 5 Structural FEA model of the single axis tracker array investigated in this study

Results and Discussion

Arizona was chosen as the baseline location for the 10MW solar plant. Here there are high solar radiation levels, little to no snow at lower elevations, and minimum earthquake considerations. The total cost of structural steel for the baseline, Arizonan plant is $3.7 million, or $.36 per watt. Designing this same system for a location with snow loads such as Colorado, increases the material cost by approximately 40%. As explained, previously, in snowy terrains, ASCE code requires simultaneously loading the panels with snow and wind. In areas with higher wind speeds such as Hawaii and southern Florida, material costs increase by 8% and 11% respectively.

California was chosen for its seismic activity. In general, seismic regions are a consideration if they are located close to faults or if the PV modules and supporting structure are located high above the ground, or if a PV panel's undercarriage is heavy. In this study, the tracker under consideration is approximately 4ft above ground and has a very light-weight, PV module support system. Also, earthquake loading is considered at Carrisa Plains, CA 93453 where USGS accelerations were not great enough to be a driving factor in the structural design of this system. Material costs for the Carissa Plains site was unaffected by earthquake loading requirements when compared to the baseline, Arizonan location. Wind loading at the Carrisa Plains, CA site was 5mph less than the baseline model, however the reduction was not substantial enough to affect material cost when compared to 90mph wind locations.

Steel Cost per Geographic Location - 10MW Solar Tracker Plant

Location	Load Consideration	Total Weight of Steel (tons)	Total Cost of Steel ($)	Cost of Steel Per Watt ($/W)	% Increase
Arizona	90 mph Wind	1,700	$ 3,700,000	$ 0.36	Baseline
Colorado	90mph Wind + 20psf Snow	2,400	$ 5,100,000	$ 0.51	40%
Hawaii	105 mph Wind	1,800	$ 4,000,000	$ 0.39	8%
California 93453	85mph Wind + Earthquake	1,700	$ 3,700,000	$ 0.36	0%
Southern Florida	120mph Wind	1,900	$ 4,100,000	$ 0.40	11%

Table 1 Material costs for the 10 MW single-axis tracker plant of fig. 4 located in various locations within the US

Conclusions

The study suggests the importance of determining terrain-specific loading such as wind, snow, and earthquake when choosing a location for a solar tracking plant. For the single-axis tracker described, material costs can vary by 40% mainly in areas with wind and snow. In sunny, windy locations without snow, material costs increase by approximately 10%.

Notes

This report is specific to the single-axis tracking system described. Values stated in this report should only be used in the beginning phases of a solar plant planning phase to bring awareness to material cost increases affected by terrain. Actual increases in material costs may vary from site to site as some areas of the country have site specific requirements that may substantially affect load values and therefore structural requirements. In this study, all aspects of the tracking system such as member lengths were held constant for the various locations. In actuality, member lengths may increase depending on load conditions which further increase the system's weight. In certain cases, building code allows for reductions of loads, which is outside the scope of this study.