ICWE 16
August 27-31, 2023
FLORENCE - ITALY
16th International Conference on Wind Engineering

Wind-induced response measurements of a dual axis photovoltaic solar tracker

Adeleke Bukola[1], Elena Dragomirescu[2], Karin Hinzer[3], Joan Haysom[4]

[1]University of Ottawa, Ottawa, Canada, badel.civilengineer@gmail.com
[2]University of Ottawa, Ottawa, Canada, elndrag@uottawa.ca
[3]University of Ottawa, Ottawa, Canada, khinzer@uottawa.ca
[4]University of Ottawa, Ottawa, Canada, jhaysom@uOttawa.ca

SUMMARY:
Photovoltaic (PV) solar trackers are more complex structures because that involve mechanical devices, a supporting slender structure, and photovoltaic modules mounted and positioned on top of the supporting structure. Solar trackers are mounted on mobile supports or racks, in order to enable the rotation and tilt of the PV modules, which thus maintains their optimum exposure to the incident sunlight. Field measurements of the wind-induced response for a dual-axis solar tracking system installed on the roof of the Mann Parking building of the University of Ottawa, were recorded for different azimuth, elevations during the months February and March. The supporting structure of the solar tracker was instrumented with 16 strain gauges and the strains were measured. The most significant response of the support structure of the solar tracker was noticed at angles of attack between 45° and 60°. Operational attack angles between 65° and 75° were found to be safer positions as the measured displacements and the stress analysis showed that the supporting structure of the solar tracker was stable for wind speeds up to 16m/s.

Keywords: solar tracker, wind-induced response, strain gauge measurements

1. INTRODUCTION

The PV solar trackers can be described as devices designed as elevated supporting structures for the photovoltaic modules such as group of panels, which can rotate and tilt so that they follow the direction of the sun in such a way that the modules are always aligned perpendicular to the sunlight during the day and thereby maximizing the energy collection efficiency as compared to the fixed PV solar systems (Francisco et al. 2009) The supporting structure of the tracker is employed to tilt the solar modules in order to minimize the azimuthal angle between the incoming light and the photovoltaic module (Risk and Chaiko, 2008). As these are more complex structures then the conventional PV solar panels, they are not widespread, thus the field measurements and wind-induced response records are also scarce. The design process for the PV solar trackers becomes a great challenge as uncertainty arises in the analysis of the structural loads and the safety and sufficiency of such constructions are not adequately addressed in any of the national or international design codes or standard. ASCE -07 (2007) is the design standard for the wind loads induced on structures but it does not provide sufficient guidance to the design professionals and the industrial companies in charge with assessing the PV Installation. A very limited number of research papers were reported for the solar trackers under the effect of wind or other loading. Libra and Poulek (1980) investigated the stability of the solar tracker with a tilt angle of 45°, subjected to wind speeds of up to 160 km/hr in a wind tunnel facility. Tests showed that the solar tracker did not encounter significant vibrations for the four angles of attack investigated between 0° and 180°. Swagat (2011) performed a wind tunnel experiment for studying the wind effects on a ground mounted photovoltaic solar tracker; Their findings focused on the parametric investigation of the system porosity, the inclination angles, the wind direction and the arrangement of the PV solar panels of the tracker system. The wind induced forces and the overturn moments measured in the wind tunnel were compared with wind loads recommended by the ASCE-7-05 and were found to be in reasonable agreement. Hernandez et al. (2009) carried out an aerodynamic study on a prototype PV solar tracker and prescribed pressure coefficients between 0.8 and 1.2 for the leading and trailing edges, for incidence wind angles of up to 70°.

2. PV SOLAR TRACKER AND INSTRUMENTATION

The dual axis steel solar tracker installed on the Mann Packing building of the University of Ottawa, is primarily designed to withstand strong winds and heavy storms; thus, the supporting structure consists of 12 precast concrete blocks each weighting approximately 1 tone, placed at the base circular frame. The A shaped legs of the tracker are seated on two steel bars which are connected to the circular frame by four rollers, technically positioned so that the entire structure can rotate up to 360°, in order to orient the two rows of poly-crystalline photovoltaic panels of 15.5 kg directly towards the direction of the sun, thereby increasing the PV performance in capturing the daily solar energy. The solar tracker is made of three different parts the upper part, the main body and the bottom part. The upper part consists of an aluminum frame on which the four poly-crystalline photovoltaic panels are mounted and a circular steel beam supporting the frame, which are vital structural elements for the overall functionality of the entire solar tracker. The aluminum frame is connected to the PV solar panels module on both lower and upper edges of the solar panel as shown in Fig. 1a), to provide structural support to the PV solar panel module. There are two elements supporting each of the solar panel rows, forming four horizontal arms denoted as K1, K2, K3 and K4 for the purpose of identifying them during the analytical investigation which is presented in detail in chapter four of this thesis. The other top part is the circular steel beam made which carries the PV solar panels modules installed on the aluminum frame and rotates the PV modules at angles between 45° and 78°. The main body of the solar tracker is formed by the truss upright frame made of steel, resembling two A-shaped legs, connecting the top circular steel beam, element M symmetrically at 500 mm to the bottom rack of the tracker denoted as element A. The solar tracker was installed on the Mann Parking building of the University of Ottawa by the SUNLab research team, from the Electrical Engineering Department of the University of Ottawa. The entire solar tracker structure was raised at 50 cm above the roof finished level (FRL) as shown in Fig. 1a), for enabling the removal of snow during the winter season and to complete the water drainage whenever it rains. For measuring the wind effect on the structure, the solar tracker specimen was instrumented with 2 bi-axial strain gauge sensors, designed to measure the strain in two dimensions and 12 uniaxial strain gauge sensors designed to measure the strain in one direction respectively. Due to the limitation of recording devices and data acquisition system channels, only some locations along the supporting frame of the solar tracker were instrumented as follows: element M was instrumented with two biaxial and

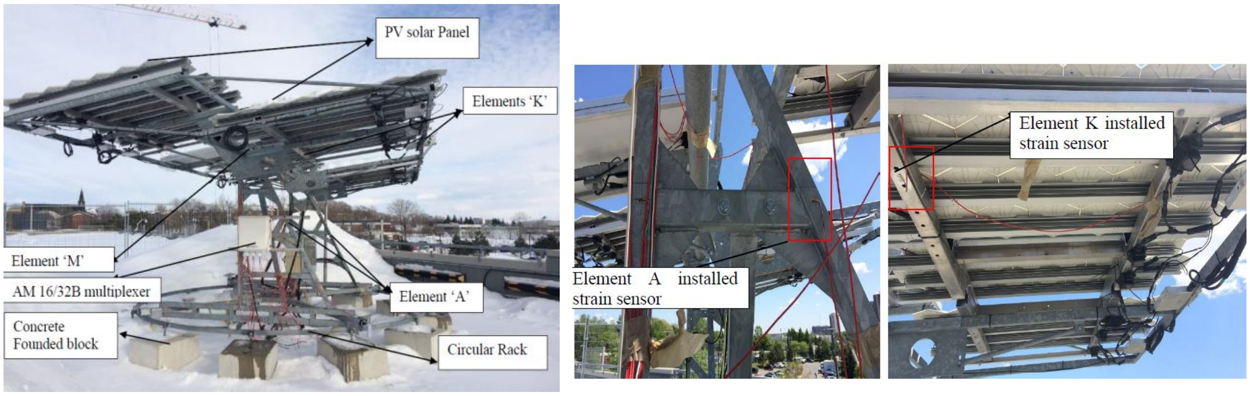

Figure 1. a) PV Solar tracker, b) Strain gauges on support frame.

two uniaxial strain gauge sensors, placed at 100cm interval along the M element. The elements K, which represent the four edge frames of the solar panels, were instrumented with four uniaxial strain gauge sensors each placed at 50 cm from the corner, where a higher displacement is expected (Fig. 1b)). The element A was instrumented with four uniaxial strain gauge sensors, each placed 60cm below the actuator, and the bottom frame of the rotating rack was instrumented with two biaxial sensors, placed on the front segment of the frame at 50 cm intervals. The complete experimental devices setup consisted of 16 strain gauges of 120 Ohms WFLA-3-11, four terminal blocks on which the Wheatstone bridge connection was set with 120 Ohms resistors, an AM 16/32B multiplexer and a CR 1000 Campbell data logger. By positioning the solar tracker for different elevation and azimuthal angles Cases 1-30° to Case 7-120°, were categorized, each representing elevation angles of 45°, 50°, 60°, 65°, 70°, 75° at one rotation angle. Thus, a total of 49 cases were investigated for the investigated operational angles of the solar tracker between 9:00 a.m. and 5:00 p.m. daily. The stow position depicts the safe angle for the tracker and it should be always employed during the night, when the devices cannot be controlled manually. However, because the data acquisition system was still running, several cases were measured for the stow position (78°) as well. Also, along with the strain measurements for the structure the weather data, such as wind speed intensity and direction, temperature, air humidity and density, were required in order to develop the estimations for the wind loading encountered at the solar tracker site for each case.

3. FIELD MEASUREMENTS RESULTS

For the solar tracker placed at 45° inclination angle, with the recorded wind speeds of 4.17m/s (Feb. 10) and 10.27m/s (Feb. 12) for 55°. From the Fig. 2 a) below it was noticed that all the stresses imposed by the wind load on the element M at instrumented locations on the element have similar load pattern and there is a high fluctuation in the stresses registered at this angle of attack, depending on the position along the M bar. However, the magnitude of the recorded stress lies between 7.14×10^7Pa and 7.56×10^7Pa for 4.17m/s and between 7.88×10^7 Pa and 6.77×10^7 Pa for 10.27 m/s and 55°. For element A, apart from the fact that this experienced greater wind exposure, also the angle of 55° added more impact on this element. The high and low stress fluctuations were recoded with maximum magnitude of 7.70×10^7Pa and minimum magnitude of 6.67×10^7Pa. For the stow position at 78° it was noticed that the stress recorded had a uniform pattern and the magnitude of stress produced by each sensor was greatly reduced under the same wind speed.

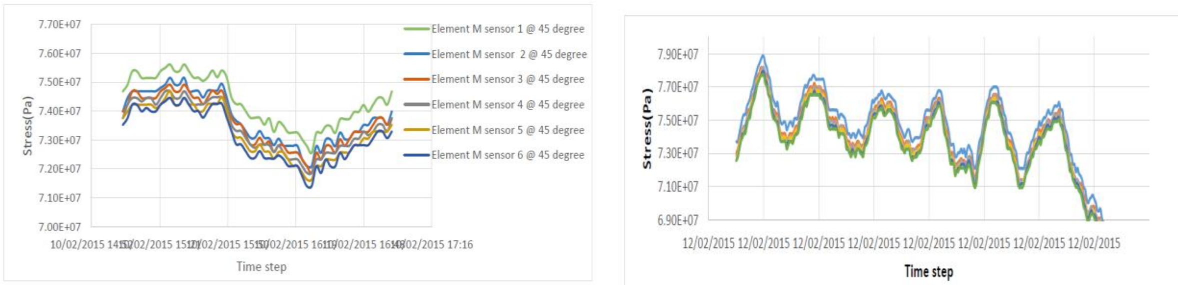

Figure 2. Recorded stresses for the element M for a) 45º and 4.17 m/s, b) 55º and 10.27 m/s.

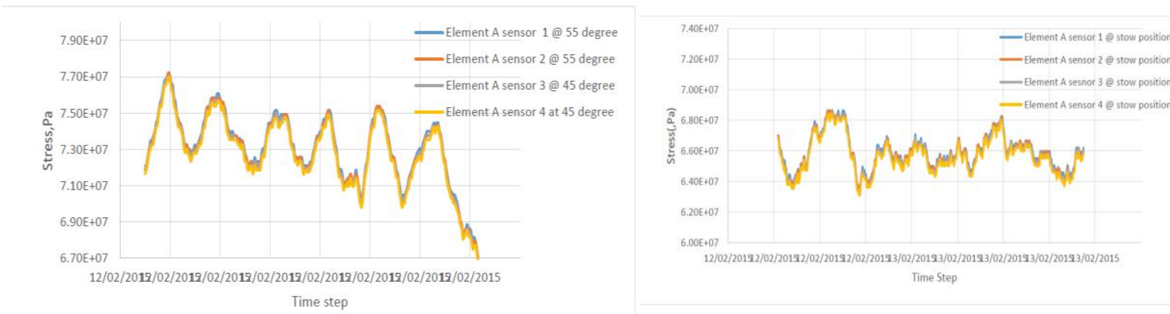

Figure 3. Recorded stresses for the element A for a) 55º and 10.27 m/s, b) 78º and 10.27 m/s.

4. CONCLUSION

It was noticed that at angle 50º, the element M experienced more deformation during the day, despite the fact that the wind speed was considerably low but thus this angle was not stable enough to resist even low wind velocities. However, at 55º angle of attack, the element was highly vulnerable to wind because of higher stresses determined by the wind speeds recorded on this. Additionally, on 19th of February, a higher wind intensity was recorded which also determined the higher value of the stress but this did not have significant impact on the element as compared to angle 50º. Also, it was established that for the lower angles, between 45º and 65, even at lower wind speeds, these inclination angles yielded higher stress values, compared to the ones recorded for 70º, 75º and 78º.

REFERENCES

Francisco, J., Gomez, G. , De, M., , Pelaez, J., V., and Justo R. 2009. A review of solar tracker patents in Spain. Electromechanical Engineering Department Burgos University EPS Avda. Cantabria, 09006, Burgos Univ. SPAIN, 292-297.

American Society of Civil Engineers 2005. Standard ASCE 7-2005. Minimum Design Loads for buildings and other structures. pp 12-24.

Hernandez, S., Mendez, J., F, Nieto, J., and Jurado, A. 2009. Aerodynamic analysis of a Photovoltaic Solar Tracker. Proceedings of EACWE 5 Conference. Florence. Italy.

Libra, M., and V., Poulek,V. 2008. Wind tunnel testing of a new Solar Tracker. Czech Technical University,faculty of mechanical engineering. 1-5.

Risk,J., Chaiko,Y. 2008. Solar tracking system: more efficient use of solar panels. International Journal of Electrical, computer, energetic, electronic and communication engineering Vol 2. No 5. 784-786.

Swagat., M. 2011. Wind tunnel Investigation of Wind load on a ground mounted photovoltaic tracker. Masters' thesis.