



DESIGN, BUILD AND ANALYZE THE STRENGTH OF THE POLE CONSTRUCTION IN THE SOLAR POWER PLANT AT THE UNESA KETINTANG CAMPUS USING THE ANSYS WORKBENCH AND SOLIDWORKS APPLICATION

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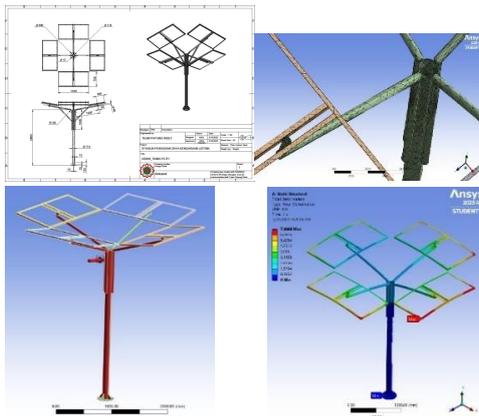
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Graphical abstract



Abstract

The utilization of solar energy in Indonesia has great potential, yet Solar Power Plant (PLTS) pole structures often fail due to excessive loads, unsuitable materials, and extreme weather. This study aims to design PLTS poles that are strong, efficient, resistant to static and dynamic loads, and economical. The research method includes literature review, load analysis, and simulations using SolidWorks and ANSYS Workbench. The upper load is solar panels, while the lower load is pole deformation due to wind. Simulation results show von Mises stresses of 72.598 MPa at 2 m/s, 72.501 MPa at 5 m/s, and 72.321 MPa at 8 m/s. The deformations were 6.0898 mm, 6.3309 mm, and 7.0668 mm. Safety factors (FoS) were stable at 3.4436, 3.4482, and 3.4568. In conclusion, the designed PLTS pole is safe, stable, and supports sustainable EV charging.

Keywords: Pole Construction, Solar Power Plant, Solar Cell, SolidWorks, Ansys.

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1. Introduction

Indonesia's potential to harness renewable energy is very large, especially solar energy, because Indonesia is located on the equator, receiving abundant sunlight. Solar photovoltaic technology has become one of the most promising renewable energy sources due to the abundance of solar radiation and its suitability for large-scale electricity generation [1]. Solar Power Plants (PLTS) are energy generation systems that convert sunlight into electricity. This technology is based on the principle of using solar cells or photovoltaic modules that can capture and convert solar energy into electric current. Photovoltaic systems convert solar radiation directly into electricity through the photovoltaic effect using solar cells [2]. Photovoltaic power plants play a crucial role in providing clean and sustainable electrical energy for various applications [3]. The potential for renewable alternative energy that is also claimed to have significant prospects in Indonesia is solar power. The choice of this renewable energy source is very reasonable considering the supply of solar energy from sunlight received in Indonesia is very large, with an average daily insolation of 4.5 - 4.8 KWh/m²/day.

The planning of the construction of this generator pole involves several factors that need to be considered. These factors affect the quantity and quality of the materials used. One important factor is the foundation according to the soil conditions in the area where the generator pole will be built, wind load, and also the load on top of the electric generator pole [4]. It can be inferred that the construction of poles at this power plant has several factors such as the load on the pole, pole material, and the variation of support pole models in the power plant.

Research on the strength of pole construction has been conducted. According to [5], support poles made of wood must be preserved first, have a shorter lifespan, and cannot safely support excessive loads. Steel pole structures supporting photovoltaic panels must be designed to withstand gravity and wind loads to ensure structural safety [6]. Furthermore, according to [7], the wind speed at the bottom is very low, so if a tower is not used, it will produce low rotation, thus requiring a support pole construction that can support solar panels. Based on previous research, it is known that wooden support poles have a shorter lifespan and lower load-bearing capacity, and that wind speed near the ground is low, requiring strong support pole construction to optimize solar panel performance. Future research needs to develop stronger and more durable support pole materials and designs that can withstand environmental factors such as wind loads, ensuring the stability and efficiency of solar power systems. Further research should utilize Finite Element Analysis (FEA) to analyze total deformation, von Mises stress distribution, and Factor of Safety for the solar power pole under operational loading conditions. Finite element analysis is widely applied to evaluate stress, deformation, and safety factors in engineering structures [8].

This research aims to develop a robust and durable solar power plant pole capable of minimizing the risk of structural damage or collapse, thereby ensuring the optimal and long-term utilization of solar power systems. The study emphasizes the design and structural analysis of support poles that can withstand various environmental factors, particularly wind loads, which significantly influence stability and safety. A comprehensive evaluation is carried out using Finite Element Analysis (FEA) to determine critical parameters such as total deformation, von Mises stress distribution, and the Factor of Safety under operational loading conditions. Understanding the underlying causes of structural damage and failure is essential for improving design reliability and preventing potential operational disruptions. Therefore, this research not only focuses on analyzing the structural performance but also aims to provide an optimized design framework for solar power plant support poles, ensuring enhanced durability, efficiency, and safety in renewable energy infrastructure.

Deformation is defined as the change in shape or dimensions of a body under the action of applied forces. Deformation refers to the change in size or shape of a body caused by the application of external loads [9]. Displacement is a change in the shape of an object that is subjected to force and displacement is the result of static structure analysis using elemental methods namely deformation, thermal deformation occurred at the printed support structure to the samples, displaying similar results in other locations such as the corners [10]. Von Mises stress is part of material elasticity analysis and is used to evaluate the condition of multiaxial stress on a structure. In materials science and engineering, von Mises stress, also known as equivalent tensile stress, is a scalar stress value calculated from the stress tensor and is used to predict the yielding of materials when the von Mises stress reaches the yield strength [11]. The factor of safety is defined as the ratio between the failure strength of a material and the allowable working stress [12]. The safety factor is used to assess the margin between the material capacity (limit strength) and the actual stress that occurs in the structure factor of safety or FoS is a direct indicator of the safety of the structure against failure. In the book *Machinery's Handbook*, Erik Oberg et al, said that the safety factor for general construction with stainless steel and 28 light to medium loads is recommended 2.0 – 3.5. Then for structures that are not systematically inspected or rough work environments, the safety factor is increased to 3.0 – 4.0.

2. Material and Method

The research was conducted through a systematic integration of structural design and numerical simulation to evaluate the mechanical integrity of a solar power plant (PLTS) support pole. The process began with the selection of high-quality structural materials, followed by the development of a 3D geometric model using SolidWorks software. Subsequently, the design was subjected to Finite Element Analysis (FEA) using ANSYS Workbench to simulate real-world loading conditions, including static panel weight and various wind speeds. This methodology aims to provide a comprehensive understanding of the stress distribution and

safety factors of the construction intended for the Unesa Ketintang Campus.

2.1. Research Design and Procedures

This research employs a numerical analysis method to evaluate the structural strength of a solar power plant (PLTS) support pole. The study was conducted at the Electric Vehicle Laboratory, State University of Surabaya, covering preparation from September 2024 to October 2025. The procedural workflow followed a systematic approach, beginning with a site survey at the Unesa Ketintang Campus and preliminary literature studies on PLTS support structures. The core methodology integrated 3D geometric modeling and Finite Element Analysis (FEA) to simulate real-world environmental challenges, specifically the interaction between static gravitational loads and dynamic wind pressures.

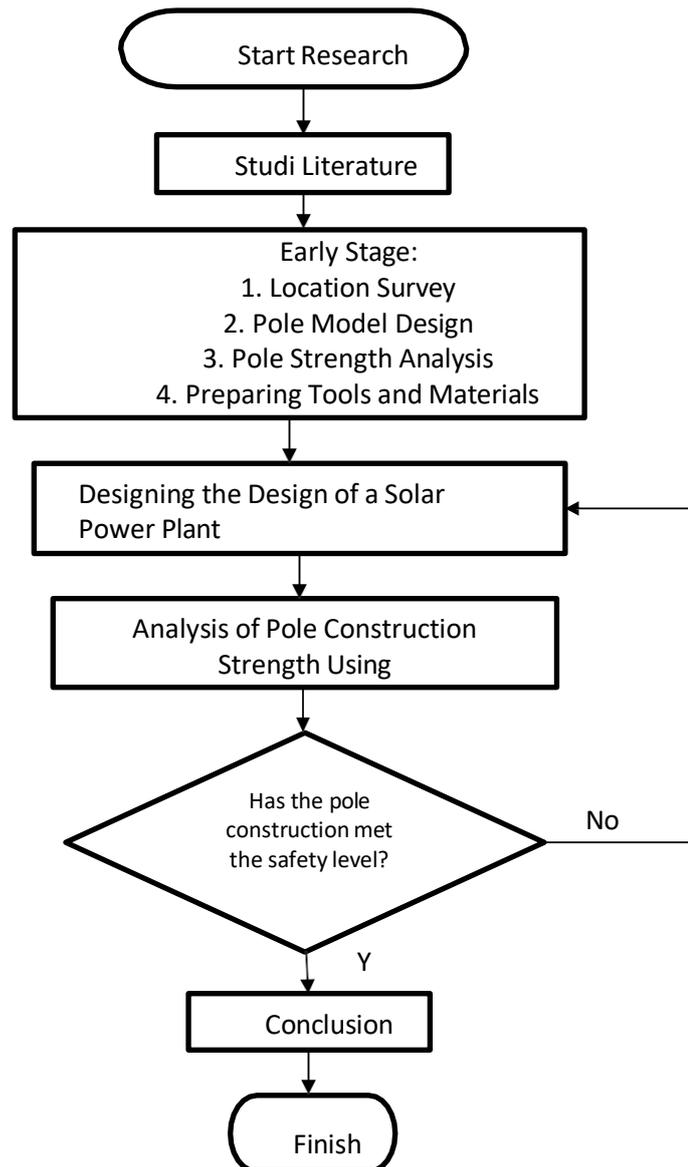


Figure 1. Research Flowchart

2.2. Materials and Components

The primary material utilized for the construction of the monopole support structure is ASTM A36 carbon steel. Construction methods significantly affect the performance and durability of steel structural systems [13]. This material was selected based on its mechanical properties, including a density of 7,850 kg/m³, a Modulus of Elasticity of 200 GPa, and a Poisson's ratio of 0.26. The structural integrity is evaluated against a yield strength of 250 MPa and an ultimate tensile strength ranging from 400 to 550 MPa.

Table 1. Mechanical Properties of ASTM A36

Properties	Value
Density	7850 Kg/m ⁻³
Young Modulus	200 Gpa
Poisson Ratio	0,26
Tensile Yield Strenght	250
Tensile Ultimate Strenght	400-550

In Figure 2. Showing the design of the solar power plant to be used to support four units of 250 WP Monocrystalline solar panels, each weighing approximately 14 kg, resulting in a total static load of 56 kg. Supporting hardware includes a lithium battery for energy storage, a control box for electrical management, and an inverter to convert the generated DC power into AC power for operational use. All components are secured using manual welding processes and mechanical fasteners such as bolts and nuts to ensure a rigid assembly.

Table 2. Solar Panel Specifications

Specification	Remarks
Type	<i>Monocrystalline</i>
Power Capacity	250 Wp
Maximum Voltage (Vmp)	18,6 V
Maximum Current (Imp)	13,45 A
Efficiency	19%
Dimensions (Per Unit)	1530 x 760 x 35 mm
Weight (Per Unit)	± 14 kg

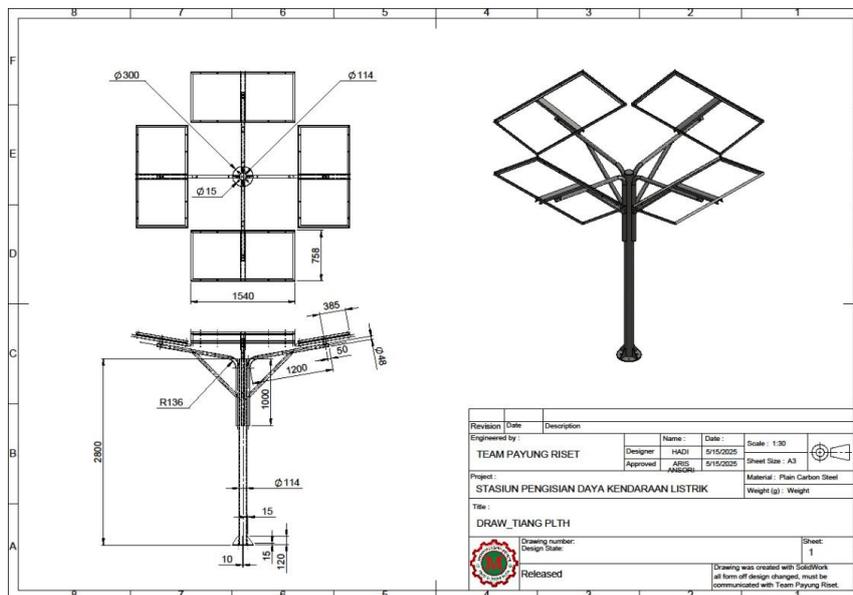


Figure 2. Design of PLTH

2.3. Loading Parameters and Simulation Variables

The study observes three primary variables to determine the structural performance: total deformation, von Mises stress, and factor of safety (FoS). These indicators are analyzed under varying wind speeds, which serve as the independent variables. Based on meteorological data on figure 2 for the Ketintang area, the simulations were performed at velocities of 2 m/s, 5 m/s, and 8 m/s.

The wind load in figure 3 is assumed to act from a single direction positive X-axis to represent the maximum potential pressure on the panel surface, while the gravitational force is applied along the negative Y-axis to account for the self-weight of the structure and the four solar cells (56 kg). The structure's base is defined as a fixed support, replicating a reinforced concrete foundation with a depth tailored to the local

alluvial soil characteristics of Surabaya.



Figure 3. Variables of Wind Speeds

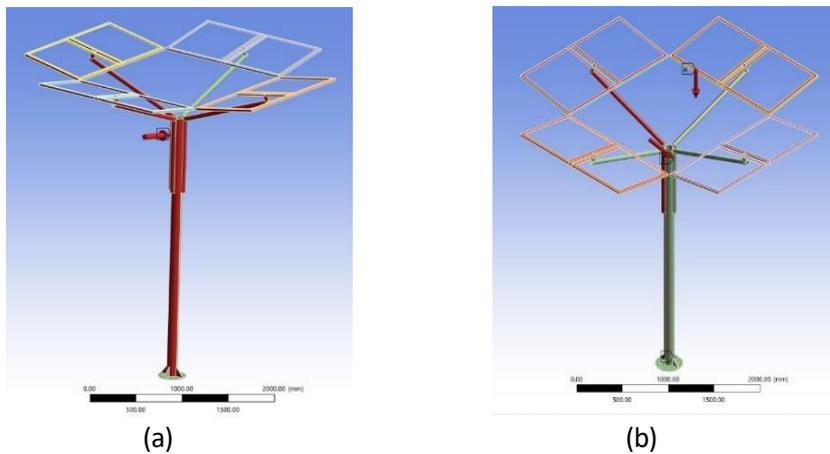


Figure 4. Load on Solar Power Pole (a) Wind Pressure, (b) Solar Panel Force

2.4. Data Analysis Techniques

The data obtained from the simulation software are processed through descriptive statistics and comparative analysis. The geometry developed in SolidWorks is discretized into a finite element mesh using a combination of tetrahedron and wedge elements. To ensure the accuracy of the numerical solution, the mesh quality is monitored via aspect ratio and skewness values. Specifically, an aspect ratio of 2.897 is maintained and ensure skewness between 0.6-0.8 for precise stress distribution and reliable results. The final analysis focuses on comparing the structural responses across different wind intensities to validate whether the design maintains a safe operational margin above the material's yield limit.

Table 3. Meshing Value

Mesh Size	Number of Nodes	Number of Elements	Aspect Ratio	Skewness
273,78 mm	87476	43708	2,897	0,78

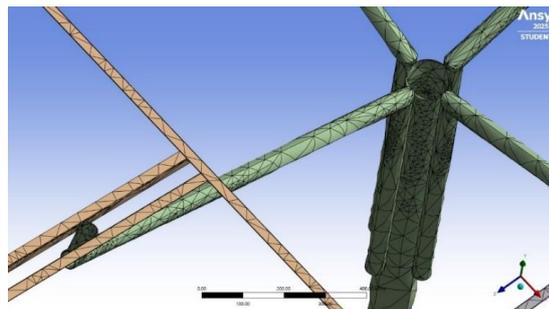


Figure 5. Meshing

3. Result and Discussion

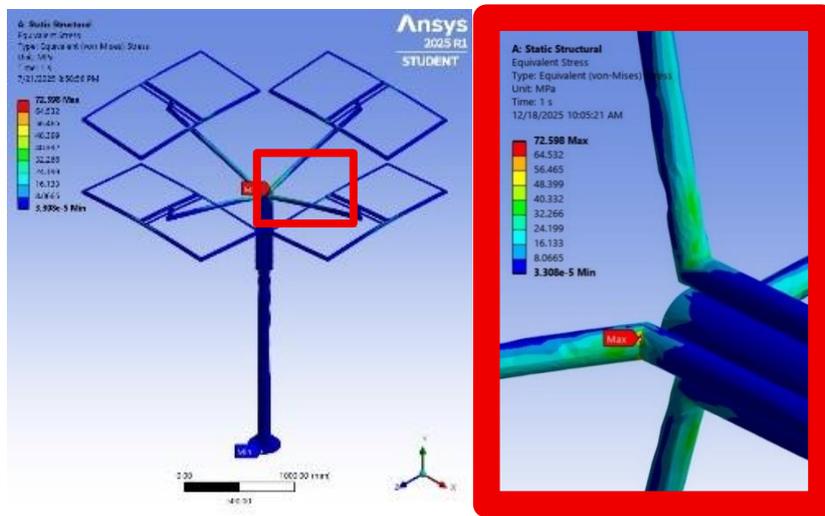
3.1 Modeling and Boundary Conditions

The initial stage of this research involved designing a single-pole structure model using SolidWorks software. The structure was engineered to support four solar panels with a total mass of 56 kg (14 kg per panel). The material selected for this construction is ASTM A36 low carbon steel, which possesses a yield strength of 250 MPa. In the ANSYS Workbench simulation, boundary conditions were established by applying a fixed support at the base of the pole plate to represent a robust connection to the foundation.

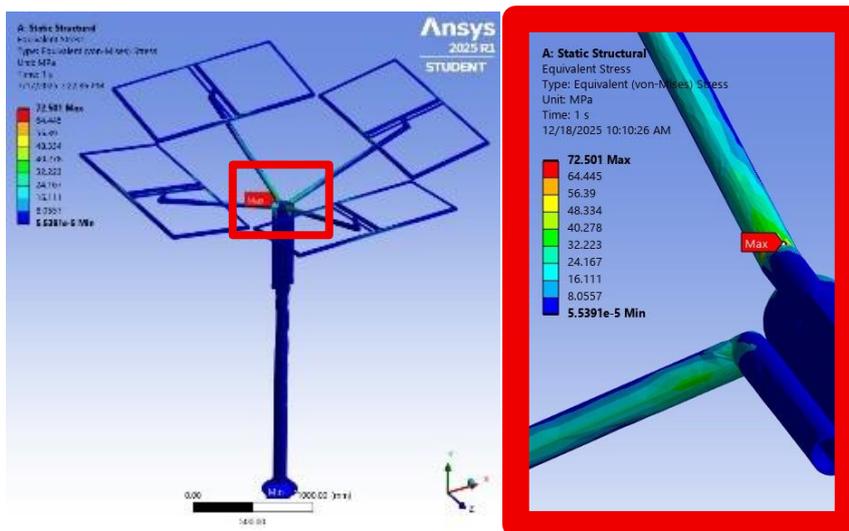
3.2 Structural Strength Simulation Results

The simulation was conducted by applying surface pressure loads calculated based on wind speed variations of 2 m/s, 5 m/s, and 8 m/s. The mechanical parameters obtained include von Mises stress, total deformation, and the Factor of Safety (FoS).

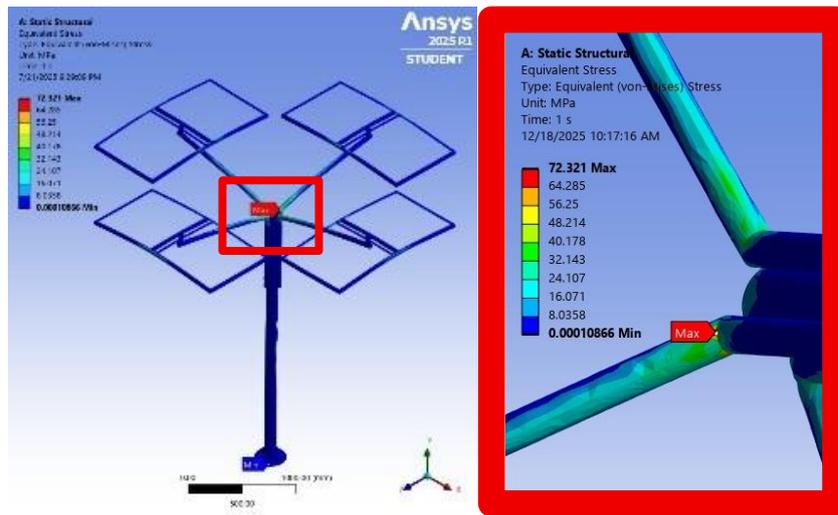
- **Von Mises Stress:** Based on the data processing, the maximum von Mises stress at a wind speed of 2 m/s was 72.598 MPa, at 5 m/s it was 72.501 MPa, and at 8 m/s it was 72.321 MPa. The peak stress (indicated by the red area in the simulation contour) is concentrated at the critical joint area at the bottom of the structure.



(a) 2 m/s



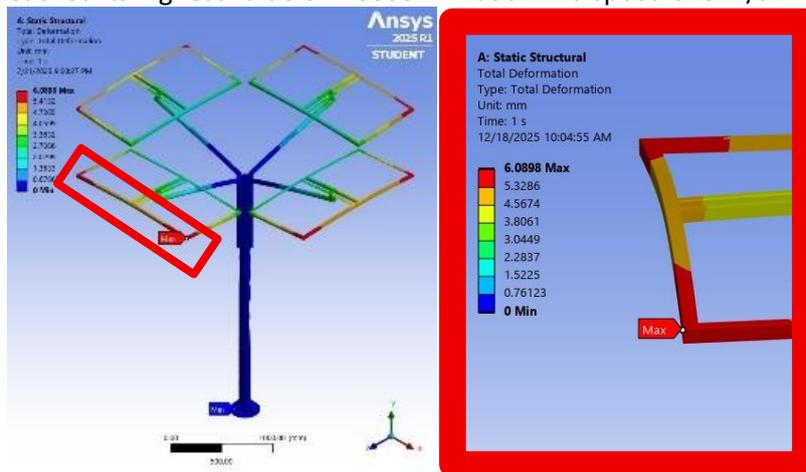
(b) 5 m/s



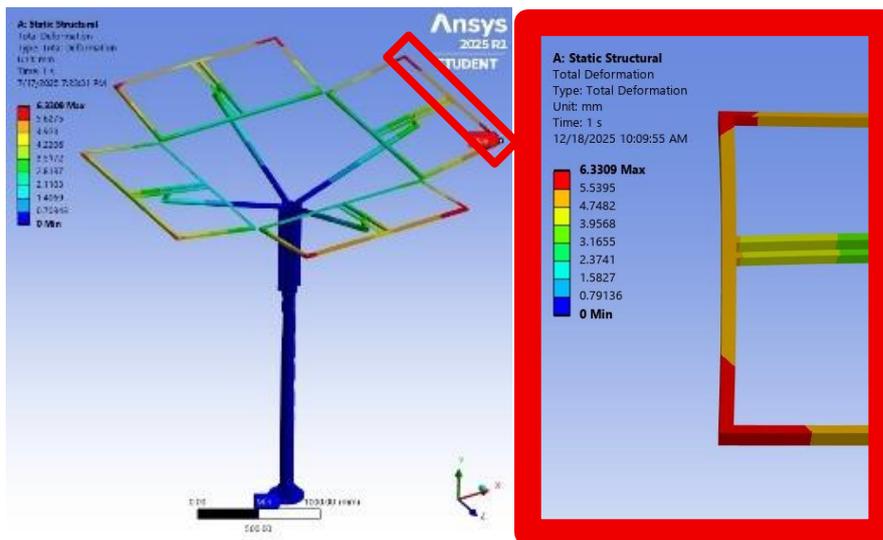
(c) 8 m/s

Figure 6. Comparison of Von Mises Voltages

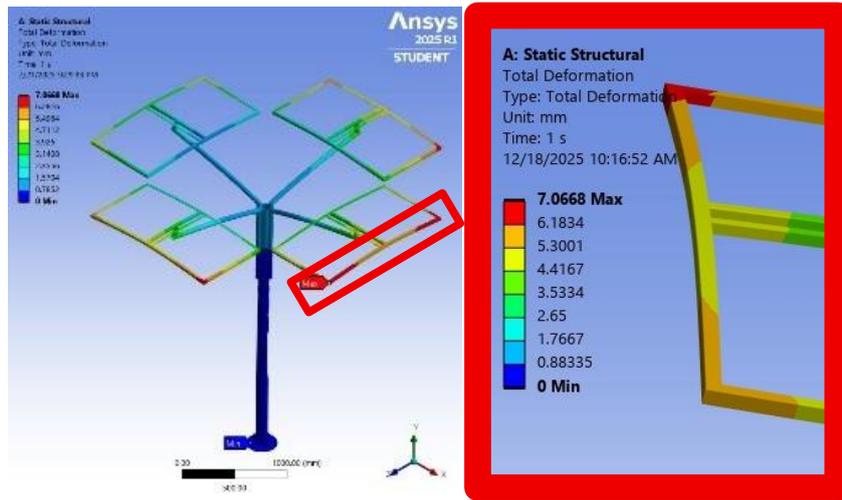
- **Total Deformation:** There is a clear correlation between wind speed and displacement. The maximum deformation was recorded at 6.0898 mm at a speed of 2 m/s, increased to 6.3309 mm at 5 m/s, and reached its highest value of 7.0668 mm at a wind speed of 8 m/s.



(a) 2 m/s



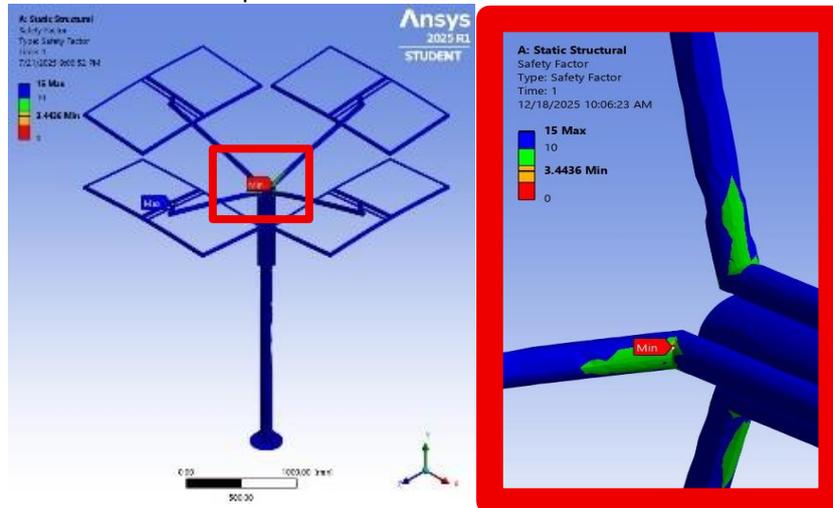
(b) 5 m/s



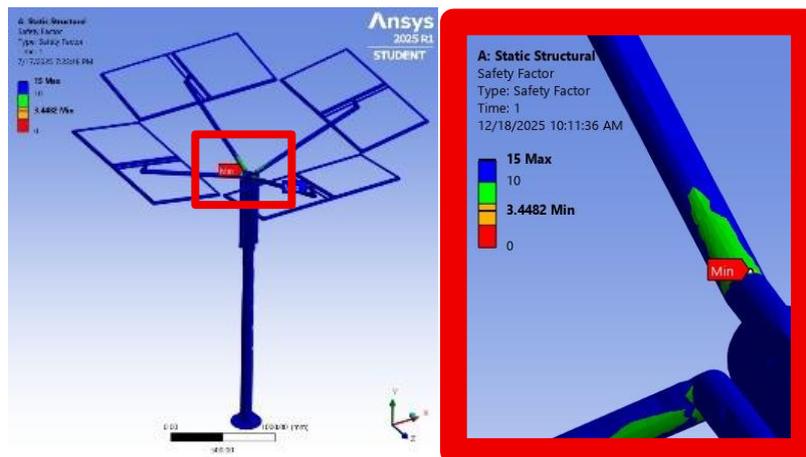
(c) 8 m/s

Figure 7. Total Deformation Comparison

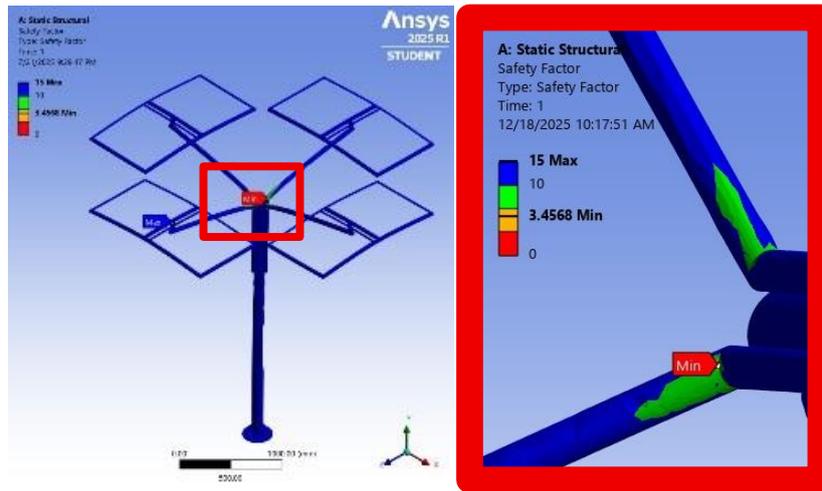
- **Factor of Safety (FoS):** The resulting safety factor remained highly stable, ranging from 3.4436 to 3.4568 across all tested wind speed variations.



(a) 2 m/s



(b) 5 m/s



(a) 8 m/s

Figure 8. Comparison of Safety Factors

3.3 Discussion

Table 4. Analysis Results

No	Wind Speed	Total Deformation (mm)	Von Mises Stress (MPa)	Factor of Safety (FoS)
1.	2 m/s	6.0898	72.598	3.4436
2.	5 m/s	6.3309	72.501	3.4482
3.	8 m/s	7.0668	72.321	3.4568

The analysis of the stress values indicates that all simulation results (maximum 72.598 MPa) are well below the yield strength limit of the ASTM A36 material (250 MPa) [14]. This suggests that the pole structure operates within the elastic zone and will not undergo permanent failure or plastic deformation under the combined loads of the solar panels and wind pressure.

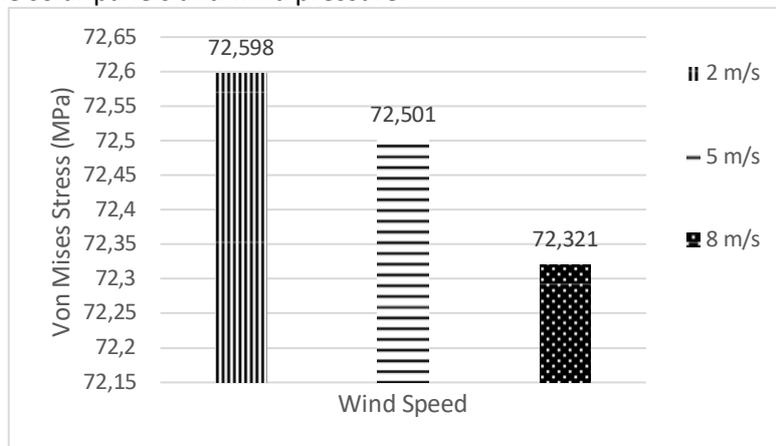


Figure 9. Von Mises Voltage Yield Diagram

From the perspective of deformation, although there is an increasing trend in displacement as wind speed rises, the maximum value of 7.0668 mm remains within the serviceability criteria. According to AISC guidelines, the allowable deflection limit typically ranges from 1/200 to 1/500 of the element's height [15]. The calculation shows that the deformation ratio for this pole falls between 1/460 and 1/396, classifying it as safe for long-term operational use.

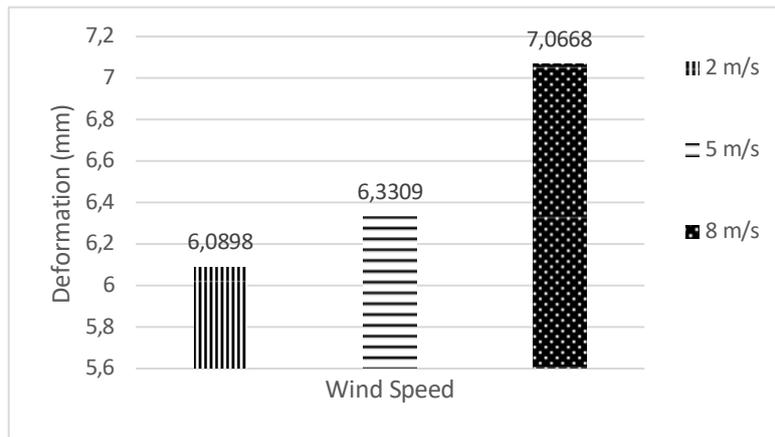


Figure 10. Total Deformation Result Diagram

A Factor of Safety exceeding 3 indicates that the construction design possesses an excellent safety margin. Theoretically, a structure is considered safe if the FoS is greater than 1; however, for public facility constructions like PLTS, an FoS above 2 is highly recommended to account for dynamic load uncertainties in the field [16].

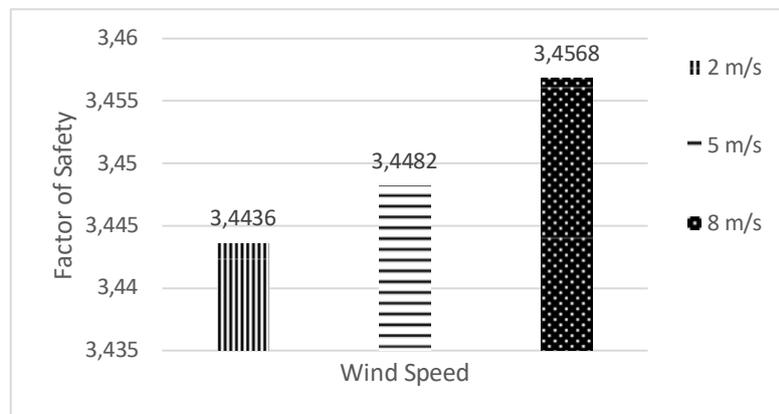


Figure 11. Factor of Safety Result Diagram

4. Conclusion

Based on the design and simulation analysis, it is concluded that the single-pole construction for the Solar Power Plant at the UNESA Ketintang Campus meets the required structural safety standards. The use of ASTM A36 material is proven effective as the maximum von Mises stress of 72.598 MPa is significantly lower than the material's yield point (250 MPa). The maximum deformation of 7.0668 mm also remains within the allowable serviceability limits according to AISC guidelines. With a stable Factor of Safety of approximately 3.4, this design is declared feasible and safe for implementation to support the electric vehicle charging system within the university environment.

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