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FEASIBILITY STUDY OF SOLAR PANEL ON TOWER SYSTEM FOR CELLULAR TOWER OPERATION

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ABSTRACT- Solar power is more reliable for cell tower power requirement at some locations it is not possible install solar panels. We can solve this space availability problem by placing solar panels vertically on the tower. In this study solar panels are arranged vertically one above other and tested output power from solar panels when arranged at different vertical distances with proper angle. In this paper analysis has been for the forces on the cell tower after fixing the solar panels vertically one above other with 4m spacing in the SOLID WORKS software by applying wind, gravitational and thermal forces on tower system.

Key words- solar panels, shadow effect, vertical arrangement, cell tower

1.INTRODUCTION

The energy from the sun is ever-present and powerful resource that people should use instead of searching for more fossil fuels. INDIA being an emerging nation and a competitor to the established countries, we need to increase our power (electricity) production without creating destructions like polluting the environment which become the major concern to be keeping in mind while consuming of natural resources. Electricity is a form of power that is used to do many different things like warming our homes, cooking food, playing music, and allows us to watch TV and many more. Primary energy sources take many forms like non-renewable sources nuclear energy, fossil energy like oil, coal and natural gas and renewable sources like wind, solar, geothermal and hydropower. These primary sources are converted to electricity secondary energy source, which flows through power lines and other transmission infrastructure to homes, agriculture and industries. Solar energy is a clean energy resource. While the production of solar technologies, such as solar panels, creates some pollution, it is far less than the pollution created by mining, reefing, and burning fossil fuels.

Mobile usage increasing day by day, traffic intensity of mobile signals increasing, for this large number of towers are to be establishing and while doing so the power requirement was also increasing. The mobile towers require continuous power supply for their operation. For this the power is obtained in two ways one is from grid connection and another one is off grid connected. But there is no continuous supply of power is available from the grid connection majorly from the off grid system. In off grid system the power is obtained from the diesel generators. The diesel prices are increasing day by day so the operational cost is increasing. Usage of Diesel creates of pollution gases which cause environmental pollution. If solar power is used at cell tower it reduces the fuel cost and environmental pollution. Solar panels installation is not possible at all places because of land space unavailablity at cell tower. If solar panels arranging vertically on cell tower no additional land space is required.

Calculation of Solar Panel Shadow Height

Principle according to Kepler's laws of planetary motion earth rotating around the sun in the elliptical orbit with varying speed and earth is revolving with tilting its axis. the sun not always is at fixed position, but the position is dependent on the time of the day and the year and of course it is dependent on the location on earth. The position of the Sun in the sky as viewed from any point on the Earth's surface is depends on variety of angles. The declination angle (δ) and the hour angle (ω), the solar altitude angle/elevation angle (α).

Sample calculations, in the entire calculation Ananthapuramu, Andhra Pradesh is considered for latitude location
Latitude of location, Φ=14.68.
Declination angle δ=23.45*sin [(360/365) *(n+284)]

Where n=266 for September 23

$\delta=23.45*\sin[(360/365)*(266+284)]=0$

Hour angle $\omega=15*(h-12)$

At 12 noon, h=12, Hour angle $\omega=15*(12-12)=0$

At 10AM, h=10, Hour angle $\omega=15*(10-12)=-30$

At 3PM, h=15, Hour angle $\omega=15*(15-12)=45$

Elevation angle, $\alpha=\sin^{-i}[\sin\delta*\sin\Phi+\cos\delta*\cos\Phi*\cos\omega]$

At 12 noon, Elevation angle $\alpha=\sin^{-i}[\sin0*\sin14.68+\cos0*\cos14.68*\cos0]=75.32$

At 10AM, Elevation angle $\alpha=\sin^{-i}[\sin0*\sin14.68+\cos0*\cos14.68*\cos(-30)]=56.39$

At 3PM, Elevation angle $\alpha=\sin^{-i}[\sin0*\sin14.68+\cos0*\cos14.68*\cos45]=43.15$

Below sizes of solar panels considered for calculation of shadow heights and arranging on cell tower.

100w panel -------119.5×54.1×3.5cm

250w panel-------164.6×98.5×4.5cm

For 100w panel

Now calculate horizontal length of Solar panels after arranged with an inclination equal to latitude angle, which is 14.68.

Horizontal length of Solar panels =119.5*cos (14.68) =115.59cm

Now calculate Height of shadow at different timings of day

At 12 noon height of shadow H=115.59*tan75.32 =441.26cm =4.421m

At 10 Am height of shadow H=115.59*tan56.39 =173.91cm =1.7391m

At 3PM height of shadow H=115.59*tan43.15 = 108.35cm =1.0835m

For 250w panel

Now calculate horizontal length of Solar panels after arranged with an inclination equal to latitude angle, which is 14.68.

Horizontal length of Solar panels =164.6*cos (14.68) =159.22cm

Now calculate Height of shadow at different timings of day

At 12 noon height of shadow H=159.22*tan75.32 =607.8cm =6.078m

At 10AM height of shadow H=159.22*tan56.39 =239.55cm =2.3955m

At 3PM height of shadow H=159.22*tan43.15 =149.256cm =1.49256m

Based on above calculation are cleared that maximum height of shadow will fall at 12 noon only, because of Elevation angle is maximum at 12 noon.

2. Solar panels vertical arrangement Experiment

In Solar panels vertical arrangement experiment two panels are considered with different sizes, here considered panels are 10watt and 12watt. 12watt panel fixed as bottom panel width of this panel is more than 10watt panel. Shadow height is depended on the width of panel because of panels are arranged in width wise direction. 10watt panel is arranged at top and it can adjustable in vertical direction, to arrange at particular vertical distance between panels.

Fig.1 Vertical arrangement of solar panels at 0.75m distance

The experiment was conducted by measuring the output voltage and current to calculate power output by arranging the solar panels at 0.75m and 0.5m distance. For measuring the output voltage and current multi-meter was used.

Output values of voltage and current taken for different distances between solar panels from 8 AM to 5PM with interval of one hour. Readings were also taken during 11AM and 1 PM with an interval of 15 minutes and output power was calculated.

Modelling and Analysis

Tower was modelled in solid works software by creating beam elements. All the elements are properly assembled by importing one by one in solid works assembly. sizes of each element is calculated as per assumed height of tower 25 m. All elements are constrained in order to restrict degrees of freedom of final assembly.

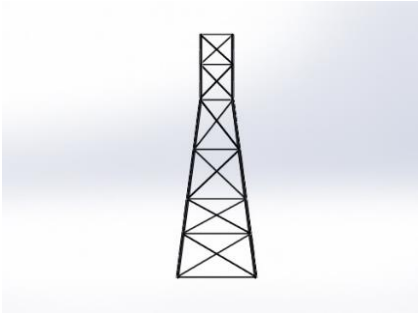

Fig2. Tower model with 25m height

Modelling of solar panel arrangement

After considering all calculations of shadow height, use of combination of 250watt and 100watt panels gives optimum arrangement for installing maximum capacity panels on the tower with 4m vertical distance. The shadow height of 100watt panel is less compared to 250watt panel but at bottom row solar panels no need to consider the shadow height. so use of 250W panel at bottom row and remaining 100W gives optimum number of panels arrangement.

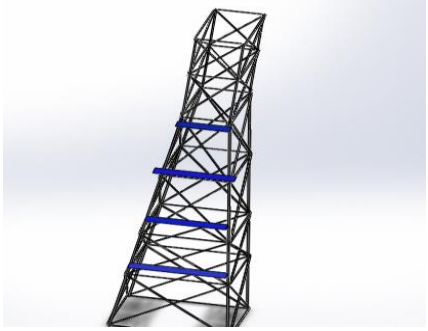

Fig.3 Tower after arranging solar panels

Solar panels are arranged as shown in figure and number of panels was decided based on tower width at particular height. Each row of panels is at 4m vertical distance, at first row of solar panels (from bottom) six solar panels with each capacity of 250watt are arranged. In second row from bottom four solar panels with each capacity of 100watt are arranged. In third row three solar panels and fourth row two solar panels with each capacity of 100watt are arranged.

Wind Load Calculations

For the calculation of wind loads by static method the following parameters were considered as per IS: 875 (part 3) 1987.Wind speed 40km/hr, Risk coefficient (k1)1.08, Terrain, height band structure size factor (k2) category 2 and class B (assumed), Topography factor (k3)1(assumed). Wind speed 40 km/hr, Risk coefficient (k1)1.05, Terrain and height factor (2k) 1.05(assumed), Topography factor (k3)1(assumed). V_b=basic wind speed of place in m/s.

Wind speed at any place can be expressed as: $V_Z = k_1 * k_2 * k_3 * V_b$

$$=1.05*1.05*1*(40*5/18) =12.25 \text{ m/s}$$

Design wind pressure, $P = 0.6*(V_z)^2 = 0.6*(12.25)^2 = 90.0375 \text{ N/m}^2$

Model is Simulated for analysis of forces in members by applying wind pressure and gravity.

RESULTS

Solar Panels Vertical Arrangement Experiment Results

Power Output of Solar Panels when Arranged at 0.75m Distance

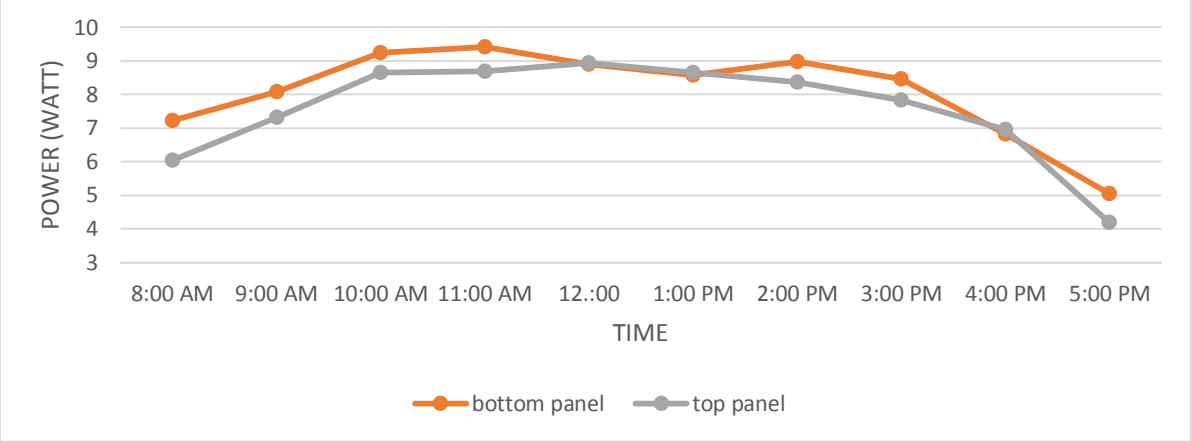

Fig4. Chart shows comparison of power output solar panels arranged at 0.75m distance

The chart shows the power output of two panels at different time. Power production from the top panel started from 8 am and increased with the time till 12 pm and after12 pm power output was decreased continuously. Power output from the bottom panel was increased till 11am and between 11am to 1pm the power was decreased due to the shadow of top panel falls directly on the bottom panel.

Power Output Solar Panel Arranged at 0.75m Distance from Another Solar Panel during 11am To 1pm

Power output readings of bottom panel and top panel between 11am and 1pm are shown in figure 5.2. top panel output is increased from 11 am to 1pm and the output of bottom panel is decreased. Maximum power output in top panel is 8.987watt and bottom panel is 9.504watt. bottom panel output decreased by 47.11% due to the shadow of top panel.

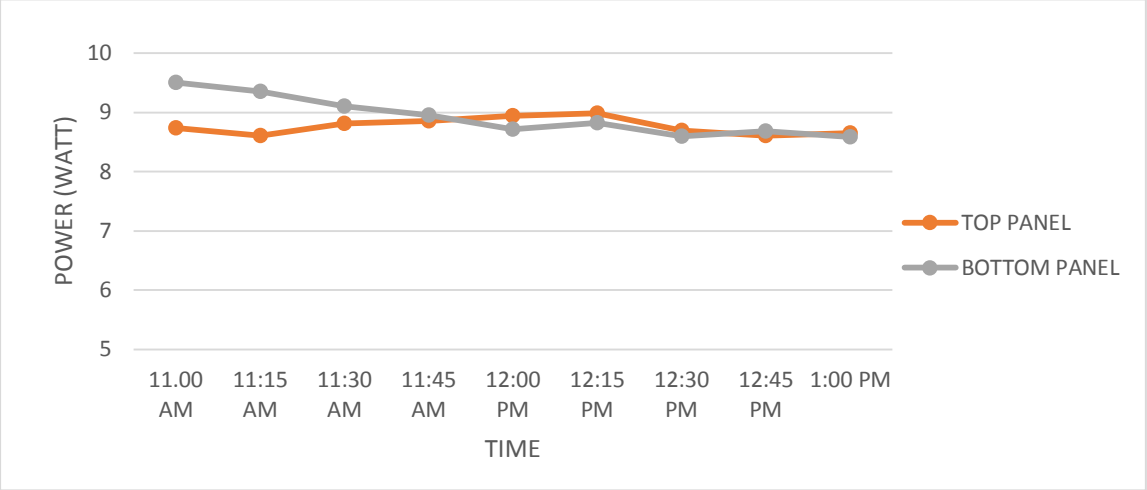

Fig5. Power output solar panel arranged at 0.75m distance from another solar panel during 11am to 1pm

Power Output Solar Panels Arranged at 0.5m Distance

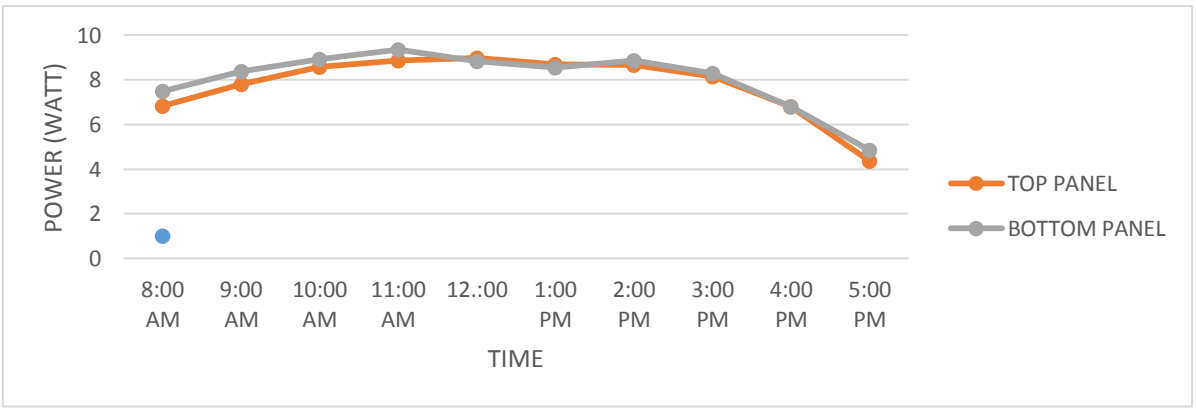

Fig.6 Chart shows comparison of power output solar panels arranged at 0.5m distance

Power output of top panel is varying as arranging at 0.75m but power from bottom panel is decreased by 47.32% during 11am and 1pm. Reason for decrement of power is panels are arranged at smaller distance so the maximum area of bottom panel fall under shadow of top panel.

Power Output Solar Panel Arranged at 0.5m Distance from Another Solar Panel during 11am To 1pm

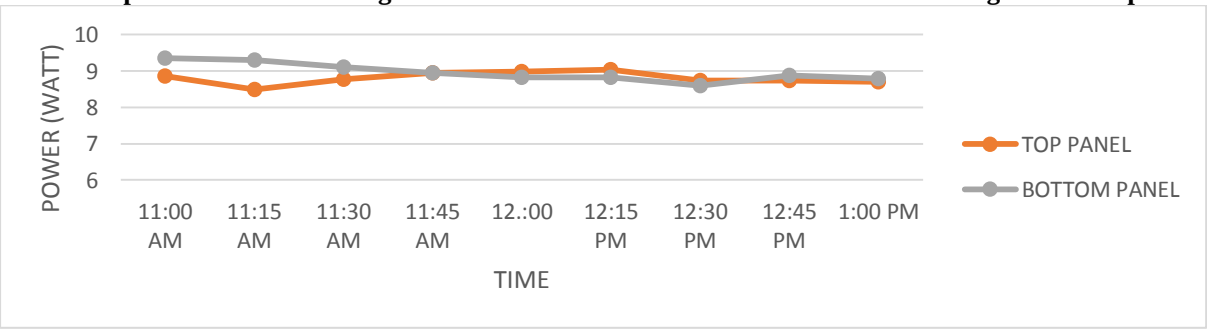

Fig.7 power output solar panel arranged at 0.5m distance from another solar panel during 11am to 1pm

Chart shows the power output between 11am and 1pm of solar panels arranged at 0.5m distance. Power from bottom panel is decreasing tremendously but top panel output is similar as in previous case.

Power Output 12watt Solar Panel Arranged at Different Distances from Another Solar Panel and Arranged Individually

Figure shows the power output of 12w solar panel when arranged at different position. Maximum power is developed from the panel when the panel is installed separately, power output of panel when arrange at 0.75m from top panel is less than individually arranged and more than arranging at 0.5m distance. This shows the shadow will affect the power output and if we arrange at proper distance we can get maximum output.

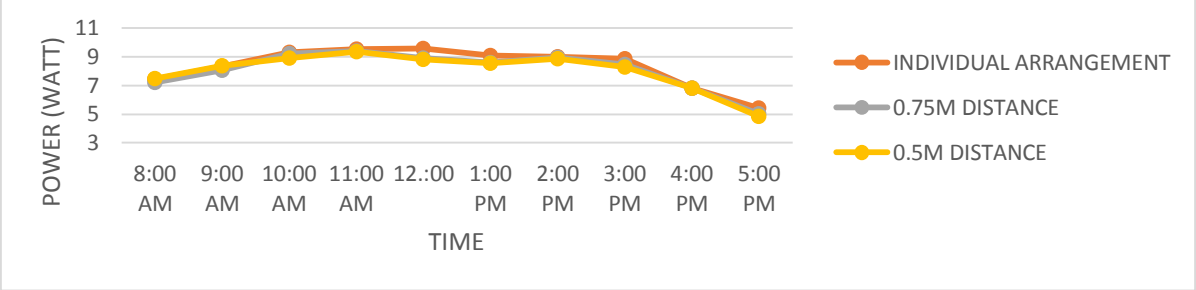

Fig.8 Power Output 12watt Solar Panel Arranged at Different Distances from Another Solar Panel and Arranged Individually

Analysis Results

In the present analysis, the stresses and strains in tower and reaction forces at fixtures of tower has been considered as the main parameter. A regular tower of 25m with regular configuration has been studied under static method.

Stress and strains in members of tower

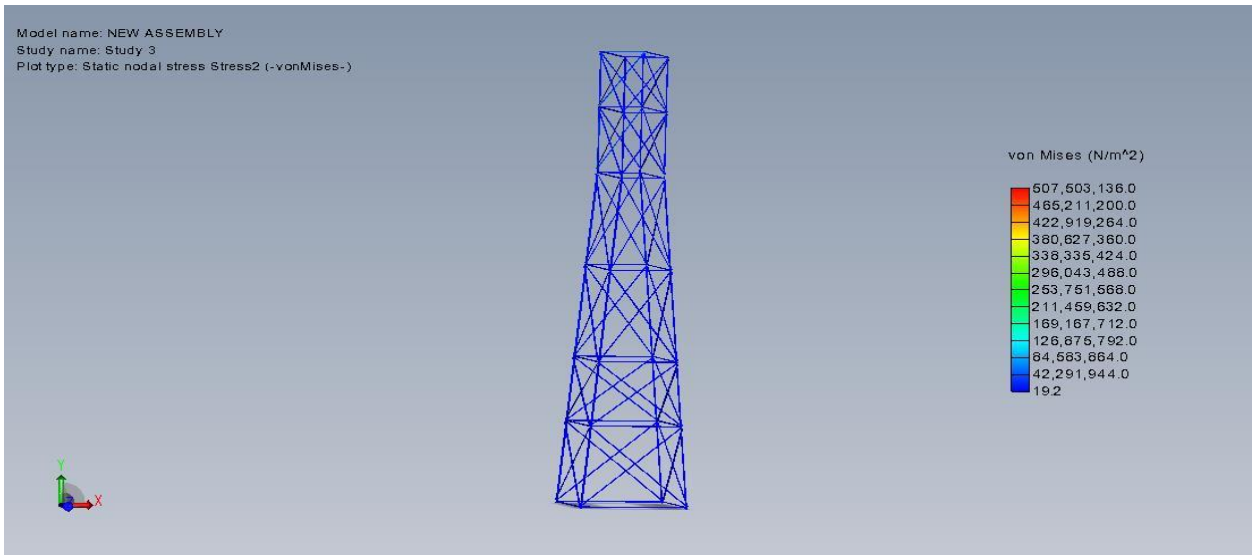

Fig.9 shows the von mises stresses in tower members subjected to wind pressure

Table1 Maximum and minimum Von Mises Stresses in tower

Name	Type	Min	Max
Stress1	VON: von Mises Stress	801.644 N/m^2 Node: 584301	1.15729e+010 N/m^2 Node: 132101

The figure shows the von misses stresses the tower when applying wind pressure and gravity forces. Maximum stresses produced in the tower is 1.15729e+010 N/m^2 which is less than the elastic modulus 2.1e+011 N/m^2 of tower, so the structure is within safety limit.

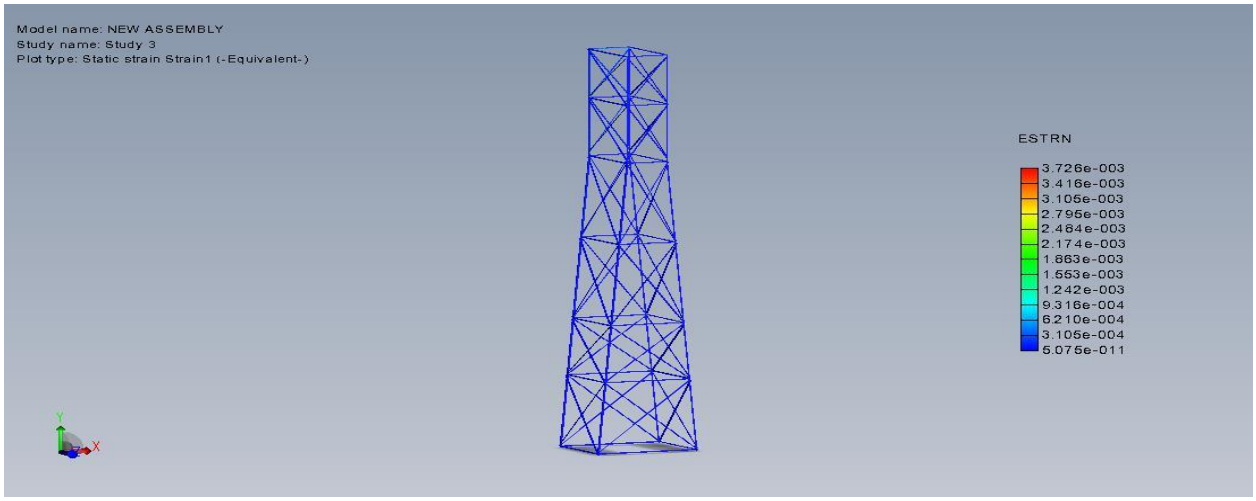

Fig.10 strain produced in tower subjected to wind pressure

Table2 maximum and minimum strains in tower

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	3.37856e-009 Element: 1525490	0.0607437 Element: 351668

The above figure5.7 shows the strain produced in the members of tower when wind pressure and gravity applied on tower. We see the strains at different members is very less and maximum strain is also less than 0.2, so we no need to consider these strains as they were in elastic limit.

Reaction Forces and Reaction Moments

Table3 Reaction forces and reaction moments in tower

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0	28740.5	0	28740.5
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N-m	0	0	0	0

Stress and strains in members of tower after installing solar panels

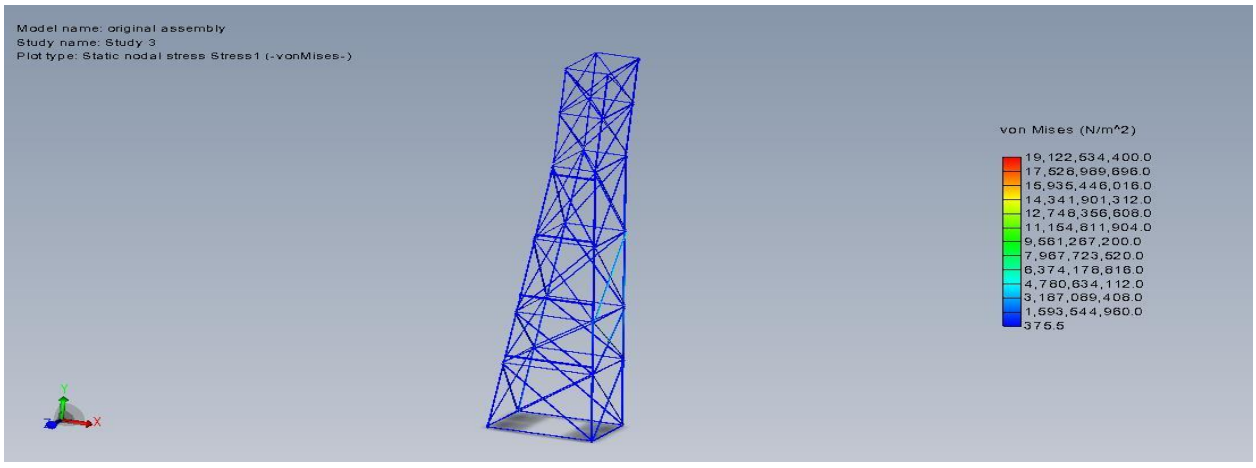

Fig.11 von mises stresses in tower after installing solar panels subjected to wind pressure

Tale4 Maximum and minimum Von Mises Stresses in tower after installing solar panels

Name	Type	Min	Max
Stress1	VON: von Mises Stress	375.464 N/m^2 Node: 599885	1.91225e+010 N/m^2 Node: 136010

The figure shows the von mises stresses in the members of tower after installing the solar panels on tower when applying wind pressure and gravity. Maximum stresses produced 1.91225e+010 N/m^2 is less than the elastic modulus of material 2.1e+011 N/m^2 so the material with stand these stresses. When compared to stresses in tower with solar panels is more than tower without solar panels but less than the elastic limit.

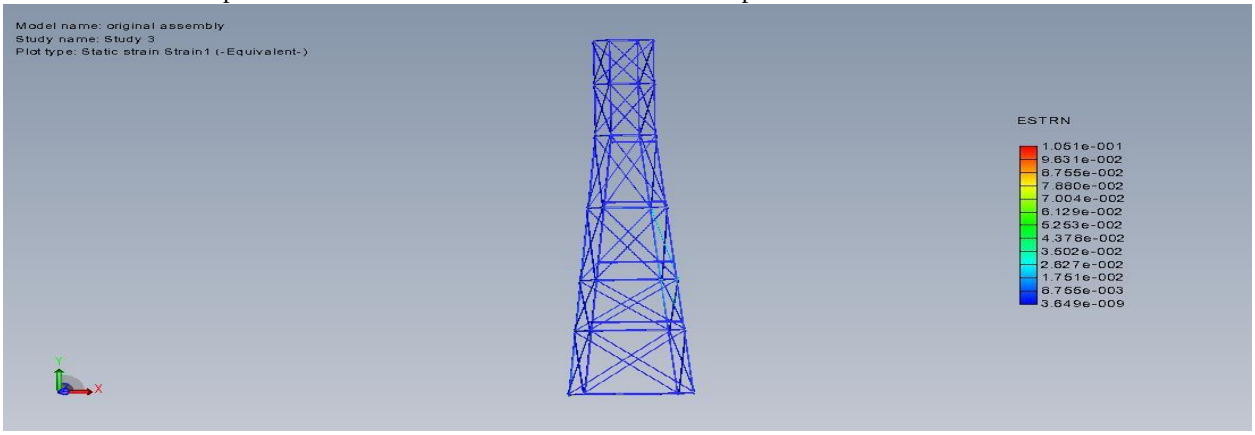

Fig.12 strains in tower after installing solar panels subjected to wind pressure

Tale5 Maximum and minimum strains in tower after installing solar panels

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	3.64881e-009 Element: 1580067	0.105061 Element: 360529

Figure shows the strains in the tower after installing solar panels when applying wind pressure and gravity. Maximum strain produced is less than 0.2 and comparing tower without solar panel it is little more.

Reaction Forces and Reaction Moments

Table6 Reaction forces and reaction moments in tower after installing solar panels

Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N	0	28689.7	0	28689.7
Selection set	Units	Sum X	Sum Y	Sum Z	Resultant
Entire Model	N-m	0	0	0	0

CONCLUSION

Power requirement at cell tower is increasing day by day because of number of users are increasing, but power availability from grid is not increasing. Cell tower operators are depending on the diesel power. It is becoming costlier because increasing prices and it also causing pollution. Solar energy is one of the best alternate to this problem, as it reduces energy cost. the next question is where to install the solar pv module. Normally, there isn't enough land space available around the cell tower. The only possibility is to install solar panels on the cell tower itself. When number of solar panels are arranged on all tower possibility of the shadow of top tower falling on the panel below it is very high.in this paper a detailed study has been carried out on the shadow effect of top solar panels on the panels located below them.

In vertical arrangement of solar panels both panels are found to be producing power entire day but during 11am to 1pm the power output of bottom panel is reduced to 47.32% due to the shadow of the upper panel and remaining day power produced as per rated. So vertical arrangement of solar panels is possible. Parallelly, theoretical structural analysis has been carried out on the all tower after the installation of the solar panels to study the effect of wind on solar panels and all tower structure itself. From the simulation results It was found that the variation in reaction forces was 0.17% and major principle stresses on the cell tower without solar panels was 11.5 GPa and principle strain is 0.06, which indicates the structure is with in elastic limit. The major principle stress on the tower after panels installation was 19 GPa and principle strain was 0.1, also indicates that the structure is with in elastic limit.

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