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Effective Utilization of Median of National Highway for Installation of PV Panel and its Interconnection with Grid

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ABSTRACT: In this paper, the use of renewable energy resources has been given importance. Worldwide nations are looking at Sun for power generation, which is a perennial source having least effect on ecology and environment. The land required for Solar Photovoltaic (SPV) panel installation is very large per MW, compared to any other types of generation. Availability of land per capita is very low in India. It is essential to explore the possibilities of utilizing land area which are neither contributing to agriculture nor for any other use. In this context the space available in median of national highways is chosen for PV panel installation and solar power generation. The location of the median on NH-4 between Tumakuru and Chitradurga of Karnataka, India is considered. The analysis is carried out for 2 cases for the median running through East – West direction and the median running through North - South direction with a power generation capacity of 50kW in either case.

Keywords: National Highway median, Photo voltaic panel, Power generation, Solar energy.

1. INTRODUCTION

Energy performs a critical role inside the socio-economic improvement and human welfare of the country. The requirement of Energy in the global is increasing daily because of increase in urbanization, population, and industrialization Growing according to capita energy intake puts plenty of strain at the traditional electricity resources. But the fossil fuel primarily based power sources are confined in quantity and also cause environmental pollution. Therefore, there may be a want for an alternative strength supply that may offer power in a sustainable way. The use of power has become an critical a part of our existence. Its supply should be secure and sustainable. The current trends in energy consumption are neither secure nor sustainable. The rising consumption of fossil fuels (and associated prices), together with increasing greenhouse gas emission, threatens to secure our energy supply. Therefore, development of clean, secure, sustainable and affordable energy sources should be our priority for developing countries. The depletion of fossil fuel resources on a international basis has necessitated an pressing search for opportunity power resources to meet the modern-day demands. Solar energy is clean, inexhaustible, environment friendly and potential resource among the available renewable energy options as on today. India lies within the latitudes of 7^{o} N and 37^{o} N, with annual average solar insolation of solar radiation between 400 to 700 cal/cm^2/day. The average solar radiation incident over India varies from 4 kWh/m^2/day -7 kWh/m^2/day.

The sun radiation obtained over the Indian land area is predicted to be approximately 5000 trillion kWh/year.

The highest annual radiation is received in western Rajasthan at the same time as the north-eastern place receives the lowest annual radiation.

2. METHODOLOGY

- Collecting the details and specifications for National Highways in India.
- Selection of the best stretch of National Highway within the state
- Analysis for finding most ideal segment of National Highway to implement the project.
- Studying and understanding the norms and standards of National Highways.
- Use of “Google Earth Pro” software for locating the median of National Highways to obtain the length and width of median for the selected stretch.
- Use of “PV syst” software to examine the complete performance of the solar plant in field conditions:

- To compute the size of the system
- To compute the optimal size of the panel
- To evaluate the energy production in the system, etc.

Use of "AutoCAD" software to sketch block diagrams, schematic diagrams of arrangement of strings and arrays of PV modules. In addition, it is used to prepare the drawings of mounting structures with dimensions to support the panels.

Softwares Used

Analysis is carried out using "Google Earth Pro", "PV syst" and "Auto CAD" software programs.

Google Earth Pro software is used in our study for more precise results. With high-resolution imagery, It gives a complete geospatial database for roads and historic imagery. This is completely a useful feature as it is easy to get the sphere statistics without visiting the place. This software enables for identity of thick vegetation, bridges, and unusable road places with its dimensional parameters.

PV Syst simulation software is used to research the specific overall performance of the solar plant in the field conditions. It may be used to analyze the distinct loads on the system, to estimate the size of the system, to decide the most fulfilling size of the panel, to assess the energy production in the system, etc. It is used to study the sizing and data analysis of complete PV system. It is used for different designs and sizes of the system. It can evaluate monthly production and performance. It also performs economic evaluation of the PV system at the design stage itself.

Auto CAD software is used to draw block diagrams, schematic diagrams of arrangement of strings and arrays of PV modules

Phases of Analysis

a) Selection of site/location
b) Selection of PV module.
c) Solar PV system sizing
d) Inverter sizing
e) Method of mounting the PV modules
f) Interconnection with grid

a) Selection of site/location

NH-4 Route: The highlighted places (in bold) from Nipani to Nangali comes under Karnataka state along NH-4.

National Highway No. 4 Route:

Thane→Nagaon→Panvel→Chauk→Khalapur→Lonavale→Karli→Wadgaon→Pune→Khed→Naraspur→Bhatghar→Khandala →Surul→Bhulnj→Satara→Borgaon→Ateet→Karad→Kasegaon→Peth→Top→Kolhapur→Kagal→**Nipani→Kanagle→Sutkat ti→Honga→Belgaum→Bagevadi→Kittur→Dharwad→Hubli→Pale→Chhabbi→Haveri→Motibennur→Ranibennur→H arihar→Devangere→Anagodu→Bharamasagara→Lakshmisagara→Aymangala→Hiriyur→ Javanagondanahalli→Sira→Nelahalu→Urkeri→Tumakuru→Dobbasapete→Nelamangala→Bangalore→Hoskote→Kol ar→Mulbagal→Nangali→**Palmaner→Bangarupalam→Chittor→Abdulapuram→Ranipettai→Kanchipuram→Sriperumbudur →Poonamalle→Chennai

Distance from **Tumakuru to Chitradurga along NH-4 – 135.5km** is selected. In this paper it is planned to install Solar Photovoltaic panels on the median width to generate power.[9], [10]

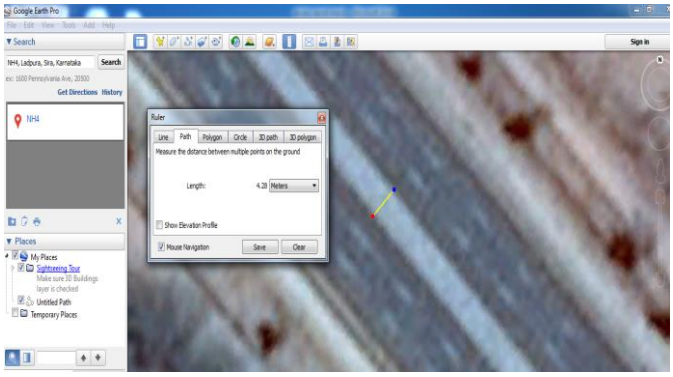

Figure.1. Median width available at Sira along NH-4: 4.28mts

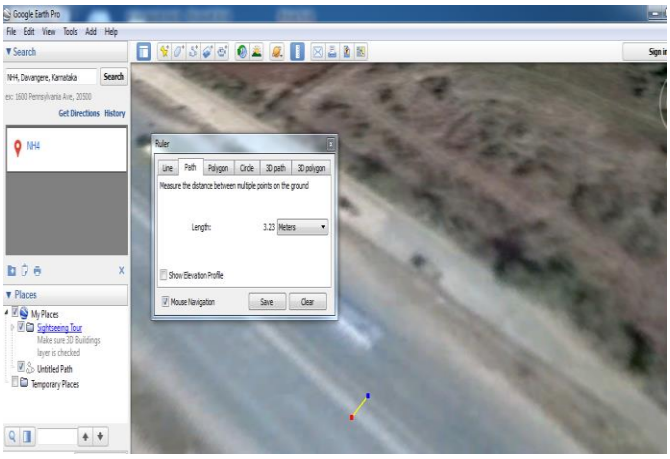

Figure 2. Median width available at Davangere along NH-4:3.23 mts

If the latitude is below 25°, the Multiplication factor for latitude angle is 0.87 [7]. Therefore, optimum tilt angle can be selected as 15^{o} and the orientation is due South [7]. This ensures that yearly average solar radiation falling on the module is higher than that on a horizontal surface.

Table 1: Tilt angle of few places along nh-4 for the selected location

Place	***Latitude***	***Tilt Angle Calculation***
Tumakuru	13.3400^{o}N	13.34*0.87=11.60^{o}
Sira	13.7450^{o}N	13.7450*0.87 =11.958^{o}
Hiriyur	13.9500^{o}N	13.9500*0.87=12.136^{o}
Chitradurga	14.000^{o}N	14.000*0.87=12.18^{o}

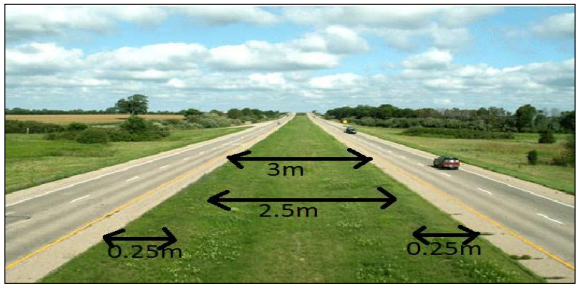

Figure 3. Median width available for the selected stretch from Tumakuru to Chitradurga along NH-4

b) Selection of SPV module

Table 2: Solar PV module specification

Make	***HBL Power Systems***
Nominal power at STC	90Wp
Isc	6.4A
Voc	21V
Impp	5.294A
Vmpp	17V
Technology	Si-poly
Temperature	25^0c
Efficiency	15.90%
No. of cells	36 in series
Dimension of module	1005mm*655mm*35mm
Weight	7.6kgs

Module dimension**:** Length=1005mm**,** Width=655mm**,** Thickness = 35mm**,**

Area of one module =1005mm*655mm = 0.658275m^2.

Selection of SPV module based on available median width 2.5m excluding clearance, the module that can be chosen is 90wp with dimension 1035*675*35 in mm.

If 2 rows of modules that can be accommodated, width of median consumed by module is 1035mm+1035mm=2070mm = 2.070m. Minimum Width of median of National Highways as per highway norms = 3mts.Clearance considered within the

median width on either side = 0.25m +0.25m = 0.5m

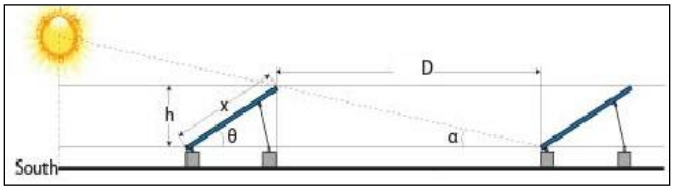

Figure 4. Inter - row shadow free spacing between the modules

Where, h- Height difference or height of obstruction, x- Solar module width = 655mm, D- Inter row shadow free spacing between pv modules or strings, Θ- Module tilt angle=15^0, α- Solar altitude angle or solar elevation angle (obtained from horizon for shading graph for the selected location or nearest location) By clicking a location on the map, you are given coordinate and time zone information, and by entering the date for the winter solstice, December 21, the "worst case" position of the sun is easily obtainable. Hence curve 7 is chosen.

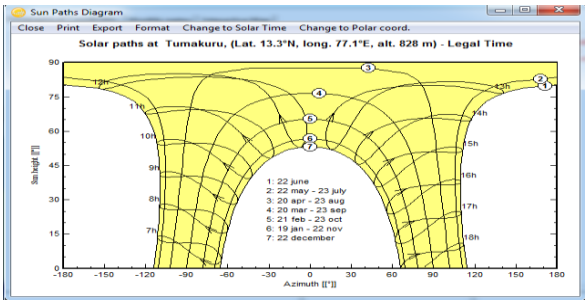

Figure 5. Solar paths at Tumakuru

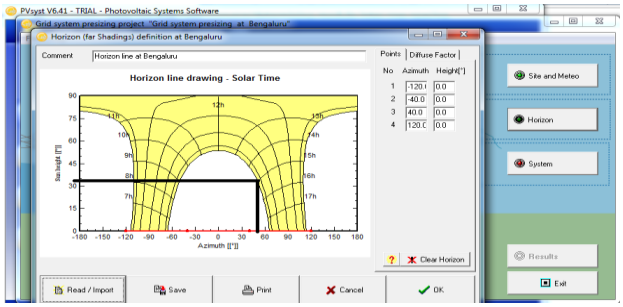

Figure 6. Horizon for shading definition at Bengaluru

- h= sin(tilt angle)*module width = sin(Θ)*x=sin(15^0)*655mm=169.526mm=170mm
- Module row spacing= h/ tan α=170mm/tan(35^0) =242.7mm =243mm
- Minimum module row spacing= Module row spacing*cos (azimuth angle correction for location) =243mm*cos (50^0) =175.48mm=175mm
- Row width = Minimum module row spacing + (cos(Θ)*module width)) = 175mm+(cos(15^0)*655mm) = 807.68mm=0.807m.

Analysis of Direction of Median

1) Median running through East-West direction:

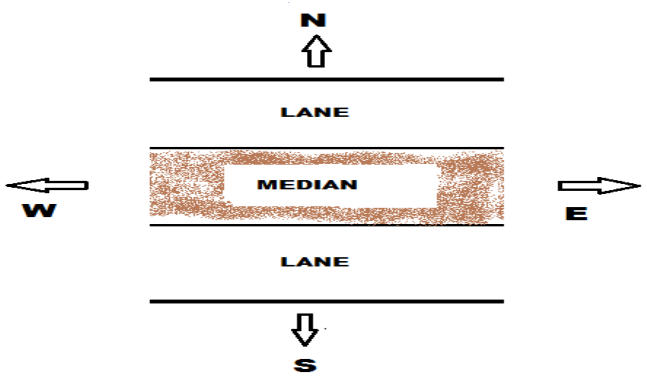

Figure 7a. National Highway median running through East – West direction

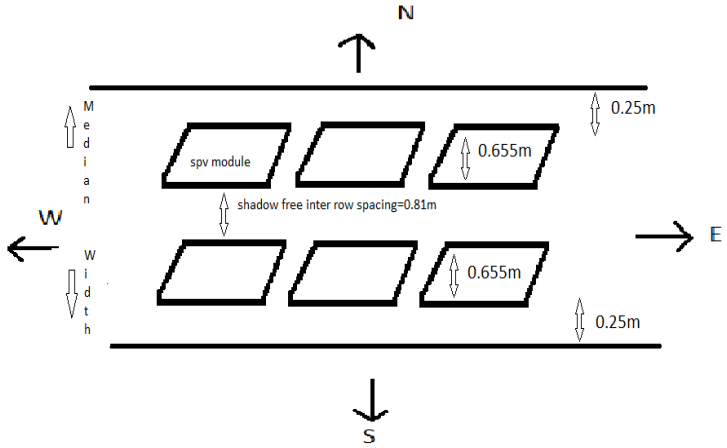

Figure 7b. Arrangement of panels within the median width available in terms of rows.

Module width=0.655m

Clearance assumed on either side within the median width= 0.25m+0.25m

Shadow free inter row spacing between the array= 0.81m (as calculated)

2) Median running through North-South direction

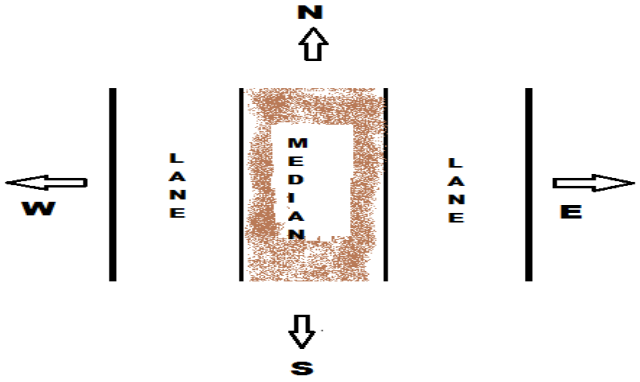

Figure 8a. National Highway median running through North -South direction

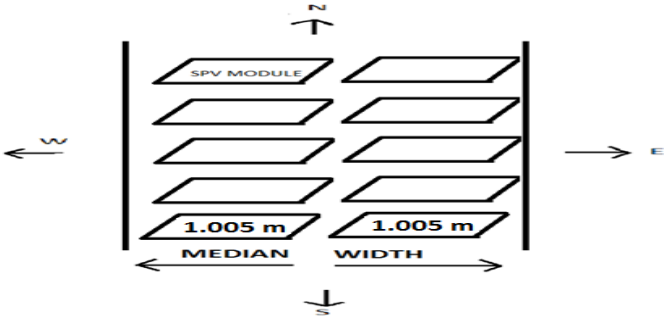

Figure 8b. Arrangement of modules facing due south in 2 rows throughout the median length

Calculation Summary of PV System Sizing for the Median

The details of computations done using the concept of Central Inverters and String inverters are tabulated below

Method 1: **Central Inverter**

Table 3. No. of SPV modules, strings using central inverter

1. Analysis done by fixing the length of median	
Length	1.5kms
No.of modules	5696
Power capacity	500kW
Max No. of modules/string	45
No. of strings	124
2. Fixing the number of modules	
a) No of modules fixed =100	
Power capacity	9000W
Max No. of modules /string	45
No. of strings	3
b) No of modules fixed = 560	
Power capacity	50kW

Max No. of modules/string	45
No. of strings	13

Method 2: **String Inverter**

Table 4. No. of SPV modules, strings, arrays using string inverter

No of modules fixed = 560 Power rating of module selected=90Wp Power capacity=50.4kW				
Inverter	***No of modules/string***	***No. of arrays***	***No. of inverters required***	***No. of Array Junction Box (AJB)***
Schneider electric	38	4	4	4
SMA -17kW	36	7	2	2
SMA- 25kW	36	7	2	2
SMA- 20kW	36	5	3	3

c) Selection of PV System Size

Out of above possible design configuration the following configuration is fixed as shown in table.4

Table 5. PV Sizing

No. of modules fixed	560
Power capacity of the design	50.4kW
Inverter: Schneider Electric	10kW
SPV Module: HBL Power Systems	90Wp
No. of modules/string	38
No. of strings	4
No. of inverters	4
No. of Arrays (parallel strings)	4

Modified no. of modules to generate around 50kWp power = No. of modules/string * No. of strings * No. of arrays= 38*4*4= 608 modules.

d) Inverter Sizing

The purpose of transformers in a solar power plant is to provide suitable voltage levels for transmission across the site and for export to the grid. In general, the inverters supply power at LV. But for a commercial solar power plant, grid connection is typically made at upwards of 11 kV (HV levels)

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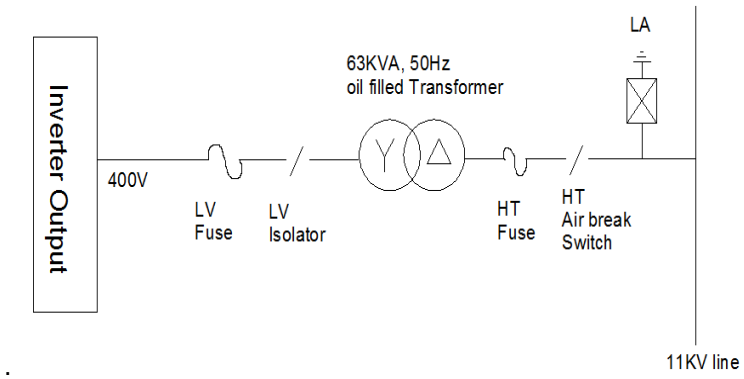

Figure 9. Schematic layout of interconnection of Inverter output to grid

Table 6. Power, voltage and current capacity of the system at the input side of inverter

Output voltage of each string	V_{dc} = 646volts
Output current of each string	I_{dc}=5.29A
Output voltage from overall string	V_{dc}= 646 volts
Output current from 4 parallel strings	I_{dc}= 21.16A
Power output of each string	13.669kW
Power output from 4 parallel strings	54.676kW

3. ARRANGEMENT OF SPV MODULES, STRINGS, ARRAYS WITHIN THE NATIONAL HIGHWAY MEDIAN WIDTH

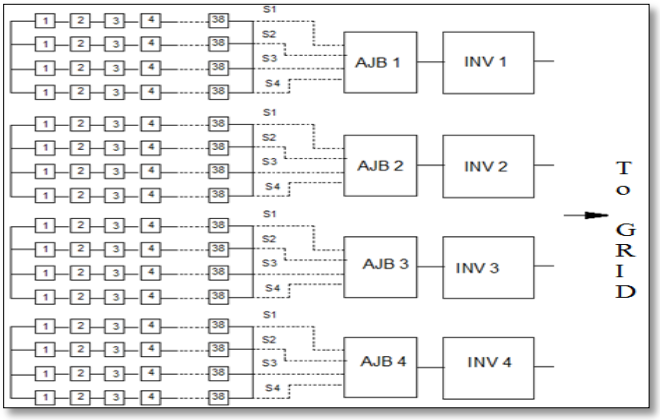

Figure 10. Schematic layout for accommodating the fixed number of modules as per design

Length of median for accommodation of SPV modules

a. For the median running through East –West direction with panels oriented due south

Length of median covered by modules for 1 AJB and 1 Inverter = (1.005m * 38 Modules) + (1.005m * 38 Modules) =38.19m+38.19m=76.38≈ 80m

- Length of median covered by 4 strings of SPV modules through 1 AJB and 1Inverter = 80m as shown in fig above

- Similarly, length of median covered by 4 arrays (parallel strings) of 560 SPV modules with 38 modules/string with arrays connected to 4 AJBs and 4 Inverters= 80m*4= 320m

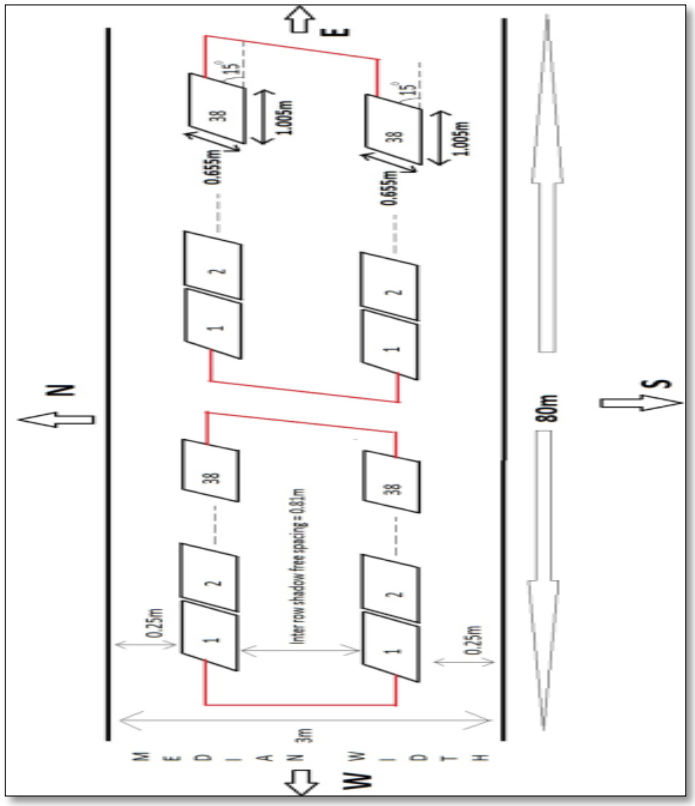

Figure 11. Arrangement of 4 strings of SPV Modules connected to 1 Inverter through 1 AJB with in median width for the median running through East – West direction

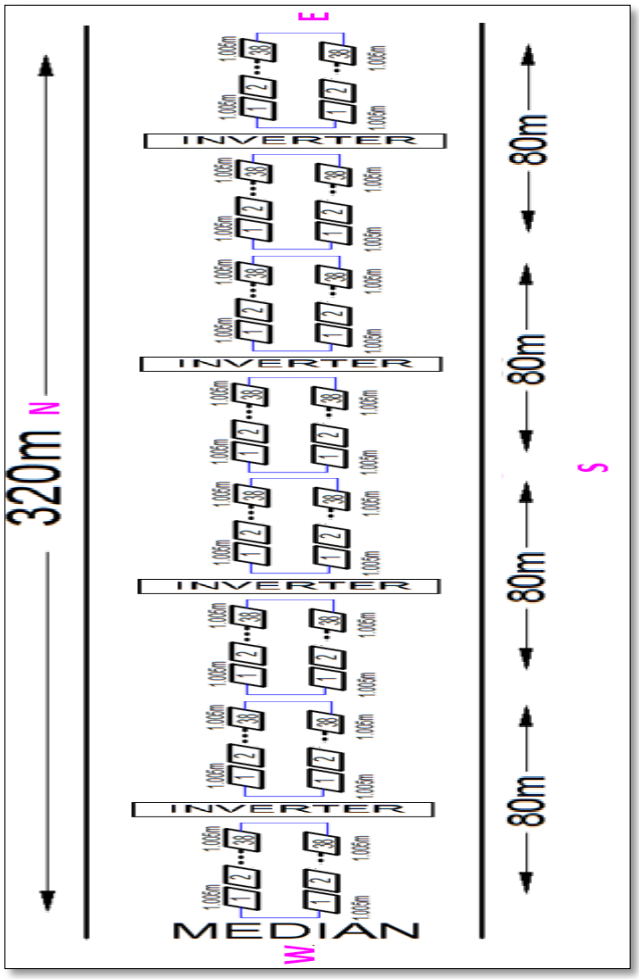

Figure 12. Arrangement of 608 SPV modules with in median width for the median running through East – West direction.

b. For the median running through North – South direction:

Width of each module=0.655m

Inter row shadow free spacing between each module = 0.81m

No. of modules / string in series = 38

No. Of arrays (parallel strings) = 4

Length of Median covered by SPV modules for 1 section for Median running through North – South Direction is calculated as shown:

Length = [(0.655m *38 modules) + (0.81m*37)] + [(0.655m *38 modules) +(0.81m*37)]

=54.86m + 54.86m=115m.

Length of median covered by 4 strings of SPV modules through 1 AJB and 1Inverter = 115m

Similarly, length of median covered by 4 arrays (parallel strings) of 608 SPV modules with 38 modules/string with arrays connected to 4 AJBs and 4 Inverters= 115m*4= 460m.

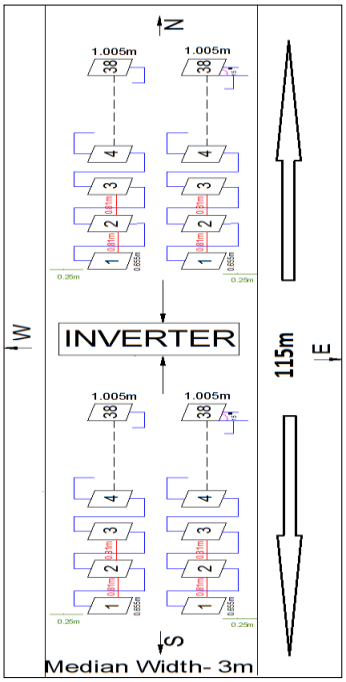

Figure 13. Arrangement of 4 strings of SPV Modules connected to 1 Inverter through 1 AJB with in median width for the median running through North - South direction.

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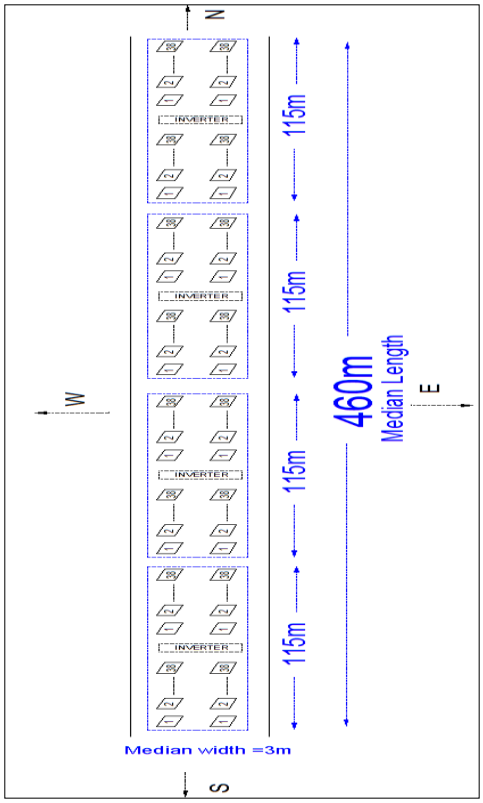

Figure 14. Arrangement of 608 SPV modules with in median width for the median running through North - South direction

4. ADVANTAGES AND DISADVANTAGES

4.1 **Advantages:**

1. Effective utilisation of available median along national highways for PV panel installations, as a result no additional price funding on land.
2. The government of India is having a bold plan to acquire generation with the aid of sun of of 10,000MW by the end of year 2017 and 20,000MW by the end of year 2022 through its national solar mission. If this project can be implemented for the medians along all the national highways it supplements to achieve the target set by govt of India.
3. The probabilities of smoke pollutants to the PV panels from automobile movement along the national highways are less because the panels are mounted at a height of 5 to 7 mts above ground level.
4. The problem of reflection from headlight of vehicles on PV panels are avoided by installing the panels at a height of 5 to 7 mts from ground level as the max height of truck comes to around 4.25 mts as per standards
5. The columns of the mounting structures are provided with caution radium stickers as a safety aspect to avoid the vehicles hitting the mounting structure columns during night.
6. Possibilities of hybridization with wind mills.
7. Minimum operating cost.

4.2 Disadvantages:

- Regular cleaning and inspection of the panels is difficult from maintenance point of view as the panels are mounted at a height of 5 – 7mts above ground level.
- Adds cost to mounting structures
- Anticlimbing device to be provided to avoid theft and intentional damage to the panels by antisocial elements

5. RESULTS AND DISCUSSIONS

Design Summary and Cost estimation for 50KW Grid Connected Solar PV Plant

Table 7. Design Summary

Plant capacity	50KW
Voltage output	400V
Current output	58A
No. of SPV modules	608
No. of 10KW Inverter (Make: Schneider)	4
No. of 3ϕ, 50Hz, 63KVA, 433V/11KV, ϒ/Δ Transformer	1
Length of median covered for 50kW PV plant for the median running through East-West direction	320m
Cost of 50kW PV plant for the median running through East-West direction	**Rs. 58,33,800**
Length of median covered for 50kW PV plant for the median running through North -South direction	460m
Cost 50kW PV plant for the median running through North -South direction	**Rs.62,83,800**

Table 8. Plant capacity extended for 1mw: 1mw/50kw = 20 (i,e 20 units of each 50kw capacity)

Plant capacity	1MW
Voltage output	400V
Current output	1160A
No. of SPV modules (Make: HBL)	608 * 20 = 12160
No. of 10KW Inverters (Make: Schneider)	4*20 =80
No. of 3ϕ, 50Hz, 63KVA,433V/11KV, ϒ/Δ Transformer	1*20 = 20
Length of median covered for 1MW PV plant for the median running through East-West direction.	320m *20 = 6400 m =6.4km ≈7km

Length of median covered for 1MW PV plant for the median running through North -South direction	460m * 20 = 9200m = 9.2km ≈ 10km
Cost of 1MW PV plant for the median running through either East –West Direction or North -South direction	Rs.12,56,76,000

6. APPLICATIONS AND FUTURE SCOPE

6.1 Applications

1. Access to charging point for electric vehicles.
2. Supply to IP sets for the surrounding villages.
3. Remote village electrification

6.2 Future Scope

Efficient monitoring and controlling of the power plant can be done by incorporating SCADA system to the proposed design The implementation of solar panels at medians of highway can be extended across the lanes by constructing a roof structure covering lanes and medians of highway. This space can contribute to additional energy generation without extra cost for land. It results in improved vehicle movement and minimises road repairs also results in longer vehicle tire life due to the effect of sun shade. This concept can be combined with other forms of renewable energy sources such as wind / biomass so as to provide full-fledged hybrid power generation.

7. CONCLUSION

This project proposes a design of effective utilization of median of National Highways for PV panel installation, solar power generation and its interconnection with grid for the stretch **Tumakuru to Chitradurga on NH-4**. From the proposed design it has been estimated that energy generation is **75000 kWh / year** from **50kWp** SPV system and cost for installation is about **Rs.63, 83,800** with payback period of **14. 81 years.** Hence the proposed system effectively utilizes the national highway median which is neither contributing to agriculture nor for any other use, for solar power generation.

8. ACKNOWLEDGEMENTS

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