Solar workstations in high-altitude remote areas using solar blinds

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Abstract:
Ladakh which is on an average altitude of around 11000 feet above sea level is one of the remotest areas of our country which gets around 300+ Sundays a year. Due to remoteness and arduous terrain, most of the remote areas are still not connected to the central gridsand hence completely depend on small solar stations or diesel generators.Keeping in view the problems faced by the people residing in high-altitude remote areas where there is an enormous shortage of centralized electricity from the main power grid due to the unavailability of electricity connections in those border areas we propose a solar workstation (solar inverter using vertical solar blinds) powered by solar energy. Our solar workstation will provide power and active shading in the peak summers where UV rays are very high, especially during winter when the hydroelectricity does not meet the demands of the remote regions due to river freezing. This demand can be simply achieved through a couple of devices used within the workstation like solar blinds which provide electrical DC power, an MPPT charge controller that tracks the maximum power extraction from the solar blinds to charge our batteries with maximum power, the solar inverter converts DC power to AC power output to use conventional appliances onboard. The key elements in the Himalayas, photovoltaic energy production and active shading are combined to have a positive economic benefit when the Solar blinds generate electrical power per square meter

Keywords: Solar workstation, solar vertical blinds, solar inverter, MPPT charge controller

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I. INTRODUCTION

Fossil fuels such as coal, oil, petroleum products, hydro, and nuclear energy constitute a significant proportion of the production of electricity all around the world and India which primarily use coal power plant for electricity generation (Roshna Nazar *et al*. [20]). The High altitude and cold regions in the Himalayas don’t use that option due to ecological and global warming sensitivity (Davide Geneletti *et al*. [8], Sonja Mueller *et al*. [21]) rather depend mostly upon the Indus River's centralized hydroelectricity which freezes during winter leading to Electricity shortages in the main cities of the upper Himalayas like Leh and south-eastern Himalayas. Therefore, the Solar rooftop power grid system has been introduced (Amit Kumar Yadav *et al.* [3]) and realized (Sunanda Sinha *et al*. [22],Aaina Dutta *et al.* [1]) in certain regions of the Himalayas.In Himalayan remote areas, the workstation specifically needs solar blinds despite conventional solar rooftop panels as an option because of snowy weather for most of the seasons therefore solar blinds would be a much better option and also provided as curtains. There are many methods to deal with the issue of snow covering of solar panel like thermal melting methods mentioned by Ali Rahmatmand *et al,* [27] but its not an efficient method to deal with the snow covering solar panels when electrical energy is consumed to thermally heat the panels. This paper describes the reasons and advantages of using Solar blinds in solar workstations in high-altitude and cold regions of the Himalayas along with the ease of installing the setup in those electrically cutoff regions. The following figure shows the merit of using a solar blind (Fig. 1. b) over conventional solar rooftop panels (Fig 1. a) in Himalayan areas. Solar blinds are panels on the curtains or shades covering our windows that convert solar energy into electrical energy that can be used in our daily electrical applications. Blinds are available in various types and fashions like Roller blinds, Photovoltachromatic blinds, Venetian blinds, and horizontal louvred blinds but the most suitable blinds applicable could be Vertical Blinds because of certain advantages as compared to other types because of certain advantages in terms of maximum solar energy efficiency, daylight quality, thermal and aesthetical comfort, easy maintenance as during winters the sun moves at an angle of 45 degrees from the ground. Solar Workstation will carry out significant operations in the Himalayan most isolated locations where centralized hydroelectricity is not an option.

a) (b)

Fig. 1.(a)Conventional Solar Rooftop panels (courtesy:Stadler.Otto, 20-02-2010), (b) Solar Blinds

The proposed ½ kW solar workstation will solve all the electricity concerns in those remote rural areas or urban households. And also, for creating an aesthetically pleasing and thermally comfortable indoor environment, lowering building energy consumption, and perhaps balancing the competing performance objectives in controlling the entry of solar radiation into buildings. These drapes will either let or keep sunlight out of a house. Currently, if a homeowner experiences excessive or insufficient sunshine, they must physically open the blinds.

Solar panels, a solar inverter, an MPPT charge controller, and a battery bank make up the proposed½ kW solar workstation. The majority of studies that suggest advanced shading principles have mostly examined horizontal and roller blinds. Vertical blinds' potential tactical options have mostly gone untapped. Traditionally manual operation has been the intended method of operation for vertical blinds, a widely used shading option. When the solar azimuth angle is high about the window normal, vertical blinds have the advantageous geometric property of blocking direct sunlight while maintaining an unobscured view of the high-altitude region of the sky, which typically contributes the most diffuse daylight. This study's goal is to assess the viability of the solar vertical-blind (SVB) idea. The study's starting point was a basic initial version of this concept for internal vertical blinds. Many choices must be made to transform this idea into a workable solution, and some of these choices have an impact on how well the workstation shading system performs for buildings in high-altitude regions. From a building physics standpoint, this study aims to support this decision-making process, focusing on control aspects that affect choices about the system hardware. In connection with aesthetic and financial considerations, the advantages and disadvantages of various configurations of the original SVB system are assessed. Simulations are used to examine the implications of each design option on the functionality of a typical cellular office area. This study makes suggestions for future research and development (R&D) into solar shading workstation systems in general as well as the SVB system's continued development considerations.

II. LITERATURE SURVEY

A. Motamed *et al.*[6] have suggested using a control technique to counter the demerits of the open-loop fuzzy logic-based control systems and discussed glare control systems for Venetian blinds. A.M. Atzeri *et al.*[7] have developed three shading control techniques and a glare control system. Samuel B. de Vries *et al.*[9] have evaluated the potential of a novel multistate solar tracking vertical blinds (ST-VB) where they discussed the shading performance and control concept by evaluating Building Performance Simulation (BPS). E. Lee *et al.*[10] have designed an automated Venetian blind system that controls thermal and daylight performances in a full-scale private office. H.Shen *et al.*[13] have examined the equivalence between daylighting and solar gains with rolled shades in private office premises and developed a daylighting calculation model. K. Konis *et al.*[15] have discussed the scope of technologies and methodologies based on performance facades and effective daylighting. R. Hart *et al.*[16] aim at the impacts of room-side ventilated voids and horizontal louvred blinds and experimentally tested thermal flow using simulated correlations from ISO 15099. Yanjin Wang*et al.*

[24] have developed an optical model to describe the combined method of ray tracing and radiosity technique is followed to automate the control of the Venetian blinds. V.Mettanant [23] has designed a simulation program that deals with the thermal controllability and daylight performance of automated vertical blinds. F. Favoino *et al.*[12] have introduced Photovoltachromatic cell (PVCC) based blinds to implement the optical control and performance of PVCC switchable glaze by simulation techniques.
The glare control and shading simulation methods with various types of modelling techniques are discussed and dealt within great discussions and simulation toolchains [[4], [6], [9],[11], [17]].

III. IMPLIMENTATION SECTION

A. Implementation of the proposed system

Solar Blinds in our workstation are implemented in the south façade building and the flow chart of the implemented solar workstationis given in Fig. 2. And shown in Fig. 3.

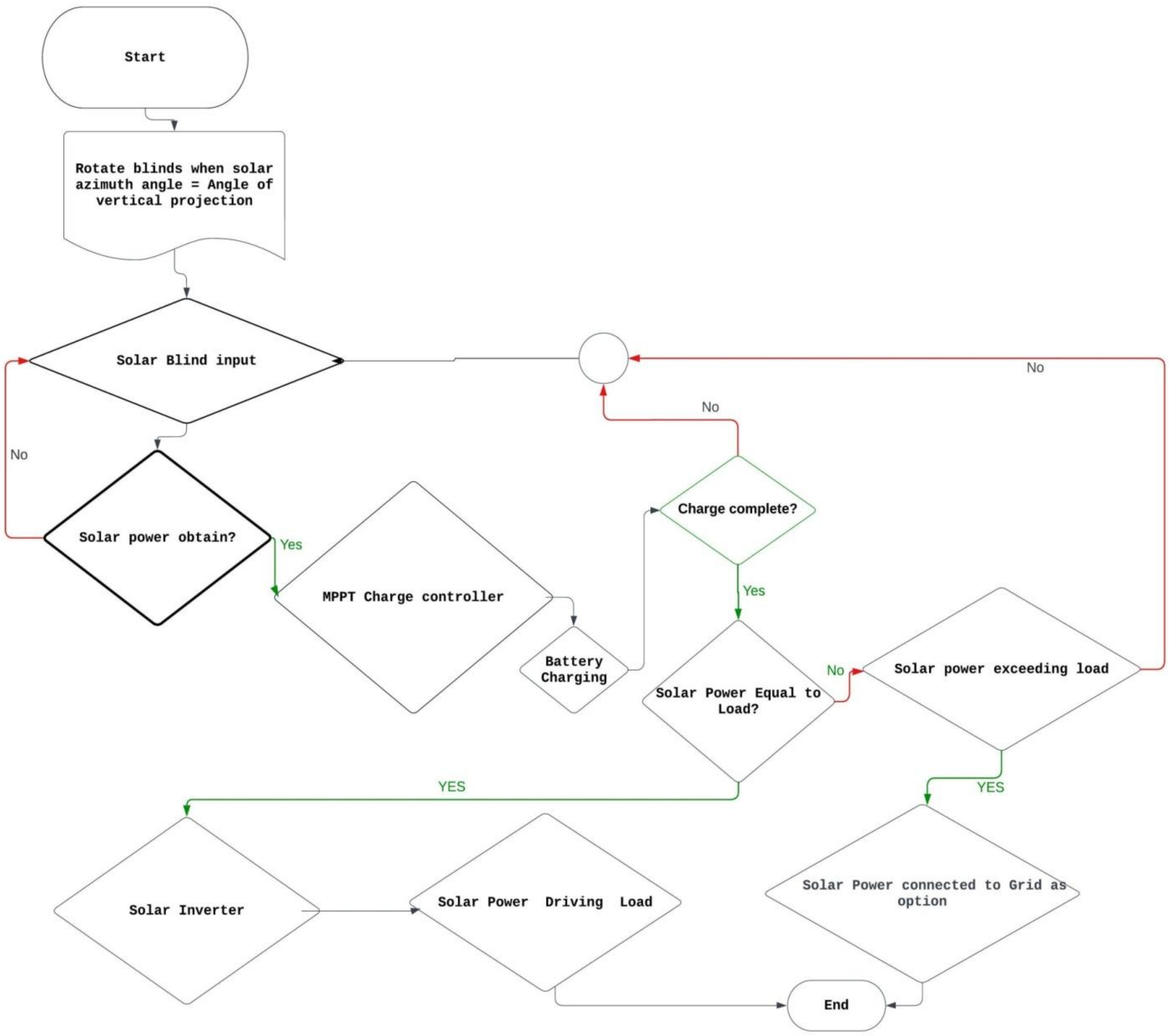


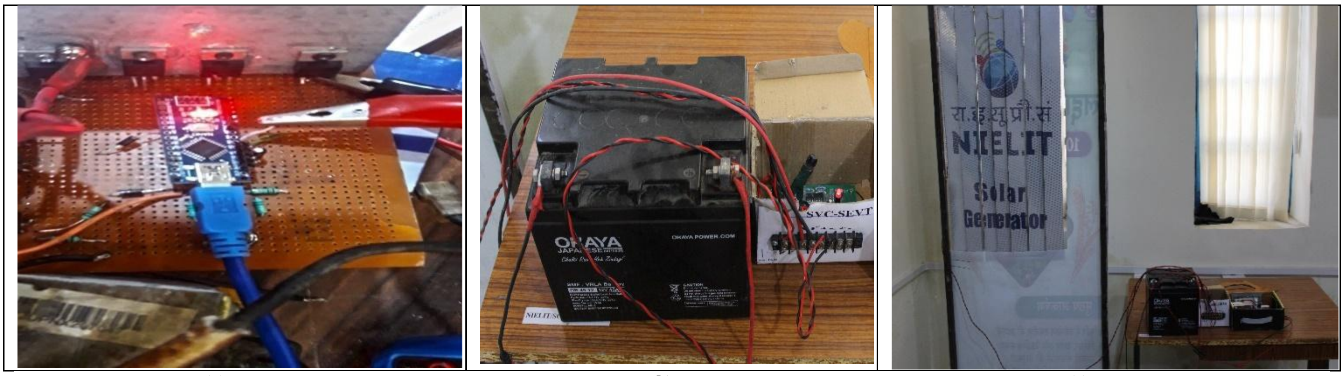
Fig. 2. Flowchart of the implemented solar workstation.

The solar vertical blinds consist of small 13 solar panels in a column and 7 solar blind slats forming the complete solar blinds that are customized using 91 solar panels of 6V,100mA.These solar slats forming SVB are fully retractable in a neat appearance (Fig. 3. a) The solar workstation is implemented by keeping the system nearby a south façade window (Fig. 8. b)

(a) **(b)**

Fig. 3. Solar vertical blinds retractable (a), solar blinds on south façade window

The following Figures representthe Solar inverter (Fig. 4. a), the MPPT charge controller along with a battery (Fig. 4. b) and the solar blinds (Fig. 4. c).



(a) **(b)** **(c)**

Fig. 4. Solar workstation has been implemented using an Inverter (on the left), MPPT charge controller and a battery (in the middle) and a complete workstation with solar blinds on the portable standee (on the right).

B. Workstation hardware and software resources

1. Solar panels
2. Blinds Pull Cord
3. Blinds hangers and rod
4. Blinds holders and rollers
5. Blinds Valance clips and clip holders
6. Metal Screws
7. Vinyl Stickers
8. Adhesive tapes and glue
9. Heat shrink tubes
10. Heat sink
11. Perforated sheets / Zero PCB
12. Transformer 12-0-12 10A
13. Capacitors
14. Resistors
15. Diodes
16. Mosfet IRF3205
17. Arduino Nano board
18. L293D motor driver IC
19. Potentiometer
20. Jumper wires
21. Wiring clips and sockets
22. Soldering station and soldering material
23. MPPT charge controller
24. Metal Casing
25. Styrene-acrylonitrile-coatedthinAluminium slats
26. Proteus software
27. Peltier Fan for exhausts
28. Indicating LEDs

C. *Comparision between previous and proposed method*

The concept and method used in previous and proposed paper are compared according to the following techniques.This section includes solar blinds with various methods and our proposed workstation premitives which are classified as paper 1 of Samuel B. de Vries *et al*.[9], paper 2 of Y.-B. Seong [26] and Ali Rahmatmand *et al*, [27] and our proposed paper of solar workstation in the following table 1:

TABLE I.

Parameters	Paper 1	Paper 2	Paper 3	Proposed paper
Blinds Illuminance	500 lux	Not mentioned	Not mentioned	800 lux
Solar power concentration	500W/m^2	Not mentioned	678W/m^2	500W/m^2
Blinds heat reduction	70%	Not mentioned	32%	30%
Inverter	Not mentioned	Not mentioned	Not mentioned	500W
Battery capacity	Not mentioned	Not mentioned	Not mentioned	12V,100Ah
MPPT output rating	Not mentioned	Not mentioned	Not mentioned	!2v,5A
Charging time	Not mentioned	Not mentioned	Not mentioned	13.3hours
Approx costing	Not mentioned	Not mentioned	Not mentioned	Rs.15000

C. EXPERIMENTATION AND METHODOLOGY SECTION

A. Solar Vertical Blinds

When a Solar workstation has been installed on a South façade building window. The solar blinds are manually controlled for opening and closing the blinds with the help of the blinds pull cord and rollers which rotate the SVB slats in the direction of the sun.Now, solar vertical blinds are implemented and controlled manually by rotating the blinds at the blind angle of rotation by pulling cords such that the angle of the vertical projection plane of solar blinds must be in correspondence with the solar azimuth angle ($\theta\alpha$) so that the solar panels can be exposed to the sunlight for workstation operation.

As far as blinds are concerned, they are indicating the Solar azimuth angle ($\theta\alpha$) while moved by the blind angle of rotation (θ_{BAR}).Samuel B. de Vries *et al*.[9] modelling Parameters AVPP, θ_{BAR}, and $WN_{\theta\alpha}$ are essentially usedfor determining Illuminance (I_l), Solar Power Concentration (P_c), and Effective Area (A_{eff}) which calculates the irradiance in the façade room along with the power generation of the workstation. The angle of the vertical projection plane (AVPP) is used to express the sun azimuth angle ($\theta\alpha$) about the window surface normal ($WN_{\theta\alpha}$) as shown in the following Fig. 5.

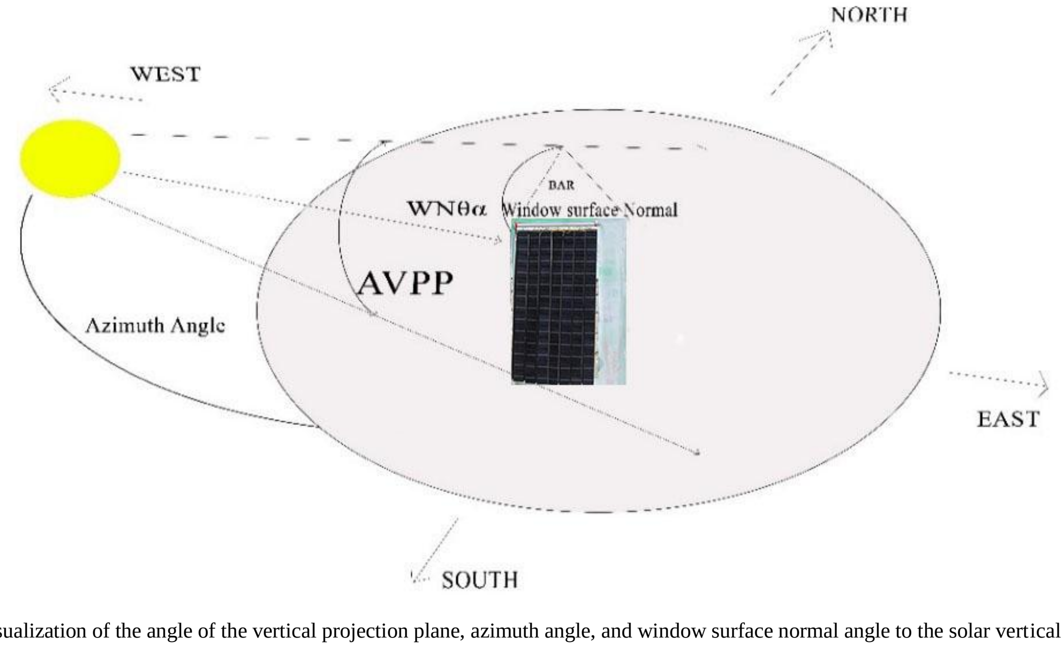


Fig. 5. Visualization of the angle of the vertical projection plane, azimuth angle, and window surface normal angle to the solar vertical blinds.

For calculation of the Illuminance and Power generation per square meter, we shall discuss some of the cases of the SVB as follows:

1) When solar vertical blinds are open:

The SVB are when retracted then maximum daylight illuminance are obtained in the inner space of our workstation or when desired to see outside glance. The following Fig. 6. shows the scenario when SVB are open, $\theta_{BAR} = 0°$.

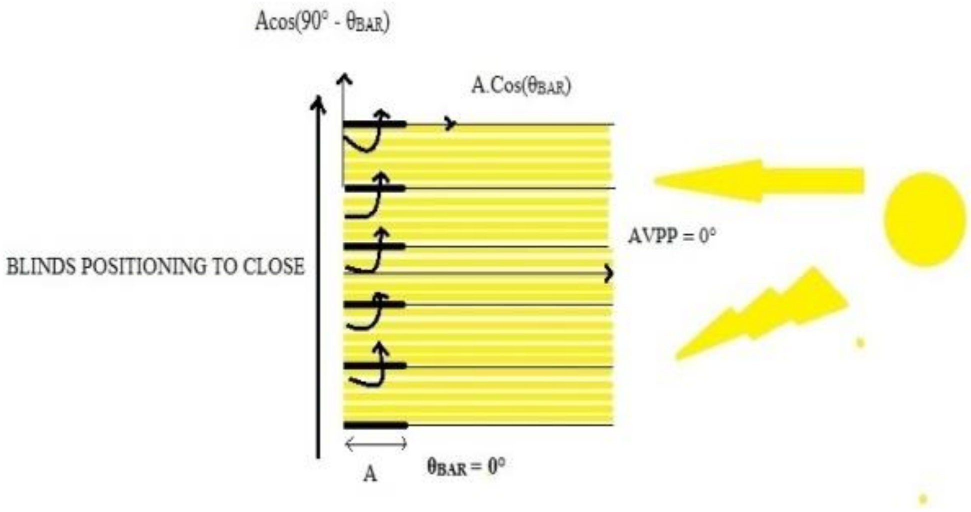


Fig. 6. When blinds are open.

The following expression represents the Solar Power Concentration when sunlight falls upon the Solar blinds per square meter and the Illuminance performance when the sun assumes to be at the middle of the SVB, which means
AVPP = 0°:

$\theta_{BAR} = 0°$, $A*Cos(\theta_{BAR}) = A$; (which represents the minimum area of the blinds which gets exposure from the sunlight).

Illuminance (I_l) = $I_{intensity}*A_{eff}$
$=I_{density}*A*Cos(\theta_{BAR}) = A*I_{intensity} \approx I_{lmax}$; (which signifies maximum Illuminance in the inner space).

Solar Power Concentration (SPC) = Total Power of the solar blinds / Effective Area
$= P_t / A_{eff} = V*I / A*Cos(\theta_{BAR}) = 0$; (which signifies minimum power generation from the solar blinds)

2) When solar blinds are retracting position:

The SVB when positioned to close, then Illuminance and solar power concentration will depend upon the effective area that gets exposure from the sunlight. The following Fig. 7. shows the scenario when SVB positioning to close.

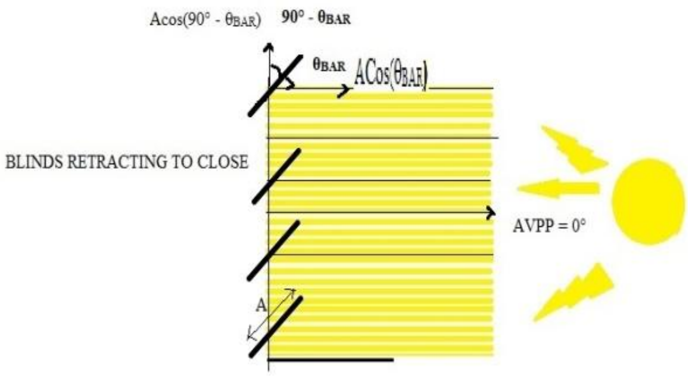


Fig. 7. When blinds are retracting position.

Illuminance (I_l) = $I_{intensity}*A_{eff} = I_{density}*A*Cos(\theta_{BAR})$

Solar Power Concentration (SPC) = Total Power of the solar blinds / Effective Area
$= P_t / A_{eff} = V*I / A*Cos(\theta_{BAR})$

3) When solar blinds are closed :

The SVB when closed, then there will be no Illuminance and solar power concentration will be maximum when effective area that gets maximum exposure from the sunlight. The following fig. 8. Shows the scenario when SVB are closed.

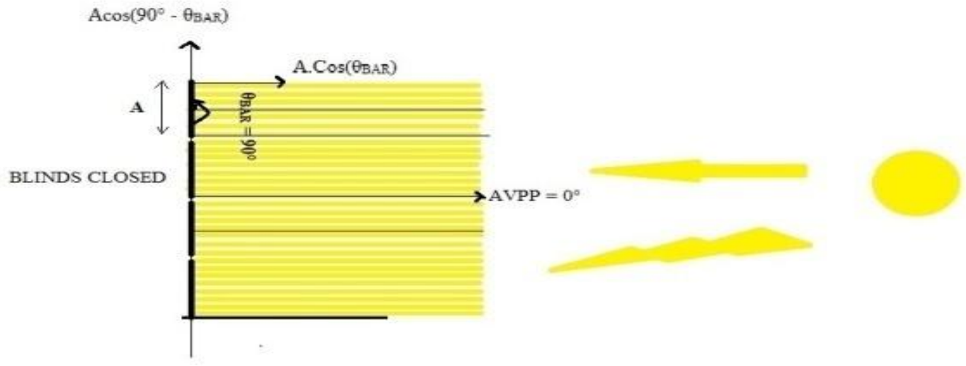


Fig. 8. When blinds are retracting position.

$\theta_{BAR} = 90°$,
Illuminance (I_l) = $I_{intensity}$*A_{eff} = $I_{density}$*A*Cos(θ_{BAR}) = 0 (which signifies minimum illuminance allowed by the blinds)

Solar Power Concentration (SPC) = Total Power of the solar blinds / Effective Area
= P_t / A_{eff} = V*I / A*Cos(θ_{BAR}) ≈ Infinite (which signifies maximum generation from the solar blinds)

B. Solar Inverter

While solar inverter converts DC energy into AC energy for powering appliances connected to the grid or battery storage through the high-quality 500W inverter that makes solar energy compatible with the efficiency of 95% with 24V and 85% with 12V battery bank. Our solar inverter has been designed using an arduino with a pure sine wave SPWM inverter circuit and inverter specifications are mentioned in the specification and dimension section. We designed the schematic and layout in the open-source Proteus software and after completion of the circuit schematic, we checked its waveforms observed in the oscilloscope and designed its layout shown in the below figures. Sinusoidal Pulse Width Modulation (SPWM) is generated via an arduino and its output is fed to the MOSFET and actuates the gate of the MOSFETs according to the SPWM signal and incorporates with the transformer primary and output is retrieved from the transformer secondary when the capacitor is being connected resulting almost a pure sine wave 230VAC output and feedback controls the load drop voltage. The inverter backup time is discussed in the formula and equation section.

1) Inverter Topology:

The Inverter Topology of solar workstations is half H-bridge or half-bridge invertertopology because its efficiency is high in half-bridge inverter.

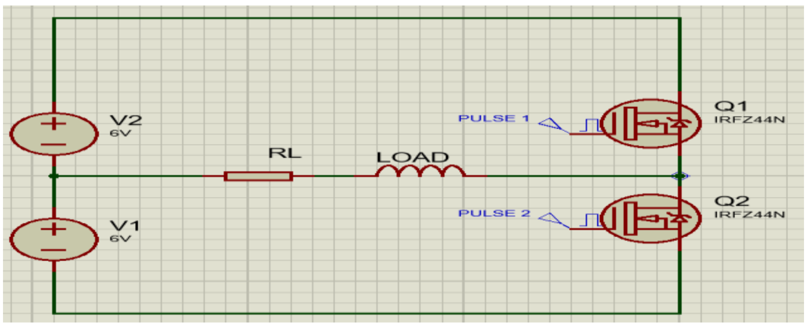


Fig. 9. Inverter topology

A single-phase inverter is divided into two varieties, such as half-bridge inverters and full-bridge inverters, depending on the type of load. Half bridge single-phase inverters are discussed in detail in this article. It has 4Mosfets, which work as switches when combined.

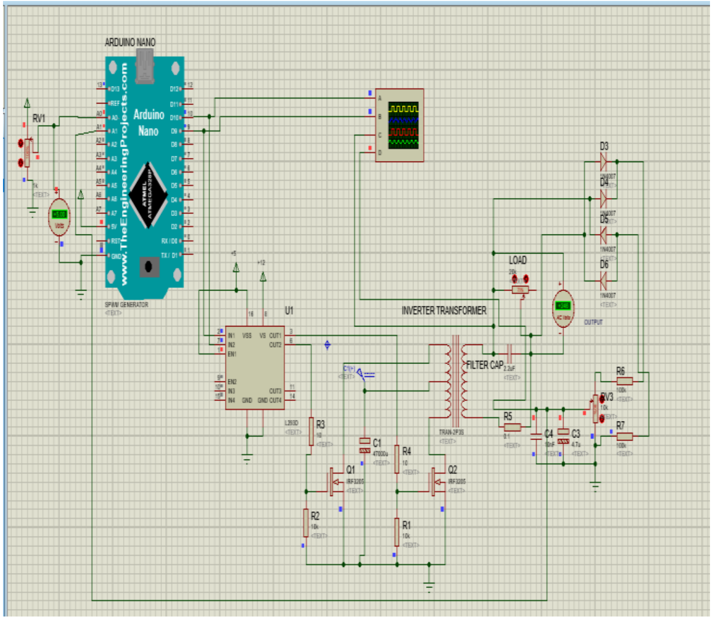


Fig. 10. Inverter schematic circuit.

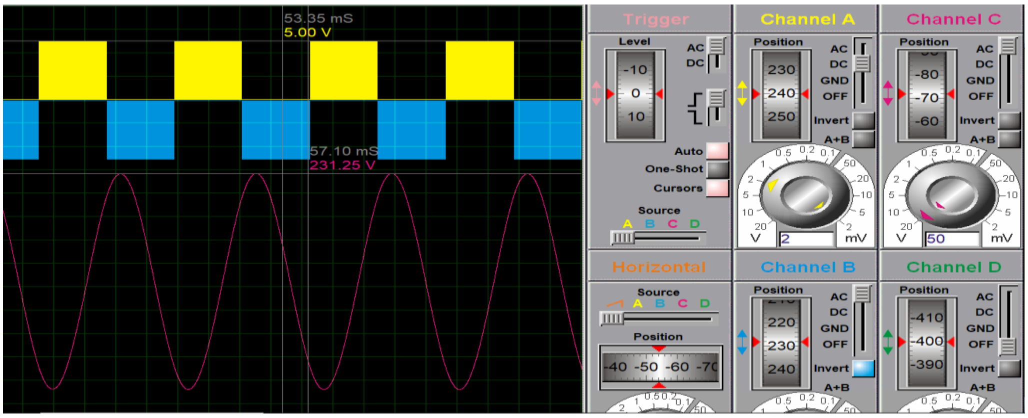


Fig. 11. Inverter simulation.

C. MPPT charge controller

MPPT Solar charge controller DC-DC converter maximizes the power output of a solar system by continuously monitoring and tracking the load voltage with the specification of 12V/24 V 30A.Under specific circumstances, we apply the MPPT algorithm to extract the maximum power possible from the photovoltaic module. The most well-liked tool for effectively utilizing solar energy (a renewable energy source) is the MPPT. We must transition to clean energy, also known as renewable energy (energy we can receive from natural resources), such as solar, hydro, wind, and so on if we want to reduce the graph of carbon footprints; otherwise, we will march directly towards global warming.

The PV side's recommended requirements for an inverter are to extract the PV module's Maximum Power Point (MPP) power (Pmpp) and to function effectively across the whole range of PV module MPP under various irradiance and temperature conditions.While MPP current varies almost linearly with irradiance, MPP voltage varies very little over the whole range of irradiance. As a result, tracking MPP currently needs a robust tracking technique.According to the controller design, the MPP tracker algorithm creates MPP voltage or current as the reference value in the case of Single Stage Inverter.

The inverter must also be able to safeguard against overload situations. As a result, the power rating of the inverter should typically be larger than 90% of the maximum power of the PV module when building a system. The inverter must be able to manage the PV module's maximum voltage while taking the temperature into account. This is because the maximum current of the PV cell will increase exponentially while the maximum voltage will decrease linearly as the temperature of the solar panel rises. As a result, it is important to assess the inverter's voltage and current ratings while taking the impacts of temperature.The relation between power, voltage, and current at maximum power point is given below:

$P_{mpp} = V_{mpp} \times I_{mpp}$

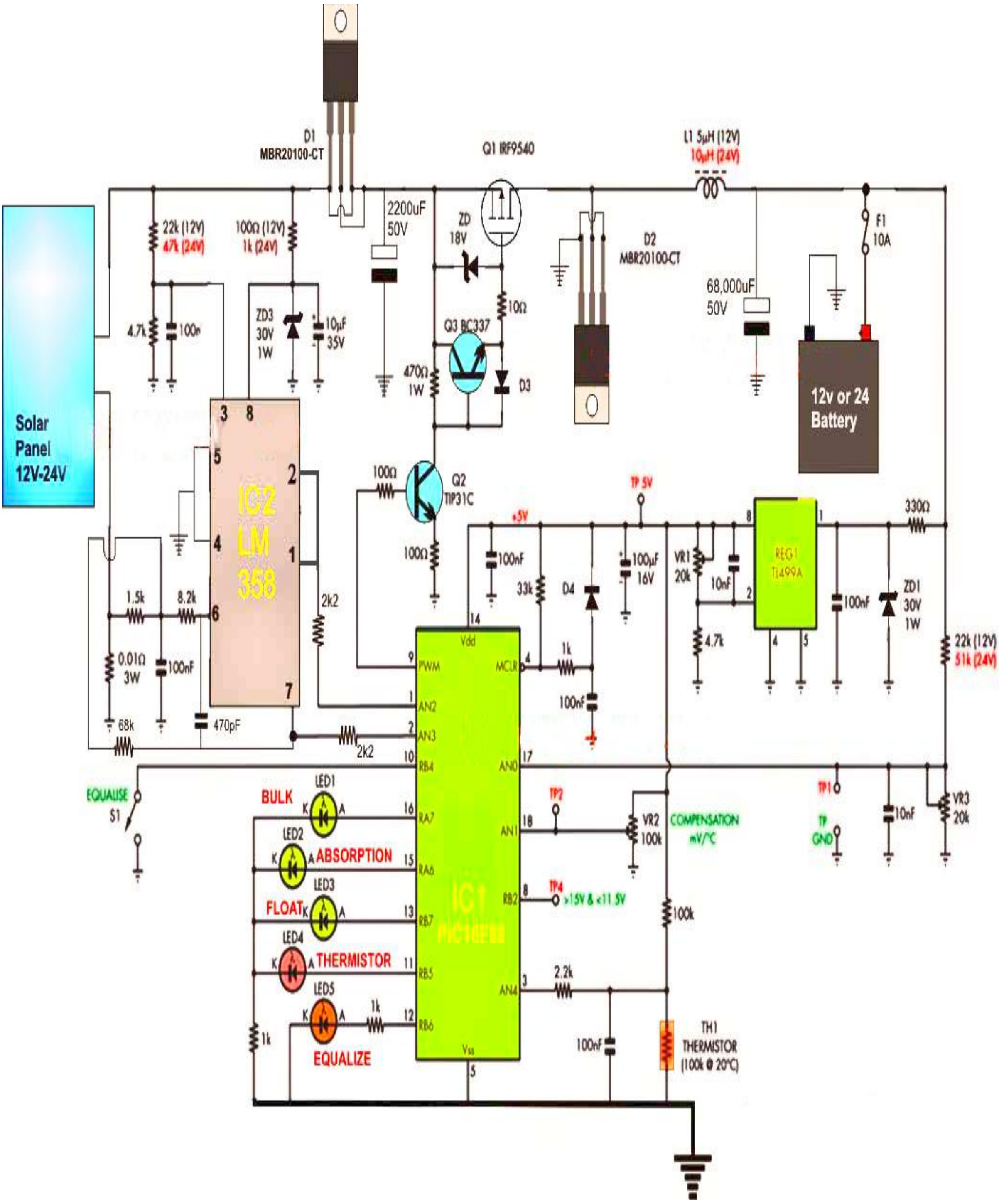


Fig. 12. MPPT circuit diagram.

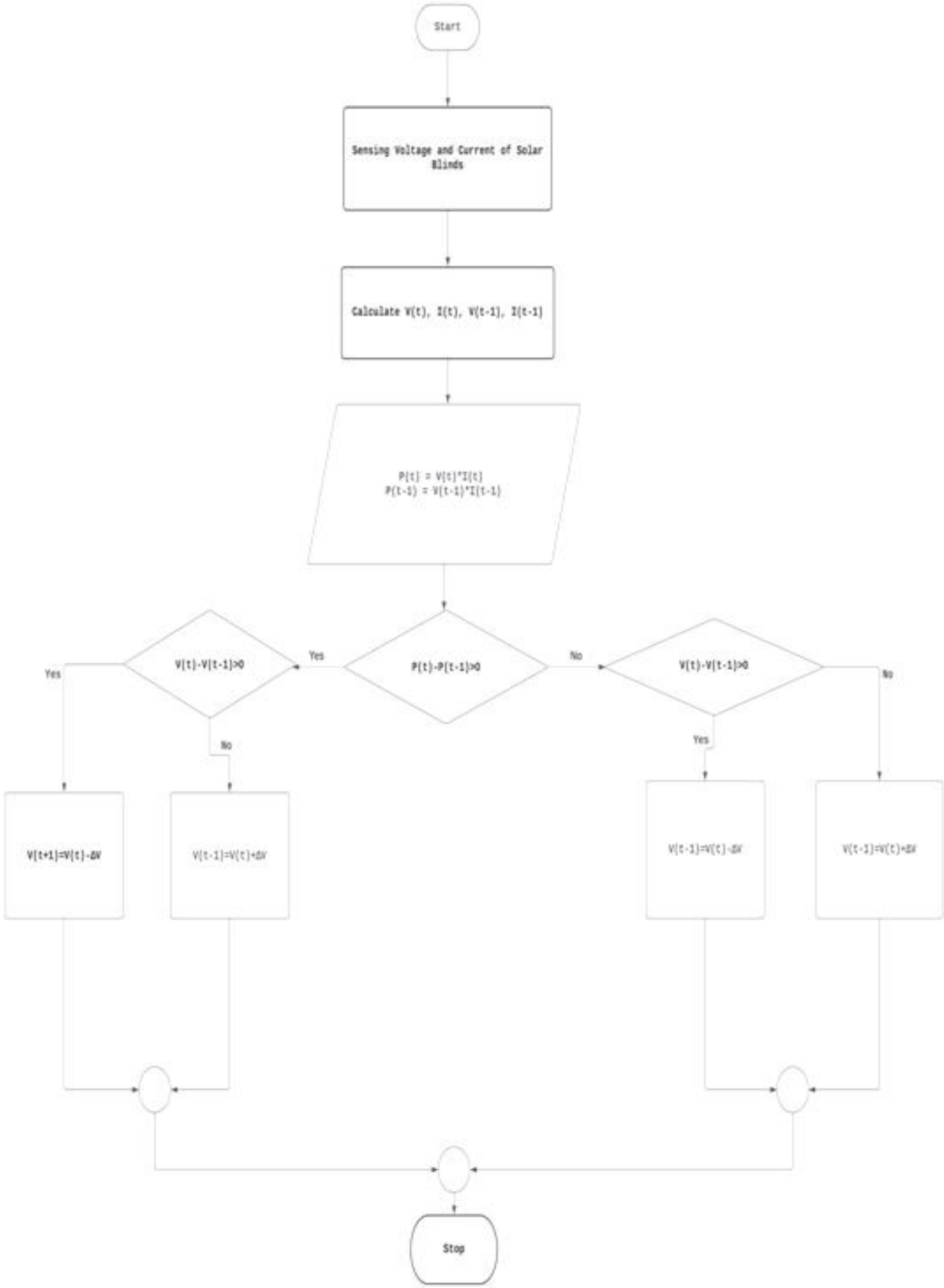


Fig. 13. MPPT control flowchart.

B. RESULT SECTION

This section includes the graphs and testing results of the solar workstation

1. Monthly power generatio,consumption and saving from the solar blinds.

The solar blinds generates power on monthly basis

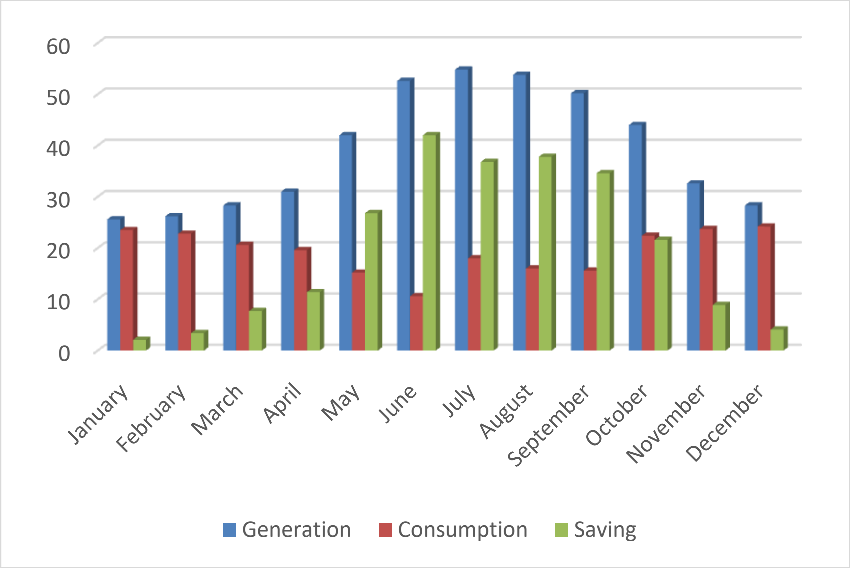


Fig. 14. Monthly solar power generation,consumption,saving profile (watt hour per square meter) from the solar blinds.

The test result shows illuminance of 500Lux on single window blinds and solar power concentration of 500W/m^2. The Solar workstation has been tested in various months with power saving capacity of 42Watts and 57.5Watts generation in the summers while 25 watts generation and 3Watts saving in the winters approx.

C. SPECIFICATION AND DIMENSION SECTION

This section contains specifications and dimensions of the workstation parts

TABLE II.

Power	62.4 Watts
Window dimension	100 cm^2
Total cells	104
Heat reduction	30%
Inverter	500 Watts
Battery capacity	12V, 100Ah
MPPT output rating	12V,5A
Charging time	13.3hrs
Approx costing	Rs.15000

D. UNITS AND ABBREVIATIONS

A. Abbreviations:

1) SVB :*Solar Vertical Blinds*
2) BAR: Blinds Angle of Rotation
3) SFB: Solar Façade Blinds
4) MPPT: Maximum PowerPoint Tracking
5) AVPP : The angle of the Vertical Projection Plane
6) $WN_{\theta\alpha:}$ Window Surface Normal Azimuth Angle
7) PVC: Polyvinyl Chloride
8) DC : Direct Current
9) MPP: Maximum Power Point
10) SSI: Single Stage inverter

B. Units and equations :

i. Inverter backup time (in hours) = Battery Capacity (in Ah) × Input voltage (V) / Total Load (in Watts)
= 80 (Ah) × 12 (V) / 1000 (W) = 0.96h = 57.6 minutes on full load

ii. MPPT Power (in Watts) = Voltage (V) × Current (A) = 12 (V) × 30 (A) = 360 (Watts)

iii. Solar panel power (in Watts) = Voltage (V) × Current (A) = 6 (V) × 0.1 (A) = 0.6 (Watts)

iv. Solar Blinds power (in Watts) = Voltage (V) × Current (A) = 12 (V) × 4.6 (A) = 55.2 (Watts)

v. Battery capacity (in Ampere hour) = 80 (Ah)

vi. Power at maximum power point ($P_{mpp)} = V_{mpp} \times I_{mpp}$

vii. Heat reduction = 30%

viii. Charging time = Battery capacity/charge current = 100/5.2 = 13.3h

CONCLUSION

We have tested our solar workstation in Ladakh, Himalayas along with all the parameters of the solar façade blinds,solar inverter, and MPPT charge controller and successfully implemented it in our office building at the National Institute of Electronics and Information Technology (NIELIT) Leh Ladakh and proposed to work on Solar workstation using solar façade blinds based on IoT and AI.This journal paper is based on the first version of a Solar workstation using solar blinds in high-altitude remote areas.Our solar workstation is specifically designed for cold and high altitude region because of the uniqueness from previous blinds which deals with various issues like snow covering conventional solar panels and controlling sun glare in high altitude with least loss of solar power generation for heating solar panels foro snow melting. Also the solar workstation has various advantages of solar power generation to run a complete household in remote areas with lack of centralized hydroelectric grid connections and geographical sensitiveness to global warming. These issue are not addressed in previous papers of solar blinds.

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