# Electric-powered wheelchair with solar cell and single axis tracker

**Ali H. A. Alwaeli**
*Solar Energy Research Institute (SERI), National University of Malaysia (UKM), Bangi, 43600Malaysia*
*Email: ali9alwaeli@gmail.com*

***Abstract*—Wheelchairs are important tools to assist seniors and people with disabilities in mobility. Manual wheelchairs present some difficulties, while electric-wheelchairs help by providing mobility to the user without need for physical effort. This paper aims to introduce single axis tracking with solar system for increase power production to assist electric-powered wheelchairs. In addition, different designs were proposed to allow user access various functions such as illumination, monitor holding etc. A load profile was made to correspond with proposed system tools. Intuitive method was used to size the solar system to supply 1471.5 Ampere-hour per day. The solar panel size is 150 W, inverter of 250W with a nominal voltage battery of 24 V.**

***Index Terms*—Electric-powered wheelchair, Solar cell, Single axis tracking.**

## I. Introduction

Senior citizens suffer from many physical challenges in their daily lives which can cause them to underperform ordinary tasks and fail to engage in society. These issues include, but not limited to, nerve and muscular degeneration, reduced motor function and balance and impaired mobility. The mobility aspect is particularly problematic as many functions and tasks depend on such ability. the United Nations (UN) ruled in the Standard Rules of 1994, under rule 4 with articles 20 and 26, that member states are requested to support development, production, distribution and servicing of assistive devices and equipment and the dissemination of knowledge about them [1]. The mobility problem can be fixed using wheelchairs; which makes them an essential assistive device to enhance mobility for those with mobility difficulties caused by physical disabilities [2]. Wheelchairs can be characterized to manual, electric-powered or power assisted. Conventional manual wheelchairs (MW) present a healthy option to the user as they require physical movement of user which can be equivalent to sports. However, these wheelchairs exhibit low gross mechanical efficiency, between 2 and 13.8%, and under certain circumstances such as being physical strain of user could cause fatigue or strain-induced injuries [3-5]. Hence, electric-powered wheelchairs (EPW) have gained much attention due to their low-risk aspect and reduced user effort [6-9]. Although electric-powered wheelchairs have gained popularity for being a more suitable solution for seniors and those with physical difficulties, some disadvantages have been associated with their designs, which include long duration of charging process, large size and weight of wheelchair and high costs, relative to MW's. Other disadvantages are associated with the design and require more attention in research and development, such as the folding issue and difficulty to maintain due to different electrical and mechanical components. The main limitation of EPW's is their travel range which is a function of battery capacity. The batteries will provide power to the motors allowing it to drive these wheelchairs. However, shortage of power supply would lead to pause of electric aspect of these wheelchairs. Hence, researchers have proposed overcoming this issues by installing or couple a solar panel on top of the wheelchair [10-13]. Before investigating the literature around this solution, a brief introduction on solar panels in terms of function and technical design is important for the interested reader. Solar energy is the energy derived from solar radiation either by absorbing its sunlight and converting it to electricity or heat from solar radiation and extracting it as thermal energy [14-17]. The first method is the function of the solar cell. These cells are made of semi-conductor material. The solar cell or photovoltaic 'PV' produces direct current (DC) and can power DC loads immediately. An inverter is coupled with the solar cell to flip the DC current into alternating current (AC) to feed AC loads [18]. Batteries can be linked to the panel to store DC current throughout the day and use it at night. Finally, charge controller provides voltage regulation and system protection [19]. Figure 1, shows a typical standalone PV system. System sizing methods and incorporation techniques grow rapidly and range from intuitive to numerical.

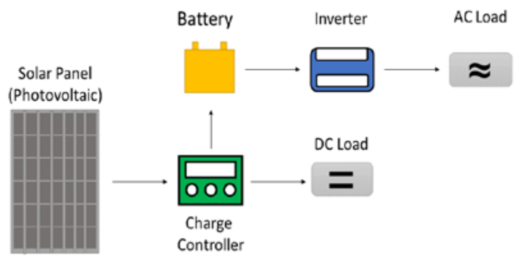


Figure 1. Typical standalone PV system

These systems, standalone, allow for autonomous use which makes them suitable candidates as power sources for the electric-powered wheelchairs. However, it is important to notice the difficulties that arise from implementing such technology. Firstly, adding a solar system to the wheelchair will contribute in increasing its mass, which will some effect on power output, physical strain, and propulsion time. The other main issue would be lack of solar irradiance during cloudy and rainy days. In addition, raise in solar cell temperature which causes a drop in its open circuit voltage [20]. Different outdoors conditions such as temperature, humidity and dust are inversely proportional to the power output of these panels [21-23]. The tilt angle is another important aspect, as selection of optimum angle would help in maximizing power production [24].This is why tracking systems are important to implement; they raise the power production [25-27].If solar systems are implementedin electric-powered wheelchair, different factors must be considered. The first of which is the mechanism its incorporated in. Reference [28] patented a design where a rigidly-fixed metal frame to the back of a wheelchair was used to carry solar panel. This is problematic as the user cannot fold the chair or dispose of the panel in case of maintenance. Furthermore, the wheelchair can only be used for electric mode. The second consideration is the overall design with respect to weight, size and affordability. Gurram et al. [11] modified solar-powered wheelchair frame structure to reduce its weight. However, the final design had to sacrifice the foldability aspect. Chi-Sheng Chien et al. [13] proposed a solar-powered wheelchair with quick disassembly function and manual/electrical switch for users. The proposed design seems effective and low in both weight and size, relatively. Moreover, the study showed that the travel range had increased by 26%. This range is affect by many factors including battery capacity, solar cell efficiency, sunlight intensity, and the travel speed.

This paper aims to introduce a single-axis tracking to solar-powered electric-wheelchairs to increase its travel time by increasing the solar radiation absorbed throughout the day. In addition, different mechanisms are embedded into the wheelchair to allow various functions to be performed by the user.

## II. PROPOSED DESIGN

People in wheel-chairs spend most of their time on wheel chairs and so they need to have supplementary tools to help them remain productive. The innovation in mobile chairs is limited to the structure designs and some of its features. Also, many senior citizens are deprived of outdoors activities, as they are not granted comfort and luxury services/items which they have at home; ventilation, lighting, desks for work, phone charging etc. Hence, there needs to be more creative work to establish wheelchairs and scooters with multiple functions for the seniors aimed to raise their productivity and engage them in society. The proposed design is a solar-powered wheelchair for outdoors activities. This innovation is specifically designed to grant access for the elderly by providing them access to functions of different dimensions to the mobile chair such as control, navigation, illumination, air-circulation and ventilation, charging unit, resting pads and personalized design. Solar powered-wheelchairs have been proposed before, in different venues, as shown in introduction. However, in this study the solar-powered EPW is designed in such way that allows sun-tracking function. Moreover, the design can be adopted for both EPW and scooters.

The first dimension opened to the user is sustainable and green power supply which allows users to have a longer range for mobility, accompanied by energy and costs savings through using a renewable energy source. The second dimension is the ability to reach destinations using the navigation system. The third dimension is providing luxurious needs such as air-ventilation using fans, illumination and roof lighting, for safety purpose. The last dimension is focused on outdoors stationary situations. In case, seniors want to set around in a park, home yard or public places. One of the limitations would be inability to charge their phones or power the fans or enjoy a painting session in broad day light. The stationary dimension allows them to perform all these tasks and more. Power supply provided by the solar panel coupled with workplace provided by seat tray allows the user various desk-work tasks; painting, writing and phone charging. The design can be tailored for ordinary wheel chairs or scooters. The first aspect of the proposed system is the power supply which is achieved using a solar panel or 'photovoltaic (PV)'. This solar panel is not installed on a fixed rooftop. It is actually used with a single-axis sun-tracking function. This means, across one axis, the panel will slightly change its tilt angle to capture more solar irradiance. The reason only single axis is used, instead of double axis, is due to it being less visible and more easily manufactured. People might find it disturbing for rapid mechanical movement over their head, hence only single axis is used. Ref. [29] shows how the efficiency of the single axis tracking system over that of the static panel is calculated to be 32.17%. The proper sizing and design of this system is location and purpose-based. For example, different solar irradiance amounts occur in different parts of the world. Hence, for people living in high solar irradiance location, more power generation can be attained, and hence more hours of performance can be achieved as well. For the manufacture a simple load profile and solar irradiance profile should be made to illustrate to the user how they can utilize the wheelchair effectively. Load profile is basically, how many watts per hour needed every day [30-34]. Table 1, shows a simple load profile for different applications of the proposed design. Based on the load profile, the solar system can be sized [35], however it could be the other way around. As in, the load profile limited to how much a fixed solar system can provide.

Table 1: Load profile of the multi-purpose chair

| No. | Item | Watts/hour | Hours of use/day | Quantity | Total power per day |
|---|---|---|---|---|---|
| 1 | LED light | 4 | 8 | 4 | 128 Wh |
| 2 | Fan | 5 | 12 | 2 | 120 Wh |
| 3 | Charing phone (e.g. Iphone 6) | 10.5 | 12 | 1 | 23.5 Wh |
| 4 | Wheel chair motor | 50 | 12 | 2 | 1200 Wh |
| Total | 1471.5 Wh/day | | | | |

From table 1, the power consumption of each component is set along with range for hours of use. This allows to design proper battery size (capacity) and PV panel size as well [36]. The structure used to incorporate the standalone solar system is illustrated in figure 2, while the block diagram for the sun tracking function and system is illustrated in figure 3.

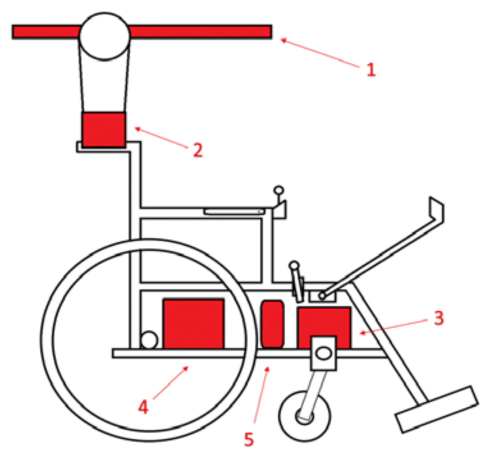


Figure 2: Chair structure for solar power incorporation (1 solar cell, 2 stepper motor, 3 battery, 4 charge controller -with motor case- and 5 Inverter)

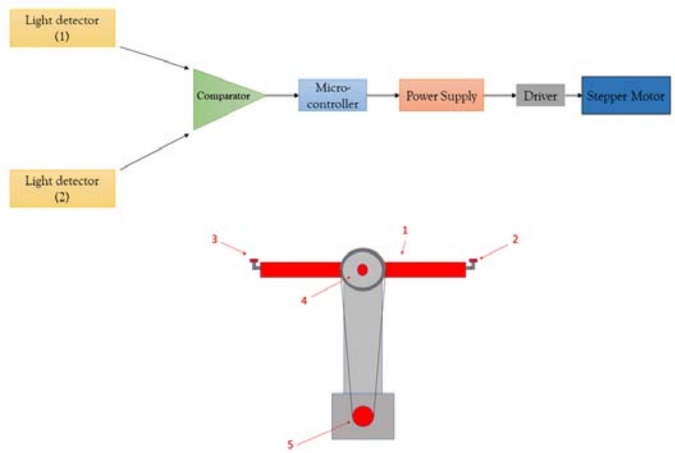


Figure 3: single axis power tracker design (1 PV panel, 2 light detector, 3 light detector, 4 motor pulley, 5 stepper motor).

Figure 2, provides a more comprehensive understanding of the chair design. It shows how the solar system is incorporated within the chair. Figure 3, shows the block diagram of the sun-tracker. The light detectors will compare between light values at each location and correspond to follow angles that allows them to reach more light. This function is carried out using a micro-controller and a driver. The single is sent to the stepper motor, part 5 in figure 3, and when the motor moves, the belt attached (to pulley as well) will move, allowing for change of solar panel tilt angle. The batteries, inverter and charge controller are installed below the seat. Based on the load profile provided in table 1, the following system design is made. For the load profile shown in figure 1which shows a daily load of 1471.5 Wh and so a PV panel of 150 Watts, inverter of 250 W, battery nominal voltage of 24 volts. These values are found using intuitive method excel sheet; based on the optimum sizing results and wheel chair concept, figure 4 shows the complete design of the wheel chair.

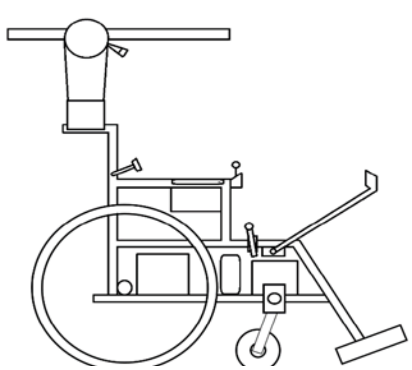

Figure 4: Side-view drawing of the wheel chair

Figure 4 shows the different pads used to providing comfort in performing different tasks. The first, second and third pads are used for holding navigation monitor, desk and fans. All the presented features are provided in figures 5 and 6.

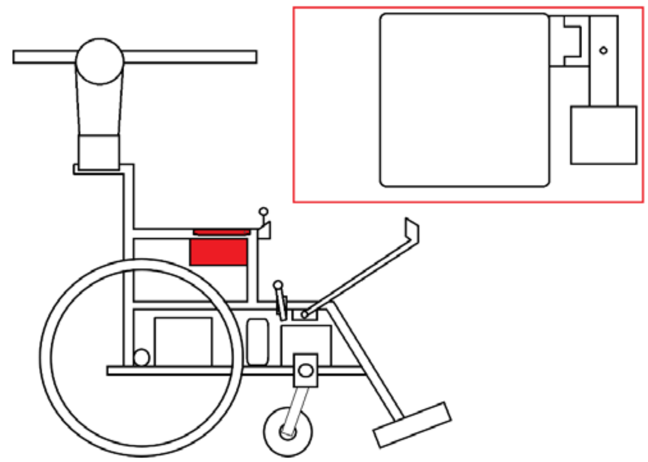

Figure 5: Folding Armrest Tray design

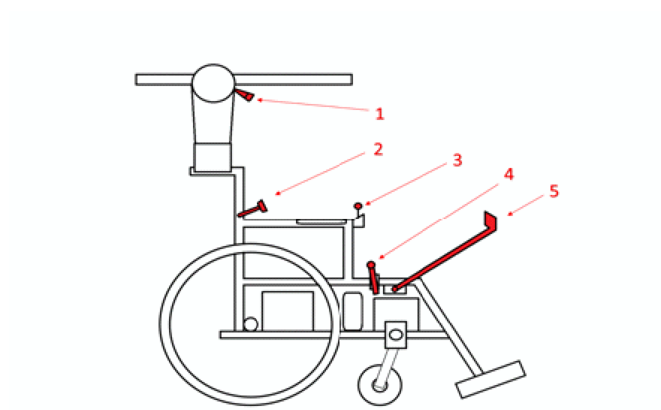


Figure 6: Wheel chair accessories (1 Led light, 2 Fan, 3 Drive control, 4 electric/manual switch, 5 monitor/phone movable-holder)

The user now can utilize different tools to serve different purposes. The tray (illustrated in figure 5) is useful for writing, drawing, placing a laptop etc. It is noteworthy to mention, wheel-chair battery could be charged using utility supply at home as well. The charging cables could be attached to either sides of the wheelchair and the user can plug their chargers to charge their phones.

## III. SYSTEM DESCRIPTION AND FUNCTIONS

The primary needs that are provided by wheelchairs include mobility enhancement and access to the various entities of the world, allowing seniors and people with disabilities to engage in educational, work and social activities.

Furthermore, there are physical health and quality of life benefits associated with wheelchairs; they assist in reducing common issues like pressure sores, progression of deformities and improve respiration and digestion. With regards to electric wheelchairs and scooters, the primary need is electricity. This could be satisfied with high quality batteries with sufficient battery capacity and a solar cell that allows to continuously generate electricity throughout the day.

3.1. Functions:

The main functions of the proposed system are to provide mobility, and main function of solar cell is to provide electricity to power the wheelchair. The hidden arm tray will allow help utilizing arm rest space while keeping chair size the same. This tray helps the seniors place various objects to perform various tasks. These trays can be used to place food trays on it, carry small mobile computers (laptops) and or carry a note book to write on. The LED lights provide suitable illumination during night time; providing safety for user of wheelchair and others surrounding them (vehicles or people); taillight. The small fans will help with breathing and conditioning, particularly in hot climates. Output electricity plug can be attached in any location; giving its simplicity. The plug will help the users charge their phones in case their batteries run out.

3.2. Activities:

These wheelchairs could be used for multiple activities ranging from leisure to working purposes. The solar powered wheelchair can assist seniors in various hobbies and adventures such as fishing, entertainment and sightseeing.

3.3. Time of the day

During daytime the solar panel will store much power to the battery. The charge controller will protect its state of charge and lifetime. The solar panel can be utilized as an umbrella to the user as well. During nighttime the user is advised to ensure full battery storage to keep the chair functioning as long as possible. LED lights are useful not only to illuminate the way and serve as taillights of wheelchair for transportation purposes but also provide illumination to the user to read or perform tasks that require vision.

## IV. CONCLUSION AND DISCUSSIONS

This paper shows the importance of solar cells in assisting electric-powered wheelchairs (EPW). A multi-functional electric wheelchair is design. The proposed system utilizes a solar cell, battery, inverter and charge controller. The solar cell implements a single-axis solar tracking system. This field needs more research to investigate the viability of solar energy solutions in assisting EPW's. The following recommendations for future research show different research directions to be followed:

1. Investigating the feasibility of single axis tracking system and solar assisted EPW using numerical approach.
2. Investigating the incorporation of double axis tracking system without causing disturbance to the user.
3. Case study for system cost-effectiveness in different countries using HOMER software.
4. Investigate factors such as; travel range, effect of mass addition, foldability, maintenance and life cycle cost analysis.

In conclusion, solar assisted electric-wheelchairs has massive potential to be a future solution for seniors and people with disabilities to access the world. Addition of solar tracking could lead to increase of power production and hence travel range.

## REFERENCES


[1] United Nations, "Convention on the Rights of Persons with Disabilities – Articles", available: Online. (Link: https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities/convention-on-the-rights-of-persons-with-disabilities-2.html) retrieved on 15th of April 2018.

[2] Yang, Y-P., W-C. Huang, and C-W. Lai. "Optimal design of rim motor for electric powered wheelchair." IET Electric Power Applications 1.5 (2007): 825-832.

[3] Janssen, T. W., and A. P. Hollander. "Physical strain in daily life of wheelchair users with spinal cord injuries." Medicine and science in sports and exercise 26.6 (1994): 661-670.

[4] Boninger, Michael L., et al. "THREE-DIMENSIONAL PUSHRIM FORCES DURING TWO SPEEDS OF WHEELCHAIR PROPULSION1." American journal of physical medicine & rehabilitation 76.5 (1997): 420-426.

[5] Rodgers, Mary M., et al. "Upper-limb fatigue-related joint power shifts in experienced wheelchair users and nonwheelchair users." Journal of Rehabilitation Research and Development 40.1 (2003): 27.

[6] Ding, Dan, and Rory A. Cooper. "Electric powered wheelchairs." IEEE Control Systems 25.2 (2005): 22-34.

[7] Cooper, Rory A., et al. "Performance assessment of a pushrim-activated power-assisted wheelchair control system." IEEE transactions on control systems technology 10.1 (2002): 121-126.

[8] Kung, Ying-Shieh, Ming-Shyan Wang, and Chih-Yuan Yang. "Realization of a motion control IC for electric-powered wheelchair." Industrial Informatics (INDIN), 2010 8th IEEE International Conference on. IEEE, 2010.

[9] Wang, Fu-Cheng, and Yu-Shu Chiang. "Design and control of a PEMFC powered electric wheelchair." international journal of hydrogen energy 37.15 (2012): 11299-11307.

[10] Takahashi, Yoshihiko, Syogo Matsuo, and Kei Kawakami. "Energy control system of solar powered wheelchair." Solar Energy. Intech, 2010.

[11] Gurram, Arun Manohar, PSV Ramana Rao, and Raghuveer Dontikurti. "Solar powered wheel chair: Mobility for physically challenged." International Journal of Current Engineering and Technology 2.1 (2012): 211-214.

[12] Sakib, Syed Nazmus, et al. "A study on low cost solar powered wheel chair for disabled people of Bangladesh." Computer and Information Technology (ICCIT), 2015 18th International Conference on. IEEE, 2015.

[13] Chien, Chi-Sheng. "Design and development of solar power-assisted manual/electric wheelchair." Journal of Rehabilitation research and Development 51.9 (2014): 1411.

[14] Kazem, Hussein A., Aljibori, H. S., Hasoon, F. N. andChaichan, Miqdam T., "Design and testing of solar water heaters with its calculation of energy" Int. J. of Mechanical Computational and Manufacturing Research 1.2 (2012): 62-66.

[15] Kazem, Hussein A., Jabar H. Yousif, and Miqdam T. Chaichan. "Modeling of daily solar energy system prediction using support vector machine for Oman." International Journal of Applied Engineering Research 11.20 (2016): 10166-10172.

[16] Chaichan, Miqdam T.,Abass, K. I., Al-Zubidi, D S, and Kazem, Hussein A. "Practical investigation of effectiveness of direct solar-powered air heater." International Journal of Advanced Engineering, Management and Science (IJAEMS) 2.7 (2016): 1047-1053.

[17] Kazem, H. A., “Renewable Energy in Oman: Status and Future Prospects”, Renewable and Sustainable Energy Review, Vol. 15, January 2011, pp. 3465-3469.

[18] Al-Waeli, A. H., H. A. Kazem, and M. T. Chaichan. "Review and design of a standalone PV system performance." International Journal of Computation and Applied Sciences IJOCAAS 1.1 (2016): 1-6.

[19] Tesfahunegn, S. G., et al. "A simplified battery charge controller for safety and increased utilization in standalone PV applications." Clean Electrical Power (ICCEP), 2011 International Conference on. IEEE, 2011.

[20] Radziemska, E. "The effect of temperature on the power drop in crystalline silicon solar cells." Renewable energy 28.1 (2003): 1-12.

[21] Kazem, Hussein A., and Miqdam T. Chaichan. "Effect of environmental variables on photovoltaic performance-based on experimental studies." International Journal of Civil, Mechanical and Energy Science (IJCMES) 2.4 (2016): 1-8.

[22] Kazem, H. A.,Chaichan, M. T, Al-Waeli, A H A, Kavish Mani, "Effect of shadows on the performance of solar photovoltaic" Mediterranean Green Buildings & Renewable Energy. Springer, Cham, 2017. 379-385.

[23] Mekhilef, S., R. Saidur, and M. Kamalisarvestani. "Effect of dust, humidity and air velocity on efficiency of photovoltaic cells." Renewable and sustainable energy reviews 16.5 (2012): 2920-2925.

[24] Kazem, Hussein A., Tamer Khatib, and Ali AK Alwaeli. "Optimization of photovoltaic modules tilt angle for Oman." Power Engineering and Optimization Conference (PEOCO), 2013 IEEE 7th International. IEEE, 2013.

[25] Moreno, José Abel González. "Single axis solar tracker." U.S. Patent 8,242,424, issued August 14, 2012.

[26] Ponniran, Asmarashid, Ammar Hashim, and AriffuddinJoret. "A design of low power single axis solar tracking system regardless of motor speed." International Journal of Integrated Engineering 3.2 (2011).

[27] Tudorache, Tiberiu, and LiviuKreindler. "Design of a solar tracker system for PV power plants." Acta PolytechnicaHungarica 7, no. 1 (2010): 23-39.

[28] Tanimoto T, inventor. Solar assist-type electric wheelchair. Japan Patent No. JP2004–167022, 2004.

[29] ROBOT, SHORTEST DISTANCE MAZE SOLVING. "Comparison of efficiencies of solar tracker systems with static panel single-axis tracking system and dual-axis tracking system with fixed mount." Classical and Quantum Gravity 32.7 (2015).

[30] Kazem, Hussein A., Ahmed Aziz Alkurwi, Majid Mohmmed Alabdul Salam, and Ali HA Alwaeli. "Levelized electricity cost for photovoltaic system in Sohar-Oman." In Ecological Vehicles and Renewable Energies (EVER), 2013 8th International Conference and Exhibition on, pp. 1-5. IEEE, 2013.

[31] Al-Karaghouli, Ali, and L. L. Kazmerski. "Optimization and life-cycle cost of health clinic PV system for a rural area in southern Iraq using HOMER software." Solar Energy 84.4 (2010): 710-714.

[32] Al-Waeli, A H A ,El-Din, MM K, Al-Mamari, A S, Al-Kabi, A H, Kazem, H A, and Chaichan, M T. "Optimum design and evaluation of solar water pumping system for rural areas." International Journal of Renewable Energy Research 7.1 (2017): 12-20.

[33] Fragaki, Aikaterini, and Tom Markvart. "Stand-alone PV system design: results using a new sizing approach." Renewable Energy 33.1 (2008): 162-167.

[34] Chaichan, Miqdam T., et al. "Optimal sizing of a hybrid system of renewable energy for lighting street in Salalah-Oman using Homer software." International Journal of Scientific Engineering and Applied Science (IJSEAS) 2.5 (2016): 157-164.

[35] Egido, M., and Eduardo Lorenzo. "The sizing of stand alone PV-system: A review and a proposed new method." Solar Energy Materials and Solar Cells 26.1-2 (1992): 51-69.

[36] Diaf, Said, et al. "A methodology for optimal sizing of autonomous hybrid PV/wind system." Energy Policy 35.11 (2007): 5708-5718.