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Quality Assurance of the Solar Lighting Systems

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Abstract: ***Solar lighting systems are safe, reliable, easily operable and portable. Solar systems have been the best way to deal with the electrifications concerns in the rural areas. Quality is the most crucial part in the engineering sector to work towards the better production, to minimize the defects and maintained the quality standard at every stage of manufacturing through various aspects of quality inspection process. To acclimatize the emerging technology in the community especially in the rural areas are complex, this paper will help in understanding the technology and basics of the quality aspects for all the individuals working in this sector. To minimize the barriers in terms of complexity, durability and enhances the efficiency & safety of the products is one of major concern for the consumers. Lack of knowledge & negative perception about the solar technologies is also one of the major hindrances to facilitate the solar technologies in the rural market. While considering all the issues is being faced by the consumers, this paper will emphasize on the quality check of the solar portable products, the factors affecting the overall performance of the products and to help beneficiaries in the decision making process, while purchasing the solar systems.***

Keywords: Fill Factor, Low Voltage Disconnect, Color Rendering Index, Color Correlated Temperature, IL luminance

1. Introduction

Off- grid solar household based products can be solar task light, solar lantern, solar home lighting system. The system consists of following components:

1) Solar Charge Controller
2) Solar Modules
3) LED Luminaries
4) Battery

Solar lanterns are different from solar task light in terms of horizontal and vertical light distribution angle, solar task light's light distribution angle lie between 0-180 degrees where solar lantern's light distribution angle lies between 0-360 degree.

In the rural areas, entrepreneurs are selling solar lighting products without ensuring the quality of the products which leads to the frequently maintenance of the products in the guarantee period. To make sure about the quality of the products, one should know all the aspects of checking it.

2. Background

It has been found in the various surveys or visits that entrepreneurs in the rural areas don't have basic knowledge of the solar technology/solar lighting systems, their policies and initiatives taken by the Government. Imparting training to the community is one of the initiatives taken by the Government to aware them about the solar products & its usage in most of the districts and majority are targeted basically the people from rural areas who are unemployed, unskilled & local entrepreneur working in solar field to sustain their livelihood for family, some NGO's have also started the initiative through knowledge transferable activities in which it include the awareness program and help in educating the local people about the solar lighting systems and local people transfer their understanding to the people who are eager to know more about benefits of solar technology . A check list consist of important points which needs to be checked in order to ensure the quality of the product can help group of entrepreneurs working in the rural areas in the solar sector.In most of the countries the government has taken the initiative to get rid of the darkness from the people life with sustainable, reliable and affordable solar technology policies.

3. Methodology

As discussed in the above section that a check list or an informative document can help local people working in the solar sector in the rural areas, methodology will consist of checking the documents, practical assessment, and troubleshooting practices.

To validate and check the quality of product, the components need to be verifying by below mentioned process:

a) Checking certifications of the products issued by Government accredited laboratory as per the required standards.
b) Practical Assessment in the rural area
c) Troubleshoot practices

The product is distributed to the beneficiaries through different channels like local distributers, Grass root NGO's, Small scaled entrepreneurs etc. in the rural market. They are responsible for delivering good quality product to the consumer. Sometimes, concerned individuals of distribution channel check the quality of a product with every aspect post delivered to the consumers. It can reduce the sociotechnical barriers about the solar technology in the rural market. Such issues have been faced in the South Africa's rural areas, where women works in a distribution model and makes sure about the quality, most women are unaware about the solar technology, some of them can't even understand the certificates and documents provided with the product.

4. Certification

Solar product should be tested in the laboratory as per the IEC standards or any other standard as per their country's norms, which can ensure the quality of product.

Check these following parameters in the certificate provided with the solar product:

1) Battery's capacity and efficiency
2) Electrical performance of the solar module under absolute environmental condition.
3) Electronic & Electrical test of charge controller & their types.
4) Light parameters of the LED such as IL luminance and luminous flux.
5) Type of protections presents in the system such as over charge, battery reverse polarity, deep discharge and stand by loss
6) Visual appearance and workmanship of the solar product
7) Validity of the certification.

For apposite selection of the product the beneficiaries should know the terms as defined in the table. To weigh between the good or poor quality and to understand the overall performance characteristics of the products these terminologies need to be considering by authorized person from Government agencies, Grass root NGO's,Local entrepreneurs who are responsible for supplying the quality products to the consumer end.

4.1 Solar Module

For solar module, check the type of the solar module, usually mono-crystalline or polycrystalline is present in the small integrated solar products because of their higher module efficiency. Check the maximum voltage (Vmp), maximum current (Imp), module efficiency (η) and maximum power at 1000W/m^2insolation; usually the smaller systems are the range of the wattage is 0.4W to 5W. Parameters are checked at Standard Temperature Condition (STC) [2], at which Ambient temperature = 25 degree C and irradiance = 1000W/m^2.

Table 1: Electrical parameter and their significance

Parameter	*Significance*
Rated Power	Power output at standard operating condition. Wattage of module determined by the rated power
Nominal Voltage	Voltage at standard operating condition
Short circuit current (Isc)	Current across the circuit is measured when both the negative & positive terminal is shorted. It is maximum possible current in the operating condition.
Open Voltage Circuit (Voc)	Maximum output voltage at given condition
Module Efficiency	η = (max output power)/ (Insolation * Area of the solar module). It indicates the output power at particular irradiance. Normally the efficiency of polycrystalline module is lies in between 14 % to 18% [1].
Fill Factor(FF)	FF = (Vmp * Imp)/(Voc * Isc). It indicates the quality of solar cell in the terms of output power which should be more than 0.7 (You can refer the parameters like Vmp, Imp, Voc, Isc from the back side of the solar module).

4.2 Battery

Battery capacity should lay under the range of capacity ± 10%*capacity, efficiency should be above 90% for li-ion batteries and should be above 80% for Sealed lead acid.

Table 2: Battery's specifications [2]

Battery Technology	*Volt /cell*	*Low voltage disconnect(LVD)/cell*	*High voltage disconnect(HVD)/ cell*
Lead Acid(SLA)	2	1.80	2.4
Lithium Ion (Li-ion)	3.7	3	4.2
Nickel Cadmium (Ni-Cd)	1.2	1	1.4

To calculate the HVD and LVD of the different technologies of battery, we need to use the above data as mentioned in the table. Let's assume that thelead acid battery's voltage is 6V then it has 3 cells each of 2 volts per cell (3 cells *2(Volt/cell) and its HVD would be 7.2V (3 cells *2.4 V/cell) and LVD would be 5.4V (3 cells *1.8 V/cell).This data interrelate that the battery should not be charging & discharging beyond 7.2V & 5.4V respectively. The charge controller direct the charging and discharging process at specified cut off range to enhances the life cycle of the battery.

Entrepreneurs should check all the type of protections present in the device for that they need to refer the test report as issued by the accredited laboratories and make sure that all protection is present in the system for optimal and desired output performances. The circuit protection like overcharged protection, deep discharge protection, reverse current flow, short circuit protection, ideal current flow protection, No-Load current flow, temperature compensation, all these protection should present in the system for eco-friendly use by the beneficiaries. Over charge protection will protect the battery from getting overcharged and cut off the charge at one particular point which can be in terms of current and voltage. For instance, let's assume that li-ion battery's specifications are 2000mAh and 3.6V normal voltage, if its mentioned in the certificate that the over charge protection is 4.1V for a li-ion battery, then it means that the charge controller would cut off the charging process when the voltage of the battery reaches to 4.1V and if its mentioned in terms of current like 40mA after achieving the HVD, then it means that this is the idle current which will flow irrespective of the battery voltage. For li-ion batteries, charging rate and discharging rate should be C/5, and for SLA it should be C/10 where C is the capacity of the battery. Charging and discharging rate would be 2000/5 = 400mA which states that current will flow 400mA for the duration of 5 hours (400mA*5hours=2000mAh). Check the charging & discharging rate by which capacity has been measured and check the standards mentioned on the certificates which have been followed for the entire testing procedure (charging and discharging rates can affect the battery's capacity and efficiencies).

4.3 Light Emitting Diode

Luminous efficacy of the LED should be at least 100 lumen/watt for reading and cooking purposes, color rendering index should be greater than 85 which tells the quality of the LED and correlated color temperature should lie between 5500K-6500K for a good quality of a LED. Also, the lumen degradation for 500 hours should be greater than 97%, which indicates that a LED's light output

degraded only 3% after the continual operation of the LED for 2000 hours.

Table 3: Photometric Parameters and its essential requirement [2]

Parameters	*Essential requirement*
Luminous efficacy	100 lumen/watt
CRI and CCT	CRI>85 and CCT= 5500K-6500K
Lumen degradation	Should not be graded more than 3% at the end of continual operation for 2000 hours

IL luminance (Lux) = Luminous flux (Lumen) / Surface Area (m^2) [3]. The above parameters are defined for the high brightness mode as the system can have more than one brightness mode. Brightness mode defines the percentage of the brightness of the system such as full brightness or high mode indicates that the product is at 100 % brightness mode and at medium brightness mode or medium mode; the system is at 70% or more than 70% of the brightness.

4.4 Backup/Battery Run Time/Duty Cycle

Full battery run time or duty cycle and solar run time are other parameters which indicate the backup of the battery. Full battery run time is the parameter which needs to be calculated after fully charging the battery and discharging with the full load, then note the time of the operation.

Solar run time can be measure after charging a battery with a solar module in real time and then discharge the battery with the full load of the solar product. The running time of the LED can be noted as a solar run time.

For instance, let's assume the specification of the solar product as follow:

Table 4: Solar components and their assumed specifications

Component	*Specification*
Battery (Li-ion)	2200mAh/3.7V/8.14Wh (2.2Ah*3.7V)
Solar Module (Mono-Csi)	0.4 W
Load (LED)	1 Watt

Battery should be charged as per the standards, charge the battery by C/5 [2] (defined in the battery section) charging rate and discharge the battery by turning ON the LED at full brightness or at high mode (If a load has more than 1 brightness mode). Note the time of turning ON the load till it gets OFF automatically. Battery will be charged in 5hours as the charging rate is C/5 and for the 1 watt load, the backup from the full battery run time test would be around 6 hours and from the solar run time test would be around 4 hours as these following losses will be including:
Solar module loss
Charge controller loss or Generator to battery efficiency
Solar operation efficiency

4.5 Ingress and water protection

Check the ingress protection and water protection present in the device, ingress protection indicates that external solid or dust material cannot touch the internal delicate components unless product has been opened. Water protection should be present in the device, which indicates that there is no way a water droplet can touch the internal components of the product. Also, check the mechanical strength of the product mention in the certificates which indicates that a product's outer body can protect the product's internal delicate parts.

4.6 Accessories and Indicators

Check all the accessories present in the box and read the instructions for using them .All the necessary information will be mentioned in the manual. Check whether the accessories can be easily removable or not like batteries and PCB, sometimes in a product battery and PCB is connected using connector which makes them easily replaceable and highly efficient.

Indicators should be present in the system to provide information to a user about the product battery and protection. Product usually has 2 indicators i.e. one indicates the charging status of the battery and other one is for the protection against the short circuit.

5. Practical Assessment

On field practical assessment can also done by the distribution team to ensure the quality of the solar products by check certain parameters as stated in the certificates and manuals using Multimeter & Light meter. They can check the following parameters on field as follows:

a) Visual Inspection
Also visualize the workmanship of product, proper wire connection, soldering defects, mechanical strength by dropping a solar product form the height of 1 meter.

b) Solar module
Wattage of the solar module can be measured by connecting black and red wires to a multimeter's black and red point.

c) Light Emitting Diode
Light output of the LED using light meter from a certain distance.

d) Indicator should be present in the system
Indicator in the form of LED blinking or sound alert should be present to inform the user of any fault or state of charge. If it is not glowing then replace it with new one.

e) Backup/Battery Run Time/ Duty Cycle
Fully charge the battery directly from the grid if an adapter is provided with the product, connect an adapter with the product and wait until the battery indicates 'fully charged' (indicator will indicate that the battery has been fully charged, user needs to read about the indicators in the manual) and the discharge the battery by turning ON the load.

1) Troubleshooting practices for solar lighting systems
Troubleshooting is the important concern for the people working in the rural areas as working on issues in the field areas would be more cost effective as compare to sending products to the manufacture, if the product is under the warranty period.

Table 5: Troubleshooting Practices

If	*Cause*	*Action*
Light does not glow & charging Indicator is not glowing	Fuse Failure	Remove the fuse and check if the fuse wire is disconnected or blown. If yes, then replace the fuse.
	Loose Terminals	Check for loose connections and make them fixed.
	Battery may be discharged.	Charge the battery as the process indicated in the manual.
	Battery is connected with wrong polarity	Accurate the connections of the battery with the load.
	Loss of electrolyte in the battery (in case of batteries which are not maintenance free)	Top up with distilled water as required
	Acid leakage in the battery (in case of batteries which are not maintenance free)	Contact the authorized service centre.
	Wiring Problem	Inspect and repair as necessary
Light does not glow & charging Indicator not glowing	Current is not drawn from solar module.	Remove the solar module from the system and check the connection & whether the current & voltage is drawn from module with the help of multimeter.
	No Solar Charging Current	Inspect the wires coming from the solar module and repair them as necessary.
	Module connected in wrong polarity	Correct the connections and then check again.
	Battery connected in wrong polarity	Correct the battery connections.
	Fault in printed circuit board of charge controller	Contact the authorized Service Centre.
Battery deep discharge not glowing	Indicator LED is faulty	Replace the LED
	Indicator LED is faulty	Replace the LED
	Battery is deep discharged	Contact the authorized service Centre
	Loose connections	Check connections and if found loose tighten them up.
Less hours of operation	Battery Deep discharged	Contact the authorized Service Centre

2) Documents provided with the product

The product should enclose with manuals, report& technical reports in the local language. This is alternating way to create awareness about the quality of product to the consumers and consumer should follow the work instructions and specifications are mentioned in the manual.

6. Result/Discussion

The above discussed methodology can help local entrepreneurs to ensure the quality of the components present in the solar systems such as battery, charge controller, LED and solar module, to conduct troubleshooting practices and to help local people in operating the device. This article consists of all the points which need to be checked to ensure the quality.

7. Future Scope

There are many un-electrified villages across the globe which relies on portable solar products as grid connection is quite difficult to be provided in those areas. Providing training is important in those areas through numerous initiatives taken by Government and Social NGO's as they are lacking of many facilities, training, awareness and understanding of product's usage can eliminate those barriers. In future, local entrepreneurs and people are more expected to be aware about the solar lighting systems, its operation, troubleshooting and ensuring quality of the product.

8. Conclusion

The Economic barrier is one of the major concerns. Along with quality need to be focus on the cost of product as well. The comparative analysis between the cost and quality should be done while selecting the product. The product with good quality & minimal cost should be opted. Quality of the solar systems can be assured by checking all the points mentioned in this paper. A good product should have all the facilities and should be reliable; product should satisfy the minimum requirement for the battery run time and IL luminance for reading and cooking purpose.

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