FORMULATING AN INSTALLATION GUIDELINE FOR PHOTO VOL TIC DC SOLAR HOME SYSTEMS IN SRI LANKA

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by
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Abstract

Although grid electrification drastically increased during the past two decades up to about almost 75% of the total households in Sri Lanka, it is noted that attempting to electrify the rest of the approximately 25% of the households is very expensive. This is due to the fact that these households are situated in very remote areas which do not permit the normal low voltage (230V Phase to Neutral / 415V Phase to Phase) transmission since the losses would make it unusable to the end user point.

Thus, in order to avoid this losses medium voltage line should be drawn at a very expensive cost which is not justified by the measly amount of end users. The cost benefit analysis would not be feasible. Thus, the rest of these 25% of un-electrified households stands the risk of not having accessibility to grid power even in another 20 to 30 years. Therefore, for such rural house holds the solution for the moment is alternative energy sources. Up to about decade or so back the solution that they had was kerosene fuel to light up their lamps, thereafter they obtained the accessibility to solar photovoltaic (PV) electricity through private sector vendors and government intervention. This solution was widely accepted by this community since the end result was the next best thing to grid power. Further it was safe in usage than kerosene fuel and even grid power. The government and world bank also subsidized the purchase of such systems from vendors. However, the supply of solar PV home systems (SHS) became very competitive, amongst the vendors who supplied them. As a result quality of these systems as well as their installation was compromised by the vendors. As result the poor rural folks who purchased these systems went through severe hardships due to malfunctioning systems. Considering that the investment for these systems would be the largest or the second largest investment in their lives it was unacceptable for them,

Therefore, author of this dissertation had set out to develop a solar PV installation guideline and has managed to develop same in order to be utilized and to be educated

by , the end users or their financing institutions. So that vendors has to deliver proper system with proper after sales procedure in order to be paid for their product or service. Thereby develop some ethical standard of professionalism to this area of engineering! Electrical installations.

DECLARATION

The work submitted in this dissertation is the result of my own investigation, except where otherwise stated.

It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.

UOM Verified Signature

R.V.S.W.T.Ranasinghe
27-02-2009

I endorse the declaration by the candidate.

UOM Verified Signature

Professor. J.R.Lucas

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List of Abbreviations

A	Ampere
AC	Alternating Current
Ah	Battery Ampere-Hour
AL	Aluminium
BS/EN	British Standards / European Norm
C_n	Nominal Capacity
C_u	Useful Capacity
CFL	Compact Fluorescent Light
DC	Direct Current
DOD	Depth of Discharge
GI	Galvanized Iron
g/cl	
INGO	International Non Government Organizations
IP 32	Protection against Solid Objects Greater Than 2.5mm Diameter and Protected Against Dripping Water When Tilted Up To 15°
LED	Light Emitting Diodes
LLP	Loss of Load Probability
MS	Mild Steel
NGO	Non Government Organizations
PDD	Depth of Discharge in the Daily Cycle
PD_{max}	Depth of Discharge
PR	Performance Ratio
PV	Photovoltaic
PV GAP	Global Approval Program for Photovoltaic
PVRS 5A	Lead-acid batteries for solar photovoltaic energy systems (modified automotive batteries).

RMS	Root Mean Squire
SHS	Solar PV Home System
SLI	Starting, Lighting & Ignition
SOC	State of Charge
V	Voltage
VRLA	Valve Regulated Lead Acid
Wp	Peak Watts- The Measurement of Electricity Produced By A Solar Generator at Noon on a Sunny Day, Under Predetermined Standard Conditions.

Chapter 1

Introduction

Efficient supply and availability of energy sources are essential requirements to ensure economic progress as well as improvement in quality of life. Sri Lanka has made rapid progress in the field of electrification. The total consumer network increased in the recent past significantly compared to two decades back, domestic and religious premise electric connections been given, much of which can be attributed to the expansion of rural electrification .

However, the status of rural electrification leaves much to be desired. Compared to a very healthy (around 95%) household electrification in the urban regions, the corresponding statistics for the rural regions stands around 35% [1]. At district level too, the disparities in household electrification are pronounced with Colombo enjoying the highest percentage of electrified houses.

Due to low availability of a better form of energy, the rural population continues to depend on inferior alternatives. Firewood and agricultural wastes provide the energy requirements for cooking. Kerosene provides energy for domestic lighting. Use of such inferior forms of energy has a direct bearing on the quality of life. The pattern of expenditure on fuel and lighting between rural consumers and urban consumers show marked variations. In the case of the urban consumer, the proportion of expenditure on electricity and gas is significant while in the case of the rural consumer, similar highs in expenditure are seen for firewood and kerosene which provide relatively inferior forms of energy.

In order to improve the quality of life among the lesser-privileged segments of people who have no access to electricity to meet their energy requirements, it has become necessary to explore sustainable energy alternatives. Based on Sri Lanka's geographical positioning in terms of its tropical climate and natural terrain, Sri Lanka has a very high potential to draw on forms of renewable energy sources to meet this need. Endowed with a tropical climate, the potential for solar energy is very high. Currently there has been approximately hundred thousand (100,000) rural house holds electrified with solar photo voltaic energy. And there is approximately another six hundred thousand (600,000) house holds which could afford this technology.

From its first commercial initiation of entering the market solar system technology in the mid eighties, product and service quality has considerably improved and evolved. But it is questionable if these are in par with international standards or have they adopted in a tight fit in consideration to the local context. Currently, there is no national standard for solar home systems. Thus, researcher expects to develop a guideline for photo voltaic solar home system (SHS) in consideration to global best practices, standards and most essentially the practically possible local requirements in current context.

1.1 The Problem Statement

Sri Lanka does not have a clear guideline for solar home systems. While there is no clear standard or a guideline, the solar industry has been highly commercialized, which has lead to many vendors offering SHS of various product, service and installation standards. Thus the consumers are subjected to various standards of SHS addressing the same need. Therefore there have been many instances where the consumer has had bitter experiences due to non standard or inferior installation standards and wrong raw material selection.

1.2 Manifestation of the Problem

The absence of a proper installation guideline has created a wrong impression on the professionalism of solar industry in Sri Lanka as a whole, as well as created many unsatisfied customers. Therefore, researcher identifies the importance of developing a guideline for solar SHS installation practices keeping in mind the local context as well as global standard.

1.3 Objectives of the Dissertation/Research

The objective of the minor research will be to identify the global best practices and standards for material selection and installation standards for solar SHS's and compare same with existing standards employed by the Sri Lankan solar industry. And subsequently prepare a general installation standard for SHS in consideration of the maturity, economical feasibility and local conditions. These may not necessarily be in par with all international standards but will be suitable for local era which the solar industry is phasing.

1.4 Significance of the Research

As explained earlier the SHS industry in Sri Lanka does not have any recognized guideline. Therefore, in is vital that such a guideline is introduce in consideration for the future growth and sustainability of the SHS industry in our country. By introducing proper guideline the low income population who benefit from this rural SHS installation will have a reliable professional product, which may be the largest or second largest investment in their entire life. As a result this area of specialization of electrical engineering will obtain the desired recognition.

1.5 Scope and Limitations

The energy source of a solar photo voltaic system is its Solar PV module. The module converts energy in the suns rays into DC power. This harnessed DC power could be consumed as it is for DC loads or could be converted into AC power via a inverter and could be used to cater AC loads. In Sri Lanka it is very seldom you come across a AC system, due to its high cost of initial investment. However, DC applications could be found in thousands. And almost all of these DC systems cater very rural areas of the country where AC grid power is not available or is inaccessible.

Therefore, research will be strictly limited to DC applications and installations of solar photo voltaic technology, that also concentrating on rural DC home systems which is the most common Solar PV application in Sri Lanka. The research will be carried out with available literature resources such as magazines, training literature and web based resources. The data will be gathered from the solar field by visiting actual end users of various vendors which is in government controlled areas. It should be noted that there is not much difference between SHS installations across the country.

Chapter 2

Methodology

2.1 Literature Review

The researcher has obtained the back ground information to establish the solar PV SHS installation and raw material selection guideline with use of available world wide standards or guidelines and on the basis of such standards researcher would study how the local industry has obtained the knowledge. The methods of obtaining such relevant literature were by means of magazines, training literature and web based resources.

As described in the literature review initially the researcher analyse the global standards and guidelines available for PV SHS and establish a common guideline. Then, he has done field visits and understood the actual standards that are in practice amongst the PV SHS vendors and had obtained data necessary to identify the practices in the country. Subsequently he will compare the global standards or guidelines against the local practices and would suggest a suitable guideline for Sri Lanka in consideration to local context, future development of the industry.

2.2 Data Gathering and Data Analysis

Data was gathered primarily via field empirically as well as through the literature survey. During the field visits observations of the installations, photography and relevant measurements was obtained. Customer comparison of products, installation and service was obtained via semi-structured interviews and physical inspection and documented via survey data sheet. Inspection was done of different vendors as much it was practically required. Details of same are as follows;

Table 2.1.1: List of Solar PV Home System Vendors Who Was Visited and Number of Customers Visited of Each Vendor

No	SHS Vendor	Number of Customers Visited
1	**Shell Solar Lanka Ltd** 98, Ward Place Colombo 7	6
2	**Vidula Energy (Private) Limited** 434, Thalawathugoda Road Madiwela Kotte	5
3	**Suriyavahini (Pvt) Ltd** 444/10/C1, Delgahawatte Road Ratmalana	8
4	**Softlogic Solar (Pvt) Ltd** 3rd Floor, Softlogic Building 14, De Fonseka Place Colombo 5	2
5	**Access Solar Pvt Ltd** 278, Acess Toowers, Colombo 2.	1
6	**Wisdom Solar (Pvt) Ltd** 434, Thalawathugoda Road Madiwela Kotte	2
7	**Alpha Solar Energy Systems Pvt Ltd** 121, Castle Street Colombo 8	2
8	**E B Creasy & Co Ltd** 98, Sri Sangaraja Mawatha Colombo 8	2
	Total	**28**

The data in each individual survey data sheet (Refer annexture1)was abstracted and a summarised "summery of survey data sheets" was build up and is attached as annexure 2 along with the actual individual data sheet and photography for each customer (Refer as annexure 3) .

The obtained data will be analyzed in consideration of global standards, local installation standards available and practical ability of the local PV SHS industry to adapt to the standards. The data abstracted from the survey has been used at each section of the guideline build-up as and when required.

Chapter 3

Specification for SHS Components and Performance

When considering solar PV as an energy source there are many forms of applications. The raw energy from the sun converted into DC electricity by the PV module could be utilized in many ways. The raw DC power obtained could be directly used to run a DC load, but this could be done only during the day time when sun shine is available. However, if it is required to operate loads during night time or when no sun is available, then it is required to have a battery/s as an energy storage which is charged via a charge controller. And the stored energy could be utilized during night time. Any DC load/ Appliances could be utilized which is equal to the designed system voltage such as lights, Televisions, door bells, radio cassettes...etc. However, any heating/heating element operation is impractical since it consumes huge amount of energy.

However, if it is required to run an AC load from the DC energy obtained from the PV modules then it could be done by introducing a inverter to the system. In this case also we may design the system with or without a battery bank. In this instant any AC load could be used as required.

SHS's available in rural areas in Sri Lanka are of simple design generally and having a common design. These systems harness the DC energy from the PV module then charge a battery via a charge controller during the day time and what ever energy stored in the battery could be utilized during day time or night. These rural SHS consist of the following basic components:

- A **PV generator** composed of one or more **PV modules** (mostly one), which are interconnected to form a DC power producing unit.
- A mechanical **support structure** for the PV generator.
- A lead acid **battery** consisting of several **cells,** each of 2 V nominal voltages.

- A charge **regulator** to prevent excessive discharges and overcharges of the battery.
- **Loads** (lamps, radio, etc.)
- **Wiring** (Cables, switches and connection boxes or terminals)

Most present Sri Lankan SHS's are low power (<100 Wp) and entirely DC. It is also possible for SHS's to supply AC power by using inverters, but cost and reliability reasons normally tend to restrict their use to larger power levels (>200 Wp).

The quality of a particular SHS may be judged in terms of its;

- Reliability,
- Energy performance,
- Safety,
- User-friendliness,
- Simplicity of installation,
- Maintainability.

In addition, particularly for large PV rural electrification programmes, it may be important for SHS to be able to operate with different components (from different manufacturers, for example) and different sizes.

When assessing SHS, each of these criteria need to be analysed and concrete requirements specified.

In some cases, two alternative requirements may be specified for the same component or system. This normally occurs where there is a choice of technical quality and costs, and the final selection must be made in the light of local availabilities and constraints. For example, the size of a solar battery is expressed in terms of Days of Autonomy, and the Standard proposes ≥ 3 as compulsory and 5 as recommended for Sri Lanka and is what commonly practiced. However in Europe ≥ 5 as compulsory and 8 as recommended since availability of sun shine is less predictable, therefore when ever it is available maximum storage should be achieved. This is not a contradiction. It is simply the case that the compulsory requirement represents an absolute minimum, whilst the recommended requirement is a more desirable but also a more expensive solution. However, the absolute minimum standard must not be compromised at any time.

3.1 Reliability

SHS reliability, in the sense of lack of failures, depends not only on the reliability of the components, but also on some other features of the system which can directly affect the lifetime of batteries and lamps, such as size, the voltage thresholds of the charge regulator, the quality of installation, etc. Each component of the system must fulfil similar quality and reliability requirements because, if there is only one bad component in an otherwise perfect system, this will limit the quality of the whole.

3.2 PV Generator (PV Module)

Solar modules are generally flat panels mounted on roofs or other structures. Solar modules convert energy from sunlight into direct current (DC) electricity. There are few types of solar module types which differ in its operating characteristics due to its construction in its cells. The types available are as follows;

- Crystalline silicon
- Thin film
- Compounds
- Dye sensitized plastic.

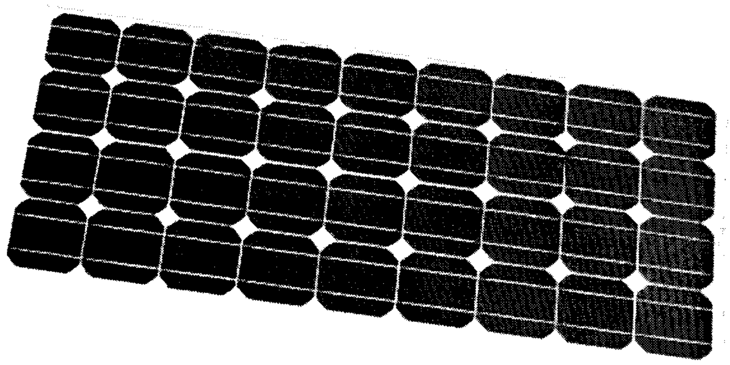


Figure 3.2.1: Typical Crystalline Solar PV Module with 36 cells

However, only crystalline and thin film technology is commercially available for usage. When selecting the PV module it is vital to know how efficient it is. Refer below table for efficiencies of different types of modules;

Table 3.2.1: Module Type Against their Efficiencies

Module Type	Laboratory Efficiencies	Pilot Production Efficiencies (%)	Production Efficiencies (%)
Crystalline Silicon - Single Crystalline - Multi-Crystalline (poly)	 24 20		 13 – 16 12 – 15
Thin-Film - Amorphous Silicon - CdTe - $Cu(InGa)Se_2$	 14 16 19	 7 – 10 10 – 12	 5 – 8
III – V **Compounds**	33		≈ 20
Dye Sensitised **Plastic**	11 3.0	5 -	- -

Therefore it obvious that only crystalline solar PV modules are efficient enough to be utilized in a SHS installation and it is not that expensive either. Therefore, it is recommended to use crystalline PV solar modules for SHS installations and to avoid other types. If required the second best option of thin film PV modules could be utilized, but recommended to avoid same if it is possible to afford crystalline ones. According to our field inspection of a SHS universe of 28 residences following was observed;

Table 3.2.2: Number of Users Found in the Sample Universe of SHS with Types of Modules

Module Type	**Number of Customers/Users**
Crystalline	27
Thin film	1
Other if any	0
Total	**28**

Thus, it is clear that the Sri Lankan SHS industry also uses crystalline PV modules against other types; therefore it fair to assume from the field observation above that these modules are commercially viable to use. The PV modules also should comply with following standards;

- ***Single-crystalline or poly-crystalline PV modules certified according to the international standard IEC-61215. (R)***
- ***If thin-film photovoltaic modules are used, they must be type tested and certified in accordance with IEC 61646 or equivalent specifications. The peak power output for thin film modules should be the value after light soaking.***
- ***To be eligible for government grant schemes the photovoltaic array should consist of one or more flat-plate photovoltaic modules. Each module should comprise no less than 36 series-connected single or poly-crystalline silicon solar cells. Flat plate thin-film modules could also be used. (This has been stipulated in the*** *RERED –*

Renewable Energy for Rural Economic Development ***Project requirement). The reason not to have 72 cells in series modules is that it has twice as much interconnecting connection between the cells than that of a 36 cell one. Thus it increases the risk of failure due to poor connections twice as much.***

- ***If more than one module is used, identical models shall be used and they shall be connected in parallel. (In practice there is a possibility that the larger module may generate a higher voltage out put than that of the small one which is coupled. Thus creating a current flow from larger module to the small one, small one becomes a load. Therefore in order to avoid such instant it is recommended to have identical modules being connected in parallel)***
- ***Each module must be clearly marked indicating: Manufacturer, Model Number, Serial Number, Peak Watt Rating, Peak Current, Peak Voltage, Open Circuit Voltage and Short Circuit Current of each module (this is to safeguard the end user from the vendor in event the vendor abandon and leave the end user, the end user could contact the manufacturer to obtain warranty claims or technical support from the module manufacturer).***
- ***The module junction*** *box* ***must be sealable and moisture resistant may it be installed on the module back or on the support structure.(this is to avoid any short circuiting between the terminals and to avoid oxidation leading to poor connection)***
- ***The modules must be framed in such a way as to allow secure connection to the module mounting structure. (this is to avoid any damage to the cells due to improper mounting mechanisms)***
- ***It is suggested that the PV Module be cleaned with water and soap once in two months least to prevent the module being in efficient due to dirt and dust residual on it as time passes. In dry seasons when dust is more this frequency could be increased.***

Some manufacturers systematically include "by-pass" diodes in their PV modules, to protect them against "hot-spot" phenomena. However, it should be noted that the probability of a PV module becoming damaged by "hot-spots" is close to negligible for DC voltages lower than 24 V. Because of this, the use of such diodes is irrelevant in SHS and they are not considered in this guideline.

3.3. Support Structure

The PV module could be mounted in few ways. However, in what ever method it is required to fix the module aligned to north to south. And tilted a bit to let the rain water to flow out, and to be perpendicular to the sun. Usually this alignments and direction is obtained in Sri Lanka with the module support. The module support assembly usually comprise of two main parts. One is the framework which is fixed to the module and it also makes the connection with the support pole.

Now let's observe the constructions that was available in the field visited SHS;

Table 3.3.1: Number of Users Found in the Sample Universe of SHS with Different types of Modules Support Assemblies

Construction of the Support Assembly	Number of Installation
GI Pole & AL frame	16
GI Pole & MS frame	12
Total Installations	**28**

From above observation it is clear that the pole which is used is always GI and has the capability of withstanding the environmental negative effects. However, it is noted that the module support framework is fabricated from both Aluminium as well as mild steel in Sri Lanka. However, mild steel does withstand the environment as much as Aluminium, therefore it is recommended to use Aluminium framework along with GI pole. There are possibilities of using galvanized iron, stainless steel frameworks, but is quite expensive than the two solutions available locally. There also instances where treated wood is being used in some countries where it is less humid, however this solution would not be feasible to our country.

The suggested module support assembly guideline would be as follows;

• *Support structures should be able to resist, at least, 10years of outdoor exposure without appreciable corrosion or fatigue. (Usually the PV module has the most warranty of ten years or more in a solar PV system, therefore the support structure also should withstand such period without any trouble)*

• *Support structures must withstand winds of 100 km/h.*
(Reference from Mr. K H M S Premaratne – Metrologies, Department of Metrology)

• *Several materials can be used for support structures, including stainless steel, aluminium, galvanised iron with a protective layer provided that above requirements are satisfied.*

• *In the case of framed PV modules, only stainless steel fasteners (screws, nuts, rings, etc.) may be used for attaching them to support. (to protect against corrosion)*

• *Tilt angle should be selected to optimise the energy collection during the worst month, i.e., the month with the lowest ratio of monthly mean daily irradiation to the monthly mean daily load. Generally, constant user load can be assumed. Then, the following formula can be used*

Tilt $(^{o}) = \max\{|\Phi|\} + 10^{o}$
where Φ *is the latitude of the installation.*

Note : Sri Lanka's latitude changes around + 4° from south to north (From Point Devundara to Point Peduru). Therefore, it is safe to use the tilt angle as 12° (10 ° + 2 °) on average as a rule of thumb.

This formula leads to a minimum tilt angle of 10 °, which is sufficient to allow rainwater to drain off the surface. It may also be useful to note that slight azimuth deviations from south/north (+/- 30 °) and in the tilt angle (+/- 10 °) have a relatively small influence on the energy output of a PV array.

Most of the consulted experts are opposed to manual tracking because it implies a risk of damage to the modules, and a risk of energy lost through poor or no adjustment. However, it has been used in some places with positive results not only in terms of energy gain, but also in terms of user participation.(Specially observed in some solar pumping systems)

Naturally, adequate training is needed and the tracking features, including any hinges and other coupling devices needed to allow the modules to be moved, must also meet the requirements specified above.

Hence:

- ***Static support structures are generally preferable to tracking-ones.***

Figure 3.3.1: Pictures Depicting Module Support Structures

- ***For static support structures where the PV array is roof mounted anchoring of the mounting structure must be to the building and not to the roofing material. And it is necessary to have at least 10 cm clearance between the PV array and the roofing material. (As per above Picture)***

Figure 3.3.2: A typical Pole Mounted Solar PV Module.

- ***And for static support structures where the PV array is pole mounted, the module/s should be attached to the top of the pole at least 4M off the ground. (As per above figure.***
- ***The panel/s should be mounted clear of vegetation, trees and structure so as to assure that they are free of shadow throughout day light hours during each season of the year. Furthermore, if more than one panel is mounted on a support structure the panels should not be mounted such that one panel will not shade the other module(s). Therefore, the user of the system should make sure that the module/s is not shaded by vegetation and same is cleared off as and when required.***

3.4 Battery

For the battery, the most important feature of its operation in SHSs is cycling. During the *daily cycle*, the battery is charged during the day and discharged by the night-time load. Superimposed onto the daily cycle is the *seasonal cycle,* which is associated with periods of reduced radiation availability. This, together with other operating parameters (ambient temperature, current, voltages, etc.) affects the battery life and maintenance requirements. In order to maximise the lifetime of lead acid batteries, the following operating conditions must be avoided:

- High voltages during charging (to prevent against corrosion and loss of water)
- Low voltages during discharge (corrosion)
- Deep discharge (to avoid sulphation, growth of dentrites)
- Extended periods without a fully charging (to avoid sulphation)
- High battery temperatures (all ageing processes are accelerated)
- Stratification of the electrolyte (to avoid sulphating)
- Very low charge currents (to avoid sulphating)

These rules lead to specifications for sizing (both battery and PV generator) and for battery protection procedures (charge regulator). However, it must be pointed out that some of the rules are generally in contradiction with each other (e.g. full charging needs high voltages but high voltages accelerate corrosion), so compromises must be found taking into account the local conditions such as: solar radiation, PV module and battery prices duties and taxes, local manufacturing, recycling infrastructure, etc.

Figure 3.4.1: Picture of a Tubular Deep Cycle Solar Battery Available in Sri Lanka

The need to prevent excessive discharge leads to the need to limit the maximum depth of discharge (PD_{MAX})to a certain value, which usually ranges from 0.3 to 0.6, but can approach 0.8 according to the type of battery. The supply to the load must be cut when this limit is reached. The available or useful capacity (C_U), is therefore less than the nominal capacity, C_B, (which refers to the whole charge that could be extracted from the battery if no particular limitations were imposed) and equal to the product C_B. PD_{MAX}, such that:

$$C_U = C_B . PD_{MAX}$$

- A good compromise between cost and reliability is typically obtained with a battery whose useful capacity at least 3 times the total daily energy consumption in the house, so that the depth of discharge in the daily cycle, *PD*d, ranges from 0.06 to 0.2. The selection of a particular capacity mainly depends on the type of the battery.The 20-hour battery ampere-hour (Ah) capacity at 12 V DC, measured at 25°C, should be such that it will permit three days of autonomy where the maximum depth of discharge is limited to 75 percent of rated capacity. The minimum ampere-hour capacity at 12 V DC (measured at the 20-hour rate) shall be as given in the table below. It is recommended that the battery be sized to permit five days of autonomy in regions where extended cloudy periods are expected.

Example: Minimum lead-acid battery capacity

Table 3.4.1: Selection of Batteries for a SHS Based on PV Module Capacity

Module Rating (Wp)	Average daily Ah to load at 12 V DC	(Daily Ah x 3 days of autonomy)/0.75	Minimum battery sizes (Ah) for autonomy of	
			3 days	5 days
10	3	12	12	20
20	6	24	24	40
30	9	36	36	60
40	12	48	48	80
50	15	60	60	100
60	18	72	72	120

These are based on five peak sunlight hours per day, 10% module de-rating and 20%

battery round-trip Wh losses.

- The maximum permissible self discharge rate is 10 percent of rated capacity per month at 25°C.
- Batteries bearing the PV GAP Mark or having been tested and certified in accordance with PVGAP PVRS5A - Lead-acid Batteries for Solar Photovoltaic Energy Systems - General Requirements and Methods of Test for Modified Automotive Batteries, or equivalent or better standard, will be accepted. Also accepted are tubular plate batteries tested and certified in accordance with Indian Standard IS 13369:1992 - Stationary Lead Acid Batteries (with Tubular Positive Plates) in Monobloc Containers, or equivalent or better standard. Accepted on an interim basis are flat plate batteries tested and certified in accordance with BS EN 50342:2001 - Lead-acid Starter Batteries; General Requirements, Methods of Test and Numbering (which supersedes BS EN 60095-1:1993), or equivalent or better standard.
- Cycle life of the battery (i.e., before its residual life drops below 80 percent of the rated Ah capacity), at 25°C must exceed 200 cycles when discharged down to an average depth of discharge (DOD) of 75 percent.
- The batteries shall be supplied to the customer in a fully charged condition ready for use. The battery and associated containers should be able to handle transport down rough dirt roads without damage.

“Good” batteries are able to resist deeper cycling than “bad” batteries. Hence, for the same application, “good” batteries can be smaller than “bad” batteries, in terms of nominal capacity.

Best quality PV batteries are made with tubular plates and grids with low Sb-Se content. More than 5 years life, with $PD_d = 0.2$ and a maintenance period of 1 or 2 times per year, are attainable with such batteries. A particular disadvantage with tubular batteries for SHSs is that they do not readily accept low rates of charge. They are also expensive and are rarely available in the current market in Sri Lanka (only one vendor has this product, only 3 SHS users out of total 28 surveyed had deep cycle, please refer table below). Nevertheless, they should not be excluded from SHS. On the contrary, it is recommended that large electrification programmes should consider encouraging vendors to put these products onto the market.

In contrast, automotive batteries, usually referred as SLI (Starting, Lighting & Ignition), have a number of advantages. They are usually the cheapest batteries when compared in terms of nominal capacity, they are often locally produced and are widely available. Local production is not only convenient for economic and social reasons, but also because it represents the best possibility to recycle old batteries and to avoid environmental damage.

Their main drawback lies in their relatively short lifetime. Because their cell design is optimised to deliver heavy currents during short periods of time (starting current/cranking current), they have large areas of thin plates, and are poorly suited to supplying smaller currents for many hours before being recharged, as is required by SHS. It is therefore necessary to use larger battery capacities leading to $PDd \leq 0.1$, and a density of electrolyte which is lower than would normally be used in this type of battery (for example, 1.24 instead of 1.28 g/cl). This is needed to reduce grid corrosion and hence to lengthen battery life. The associated increase in internal resistance in the battery does not represent any problem in SHS, because the charge and discharge currents are relatively low in comparison with conventional battery charge and discharge regimes. *Classical SLI batteries* use lead grids alloyed with antimony and require periodic topping up with water.

Table 3.4.2: Number of Users Found in the Sample Universe of SHS with Different Types of Batteries

Battery Type	**No. of SHS**
Normal Lead Acid batteries - SLI (Automotive)	24
Sealed Lead Acid (SLI)batteries	1
Deep cycle Lead Acid batteries	3
Total Batteries	**28**

The short lifetimes of automotive batteries can also be compensated to some extent by introducing relatively simple modifications to the battery design but not to its technology. The most common modifications are thicker electrode plates and a larger quantity of acid solution in the space above the plates. Such *modified SLI* batteries are sometimes marketed as "solar" batteries and represent a promising alternative for the future of SHSs. Wherever possible, modified SLI batteries should be selected (and local manufacturers should be encourage to make them) in preference to conventional SLI batteries. Certain conditions must be required for a battery to be categorised as "modified SLI", as follows:

- ***The thickness of each plate must exceed 2mm.***
- ***The amount of electrolyte must exceed 1.15 l per 100 Ah of 20-hour nominal capacity and per cell.***
- ***The separator must be made of micro-porous polythene.***
  (To allow free movement & circulation of acid, but maintain insulation)
- ***The density of electrolyte must not exceed 1.25 g/cl.***
- ***It is recommended that the user top up acid level of the battery/s with distal water to be at battery manufacturers indicated level as and when required.***
- ***Check frequently if oxidation has occurred on the battery terminals frequently, clean with hot water and apply a petroleum-gel in order to prevent oxidation setting in again. Further clean the battery surface of any excess acid/liquid or dust in order to prevent any leakage current between the two terminals. (+ve and the – ve)***

"Low-Maintenance" SLI batteries, sometimes marketed as maintenance free batteries(sealed SLI batteries), often employ grids containing calcium alloys. The calcium increases the voltage at which gassing begins, but reduces the cohesion of the active material to the grids. Hence, it cuts down the loss of water but also reduces the cycle life. Such batteries are particularly vulnerable to damage from deep discharge. In addition, they are also liable to be damaged by high temperature variations. Hence, many PV system designers strongly recommend against their use in PV applications in hot countries such as ours. However, from our sample SHS universe we see there was one

installation out of the 28 total which had sealed SLI battery, such applications should not be allowed as explained.

"No-maintenance" batteries are also made for professional applications by using a semi-solid electrolyte (gel or malting). Such batteries, referred as VRLA (valve regulated lead acid), are more often resistant to deep discharges, but they are usually very expensive for SHSs, and they require specific recycling facilities. They are not considered in this guideline although they represent a definite technology choice in some cases. The same is valid for NiCd batteries. These batteries currently do not seem to be a commercial viability and maturity of the industry in our country does not support same.

When specifying batteries, it should be noted that cycle life testing under representative SHS operation conditions is both time-consuming and difficult. Despite some past attempts, widely accepted test procedures do not yet exist and this situation is likely to remain in the years to come. For this reason, the most practical approach is to rely on well-established battery standards for conventional uses that means, capacity values corresponding to a discharge of 20 hours and cycle lives corresponding to a depth of discharge of 50%. Once it has been confirmed that the energy production will exceed the demand of the load during the worst month.

3.5 The Charge Controller

The charge controller serves primarily to protect the battery against both deep discharging and overcharging. It is also used to protect the load under extreme operating conditions, and to provide operational information to the users. Ideally, charge regulation should be directly controlled by the state of charge (SOC) of the battery, and sophisticated charge regulators based on that principle are available in the current market.

However, they are still rather complex and expensive, so their use in small SHSs is scarcely justified. For this reason, only charge regulators which are based on voltage control are considered in this standard.

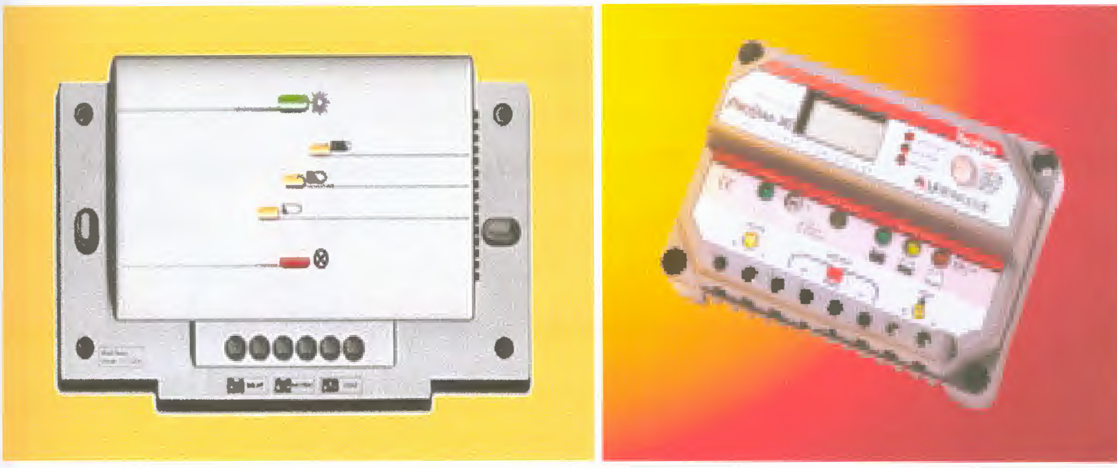


Figure 3.5.1: Typical pictures of charge regulators

Following specifications are proposed here for Charge Controllers:

- ***The charge controller must have some type of display or an indicator to indicate when it is in the charging mode. (in order to be aware that the module is generating power or not and to make sure connections between module and charge controller is in good condition)***

- ***Some form of a battery state-of-charge indicator must be provided on or near the controller or load centre.(in order to identify whether the connections are ok, if the battery holds charge or if the charge controller is functioning properly and charging the battery)***
- ***The chosen device must come appropriately labelled such that the user does not have to refer to a manual to understand the existing battery condition.***
- ***Deep discharge protection must be included. (in order to protect the battery against over usage)***
- ***Manual release of the deep-discharge protection is not permitted (in order to protect the battery against over usage)***
- ***Warning facilities must be included***
    - ***"Warning" voltage (low voltage) must be 0.2V (for 12V systems) higher***

than the consumption disconnection voltage. For example, a disconnect voltage of 11.7 V DC + 0.1 V DC and reconnect voltage of 12.9 V DC + 0.2 V DC is suitable for safe operation of lead-acid batteries used in SHS. (R) should be selected such that the warning signal is activated 30 minutes before "load disconnect" occurs, assuming all the loads are "on"

- *This device must, at a minimum, indicate when the battery condition is :*
  - *Suitable to operate all loads (e.g. voltage greater than 12.5 V DC)*
  - *Energy conservation required (e.g., battery voltage less than 11.9 V DC) (in order to protect the battery against over usage)*
- *End-of-charge voltage should lie in the range from 2.3 to 2.4 V/cell, at 25°C.*
- *All the charge controller terminals should easily accommodate, at least, 4 mm2 section cables.*
- *Internal voltage drops between the battery and generator terminals of the charge controller must be less than 4% of the nominal voltage (≈0.5 V for 12 V) in the worst operating conditions, i.e., with all the loads "off" and the maximum current from the PV generator.*
- *Internal voltage drops between the battery and load terminals of the charge controller must be less than 4% of the nominal voltage (0.5 V for 12 V) in the worst operating condition, i.e., with all the loads "on" and no current from the PV generator.*

In All Cases:

- *Reverse current leakage protection must be provided. (to prevent energy loss and prevent damage to module)*
- *The charge controller must be able to resist any possible "non-battery" operating condition, when the PV generator is operating at Standard Test Conditions and with any allowed load.*
- *The charge controller must also protect the load in any possible "non-battery" condition, as defined above, by limiting the output voltage to a maximum of 1.3 times the nominal value. (Full interruption of output voltage is also allowed).*

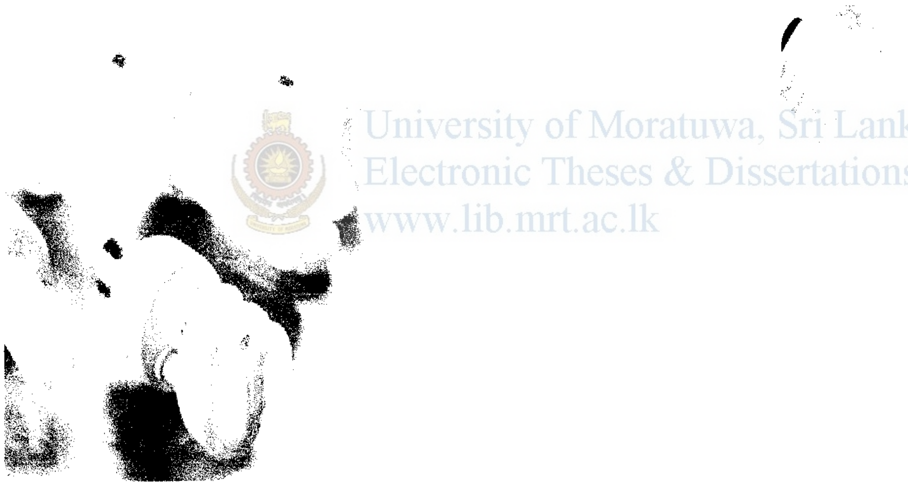
- *The charge regulator should allow battery charging from the PV module for any voltage greater than 1.5V/cell.*
- *The charge controller must resist without damage the operating condition defined by: ambient temperature of 40°C, charging current 25% greater than the short circuit current of the PV generator at Standard Test Conditions, and discharging current 25% greater than that corresponding to the full load "on" at the nominal operating voltage.*
- *Battery temperature compensation circuitry is not required if flooded lead-acid batteries are used. However, if temperature compensation is not provided, then the set points must correspond to the type of battery and the ambient temperature of the site where the SHS is to be used. Temperature compensation is required if sealed lead-acid batteries are used.*
- *charge controller boxes must provide protection to at least IP 32.*
  (Protection against solid objects greater than 2.5mm diameter and protected against dripping water when tilted up to 15°)

- *The charge regulator must be protected against reversed polarity in both PV generator and batter y lines. Diode-fuse or other arrangements can be used.*
- *Some means must be provided to safely disconnect the battery and the module during servicing repair by a technician.*
- *The model number, serial number, rated voltages and currents, set points and indicator settings should be noted on the charge regulator case.*
- *The charge controller must not produce radio frequency interference in any operation conditions.*
- *Maximum current draw of the controller, when no LEDs are lit should not exceed 10mA.*
- *Maximum current draw of the controller, when no LEDs are lit should not exceed 10mA.*
- *It is recommended that a trained technical person check on the contacts/terminals of the charge controller for oxidation, loose connection and dry sold once in six months at least for proper maintenance.*

3.6 **The Lighting** (Loads are Mainly Lighting)

Typical loads in SHSs are lamps, radios and TV-sets, and lighting usually represents a substantial part of the total energy consumption of the house. Lamps are usually included in SHSs kits, but they have not yet been widely standardised. In contrast, radios and TV-sets are directly acquired by the users from the conventional appliances market, their energy consumptions tend to be modest and they are highly standardised products. For these reasons, only lamps are reviewed in this guideline, while information concerning radios and TV-sets (low standby losses, protection against reverse voltage, required voltage, etc.) are entrusted to training and general information activities in the industry.

The requirements proposed here are as follows for Lighting:



CFL's ***Fluorescent*** ***LED's***

Figure 3.6.1: Pictures of typical light loads available in SHS in Sri Lanka

- ***Fluorescent lamps are recommended due to their higher efficiency for area or task lighting applications, but LED or halogen lamps may be used for special purpose applications such as night lights. If fluorescent lamps are to be used, they must meet the following specifications.***

- *Minimum operating voltage when the tube light or compact fluorescent light (CFL) will still strike shall be less than 85% of the rated voltage.*
- *Ballasts must ensure safe and regulated ignition in the voltage range from –15% to +25% of the nominal voltage (10.3 V to 15 V for 12 V battery).*
- *Maximum continuous operating voltage without damage to the circuit must be at least 125% of the rated voltage.*
- *The minimum operating frequency should be 20 kHz and the wiring length from the inverter to the fluorescent light bulb must be kept short to minimize radio interference.*
- *Ballasts must ensure safe and regulated ignition in the voltage range from –15% to +25% of the nominal voltage (10.3 V to 15 V for 12 V batteries).*
- *Ballasts must ensure safe and regulated ignition in the range of ambient temperature from 0 ºC to +40oC.*
- *The electrical waveform on the fluorescent tube terminals must be symmetrical in time to within 10 percent (i.e., 60%/40% waveform maximum difference in symmetry over the voltage range of 11.0 to 12.5 V DC at an ambient temperature of 25 degrees C).*
- *The maximum crest factor (ratio of maximum peak to RMS voltage of the waveform applied to the fluorescent tube light) shall be less than 2)*
- *Lenses, covers, grids etc. (if used) must be easily removable by the user for bulb replacement or for cleaning.*
- *No blackening or reduction in the lumen output by more than 10% should be observed after 1,000 ON/OFF cycles (two minutes ON and four minutes OFF is one cycle).*
- *The luminous efficacy of the light, inclusive of the power requirement of the inverter, must be either:*
  - *(a) greater than 30 lumens/watt with any reflectors, lenses, covers or grids (if used) in place; or*
  - *(b) greater than 35 lumens/watt without reflectors, lenses, etc in place.*

- *Light fittings must be insect proofed and corrosion and weather protected.*
- *Light fittings must be marked with the manufacturer, model number, rated operating voltage, rated current and date of manufacture or batch number.*

- *Ballasts must be protected against destruction when:*
  - *The lamp is removed during operation or the ballasts are operated without the lamp.*
  - *The lamp does not ignite.*
  - *The supply voltage is reverse-poled.*
  - *The outputs of the electronic ballast are short circuited.*

- *Ballasts must not produce radio frequency interference.*
- *The consumption of ballasts when they are operated without lamps must be lower than 20% of their nominal power.*
- *Minimum DC power requested at the ballasts input must be 90% of the nominal value of the lamp, in all the range of the operating voltage (-15% to +25% of the nominal value .*
- *The simultaneous use of both fluorescent and low power (< 2W) incandescent lamps should be allowed, as long as the total design load consumption is not exceeded.*
- *The luminous efficiency could be increased adding reflectors to the bulb mountings.*

Socket Outlet

- *A 12 V DC socket outlet for a TV or similar appliance shall be provided for systems having a capacity of 30 Wp or more. The outlet must be rated to carry the maximum expected DC current. The outlet must be protected from reversing the polarity of the voltage applied to the appliance. An optional 6/9V outlet for use with radio/cassette player is recommended.*

3.7 The Wiring

Relatively low voltages and high currents are characteristics of SHSs, so even small voltage losses tend to be important, and can negatively affect the current from PV generators (an increase in operating voltage moves the operating points towards the low-current region of the I-V curve of the PV generators),

Therefore,

- ***The sections of cables must cause less than 3% of voltage losses between PV modules and charge regulator, less than 1% between battery and charge regulator, and less than 5% between charge regulator and load. All of these apply at the maximum current condition.***
- ***Notwithstanding the above maximum voltage requirements, the minimum acceptable cross-section of the wire in each of the following sub-circuits is as follows:***
    - ***from PV module to charge regulator: 2.5 mm^2***
    - ***from charge regulator to battery: 2.5 mm^2***
    - ***from charge regulator to intermediate junction point/switch on the way to load 2.5 mm^2***
    - ***from junction point to the load 1.5mm^2***

Table 3.7.1: Number of Users Found in the Sample Universe of SHS with Different Types of Wire Gauges for Installation

Connection	**SHS with 4 mm^2**	**SHS with 2.5 mm^2**	**SHS with 1.5 mm^2**	**SHS with <=1 mm^2**	**Total SHS**
PV module to charge regulator	8	15	5	0	28
charge regulator to battery	5	17	6	0	28
charge regulator to intermediate junction/switch	0	21	7	0	28
from junction point to the load	0		26	2	28

- *External cables must be specifically adapted to outdoor exposure according to the international standard.*
- *All cable terminals must allow for a secure and mechanically strong electrical connection. They must have low electrical resistance; leading to voltage losses less than 0.5% of the nominal voltage. This applies for each individual terminal at the maximum current condition.*
- *Cable terminals should not be prone to corrosion arising from junctions or dissimilar metals.*
- *Field-installed wiring must be joined using terminal strips or screw connectors. Soldering or crimping in the field must be avoided if at all possible. Wire nuts are not allowed. The rated current carrying capacity of the joint must not be less than the circuit current rating. All connections must be made in junction boxes. Fittings for lights, switches, and socket outlets may be used as junction boxes where practical.*
- *All wiring shall be colour coded and/or labelled.*
- *All exposed wiring (with the possible exception of the module interconnects) must be in conduits or be firmly fastened to the building structure with wiring clips with a span between them of 6"~8". Wiring through roofing, walls and other structures must be protected through the use of bushings. Wiring through roofing must form a waterproof seal. Where the wiring is through flammable material (e.g. thatched roofs), they must be in a metal conduit. Adequate fasteners, conduits, bushings and other installation hardware must be supplied.*
- *It is recommended to carryout a full inspection of the wiring of the SHS by a competent technician once in one year. Through this identification of loose connections, open circuits, potential short circuits, rodent damage, insulation failure…etc if any could be identified and rectified.*

3.8 Safety

Concerning users' safety, SHSs offer the advantage of low voltage (typically 12 V) and the disadvantage of the existence of a battery, which has very high short-circuit power, contains sulphuric acid, and releases inflammable gases. To avoid the associated risks, it is appropriate to meet the following requirements:

• ***Both battery and charge regulator must be protected against over-currents and short-circuit currents by the placement of fuses, diodes, etc. in both PV generator and load lines.***

Over-current and short-circuit protection can be practically implemented in several ways (fuses, diodes, etc.) and may or may not be built into the regulator box. In either case, such protection should be considered as a part of the charge regulator and the requirements concerning voltage drops that have been proposed earlier under specifications for charge regulators.

Battery accidents can result from tipping over the battery and its container –if used–, or any accidental placement of an electrical conductor, such as a screw driver or spanner, across the battery terminals.

Concerning the mounting and location of batteries, the following requirements apply:

- ***The battery must be located in a well ventilated space with restricted access.***
- ***Provisions must be taken to avoid accidental short circuit of the battery terminals.***

Both of these requirements can be met in several ways. Dedicated battery cases are being extensively used in Sri Lanka and many other Asian countries. These have the advantages of being standardised products which are quick to install, but they add to the cost of SHSs, and may represent an intrusion into the house which users find difficult to accept.

- ***In regions with frequent storms, manual isolation of both the positive and negative poles should be installed on the PV side, so that the PV generator can be isolated when there is a risk of lightning strikes.***

Finally, to avoid shock hazards when changing fluorescent lamps:

- ***Electrodes of ballasts must never be connected to lighting fixtures.***

3.9 Energy Performance

The energy performance of a SHS should be judged by the reliability of its electricity supply to the load, and the efficiency with which it uses the electricity from the PV generator. Both aspects are essentially related to system size, component efficiencies and consumers' use.

Reliability can be quantified in terms of *Loss of Load Probability* (*LLP*), which is the probability of getting a blackout caused by a lack of solar radiation availability. Due to the random nature of solar radiation the value of *LLP* is always greater than zero, even if the PV system never breaks down. Obviously, for a given load, the bigger the PV system, the lower the *LLP* and the higher the reliability.

The *Performance Ratio (PR)* quantifies how well the energy from the PV generator is used. It is defined as: "useful energy supplied to the load" divided by "the maximum theoretical energy which the PV generator can produce". This includes all of the losses occurring in the PV generator (cell temperature, mismatching, etc.), the losses from the rest of the system (self consumption of the charge regulator, battery efficiency, etc.) and also the available energy which is not consumed by the users. Obviously, a PV system which is "too big" can deliver much more energy than the users require, and this leads to energy waste and low *PR* values.

3.10 Reliability and Sizing

The size of a PV- system is a general concept which involves the dimensions of the PV-array and the battery, and it is useful to define these dimensions relative to the load. The sizes of the generator and the battery are simply obtained from rules of thumb based on previous experience. Widely used rules of thumb are:

• The size of the PV generator should be chosen to ensure that the energy produced during the worst month can, at least, equal the demand of the load.
• The useful capacity of the battery (nominal capacity multiplied by the maximum depth of discharge) should allow for a three to five day period of autonomy.
• In cases where manual tracking is provided, the estimated surplus in collected irradiation should not be considered for sizing purposes.

3.11 Energy Efficiency

An ideal PV system operating with its modules at 25oC throughout the day would have a *Performance Ratio* of 100%, and the reasons why real operating values will be lower than this (typically about 60%) are:

- Array losses (shadowing, cell temperature higher than 25oC, mismatch, losses in cables, operating voltage different from that corresponding to the maximum power point)
- System losses (charge regulators, batteries, and cables)
- Poor use of the available energy

Array losses are minimised by careful installation (module ventilation and suitable cable sizes) and by using PV modules whose electrical characteristics are well adapted to the task of charging batteries in the particular climate concerned. System losses are minimised by using low consumption regulators and good quality batteries. The following requirements are therefore proposed:

- ***The PV generator must be entirely free of shadows during, at least, 8 hours per day, centred at noon, all through the year.***
- ***With an irradiance of 800 W/m2, the maximum power voltage of the PV generator at the annual maximum ambient temperature of the site $V_{MAX}(T_{MAX})$ should lie between 14.5 and 15 V.***

This requirement ensures that the current from the PV generator is greater than the maximum power current for most of the time, provided that the requirements concerning voltage drops in the wires and charge regulator are also met.

It should be mentioned that specifications issued by the World Bank sometimes impose the exclusive use of PV modules with no less than 36 series connected solar cells. However, this appears to be rather a conservative approach. In fact, PV modules with 32 and 33 solar cells are being used in many places without problems, providing the voltage losses in the charge regulator and wiring are kept low. Hence,

- ***The freeloading electrical consumption of the charge regulator in normal operation must not exceed the 3% of the foreseen daily consumption.***

This requirement for the freeloading electrical consumption of the regulator is generally accepted. However, existing technology allows for still less charge regulator consumption, so it is also possible to consider:

- ***The freeloading electrical consumption of the charge regulator in normal operation should not exceed the 1% of the foreseen daily consumption.***

3.12 User Friendliness

SHSs are rather simple. Generally, their users do not face significant difficulties to learn the right way to use them, once they properly understand the intrinsic limitation of energy availability. Information displayed by the charge regulator can also help with this.

Regulators which display information on electrical parameters (charging current, battery voltage, etc.) have been extensively used in the past. Nowadays, however, it is widely accepted that this is not very useful. When the supply is cut off, the most important information for users is to know whether this was due to equipment failures or to exhaustion of energy availability.

Further, in order that users can adopt energy saving procedures in advance, it is also useful to indicate the level of risk that the battery will soon be disconnected from the load due to low energy availability. For this, a simple two or three level display can be mounted on the charge regulator to show the state of charge of the battery. It is therefore proposed that the following approach be adopted:

- ***If the load can be used without any restriction, then the battery state of charge should be indicated by means of visual indicator/s..***
- ***If the battery has been disconnected from the load because its state of charge is too low, then this is indicated by a red signal.***
- ***If there is a risk that the battery will soon be disconnected from the load, then it should be indicated by a audio and visual indication.***

It is worth mentioning that many existing regulators provide additional information, which is mainly of use to maintenance personnel. Experience suggests that most users should not have to carry out any task other than cleaning the PV modules. There are worrying examples of what can happen when other maintenance tasks are left to the users. Each rural community, or similar, should have a person who is responsible for primary maintenance (failure diagnostics, replacing fuses, modifying the wiring, etc.), and they must be previously trained. Any additional information from regulators should be addressed to them, and therefore adapted to their skills and role in the maintenance scheme.

3.13 Installation and Maintenance

SHSs should preferably be understood as turn-key systems, which are fully installed and operating before being handed over to their users. After handing over main maintenance works of the system is carried out by the vendor who supplied the SHS.

SHS maintenance tasks which can be carried out directly on site are: cleaning of PV modules, modifying the wiring, topping up of battery water levels, and the substitution of fuses, lamps and charge regulators. To help with this, and also to simplify initial installation of the SHS, it is appropriate to require that:

- ***Support structures must be mounted to allow easy access for PV module cleaning and connection boxes inspection.***
- ***Support structures must be mounted such that their resistance to corrosion, fatigue and wind are preserved.***
- ***If roof mounting is done, support structures should not be fixed onto roofing sheets, but to a roof beam or an integral part of the structure of the house.***
- ***The battery should be placed in an easily accessible location (Note: access should normally be restricted, for example by means of a locked door.)***
- ***It is recommended to do routine service visit once in four months i.e. three times a year or at least once in six months i.e. two times a year compulsorily by a trained technical personnel.***

"Easily accessible" means that cleaning of the battery terminals, checking the level of electrolyte, topping up the water levels and replacing fuses (if existing) can be easily done without moving the battery.

- ***Charge regulators and lamps must be provided with suitable mounting brackets / fixings (installation must be relatively simple).***
- ***Charge regulators and lamps must be designed in such a way that access to fuses***

and wiring terminals is relatively easy

- *Lamp lenses, covers grids, etc. (if used) must be insect proof.*
- *Lamp lenses, covers grids, etc. (if used) must be easily removable by the users for bulb replacement or for cleaning.*
- *All fluorescent tubes must be available locally.*
- *Tooling requirements must be minimised (avoid different bolt / screw sizes, etc.)*

Finally, all the wiring should be installed in compliance with the state of the art. In particular

- ***Cables must be secured to support structures or walls to fully avoid mechanical forces on other elements (connection boxes, ballasts, switches, etc)***
- ***Cables must be stapled into the wall at appropriate intervals (6"~8" span is recommended) to secure them both horizontally and vertically if exposed, otherwise they should be buried, or taken through conduits and casings or recessed and plastered into walls.***
- ***Cables must be kept out of reach of small children.***
- ***In general, all cable lays must be horizontal or vertical, never oblique.***

3.14 Flexibility

On the assumption that all the above mentioned requirements are fulfilled, it is also important that a SHS would be designed in a flexible way such that any component can be substituted by a similar component from another supplier or by a technically improved component from the same supplier. Flexibility in terms of system sizing is also important. For this, special attention needs to be paid to the possibility of enlarging a SHS by increasing the size of its PV generator or its battery. The compatibility of the battery and regulator is also a key issue.

PV modules of identical nominal voltage can be connected in parallel without any restriction, so when PV generators are enlarged it is only necessary to check wiring sizes and the ability of the regulator to manage the increased value of the maximum current.

To enlarge the storage capacity of a SHS it is necessary to replace the complete former battery with a new one, because parallel connections of old and new batteries are never satisfactory. It should be mentioned that specifications from the World Bank typically allow up to two identical batteries to be connected in parallel, though they also indicate that only one is preferable, and some battery manufacturers agree with this opinion. Hence, the following points need to be stressed :

- ***Parallel connections of more than two batteries are not permitted.***
- ***Parallel connections of different batteries are not permitted.***
- ***Parallel connections of old and new batteries are not permitted.***

Chapter 4

Solar PV Home Systems Installation Guideline

4.0 Introduction

Field experience with PV rural electrification has shown that the performance of solar home systems SHSs is not always entirely satisfactory. However, in-depth studies of the problems encountered in existing installations have revealed that the pure solar part, i.e. the PV generator, rarely fails. The PV system is often initially blamed for the failure but, when things go wrong, it is usually the other PV system components or the appliances which are powered by the PV generator which are found to have failed. This is mainly because, while PV modules are highly standardized and certified using internationally validated procedures, there are no equivalent standards and procedures available for balance-of-system components, component matching or installation quality, even though the quality of these components has a dramatic influence on user satisfaction and operating costs.

This guideline results from work which has been done as a research thesis of the author and is designed to form the basis for a basic guideline for Solar PV Home Systems (SHS). In preparing this report, each of the different approaches has been assessed using scientific reasoning, empirical evidence and the personal experience of the authors. To a large extent, the guideline proposed here can therefore be considered as general guideline, because each of the existing literature has provided extremely valuable inputs.

This proposed guideline is intended to provide a basis for technical quality assurance procedures, to the extent that meeting the specified requirements will produce a SHS that will perform adequately. In particular, it is intended to provide a quality reference for procurement specifications issued by government grants, financial investors and even the INGO's or NGO who wish to give these systems to underprivileged. In addition, it is intended to be useful as a design guideline for SHS manufacturers and installers.

The guideline is as follows, it has been divided in to SHS main components and other important areas which the researcher felt important.

4.1 PV Generator (PV Module)

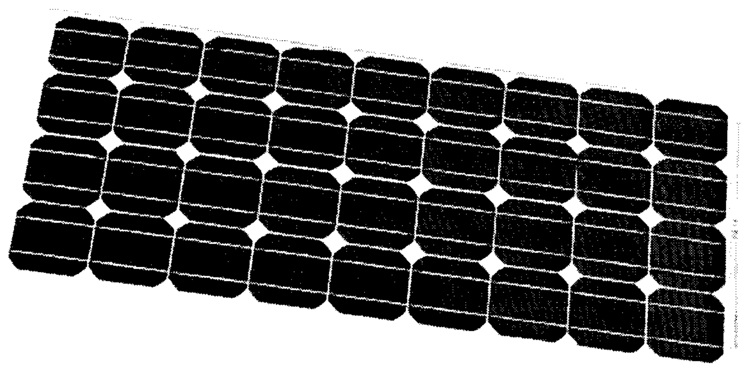


Figure 4.1.1: Typical Crystalline Solar PV Module with 36 cells

Solar modules are generally flat panels mounted on roofs or other structures. Solar modules convert energy from sunlight into direct current (DC) electricity. There are few types of solar module types which differ in its operating characteristics due to its construction in its cells. The types available are as follows;

- Crystalline silicon
- Thin film
- Compounds
- Dye sensitized plastic.

However, only crystalline and thin film technology is commercially available for usage. When selecting the PV module it is vital to know how efficient it is. Crystalline solar PV modules are efficient enough to be utilized in a SHS installation and it is not that expensive either. Therefore, it is recommended to use crystalline PV solar modules for SHS installations and to avoid other types. If required the second best option of thin film PV modules could be utilized, but recommended to avoid same if it is possible to afford crystalline ones. The PV modules also should comply with following guidelines;

PV Module Selection

- Single-crystalline or poly-crystalline PV modules certified according to the international standard IEC-61215. (R) (See over view of standard in annexure-4)
- If thin-film photovoltaic modules are used, they must be type tested and certified in accordance with IEC 61646 (See over view of standard in annexure-4) or equivalent specifications. The peak power output for thin film modules should be the value after light soaking.

Table 4.1.1: Module Type Against their Efficiencies

Module Type	Laboratory Efficiencies	Pilot Production Efficiencies (%)	Production Efficiencies (%)
Crystalline Silicon - Single Crystalline - Multi-Crystalline (poly)	24 20		13 – 16 12 – 15
Thin-Film - Amorphous Silicon - CdTe - $Cu(InGa)Se_2$	14 16 19	 7 – 10 10 – 12	5 – 8

- To be eligible for government grant schemes the photovoltaic array should consist of one or more flat-plate photovoltaic modules. Each module should comprise no less than 36 series-connected single or poly-crystalline silicon solar cells. Flat plate thin-film modules could also be used. If more than one module is used, identical models shall be used and they shall be connected in parallel.
- Each module must be clearly marked indicating: Manufacturer, Model Number, Serial Number, Peak Watt Rating, Peak Current, Peak Voltage, Open Circuit Voltage and Short Circuit Current of each module (this is to safeguard the end user from the vendor in event the vendor abandon and leave the end user, the end user could contact the manufacturer to obtain warranty claims or technical support from the module manufacturer).

PV Module Installation

- The module junction box must be sealable and moisture resistant may it be installed on the module back or on the support structure.
- The modules must be framed in such a way as to allow secure connection to the module mounting structure.

PV Module Maintenance

- It is suggested that the PV Module be cleaned with water and soap once in two months least to prevent the module being in efficient due to dirt and dust residual on it as time passes. In dry seasons when dust is more this frequency could be increased.

4.2 Support Structure for PV Module

Figure 4.2.1: Pictures Depicting Module Support Structures

The PV module could be mounted in few ways. However, in what ever method it is required to fix the module aligned to north to south. And tilted a bit to let the rain water to flow out, and to be perpendicular to the suns movement. Usually this alignments and direction is obtained in Sri Lanka with the module support. The module support assembly usually comprise of two main parts. One is the framework which is fixed to the module and it also makes the connection with the support pole.

It is noted that the pole which is used is always GI in Sri Lanka and has the capability of withstanding the environmental negative effects. However, it is noted that the module support framework is fabricated from both Aluminium as well as mild steel in Sri Lanka. However, mild steel does withstand the environment as much as Aluminium, therefore it is recommended to use Aluminium framework along with GI pole. There are possibilities of using galvanized iron, stainless steel frameworks, but is quite expensive than the two solutions available locally. There also instances where treated wood is being used in some countries where it is less humid, however this solution would not be feasible to our country.

The suggested module support assembly guideline would be as follows;

PV Module Support Structure Selection

- Support structures should be able to resist, at least, 10years of outdoor exposure without appreciable corrosion or fatigue.
- Several materials can be used for support structures, including stainless steel, aluminium, galvanised iron with a protective layer provided that above requirements are satisfied.
- Support structures must withstand winds of 100 km/h.

PV Module Support Structure Installation

- In the case of framed PV modules, only stainless steel fasteners (screws, nuts, rings, etc.) may be used for attaching them to support.
- Tilt angle should be selected to optimise the energy collection during the worst month, i.e., the month with the lowest ratio of monthly mean daily irradiation to the monthly mean daily load. Generally, constant user load can be assumed. Then, the following formula can be used

Tilt (^{o}) = max {|Φ|}+ 10°

where Φ is the latitude of the installation.

Note : Sri Lanka's latitude changes around + 4° from south to north (From Point Devundara to Point Pedro). Therefore, it is safe to use the tilt angle as 12° (10 ° + 2 °) on average as a rule of thumb.

- Static support structures are generally preferable to tracking-ones
- For static support structures where the PV array is roof mounted anchoring of the mounting structure must be to the building and not to the roofing material. And it is necessary to have at least 10 cm clearance between the PV array and the roofing material.

Figure 4.2.2: A typical Pole Mounted Solar PV Module

- And for static support structures where the PV array is pole mounted (Figure 4.2.2), the module/s should be attached to the top of the pole at least 4M off the ground.

PV Module Support Structure Maintenance

- The panel/s should be mounted clear of vegetation, trees and structure so as to assure that they are free of shadow throughout day light hours during each season of the year. Furthermore, if more than one panel is mounted on a support structure the panels should not be mounted such that one panel will not shade the other module(s). Therefore, the user of the system should make sure that the module/s is not shaded by vegetation and same is cleared off as and when required.

4.3 Battery

Figure 4.3.1: Picture of a Tubular Deep Cycle Solar Battery Available in Sri Lanka

For the battery, the most important feature of its operation in SHSs is cycling. During the *daily cycle*, the battery is charged during the day and discharged by the night-time load. Superimposed onto the daily cycle is the *seasonal cycle,* which is associated with periods of reduced radiation availability. This, together with other operating parameters (ambient temperature, current, voltages, etc.) affects the battery life and maintenance requirements. In order to maximise the lifetime of lead acid batteries, the following operating conditions must be avoided:

- High voltages during charging (to prevent against corrosion and loss of water)

- Low voltages during discharge (corrosion)
- Deep discharge (to avoid sulphating, growth of de-nitrites)
- Extended periods without a fully charging (to avoid sulphating)
- High battery temperatures (all ageing processes are accelerated)
- Stratification of the electrolyte (to avoid sulphating)
- Very low charge currents (to avoid sulphating)

These rules lead to specifications for sizing (both battery and PV generator) and for battery protection procedures (charge controller). Further it is required following guidelines be followed in selection, installation and maintenance of batteries.

Battery Selection

- Batteries bearing the PV GAP Mark (Global Approval Program For Photovoltaics) or having been tested and certified in accordance with PVGAP PVRS5A - Lead-acid Batteries for Solar Photovoltaic Energy Systems - General Requirements and Methods of Test for Modified Automotive Batteries, or equivalent or better standard, will be accepted. Also accepted are tubular plate batteries tested and certified in accordance with Indian Standard IS 13369:1992 - Stationary Lead Acid Batteries (with Tubular Positive Plates) in Monobloc Containers, or equivalent or better standard. Accepted on an interim basis are flat plate batteries tested and certified in accordance with BS EN 50342:2001 - Lead-acid Starter Batteries; General Requirements, Methods of Test and Numbering (which supersedes BS EN 60095-1:1993), or equivalent or better standard.
- The maximum permissible self discharge rate is 10 percent of rated capacity per month at 25°C is allowed.
- Cycle life of the battery (i.e., before its residual life drops below 80 percent of the rated Ah capacity), at 25°C must exceed 200 cycles when discharged down to an average depth of discharge (DOD) of 75 percent. Certain conditions must be required for a battery to be categorised as "modified SLI", as follows:

Table 4.3.1: Selection of Batteries for a SHS Based on PV Module Capacity

Module Rating (Wp)	Average daily Ah to load at 12 V DC	(Daily Ah x 3 days of autonomy)/0.75	Minimum battery sizes (Ah) for autonomy of	
			3 days	5 days
10	3	12	12	20
20	6	24	24	40
30	9	36	36	60
40	12	48	48	80
50	15	60	60	100
60	18	72	72	120

- The thickness of each plate must exceed 2mm.
- The amount of electrolyte must exceed 1.15 l per 100 Ah of 20-hour nominal capacity and per cell.
- The separator must be made of micro-porous polythene.
- (To allow free movement & circulation of acid, but maintain insulation)
- The density of electrolyte must not exceed 1.25 g/cl.

Battery Installation

- The batteries shall be supplied to the customer in a fully charged condition ready for use. The battery and associated containers should be able to handle transport down rough dirt roads without damage

Battery Maintenance

- It is recommended that the user top up acid level of the battery/s with distal water to be at battery manufacturers indicated level as and when required.
- Check frequently if oxidation has occurred on the battery terminals frequently, clean with hot water and apply a petro-gel in order to prevent oxidation setting in again. Further clean the battery surface of any excess acid or dust in order to prevent any leakage current between the two terminals. (+ve and the – ve)

4.4 The Charge Controller

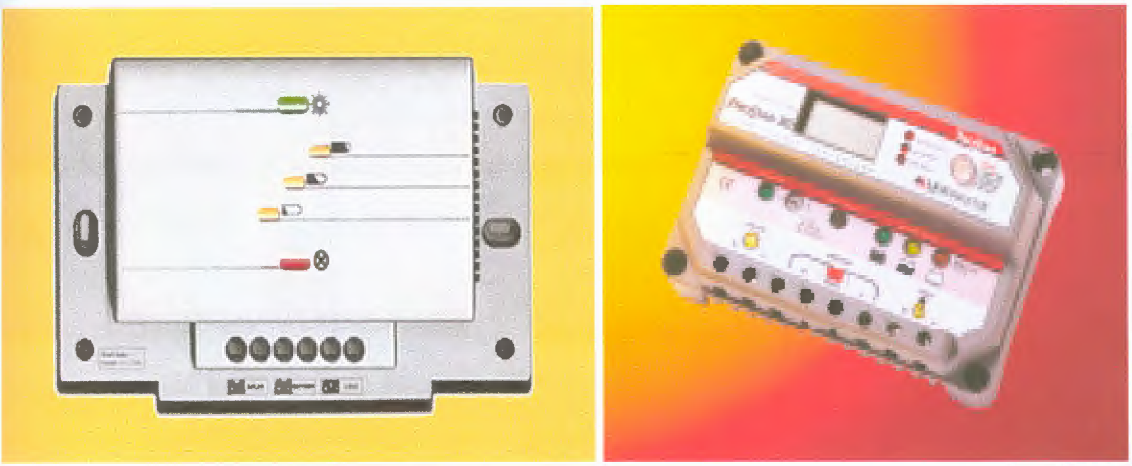


Figure 4.4.1: Typical pictures of charge regulators

The charge controller serves primarily to protect the battery against both deep discharging and overcharging. It is also used to protect the load under extreme operating conditions, and to provide operational information to the users. Ideally, charge regulation should be directly controlled by the state of charge (SOC) of the battery, and sophisticated charge regulators based on that principle are available in the current market.

However, they are still rather complex and expensive, so their use in small SHSs is scarcely justified. For this reason, only charge regulators which are based on voltage control are considered in this guideline. Following specifications are proposed here for selection, installation and maintenance of Charge Controllers:

<u>The Charge Controller Selection</u>

- The charge controller must have some type of display or an indicator to indicate when it is in the charging mode
- Some form of a battery state-of-charge indicator must be provided on or near the controller or load centre.
- Deep discharge protection must be included .
- Manual release of the deep-discharge protection is not permitted (S)
- Warning facilities must be included (R)

- "Warning" voltage (low voltage) must be 0.2V (for 12V systems) higher than the consumption disconnection voltage. For example, a disconnect voltage of 11.7 V DC + 0.1 V DC and reconnect voltage of 12.9 V DC + 0.2 V DC is suitable for safe operation of lead-acid batteries used in SHS. should be selected such that the warning signal is activated 30 minutes before "load disconnect" occurs, assuming all the
  - loads are "on"
- This device must, at a minimum, indicate when the battery condition is :
  - Suitable to operate all loads (e.g. voltage greater than 12.5 V DC)
  - Energy conservation required (e.g., battery voltage less than 11.9 V DC)
- End-of-charge voltage should lie in the range from 2.3 to 2.4 V/cell, at 25°C.
- The charge regulator must be able to resist any possible "non-battery" operating condition, when the PV generator is operating at Standard Test Conditions and with any allowed load.
- The charge regulator must also protect the load in any possible "non-battery" condition, as defined above, by limiting the output voltage to a maximum of 1.3 times the nominal value. (Full interruption of output voltage is also allowed).
- The charge regulator should allow battery charging from the PV module for any voltage greater than 1.5V/cell.
- The charge regulator must resist without damage the operating condition defined by: ambient temperature of 40°C, charging current 25% greater than the short circuit current of the PV generator at Standard Test Conditions, and discharging current 25% greater than that corresponding to the full load "on" at the nominal operating voltage.
- Battery temperature compensation circuitry is not required if flooded lead-acid batteries are used. However, if temperature compensation is not provided, then the set points must correspond to the type of battery and the ambient temperature of the site where the SHS is to be used. Temperature compensation is required if sealed lead-acid batteries are used.
- Charge regulator boxes must provide protection to at least IP 32.

  (Protection against solid objects greater than 2.5mm diameter and protected against dripping water when tilted up to 15°)

- The charge regulator must be protected against reversed polarity in both PV generator and batter y lines. Diode-fuse or other arrangements can be used.
- The model number, serial number, rated voltages and currents, set points and indicator settings should be noted on the charge regulator case.
- The charge regulator must not produce radio frequency interference in any operation conditions.
- Maximum current draw of the controller, when no LEDs are lit should not exceed 10mA.

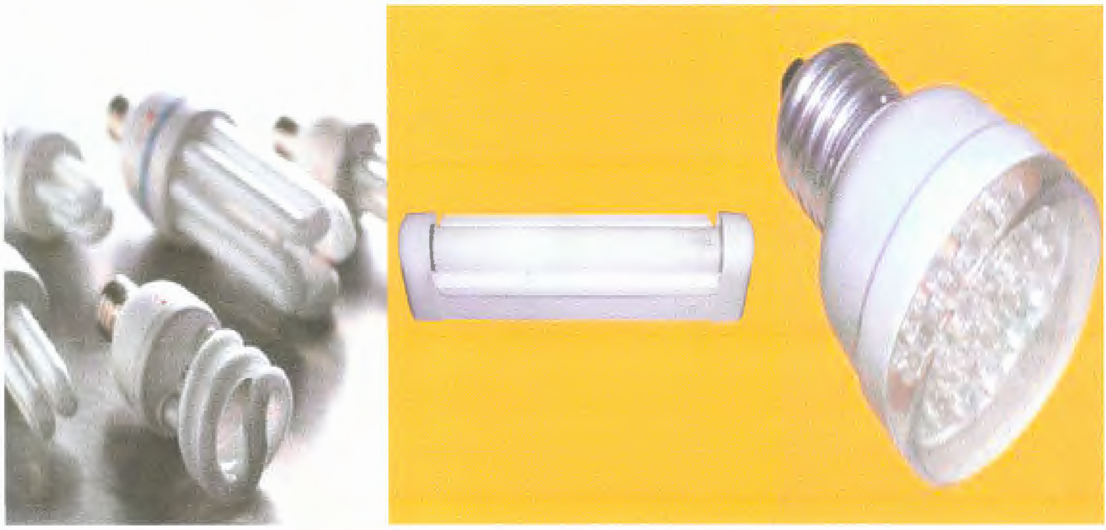
The Charge Controller Installation

- All the charge regulator terminals should easily accommodate, at least, 4 mm2 section cables.
- Internal voltage drops between the battery and generator terminals of the charge regulator must be less than 4% of the nominal voltage (≈0.5 V for 12 V) in the worst operating conditions, i.e., with all the loads "off" and the maximum current from the PV generator.
- Internal voltage drops between the battery and load terminals of the charge regulator must be less than 4% of the nominal voltage (0.5 V for 12 V) in the worst operating condition, i.e., with all the loads "on" and no current from the PV generator.
- Reverse current leakage protection must be provided.

The Charge Controller Maintenance

- The chosen device must come appropriately labelled such that the user does not have to refer to a manual to understand the existing battery condition.
- Some means must be provided to safely disconnect the battery and the module during servicing repair by a technician.
- It is recommended that a trained technical person check on the contacts/terminals of the charge controller for oxidation, loose connection and dry sold once in six months at least for proper maintenance.

4.5 The Lighting (Loads are Mainly Lighting)



CFL's ***Fluorescent*** ***LED's***

Figure 4.5.1: Pictures of typical light loads available in SHS in Sri Lanka

Typical loads in SHSs are lamps, radios and black and white TV-sets. And lighting usually represents a substantial part of the total energy consumption of the house. Lamps are usually included in SHSs kits, but they have not yet been widely standardised. In contrast, radios and TV-sets are directly acquired by the users from the conventional appliances market, their energy consumptions tend to be modest and they are highly standardised products. For these reasons, only lamps are reviewed in this guideline, while information concerning radios and TV-sets (low standby losses, protection against reverse voltage, required voltage, etc.) are entrusted to training and general information activities in the industry.

The requirements proposed here are as follows for loads are as follows:

<u>The Lighting Selection</u>

- Fluorescent lamps are recommended due to their higher efficiency for area or task lighting applications, but LED or halogen lamps may be used for special purpose applications such as night lights. If fluorescent lamps are to be used, they must meet the following specifications.

- Minimum operating voltage when the tube light or compact fluorescent light (CFL) will still strike shall be less than 85% of the rated voltage.
- Ballasts must ensure safe and regulated ignition in the voltage range from –15% to +25% of the nominal voltage (10.3 V to 15 V for 12 V batteries).
- Maximum continuous operating voltage without damage to the circuit must be at least 125% of the rated voltage.
- Ballasts must ensure safe and regulated ignition in the voltage range from –15% to +25% of the nominal voltage (10.3 V to 15 V for 12 V batteries).
- Ballasts must ensure safe and regulated ignition in the range of ambient temperature from 0 °C to +40oC.
- The electrical waveform on the fluorescent tube terminals must be symmetrical in time to within 10 percent (i.e., 60%/40% waveform maximum difference in symmetry over the voltage range of 11.0 to 12.5 V DC at an ambient temperature of 25 degrees C).

- The maximum crest factor (ratio of maximum peak to RMS voltage of the waveform applied to the fluorescent tube light) shall be less than 2.
- No blackening or reduction in the lumen output by more than 10% should be observed after 1,000 ON/OFF cycles (two minutes ON and four minutes OFF is one cycle).
- The luminous efficacy of the light, inclusive of the power requirement of the inverter, must be either:
  - (c) greater than 30 lumens/watt with any reflectors, lenses, covers or grids (if used) in place; or
  - (d) greater than 35 lumens/watt without reflectors, lenses, etc in place.
- Light fittings must be insect proofed and corrosion and weather protected.
- Light fittings must be marked with the manufacturer, model number, rated operating voltage, rated current and date of manufacture or batch number.
- Ballasts must not produce radio frequency interference.

- *The consumption of ballasts when they are operated without lamps must be lower* than 20% of their nominal power.
- Minimum DC power requested at the ballasts input must be 90% of the nominal value of the lamp, in all the range of the operating voltage (-15% to +25% of the nominal value.)
- The simultaneous use of both fluorescent and low power (< 2W) incandescent lamps should be allowed, as long as the total design load consumption is not exceeded.
- The luminous efficiency could be increased adding reflectors to the bulb mountings.

The Lighting Installation

- The minimum operating frequency should be 20 kHz and the wiring length from the inverter to the fluorescent light bulb must be kept short to minimize radio interference.

The Lighting Maintenance

- Lenses, covers, grids etc. (if used) must be easily removable by the user for bulb replacement or for cleaning.
- Ballasts must be protected against destruction when:
    - The lamp is removed during operation or the ballasts are operated without the lamp.
    - The lamp does not ignite.
    - The supply voltage is reverse-poled.
    - The outputs of the electronic ballast are short circuited.

Socket Outlet

- A 12 V DC socket outlet for a TV or similar appliance shall be provided for systems having a capacity of 30 Wp or more. The outlet must be rated to carry the maximum expected DC current. The outlet must be protected from reversing the polarity of the voltage applied to the appliance. An optional 6/9V outlet for use with radio/cassette player is recommended.

4.6 The Wiring

The Wiring Selection

- The sections of cables must cause less than 3% of voltage losses between PV modules and charge regulator, less than 1% between battery and charge regulator, and less than 5% between charge regulator and load. All of these apply at the maximum current condition.
- Notwithstanding the above maximum voltage requirements, the minimum acceptable cross-section of the wire in each of the following sub-circuits is as follows:
  - from PV module to charge regulator: 2.5 mm^2
  - from charge regulator to battery: 2.5 mm^2
  - from charge regulator to intermediate junction point/switch on the way to load 2.5 mm^2
  - from junction point to the load 1.5mm^2

Table 4.6.1: Recommended Wire Cross-Sections for Each Section of SHS Installations

Connection	**SHS with 2.5 mm^2**	**SHS with 1.5 mm^2**
PV module to charge regulator	X	
charge regulator to battery	X	
charge regulator to intermediate junction/switch	X	
from junction point to the load		X

Note : 2.5 mm^2 stands good up to module capacity of 60W. Thereafter, it is necessary to use 4 mm^2.

- External cables must be specifically adapted to outdoor exposure according to the international standard.

The Wiring Installation

- All cable terminals must allow for a secure and mechanically strong electrical connection. They must have low electrical resistance; leading to voltage losses less than 0.5% of the nominal voltage. This applies for each individual terminal at the maximum current condition.
- Field-installed wiring must be joined using terminal strips or screw connectors. Soldering or crimping in the field must be avoided if at all possible. Wire nuts are not allowed. The rated current carrying capacity of the joint must not be less than the circuit current rating. All connections must be made in junction boxes. Fittings for lights, switches, and socket outlets may be used as junction boxes where practical.
- All wiring shall be colour coded and/or labelled.
- All exposed wiring (with the possible exception of the module interconnects) must be in conduits or be firmly fastened to the building structure with wiring clips with a span between them of 6"~8". Wiring through roofing, walls and other structures must be protected through the use of bushings. Wiring through roofing must form a waterproof seal. Where the wiring is through flammable material (e.g. thatched roofs), they must be in a metal conduit. Adequate fasteners, conduits, bushings and other installation hardware must be supplied.

The Wiring Maintenance

- Cable terminals should not be prone to corrosion arising from junctions or dissimilar metals.
- It is recommended to carryout a full inspection of the wiring of the SHS by a competent technician once in one year. Through this, identification of loose connections, open circuits, potential short circuits, rodent damage, insulation failure…etc if any could be identified and rectified.

4.7 Safety

- Both battery and charge regulator must be protected against over-currents and short-circuit currents by the placement of fuses, diodes, etc. in both PV generator and load lines.
- The battery must be located in a well ventilated space with restricted access.
- Provisions must be taken to avoid accidental short circuit of the battery terminals.
- In regions with frequent storms, manual isolation of both the positive and negative poles should be installed on the PV side, so that the PV generator can be isolated when there is a risk of lightning strikes.
- Electrodes of ballasts must never be connected to lighting fixtures.

4.8 Reliability and Sizing

- The size of the PV generator should be chosen to ensure that the energy produced during the worst month can, at least, equal the demand of the load.
- The useful capacity of the battery (nominal capacity multiplied by the maximum depth of discharge) should allow for a three to five day period of autonomy.
- In cases where manual tracking is provided, the estimated surplus in collected irradiation should not be considered for sizing purposes.

4.9 Energy Efficiency

- The PV generator must be entirely free of shadows during, at least, 8 hours per day, centred at noon, all through the year.
- With an irradiance of 800 W/m2, the maximum power voltage of the PV generator at the annual maximum ambient temperature of the site V_{MAX} (T_{MAX}) should lie between 14.5 and 15 V.
- The freeloading electrical consumption of the charge regulator in normal operation must not exceed the 3% of the foreseen daily consumption. .
- The freeloading electrical consumption of the charge regulator in normal operation should not exceed the 1% of the foreseen daily consumption. .

4.10 User Friendliness

- If the load can be used without any restriction, then the battery state of charge should be indicated by means of visual indicator/s.
- If the battery has been disconnected from the load because its state of charge is too low, then this is indicated by a red signal .
- If there is a risk that the battery will soon be disconnected from the load, then it should be indicated by a audio and visual indication .

4.11 Installation and Maintenance

- Support structures must be mounted to allow easy access for PV module cleaning and connection boxes inspection.
- Support structures must be mounted such that their resistance to corrosion, fatigue and wind are preserved
- If roof mounting is done, support structures should not be fixed onto roofing sheets, but to a roof beam or an integral part of the structure of the house The battery should be placed in an easily accessible location (Note: access should normally be restricted, for example by means of a locked door).
- It is recommended to do routine service visit once in four months i.e. three times a year or at least once in six months i.e. two times a year compulsorily by a trained technical personnel.
- Charge regulators and lamps must be provided with suitable mounting brackets fixings.
- Charge regulators and lamps must be designed in such a way that access to fuses and wiring terminals is relatively easy.
- Lamp lenses, covers grids, etc. (if used) must be insect proof.
- Lamp lenses, covers grids, etc. (if used) must be easily removable by the users for bulb replacement or for cleaning.
- All fluorescent tubes must be available locally.
- Tooling requirements must be minimised (avoid different bolt / screw sizes, etc.)
- Cables must be secured to support structures or walls to fully avoid mechanical forces

on other elements (connection boxes, ballasts, switches, etc)

- Cables must be stapled into the wall at appropriate intervals to secure them both horizontally and vertically if exposed, otherwise they should be buried or recessed and plastered into walls.
- Cables must be kept out of reach of small children. In general, all cable lays must be horizontal or vertical, never oblique. .

4.12 Flexibility

Parallel connections of more than two batteries are not permitted .

- Parallel connections of different batteries are not permitted.
- Parallel connections of old and new batteries are not permitted .

4.13 Summery of Vital/Salient Features of SHS Not to Be Violated

PV Generator (PV Module)

- Single-crystalline or poly-crystalline PV modules certified according to the international standard IEC-61215. (R) (See over view of standard in annexure-4)
- If thin-film photovoltaic modules are used, they must be type tested and certified in accordance with IEC 61646 (See over view of standard in annexure-4) or equivalent specifications. The peak power output for thin film modules should be the value after light soaking.
- Each module must be clearly marked indicating: Manufacturer, Model Number, Serial Number, Peak Watt Rating, Peak Current, Peak Voltage, Open Circuit Voltage and Short Circuit Current of each module (this is to safeguard the end user from the vendor in event the vendor abandon and leave the end user, the end user could contact the manufacturer to obtain warranty claims or technical support from the module manufacturer).
- The module junction box must be sealable and moisture resistant may it be installed

on the module back or on the support structure.

- The modules must be framed in such a way as to allow secure connection to the module mounting structure.

Support Structure for PV Module

- Support structures should be able to resist, at least, 10years of outdoor exposure without appreciable corrosion or fatigue.
- In the case of framed PV modules, only stainless steel fasteners (screws, nuts, rings, etc.) may be used for attaching them to support.
- Tilt angle should be selected to optimise the energy collection during the worst month, i.e., the month with the lowest ratio of monthly mean daily irradiation to the monthly mean daily load. Generally, constant user load can be assumed. Then, the following formula can be used

$$\text{Tilt}\,(^{\circ}) = \max\{|\Phi|\} + 10^{\circ}$$

where Φ is the latitude of the installation.

Note : Sri Lanka's latitude changes around + 4° from south to north (From Point Devundara to Point Pedro). Therefore, it is safe to use the tilt angle as 12° (10 ° + 2°) on average as a rule of thumb.

Battery

- Batteries bearing the PV GAP Mark (Global Approval Program For Photovoltaics) or having been tested and certified in accordance with PVGAP PVRS5A - Lead-acid Batteries for Solar Photovoltaic Energy Systems - General Requirements and Methods of Test for Modified Automotive Batteries, or equivalent or better standard, will be accepted. Also accepted are tubular plate batteries tested and certified in accordance with Indian Standard IS 13369:1992 - Stationary Lead Acid Batteries (with Tubular Positive Plates) in Monobloc Containers, or equivalent or better standard. Accepted on an interim basis are flat plate batteries tested and certified in accordance with BS EN 50342:2001 - Lead-acid Starter Batteries; General Requirements, Methods of Test and Numbering (which supersedes BS EN 60095-1:1993), or equivalent or better standard.

The Charge Controller

- The charge controller must have some type of display or an indicator to indicate when it is in the charging mode
- Some form of a battery state-of-charge indicator must be provided on or near the controller or load centre.
- Deep discharge protection must be included .
- This device must, at a minimum, indicate when the battery condition is :
    - Suitable to operate all loads (e.g. voltage greater than 12.5 V DC)
    - Energy conservation required (e.g., battery voltage less than 11.9 V DC)
- The charge regulator must be able to resist any possible "non-battery" operating condition, when the PV generator is operating at Standard Test Conditions and with any allowed load.
- Charge regulator boxes must provide protection to at least IP 32.
  (Protection against solid objects greater than 2.5mm diameter and protected against dripping water when tilted up to 15°)
- The charge regulator must be protected against reversed polarity in both PV generator and batter y lines. Diode-fuse or other arrangements can be used.
- The model number, serial number, rated voltages and currents, set points and indicator settings should be noted on the charge regulator case.
- All the charge regulator terminals should easily accommodate, at least, 4 mm2 section cables.
- Reverse current leakage protection must be provided.

The Lighting (Loads are Mainly Lighting)

- Minimum operating voltage when the tube light or compact fluorescent light (CFL) will still strike shall be less than 85% of the rated voltage.
- Ballasts must ensure safe and regulated ignition in the voltage range from –15% to +25% of the nominal voltage (10.3 V to 15 V for 12 V batteries).
- Maximum continuous operating voltage without damage to the circuit must be at least 125% of the rated voltage.
- Ballasts must ensure safe and regulated ignition in the voltage range from –15% to +25% of the nominal voltage (10.3 V to 15 V for 12 V batteries).
- No blackening or reduction in the lumen output by more than 10% should be observed after 1,000 ON/OFF cycles (two minutes ON and four minutes OFF is one cycle).
- The consumption of ballasts when they are operated without lamps must be lower than 20% of their nominal power.
- The minimum operating frequency should be 20 kHz and the wiring length from the inverter to the fluorescent light bulb must be kept short to minimize radio interference.

Socket Outlet

- A 12 V DC socket outlet for a TV or similar appliance shall be provided for systems having a capacity of 30 Wp or more. The outlet must be rated to carry the maximum expected DC current. The outlet must be protected from reversing the polarity of the voltage applied to the appliance. An optional 6/9V outlet for use with radio/cassette player is recommended.

The Wiring

- The sections of cables must cause less than 3% of voltage losses between PV modules and charge regulator, less than 1% between battery and charge regulator, and less than 5% between charge regulator and load. All of these apply at the maximum current condition.

- Notwithstanding the above maximum voltage requirements, the minimum acceptable cross-section of the wire in each of the following sub-circuits is as follows:
  - from PV module to charge regulator: 2.5 mm^2
  - from charge regulator to battery: 2.5 mm^2
  - from charge regulator to intermediate junction point/switch on the way to load 2.5 mm^2
  - from junction point to the load 1.5mm^2

Table 4.13.1: Recommended Wire Cross-Sections for Each Section of SHS Installations

Connection	**SHS with 2.5 mm^2**	**SHS with 1.5 mm^2**
PV module to charge regulator	X	
charge regulator to battery	X	
charge regulator to intermediate junction/switch	X	
from junction point to the load		X

Note : 2.5 mm^2 stands good up to module capacity of 60W. Thereafter, it is necessary to use 4 mm^2.

Safety

- Both battery and charge regulator must be protected against over-currents and short-circuit currents by the placement of fuses, diodes, etc. in both PV generator and load lines.
- The battery must be located in a well ventilated space with restricted access.
- Provisions must be taken to avoid accidental short circuit of the battery terminals.

Reliability and Sizing

- The size of the PV generator should be chosen to ensure that the energy produced during the worst month can, at least, equal the demand of the load.

Energy Efficiency

- The PV generator must be entirely free of shadows during, at least, 8 hours per day, centred at noon, all through the year.
- With an irradiance of 800 W/m2, the maximum power voltage of the PV generator at the annual maximum ambient temperature of the site $V_{MAX}(T_{MAX})$ should lie between 14.5 and 15 V.

User Friendliness

- If the load can be used without any restriction, then the battery state of charge should be indicated by means of visual indicator/s.
- If the battery has been disconnected from the load because its state of charge is too low, then this is indicated by a red signal .
- If there is a risk that the battery will soon be disconnected from the load, then it should be indicated by a audio and visual indication .

Installation and Maintenance

- Support structures must be mounted to allow easy access for PV module cleaning and connection boxes inspection.
- Support structures must be mounted such that their resistance to corrosion, fatigue and wind are preserved
- If roof mounting is done, support structures should not be fixed onto roofing sheets, but to a roof beam or an integral part of the structure of the house The battery should

be placed in an easily accessible location (Note: access should normally be restricted, for example by means of a locked door).

Flexibility

Parallel connections of more than two batteries are not permitted .

- Parallel connections of different batteries are not permitted.
- Parallel connections of old and new batteries are not permitted .

4.14 References

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------------------------------------ *End of Guideline* ------------------------------------

Chapter 5

Conclusions

The attempt by the researcher to develop an installation and material selection guideline has been materialized in this dissertation. The researcher did extensive field visits to SHS provided by various vendors and noted the relevant data, meanwhile he carried out a reasonable literature review on the available papers on the topic. After comparing both sources of data the researcher developed this guideline. This guideline may not be suitable for international application, but is more than adequate to cater the current era that the local solar home system (SHS) is phasing. By implementing this guideline trough the financial institutions which facilitate the purchase of these expensive systems to low income rural families and the government bodies who allow grants for these systems the standard of the SHS could be maintained and could avoid the end user being hoaxed for poor quality products and service.

And also application of this guideline will help to reduce or eliminate the poor reputation which this area of electrical engineering has been facing, due to poor material usage, installation standards and after sales maintenance. In this guideline researcher has clearly separated the selection of materials, installation of same and after sales requirements so that the user of the guideline has a clear idea and could make use of it during the whole product lifecycle.

5.1 Remarks and Discussion

During our field visits we clearly observed that most of the vendors did not give proper after sales maintenance and as a result the systems were not properly maintained. Even if the raw materials were selected properly and installed to proper guidelines, it would be in vain if the systems are not properly looked after. Therefore, it is suggested that the financial institutions retain a amount of the payment (say 5 ~ 10%) to the solar vendor until the end of the defects liability period of the system so that in event that the vendor has not maintained the system during the said period the retention will be given to the customer to utilize for the systems maintenance.

5.2 Recommendations for Future

Overall the researcher feels he has delivered a reasonable research out come as means of a "Solar PV SHS Installation Guideline" for the industry. This guideline is suitable for the current context the solar PV industry is phasing and would not be sufficient as the industry evolves with time. However, researcher assumes that this guideline would be sufficient for the next few years to come.

But thereafter the guideline should be revised by a committed researcher to meet the demands and the technological advancements of the solar PV industry. He/she also would have to study global practices and local practices and do extensive field visits to be abreast of the industry and upgrade the guideline and may be introduce it as a regulation or a standard, supported by the government standard institutions.

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ANNEXURE 1

Solar Home System Survey Data Sheet

Owner of the system : Mr/Mrs/Miss

Address :

Solar System Vendor:

Type/ Model :

Installed Date :

Funded by :

PV Module :

Module Mounting :

Wires Used :

Wiring Method :

Charge Controller :

Battery & Housing :

Loads :

After Sales :

Other Comments :

SHS Survey Data Sheet Summery

No	SHS Owner	Address	SHS Vendor	Funded by	Installed Date	PV Module	Module Monting	Wires Used	Wiring Mathod	Charge Controller	Battery	Battery Housing	Loads	After Sales	General Comments
1	Mrs. A R M D Wickramasinghe	Havenitenna, Palliyadha	Shell Solar	LOLC	31.10.2006	40W - Multi crysterline	GI Pole & AL frame	M-C 4mm², C-B 4mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 8" apart	5A	70Ah Deep cycle lead acid	Plastic housing for battery	7 W CFL - 1, 6 W tubelight - 4, DC point for 14" B/W TV	3 Visits per year on average	System spareringly used by user.
2	Mrs. D M Irangani	Havenitenna, Palliyadha	Vidul Energy	LOLC	30.05.2006	40W - Multi crysterline	GI Pole & MS frame	M-C 1.5mm², C-B 1.5mm², C-S 1.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 6" apart	8A	70Ah Lead acid	Fiber housing for battery	7 W tubelight - 5, CFL 3W - 1	No after sales done after installation	System spareringly used by user. Although material selection is poor by the vendor,the installation has been done by the technician properly
3	Mrs. Manel Wickramasighe	Havenitenna, Palliyadha	Vidul Energy	LOLC	10.07.2007	30W - Amophous thin film	GI Pole & MS frame	M-C 1.5mm², C-B 1.5mm², C-S 1.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 6"~8" apart	8A	50Ah Lead acid	MS housing painted for battery	7 W tubelight - 3, incandecent night light	No after sales done after installation	System spareringly used by user. Although material selection is poor by the vendor,the installation has been done by the technician properly
4	Mr. P S J Kumara	Havenitenna, Palliyadha	Vidul Energy	Self	12.07.2007	40W - Multi crysterline	GI Pole & MS frame	M-C 1.5mm², C-B 1.5mm², C-S 1.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 6" apart	8A	70Ah Lead acid	Fiber housing for battery	7 W tubelight - 5, CFL 3W - 1	No after sales done after installation	System spareringly used by user. Although material selection is poor by the vendor,the installation has been done by the technician properly
5	Mr. M A Peiris	Ehalagalyaya	Vidul Energy	LOLC	12.07.2007	40W - Multi crysterline	GI Pole & MS frame	M-C 1.5mm², C-B 1.5mm², C-S 1.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 6" apart	8A	50Ah Lead acid	Fiber housing for battery	7 W tubelight - 5, DC Point - 1	No after sales done after installation	System spareringly used by user. The material selection is poor by the vendor the installation has been done by the technician poorly
6	Mrs. H A Somawathie	Havenitenna, Palliyadha	Vidul Energy	LOLC	16.06.2006	40W - Multi crysterline	GI Pole & MS frame	M-C 1.5mm², C-B 1.5mm², C-S 1.5mm², S-L 1mm²	Conduits on wall surface & wiring clips used on roof rafters 6" apart	8A	70Ah Lead acid	Fiber housing for battery	7 W tubelight - 5, CFL 3W - 1	One after sales visit done after installation	System spareringly used by user. The material selection is poor by the vendor,the installation has been done by the technician poorly

7	Mrs. E G S Kumari	Haveniterma Palliyadha	Suryavahini	LOLC	19 03 2005	30W x 2 no s - Multi crysterline	GI Pole & AL frame	M-C 2.5mm², C-B 2.5mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 8" apart	15A	100Ah Lead acid	Plastic housing for battery & Charge Controller	6 W CFL - 6, DC point for 14" B W TV	One after sales visit done after installation	Wiring installation done properly, material selection to be discussed
8	Mr. K A Podiappuhami	Haveniterma, Palliyadha	Shell Solar	SEEDS	09 02 2000	45W - Multi crysterline	GI Pole & MS frame	M-C 2.5mm², C-B 2.5mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 6" apart	6.6A	70Ah Deep cycle lead acid	None	6 W Tubelight - 6, DC point	One after sales visit done after installation	System spareringly used by user.
9	Mr. W A Jayarathne	Dummiya Pansiyagama	Shell Solar	SEEDS	09 02 2000	45W - Multi crysterline	GI Pole & MS frame	M-C 4mm², C-B 4mm², C-S 2.5mm², S-L 1.5mm²	Conduits on wall surface & wiring clips used on roof rafters 6" apart	8A	70Ah Lead acid	None	6 W Tubelight - 6, DC point	Ten visits done up to date	System spareringly used by user.
10	Mr. S M P S Dasanayake	Dummiya, Pansiyagama	Suryavahini	LOLC	07 06 2005	40W - Multi crysterline	GI Pole & AL frame	M-C 2.5mm², C-B 2.5mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 8" apart	10A	70Ah Lead acid	Plastic housing for battery & Charge Controller	6 W CFL - 5, Night Light - 1, DC point	One after sales visit done after installation	Wiring installation done properly, material selection to be discussed
11	Mr. R M Rohana Ravindra	Dummiya, Pansiyagama	Suryavahini	SEEDS	30 04 2008	40W - Multi crysterline	GI Pole & AL frame	M-C 2.5mm², C-B 2.5mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 6" apart	6.5A	70Ah Lead acid	fibre housing for battery	6 W CFL - 5, DC point	One after sales visit done after installation	Wiring installation done properly, material selection to be discussed
12	Mr. I M Herath Banda	Dummiya Pansiyagama	Shell Solar	Allience Finance	Not Avaolable	45W - Multi crysterline	GI Pole & AL frame	M-C 4mm², C-B 4mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 6" apart	8A	70Ah Lead acid	Plastic housing for battery & Charge Controller	6 W CFL - 6, DC point, Night Light	Ten visits done up to date	System negligently used by user.
13	Mr. R C Perera	Dummiya Pansiyagama	Soft Logic	Self	30 06 2008	40W - Multi crysterline	GI Pole & AL frame	M-C 2.5mm², C-B 2.5mm², C-S 2.5mm², S-L 1.5mm²	Conduits on wall surface & wiring clips used on roof rafters 6" apart	8A	75Ah sealed Lead acid	MDF Box	5 W CFL - 4 DC point	No after sales done after installation	The material selection is to be discussed,the installation has been done by the technician poorly
14	Mr. R M Gunarathne	Dummiya, Pansiyagama	Access Solar	Ceylinco Leasing	25 07 2003	40W - Multi crysterline	GI Pole & MS frame	M-C 2.5mm², C-B 2.5mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 6" apart	12A	90Ah Lead acid	MDF Box	7 W CFL - 7, DC point	Two visits done up to date	The material selection is to be discussed the installation has been done by the technician averagely
15	Mr. S M P Dissanayake	Dummiya, Pansiyagama	Suryavahini	SEEDS	05 07 2008	40W - Multi crysterline	GI Pole & AL frame	M-C 2.5mm², C-B 2.5mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 6" apart	6.5A	70Ah Lead acid	fibre housing for battery	6 W CFL - 6, DC point	Not done	Wiring installation not done properly, material selection to be discussed. Customer over usage clearly evedent

16	Mr. J A Jayarathne	Kumaragama Anamaduwa	Shell Solar	SEEDS	22.07.2008	30W - Multi crysterline	GI Pole & AL frame	M-C 4mm², C-B 4mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 6" apart	6A	50Ah Lead acid	Plastic housing for battery	7 W CFL - 4, DC point	Two visits done up to date	Wiring installation done properly, material selection to be discussed
17	Mr. J A G Jayakody	Kumaragama, Anamaduwa	Suryavahini	SEEDS	19.02.2007	40W - Multi crysterline	GI Pole & AL frame	M-C 2.5mm², C-B 2.5mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 1'~2'apart, very poor quality	10A	70Ah Lead acid	Plastic housing for battery & Charge Controller	6 W CFL - 5, DC point	Not done	Wiring installation not done properly, material selection to be discussed.
18	Mrs. J A I Damayanthi	Kumaragama, Anamaduwa	Wisdom Solar	SEEDS	26.04.2008	35W - Multi crysterline	GI Pole & AL frame	M-C 2.5mm², C-B 2.5mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 6" apart	10A	50Ah Lead acid	Plastic housing for battery & Charge Controller	6 W CFL - 4, Night Light DC point	No after sales done after installation, only visited once for a breakdown	Wiring installation done properly, material selection to be discussed
19	Mr. J A C G Jayakody	Kumaragama, Anamaduwa	Wisdom Solar	SEEDS	11.06.2008	40W - Multi crysterline	GI Pole & AL frame	M-C 2.5mm², C-B 2.5mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 6" apart	10A	70Ah Lead acid	Plastic housing for battery & Charge Controller	6 W CFL - 5, Night Light DC point	Not done	Wiring installation done properly, material selection to be discussed
20	Mrs. J A Nishamalee	Kumaragama, Anamaduwa	Suryavahini	SEEDS	17.02.2007	40W - Multi crysterline	GI Pole & AL frame	M-C 2.5mm², C-B 2.5mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 6" apart, very poor quality	10A	70Ah Lead acid	Plastic housing for battery & Charge Controller	6 W CFL - 5, Night Light,DC point	Not done	Wiring installation not done properly, material selection to be discussed.
21	Mrs. J M N Jayalatha	Kumaragama, Anamaduwa	Suryavahini	SEEDS	31.10.2005	30W - Multi crysterline	GI Pole & AL frame	M-C 2.5mm², C-B 2.5mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 1'apart very poor quality	10A	60Ah Lead acid	Plastic housing for battery & Charge Controller	6 W CFL - 3, Night Light,DC point	Not done	Wiring installation not done properly, material selection to be discussed
22	Mrs. J A Sittamma	Kumaragama, Anamaduwa	Suryavahini	SEEDS	08.08.2007	30W - Multi crysterline	GI Pole & AL frame	M-C 2.5mm², C-B 2.5mm², C-S 2.5mm², S-L 1.5mm²	Casing on wall surface & wiring clips used on roof rafters 1'apart very poor quality	10A	60Ah Lead acid	Plastic housing for battery & Charge Controller	6 W CFL - 4, Night Light,DC point	Not done	Wiring installation not done properly, material selection to be discussed.

23	Mr Priyantha Samarasinghe	Kumaragama, Anamaduwa	Soft Logic	SEEDS	26/06/1905	40W - Multi crysterline	GI Pole & MS frame	M-C 4mm^2, C-B 2.5mm^2, C-S 2.5mm^2, S-L 1.5mm^2	Conduits on wall surface & wiring clips used on roof rafters 4" apart	10A	70Ah Lead acid	Wood Box	7 W CFL - 6, DC point, 2 no.s LED night lights	No after sales done after installation	Wiring installation done properly, material selection to be discussed
24	Mrs. R M C Damayanthi	Arasanwewa, Adigama	Alpha Solar	SEEDS	24/12/2006	40W - Multi crysterline	GI Pole & MS frame	M-C 2.5mm^2, C-B 2.5mm^2, C-S 2.5mm^2, S-L 1.5mm^2	Casing on wall surface & wiring clips used on roof rafters 6" apart, very poor quality	10A	70Ah Lead acid	MS housing for battery & Charge Controller	7 W CFL - 6, DC door bell,DC point	One visit per year	Wiring installation done properly, material selection to be discussed
25	Mr. W M W M Senerath Bandara	Ihalaarasanwewa, Nagawila	Alpha Solar	SEEDS	30/06/2006	40W - Multi crysterline	GI Pole & MS frame	M-C 2.5mm^2, C-B 2.5mm^2, C-S 2.5mm^2, S-L 1.5mm^2	Casing on wall surface & wiring clips used on roof rafters 6" apart, very poor quality	10A	70Ah Lead acid	MS housing for battery & Charge Controller	7 W CFL - 6, DC door bell,DC point, incadecent night light	Not done	Wiring installation done properly, material selection to be discussed
26	Mr. J A Jayarathne	Wilpotha, Chilaw	Shell Solar	Allience Finance	20/09/2008	30W - Multi crysterline	GI Pole & AL frame	M-C 4mm^2, C-B 4mm^2, C-S 2.5mm^2, S-L 1.5mm^2	Casing on wall surface & wiring clips used on roof rafters 6" apart	6A	70Ah Lead acid	fibre housing for battery	7 W CFL - 4, DC point	One visit done up to date	Wiring installation done properly, material selection to be discussed
27	Mr. Sunil Premarathne	Wilpotha, Chilaw	E B Creasy	SEEDS	31/08/2007	35W - Multi crysterline	GI Pole & AL frame	M-C 4mm^2, C-B 1.5mm^2, C-S 1.5mm^2, S-L 0.75/1.5mm^2	Casing on wall surface & wiring clips used on roof rafters 6" apart	10A	50Ah Lead acid	MDF Box	7 W CFL - 4, DC point	Three visits done up to date	Wiring installation done properly, material selection to be discussed
28	Mrs.Abagahage Anulawathie	Wilpotha, Chilaw	E B Creasy	SEEDS	23/08/2007	40W - Multi crysterline	GI Pole & AL frame	M-C 4mm^2, C-B 2.5mm^2, C-S 1.5mm^2, S-L 0.75/1.5mm^2	Casing on wall surface & wiring clips used on roof rafters 6" apart	10A	70Ah Lead acid	Plastic Box	7 W CFL - 5, DC point -2	One visit done up to date	Wiring installation done properly, material selection to be discussed

Annexure 3

Case 1: Mrs. A R M D Wickramasinghe, Havenitenna, Palliyadha **Vendor:** Shell Solar

Module & Module Support

Charge Controller & Battery Box

DC Loads

Wiring on Walls Surface

Wiring on Walls Surface

Deep Cycle Solar Battery

Case 2: Mrs. D M Irangani**,** Havenitenna, Palliyadha **Vendor:** Vidul Energy

Module & Module Support

Charge Controller & Battery Box

Wiring on Walls Surface

Charge Controller

Wiring on Roof Rafters & Light

Case 3: Mrs. Manel Wickramasighe, Havenitenna, Palliyadha **Vendor:** Vidul Energy

Module & Module Support

Charge Controller & Battery

Charge Controller

DC Light – CFL

Wiring on Roof Rafters

Case 4: Mr. P S J Kumara, Havenitenna, Palliyadha **Vendor:** Vidul Energy

Module & Module Support

Module & Module Support

Battery Box

Wiring on Walls Surface

Wiring on Roof Rafters

Wiring on Roof Rafters

Case 5: Mr. M A Peiris, Ehalagalyaya **Vendor:** Vidul Energy

Module & Module Support

Charge Controller, Battery & Battery Box

Wiring on Walls Surface

Wiring on Roof Rafters

Wiring on Walls & Roof Rafters

DC Loads

Case 6: Mrs. H A Somawathie, Havenitenna, Palliyadha **Vendor:** Vidul Energy

Module & Module Support

DC Light – Florescent

Charge Controller & Battery Box

Charge Controller & Battery

Wiring on Walls Surface & Loads

DC Light – Florescent

Case 7: Mrs. E G S Kumari, Havenitenna, Palliyadha **Vendor:** Suriyavahini

Module & Module Support

Charge Controller & Battery Box

Charge Controller & Battery

Wiring on Walls Surface

Wiring on Roof Rafters & Light

DC Light – CFL

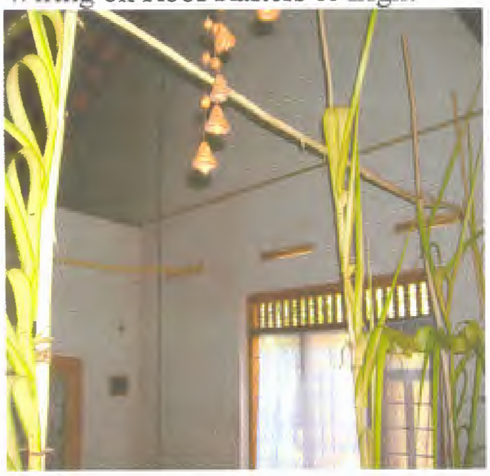
Case 8: Mr. K A Podiappuhami, Havenitenna, Palliyadha **Vendor:** Shell Solar

Module & Module Support

Charge Controller & Battery

Wiring on Roof Rafters & Light

Wiring on Roof Rafters & Light

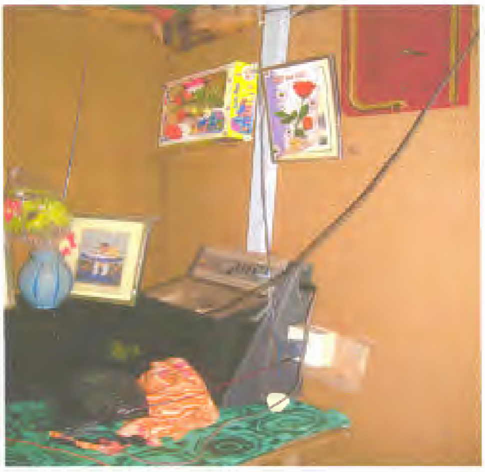


Wiring on Walls Surface

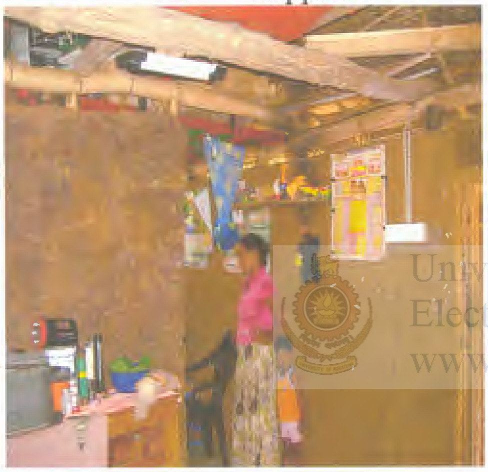
Deep Cycle Solar Battery

Case 9: Mr. W A Jayarathne, Dummiya, Pansiyagama**Vendor:** Shell Solar

Module & Module Support



Charge Controller & Battery Box



Wiring on Roof Rafters & Light

DC Light – Florescent

Wiring on Walls Surface

Case 10: Mr. S M P S Dasanayake, Dummiya, Pansiyagama**Vendor:** Suriyavahini

Module & Module Support

Charge Controller & Battery Box

Charge Controller

Battery and Box

Wiring on Roof Rafters & Light

Wiring on Roof Rafters

Case 11: Mr. R M Rohana Ravindra, Dummiya, Pansiyagama **Vendor:** Suriyavahini

Module & Module Support

Module & Module Support

Lead Acid Battery

Charge Controller & Wiring on Wall

DC Light – CFL

Case 12: Mr.I M Herath Banda, Dummiya, Pansiyagama **Vendor:** Shell Solar

Module & Module Support

Charge Controller & Battery Box

Wiring on Roof Rafters & Light

DC Light – CFL

Wiring on Roof Rafters

Incandescent Night Light

Case 13: Mr.R C Perera, Dummiya, Pansiyagama **Vendor:** Soft Logic

Module & Module Support

Module & Module Support

Charge Controller & Battery

Wiring on Walls Surface

DC Light – CFL

Wiring on Roof Rafters & Light

Case 14: Mr.R M Gunarathne, Dummiya, Pansiyagama **Vendor:** Access Solar

Module & Module Support

Charge Controller & Battery Box

Charge Controller

Battery and Box

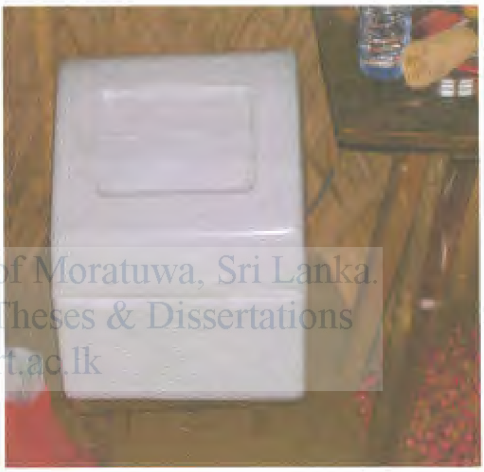
DC Light – CFL

Case 15: Mr. S M P Dissanayake, Dummiya, Pansiyagama **Vendor:** Suriyavahini

Module & Module Support

DC Loads

Charge Controller



Battery Box

Wiring on Walls Surface

DC Light – CFL

Case 16: Mr. J A Jayarathne, Kumaragama, Anamaduwa **Vendor:** Shell Solar

Module & Module Support

Module & Module Support

Charge Controller & Battery Box

Wiring on Roof Rafters & Light

Wiring on Roof Rafters

Wiring on Walls Surface

Case 17: Mr. J A G Jayakody, Kumaragama, Anamaduwa **Vendor:** Suriyavahini

Module & Module Support

Charge Controller & Battery Box

Wiring on Roof Rafters

Wiring on Roof Rafters & Light

Wiring on Roof Rafters

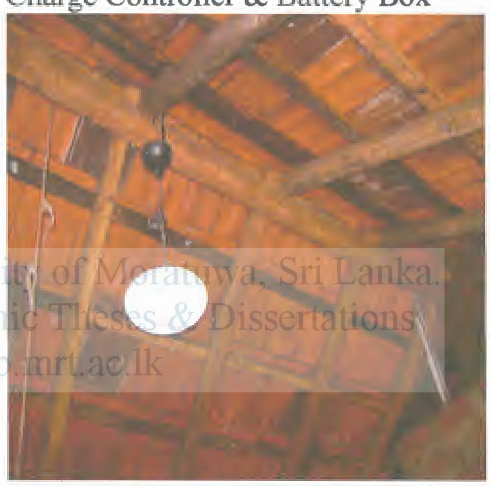
Wiring on Roof Rafters & Light

Case 18: Mrs. J A I Damayanthi, Kumaragama, Anamaduwa **Vendor:** Widsdom Solar

Module & Module Support

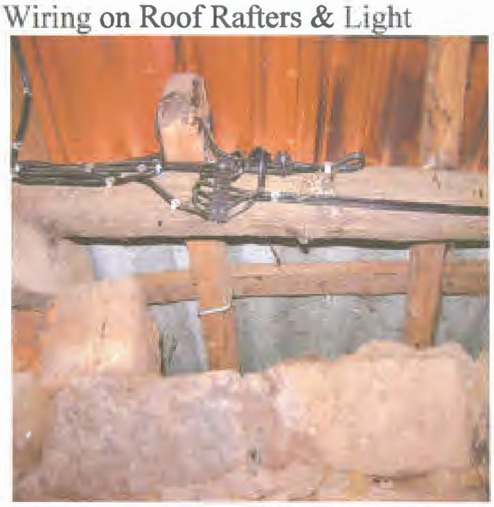
Charge Controller & Battery Box

Charge Controller & Battery



Wiring on Roof Rafters & Light

Wiring on Roof Rafters



Wiring on Roof Rafters

Case 19: Mr. J A C G Jayakody, Kumaragama, Anamaduwa **Vendor:** Widsdom Solar

Module & Module Support

Wiring on Roof Rafters

Charge Controller & Battery Box

Charge Controller & Battery

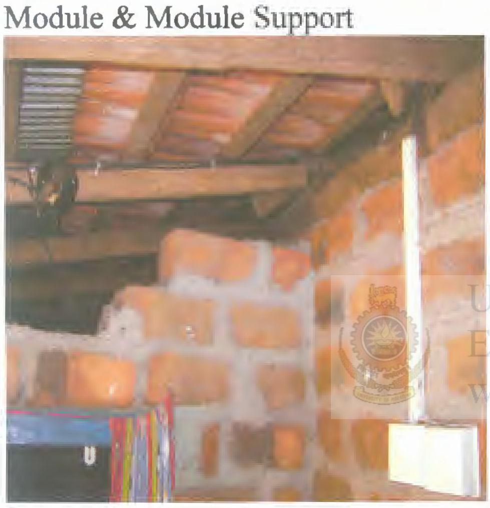
Wiring on Roof Rafters & Light

DC Light – CFL

Case 20 : Mrs. J A Nishamalee, Kumaragama, Anamaduwa **Vendor:** Suriyavahini

Module & Module Support

Charge Controller & Battery



Wiring on Roof Rafters

Wiring on Roof Rafters

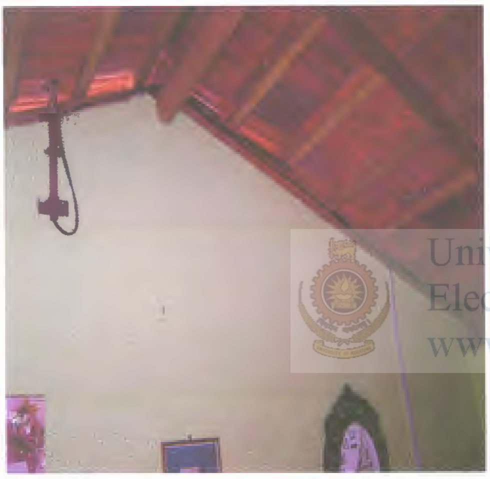
Wiring on Roof Rafters & Light

Wiring on Roof Rafters

Case 21 : Mrs. J M N Jayalatha, Kumaragama, Anamaduwa **Vendor:** Suriyavahini

Module & Module Support

Charge Controller & Battery Box



Wiring on Roof Rafters

Wiring on Roof Rafters

Wiring on Roof Rafters & Light

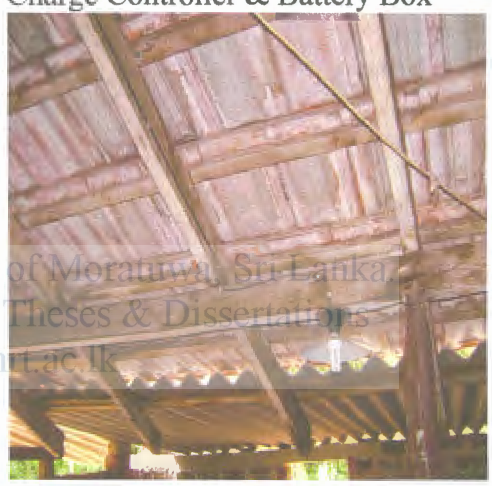
DC Incandescent Night Light

Case 22 : Mrs. J A Sittamma, Kumaragama, Anamaduwa **Vendor:** Suriyavahini

Module & Module Support

Charge Controller & Battery Box

Wiring on Roof Rafters & Light



Wiring on Roof Rafters & Light

Wiring on Walls Surface

DC Incandescent Night Light

Case 23 : Mr.Priyantha Samarasinghe, Kumaragama, Anamaduwa **Vendor:** Soft Logic

Module & Module Support

Wiring on Walls & Roof Rafters

Charge Controller

Battery and Box

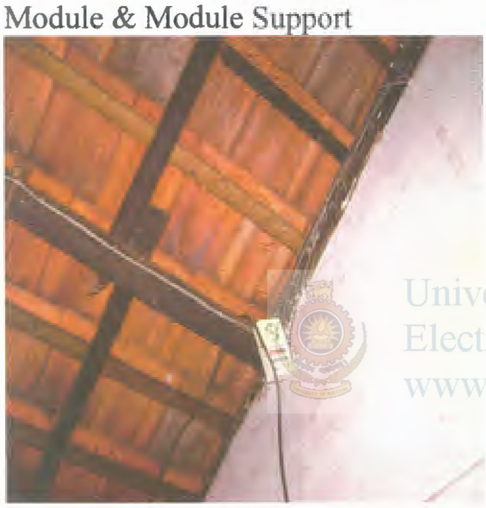
Wiring on Roof Rafters & Light

Wiring on Roof Rafters & Light

Case 24 : Mrs. R M C Damayanthi, Arasanwewa, Adigama **Vendor:** Alpha Solar

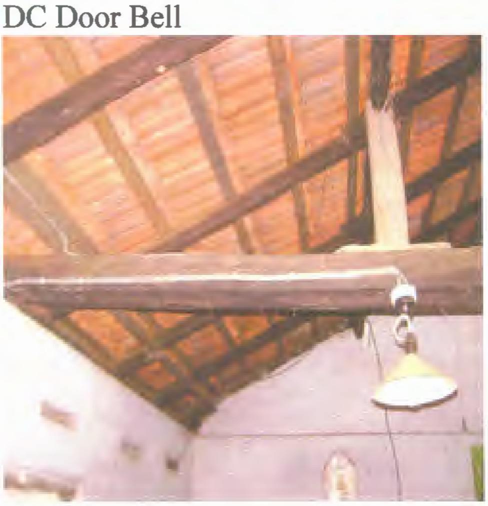
Module & Module Support

Charge Controller & Battery Box

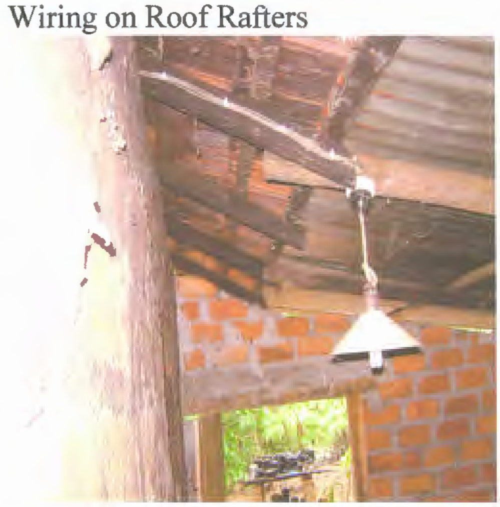


DC Door Bell

Wiring on Roof Rafters



Wiring on Roof Rafters & Light



Wiring on Roof Rafters & Light

Case 25 : Mr.W.M.W.M.S.Bandara, Ihalaarasanwewa, Nagawila **Vendor:** Alpha Solar

Module & Module Support

Charge Controller & Battery

Wiring on Walls & Roof Rafters

DC Door Bell

Wiring on Roof Rafters & Light

Wiring on Roof Rafters & Light

Case 26: Mr. J A Jayarathne, Wilpotha, Chilaw **Vendor:** Shell Solar

Module & Module Support

Charge Controller

Battery and Box

Wiring on Walls & Roof Rafters

Wiring on Roof Rafters & Light

Wiring on Roof Rafters & Light

Case 27: Mr. Sunil Premarathne, Wilpotha, Chilaw **Vendor:** E B Creasy

Module & Module Support

Battery Box

Charge Controller

Battery and Box

Wiring on Walls & Roof Rafters

Wiring on Roof Rafters & Light

Case 28: Mrs.Abagahage Anulawathie, Wilpotha, Chilaw **Vendor:** E B Creasy

Module & Module Support

Battery and Box

Charge Controller

Wiring on Walls Surface

Wiring on Roof Rafters & Light

Wiring on Walls & Roof Rafters