IEA PVPS
International Energy Agency
Implementing Agreement on Photovoltaic Power Systems

Task 3
Use of Photovoltaic Power Systems in Stand-Alone and Island Applications

Report IEA PVPS T3-09: 2002

Use of appliances in Stand-Alone PV Power supply systems: problems and solutions

September 2002

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FOREWORD

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation among its 20 member countries. The European Commission also participates in the work of the Agency.
The IEA Photovoltaic Power Systems (PVPS) Programme is one of the collaborative R&D agreements established within the IEA and, since 1993, its Participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual research projects (Tasks) is the responsibility of Operating Agents. Currently nine tasks have been established. The twenty-one members of the PVPS Programme are:
Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), European Commission, Finland (FIN), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Mexico (MEX), Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), United Kingdom (GBR), United States (USA).

This International Technical Report has been prepared under the supervision of PVPS Task 3 by Xavier Vallvé, Gerard Gafas from Spain,Michel Villoz from Switzerland, Alison Wilshaw from UK and Philippe Jacquin from France, in co-operation with experts of the following countries: Australia, Canada, France, Germany, Italy, Japan, Norway, Portugal, Sweden.

Task 3 deals with the Use of Photovoltaic Power Systems in Stand-Alone and Island Applications. The long term objective of this work is to facilitate large scale dissemination of stand-alone PV systems by addressing technical issues including load management, and by exploring cost efficient appliances management strategies, that can contribute to cost reduction through standardisation and modularity.

The report expresses, as nearly as possible, a consensus of opinion of the Task 3 experts on the subjects dealt with.

EXECUTIVE SUMMARY

In Stand-Alone Photovoltaic Systems (SAPV systems), special attention must be paid to the used appliances and loads.

Inappropriate loads are very often the origin of PV system malfunction or failure. Start-up power peaks, or reactive power and harmonic distortion can cause system signal instability and protective devices will close the system down.

A well-matched load together with a carefully selected choice of appliances can lead to significant savings in terms of reduced need for PV and electricity storage capacity. Conversely, inefficient appliances and processes, standby loads and inappropriate loads will increase the requirement for expensive PV and storage capacity.

This paper presents a survey of real cases with load related problems in worldwide applications, their effect on quality and cost of the service and the solutions that were adopted and suggested alternative solutions.

One of the main conclusions of the work is the importance to integrate the choice of the appliance while designing the SAPV system.

Keywords: Appliances; Loads; Stand-alone PV Systems; Problems

RESUME

Dans la conception et la mise en œuvre des systèmes autonomes, la plus grande attention doit être portée au choix des récepteurs et à leurs conditions de mise en œuvre.

La présence de récepteurs inappropriés est souvent à l’origine de dysfonctionnements et de pannes des systèmes. Des phénomènes tels que surintensités de démarrage de moteurs, puissance réactive, harmoniques, peuvent générer des instabilités qui conduisent à l’altération voire l’interruption du service rendu.

D’autre part, l’attention portée au choix des appareils raccordés, à leurs conditions d'installation, peuvent conduire à réduire le dimensionnement des générateurs PV et des moyens de stockage de l’énergie produite.

Ce document présente les résultats d’observations menées sur une grande variété de systèmes : dysfonctionnements constatés, classés par type d'appareil, solutions adoptées localement et recommandations à prendre en compte pour prévenir ces types d’incidents.

L’un des enseignements majeurs tirés de ces observations est l’importance à accorder le plus tôt possible aux spécifications techniques des appareils. De ce choix initial résulte en grande partie la performance technique et économique des systèmes ainsi que la qualité du service rendu à l’utilisateur.

Sur ce thème « du bon choix et du bon usage des appareils », ce qui pourrait être considéré comme banal et anecdotique dans un système raccordé au réseau peut avoir des conséquences importantes dans un système autonome.

INTRODUCTION

In a stand-alone PV (SAPV) systems special attention must be paid to the load. In fact the bulk of the problems encountered with system operation can be traced back to inefficient appliances and processes or unmatched loads.

The present paper describes the work being done within Task 3 to categorise the more common problems and prescribe cost-effective solutions.

Policy and market development can have an impact on the availability of high efficiency appliances. The authors recognise that this can play a role in many PV solutions more cost effective, but it is outside the scope of this document.

SCOPE AND OBJECTIVES

With the aim of contributing to a better understanding of these issues and to help systems designers, engineers and troubleshooting field technicians we have gathered real examples of problems related to loads from several operating systems throughout the world.

This document will provide system designers and users with some recommendations based on these case studies in order to prevent problems relative to the implementation of loads and appliances in SAPV systems.

DESCRIPTION

The first section of this report deals with an introduction and a proposed classification of load-related problems. Some figures and examples are given.

In a second part, as an appendix, are listed real experiences as collected from the field by the Task 3 participants dealing with observations, causes (observed or assumed), problem category (in relation with the above classification), local solutions adopted, recommended solution for an alternative action.

DEFINITIONS, SYMBOLS AND ABBREVIATIONS

AC	Alternative current
DC	Direct current
PV	Photovoltaic
SAPV	Stand-Alone Photovoltaic
SHS	Solar Home System
SOC	State of charge

1 LOAD RELATED PROBLEMS

1.1 Summary

PV system components have high reliability and are currently meeting or exceeding high quality standards. Nevertheless, rural electrification projects frequently do not perform as expected and more often than not, longterm service sustainability is not achieved. It is commonly found that the lack of performance is attributable to non-technical factors. [1]. However, there are also technical breakdowns of systems and the frequency of their occurrence has to be reduced to improve the acceptability of this technology [2]. Improvements can be made through better system design and component match, but they may prove insufficient if one does not consider that especially in small systems, the loads and the user behaviour can have a big influence on system failure [3].

With the aim of contributing to a better understanding of these issues and to help designers, engineers and troubleshooting field technicians we have gathered real examples of problems related to loads from several operating systems throughout the world.

Experience gained from stand-alone PV systems installed all around the world confirms the importance of appliance efficiency, system typology, system management, and the correct housewiring that ensures good performance of the system and quality of service to the user. A large list of such experience originating from the field is shown in the Appendix 1 and updates are available on the Task 3 website. The case studies used are fully documented at the Task 3 website and this paper will also be available in French and Spanish.

1.2 Detailed description

The wide range of problems identified have been classified in eight groups:

For all systems (AC and DC supply systems):

A1 - Wrong selection: some loads are non-adapted for stand-alone PV systems.
A2 - Housewiring: substandard or inadequate wiring and protection devices will also cause poor system response.
A3 – Low efficiency: low electrical efficiency loads lead to over energy consumption.
A4 - Stand-by loads: stand-by mode of some loads waste energy.
A5 - Start-up: current spikes during the start-up of some loads can create temporal overload of the system.

Only for AC:

AC1 - Reactive power: when appliances with capacitive or inductive loads are used, real circulating current differs from the consumed.
AC2 - Harmonic distortion: some electronic appliances with non-linear loads can create waveform deformation of the inverter output signal.
AC3 - Mismatch between load and inverter size: Low overall efficiency can result from oversized inverters operating at lowpower for long periods.

1.2.1 AC & DC supply systems

A1 Wrong Selection.

For good overall rural energisation it is better not to use electricity for all types of load. For example, generally it is not appropriate to use PV electricity to produce heat.

Problems:

These thermal appliances can have dramatic consequences for the system:

- High consumption will cause a system cutout.
- Permanent low SOC of batteries and deep discharge can damage batteries.
- For a PV hybrid (genset) system, increased running hours of the genset causing increased operation costs.

Solutions:

- The appliances that convert electric to thermal energy can be replaced, using gas, liquid fuel, solar-thermal collectors or firewood where appropriate.
- If electrical to thermal energy conversion is difficult to avoid –e.g. autoclave sterilizers- use only high efficiency appliances and make sure that user is aware of the energy consumption of their operation.

Example in box 1: Wrong selection for heating

· *The energy needed to take a shower is about 1 kWh, this daily habit accounting 30 kWh/month, or 500 Wp of installed PV power**

· *Using thermal collectors to directly heat water is much more cost-effective for this usage (about 10 times cheaper than PV)*

** Assuming a water temperature of 10 ºC, and raise it to 38 ºC; for heating 30 l of water to take a shower we need: 30 l_{water} * 4,18 kJ/(kg*ºC) * 1 kg/1l_{water} * (38-10)ºC_{water} * 3600s = 1kWh.*
*Calculation of installed Wp: assuming a daily average irradiation of 4000 Wh/m^2, and a performance of the system of 50%, the Wp needed are: 1 kWh/day/50% * 1kWp/4hp = 500Wp*

A2 Housewiring.

Wiring is an important issue to guarantee correct performance when using appliances. Having undersized or damaged distribution cables, can lead to the following problems:

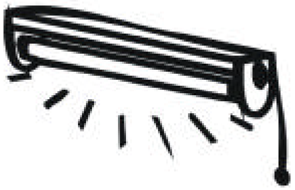
Problems:

- If section of wires is undersized or selection of fuses is incorrect, high current through these can cause a fire (by resistive heating).
- Undervoltage may detrimentally affect the performance of some appliances.

Solutions:

- An accredited electrician should implement Housewiring.
- Current limiters and switches must be installed to avoid high currents and drains

Example in box 2: effects of undervoltage in a fluorescent lamp



· *Undervoltage will cause a fluorescent lamp to oscillate continuously preventing start up. In addition, using glow starters, the consumption can continuously be about 5 times the nominal. This abnormal mode can sometimes damage the starter !*

A3 Low efficiency

On the market there are electric appliances that provide an identical service, but with different efficiency. Generally speaking, inefficient appliances are cheaper to buy. Often the user will be poorly advised and will select the appliance according to price rather than efficiency considerations.

Problems:

If the system was sized for efficient loads and, inefficient devices are used, insufficient energy is available, resulting in:

- Frequent cut-offs.
- Frequent low SOC of batteries resulting in low life.
- System undersized.
- User unsatisfied and may even by-pass the controller.
- If diesel genset runs periodically, operating costs can increase dramatically due to increase in demand/ or increased demand.

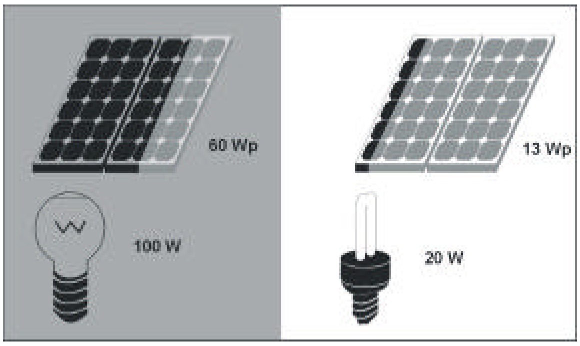
Where the overall system cost is taken to include capital, operating and appliance costs, the cheapest system will be the one that includes efficient appliances. The problem is getting users to realise this.

Solutions:

- It is usually cheaper to invest in efficient appliances than to invest in generation capacity to meet the incremental demand from inefficient appliances. In addition, almost all high-efficiency? appliances have longer operation lifetime than conventional ones, resulting in self-saving of its own extra costs [2].
- Some users of remote systems can have problems in purchasing efficient appliances. A solution would be to make provision for the purchase of these appliances in the project.
- In the cases where the appliances are already existing, it is advised to measure the actual consumption before sizing. The advantage of replacement with efficient appliances can be calculated.
- Raise the awareness of the end-user through training and dissemination.

Examples in box 3: saving energy with high-efficiency appliances.

1. Lamps



· *A high efficiency 20 W lamp generates 1200 lm, as much as a conventional 100 W one, with almost six times less energy consumption. Moreover, its lifetime is eight times longer (8000 vs. 1000 h) [5].*

2. Refrigerators

· *A European Class A refrigerator of 373 l (291 l fridge; 82 l freezer) consumes 1000 Wh/day. Another conventional class C refrigerator with similar capacity consumes 1660 Wh/day [6]. The first one would need 500 Wp and the second one 830 Wp, under the circumstances assumed in box 1.*

A4 Stand-by loads

The stand-by mode of some electronic appliances consumes expensive watt-hours.

Problems:

- When these appliances are left on stand-by for hours or even days, their cumulative effect can become a significant part of system consumption. This may be reflected as low charge of the batteries and earlier cutoff of the system.

Solutions:

- If the appliances that aren't useful on this mode (e.g. TV, hi-fi) were disconnected, the useless consumption would be reduced. With the appliances, which cannot be disconnected (e.g. emergency lamp) it would be good to choose those that have higher efficiencies.

Examples in Box 4: stand-by loads

· *A conventional hi-fi consumes 5W in stand-by mode. If it was all the time connected, it would consume 0.12 kWh/day, 3.6 kWh in a month, about 60 Wp under the circumstances assumed in box 1.*

· *A recent study carried out in Japan estimated that about 10% of domestic electricity consumption is used to power appliances on stand-by [4].*

A5 Start-up

Some appliances consume high electric power (several times its rated power) at start-up.

Problems:

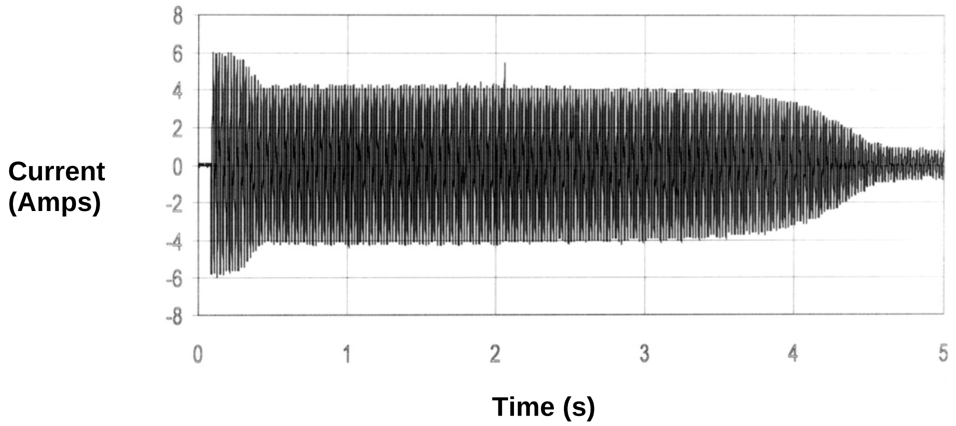
If the system was not sized to deliver the peak power:

- Cutoff of the supply.
- Low voltage transient.

***Solutions**:*

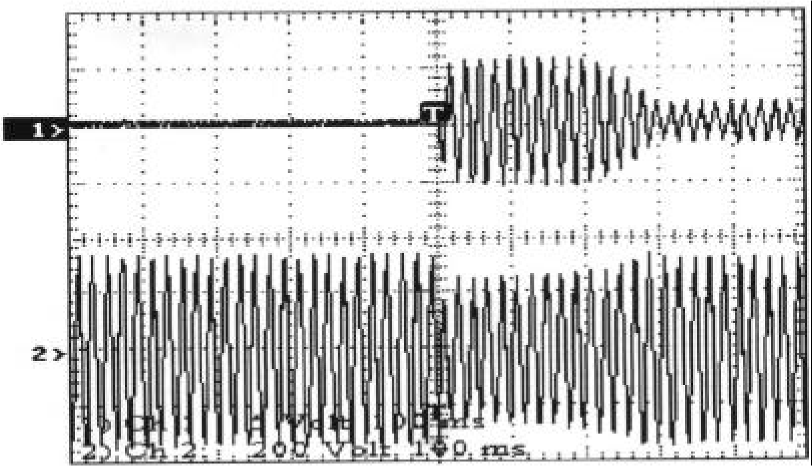
- In case of AC current, the inverters should resist peaks of power several times higher than its rated power value, during the short start-up periods.
- The loads affected should have a starter, which could “soften” the start-up.
- The problem would be solved using loads according to the availability of power, always considering energy-availability (e.g. water pump with less kW but operating during longer time).
- In case of simultaneous start-up of the appliances, the peak power would be the sum of each one. Progressive start-up of the loads connected should be done, controlled by the inverter or another device.
- The last solution would be to use an alternative power source for problematic loads (e.g. a diesel generator,...).
- Specify the inverter continuous watts and surge watts by estimating the surge requirements correctly.
- Use a linear current booster or use permanent magnets in pumping systems to assist start-up.
- A starter used for a water pump could be a device, which produces a frequency variation of the output inverter AC signal, to improve the start-up of the water pump.

Example in box 5: start-up of a refrigerator



· *The maximum peak power of the start-up is 933 W (6 A), six times greater than its nominal value (155 W, 1 A). Also note the long duration of the surge (4.5 seconds).*

Example in box 6: start-up of a water pump



The first channel is Current, and the second is Voltage versus time.

· *The water pump of consumes 5000 watts during the start-up, more than twice of its rated power value. The output voltage of the inverter decreases until 190 V (of 230 V).*

1.2.2 AC supply systems

AC1 Reactive power

All the non-ohmic loads consume reactive power. So, the phase between voltage and current is not zero.

Problems:

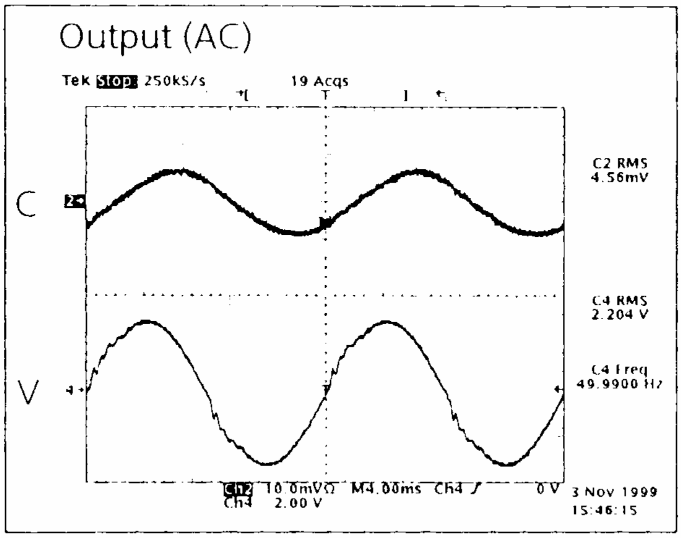
- The current to be delivered by the inverter is much higher than the real consumption, resulting in a possible overcharging of the system.
- Current through the cables is higher than necessary, resulting in the need to increase the wire section to reduce voltage drops. This will add to the cost of cabling.

Solutions:

- Reduce the need for inductive loads like conventional ballasts, etc.
- Use of synchronous motors instead of induction motors in the relevant appliances.
- Install capacitors at the inductive load or the distribution panel to provide the required amount of capacitive reactance.

Box 7 shows two typical examples of reactive power

Example in box 7: reactive power



Output current and voltage of a sinusoidal inverter, feeding a 110 W fridge.

· *The consumption of an electric motor can have a phase between current and voltage of 50º (cos(50º)=0.64). The inverter has to supply, in this case, 1 / 0.64 of the current used by the load (1.56 x the motor current).*

AC2 Harmonic distortion

Some non-linear electric loads are generating signal distortion on the power line.

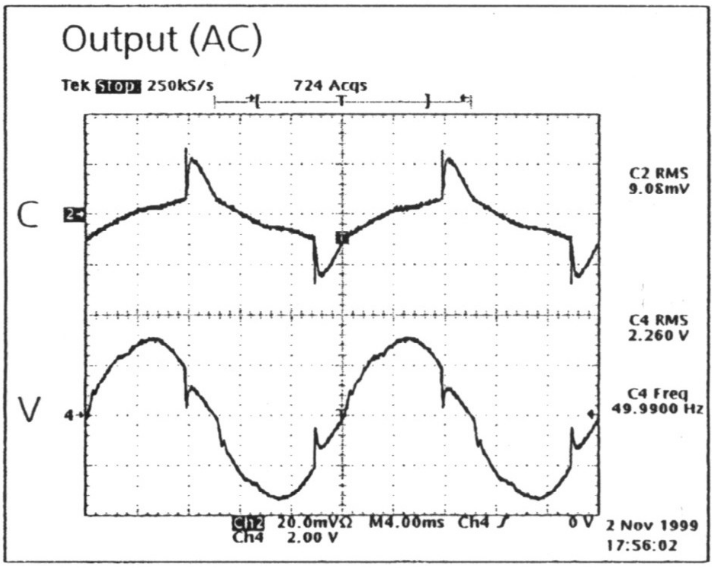
Problems:

- This causes voltage deformation in the output signal of the inverter, which may occasion problems with the other loads.
- Harmonics can shorten the life of the appliances by voltage stress and increased heating of electrical insulation.
- Some devices need to sense ‘zero-crossings’ to control internal switching and could malfunction as the ‘zero-crossings’ may appear to shift because of harmonics.

Solutions:

- Use of output filtering or use of inverters with high switching frequency in situations where harmonics are expected.

Example in box 8: harmonic distortion induced by a non-linear load



Output current and voltage of a sinusoidal inverter, when a non-linear load is connected (Load level 55%). The voltage deformation created by irregular and sudden current consumption can be seen.

AC3 Mismatch between load and inverter size

Low overall efficiency can result from oversized inverters operating at low power for long periods.

Problems:

The energy consumed is higher than the expected one, resulting in:

- Cutout of the system or permanent low SOC of batteries
- High non-useful energy consumption.

Solutions:

- Use of a specific dedicated inverter for the application, or a modular inverter with working points of good performance ranging from low to its maximum power.

Examples:

- Generally, loads during the night have low power with respect to the size of the inverter. If the inverter doesn't have a specific function (small inverter) for these periods, consumption will be higher than the expected.

2 CONCLUSIONS

Problems that we consider trivial in grid-connected systems (wrong selection, etc) can be critical in a Stand-Alone PV system.

Buying appropriate appliances can solve some of these problems.

For the consumption issue, there are in the market high efficiency lamps, freezers, and other appliances, with consumption rates several times lower than the conventional ones. Even though, it's also very important to raise the users' awareness on efficiency .

Relating to the reactive power, there are e.g. fluorescent lights with electronic ballast which allow a phase to phase voltage-current consumption.

Other problems like harmonic distortion, stand-by loads, and start-up currents can't be easily solved, because these are basically technical problems that are always present in some of the shelf appliances.

Furthermore, PV-market is not yet large enough to manufacture adequate appliances – without these problems - at reasonable prices. In these cases, the best solution is to modify the design of the system (mainly batteries and inverters) to account for the losses introduced by appliances.

Housewiring carried out by an accredited electrician can avoid unnecessary troubles to the user when using appliances.

Since installation requirements are considered as an integral part of the implementation of projects, it's advisable to have an identification and a choice for loads from stand-by.

To summarize, , a good social approach and technical design of the systems are crucial to succeed in achieving an adequate electric supply and satisfaction of the users.

3 REFERENCES

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4 APPENDIX: LIST OF REAL EXPERIENCES FROM THE FIELD

Type of load or application	Observations	Causes (observed or assumed)	Problem	Solutions adopted	Task 3 opinion for an alternative action
All appliances	An inside installation is fed with a battery module of 24 V, 2 modules in series (2*12 V). The user decides to add an extra load of 12 V. He connects this load in a submodule of 6x2 V. Fast deterioration of batteries.	Load unmatching the characteristics of the installation. The user doesn't know the consequences of its initiative.	Bad choice	Replacement of batteries	Install a dc/dc converter of 24 to 12 V and Formation/information to the user
All appliances	Battery fuse blowing when overload occurs	Magnetic Circuit Breaker (MCB) trip characteristics too slow	Bad choice		Change the Magnetic Circuit Breaker. Change the battery fuse rating
All appliances	The energy consumed is higher than expected.	Contractors use other materials than these prescribed by the manager of the construction, without informing him. Wrong realisation. Quality procedure non-existent	Housewiring	none	Realisation of projects function of whatever is available at the site. Implementation of quality procedure in the projects.
All appliances in stand-by mode	The 24h-stand-by mode has as a consequence: Energy consumption without an actual value by the user.	Maintain the inverter in a working point with very low performance.	Stand-by loads	none	Dedicated or multistage inverter or disconnect the appliances when not used.
All types of electric devices	The energy consumed is higher than expected.	Deterioration of maintenance tasks E.g.: isolation of damaged refrigerators, oxidised bulbs,...	Bad choice	Replacement of the old appliances	In addition to the solutions adopted, maintain recurrently the new appliances installed

Type of load or application	Observations	Causes (observed or assumed)	Problem	Solutions adopted	Task 3 opinion for an alternative action
All types of electric devices	The energy consumed is higher than expected.	Current leaks due to the deterioration of conductors, related to the aggressions of insects (e.g. beetles)	Housewiring	Reduction of operating hours of the other appliances due to low availability of energy	Replace the wiring
Appliances integrating electronics of "vigilance" e.g. : " super class " refrigerator, integrating stand-by visual display	Consumed energy higher than expected	The loads of the electronics of the display haven't been considered.	Stand-by loads	Reduction of operating hours of the other appliances	Reduction of operating hours of the other appliances. Check operation point of the inverter
Appliances used in Solar Home Systems	The energy available is lower than expected	Charge controllers for 25W PV panel spent 2,9-4,3 Ah/day, because of power consumption of relay coils	Not appliance related	Reduce energy consumption due to unavailability of power	
Appliances used in Solar Home Systems	If other appliances were connected, when the fluo lamp was started up, there was a cutoff.	Some lamps used glow starters and, therefore, more than 5 times current was necessary when lamps were lighted.	Start-up	Switch off all the appliances when connecting the fluo lamp	Change the lamp

Type of load or application	Observations	Causes (observed or assumed)	Problem	Solutions adopted	Task 3 opinion for an alternative action
Aquarium	The user complains not having sufficient energy available. His system feeds among others, the AC electric equipment of an aquarium, which has an installed power of 5 W. The user thinks that it is negligible, because he has a PV generator of 1 kWp.	The aquarium is the only continuous load. Because of its few installed power, the inverter is working in a low performance point, and needs a DC energy 4 to 5 times higher than expected.	Stand-by power	Disconnection of the aquarium during the night (low load profile)	Specific inverter dedicated to this application
Ceiling fans	High consumption rates without many appliances.	Ceiling fans are a large load on the system as they are often left on all day.	Bad choice	Increase in running hours of genset, and fuel consumption	Use more efficient appliances more in accordance with the PV system limitations. Turn off automatically the load when not required. Change behaviour
Domestic lighting in a AC installation	Some lamps don't work	Incompatibility of lights with the non-sinusoidal inverter	Bad choice	Replacement of lights	Replacement of the inverter
Evaporative air coolers	High consumption rates without many appliances.	Evaporative air coolers are made with cheap heavy motors that wind up to speed laboriously	Bad choice	Increase in running hours of genset, and fuel consumption	
Fax	Sudden cutoff of the supply due to low energy	Important stand-by power consumption.	Stand-by energy	To put a relay into the fax; so, only consumption will be permitted during a call.	

Type of load or application	Observations	Causes (observed or assumed)	Problem	Solutions adopted	Task 3 opinion for an alternative action
Lighting	The energy consumed is higher than expected.	The application was not the supposed one.E.g. some lights are on during all night to send away bad spirits	Bad choice	Replacement of some lights with LEDs (lower consumption)	
Lighting	Sparks of connections in humid spaces	Wrong appliance	Bad choice	none	Water resistant lamps
Lighting	The electronic lamp operates only 10 min and gets broken	In the electronic labels figures 24V, when actually it's 12V.	Bad choice	Buy a new one 24V electronic lamp	
Lighting	Consumed energy higher than announced	Use of incandescent lamps as a source of heat to dishumidify the environment.	Bad choice	Support PV power generation with a diesel genset	Use a dishumidifier. Use another heat source
Lighting	Fluo lamps don't work well, but the energy available is sufficient. The user changes fluo for incandescent lamps!	Housewiring conductor section is very small, producing an important voltage drop that hinders the possibility to trigger the starters of the tubes.	Housewiring	The user changes fluo for incandescent lamps	Replace the wiring
Lighting	The energy consumed is higher than expected.	String switches of bad quality, broken down in a short time. The user bypasses the connection; the light is on 24h a day.	Housewiring	Bypass the connection	Replace switches for better quality

Type of load or application	Observations	Causes (observed or assumed)	Problem	Solutions adopted	Task 3 opinion for an alternative action
Lighting	The energy available is lower than expected	The lights stay on during long periods, due to intermittent visits to the place (cellar, WCs, exterior lighting...)	Housewiring	none	Install a timer or switches with pilot
Lighting	Fluo lamps age fast (darkness of tubes)	Lamps are fed in 9V instead of 12V	Housewiring	Replace the lamps when they are old	Replace and size correctly Housewiring
Lighting	The energy available is lower than expected	Replacement of fluo tubes with incandescent lights	Low efficiency	Restriction of lighting due to high consumption of incandescent lamps	Increase awareness and encourage local stocks forecasts
Lighting	Low light level	Tubes blackening	N/A		Replacement of lights;
Lighting	When using a 24V/230 Vac-250W SHS, and having connected two infrared sensors and one timer to limit consumption, the stand-by current was 2.7 A at 24 Vdc and the fan of the inverter was running.	Small appliances using reactive current can destabilise inverters and produce high losses. These three apparatus were used to limit usage of lamps of 13 W and the final result was a current bigger than if these lamps had been "on" all the time!	Reactive power + mismatch	Formation / Information of users and removal of the reactive sensing devices	Use of other low consumption and specially adapted energy management devices
Lighting	Emission / reception quality of phone/radio is disturbed by interference induced by the ballast	Quality of components	Bad choice	Turning off	Change the ballast of the lamp

Type of load or application	Observations	Causes (observed or assumed)	Problem	Solutions adopted	Task 3 opinion for an alternative action
Numerous appliances of the same installation, integrating various devices with stand-by mode.	The energy available is lower than expected in the design. In addition, there are also restricted applications like electric ironing	Video + TV + aquarium in stand-by mode = 1kWh per day, being the equivalent to an hour of ironing	Stand-by and bad choice	Avoid unnecessary loads like the aquarium	Switch off the loads to avoid useless consumption of electricity.
Percolator	The output inverter protections cut off the system, due to overconsumption	The user, get used to traditional solutions of electrification, doesn't have enough sensibility with the RE context, limited energy.	Bad choice	Increase of PV power due to complaints of user	Education / information provided to the user about rational use of energy. Use another energy source
Portable lamp, individual lighting	Premature ageing	Yearly inactivity rate near 50%	N/A	Use again conventional lighting portable devices like Kerosene lamps, etc.	Recharge periodically
Portable lamp, individual lighting	Quick ageing of the lamp	Recharging of the lamp only once a week, instead of a daily habit.	N/A	Use again conventional lighting portable devices like Kerosene lamps, etc.	User education / information about lamp possibilities and modes of usage
Portable lamp, individual lighting	Quick ageing of the lamp	The villagers use the lamps until total exhaustion of power source, like petrol lamps: the tube can't stand up the frequent sub-tensions (8V instead of 12V)	N/A	Replacement of the lamps when they are seriously damaged	Education / information provided to the users. If necessary, use portable lamps with more power autonomy. Raise user's awareness

Type of load or application	Observations	Causes (observed or assumed)	Problem	Solutions adopted	Task 3 opinion for an alternative action
Public lighting	Public lighting of fluorescent lamps, fed with a 50 kWp generator. When starting up the public lighting, the 25 kVA inverter cuts off the signal.	Tubes of medium quality, using starters which almost cause a short-circuit. Inverter with too much sensibility	Bad choice	Adapt the inverter t for this situation. Use tubes with different lighting characteristics to put resistance in series with the tubes, thus limiting the short circuit current.	Switch on the lights progressively if appropriate. Check the starter of the lamps
Public lighting	Low pressure sodium lamps diffuse a yellow light, and they are declared unsuitable for this service by the users	Intolerance of villagers to the yellow light, which deforms the aspect of their faces (black skin). Unsuitable to the socio-cultural context	N/A	Replacement of lights	Education /information provided to system designers. Socio-economic study before the introduction of a technology
Pumping	Weakness of Electro-pumps	Insufficient quality of equipment. Electronic devices break down easily.	N/A	Mend the Electro-pump (if possible under the warranty effects)	To buy a new one of better quality
Pumping	Lost water flow in the early hours of the day until insolation levels are high enough. Delays in restarting during days with intermittent levels of high insolation	Both positive displacement and multistage centrifugal pumps are known to only start rotating when solar insolation is sufficient to overcome both 'stich-tion' (the sticking of the pump when it has been stationary) and starting torque due to standing water column in the riser pipe.	Start-up	Some pump installers and manufacturers now provide a small (6mm) bleed hole immediately about the impeller casing so that the water column in the riser is reduced to static water level overnight or during periods of low insolation. This simple modification reduces load at start-up and improves daily operating efficiency.	In addition to solution adopted, use of pumps with lower start-up current required, or install a starter

Type of load or application	Observations	Causes (observed or assumed)	Problem	Solutions adopted	Task 3 opinion for an alternative action
Refrigeration	High levels of consumption of refrigerators	Great efforts are made with PV refrigerator cabinets to ensure good thermal insulation around the cabinets in order to reduce loads to maintain required refrigerated temperatures.	Low efficiency; bad choice	Placement of the condenser in a better-ventilated environment yields substantial improvements in cooling circuit efficiency. Recent tests using HC refrigerants rather than HFC refrigerants of PV refrigerators reduce compressor power consumption by 6-15%.	Use of new refrigerators with high efficiency
Refrigerator	Over-consumption contrasting with the provisional balance.	Observed causes: use of refrigerators to freeze other charges than these initially expected: frozen mass very important, and open/close cycles very numerous	N/A	Reduction of extra load that can't be frozen with the present system	Awareness of users
Safety lighting	A cottage is fed with a PV system; it has been equipped with security blocks because it has visits of public; the added models have each 2 bulbs of 2,5 W, operating 24h/24. Considerable energy consumption	Safety regulation	Low efficiency	Solution adopted: modification by the contractor of the safety blocks, replacing the bulbs with LEDs leds; consumption is now 5 times lower. The modification is locally accepted by the authority in charge of the cottage, accepting a derogation for the usage of non-homologated material... but complying perfectly with the requested function.	Modification of homologated materials for some environments, like for SAPV power systems. Develop an adequate product.

Type of load or application	Observations	Causes (observed or assumed)	Problem	Solutions adopted	Task 3 opinion for an alternative action
Street lighting, Police booths and stand-alone equipment installed in public locations	Many of these installations fail prematurely or function partially due to poor service quality and regularity. The performance of many such systems decreases within months of installation. Lamps and reflectors become tarnished from insects and dust. Water accumulation in the lamp housing corrodes terminals and creates short circuits on PC boards, etc.	(i) Poor maintenance: Poor service quality and regularity results in PV modules not being cleaned in urban environments where extensive pollution (particularly in developing countries) and dust rapidly decrease electrical output.(ii) Poor design (inadequate enclosure): lamp housing are not insect, water and dust proof	N/A	(i) Implement, in parallel with the PV systems, a maintenance scheme to ensure good operating conditions.	In addition to (i), (ii) ensure adequate enclosure and test of the appliances under insect, water and dust conditions
Thermal converters of electricity	The devices don't work or they consume quickly the energy remaining.	Inappropriate information of users about the capabilities of the system that doesn't follow the recommendations for usage.	Bad choice	Recharging of batteries with the diesel genset	Uses of more appropriate thermal devices like these feed with gas, biomass, etc.
TV	With the lack of a discharge regulator, the user manages the state of charge of the batteries according to the quality of the image. When the image isn't appropriate, he concludes that the voltage level is so low, and blames (who?) for it.	Rusticity of the installation of distribution. Are the elementary user-behaviour-rules respected? Lack of a discharge controller	N/A	None	Install a discharge controller. Awareness of users

Type of load or application	Observations	Causes (observed or assumed)	Problem	Solutions adopted	Task 3 opinion for an alternative action
TVs / AC videos	Start-up problems with a 80 W TV fed with a 150 VA inverter.	Overload of the inverter	Start-up	Replace the TV with a new one.	Choose an inverter with a higher peak starting power
TVs / AC videos	When using a 93 W TV simultaneously with a 20 VA tape recorder, fed with a 150 VA inverter: If we only start TV, OK; If we first start TV and after the tape recorder, OK; If we first start the tape recorder we can't start the TV afterwards.	The power of the inverter can't afford the start-up characteristics of the system.	Start-up	Switch off the tape recorder if we want to start the TV	
TVs / AC videos	High energy consumption	Replacement of an "old" device with a more recent one, integrating a stand-by function.	Stand-by	none	Switch off mechanically the device when not using it