Using locally available components and local knowledge to build sustainable stand-alone power systems

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Abstract

The aim of this paper is to point out benefits as well as disadvantages associated with the use of locally available, not necessarily standardized, components in stand-alone electrical power systems at rural locations. Advantages and challenges arising when the direct involvement in design, construction and maintenance of the power system is reserved to people based in the area of implementation are discussed. The presented research is centered around one particular PV-diesel hybrid system in Tanzania; a case study in which technical and social aspects related to the particular power system are studied.

Introduction

Any technical system is dependent on its technical components in order to function. To be long term sustainable though, it is also dependent on social components. The choice of technical components to a system, as well as the choice of who to involve in a technology implementation project influences the way a technical system will function and accomplish the needs it is there to fulfill.

Stand-alone power systems can be built in many different ways. Different generation technologies can be used, such as PV, wind, fuel based generators, or combinations of those. Also different design strategies are applied, for example AC or DC coupled systems, AC or DC distribution, and centralized or decentralized power generation. There are products on the world market especially developed for certain designs of systems. In many cases however, it is also possible to use standard components not dedicated to a certain system design or generation technology. A specialized product in its right environment will often perform better, from a technical point of view, than a more general type of component. Such niche components are however not always available at the often remote and rural markets were stand-alone power systems are needed. That does not only challenge the possibilities of finding the components themselves, but also to get hold of spare parts and people with relevant knowledge.

Many stand-alone systems are designed and constructed by other people than the final users of the power system. Whether the designer/constructor is a person based locally or not will affect the person's knowledge about local market and competences. That in turn may influence the choice of components. Where the designer/constructor is based will also determine the possibilities for that person or company to give advice and perform maintenance and repair work on the system. Also the users' awareness about who to turn to if or when problems arise is affected.

This paper discusses the relation between optimal technical performance, and stand-alone power systems which have the social prerequisites to function on a long-term basis. How human resources and technical components have been used in a research project in Tanzania will serve as the main case study for the discussion.

The case study

Dalarna University (DU) has an ongoing interdisciplinary research project with focus on social and technical aspects of a stand-alone power system at the organization Ihushi Development Centre (IDC) in Tanzania. The organization runs a vocational training centre, a carpentry workshop, and a business centre where computers can be used and courses are held. There is also a preschool, a meeting hall, a guest house, two offices and a kitchen.

In 2008, a PV-diesel hybrid system was installed at the center [1]. The system supplies power for lighting, computers, a copy machine, a TV, a refrigerator, the charging of mobile phones for the villagers, and tools of varying kind. The power system was designed and installed by an electrician from a nearby located town, with some initial advice from DU regarding general layout and sizing of components. The electrician was contracted by IDC. Neither IDC nor the electrician had any earlier experience in PV-hybrid systems, or any such systems in the area to gain knowledge from. They both had earlier experience in PV technology though.

All technical components in the power system at IDC are standard components, not especially designed for hybrid systems. Some components were taken from earlier used stand-alone PV systems and some were bought especially for the construction of the hybrid system. Due to that, the system has two different types of PV panels, which is not in favor for its energy efficiency. The second power source in the system, a diesel generator, was purchased to power machines in a carpentry workshop. The generator is hence not sized to be optimal for the PV-hybrid system, but to power carpentry machines. Power is fed into the PV system from one of the generator's three phases, making it a hybrid system. The generator is operated when needed in the workshop, rather than when it is desirable from a system standpoint. The system has one DC and one AC distribution network. The charge controller is a standard solar charge controller regulating the energy flow between the batteries, the PV panels and the DC loads. The inverter is a bi-directional inverter, controlling supply of energy from the generator to the DC side of the system, from the DC side to the AC loads, and from the generator to the AC loads. All components are chosen by the Tanzanian electrician and bought in Tanzania. The power system has a monitoring system, following the IEC 61724 guidelines, installed by researchers from DU. There is a clear division of work and responsibilities between DU and IDC; IDC manage their power system, and DU handles the monitoring system.

Discussion

The power system used in our case study at IDC does not have the highest energy efficiency available with today's technologies [1]. That is partly due to the use of components not specifically selected with the efficiency of the PV-hybrid system as the main priority. Instead, old components have been re-used, components were selected to perform independent of the PV-hybrid system, and remaining parts were selected to fit already chosen components in the best way possible. The components in the system are hence not especially developed for hybrid systems, neither are they selected to fit each other in an optimum way.

The disadvantages constructing a not optimized power system may seem obvious; you could get more energy out of your system if components were well coordinated, or you could have a smaller system and still get the same energy output. A more optimized design could lead to lower investment and running costs. In our case study at IDC however, the investment cost could be kept low thanks to the reuse of old PV panels. The generator would have been purchased anyways, since the main aim of getting it was to supply power to a carpentry workshop. With the setup of the hybrid system, the components could be used together to enhance the usability of them.

Another reason for a not optimized system to be constructed may be that the design is done by someone with limited or outdated knowledge in system design. Places in need of a stand-alone power system do sometimes not have the resources to carry out advanced design. Often, electricians in rural areas, as in our case in Tanzania, have limited earlier experience or limited possibilities of accessing new knowledge and findings. Further, they rarely have access to the useful computerized design and sizing tools that are used by many designers. The system at IDC has been simulated with the software Homer [2], by the research team at DU, after it was built [3]. The simulations show that quite simple changes could be done to improve the technical performance of the system. Those conclusions would have been difficult to draw without quite in depth knowledge in the specific technology, together with the use of modern tools and methods, but are easy to implement once the insight is there.

A technical solution is necessary for successful technology implementation, but it is never enough. To achieve long term sustainability of an introduced technology, a range of criteria have to be met. To mention some key factors; the promoters and the technique have to be perceived credible; producers, suppliers and consumers have to have relevant knowledge; the technology needs to be accessible and desired by the costumers; enough economic and political strength to carry through the project has to be available; management and long term commitment must be present; and a complete chain of coordinated companies and products must be established and be accessible when and where they are needed [4] [5] [6] [7].

With this insight on one hand, it is also obvious that ‘Rome wasn’t built in a day’. Research and product development is essential for our possibilities to have and to use new technologies. In the field of stand-alone power systems, valuable research is ranging from small hand held lamps to components and system solutions for mini-grids of varying sizes, types and complexity levels. New technical artifacts are usually developed to provide the desired service in a better way than earlier versions. One can however never be sure that all criteria required for successful technology implementation are fulfilled even if a new technical artifact has obvious benefits. That means that a risk is taken by all actors in the chain of producers, distributors, resellers, customers and users, when a new product or technology is introduced. If looking beyond the individual actors though; without people and companies ready to try and invest (money or time) in the latest, sometimes expensive, technologies or products, we would naturally not have any offer of good value, well tested and experienced products and technologies either. A challenge especially linked to stand-alone power systems is that they are often desired in societies with limited margins to make high risk investments. Lack of electricity access is strongly linked to poverty, and energy is regarded fundamental to poverty reduction [8].

Products and technologies that have been on the market for a while have naturally proven that there is what it takes for the technology to be sustainable. Sustainable does however not mean ‘forever’, and ‘on the market’ can mean on one specific market, but not on another. Areas coming in question for stand-alone power solutions are often remote and rural. Products needed to use a technology hence have to be transported over sometimes long distances and sometimes under harsh conditions. For a technology with a limited customer base, that challenges the access not only the product itself but also to spare parts and service.

It can be regarded a rule that all technical artifacts, at some point in time, need maintenance and replacement of components. This is where the real benefits of using locally available components and local knowledge to build sustainable stand-alone power systems come in. An example from another part of Tanzania will illustrate problems which may arise when products, no matter how good they are, are newly introduced in an area.

In Karagwe district in Tanzania, a solar powered water pumping system was constructed in 2006 in collaboration between a local organization and Swedish organizations. Water was pumped from a natural water source in a valley, up to a storage tank in a village. The pumps used in the project were selected carefully to be robust, and came from a Scandinavian manufacturer. After some years of use, the pumps started to be worn out and needed maintenance. The problem was, that no technician in Karagwe seems to know how the selected type of pump works. Up to now, spare parts have not been obtained in the region. In this case, it would possibly have been more long term beneficial if a locally established model of water pump was chosen, even if it would have been of lower technical quality. Although such a pump may had broken down earlier, the system would have been more sustainable if there was competence and equipment available to solve the arisen problems.

An incident from our case study at IDC serves as an example of how locally based knowledge can help make a system sustainable, although the quality of the components are causing problems. At IDC, there was a fire in an energy meter installed for research purposes by DU. It was found out that the fire was caused by a defect in the system's inverter. The fire did not only destroy the monitoring system, but also IDC's power system was harmed. As explained earlier, the power system was designed and built by an electrician from a nearby town. To solve the problems that the fire caused, the electrician was called in. He could repair the system without any difficulties as a part of his routine work. Since all components were purchased locally it was easy for the owners and the electrician to know where to turn for spare parts, support and technical advice. That, we think, gives advantages superior to the better energy efficiency and possibly longer lifetime of components that could be obtained by using an optimized system solution or components of better quality.

Since the electrician is not continuously present at IDC, it is essential that people in daily contact with the system know how to operate it properly. Those people also need to be knowledgeable enough to understand when it is necessary to call in an expert. The power system at IDC is most of the time used in a way that precaution does not need to be taken regarding overconsumption of power or energy [1]. That simplifies the daily operation of the system. Evaluations have shown though, that at occasions with high loads and low power generation, the system has been operated in a not optimal way from a technical point of view. So, even though the competence about the system is found locally, in town nearby, there are challenges regarding users' knowledge about the technology and operation of the system.

Conclusions

We think that a key factor to successful implementation of stand-alone power systems is to use local knowledge to build them. Local actors most certainly choose components that are locally known. In some cases, the locally established technology, design or product may be less energy efficient and less robust than other possible solutions. Further, a local designer or constructor may have limited earlier experience or limited possibilities of accessing new knowledge and findings about the technology. Those are disadvantages. The advantages associated with having the knowledge close to the technical system go beyond that though. The local access not only to a technical artifact itself, but also to service and spare parts, creates long-term sustainable stand-alone power systems.

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