On the Importance of Power Quality in Solar Home Systems for Energy Access

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***Abstract*—Solar home systems are a prevalent method to enter the electrification ladder, and may gain even more popularity as the load diversity increases, or when they can be adopted into projects in which they can be extended into larger electrical networks. DC power quality needs to be regarded if such future perspectives are to become a durable reality. This paper discusses the need for power quality in solar home systems, proposes a methodology for researching it, and illustrates potential issues for solar home systems by an example.**

***Index Terms*—DC, Energy Access, EMC, Multi-tier Framework, Power Quality, Solar Home System**

I. Introduction

The multi-tier framework (MTF) is one of the core concepts within energy access (EA) and universal electrification. In short, the MTF [1] describes electrification in five (or six, if tier 0 with no electricity is included) different tiers, where the lowest category describes situations in which few low power appliances such as LED lamps can be used, and the highest tier illustrates energy provision systems of at least 8.2 kWh and 2 kW peak power ratings [2]. The MTF does not only describe power and energy ratings however, as it also expresses the electricity's availability, reliability, quality, affordability, legality, and safety measures (see also [3] for the MTF in the context of Maluku, Indonesia).

Decentralized EA solutions have emerged as a response to the failure of centralized grids reaching everyone. One of the most straightforward decentralized methods to enter either the first or second tier of the MTF is through solar home systems (SHSs). These devices typically consists out of a small battery pack and few integral systems like balancing circuits, voltage controllers, and a charge controller (e.g. a maximum power point tracker (MPPT)), to which a photovoltaic (PV) panel and low voltage dc loads can be connected (see Fig. 1).

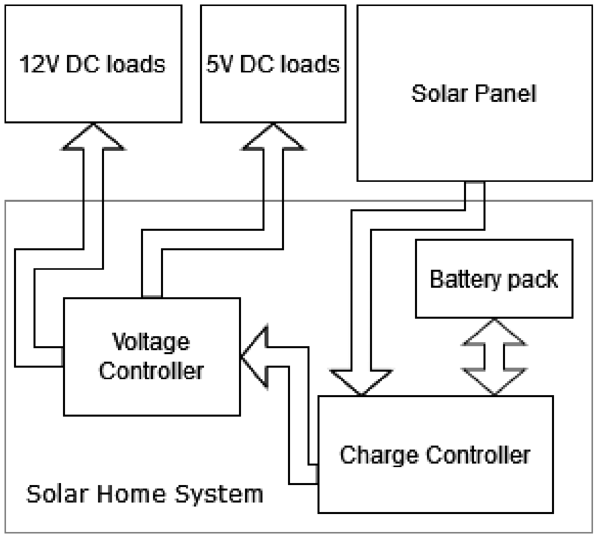

Fig. 1. Simplified diagram of a typical SHS

It may seem superfluous to consider power quality in SHSs when they are regarded as little more than fancy PV-connected power banks. But considering that the SHS is intended as the first step on the electrification ladder it becomes clear how the attributes of the MTF gain entrée for two apparent reasons. Firstly, ascending the MTF is predominantly an effort towards more diverse electrical loads, that may emit unexpected noise, require certain levels of power quality, or demand higher power ratings. Secondly, expanding the SHSs capacity through modular design or connecting them to e.g. micro-grids requires thoughtful considerations of power quality and electromagnetic compatibility (EMC) design *a priori*.

II. Theory

In contrast to ac supplies, dc supplies do not have multiples of its fundamental frequency of 0 Hz. Harmonics can arise however, due to e.g. dc-dc converters and connected loads [4]. These dc-dc converters are commonly operated at high switching frequencies and could therefore cause electromagnetic interference (EMI) [5]. If the resonance frequencies are excited, e.g. by power electronics, problems with power quality can occur. Furthermore, turning loads on and off can cause significant transients, as a result of the inrush currents [6]. Besides, power quality issues occur by cause of loads connected to the dc bus which can propagate in the system. Such power quality issues in dc grids are currently under researched and mostly undefined in standards [4].

Where the MTF frames power quality predominantly as a metric that affects the user's ability to use their desired

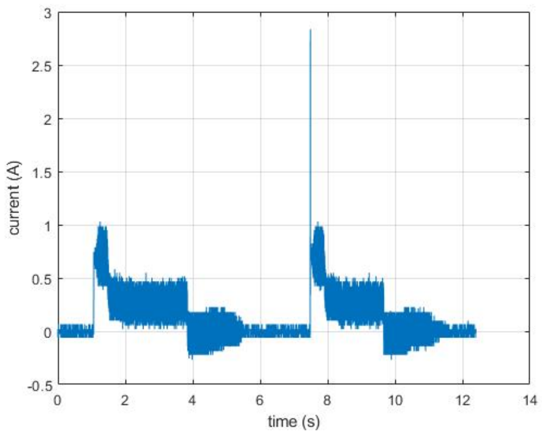

Fig. 2. Captured current from a 12 V dc power supply towards a small brushed electric motor, introducing a 400 Hz noise signal. The connected motor is switched on at t = 1 s, and turned off at t = 3.8 s, causing a backwards current into the power supply. At t = 7.5 s, the switched-on motor is plugged into the power supply, and switched off at t = 9.7 s, creating inrush currents of 1 A and a peak current of 2.8 A.

loads [1], it should also be associated to preventing the malfunctioning of, or damages to both the SHS and its auxiliary equipment. Simple low voltage loads, such as shown in Fig. 2, can cause transients due to relatively large inrush currents that could damage or interfere with the functioning of the SHS, and other loads connected to that SHS. But the SHSs energy provision itself is also dependent on good EMC practices, as it has e.g. been shown that EMI such as current ripples and transients disturbs the MPPT, therewith rendering the whole system to be less efficient [7]. Additionally, if EMC is thoughtfully taken into account from the start, more expensive EMI filters may be avoided in the future.

III. Methodology

Given the absence of research on power quality for SHSs and the overall lack of clear standards for SHSs and its utilities, we propose an extensive empirical and analytic research. First, it is vital to know what components, safety measures and EMC designs are generally considered by SHS manufacturers. Subsequently, the expected load-, and noise profiles of dc-loads have to be gathered and stochastically evaluated in order to make a thorough risk assessment.

Collecting such profiles is not a straightforward endeavor however. Technologies in low-income communities are often overtly distinct from ‘western’ technologies, even when they are hybridized with each other [8]. So making a definitive list of ‘possible’ load types is likely to be a task doomed from the outset. Some SHS manufacturers use non-universal 12 V plugs to prevent users from using other loads that might damage the SHS, reduce the battery’s lifetime, curtail the specified daily run-time, or decrease its efficiency. But such a solution is undesirable as it actively limits the consumers opportunities in electrification, and may very well bring paternalistic interpretations of SHSs in general [9].

Accepting this limitation, we propose to complement the research by analyzing which worst-case scenarios need to be considered from the perspective of the SHS itself i.e. to find the weak spots of the SHS. Such research should then help to maximize the utility of SHSs, bringing them more robustness, and make them ready to be adopted in projects of electrification and swarm electricity.

IV. Summary

This paper discussed the virtue of good power quality in SHSs and proposed a methodology to research it.

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