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Off-grid electrification with solar home systems: An appraisal of the quality of components

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ABSTRACT

Solar home systems (SHS) are seen as an attractive option for off-grid electrification in rural areas in developing countries. The combined effect of declining photovoltaic module costs and success in micro-finance has resulted in increased SHS installations in emerging economies in Asia such as Bangladesh. Majority of the SHS components are now manufactured locally with the exception of PV cells. Considering the role of component quality in SHS performance, technical quality of four key SHS components: solar panel, battery, charge controller and lamp circuit (inverter) from market-leading manufacturers were evaluated in this study in laboratory settings, against national and international standards. All of the tested components met some evaluation criteria in their respective categories but none met all. Key performance failures were found to be related to inverter efficiency, reverse polarity protection in charge controllers and battery capacity, which are critical for optimum performance of the system. Findings in this study point towards an ineffective regulatory mechanism for quality assurance and the protection of consumer rights, which needs to be rectified for maintaining public confidence and sustaining the growth of SHS based off-grid electrification.

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1. Introduction

1.1. Energy infrastructure development challenges

Access to modern energy services is essential for economic development and human wellbeing; and yet 1.2 billion people or 17% of global population lack access to electricity, more than 95% of whom are in countries in sub-Saharan Africa and developing Asia.[2] One of the key challenges faced by most, if not all developing countries, is the sustainable development of energy infrastructure to provide the population with access to convenient forms of energy at an affordable price, against a backdrop of growing demand [1]. The increasing demand for electricity is a particular challenge for both developed and developing countries and will require the installation in the coming decades of as much power generation capacity as was installed in the entire 20th century [2]. Much of the growth in demand for electricity is coming from non-OECD (Organization for Economic Cooperation and Development) nations [3]. Countries with high economic growth and significant population such as China and India are leading the trend in electricity demand growth. Although the development and expansion of electricity generation in most energy intensive countries were predominantly based on fossil fuel [4], the importance of increasing the share of renewable energy in the generation mix to reduce greenhouse gas emissions and to enhance energy security is well recognized [5,6].

Bangladesh demonstrates a number of energy infrastructure development challenges faced by developing countries with relatively higher rates of economic growth, growing demand for electricity and lower rates of access to electricity [1]. The country experienced steady economic growth during the past decades and since 2004 annual growth in gross domestic product (GDP) has been around 6% [7], against an electrification coverage of 62%[3] and

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[2] Around 80% of the population without electricity live in rural areas in developing countries. The statistic is obtained from the International Energy Agency (IEA). http://www.iea.org/topics/energypoverty.

[3] Electricity access is disproportionately distributed in Bangladesh. The share of access is 90% in urban areas compared to 48% in rural areas in 2013. Source: IEA World Energy Outlook 2015. http://www.worldenergyoutlook.org.

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one of the lowest per capita electricity use of 290 kW h [8]. The average rate of annual growth in demand for electricity was 7.16% for the period 2001–2011. Increases in energy intensive industries and rising energy use from urban buildings are two of the primary reasons for the burgeoning growth in demand for electricity. A relatively high population growth [9], rapid urbanization [10], the lack of suitable land for buildings and increasing urban temperatures due to urban heat island and global climate change [11] are suggested to contribute further to the growing demand. In contrast, annual growth in electricity generation capacity was variable with a range of −1.69 to 25.95%[4] between 2001 and 2011. Demand always outstripped supply [8], resulting in rolling blackouts throughout the year, albeit with varying intensities due to variations in seasonal demand. Chronic power outages, coupled with low levels of electrification had a severe impact on the economic performance of the country [12] and growth [13], with a significant knock-on effects on quality of life and society.

1.2. Access to electricity and policy directions

Apart from the impacts on industry and economy as a whole, the lack of adequate supply affects the population disproportionately. Rural areas suffer from blackouts and brownouts more often than urban areas where economic activities are concentrated.[5] On the other hand, expansion of the electricity grid is frozen or kept to a minimum in rural areas until a reasonable level of parity is achieved between the growing demand and generation in the existing grid-connected areas. Evidence of the slow progress in increasing access can be found in the recently published (2010) power sector master plan (PSMP) of Bangladesh, which appears to be biased towards increasing generation capacity [15]. The 2010 PSMP illustrates long-term policies until 2030 and focuses on the development of offshore facilities for importing coal and liquefied natural gas (LNG) to create a resilient supply chain in the context of dwindling local gas reserve. Planned increases in the generation capacity are based on the proposed extension of coal and LNG supply chains. There are plans to import hydroelectricity from neighboring countries such as Nepal and Bhutan via India and to construct a cross-border grid for the import of electricity. However, the 2010 PSMP does not discuss in detail how access to electricity will be improved, in particular in rural areas, other than suggesting the development of domestic wind and solar-based generation.

1.3. Solar off-grid electrification in Bangladesh

Solar and wind are the two key renewable energy technologies highlighted in the PSMP and other energy sector policies in Bangladesh [15,16]. However, the potential for off-grid wind is low, except in coastal areas [17]. Solar, mostly photovoltaic, appears to be the preferred policy direction for off-grid electrification. Solar PV is particularly suitable for areas with low consumer density, where grid connection may not be economically feasible in the short term [18]. A standalone solar home system (SHS) with battery for energy storage is widely accepted as a mature and effective means for off-grid electrification where demand for electricity is relatively low [19,20], typically less than 100 W. Large-scale implementations of SHS was initiated by the Infrastructure Development Company Limited (IDCOL), a wholly owned subsidiary of the Government of Bangladesh (GoB) [21]. Funds for the project came from GoB, as well as from donor agencies such as International Development Association (IDA), Global Environment Facility (GEF), Asian Development Bank (ADB), Islamic Development Bank (IDB), Gesellschaft für Internationale Zusammenar-beit (GIZ) and Kreditanstalt für Wiederaufbau (KfW) [22]. The program is implemented through 47 partner organizations (PO), mostly non-governmental organizations (NGO), who receive grants and concessionary loans from IDCOL upon installation of SHSs in rural households. Over the lifetime of the project, only 17% of the project cost has been disbursed as grants while the rest (83%) has been provided as loan, indicating the long-term financial viability of the project [22].

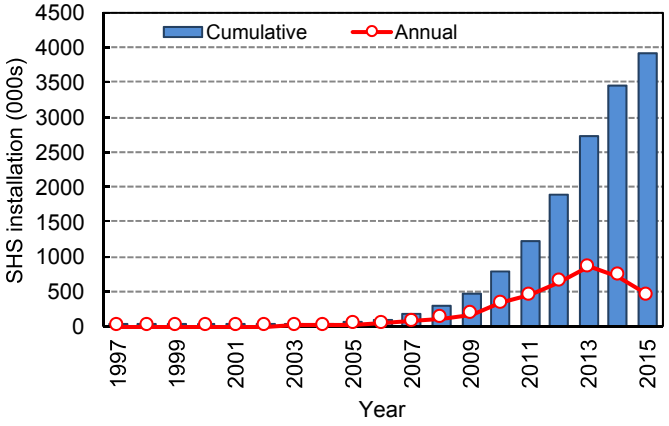

Fig. 1. Solar home system installations in Bangladesh. Data source: IDCOL [22].

Partner organizations are primarily responsible for the design, installation and after-sales service of the SHS and operate under approved guidelines from IDCOL. Most of these POs have extensive national microcredit networks and have the necessary infrastructure to provide service to the majority of the rural population. An enduser's purchase of an SHS is administered by the PO's microcredit financing system. The majority of the system components are sourced from local IDCOL-approved suppliers and original equipment manufacturers (OEM). The segregation of administration, manufacturing and sales of SHS in Bangladesh has encouraged the development of a local supply chain [19], creating up- and downstream jobs in all stages of the system lifecycle. The market has grown steadily over the past decade and as of December 2015, over 3.90 million SHSs have been installed in off-grid areas of Bangladesh [22]. Year-wise installations of SHS in Bangladesh for the period 1997–2015 are given in Fig. 1, showing exponential growths in annual and cumulative installations.

1.4. Solar home system and components

SHSs discussed here are standalone solar power systems to provide electrical energy to households in off-grid rural areas. An SHS comprises a solar panel to convert sunlight into useful electrical energy, a battery as the energy storage medium to meet demand during low/zero solar resource availability, a charge controller to regulate the charging and discharging of the battery,

[4] The highest annual growth in generation of 25.95% occurred in 2011 and the lowest of −1.69% was in 2007.

[5] An evaluation of daily generation, demand and load shedding in Bangladesh suggests that on a typical day the intensity of blackout in regional cities and rural areas is more than the intensity in the capital, Dhaka. The intensity refers to the percentage of load shed as well as the duration of load shedding (blackout). In some cases, the percentage of load shed outside Dhaka is twice the percentage in the capital. Daily demand, generation and shortfall data can be found on the website of Power Grid Company of Bangladesh (PGCB), the organization responsible for the maintenance and upgrade of the electricity grid in Bangladesh [14].

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