Renewable and Sustainable Energy Reviews 65 (2016) 568–576

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Potential and economic feasibility of solar home systems implementation in Bangladesh

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ARTICLE INFO

Article history:
Received 26 January 2016
Received in revised form
16 June 2016
Accepted 14 July 2016

Keywords:
Power crisis
Solar energy
SHSs
Economic viability
Bangladesh

ABSTRACT

Solar home systems (SHSs) are the real hope for electrification of the off-grid areas in Bangladesh by utilizing the solar energy in renewable and sustainable basis. This paper demonstrates the solar energy prospect, the present status and dissemination schemes of SHSs in off-grid and coastal areas of Bangladesh by several government and Non-government organizations (NGOs). The country has an average daily solar radiation ranges between 4–6.5 kWh/m^2. Currently, more than 3.8 million SHSs of capacity range 10–135 Wp (watt peak) with a total capacity of 150 MW have been disseminated in rural and isolated areas in Bangladesh. In this paper, ten case studies of capacity 20 Wp, 30 Wp and 42 Wp were investigated to evaluate economic viability at two randomly selected villages in Sirajgonj district and Jessore district, Bangladesh. The analysis showed that the SHSs for small business enterprise and household with small income generation are economically viable rather than only household lighting.

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1. Introduction

Solar photovoltaic (PV), a silicon made device which converts the solar energy into electrical energy through photoelectric effect. Although the PV technology is still expensive, the popularity is climbing hastily due to its simplicity in design and installation. Moreover, it is environment friendly, sustainable and almost maintenance free [1]. In the year 2014, the total global solar PV capacity was approximately 177 GW of which the Asian countries contribute almost 60% of the total capacity. The electric power generation from solar energy through PV technology have a

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http://dx.doi.org/10.1016/j.rser.2016.07.062
1364-0321/

leading position in some countries including Asian countries, European countries and United States of America [2,3]. In Serbia, using Photovoltaic Geographical Information System, it has been estimated that about 1 MW of electricity can be generated from solar energy through different PV solar plant for 23 cities of the country [4].

The efficiency of PV cell is affected by local environmental temperature, relative humidity, dust in air, and global solar radiation intensity [5–7] and it varies between 40–60% for low to medium temperature. Therefore, several researchers have introduced maximum power point tracker-technique in PV to obtain the maximum power output through continuous adjustment of operating point to the solar radiation [8–11]. PV technology is more suitable for off-grid or micro-grid applications of low to medium power in remote and coastal areas due to its reliability and ease scaling of input source [12,13]. However, along with the efficiency improvement, techno-economic feasibility of the technology is another concern for its successful implementation. Recently, emphasis has been given on investigation of the techno-economic analysis of alternative energy technologies like solar collectors, heat pumps, biomass, ground energy and cogeneration systems for greenhouse heating because of high heating loads [14–16]. In Pakistan, the design and economic analysis of 1928 Wp stand-alone solar PV system for a residential household found its suitability compared to conventional electric supply [17]. Besides, the hybrid systems of solar PV with wind/biomass/diesel are another stand-alone suitable option for coastal and isolated areas. The modeling, simulation, and techno-economic evaluation of diesel generator-renewable energy systems (PV–wind–diesel–battery hybrid system) by means of HOMER software package were found as a feasible option for the most remote regions in different nationalities [18–20]. In India, 9 different combinations of renewable energy resources were analyzed based on economic, technical and social aspect to find out the best hybrid system for a cluster of village at Uttarakhand state [21]. The techno-economic and environmental assessment found that the hybrid micro-grid or hybrid mini-grid system is the most potential to meet the energy demand for the households in a cost effective manner [22–24]. Therefore, various techniques were investigated for pre-feasibility analysis, optimum sizing, modeling, control aspects and reliability issues because of the stochastic nature of the systems [25,26].

However in Bangladesh, PV technology is widely used in SHS for off-grid rural electrification with no connection with electrical grid. Major portion of the population in the country are poor and live in rural isolated areas. Only few of them have access to grid electricity due to inadequate generation compared to demand and poor infrastructure. Solar home systems are the effective way to supply uninterrupted electricity to these off-grid areas. In Bangladesh, the first solar PV based project was initiated with the financial support of France of capacity 62 kW peak [27]. Besides, PV micro-utility system is getting popularity as the owner of the system shares the electricity with his neighbors. A study in Bangladesh showed that almost 10.554 km^2 of bright roof-tops are available for the application solar PV technology in Dhaka City Corporation [28]. The economic and environmental evaluation found that the stand-alone PV technology is feasible in remote and rural areas of Bangladesh where no grid connection is available [29,30]. However, the hybrid system of wind–solar PV-diesel-battery is economically feasible technology as a replacement for conventional grid connection and found to be the most suitable for electrifying the coastal and isolated Island of Bangladesh [31–36]. Moreover, the analysis of different financial parameters of proposed 1 MW grid-connected solar PV system in Bangladesh showed the favorable condition for its successful implementation [37].

This review paper presents a detailed study of solar energy potential in Bangladesh, current status of SHSs and implementation methodology, issues and challenges for its successful promotion as well as its benefits. The paper also investigates an economic analysis for identifying whether the technologies are financially feasible or not in putting into practice in Bangladesh.

2. Present energy scenario in Bangladesh

Bangladesh is a densely populated south Asian country with population of almost 164 million. The primary energy consumption in the country increased to nearly 28.2 million tons oil equivalent (Mtoe) in 2014 [38]. However, the country has unsatisfied electricity demand and all the peoples have no electricity access yet. Although the installed electricity generation capacity has increased to 12,071 MW in December 2015 from 5936 MW in 2010, it is still insufficient to meet the increasing demand of electricity required for economic and industrial development [39]. Table 1 presents the overall power scenario in Bangladesh [39,40]. Adequate electricity supply is the pivotal ingredient for alleviating poverty and increasing GDP of any country. However, approximately 68% people have the electricity access in Bangladesh. Likewise, the average rate of electricity generation per year is 316 MW still remains insufficient to meet the country's increasing demand [41] and causes average load shedding of 1000–1500 MW [39]. Thus, it is a great challenge for the country to meet the future power demand 34,000 MW by the year 2030 from the existing level [40].

Electricity generation scenario in Bangladesh says shocking news that indigenous energy sources are depleting hastily and producing environmental pollution. Power generation in the country largely depends on fossil fuel and only natural gas accounts about 7628 MW which is almost 63.19% of total installed generation capacity [39]. The country has approximately 0.3 trillion cubic meters natural gas reserve and 1062.50 million tons recoverable coal reserve at the end of year 2014 [38]. It is expected that the reserve of natural gas will be exhausted by 2020 [39]. Therefore, considering environmental impact and rapid depletion of fossil fuel it is necessary to find out renewable and sustainable energy sources immediately to meet the country's demand.

3. Methodology and study area

3.1. Demography of survey area

Two villages namely, Hatikumrul in Sirajgonj district and Abdulpur in Jessore district, Bangladesh (Fig. 1) were randomly selected for evaluation of economic feasibility for implementing SHS. Majority of the households in the selected villages are in low and

Table 1
Recent summary of electricity situation in Bangladesh, 2015 [39,40].

Sector	Status
Generation capacity	8525 MW
Maximum generation	8177 MW (August 13, 2015)
Transmission line	9250 km
Distribution line	300,000 km
Distribution loss	12%
Per capita electricity generation (including captive generation)	370 kWh
Number of consumers (connection wise)	17 million
Total beneficiaries	95.60 million
Access to electricity (including renewable sources)	68% (2014)