Sustainable Energy Technologies and Assessments 30 (2018) 121–138

Contents lists available at ScienceDirect

Sustainable Energy Technologies and Assessments

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

Hybrid renewable energy supply for rural healthcare facilities: An approach to quality healthcare delivery

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ARTICLE INFO

Keywords:
Electricity demand
Energy supply
Healthcare services
Renewable energy
Reliable supply

ABSTRACT

The lack of modern electricity supply has been a major impediment to proper functioning of the healthcare centers in the rural areas, contributing to high maternal and child mortality rates in a country. Therefore, this study focuses on how to address the identified problem so that the healthcare centers or clinics in the remote areas can provide timely delivery of medical services for the concerned people. This paper, then, presents the analysis of stand-alone hybrid renewable energy systems for basic healthcare services in the rural areas, where there is no grid energy supply or the supply from the existing grid is erratic and unreliable. One major factor that informs the selection of the hybrid energy system in this study is that it promises high reliability compared to a single energy system. The research presents a statistical analysis of the potential of wind and solar energies for a selected rural locations in Nigeria based on the available long-term hourly and daily meteorological data. It employs an optimal technical and economic design and sizing of hybrid electrical power systems' components such as the wind, PV, battery and inverter systems, using the hybrid optimisation software (HOMER). Results show that Sokoto and Jos sites exist in the high wind potential regions, while the remaining sites are only suitable for small wind applications. Values obtained for global radiation show that all the sites enjoy considerable solar energy potential suitable for varying degree of solar energy applications. PV/wind/diesel/battery hybrid system configuration is considered optimum for rural health center at Iseyin, Sokoto, Maiduguri, Jos and Enugu, while hybrid systems involving PV/diesel/battery is considered ideal for Port-Harcourt, due to the quality of renewable energy potential. Hence, it was concluded that, the abundance of wind and solar resources in the country create an ideal environment for inclusion of renewable energy systems in the design and implementation of standalone power supply systems to improve rural healthcare delivery.

Introduction

Reliable electricity access is a pre-requisite for improving the social and economic lives of the people in rural areas. It enhances healthcare delivery, education as well as other developmental growth within the local communities. At present, 17% of world population have no access to electricity, 85% of which lives in rural areas of Sub-Saharan Africa (SSA), South Asia and other developing countries, with SSA having the largest share of the electricity deficit rate [1].

The majority of these people have limited prospects of gaining access to electricity in the near future. The implication of this can be translated as close to 1 billion people around the world are being served with healthcare facilities with no electricity access [2]. This deficiency implies that medical equipment such as ultra sound, autoclave, centrifuge and medical x-ray cannot be used in such places as presented in Fig. 1. Surgery services sometimes delivered by depending on the ambient light from windows or kerosene lamps at nights. Reports indicated that, quite a number of women die on a daily basis during pregnancy and childbirth in rural places due to poor medical care. By providing at least a minimum lighting and electric power supply to minor surgical equipment could reduce the high maternal mortality rate by 70% [2].

Diesel generators have traditionally been used to power most off-grid clinics and hospitals for supplementing the unreliable grid supply for grid-connected facilities, but this is associated with attendant costs of diesel fuel and unreliable delivery as well as high CO_2, CO and particulate emissions contributing to air pollution and climate change.

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https://doi.org/10.1016/j.seta.2018.09.007
Received 15 February 2018; Received in revised form 29 August 2018; Accepted 24 September 2018

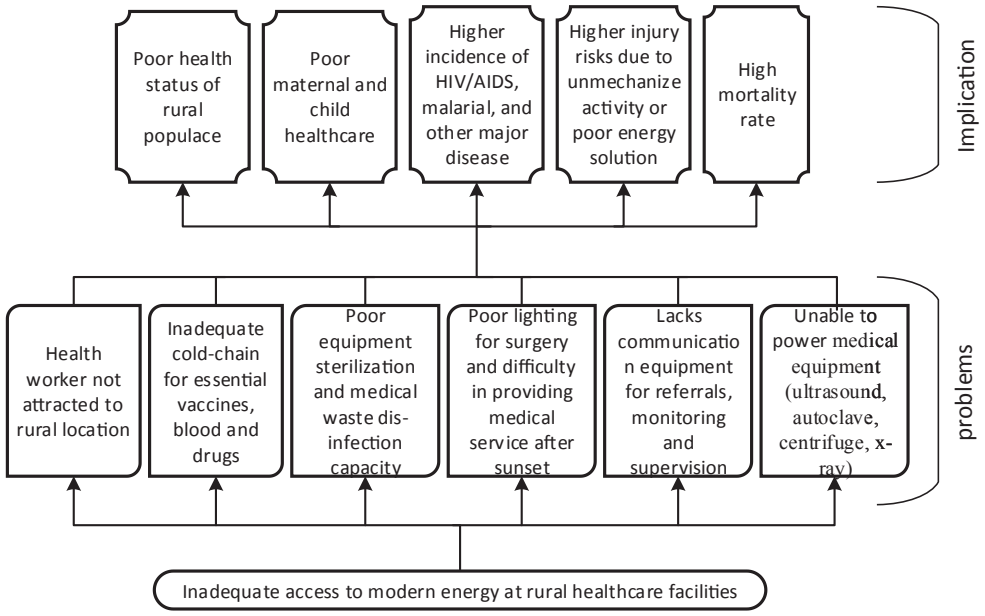

Fig. 1. Impact of energy access on rural healthcare services.

The rural health sector in developing nations are challenged with several problems, which have hindered effective delivery of healthcare services to the people living in the rural communities. For instance, unreliable power supply can render cold-chain activities inoperable; furthermore, the lack of illumination (light) at the clinics at nights usually keeps patients arriving late in the night for medical attention to wait until the following morning before medical attention can be rendered to them. This has led to many problems including obstetric complications, which is one of the root causes of high maternal mortality rate in sub-Saharan Africa region [3]. A lack of antenatal care, absence of skilled birth attendants and limited availability of emergency obstetrics procedures due to lack of electricity are reasons for this situation. Therefore, electricity should be a priority for effective public healthcare delivery.

In rural areas with no access to electricity from the grid, renewable energy technology could be a viable option. These alternative technologies for producing electricity have received greater attention in recent years, due to their cost effectiveness in operation, environmental friendliness as well as sustainability [4–12]. In the case of rural health facilities, a solar/wind/diesel generator hybrid system can be deployed to cater for the need of un-electrified rural health centres. It will provide means to power critical lighting, mobile communication devices and certain medical equipment for delivering timely and critical medical care for the rural dwellers. Hence, the role of energy supply in healthcare services delivery in the rural areas where there is no grid extension or reliable power supply cannot be over emphasized.

Renewable energy sources have proven their ability to contribute substantially to global climate protection efforts by reducing the greenhouse gas emission while meeting rapid energy growth demand [13–19]. However, in technical terms, a system that wholly depends on single-source renewable energy alone is not necessarily considered reliable, especially for isolated loads in remote areas [4]. This is because electricity supply through a renewable energy source that has a variable or intermittent characteristic, may not guarantee energy production be available at all times. This is why a hybrid power system that combines more than one source, e.g. conventional and renewable energy systems or two/more renewable energies, are proposed. A properly selected renewable power system is expected to considerably reduce the need for fossil fuel system use by ensuring a relatively higher renewable energy penetration. Such a system is also expected to achieve a reliable power supply, as the conventional power sources will assist the renewable sources during varying environmental conditions, by balancing the electrical power. Therefore, a hybrid system consisting of solar PV, wind, battery and diesel generator systems can be considered a better option for isolated loads. Such an option, where the wind and solar PV systems are used as main sources of energy, while the diesel generator serves as a backup source, and battery bank as a storage system is expected to; (i) satisfy the energy demands, (ii) minimize the costs, (iii) maximize the utilization of renewable sources, (iv) optimize the operation of battery bank, (v) ensure efficient operation of the diesel generator, and (vi) reduce environment pollution emissions.

Several research studies on off-grid energy systems analysis exist in the literature for both single-source and hybrid configurations. This paper provides a brief survey on them. The techno-economic design of hybrid systems has been discussed [5]. The techno-economic sizing of off-grid hybrid renewable energy system for rural electrification in Sri Lanka has been presented [20]. The design and economics analysis of an off-grid energy system has been published with a focus on the household electrification [21]. A paper has been published on techno-economic feasibility of photovoltaic, wind, diesel and hybrid electrification systems for Colombia [22]. Furthermore, the techno-economic analysis of stand-alone hybrid photovoltaic-diesel-battery systems for rural electrification in eastern part of Iran has been presented [23]. A study has been discussing which focuses on the integrated optimal design and sensitivity analysis of a standalone wind turbine system with storage for rural energy supply [24]. The techno-economic feasibility analysis of a solar-biomass off-grid system has been discussed, with focus on the electrification of remote rural areas in Pakistan using HOMER software [25]. A study has been published on the optimal design configuration using HOMER [14,26].

In addition, a review of sustainable energy access and technologies has been discussed on healthcare facilities focusing on the global south [27]. A study has been published on off-grid systems for rural electrification in developing countries with emphasis on definitions, classification and a comprehensive review [28]. A review on planning, configurations, modelling and optimization techniques has been discussed focusing on renewable energy systems for offgrid applications [29].

These existing studies provide relevant simulation, analysis and background for this current paper, especially on the technical and economic evaluation of the proposed electricity systems. The academic contributions of these studies are useful for understanding and