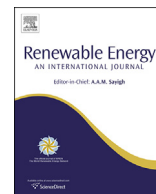




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Design of a photovoltaic–wind charging station for small electric Tuk–tuk in D.R.Congo

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ABSTRACT

Renewable energy charging stations can play a key role in the successful development and deployment of electric vehicles in the areas not connected to the electrical grid. This paper discusses the possibilities of using electric Tuk–tuk battery charging station in the rural areas of the Democratic Republic of Congo (DRC); the basic specifications of the proposed vehicle propulsion system are taken into account. The proposed charging station is powered by renewable energy source such as wind or photovoltaic (PV) used as stand alone or in hybrid configuration with battery storage system to avoid the use of diesel generators or additional stresses on the very weak electrical grid, where it is available. Different feasible configurations of the charging station using renewable energies are simulated using HOMER software and the results compared to the corresponding diesel generator while responding to the battery charging energy requirements of the Tuk–tuk. Two different strategies for operating the charging station are simulated and the results are analyzed and discussed in order to select the best configuration. The decision criteria used for these comparisons include the equipment setup, energy production, financial viability for a project lifetime of 20 years.

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1. Introduction

Rapid and unplanned expansion combined with the economic growth of many cities in developing countries has led the local population to adapt their means of transport in those areas. Three-wheeler motorized Tuk–tuks are currently extensively used as a form of urban transport of people and goods in many developing countries [1]. The design and operation mode of these vehicles are cost-effective and well suited to narrow and ill-conditioned roads as it most of the case in the Democratic Republic of Congo [2]. One of the major disadvantages of the use of Tuk–tuk is the permanent reliance on fuel which presents a growing pollution problem due to the harmful gas emission such as carbon dioxide, carbon monoxide, particulate matter, sulfur dioxide as well as nitrogen oxides from the internal combustion engines through their exhaust system [3]. Beside the environmental problems, Tuk–tuks currently operating in DRC are not manufactured locally but imported from other countries; this significantly increases the price of the spare parts and petrol delivered to the Tuk–tuk users in remote locations [4].

The proposed solution to this problem is to substitute the Tuk–tuk's internal combustion engine with electric propulsion systems such as DC motors supplied by batteries [5]. We have to emphasize that DRC has poor electrical grid coverage with a very low and unreliable electrification rate of 11%. Most of the electrical equipments are then supplied by stand alone diesel generators [6]. Thus provision must be made for alternative, reliable, cost-effective and available energy sources for battery charging such as renewable energy systems. Hybrid renewable energy system has already been studied in Ref. [7] for electricity supply of off-grid remote Base Transceiver Stations for network operators in the DRC. These hybrid renewable energy systems can also play a major role in the development of electric vehicle's charging stations in isolated areas not served by the grid. In this paper the use of electric Tuk–tuk in the DRC is proposed with the emphasis on the electrical design of the corresponding battery charging station. The proposed charging station is powered by renewable energy sources such as wind or PV system in conjunction with a battery pack used stand alone or in hybrid system configuration to avoid the use of diesel power generators or additional stresses on the very weak electrical grid, where it is available. The design of a feasible charging station is simulated using HOMER software. The decision criteria used for these assessments include, the equipment setup, energy production, financial viability for a project lifetime of 20 years.

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Table 1
EV infrastructure charging standards overview.

Type	Specifications
Home charging	Level 1/2, mode 1/2, 8–12 h for complete battery charge, Residential, workplace, etc.
Semi public charging	Level 2, mode 2, 3–6 h for complete battery charge, Workplace, super markets, community facilities, etc.
Public charging	Level 2/3, mode 2/3, DC charging (mode 4), 1–6 h for complete battery charge, City centers, high streets, tourist attractions, etc.

The charging levels 1–3 in the table above are related to the typical charging power categorized as follows: level I (1.5–3 kW), level II (10–20 kW) and level III (40 kW and up).

The charging modes 1–3 are linked to the amount of protection of the socket-outlet where the vehicle is plugged; as well as to the conversion from the AC main power to DC high voltage. Mode 4 defines DC charging using an external battery charger and is used for fast charging. In addition to fast charging, the exchange of empty batteries with charged ones (called battery switching) is another method to power the vehicle in a short time. Level I – mode 4 is suitable to the remotes areas not served by the grid and can be used in this paper as a charging option for electric Tuk–tuk in the DRC.

2. Motivation

The different country's crisis saw great deterioration of public transport infrastructure from which DRC is recovering very slowly [8]. Many roads are in poor condition and the fuel supply system to the different regions was also deeply affected. Consequently, outside of the main cities, private and commercial road transports throughout the country are narrow and generally not in good condition, operating at only a fraction of their original design capacity. Therefore, due its size and ability to move in small places at low speed, electric Tuk–tuk can play a major role in the transport of goods and persons in the country. Even if only eleven percent of the population has access to electricity (25% percent in urban areas, and 4% in rural areas), the country is endowed with rich renewable energy resources such as biomass, wind, hydro or solar that can be used as a primary source of electricity and contribute to the development of Tuk–tuk charging station in isolated areas without or with poor grid connection.

3. Global overview charging station infrastructure

Different types of charging station are already operating in developed countries. Some standards have been set contributing to the ease of use of electric vehicles while at the same time contributing to an efficient integration into the electrical grid [9]. But in practice, it is impossible to have a single standard to meet the needs of different vehicle types, different charging scenarios in different environments. It has to be noted that both AC and DC charging station can be used. An overview of the current charging station types is presented on the table below.

4. Vehicle analysis and electrical load

The parameters of the electric motor used in the Tuk–tuk are given in Table 1 below [10]:

Table 2
Tuk–tuk general description.

Specification	Remarks
Electric motor	1000 W/48 V brush DC motor
Energy consumption	6–10 kWh/100 km
Maximum speed	30 km/h
Weight	30 kg
Outline ($L \times W \times H$)	$2.67 \times 1.24 \times 1.69$ m
Distance per recharge	Close to 100 km

Table 3
Battery general description.

Specification	Remarks
Voltage	$12 \text{ V} \times 4 \text{ pcs}$ (48 V)
Capacity	120 Ah
Total energy	5.760 kWh
Total weight	160 kg
Charging time	6–8 h
Charging current	10 A

Four 12-V deep cycle lead acid batteries connected in series are selected to provide 48 V as an electrical input to the DC motor. Regardless of its larger size and weight, lead acid batteries are inexpensive compared to Ni-MH or lithium-ion and they readily available in DRC.

The parameters of the Tuk–tuk battery system are given in Table 2 below [11]:

It is the energy needed to recharge the electric Tuk–tuk batteries that is considered as an electrical load drawing energy from the charging station. Symmetric load profile has been used to establish the maximum system capacity which is equal to the maximum load demand that the charging station can cover during the charging time. In this case the load is 1.3 kW peak and 5.3 kWh energy consumption per day (Table 3).

5. Renewable resources assessment

The country has adequate potential in wind and solar resources for the development of renewable energy sources. The average daily solar radiation is 5.2 kWh/m^2 and the wind speed in some locations can reach 4.3 m/s [12]. Figs. 1 and 2 give the average monthly solar and wind energy resource profiles for three different cities in the DRC. From these profiles it is noticeable that the resources are almost alike for these different locations, so only the worst site in energy resources “Mbuji-Mayi” is selected to investigate the design and simulation of the charging station.

6. System configuration and sizing of the mains components

6.1. System layout

The proposed system is composed of PV and wind with battery storage system as shown in Fig. 3. The power is flowing from the renewable energy sources toward the electric vehicle through the DC bus; it can also be stored in a battery pack when the production from the renewable energy sources is greater than the load, and be used later when the production is lower than the demand. The system has to be sized and operated in such a way to make sure that the station always has enough energy to respond to the Tuk–tuk

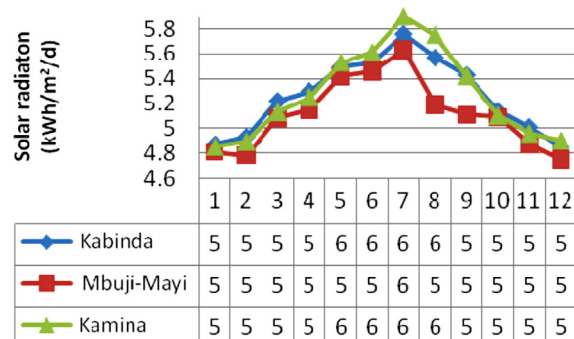


Fig. 1. Average monthly solar radiation at different location in the D.R.Congo.

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