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Simulation of off-grid generation options for remote villages in Cameroon

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Abstract

Off-grid generation options have been simulated for remote villages in Cameroon using a load of 110 kWh/day and 12 kWp. The energy costs of proposed options were simulated using HOMER, a typical village load profile, the solar resource of Garoua and the flow of river Mungo. For a 40% increase in the cost of imported power system components, the cost of energy was found to be 0.296 €/kWh for a micro-hydro hybrid system comprising a 14 kW micro-hydro generator, a 15 kW LPG generator and 36 kWh of battery storage. The cost of energy for photovoltaic (PV) hybrid systems made up of an 18 kWp PV generator, a 15 kW LPG generator and 72 kWh of battery storage was also found to be 0.576 €/kWh for remote petrol price of 1 €/l and LPG price of 0.70 €/m^3. The micro-hydro hybrid system proved to be the cheapest option for villages located in the southern parts of Cameroon with a flow rate of at least 200l/s, while the PV hybrid system was the cheapest option for villages in the northern parts of Cameroon with an insolation level of at least 5.55 kWh/m^2/day. For a single-wire grid extension cost of 5000 €/km, operation and maintenance costs of 125 €/yr/km and a local grid power price of 0.1 €/kWh, the breakeven grid extension distances were found to be 15.4 km for micro-hydro/LPG generator systems and 37.4 km for PV/LPG generator systems respectively. These results could be used in Cameroon's National Energy Action Plan for the provision of energy services in the key sectors involved in the fight against poverty.

Keywords: Rural electrification; Off-grid generation options; Cost of energy; Breakeven grid distance

1. Introduction

Situated in central Africa, Cameroon lies between latitudes 1°40′ and 13°05′ to the north of the equator and longitudes 8°30 and 16°10 to the East of longitude 0°. The country is organised into 10 provinces and each province is further structured into divisions, sub-divisions, districts and sub-districts as administrative units. The population of Cameroon in 2001 was estimated at 15.5 million inhabitants unequally distributed on a surface area of 475,440 km^2 [1].

In terms of energy resources, Cameroon has the second hydroelectric potential (294 TWh) in Africa after the Democratic Republic of Congo (about 1000 TWh) [2]. In 2002, the installed hydroelectric and thermal generation capacity in Cameroon was 847 MW of which hydroelectricity accounted for 85% and thermal electricity 15%. There are three independent grids in the South, East and North of the country. The southern grid is supported by two hydroelectric stations at Songloulou and Edea and four thermal plants in Limbe, Douala, Yaoundé and Bafoussam. The northern grid is supported by a hydroelectric station at Lagdo and a thermal plant at Garoua. The eastern grid is supported by a unique thermal plant at Bertoua [2]. These grids supply electricity mainly to provincial and divisional capitals, while most sub-divisional and district capitals run on independent mini-grids supported by thermal stations. The locations of existing grids in the South, East and North of the country are indicated by the shaded areas of Fig. 1.

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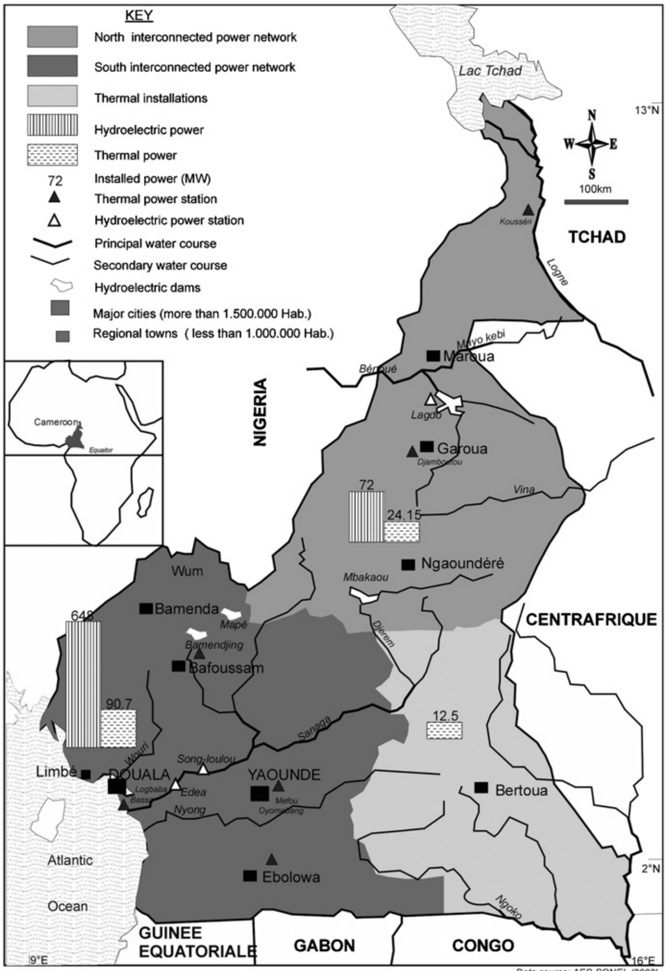

Fig. 1. Map of electricity generation and distribution networks in Cameroon in 2002.

In spite of the substantial availability of hydroelectric resources in Cameroon, electricity supply remains a serious problem as evidenced by frequent power cuts during the months of January to June since 1999 [2,3]. Power cuts affect the activities of industries, administrative and social services as well as those of urban and rural households with utility connections. Consequently, the total access rate to electricity in Cameroon is quite low and has been estimated at 11% [3]. This low access rate is partly due to the slow rate of exploitation of the hydroelectric potential of the country and partly due to the slow rate of expansion and/or upgrading of existing grids to match growing energy needs. To redress the energy crisis specifically in the southern interconnected grid where low water volumes in dams during the dry season affect hydroelectric production [3], the electricity power corporation and the government have embarked on hydrothermal expansion. This approach has been proposed in [4]. However, optimal scheduling of large-scale hydrothermal power systems that has been proposed in [5] is yet to be implemented. In spite of the expansion of thermal generation capacities and future development of hydroelectric installations, many villages will still remain without electricity for many years.

In Cameroon, villages at the periphery of sub-urban grid connected areas are often electrified through the extension of medium voltage 30-kV single-wire lines over distances that are often less than 5 km, the installation of auto-transformers in the power range 10–50 kVA and a mini-grid supplying power in a radius in the range 500–1000 m. This practice has produced low electrification rates estimated to be in the range 4–6% for sub-urban and rural areas that harbour 62–67% of the population [2]. The electrification rate in rural areas is limited by the absence of small-scale decentralised options that could meet the low energy needs of remote villages that often lack income to pay for grid connected service.

Households in most remote villages use electricity mainly for lighting, and to power radios and small black and white television sets. These DC loads can be met in a village by a centralised battery charging station, with households owning batteries or individual solar home systems [6,7]. These household energy needs have been found to be in the range 0.3–0.6 kWh/day in Inner Mongolia Autonomous Region (IMAR) of China and 0.5–0.6 kWh/day in Mekong countries. When a small refrigerator is included, the daily energy needs are raised to 1.2–1.6 kWh/day for households in IMAR and to 1.0–1.5 kWh/day for households in Mekong countries [8,9]. An energy survey in Cameroon has also established low energy needs in the range 0.2–1 kWh/day for lighting and powering of a radio and a television set [10]. In Nigeria [11], the proposed household load (300–340 W) in a decentralised power supply option has daily energy needs in the range 1.5–1.66 kWh. The household load consists of nine lights each rated 20 W, a radio/cassette rated 60 W and a television set rated 60 or 100 W [11]. The use of energy efficient lamps in the proposed household load can greatly reduce the power demand of each rural household. In Kenya, two community pico-hydro schemes with rated outputs of 1.1 and 2.2 kW have electrified 65 and 110 households, respectively, with light packages of 10 W. One light package is enough power for one 8 W compact fluorescent lamp (CFL) and a radio [12].

Small-scale off-grid generation options that exploit local renewable energy resources such as hydro, biomass (animal and/or human waste), solar and or wind energy can be used for the low energy needs of most remote villages. Research efforts for the promotion of renewable energy options in Cameroon include the feasibility of wind energy conversion systems for hypothetical villages requiring 70 kWh/day in northern Cameroon [13] and the modelling of solar/diesel/battery hybrid systems for remote households, clinics and a school [10]. In spite of these research efforts, the economic performance of feasible off-grid generation options for village power systems below 50 kW have not been evaluated to encourage the use of small off-grid renewable energy systems in the rural electrification policy of Cameroon.