About:

The global electricity systems are currently witnessing a paradigm shift from the traditional centralized to distributed generation technologies. This development, coupled with the necessity to address the concerns of an energy shortage, ensures energy security and realizes the environmental sustainability is part of the critical factors responsible for growing interests in microgrid systems across the world . In addition, it is necessary to develop more diversified electrical energy production resources beyond the current solar, wind, hydro, biomass, diesel, and battery technologies for microgrid systems. Interestingly, fuel cell (FC) systems are considered as promising energy resources on the basis of being clean, pollution-free, including their potential to store higher calorific value, in the hydrogen form, compared to the chemical energy that may be stored by using most other materials, and the capability to supply energy for a relatively longer time. It was of interest in this paper to discuss the potential of the FC technologies for microgrid system applications. One way to engage the technologies is by integrating them with the renewable energy resources, in which they operate as a storage device for harnessing relatively high renewable energy; another option is to use them as the source of energy in microgrid systems.

Microgrid systems are being employed both for on-grid and islanded purposes in several developed countries and are fueled by several resources like solar, wind, biomass, hydro, diesel, and natural gas. While the on-grid configuration seeks to support the existing grid, the islanded mode is used for serving remote or grid-independent applications since the microgrid is disconnected from the grid. However, microgrid systems are limited to the grid-independent application in several communities in developing countries due to the challenge of poor and ine_cient power grid infrastructure, as is the case in Nigeria . O_-grid microgrids, in this instance, are not only

employed for powering remote houses or business premises but also used for meeting a proportion of the energy demand of those houses or facilities that also have a connection with the national grid since the supply from the network is erratic in several parts of the country. This paper was, therefore, motivated by the developments in microgrids and the possibility of powering them by FCs. Such e_orts can help achieve energy security by growing a diversified energy system.

The issue of reliability of some of the existing microgrid systems in developing countries, especially the solar-photovoltaic (PV) microgrids, using Nigeria as a typical example, is another compelling factor that motivates exploring the potential of other energy resources such as FCs. A lack of understanding of the intermittent characteristics of solar irradiation and poor technical design is part of the key factors responsible for systems' failure. FCs can provide continuous operation, that is, they can be operated all the time, as long as the fuel is fed to the system [19], making them a highly reliable energy option that can serve as a backup for variable characteristics in renewable energies and the limitation on battery systems by the charge/discharge characteristics. The abundance of hydrogen fuel is one critical factor that favors the energy generation capability of fuel cell technologies . Several studies exist in the

literature that examined the application of microgrid systems for electrification purposes based on solar, wind, hydro, and biomass. However, this paper pays attention to the application of FC technologies in microgrid systems. Therefore, reviewing current contributions on the energy-generation capacity of stationary FC systems was among the major goals of this paper. Relevant background on FCs was discussed, which provided an introduction of inherent features of the technology, developmental status, and the types that are recognized in the market and being researched by scientists in the energy research community. A review was published on fuel cell systems with a power electronic interface, which focused on different FC technologies and their operating principles [21]. The study also examined the advantages, shortcomings, and possible application of the technologies for grid-connected systems in household, mobile, industrial, and commercial systems. Another research study also examined the potential of solid oxide FC systems for micro-power sources in portable devices.

A comparative study was conducted that discussed the di_erent FC technologies. The authors first presented the general working principle of the technologies and then compared them on the basis of fuel types, operational specifications, and technical characteristics. The concept of hydrogen and fuels was discussed with the intent of providing insights into hydrogen production methods, distribution, delivery, storage, and applications. The paper also discussed the principle of hydrogen FCs and the stand-alone and co-generation applications. The study published in presented the review of FC technologies that are engaged for built environment applications. It examined the potential of FCs for co-generation and tri-generation applications, including their maintenance and benefits such as emissions savings and reliable energy and heat generation.