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Optimal planning and design of hybrid renewable energy systems for microgrids

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ABSTRACT

This paper presents a technique for the optimal planning and design of hybrid renewable energy systems for microgrid applications. The Distributed Energy Resources Customer Adoption Model (DER-CAM) is used to determine the optimal size and type of distributed energy resources (DERs) and their operating schedules for a sample utility distribution system. Using the DER-CAM results, an evaluation is performed to evaluate the electrical performance of the distribution circuit if the DERs selected by the DER-CAM optimization analyses are incorporated. Results of analyses regarding the economic benefits of utilizing the optimal locations for the selected DER within the system are also presented. The electrical network of the Brookhaven National Laboratory (BNL) campus is used to demonstrate the effectiveness of this approach. The results show that these technical and economic analyses of hybrid renewable energy systems are essential for the efficient utilization of renewable energy resources for microgrid applications.

1. Introduction

Renewable energy is regarded as an appealing alternative to conventional power generated from fossil fuel [1,2]. This has led to increasingly significant levels of distributed renewable energy generation being installed on existing distribution circuits. Although renewable energy generation has many advantages, circuit problems can arise due to the intermittency and variability of the renewable energy resources.

A hybrid renewable energy system, consisting of two or more renewable energy sources used together, mitigates the intermittent nature of renewable energy resources, improves the system efficiency, and provides greater overall balance to the energy supply. However, hybrid renewable energy systems have received limited attention due to the complexities involved in achieving optimal planning and design. Conventional approaches can sometimes result in renewable energy combinations that are over-sized or not properly planned or designed [3].

A microgrid is a group of interconnected loads and Distributed Energy Resource (DER) generation that acts as a single controllable entity with respect to the grid, but with the capability to connect and disconnect from the main grid. Microgrids are increasingly being considered to enhance a local grid's reliability, resiliency, quality, and efficiency. Furthermore, microgrids increase the effectiveness of renewable energy and help implement net-zero buildings, campuses, and communities [4]. For these reasons, techniques for the optimal planning and design of hybrid renewable energy systems for microgrids are studied in this paper.

The technical and economic analyses of hybrid renewable energy systems for microgrids are essential for the efficient utilization of renewable energy resources. Several software tools are introduced and compared to analyze the electrical, economical, and environmental performance of hybrid renewable energy systems [5–14]. A survey of recent studies in this field shows that various hybrid renewable energy systems have been investigated using the Hybrid Optimization of Multiple Energy Resources (HOMER) [15–38]. However, there are not many comparable studies that utilize the Distributed Energy Resources Customer Adoption Model (DER-CAM). The survey also shows that in some cases, the DER-CAM is the preferred tool for hybrid renewable energy system design modeling, mainly due to the robust and flexible three-level optimization algorithm, hourly time step, and other scale considerations, but particularly due to the several successful applications with modeling microgrid systems [5,39,40]. Thus, the DER-CAM is selected for this study.

The DER-CAM is a tool that was developed by Lawrence Berkeley National Laboratory (LBNL) to help optimize the selection and

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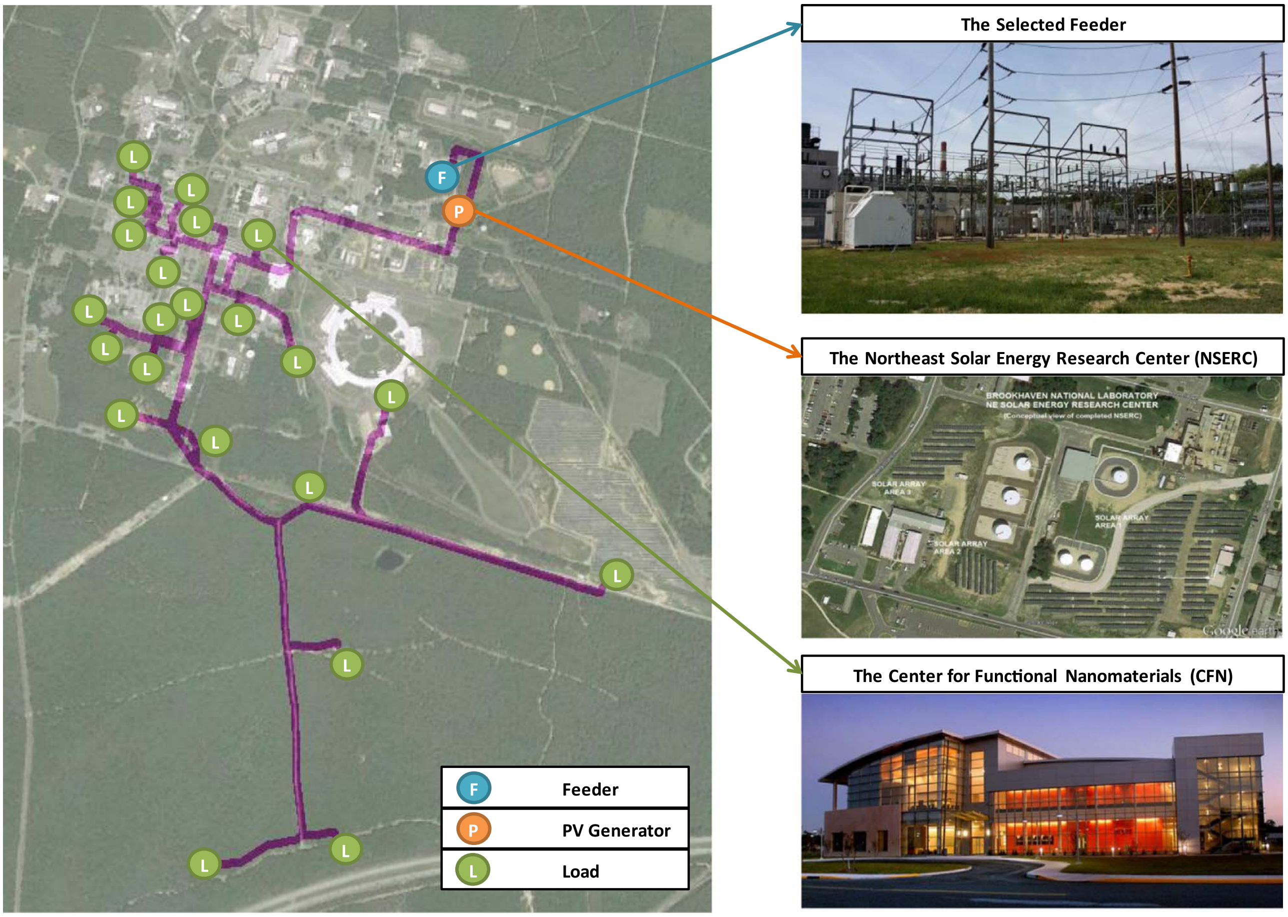
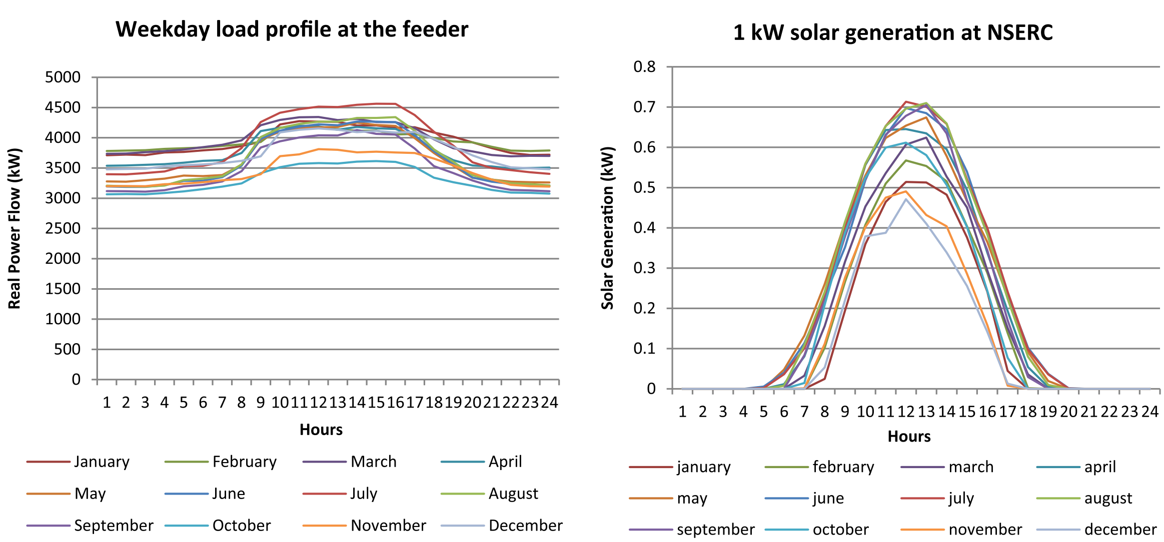


Fig. 1. the selected feeder for the simulation.



(a) Weekday load profile at the feeder

(b) 1 kW solar generation at NSERC

Fig. 2. Key input data into DER-CAM. (a) Weekday load profile at the feeder, (b) 1 kW solar generation at NSERC.

operation of distributed energy resources on a utility distribution system [41]. The main objective of the DER-CAM is to minimize either the annual costs or the CO_2 emissions of providing energy services to the modeled site, including utility electricity and natural gas purchases, plus amortized capital and maintenance costs for any DER investments. The key inputs into the model are the customer's end-use energy loads, energy tariff structures and fuel prices, and a user defined list of preferred equipment investment options. The program then outputs the optimal DER and storage adoption combination, and an hourly operating schedule, as well as the resulting costs, fuel consumption, and CO_2 emissions.

However, the focus of the DER-CAM model is primarily to perform an economic analysis that does not in any way take into consideration the electrical distribution circuit performance that will result from the implementation of the microgrid. Further research is required to develop an integrated analytical tool that will combine the economic