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Optimal Planning Of Solar PV/WTG/DG/Battery Connected Integrated Renewable Energy System For Residential Application Using Hybrid Optimization.

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A b s t r a c
Renewable energy sources are gradually being recognized as important options in supply side planning for microgrids. This paper focuses on the optimal design, planning, sizing and operation of a hybrid, renewable energy based microgrid with the goal of minimizing the lifecycle cost, while taking into account environmental emissions. Four different cases including a diesel-only, a fully renewable-based, a diesel-renewable mixed, and an external grid-connected microgrid configurations are designed, to compare and evaluate their economics, operational performance and environmental emissions. Analysis is also carried out to determine the break-even economics for a grid-connected microgrid. The well- known energy modeling software for hybrid renewable energy systems, HOMER is used in the studies reported in this paper..

1. Introduction

With the price of oil reaching its highest levels and the costs of transmission line expansion rapidly increasing, combined with the desire to reduce carbon dioxide emissions, renewable energy has become an important alternative as a power provider in rural systems. The cost of energy from conventional sources is less than that from renewable energy sources, but a supply-mix of renewable energy and diesel can reduce the cost of energy [1].

Energy demands are increasing rapidly, requiring energy resources to meet these demands, resulting in an exponential increase in environmental pollution and global warming. On the other hand, these days renewable energy, which is clean and limitless sources of energy, is catching the attention of energy developers. However, the estimation of the correct type of renew- able energy system needs to be done under optimizations tech- nique. In addition, for remote, rural isolated power systems, renewable energy sources are being increasingly recognized as cost-effective generation sources. In isolated areas, the high cost of transmission lines and higher transmission losses are encouraging the use of green sources of energy. Combining two or more renewable energy sources, such as solar, wind, hydro, diesel, etc., together gives a stable energy supply in comparison to non-

Particle Swarm Optimization (PSO) technique is applied in [2] to locate the optimal number of PV modules installed, such that the total net economic benefit achieved during the system operational life is maximized. In [3] it has been brought out that a wind/PV/ diesel hybrid system implemented in three remote islands in Maldives provide very good opportunities to showcase high penetration of renewable energy sources. In [4] a feasibility analysis considering off-grid stand-alone renewable energy technology systems for remote areas in Senegal show that the levelized elec- tricity costs with renewable energy technology is lower than the cost of energy from the grid extensions. In addition, the renewable energy technologies have a friendly impact on the environment.

In high rainfall areas near to rivers which flow all year round, solar and wind energy systems should be considered only after careful consideration of installation strategies. On other hand, water power should be considered as an option for electricity generation in these remote areas. In [5] the use of micro-hydro power is proven, and has gained favor in remote area electrifica- tion instead of diesel generation, but it requires significant head. In [6] the authors develop an optimum sizing methodology to deter- mine the dimensions of a hybrid energy supply system, while minimizing the capital cost. It is seen that the most attractive energy supply solution for the support of remote telecommunica- tion stations is the proposed hybrid power system comprising pv, diesel, inverter and batteries.

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In Ref. [7] a Mixed Integer Linear Programming (MILP) model is proposed for optimal planning of renewable energy systems for Peninsular Malaysia to meet a specified CO_2 emission reduction target. Mizani and Yazdani in [8] demonstrate a mathematical model and optimization algorithm as well as use the HOMER software [9] to identify the optimal microgrid configuration and their optimal generation in the mix. The results show that optimal selection of renewable energy sources and energy storage devices in a grid-connected microgrid, in conjunction with an optimal dispatch strategy, can significantly reduce the microgrid lifetime cost and emissions.

The authors in [10] discuss ways to reduce fuel usage and hence minimize CO_2 emissions while maintaining a high degree of reli- ability and power quality for microgrids. This is achieved by maximizing the utilization of renewable resources, dispatching and scheduling the fossil fuel generators at their optimal efficiency operating points, by storing excess energy in a storage system, while reducing the dependency on the utility grid. A methodology for microgrid village design and its economic feasibility evaluation with renewable energy sources is proposed in [11].

The economic operation of a combined heat and power (CHP) system consisting of wind power, PV, fuel cells, heat recovery boiler, and batteries is discussed in [12], using a non-linear optimization model. Forecasting of 24-h, wind speed, solar radiation, heat and electricity demand is considered on as well. The optimal operation of a microgrid comprising wind power, PV, and battery, discussed in [13], using a heuristic algorithm and linear model, and test results indicate that effective use of batteries can reduce the operating costs. The off-grid electrification by utilizing Integrated Renewable Energy System (IRES) is proposed in [14] to satisfy the electrical and cooking needs of seven non-electrified villages in India. Four different scenarios are considered during modeling and optimiza- tion of IRES to ensure reliability parameters. The National Renew- able Energy Laboratory (NREL) provides information to the community on hybrid renewable energy and microgrid power systems, presents lessons learned from operational experience, and provides analysis of challenges and success of the assessed systems [15]. A comparative analysis between diesel, hydro-diesel, and photovoltaic-diesel technologies is presented in [16] to analyze the field performance of different off-grid generation technologies applied to the electrification of rural villages. The relevance of distributed generation in India is discussed in [17]. The paper elaborates on the initiatives in the islands of the Sundarbans region in India and reviews microgrids in light of the emerging technol- ogies suitable for small islands.

The planning of microgrid in rural areas, considering

- Compare the overall benefits from the optimally designed renewable energy based microgrid with existing microgrid configurations.

The rest of the paper is organized as follows: Section 2 presents the problem definition, Section 3 briefly discusses the system under consideration and the system input data, Section-4 gives a brief description of the HOMER simulation tool and its capabilities, in Section 5 different study cases considering the optimal microgrid design is carried out and the results are presented and discussed, and finally Section-6 presents the summary and conclusions of this work.

2. Problem definition

The two principal economic elements, which are the total net present cost (NPC) and the levelized cost of energy (COE), depend on the total annualized cost of the system. Because of that, the user needs to calculate the annualized costs of the system, which is the components' annualized cost minus any miscellaneous costs. To calculate the total net present cost the following equation was used:

$$C_{NPC} = \frac{C_{TANN}}{CRF(i,N)} \quad (1)$$

where C_{TANN} is the total annualized cost, i is the annual real interest rate (the discount rate), N is the number of years, $CRF_{i;N}$ is the capital recovery factor, and it is calculated as a following equation:

$$CRF_{i;N} = \frac{i(1+i)^N}{(1+i)^N - 1} \quad (2)$$

In addition, the following equation is used to calculate the lev- elized cost of energy:

$$COE = \frac{C_{TANN}}{E_{ls} + E_{grid}} \quad (3)$$

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renewable energy sources, requires the definition of several factors, such as: the best sources of renewable energy to be used, the number and capacity of these generation sources, the total system cost, the amount of emissions that can be saved, the distance from the nearest grid connecting point, the excess energy, unmet load, diesel prices, different loads, and grid-connected systems. In addition, in many countries governments strongly encourage the planners of microgrids to be motivated towards investment in the renewable energy sector. In this paper, all of the above factors, as well as their effect on the proposed system, are examined. The main objectives of the work can be outlined as follows:

- Optimal design and planning of a renewable energy based microgrid considering various renewable energy technology options and with realistic inputs on their physical, operating and economic characteristics.
- To determine the break-even distance for connection of the microgrid with the main grid, and compare that with the cost of the isolated microgrid.

where E_{ls} is the electrical energy that the microgrid system actually serves and E_{grid} is the amount of electricity sold to the grid by microgrid. In the levelized cost of energy Equation (3), the total annualized cost is dividing by the electrical load that the microgrid actually serves. Also, in the levelized cost of energy equation the amount of electricity sold to the grid by microgrid is added. In HOMER, the total net present cost is the economically preferable element and has been used in the optimization process, not the levelized cost of energy, because each of these decisions is some- what arbitrary [18].

In HOMER, the lifecycle cost of the system is sorted by the total net present cost (NPC). All the system costs, such as the capital cost, replacement cost, operation and maintenance cost, fuel consump- tion cost, and miscellaneous costs, for example, the credits that are caused by the pollutant emissions, and the grid cost (purchase power from the grid), are included in the total net present cost (NPC). The difference between the nominal interest rate and the inflation rate is equal to the real interest rate that has to be entered by HOMER's programmer. In addition, HOMER's programmer has to enter all costs into the system in terms of constant dollars [9,18].

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