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ScienceDirect

Energy Procedia 142 (2017) 43–48

Energy Procedia

www.elsevier.com/locate/procedia

9th International Conference on Applied Energy, ICAE2017, 21-24 August 2017, Cardiff, UK

Reliability and economic evaluation of a microgrid power system

T. Adefarati, R.C. Bansal*, Jackson. J. Justo

Department of Electrical, Electronic and Computer Engineering, University of Pretoria, South Africa

Abstract

The renewable energy resources (RERs) have been globally accepted for power generation due to the high prices of fossil fuels, environmentally friendly, low operation and maintenance (O&M) costs, no carbon emission and escalation in power demand due to rapid growth in population and industrialization. A microgrid (MG) power system that consists of the diesel generator, wind turbine generator (WTG), photovoltaic (PV) and electric storage system (ESS) is utilized in this study with the aim of improving the reliability and minimizing the cost of energy (COE) and annualized cost of the system (ACS). This objective is achieved by using the expected energy not served (EENS), loss of load expectation (LOLE), cost of load loss, loss of load probability (LOLP), net present cost (NPC), annualised fuel cost (AFC), annualised emission cost (AEC), annualised maintenance cost (AMC), annualised capital cost (ACC) and annualized replacement cost (ARC) of the system. These operating parameters are used in this work to investigate the effects of RERs in a power system. To achieve the main objective of this paper, the basic probability concept is utilized to find the reliability indices of the proposed power system as well as the development of a software in the MATLAB programming environment by using fmincon optimization tool to investigate the economic impact of RERs in a micro grid power system. The results obtained from the research work show that RERs can be used to improve the reliability and reduce the COE and ACS of a power system.

Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.

Keywords: Renewable energy resources, reliability, anaulized cost of the system, cost of energy, net present cost, cost of loss load.

1. Introduction

The incorporation of the RERs into a power system has received considerable global attentions because of their significant impacts such as improved reliability of a power system and reduction of fuel cost, O&M costs and emission

* Corresponding author. Tel.: +27 12 4203677; fax: +27 12 362 5000.
E-mail address: rcbansal@ieee.org

1876-6102
Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.
10.1016/j.egypro.2017.12.008

cost [1]. These unique characteristics have facilitated many power utilities in the world to encourage utilization of RERs as measures to increase the capacity of electric power generation. The micro grid energy systems are considered to be the most cost effective power solutions to meet the load requirements of the people that live in the rural areas. Due to the intensive cost of extending the transmission and distribution lines to the remote communities, the power demands in such areas can be met by using a micro grid power system that consists of the diesel generator, PV, WTG and ESS. Solar and wind resources are potential renewable energy technologies which have recently received global attention because of their economic and technical benefits [2]. These resources can be efficiently and economically harnessed by the power utilities for climate change mitigation as well as for reduction of the side effects of greenhouse gas emission to the public.

In the past, RERs have been the subject of many researchers with an emphasis on the optimization technique that involves a combination of operating cost, reliability and emission of a power system. In view of this, Caballero [3] et al. [3] have presented a technique for the optimal operation of a hybrid system that consists of PV and wind system. The objective of the study is to limit life cycle of the system and to improve the reliability of the system by using loss of power supply probability. Ramli et al. [4] have performed a technical and economic analysis of wind and solar hybrid system by using energy production and cost of energy as the benchmarks to assess the impacts of RERs in a hybrid system. Meanwhile, Bilil et al. [5] have presented a multi-objective genetic algorithm for optimization of the annualized renewable energy cost and the reliability indices of a power system. The main challenge faced in the aforementioned body of literature is the complexity to design an optimal energy management system that will satisfy the load demand by considering the non-linearity of renewable energy resources, diesel generator fuel consumption and load demand. The body of literatures described above has not established the relationship between the reliability, operating cost, emission and cost of energy of a power system. In the perspective of this weakness, this work exhibits a streamlining technique that incorporates reliability, AFC, AMC, COE, AEC and ACS of a power system.

Nomenclature

ACS	Annualized cost of system ($/yr)	RI	Reliability index
AEP	Annual energy production (kWh/yr)	EENS	Expected energy not supplied (kWh/yr)
COE	Cost of energy ($/kWh)	C_{loss}	Value of lost load ($/kWh)
AMC	Annualized O&M cost ($/yr)	AFC	Annualized fuel cost ($/yr)
AEC	Annualized emission cost ($/yr)	ACC	Annualized capital cost ($/yr)
$P(C_i)$	Probability of the state i	ARC	Annualized replacement cost ($/yr)
AEC	Annualized emission cost ($/yr)	C_i	Generation capacity
L_i	Expected load demand	C_k	Amount of load curtailment
P_1	power generated by the diesel generator	P_2	Power generated by the PV system
P_3	Power accepted by the battery for charging application	P_4	Power discharged by the battery
P_5	Power generated by the wind system	P_L	Power demand at load points
P_i	Probability of specific capacity outage	$P(C_i)$	Probability of loss of capacity
p_k	Individual probability of capacity in outage	t_k	Duration of loss of power supply in days
$P(L_i > C_i)$	Duration of loss of capacity in percent	FOR	Forced outage rate

2. Micro grid power system

The proposed MG power system consists of diesel generator, WTG, PV and ESS for the purpose of meeting the consumers' load requirements. It is designed to supply the consumers' load points based on the availability of the local RERs. The MG system is the most economical viable solution for supplying electricity to the remote areas or standalone systems that are not connected to the national grid owing to technical, economic and complexity of the terrain [6]. It can be used by the utilities to enhance the reliability and minimize the COE and ACS of a power system [7]. The capability of the proposed methodology is validated with a number of case studies by using the meteorological