Electrical Power and Energy Systems 64 (2015) 635–645

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Sources' Response for supplying energy of a residential load in the form of on-grid hybrid systems

Mohammad Reza Ranjbar *, Sajjad Kouhi

Graduate University of Advanced Technology, Kerman, Iran

ARTICLE INFO

Article history:
Received 13 December 2013
Received in revised form 21 April 2014
Accepted 25 July 2014
Available online 20 August 2014

Keywords:
Economic model-fuel cell power plant (FCPP)
Genetic Algorithm (GA)
Imperialist Competition Algorithm (ICA)
Particle Swarm Optimization (PSO)
Photovoltaic (PV)
Wind turbine (WT)

ABSTRACT

Because of the nonrenewable conventional sources of energy and rising of energy prices, these kinds of energy sources are not responsible to meet increasing of demand any more. So the use of on-grid hybrid systems for their unique characteristics has increased. These forms of organizations would result in reducing of transmission losses, pollution and the ability to exert energy management. This report introduces an economic model for the fuel cell, photovoltaic panels and wind turbine. Three sources of energy beside the local grid can respond to all variations of demand. Since sources of energy should change their productions according to the demand variations, we call it sources' response. The model consists of the cost of supplying energy, cost of recovered thermal energy from the fuel cell, wind turbine power production cost, solar power generation cost, cost of exchange power with the local grid and the cost of maintenance. Finally, it is trying to minimize total cost by the help of three different evolutionary planning methods. Encouraging results promise the use of hybrid systems in supplying residential load in near future.

© 2014 Elsevier Ltd. All rights reserved.

Introduction

Due to the removing subsidized energy prices in Iran and rising cost of energy, is there any way to reduce household spending in supplying thermal and electrical power or not? Nowadays, renewable-energy sources such as solar, wind, biomass and geothermal energy are used as a source of clean energy because of their low costs, absence of losses and ignoble emission. Since the nature of some renewable-energy sources is unpredictable, using of multiple production units (Hybrid systems) is a suitable case to meet the requirement of demand [1,2]. These systems can be on-grid or off-grid. Off-grid systems always need battery to respond to load and source changes. Battery usage not only makes the system more complicated and expensive, but also reduces the efficiency of electricity generation to 20% or more. Therefore, in this paper, the battery cannot be found. However, grid-connected systems can be supplied by local grid and are able to exchange electricity with it. These systems use, the local grid as a mechanism for unlimited storage. It will be seen from the results that the use of grid-connected hybrid systems is one of the most efficient and most cost-effective ways to reduce household spending for supplying its load.

Nowadays, researchers are studying the possibility of using hybrid systems in supplying the required power. For instance, in [3] electrical demand of the biggest island of Turkey was examined to realize how it could be possible to supply that with renewable-energy sources. In [4] hybrid system is used to satisfy the thermal and electrical load requirements. In [5] the viability of adding wind turbines to an existing diesel plant of a remote aria in Saudi Arabia was studied. Another feasibility study is described in [6], where hybrid systems supplied by hydrogen are evaluated for applications in Newfoundland, Canada. So in most of these studies, and also [7], hybrid electricity generation systems are often considered less costly and more reliable than systems that rely on an individual source of energy. Wind or photovoltaic energy sources, due to the fluctuating behavior, employ as the sole source of power supply. But, they can be used with local grid or fuel cell and make a powerful hybrid system to response load changes. Recently, the combined use of renewable-energy sources, especially FCPP has become increasingly fascinating [8]. So in the paper a combination of grid-connected wind-photovoltaic and FCPP in the form of CHP system can be considered as a potential choice to satisfy electrical and thermal demand of a residential house. In such a kind of system, wind turbine and photovoltaic output power is considered as a negative load and would be added to the residential load.

Three different evolutionary algorithms (GA, PSO and ICA) are used to minimize total cost of the system. By minimizing the total cost, the amount of power that the fuel cell should produce can be determined. In the paper, different tariffs for selling and buying of electricity are intended to see the response of each algorithm

* Corresponding author.

http://dx.doi.org/10.1016/j.ijepes.2014.07.062
0142-0615/© 2014 Elsevier Ltd. All rights reserved.

Nomenclature

$c_{el,pi}$	purchasing electricity tariff from Grid at interval i ($)
$C_{EL,pi}$	the daily cost of purchasing electrical energy from the local grid ($)
$c_{el,si}$	tariff for selling electricity ($/kW h)
c_f	price of natural gas for FCPP ($/kW h) = 0.04
$C_{fuel,i}$	daily cost of fuel ($)
c_{n2}	fuel price for residential load ($/kW h) = 0.06
$C_{Gas,pi}$	the daily cost of purchasing gas ($)
C_{Mnt}	maintenance cost ($/kW h)
$C_{O\&M}$	daily operation and maintenance cost ($)
$c_{th,s}$	thermal energy selling price ($/KW h)
i,j,k	time intervals
$I_{EL,si}$	daily income from selling electric energy to the local grid ($)
$I_{TH,si}$	daily income from sale of thermal energy ($)
$L_{el,i}$	electrical load demand at interval i (kW)
$L_{th,i}$	thermal load demand at interval i (kW)
Δp_D	lower limit of the ramp rate (kW)
Δp_U	upper limit of the ramp rate (kW)
MDT	minimum down-time (number of intervals)
MUT	minimum up-time (number of intervals)
$N^{\max}$	maximum number of starts–stops
$n_{start-stop}$	number of starts–stops of FCPP
p_a	power of auxiliary devices (kW)
$P^{\max}$	maximum limit of generating power (kW)
$P^{\min}$	minimum limit of generating power (kW)
$P_{FC,i}$	FCPP electrical power productions at interval i (kW)
$P_{FC}^{\max}$	maximum power production of fuel cell
P_r	rated electrical output power of wind turbine (kW)
P_{rs}	rated power of solar panel (0.11 kW)
$P_{th,i}$	recovered thermal energy from FCPP at interval i
$P_{th\text{-}storage,i}$	thermal energy saving at interval i
$P_{th\text{-}storage}$	thermal energy saving at the end of the day
$P_{PV,i}$	PV panel power production at interval i (kW)
$P_{WT,j}$	wind turbine electrical power production at interval j (kW)
PLR	part load ratio $\text{PLR}_i = P_{FC,i}/P_{FC}^{\max}$
r_i	mean solar radiation at interval i
R_C	a certain radiation point set usually as 150 (W/m^2)
R_{STD}	solar radiation in the standard environment set usually as 1000 (W/m^2)
$r_{TE,i}$	thermal to electrical ratio at interval i
T	the length of time interval (h) = 0.1
t_{off}	time the FCPP has been off (h)
T^{off}	FCPP off time (number of intervals)
τ	FC cooling time constant (h)
U	FCPP on–off status, U = 1 for running, U = 0 for stopping.
V_i	cut in wind speed (m/s)
V_o	cut out wind speed (m/s)
v_j	wind speed at interval j (m/s)
V_r	rated wind speed (m/s)
α	hot startup cost ($)
β	cold startup cost ($)
η_i	fuel cell electrical efficiency (%)
$\eta_{st,th}$	thermal storage efficiency (%)

toward changes of tariffs. Selling tariffs are always considered lower than purchasing tariffs so that the grid is willing to buy electrical power from the hybrid system. For thermal power, the same procedure is used except that thermal energy with lower price sell to neighbors not to the grid.

In the paper, three different strategies have been used, and the most effective one is selected. In all of them, local grid and the hybrid system are used for supplying the electric load, but in the first strategy, we don't have any thermal recovery from FCPP. In the second one, we have thermal recovery while in the last strategy, we use thermal storage tank to store thermal energy and reused it according to the system economy. Finally, the best strategy is selected and will be compared with the time that only the fuel cell is connected to the grid to show that the hybrid system performs better than a single source system.

The remaining part of the paper is organized as follows: Section 'Type of proposed FC, PV and WT unit' gives a complete structure of the system besides the type of FC, WT and PV unit. Formulation of the economic model is presented in subsection of 'Type of proposed FC, PV and WT unit'. The solution methodology and evolutionary algorithm with its parameter adjustments are explained in Section 'Evolutionary programing based solution methodology'. Test and results are presented in Section 'Test and results'. Conclusions are discussed in Section 'Conclusion'.

Type of proposed FC, PV and WT unit

Fuel cell

Proton Exchange Membrane (PEM) fuel cells for having a lot of advantages such as: high efficiency (35%–45%), low to zero emissions, quiet operation, high reliability, modularity, scalability, quick installation and the ability to be placed on any site in the distribution system without geographic limitations [9–12] show great promise for use in hybrid systems. All of these advantages lead to a deep study of this type of fuel cell for supplying the residential load.

PEM fuel cell approximately operates with 35% efficiency. The efficiency is slightly lower at full load compared to low load operation. According to [13] at full load, the FCPP produces thermal energy roughly equal to the electrical energy. In [13] efficiency and thermal energy to electrical energy ratio curves have been developed completely Fig. 1.

Technical specification data for the fuel cell is shown in Table 1.

The thermal energy to electrical energy ratio and the efficiency are functions of the part load ratio. Part load ratio can be obtained from (1).

$$\text{PLR}_i = P_{FC,i}/P_{FC}^{\max} \quad (1)$$

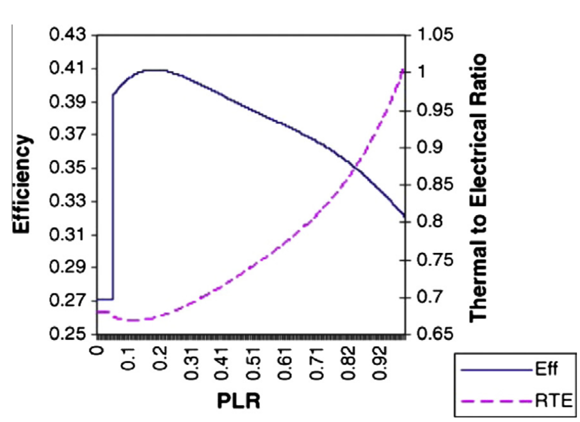

Fig. 1. Performance curves of FCPP.

Download English Version:

https://daneshyari.com/en/article/6859986

Download Persian Version:

https://daneshyari.com/article/6859986

Daneshyari.com