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Evaluation economic and reliability issues for an autonomous independent network of distributed energy resources

M.H. Moradi *, A. Khandani

Department of Electrical Engineering, Faculty of Engineering, Bu Ali Sina University, Hamadan, Iran

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ABSTRACT

Electrical energy can be supplied in different ways, but consumers want to do it with the highest quality, lowest cost and highest reliability. The purpose of this paper is evaluating the effect of creating a micro grid and using of distributed generation resources to reduce costs and increase the reliability of supplying energy. Economic issues and reliability are two dimensions of proposed objective function. Economical dimension consists of the initial costs and operational costs. Reliability dimension includes non-delivered energy (NDE) for the consumers. The two dimensional objective function is optimized by using weighting method. For this, four scenarios are compared to each other in case of economic and reliability issues. The four scenarios are providing energy by main grid, main grid and distributed generation resources, isolated micro grid and a micro grid connected to an upstream network. Each scenario is considered in two cases for evaluating reliability. First, the loads on one feeder and second is the loads on separated feeders.

The proposed method is compared with a similar method and the comparison results show that it is more efficient and applicable.

1. Introduction

Micro grids are the small grids which supply consumers load. These grids have the generators near the consumers, therefore it decreases distribution line cost and the power losses, also increase reliability. Micro grid power suppliers are distributed generators (DGs) and the upstream grid. Those DGs generate more power and if DGs could not supply all loads, then the upstream grid will supply them. Economical and technical issues must be considered when micro grid is installed. In micro grid installation, the first thing is to examine costs reduction and the benefit. In [1], the authors used a linear programming to optimize the MG (micro grid) initial cost and the operation cost. In [2] authors found best solution for supplying the power to the loads by combining linear programming with genetic algorithm. Nonlinear programming was used to optimize the costs of micro grid and pollutions reduction in [3].

Reliability is another issue which has an impact on micro grid installation. In [4,5], the authors evaluated the effects of micro grid installation on reliability improvement and they explained that failure rate and failure time reductions will increase the reliability. In [6] authors evaluated the impact of micro grid on reliability and power quality.

Other issues that impact the micro grid installation and operation are the upstream network connection [7], the micro grid protection [8,9], the micro grid control system of power generation and load [10–12] and the load forecasting [13].

Considering economical and reliability issues together in objective function is more realistic. In previous work, the reliability was considered as a non-delivered energy and then by multiplying it to the penalize coefficient is taken as cost in objective function. In [14], authors included reliability, initial cost, and operation cost in the objective function. Besides the micro grid capacity and the operational cost were optimized for a year. The authors considered a simple formula for calculating the reliability by taking it as 100% for the isolated micro grid. While in reality the failure probability is not zero for an isolated operation of micro grid. In [15], authors assumed the existence of micro grid and known capacity for the generator, then, they optimized the objective function for the cost of power supply in 24 h, the reliability and pollution reduction.

In this paper, long-term energy management on consumer's demands done by considering energy generation cost and reliability as two dimensions of objective function. Energy generation cost is the sum of initial cost and operational cost. The Initial cost conversion to annual cost needs a depreciation rate adjustment which is a function of micro grid lifetime. But to solve this two-dimensional objective function, the reliability of Non-Delivered Energy (annual) expressed and then dimensions of the objective function multiplied by the weighting coefficients and optimized by using linear programming. Proposed methodology was

* Corresponding author. Tel.: +98 811 8220954; fax: +98 811 2511176.
E-mail addresses: Mh_moradi@yahoo.co.uk (M.H. Moradi), alikhandoon@gmail.com (A. Khandani).

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Nomenclature

$C(x)$	energy costs
$C_1(x)$	initial costs
$C_2(x)$	operational costs
d_s	number of days in season
F_B	fuel cost of boiler
F_{FC}	fuel cost of fuel cell
HR	heat recovering rate
IC_B	initial cost of boiler
IC_{FC}	initial cost of fuel cell
IC_{MG}	initial cost of micro grid installation
IC_{SS}	initial cost of energy storage system
IB	installed capacity of boiler
IFC	installed capacity of fuel cell
ISS	installed capacity of energy storage system
l	load index
L_C	load of consumer C
L_e	electric load
L_h	heat load
M_B	maintenance cost of boiler
M_{FC}	maintenance cost of fuel cell
M_{SS}	maintenance cost of energy storage system
NDE_c	non-delivered energy for consumer C
P_B	output power of boiler
PC_{SS}	charged electric power
PD_{SS}	discharged electric power
P_{FC}	output power of fuel cell
P_{SS}	output power of energy storage system
P_{buy}	bought electric power from upstream network
P_{sell}	sold electric power to upstream network
PR_{buy}	buying energy cost
PR_{sell}	selling energy cost
PR_{base}	base charge of power contract
P_M	failure probability of protection device
P_L	failure probability of micro grid
r_i	time for removing fault
$R(x)$	reliability function
S	season index
t	time index
t_{repair}	time of repair
$t_{isolate}$	time of isolate
$t_{reconfig}$	time of reconfiguration
T_a	time for repairing micro grid
U	interest rate
U_C	lack of access for consumer C
U_{up}	lack of access for upstream network
U_{MV}	lack of access for MV network
X	objective function variables
α, β, λ	depreciation rate
λ_i	failure probability of section i
λ_C	failure probability of consumer C
λ_{up}	failure probability of upstream network
λ_{MV}	failure probability of MV network

evaluated in low voltage network with 4 loads for 4 different scenarios. In these scenarios the load demands are supplied by main grid, main grid and distributed generation resources, isolated micro grid and a micro grid connected to an upstream network.

This paper is organized as follows: micro grid definition, economical and reliability issues and weighting-method optimization will be explained in Section 2. In Section 3, problem formulation and in Section 4 case studies described. Simulation results and discussion in Section 5 and the conclusion in Section 6 are described.

2. Background

2.1. Micro grid

Fig. 1 shows a micro grid. The micro grid includes control system, generators, power storage system and loads. Connecting micro grid to upstream network or an isolated micro grid, the loads type and amount of load have effects on micro grid operation.

Control system: each micro grid has a control system that controls the load and the generation. Control system installation implies capital cost which will be considered in proposed objective function costs.

Load: types and amounts of loads are the most important factors for the micro grid operation. In this paper, 4 consumers are selected to find an optimized way of supplying electrical and thermal demands for supporting the loads.

Power generators: power generators in micro grid can consider as different DGs, such as the wind turbine, the solar cell, the fuel cell and the micro turbine. Each of those DGs has various characteristics in power generating in regards with the economy and the climate condition. In this paper, fuel cell is used as power supplier. Fuel cell is chosen because of the need to both electrical and thermal energies and also for the independency of climate conditions.

Storage system: the storage system is another factor affecting on micro grid operation. The storage system supply power in peak times by saving it in the midnight, so this plays an important role in unifying the demands. Storage system type is dependent on power generator type. Battery and electrolyzer could be used as storage system if a fuel cell generates energy. In this paper battery is chosen as storage.

Micro grid operations modes: There are two different operational modes for micro grids as connected micro grid to upstream network and isolated micro grid. In peak times, the micro grid buys energy from upstream grid and in off-peak times it sells extra energy when a connected micro grid to upstream is operating. Off

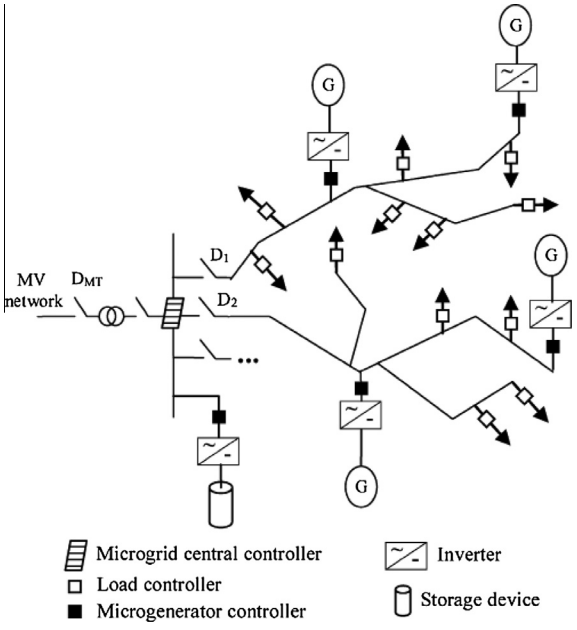

Fig. 1. Micro grid [4].