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Operation cost minimization of a Micro-Grid using Quasi-Oppositional Swine Influenza Model Based Optimization with Quarantine

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Abstract The increasing concern of power systems toward distributed generation enables modern power grids and energy management systems to focus their concentration to derive an optimal operational planning with regard to energy costs minimization of Micro-Grid and better utilization of Renewable Energy Sources in the presence of Battery Energy Storage. This paper presents Quasi-Oppositional Swine Influenza Model Based Optimization with Quarantine (SIMBO-Q) to minimize total operation cost of Micro-Grid considering optimal size of Battery Energy Storage. SIMBO-Q performs the optimization through quarantine and treatment loop based on probability. However SIMBO-Q algorithm takes large number of iterations to reach to the optimum solution if the system has large number of variables. To overcome this limitation and to improve computational efficiency, quasi-opposition based learning concept is introduced in basic SIMBO-Q algorithm. The proposed algorithm is tested on a typical Micro-Grid and simulation results establish that the proposed approach outperforms several existing optimization techniques.

1. Introduction

Micro-Grid (MG) is defined as an aggregation of electrical loads and Distributed Generation sources (*DGs*) (mainly renewable resources such as solar and wind energy systems) along with the energy storage options operating as a single system providing both power and heat. Micro-Grid (MG) combined with Renewable Energy Sources (*RESs*) and small scale *DG* sources (*DGs*) can be a preferable solution to the raised energy crisis as well as a complement to the centralized modern power grids [1]. Nowadays, due to the increasing concerns and challenges about the fluctuation and intermittency of Wind Turbine (*WT*) and Photo-Voltaic (*PV*) units

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Nomenclature

Indices

- PV, WT, FC, MT, BES, $grid$ — Photo-Voltaic (PV), Wind Turbine (WT), Fuel Cell (FC), Micro-Turbine (MT), Battery Energy Storage (BES) and grid indices respectively
- t — time index
- $iter$ — iteration index of the SIMBO-Q algorithm

Constants

- $B_{grid,t}$, $B_{BES,t}$, $B_{MT,t}$, $B_{FC,t}$, $B_{PV,t}$, $B_{WT,t}$ — Bid of utility, BES, MT, FC, PV, WT at time t, respectively (€ct/kW h)
- FC_{BES}, MC_{BES} — fixed and maintenance cost for BES, respectively (€ct/kW h)
- IR, LT — interest rate and lifetime of the installed BES
- T — operation time horizon (h)
- OR_t — minutes operating reserve requirements (kW)
- OM_{DG}; OM_{MT}; OM_{FC}; OM_{PV}; OM_{WT} — fixed operation and maintenance cost of DG, MT, FC, PV and WT respectively (€ct/kW h)
- $P_{grid,max}$, $P_{grid,min}$ — maximum/minimum limits of power production for the utility (kW)
- $P_{D,t}$ — electrical load demand at time t (kW)
- $P_{MT,max}$, $P_{FC,max}$, $P_{PV,t\max}$, $P_{WT,t\max}$, $P_{BES,max}$ — maximum producible power of MT, FC, PV, WT and BES respectively (kW)
- $P_{MT,min}$, $P_{FC,min}$, $P_{PV,t\min}$, $P_{WT,t\min}$, $P_{BES,min}$ — minimum producible power of MT, FC, PV, WT and BES respectively (kW)
- SU_{MT}, SU_{FC}, SD_{MT}, SD_{FC} — start-up and shutdown cost coefficient for MT and FC (€ct)
- tax — tax rate of utility power grid
- Δt — time interval duration
- η_d, η_c — discharge and charge efficiency of BES, respectively
- $Iter\_max$ — maximum number of iteration for the SIMBO-Q algorithm
- TI — total number of individuals in the population of SIMBO-Q algorithm
- TD — total number of days or generations of SIMBO-Q algorithm

Variables

- $C_{BES,min}$, $C_{BES,max}$ — minimum and maximum size of BES (kW h)
- $C_{BES,t}$ — energy stored in the BES at time t (kW h)
- $Cost_{grid,t}$ — cost of trade with the up-stream grid at time t (€ct)
- $Cost_{DG,t}$, $Cost_{BES,t}$ — cost of fuel and operating power of DGs and BES at time t (€ct)
- F — total costs (€ct)
- $P_{grid,t}$, $P_{BES,t}$, $P_{MT,t}$, $P_{FC,t}$, $P_{PV,t}$, $P_{WT,t}$ — power of utility, BES, MT, FC, PV and WT, respectively (kW)
- $\overline{P}_{BES,t}$, $\underline{P}_{BES,t}$ — maximum discharge and charge rates of BES at time t (kW)
- $SUC_{MT,t}$, $SUC_{FC,t}$ — start-up cost for MT and FC at time t, respectively (€ct)
- $SDC_{MT,t}$, $SDC_{FC,t}$ — shutdown cost for MT and FC at time t, respectively (€ct)
- $TCPD_{BES}$ — total cost per day of BES (€ct)
- $u_{BES,t}$, $u_{MT,t}$, $u_{FC,t}$ — status (On or Off) of BES, MT and FC at time t, respectively
- Day — current generation or iteration of SIMBO-Q algorithm
- S — state or position of individual of SIMBO-Q algorithm
- PS, PH — pandemic state and pandemic health among all individuals
- Fe, Co, $fathead$, NV, Dai — fever, cough, fatigue and headache, nausea and vomiting, diarrhea respectively
- $\mathrm{Pr}imary(Day)$ — primary symptoms of swine flu caused due to fever, cough, fatigue and headache, nausea and vomiting and diarrhea during each day
- $R0(Day)$ — secondary symptom of swine flu caused per day
- $Dose$ — anti-viral drugs given to swine flu patient as a curative strategy
- α, β, μ — probability of recovery, probability of quarantined and probability of vaccination of SIMBO-Q algorithm
- Md, Ms — momentum factor of dose and momentum factor of state

Subscript

- t — t-th time step (h)

as $RESs$ in the MG system, the Micro-Grid Central Controller (MGCC) feels the urge to implement Battery Energy Storage (BES) within the MG system for storing excess energy throughout the times of high availability and to inject it to the MG during a power shortage. So, determination of appropriate capacity or size of BES plays an important role for an optimized operation cost minimization problem of MG.

Many research works have been done in the field of operation cost minimization of MG, considering the impact of optimum size of BES on operation cost minimization problem, some of which are discussed here. Mitra [2] described an analytical approach to determine the size of backup storage unit to meet a specified reliability target. Ekren and Ekren Banu [3] presented Simulated Annealing (SA) algorithm to optimize the size of a PV/wind integrated hybrid energy system with battery storage to minimize the total cost of the hybrid energy system. Kaldellis et al. [4] developed a complete methodology able to define the dimensions of an autonomous electricity generation system based on the maximum available solar energy at minimum electricity generation cost by selecting the most cost efficient energy storage configuration. Mohammadi et al. [5] presented a Genetic Algorithm (GA) based optimization method to obtain optimum power and price of MG consisting of PV array, Fuel Cell (FC) and battery bank with multiple DG units under hybrid electricity market to maximize net present worth of the MG. Chen et al. [6] presented a Mixed Linear Integer Problem (MLIP) solved in a Modeling Language for Mathematical Programming