Ain Shams University
Faculty of Engineering
Electric Power and Machines Department

Optimal Control of Micro Grids for Fault Tolerant Operation

Ph.D. thesis
By:

Eng. Alaa Mohamed Abdel-hameed El-sayed
M.Sc. in electrical power engineering

A thesis submitted to the Faculty of Engineering, Ain Shams University in partial fulfillment of the requirements for the Ph.D. degree in Electrical Power and Machines Engineering

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Cairo 2017

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STATEMENT

This thesis is submitted to Ain Shams University in partial fulfillment of the requirement for the Ph.D. degree in Electrical Engineering. The included work in this thesis has been carried out by the author at the Electrical Power and machine department, Ain-Shams University. No Part of this thesis has been submitted for a degree or a qualification at other university or institute.

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Date: **22 /1/ 2017**

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ABSTRACT

Driven by energy resources conservation, environmental protection, economic considerations, and technical challenges, the Micro Grid (MG) has significantly emerged as an innovative small-scale power generation system. The MG concept assumes a cluster of Distributed Generation Sources (DGSs) and loads operate as a single controllable system. There are frequency and power fluctuations in the MG which are caused by the variation in power from renewable energy sources, characteristics of power generating sources, and the load demand variation. To avoid this problem, controllable micro sources are used to balance out the reduction in power generation or the increase in load demand. However, because of the delay in the output of such controllable sources, the frequency/power oscillations are still present in the MG. Therefore, necessity of designing the proper controller parameters to these controllable sources for optimal employment and also to maintain minimum frequency/power deviations is the first focus of this thesis.

This research investigates an isolated MG system operation via a novel optimized control scheme. The proposed MG system employs various units like Photovoltaic (PV), Wind, Diesel Engine (DE), Fuel-Cell (FC), Aqua-Electrolyzer (AE) and battery. A simulation model for this proposed MG system components is developed using MATLAB/SIMULINK (The MathWorks, Natick, Massachusetts, USA). A Proportional-Integral-Derivative (PID) control scheme is employed and the parameters of the PID controllers for various controllable sources are tuned with a Firefly Algorithm (FA). The results of the designed PID controllers tuned by FA are compared with those obtained by classical and Bacterial Foraging Optimization (BFO) methods. The FA-PID control is designed using various fitness functions such as ISE, IAE, ITAE and Weighted Goal Attainment Method (WGAM) for achieving improved fault tolerance operation. The proposed FA-PID control scheme using the new WGAM shows better performance over the classical-PID, and Bacterial Foraging-PID (BF-PID) controllers in both transient and steady state conditions. In comparison with the other designed controller structures, the desired FA-PID controller shows also stronger robustness properties versus system perturbations, disturbances and faults.

Proper selection of Distributed Energy Resources(DERs) and optimal sizing for them for specified objective are challenging and very important tasks in isolated MGs design. This is because the coordination among the MG components besides constraints is very difficult and complicated process. The problem may be formulated to be a non-linear optimization problem. A suitable optimization technique is then used to solve such a problem. A generalized formulation for deciding the optimal configuration with the goal of minimizing the Total Investment Cost (TIC) as well as the emissions level reduction for an isolated MG is introduced as the second focus in this thesis.

A novel optimization scheme used with Cuckoo Search Optimization Algorithm (CSOA), for optimal configuration and energy management of an isolated MG components, is proposed. The MG is used for supplying a load profile located between (30.119 latitude and 31.605 longitude). For solving such a configuration and management problem, it is first formulated as a non-linear constrained cost problem. Different optimization techniques are applied to solve the problem for comparison, such as GA, PSO, and BFOA. Case studies are checked for comparing the results and to verify the efficiency of the proposed scheme.

A MATLAB code is designed and used to calculate the energy produced by the MG generation sources according to meteorological data of the proposed location. The fitness function is modeled and designed to minimize the TIC including capital, investment, and running costs. A new proposed Weighted Goal Attainment Function (WGAF) is designed to take into account the cost of the CO_2 emissions and also to limit the emissions by applying higher taxes on the amount that exceeds the governmental approved limits. Various weighting coefficients of the proposed WGAF are performed to investigate its effects on the TIC in \$/year, annual cost of energy in \$/kWh and CO_2 emissions. According to the final results, it has been proved that the designed scheme with the help of CSOA can robustly and efficiently obtain the optimal MG configuration which is Eco-friendly and has great economic benefits.

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