بسم الله الرحمن الرحيم

MONA MAGHRABY

شبكة المعلومات الجامعية

التوثيق الالكتروني والميكروفيلم

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شبكة المعلومات الجامعية

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جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

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MONA MAGHRABY

AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electrical Power and Machines Engineering

Energy Management in Microgrids Considering Uncertainties

A Thesis submitted in partial fulfilment of the requirements of the degree of

Doctor of Philosophy In Electrical Engineering

(Electrical Power and Machines Engineering)

by

Shady Mamdouh Sadek Abdul-Mawla

Master of Science in Electrical Engineering

(Electrical Power and Machines Engineering)

Faculty of Engineering, Cairo University, 2016

Supervised by

Prof. Hossam Eldin Abdalla Talaat

Prof. Mohammed Ahmed Moustafa Hassan

Associate Prof. Walid Atef Omran

Cairo - (2021)

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Examiners' Committee

Name and Affiliation	**Signature**
Prof. Mohamed Salah Elsobki Electrical Power Engineering, Cairo University	…….
Prof. Hany Mohamed Hassanein Electrical Power and Machines , Ain Shams University	…….
Prof. Hossam Eldin Abdalla Talaat Electrical Power and Machines , Ain Shams University	…….
Prof. Mohammed Ahmed Moustafa Hassan Electrical Power Engineering, Cairo University	…….

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Statement

This thesis is submitted as a partial fulfilment of Doctor of Philosophy in Electrical Engineering, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

Student name

Shady Mamdouh Sadek

Signature

……

Date: 06 May 2021

Researcher Data

Name	: Shady Mamdouh Sadek Abdul-Mawla
Date of birth	: 24/12/1989
Place of birth	: Saudi Arabia
Last academic degree	: Master of Science in Electrical Engineering
Field of specialization	: Electrical Power and Machines
University issued the degree	: Cairo University
Date of issued degree	: 15/6/2016
Current job	: Teaching Assistant - International Academy for Engineering and Media Science

Thesis Summary

Recently, the increased concerns about environmental and economic aspects in power systems lead to searching for alternative electrical power sources that are both clean and cheap. In this respect, Renewable Energy Sources (RESs) can be utilized to provide such alternative solutions to the problems of the conventional power sources like environmental pollution, global warming, fossil fuel depletion and fuel increasing prices but their integration in power systems have many challenges. RESs are intermittent and uncertain as their output power changes with the weather conditions which results in forecast errors. These forecast errors should be considered carefully in the operation problems of the power systems particularly small systems such as Microgrids (MGs) as any small variations may have a large influence in the optimal operation decisions.

MGs have gained a great interest nowadays mainly in remote areas where there is no electrical infrastructure support. These MGs are called isolated MGs and are basically depend on their local sources so that effective Energy Management (EM) are strongly required to manage the different power sources like conventional diesel generators and different inverter interfaced Distributed Energy Resources (DERs) such as Wind Turbines (WTs), Photovoltaic (PV) systems, and Battery Energy Storages Systems (BESSs) in the most techno-economic way while considering the uncertainties coming from the RESs.

Therefore, in this thesis, the aim is to provide an accurate modelling of the isolated MG EM problem to decide for the optimal day-ahead dispatch while considering RESs uncertainties. First, the isolated MG components are modelled. The diesel generators and inverter interfaced DERs are modelled through considering their reactive power capability curves instead of the widely used box constraints. The reactive power costs related to diesel generators are considered in the EM problem objective that were neglected in the previous studies. Neglecting the reactive power costs will result in errors in the calculated operation costs and the optimal dispatch decisions will be affected. The reactive power capabilities of the inverter interfaced DERs are considered to reduce the stress on diesel generators in reactive power supplying. Simultaneous active/reactive power dispatch is optimized in the EM problem instead of the widely utilized active or reactive power dispatch alone. In addition, the EM problem is based on solving the AC Optimal Power Flow (OPF) instead of the common DC OPF to give a more detailed characterization of the system variables and accurately model the MG power flow. The DC OPF neglects the line resistances and reactive powers and bus voltage magnitudes are assumed unity which are not accepted in the framework of small power systems in distribution systems and MGs.

The uncertainties are modelled using two different techniques namely the two-stage Stochastic Optimization (SO) and the adaptive Robust Optimization (RO). The SO requires generating a large number of RESs scenarios to accurately represent the RESs uncertainties but accurate modelling and fitting of probability distributions are not guaranteed to precisely represent the uncertainties. Thus, Generative Adversarial Networks (GANs) are utilized as a scenario generation method which can give more accurate scenarios without the need for

probability distributions or fitting models. Then, the Fast Forward Selection (FFS) algorithm is used to reduce the number of scenarios to enhance the problem tractability. The SO EM model is compared with the deterministic model to interpret the effect of considering the uncertainties. Various sensitivity analyses are carried out to study the impacts of the selected number of scenarios, Value of Lost Load (VOLL), RESs penetration level, and uncertainty level on the EM problem performance.

Then, the adaptive RO based EM model is proposed to model the RESs uncertainties. The deviations of the uncertain variables in RO are characterized to lie within a pre-defined uncertainty set. Thus, no need for scenario generation nor reduction in RO which results in reduced computational complexity compared to the SO model. The RO EM model is more conservative as it concerns with optimizing the worst-case condition to assure robust decisions which increases the MG operation costs. The effect of the number of deviation points and the budget of uncertainty on the RO EM problem performance are analysed via sensitivity analyses.

Finally, comparisons between the SO and RO are executed to decide which technique is more eligible in the framework of RESs uncertainty modelling in isolated MGs. The SO EM model gives better results in terms of the day-ahead operation costs but with increased computational complexity while the RO EM model results in higher day-ahead operation costs with less computation complexity. Trade-off studies are required according to the MG operator preferences to efficiently decide which technique is more suitable in RESs uncertainties modelling in the isolated MGs.

Keywords:

microgrids; optimization; energy management; decision-making under uncertainty; renewable energy sources; distributed generation; energy storage systems; stochastic programming; robust optimization; reactive power capability.

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[1] Sunan Abi Dawoud 4811