MODIFIED PARTICLE SWARM OPTIMIZATION ALGORITHM BASED POWER FLOW CONTROLLER FOR GRID-CONNECTED MICROGRIDS

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Specially dedicated
to my supervisor and family who encouraged
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ABSTRACT

Due to the fast depletion of fossil fuels and environmental concerns, the Microgrids (MGs) have emerged as an alternate source of electrical power generation. Renewable power sources like wind turbines, microturbines, solar Photo-voltaic (PV) and fuel cells connected together in a local grid to form a MG system and provide energy to communities living too far from the utility grid. In spite of the vast benefits of employing MGs in islanding or connecting them with the existing utility grids, they create some serious power quality issues. This is mainly due to the "plug and play" capability of connected DGs and loads within MGs and the use of a non-linear power electronic interface like voltage source inverter or converter used to integrate DGs with the MG. These power quality issues like high harmonic distortion, increased voltage and frequency flickers, high current transients and ineffective active and reactive power regulation limits the wide applicability of these small scale distributed MGs. Therefore, an optimal power control strategy is required to smoothly integrate these DGs within MG and into the main grid with desired active and reactive power sharing ratio and minimized harmonic distortion. This research work is carried out to develop an optimal power controller for the grid connected MGs in order to regulate the active and reactive power flow between the MG and the utility grid according to the desired setpoint with enhanced power quality. Furthermore, in order to improve the performance of the proposed controller under different operating conditions, its gain parameters (Kp and Ki) are optimally selected by using Modified Particle Swarm Optimisation (MPSO) algorithm. Moreover, to validate the effectiveness of the proposed MPSO based controller, its performance is compared with that of the conventional PSO based controller for the same operating conditions. As a result, MPSO provided improvement of 21.6% in overshoot, in 24.8% rise time and 15% in settling time has been obtained. Furthermore, the proposed controller provides an excellent response in regulating active and reactive power along with good power quality, in particular when the high DG penetration is required.

ABSTRAK

Faktor penyusutan bahan api fosil secara drastik dan kesedaran tentang alam sekitar telah menyebabkan wujudnya grid mikro (MG) sebagai sumber alternatif bagi penghasilan kuasa elektrik. Sumber tenaga yang boleh diperbaharui seperti turbin angin, mikroturbin, solar fotovolta (PV) dan sel bahan bakar dihubungkan bersama dalam satu grid untuk membentuk sistem MG serta membekalkan tenaga bagi masyarakat yang tinggal terlalu jauh dari grid utiliti. Meskipun penggunaan MG memberi memberi manfaat yang banyak samada dalam keadaan sendirian atau ketika disambungkan dengan grid utiliti, ia tetap menghasilkan beberapa isu kualiti tenaga yang serius. Ini terutamanya disebabkan oleh pengoperasian “pasang dan guna” oleh DG dan beban dalam MG serta penggunaan penukar elektronik kuasa yang tidak linear seperti penukar sumber voltan atau penukar yang digunakan untuk mengintegrasikan DGs dengan MG. Isu-isu kuasa kualiti seperti gangguan harmonik yang tinggi, kelipan voltan dan frekuensi yang bertambah, arus sementara yang tinggi dan regulasi kuasa aktif dan reaktif yang tidak efektif telah menghadkan fungsi sebenar MG. Oleh itu, strategi kawalan kuasa yang optimum diperlukan untuk mengintegrasikan DGs, samada dalam MG dan juga grid utama, dengan nisbah perkongsian kuasa aktif dan reaktif yang dikehendaki dan meminimumkan penyimpangan harmonik. Kajian penyelidikan ini dijalankan untuk membangunkan pengawal kuasa yang optimum bagi mengawal aliran kuasa aktif dan reaktif antara MG dan grid utiliti mengikut nilai yang dikehendaki serta kemeningkatan kualiti kuasa. Selain itu, untuk meningkatkan prestasi pengawal yang dicadangkan di bawah keadaan operasi yang berbeza, parameter gandaan (Kp dan Ki) dipilih secara optimum dengan menggunakan algoritma pengubahsuaian pengoptimum zarah terkumpul (MPSO). Bagi mengesahkan keberkesanan pengawal berasaskan MPSO yang dicadangkan, prestasinya dibandingkan dengan pengawal yang berasaskan PSO konvensional untuk keadaan operasi yang sama. Hasilnya, MPSO berjaya menambahbaik 21.6% dalam masa terlajak, 24.8% masa menaik dan 15% masa penyelesaian. Selain itu, pengawal yang dicadangkan memberikan tindak balas yang sangat baik dalam mengawal selia kuasa aktif dan reaktif bersama dengan kualiti tenaga yang baik, khususnya apabila jumlah keluaran DG yang tinggi diperlukan.

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LIST OF ABBREVIATIONS

MG - Microgrid
MPSO - Modified Particle Swarm Optimization
DG - Distributed Generation
DER - Distributed Energy Resources
P - Active Power
Q - Reactive Power
PWM - Pulse Width Modulation
SVPWM - Space Vector Pulse Width Modulation
VSI - Voltage Source Inverter
IGBT - Insulated-Gate Bipolar Transistor
UPEC - Unified Power Flow Controller
GA - Genetic Algorithm
FL - Fuzzy Logic
PSO - Partice Swarm Optimization
PV - Photovoltaic
HCC - Hysteresis Current Control
VSFC - Variable Switching Frequency Controller
CSFC - Constant Switching Frequency Controller
PLL - Phase-Locked-Loop
PCC - Point of Common Coupling
PI - Proportional Integral
ITAE - Integral time absolute error
THD - Total Harmonic Distortion
ref - Reference Value
i - Current
V - Voltage

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Nowadays, a large part of the world population lives without access to electricity. According to IEA (International Energy Agency) report, there are still 1.3 billion people who don't have access to electricity. This lack of energy access is due to the fact that a large part of the population in developing countries lives in rural areas far away from the main utility grid [1]. Furthermore, the fuel assets are turning out to be rare in recent future and hence their cost is increasing rapidly due to their limited availability. Renewable power sources like wind turbines, microturbines, Solar Photovoltaic (PV) and fuel cells connected in a local grid are a real opportunity to overcome the stated issues. Such distributed electrical grids are called Microgrid (MG).

Renewable Energy Sources are environment-friendly resources which give clean energy and naturally replenished sources of power generation which are quickly getting to be viewed as best alternatives as compared to conventional resources such as fossil fuel power generation plants. Nonetheless, not at all like conventional power plants, which are localized and give a high amount of power generation, the renewable energy sources give a low amount of power generation. Thus, these electrical sources are called "distributed generation". Renewable-based distributed generators commonly utilize power electronic converters, for example, DC/AC inverters, AC/DC rectifiers, DC/DC converters, to give the suitable kind of electrical energy for utilization. The term distributed generation is not only used for renewable energy sources but also used for non-renewable based power generation which utilizes fossil fuels, for example, rotating generators driven by a diesel engine.

Interfacing distributed generation units into the existing power distribution grid or using them in an islanded electrical network is a challenging task. To encourage the administration and control of these systems, distributed generators and their related loads are regularly considered as an independent system called a Microgrid. MG is a concept of small-scale power production using DGs. It is used to supply Combined Heat and Power (CHP). MG can operate in two modes; grid-connected and autonomous [2-10]. In autonomous mode it is responsible to meet the local area demand with required level of power quality supply [11]. A control strategy is required to control voltage and frequency to meet high-quality power supply requirement [12]. In grid-connected mode, the MG is connected with the utility grid to supply power. The voltage and frequency values are maintained fixed at the point of common coupling (PCC) by the utility grid. Furthermore, in this mode of operation the MG either can export power to grid or import power from grid depending upon the condition. MG consisting of distributed energy resources need power electronics devices to interface such as voltage source inverter [13-15]. The install distributed energy resources may be solar, wind, fuel cell, biomass, geothermal or gas turbines. The advantages of these micro sources have less cost, low voltage environment-friendly and can easily place at customer side.

The objective of this study is to explore the grid-connected operation of MGs and to get a better dynamic response from power flow controller. This chapter describes the problem statement and the research objectives for these investigations. In addition, the contribution of this research and the structure of the project report is outlined .

1.2 Problem Statement

Currently, due to simplicity and robustness of the Proportional Integral (PI) controller, it is still the most widely used as a controller in MG control structures. However, the performance of these controllers purely depends on the values of its Kp and Ki gain values. These parameters are mostly selected on trial and error or well-known Ziegler Nichols method. However, the selected parameters may not be ensured as the optimal selection. In order to avoid the old PI tuning processes, the recent literature propose the tuning of the PI controllers using metaheuristic techniques in order to optimize the stated parameters under all operating conditions. However, these techniques for MG active and reactive power regulation suffers from the limitations of slow and pre-mature convergence in the iterative process, trapping into local minimum in high-dimensional space and uncertainty in its parameter selection. In this research work, the MPSO has been proposed to overcome the stated issues in order to obtain the optimal dynamic response of grid-connected MG.

1.3 Objective

The objectives of this research work are as under

1. To develop a Grid-connected MG model along with a robust power controller in MATLAB/Simulink to regulate the active and reactive power flow.
2. To evaluate the effectiveness of the proposed controller in maintaining the reference active and reactive power values during and after MG insertion and abrupt load changes.
3. To optimize the proposed controller parameters (Kp and Ki) using MPSO and comparing its performance with that of the manual PI and PI-PSO tuning for the same configuration and operating conditions in order to validate the effectiveness of the proposed controller.

1.4 Scope

This research investigates the power flow control techniques in grid-connected MG system for examining the power flow controller response. It undertakes the development of MPSO based controller for regulating active and reactive power flow in an inverter-based DG unit in a grid-connected AC MG. The case study has only considered the solar PV as DG. Furthermore, the DC to AC conversion is done with IGBT based inverter. Space Vector Pulse Width Modulation (SVPWM) has been used to fire Insulated Gate Bi-polar Transistor (IGBT) based Voltage Source Inverter (VSI) as it provides the desired output voltage with minimized harmonic distortion. Lastly, the study is based on simulation work in MTALB SIMULINK software 2017a version and does not focus on its practical implementation.

1.5 Contributions of research work

The major contributions of this research work are listed as follows,

1. In this research work an intelligent power flow controller for grid connected MG has been developed.

2. The performance evaluation of the proposed controller has been carried out under two different conditions; MG insertion and load change.
3. Furthermore, the MPSO has been implemented to optimize the power controller PI parameters (Kp and Ki) in order to obtain the optimal dynamic response of the studied grid-connected MG system and the results were compared with that of manual PI and PI-PSO for the same operating conditions.

The outcomes of this research show the effectiveness of the proposed MPSO based controller in regulating the active and reactive power with minimum overshoot and settling time which makes it an effective choice to be used in modern MG controls

1.6 Report Organization

This report consists of five chapters. The first chapter discusses about the background study of MG, problem statement, objective, scope, contributions made and significance of the project. In Chapter 2, presents the theory and literature reviews on concept of MG, distributed generation and their interfacing, power flow control problems in grid-connected MG systems. Chapter 3 will discuss the proposed methodology which is used in this project. The result and discussion will be presented in Chapter 4. Last but not least, Chapter 5 will present the conclusion of this research and some recommendations for future work.

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