A Novel Control Strategy for Reduce Voltage Unbalance in an Islanded Microgrid

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Abstract - *Micro Grids (MG) provide advantages such as providing energy supply to areas far from the distribution grid, efficient use of resources by supporting demand management and having a more dynamic grid. However, if an advanced control system is not implemented in the islanded MG, problems of power quality may arise. One of these problems is the voltage unbalance. Increasing the number of single-phase roof-mounted PV plants and the number of electric vehicle charging stations in recent times may negatively affect voltage unbalance. One of the methods used to mitigate this problem is the Demand-Side Management (DSM). Here, a solution method based on DSM is presented for the voltage unbalance problem that may occur in an islanded MG. The proposed Direct power control algorithm reduces successfully both the voltage unbalance factor.*

Key Words: Micro Grids (MG), PV plants, Demand-Side Management (DSM), Islanded MG

1. INTRODUCTION

Microgrids (MG) have been widely used in electric systems because of global increasing energy demand, and the worldwide concern about the environment issue caused by fossil fuels power generation. MG can include different renewable energy sources, which supplies energy by a primary source and distributed storage characterized by utilizing energy storage system and electric vehicles. Renewable energy sources and their integration into grid have a very critical role in energy management system applications. By enabling this integration, micro-grids consisting of renewable energy sources, energy storage units, and load components are emerging as a new and effective solution to today's electric power system networks.

Summarizing, an Energy Storage Systems (ESS) can be used to store energy surplus, due to overproduction contextual to low power demand, and to allow its post-usage when required.

1.1 Use of ESS (Three Situations)

a) Storage makes possible the deferred use of the produced energy in the complete or partial absence of a concurrent energy demand.

b) Storage allows to the user to exploit power at a different power level than that at which it is available during production.

c) Storage system must be reversible (not in thermodynamic sense), i.e. it must allow the deferred use of almost all accumulated energy according to its energy efficiency.

1.2 Renewable Energy

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on a human time such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy replaces conventional fuels in four distinct areas: electricity generation, air and water heating/cooling, motor fuels, and rural (off-grid) energy services This energy consumption is divided as 9% coming from traditional biomass, 4.2% as heat energy (non-biomass), 3.8% hydroelectricity and 2% is electricity from wind, solar, geothermal, and biomass, with countries like China and the United States heavily investing in wind, hydro, solar and biofuels.

While many renewable energy projects are large-scale, renewable technologies are also suited to rural and remote areas and developing countries, where energy is often crucial in human development. United Nations' Secretary-General Ban Ki-moon has said that renewable energy has the ability to lift the poorest nations to new levels of prosperity. Renewable hydroelectric energy provides 16.3% of the world's electricity. When hydroelectric is combined with other renewable such as wind, geothermal, solar, biomass and waste: together they make the "renewable" total, 21.7% of electricity generation worldwide.

Renewable power generators are spread across many countries, and wind power alone already provides a significant share of electricity in some areas: for example, 14% in the U.S. state of Iowa, 40% in the northern German state of Schleswig-Holstein, and 49% in Denmark. Some countries get most of their power from renewables, including Iceland (100%), Norway (98%), Brazil (86%), Austria (62%), New Zealand (65%), and Sweden (54%).

2. LITERATURE SURVEY

2.1 Integration issues of distributed generation in distribution grids [1]

In today's distribution grids the number of distributed generation (DG) units is increasing rapidly. Combined heat and power (CHP) plants and wind turbines are most often installed. Integration of these DG units into the distribution grid leads to planning as well as operational challenges. Based on the experience of a Dutch distribution system operators (DSO), this paper addresses several possibilities to handle grid planning issues. Effects on voltage control, grid protection, and fault levels are investigated and described.

2.2 System and method for phase balancing in a power distribution system [3]

A phase balancing system includes a load forecasting module, a phase unbalance identification module and a demand response module. The load forecasting module determines a load forecast for the distribution system for the period of interest and the phase unbalance identification module determines voltage unbalance on the distribution system for the period of interest.

2.3 Voltage unbalance reduction in low voltage feeders by dynamic switching of residential customers among three phases [7]

To dynamically reduce voltage unbalance (VU) along low voltage distribution feeders, a distributed intelligent residential load transfer scheme is proposed. In this scheme, residential loads are transferred from one phase to another to minimize VU along the feeder. The central controller, installed at the distribution transformer, observes the power consumption in each house and determines the house(s) to be transferred from an initially connected phase to another.

2.4 Management of Power Quality Issues in Low Voltage Networks Using Electric Vehicles: Experimental Validation [8]

As Electric Vehicles (EVs) are becoming more wide spread, their high power consumption presents challenges for the residential low voltage networks, especially when connected to long feeders with unevenly distributed loads. However, if intelligently integrated, EVs can also partially solve the existing and future power quality problems. One of the main aspects of the power quality relates to voltage quality. The aim of this work is to experimentally analyse whether series-produced EVs, adhering to contemporary standard and without relying on any V2G capability.

2.5 Distributed control of multiple electric springs for voltage control in microgrid [9]

Dispersed distribution of many inverter-based electric springs (ESs) over the power grid as a means to provide stability support for smart grid against high penetration of intermittent renewable power has been suggested recently. While single ES has its own local controller, their wide dispersion makes it difficult to coordinate multiple ESs operation. In this paper, a complete design and implementation procedure of the consensus control methodology for the distributed voltage control of multiple ES is presented.

2.6 Harmonics suppression for critical loads using electric springs with current-source inverters [10]

A novel control strategy of direct current control and harmonic suppression function, similar to the control of active power filter (APF), is proposed using a new type of electric spring (ES) with current-source inverters (CSIs) to improve the performances of ESs. Compared with the existing control methods, total harmonic distortion can be greatly reduced by changing voltage-source inverters to CSIs and also by replacing voltage control with direct current control.

2.7 Use of adaptive thermal storage system as smart load for voltage control and demand response [11]

This paper describes how a large-scale ice-thermal storage can be turned into a smart load for fast voltage control and demand-side management in power systems with intermittent renewable power, while maintaining its existing function of load shaving. The possibility of modifying a conventional thermal load has been practically demonstrated in a refrigerator using power electronics technology. With the help of an electric spring, the modified thermal load can reduce power imbalance in buildings while providing active and reactive power compensation for the power grid.

2.8 Distributed voltage unbalance compensation in islanded microgrids by using a dynamic consensus algorithm [16]

In islanded microgrids (MGs), distributed generators (DGs) can be employed as distributed compensators for improving the power quality in the consumer side. Two-level hierarchical control can be used for voltage unbalance compensation. Primary level, consisting of droop control and virtual impedance, can be applied to help the positive sequence active and reactive power sharing. Secondary level is used to assist voltage unbalance compensation. However, if distribution line differences are considered, the negative sequence current cannot be well shared among DGs.

3. WORKING AND OPERATION

In this work, a new DSM method is proposed to reduce the voltage unbalance. A novel control algorithm is designed for controllable loads. In the literature, TCLs are frequently used as flexible and controllable loads. So, residential TCL (refrigerator, air conditioner etc.) was selected as the controllable load and is used for voltage regulation of the network. However, in the literature, TCL-based voltage regulation studies were generally carried out for balanced power systems.

3.1 The Proposed Model

We propose a novel method based on voltage sensitivity analysis for unbalanced power systems. Our aim is to reduce the voltage unbalance by controlling minimum number of load. To achieve this, most appropriate way is voltage sensitivity analysis. With help of this method, it is possible to detect the most effective bus that affects point of common coupling (PCC) voltage. After the most effective bus is detected, the TCLs in that bus are controlled to reduce the voltage unbalance. Thus, with less TCL control, more successful voltage regulation will be ensured. If the selection process is not performed properly, more loads will be controlled. So, more consumer will be affected by this. This is not an appropriate control strategy for DSM. To obtain more accurate and stable results, neutral current is taken into account. The most important feature of unbalanced systems is the increase of neutral current and voltage due to the imbalance between the phases. The inclusion of neutral components in the model will help to achieve more accurate results. According to the author's latest knowledge, voltage sensitivity analysis considering neutral current and reactive power of TCL has not been addressed in the literature yet. In addition to this, studies conducted in the literature have considered the active powers of TCLs. Reactive power are also included in this project.

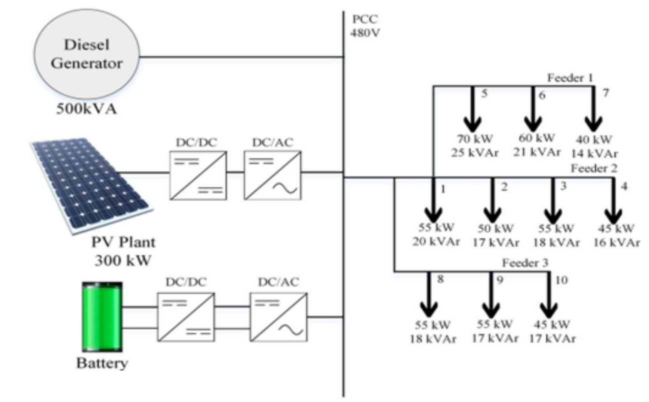

Fig -1: Name of the figure

The block diagram of the load connected micro grid system is represented in Fig. 1. The block diagram comprises of a Solar PV panel, battery, diesel generator and grid with three phase residential load.

3.1.1 Modelling of generation side

Diesel generator, PV plant, and a battery were used in MG as generation part. The capacity of the diesel generator is 500 kVA. The generator is directly connected to PCC. The capacity of the PV plant is 300 kW. PV plant is connected to PCC bus with a boost converter and a voltage source converter. To make the PV plant operate at maximum efficiency, perturbation & observation algorithm is used. The capacity of the battery is determined as 80 kWh. The battery is connected to PCC bus with bi-directional converter and a voltage source converter. The efficiency of the battery is increased by considering the SOC situation of the battery. The voltage and system frequency of the PCC are set as 0.480 kV and 60 Hz, respectively. Diesel generator and PV plant were designed to be able to generate reactive power. The power-sharing between the plants is done with the droop control method.

3.1.2 Voltage sensitivity analysis for unbalanced power systems

Voltage sensitivity is a useful variable used in the analysis of transmission and distribution systems. After the load or generation change occurring in the system, the change of the voltage value of the buses can be examined with this method. This method has gained more importance especially when DG is included in the distribution grid in recent years. Finding buses have the highest sensitivity value and the plants that will be added to the system can be connected to the most sensitive buses. This will increase the stability and power quality of the grid. Balanced power systems have a single value for each bus, depending on the active and active power. Voltage sensitivity analysis can be performed depending on these values. However in unbalanced systems, the analysis is a little more complicated. As each bus has a total of four variables including three phases and one neutral.

3.2 Simulation Result

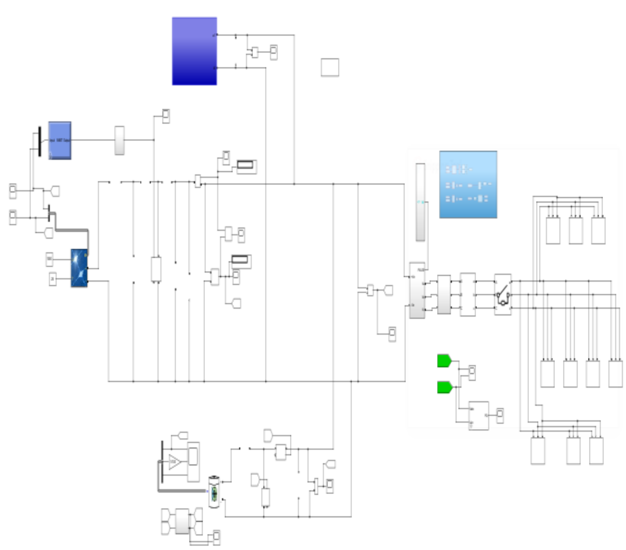

Fig -2: Simulation of the proposed micro-grid

3.3 Classification of Artificial Neural Network

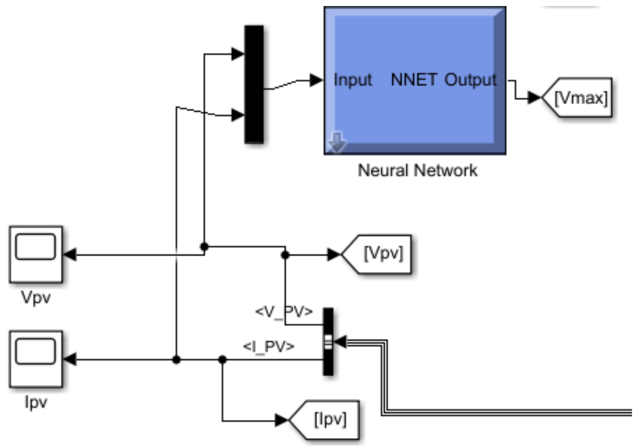

Fig -3: Structure of (ANN) classifier

The Neural Network consists of, Error back propagation (BP) Neural Network was applied for diagnosis of fault in power system. However slow speed training and the shortcomings of local optimal lead to the introduction of additional momentum factor for problem solving. . It is employed for fault detection and classification for transmission line protection system.

Artificial Neural Network (ANN) can be applied to fault detection and classification effectively because it is a programming technique, capable to solve the nonlinear problems easily. The ANNs are able to learn with experiences. They are widely accepted and used in the problem of fault detection and fault classification of the result.

ANN based method, the entire data that is collected is subdivided into three sets namely the training, validation and the testing data sets. The first step in the process is fault detection. Once we know that a fault has occurred on the transmission line, the next step is to classify the fault into the different categories based on the phases that are fault

3.4 Neural Network Structure of Fault Classifier

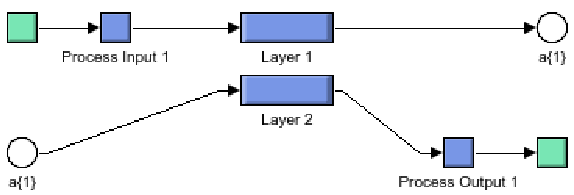

Fig -4: Structure of (ANN) Layer

To obtain accurate outputs for fault classification, several trainings are carried out during simulations. Once trained, the networks performance was tested using a validation data set. The suitable network which showed satisfactory results was finally selected. When acceptable output and negligible error is obtained, Simulink model output for fault classification is generated from 'MATLAB tool'. According to the ANN training, the resulting of simulation. Fig 4 shows the snapshot of the trained ANN with the 6-20-6-6 configuration it is to be noted that the number of iteration required for training process .It can been seen that the mean square error in fault detection achieved by the end of the training process value was shown in fig 4 and the number of validation check 6 by the end of the training process. Neural Network are indeed a reliable and attractive method for transmission line faults scheme especially in view of increase complexity of the modern power systems. Back propagation network are very efficient when a sufficient large no. of data set is available. The results show that the method is suitable for design a protective scheme for transmission line base on Artificial Neural Network. The method is easy applicable and flexible.

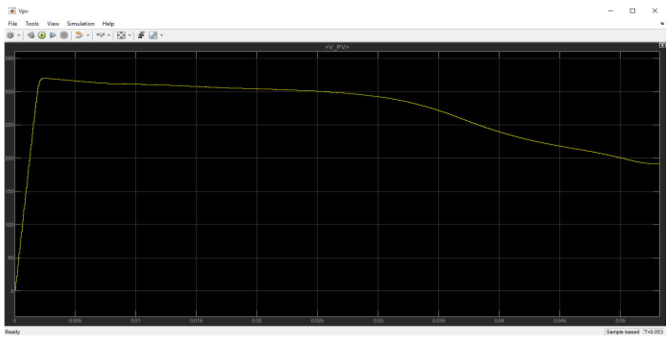

Fig -5: Input voltage of PV

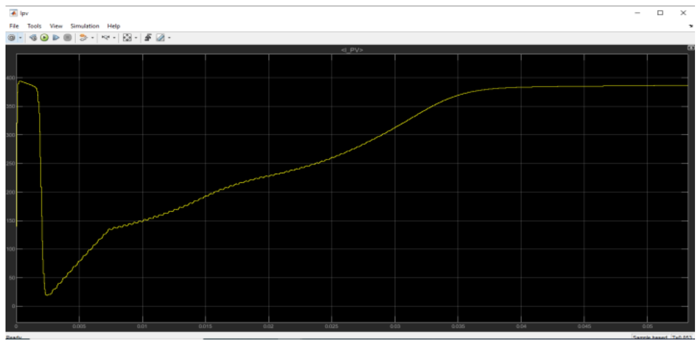

Fig -6: Input current of PV

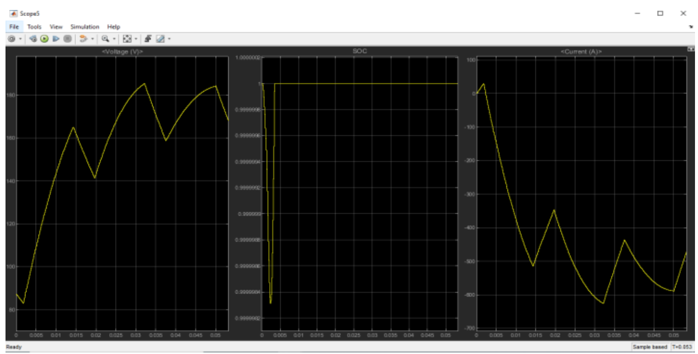

Fig -7: Battery Voltage, Current and SOC

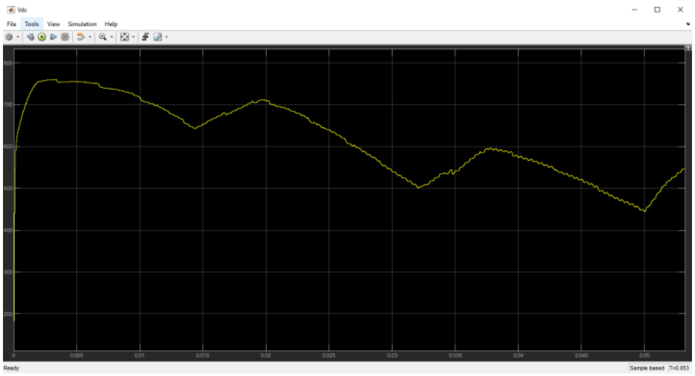

Fig -8: DC voltage of Microgrid

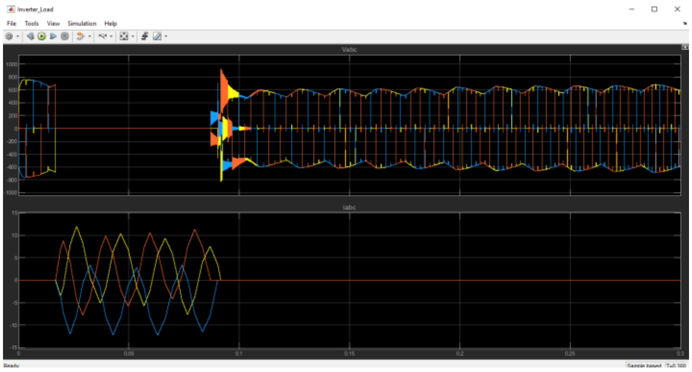

Fig -9: Inverter Load

Fig -10: Power Quality

4. TESTING AND ANALYSIS

Simulink Test provides tools for authoring, managing, and executing systematic, simulation-based tests of models, generated code, and simulated or physical hardware. It includes a Test Sequence block that lets you construct complex test sequences and assessments, and a test manager for managing and executing tests. Simulink Test enables functional, baseline, equivalence, and back-to-back testing, including software-in-the-loop (SIL), processor-in-the-loop (PIL), and real-time hardware-in-the-loop (HIL). Can apply pass and fail criteria that include absolute and relative tolerances, limits, logical checks, and temporal conditions. Setup and cleanup scripts help automate or customize test execution.

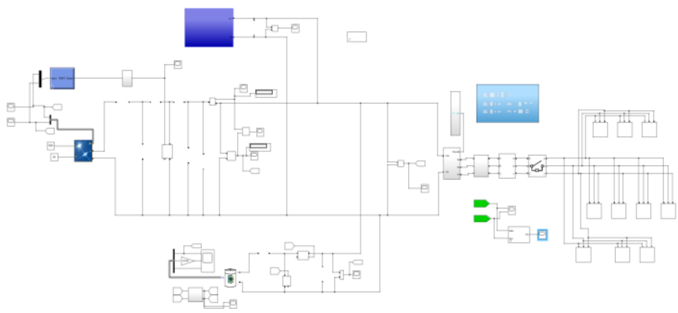

Fig -11: Testing and Analysis

Model-based testing is a systematic method to generate test cases from models of system requirements. It allows to evaluating the requirements independent of algorithm design and development.

4.1 Model-based testing involves

- Creating a model of system requirements for testing
- Generating test data from this requirements-model representation
- Verifying your design algorithm with generated test cases

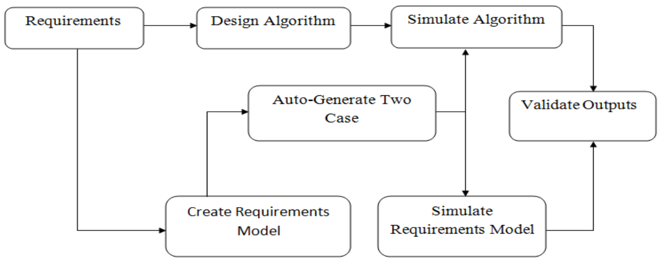

Fig -12: Generate tests from requirements using model-based testing

In model-based testing, you use requirement models to generate test cases to verify your design. This process also helps automate other verification tasks and streamlines the review process by linking test cases and verification objectives to high-level test requirements. Using Simulink test manage the test cases and systematically execute them to confirm that design meets requirements. To increase the quality of generated test cases beyond traditional stochastic and heuristic methods, can generate tests with Simulink Design Verifier, which uses formal analysis techniques. With Simulink Coverage can use model and code coverage metrics to assess the completeness of model-based testing efforts. These metrics can identify missing requirements and unintended functionality.

5. CONCLUSIONS

The use of MG structures in future electrical systems is predicted to increase. However, when MGs are not controlled in an advanced manner, some power quality problems may arise. One of the problems is voltage unbalance.

In this work, a new algorithm based on DSM is proposed to reduce the voltage unbalance. In the developed algorithm, residential TCL (refrigerator, air conditioner etc.). The main purpose is to control minimum number of TCL. It means that minimum number of consumer will be affected by this.

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