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Original Research Article

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Improving Flexibility and Control the Voltage and Frequency of the Island Micro-Grid Using Storage Devices

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ABSTRACT. Micro-grid is a small low voltage power supply network designed to power a local sensitive load set including distributed generation systems, distributed energy storage devices, and loads. Mostly, the required power by the system is provided by renewable resources that are unsafe and changeable yielding difficulties to control these systems in comparison with conventional power systems. Fluctuations in the generated power may cause some problems with normal control performance, in which proper performance of a micro-grid is possible only if there is a proper control system. Moreover, modern power systems need to increase information and flexibility in control and optimization to ensure the balance of production and load under severe disruption. In this paper, the performance of voltage and frequency control of the islanded micro-grid is investigated using the developed VBD control and its purpose is to increase the flexibility in the applications of energy storage devices. The micro-grid and power generation resources and VBD control method and its control over the storage devices are discussed in details. Performed simulation in MATLAB software includes a transient and dynamic micro-grid response with a comparison of the presence of storage devices on the voltage and frequency control of the micro-grid.

Keywords: Micro-grid, VBD control, Energy storage, Flexibility.

INTRODUCTION

The concept of micro-grid, a group of loads and micro-resource performance, is assumed to be a controllable system providing both electricity and heat in an area introducing production and distribution performance.[1] The advantage of the micro-grid is that it could be used as a controlled battery of the power system. For example, this battery could be distributed as a single charge following with a second response to the needs of the transmission system.[2] For the customer, the micro-grid could be designed for specific needs, such as increasing local reliability, reducing feeder drop, local voltage support, providing increased efficiency through the use of heat loss, correcting voltage weakness or providing support maps.[3] A micro-grid could serve as a low-voltage network of power generation units, with storage devices and loads capable of providing a local area such as suburban areas, industrial or commercial areas with electricity and electric heat.[4] With rapid response by power electronics and their presence as a single interface, the micro-grid could be connected to a traditional power grid or it could act as a self-supporting power system on its own.[5, 6] The micro-grid could be connected to the mains at the point of common coupling (PCC), in which insulation tools are used to insulate the micro-grid from the main grid. Scattered production units are responsible for generating electricity, which includes the rotary type and the inverter type.[7] Torque types include AC motors, gas turbines, micro alternators (alternating current generators), while inverter types include photovoltaic, fuel cells and wind turbines.[8] Both of the rotary and inverter types require electronic power converters as the interface between the manufacturer and the network.[9] The power range of the DG unit on a small scale is about 4kw to 10,000 KW. Energy storage units are essential for coordinating the power supply in island mode as well as using the mains power control helping to improve the quality of electricity and

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participate in voltage control.[10] Batteries, flywheels, super capacitors, magnetic energy storage superheroes, etc. could help store energy still requiring electronic power tools.[11] There is a control system for the proper operation of the micro-grid in different operating modes based on a central controller or a scattered controller.[12] The choice of controller depends heavily on the operation of the micro-grid and its needs. The purpose of the micro-grid is to use rated voltage and frequency by a stable system during all operating modes.[13]
The purpose of this work is to use energy storage devices to control the voltage and frequency of the micro-grid. Nowadays, the use of renewable resources and energy storage devices have been increased due to benefits of micro-grids, and therefore these systems must be able to control micro-grids. The VBD method is recommended to coordinate these forces with energy storage to help regulate the micro-grid voltage and frequency and provide more power to the micro-grid when needed.

MATERIALS AND METHODS

Voltage-Based Droop Control

Voltage-based droop control (VBD) for isolated micro-grid is another type of P/V droop control that focuses on optimal network renewable energy integrity and also includes a dc bus controller (Fig. 1). Just as a local primary controller has no connection, the VBD controller is responsible for building system reliability. This VBD controller has received attention due to the lack of inertia, resistance lines, and a high share of renewable energy, which are specific features of low voltage isolated micro-grids.[14]

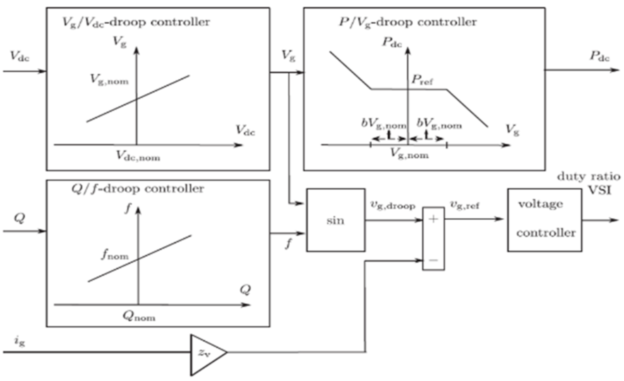

Fig. 1: VBD controller and virtual impedance loop.

This controller provides high flexibility to respond to a variety of scattered energy sources to ensure stable micro-grid performance. These units are used in a predefined priority command without the need for communication. This control goes beyond the state that uses the fits-and-forget approach to integrate DG, which determines the limit on the number of renewable resources on the network. In VBD control, the P/V droop controller is divided into two droop controllers, the V_g/V_{dc} and P_{dc}/V_g droop controllers.

Simulating Desired System

In this section, how to simulate micro-grid and the results of simulation in MATLAB/Simulink environment are presented. The micro-grid consists of two DG units, an energy storage unit, and eight consumers, six of which can be disconnected and reconnected.

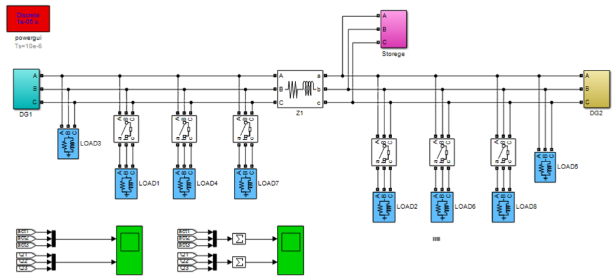

Fig. 2: General simulation diagram.

As can be seen, the micro-grid has two DG units and one energy storage unit, each of which has an internal structure in Figs. 3 and 4.

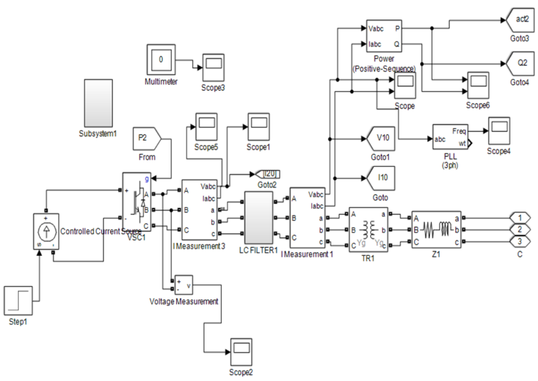

Fig. 3: Diagram of the internal structure of the first DG unit.

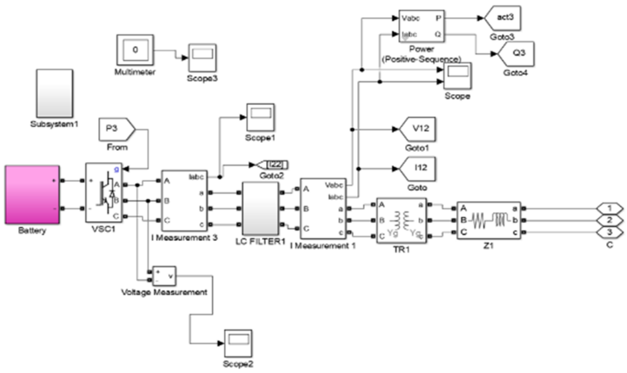

Fig. 4: Diagram of the internal structure of energy storage unit.

Fig. 5 shows the DG active and reactive power control section with voltage-frequency control and droop control and Fig. 6 shows the storage-control sections.

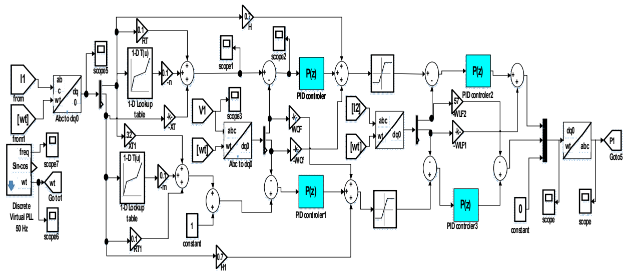

Fig. 5: DG active and reactive power control with voltage-frequency control and droop control.

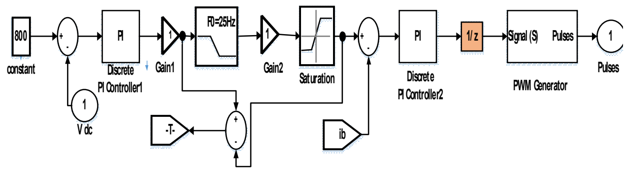

Fig. 6: Storage control unit (battery).

RESULTS AND DISCUSSION

The simulation shows that the storage element alone has a significant positive effect on micro-grid performance. Cooperation between the storage element and DG's flexible units, through VBD control, helps to prevent voltage limitations by minimizing the renewable energy limit. Also, the VGD controllers of the DG unit and the storage element are suitable in providing reliable operation, prioritizing in activating the output power changes and in controlling the voltage together. To see these things in detail, the micro-grid has been examined in both transient and dynamic modes.

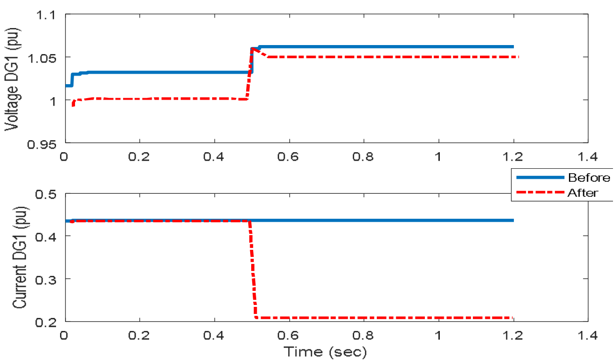

Fig. 7: DG1 voltage and current for the transient state in the state without / with the storage element.

Transient Mode Evaluation

The DG2 unit is connected to a 15-ohm load via a 0.5-ohm line impedance, which in turn is connected to the storage element via a 2-ohm line impedance. The transient effects are examined after the output changes of the DG unit. From 0 <t <0.5 seconds the nominal output power of the DG2 unit is 2 KW, from 0.5 <t <1.2 seconds it increases to 2.5 KW. There are two cases in which the storage element does not exist in the first case and the storage element in the second case. In the second case, there is a storage element in the micro-grid. This storage element has a maximum output power of 3 KW and has sufficient capacity so that the SOC does not significantly affect this simulation. This operation is fixed without a power band. A small-scale micro-grid is designed with large power changes and can clearly show the effects of controllers. In the first time range, the terminal voltage of the storage element is below the nominal value, so that it plays a role in controlling the network by providing active power to the micro-grid. In the last period, the DG unit provides significantly more power, so that the storage element starts to charge.

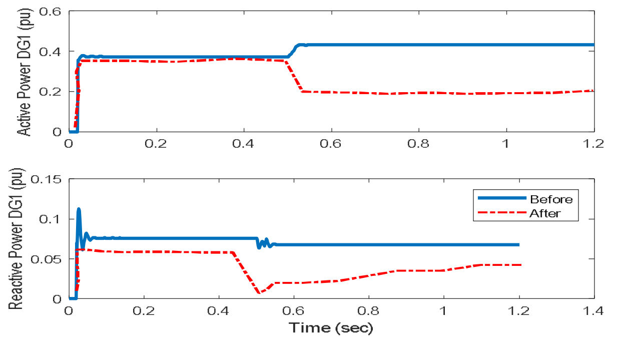

Fig. 8: Active and reactive power of DG1 for transient mode without / with storage element.

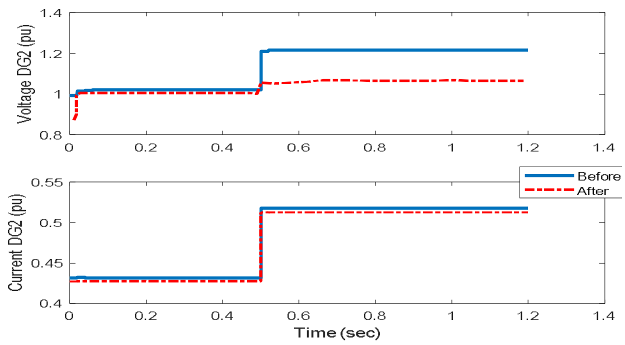

Fig. 9: DG2 voltage and current for the transient state in the state without / with the storage element.

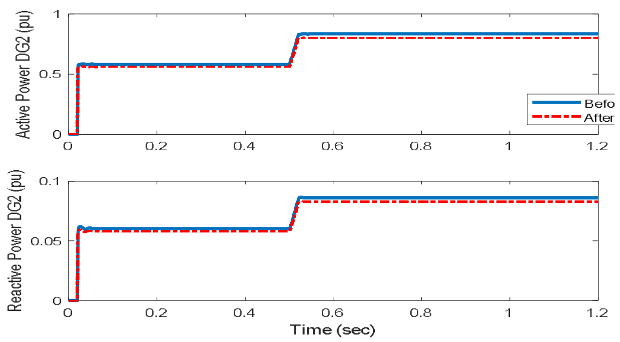

Fig. 10: Active and reactive power of DG2 for transient mode without / with storage element.

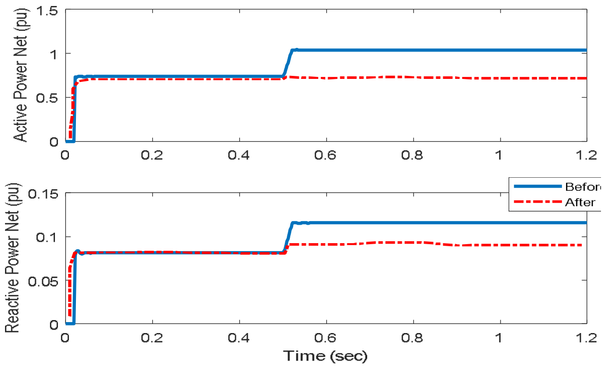

Fig. 11: Active and reactive power of the network for the transient state in the state without / with the storage element.

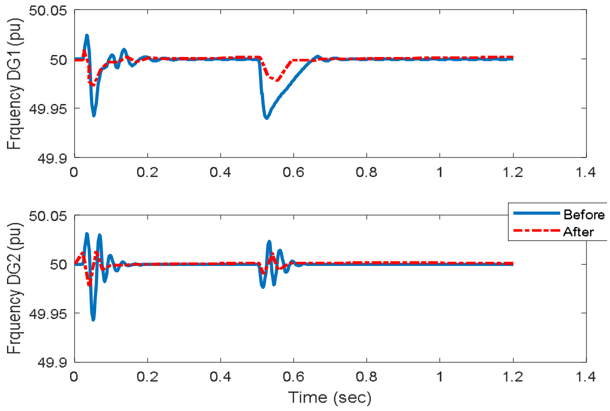

Fig. 12: Frequency of DG units in stateless / with storage element.

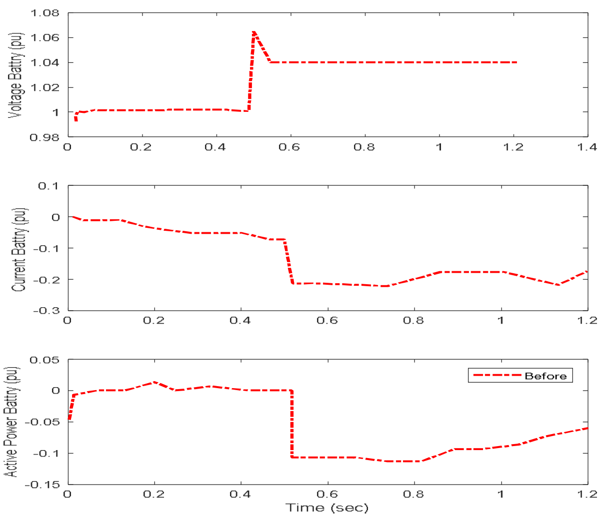

Fig. 13: Activator storage voltage, current and power.

Dynamic Mode Evaluation

In the previous simulation, the SOC storage element had not changed significantly due to the short simulation time. The following simulations use average models that can simulate a longer time. In average models, storage elements and DG units are displayed as voltage sources with a voltage reference derived from the VBD controller. Therefore, compared to previous simulations, no switches and voltage controllers are included. The diversity of active capabilities has been studied (frequency changes and reactive power have been studied). The reason for leaving the special DG and storage details is that here, network interaction is generally considered. The time scale is still small in terms of storage / DG (16 seconds), they are large in terms of the network. First, a small micro-grid with significant changes in SOC and then a larger micro-grid with more dynamic events are studied. Dynamic changes in load and output include summarized changes in Table 1. Three cases have been compared. First, the completely inflexible DG unit is simulated in a micro-grid without storage.

Table 1: Dynamic changes in load and power generated.

Unit	Time	Amount
Load 1	0 < t < 16 s	20 Ω
Load 2	0 < t < 3:5 s	20 Ω // 20 Ω //100 Ω
	3:5 < t < 5:0 s	20 Ω // 100 Ω // 100 Ω
	5:0 < t < 16:0 s	20 Ω // 100 Ω
Load 3	t < 16 s	25 Ω
DG1	t < 16 s	P_{ref}= 2 kW
DG2	0 < t < 10 s	P_{ref} = 4 kW
	10 < t < 16 s	P_{ref} = 6 kW

CONCLUSION

Nowadays, due to the increasing expansion of the penetration of scattered production in the electricity network and also the creation of an island state due to switching due to various reasons such as error or switching has already been determined, strategies for exploiting scattered products are of special importance. It depends on both economic reasons and the electricity market, as well as maintaining the stability of the network. In this study, after fully introducing micro-networks and scattered production and types of scattered products, as well as how to model them in simulation, we examined a specific strategy in exploiting scattered production when the micro-network became an island. Suggests scattered production units when island mode. This paper provides a voltage drop control for storage elements in island micro-grids. This storage controller works well enough to control similar voltage drop across other micro-grid elements such as controllable loads and DG units. As micro-grid control is unrelated, and storage elements help control micro-grids in a coordinated manner with other network elements, this micro-grid stability strategy offers the benefits of a consistent control strategy. In practice, this adaptation leads to the rapid implementation and understanding of micro-grid management. Some simulations were discussed, first showing the effectiveness of the control strategy, and second, more extensive simulations, the voltage response caused by the generator controller, and the storage elements on the simulator. Show different dynamic constructions. This study shows that the use of terminal voltage for primary control is effective in establishing proper cooperation of different network elements in micro-grid control with a similar control strategy and without interconnection between units. The simulation results showed that the presence of the storage only could improve between 4.5 and 9.5% of the voltage, but when the SOC of the storage reaches its maximum value, it is no longer able to stabilize the voltage. It also improved the use of VBD and voltage storage between 4.5 and 12 percent, and even when the SOC of the storage reaches its maximum value, the system is still able to stabilize the voltage.

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