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Control Scheme for Power Quality Improvement in Islanded Microgrid operation

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Abstract

The growing demand for reliable, flexible and high quality power with a concern for environment has lead to the concept of microgrid. When the microgrid is islanded either by fault or by design, it creates number of control challenges with respect to stability, power quality and harmonics. Control of Islanded microgrid is even more challenging due to the penetration of large number of intermittent Distributed Renewable Energy Sources (DRES) such as wind and solar. This paper proposes a control scheme to improve the power quality through voltage sag mitigation of islanded microgrid by injecting reactive power using Distribution- Static compensator (D-Statcom). The simulation results show that the proposed control scheme provides required voltage stability under Voltage Sag, thereby improves the power quality in an Islanded microgrid. The simulations are carried out in MATLAB/Simulink environment.

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Keywords: Islanded Microgrid, Power Quality, D-Statcom, Distributed Renewable Energy Sources (DRES), Voltage Sag.

1. Introduction

Recent Economic growth around the world has created the increased demand for Electric power not only in major cities but also in rural and remote locations. This demand for power cannot be met with conventional grid system due overloading of existing lines, with associated losses, Complexity as well as high cost of installation of new lines for rural and remote locations. One of the emerging solutions for such demand for power is microgrid or distributed generation.

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Microgrid is an integrated energy system consisting of Distributed Energy sources (predominately renewable sources such as wind, and solar) along with distributed loads and storage [1]-[2]. Microgrid can operate in Grid connected mode or Islanded mode. The Bidirectional Static Transfer Switch (BSTS) at the Point of Common Coupling (PCC) either connects or disconnects the microgrid from the main grid. Controlling microgrid in islanded mode is of great challenge due to the absence of dominant source of energy for providing stability to the grid and voltage unbalance [3]. The benchmarks for power quality are defined by parameters such as voltage, frequency, harmonic content and reactive power imbalance [4]. Therefore it is very much important to maintain the voltage and frequency with in specified limits in order to provide high quality power to the customers. The objective of this paper is to mitigate voltage sag in an islanded microgrid. Voltage Sag is defined as decrease in the Root Mean Square voltage from 0.1p.u to 0.9p.u at the power frequency level for durations of half cycle to one minute [5]. In an Islanded microgrid this is caused either due to fault in the customer facility or due to starting of large motor load (Induction). The voltage sag causes high inrush current in order to provide rated power, there by cause's damage to equipments.

1.1. Configuration of D-Statcom for Islanded Microgrid

The different methods of Power Quality improvement in microgrid have been studied in [6].In the proposed model D-Statcom is preferred for microgrid, as it can be applied for low voltage distribution system or in load side, as compared to other FACTS devices which are basically connected in the transmission system. D-Statcom is connected across the distribution line through a coupling transformer and it consists of Voltage Source Inverter that converts DC link voltage (V_{dc}) on the bus capacitor to the required voltage level. In this proposed model VCDS control is used to control the power with respect to real and reactive power current produced by the D-Statcom.

The proposed D-Statcom is connected to the microgrid with the help of small reactance (X_{DS}) at the point of Common Coupling (PCC). In the D-Statcom, DC input voltage is converted into three phase AC output voltage of adjustable voltage and frequency. The output voltage of D-Statcom (V_{DS}), is in phase with the Grid voltage (V_G) and it produces a lagging or leading current with respect to Grid voltage (V_G). Based on the value of this current, D-Statcom either absorbs or injects the reactive power (Inductive or Capacitive) and it is achieved dynamically by adjusting the output voltage of D-Statcom (V_{DS}) with respect to load angle (δ).

Lagging current I_{lag}, for $V_{DS} < V_G$ (Current lags Grid Voltage, V_G) (1)

Leading Current I_{lead}, for $V_{DS} > V_G$ (Current leads Grid Voltage, V_G) (2)

Reactive Current supplied by D-Statcom is given by,

$$I_{DS} = \frac{(V_{DS} - V_G)}{X_{DS}} \tag{3}$$

Where, I_{DS} – Output current of D-statcom

V_G – Islanded microgrid voltage

X_{DS} – Reactance between D-Statcom and Point of common coupling (Coupling Transformer)

Based on the value of Reactive current (I_{DS}), D-Statcom provides required voltage stability under voltage sag in an Islanded microgrid, by compensating the reactive power unbalance.

Reactive power supplied is given by D-Statcom is given by,

$$Q_{DS} = I_{DS} V_G. \tag{4}$$

Q_{DS} is positive, it supplies reactive power to the Islanded microgrid and if Q_{DS} is negative it absorbs the reactive power.

1.2. Controller for D-Statcom in Islanded Microgrid

The objective of the proposed controller is to maintain constant voltage in an islanded microgrid. The proposed D-Statcom controller is implemented using Rotating Reference Frame to generate reference. The actual voltage of the bus is measured and it is converted into phase using phase sequence analyzer. Based on the reference voltage and actual measured voltage, voltage error is generated using PI Controller which forms q-axis component. The d-axis components is generated by decoupling three phase compensating current (I_{ac},I_{bc} and I_{cc}) into orthogonal frame using abc/dq transformation block. The dq current component is given to the current controller and it generates required control signal (Pulse signal) for PWM block. The PWM switches the D-Statcom inverter to maintain the constant voltage in an islanded microgrid, either by absorbing or injecting the required reactive power.

The main purpose D-Statcom is to compensate for reactive power but studies shows that there is a considerable real power loss in the distribution system and this might cause variation in DC-side capacitor. Therefore it is very much essential to maintain constant voltage on the dc side and this is can be achieved using the PI Controller. The dc side PI controller regulates (voltage deviation) the DC side voltage in order to maintain V_{dc} at $V_{dc\text{-}ref}$.

$$\text{Real power given by D-Statcom, } P_{DS} = \frac{V_G V_{DS}}{X_{DS}} \sin\delta \quad (5)$$

1.3. Simulation system

The test microgrid consists of two photovoltaic (PV) systems on the low voltage distribution system along with the connected load. The reason behind considering only PV system is to make use of poor dynamic response PV system to highlight the severity of the system as well as to show the effectiveness proposed D-Statcom controller for the Islanded microgrid. The other reason for the use of PV system is to ensure only renewable energy sources because for remote electrification (Village or Mountainous place) PV system is most suited as compared to wind Turbines (Due to Factors like Wind velocity, Tower Height, Complexity of Installation). The microgrid is connected to the main grid through the circuit breaker, and the breaker isolates the microgrid after 2 Seconds creating an island, with only PV system to support the islanded microgrid. The D-Statcom is connected to the point of common coupling.

1.4 Power flow in the system

In an Islanded microgrid, the main grid is not available to supply the both Real and Reactive Power (PQ) to the microgrid. Therefore, an Islanded microgrid without D-Statcom, depends only on PV, and it can provide reactive power support. The proposed D-Statcom Controller supplies the Reactive power based on the load condition as well as Real power (DC-Stabilization) and therefore improves Power Quality of the Islanded microgrid.D-Statcom is designed based on the rating of the PVs and load inside the microgrid and to completely support the microgrid during Islanding. The system under study is simulated with and without D-Statcom controller. The test microgrid is modelled in MATLAB Simulink and it is simulated for the following condition (i) Islanding without D-Statcom (ii) Islanding with D-Statcom and fault. The results are obtained as follow:

(i) Islanding without D-Statcom

The microgrid is connected to the main grid till 2 seconds and then disconnected from the main grid at 2 seconds. Due to poor dynamic response of PV system as well as lack of storage energy system, the islanded microgrid is under severe voltage stress and system voltage drops rapidly.Fig. 1 shows the result.

(ii) Islanding with D-Statcom

Micro gird gets islanded at the moment of 2 Seconds due to lack of dominant source the voltage drops considerably but the D-Statcom is connected at 3rd Second and this improves the voltage profile of the microgrid. Thus improves the power quality of the system. Fig. 2 shows the result.

2. Conclusion

The simulation results shows that proposed control scheme provides required voltage stability in an islanded microgrid and thereby improves power quality at the consumer terminal. Different test conditions have been identified and simulated under islanded microgrid to analyse the effectiveness of D-statcom. The simulation clearly shows that proposed D-statcom can provide required voltage stability for an islanded microgrid. The work can be further extended by modifying the algorithm for tuning the PI controller.

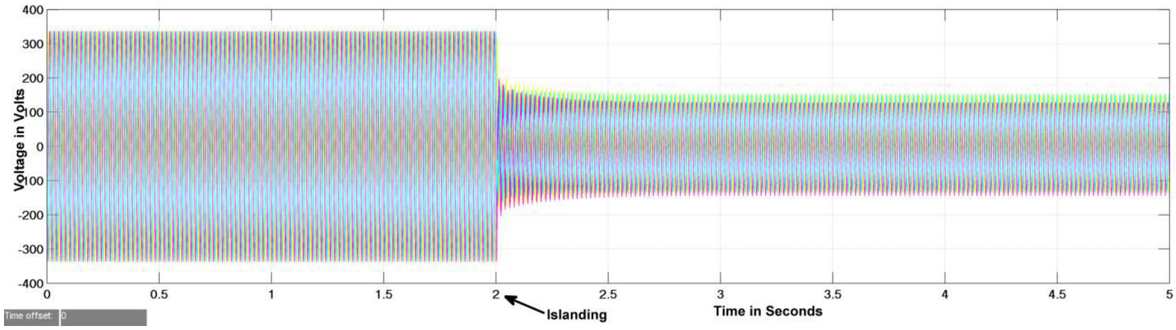

Fig. 1. Grid voltage with Islanding without D-Statcom

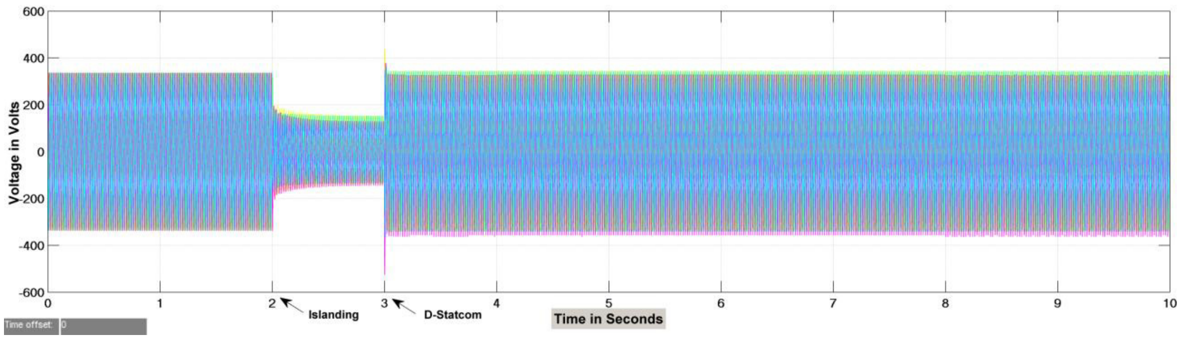

Fig. 2 Islanded Grid Voltage with D-Statcom

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