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Original Article

Power Quality Analysis of Micro-Grid (MG) Based on DVR

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Abstract *— In this paper we investigate the performance analysis of Dynamic Voltage Restorer (DVR) in Microgrid for voltage stability. Based on VSC principle, DVR injects/consume Voltage in series through injection transformer to correct voltage abnormalities including voltage sag and swell in a Microgrid System. The modelling and simulation of DVR in MATLAB/Simulink is based on different loading/disturbance conditions. The controller to be used in DVR used in Microgrid system is based on phase locked loop (PLL) techniques to trigger Inverter using Pulse width modulation (PWM) in which only voltage measurement is required to operate when error signal generated. This paper used to analyze performance of DVR to compare their performance results of Microgrid system to mitigate voltage sag and voltage swell as power quality issues.*

Keywords *— DVR, Microgrid, Voltage sag, Voltage stability, Voltage swell.*

I. INTRODUCTION

The quality of electricity supplied using Microgrid system is the delivery of electronic services to the consumer requires reliability. The issue of electrical status is an event that occurs when nonstandard level of current, frequency and voltage causes failure of equipment. Power distribution systems like DVR to be used in Microgrid system provides an uninterrupted power supply in smoothly and precisely voltage level [1], but in actual there are nonlinear loads in Microgrid distribution system which supply distorted wave, a momentary breakdown, is the result of a voltage drop due to sensitive electrical equipment, resulting in a frequency deviation due to disconnected power flow, damaged waveform, unexpected Microgrid system interruption and failure of equipment. Sometimes events can cause general including motor starting, capacitor switching and abnormal (eg. electrical faults) in electrical system problems [5]. During heavy load condition, a significant voltage drop usually occurs in the system which lasts less than a minute in which the per unit voltage drop is between 0.1 and 0.9 p.u which is treated as a dip in voltage which is considered as barrier when voltage is greater than 0.1 p.u or considered as voltage sag when voltage falls between 10-90 percent of nominal voltage. The dimensions of dip and the half cycle take up to an hour [2]. Using DVR in the power system, the quality of power of Microgrid system can be improved, so as to ensure pre-determined quality and supply reliability to the sensitive devices. This pre-specific criterion may consist of the following specifications: Low phase imbalance, no power interruption, fluctuation acceptance, and poor power factor without impact on the terminal voltage. Load voltage at low fluctuating range and duration of voltage and within fixed range of voltage. [6]

II. DYNAMIC VOLTAGE RESTORER

It is a series device used to minimize voltage sag by injecting voltage into the load by adjusting voltage in the system. Voltage imbalance and voltage adaptation present at point of normal coupling [10, 11, 12]. Dynamic Voltage Restorer is based on pulse width modulation (PWM) voltage source inverter, in which voltage is produces or absorbs, as per need, real or actual reactive power.

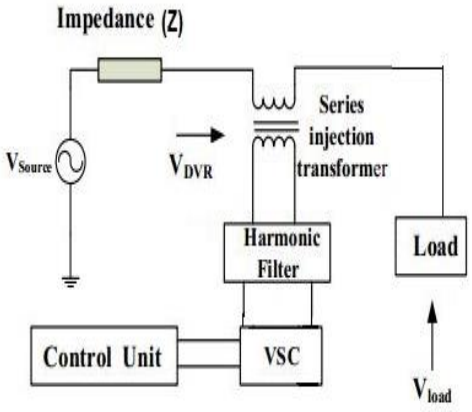


Fig. 1 Schematic diagram of DVR

DVR is usually installed in a High Tension (HT) distributed system between the supply grid and critical load in the feeder [4]. This is the system which compensate the voltage by inserting in the series in case of voltage sag to avoid power loss. Due to inductive and capacitive loads, voltage sag/swell created and the affected voltage is injected by DVR to restore and maintain the normal value of the voltage in the system. The DVR has main function to increase voltage at the load point in the event of any miss appropriate variations in the voltage to maintain electrical equipment and system [3, 7].

III. THE BASIC COMPONENTS OF DVR

DVR has capability to alter unbalanced voltage in the system. It can be used for medium voltage level [13, 14] as well as for low voltage level [15]. The components of DVR are discussed here. Fig. 1 shows circuit sequence of DVR. The Dynamic voltage Restorer mainly consists of following:

A. Series Voltage Injection/Booster Transformer

It is a series injection / booster transformer limits down the noises and transients surging transformation of transformer voltage from primary to secondary side [23]. Typically the distribution system is connected to the high voltage side of the series injection transformer and that of low voltage side of DVR is connected to the power circuit side. The DVR connects to the distribution system through High Voltage winding and injects the voltage used for compensation using VSC to the system at desired level and isolates system which injects voltage i.e., VSC and control mechanism. The transformer winding ratio usually kept same i.e,. 1:1. the higher winding ratio increases voltage which adversely affects the devices connected through VSI. [24].

B. Voltage Source Inverter (VSI)

It is an electronic system having storage devices from supply of energy and switching devices through which triggering system initiated. It generates sinusoidal voltage at desired frequencies, phase angle and magnitude. Inverter in VSI converts DC voltage into AC voltage [29]. The dip in voltage is compensated by using required magnitude to compensate dip. [26]

C. Passive Filters

The passive filters are used to eliminate unwanted voltages to create a sinusoidal voltage. The wave is created by using PWM and passive filters treats to block harmonic components using VSS action. [25].

D. DC Charging Circuit

It is a circuit consists of switching components used to charge the storage source and maintain DC-Link voltage. There are various techniques used to charge DC-link by connecting rectifiers. The controlled or uncontrolled rectifier used to connect DC side of DVR from external source.

E. Control and Protection

A hardware and programmable logic is used for controlling. There are various types of algorithms but we use Phase-locked-Loop (PLL). The maximum dynamic-performance of DVR and fast response can be achieved by using direct feed type control architecture (approximately 1 ms). [27,28].

IV. DVR OPERATING PRINCIPLES

The very basic function of Dynamic Voltage Restorer (DVR) is to control changes in voltage which it injects through a series transformer by forced commuted inverters connected in series with the voltage bus bar. A sudden dip or any changes in voltage is provided by DVR to eliminate the required voltage to the load.

There are three operation modes of DVR. Which are Protection mode, Standby mode and injection mode.

A. DVR in Protection Mode

In case of any fault, the current exceeds limits, the isolator switches are used to isolate/disconnect DVR and at the same time by pass the current from a different path.

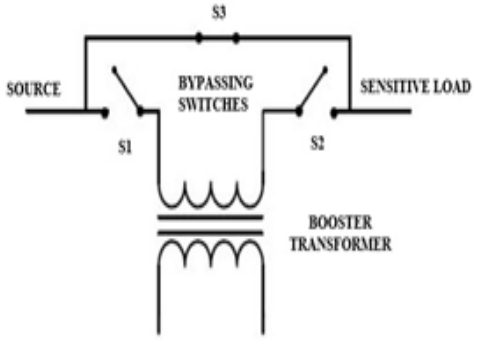


Fig. 2 Protection mode

B. Standby Mode: (V_{DVR}= 0)

In this mode the DVR remains on standby. No voltage is supplied by booster transformer by short circuiting low voltage winding of booster transformer. Hence the current only passes through primary.

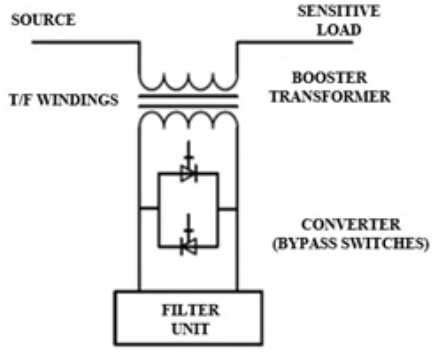


Fig. 3 Stand by mode

C. Injection/Boost Mode: ($V_{DVR}>0$)

In this mood, there becomes need of voltage to compensate the voltage. The compensation voltage is provided by booster transformer.

V. COMPENSATION TECHNIQUES IN DVR

The following compensation technologies are used using DVR.

A. Pre-sag compensation technique

In pre Sag compensation technique, the Magnitude of changes in voltage and Phase angle both are considered. DVR detects sag voltage and compares it with pre sag voltage. If found any difference the booster transformer injects voltages to restore both magnitude and phase angle.

B. In- Phase Compensation technique

In In-Phase compensation technique, the injected voltage is in phase with source voltage [31]. When the source voltage found abnormal, the voltage is injected produced by Voltage Source Inverter (VSI) to compensate magnitude of voltage. [18, 32].

C. Phase Advanced or Minimum Energy Compensation

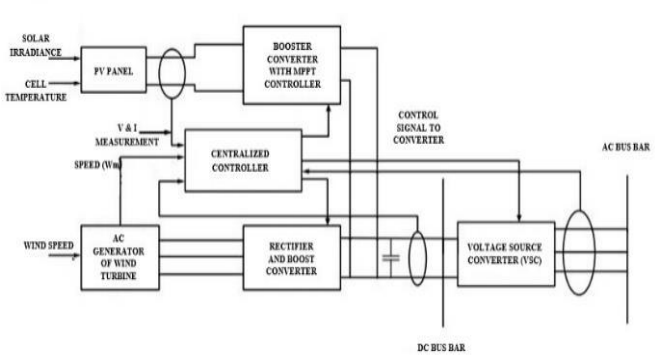
In this technique the real power P_{DVR} to be supplied by DVR is depends upon phase angle alpha. During a sag the angle changes some steps. The compensation voltage is injected according to phase angle altered from pre-sag voltage [5].

VI. MICROGRID WITH ITS STRUCTURE

A microgrid considered as combination of number of generators and static sources. It includes a wind generator, a Photovoltaic source and a static source. The load (resistive, inductive and capacitive) is supplied by AC bus considered from combined devices which acts as an AC source.

The modelling of Microgrid is as it consists of a wind generator, a PV generator and two Distributed Energy Resources (DERs) with energy storage device.

Fig. 4 Microgrid Block Diagram



VII. SIMULATIONS AND RESULTS

The MATLAB software used for graphical representation and result using Simulink. The major focus considered on voltage sag in this simulation. In the system, the DVR is connected through series transformer which has capability to compensate up to 50% voltage that of phase to ground. For removing high frequency components, series-filter is used which block higher frequency components. The compensating role of Dynamic Voltage Restorer (DVR) will be analyzed during various conditions. The conditions including voltage sag and voltage swell. The aim of analyzation of control scheme is to maintain the voltage during various condition of disturbances to be given to DVR. The compensation scheme is created in order to achieve results to mitigate voltage sag and swell.

The DVR produce required sag voltage components for three phases to compensate nominal voltage (415 V) using In-Phase compensation.

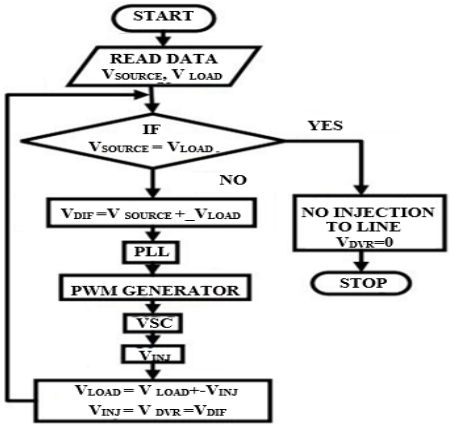


Fig. 5 Flow of DVR in microgrid

The parameters used in MATLAB simulation are:

The Micro-Grid is developed by using a Photovoltaic generator, a wing generator and 2 DERS along with storage device to deliver an output voltage of 415 Vrms phase to ground voltage- 345 V which is common at AC bus in MATLAB Simulink. The PWM Generator with Double 3-arm bridge (12 pulses). DC Capacitor 90 V, 1800 W resistive, W, 900 kVAR inductive and 90 W for Load 1,2 and 3 respectively with 1500 kVAR Capacitive.

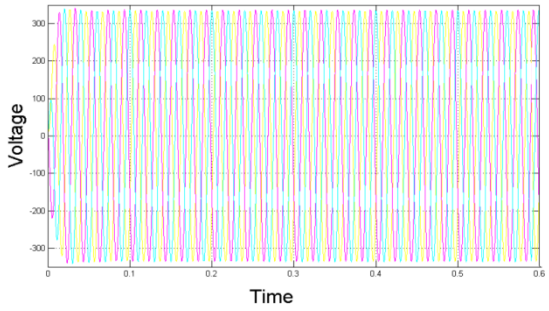


Fig. 6 MG reference voltage

The Fig. 6 shows reference voltage in microgrid. The load (inductive) is applied which caused voltage sag shown in Fig. 7. The voltage sag mitigated by DVR shown in Fig. 8 and 9.

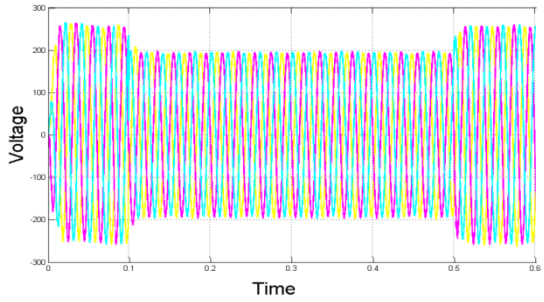


Fig. 7 MG sag voltage.

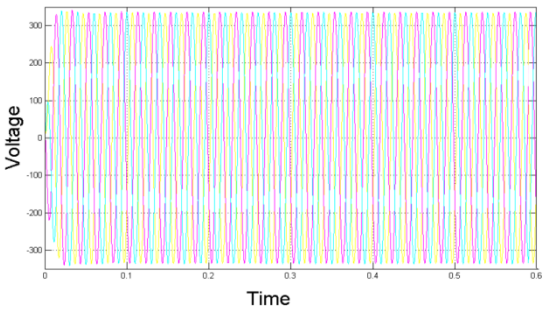


Fig. 8 MG Load voltage after compensation.

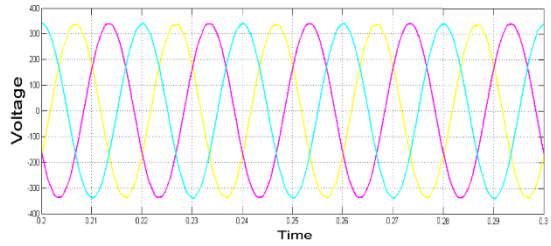


Fig. 9 MG inductive Load voltage after compensation.

Similarly the load (capacitive) is applied which caused voltage swell shown in Fig.10. The voltage sag mitigated by DVR shown in Fig. 11 and 12.

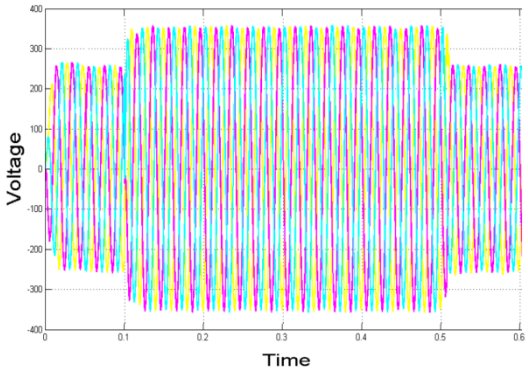


Fig. 10 MG voltage swell

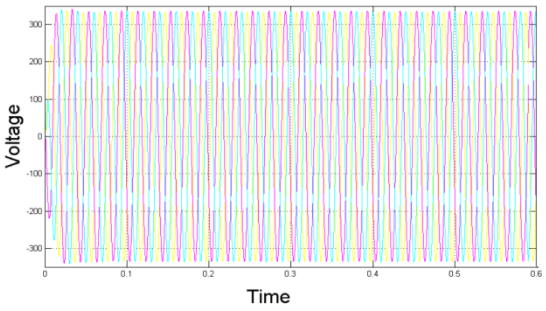


Fig. 11 MG Load voltage after compensation.

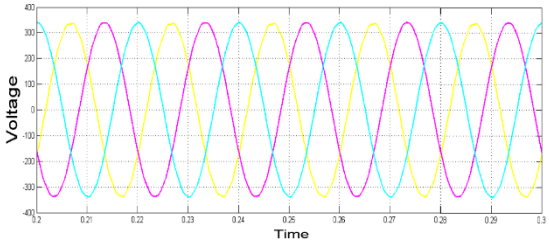


Fig. 12 MG capacitive Load voltage after compensation.

Hence DVR is effective in microgrid to mitigate voltage sag and swell.

VIII. CONCLUSION

This research paper the micridgrid system, including PV cell and wind generator, using DVR has been modeled and simulated to analyze performance of DVR in microgrid. The voltage sag and swell mitigated by DVR using PLL technique and its performance got satisfactory. The characteristics using DVR are voltage sag, and voltage swell are mitigated by the mean of using storage devices and inverters using VSI technique. Hence it's recommended that a DVR may use to mitigate voltage imbalances for sensitive load devices.

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