Volume-03
Issue-10
October -2018

ISSN: 2455-3085 (Online)
RESEARCH REVIEW International Journal of Multidisciplinary
www.rrjournals.com [UGC Listed Journal]

A Study on Compensation Strategies for Dynamic Voltage Restorer

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ARTICLE DETAILS

Article History
Published Online: 10 October 2018

Keywords
dynamic, voltage, restorer, compensation, inverter

ABSTRACT

In this paper we have focused on compensation strategies for dynamic voltage restorer using Z-source inverter. The application of Z-source inverter is proposed in this postulation, so as to optimize DVR operation. The compensation capacity of a dynamic voltage restorer essentially relies upon the maximum voltage injection capacity and the measure of put away energy accessible inside the restorer. Z source inverter is acquainted with upgrade the voltage compensation ability of DVR and to guarantee the constant dc link voltage.

1. Introduction

Among the voltage transients (sags, swells, harmonics…), the voltage sags and swells are the most extreme disturbance. So as to beat these problems, power electronic converter based custom power devices are presented as of late. One of these devices, the dynamic voltage restorer is the most effective and affordable device to shield touchy loads from voltage sags and swells. DVR is a series connected device situated between touchy load and grid in system. It identifies both voltage sag/swell problems and infuses controlled voltage to system. Also, it very well may be utilized for harmonics compensation and transient reduction in voltage and fault current limitations in accessible literature. To play out these cycles, DVR infuses a controlled voltage in series with the supply voltage in phase by means of infusion transformer to reestablish the power quality. The fundamental structure of a conventional DVR is appeared in Figure 1

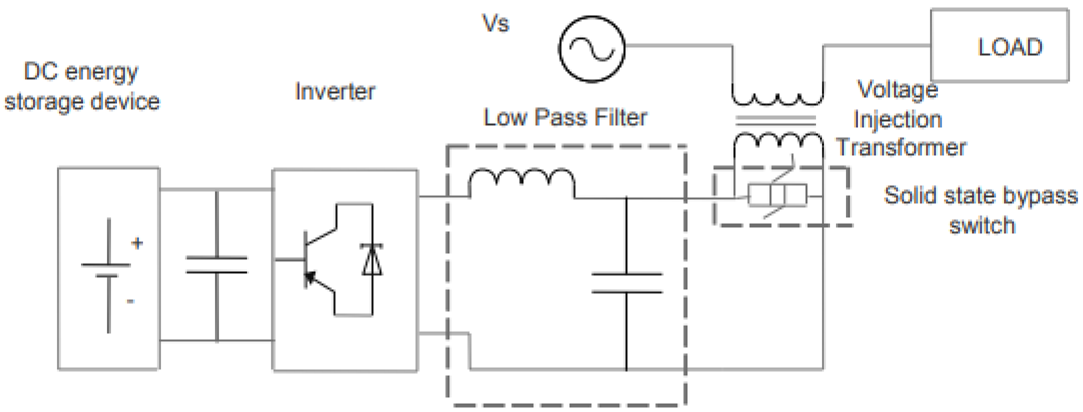

Figure 1 Basic structure of a conventional DVR

It very well may be partitioned into four classes: inverter, DC-link capacitor, and filter and infusion transformer. An inverter system is utilized to change over dc storage into air conditioning structure. Aloof filter is liable for taking out the undesirable harmonic components produced in inverter. Thusly, it changes over inverter PWM output to sinusoidal waveform. Another component, energy storage unit, for example, batteries, super capacitors, SMES and so forth is utilized to give energy requirement in DC structure. Ultimately, transformer infuses controlled voltage and gives separation among load and the system.. The fundamental capacity of DVR is to compensate the voltage sag/swell by transfer the voltage from DC side of the inverter to the infused transformer after the filter. The compensation limit of a specific DVR relies upon the maximum voltage infusion ability and the active power that can be provided by the DVR. At the point when DVR's voltage disturbances happen active power or energy ought to be infused from DVR to the distribution system. A DC system which is connected to the inverter input contains a huge capacitor for storage. It gives reactive power to the load during faulty conditions. At the point when the energy is drawn from the energy storage capacitors, the capacitor terminal voltage diminishes. In this manner, there is a minimum voltage required underneath which the inverter of the DVR can't create the require voltage accordingly, size and rating of capacitor is significant DVR power circuit. The DC capacitor value for a three phase system can be inferred. The most significant advantage of these capacitors is the ability to supply high current pulses consistently for countless cycles.

2. DVR operation modes

The fundamental capacity of DVR is estimating the missing voltage by utilizing control unit and infusing the dynamically controlled voltage (V_{dvr}) produced by a voltage source inverter in series to the bus voltage by methods for injection transformer. During sag/swell the momentary plentifulness of the infused voltage are controlled, for example, to take out any impeding impacts of a bus fault to the load voltage (VL). This implies any differential voltages brought about by disturbances will be compensated by a comparable produced voltage by the converter and infused on the medium voltage level through the injection transformer. The DVR has three modes of operation which are: security mode, standby mode, injection/boost mode.

Protection Mode

The DVR will be confined from the system if the over current on the load side surpasses a foreordained limit because of short circuit on the load or enormous inrush current the disconnection is shielding the DVR from the over current in the load side because of short circuit on the load or huge inrush currents. The control system recognizes faults or abnormal conditions and oversees sidestep (transfer) switches to eliminate the DVR from system in this manner preventing it from harms

Standby Mode (V_{dvr}= 0)

In the standby mode (normal consistent state conditions) either the booster transformer's low voltage winding is shorted through the converter or DVR infuse little voltage to compensate the voltage drop on the transformer reactance or losses. For the most part in consistent state the Short circuit operation is favored in light of the fact that the little voltage drops don't upset the load requirements. The short circuit operation is performed by strong state by pass switches and they are put between the inverter and auxiliary of series injection transformer

Injection Mode (V_{dvr}>0)

In the Injection/Boost mode the primary function of DVR is injecting a compensating voltage through the booster transformer due to the detection of a disturbance in the supply voltage on distribution system. To achieve this compensation, three single-phase ac voltages are injected in series with required magnitude, phase

3. Location of DVR

The DVR can be located either in medium voltage level or low voltage level i.e. close to a customer. The Figure 2shows the simplified model of the DVR and it can help to evaluate the best location of a DVR.

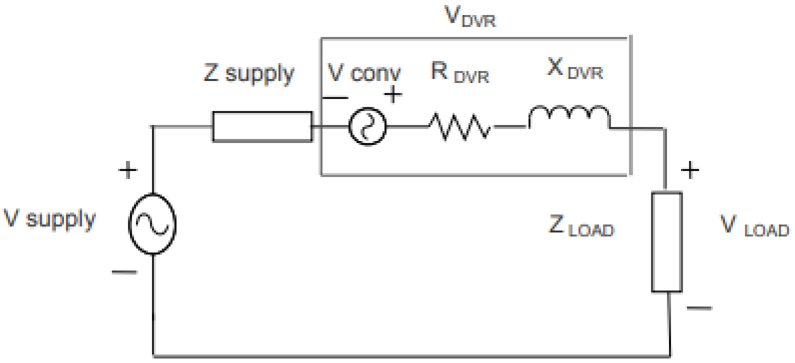

Figure 2 Single-phase simplified model of the DVR

The DVR is represented as an ideal voltage source (V_{conv}) with a series reactive element (X DVR) and resistive element (R_{DVR}) .The reactive element represents the reactive element of the injection transformer and line filters. The Resistive element represents the losses in the DVR. The size of the impedance is related to the DVR voltage rating ($V_{DV\,R}$) and the DVR power rating ($S_{DV\,R}$) according to:

$$X_{DVR} = \frac{V^2{}_{DVR}}{S_{DVR}} . X_{DVR.pu} \quad (1)$$

$$R_{DVR} = \frac{V_{DVR}^2}{S_{DVR}} . R_{DVR.pu} \quad (2)$$

$$Z_{DVR} = \frac{V_{DVR}^2}{S_{DVR}} . Z_{DVR.p.u} \quad (3)$$

$$Z_{DVRpu} = R_{DVRP.U} + jX_{DVRPU} \quad (4)$$

A DVR has a large equivalent DVR impedance ($Z_{DV\,R}$).When going from a LV-level DVR to a higher voltage level DVR the pu value of the reactance ($X_{DV\,R,p.u}$) tends to increase, and the pu value resistance ($R_{DV\,R,p.u}$) tends to decrease. Hence a high resistive part increases the energy, which should be dissipated from the DVR and the costs associated with the losses. So high total inserted DVR impedance increases the potential load voltage distortion and load voltage fluctuations if the load is non-linear and/or has a fluctuating load behavior.

4. Voltage injection methods of DVR

The primary capacity of the DVR is to keep up constant load voltage with minimum energy dissipation. The control strategy of the DVR relies on the qualities of load since certain loads are extremely touchy towards phase heavenly attendant hop and some are delicate towards change in magnitude and others are open minded to these. So as to give the solid DVR operation and excellent voltage regulation, the control strategy of DVR ought to fulfill the accompanying rules:

- Reliable and fast response for transient states as well as steady states
- Compensation of different types of sags at deep variation and different load connection
- Robustness for non-linear load conditions, sudden load changes and system parameter variations

There are four different methods for the injection of missing voltage of DVR which are

- Pre-sag compensation method
- In-phase compensation method
- In-phase advanced compensation method
- Voltage tolerance method with minimum energy injection

5. Control Algorithm

There are some techniques mentioned below for detection of voltage sag and swell:

- Fourier Transform
- Phase Locked Loop (PLL)
- Vector control (Software Phase Locked Loop –SPLL)
- Peak value detection
- Wavelet Transform

Out of these techniques the Fourier transforms, Vector control and wavelet transform strategies give both the voltage magnitude and phase shift data. PLL strategy can give just the phase shift data while top value identification technique empowers to get the magnitude change (voltage sag) data. Thus it is conceivable to consolidate at least one techniques referenced above to acquire precise voltage sag compensation.

6. DVR Using Z Source Inverter

In numerous references, Voltage source inverter (VSI) is utilized because of the suitable output voltage with low harmonics level. The primary defect of VSI is its lessening qualities whose maximum output voltage is limited by DC link voltage. This implies the compensation capacity of DVR diminishes when the DC link voltage falls because of energy reduction in energy storage component. A DC-DC boost converter application among inverter and the energy storage component is proposed. Utilizing boost converter leads to an expansion in size, cost and integration of system. In it is proposed to apply a Z-source inverter (ZSI) rather than VSI. Z-source inverter is another converter with some exceptional advantages, introduced as of late as a replacement to conventional converters the one of a kind highlights to the Z-Source Inverter are:

- The ZSI provides the buck-boost function by one-stage conversion.
- In this technology unwanted on and off by EMI noise will not destroy the converter.
- The ZSI has the advantages of both VSI and Current Source Inverter (CSI).
- It solves the problems of the traditional converters.
- The ZSI has low or no in-rush current as compared to the VSI and CSI.
- Due to low losses efficiency of the system is improved.

As shown in Figure. 3, DVR is composed of a Z source inverter, an energy storage element, LC filter, and a transformer.

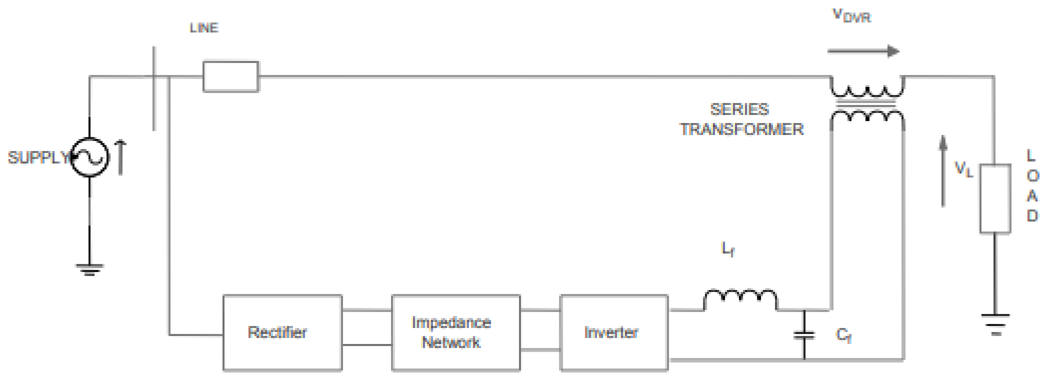

Figure 3 Z-source based structure of DVR

Mathematical Modeling of Z Source Inverter

Assume the inductors (L1 and L2) and capacitors (C1 and C2) have the same inductance and capacitance values respectively to make the Z source network symmetrical.

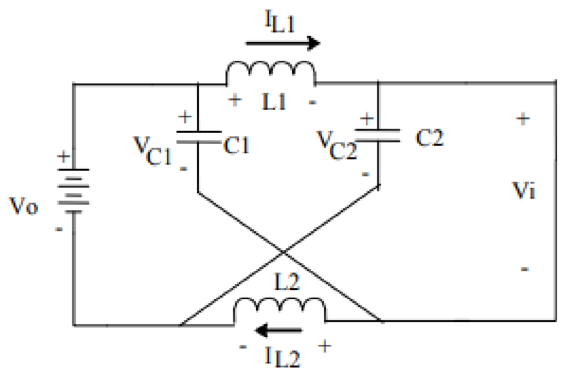

Figure 4Equivalent circuit of Z Source Inverter

$$L_1 = L_2 = L \quad (5)$$

$$C_1 = C_2 = C \quad (6)$$

$$V_{L1} = V_{L2} = V_L \quad (7)$$

$$V_{C1} = V_{C2} = V_C \quad (8)$$

Where V_L is the inductor voltage and VC is the capacitor voltage.

Consider the Z source inverter is operating in shoot through mode for an interval of T_0 during a switching cycle T. In this state both switches of any one phase leg, any two phase legs are conducting. It is inserted in every switching cycle by PWM control. This shoot through state is only a fraction of the switching cycle. Figure 5 shows the equivalent circuit of ZSI under the shoot through mode.

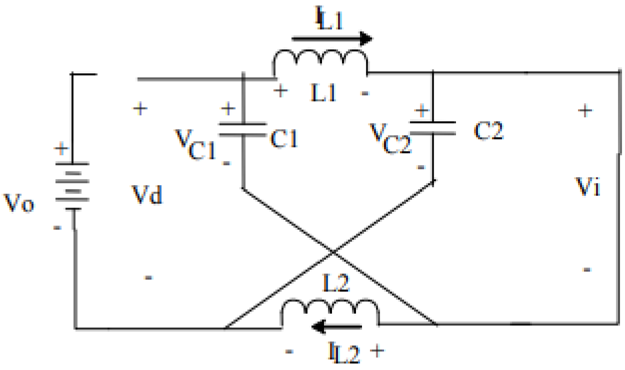

Figure 5 Equivalent circuit of ZSI in shoot through mode

In this state the circuit can be described by the following equations.

$$Vi = 0 \quad \textbf{(9)}$$

$$V_L = V_C \quad \textbf{(10)}$$

$$V_d = 2V_c \quad \textbf{(11)}$$

Where V_d is the input dc voltage and V_i is the average dc link voltage

Now consider the inverter is operating in active states for an interval of T_1 during a switching cycle T. The equivalent circuit of ZSI in this mode is as shown is Figure 6

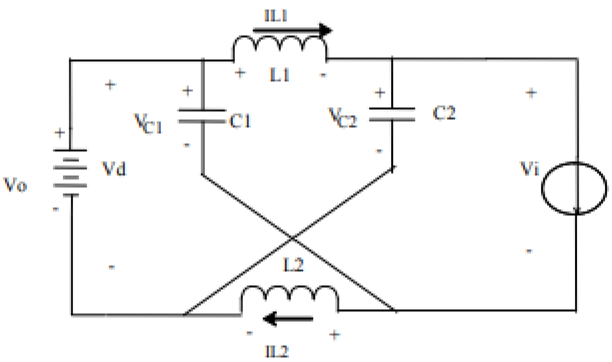

Figure 6 Equivalent circuit of ZSI in active states

The following equations can be obtained

$$V_L = V_0 - V_C \quad \textbf{(12)}$$

$$Vd = V_0 \quad \textbf{(13)}$$

And

$$V_i = V_C - V_L = 2V_C - V_0 \quad (14)$$

Where V_0 is the dc source voltage and $T= T_0+T_1$

The average voltage of the inductors over one switching period T should be zero in steady state.

$$T_0 * V_c + T_1 * (V_0 - V_C) = 0 \quad (15)$$

$$\frac{V_C}{V_0} = \frac{T_1}{T_1 - T_0} \quad (16)$$

The capacitor voltage of the Z source network can be as follows

$$V_C = \frac{T - T_0}{T - T_0 - T_0} * V_0 \quad (17)$$

$$V_c = \frac{1 - \frac{T_0}{T}}{1 - \frac{2T_0}{T}} * V_0 \quad (18)$$

The average dc link voltage across the inverter can be found as follows.

$$Vi = V_C - V_1 = 2V_C - V_0 = \frac{T}{T_1 - T_0} * V_0 = B * V_0 \quad (19)$$

Where B is a boost factor

$$B = \frac{T}{(T_1 - T_0)} \quad \text{i.e} \geq 1 \quad (20)$$

The output peak phase voltage from the inverter

$$V_{ac} = M\frac{V_i}{2} \quad (21)$$

Where M is the modulation index

In this Z source inverter

$$Vac = M.B.\frac{V_0}{2} \quad (22)$$

From the above equations it is clear that the output voltage can be stepped up and stepped down by choosing proper value of boost factor and modulation index. The boost factor B can be controlled by duty cycle of the shoot through zero state over the non-shoot through state of the PWM inverter.

7. Conclusion

Dynamic voltage restorers (DVR) are utilized to shield touchy loads from the impacts of voltage sags and voltage swells on the distribution feeder. The DVR is a cost – powerful device which is set in series with a touchy load, must have the option to react rapidly if end users of delicate equipment are to encounter voltage sags/swells. The complete literature research was done so as to clarify and design the contemplated equipment. T. The Three unique configurations of DVR have been completely researched in detail in this proposition. First, The voltage source inverter (VSI) based DVR has been designed with uncommon significance at the control of PWM inverter. The application of Z-source inverter is proposed in this postulation, so as to optimize DVR operation. The compensation capacity of a dynamic voltage restorer essentially relies upon the maximum voltage injection capacity and the measure of put away energy accessible inside the restorer. Z source inverter is acquainted with upgrade the voltage compensation ability of DVR and to guarantee the constant dc link voltage. The proposed system is recreated under voltage sag and swell. The simulation results show that Z source inverter defeats the disadvantages of voltage and current source inverter. It is additionally demonstrated from the simulation results; the impedance source inverter can be utilized in buck just as boost mode of operation.

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