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Neuro fuzzy based interline dynamic voltage restorer for multiline power system

A.Sathish Kumar[1], Dr.Birru Devender[2]
[1]Faculty, Department of EEE, Holy Mary Institute of Technology and Science, Hyderabad.
[2]Faculty, Department of CSE, Holy Mary Institute of Technology and Science, Hyderabad.

***Abstract**:*

Power quality is one of the major problems in the present era. It has gained its importance because of the introduction of the sophisticated devices, whose performance is very sensitive to quality of power supply. Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end user equipment. One of the major problem dealt here is the voltage sag of the multiline power system. The aim of this paper is to design an Interline Dynamic Voltage Restorer which is able to compensate voltage sag and voltage regulation at critical load terminals. In our project, the Interline Dynamic Voltage Restorer (IDVR) has two IDVRs are connected to a common DC Link with Adaptive Neuro-Fuzzy Inference System (ANFIS). One of the IDVRs compensates for a voltage sag, the other IDVRs connected to common DC-Link energy storage. A current mode control strategy is incorporated into the IDVR system in both the working modes, voltage sag compensation and power flow control. The reference voltage for power flow control mode is derived from instantaneous active current calculated using DC-Link voltage error signal.

Keywords

Interline Dynamic Voltage Restorer, Adaptive Neuro-Fuzzy Inference System

1. Introduction

An Interline dynamic voltage restorer (IDVR) is a power quality device capable of protecting sensitive loads against the voltage variations or disturbances. An IDVR is a forced commutated voltage source converter that injects a dynamically controlled voltage in series with the supply voltage through a booster transformer to correct the load voltage. When the injected voltage is in phase with the supply voltage, the desired voltage correction can be achieved with a minimum voltage injection but it may require a considerable amount of active power injection into the system. When the injected voltage leads the supply voltage, however the same correction can be made with a lower value of active power injection. This is possible at an expense of higher voltage injection. The IDVRs connected to different distribution feeders in the power system. The IDVRs in the system shares the common energy storage.Thus, one DVR in the IDVR system works in voltage-sag compensation mode while the other DVRs in the IDVR system operate in power-flow control mode. When the power injection by the IDVR is minimized, the same energy storage can be used for a longer period. Such an operation requires careful determination of injected voltage magnitude and angle, however the objective of this letter is to determine the magnitude and angle of the IDVR injected voltage so that a given voltage drop or sag can be corrected with minimum active power injection into the system. Analytical expressions for the injected voltage magnitude and angle, in terms of voltage drop and load power factor, are also derived.

There are many different methods to mitigate voltage sags and swells, but the use of a custom power device is considered to be the most efficient method, there are different types of Custom Power devices used in electrical network to improve power quality problems. Each of the devices has its own benefits and limitations. A few of these reasons are as follows. The SVC pre-dates the IDVR, but the IDVR is still preferred because the SVC has no ability to control active power flow. Another reason include that the IDVR has a higher energy capacity compared to the SMES and UPS devices. Furthermore, the IDVR is smaller in size and cost is less compared to the DSTATCOM and other custom power devices. Based on these reasons, it is no surprise that the IDVR is widely considered as an effective custom power device in mitigating voltage sags. In addition to voltage sags and swells compensation, IDVR can also add other features such as harmonics and power factor correction. A new approach for the dynamic control of a current source inverter (CSI) using Super Conductive Magnetic energy storage (SMES) based DVR. The drawback of reverse voltage for the power flow in

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multiline for mitigating voltage sag can be overcome by the use of SMES as a common DC link[1]. Fuzzy Logic based feedback controller which utilizes the error signal to control the triggering of the switches of an inverter using a Sinusoidal Pulse Width Modulation (SPWM) scheme[2]. A new topology based on Z-source inverter is presented in order to enhance the voltage restoration property of DVR. The derived controllers are based on a suitable stabilizing damping injection scheme[3]. Dynamic Voltage Restorer (DVR), which is the most effective modern custom power device used in power distribution networks. Its appeal includes lower cost, smaller size. It`s efficiency and the power factor value is low[4,5]. The power quality enhancement in power system using one of the most famous series converter based FACTS controller like IPFC in Power Injection Model in order to improve the real power, compensating the reactive power[6]. DVR's of different feeders is proposed. The phase advance angle of the load during fault condition is taken for generating the reference voltage. This voltage is compared with the load voltage using a fuzzy logic controller to generate pulses required for triggering the VFSCII[7]. DVR used to correct the voltage disturbances by injecting voltage as well as power into the system[8]. Dynamic current restorers are examined with particular focus on the new method accustomed to minimize the rating from the voltage source ripper tools utilized in Digital recording device[9]. SVPWM is an alternative method for the determination of switching pulse width and their position. The major advantage of SVPWM system from the fact that, there is a degree of freedom of space vector placement in a switching cycle[10]

2. Neuro Fuzzy based IDVR Controller

IDVR is a Custom Power Device used to eliminate supply side voltage disturbances. DVR also known as Static Series Compensator maintains the load voltage at a desired magnitude and phase by compensating the voltage sags/swells and voltage unbalances presented at the point of common coupling. To control a multi distribution line, for example, we consider two distribution line.

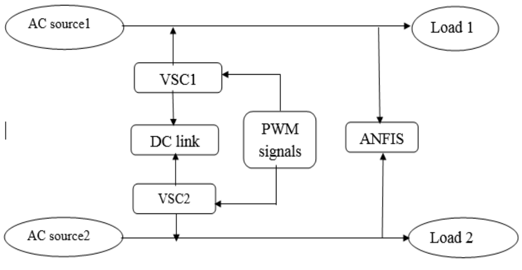

Fig 1.Block diagram of Neuro fuzzy based IDVR.

If there is any fault occur in the line the ANFIS sense the particular error in the line. The ANFIS generate the square wave pulse or triangular pulse. The ANFIS compare the signal with the PWM produce output as sinusoidal wave form. The error are not rectified in ac supply so need to convert ac to dc. Hence we use VSC to convert the source from one form to another form. Then dc link is used to link the two VSC devices and also act as a capacitor to filtering the error occur in the line. After the fault are rectified, again the VSC convert the voltage as dc to ac form. The basic function of the IDVR is to inject a dynamically controlled voltage IDVR generated by a forced commutated converter in series to the bus voltage by means of a booster transformer. The momentary amplitudes of the three injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage VL.This means that any differential voltages caused by transient Disturbances in the ac feeder will be compensated by an equivalent voltage generated by the converter and injected on the medium voltage level through the booster transformer. The IDVR works independently of the type of fault or any event that happens in the system, provided that the whole system remains connected to the supply grid, i.e. the line breaker does not trip. For most practical cases, a more economical design can be achieved by only compensating the positive and negative sequence components of the voltage disturbance seen at the input of the IDVR.

3. Compensation Methods

Compensation of voltage sags/swells is dependent upon a number of factors including DVR power rating, different load conditions and different types of voltage sags/swells. Some loads are very sensitive to phase angle jump while others are tolerant to it. Therefore, the compensation strategy depends upon the type and characteristics of the load connected to DVR. There are three different methods for DVR voltage injection which are presented below.

4. Pre-Dip Compensation

The PDC method tracks the supply voltage continuously and compensates load voltage during fault to pre-fault condition. In this method, the load voltage can be restored ideally, but the injected active power cannot be controlled and it is determined by external conditions such as the type of faults and load conditions. This method is achieved by using a fault detector to freeze the output from the Phase Locked Loop (PLL) circuit, when the fault occurs. Then, the frozen angle is used to restore the previous balanced load voltages by using the Park transform.The lack of the negative sequence detection in this method leads to the phaseoscillation in the case of single-line faults. Figure shows the single-phase vector diagram of this method. According to Figure, the apparent power of DVR is:

$S1DVR=ILV1DVR$
$=ILVL2+VS2-2VLVS \cos \theta L-\theta S$

And the active power of DVR is:
$P1DVR = (VL \cos\theta L-VS\cos\theta S)$

The magnitude and the angle of DVR voltage are:
$V1DVR = VL2+VS2-2VLVS\cos \theta L- \theta S.$

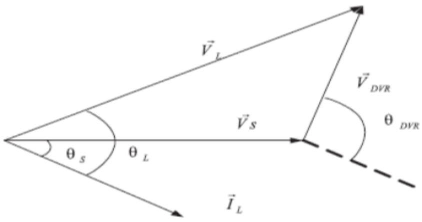

Fig 2. Single phase vector diagram PDC method

5. In Phase Advance Compensation

Pre-Dip and in-phase compensation method must inject active power to loads to correct voltage disturbance. However, the amount of possible injection active power is confined to the stored energy in DC link, which is one of the most expensive components in DVR. Due to the limit of energy storage capacity of DC link, the DVR restoration time and performance are confined in these methods. For the sake of controlling injection energy, in phase advance compensation method was proposed. The injection active power is made zero by means of having the injection voltage phasor perpendicular to the load current phasor.

This method can reduce the consumption of energy stored in DC link by injecting reactive power instead of active power. Reducing energy consumption means that ride-through ability is increased when the energy storage capacity is fixed.On the other hand, the injection voltage magnitude of in-phase advance compensation method is larger than those of pre-dip or in-phase compensation methods and the voltage phase shift can cause voltage waveform discontinuity, inaccurate zero crossing and load power swing. Therefore, in phase advance compensation method should be adjusted to the load that is tolerant to phase angle jump, or transition period should be taken while phase angle is moved from pre-fault angle to advance angle.

6. Simulation Model of IDVR

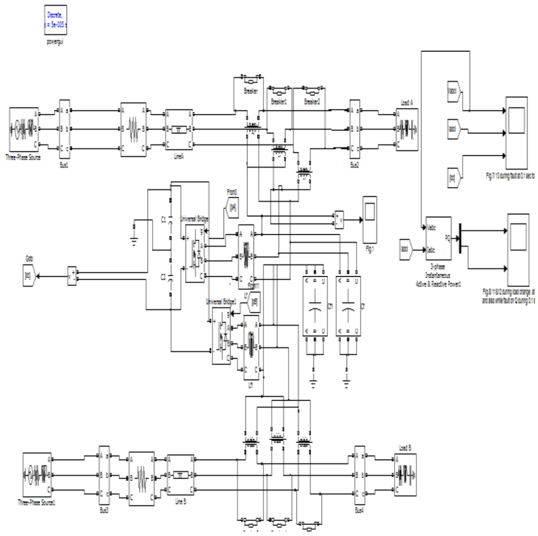

Fig.3.Simulation model of Neuro fuzzy based IDVR

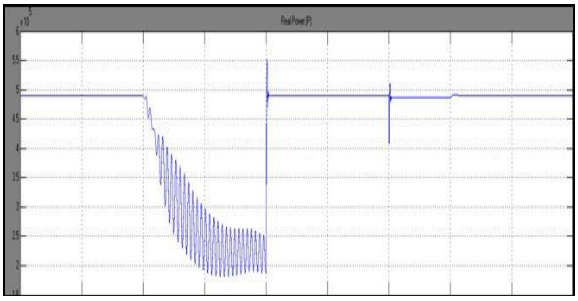

Fig.4 Simulation Output of Real Power

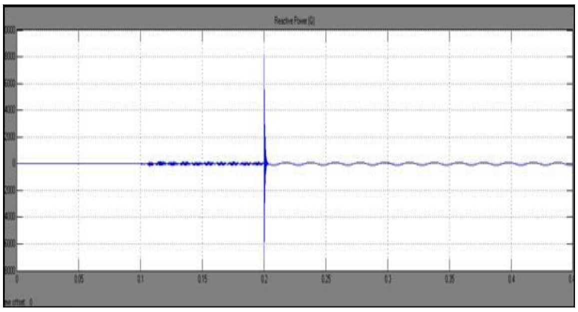

Fig.5 Simulation Output of Reactive Power

The above fig shows the output of the real and the reactive power. The X- axis of the graph gives the time and the Y-axis gives the voltage. Thus the output produced as the distortions occurs in the certain period of graph, that was eliminated by using the Neuro fuzzy based IDVR.

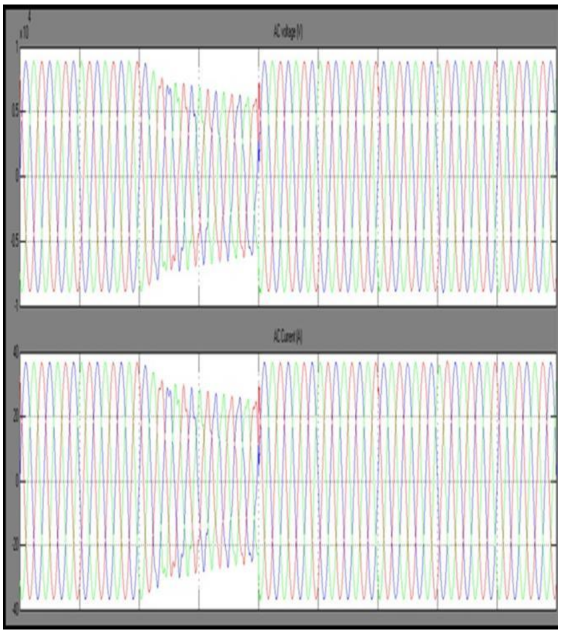

Fig 6 simulation output waveform for voltage and current.

The above fig shows the output waveform for ac voltage and the current. The X-axis of the graph gives the time and the Y-axis of the graph gives voltage and current. There is some distortions are occurred due to the non linear loads. This was eliminated by using the Neuro fuzzy based system of the IDVR.

7. Conclusion

IDVRs are effective custom power devices for voltage sags and swells mitigation; they inject the appropriate voltage component to correct rapidly any anomaly in the supply voltage to keep the load voltage balanced and constant at the nominal value. In this paper Interline dynamic voltage restorers was proposed which can minimize the dc-link energy storage connecting two or more DVRs to a common dc link. The proposed controller is generated by ANFIS training according to a given input output data. The performances of proposed IDVR system and its controller were tested with MATLAB software. It was observed that the IDVR compensates the disturbance caused by the sag effectively and improve the power quality by means of increasing the efficiency and the power factor. Then the results show that there is considerable reduction in real and reactive power loss using IDVR.

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