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Mitigation Of Voltage Sags/Swells By Dynamic Voltage Restorer Using Pi And Fuzzy Logic Controller

CH SRISAILAM[1],A SREENIVAS[2]
Asst.Professors, Department Of Electrical And Electronics Engineering
Jawaharlal Nehru Institute of Technology(JNIT),Hyderabad,Andrapradesh,India

Abstract:

Dynamic Voltage Restorer can provide the most cost effective solution to mitigate voltage sags and swells by establishing the proper voltage quality level that is required by customer. This device is connected in series with the distribution feeder at medium voltage. The PI controller is very common in the control of DVRs. However, one disadvantage of this conventional controller is the fact that by using fixed gains, the controller may not provide the required control performance, when there are variations in the system parameters. To overcome this problem the fuzzy logic controller is proposed. And the simulation results have proved that the proposed control method greatly improves the performance of the DVR compared to the conventional PI controller.

Keywords: PI, Fuzzy controller, DVR, Voltage sags, Voltage swells.

I. INTRODUCTION

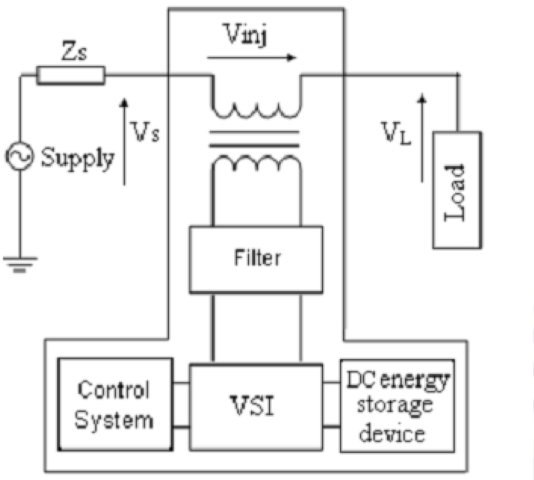
Dynamic Voltage Restorer (DVR) can provide the most cost effective solution to mitigate voltage sags and swells by establishing the proper voltage quality level that is required by customer. When a fault happens in a distribution network, sudden voltage sag will appear on adjacent loads. DVR installed on a sensitive load, restores the line voltage to its nominal value within the response time of a few milliseconds thus avoiding any power disruption to the load.

There are many different methods to mitigate voltage sags and swells, but the use of a DVR is considered to be the most cost efficient method. The most common choice for the control of the DVR is the PI Controller since it has a simple structure and It can offer relatively a satisfactory performance over a wide range of operation. The main problem of this simple controller is the correct choice of the PI gains and the fact that by using fixed gains, the controller may not provide the required control performance, when there are variations in the system parameters and operating conditions. Various control strategies have been developed to mitigate the voltage sag and swell have been proposed for three phase voltage source PWM converters. They can be divided into two main groups: linear and non-linear, linear controllers include the ramp-comparison current regulator, Synchronous PI regulator, state feedback regulator and predictive and dead-beat regulator. The hard-switched converter. And the neural network and Fuzzy Logic (FL) based regulators belong to the non-linear controllers. It appears that the non-linear controller is more suitable than the linear type since the DVR is truly a non-linear system. The DVR is a non-linear device due to the presence of power semiconductor switches in the inverter bridge.

This paper introduces Dynamic Voltage Restorer (DVR) and its operating principle, also presents the proposed controllers of PI and fuzzy controllers. Then, simulation results using MATLAB-SIMULINK provide a comparison between the proposed and the conventional PI controllers in terms of performance in voltage sag/swell compensation at the end, discussions of the results and conclusion are given.

II. DYNAMIC VOLTAGE RESTORER (DVR)

Dynamic Voltage Restorer is a series connected device that injects voltage into the system in order to regulate the load side voltage. The DVR was first installed in 1996 It is normally installed in a distribution system between the supply and the critical load feeder. Its primary function is to rapidly boost up the load-side voltage in the event of a disturbance in order to avoid any power disruption to that load there are various circuit topologies and control schemes that can be used to implement a DVR. In addition to its main task which is voltage sags and swells compensation, DVR can also added other features such as: voltage harmonics compensation, voltage transients'
Reduction and fault current limitations
The general configuration of the DVR consists of a voltage injection transformer, an output filter, an energy storage device, Voltage Source Inverter (VSI), and a Control system as shown in Figure 1.



DVR
Fig.1 Structure of DVR

Voltage Injection Transformer:

The basic function of this transformer is to connect the DVR to the distribution network via the HV-windings and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage. The design of this transformer is very crucial because, it faces saturation, overrating, overheating, cost and performance. The injected voltage may consist of fundamental, desired harmonics,
Switching harmonics and dc voltage components. If the transformer is not designed properly, the injected voltage May saturate the transformer and result in improper operation of the DVR

Output Filter:
The main task of the output filter is to keep the harmonic voltage content generated by the voltage source inverter to the permissible level (i.e. eliminate high frequency switching harmonics).It has a small rating approximately 2% of the load VA

Voltage Source Inverter:
A VSI is a power electronic system consists of a storage device and switching devices, which can generate a sinusoidal voltage at any required frequency, Magnitude, and phase angle. In the DVR application, the VSI is used to temporarily replace the supply voltage or to generate the part of the supply voltage which is missing.

DC Energy Storage Device:
The DC energy storage device provides the real power requirement of the DVR during compensation. Various storage technologies have been proposed including flywheel
Energy storage, super-conducting magnetic energy storage (SMES) and Super capacitors these have the advantage of fast response. An alternative is the use of lead-acid battery
Batteries were until now considered of limited suitability for DVR applications since it takes considerable time to remove energy from them. Finally, conventional capacitors also can be used

Control system:
The aim of the control system is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The control system of the general configuration typically consists of a voltage correction method which determines the reference voltage that should be injected by DVR and the VSI control which is in this work consists of PWM with PI or Fuzzy Logic controller. The controller input is an error signal obtained from the reference voltage and the value of the injected voltage (Fig. 2). Such error is processed by a PI or FL controller then the output is provided to the PWM signal generator that controls the DVR inverter to generate the required injected voltage.

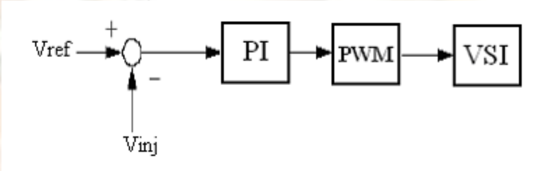


Fig. 2. PI controller

Fuzzy Controller

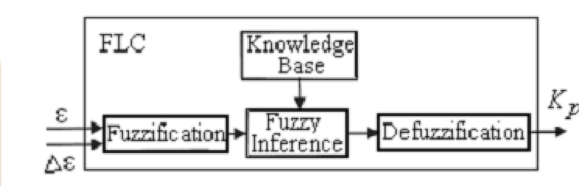


Fig. 3. Schematic of FLC

The fuzzy logic controller unlike conventional controllers does not require a mathematical model of the system process being controlled. However, an understanding of the system process and the control requirements is necessary.The fuzzy controller designer must define what information data flows into the system (control input variable), how the information data is processed (control strategy and decision) and what information data flows out of the system (Solution output variable). The fuzzy logic controller consists of three basic blocks. i) Fuzzifier ii) Inference Engine iii) Defuzzifier.

i) Fuzzifer: The fuzzy logic controller requires that each control/solution (input/output) variables which define the control surface be expressed in fuzzy set notations using linguistic labels. Seven classes of linguistic labels (Large Positive) LP,(Medium

Positive) MP, (Small Positive) SP, (Very Small) VS, (Small Negative) SN, (Medium Negative) MN, (Large Negative) LN characterized by membership grade are used to decompose each system variable into fuzzy regions. The membership grade denotes the extent to which a variable belongs to a particular class/label. This process of converting input/output variable to linguistic labels
is termed as fuzzification. It is executed using reference fuzzy sets shown in Fig. 4 and used to create a fuzzy set that semantically represents the concept associated with the label. To have a smooth, stable control surface, an overlap between adjacent labels is provided such that the sum of the vertical points of the overlap should never be greater than one. In the proposed controller, the error in power
e = (Pre-Po) and its rate of change ei are normalized, fuzzified, and expressed as
Fuzzy sets.

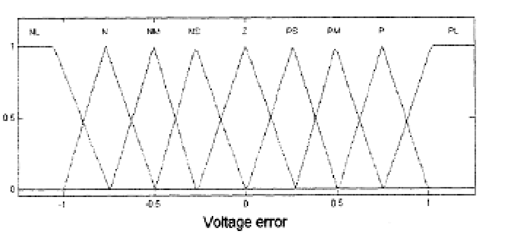


Fig.4 membership function

ii) Inference Engine: The behavior of the control surface which relates the input and output variables of the system is governed by a set of rules. A typical rule
Would be If (fuzzy proposition), then (fuzzy proposition). The set of rules for the fuzzy controller are based on MacVicar- Whelan's decision table shown in Table 1, which proposes a definite control action for a given error e and its rate of change e.
Thus, each entry in the table is a rule and there are 49 rules that form the
Knowledge repository of the fuzzy logic controller. These rules are used to decide the appropriate control action. When a set of input variables are read, each of the rule that has any degree of truth (a nonzero value of membership grade) in its premises is fired and contributes to the forming of the
Control surface by appropriately modifying it. When all the rules are fired, the resulting control surface is expressed as a fuzzy set (using linguistic labels characterized by membership grades) to represent the controller's output.
iii) Defuzzifier: The fuzzy set representing the controller output in linguistic labels has to be converted into a Crisp solution variable before it can be used to control the system. This is achieved by using a defuzzifier. Several methods of defuzzification are available. Of these, the most commonly used methods are

i) Mean of Maxima (MOM) and ii) Center of Area (COA). Most control applications use the COA method. This method computes the centre of gravity of the final fuzzy space (control surface) and produces a result which is sensitive to all the rules executed. Hence, the results tend to move smoothly across the control surface.

	Rate of change of error							
		LP	MP	SP	ZE	SN	MN	LN
Error	LN	ZE	SP	MP	MP	LP	LP	LP
	MN	SN	ZE	SP	MP	MP	MP	LP
	SN	MN	SN	ZE	SP	SP	MP	LP
	ZE	MN	MN	SN	ZE	SP	MP	MP
	SP	LN	MN	SN	SN	ZE	SP	MP
	MP	LN	MN	MN	MN	SN	ZE	SP
	LP	LN	LN	LN	MN	MN	SN	ZE

Table 1. Fuzzy control Rules

III.SIMULATION

The PerformanceImprovement of DVR in voltage sag/swell mitigation usingthe proposed controller, a simple distribution network is simulated using MATLAB/SIMULINK.The system parameters and constant value are listed in Table. It is assumed that the voltage magnitude of the load bus is maintained at 1 p.u during the voltage sags/swells condition. The results of the most important simulations are represented in Figures. The load has been assumed linear with power factor pf =0.85 lagging and its capacity of
5 KVA

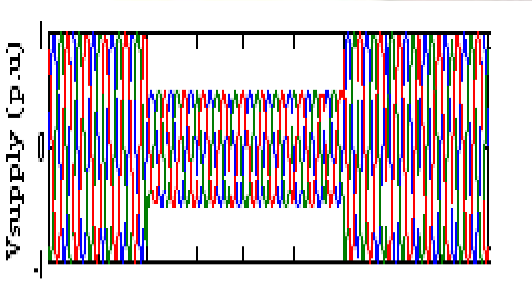
Table 2. System Parameters and Constants.

Main Supply Voltage per phase	200V
Line Impedance	Ls =0.5mH Rs = 0.1 Ω
Series transformer turns ratio	1:1
DC Bus Voltage	100V
Filter Inductance	1mH
Filter capacitance	1uF

Load resistance	40Ω
Load inductance	60mH
Line Frequency	50Hz

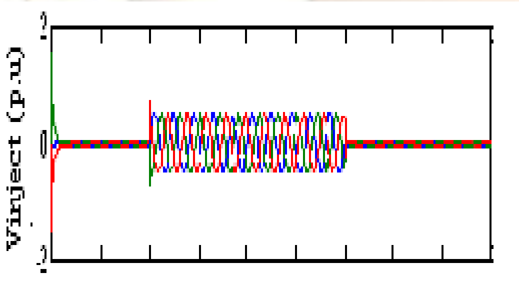
Voltage Sags:

The first simulation shows of three phase voltage sag is simulated. The simulation started with the supply voltage 50% sagging as shown in Figure 5 (a).In Figure 5 (a) also shows a 50% voltage sag initiated at 0.15s and it is kept until 0.35s, with Total voltage sag duration of 0.2s. Figures 5 (b) and (c) show the voltage injected by the DVR and the corresponding load voltage with compensation. As a result of DVR, the load voltage is kept at 1 pu.



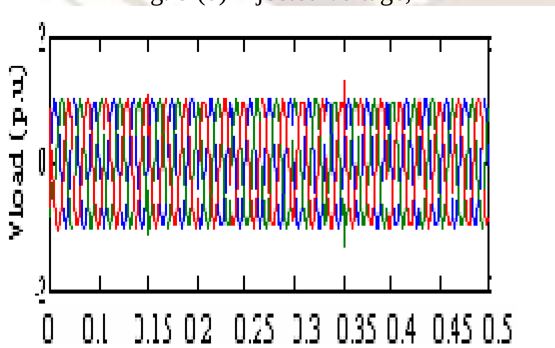
Time (sec)

Fig. 5 (a) Source voltage



Time (sec)

Fig. 5 (b) Injected voltage,



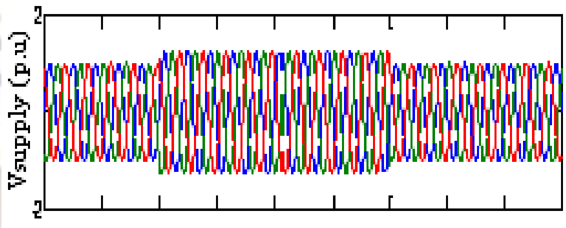
Time (sec)

Fig. 5 (c) Load voltage,

Voltage Swells:

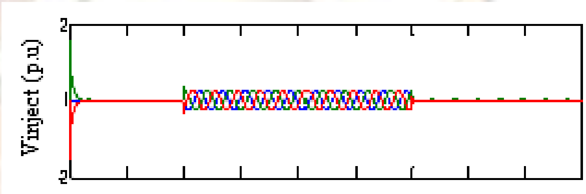
The second simulation shows the DVR Performance during a voltage swells condition. The simulation started with the supply voltage swell is generated as shown in Figure 6 (a). As observed from this figure the amplitude of supply voltage is increased about 25% from its nominal voltage. Figures 6(b) and (c) show the injected and the load voltage respectively. As can be seen

From the results, the load voltage is kept at the nominal value with the help of the DVR. Similar to the case of voltage sag, the DVR reacts quickly to inject the appropriate voltage component (negative voltage magnitude) to correct the supply voltage.



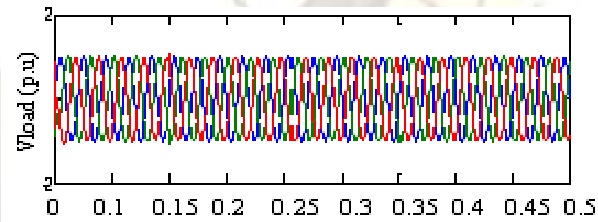
Time (sec)

Fig. 6 (a) Source voltage



Time (sec)

Fig. 6 (b) Injected voltage



Time (sec)

Fig. 6 (c) Load voltage,

IV CONCLUSION

The modeling and simulation of a DVR using MATLAB/SIMULINK has been presented in this project. A control system based on d-q-o technique which is a scaled error of the between source side of the DVR and its reference for sags/swell correction has been presented. The simulation shows that the DVR performance is satisfactory in mitigating voltage sags/swells.

Simulation results also show that the DVR compensates the sags/swells quickly and provides excellent voltage regulation. The DVR handles both balanced and unbalanced situations without any difficulties and injects 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 project the two controlling techniques i.e. for PI controller and FL controller are presented from the results it is concluded that compared to PI, FL controller is giving better performance. The THD with PI is 2.05% is reduced to 0.44% by using FL controller.

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