Abhishek Kumar Singh, et. al. International Journal of Engineering Research and Applications
www.ijera.com
ISSN: 2248-9622, Vol. 10, Issue 8, (Series-I) August 2020, pp. 29-32

RESEARCH ARTICLE OPEN ACCESS

Modelling and control of dynamic voltage restorer to protect sensitive load under non linear loading conditions

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ABSTRACT:
Dynamic voltage restorer (DVR) is used for the protection of sensitive loads from the voltage disturbance like, voltage sag/voltage swell. In this paper, Dqo based PI controller has been used for the detection of voltage sag as well as for yhe generation of compensatingvoltages for controlling DVR. The proposed algorithm works well with any types of loads connected whether linear or non linear. To simulate the actual scenario a double circuit distribution line modelling is being done in matlab and fault is being created in one line to produce voltage sag in the other line.A three phase reference voltage is being generated and the load voltages and the reference voltages are being compared by converting both voltages into Dqo frame using Dqo transformation. The Dqo error is again converted into abc frame to obtain the compensating voltage.The compensating voltage is give to the pi controller which controls the power circuit to inject a voltage in phase with the source voltage to maintain the voltage profileof the load to be purely sinusoidal.Whole of the simulation model is simulated in MATLAB simulation power system. The fourier analysis of the load voltage is performed for harmonic analysis. The result obtained proves the effectiveness of the proposed algorithm.
Keywords: dynamic voltage restorer, PI controller, Dqo transformation, voltage sag, balanced and unbalanced fault,total harmonic distortion.

Date of Submission: 21-07-2020 Date of Acceptance: 06-08-2020

I. INTRODUCTION:

Power quality is defined in the IEEE 100 AuthoritativeDictionary of IEEE Standard Terms as "The concept ofpowering and grounding electronic equipment in a mannerthat is suitable to the operation of that equipment andcompatible with the premise wiring system and otherconnected equipment Utilities may want to define powerquality as reliability" (IEEE 100, 2000). Voltage sag (dip) isthe power quality problem that is defined by IEEE Std. 1159(1995) as a decrease in rmsvoltage between 0.1 to 0.9 ofnominal voltage at power frequency for duration of 0.5 cycle to 1 minute.Voltage swell is also a power quality problem that isdefined by IEEE Std. 1159 (1995) as an increase in rmsvoltage or current at the power frequency for durations from0.5 cycles to 1 minute. Typical magnitudes are between 1.1and 1.8 pu (IEEE Std. 1159, 1995). Custom power devices are used to eliminate the power quality problems. The fact devices in the distribution system for improving the power quality are termed as the custom power devices. There are basically three types of custom power devices, the first is the shunt connected custom power device which is used to do the current compensation for example distribution static compensator (DSTATCOM), second is the series connected custom power devices for doing the voltage compensation for example dynamic voltage restorer (DVR), the is the hybrid custom power device for doing voltage as well as the current compensation for example unified power quality conditioner (UPQC). Proper installation of the custom power devices are required as per the power quality problem as well astaking economic considerations.This paper discuss the capability of DVR as well as itsmodelling to prove its effectibility is done.

DVR is the cost effective solution of the voltage quality problems. DVR is placed near a voltage sensitive loads to cope up with the voltage disturbances like voltage sag and swell. In this paper a Dqo based PI controller is modelled which have the capability to protect the sensitive loads even if non linear loads are connected. All the types of fault is being simulated causing voltage sag in various phase. The sag is balanced in a three phase fault and it is unbalanced in an unbalanced fault (LG, LL, LLG). The variation of Dqo values of the load voltage under various faults is illustrated

DVR structure

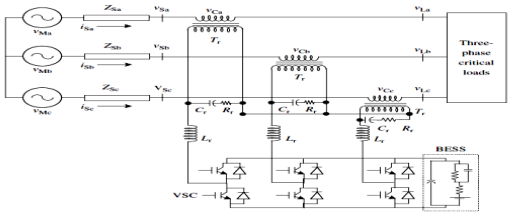

Fig: 1 structure of a battery supported DVR

The structure of a typical battery supported DVR is as shown in figure 1. Vma, Vmb and Vmv are the three phase voltages of the source. Zsa, Zsb and Zsc are the three line impedance Vsa ,Vsb and Vsc are the bus voltage before the section where DVR is connected. Vla, Vlb and Vlc are the three load voltage whose voltage quality has to be improved, Vca ,Vcb and Vcc are the compensation voltage that should be injected . Lr, Cr and Rr comprise the filter unit to smooth the injected voltage waveform.

Circuit under simulation

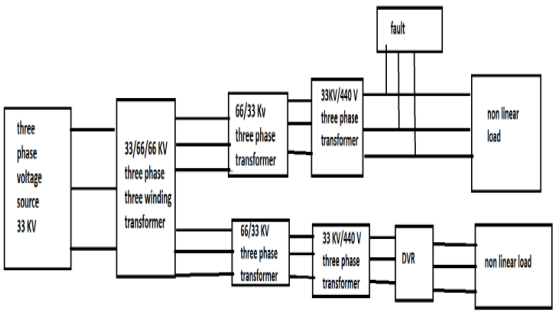

Fig 2 block diagram of circuit under simulation

The block diagram of circuit under simulation is shown in figure 2. As is seen it consists of a double circuit line. In one line fault is simulated and in other line DVR is connected. Fault in one line causes the voltage sag in the other line. The DVR is connected in other line to eliminate voltage sag in that line.

Control Algorithm

The control algorithm of the proposed work can be explained using figure 3. As seen from the figure the reference voltage and the load voltage is converted into Dqo frame. The Dqo value of reference voltage and load voltage are compared and the difference between them gives the Dqo value of the error voltage, then the P-I controller which adjust the error signal so as to minimize the error. Then the signal is again converted into phase voltage form using Dqo to abc transform. Output from that block gives the reference signal for the PWM inverter. This reference signal is compared with the carrier signal and gate pulse is being generated so as to produce the voltage equal to the reference voltage input of the inverter.

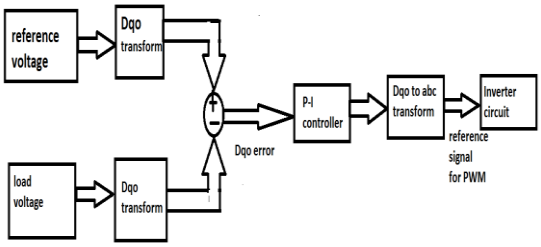

Fig 3 proposed control algorithm

Simulation diagram

The MATLAB simulation diagram representing the block diagram of figure 2 is shown in figure 4. It is seen that at the end of the both line a non linear load with different rating and power factor is connected. In the intermediate line various transformers and line impedances are connected to simulate the actual scenario of the power system. The DVR circuit is shown in figure 5. The control circuit is shown in figure 6

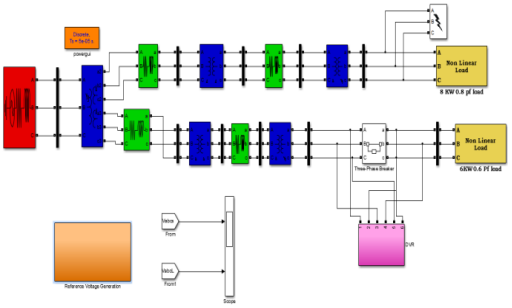

Fig 4 simulation diagram

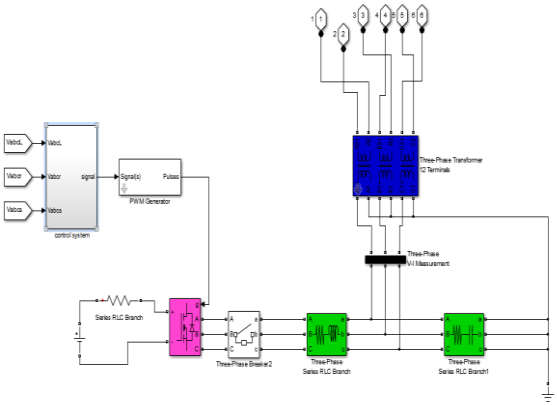

Fig 5 DVR circuit

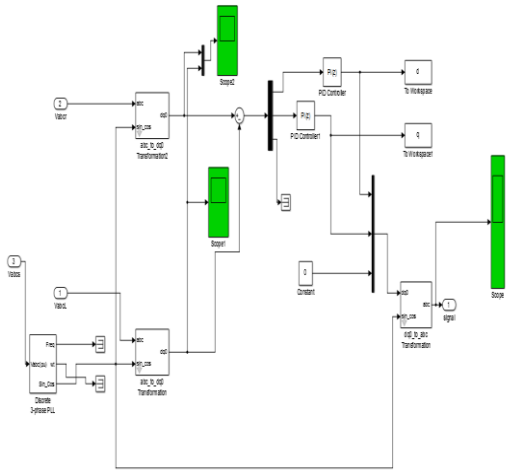

Fig 6 Control circuit of DVR

II. RESULT

The testing of the model shown is done for voltage sag produced by all types of fault. Voltage of bus before point of common coupling (PCC) is termed as source voltage and the voltage of bus after PCC which supplies the load are termed as the Load voltage. These two voltage waveforms are shown for all types of fault. Figure 7 shows the result for single line to ground fault.

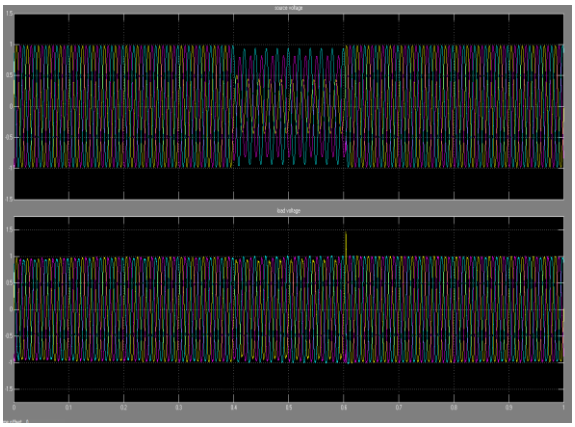

Fig 6 Result for single line to ground fault

As seen in figure 6 the source voltage waveform has a sag in phase a as single line to ground fault for phase A is simulated. But the load voltage waveform doesnot have sag it is being cleared by the DVR.

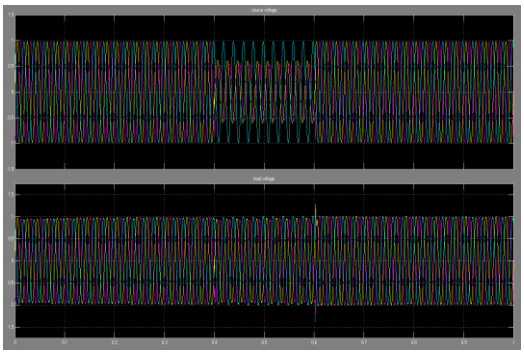

Fig 7 Result for Line to Line fault

As seen in figure 7 the source voltage waveform has a sag in phase a and phase b as line to line fault in phase A and B is simulated. But the load voltage waveform doesnot have sag it is being cleared by the DVR.

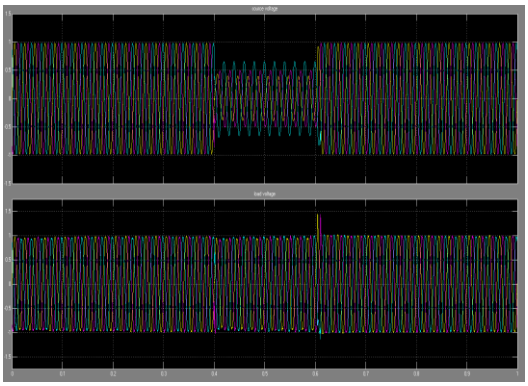

Fig 8 Result for double line to ground fault

As seen in figure 8 it is clear that there is sag in all the phases due to the presence of ground in double line fault. It is seen that sag is also not balanced. But the load voltage waveform doesnot have any sag it means sag is cleared by the DVR.

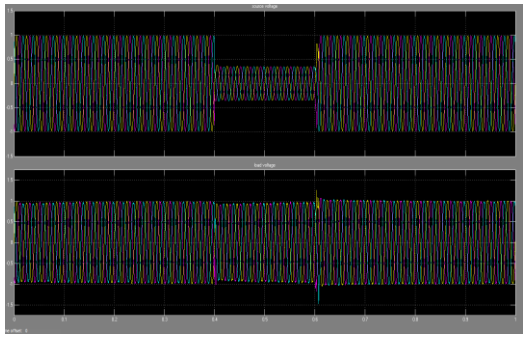

Fig. 9 Result for three phase fault

As seen in figure 9 three phase fault results in voltage sag in all the three phases. From the second waveform which is the waveform of load voltage it is clear that voltage sag is being eliminated by the DVR.

The total harmonic distortion data (THD) for voltage waveform of source voltage and the load voltage is shown in Table 1

Fault types\Voltage	Source voltage THD	Load voltage THD
Single line to ground fault	29.38%	4.93%
Double line fault	25.83%	5.13%
Double line to ground fault	36.99%	4.6%
Three phase fault	33%	4.77%

Table 1 THD data for various faults

It is clear from the table that the DVR not only eliminates sag but it also reduces harmonics in the voltage waveform.

III. CONCLUSION

From the various result obtained it is clear that the proposed control startegy works very good on elimination of voltage sag and protection of the sensitive loads connected at the distribution centers. From table 1 it is also clear that the DVR also reduces the total harmonic distortion THD from the load voltage waveform in all types of fault.

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