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POWER QUALITY IMPROVEMENT USING REPETITIVE CONTROLLED DYNAMIC VOLTAGE RESTORER FOR VARIOUS FAULTS

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Voltage Sag.

ABSTRACT

In this work a repetitive controller has been used in the control system of the DVR to compensate for key power quality problems namely voltage sags, harmonic voltages and voltage imbalances. This control system contains a feed forward term to improve the transient response and a feedback term to enable zero error in steady state. This paper proposes to verify results given for a line to line fault in the reference and extends to conduct three phase fault and single line to ground fault. All results are presented and analysed. MATLAB/SIMULINK software is used for simulation. The Simulation results shows that the repetitive control approach performs very effectively and yields excellent improvement in voltage quality problems.

1. INTRODUCTION

The importance of power quality (PQ) has risen very considerably over the last two decades due to a marked increase in the number of equipment which is sensitive to adverse PQ environments, the disturbances introduced by nonlinear loads, and the proliferation of renewable energy sources, among others. At least 50% of all PQ disturbances are of the voltage quality type, where the interest is the study of any deviation of the voltage waveform from its ideal form . The best well-known disturbances are voltage sags and swells, harmonic and inter harmonic voltages, and, for three-phase systems, voltage imbalances.

A voltage sag is normally caused by short-circuit faults in the power network [2], [3] or by the starting up of induction motors of large rating [4]. The ensuing adverse consequences are a reduction in the energy transfers of electric motors and the disconnection of sensitive equipment and industrial processes brought to a standstill. A comprehensive description of voltage sag can be found in [5].

Harmonics are produced by nonlinear equipment, such as electric arc furnaces, variable speed drives, large concentrations of arc discharge lamps, and loads which use power electronics. Harmonic currents generated by a nonlinear device or created as a result of existing harmonic voltages will exacerbate copper and iron losses in electrical equipment. In rotating machinery, they will produce pulsating torques and overheating [6].

The DVR is essentially a voltage source converter connected in series with the AC network via an interfacing transformer, which was originally conceived to improve voltage sags [7]. The basic operating principle behind the DVR is the injection of an in phase series voltage with the incoming supply to the load, sufficient enough to reestablish the voltage to its present state. Its rate of success in combating voltage sags in actual installations is well documented [8], this being one of the reasons why it continues to attract a great deal of interest in industry and in academic circles. Research work has been reported on DVR two-level [9] and multilevel topologies [10] as well as on control and operation. The latter may be divided into several topics. The configuration, whether two-level or multilevel, relates to the availability, or otherwise, of energy storage [2] , the output filter [11], and the capacity to cancel out unbalanced voltages in three-phase four-wire systems [12]. The voltage-sag detection. Several techniques have been used to detect the instant of sag appearance, such as measurement of the peak value of the grid voltage. A comprehensive analysis of these can be found in [13]. The control strategy. The DVR may be operated to inject the series voltage according to several criteria, such as minimum energy exchange with the grid. The three most popular strategies to compensate voltage sags are [14].Although these are the best well-known control strategies, many efforts are being made to develop new ones to enable better DVR utilization as discussed in [15]-[18]. The design of the control law. The controller is normally designed with some specific aims firmly in mind, such as the kind of disturbances it should ameliorate, the velocity of time response, error in steady-state, etc.

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This paper is organized as follows. The DVR model is presented in section II. The fundamentals of the control system and the proposed control scheme are studied in section III. The modelling of the repetitive controller using the graphical facilities available in MATLAB/ SIMULINK and the simulation results are presented in section IV. The main conclusions are drawn in section V. The design of the closed loop control scheme is given in [1] along with the necessary equations. The same control system has been used here for the design of DVR.

2. MODEL OF THE DVR CONNECTION SYSTEM

A typical test system, incorporating a DVR, is depicted in Figure.1. Various kinds of loads are connected at the point of common coupling (PCC), including a linear load, nonlinear load, and a sensitive load. The series connection of the voltage-source converter (VSC) making up the DVR with the ac system is achieved by means of a coupling transformer whose primary is connected in series between the mains and the load. Although a passive LC filter is normally used to obtain a switching-ripple-free DVR voltage, in this paper, this filter is not considered in order to fully assess the harmonic cancelling properties of the repetitive controller

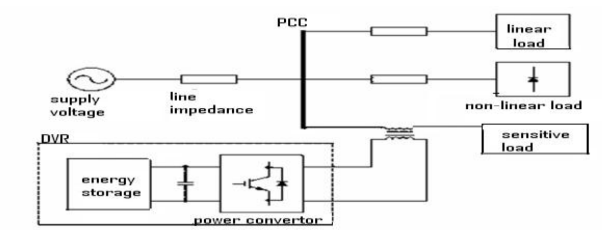


Figure. 1 test system with DVR

3. DESIGN OF THE CONTROL SYSTEM

The aim of the control system is to regulate the load voltage in the presence of various kinds of disturbances. The control structure proposed in this paper is based on the use of a feed forward term of the voltage at the PCC to obtain a fast transient response, and a feedback term of the load voltage to ensure zero error in steady state. Since all the poles of Q(S) are stable, which implies that P=0, then N must be zero to guarantee stability, and a sufficient condition for Q(S) can be obtained by making

$$|G(s)| = |Q(s)e^{-Ts}\left(e^{-\delta s}-1\right) \quad \forall \quad |< 1 \; \omega \qquad (1)$$

4. CASE STUDY

Simulink Model

The power system and the control system have been implemented in MATLAB. The test system is comprised of a 400 V 50 Hz source which feeds three different loads:

***Case 1: Two Phase Short Circuit Fault**:*

Table 1 parameters of the system

PARAMETER	VALUE
RMS line-to-line voltage	400V
Resistance and inductance of line	RS=10mΩ, Ls=750μH
Motor connection inductance	L1=50μH
Nonlinear load connection inductance	L2=50μH
Mechanical power of the motor	Pm=46KW
DC load: resistance and inductance	R_{DC}=10Ω, L_{DC}=0.4H
Sensitive load: resistance and inductance	R_{SL}=3Ω, L_{SL}=50mH
Transformer: resistance and inductance	R=0.3Ω, L=6mH

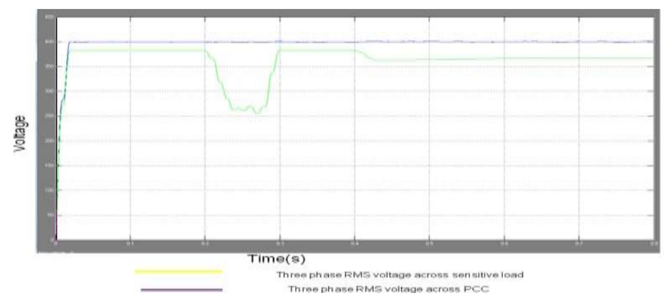


Figure 2 Sensitive Load Line to Line Voltages Corresponding to the interval 0.2<t <0.28. The results indicate that the line-toline voltages across the sensitive load remain unaffected when a two phase short circuit fault is applied.

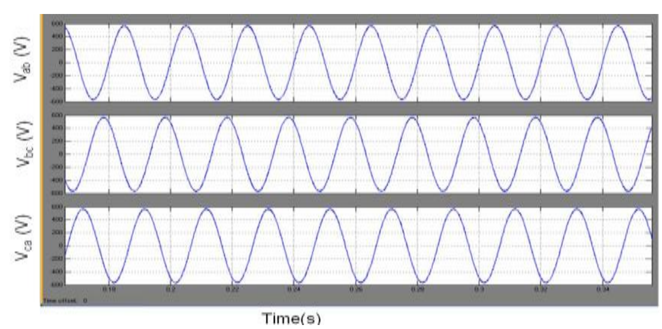


Figure 3 shows the RMS voltage for the sensitive load and at PCC for the interval of 0.8 seconds. A non-linear load and DVR are connected at t=0 secs. A two phase short circuit fault is applied at PCC from t=0.2 s to t=0.28 s. The induction machine is connected at t=0.4 s to t=0.65 s. The non-linear

Case 2: Three Phase Short Circuit Fault

The same process is repeated by taking a three phase short circuit fault and results are obtained and the corresponding RMS voltages and THD values are given in table below

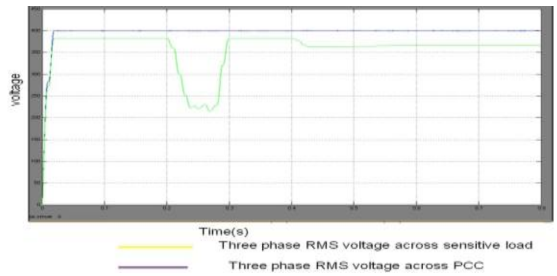


Figure 4 Three Phase RMS Voltage across Sensitive Load and at PCC for 3 Phase Fault

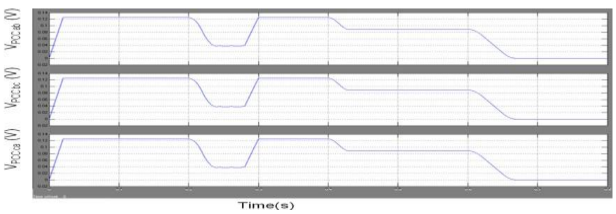
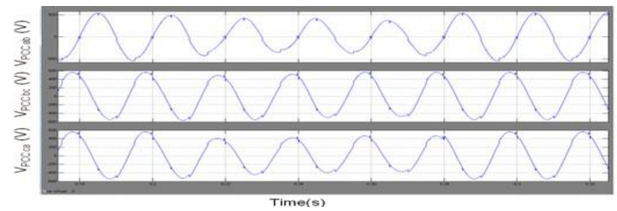


Figure 5 THD Values of Source Voltage at PCC

Case 3: Single Line to Ground Fault

The same process is repeated by taking a single line to ground fault and results are obtained and the corresponding RMS voltages and THD values are given in table below.



.**Figure 6** Line to Line Voltages at PCC Corresponding to the Interval 0.2<t <0.28 for Line to Ground Fault

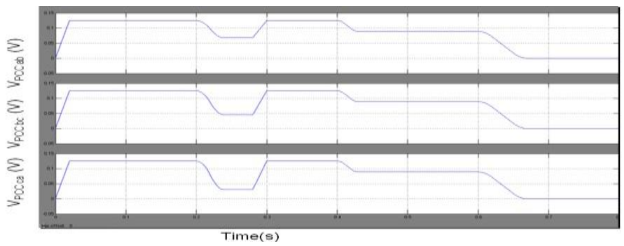


Figure 7 THD Values of Source Voltage at PCC for 0.8 S

The table 2 summarizes the most significant results obtained during simulation for different types of faults (balanced and unbalanced). The table clearly indicates that the unbalanced faults cause deep sag for a short duration and balanced faults cause a balanced sag which is not that deep as compared to the unbalanced sags for a long duration

Table 2 comparison of the results of the three faults.

	For two phase S.C fault			For 3 phase S.C fault			For L.G fault	
	$V^{(1)}_{rms}$ (V)	THD_V (%)		$V^{(1)}_{rms}$ (V)	THD_V (%)		$V^{(1)}_{rms}$ (V)	THD_V (%)
Time interval (s):		0<=t<0.2			(balanced conditions)			
PCC	385	12.52		385	12.52		385	12.52
Sens. load	399.63	3.07		399.63	3.07		399.63	3.07
Time interval (s):		0.2<=t<0.2 8			(unbalanced conditions)			
PCC(ab)	225.37	6.71		220	3.8		275	6.82
PCC(bc)	363.23	4.07		220	3.8		360	4.56
PCC(ca)	242.07	2.30		220	3.8		293	3.02
Sens. Load(ab)	399.33	6.88		399.63	4.2		399.23	7.05
Sens. Load(bc)	400.19	6.56		399.63	4.2		400.10	6.92
Sens. Load(ca)	399.77	3.77		399.63	4.2		400.15	7.25

V. CONCLUSION

The DVR with the repetitive controller presented in this thesis is able to improve the Power Quality problems like the voltage sags, harmonic voltages and voltage imbalances for different types of faults .

A special feature of this control scheme is its simplicity; only one controller does three jobs i.e., one controller eliminates the three power quality disturbances. To achieve this, the controller has been provided with a feed forward term and feedback term. Simulation results using MATLAB show that the repetitive controller and the DVR have yielded good results in eliminating the PQ disturbances across the sensitive load.

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