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A Novel Control Strategy for Compensation of Voltage Quality Problem in AC Drives

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ABSTRACT

This paper presents a novel control strategy for the compensation of voltage quality issues in power system networks with AC drives. Voltage quality is one of the key parameter for power engineers and to deliver the power with good quality should be given at most priority. Voltage quality mitigation in power system network is done by employing dynamic voltage restorer (DVR). DVR consists of power switches and power switches are to be controlled. DVR in this paper is controlled using a novel control strategy. A novel control strategy can effectively control DVR by improving voltage quality reducing the adverse effects of voltage sag and voltage swell in power system networks. The paper presents the DVR controlled with novel control strategy for electrical machine (induction motor) drive load application.

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1. INTRODUCTION

Consistency is a key word for utilities and their customers in general, and it is crucial to companies operating in a highly competitive business environment, because it affects profitability, which definitely is a driving force in the industry. Although electrical transmission and distribution systems have reached a very high level of reliability, disturbances cannot be totally avoided [1-3]. Power quality issues are not new to power system but their existence creates new problems due to advancements in power electronic sector. Voltage quality is the main concern on load side and power engineers should ensure that the load voltage is same throughout the conditions in power system. Custom power devices might be a solution to eliminate or reduce power quality problems caused from many loads. FACTS devices are type of custom power devices employed to reduce the risk of power quality problems using power electronics circuits [4-6].

DVR is one such device used to address voltage sag and swell issues in power system. The DVR is a power quality device, which can protect these industries against the bulk of these disturbances, i.e. voltage sags and swells related to remote system faults. A DVR compensates for these voltage excursions, provided that the supply grid does not get disconnected entirely through breaker trips. DVR [7-8] is power electronic voltage source converter placed in series to power line as in figure 1 and power switches in DVR is to be controlled by employing a suitable control strategy to produce gating signals to power switches of DVR [9-11].

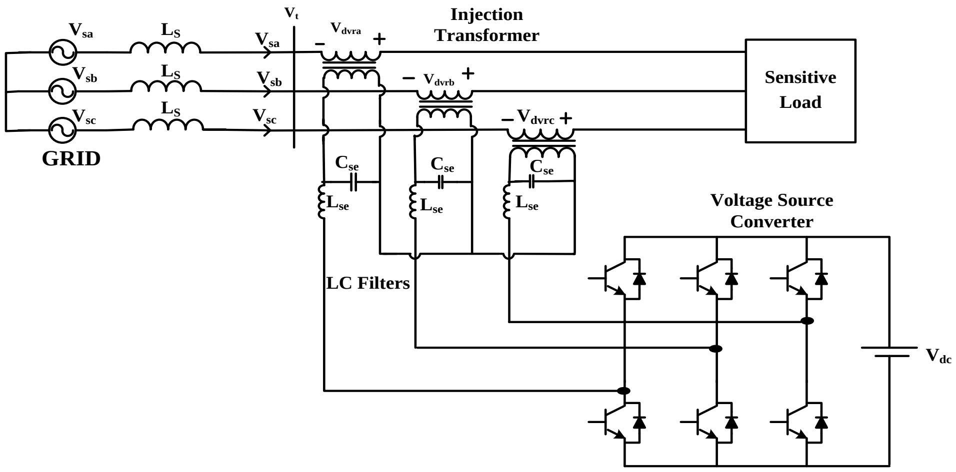

Figure 1. Power system with DVR

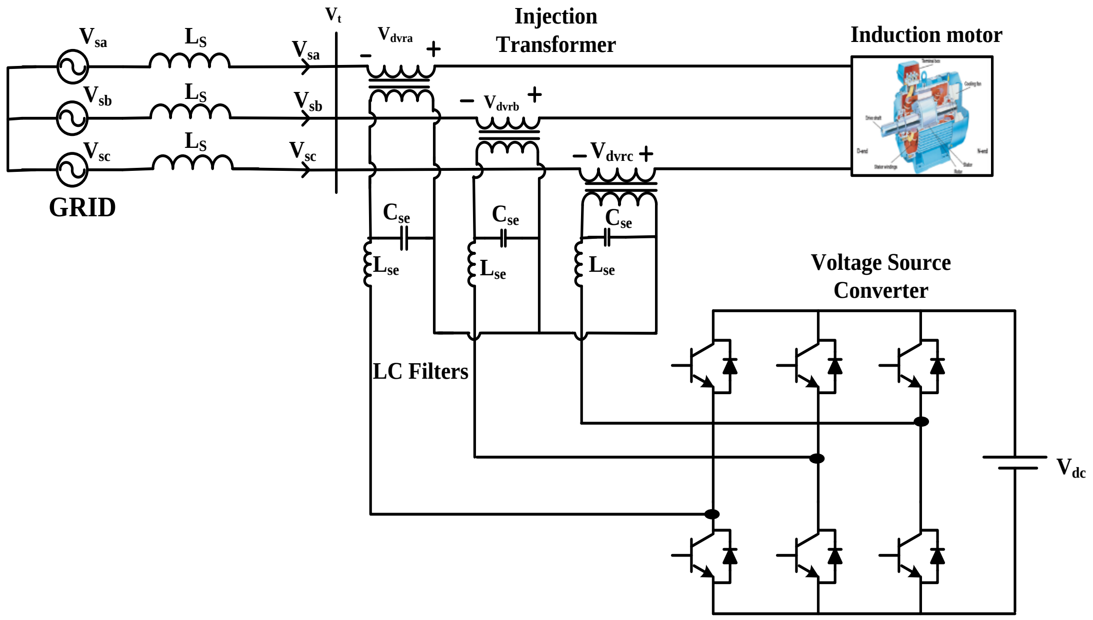

Figure 2. Configuration of DVR connected to power system with induction motor drive load

This paper presents a new control strategy to control power switches of DVR to be triggered to compensate voltage quality disturbances in power system. The said novel control strategy was tested for AC drive load applications. The performance of DVR controlled with proposed novel control strategy was tested to compensate sag and swell in power system with induction motor drive load.

2. DVR IN POWER SYSTEM WITH INDUCTION MOTOR LOAD CONFIGURATION

The system configuration with power system having induction motor load and DVR connected to power system for voltage quality improvement was shown in Figure 2. The three-phase source is connected to induction (AC) motor load through source impedance. Since induction motor is an inductive load, it may cause voltage quality problems in power system and this problem needs to be addressed. To address voltage quality issues, mitigation of voltage is performed using a compensator. DVR is series converter addresses the voltage quality issues by inducing compensating signals to power system. DVR is a compensating device compensates the system voltage by absorbing/delivering required voltage with the use of IGBT/MOSFET. DVR is the commonly used compensating device for voltage sag and voltage swell problem in power system. load voltage profile should be maintained as close to ideal system such that the sensitive loads are not much affected by voltage unbalance. Voltage unbalance can cause serious malfunctioning or even damage to sensitive loads connected to power system. Machine drive loads are also much affected by unbalance in voltage at load.

DVR is a voltage source converter with power switches and a DC voltage source placed nearer to load for voltage compensation. It is placed nearer to load because a small change in load efficiency can increase much efficiency at source side in power system. DVR senses the load voltage continuously and a minor change in load voltage causes DVR to act accordingly depending on the load voltage profile either to boost up the load voltage during sag condition and decrease the load voltage during swell condition. To mitigate sag and swell conditions, DVR needs a voltage source.

3. PROPOSED NOVEL CONTROL OF DVR IN POWER SYSTEM WITH INDUCTION MOTOR LOAD CONFIGURATION

In conventional unit vector theory it is assumed that the three ac mains voltages are balanced and the dc link output is ripple free. The control scheme comprises of PI controller and 3-phase sine wave generator for reference current generation and switching signals. The peak values of reference currents are studied by regulating the DC link voltage. The definite capacitor voltage will be compared with a set of reference value. The RMS voltage source amplitude is calculated from source phase voltage va , vb, vc for the three phase balanced system.

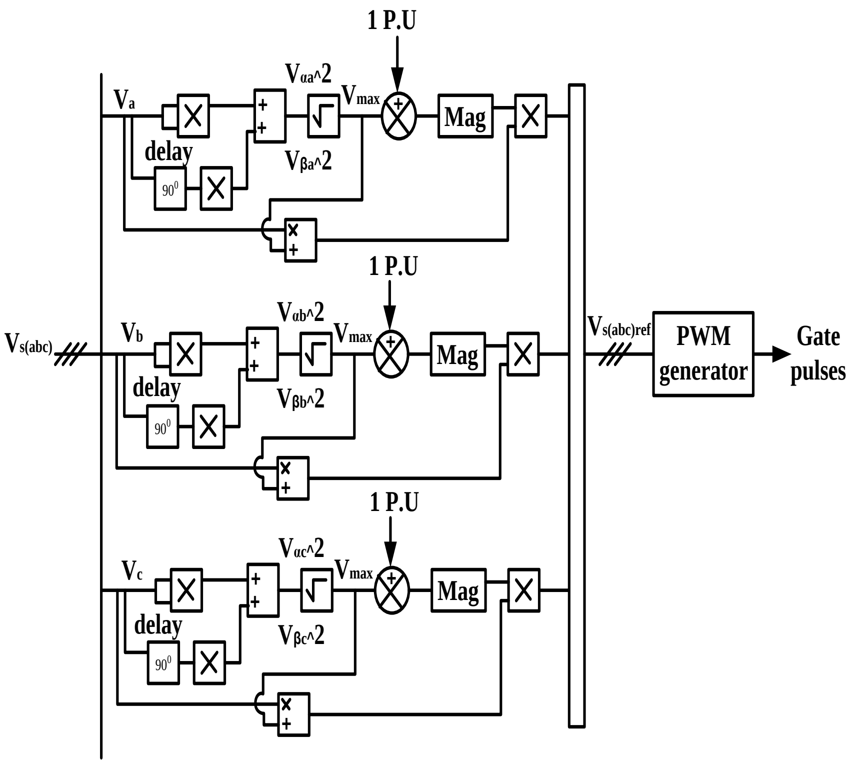

Figure 3. Proposed novel control theory for DVR

The in phase generated reference currents are derived using in-phase unit voltage. the peak value of the current I so found will be multiplied by the unit sine vectors in phase with the individual source voltages to obtain the reference compensating currents. These expected reference currents and detected actual currents are equated at a hysteresis band which delivers the error signal for the modulation technique. The current controller generates the finring pulses to the VSI by comparing the reference and actual current hence the hysteresis current control scheme is used to generate the switching signals to the DVR.

Figure 3 shows the block diagram of proposed control theory and Figure 4 shows DVR with simplified unit vector theory. In this control method of controlling DVR, the information regarding sine or cosine is not needed and transformations are also not needed as well. This avoids complex calculations and makes the control method easy. Initially information regarding Va, Vb, Vc are obtained from the source voltage. Va multiplying with Va gives $V\alpha a^{2}$. This signal is added to the signal $V\beta a^{2}$ obtained by adding 90^0delay to Va. Obtained signal was applied square-root and maximum value is obtained.

The maximum value obtained is compared with 1 pu value and magnitude was obtained. This magnitude was multiplied with the signal obtained by arithmetic operation of Va and maximum value. Obtained signal is reference value. The explained procedure is for Va. Similar procedure is followed to obtain reference signal for Vb and Vc. The combined reference signal is sent to PWM generator producing gate pulses to static switches in DVR. Complex calculations involving transformations and all are eliminated in this type of control method making control design easy.

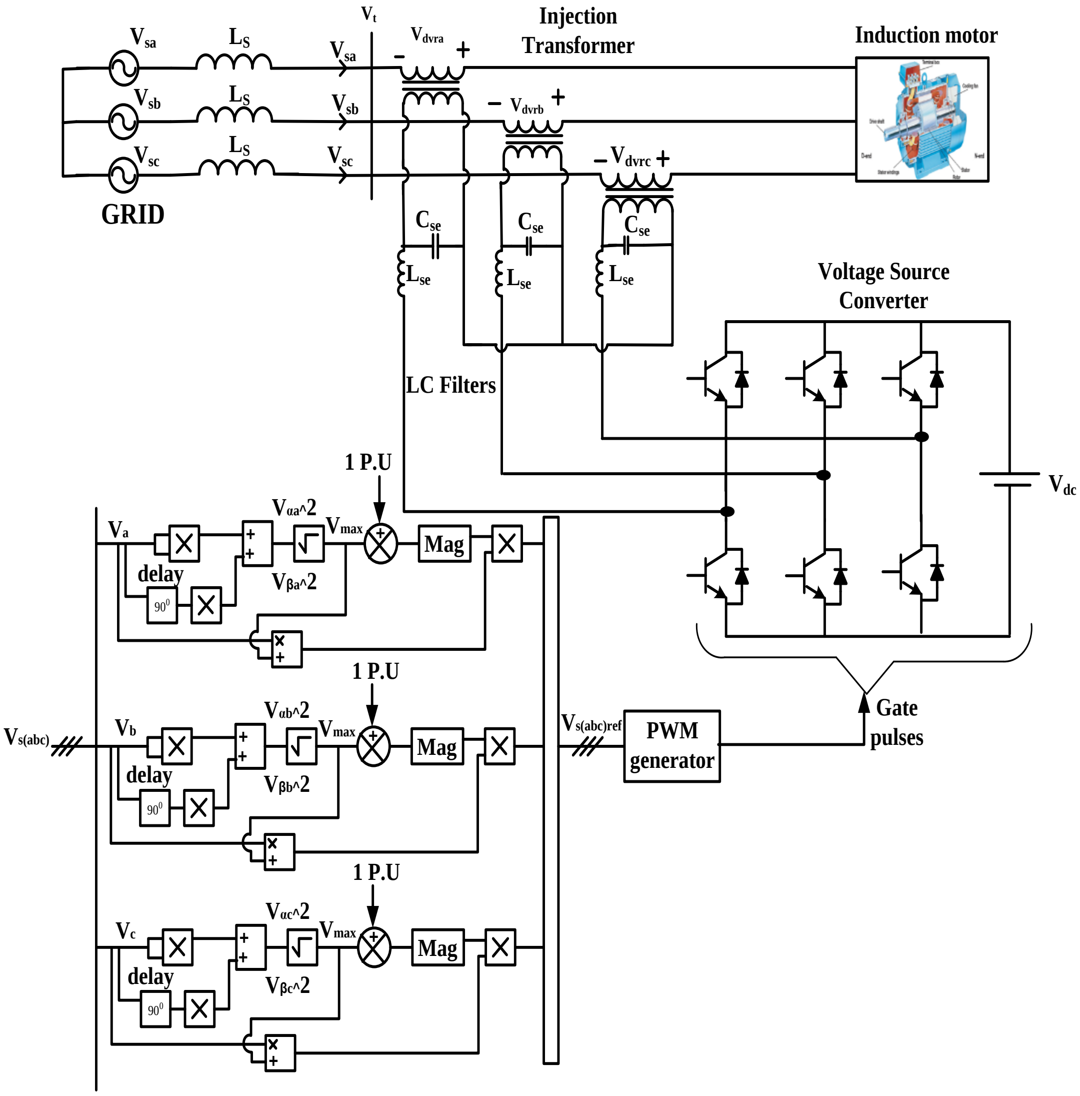

Figure 4. Power system network with DVR connected and having induction motor drive load

4. RESULTS AND ANALYSIS

4.1. DVR for sag condition with no induction motor load in power system

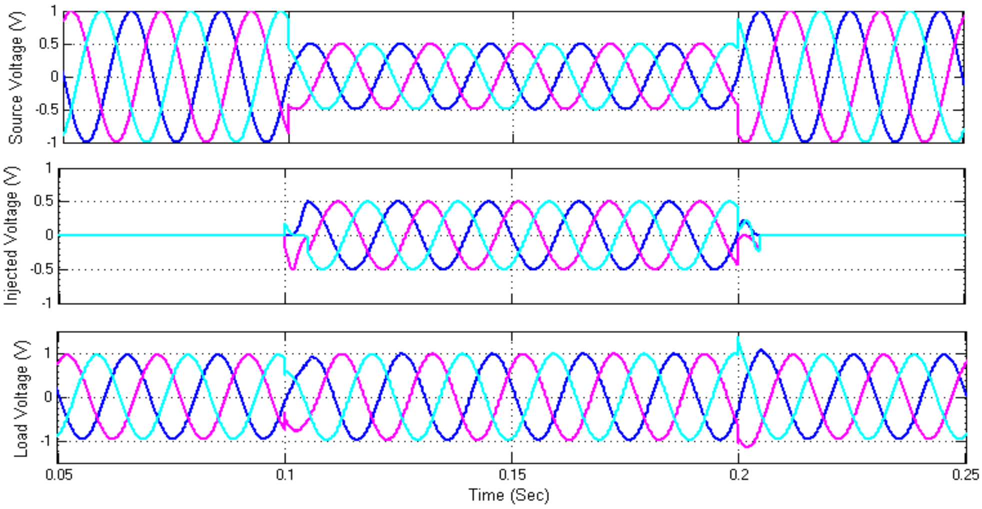

Figure 5. Source voltage, DVR voltage and load voltage of power system with no induction motor load

Figure 5 shows the three-phase source voltages in power system without induction motor load, injected voltages from DVR and load voltage profile. From time instant 0.1 s to 0.2 s, sag is observed in source voltage and at the same instant of time DVR injects filter voltages such that the load voltage profile is maintained constant.

4.2. DVR for swell condition with no induction motor load in power system

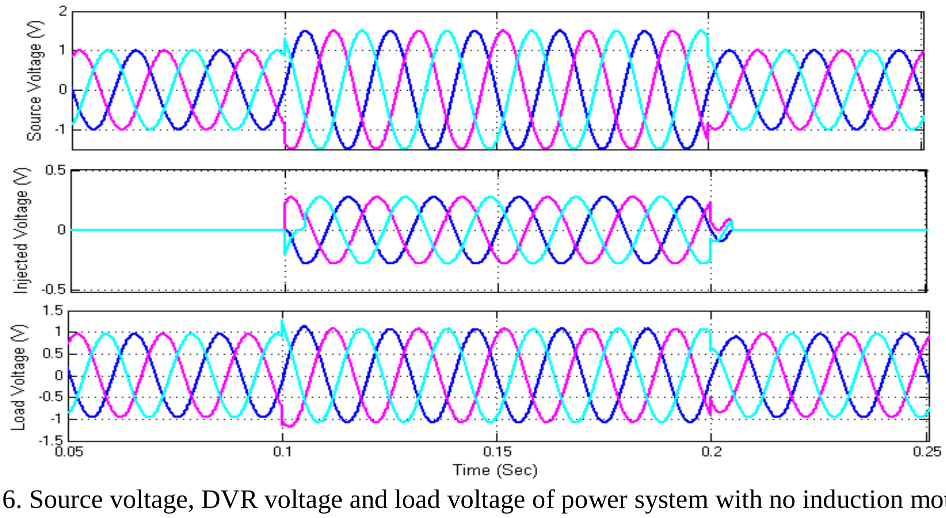

Figure 6. Source voltage, DVR voltage and load voltage of power system with no induction motor load

Figure 6 shows the three-phase source voltages in power system without induction motor load, injected voltages from DVR and load voltage profile. From time instant 0.1 s to 0.2 s, swell is observed in source voltage and at the same instant of time DVR acts accordingly such that the load voltage profile is maintained constant.

4.3. DVR for sag and swell condition with no induction motor load in power system

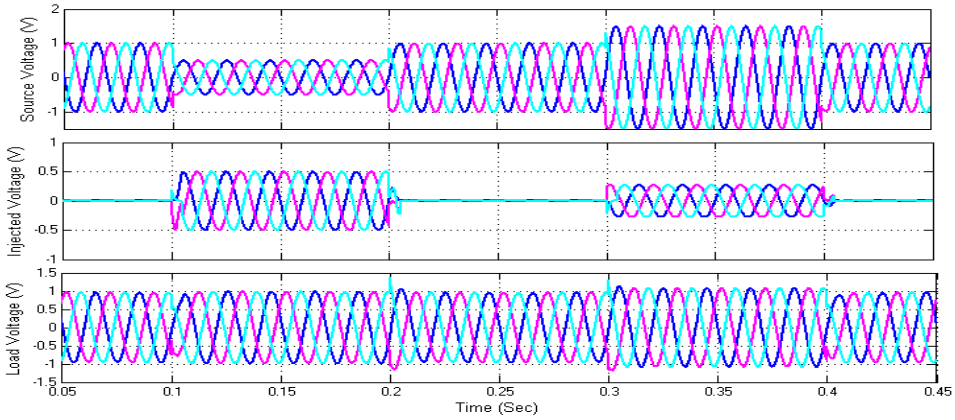

Figure 7. Source voltage, DVR voltage and load voltage of power system with no induction motor load

Figure 7 shows the three-phase source voltages in power system without induction motor load, injected voltages from DVR and load voltage profile. From time instant 0.1 s to 0.2 s, sag is observed in source voltage and swell is observed to be exists during 0.3s to 0.4s, at the same instant of time DVR injects filter voltages such that the load voltage profile is maintained constant reducing the affect of sag and swell.

4.4. Sag condition in power system with induction motor load in power system, no DVR

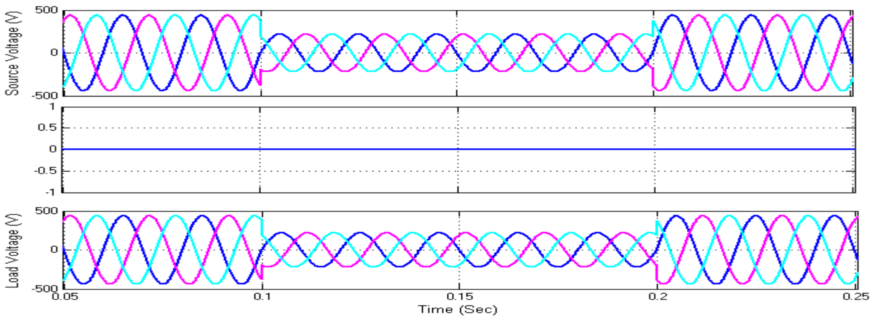

Figure 8. Source voltage, DVR voltage and load voltage of power system with no induction motor load

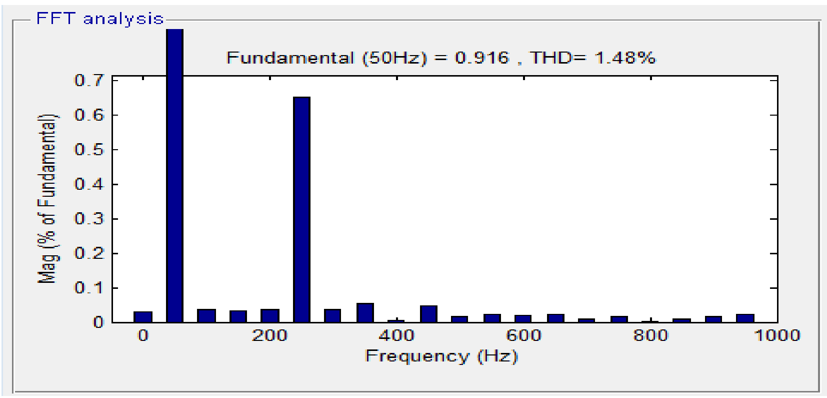

Figure 9. Total harmonic distortion in load voltage

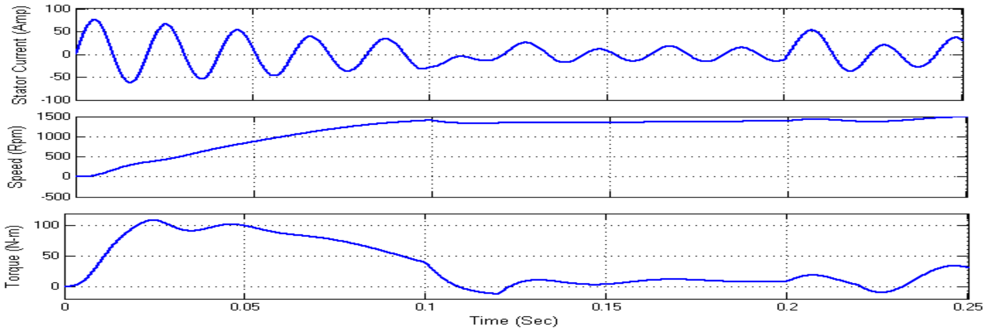

Figure 10. Stator current, speed and torque of induction motor

Figure 8 shows the three-phase source voltages in power system without DVR in power system consisting of induction motor load, injected voltages from DVR and load voltage profile. From time instant 0.1 s to 0.2 s, sag is observed in source voltage and at the same instant of time DVR injects no filter voltages and the load voltage profile is not maintained constant but sag exists in load voltage. Figure 9 shows the harmonic distortion in load voltage with no DVR but with induction motor connected at load. THD is maintained well below nominal limit of 5% maintained at 1.4%. Figure 10 shows stator current, speed and torque of induction motor. Drop in stator current is observed due to presence of sag in load voltage.

4.5. Sag condition in power system with induction motor load in power system, with DVR

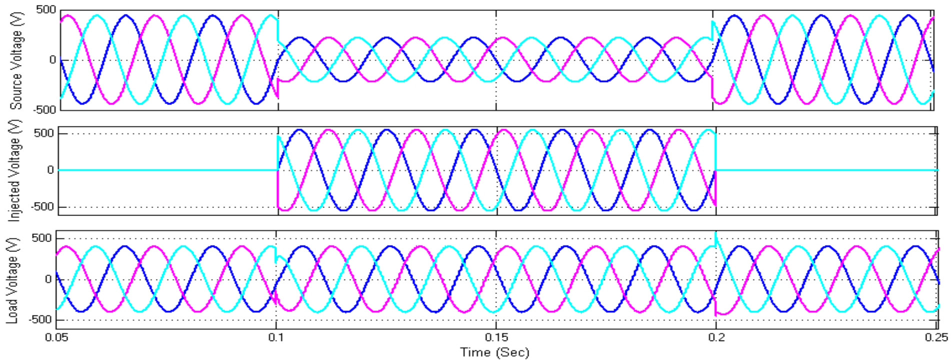

Figure 11. Source voltage, DVR voltage and load voltage of power system with no induction motor load

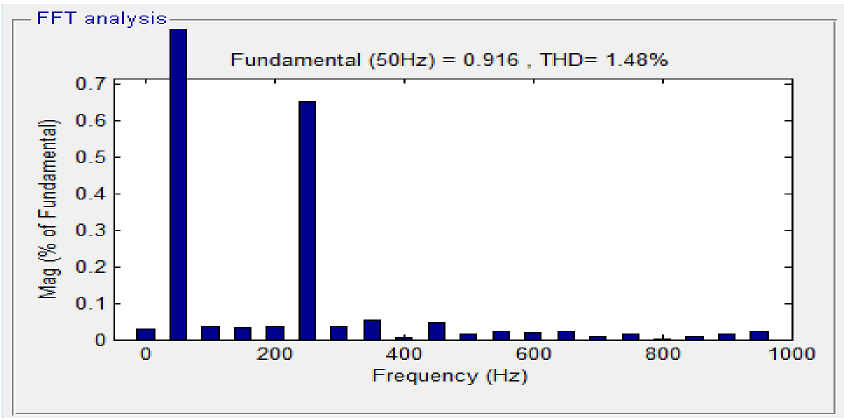

Figure 12. Total harmonic distortion in load voltage

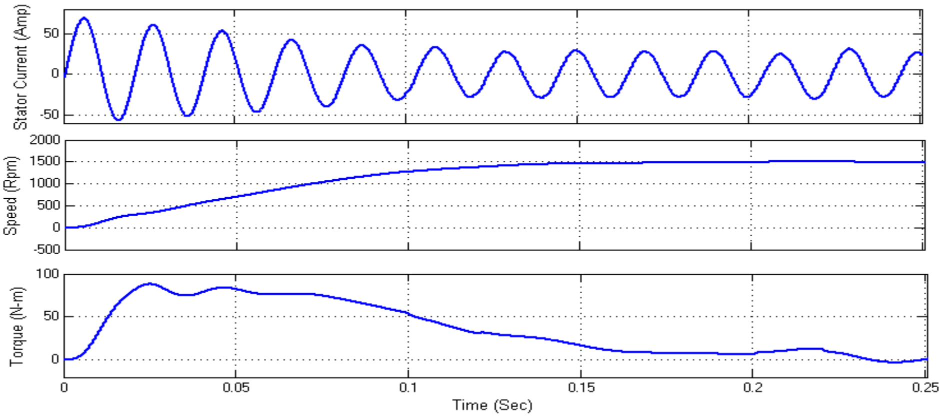

Figure 13. Stator current, speed and torque of induction motor

Figure 11 shows the three-phase source voltages in power system with DVR in power system consisting of induction motor load, injected voltages from DVR and load voltage profile. From time instant 0.1 s to 0.2 s, sag is observed in source voltage and at the same instant of time DVR injects filter voltages and the load voltage profile is maintained constant. Figure 12 shows the harmonic distortion in load voltage with no DVR but with induction motor connected at load. THD is maintained well below nominal limit of 5% maintained at 1.48%. Figure 13 shows stator current, speed and torque of induction motor. Drop in stator current is not observed as DVR compensated for sag in source voltage and load voltage.

5. CONCLUSION

The paper presents a novel control strategy to control DVR connected to power system with induction motor load. The control strategy was tested for sag condition with and without induction motor and found suitable to control DVR in different test conditions discussed in results. During sag conditions without and with induction motor, DVR with proposed control strategy injects compensating voltages to maintain constant load profile.

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