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Transformerless DVR Super Capacitor Based Induction Motor Drive Applications

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ABSTRACT

In modern power distribution systems power quality is considered as a major factor. For the fulfillment of industrial goals, modern industries are looking forward for new innovative technologies. The key requirement in any utility work is a disturbance free continuous power supply. The high quality power generated at the power stations are not delivered in the same form at the utility centers. This is mainly because of the widespread use of power electronic devices which introduced harmonics and other nonlinearities to the systems. The paper describes the application of super capacitor energy storage system for induction traction drive test bench that replaces a real electric public transport for performing testing and researches. The suitability and usage of such bench for research purposes is explained and the importance of the development of software mathematical model for performing simulations to be done before physical implementation measures is reasoned. The working principle of the bench and applied components are described. A virtual model of the bench was built and simulations were performed using Matlab/Simulink software. This concept results shows the superiority of the developed topology in voltage compensation capability and reliability. The proposed DVR has provided a regulated and sinusoidal voltage across the sensitive load.

I. Introduction

For the fulfillment of industrial goals, modern industries are looking forward for new innovative technologies. The key requirement in any utility work is a disturbance free continuous power supply [4].The high quality power generated at the power stations are not delivered in the same form at the utility centers. This is mainly because of the widespread use of power electronic devices which introduced harmonics and other nonlinearities to the systems.

Major focus for power system reliability was given on generation and transmission only as more capital cost is involved in these areas. But recently, distribution systems found to receive more attention for reliability assessment. The major power quality disturbances faced by customers are voltage sag, voltage swell, impulsive and oscillatory transients phase jumps, short interruptions as well as steady state deviations such as harmonics and flicker. Among the disturbances, voltage sag is considered more severe since the sensitive loads are susceptible to temporary changes in voltage.

In cooperating power electronics based technology to improve power quality is referred to as custom power technology. Disturbance/interruption free service to the customers is offered by using switching equipments and controllers. Many types of custom power devices are in use which differs in the type of connection with the system.Dynamic voltage restorer is custom power device which is series connected with the distribution line to compensate the voltage disturbance.

DVR is basically a voltage source inverter which is connected in series between the supply and a critical load. A series connected injection transformer is used to inject the compensation voltage to the system. Different topologies of DVR are discussed in [2]. The design of a capacitor supported DVR that protects sag, swell, distortion, or unbalance in supply voltages is discussed in [8]. Different energy storage schemes are discussed in [5]. The super capacitor energy storage has high specific power density. In this work the energy storage for the DVR is replaced with a super capacitor and also the series injection transformer is eliminated. The SRF theory is used for control of DVR. A comparative analysis of capacitor supported, super capacitor supported and transformer less topology is also presented.

II. Principle of DVR Operation

Dynamic voltage restorer is a series compensator that provides technically and economically advanced solution to most of the PQ issues. The super capacitor supported dynamic voltage restorer system is discussed in [11]. In this paper we will discuss in detail about transformer less Super capacitor connected system. The schematic diagram of a transformer less SC connected system is shown in Fig. 1.

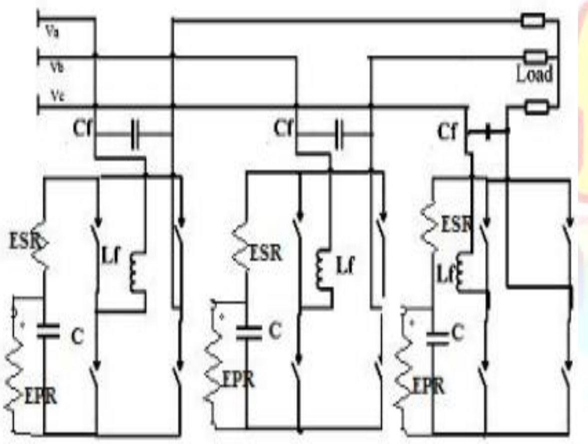

Fig 1 Schematic diagram of transformer less SC connected system

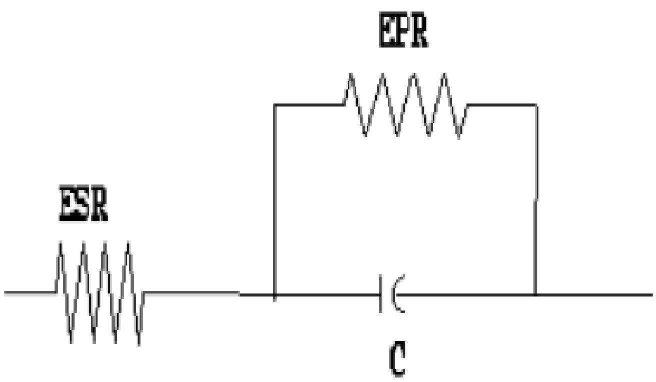

Fig 2 Equivalent circuit of a super capacitor

The pattern of coupling between the distribution network and the DVR can be either transformer coupling mode or capacitor coupling mode. The main disadvantages of transformer coupling mode includes high harmonic distortion, increased size and cost of device, issues like transformer saturation and inrush currents. So capacitor coupling mode along with an inductor in series thus forming a low pass filter will reduce the above discussed disadvantages to a great extend.

The proper design of the filter circuit can thus avoid the bulky transformer and thereby reduce the size and cost of the overall system. The series inductor in the low pass filter section serves the purpose of voltage injection instead of the transformer.Also it can be seen that the energy storage in this system is a super capacitor. Fig. 2 represents the equivalent circuit of a super capacitor which consists of a capacitor in series with a low resistance called equivalent series resistance (ESR), and in parallel with a high value resistance called equivalent parallel resistance (EPR).

III. Control of Transformerless DVR

The control part involves Synchronous Reference Frame (SRF) control. The direct axis, quadrature axis and zero sequence components are calculated by using Park's transformation. The control of dc signal is easier compared to the control of ac signal. So converting from stationary to rotating reference frame is justifiable.

For making the calculations simpler and hence faster, p. U values of the corresponding signals are taken.

The control algorithm for the transformer less system shown in Fig.3. Here the output voltage Vload is converted to d-q reference frame. Then the actual d and q signals are compared with the reference d and q values, i. e, dref=1 and qref=0. The error signals are entered to PI controllers. The outputs of the PI are converted back to abc signals by reverse Park's transformation and are used to generate the pulses by sinusoidal PWM technique.

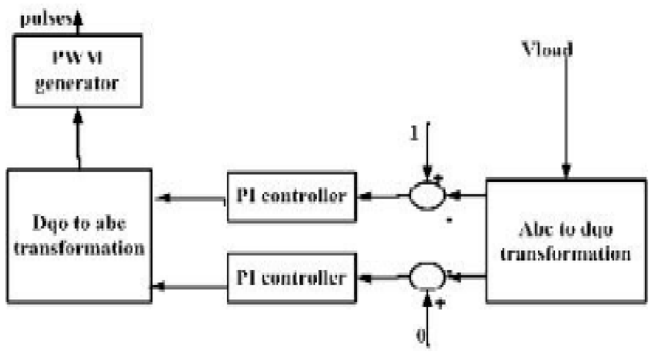

Fig 3 Control algorithm for transformer less DVR

IV. INDUCTION MACHINE

An induction motor is an example of asynchronous AC machine, which consists of a stator and a rotor. This motor is widely used because of its strong features and reasonable cost. A sinusoidal voltage is applied to the stator, in the induction motor, which results in an induced electromagnetic field. A current in the rotor is induced due to this field, which creates another field that tries to align with the stator field, causing the rotor to spin. A slip is created between these fields, when a load is applied to the motor. Compared to the synchronous speed, the rotor speed decreases, at higher slip values. The frequency of the stator voltage controls the synchronous speed. The frequency of the voltage is applied to the stator through power electronic devices, which allows the control of the speed of the motor. The research is using techniques, which implement a constant voltage to frequency ratio. Finally, the torque begins to fall when the motor reaches the synchronous speed. Thus, induction motor synchronous speed is defined by following equation,

$$n_s = \frac{120f}{P}$$

Where f is the frequency of AC supply, n, is the speed of rotor; p is the number of poles per phase of the motor. By varying the frequency of control circuit through AC supply, the rotor speed will change.

Power electronics interface such as three-phase SPWM inverter using constant closed loop Volts l Hertz control scheme is used to control the motor. According to the desired output speed, the amplitude and frequency of the reference (sinusoidal) signals will change. In order to maintain constant magnetic flux in the motor, the ratio of the voltage amplitude to voltage frequency will be kept constant. Hence a closed loop Proportional Integral (PI) controller is implemented to regulate the motor speed to the desired set point. The closed loop speed control is characterized by the measurement of the actual motor speed, which is compared to the reference speed while the error signal is generated. The magnitude and polarity of the error signal correspond to the difference between the actual and required speed. The PI controller generates the corrected motor stator frequency to compensate for the error, based on the speed error.

V. SIMULATION RESULTS

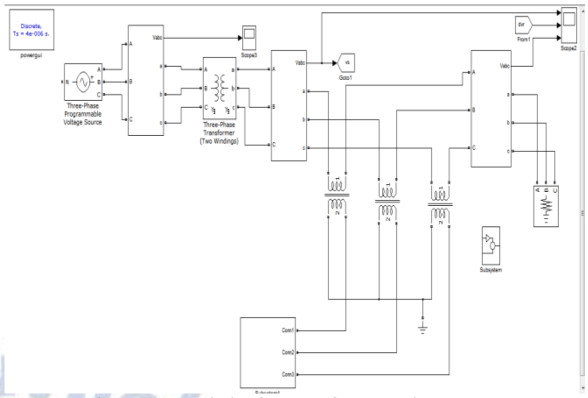

Fig 4 Simulation model of transformer less SC connected system

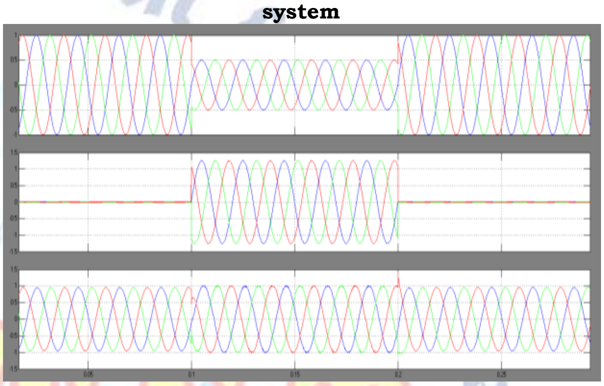

Fig 5 Simulation waveform of Load voltage with sag, Injected voltage, compensated load voltage

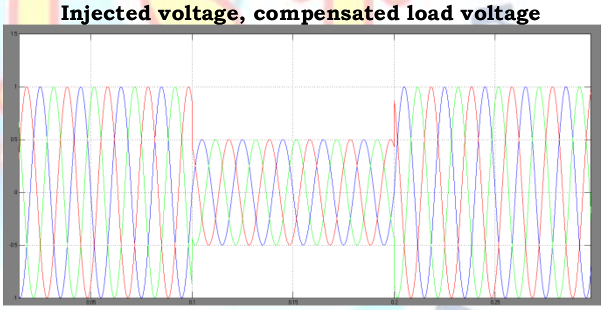

Fig 6 Simulation waveform of input sag voltage

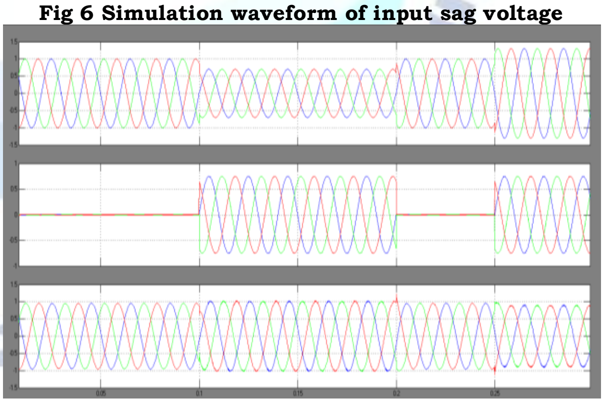

Fig 7 Simulation waveform of Load voltage with sag, and swell, injected voltage, compensated load voltage

Fig 8 Simulation waveform of Sag and swell

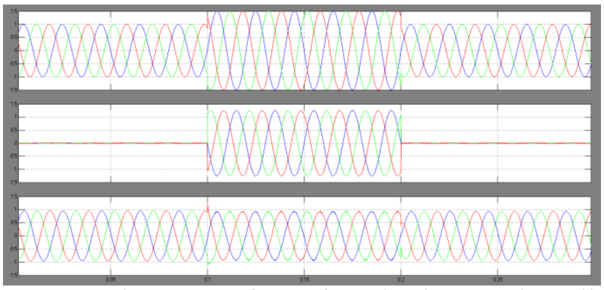

Fig 9 Simulation waveform of Load voltage with swell, Injected voltage, compensated load voltage

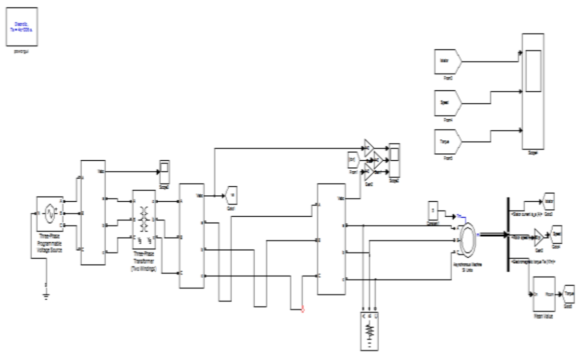

Fig 10 Simulation model of sag compensation without DVR connected to IM

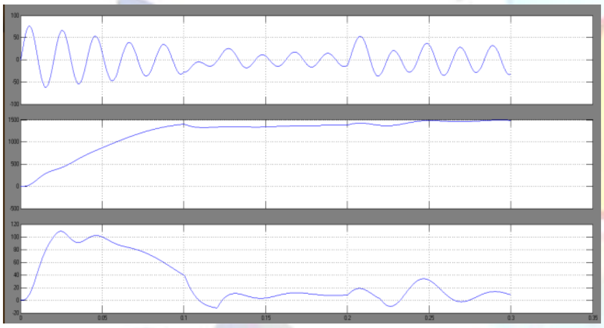

Fig 11 Simulation waveform of current, speed and torque

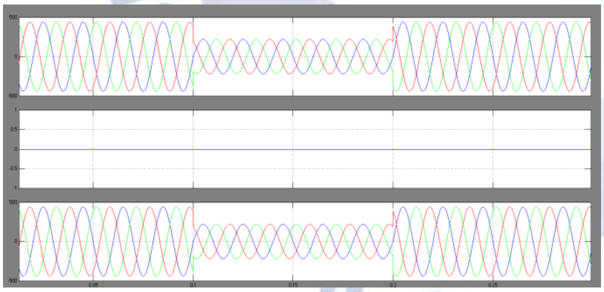

Fig 12 Simulation waveform of without DVR

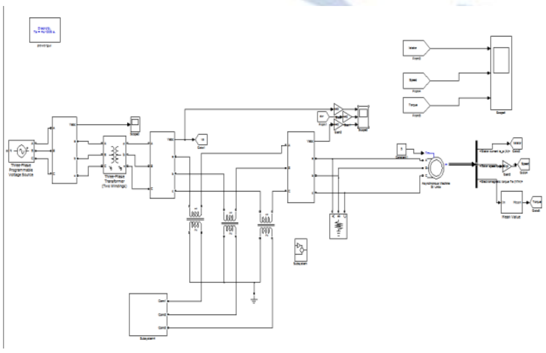

Fig 10 Simulation model of Sag compensation connected to IM with DVR

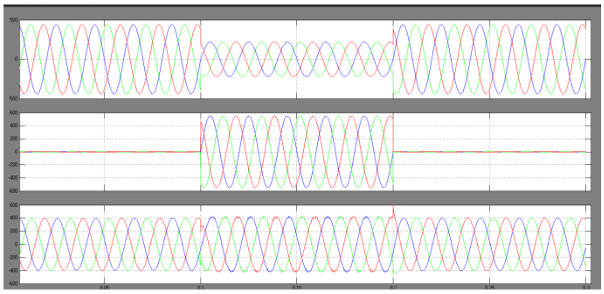

Fig 14 Simulation waveform of Sag compensation

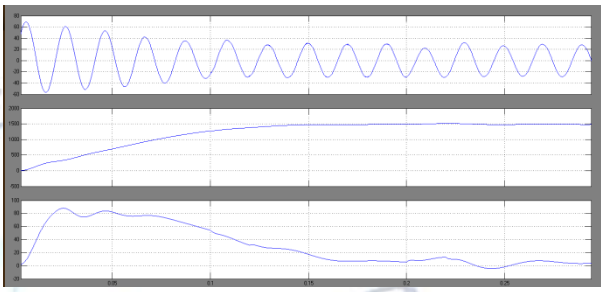

Fig 15 Simulation waveform of Stator current, rotor speed and magnetic torque

VI. Conclusion

The SRF controller based transformer less super capacitor supported DVR is simulated in MATLAB. The simulation result shows the superiority of the developed topology in voltage compensation capability and reliability. An induction motor is an example of asynchronous AC machine, which consists of a stator and a rotor. This motor is widely used because of its strong features and reasonable cost. The designed DVR has provided a regulated and sinusoidal voltage across the sensitive load. The system has successfully met the IEEE 519 harmonic standard.

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