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High Performance of Adjustable Speed Drives by Maintaining DC-Link voltage

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ABSTRACT
During the voltage unbalance, the resulting adverse effects on equipments such as induction motors and power electronic converters and drives on ASDs have been described. It has been observed that during unsymmetrical fault, the input rectifier slips into the single phase operation and draw heavy currents which may actuate the overload protection and trip the ASDs. The application of supercapacitors bank with boost converter to inject energy at DC-Link under voltage unbalance condition has been incorporated. The supercapacitor provides ride-through and reduces the current overshooting by injecting energy at DC Link. Based on the designed topology, simulation model in MATLAB 10 (Sim Power Block set) has been developed for voltage unbalance conditions with supercapacitor as an energy storage device. The designed control technique is modelled, simulated successfully implemented in the laboratory. The extensive simulation results supported by experimental results were provided to validate the proposed system.

Keywords
Power Quality, Adjustable speed drives, direct torque controlled method, dc link voltage.

1. INTRODUCTION
The greatest effect of voltage unbalance is on three-phase induction motors. Three-phase induction motors are one of the most common loads on the network and are found in large numbers especially in industrial environments. When a three-phase induction motor is supplied by an unbalanced system the resulting line currents show a degree of unbalance that is several times the voltage unbalance. An excessive level of voltage unbalance can have serious impacts on mains connected induction motors. Although induction motors are designed to tolerate a small level of unbalance they have to be derated if the unbalance is excessive. Voltage unbalance also has an impact on ac variable speed drive systems where the front end consists of three-phase rectifier systems. The triplen harmonic line currents that are uncharacteristic to these rectifier systems can exist in these situations leading to unexpected harmonic problems. Although it is practically impossible to eliminate voltage unbalance it can be kept under control at both utility and plant level by several practical approaches. Voltage unbalance is regarded as a power quality problem of significant concern at the electricity distribution level. Although the voltages are quite well balanced at the generator and transmission levels the voltages at the utilization level can become unbalanced due to the unequal system impedances and the unequal distribution of single-phase loads. The level of current unbalance that is present is several times the level of voltage unbalance. Such an unbalance in the line currents can lead to excessive losses in the stator and rotor that may cause protection systems to operate causing loss of production. Three-phase diode rectifier systems are an essential part of conventional Adjustable Speed Drives as shown in . 1 and uninterruptible power supplies. These rectifier systems draw non-sinusoidal current waveforms from the ac mains. If the ac supply system is balanced the line current waveform may take the “double pulse per half cycle” shape that contains characteristic harmonic orders given by:

$$h = kq \pm 1$$

where h = harmonic order ,k = 1, 2,….and q=number of pulses of the rectifier system giving only 5th ,7th , 11th, 13th… order harmonics.
As the supply system becomes unbalanced the line current waveform deviates away from the double pulse formation to single pulse formation leading to uncharacteristic triplen harmonics. Supply voltage unbalance can lead to tripping of drive systems that is caused by excessive ac line currents on some phases and under voltage on the DC-Link. This can also lead to excessive thermal stress on diodes and dc link capacitor. Increase in the unwanted triplen harmonic currents can also lead to undesirable harmonic problems in the supply system. The different ride-through require energy storage devices injecting power at the DC-link during voltage sags. Most of the mitigation techniques are based on the injection of active power, thus compensating the loss of active power supplied by the system. An important distinction between each of the possible ride-through approaches is their ability to provide full-power ride-through, which is required by many applications. The conventional topology of a boost converter can be used to maintain the DC-Link voltage during voltage sag, and can either be integrated into new drives between the rectifier and the DC-Link capacitors or retrofitted as an add-on module. The add-on module is used to retrofit existing drives with ride-through capabilities. Besides energy storage systems, some other devices Constant voltage transformers (CVT), DVR may be used to solve Electric Power Quality problems. It may be seen that the ASD’s can withstand a reduction in the line voltage up to 85% of nominal value for an extended duration of time. Specifies the required voltage sag tolerance for semiconductor fabrication equipment. SEMI F47 requires that semiconductor processing equipment tolerate voltage sags connected onto their AC power line. They must tolerate sags to 50% of equipment nominal voltage for duration of up to 200 ms, sags to 70% for up to 0.5 seconds, and sags to 80% for up to 1.0 second.

BASIC CONTROLLED SCHEME

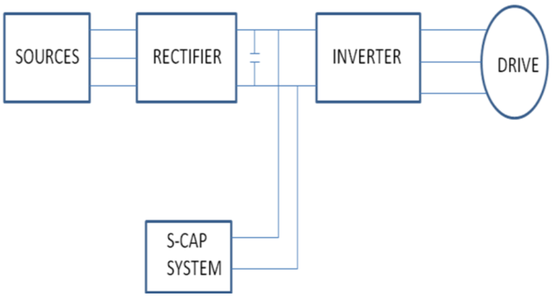

Fig No. 01 Basic Controlling Scheme

1.2 PROPOSED TOPOLOGIES

The objective of this section is to investigate the performance of an ASD's under three-phase symmetrical and unsymmetrical fault leading to balanced and unbalanced voltage sag at PCC. The proposed topology is designed by using supercapacitor as energy storage device along with boost converter across DC-Link as a ride-through alternative for ASD's. The performance of ASD's under various fault conditions has been simulated using MATLAB Simulink Power System Block set tool box. The functional block diagram is shown in Figure 4. A three-phase programmable voltage source feeds the power bus to PCC through series impedance (taken as resistance of 0.1 ohm assuming the length of line to be very small). Two independent feeders are connected at this PCC bus; one feeds the ASD's and the other is connected to the load. The faults are created at the load feeder to study the impact of voltage sags on the ASD's connected at the same PCC. The shunt impedance method has been used to generate voltage sags. At the time of faults the fault current flows through the impedance leading to a voltage drop across it, thereby causing voltage sags at PCC.

2.1 ANALYSIS OF SYMMETRICAL AND UNSYMMETRICAL FAULTS.

SYMMETRICAL

The classification of different types of voltage sags such as type A,B,C,D, E Voltage sag of Type A occurs because of balanced three-phase faults or power failure. This type of voltage sag is the most severe. Voltage sags of type A are symmetrical, all phases experience the same retained voltage and phase-angle jump. It results in the reduction of the voltage on the DC-Link which is proportional to the AC source voltage. The under-voltage or over current protection on the DC-Link may trip the ASD's.

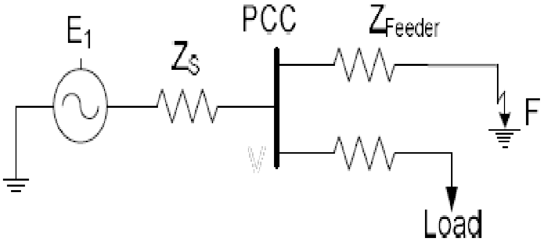

Fig.02 Basic model for fault analysis

Basic model for fault analysis for a symmetric three-phase fault the voltage at the Point-of-Common-Coupling (PCC) can be estimated using a simple voltage-divider model represented by the equation (3). In this case the fault impedance is not considered.

$$V = \frac{Z_{Feeder}}{Z_{Feeder+Z_S}} E_1 ------------ (3)$$

Here V is the retained voltage at PCC, E1 is the pre-fault voltage in phase A, Z Feeder is the feeder impedance and ZS is the source impedance.

UNSYMMETRICAL FAULTS

A phase to ground fault will result in a type B. A phase to phase fault results in a type C. If the voltage sag is of Type B or Type C, the circuit will behave as a single-phase rectifier. Even 10% voltage sag will result in a single-phase operation of the three-phase diode rectifier. The voltage between the two non faulted phases is unaffected and the DC Link voltage will not be reduced, however the current amplitude will increase. The same amount of energy must be transferred, but now in two pulses instead of six pulses. The peak value of the current will be 200% larger, and may cause an over-current or a current unbalance. The over-current or unbalance protection may trip the ASD's. A phase angle jump will affect the phase voltages and the DC-Link voltage. For sag magnitude of 50%, the DC-Link voltage does not drop below 70%, even for a small capacitance. This is because there is at least one phase that is still at 100% magnitude, and this phase stabilizes the DC-Link voltage.

If there is a transformer that removes the zero-sequence between the fault location and the load for phase to ground fault, the voltage sag will be of type D. The voltage sags of type E, F and G are due to a two phase to ground fault. For sag magnitude 50% in Type D, there is no phase which has 100% magnitude and, therefore, the effect is more harmful on the DC-Link. In case of type B, C, D or E voltage sag, input rectifier passes into single-phase operations with the consequences such as input current distortion and DC voltage ripple increase with dominant component at double frequency and with average voltage reduction in C type voltage sag case. Consequently torque contains the second and fourth harmonic components along with the fundamental. The motor torque oscillatory component presence can leads to mechanical resonance exciting in coupled multi-motor drives besides noise increase, for e.g. in paper production machines. Thus, the unsymmetrical faults lead to three major negative effects that unbalanced input voltages can have on ASD's performance. :

a) Significant input current unbalances which stresses the diode bridge rectifiers and input protective devices such as fuses, contactors and circuit breakers.

b) Injects a second harmonic voltage component on the DC-Link voltage which increases the electrical stresses on the DC-Link choke inductor (if used) and the DC-Link electrolytic capacitors. It potentially shortens the capacitor lifetime.

c) May give rise to ripple torque of magnitude double the fundamental frequency of induction machine which increases the mechanical and thermal stresses.

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TYPE OF FALUTS

SR.NO	DIP TYPE	FAULT TYPE
1	A	Three Phase
2	B	Single Phase to Ground
3	C	Phase to Phase
4	D	Phase to Phase (Delta Connected Load)

Table No. 2.1

2.2 PRINCIPLE DIRECT-TORQUE CONTROLLED METHOD.

DTC provides very quick response with simple control structure and hence this technique is gaining popularity in industries. In DTC, stator flux and torque are directly controlled by selecting the appropriate inverter state. The stator currents and voltages are indirectly controlled hence no current feedback loops are required. Nearly sinusoidal stator fluxes and stator currents enable high dynamic performance even at standstill. The generic DTC scheme for a Voltage source PWM inverter-fed IM drive is shown in Fig.1. The scheme includes two hysteresis controllers. The stator flux controller imposes the time duration of the active voltage vectors, which move the stator flux along the reference trajectory, and the torque controller determinates the time duration of the zero voltage vectors which keep the motor torque in the predefined hysteresis tolerance band. At every sampling time the voltage vector selection block chooses the inverter switching state (SA, SB, SC) which reduces the instantaneous flux and torque errors.

(DTC) IM drives in speed- and torque-controlled application under voltage sag circumstances. DTC consists of a three-level Hysteresis comparator for torque control and a two-level hysteresis comparator for flux control. The main problem in DTC ASD applications is a high value of the torque ripple, which can be minimized by reducing the calculation time for the switching states or by using switching table

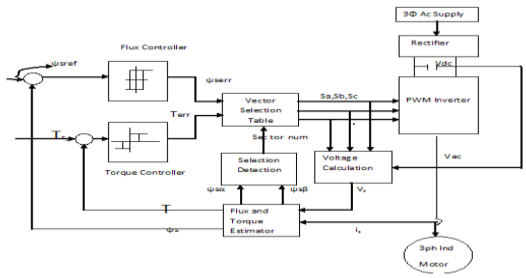


Fig.03 Direct Torque Control -Basic Control Scheme

2.3 PARAMETERS OF THE INDUCTION MOTOR

INDUCTION MOTOR	
3 phase, 220 Volt, 50Hz, 4 Pole	
RATED POWER	3 HP , 2238W
STATOR PHASE RESISTANCE	0.435 ohm,
ROTOR RESISTANCE	0.816 ohm
MUTUAL INDUCTANCES	$69.31e^{-3}$H
STATOR LEAKAGE INDUCTANCES.	$2e^{-3}$H
ROTOR LEAKAGE INDUCTANCES	$2e^{-3}$H.
ROTOR RESISTANCE	0.816 ohm
INERTIA (J)	0.089kgm^2
FRICTION FACTOR (f)	0.005
RATED SPEED	1800 rpm

Table No. 2.2

2.6 CONTROLLING PARAMETERS

Following are the Controlling parameters of a drive (3-phase-Induction Motor) during sag on input supply voltage due to power system faults unsymmetrical or load are increased suddenly on the adjustable speed drive

a. Line currents I_{abc} or I_{ryb},
b. Electromagnetic Torque T_e,
c. Rotor speed N_r,
d. DC –link voltage (V_{dc})

3.1 SYSTEM SIMULATION

Mat lab Simulation

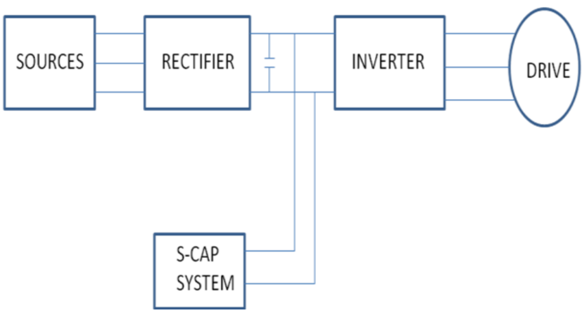


Fig. 3.1 Basic Control Scheme

The proposed topology has been designed in matlab 10. Shown in figure 3.1 and figure 3.2 used block set in matlab system, this system ASD operate in normal condition, it means there is no any unsymmetrical or symmetrical fault occur in PCC. So there is no issue to voltage dip or sag in dc link voltage (DC bus voltage). Because of that ASD parameters unaffected. Like stator voltage, speed, torque.

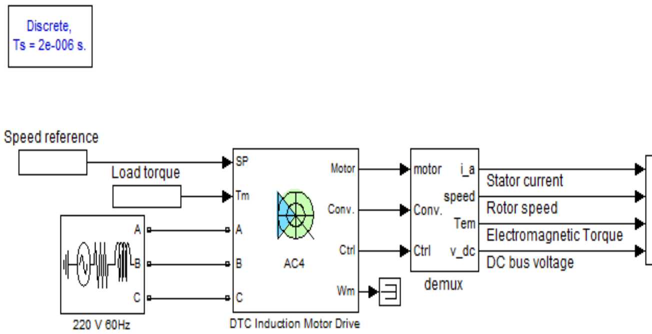


Fig. 3.2(a) Matlab Modeling ASD Using DTC

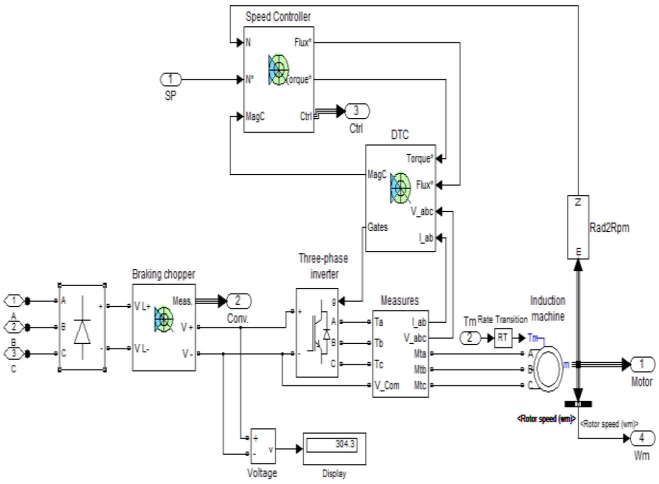
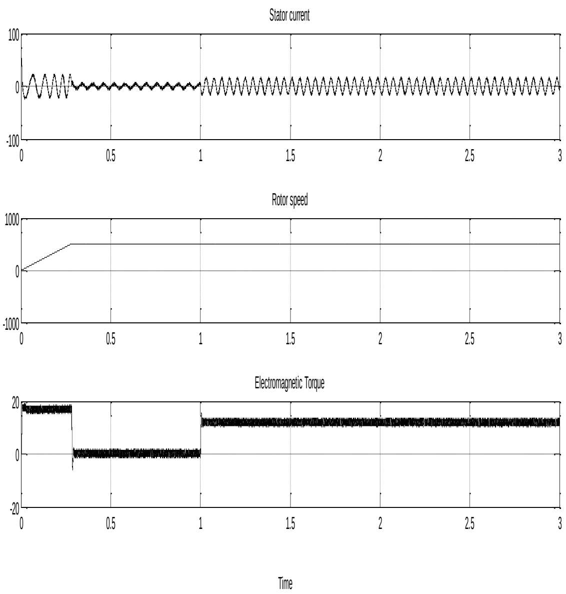


Fig. 3.2(b) Matlab Modeling ASD Using DTC



3.2 Performance of ASD's during Three-Phase Unsymmetrical Fault.

Fig.3.2 shows the behaviour of ASD's with an unsymmetrical fault (line- line fault). The source currents are unbalanced. The machine becomes unstable with large variations in DC-link voltage, which are reflected in the torque pulsations. With the application of Ultracapacitors, the performance of the machine improves having small torque pulsations. However, the three phase rectifier slips into the single-phase operation during the sag period.

During the fault period the three-phase uncontrolled rectifier operates in unbalanced mode and draws unbalanced peaky currents The DC-Link voltage drops from 195V to 155 V which is below the threshold setting at the DC-Link which may actuate the under voltage protection and trips the ASD's. The electromagnetic torque (Te) and the speed ($_{W}$r) drop slightly.

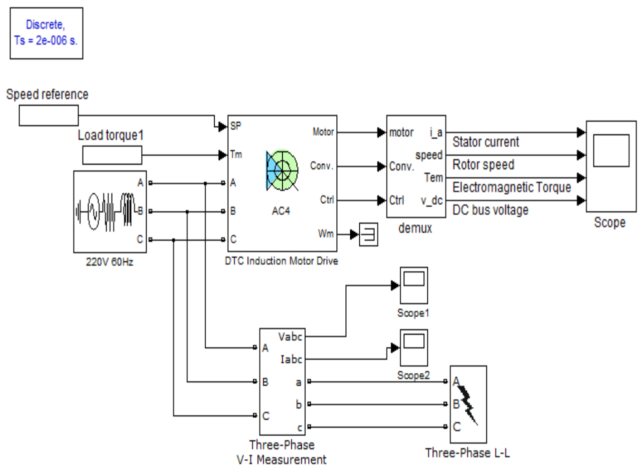


Fig.3.2 Matlab Modeling ASD duringUnsymmetrical Fault. (L-L)

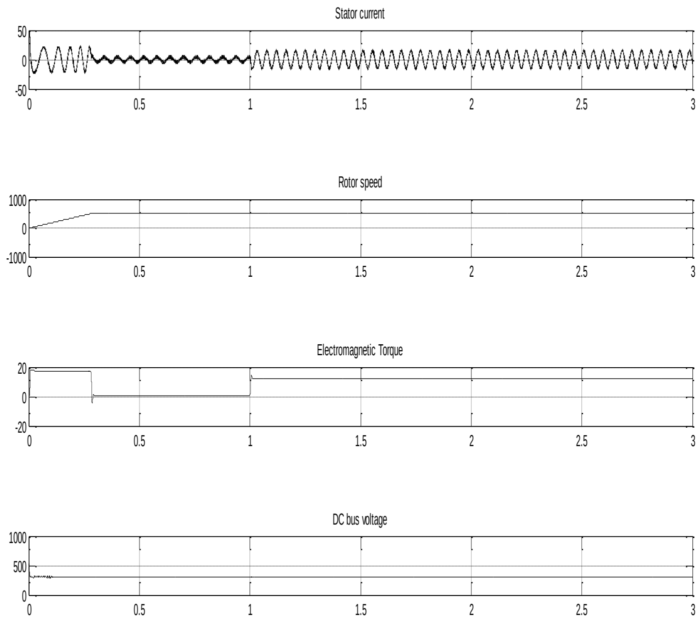


Fig.3.2 (a) Matlab Simulation of ASD under Unsymmetrical Fault

3.3 Performance of ASD's during Three-Phase Unsymmetrical Fault. (Line-Line)

Fig. shows the behavior of ASD's with an unsymmetrical fault (line- line fault). The source currents are unbalanced. The machine becomes unstable with large variations in DC-link voltage, which are reflected in the torque pulsations. With the application of Ultracapacitors, the performance of the machine improves having small torque pulsations. However, the three phase rectifier slips into the single-phase operation during the sag period.

During the fault period the three-phase uncontrolled rectifier operates in unbalanced mode and draws unbalanced peaky currents The DC-Link voltage drops from 195V to 155 V which is below the threshold setting at the DC-Link which may actuate the under voltage protection and trips the ASD's. The electromagnetic torque (Te) and the speed (wr) drop slightly.

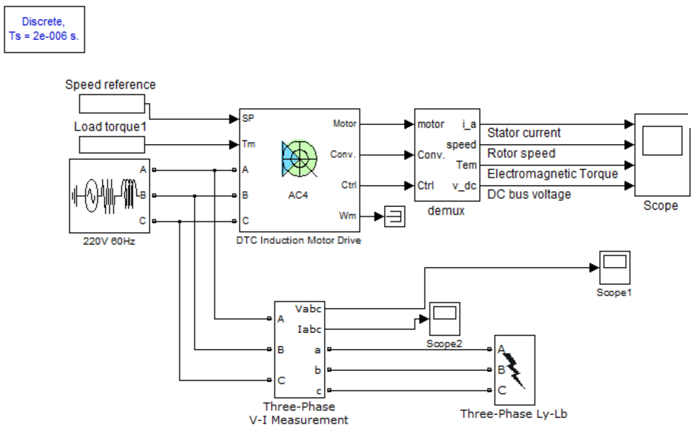


Fig.3.3 (a) Matlab Modeling ASD during Unsymmetrical Fault. (Ly-Lb)

3.4 Performance of ASD's during Double Line to Ground Faults.

The simulation results during double line to ground fault are shown in Figure3.4(a) Simulated results shows that the

Fig.3.2(c) Matlab Simulation of ASD under Normal

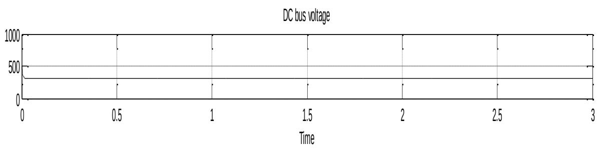


Fig.3.2 (d) Matlab Simulation of ASD under Normal Condition (DC Bus Voltage)

amplitude of line voltage 'ry' drops to a value of about 40% of the pre-event voltage and that of 'yb' and 'br' drops to 80% of the pre-event voltage. During the fault period the three-phase uncontrolled rectifier operates in unbalanced mode and draws unbalanced peaky currents The DC-Link voltage drops from 195V to 155 V which is below the threshold setting at the DC-Link which may actuate the under voltage protection and trips the ASD's. The electromagnetic torque (Te) and the speed (wr) drop slightly as shown in Figure . It can be observed that the effective motor current during the fault period increases so as to maintain the desired torque.The simulation results under unsymmetrical fault condition are shown in Figure.3.4

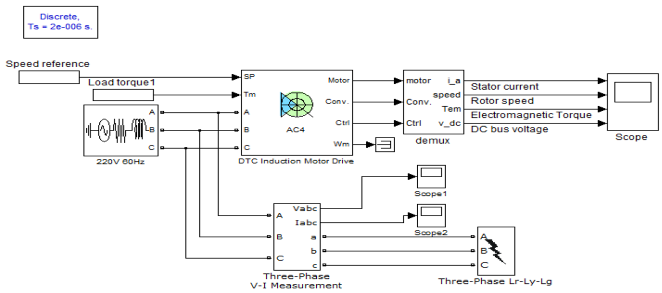


Fig.3.4 (a) Matlab Modeling ASD's during Double Line to Ground Faults.

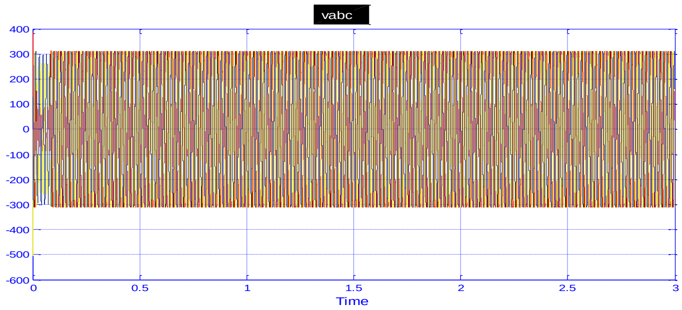


Fig.3.4 (b) Three phase Voltage under unsymmetrical Fault condition.

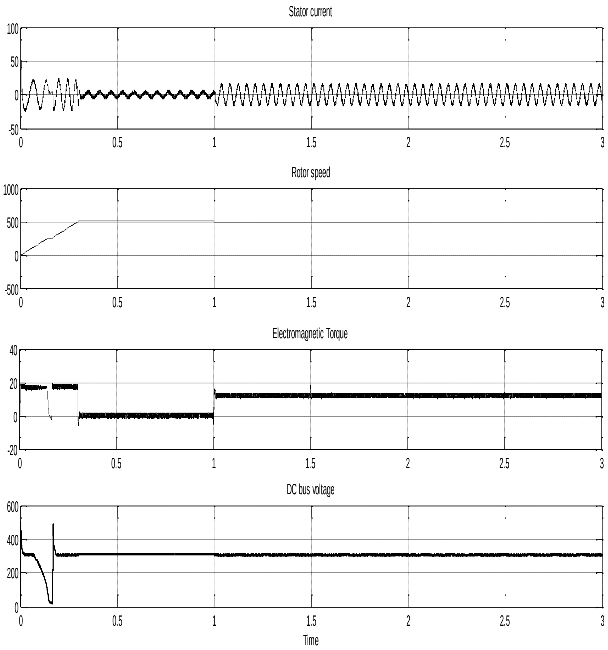


Fig.3.4 Matlab simulation of ASD's during Double Line To Ground Faults

3.5 Performance of ASD's during Double Line to Ground Faults with Ultracapacitor.

The simulation results during double line to ground fault are shown in Figure.3.5 Simulated results shows in figure 3.5(a) that the amplitude of line voltage '*ry*' drops to a value of about 40% of the pre-event voltage and that of '*yb*' and '*br*' drops to 80% of the pre-event voltage. During the fault period the three-phase uncontrolled rectifier operates in unbalanced mode and draws unbalanced peaky currents The DC-Link voltage drops from 195V to 155 V which is below the threshold setting at the DC-Link which may actuate the under voltage protection and trips the ASD's. The electromagnetic torque (*Te*) and the speed (*wr*) drop slightly as shown in Figure3.4It can be observed that the effective motor current during the fault period increases so as to maintain the desired torque.

The simulation results under unsymmetrical fault condition are shown in Figure 3.5 with ultra capacitor as a ride-through capability connected across DC-Link using a buck-boost Converter. It is clearly seen from Figure, the ultracapacitor bank provides ride-through during the fault as well as post fault; since there is no inrush current after fault recovery in figure 3.5(a).

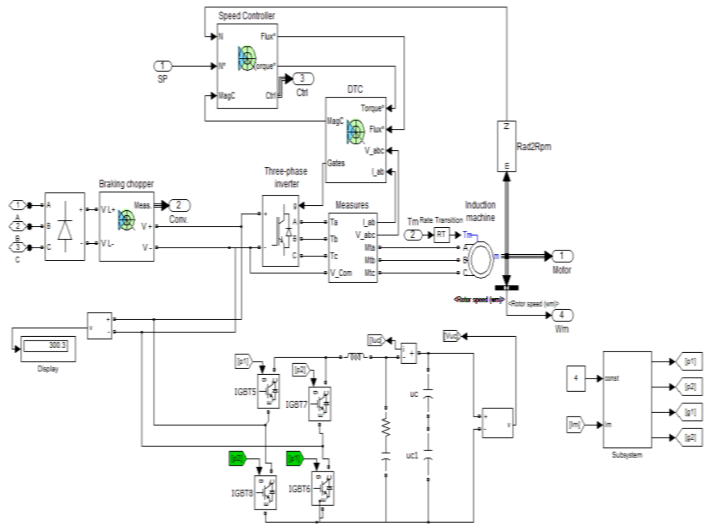


Fig.3.5 Matlab Modeling of ASD Double Line to Ground Faults ride through using Ultracapacitor

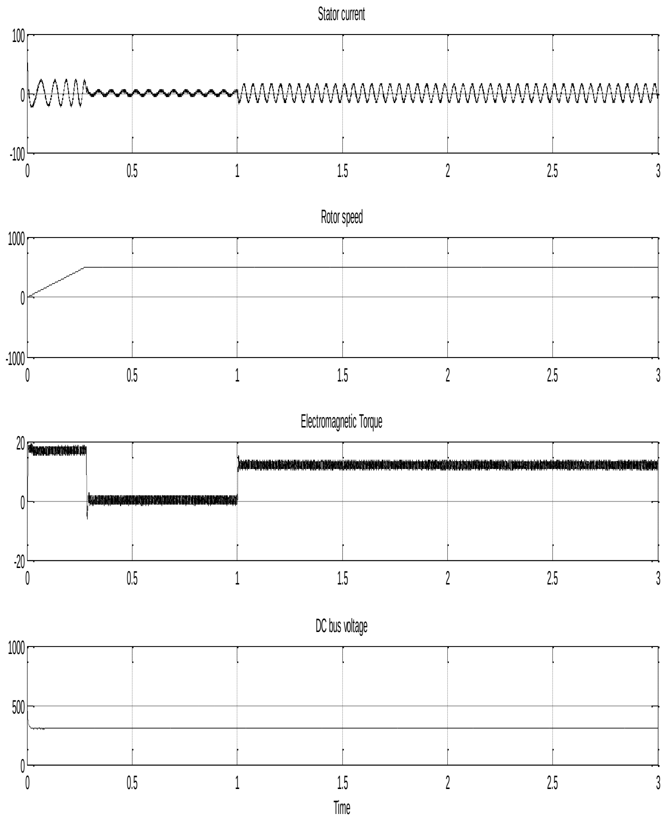


Fig.3.5 (a) Matlab simulation Result of ASD's during Double Line to Ground Faults ride through using Ultracapacitor,

CONCLUSION

Modern ASDs can have different behaviour under voltage Sag, in terms of momentary tripping or partial performance Degradation. This paper, based on analytical analysis, Predicts IM drives' response in case of SLGFs caused voltage sags with respect to different control schemes. High-performance drives (with DTC algorithm), owing to inner current/torque control loops, are less sensitive to voltage sag occurrence, particularly drives with traditional DTC technique with hysteresis

RESULT:

The objective of result to investigate the performances of an ASD under various power system Fault figures 3.2(a) and 3.4(a) shown the performances of ASD with the proposed scheme during unbalanced condition voltage sag Figure3.2.2 and 3.3.1 line to line fault and double line To ground fault. The simulation have been carried out to get three phase voltage Vryb(Vr,Vy,Vb) , electromagnetic torque (Te) , rotor speed(wr) and DC bus voltage (Vdc) respectively.

The matlab simulation results during double line to ground fault shown in figure 3.4(f). amplitude of the line voltage drop 'ry' drops to value of about 40% to 60%(120V to 100V) prevent voltage 'yb' 80% (240V) prevent voltage during 0 to 0.5 sec. during the fault period the three phase controlled rectifier operates in unbalanced mode draws unbalanced peak current the DC link voltage drop from 195V to 155V.

The simulation results under unsymmetrical fault condition are shown in Figure 3.5(a) Ultracapacitor as a ride-through capability connected across DC-Link using a buck-boost Converter. It is clearly seen from Figure 3.5(a) the ultracapacitor bank provides ride-through during the fault as well as post fault; since there is no inrush current after fault recovery.

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