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EFFECT OF VOLTAGE SAG OF INDUCTION MOTOR

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ABSTRACT

In this paper Power quality issues that affect the induction motor behaviour are voltage sag and their impact on customer loads constitute the most prevalent power quality problem in various type of industry (like spinning, rolling ,textile etc.).The impact of most severe symmetrical type voltage sag (type A) on an induction motor drive is analyzed with varying load and also duration of time varying at fixed load 75% of total load. The simulation results are provided to describe the load and time varying performances (speed and power drawn profile) of the motor under voltage sag. The results are taken with induction motor connected to three phase supply directly i.e. without any control in supply transients. Matlab based simulation model is used to implement the said control. The effect of voltage sag in the operation of mat lab based simulation model is analyzed. To enhance voltage variation capability of induction motor and the effect of voltage sag.

KEYWORDS: Power Quality, Induction Motor, Voltage Sag.

I. INTRODUCTION

Voltage sag is one of the biggest problems in power quality, having a particular influence in motors. The effect of power quality in electric motor is very important; for example, more than 70% of the electricity consumption in the developed countries is used in electric motor. The main effects produced by voltage sag in electric motors are speed loss, peak current and torques that appear with the voltage recovery.

This type of problems is intensified today because power requirements of sensitive equipment and voltage sag have increased drastically during recent years. The actual trend is anticipated to be maintained in the near future. Besides, the system should be kept operating until the last extreme situation, since any system dropout would have very high economic consequences.

II. SIMULINK MODEL FOR INDUCTION MOTOR PERFORMANCE ANALYSIS DURING VOLTAGE SAG

We have taken three phase supply as Va,Vb Vc (Va is taken as reference) and subtracting faulted voltages as Va', Vb' and Vc' (magnitude as well as phase) from input voltages Va, Vb, Vc respectively for some duration by using repeating sequence. Resultant there is some dip occur in output voltage for that duration for which we are subtracting Va',Vb ',Vc' respectively from input voltages. In the MATLAB environment using type A voltage sag. In this we analyze normal condition without voltage sag ,20% voltage sag,40%voltagee sag and variation in time duration for different load condition (25%,50%,75% and 100%)

Machine Rating Information

Table 4.8: Machine Rating

Voltage	420 V
Power	746W
Frequency	50Hz
Stator Resistance	11.125 Ohm
Stator Inductance	33.36mH
Rotor Resistance	8.8938ohm
Rotor Inductance	33.36mH

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Mutual Inductance	490mH
Inertia(without load)	0.0018 Kg / Square meter
Power Factor	0.8
No. Of Poles	2
Friction Factor	0

4.5.1. Normal Condition

Figure 4.11 depict normal operating condition for voltage sag .The effect voltage sag on induction motor. Starting Current drawn by the induction motor is 1.5 to2.0 time of motor rated full load current capacity .when load applied on induction motor respectively 25%, 50%, 75%, and 100%. Mean while time period is 1-2 s, 2-3 s, 3-4s, and 4-5ms respectively. The current drawn by the motor is increased and finally it raises the full load current capacity of induction motor drive. During this period load torque is also increased. Finally speed is decreased respectively. Power drawn by is also increased.

Table 4.9: Variation of different parameter during Normal voltage sag condition

Time duration	Load applied	speed	Power drawn
1-2 sec	25%	2942 rpm	189 watt
2-3 sec	50%	2880 rpm	363 watt
3-4 sec	75%	2810 rpm	548 watt
4-5 sec	100%	2728 rpm	748.33 watt

4.5.2. 20% Voltage Sag Condition

Figure 4.12 depict when voltage sag occur in the system (20% voltage sag).Machine performance during this condition.

When voltage sag come in the time period 1.5ms-1.8ms at 25% load .in above said condition current drawn by the induction motor drive is slightly decreases in comparison with normal voltage condition after this instantaneous increase in the current is in the stable .when the sag is removed current is increased. Torque is also reduced when voltage sag come in the supply voltage .After removing the sag load torque is slightly increased and then is in stable condition. Speed is also decreases when the sag comes in supply voltage after sag removes speed is normal and then is in stable position. Power drawn by the motor is instantaneously increase and then in stable condition. After sag condition power drawn by the motor is increase momentary and then in stable condition.

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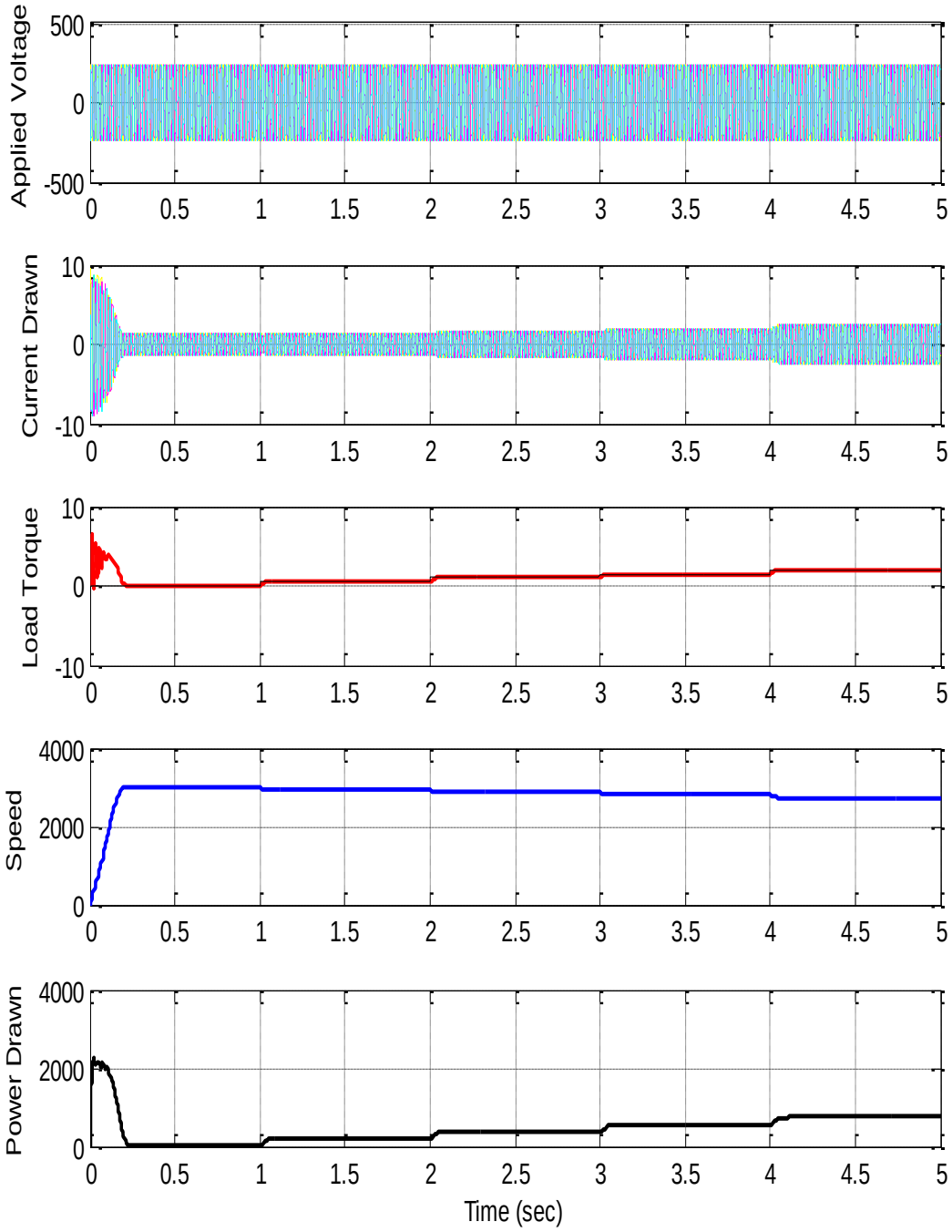

Figure: 4.11. Normal condition without sag

When voltage sag come in the time period 2.5ms-2.8ms at 50% load .Above said condition current drawn by the induction motor drive is decreases more than first condition after removal the voltage sag current is increased after that is in stable condition. Torque is also reduced when voltage sag come in the supply voltage .After removing the sag torque is increased and then is in stable condition. Speed is also decreases when the sag comes in supply

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voltage after sag condition speed is increased and then is in stable position. Power drawn by the motor is increase and then in stable condition.

When voltage sag comes in the time period 3.5ms-3.8ms at 75% load .in above said condition current drawn by the induction motor drive is decreases more than first condition after removal the voltage sag current is increased more than first two conditions after that is in stable condition. Torque is also reduced in large when voltage sag come in the supply voltage .after removing the sag load torque is increased and then is in stable condition. Speed is also decreases when the sag comes in supply voltage after sag condition speed is increased and then is in stable position. Power drawn by the motor is increase in large quantity and then in stable condition. After sag condition power drawn by the motor is increase in large quantity and then in stable condition.

When voltage sag come in the time period 4.5ms-4.8ms at 100% load in above said condition current drawn by the induction motor drive is decreases more than above said condition after removal the voltage sag current is increased more than above three condition after that is in stable condition .load torque is also reduced in large when voltage sag come in the supply voltage .after removing the sag load torque is increased in large proportions and then is in stable condition. Speed is also decreases in large ratio when the sag comes in supply voltage after sag condition speed is increased in large amount and then is in stable position. Power drawn by the motor is increase in large quantity and then in stable condition. After sag condition power drawn by the motor is increase in large quantity and then in stable condition.

Table 4.10: Variation of different parameter during 20% voltage sag condition

Time duration	Load applied	speed	Power drawn
1.5-1.8 sec	25%	2586 rpm	430 watt
2.5-2.8 sec	50%	2516 rpm	630 watt
3.5-3.8 sec	75%	2480 rpm	870 watt
45-4.8 sec	100%	2446 rpm	1180 watt

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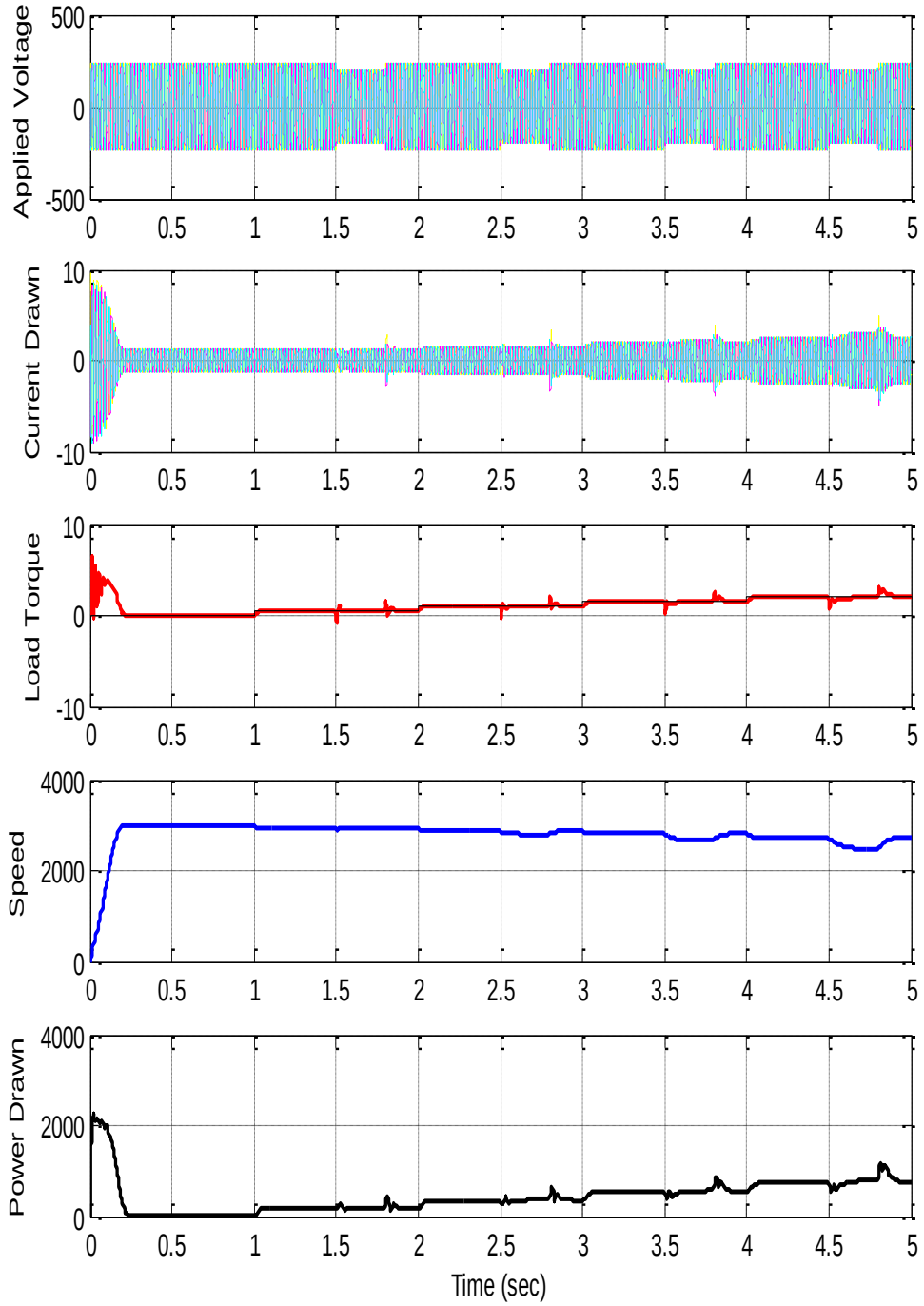

Figure 4.12: 20% voltage sag

4.5.3. 40%Voltage Sag Condition

Figure 4.13 depict when voltage sag occur in the system 40% Voltage sag .Machine performance during this condition.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

When voltage sag come in the time period 1.5ms-1.8ms at 25% load .In above said condition current drawn by the induction motor drive is slightly decreases in comparison with normal voltage condition after this instantaneous increase in the current is in the stable .when the sag is removed current is increased .load torque is also reduced when voltage sag come in the supply voltage .after removing the sag load torque is slightly increased and then is in stable condition. Speed is also decreases when the sag comes in supply voltage after sag condition speed is increased slightly and then is in stable position. Power drawn by the motor is instantaneously increase and then in stable condition. After sag condition power drawn by the motor is increase momentary and then in stable condition. .

When voltage sag comes in the time period 2.5ms-2.8ms at 50% load .in above said condition current drawn by the induction motor drive is decreases more than first condition after removal the voltage sag current is increased after that is in stable condition. Torque is also reduced when voltage sag come in the supply voltage .after removing the sag load torque is increased and then is in stable condition. Speed is also decreases when the sag comes in supply voltage after sag condition speed is increased and then is in stable position. Power drawn by the motor is increase and then in stable condition. After sag condition power drawn by the motor is increase and then in stable condition.

Table.4.11: variation of different parameter during 40% voltage sag condition

Time duration	Load applied	speed	Power drawn
1.5-1.8 sec	25%	2828 rpm	730 watt
2.5-2.8 sec	50%	2580 rpm	1014 watt
3.5-3.8 sec	75%	2160 rpm	1500 watt
4.5-4.8 sec	100%	1464 rpm	2040 watt

When voltage sag come in the time period 3.5ms-3.8ms at 75% load .in above said condition current drawn by the induction motor drive is decreases more than first condition after removal the voltage sag current is increased more than first two condition after that is in stable condition .load torque is also reduced in large when voltage sag come in the supply voltage .after removing the sag load torque is increased and then is in stable condition. Speed is also decreases when the sag comes in supply voltage after sag condition speed is increased and then is in stable position. Power drawn by the motor is increase in large quantity and then in stable condition. After sag condition power drawn by the motor is increase in large quantity and then in stable condition.

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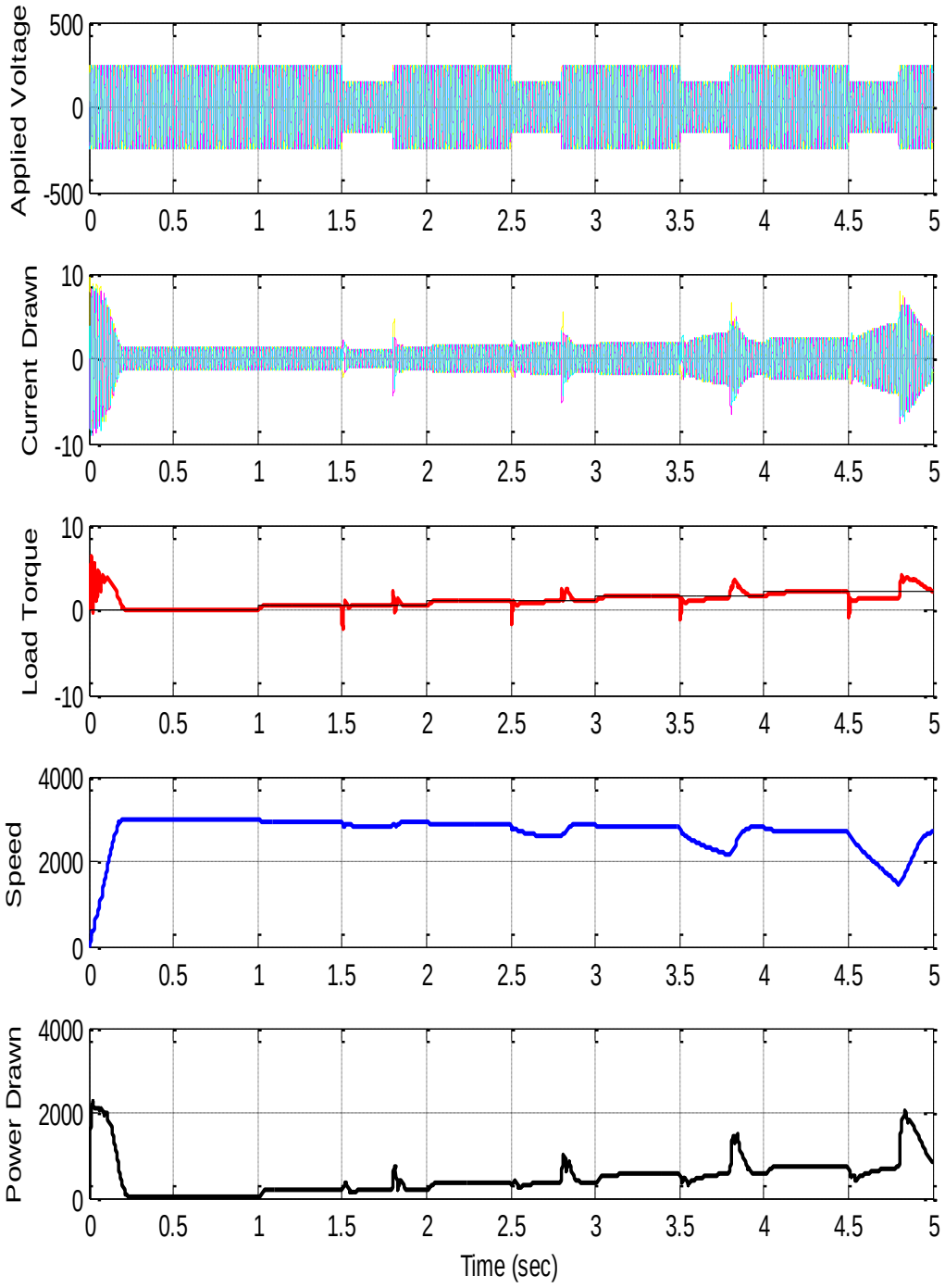

Figure 4.13: 40% voltage sag

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CODEN: IJESS7

4.6. MATLAB/Simulink Model for Induction Motor Performance Analysis during Variation in Time

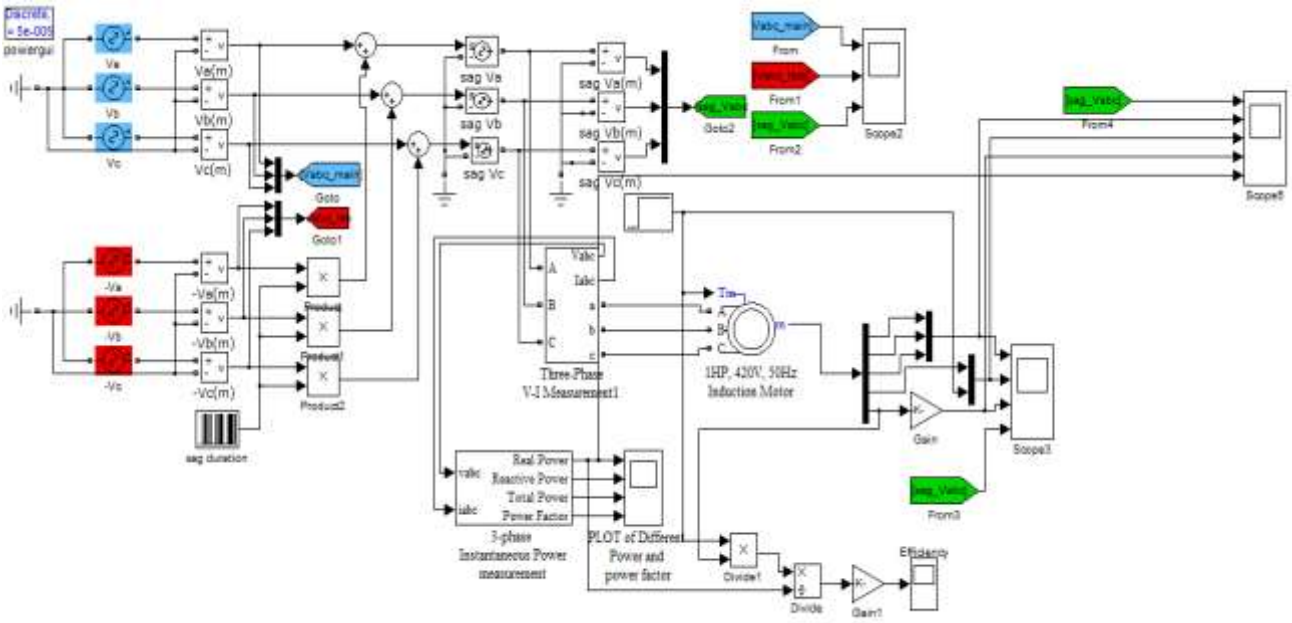

Figure 4.14: Simulink Model for Induction Motor Performance Analysis during Time Variation

4.6.1. Varying sag duration Condition

Figure 4.15 depict when voltage sag occur in the system (voltage duration).Machine performance during this condition.

When voltage sag come in the time period 1.4ms-1.5ms at 75% load in above said condition current drawn by the induction motor drive is slightly decreases in comparison with normal voltage condition after this instantaneous increase in the current is in the stable .when the sag is removed current is increased .load torque is also reduced when voltage sag come in the supply voltage .after removing the sag load torque is slightly increased and then is in stable condition. Speed is also decreases when the sag comes in supply voltage after sag condition speed is increased slightly and then is in stable position. Power drawn by the motor is instantaneously increase and then in stable condition. After sag condition power drawn by the motor is increase momentary and then in stable condition.

Table 4.12: Variation of Time during sag duration condition

Time duration	Load applied	speed	Power drawn
1.4-1.5 sec	75%	2586 rpm	1000 watt
2.4-2.6 sec	75%	2516 rpm	1100 watt
3.4-3.7 sec	75%	2480 rpm	1120 watt
4.4-4.8 sec	75%	2446 rpm	1135 watt

When voltage sag come in the time period 2.4ms-2.6ms at 75% load .in above said condition current drawn by the induction motor drive is decreases first condition after removal the voltage sag current is increased after that is in stable condition .load torque is also reduced when voltage sag come in the supply voltage .after removing the sag load torque is increased and then is in stable condition. Speed is also decreases when the sag comes in supply voltage after sag condition speed is increased and then is in stable position. Power drawn by the motor is increase and then in stable condition. After sag condition power drawn by the motor is increase and then in stable condition.

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Impact Factor: 5.164
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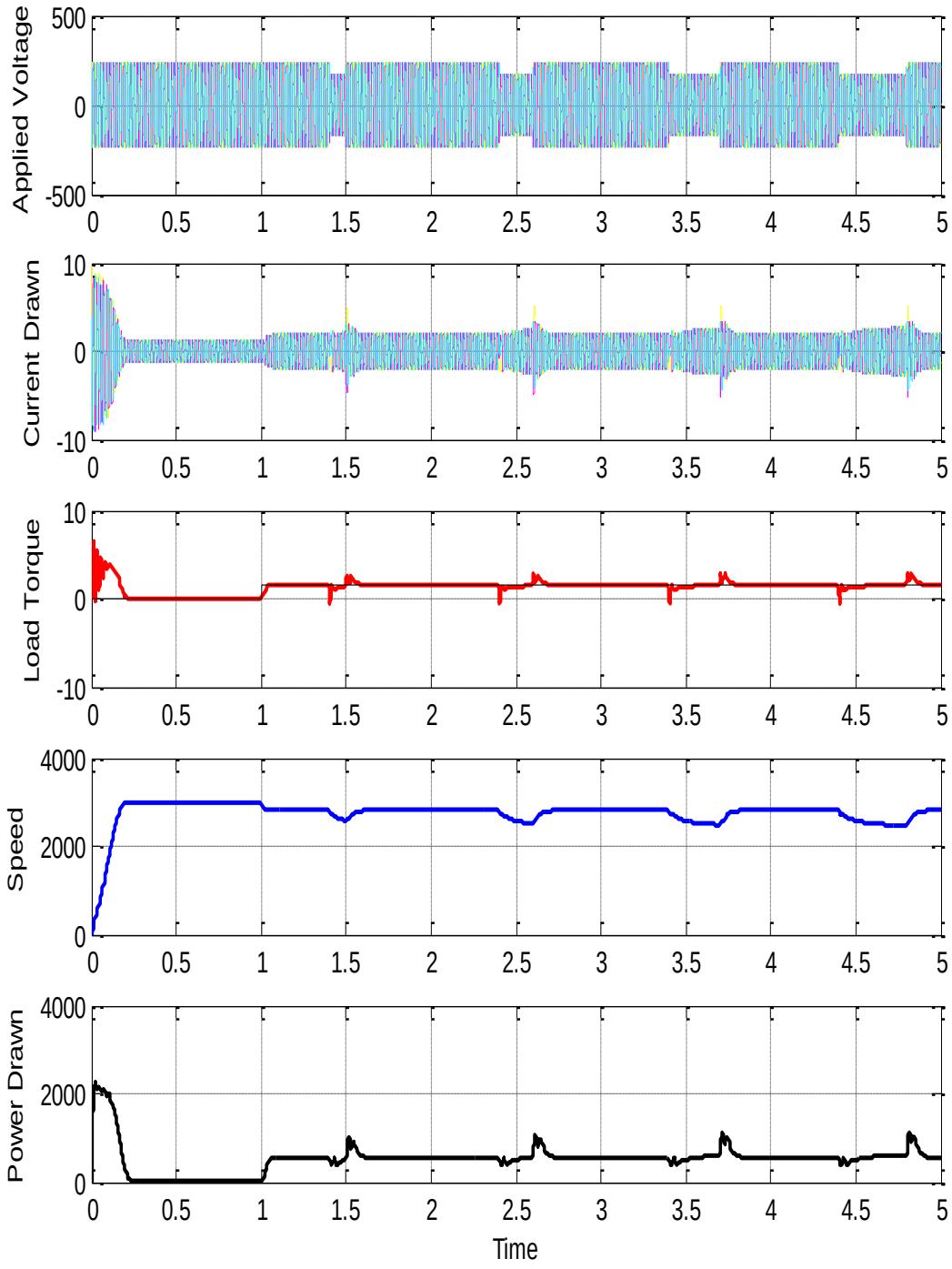

Figure 4.15: Varying time duration

When voltage sag come in the time period 3.4ms-3.7ms at 75% load .in above said condition current drawn by the induction motor drive is decreases more severely condition after removal the voltage sag current is increased severely than first two condition after that is in stable condition .load torque is also reduced in severely when

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Impact Factor: 5.164
CODEN: IJESS7

voltage sag come in the supply voltage .after removing the sag load torque is increased and then is in stable condition. Speed is also decreases when the sag comes in supply voltage after sag condition speed is increased and then is in stable position. Power drawn by the motor is increase in large quantity and then in stable condition. After sag condition power drawn by the motor is increase in large quantity and then in stable condition.

When voltage sag come in the time period 4.4ms-4.8ms at 75% load in above said condition current drawn by the induction motor drive is decreases dangerously low than above said condition after removal the voltage sag current is increased dangerously high after that is in stable condition .load torque is also reduced in large when voltage sag come in the supply voltage .after removing the sag load torque is increased in large proportions and then is in stable condition. Speed is also decreases in large ratio when the sag comes in supply voltage after sag condition speed is increased in large amount and then is in stable position. Power drawn by the motor is increase in large quantity and then in stable condition. After sag condition power drawn by the motor is increase in large quantity and then in stable condition.

4.7 Variation of Sag Depth and Duration

In the tables shown below in this section, we can see the effect of sag duration and sag depth with variation of load.

NOTE: In the tables shown below,

X= depicts that the system is running without reduction in speed and torque
Y =depicts that the system is running with reduction in speed and torque
F =depicts that the system gets fail or shutdown

Case 1: When the motor is 100% loaded, we can see that for very less duration of sag, there is no effect when the depth is 90%-70%. As the duration is increased and sag depth is high, then also there is no effect of sag. When the duration is increased and depth is also decreased from 60%-10%, then there will be some effect on the motor and when the duration is very high and depth is low, the motor will get shutdown.

Table 4.13: Variation with 100% load

SAG DEPTH →

SAG DURATION ↓

	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
0.5T	X	X	X	X	X	X	X	X	X
1T	X	X	X	X	X	X	X	X	Y
2T	X	X	X	X	X	Y	Y	Y	Y
3T	X	X	X	Y	Y	Y	Y	Y	F
4T	X	X	X	Y	Y	Y	Y	F	F
5T	X	X	X	Y	Y	Y	F	F	F
10T	X	X	X	Y	Y	F	F	F	F
15T	X	X	X	Y	F	F	F	F	F
20T	X	X	X	F	F	F	F	F	F
25T	X	X	X	F	F	F	F	F	F

Case 2: When the motor is 75% loaded, we can see that there is no effect of duration of sag when the depth is 90%-60%. As the duration is increasing and depth is decreasing there will be some effect on the motor when the depth is decreased from 50%-10% and when the duration is very high and sag depth is low, the system will get shutdown.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 4.14: Variation with 75% load

SAG DEPTH →

SAG DURATION ↓	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
0.5T	X	X	X	X	X	X	X	X	X
1T	X	X	X	X	X	X	X	X	Y
2T	X	X	X	X	X	Y	Y	Y	Y
3T	X	X	X	X	X	Y	Y	Y	F
4T	X	X	X	X	Y	Y	Y	F	F
5T	X	X	X	X	Y	Y	F	F	F
10T	X	X	X	X	Y	F	F	F	F
15T	X	X	X	X	Y	F	F	F	F
20T	X	X	X	X	Y	F	F	F	F
25T	X	X	X	Y	F	F	F	F	F

Case 3: When the motor is 50% loaded, we can see that there is no effect of duration of sag when the depth is 90%-50%. As the duration is increasing and depth is decreasing there will be some effect on the motor when the depth is decreased from 40%-10% and when the duration is very high and sag depth is very low, the system will get shutdown.

Table 4.15: Variation with 50% load

SAG DEPTH →

SAG DURATION ↓	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
0.5T	X	X	X	X	X	X	X	X	X
1T	X	X	X	X	X	X	X	X	X
2T	X	X	X	X	X	X	X	X	Y
3T	X	X	X	X	X	Y	Y	Y	Y
4T	X	X	X	X	X	Y	Y	Y	Y
5T	X	X	X	X	X	Y	Y	Y	Y
10T	X	X	X	X	X	Y	Y	Y	F
15T	X	X	X	X	X	Y	Y	F	F
20T	X	X	X	X	X	Y	Y	F	F
25T	X	X	X	X	X	Y	F	F	F

Case 4: When the motor is 25% loaded, we can see that there is no effect of duration of sag when the depth is 90%-40%. As the duration is increasing and depth is decreasing there will be some effect on the motor when the depth is decreased from 30%-10% and when the duration is very high and sag depth is too much low , the system will get shutdown i.e. in this case the system will get shutdown in very rare condition.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 4.16: Variation with 25% load

SAG DEPTH →

SAG DURATION ↓

0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1
X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	Y
X	X	X	X	X	X	X	Y	Y
X	X	X	X	X	X	Y	Y	Y
X	X	X	X	X	X	Y	Y	Y
X	X	X	X	X	X	Y	Y	Y
X	X	X	X	X	X	Y	Y	F
X	X	X	X	X	X	Y	Y	F

We conclude from the above four cases that

- With the decrease in load the chances of failure of motor gets reduce but this condition is not good as the system efficiency gets reduce with the reduction in load.
- There is no effect on the motor when the duration is very low and the sag depth is varied even if the load is varied.
- When the motor is fully loaded, there will be large effect of the variation of sag duration and depth

III. CONCLUSION

To avoid high financial losses in power system operations, the need to keep the process equipment running is of extreme importance. Any disruption can lead to downtime which can directly result in loss of production, revenues and profits. From various power quality disturbances, voltage sags are most frequent and result in highest financial loss because voltage sag cause frequent mal-operation of the equipment .The occurrence of voltage sag events is far more than the number of power interruptions. Therefore, for specific customers, the financial losses caused by voltage sag events may even be greater than the cost associated with power interruptions.

Voltage sag is a common power quality problem. Despite being a short duration (10ms to 1s) event, during which a reduction in the RMS voltage magnitude takes place, a small reduction in the system voltage can cause a serious consequence.

Faults in the system are the main reason for voltage sags in the power system. Along with the type and location of faults in the system characteristics of sag created in the system due to faults depend on the many parameters of circuit configuration.

Voltage sags have been mainly characterized by depth and phase-angle. This report presents a voltage sag characterization in terms of sag depth, sag duration and phase-angle. By using MATLAB/SIMULINK software, simulation result has been presented in terms of the magnitude, duration and phase-angle due to faults. This value enables a prediction of the fault of the event on most single-phase and three-phase equipment.

ABC classification was developed to analyze the propagation of sag or dip from transmission to distribution levels, when a disturbance propagates through Induction Motor.

The behaviour of Induction Motor Drives under different voltage sag conditions is studied in this report using MATLAB. Different types of Voltage sag are produced and applied to Induction Motor Drive system model under different loads. The variation of motor's current, speed, output torque and output power are analyzed during and after clearing voltage sags.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

The maximum reduction of voltage happens during voltage sag type A due to three-phase fault. For unsymmetrical types, E and G cause the maximum reduction and type B causes the minimum reduction of voltage.

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