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DETECTION, CHARACTERIZATION & ASSESSMENT OF VOLTAGE SAG FOR FAILURE MODE ANALYSIS OF EQUIPMENTS

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ABSTRACT

In this paper, voltage sag due to power system faults such as three-phase-to-ground, single-phase-to-ground, phase-to-phase and two-phase-to-ground are created in transmission line model for generation of different types of voltage sag[1]. This paper describes a methodology for voltage sag generation using Matlab/Simulink. It includes fault simulations for generation of different types of voltage sag using MATLAB Simulink, based on the Sim Power Systems toolbox[3].

This paper summarizes the results from a number of different voltage sag investigations. These investigations involve characterizing the voltage sag performance at a customer facility and evaluating equipment sensitivity to different voltage sag magnitudes and durations. Voltage sags are normally described by magnitude variation and duration[4]. This paper describes generation of voltage sags and classification of voltage sags. It gives the detail idea of how voltage sags are produced and their effects on the electronics and electrical equipments[1]. It described the basic reasons behind the interruption, damage and improper operation of equipments due to voltage sags.

This paper deals with generation of ITIC curve and area of vulneribility curve of personal computer,induction motor and DC drive using MATLAB simulation and programming.

Keywords-Voltage-Sag, Fault, Simulation, Transformer, Induction Motor Results (Waveforms).

I. INTRODUCTION

Voltage sags are considered one of the most harmful power quality disturbances, because they adversely affect the satisfactory operation of several types of end-user equipment[1]. This phenomenon is a sort duration reduction in rms value of voltage caused by events such as power system faults, load variations, transformer energization and the start of large induction motors. The most common cause of voltage sags is the flow of fault current through the power system impedance to the fault location[2]. Hence, power system faults in transmission or Distribution can affect respectively a large or small number of customers.

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A fault in a transmission line affects sensitive equipment up to hundreds of kilometers away from the fault. In this paper, the line fault model is simulated to obtain the different types of voltage sags. In addition, the characteristics of Voltage sag are briefly described[1].

A voltage sag is a momentary decrease in the rms voltage magnitude. A decrease in rms voltage for durations of 0.5 cycle to 1 min from 0.9 pu to 0.1 pu at the power frequency is voltage sag[4] . The duration of voltage sag is the time during which the rms value of voltage is under the threshold.

The Phase-angle jump of voltage sag is difference between the phase angle of the voltage during an event and the phase angle of the voltage before the event.Voltage sags are classified as rectangular and non-rectangular is Shape of voltage sag[4] . The Point-on-wave of sag initiation is phase-angle of the fundamental voltage wave at the instant of sag initiation.The Point-on-wave of voltage recovery is the phase-angle of the fundamental voltage wave at the instant of voltage recovery[3].

In this paper effect of voltage sag on personal computer,DC drive & induction motor is described using ITIC curve.the effect of magnitude of voltage sag,length of conductor & area of conductor is also described using area of vulneribilty curve.

II. IMPACT OF VARIOUS FACTORS ON VOLTAGE SAG

2.1 Voltage Level

Voltage level of every equipment is specified during manufacturing of equipment.When the equipment voltage value goes down due to some reason voltage sag occurs[9].The minimum voltage value of every equipment is fixed,below which which it cannot operate.along with the voltage value the duration till which the equipment operates normally at its minimum voltage is also considered[10].

2.2 Length of Conductor

Distance of fault from the equiopmant is also effect the voltage sag values[7].When the fault occurs near the equipment ,its effect on the voltage of equipment will be high and therefore the voltage sag percentage value lowers down i.e 20%,40% etc ,while when the fault occurs at long distance from the equipment its effect of equipment will be negligible therefore voltage sag value percentage value will be high, we say it as 100% sag[6].That means as the distance of fault occurance increases ,its effect on the equipment decreases.

2.3 Cross Sectional Area

Cross sectional area of conductor has inverse effect on voltage sag.If the conductor is low effect of lowering of voltage will be high i.e percentage esag wil be high and vice versa.Therefore while choosing the conductor for particular equipment it is necessary to keep in mind it area required.every conductor requires different area of conductor.

III IMPACT OF VOLTAGE SAG ON ELECTRICAL AND ELECTRONICS EQUIPMENT:

3.1 Personal Computers (PC)

Sensitivity of the PC to voltage sags is represented by characteristic curve provided by Information Technology Industry (ITI). It was published by Technical Committee 3 (TC3) of the Information Technology Industry Council, formally known as the Computer & Business Equipment Manufacturers' Association, (CBEMA The ITI (CBEMA) curve describe an AC input voltage envelope which typically can be tolerated (no interruption in function) by most Information Technology[11]

Equipment (ITE) like PC. The curve basically assumes nominal voltage to be 120 VAC RMS and it is meant for single phase ITE [IEEE 1100-1999][11]. Although it is mentioned in its scope that it is not intended to serve as a design specification for AC distribution systems but it is used by designers in many manufacturing companies.

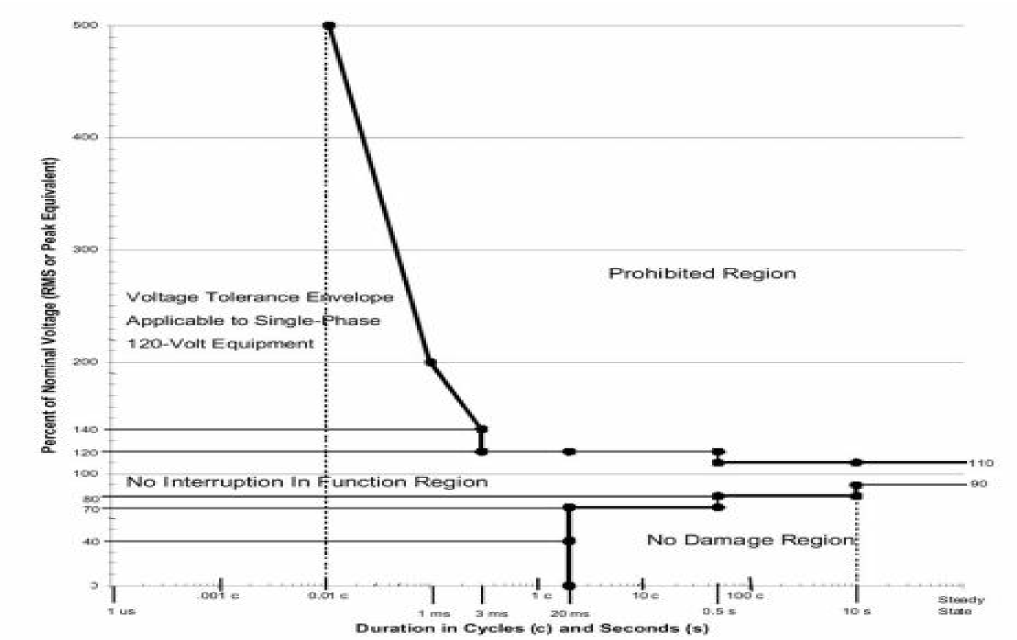

Fig 1. Characteristic curve of pc (iti curve)

3.2 Semi Conductor Devices (SD)

Semiconductor Equipment and Materials International (SEMI) offers international standards and recommendations for improving the voltage sag tolerance capabilities in equipment system design for semiconductor industries[13]. The SEMI F47-0200 standard specifies the required voltage sag ride-through for semiconductor fabrication equipment. It specifies set of minimum voltage sag immunity requirements for equipment used in the semiconductor industry[13]. Immunity is indicated in term of voltage sag duration (cycle/seconds) and voltage sag depth (percentage of the remaining nominal voltage). Minimum voltage sag immunity requirements are presented in the following graph.

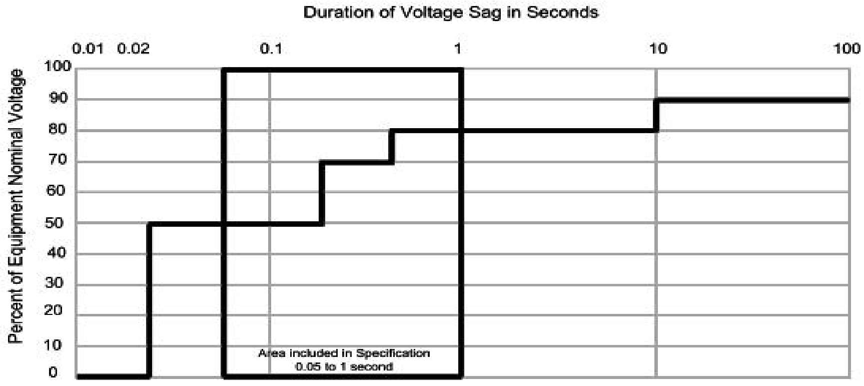

Fig 2: Recommended semi conductor equipment voltage sag ride through tolerance curve

3.3 Adjustable Speed Drive (ASD)

The main purpose of ASD is to control the speed of a synchronous or induction motor[15]. The change in behaviour of the ASD to voltage sag conditions can have a deep effect on the industrial operations involving ASD. The ASD must be able to work smoothly in order to avoid any disturbances for the sensitive loads. It should be immune to limited number of disturbances . The IEEE Standard 1346-1998 provides a methodology for the technical and economic analysis of compatibility of sensitive process equipment with an electric power system[14]. It also contains some examples of performance of sensitive devices to voltage sag events.

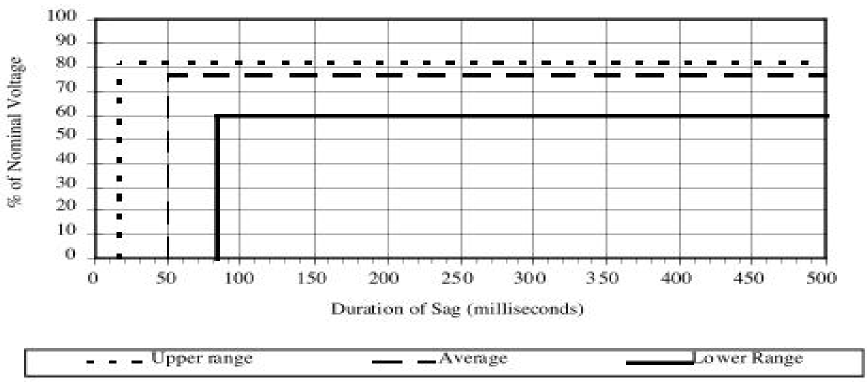

Fig 3:ASD voltage sag ride through tolerance curve

3.4 Programmable Logic Controllers (PLC)

The success of the modern industrial world lies within the automation of the processes. The automation of most of the elctromechanical processes in industries is done by digital microprocessor based device called PLC. Majority of the sensitive devices working in a process are given control signal by PLC[15]. Thus the smooth running of the industrial operation is dependent on successful operation of it. Voltage dip is one of the most critical power quality problems which can have a serious effect on the operation of PLC as it is quite susceptible to the voltage value[17].

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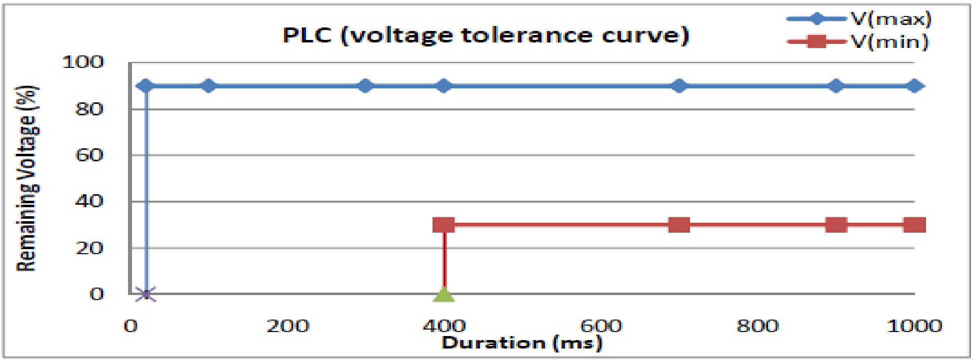

Fig 4:PLC Characteristics Curve

IV. SYSTEM DEVELPOMENT

Simulation model for analysis of sensitivity of three loads using area of vulnerability curve is shown below . MATLAB programming is used for generation of area of vulnerability curve.

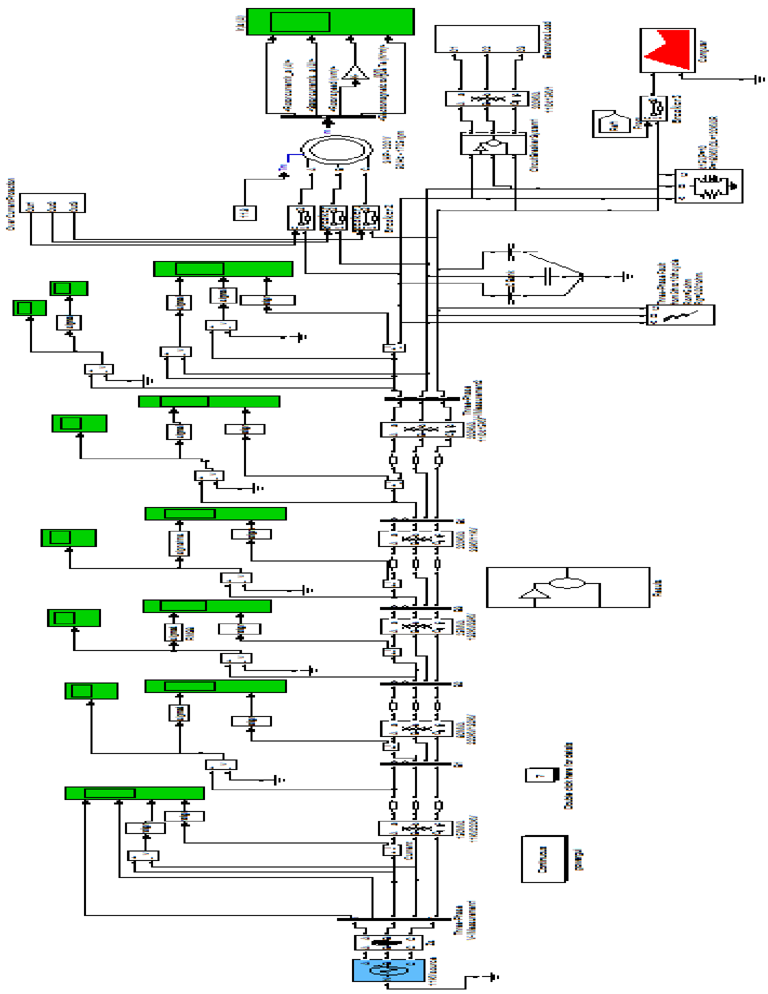

Fig 4.Simulink Model

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V MATLAB PROGRAM LINKED WITH THE SIMULATION MODEL:

1. PROGRAMMING FOR GENERATION OF ITI CURVE

```
%ITI curve
function [sys,x0,str,ts]=ITIC(t,x,u,flag)
switch flag,
case 0
  [sys,x0,str,ts]=mdlInitializeSizes;
case 3
  sys=mdlOutputs(t,x,u);
case {1,2,4,9}
  sys=[];
otherwise
  error(['Unhandled flag=',num2str(flag)]);
end;
function [sys,x0,str,ts]=mdlInitializeSizes
sizes=simsizes;
sizes.NumContStates=0;
sizes.NumDiscStates=0;
sizes.NumOutputs=0; % Number of outputs of your Block
sizes.NumInputs=0; % Number of Inputs of Your Block
sizes.DirFeedthrough=0;
sizes.NumSampleTimes=1;
sys=simsizes(sizes);
x0=[];
str=[];
ts=[0.4];
function sys=mdlOutputs(t,x,u,X,Y,V1,V2,V3)
X=logspace(-3,2);
Y=(100^10)*-exp(X);
V1=(0.97-(0.25*exp(-0.85.*X))-(0.95*exp(-7.25.*X)))./(1-exp(-7.25.*X));
V2=(0.5-(0.25*exp(-0.5.*X))-(0.75*exp(-7.25.*X)))./(1-exp(-7.25.*X));
V3=(0.25-(0.25*exp(-0.5.*X))-(0.5*exp(-7.25.*X)))./(1-exp(-7.25.*X));
figure
loglog(X,V1,'r-s','LineWidth',2)
xlabel('Time');
ylabel('Percentage Voltage');
title('ITI Curve Electronic & DC Drive Load');
```

```
figure
loglog(X,V2,'g-o','LineWidth',2)
xlabel('Time');
ylabel('Percentage Voltage');
title('ITI Curve for Computer Load');
figure
loglog(X,V3,'m-*','LineWidth',2)
xlabel('Time');
ylabel('Percentage Voltage');
title('ITI Curve for Motor Curve');
sys=[];% The output of your s-function block.
```

2. PROGRAMMING FOR GENERATION OF AREA OF VULNERIBILITY CURVE (VOLTAGE SAG VS DURATION):

```
clc
clear all
close all
x=[85 125 180 270 275 280]
t=10:10:60;
plot(t,x)
title('DC drives')
y=[140 180 230 260 270 280]
figure
plot(t,y)
title('3 Phase IM with Star connected')
z=[280 330 380 400 440 480]
figure
plot(t,z)
title('3 Phase IM with delta connected')
figure
w=[110 190 230 250 260 285]
plot(t,w)
title('Computer load')
```

3. PROGRAMMING FOR GENERATION OF AREA OF VULNERABILITY(VOLTAGE SAG VS AREA OF CONDUCTOR & VOLTAGE SAG VS LENGTH OF CONDUCTOR)

```
clc
clear all
close all
Rho=1.093;
Zl=0.085;
Zs=[0.8160 1 500];
l=[50:50:500];
Zf=0.6.*l;
E1=440;E2=200;E3=230;
Vsag1=(E1./(Zf+Zs(1,1))).*Zf
Vsag2=(E2./(Zf+Zs(1,2))).*Zf
Vsag3=(E3./(Zf+Zs(1,3))).*Zf
plot(l,Vsag1)
title('Voltage sag Vs Length of Conductor for motor load')
xlabel('lenght of conductor')
ylabel('Voltage')
figure
plot(l,Vsag2)
title('Voltage sag Vs Length of Conductor electronics load')
xlabel('lenght of conductor')
ylabel('Voltage')
figure
plot(l,Vsag3)
title('Voltage sag Vs Length of Conductor for computer load')
xlabel('lenght of conductor')
ylabel('Voltage')
%%
R=195;
A=(1.95./R).*l;
figure
plot(A,Vsag1)
title('Voltage sag Vs Area of Conductor for motor load')
xlabel('lenght of conductor')
ylabel('Voltage')
figure
plot(A,Vsag2)
title('Voltage sag Vs Area of Conductor electronics load')
```

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```
xlabel('lenght of conductor')
ylabel('Voltage')
figure
plot(A,Vsag3)
title('Voltage Sag Vs Area Of Conductor');
xlabel('lenght of conductor')
ylabel('Voltage')
```

VI. RESULTS

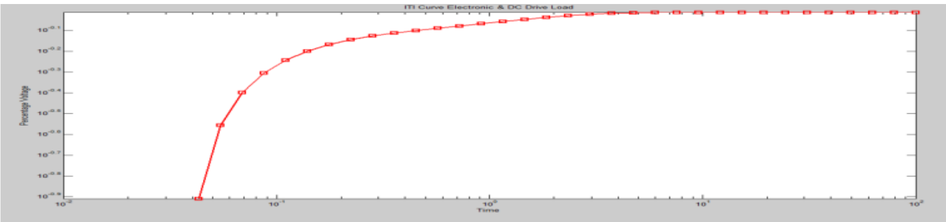

Fig.5.ITI curve for dc drive

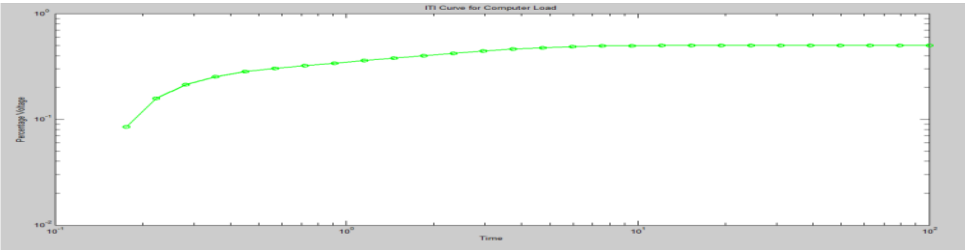

Fig.6.ITI curve for computer load

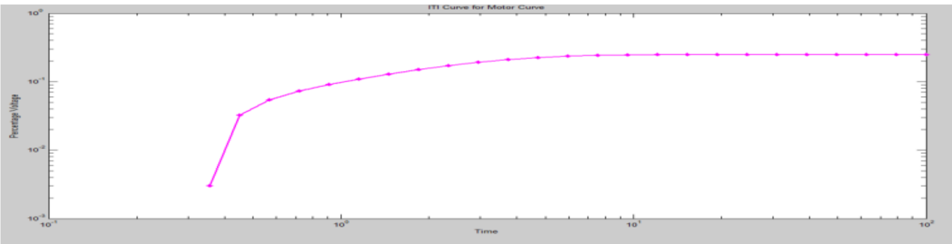

Fig.7.ITI curve for motor load

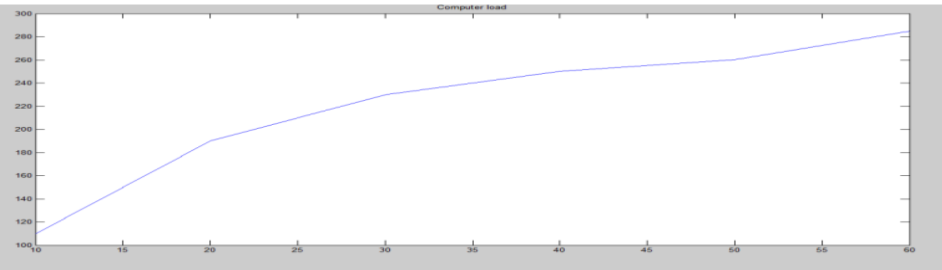

Fig.8.voltage sag vs duration for computer load

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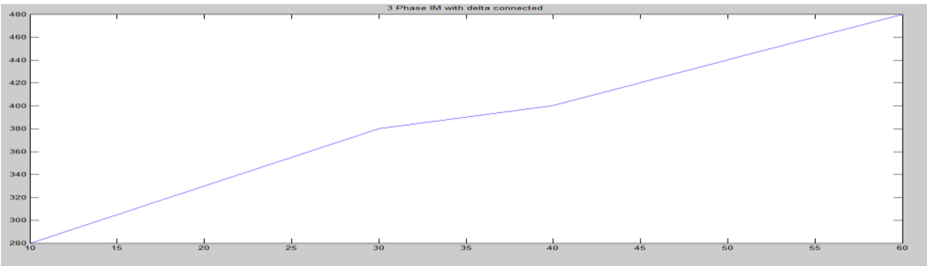

Fig.9.voltage sag vs duration for delta connected motor

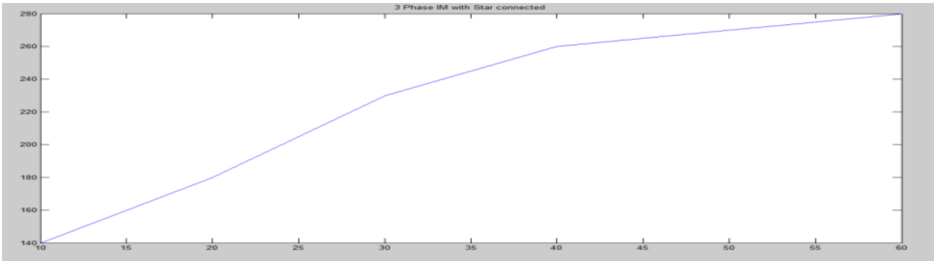

Fig.10 voltage sag vs duration for star connected motor

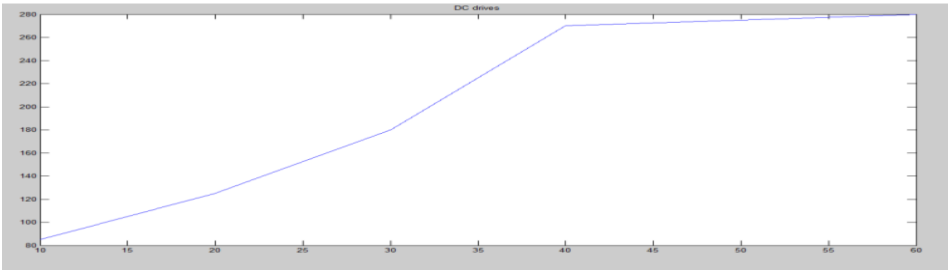

Fig.11voltage sag vs duration for DC drive

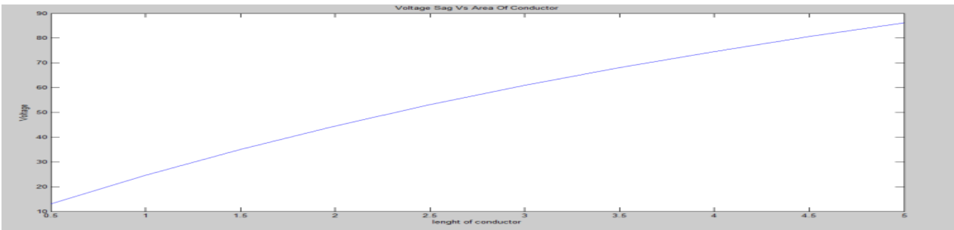

Fig.12.voltage sag vs area of conductor for computer load

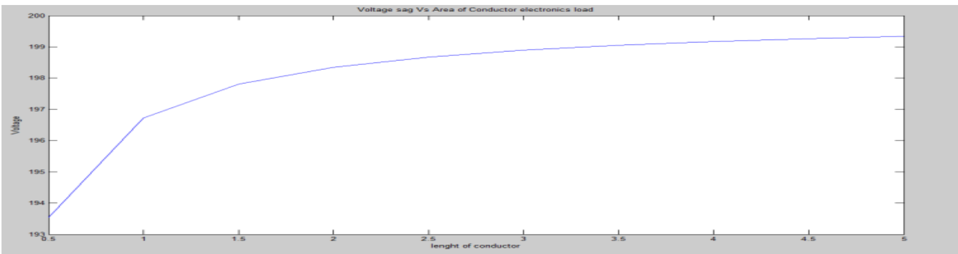

Fig.13. voltage sag vs areaof conductor for DC drive

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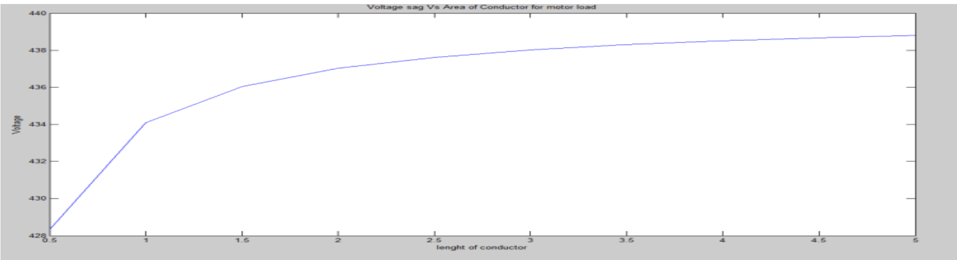

Fig.14.voltage sag vs area of conductor for motor

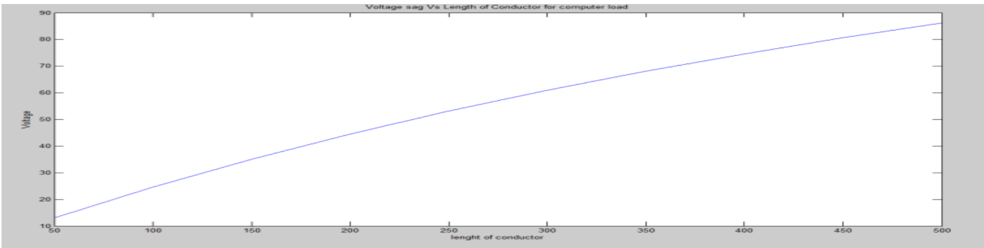

Fig.15.voltage sag vs length of conductor for computer

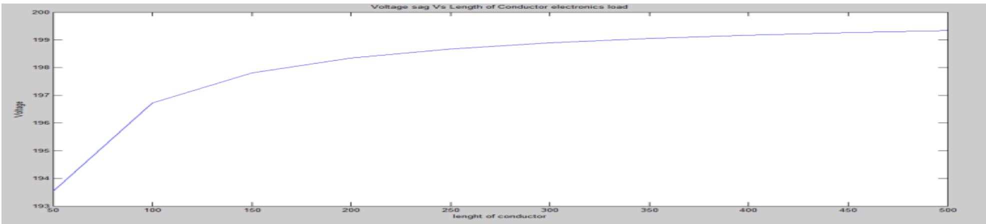

Fig.16.voltage sag vs length of conductor for Dcdrive

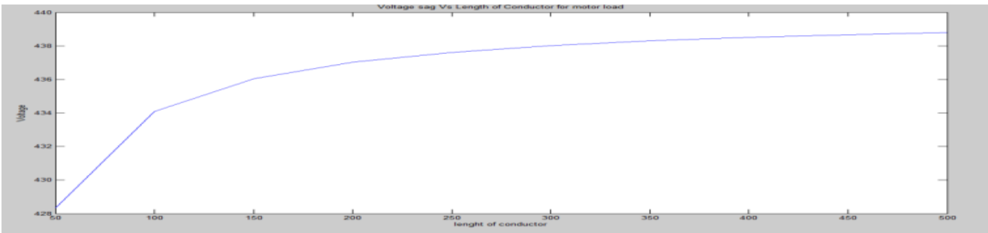

Fig.17.voltage sag vs length of conductor for motor

The sensisitivity of personal computer,induction motor and dc drive is studied.Thus following results are obtained:

Minimum voltage value at 10 ms:

Equipment	Voltage
1.Computer	110V
2.Induction motor(star)	140V
3. Induction motor(delta)	280V
4. DC drive	85V

Minimum voltage value at 0.5mm^2 area of conductor:

Equipment	Voltage

1.Computer	13.0
2.Induction motor	428.3
3.DC drive	193.54

Minimum voltage value at 50m length of conductor:

Equipment	Voltage
1.Computer	13.01
2.Induction motor	428.3
3.DC drive	193.54

VII CONCLUSION

Voltage sags are one of the most important power quality problems affecting industrial and commercial customers. Industrial processes are particularly sensitive to relatively minor voltage sags.Utilities can improve system fault performance but it is not possible to completely eliminate faults on the system. Therefore, customers will have improve the ride through capability of the sensitive equipment in their facilities. This can be accomplished with power conditioning or in the equipment itself.

When the susceptibility of the consumer operations is increasing to the voltage sags, power distribution companies and also the customer should have comprehensive understanding of the effect of voltage sags in their premises.ITI curve and area of vulnerability curve are generated and studied in this paper. Using ITI curve and area of vulnerability curve,sensitivity of induction motor,DC drive & personal computer is studied. Accordingly,induction motor trips at 40% voltage sag,DC drive trips at 30% voltage sag & personal computer trips at 38.5% voltage sag .

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