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Analysis of Voltage Sag on Power Distribution Networks with Different Transformer Connections

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Abstract: **In present era, power engineers need to plan the power system design in such a way that the system can sustain its Power Quality (PQ) even after facing all the above said problems. Along with that the system should also be compatible with the increasing demand of power supply. Quality of power depends on the system design, reliability and efficiency so study of PQD is important. PQD affects industrial as well as large commercial customers. Voltage sag is also referred as voltage dip. Voltage dip is the term given by IEC while the term "voltage sag" (VS) is used by North American power quality commission. VS creates disturbance in the pure sinusoidal waveform of voltage which in turn deteriorates the power quality of the system. VS occur for very short duration of 0.5 to 30 cycles. It is decrease in RMS voltage of about 90 % to 10 % of nominal voltage. Although VS occurs for very short duration but its effects deteriorates system with time decreases life period of the system. The present work is an attempt to analyse the voltage sag on power distribution network with different transformer connections. The field specifications obtained are used in MATLAB/SIMULINK and the results are discussed.**

Keywords: **Power Quality, Voltage Sag, MATLAB/SIMULINK.**

I. INTRODUCTION

VS occurs for short duration of time due to short circuit in the system. Causes of VS are from both sides that is utility side as well as end users side. VS arises due to utility side because of continuous switching on and off of equipments connected in the system with the help of circuit breakers, disconnection of reclosures and switches. VS occurred due to end users side is because of use of non-linear loads starting of large motor which requires heavy current, disturbs the sinusoidal waveform of voltage. Apart from these, there are some natural reasons which causes voltage drop such as lightning strikes, car hitting power pole, animal and trees touching or falling on power lines etc. All these faults are categorized under single line to ground or double line, three phase to ground or three phase faults. Variation in voltage is the result of significantly varying loads connected in the system. Mostly it is observed that VS occurs due to SLG fault in the system more as compared to other types of fault. Some of the causes VS are listed below -

1. Electric motors need more current at the starting time than that at the running time, which causes VS in the system.
2. During SLG fault, until the protective switch gear comes to its action there will be VS in the line.
3. Accidents in power line such as lightning or falling of an object.
4. Excessive load or sudden load change can cause VS.
5. Depending on transformer connections, transformer energizing also gives birth to VS.
6. VS is seen when air-conditioner, refrigerator or furnace fan start.

II. LITERATURE REVIEW

J. Caicedo, Felipe Navarro, Edwin Rivas and Francisco Santamaria displayed a method for voltage sag characterization by using MATLAB/ SIMULINK has been suggested. In this fault simulation, VS magnitude calculation is done by using

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sim power system tools. In this over-current protection has been simulated and also model developed in MATLAB/ SIMULINK. Phase angle jump in case of induction motor has been discussed with the simulation model. Suresh Kamble, Chandrashekhar Thorat studied Voltage sag characterization in a distribution systems : A case study . VS due to SLG, DL and DLG faults are characterize by using symmetrical component analysis and their effect on magnitude and phase angle jumps on each phase being analyzed. In this VS has been calculated by RMS method for which a model has been simulated on MATLAB/ SIMULINK and different types of faults applied on it and their VS behavior or effects have been studied out. These effects are studied on the basis of magnitude, duration and phase angle jump. D.J.Won, Seon-Ju Ahn and Y.Chung in their paper A new defination of voltage sag duration considering the voltage tolerance curve. . A new VS duration which consider voltage tolerance characteristics of each electrical devices has been discussed. In conventional method, VS for rectangular sag has been consider whenever the sag is non-rectangular, VS has always been overestimated. To overcome from this, method proposed takes into account minimum voltage of voltage tolerance curve of each equipment. This new method have been applied on non-rectangular sag generated from induction motor starting and compared with the maximum time to calculate VS effect on equipment. E.Styvaktakis, M.J.H.Bollen shows Automatic classification of power system events using RMS voltage measurements" (2002) IEEE Power Engineering Society Summer Meeting. In this paper PQ monitoring in depth has been discussed. For this a method have been suggested for automatic power system event classification using RMS voltage measurement and results show that this classification can be applied on specific events and its limitations have been discussed. In this events covered are energizing, non-fault interruption, fault interruption, transformer saturation, induction motor starting, step change and faults.

Study of Area Effected: To establish compatibility in between supply system and the consumers following important steps must be taken.

1. Find out the characteristics and number of voltage sag events.
2. Find the equipments those which are sensitive to the sag event.
3. Search for best economical solution in order to improve the performance of system and also immunity of the devices installed in the system.

All these above mentioned steps help in making the proper co-relation between the system and consumers. The study of area effected by the sag is termed as area of vulnerability (AV). This study of area effected, at a small scale helps in minimizing its effect on the system. So, for making decision regarding ratings of the devices to be installed, this study is proved to be quite beneficial. The city area and one 11 KV feeder is selected and simulated on MATLAB

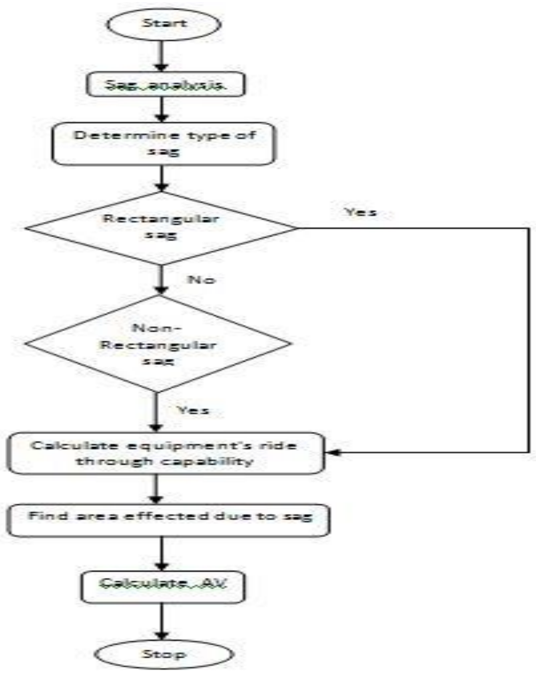

Table shown below gives the details of parametric configuration taken under MATLAB/ SIMULATION.

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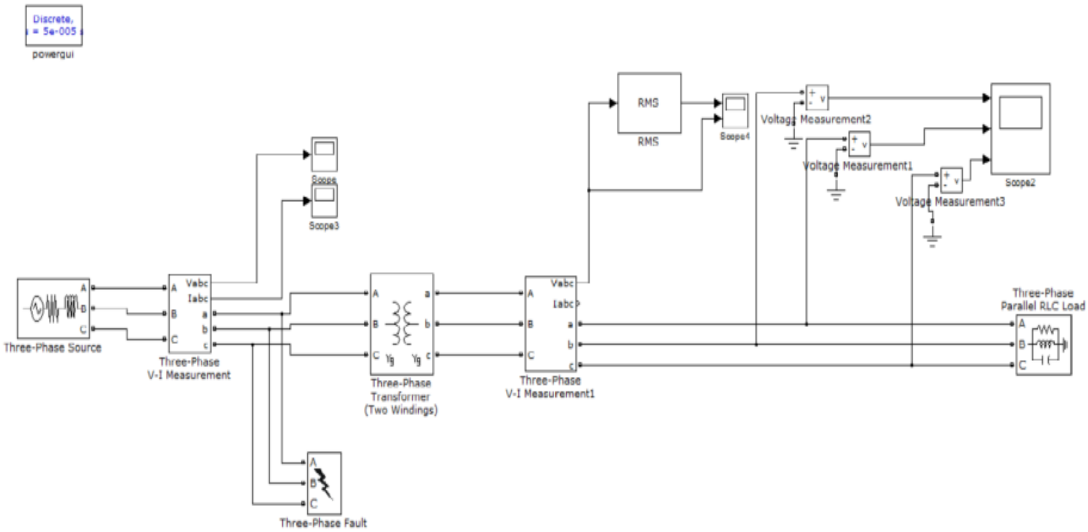

Fig.1: MATLAB/SIMULINK model

Transformer Y_g-Y_g connected:

For Y_g-Y_g transformer connection different types of fault giving birth to VS is shown in table below with percentage sag.

Table.1: Percentage sag on different fault on Y_g-Y_g transformer connection

Type of fault	*Pre-fault RMS Voltage*	*Post-fault RMS Voltage*	*% Sag*
Single line to ground	220	34.97	84.10
Double line to ground	220	167.32	23.94
Double line	220	196.16	10.83
Three phase to ground	220	172.48	21.60
Three phase	220	213.24	3.07

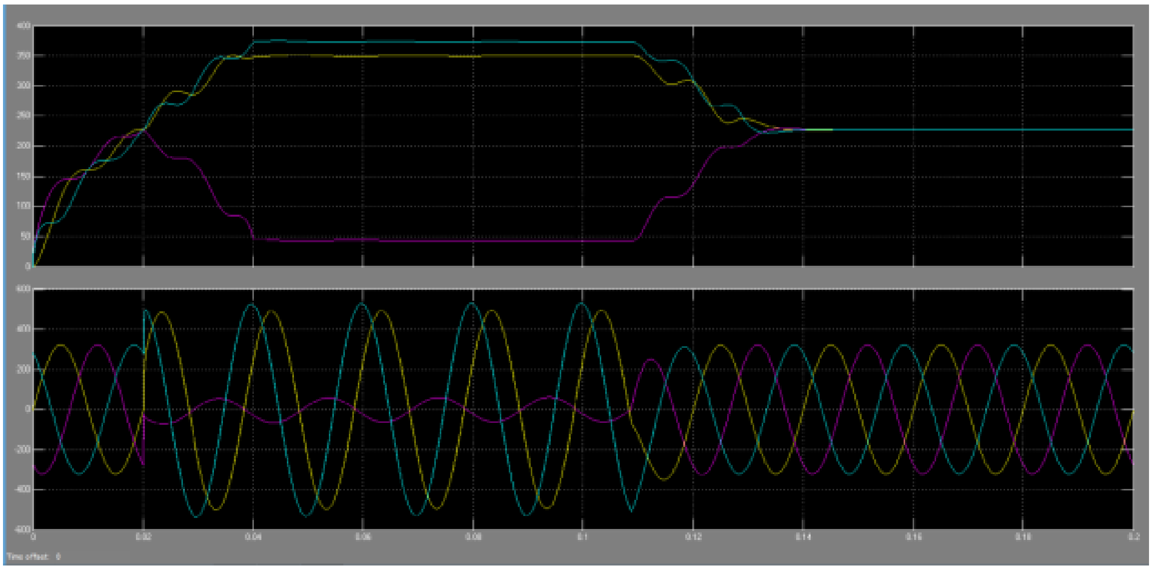

Fig.2: SLG fault

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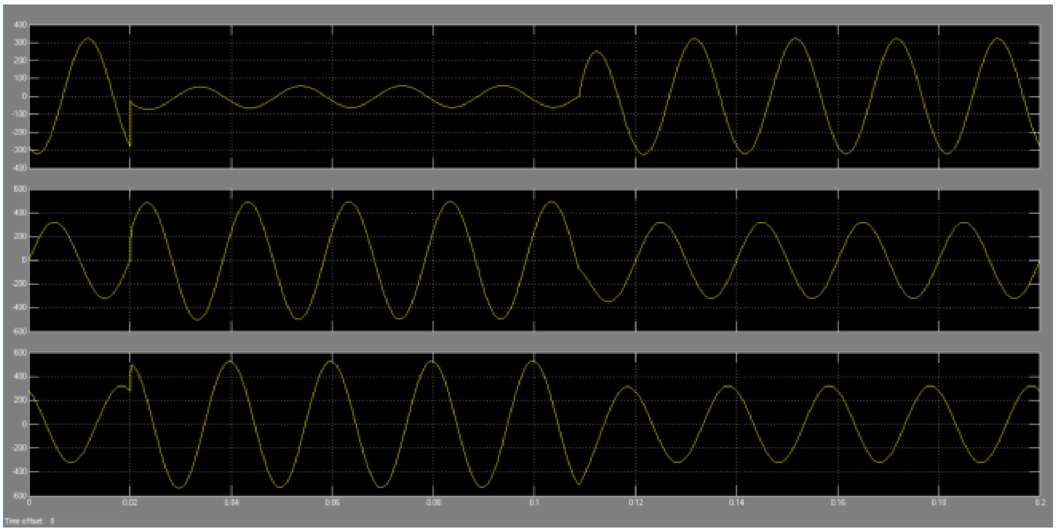

Fig.3: Voltage waveform of all three phases during SLG

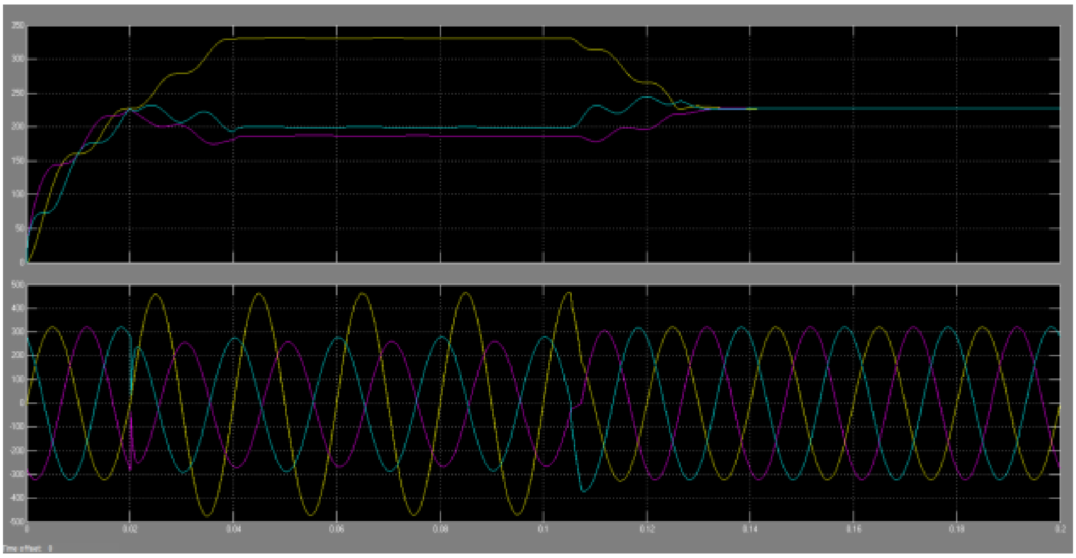

Fig.4: DLG fault (a) RMS waveform (b) Instantaneous waveform

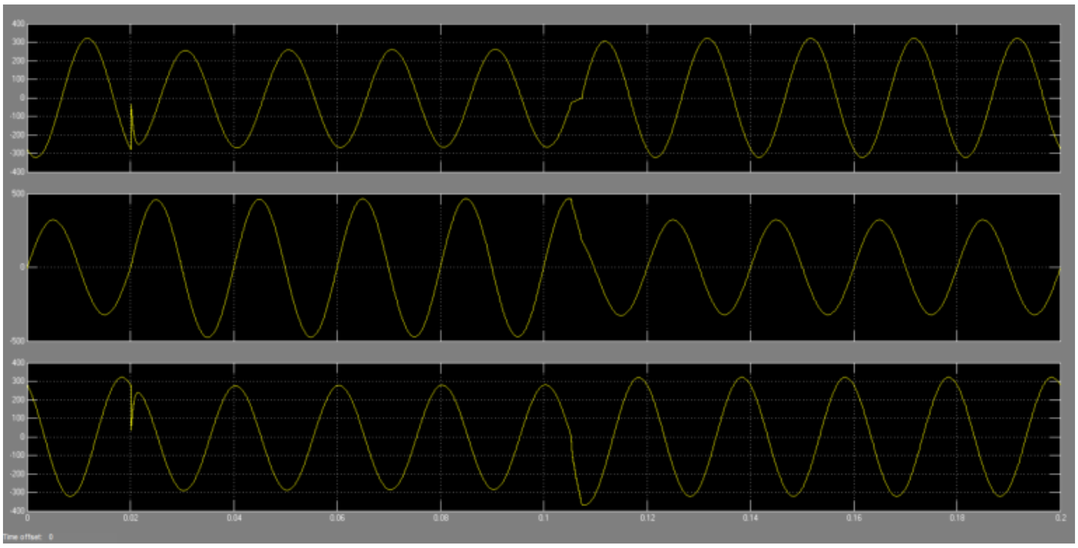

Fig.5: Voltage waveform of all three phases during DLG

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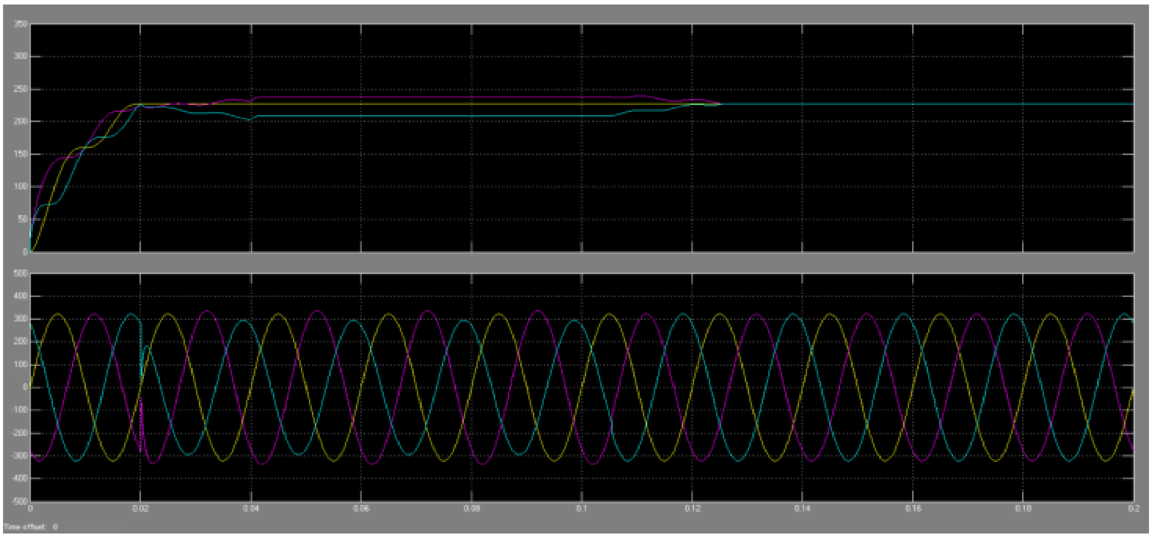

Fig.6: DL fault (a) RMS waveform (b) Instantaneous waveform

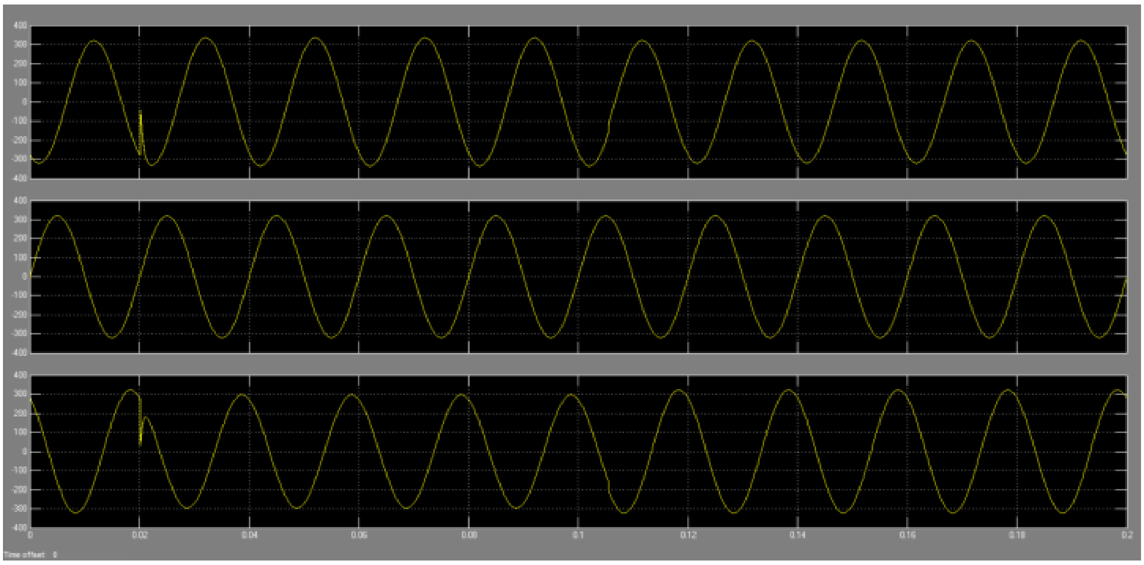

Fig.7: Voltage waveform of all three phases during DL

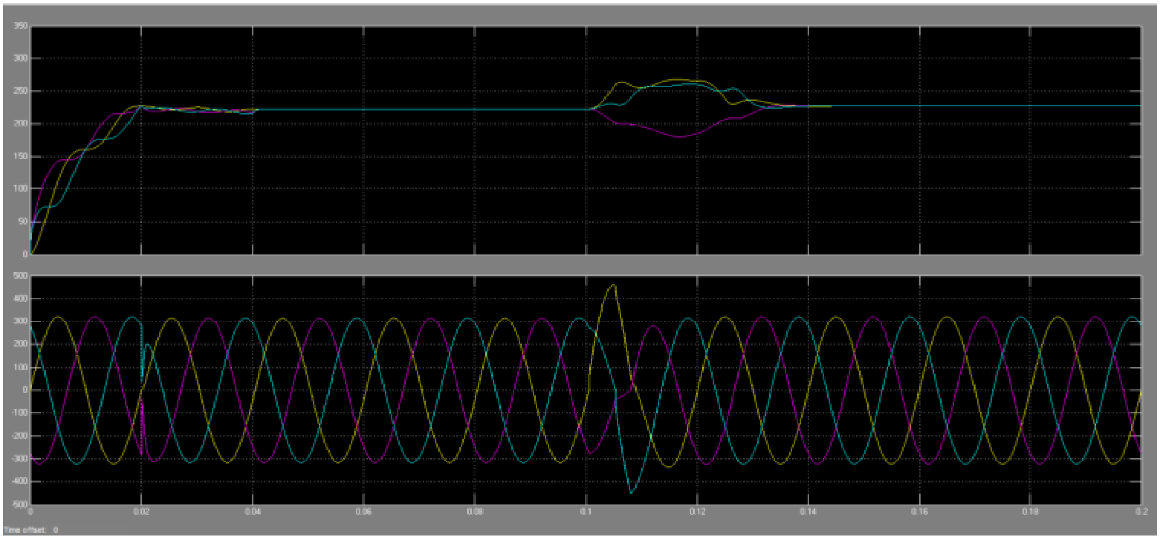

Fig.8: 3-Φ G fault (a) RMS waveform (b) Instantaneous waveform

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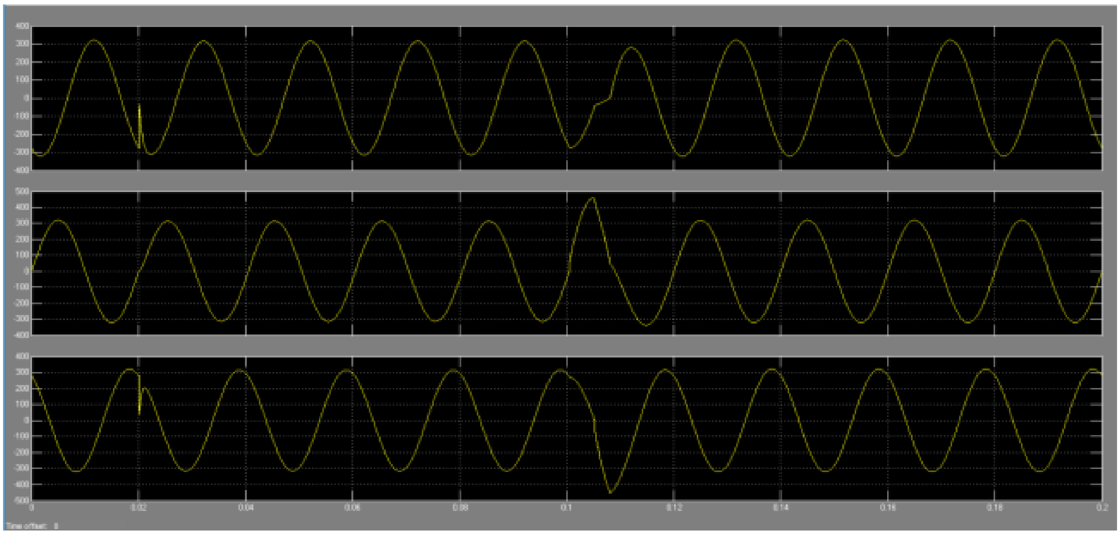

Fig.9: Voltage waveform of all three phases during 3-Φ G

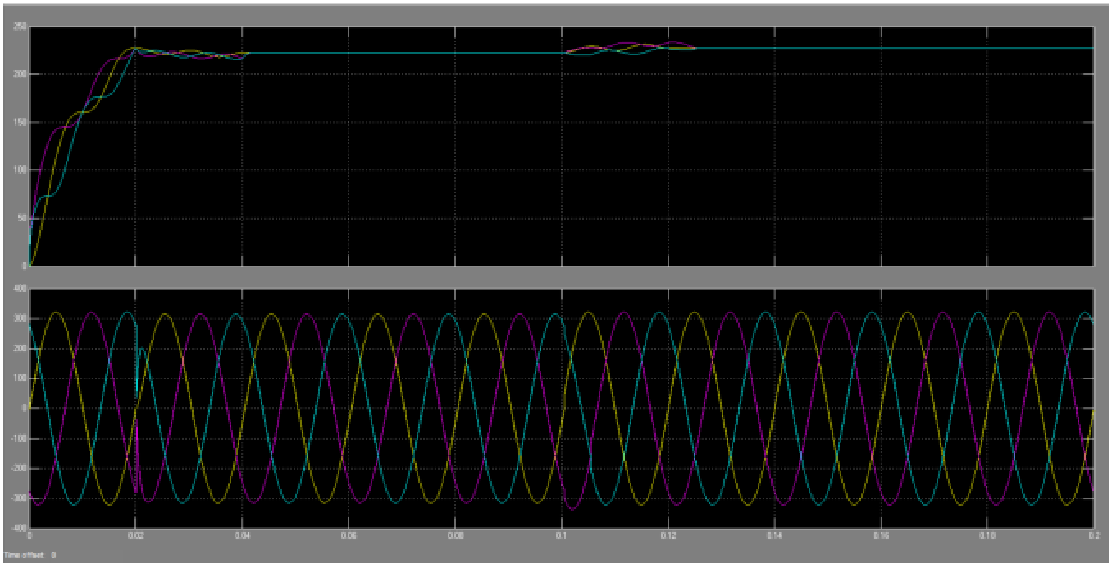

Fig.10: 3-Φ fault (a) RMS waveform (b) Instantaneous waveform

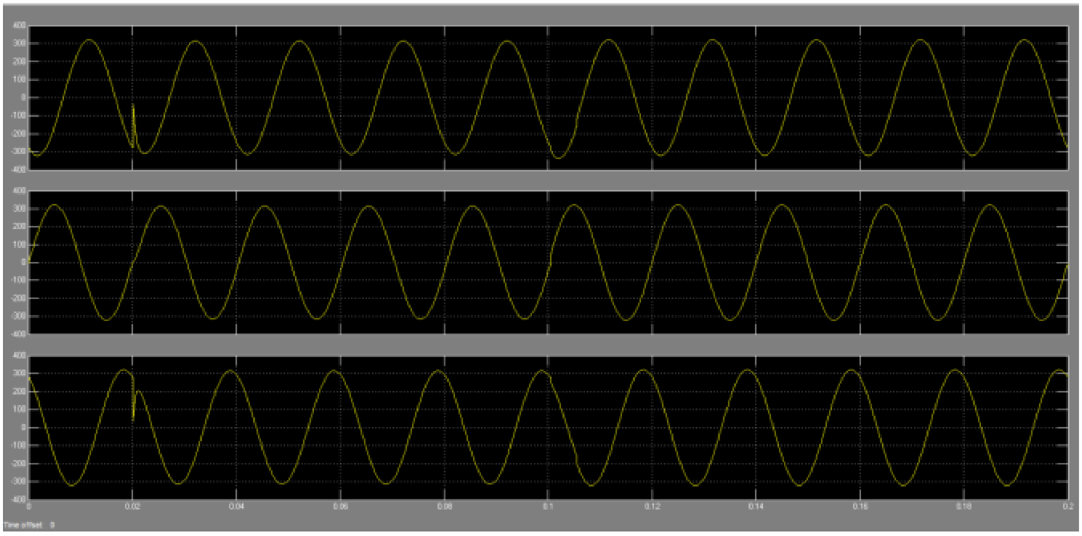

Fig.11: Voltage waveform of all three phases during 3-Φ

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Transformer Y_g-Δ11 connected:

For Y_g-Δ11 transformer connection different types of fault giving birth to VS is shown in table below with percentage sag.

Table.2: Percentage sag on different fault on Y_g-Δ11 transformer connection

Type of fault	*Pre-fault RMS Voltage*	*Post-fault RMS Voltage*	*% Sag*
Single line to ground	220	216.52	1.58
Double line to ground	220	196.35	10.75
Double line	220	196.16	10.83
Three phase to ground	220	213.32	3.03
Three phase	220	213.24	3.07

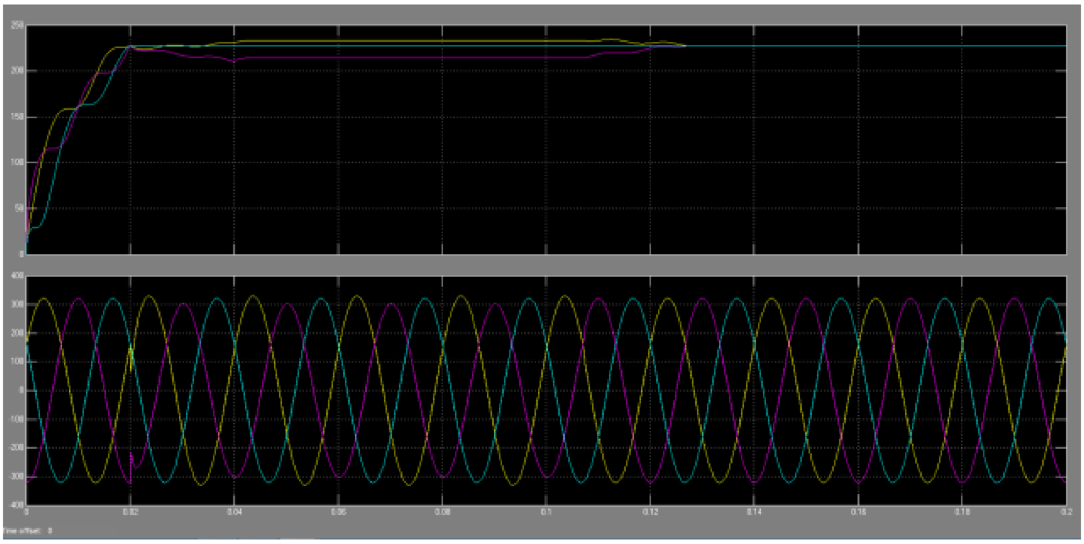

Fig.12: SLG fault (a) RMS waveform (b) Instantaneous waveform

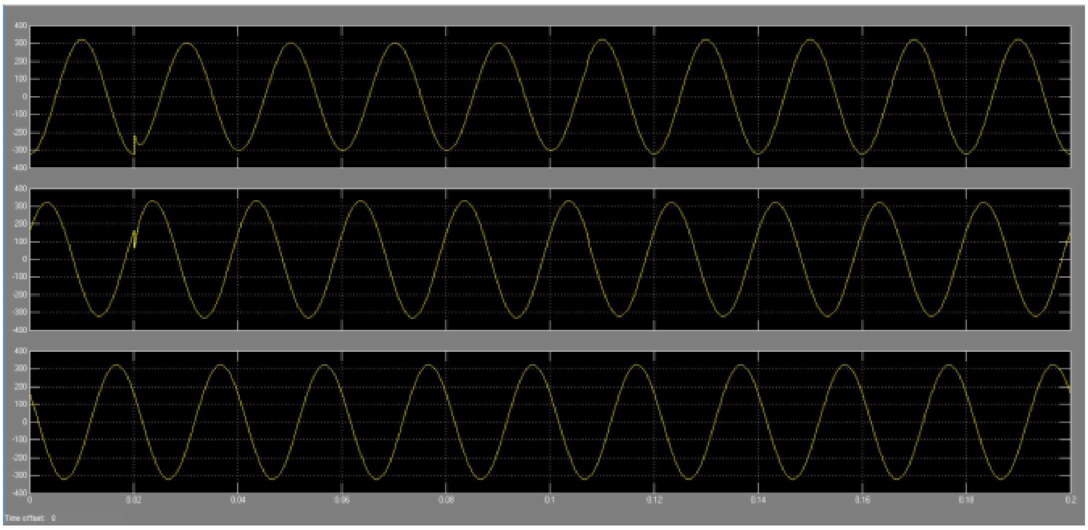

Fig.13: Voltage waveform of all three phases during SLG

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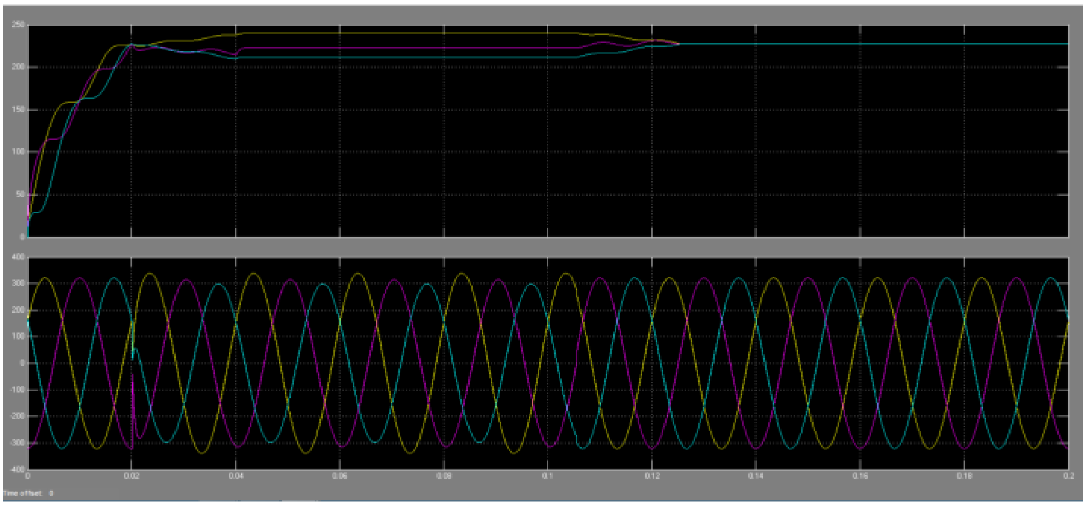

Fig.14: DL fault (a) RMS waveform (b) Instantaneous waveform

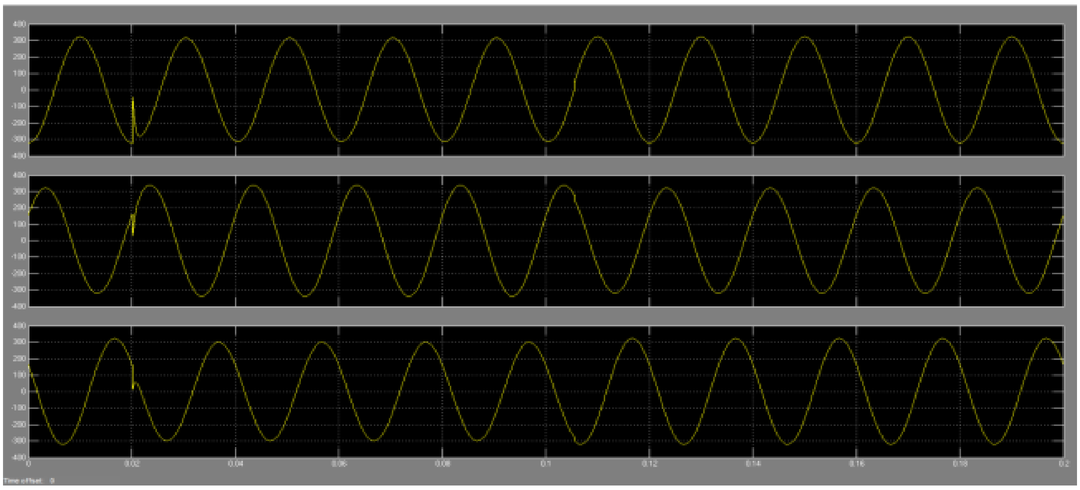

Fig.15: Voltage waveform of all three phases during DL

Transformer Y_g-Y connected:

For Y_g-Y transformer connection different types of fault giving birth to VS is shown in table below with percentage sag.

Table.3: Percentage sag on different fault on Y_g-Y transformer connection

Type of fault	*Pre-fault RMS Voltage*	*Post-fault RMS Voltage*	*% Sag*
Single line to ground	220	216.52	1.58
Double line to ground	220	196.35	10.75
Double line	220	196.16	10.83
Three phase to ground	220	213.32	3.03
Three phase	220	213.24	3.07

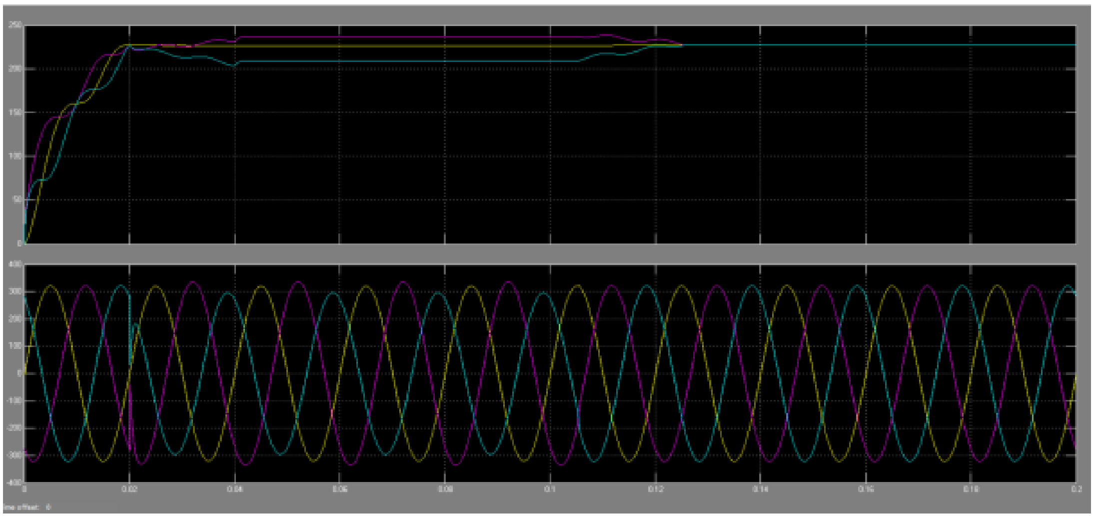

Fig.16: DLG fault (a) RMS waveform (b) Instantaneous waveform

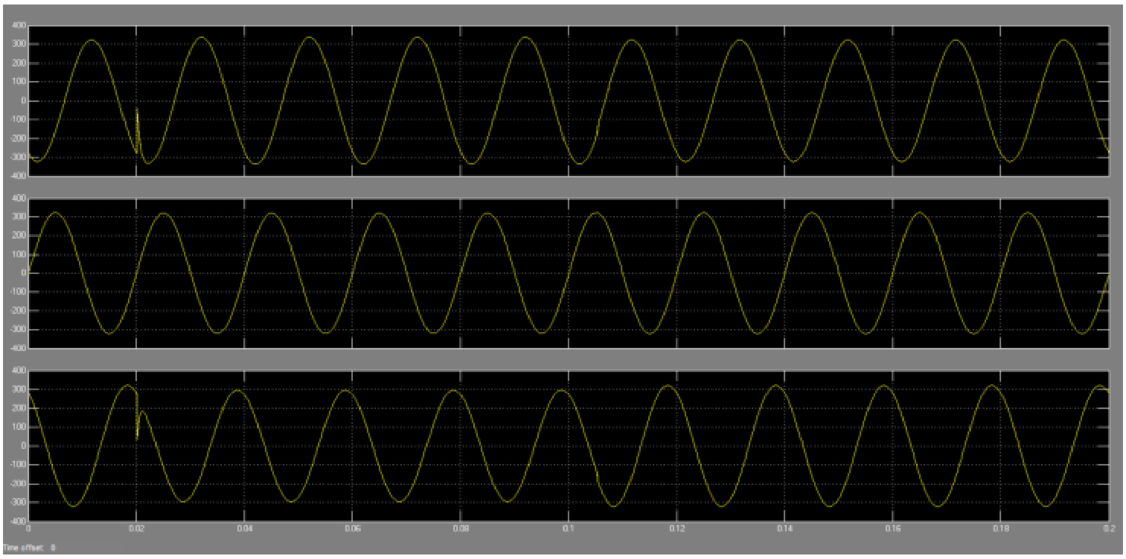

Fig.17: Voltage waveform of all three phases during DLG

IV. CONCLUSION

From this thesis work it is concluded that during SLG fault when transformer is Y_g-Y_g connected VS is quite high compare to transformer when Y_g-Y connected. Similarly, in case of 3-Φ fault VS is observable when transformer is Y_g-Y_g connected. When transformer connection is Y_g-Y DL fault is observable more clearly then in transformer connection Y_g-Δ11.

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