Performance Analysis of 33/11kv Substation and its Feeders

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Abstract —Electrical power system provide a vital service to the society. For healthy operation of electrical power generation, transmission and distribution, it is important that system should be balanced. Load flow is basic requirement to conduct power system analysis of any system. The load flow gives us information about voltages, real and reactive power generated and absorbed and line losses across the entire system. Short Circuit Analysis provides the information required to determine whether the interrupting capacities of the power system components are adequate enough to protect your power system. Also this data is used to evaluate the proper sizing of protective relays and sensing equipment. All the data used for analysis is real time and collected from 33/11kV substation.This paper deals with the simulation of 33/11kV substation. The analysis is done by using advance software Electrical Transient Analyser Program (ETAP) and MI POWER with detailed load flow analysis.Also, carried out the short circuit study of 33/11 kV substation system using ETAP software. From the ETAP and MI POWER generated load flow details and the short circuit details are studied.

Index term— ETAP, MI POWER, load flow, short circuit, 33/11kv substation, comparision, reactive compensation, Newton raphson method

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1 INTRODUCTION

Electrical power system is back bone of the development of a nation. There is big issue of power quality for developed nations but the developing countries like India the load is increasing rapidly but generation is not up to the level of demand [1]. Hence there is need of load flow management. Load flow analysis using software is accurate and gives highly reliable results. This research makes effective use of Electrical Transient Analyzer Program (ETAP) to carry out load flow analysis of 33kV substation. The actual ratings of Power Transformers, Circuit Breakers, Current Transformers, Potential Transformers and Isolating switches are taken and modelled accordingly in ETAP.[2] This 33kV substation is located in Bagalkot district jamkahndi taluk Hirepadsalgi owned by Karnataka HESCOM.

The major cause of almost all power system disturbances is under voltage, voltage drops and power factor. In order to identify and pinpoint these disturbances, load flow studies are conducted. The result of these studies help to address the system disturbances with the help of additional devices (capacitors..etc). [3][4]

Short circuits can occur anywhere in the system. In order to protect the system against short circuits, it is necessary to install circuit breakers which can safely isolate the circuit in fault conditions. The results of these studies help in proper selection & settings of protective device such as fuses, circuit breakers, and relays used in the protection scheme. Thus helping utilities maintain a safe, reliable and efficient electrical distribution system [5].

The single line diagram of the substation is simulated in ETAP based upon actual data, and it is seen that at the 11kV feeder buses. To overcome the under voltage at the 11kV feeder buses buses capacitor bank of suitable ratings are added. [6]

Section 1 is introduction of ETAP software. Section 2 is the details of the components. Section 3 is the simulation of single line diagram of 33 kV substation in ETAP based upon practical data. Section 4 is the Load Flow Analysis of the substation. Three conditions have been simulated in order to analyse the behaviour of the power system in these situations. Section 5 contains the observations on the load flow analysis. Section 6 is the recommendation to correct the problems encountered.[10]

2 METHEDOLOGY

2.1 The step by step methods involves the analysis are:

1. Data collection from the Herepadsalgi 33kv Substation
2. Simulation of the Herepadsalgi Substation using ETAP
3. Calculation of Fault Current and Line Impedance using symmetrical method for fault analysis
4. Validation of Fault current using ETAP
5. Determination of the bus voltage, Real and reactive power from the load flow analysis using MI POWER

2.2 Data Collected for 33KV Current Transformer

Product of C. T=ABB
C.T Ratio=300:1
RHSV 36KV, 800A
Type =outdoor
Frequency =50 Hz
Burden =15VA core
C.T Ratio=300:5[7]

2..3 CALCULATION

The 10 MVA transformer is connected in Delta/Star

Base current = $1000 (MVA)b / \sqrt{3} (KV)b$
Base impedance = $(KV)b^2 / (MVA)b$
Reactive Power=$V_{rms}I_{rms} = I_{rms}^2 X$
Active Power=$\sqrt{3} VI \cos \phi$

Apparent Power $= V_{rms} I_{rms} = I^2_{rms} Z = V_{rms}^2/Z$

2.4 Sequence impedance

$Z0=(Zs+2Zm)$
$Z1=Z2=(Zs-Zm)$
$z = \sqrt{R2 + (wL)^2}(11)$

2.5 Single line to groun

$Ia1=Ia2=Ia0=[Vf/(Z1+Z2+Z0+3*Zf)]$
Where $Ib=Ic=0$;
Symmetrical components of voltage from terminals 'a' to ground
$Va1=Va2=Vf-Ia1*Z1$
$Va0=-Ia0*Z0$
Line to ground voltage
$Va=Va1+Va2+Va0$
$Vb=a^2*Va1+a*Va2+Va0$
Where $a =0.5+j0.86660$
$Vc=a*Va1+a^2*Va2+Va0$
Line to line voltage fault
$Vab=Va-Vb$
$Vbc=Vb-Vc$
$Vca=Vc-Va$

2.6 line to line

Fault occurred between b and c
$Vb-Vc=Ib*Zf; Ia=-Ic$
$Ia1=[Vf/(Z1+Z2+Zf)]=-Ia1$
$Ia0=0$
$Ia=Ia1+Ia2+Ia0$
$Ib=a^2*Ia1+a*Ia2+Ia0$
$Ic=a*Ia1+a^2*Ia2+Ia0$
Symmetrical components of voltage from terminal a to ground
$Va1=Vf-Ia1*Z1$
$Va2=-Ia2*Z2$
$Va0=0$
Line to ground voltage
$Va=Va1+Va2+Va0$
$Vb=a^2*Va1+a*Va2+Va0$
Where $a =0.5+j0.86660$
$Vc=a*Va1+a^2*Va2+Va0[8][9]$

2.6 line to line ground

Fault occurred between b, c and ground with $Zf=0$
$Ia1=[Vf/\{Z1+(Z2*Z0/Z2+Z0)\}]$
$Ia2=-Va2/Z2$
$Ia0=Va0/Z0$
$If=Ib+Ic$
$Vb=Vc=0$
$Va=Va0+Va1+Va2$

2.7 3 phase fault

$Ia1=Vf/Z1$
$If=4*base current$

Fault	SLG	LL	DLG	3 PHASE	TOTAL
F1	10	4	1	Nil	15
F2	6	1	Nil	Nil	7
F3	5	Nil	2	Nil	7
F4	7	2	1	Nil	10
F5	8	3	2	Nil	13
F6	2	2	Nil	Nil	4
Total	38	12	6	0	56

TABLE 2
SHOWS THE IMPEDENCE OF VARIOUS NODE OF SUBSTATION

Node	Resistivity (ohm/Km)	Inductance (mH)	Length (Km)	Resistance	Impedance
4	0.00002	4.78	1.1	1.5	1.5
5	0.00003	6.31	1.4	2	2
6	0.00004	3.18	1	2	2
7	0.00003	4.78	1.2	1	1
8	0.00002	3.18	1.5	1	1
9	0.00003	3.18	1.5	1	1

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. Fig 1. Daily load current vs time in hours

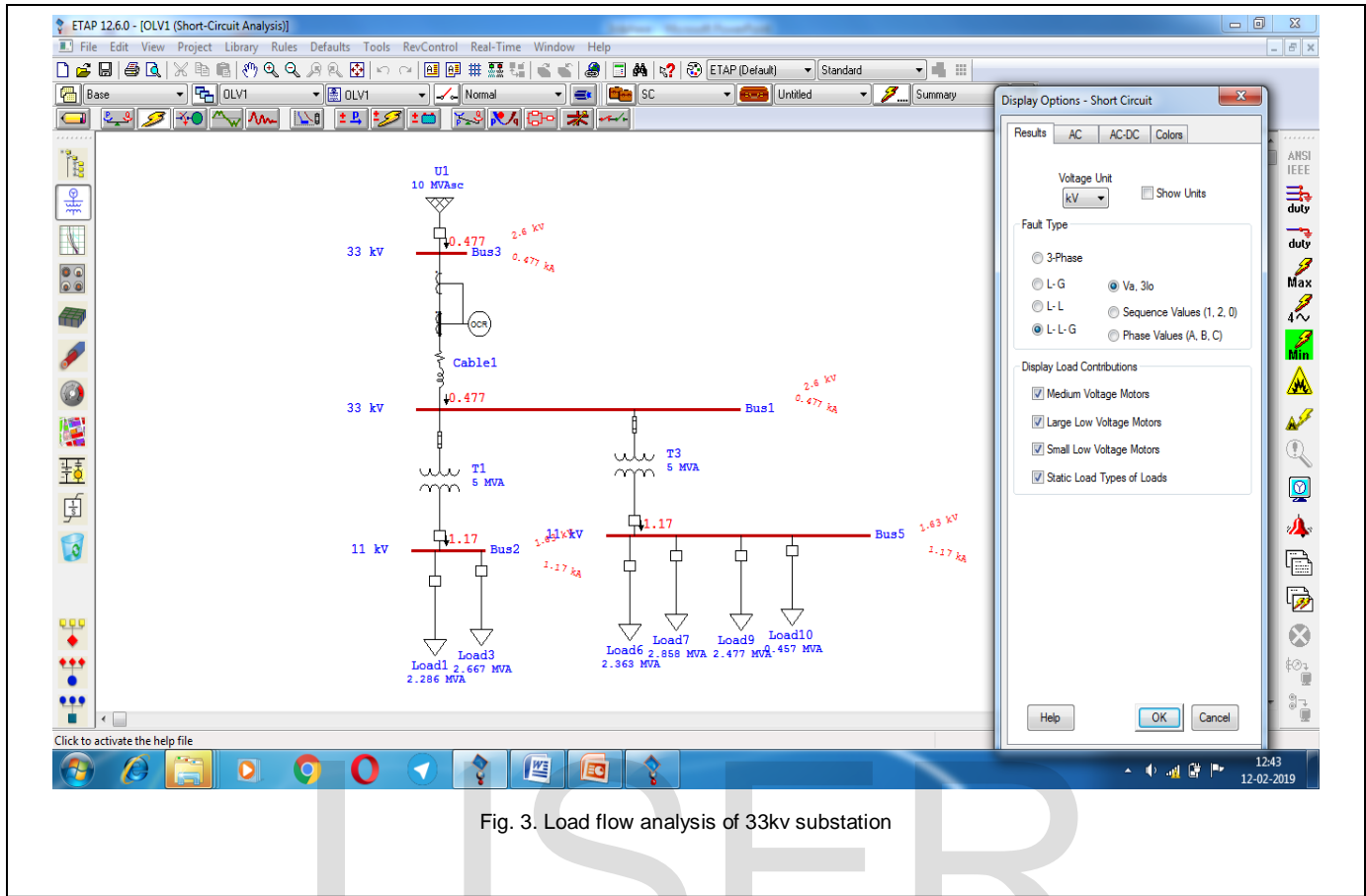Fig. 2. Representation of line to ground fault
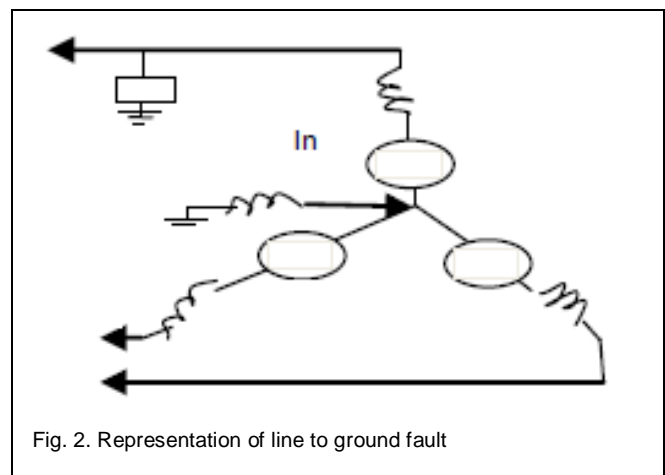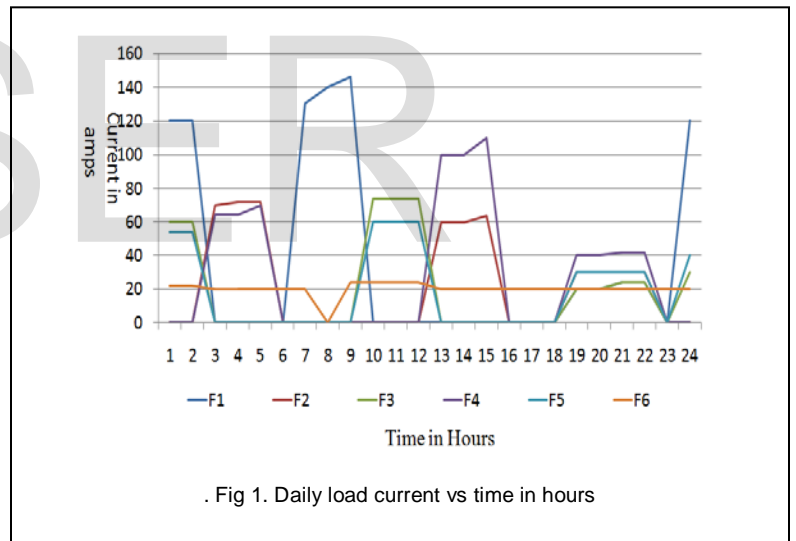
Fig. 3. Load flow analysis of 33kv substation

TABLE 3
LOAD FLOW OF 33/11KV SUBSTATION

Feeder no.	Mw	Mvar	Mva	%P.F	Amps	%Line drop	Maximum loading %
F1	2	1.09	2.86	89.51	120	14.34	143
F2	2.3	0.43	2.367	98.67	140	8.1	102
F3	2	1.053	2.26	88.49	124	18.8	113
F4	2.5	1.38	2.858	87.48	150	12.4	114
F5	2.1	1.313	2.477	84.79	130	15.5	117
F6	0.4	0.222	0.4577	87.48	24	13.2	114

3 OBSERVATION ON LOAD FLOW ANALYSIS

Fig 3 Load flow analysis from quite clear that the line drops/losses are higher than the tolerable limits. This is resulting in reduced voltages at the load buses. Hence the load is getting operated at reduced voltages which might lead to over current and overheating of the load equipment. In the 'maximum load' simulation, the transformers are getting overloaded, which might lead to unnecessary tripping. In order to limit the line voltage drops and reduced voltages, the transmission lines connected to the loads need to be upgraded.
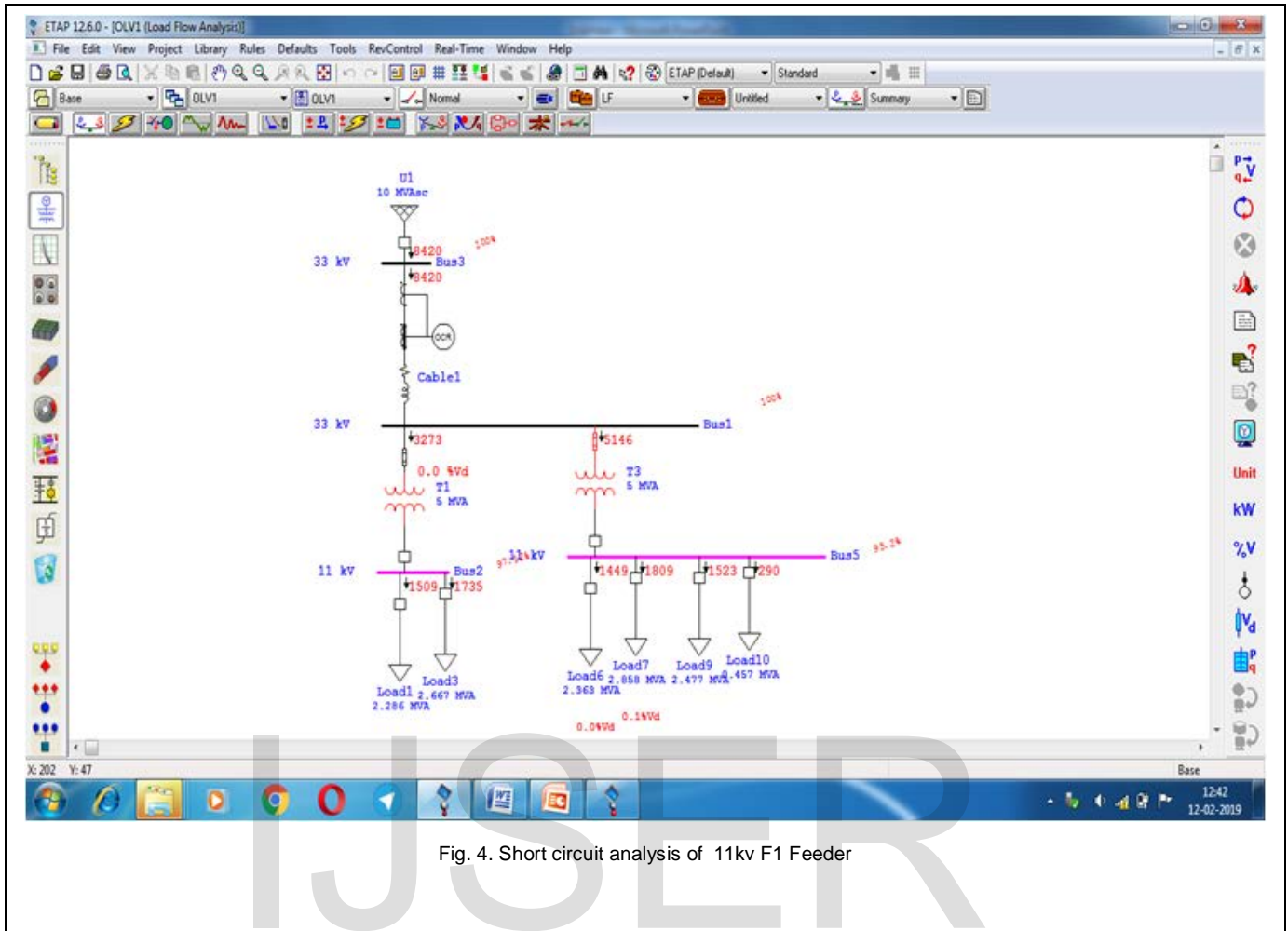
Fig. 4. Short circuit analysis of 11kv F1 Feeder

TABLE 3
SHORT CIRCUIT OF 11KV F1 FEEDER

Faults	Fault current in amp	Voltage magnitude (kv) of line Vab	Voltage magnitude (kv) of line Vbc	Voltage magnitude (kv) of line Vca
SLG	4236.142	5.43	10.44	5.43
LL at b,c	3458.3	9.53	0.227	9.53
DLG at b,c to ground	4568.5	4.48	0	4.48
3PHASE	3277.2	0	0	0

Fig 4 shows the short circuit analysis of 11kv F1 feeder, from Table 3 we observe the various fault which occurs in the system DLG fault is maximum in the system. As per the values, it indicates that some of the devices (circuit breakers) are not capable enough to handle the short circuit currents. Hence these devices were upgraded and short circuit study was conducted again.
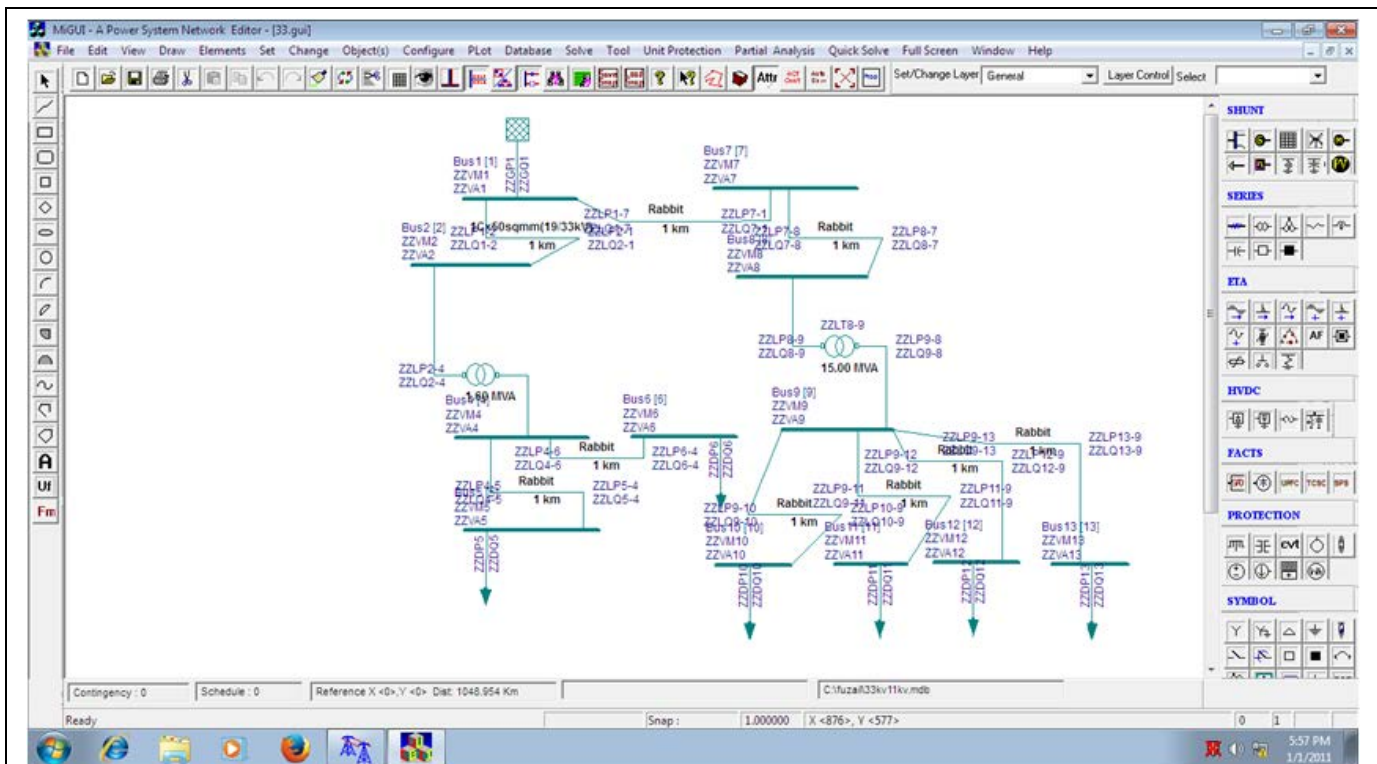
Fig. 4. Load flow analysis of 33kv substation in MI POWER

4 RESULT AND DISCUSION

TABLE 4
LOAD FLOW OF 33/11KV SUBSTATION MI POWER

Feeder no.	Mw	Mvar	Mva	%P.F	Amps	%Line drop	Maximum loading %
F1	2	1.09	2.86	89.51	120	14.34	143
F2	2.3	0.43	2.367	98.67	140	8.1	102
F3	2	1.053	2.26	88.49	124	18.8	113
F4	2.5	1.38	2.858	87.48	150	12.4	114
F5	2.1	1.313	2.477	84.79	130	15.5	117
F6	0.4	0.222	0.4577	87.48	24	13.2	114

TABLE 5
SIMULATED AND CALCULATED RESULTS OBTAINED FROM 10MVA SUB-STATION ARE ANALYZED. THE STUDY WAS CARRIED OUT CONSIDERING VARIOUS FAULTS IN THE SUBSTATION.

Faults	R0	X0	Z0 in pu	R1	X1	Z1in pu	R2	X2	Z2 in pu	Zf
SLG	0	1	j0.125	0	2	j0.2	0	1.5	j0.2	0
LL	0	1	j0.125	0	1.5	j0.25	0	1.5	j0.2	0.01
DLG	0	1	j0.125	0	2	j0.2	0	1.5	j0.2	0
3Phase	0	1	j0.125	0	2	j0.25	0	1.5	j0.2	0

TABLE 6

COMPARING THE CALCULATED AND SIMULATED RESULTS

Faults	Line voltage	Hand calculations	ETAP 12.6.0
SLG	Vab(kv)	5.43	5.41
	Vbc(kv)	10.04	10.0
	Vca(kv)	5.43	5.41
	If in amps	4236.145	4.3(kA)
LL	Vab(kv)	9.53	9.43
	Vbc(kv)	0.22	0.221
	Vca(kv)	9.53	9.43
	If in amps	3458.3	3.2kA
DLG	Vab(kv)	4.45	4.35
	Vbc(kv)	0	0
	Vca(kv)	4.45	4.35
	If in amps	4568.5	4.6kA

CONCLUSION

In this paper, fault analysis was carried out for 33/11kv Substation. The analysis was carried manually using symmetrical components method. The results were compared with software solutions obtained from 'ETAP and MI POWER ' to validate the hand calculations' accuracy. The error was between the acceptable limit of 3.2% for all type of fault. Load-flow studies are important for planning future expansion of power systems as well as in determining the best operation of existing systems. In this paper analysis of 33/11 kV substation using ETAP and MI POWER software is carried out with an approach to overcome the problem of an under voltage, line losses and voltage drops. Load Flow Studies using ETAP software is an excellent tool for system planning. A number of operating procedures can be analysed such as the loss a Distribution line, a transformer or a load. This can be used to determine the optimum size and location of capacitors to surmount the problem of an under voltage. Also, they are useful in determining the system voltages under conditions of suddenly applied or disconnected loads. Load flow studies determine if system voltages remain within specified limits under various contingency conditions, and whether equipment such as transformers and conductors are overloaded. It was often used to identify the need for additionalgeneration, capacitive, or inductive VAR support, or the placement of capacitors and/or reactors to maintain system voltages within specified limits. Short circuits studies are the most required in a power system in order to adequately size the devices, so that they are capable to handle the short circuit currents. Also these studies provide information regarding the intensity and the probable damage which can be caused in the event of the short circuit. These studies also help to adequately design the protection system. And, equally important, short circuit study is the prerequisite for Relay Co-ordination and Arc Flash Studies.

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