Sample Report on Short circuit analysis, Load flow study and Protection Relay coordination using ETAP.
Chemical Company in Lote MIDC - Maharashtra

Report Prepared by.

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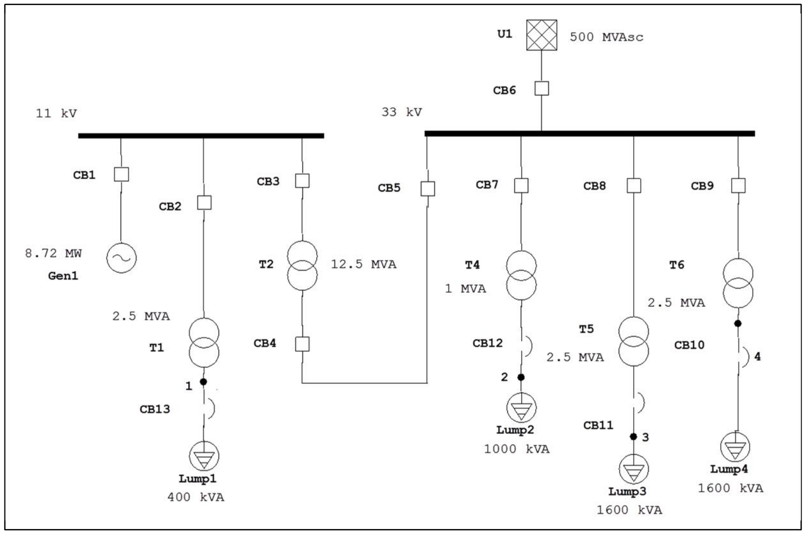
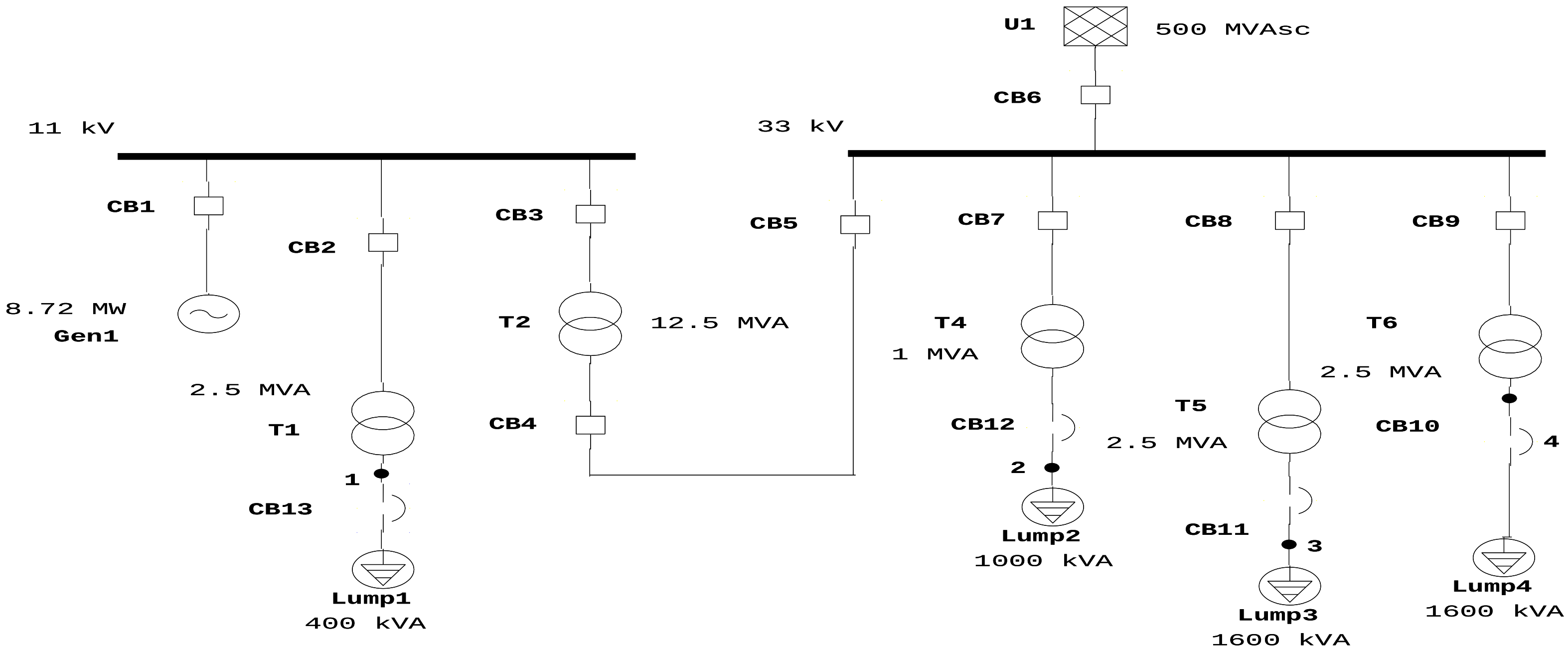


Schematic of electrical system at Chemical Company in Lote.



- As shown above this system has two sources, namely 33KV – 500MVAC and 8.72KW – 11KV T.G.
- There are three main transformers 33KV/433V with ratings 1MVA, 2.5MVA and 2.5MVA which supply load.
- 11KV/433V – 2.5 MVA transformer is installed on 11KV bus, which supplies to TG Auxiliaries.
- Lump 1 to Lump 4 are various MCCS and PCCS for different sections of the plant. Majority of loads are motor loads either fed directly or through VFDs.
- T.G. Output 11KV is stepped up to 33KV and then connected to 33KV bus. This is done using a 12 MVA transformer. The same transformer steps it down when TG auxiliaries are fed from MSEDCL – initially. There is proposed provision of installing a DG to start TG auxiliaries to start the TG auxiliaries and further generation. There is provision to synchronize TG either at 11KV or at 33KV.
- The system will work in three modes. A) Only T.G. B) Only MSEDCL C) T.G. floated on MSEDCL at 33KV bus and will draw only inrush power from GRID if required.
- Three load transformers have Hybrid harmonic filters which are combination of detuned and active filters. They maintain power factor at unity and current harmonic distortion around 5%.
- The captive power generation is under commissioning at present. The MSEDCL contract demand is 4600KVA and recorded demand in April 2017 was 4546KVA.

Methodology followed for short circuit analysis:

Chemical Company in Lote has recently installed 8.72MW captive thermal power generation in the plant and has planned to synchronize this with Grid and use in Float mode. In view of avoiding possibility of nuisance tripping and malfunctioning of system in float and all other modes, the project and maintenance team decided to get formal "Short circuit analysis" done on the system and get recommendations for protection relay coordination settings. SAS Powertech P Ltd (SASPPL) was engaged to do the task.

- SASPPL decided to simulate Electrical system on ETAP – a system simulation tool to undertake load flow analysis and short circuit analysis.
- SASPPL deputed their team to Lote plant to record electrical parameters for sufficient time.
- The team recorded 33KV main input and secondaries of all three transformers for 24 hours. Major feeders of all the transformers were recorded for sufficient time.
- Captive generation was under commissioning during this visit.
- The team also collected various parameters of 8.72MW alternator, all transformers, and major cables.
- Data related to all protection relays at various locations, various circuit breakers at 433V, 11KV, 33KV was collected by the team.

Once this data is available, the electrical system was simulated in ETAP up to individual downstream PCC / MCC level – which directly feed various plant loads and analysis was carried out.

Summary of "LOAD FLOW STUDY" conducted in ETAP along with individual branch loading and branch losses.

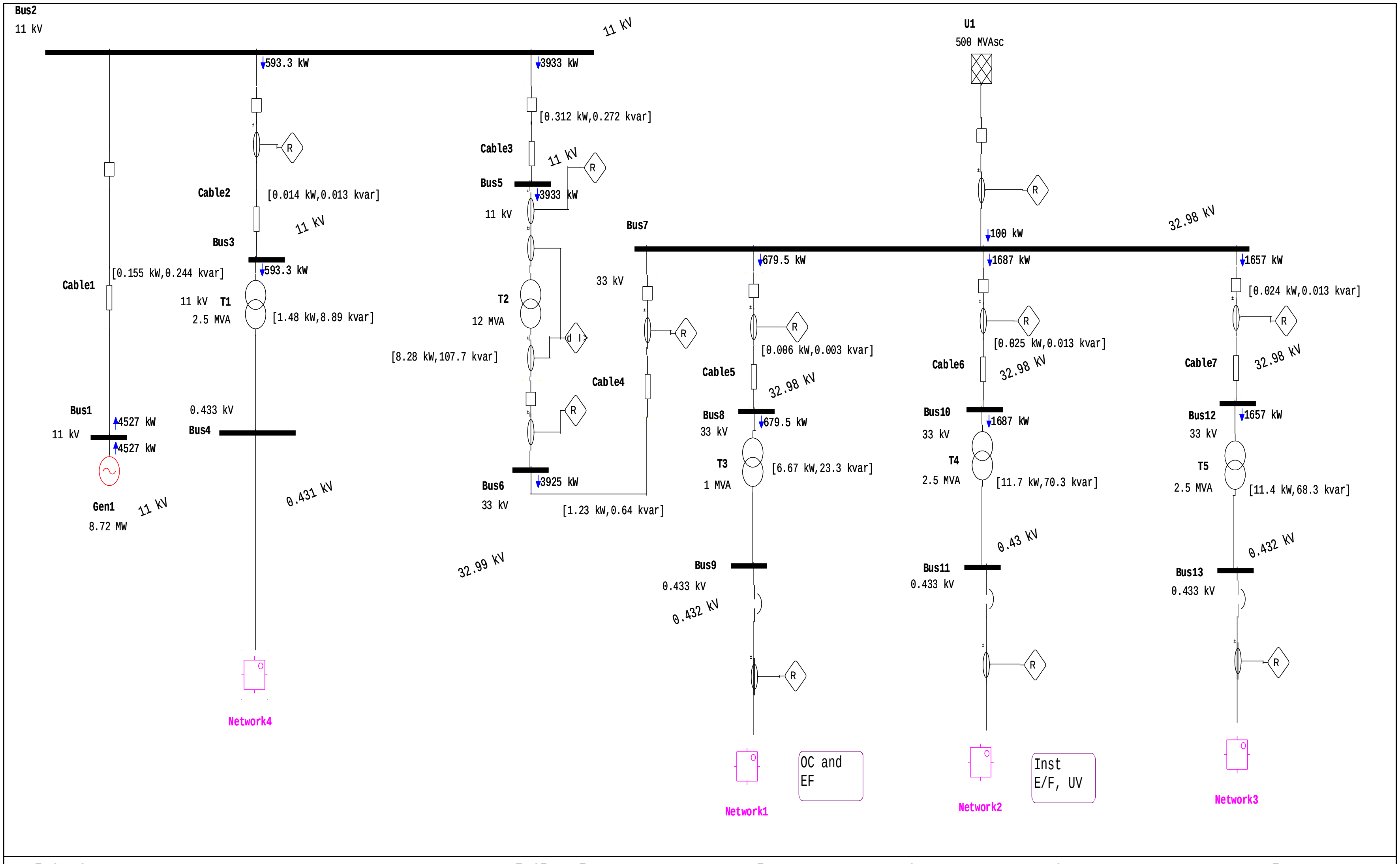
LOAD FLOW Through the system			
Branch ID	**From**	**To**	**KW Loss**
TG	TG	System	4527
GRID	GRID	System	100
		Total Input	**4627**
		TG Aux	592
		1 MVA Tx	673
		2.5 MVA Tx 1	1675
		2.5MVA Tx 2	1645
		Total Load	**4585**
		Total Losses	**42**
Cable1	TG	11KV Panel	0.2
Cable2	11KV Panel	Aux Tx 2.5MVA Primary	0.0
Cable3	11KV Panel	12MVA Tx - 11KV side	0.3
T1	2.5MVA		1.5
T2	12MVA		8.3
Cable4	ICOG Panel	33KV MSEDCL Bus	1.2
Cable5	33KV Bus	1 MVA Tx Primary	0.0
Cable6	33KV Bus	2.5MVA Tx1 Primary	0.0
Cable7	33KV Bus	2.5MVA Tx2 Primary	0.0
T3	1 MVA		6.7
T4	2.5MVA		11.7
T5	2.5MVA		11.4
		Total Losses	**41.3**

ETAP simulation was conducted using load profiles recorded at site. The load profile was recorded to know 24 hours load patterns on all three transformers which supply power to all plant processes. Above report assumes that plant runs in "CAPTIVE GEN FLOAT" mode and TG is supplying power to plant. Input from Grid was restricted to 100KW forcefully. The simulation shows that about 75% of branch loss is "loss in transformers".

Bus load currents as per "LOAD FLOW STUDY" conducted in ETAP along with load currents in three proposed modes of operation.

Nominal Voltage and FLC under various modes				
ID	KV	FLOAT	CP	MSEDCL
		Amp	Amp	Amp
Bus1	11.000	247.5	247.5	
Bus2	11.000	247.7	247.7	31.5
Bus3	11.000	31.5	31.5	31.5
Bus4	0.433	800.8	800.8	801.0
Bus5	11.000	216.5	216.5	31.5
Bus6	33.000	72.2	72.2	10.5
Bus7	33.000	72.2	72.2	82.5
Bus8	33.000	13.6	13.6	13.6
Bus9	0.433	1037.2	1037.2	1037.3
Bus10	33.000	29.5	29.5	29.5
Bus11	0.433	2251.3	2251.3	2250.9
Bus12	33.000	29.1	29.1	29.1
Bus13	0.433	2220.1	2220.1	2219.3
Bus14	0.433	1292.4	1292.4	1292.9
Bus15	0.433	2544.3	2544.3	2544.4
Bus16	0.433	2443.9	2443.9	2443.6

This table is also output of ETAP – load flow study and gives bus nominal currents under running conditions. The power parameters are also recorded for 24 hours. Maximum parameter values are chosen and used as input to ETAP / RELAY coordination.



This is a ETAP LOAD FLOW output while the system works on “Captive Generation FLOAT” mode.

For eaze of reading – please Zoom this diagram on computer.

Summary of "Short circuit STUDY" conducted in ETAP.

Short circuit currents at various buses under various fault conditions are calculated as per IEC 60909.

1) 1MVA Process Load transformer primary and secondary. (All currents are in KA.)

BUS 9 - 1MVA Sec to Network 1 Fault current KA															
	3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				Line to Line to Ground Fault			
kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
CP FLOAT															
0.433	31.44	63.61	27.73	30.54	61.78	30.54	30.54	27.22	55.08	27.22	27.22	31.08	62.87	31.08	31.08
MSEDCL Only															
0.433	31.36	63.47	27.65	30.49	61.70	30.49	30.49	27.16	54.97	27.16	27.16	31.01	62.75	31.01	31.01
CP Only															
0.433	24.00	50.48	19.55	25.11	52.81	25.11	25.11	20.41	42.93	20.41	20.41	24.73	52.01	24.73	24.73
BUS 8- 1MVA Primary to 33KV MSEDCL Bus Fault KA															
	3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				Line to Line to Ground Fault			
kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
CP FLOAT															
33.000	9.69	24.52	9.41	10.14	25.67	10.14	10.14	8.34	21.10	8.34	8.34	9.95	25.18	9.95	9.95
MSEDCL Only															
33.000	9.02	22.74	8.72	9.68	24.41	9.68	9.68	7.81	19.69	7.81	7.81	9.40	23.70	9.40	9.40
CP Only															
33.000	0.98	2.40	0.35	1.18	2.89	1.18	1.18	0.80	1.95	0.80	0.80	1.23	3.01	1.23	1.23

- This shows that breaking capacity of LT side breakers should be more than 32 KA.
- Short circuit withstanding capacity of LT side panels should be better than 65 KA.
- Short circuit withstand capacity of HT panels at 26KA is just adequate as I peak is 25.18KA.
- Short circuit and E/F currents vary substantially between system running only on CP and while running with CP float.
- "Only CP short circuit currents" are less as TG fault level and GRID fault level differ from each other.
- As there is adequate derating in load current at HT level, we have recommended lesser fault currents for deciding HT side relay settings.

2) 2.5 MVA Process Load transformer primary and secondary. (All currents are in KA.)

BUS 13 - 2.5 MVA - 1 Sec to Network 3 Fault Current KA															
	3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				Line to Line to Ground Fault			
kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
CP FLOAT															
0.433	63.82	142.66	53.68	61.83	138.21	61.83	61.83	55.25	123.50	55.25	55.25	63.45	141.83	63.45	63.45
MSEDCL Only															
0.433	63.51	141.98	53.35	61.65	137.82	61.65	61.65	55.00	122.96	55.00	55.00	63.19	141.27	63.19	63.19
CP Only															
0.433	40.28	91.30	22.37	44.02	99.75	44.02	44.02	33.96	76.97	33.96	33.96	43.67	98.97	43.67	43.67
BUS 12 - 2.5MVA 1 Primary to 33KV MSEDCL BUS															
	3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				Line to Line to Ground Fault			
kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
CP FLOAT															
33.000	9.70	24.61	9.42	10.16	25.78	10.16	10.16	8.35	21.18	8.35	8.35	9.97	25.29	9.97	9.97
MSEDCL Only															
33.000	9.03	22.82	8.73	9.70	24.52	9.70	9.70	7.82	19.76	7.82	7.82	9.42	23.80	9.42	9.42
CP Only															
33.000	0.98	2.40	0.35	1.18	2.89	1.18	1.18	0.80	1.95	0.80	0.80	1.23	3.01	1.23	1.23

- This shows that breaking capacity of LT side breakers should be at least 65 KA.
- Short circuit withstanding capacity of LT side panels should be better than 142 KA.
- Short circuit withstand capacity of HT panels at 26KA is just adequate as I peak is 25.18KA.
- Short circuit and E/F currents vary substantially between system running only on CP and while running with CP float.
- “Only CP short circuit currents” are less as TG fault level and GRID fault level differ from each other.
- As there is adequate derating in load current at HT level, we have recommended lesser fault currents for deciding HT side relay settings.

3) 2.5 MVA Process Load transformer primary and secondary. (All currents are in KA.)

BUS 11 - 2.5MVA - 2 Sec to Network 2 Fault current KA															
	3-Phase Fault			**Line-to-Ground Fault**				**Line-to-Line Fault**				**Line to Line to Ground Fault**			
kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
CP FLOAT															
0.433	62.76	140.66	53.68	61.16	137.08	61.16	61.16	54.33	121.77	54.33	54.33	62.49	140.08	62.49	62.49
MSEDCL Only															
0.433	62.45	139.98	53.35	60.98	136.69	60.98	60.98	54.08	121.23	54.08	54.08	62.24	139.52	62.24	62.24
CP Only															
0.433	39.40	89.62	22.37	43.28	98.44	43.28	43.28	33.21	75.53	33.21	33.21	42.86	97.48	42.86	42.86
BUS 10 - 2.5MVA - 2 Primary to 33KV MSEDCL BUS															
	3-Phase Fault			**Line-to-Ground Fault**				**Line-to-Line Fault**				**Line to Line to Ground Fault**			
kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
CP FLOAT															
33.000	9.70	24.61	9.42	10.16	25.78	10.16	10.16	8.35	21.18	8.35	8.35	9.97	25.29	9.97	9.97
MSEDCL Only															
33.000	9.70	24.61	9.42	10.16	25.78	10.16	10.16	8.35	21.18	8.35	8.35	9.97	25.29	9.97	9.97
CP Only															
33.000	0.98	2.40	0.35	1.18	2.89	1.18	1.18	0.80	1.95	0.80	0.80	1.23	3.01	1.23	1.23

- This shows that breaking capacity of LT side breakers should be atleast 65 KA.
- Short circuit withstanding capacity of LT side panels should be better than 142 KA.
- Short circuit withstand capacity of HT panels at 26KA is just adequate as I peak is 25.78KA.
- Short circuit and E/F currents vary substantially between system running only on CP and while running with CP float.
- “Only CP short circuit currents” are less as TG fault level and GRID fault level differ from each other.
- As there is adequate derating in load current at HT level, we have recommended lesser fault currents for deciding HT side relay settings.

4) 33KV main MSEDCL bus, 33KV side of 12 MVA Tx, 11KV side of 12 MVA Tx. (All currents are in KA.)

BUS 7- 33KV MSEDCL Bus Fault KA															
	3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				Line to Line to Ground Fault			
kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
CP FLOAT															
33.000	9.73	24.81	9.09	10.20	26.03	10.20	10.20	8.37	21.35	8.37	8.37	10.01	25.54	10.01	10.01
MSEDCL Only															
33.000	9.05	22.99	8.75	9.74	24.73	9.74	9.74	7.84	19.91	7.84	7.84	9.46	24.02	9.46	9.46
CP Only															
33.000	0.98	2.40	0.35	1.18	2.90	1.18	1.18	0.80	1.95	0.80	0.80	1.23	3.02	1.23	1.23
BUS6 - 33KV 12MVA Secondary Fault KA															
	3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				Line to Line to Ground Fault			
kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
CP FLOAT															
33.000	9.53	23.34	8.91	9.95	24.38	9.95	9.95	8.20	20.08	8.20	8.20	9.78	23.95	9.78	9.78
MSEDCL Only															
33.000	8.85	21.51	8.56	9.49	23.06	9.49	9.49	7.66	18.63	7.66	7.66	9.23	22.43	9.23	9.23
CP Only															
33.000	0.98	2.41	0.35	1.18	2.91	1.18	1.18	0.80	1.96	0.80	0.80	1.24	3.05	1.24	1.24
BUS 5 - 11KV side of 12MVATx Fault KA															
	3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				Line to Line to Ground Fault			
kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
CP FLOAT															
11.000	9.23	23.76	7.38	0.11	0.28	0.11	0.11	7.72	19.86	7.72	7.72	7.75	19.93	7.75	7.75
MSEDCL Only															
11.000	6.45	16.16	6.29	0.00	0.00	0.00	0.00	5.59	14.00	5.59	5.59	5.59	14.00	5.59	5.59
CP Only															
11.000	3.62	9.24	1.09	0.11	0.28	0.11	0.11	2.85	7.28	2.85	2.85	2.88	7.36	2.88	2.88

- Required Short circuit withstand capacity of HT panels is 25.54KA max.
- Short circuit and E/F currents vary substantially between system running only on CP and while running with CP float.
- "Only CP short circuit currents" are less as TG fault level and GRID fault level differ from each other.
- As there is adequate derating in load current at HT level, we have recommended lesser fault currents for deciding HT side relay settings.

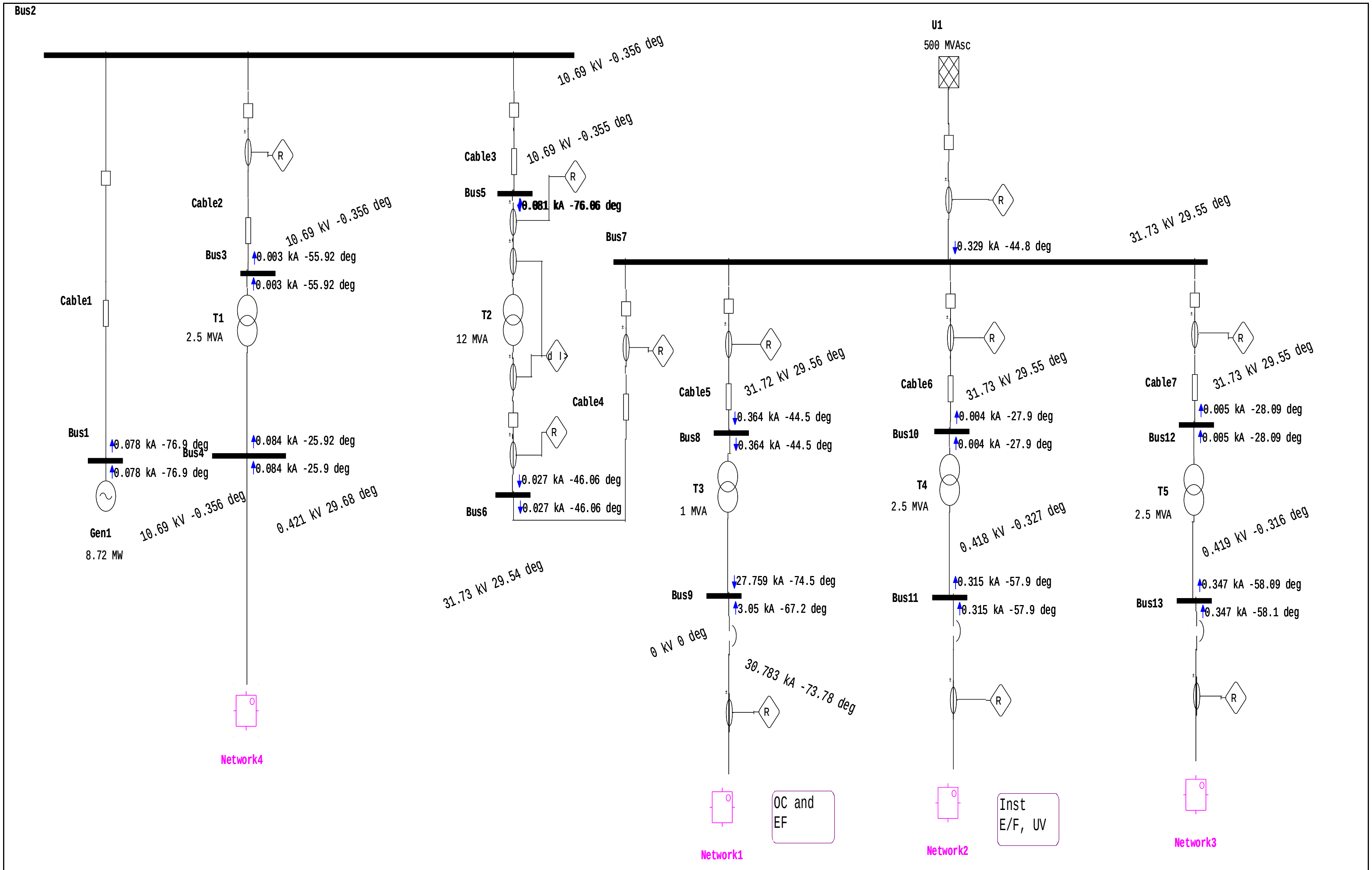
5) 11KV main TG bus, 11/0.433KV 2.5 MVA TG Aux Tx, 11KV TG output. (All currents are in KA.)

BUS 2 - 11KV Main bus															
	3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				Line to Line to Ground Fault			
kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
CP FLOAT															
11.000	9.22	23.70	7.37	0.11	0.28	0.11	0.11	7.71	19.81	7.71	7.71	7.74	19.88	7.74	7.74
MSEDCL Only															
11.000	6.44	16.09	6.28	0.00	0.00	0.00	0.00	5.58	13.93	5.58	5.58	5.58	13.93	5.58	5.58
CP Only															
11.000	3.62	9.26	1.09	0.11	0.28	0.11	0.11	2.85	7.29	2.85	2.85	2.88	7.37	2.88	2.88

BUS 4 - CP Aux Tx Secondary Main bus															
	3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				Line to Line to Ground Fault			
kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
CP FLOAT															
0.433	48.98	113.09	46.00	51.45	118.80	51.45	51.45	42.11	97.23	42.11	42.11	50.41	116.39	50.41	50.41
MSEDCL Only															
0.433	45.11	104.14	42.09	48.77	112.59	48.77	48.77	39.07	90.19	39.07	39.07	47.27	109.14	47.27	47.27
CP Only															
0.433	37.49	88.28	23.34	41.32	97.30	41.32	41.32	31.25	73.59	31.25	31.25	40.75	95.95	40.75	40.75

BUS 1 - 11 KV CP Output															
	3-Phase Fault			Line-to-Ground Fault				Line-to-Line Fault				Line to Line to Ground Fault			
kV	I"k	ip	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik	I"k	ip	Ib	Ik
CP FLOAT															
11.000	9.21	23.67	7.36	0.11	0.28	0.11	0.11	7.70	19.78	7.70	7.70	7.73	19.86	7.73	7.73
MSEDCL Only															
CP Only															
11.000	3.63	9.27	1.09	0.11	0.28	0.11	0.11	2.85	7.30	2.85	2.85	2.88	7.37	2.88	2.88

- 11KV main bus SC current Levels are up to 23.7 KA. So panels must be rated for atleast 25KA SC withstand capacity.
- TG Aux 2.5 MVA transformer LT side max SC fault level is 116 KA.
- TG output max fault level is 19.86KA, when on float and the same is 9.27KA when only TG is running as a source.

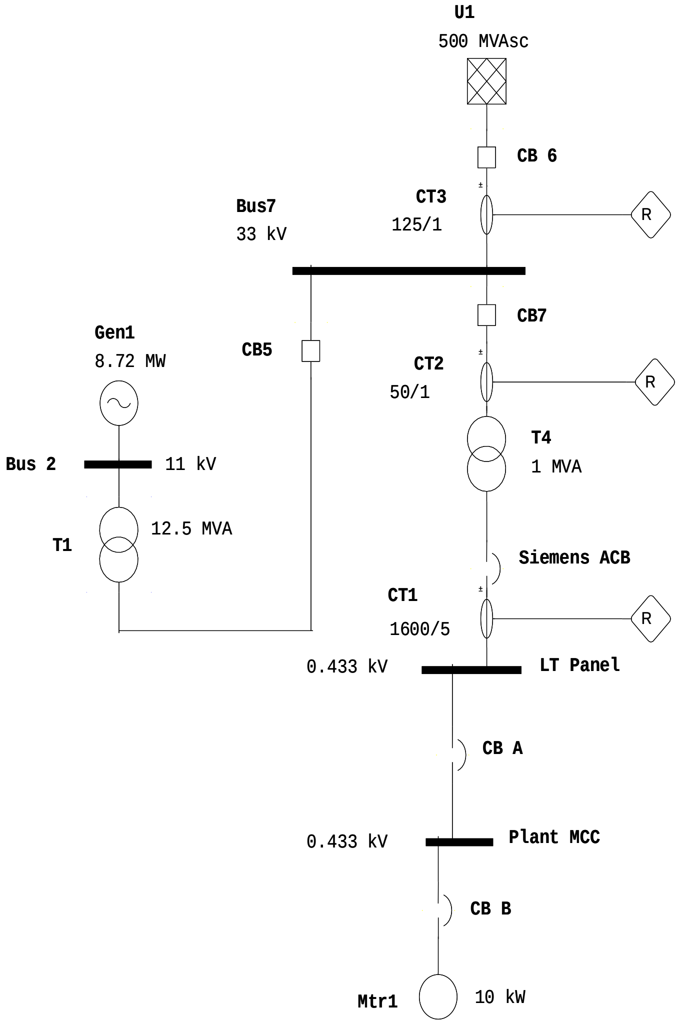


This is a typical SC analysis output from ETAP showing SC fault at Bus 9 - secondary of 1 MVA process load transformer.

For eaze of reading – please Zoom this diagram on computer.

Kindy note:	**Relay changes at site might need some adjustments to suit tollarances of working system.**

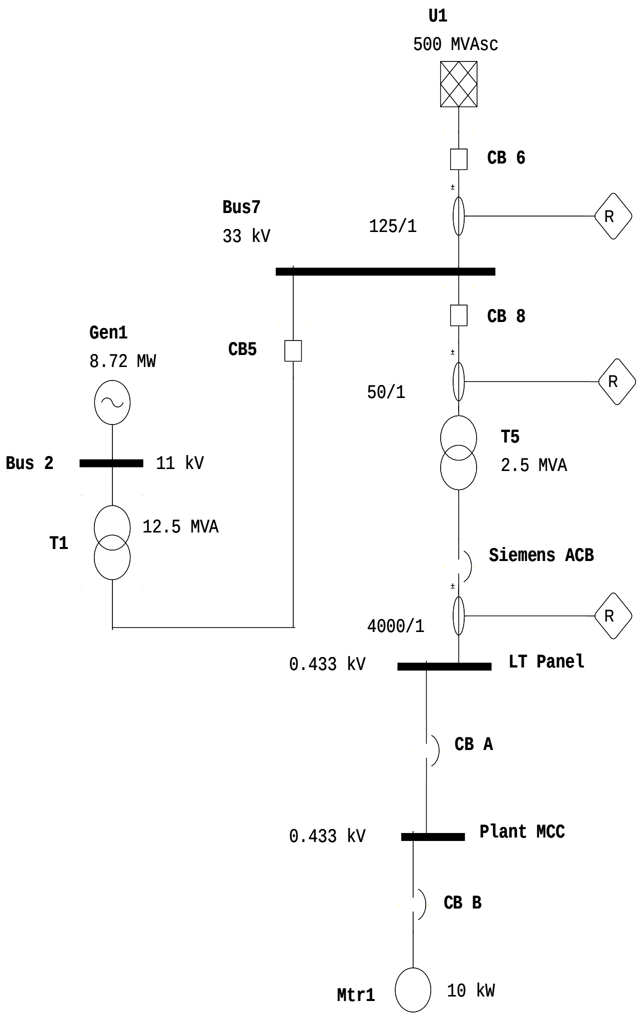
1 MVA Plant Transformer Protection Zone.



Zone 1 CB B and A: These are MCCBs and needs to be coordinated locally for fault isolation based on facilities available on breaker.
Zone 2: Siemens ACB – CB 7 (VCB)

Circuit Breaker	**Siemens ACB**	**CB7**
CT	1600/5	50/1
Normal Amps	1100	14
O/L Amps	1375	18
L-L S/C Amps	21000	276
L-G S/C Amps	25000	276
Recommended Relay settings and expected trip time		
Relay	IRI 1-20	Micom P 111
O/L Low set i>		
Curve	VI	NI
Plug setting	0.8	0.4
TMS	0.15	0.2
Exp Trip Time msec	697+145 = 845	917+145=1065
O/L High set i>>		
Curve	DMT	DMT
Plug setting	2.5	2.5
DM Time msec	200	300
Exp Trip Time msec	200+145 = 345	300+145 = 445
E/F Low set ie>		
Curve	NI	NI
Plug setting	0.2	0.15
TMS	0.2	0.15
Exp Trip Time msec	892+145 = 1037	1060+145 = 1205
E/F High set ie>>		
Curve	DMT	DMT
Plug setting	2.5	2.5
DM Time msec	200	300
Exp Trip Time msec	200+145 = 345	300+145 = 445

2.5 MVA Tx 1 Plant Transformer Protection Zone.

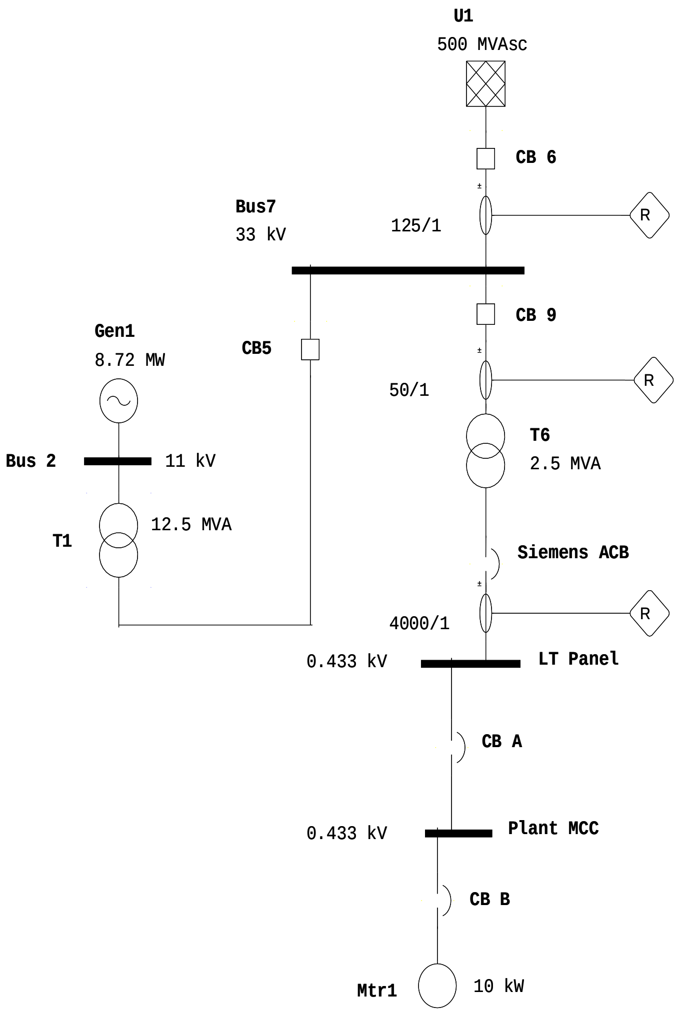


Zone 1 CB B and A: These are MCCBs and needs to be coordinated locally for fault isolation based on facilities available on breaker.

Zone 2: Siemens ACB – CB 8 (VCB)

Circuit Breaker	**Siemens ACB**	**CB 8**
CT	4000/1	50/1
Normal Amps	3341	44
O/L Amps	4167	55
L-L S/C Amps	40000	525
L-G S/C Amps	40000	525
Recommended Relay settings and expected trip time		
Relay	CAG 14AF	Micom P 111
O/L Low set i>		
Curve	VI	NI
Plug setting	1	1
TMS	0.2	0.25
Exp Trip Time msec	675+145 = 820	1009+145=1154
O/L High set i>>		
Curve	DMT	DMT
Plug setting	2.5	2.5
DM Time msec	200	300
Exp Trip Time msec	200+145 = 345	300+145 = 445
E/F Low set ie>		
Curve	NI	NI
Plug setting	0.2	0.2
TMS	0.2	0.15
Exp Trip Time msec	935+145 = 1070	1321+145 = 1466
E/F High set ie>>		
Curve	DMT	DMT
Plug setting	2.5	2.5
DM Time msec	200	200
Exp Trip Time msec	200+145 = 345	300+145 = 445

2.5 MVA Tx 2 Plant Transformer Protection Zone.



Zone 1 CB B and A: These are MCCBs and needs to be coordinated locally for fault isolation based on facilities available on breaker.

Zone 2: Siemens ACB – CB 9 (VCB)

Circuit Breaker	**Siemens ACB**	**CB 9**
CT	4000/1	50/1
Normal Amps	3334	44
O/L Amps	4167	55
L-L S/C Amps	40000	525
L-G S/C Amps	40000	525
Recommended Relay settings and expected trip time		
Relay	CAG 14AF	Micom P 111
O/L Low set i>		
Curve	VI	NI
Plug setting	1	1
TMS	0.2	0.25
Exp Trip Time msec	675+145 = 820	1009+145 = 1145
O/L High set i>>		
Curve	DMT	DMT
Plug setting	2.5	2.5
DM Time msec	200	300
Exp Trip Time msec	200+145 = 345	300+145 = 445
E/F Low set ie>		
Curve	NI	NI
Plug setting	0.2	0.2
TMS	0.2	0.15
Exp Trip Time msec	935+145 = 1080	1321+145 = 1466
E/F High set ie>>		
Curve	DMT	DMT
Plug setting	2.5	2.5
DM Time msec	200	300
Exp Trip Time msec	200+145 = 345	300+145 = 445

Detail Relay setting calculations: Over current I>. For I>> DMT curve is chosen. T4,T5,T6

Low set O/L Trip setting 51 @ LT I>	T4 1MVA	T5 2.5MVA	T6 2.5 MVA
Normal current	1100	3334	3334
Overload 125%	1375	4167	4167
Min Fault current Line to Line	21000	40000	40000
Mx Faultcurrent Line to Line	28000	63000	63000
Mx Fault Considered for setting	5000	20000	20000
CT Primary Current	1600	4000	4000
CT Secondary Current	5	1	1
Plug setting calculated	0.86	1.04	1.04
Plug setting to be done i>	**0.80**	**1.00**	**1.00**
Secondary current reqd for relay pick up	4.00	1.00	1.00
Corresponding Primary current = Sec current * CT Ratio	1280.00	4000.00	4000.00
Plug setting Multiplier @ Min Fault PSM	3.91	5.00	5.00
TMS	**0.15**	**0.2**	**0.2**
VI Trip time in Sec = TMS x [13.5/(PSM -1)]	**0.697**	**0.675**	**0.675**
VI fault clearing time =(Relay +Master+CB+safety) msec	**842**	**820**	**820**

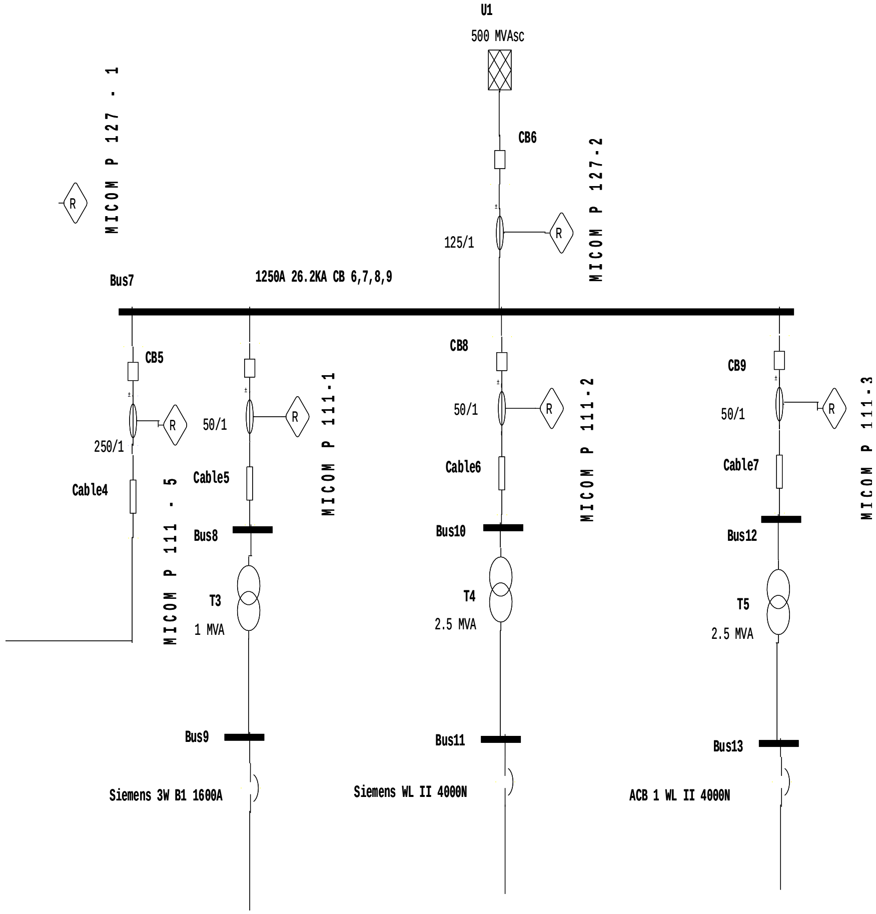
Low set O/L Trip setting 51 @HT I>	T4 1MVA	T5 2.5MVA	T6 2.5 MVA
Normal current	14	44	44
Overload 125%	18	55	55
Min Fault current Line to Line	276	525	525
Mx Faultcurrent Line to Line	367	827	827
Mx current consiidered for relay setting	90	275	275
CT Primary Current	50	50	50
CT Secondary Current	1	1	1
Plug setting calculated	0.36	1.09	1.09
Plug setting to be done i>	**0.40**	**1.00**	**1.00**
Secondary current reqd for relay pick up	0.40	1.00	1.00
Corresponding Primary current = Sec current * CT Ratio	20.00	50.00	50.00
Plug setting Multiplier @ Min Fault PSM	4.50	5.50	5.50
TMS	**0.2**	**0.25**	**0.25**
NI Trip time in Sec = TMS x [0.14/(PSM)^0.02 - 1)]	**0.917**	**1.009**	**1.009**
NI fault clearing time =(Relay +Master+CB+safety) msec	**1062**	**1154**	**1154**

Detail Relay setting calculations: Earth Fault Ie>. For Ie>> DMT curve is chosen. T4, T5, T6

Low set E/F Trip setting 51N @ LT I>	T4 1MVA	T5 2.5MVA	T6 2.5 MVA
Normal current	1100	3334	3334
E/F current ---- imbalance 25% of above	275	833	833
Min Fault current Line to Earth	25000	40000	40000
Mx Faultcurrent Line to Earth	31000	63000	63000
Mx Fault current considered for setting	1500	3500	3500
CT Primary Current	1600	4000	4000
CT Secondary Current	5	1	1
Plug setting calculated	0.17	0.21	0.21
Plug setting to be done i>	**0.20**	**0.20**	**0.20**
Secondary current reqd for relay pick up	1.00	0.20	0.20
Corresponding Primary current = Sec current * CT Ratio	320.00	800.00	800.00
Plug setting Multiplier @ Min Fault PSM	4.69	4.38	4.38
TMS	**0.2**	**0.2**	**0.2**
NI Trip time in Sec = TMS x [0.14/(PSM)^0.02 - 1)]	**0.892**	**0.935**	**0.935**
NI fault clearing time =(Relay +Master+CB+safety) msec	**1037**	**1080**	**1080**

Low set E/F Trip setting 51N @ HT I>	T4 1MVA	T5 2.5MVA	T6 2.5 MVA
Normal current	14	44	44
E/F current ---- imbalance 25% of above	4	11	11
Min Fault current Line to Earth	276	525	525
Mx Faultcurrent Line to Line	367	827	827
Mx current consiidered for relay setting	20	22	22
CT Primary Current	50	50	50
CT Secondary Current	1	1	1
Plug setting calculated	0.072	0.22	0.22
Plug setting to be done i>	**0.15**	**0.20**	**0.20**
Secondary current reqd for relay pick up	0.15	0.20	0.20
Corresponding Primary current = Sec current * CT Ratio	7.50	10.00	10.00
Plug setting Multiplier @ Min Fault PSM	2.67	2.20	2.20
TMS	**0.15**	**0.15**	**0.15**
NI Trip time in Sec = TMS x [0.14/(PSM)^0.02 - 1)]	**1.060**	**1.321**	**1.321**
NI fault clearing time =(Relay +Master+CB+safety) msec	**1205**	**1466**	**1466**

Main 33KV HT MSEDCL side incoming breaker



Circuit Breaker	**CB VCB**
CT	125/1
Normal Amps	83
O/L Amps	124
L-L S/C Amps	980
L-G S/C Amps	1180
Recommended Relay settings and expected trip time	
Relay	MICOM P 127
O/L Low set i>	
Curve	NI
Plug setting	0.9
TMS	0.2
Exp Trip Time msec	822+145=967
O/L High set i>>	
Curve	DMT
Plug setting	2.5
DM Time msec	200
Exp Trip Time msec	200+145 = 345
E/F Low set ie>	
Curve	NI
Plug setting	0.2
TMS	0.15
Exp Trip Time msec	747+145=892
E/F High set ie>>	
Curve	DMT
Plug setting	2.5
DM Time msec	200
Exp Trip Time msec	200+145 = 345

Detail Relay setting calculations: Over current I>. For I>> DMT curve is chosen. 33KV MSEDCL breaker

This breaker is expected to trip under

a) 33KV main bus earth fault
b) Over current due to fault in downstream transformers or bus faults before the transformer. (As back up).
c) Over current due to synchronizing issues.
d) Substantial reverse power flow for substantial time period.

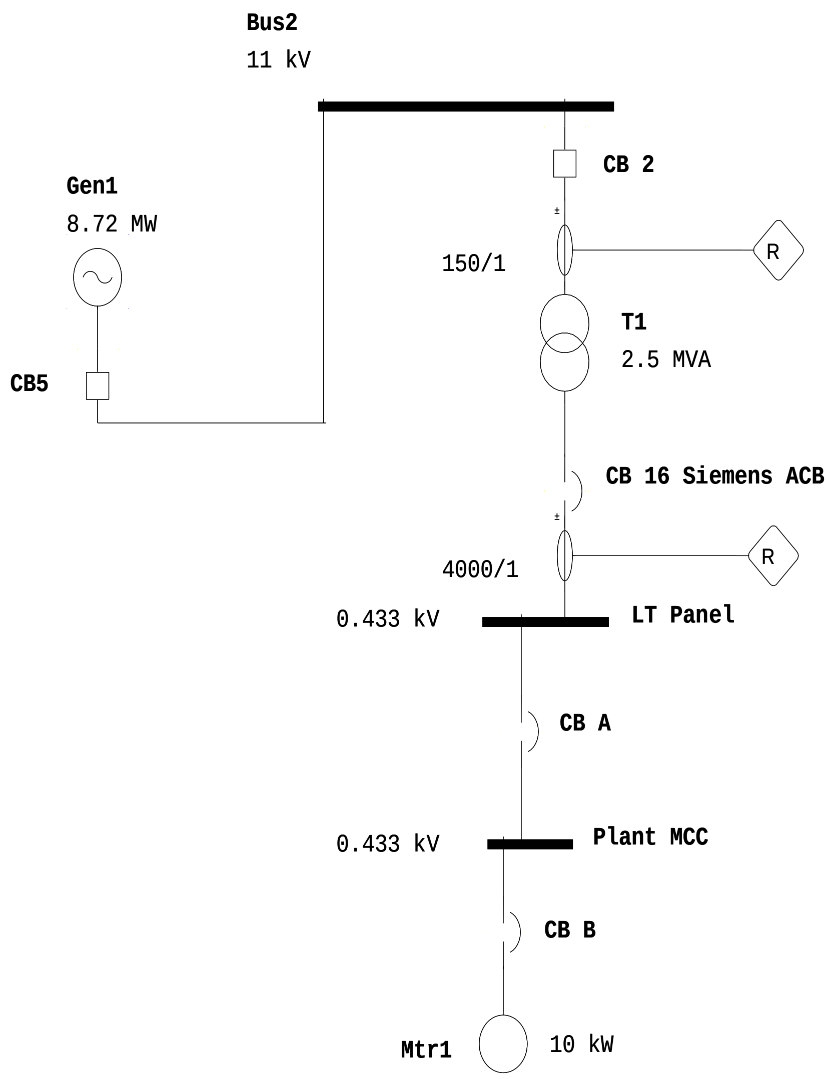
Relay settings for Elements related to "a and b" are given bellow, while those for c and d will depend upon TG settings and arrangements with MSEDCL.

Low set O/L Trip setting 51 @HT I>	Values
Normal current	83
Overload 150%	124
Min Fault current Line to Line	980
Mx Faultcurrent Line to Line	9730
Mx current considered for relay setting	600
CT Primary Current	125
CT Secondary Current	1
Plug setting calculated	1.00
Plug setting to be done i>	**0.90**
Secondary current reqd for relay pick up	0.90
Corresponding Primary current = Sec current * CT Ratio	112.50
Plug setting Multiplier @ Min Fault PSM	5.33
TMS	**0.2**
NI Trip time in Sec = TMS x [0.14/(PSM)^0.02 - 1)]	0.822
NI fault clearing time =(Relay +Master+CB+safety) msec	**967**

Detail Relay setting calculations: Earth Fault Ie>. For Ie>> DMT curve is chosen. 33KV MSEDCL breaker.

Low set E/F Trip setting 51N @ HT I>	T1 1MVA
Normal current	83
E/F current ---- imbalance 25% of above	21
Min Fault current Line to Earth	1180
Mx Faultcurrent Line to Line	10200
Mx current considered for relay setting	100
CT Primary Current	125
CT Secondary Current	1
Plug setting calculated	0.166
Plug setting to be done i>	**0.20**
Secondary current reqd for relay pick up	0.20
Corresponding Primary current = Sec current * CT Ratio	25.00
Plug setting Multiplier @ Min Fault PSM	4.00
TMS	**0.15**
NI Trip time in Sec = TMS x [0.14/(PSM)^0.02 - 1)]	**0.747**
NI fault clearing time =(Relay +Master+CB+safety) msec	**892**

11KV HT TG Aux Branch.



Zone 1 CB B and A: These are MCCBs and needs to be coordinated locally for fault isolation based on facilities available on breaker.
Zone 2: Siemens ACB – CB 9 (VCB)

Circuit Breaker	**ACB CB 16**	**CB 2**
CT	4000/1	150/1
Normal Amps	812	32
O/L Amps	1015	40
L-L S/C Amps	31000	1220
L-G S/C Amps	40000	1575
Recommended Relay settings and expected trip time		
Relay	ACB Built in	Micom P 111
O/L Low set i>		
Curve	NI	NI
Plug setting	0.25	0.3
TMS	0.2	0.25
Exp Trip Time msec	856+145=1001	1156+145=1301
O/L High set i>>		
Curve	DMT	DMT
Plug setting	2.5	2.5
DM Time msec	200	300
Exp Trip Time msec	200+145 = 345	300+145 = 445
E/F Low set ie>		
Curve	NI	NI
Plug setting	0.1	0.1
TMS	0.1	0.15
Exp Trip Time msec	757+145=902	1060+145=1205
E/F High set ie>>		
Curve	DMT	DMT
Plug setting	2.5	2.5
DM Time msec	200	300
Exp Trip Time msec	200+145 = 345	300+145 = 445

Low set O/L Trip setting 51 @ LT I>	T1 2.5 MVA TG AUX
Normal current	812
Overload 125%	1015
Min Fault current Line to Line	31000
Mx Faultcurrent Line to Line	42000
Mx Fault Considered for setting	5000
CT Primary Current	4000
CT Secondary Current	1
Plug setting calculated	0.25
Plug setting to be done i>	**0.25**
Secondary current reqd for relay pick up	0.25
Corresponding Primary current = Sec current * CT Ratio	1000.00
Plug setting Multiplier @ Min Fault PSM	5.00
TMS	**0.2**
NI Trip time in Sec = TMS x [0.14/(PSM)^0.02 - 1)]	0.856
NI fault clearing time =(Relay +Master+CB+safety) msec	**1001**

Low set O/L Trip setting 51 @HT I>	T1 2.5 MVA TG AUX
Normal current	32
Overload 125%	40
Min Fault current Line to Line	1220
Mx Faultcurrent Line to Line	1653
Mx current consiidered for relay setting	200
CT Primary Current	150
CT Secondary Current	1
Plug setting calculated	0.27
Plug setting to be done i>	**0.30**
Secondary current reqd for relay pick up	0.30
Corresponding Primary current = Sec current * CT Ratio	45.00
Plug setting Multiplier @ Min Fault PSM	4.44
TMS	**0.25**
NI Trip time in Sec = TMS x [0.14/(PSM)^0.02 - 1)]	1.156
Actual estimated fault clearing time msec	**1301**

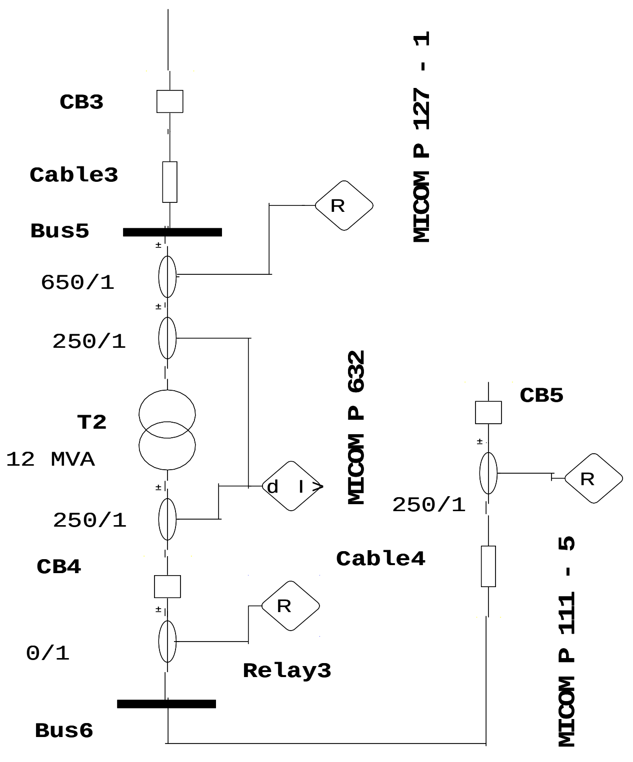
Low set E/F Trip setting 51N @ LT I>	T12.5 MVA TG AUX
Normal current	812
E/F current ---- imbalance 25% of above	203
Min Fault current Line to Earth	40000
Mx Faultcurrent Line to Earth	50000
Mx Fault current considered for setting	1000
CT Primary Current	4000
CT Secondary Current	1
Plug setting calculated	0.05
Plug setting to be done i>	**0.10**
Secondary current reqd for relay pick up	0.10
Corresponding Primary current = Sec current * CT Ratio	400.00
Plug setting Multiplier @ Min Fault PSM	2.50
TMS	**0.1**
NI Trip time in Sec = TMS x [0.14/(PSM)^0.02 - 1)]	**0.757**
NI fault clearing time =(Relay +Master+CB+safety) msec	**902**

Low set E/F Trip setting 51N @ HT I>	T1 2.5 MVA TG AUX
Normal current	32
E/F current ---- imbalance 25% of above	8
Min Fault current Line to Earth	1575
Mx Faultcurrent Line to Line	1968
Mx current consiidered for relay setting	40
CT Primary Current	150
CT Secondary Current	1
Plug setting calculated	0.053
Plug setting to be done i>	**0.10**
Secondary current reqd for relay pick up	0.10
Corresponding Primary current = Sec current * CT Ratio	15.00
Plug setting Multiplier @ Min Fault PSM	2.67
TMS	**0.15**
NI Trip time in Sec = TMS x [0.14/(PSM)^0.02 - 1)]	**1.060**
Actual estimated fault clearing time msec	**1205**

BUS 6, cable 4 and CB 5 form an interlink between Tr2 secondary and 33KV bus. This link carries almost 4100KW, when the system works either on “TG only” or “TG” Float mode. The same link carries around 600KW at present when the system works on “MSEDCL only” mode for supplying to TG auxiliaries.

This is recommended O/L and E/F setting, however CB5 is expected to be tripped by logic signal from TG protection scheme already designed. (We have considered max load flow from TG to Plant while recommending this.)

33KV link between TG and MSEDCL



Circuit Breaker	CB 5 VCB
CT	250/1
Normal max Amps	150
O/L Amps	188
L-L S/C Amps	9530
L-G S/C Amps	9780
Recommended Relay settings and expected trip time	
Relay	MICOM P 111
O/L Low set i>	
Curve	NI
Plug setting	0.7
TMS	0.2
Exp Trip Time msec	948+145=1093
O/L High set i>>	
Curve	DMT
Plug setting	2.5
DM Time msec	200
Exp Trip Time msec	300+145=445
E/F Low set ie>	
Curve	NI
Plug setting	0.15
TMS	0.2
Exp Trip Time msec	996+145=1141
E/F High set ie>>	
Curve	DMT
Plug setting	2.5
DM Time msec	300+145=445
Exp Trip Time msec	

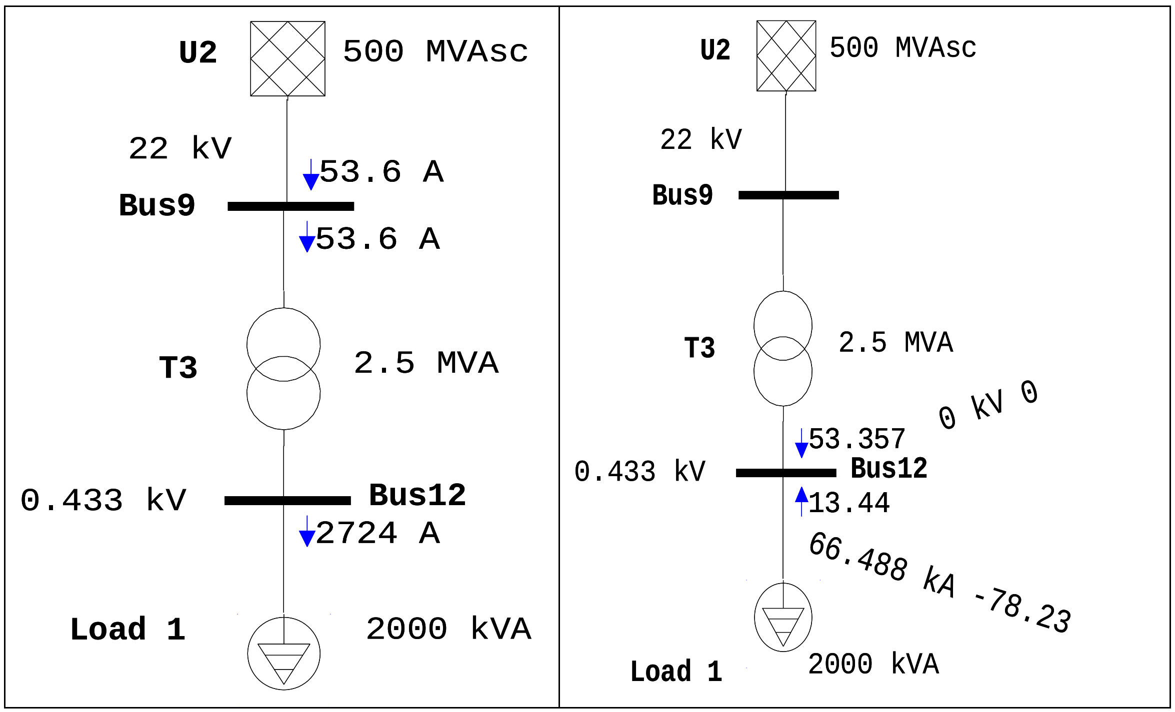
Low set O/L Trip setting 51 @HT I>	33KV Link bus
Normal current	150
Overload 125%	188
Min Fault current Line to Line	9530
Mx Faultcurrent Line to Line	9780
Mx current consiidered for relay setting	750
CT Primary Current	250
CT Secondary Current	1
Plug setting calculated	0.75
Plug setting to be done i>	**0.70**
Secondary current reqd for relay pick up	0.70
Corresponding Primary current = Sec current * CT Ratio	175.00
Plug setting Multiplier @ Min Fault PSM	4.29
TMS	**0.2**
NI Trip time in Sec = TMS x [0.14/(PSM)^0.02 - 1)]	0.948
Actual estimated fault clearing time msec	**1093**

Low set E/F Trip setting 51N @ HT I>	33KV Link bus
Normal current	150
E/F current ---- imbalance 25% of above	38
Min Fault current Line to Earth	9530
Mx Faultcurrent Line to Line	9780
Mx current consiidered for relay setting	150
CT Primary Current	250
CT Secondary Current	1
Plug setting calculated	0.150
Plug setting to be done i>	**0.15**
Secondary current reqd for relay pick up	0.15
Corresponding Primary current = Sec current * CT Ratio	37.50
Plug setting Multiplier @ Min Fault PSM	4.00
TMS	**0.2**
NI Trip time in Sec = TMS x [0.14/(PSM)^0.02 - 1)]	**0.996**
Actual estimated fault clearing time msec	**1141**

Short circuit analysis

Electrical systems in Industrial establishment generally feature following

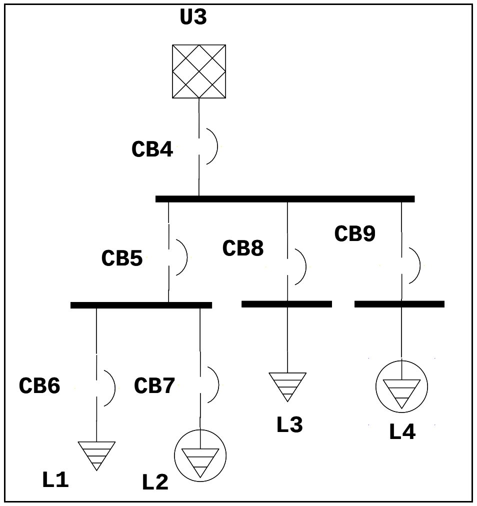
- They work on HT power supply connected to grid **and / or** local generation **and / or** standby generation having large but different source capacities and fault levels.
- They involve lot of electrical equipment like transformers, HT – LT switchgear, cables etc costing lot of money.
- These electrical systems supply and control electrical power to various complex Industrial processes and machines.
- Process complexity demands continuous supply to critical parts of the process to avoid production loss and to avoid hazards situations in few cases.
- Such electrical systems need protection against overloads and short circuits to ensure safety of human life and property.



In example as shown above, Bus 12 load current is 2724 Amps, while the 3-phase bolted fault short circuit current is 66.488KA. This system needs protection against overload above 2724 Amps and against short circuit current of 66 KA. The protection must allow inrush currents required by load and should differentiate between inrush and short circuit.

Fault in electrical distribution:

Fault in electrical system typically means direct interconnection of two electrical conductors having unequal voltages. For example, interconnections between L1 – L2 – L3, L1-G, L1-L2-G etc. In complex electrical systems, the fault or over load needs to be isolated at a point as close to the location of fault as possible so that rest of the healthy system remains in operation without any disturbance.
Critical disconnection points in electrical systems are equipped with suitable fast acting circuit breakers. Current and voltage transformers are inserted in these circuits to sense load current as well as fault current and generate suitable proportional signals, which are fed to Relays. These relays in turn develop trip signals which are used to trip the circuit breakers. Such relays offer various relationships between "Current" and "Time" to decide the trip point. Flexibility offered due to this is used for coordinating trip times of upstream and down stream circuit breakers.



As shown above,
Supply available at U3 is given to load L1 through CB4, CB5 and CB6.
CB4 also supplies to CB8 and CB9.
CB8 supplies to L3 and CB9 supplies to L4.
L1 may be a PCC or MCC having individual feeders protected by circuit breakers.

If a fault / Overload develops in a feeder in MCC connected to L1, the circuit breakers CB6, CB5, CB4 should be coordinated in such a way that

- Feeder CB should trip 1st isolating faulty feeder from L1 bus.
- If feeder CB fails to operate for some reason then CB6 should operate
- IF CB 6 does not operate then CB 5 should operate.
- If CB 5 does not operate, then CB 4 should operate.

This will ensure that if fault sensing and circuit breaker tripping is healthy then the fault will be cleared at farthest location from main input and rest of the system will keep running. This is known as protection coordination.

Fault clearing process:
Following sequence of operations take place once the fault is detected.

- The fault current is sensed by CTs.
- These fault signals are given to "RELAY".
- The relay actuates a contact which is wired in circuit breaker TRIP circuit.
- Operation of this contact initiates circuit breaker TRIP action.
- Circuit breaker Contact separation is associated with an Arc.
- Once the arc is quenched during contact separation, the fault is said to be cleared and faulty circuit is disconnected from the supply.

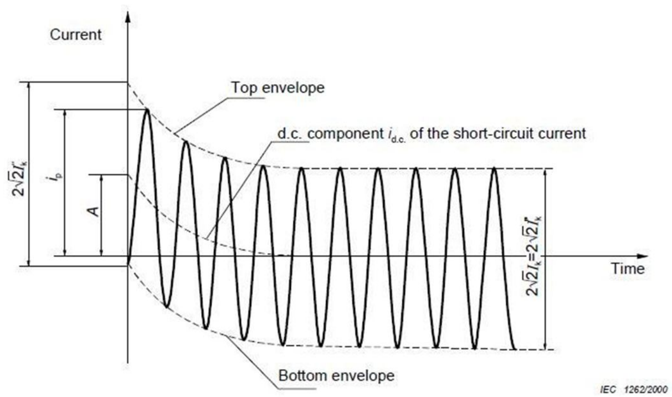
Most of the time various relays are connected in a circuit to detect various faults. Hence relay contacts of these individual relays are connected to a "Master Trip Relay" and in turn it's contact is wired to trip coil of circuit breaker. "Trip Circuit Supervision Relay" is used to ensure that the circuit breaker trip circuit wired through relay contact is healthy.
Other most popular fault clearing relays are "Overload Relays" and "Earth Fault relays". There is other class of relays which offer equipment protection.

This whole process of fault clearing takes finite time typically few hundred milliseconds. All the system components involved in carrying fault current, should withstand it, till the fault is cleared as above. Thermal withstand characteristics of such components are used to decide fault clearing time, which ensures that faults are cleared before the component gets damaged.

The fault currents generate excessive heat, and develops huge mechanical forces between adjacent electrical conductors like cables, busbars etc. Such busbars should withstand these dynamic forces, till the fault is cleared, otherwise they can increase complexity and damage due to such faults.

Arcs formed due to such faults contain huge heat, light and are associated with huge sound as well. This can harm human in vicinity and may cost life. An example may be seen in the photograph bellow.

Nature of short circuit currents:



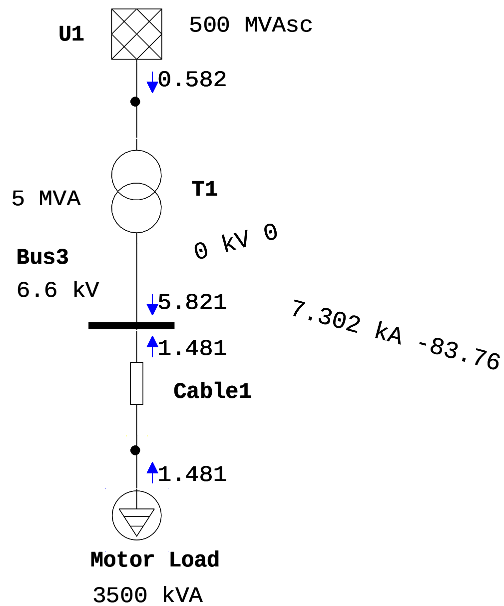
Short circuit is a disturbance in electrical system and usually it starts with **huge** (several times more) asymmetric current having DC component and then after some cycles it settles down to a symmetric value.

- The maximum initial peak value is important as the dynamic electromechanical forces are maximum at this current.
- DC component is decided by "X/R" ratio of the fault circuit and decides swing of this short circuit current. This decays with time.
- The current settles to some symmetric value after few cycles and this value is important as the breaker involved must break this current to clear the fault.

The Fault circuit is equivalent circuit of the entire network calculated at the point of fault and consists of

- Equivalent voltage source.
- Equivalent source impedance and
- Equivalent fault impedance

If more than one sources are involved, then all the sources contribute to fault current. Fault currents vary within the network at different points. Rotating machines also contribute additional fault current till they become standstill after the fault occurs.



As shown above, if motor loads are involved, then at the time when short circuit happens, the motor acts as generator till they come to stand still and feed to the fault. In above case 7.302 KA is fault current and it comprises of 5.821KA coming from source and 1.418 KA from motor load. Large inertia motor loads can keep feeding the fault, till the fault is cleared and hence need to be considered while designing breaker short circuit capacities.

Short circuit analysis is a process in which such short circuit currents are calculated for a given network. The faults considered are

- 3 Phase short circuit
- L – G Fault.
- L – L Fault
- L – L – G Fault.

Calculating these short circuit currents involves solving complex mathematical equations. Simpler way to arrive at accurate results is using electrical system simulation software tools. System data can be collected and then system is modelled in such software for further analysis. Software tools provide various modules (Computer programs) which undertake calculations and results are available in ready to use format. **ETAP is one such tool** developed in USA and is being used in the Industry world over.
Once peak load currents and short circuit currents are available after the calculations, they can be used for validating breaker, panel and cable short circuit ratings. These fault currents and Relay trip characteristics then can be used for time graded coordination to achieve fault isolation as required.

Such software tools are further useful for **arc flash study**, which determines level of energy released at each breaker location under short circuit conditions. This data is further useful to decide which grade of PPE (Personal protection equipment) should be used by operator / maintenance staff while handling a switchgear so that he can be safe under an accidental arc flash incidence.

The protection-system study must take the following parameters into account:

- Power system architecture and size, as well as the various operating modes,
- The neutral-earthing systems,
- The characteristics of current sources and their contributions in the event of a fault,
- The types of loads,
- The need for continuity of service.

IEC 60909: IEC standard which defines methods of short circuit current calculations and defines various instantaneous current values during short circuit. This standard is applicable for all radial and meshed power systems, 50 or 60 Hz and up to 550 kV.

It may be used to handle following types of solid short-circuit that can occur in an electrical installation:

- Three-phase short-circuit (all three phases), generally the type producing the highest currents,
- Two-phase short-circuit (between two phases), currents lower than three-phase faults,
- Two-phase-to-earth short-circuit (between two phases and earth),
- Phase-to-earth short-circuit (between a phase and earth), the most frequent type (80% of all cases).

When a fault occurs, the transient short-circuit current is a function of time and comprises of two components

- An AC component, decreasing to its steady-state value, caused by the various rotating machines and a function of the combination of their time constants,
- A DC component, decreasing to zero, caused by the initiation of the current and a function of the circuit impedances.

IEC 60909 defines the short-circuit values that are useful in selecting system equipment and the protection system:

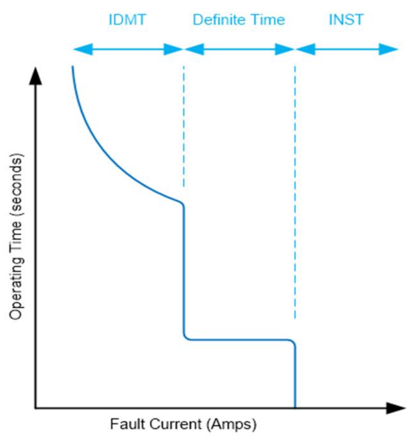
- **I’’k:** rms value of the initial symmetrical current,
- **Ib:** rms value of the symmetrical current interrupted by the switching device when the first pole opens at t min (minimum delay),
- **Ik:** rms value of the steady-state symmetrical current,
- **Ip:** maximum instantaneous value of the current at the first peak,
- **IDC:** DC value of the current.

There are 2 types of system equipment, which are exposed to short circuits.
Passive equipment:
They must have the capacity to transport both normal current and short-circuit current. This equipment includes cables, lines, busbars, disconnecting switches, transformers, series reactances and capacitors, instrument transformers. For this equipment, the capacity to withstand a short-circuit without damage is defined in terms of

- Electrodynamic withstand (expressed in kA peak), characterizing mechanical resistance to electrodynamic stress,
- Thermal withstand (expressed in rms kA for 1 to 5 seconds), characterizing maximum permissible heat rise.

Active equipment:
This category comprises the equipment designed to clear short-circuit currents, i.e. circuit breakers and fuses. This property is expressed by the breaking and making capacity when a fault occurs.

Relay Trip characteristics:



Heat generated due to electric current is proportional to I^2 as such the trip time should reduce in proportion to increase in I^2.

In practical systems, one must accommodate inrush currents demanded by loads. The time graded coordination in radial systems requires adjustable “Delay” in tripping after “Trip current” is reached. The same relay and CT sees normal load current, inrush current and short circuit current.

One needs

- Inverse characteristics for load / overload.
- Inverse Definite Minimum Time may be for accommodating inrush.
- Instantaneous for short circuit.

One also needs modified inverse characteristics and adjustable time delays to accommodate coordination between trip relays at various levels in distribution. IEC has standardized following characteristics for relays.

1) Normal Inverse
2) Very Inverse
3) Extreme Inverse.
4) Adjustable **T**ime **M**ultiplier **S**etting. TMS

As shown above various characteristic curves offered by relays can be used to advantage while co ordinating relays in a group of switchgears in a given electrical system network.

There are lot of protection functions available and are widely used on field. Major functional groups are equipment protection and over current protection. ANSI has standardized codes for these functions which are practiced worldwide. This has created a common language among protection engineers and also helps in saving space on documentation. Following table gives these codes.

Protection functions (ANSI CODES)

Code	Function Definition
12	Over speed Detection of rotating machine overspeed
14	Under speed Detection of rotating machine under speed
21	Distance protection Impedance measurement detection
21B	Under impedance Back-up phase-to-phase short-circuit protection for generators
24	Flux control Overfluxing check
25	25 Synchro-check Check before paralleling two parts of the power system
26	Thermostat Protection against overloads
27	Under voltage Protection for control of voltage sags
27D	Positive sequence under voltage Protection of motors against operation with insufficient voltage
27R	Remanent under voltage Check on the disappearance of voltage sustained by rotating machines after the power supply is disconnected
27TN	Third harmonic under voltage Detection of stator winding insulation earth faults (impedant neutral)
32P	Directional active overpower Protection against active overpower transfer
32Q	Directional reactive overpower Protection against reactive overpower transfer
37	Phase undercurrent 3-phase protection against undercurrent
37P	Directional active underpower Protection against active underpower transfer
37Q	Directional reactive underpower Protection against reactive underpower transfer

38	Bearing temperature monitoring Protection against overheating of rotating machine bearings
40	Field loss Protection of synchronous machines against faults or field loss
46	Negative sequence / unbalance Protection against unbalanced phase current
47	Negative sequence overvoltage Negative sequence voltage protection and detection of reverse rotation of rotating machines
48 - 51LR	Excessive starting time and locked rotor Protection of motors against starting with overloads or reduced voltage, and for loads that can block
49	Thermal overload Protection against overloads
49T	RTDs Protection against overheating of machine windings
50	Instantaneous phase overcurrent 3-phase protection against short-circuits
50BF	Breaker failure Checking and protection if the circuit breaker fails to trip after a tripping order
50N	Instantaneous earth fault Protection against earth faults: residual current calculated or measured by 3 CTs
50G	Instantaneous earth fault Protection against earth faults residual current measured directly by a single sensor (CT or core balance CT)
50V	Instantaneous voltage-restrained phase overcurrent 3-phase protection against short-circuits with voltage-dependent threshold
50/27	Inadvertent generator energization Detection of inadvertent generator energization
51	Delayed phase overcurrent 3-phase protection against overloads and short-circuits
51N	Delayed earth fault Protection against earth faults: residual current calculated or measured by 3 CTs
51G	Delayed earth fault Protection against earth faults: residual current measured directly by a single sensor (CT or core balance CT)
51V	Delayed voltage-restrained phase overcurrent 3-phase protection against short-circuits with voltage-dependent threshold
59	Overvoltage Protection against excessive voltage or sufficient voltage detection
59N	Neutral voltage displacement Insulation fault protection
63	Pressure Detection of transformer internal faults (gas, pressure)
64 REF	Restricted earth fault differential Earth fault protection for star-connected 3-phase windings with earthed neutral

64G	100% generator stator earth fault Detection of stator winding insulation earth faults (impedant neutral power systems) 66
66	Successive starts Protection function that monitors the number of motor starts
67	Directional phase overcurrent 3-phase short-circuit protection according to current flow direction
67N/67NC	Directional earth fault Earth fault protection depending on current flow direction (NC: Neutral compensated)
78	Vector shift Vector shift disconnection protection
78PS	Pole slip Detection of loss of synchronization of synchronous machines
79	Recloser Automated device that recloses the circuit breaker after transient line fault tripping
81H	81H Over frequency Protection against abnormally high frequency
81L	Under frequency Protection against abnormally low frequency
81R	Rate of change of frequency (ROCOF) Protection for fast disconnection of two parts of the power system
87B	Busbar differential 3-phase protection against busbar internal faults
87G	Generator differential 3-phase protection against internal faults in AC generators
87L	Line differential 3-phase protection against line internal faults
87M	Motor differential 3-phase protection against internal faults in motors
87T	Transformer differential 3-phase protection against internal faults in transformers

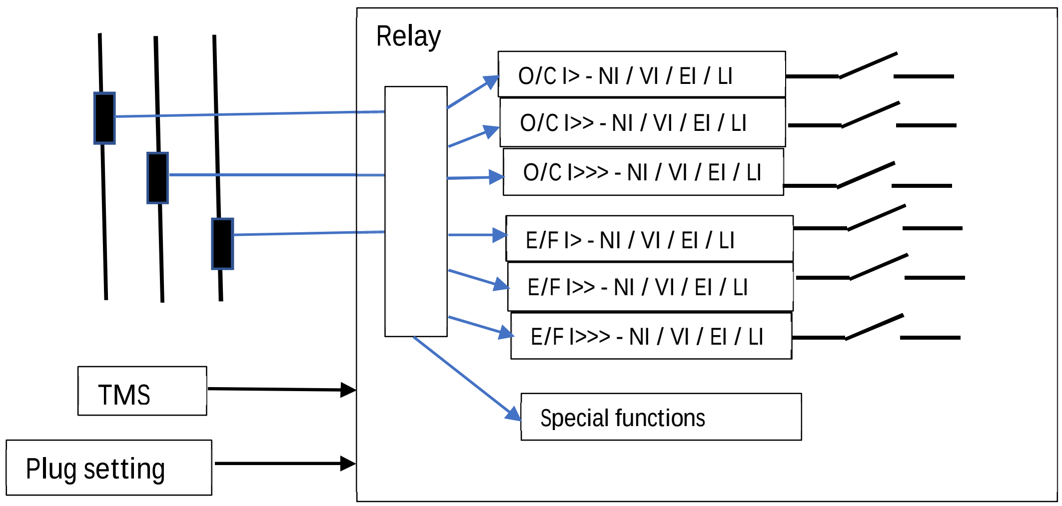
Supervisory functions (ANSI CODES)

Code	**Function Definition**
86	Master trip relay.
95	Trip circuit supervision relay
30	Annunciator Relay
80	DC circuit supervision Relay

Relay settings:
Protection Relays get their driving signals from current and voltage transformers with various transformation ratios.
Voltage relaying is comparatively easy as it has to do deal with high or low voltages across a preferred value and as such relay settings are also easy.

Setting a current relay is quite complex as the relay has do deal with

a) CT ratios
b) Load / Overload currents
c) Line to Line faults
d) Line to ground faults.
e) Selection of trip characteristics from NI, VI, EI, LI etc.
f) Most of the modern electronic relays offer two or three stage protection for same incoming signals with a flexibility to select any of above characteristics for any of the stages. These stages are popularly known as “low set or I>”, “High set or I>>”, “Very High set or I>>>”. Four characteristics and three stages can be programmed for “Over current”.
g) Once the three phase current signals are taken inside the relay, ONLINE fast calculations can find out presence of “Zero sequence current component” which indicates huge current imbalance and possible earth fault. All above combinations of characteristics and stages are also available for Earth fault trip processing.



Relay setting process can be explained with some ease by taking example of conventional electromagnetic relay. There are some TERMS which need to be explained / defined.

a) Relay Plug setting:

Movement of contact of an electromagnetic relay depends upon available N (no of turns) x I (amps). Such movement is produced by generating magnetic force which is more than controlling force in a relay (force created may be by a spring.) So, one can change N i.e. number of turns of current through relay coil. Normally CT secondary and Relay coil - nominal currents are same. If 50/1 CT is used, relay will operate when 50 Amps pass through relay primary. If maximum load current is only 40 Amps, then one can select more number of turns so that relay will operate at 40 Amps. This selection of turns can be done using relay plug. 40/50 = 0.8 is known as Relay Plug Setting.

b) Relay Plug multiplier setting:

Ratio of fault current expected to flow through CT primary and expected primary current after plug setting is known as Plug Multiplier Setting – PMS. As discussed earlier for over current protection these relays offer different relationships namely NI, VI, EI, SI between trip time and current. These relationships are functions of PMS and if any one characteristics is selected then also, the trip time changes if PMS is changed.

c) Time multiplier setting:

In electromagnetic relays, the magnetic plunger must travel defined distance to activate the contact. For fixed “N x I” this distance is predetermined and plunger takes defined TIME to travel this distance. If this distance is increased or decreased, the time taken by plunger to travel the required distance can be changed. This change in timing is represented as TMS or time multiplier setting of a relay.

Some or all above facilities are available in any over current relay, which offer required flexibility to adjust the trip time less than that required by Thermal characteristics of the system component to be protected. This flexibility also offers required grading between upstream and downstream relays in a redial system so that trip coordination can be achieved as required.
These characteristics and specifications offered by an electromagnetic relay are now days available in modern ELECTRONIC RELAYS and are adjustable through programming.

Such relays also offer what is known as **“HIGH SET” and “LOW SET” elements** to offer two or three stage protection in the same relay. The trip characteristics of these elements can be set / programmed for say **Short circuit trip** and **Overload trip** independently. Both these elements receive signal proportional to current through same CT, but they actuate two different contacts as per selected relay characteristics.

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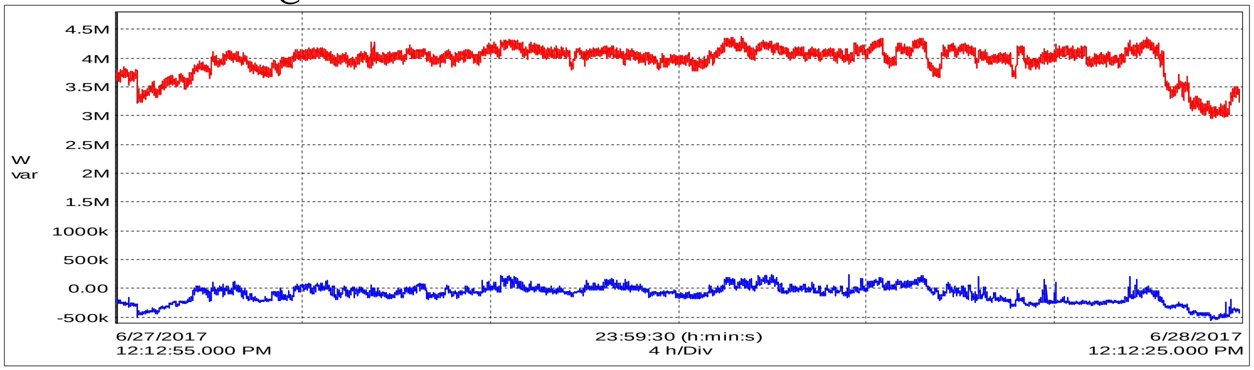
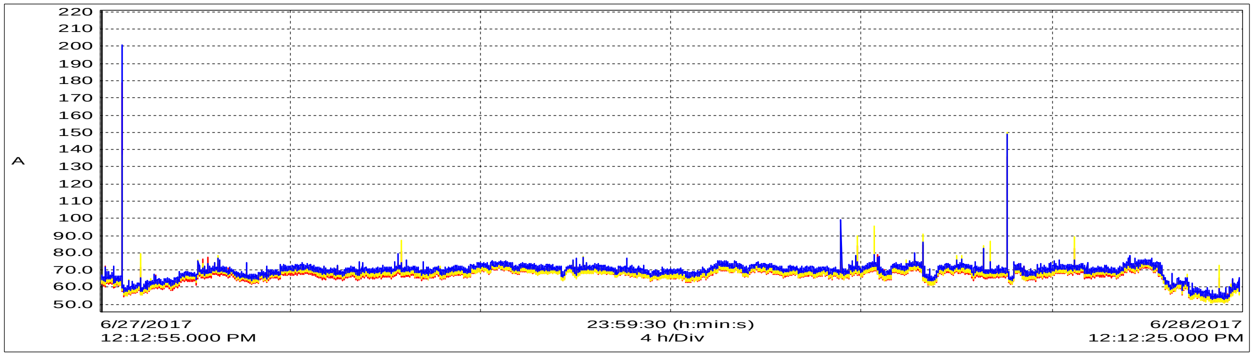
Summary of Recorded data from site:

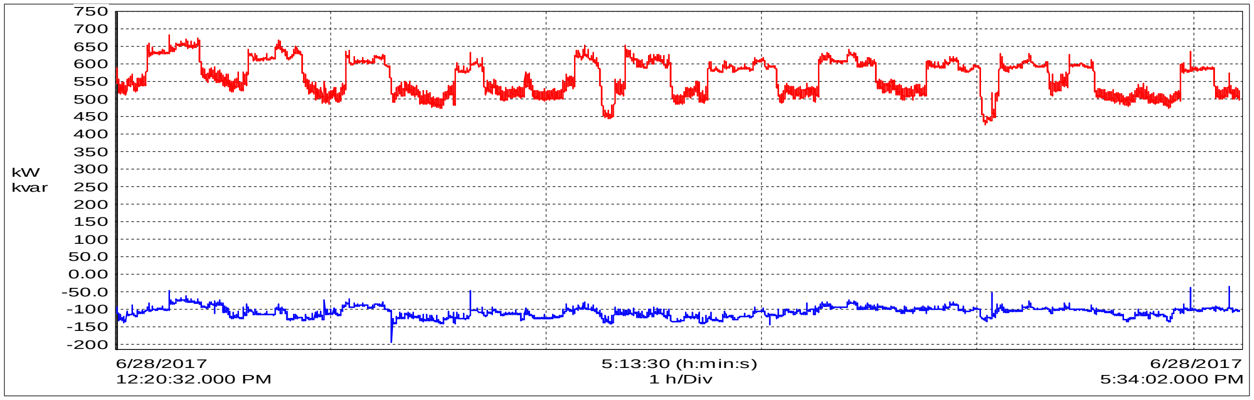
Generator, Transformer, Cable, Circuit breaker and Relay data was collected from respective ratings plates, test reports. While load data was recorded with the help of power analyzers to know load trends.

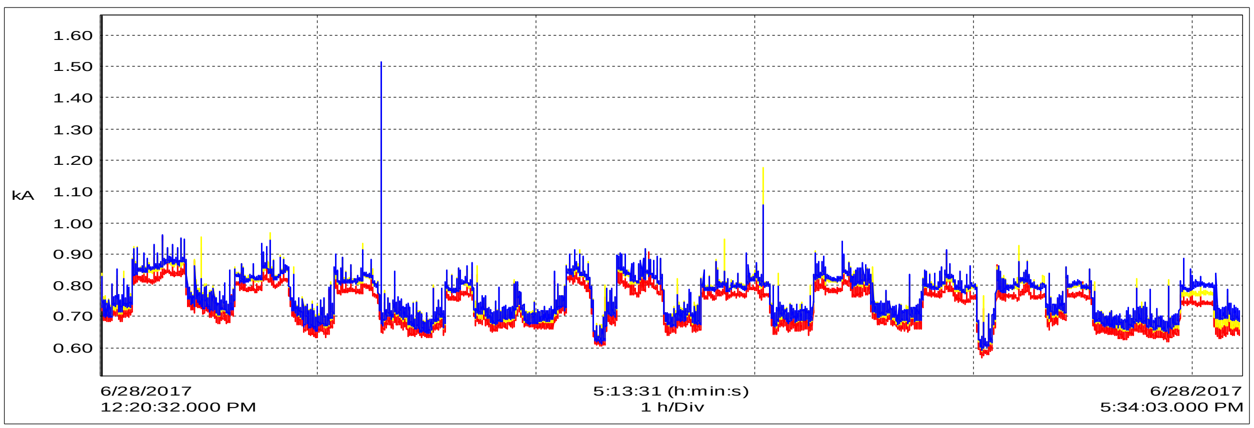
Load measurement @ 33KV



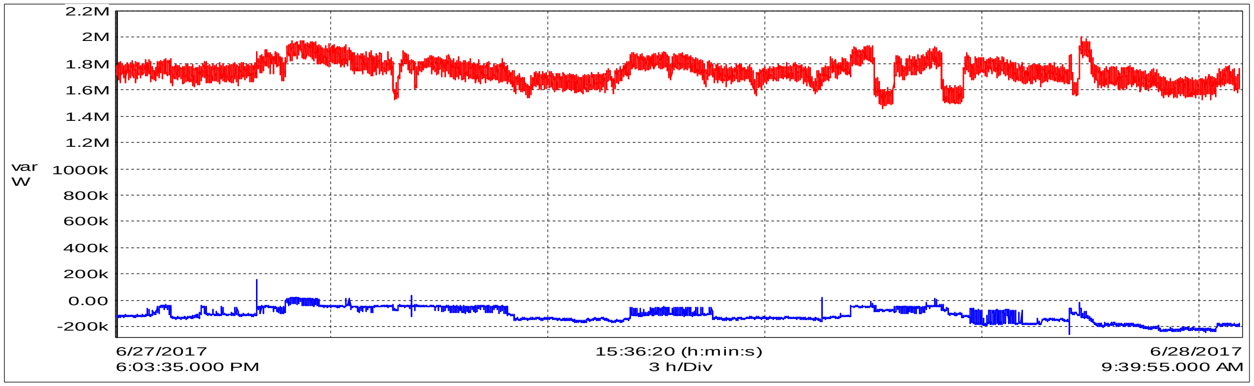


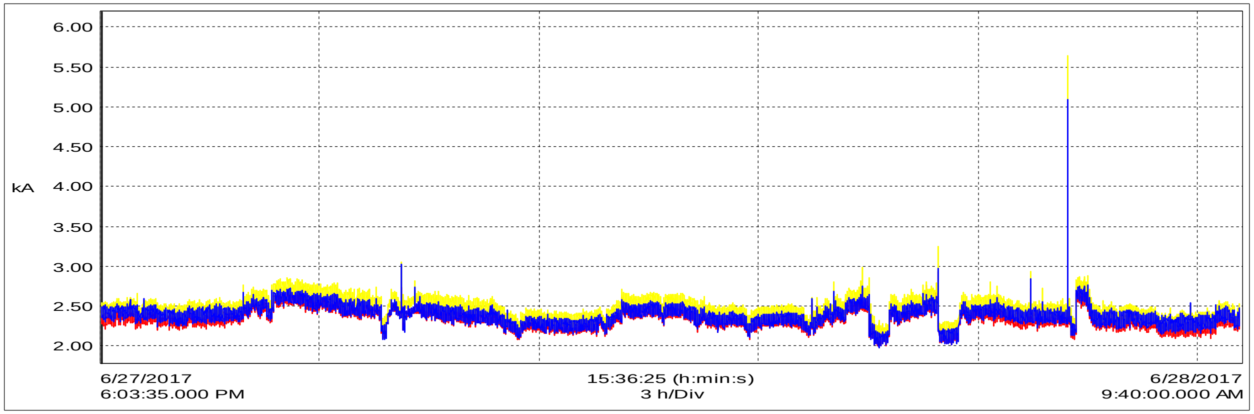
Load measurement @ 1MVA Tx secondary



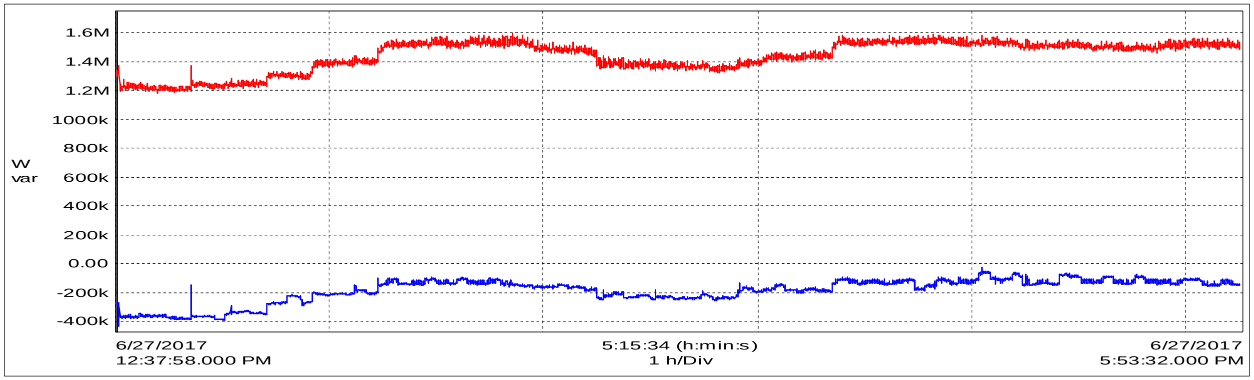


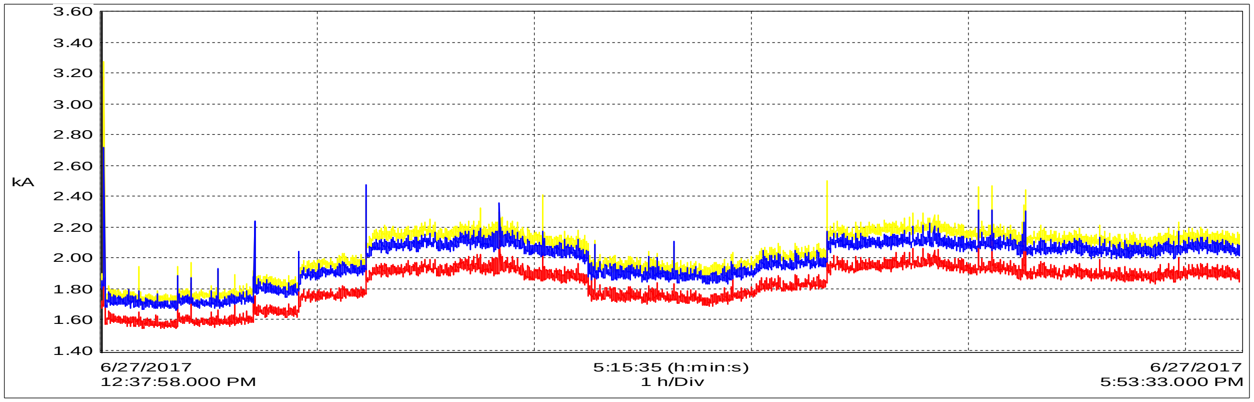
Load measurement @ 2.5MVA Tx 2 secondary





Load measurement @ 2.5MVA Tx - 3 secondary





Power quality parameters																
Sr. No	Feeder Name	Voltage L-L		Voltage THD%		Line Current		Current THD%		KW		KVAR		PF		
		Avg.	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	
1	33 KV HT Main Incomer	34336.0	34980.0	0.6	0.9	68.1	75.2	1.8	3.8	3960	4364	-96	235	0.998	0.999	

TRANSFORMER -1

Power quality parameters																	
Sr. No	Feeder Name	Voltage L-N		Voltage L-L		Voltage THD%		Line Current		Current THD%		KW		KVAR		PF	
		Avg.	Max	Avg.	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max
1	Tr-1 Main incomer	259	262	448	454	0.6	1.1	747	905	1.0	1.5	558	681	-110	-196	0.98	1.00
2	ATBS OLD (MCC 4)	255	256	443	443	0.575	0.7	177	219	12.3	14.2	120	143	39	69	0.95	0.96
3	ATBS OLD (MCC 5)	257	258	446	447	0.597	0.8	45	53	3.06	3.4	15	18	30	35	0.43	0.45
4	Polymer Plant	258	258	447	448	0.534	0.9	88	92	7.84	9.9	15	19	-66	-70	0.23	0.27
5	Old MLDB	253	258	446	448	0.585	0.7	18	23	7.27	15	7	11	5	6	0.80	0.88
6	ATBS (MCC-2)	256	257	444	445	0.6	0.7	51	90	19.0	21.0	37	51	-4	44	0.98	0.98
7	Air Comp D	257	260	447	448	0.6	0.7	163	166	1.9	2.1	94	96	81	82	0.76	0.77
8	New ETP	258	259	448	448	0.622	0.8	58	61	1.67	1.9	31	32	30	31	0.71	0.71
9	P-5101 G-H	258	259	448	449	0.677	0.8	140	163	66.86	95.9	84	85	60	84	0.82	0.84
10	15 TPH Boiler	258	259	448	449	0.6	0.7	193	262	36.9	46.6	136	187	-33	21	0.92	0.95
a)	C.T. Pump room	251	252	432	434	0.9	1.2	115	116	3.2	4.0	79	80	24	24	0.96	0.96
11	ATBS (MCC-1)	256	257	444	445	0.5	0.6	68	69	2.3	2.7	33	33	40	40	0.64	0.64

TRANSFORMER -2

Power quality parameters																	
Sr. No	Feeder Name	Voltage L-N		Voltage L-L		Voltage THD%		Line Current		Current THD%		KW		KVAR		PF	
		Avg.	Max	Avg.	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max
1	Tr-2 Main incomer	253	257	434	441	2.5	3.4	2392	2792	4.4	9.5	1740	2000	-112	158	0.997	0.999
2	Brine Panel (Utility-4)	250	250	430	431	0.6	0.7	79	80	2.0	2.2	47	47	34	34	0.811	0.833
3	VOLTAS -C & Harmonic panel	249	250	429	430	0.585	0.7	219	233	-	-	7	7	-156	-165	-	-
4	MCC-9 (Utility)	250	250	430	431	0.602	0.7	526	557	28.37	29.5	372	394	-115	-118	0.955	0.959
5	IB Plant (PCC-3)	250	251	430	432	0.632	0.7	359	390	12.98	13.9	258	275	50	53	0.981	0.984
6	Daikin Chiller -1	251	252	433	434	0.6	1.2	267	270	2.5	3.9	161	163	114	116	0.815	0.819
7	MCC-6	251	252	433	434	0.596	0.8	110	117	2.06	3.5	62	67	52	55	0.766	0.778
8	MCC-8 (Utility)	252	253	433	434	1.6	2.1	113	135	22.42	27.6	35	60	-70	-79	0.429	0.667
9	VCB Battery Supply	252	253	434	435	0.639	0.9	16	16	33.43	34	6	6	8	8	0.612	0.613
10	MCC-7	252	253	433	434	1.79	2.1	67	70	25	30	44	46	15	17	0.943	0.949
11	30 TFH Panel	249	250	428	429	1.7	2.1	70	73	40.7	50.7	9	10	-50	-51	0.185	0.209
12	Construction Supply	252	253	433	434	1.8	2.4	45	77	18.2	30.0	17	34	25	42	0.560	0.673
13	EM Panel H-1 (MCC Room)	249	250	429	430	1.2	1.7	25	34	6.71	8.1	15	17	11	12	0.798	0.833
14	MLDB (PCC-2)	249	249	428	430	1.352	1.7	58	68	13.36	15.7	32	34	19	20	0.846	0.862
15	ATBS-C-EM 6	249	250	430	430	1.4	1.7	45	46	3.7	4.3	16	17	29	29	0.495	0.505
16	EM-8 (Utility-1)	250	250	429	430	1.88	2.6	123	156	4.7	7.6	74	99	46	51	0.804	0.891

TRANSFORMER -2																	
Power quality parameters																	
Sr. No	Feeder Name	Voltage L-N		Voltage L-L		Voltage THD%		Line Current		Current THD%		KW		KVAR		PF	
		Avg.	Max	Avg.	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max
1	Tr-3 Main incomer	256	262	439	450	0.6	1.9	2006	2227	0.8	6.7	1437	1590	-187	-431	0.987	0.998
2	Utility-3 (Voltas D)	254	254	434	435	0.612	0.7	431	479	39.03	41.6	280	313	119	130	0.919	0.926
3	New TBA (Pump House)	254	255	434	435	0.542	0.8	32	34	22.21	31.2	15	16	-16	-19	0.697	0.866
4	TB Amine 1/2	254	255	435	436	0.56	0.7	90	116	10.07	11.2	40	45	40	50	0.706	0.729
5	Utility Sub PCC	259	260	446	447	0.571	1.1	408	418	13.75	25	261	263	-138	-144	0.882	0.886
6	MCC-15 (Utility-3)	255	255	435	436	0.558	0.7	810	814	4.59	5.2	568	570	-34	-35	0.996	0.996
7	Daikin Pri & Sec pump panel	255	255	435	436	0.6	0.7	96	96	1.3	1.5	56	56	41	41	0.805	0.807
8	MCC-16 (Utility-4)	261	261	448	449	0.621	0.8	131	131	1.856	2.3	74	75	62	63	0.765	0.77
9	MLDB-3	255	255	435	436	0.575	0.7	69	70	14.72	15.8	33	34	16	17	0.901	0.908
10	D' Plant MCC14/14A	259	259	446	446	0.574	0.8	233	235	35.39	36.9	157	158	64	65	0.926	0.928
a)	MCC-14	233	234	-	-	1.04	1.2	82	87	43.35	46.3	51	55	-26	-27	0.893	0.906
b)	MCC-14 A	245	246	419	420	1	1.1	111	118	40.03	41.9	66	71	39	42	0.847	0.855

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