Arc Flash Analysis Report

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By

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INDEX

SOME BASICS OF ARC FLASH HAZARD

Origin of Arc flash study and governing codes and standards

In the early 1980's Mr. Ralph Lee published a paper "The Other Electrical Hazard: Electric Arc Blast Burns" in the IEEE Transactions on Industrial Applications. This paper made the world realize need to protect people from the hazards of arc flash.

Following four industry standards are available to guide us on minimizing arc flash incidents:

- OSHA 29 Code of Federal Regulations (CFR) Part 1910 Subpart S.
- NFPA 70-2002 American National Electrical Code.
- NFPA 70E-2000 Standard for Electrical Safety Requirements for Employee Workplaces.
- IEEE Standard 1584-2002 - Guide for Performing Arc Flash Hazard Calculations.

Compliance with OSHA involves adherence to a six-point plan:

- A facility must provide, and be able to demonstrate, a safety program with defined responsibilities.
- Calculations for the degree of arc flash hazard.
- Correct personal protective equipment (PPE) for workers.
- Training for workers on the hazards of arc flash.
- Appropriate tools for safe working.
- Warning labels on equipment. Note that the labels are provided by the equipment owners, not the manufacturers. It is expected that the labels contain the equipment's flash protection boundary, its incident energy level, and the required personal protective equipment (PPE).

- Arc Flash is the result of a rapid release of energy due to an arcing fault between a phase bus bar and another phase bus bar, neutral or a ground. During an arc fault the “ionized air” is the conductor. Arc faults are generally limited to systems where the bus voltage is more than 120 volts. Lower voltage levels normally will not sustain an arc. An arc fault is like the arc obtained during electric welding and the fault must be manually started by something creating the path of conduction or a failure such as a breakdown in insulation.
- The cause of the short normally burns away during the initial flash and the arc fault is then sustained by the establishment of a highly-conductive plasma. The plasma will conduct as much energy as is available and is only limited by the impedance of the arc. This massive energy discharge burns the bus bars, vaporizing the copper and thus causing an explosive volumetric increase, causing arc blast. The volumetric increase conservatively estimated, is in in the range of 40,000 : 1. This fiery explosion devastates everything in its path, creating deadly shrapnel as it dissipates.
- The arc fault current is usually much less than the available bolted fault current and below the rating of circuit breakers. Unless these devices have been selected to handle the arc fault condition, they will not trip and the full force of an arc flash will occur. The electrical equation for energy is volts x current x time. The transition from arc fault to arc flash takes a finite time, increasing in intensity as the pressure wave develops. *The challenge is to sense the arc fault current and shut off the voltage in a timely manner before it develops into a serious arc flash condition. **Time taken is Fault clearing time**.*
- ARC FLASH study involves determination of actual arc flash energy levels at working distances (From where a maintenance or operating person usually works with the panel boards.) from ARC SOURCE. These energy levels are dependent on
    a) Source Fault levels,
    b) Fault currents at location,

c) Physical arrangements and clearances between electrically conducting parts inside the panel,

d) Time taken by fault clearing devices to clear the fault.

Once this is known and optimized, one can select personal protective equipment like Arc suits, shields, gloves etc to get adequate protection while working on these feeders. The calculations being quite involved, use of electrical system simulation software tool helps in ensuring compliance with standards and also bring in accuracy and safety in real life.

Important Definitions

- **Bolted Fault -** Short circuit current resulting from conductors at different potentials becoming solidly connected.
- **Arc Fault -** Short circuit current resulting from conductors at different potentials making a less than solid contact. This results in a relatively high resistant connection with respect to a bolted fault.
- **FCT** – Fault clearing time – Protective devices arranged ensure disconnecting the circuit. The energy released during this arcing is proportional to square of arcing current and time taken to disconnect this fault.
- **AFB -** Arc Flash Boundary **-** This is distance from arc source at which the released arc energy becomes less than 1 Calories per Cm^2
- **IE** – Incident energy – Calorie per Cm^2.
- **PPE** – Personal Protective Equipment.

Energy Levels defined by NFPA 70E -2000 – 2015

Level ID	**Cal / Cm^2**	**PPE Specifications to withstand Cal / Cm^2mentioned in earlier column**
A	**2**	Untreated Cotton
B	**4**	Flame retardant (FR) shirt and FR pants
C	**8**	Cotton underwear FR shirt and FR pants
D	**25**	Cotton underwear FR shirt, FR pants and FR coveralls
E	**40**	Cotton underwear FR shirt, FR pants and double layer switching coat and pants
F	**100**	Levels defined but tested PPEs are not readily available.
G	**120**	
Note that a hard hat with full-face shield and the appropriate gloves are also required also.		

Drivers which make Arc Flash study a standard safety SOP.

- Now a days voltages levels used have increased in commercial and industrial facilities and regularly include MV/HV/EHV levels. As a result, employees are exposed to higher voltages and fault duties than ever before. Without adequate training, employees may not be aware of the proper safe procedures to be followed while working on electrical systems. Statistics shows that almost 80% of electrical incidents are caused by human error.

- Such exposure has increased due to more demands on system reliability and reducing downtime. Examinations such as infrared investigation, power quality and load recording, partial discharge testing are done on live systems to identify potential problems before they result in an unplanned outage. Insurance companies offer discounts if routine infrared investigations are performed.
- Commercial liability and costs associated with incidents in terms of lawsuits, lost production and repair costs also drive the risk assessment.
- Corporate policy decisions compel to comply with Occupational Safety and Health Administration (OSHA) codes with National Fire Protection Association (NFPA) standards on employee safety, NFPA-70E.

ARC FlASH HAZARD STUDY SUMMARY

Sr	ID	kV (kV)	Total Energy (cal/cm^2)	PPE Description	AFB (m)	Energy Levels	Final FCT (cycles)	Source PD ID	Total Ibf at FCT (kA)	Total Ibf" (kA)	Total Ia" (kA)
1	Bus2	33	388.23		16.5	> Level G	110.58	CB1	8.684	8.684	8.684
2	Bus3	33	68.92		6.9	Level F	19.79	CB3	8.615	8.615	8.615
3	Bus4	0.433	2.76	FR long-sleeve shirt (minimum arc rating of 4), worn over untreated cotton T-shirt with FR pants (minimum arc rating of 8)	1.1	Level B	4	CB5	34.15	34.15	15.798
4	Bus5	0.433	2.76	FR long-sleeve shirt (minimum arc rating of 4), worn over untreated cotton T-shirt with FR pants (minimum arc rating of 8)	1.1	Level B	4	CB5	34.15	34.15	15.798
5	PCC 1	0.433	2.76	FR long-sleeve shirt (minimum arc rating of 4), worn over untreated cotton T-shirt with FR pants (minimum arc rating of 8)	1.1	Level B	4	CB5	34.15	34.15	15.798
6	MCCHVAC	0.433	1.01	Non-melting or untreated natural fiber long-sleeve shirt and long pants	0.5	Level A	2	CB 10	23.769	23.769	11.794
7	SLDB R&D	0.433	1.01	Non-melting or untreated natural fiber long-sleeve shirt and long pants	0.5	Level A	2	CB11	23.769	23.769	11.794
8	UPS IC	0.433	2.22	FR long-sleeve shirt (minimum arc rating of 4), worn over untreated cotton T-shirt with FR pants (minimum arc rating of 8)	0.9	Level B	4	CB12	26.567	26.567	12.902
9	B1MDB1	0.433	3.26	FR long-sleeve shirt (minimum arc rating of 4), worn over untreated cotton T-shirt with FR pants (minimum arc rating of 8)	1.2	Level B	7	CB13	26.567	26.567	10.966
10	B1MDB2	0.433	0.784052	Non-melting or untreated natural fiber long-sleeve shirt and long pants	0.5	Level A	1.51	CB14	24.542	24.542	12.102
11	Chiller2	0.433	3.53	FR long-sleeve shirt (minimum arc rating of 4), worn over untreated cotton T-shirt with FR pants (minimum arc rating of 8)	1.3	Level B	7	CB15	23.769	23.769	11.794
12	Boiler	0.433	0.523588	Non-melting or untreated natural fiber long-sleeve shirt and long pants	0.3	Level A	3	CB16	7.047	7.047	4.423
13	Utility	0.433	1.01	Non-melting or untreated natural fiber long-sleeve shirt and long pants	0.5	Level A	3	CB17	14.904	14.904	8.094
14	ETP	0.433	1.18	Non-melting or untreated natural fiber long-sleeve shirt and long pants	0.6	Level A	3	CB18	17.892	17.892	9.379
15	Gate	0.433	0.090102	Non-melting or untreated natural fiber long-sleeve shirt and long pants	0.1	Level A	3	CB19	0.937	0.937	0.868
16	U LDB	0.433	0.090102	Non-melting or untreated natural fiber long-sleeve shirt and long pants	0.1	Level A	3	CB20	0.937	0.937	0.868
17	MGate	0.433	0.090102	Non-melting or untreated natural fiber long-sleeve shirt and long pants	0.1	Level A	3	CB21	0.937	0.937	0.868
18	IC LDB	0.433	0.747836	Non-melting or untreated natural fiber long-sleeve shirt and long pants	0.4	Level A	3	CB22	10.605	10.605	6.151

Sr	ID	kV (kV)	Total Energy (cal/cm²)	PPE Description	AFB (m)	Energy Levels	Final FCT (cycles)	Source PD ID	Total Ibf at FCT (kA)	Total Ibf" (kA)	Total Ia" (kA)
19	PCC2	0.433	2.76	FR long-sleeve shirt (minimum arc rating of 4), worn over untreated cotton T-shirt with FR pants (minimum arc rating of 8)	1.1	Level B	4	CB5	34.15	34.15	15.798
20	Utility P	0.433	2.22	FR long-sleeve shirt (minimum arc rating of 4), worn over untreated cotton T-shirt with FR pants (minimum arc rating of 8)	0.9	Level B	4	CB5	26.567	26.567	12.902
21	BLK2MDB	0.433	2.41	FR long-sleeve shirt (minimum arc rating of 4), worn over untreated cotton T-shirt with FR pants (minimum arc rating of 8)	1	Level B	4	CB5	29.241	29.241	13.939

- 33KV voltage level is not covered under arc energy calculations under IEEE 1584. It is advised that any work in this area should be done when panels are isolated and discharged. (Sr No 1,2 – Bus 2 and 3 in above tables)

- Arc energy developed at these feeders under arc flash conditions is of LEVEL B or A.
  It is advised that any work on these feeders should be done after wearing appropriate PPES as recommended (Sr No 3 to 18 in above tables).

- Arc energy developed at these feeders under arc flash conditions is of LEVEL B.
  It is advised that any work on these feeders should be done after wearing appropriate PPES as recommended (Sr No 19 to 21 in above tables).

- PCC 1 BUS (Sr No 5) supplies to feeders Sr no 6 to 18 and will get isolated by upstream breaker CB 5 in case of any fault on this bus. Lebel generated for PCC 1 should be stuck here and is applicable for entire PCC1 as well as upstream panel housing CB5.
- Labels generated for feeder Sr nos 6 to 18 should be fixed on respective down stream panels. For any arc flash in these down stream panels, the fault interrupter would be respective breaker in PCC1. For example, for any fault in MCCHVAC (Sr No 6) the same will be interrupted by CB 10 located in PCC1.

- The results of Arc Flash Hazard Analysis are presented in this document as ETAP crystal reports. The ETAP summary report contains
  a) ID of Bus,
  b) Bus voltage rating,
  c) Type of equipment,
  d) Gap between conductors,
  e) Bolted Fault Current,
  f) Arc Fault Current,
  g) Trip device ID and opening time,
  h) Fault Clearing Time (FCT),
  i) Arc Flash Boundary,
  j) Incident Energy,
  k) Working Distance
  l) Energy Level.

- In the report, wherever the voltage rating is above 15kV, it is marked by #. The theoretically derived Lee method was used to determine the incident energy and arc flash boundary for these locations since the bolted fault current or nominal voltage are outside the empirical method range. *((Ibf" < 0.7 kA or Ibf" > 106 kA) and (0.208 ≤ Nominal kV ≤ 15 kV)).*

- Two of the plant buses, BUS 2 and BUS3 (References as per attached ETAP drawings) on HT side are falling in above criteria. The incident energy levels for these buses are 388 and 68 cal /cm^2. The report also shows >MAX in the energy level column of these buses. There are no personal protective equipment categories specified by NFPE for these locations, even though protective clothing capable of providing flash protection at incident energy levels up to 112cal /cm^2 is commercially available.

- NFPA 70E 2009 explicitly does not prohibit work at locations with energy levels above 40cal /cm^2, but such high-energy levels can cause dangerous injuries. We do not recommend any work at these locations, unless the equipment is completely deenergized and discharged. Suitable precautionary labels for these high energy buses are provided with this report.

- For the rest of the locations, calculated energy level is below 40cal/cm2, hence personal protective equipment (PPE) of 5 different levels is suggested as per the standards NFPA-70E-2009. For these locations warning labels are provided with this report and it is recommended that these labels need to be stuck on respective feeders and recommended PPEs should be used while working at these locations.

- ***Arc Flash energy calculations reported here are carried out based on the recommended relay and release settings listed in this report. Any changes in those settings will invalidate the calculations of Arc Flash, and needless to say that PPE requirements also will differ.***

- The calculations of Arc Flash Analysis are carried out by IEEE 1584 standard methods. In calculations, worst fault levels are considered to evaluate the arc energies. The upstream protective device is considered to evaluate the Fault Clearing Time.

- It should be noted that shock hazard and arc flash hazards are two different dangerous situations and precautions against arc flash will not protect against electric shocks. We recommend shock hazard analyses may also be required before qualified employees are able to work on or near energized equipment. NFPA 70E-2009 defines shock hazard as "a dangerous condition associated with the possible release of energy caused by contact or close approach to live parts."

- The NFPA standard defines the *Limited Approach Boundary* as "an approach limit distance from an exposed live part within which a shock hazard exists." Only qualified employees can cross the Limited Approach Boundary and enter the limited space in to perform a given task. A shock hazard analysis shall determine the voltage to which the personnel will be exposed, boundary requirements, and the personal protective equipment necessary in order to minimize the possibility of electric shock.

- In addition to the Limited Approach Boundary, the *Restricted and Prohibited Approach Boundaries* are also applicable to situations in which qualified personnel are exposed to live parts. One may refer NFPA 70E(2018) Table 130.4 (D)(a) for the boundary distances associated with various system voltages.

- The possible methods for reducing arc flash hazard are
  a) reduce fault clearing time.
  b) increasing the working distance.

  Keeping minimum fault clearing time is taken care in relay coordination calculations and the working distance is taken as per the standards, still at few buses the incident energy is beyond tolerable limit.

- Normal relays do not provide fast enough protection against arc fault currents and the short arc burning times are critical, especially when the arc develops during maintenance work on the switchgear, endangering personnel safety and life. Under such conditions special light sensitive Arc detection relays may be used. They are not very popular in the Industry yet.

SYSTEM DESCRIPTION:

Existing system Description

- The plant receives 33 KV input supply from GEB through RMU arrangement with 33 KV VCB's which is located in the plant.
- This 33 KV supply distributed in the plant through two transformers of 2500 KVA each with voltage ratio 33Kv/433 Volts. Plant has bus coupler arrangement in-between to shift total load of the plant on any transformer.
- At present the plant is supplied through transformer No. 2 whereas transformer N. 1 is not in operation.
- 3 DG sets of capacity 1060 KVA X2 & 1010 KVA X 1 are installed in the plant to take care of plant load during power failure.
- Contract Demand of the plant is 2800 KVA whereas MD recorded in FEB 2018 is 1395 KVA.
- Peak load recorded during audit period is 1295 KW, billed power factor is 0.99.
- Plant is divided into two blocks i.e. Block 1 & Block 2. Block 1 receives supply from PCC-1; similarly Block 2 receives supply from PCC-2.
- During audit load on PCC1 was 870KVA, where as that on PCC2 was 660KVA.

Loading on major feeders is as under.

Sr. No.	Feeder Name	Voltage L-N		Voltage L-L		Voltage THD%		Current		Current THD%		KW		KVAR		PF	
		Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Avg	Max
HT 33KV																	
1	HT 33 KV	-	-	32741	34380	1.9	3.5	20.92	45	6.1	7.4	1075	1310	288.59	699	0.96	0.98
TR 2																	
2	Incomer from TR 2	237	241	410	416	3	3.7	1848	2161	5.1	6.5	1224	1295	401.5	658.7	0.946	0.971
PCC-2																	
3	PCC 2 Main Incomer	239	242	412	419	2.8	3.4	899	1050	7.9	9.3	548.3	596.3	278	347.9	0.89	0.91
4	Utility Panel	240	242	415	419	2.5	2.8	676.5	712	3.7	4.3	373	390	281	289	0.8	0.81
5	Block 2 MDB	242	244	417	421	2.9	3.1	261.6	389.5	12.2	14	169.3	213.2	55.5	66.7	0.94	0.95
PCC-1																	
6	PCC 1 Main Incomer	239	243	413	420	3	3.7	957	1269	13.7	17.1	674	695	152.1	335	0.96	0.992
7	MCC - HVAC	242	244	418	422	3	3.2	146.6	150	31	31.6	90	90.3	40.2	40.5	0.87	0.87
8	SLDB R&D	241	242	416	419	3.1	3.3	70.1	71	60.7	63.2	35.8	36.2	-1.25	-1	0.92	0.93
9	UPS Main Incomer	239	241	415	418	3.1	3.3	282.6	321.5	66.3	68.5	136	148	98	105.8	0.68	0.7
10	Block 1 MDB 1	240	241	416	419	3.2	3.3	130	203	15.52	18.7	84	93	27	28	0.935	0.946
11	Block 1 MDB 2	239	241	414	417	3.15	3.4	197	232	16.39	19.8	108	123	45	46	0.906	0.916
12	Chiller No.2	236	240	415	418	3.03	3.31	290	294	4.17	4.3	170	170	113	114	0.833	0.836

Circuit breaker configurations

- There is a two level HT distribution in the plant which uses VCB 1,2,3,– These are normally closed and route the power to Bus 3. (Some VCBs installed as spare feeders are not considered in this analysis, however their energy levels under fault conditions will be same as their upstream buses)

- Bus 3 feeds both 2.5MVA transformers through VCB 4 and 6. At present transformer 2 is working and is fed through VCB4. Transformer 1 is kept on standby.
- ACB 5 and 7 on LT side connect these transformers to PCC1 and PCC2. There is a coupler arrangement which allows entire plant to be taken on any of the transformers. At present Tr2 feeds the plant through ACB 5 and ACB7 is kept OFF.
- The incomer breaker from synchronized DG set is in open position.
- The bus coupler between LT buses of two transformers is in closed position, while ACB 7 is kept in OFF position to ensure entire load to be fed by Tr2.
- It is assumed that Transformers will not run in parallel at 415V.

STUDY METHODOLOGY
AND
BASIC SYSTEM PARAMETERS

Methodology adopted by SASPPL:

- LT panel feeder loads were measured at site.
- Data related to all system components was collected from site which includes data related to transformers, circuit breakers, relays, cables, panel busbar distances etc.
- Electrical system was simulated in electrical system simulation software ETAP.
- Load flow – short circuit analysis study was conducted on the simulation.
- ETAP based Protection coordination module was used to determine appropriate relay settings.
- Arc flash study was conducted using SLD prepared as above.
- Report is generated based on various ETAP simulations results and are presented here.
- We have used ETAP 16.2 version for this analysis.
- HT / LT breakers which are in operating condition are shown on SLD and are used in simulation.

Main system data required for simulation:

Power grid parameters:
- Source voltage [Vs]: 33KV
- Source fault level [MVAsc]: 500MVAsc
- X/R ratio value : 14 9Assumed)

Transformer Parameters:
- MVA rating : 33/0.433KV – 2500KVA x 2, (Present configuration – one working one standby.
- Percentage impedance [%Z]: 6.79% - Source: transformer rating plates.
- X/R Ratio for positive and zero sequence: ETAP recommended data used.
- Winding connection and Neutral Grounding Transformer / Resistance if any: Delta – Star – solid neutral grounding.
- Tap data: not considered for simulation.

Parameters of HT /LT cables:
- Cable/Conductor type
- Cable length and cable size. (Size data collected from site. Lengths are approximate.)
- Once above values are fed, ETAP calculates respective impedance values.
- All 33kV cables have been modeled with their typical impedance data directly used from ETAP library. Cable conductor, length and size have been taken as per data collected.

Load Parameters:
- Process plant and other loads have been considered as 80% constant KVA and 20% constant impedance lumped load working at recorded power factor and KW data.
- Peak and average loads were recorded and judiciously used in simulation to match energy billing data for previous period.

Data related Switching devices:
- Voltage Rating [kV / V]
- Rated current [Amp]
- Breaking capacity [kA] as applicable
- Making capacity [kA] as applicable
- Thermal capability [Sec] as applicable
- Min. time delay [mSec] as applicable

- All circuit breakers at 33kV and 415V have been modeled as per data collected from site. Circuits have been modeled with LV power breakers up to LV incomer feeder from distribution transformers and major LV Feeders.

Data related to Protective devices:

- Type, model and manufacturer's name
- CT / CBCT ratio
- Plug setting and time multiplier setting range for IDMT element
- Pick-up or time setting range for DMT or Instantaneous
- All phase and ground over-current protective relays have been modeled as per collected data with their unique ID for the ease of recognition while referring to this report.
- Unit protection relays or voltage operated relays have not been modeled.
- Relay setting sheets are furnished for all required settings.

PCC2 – Switchgear data

Sr.	Feeder	Model/ Make	Rating (Amp)	Pot setting	KA Rating	Measured Current (Amp)	Remark
1	Transformer 2 sec.	L & T Omega UW 3-50H ACB	5000	-	80KA	2319	Adequate
	PCC 2						
2	PCC 1 Main Incomer	Merlin Gerin NW 25 H1- ACB	2500	Ir=0.98 x In	65KA	1269	Adequate
3	PCC 1 O/G Feeder	L & T Omega UW 2-32S ACB	3200	-	65KA	1269	Adequate
4	PP-16 Boiler	MCCB MG-NS 400H	400	-	65KA	3.3	Load current is very small as compared to rating. MCCB may not provide overload protection.
5	PP-17 Utility	MCCB MG-NS 400H	400	-	65KA	8.2	
6	ETP	MCCB MG-NS 400H	400	-	65KA	21	
7	Gate Cabin -2	MCCB MG-NS 100H	100	Io=0.9 x In, Ir=0.95 x Io	65KA	2.36	
8	LDB- Utility Building	MCCB MG-NS 100H	100	Io=0.9 x In, Ir=0.93 x Io	65KA	1.2	
9	LDB- Main gate building	MCCB MG-NS 100H	100	Io=0.9 x In, Ir=0.93 x Io	65KA	18.8	
10	ETP Main Incomer	MCCB MG-NS 400H	400	-	65KA	14	
11	I/C to LDB's	MCCB MG-NS 100H	100	Io=1 x In, Ir=0.9 x Io	65KA	65	Adequate
12	Chiller No.2	MCCB MG-NS 630H	630	-	65KA	294	Adequate
13	MCC - HVAC main I/C	MCCB MG-NS 630H	630	-	65KA	150	Adequate
14	Block 1 MDB 1 I/C	ACB MG-NW10H1	1000	Ir=0.4 x In	65KA	203	Adequate
15	Block 1 MDB 2 I/C	ACB MG-NW08H1	800	Ir=0.8 x In	65KA	232	Adequate
16	UPS Main Incomer	ACB MG-NW08H1	800	Ir=0.8 x In	65KA	321.5	Adequate
17	PP - 5 (Equipment) panel-main	MCCB MG-NS 250N	250	Ir=0.93 x In	65KA	54	Adequate
18	SLDB R&D	MCCB MG-NS 250H	250	Io=0.9 x In, Ir=0.93 x Io	65KA	71	Adequate
A	HVAC -Utility MCC 1						
i	Utility MCC 1	MCCB MG-NS 400H	400	Io=0.9 x In, Ir=0.93 x Io	65KA	144	Adequate
ii	Condenser pump 3	MCCB MG-NS 160H	100	Io=0.9 x In, Ir=0.93 x Io	50KA	45.8	Adequate
iii	Pri. Chilled water pump 3	MCCB MG-NS 100H	100	-	65KA	50	Adequate
iv	Sec. chilled water pump 1	MCCB MG-NS 160H	100	Io=1 x In, Ir=0.93 x Io	50KA	43	Adequate

PCC2 – Switchgear data

Sr.	Feeder	Model/ Make	Rating (Amp)	Pot setting	KA Rating	Measured Current (Amp)	Remark
	PCC 2						
1	PCC 2 main I/C	ACB L&T UN2-32S	3200	Ir=0.9	-	1050	Adequate
2	Utility Panel	ACB L&T UN1-16N	1600	Ir=0.6 x In	65KA	712	Adequate
3	Block 2 MDB	ACB L&T UN2-25S	2500	Ir=0.6 x In	-	389.5	Load current is very small as compared to rating. ACB may not provide overload protection.
A	Utility MCC 2						
i	Air Compressor - 2	MCCB L&T DN2-250D	125	-	36KA	72	Adequate
ii	New Cooling tower (3F1)	MCCB L&T DN2-250D	125	-	36KA	30	Adequate
iii	HVAC MCC Block 2	MCCB L&T DN3-630N	630	-	50KA	178	Adequate
iv	Pump house	MCCB L&T DN2-250D	125	-	36KA	11	Adequate
v	Phase 2 Chiller no. 2	MCCB L&T DN3-630N	630	-	50KA	155	Adequate
vi	Phase 2 Chiller no. 1	MCCB L&T DN3-630N	630	-	50KA	188	Adequate
vii	3 TPH Boiler	MCCB L&T DN2-250D	100	-	36KA	10	Load current is very small as compared to rating. MCCB, MCB may not provide overload protection
viii	Auto Tube Cleaner	MCB Hager 63A	63	-	-	2.7	
B	Block 2- Utility MCC 3						
i	Utility MCC 3	MCCB L&T DH630	630	-	35KA	170	Adequate
ii	Pri. Chilled water pump 1	MCB Legrand C32	32	-	-	11.3	Adequate
iii	Pri. Chilled water pump 3	MCB L&T 25A	25	-	-	20	Adequate
iv	CDS water pump 1	MCCB L&T DH100	63	-	25KA	28	Adequate
v	CDS water pump 3	MCCB L&T DH100	63	-	25KA	35	Adequate
vi	Sec. chilled water pump 2	MCCB L&T DH100	63	-	25KA	26	Adequate
vii	Sec. water pump 3	MCCB L&T DH100	63	-	25KA	30	Adequate

PCC-1 – Cable data

Sr. No.	Feeder Name	Cable	Line Current		Cable Current Capacity	Remark
			Avg.	Max.		
1	HT 33KV	400 sq.mm/3/AL/1	20.92	45	375	Adequate
	PCC 1					
2	PCC 1 main I/C	300 sq.mm/3.5/AL/11 Run	957	1269	3465	Adequate
3	PP-16 Boiler	50 sq.mm/3.5/AL/1	3.3	3.3	105	Adequate
4	PP-17 Utility	150 sq.mm/3.5/AL/1	8.2	8.2	205	Adequate
5	ETP	240 sq.mm/3.5/AL/1 Run	21	21	280	Adequate
6	Gate Cabin -2	16 sq.mm/4/CU/1 Run	2.36	2.36	66	Adequate
7	LDB- Utility Building	16 sq.mm/4/AL/1 Run	1.2	1.2	51	Adequate
8	LDB- Main gate building	16 sq.mm/4/AL/1 Run	18.8	18.8	51	Adequate
9	I/C to LDB's	50 sq.mm/4/CU/1	65	65	135	Adequate
10	Chiller No.2	240 sq.mm/3.5/AL/2 Run	290	294	560	Adequate
11	MCC - HVAC main I/C	240 sq.mm/3.5/AL/2 Run	146.6	150	560	Adequate
12	Block 1 MDB 1 I/C	240sq.mm/3.5/AL/3 Run	130	203	720	Adequate
13	Block 1 MDB 2 I/C	300 sq.mm/3.5/AL/2	197	232	630	Adequate
14	UPS Main Incomer	240sq.mm/3.5/AL/3 Run	282.6	321.5	720	Adequate
15	PP - 5 (Equipment) panel-main I/C	50 sq.mm/4/CU/2	54	54	270	Adequate
16	ETP Main Incomer	240 sq.mm/3.5/AL/1	14	14	280	Adequate
17	SLDB R&D	240 sq.mm/3.5/AL/2	70.1	71	560	Adequate

PCC-2 – Cable data

Sr. No.	Feeder Name	Cable	Line Current		Cable Current Capacity	Remark
			Avg.	Max.		
			PCC 2			
1	PCC 2 main I/C	300 sq.mm/3.5/AL/11	899	1050	3465	Adequate
2	Utility Panel	240 sq.mm/3.5 core/AL/6	676.5	712	1680	Adequate
3	Block 2 MDB	240 sq.mm/3.5 core/AL/10	261.6	389.5	2800	Adequate
A			**Utility MCC 2**			
i	Air Compressor - 2	70 sq.mm/3.5/AL/1	72	72	130	Adequate
ii	New Cooling tower (3F1)	16 sq.mm/4 core/AL/1 run	30	30	51	Adequate
iii	HVAC MCC Block 2	240 sq.mm/3.5/AL/2 Run	178	178	560	Adequate
iv	Pump house	70 sq.mm/3.5/AL/1	11	11	130	Adequate
v	Phase 2 Chiller no. 2	240 sq.mm/3.5/AL/2 Run	155	155	560	Adequate
vi	Phase 2 Chiller no. 1	240 sq.mm/3.5/AL/2 Run	188	188	560	Adequate
vii	3 TPH Boiler	35 sq.mm/3.5/CU/1	10	10	110	Adequate
viii	Auto Tube Cleaner	10 sq.mm/4/CU/1	2.7	2.7	52	Adequate
B			**Block 2 Utility MCC 3**			
i	Utility MCC 3	240 sq.mm/3.5/AL/2 Run	170	170	560	Adequate
ii	Pri. Chilled water pump 1	10 sq.mm/4/CU/1	11.3	11.3	52	Adequate
iii	Pri. Chilled water pump 3	25 sq.mm/3/CU/1	20	20	90	Adequate
iv	CDS water pump 1	25 sq.mm/3/CU/1	28	28	90	Adequate
v	CDS water pump 3	25 sq.mm/3/CU/1	35	35	90	Adequate
vi	Sec. chilled water pump 2	35 sq.mm/3/CU/1	26	26	110	Adequate
vii	Sec. water pump 3	35 sq.mm/3/CU/1	30	30	110	Adequate

Standards used in Arc Flash Hazard Analysis

NFPA 70E:
National Fire Protection Association (NFPA) formed a standard NFPA 70E Standard for Employee Safety in the Workplace. This standard state that facilities must provide:
1. A safety program with defined responsibilities
2. Calculations for the degree of arc flash hazard
3. PPE for workers
4. Training for workers
5. Tools for safe work practices

NFPA has also defined various protection boundaries for classification of the arc flash hazard analysis. PPE is rated by the Arc Thermal Performance Value (ATPV) with units in cal/cm2. The required PPE is determined by comparing the calculated incident energy to the ratings for specific combinations of PPE. NFPA 70E provides Hazard/Risk Category tables, which highlight specific personnel protective equipment to be used on various electrical distribution equipment. However, these tables are based on fundamental assumptions about the available fault current and the over-current device clearing time.

IEEE 1584-2002:
IEEE Std. 1584-2002, IEEE Guide for Performing Arc-Flash Hazard Calculations, presents a more comprehensive methodology for arc flash hazard analysis. This standard, based on extensive testing carried out on low-voltage and medium voltage systems (to 15kV), is applicable to a wider range of systems than previous calculation methods. For systems above 15kV, where sufficient test data is not yet available, IEEE 1584 relies on the Lee method for calculation of arcing energy levels. The results presented in this report are based solely on the IEEE 1584 calculation procedures. IEEE 1584 is applicable only to three-phase arcing faults (though single-phase or phase-phase arcing faults are generally expected to quickly escalate to three-phase faults), and it does not consider the effects of arc blast or other by-products of an arcing fault (sound levels, molten metal droplets, toxic vapors, and so on).

Outcomes of Arc Flash Studies
The results of this study assume that protective devices considered are in working order and will operate within their specified tolerances to clear faults from the system. Non-functioning over-current protective devices can allow arcing faults to persist for much longer than normal, producing a very significant arc flash hazard beyond the results of the calculations presented in this report. Failure to properly maintain equipment may invalidate these results. Protection from arc flash hazards can best be provided by working only on circuits or equipment that have been placed in an electrically safe work condition.
The results of the arc flash analysis show both the calculated arc flash incident energy (AFIE) and flash protection boundary distances at each bus under study. In some locations, more than one value for AFIE levels and/or the flash protection boundary are given (e.g., one for the main section and one for the feeder sections of a switchgear lineup) to reflect different zones of protection for a given piece of equipment. Equipment warning labels or safety programs should take these variations in energy levels and flash protection boundaries into account.

More about various boundaries suggested by Arc flash study.

Flash Protection Boundary
The Flash Protection Boundary is the distance from the arc source at which the potential incident heat energy from the arcing fault falling on the surface of the skin is 1.2cal/cm2. An exposure to 1.2cal/cm2 would normally result in curable second degree burn. Within this boundary workers are required to wear protective clothing like fire resistance shirts and pants and other equipment to cover the various parts of the body.

Limited Approach Boundary
An approach limit at a, distance from an exposed live part within which shock hazard exists. For a person to cross the Limited Approach Boundary and enter the limited space, he or she must be qualified to perform the job/task.

Restricted Approach Boundary
An approach limit at a distance from an exposed live part within which there is an increased risk of shock, due to electrical arc over combined with inadvertent movement, for personnel working in close proximity to the live part.

Prohibited Approach Boundary
An approach limit at a distance from an exposed live part within which, work is considered to be the same as making contact with the live part. Crossing the Prohibited Approach Boundary and entering the prohibited space is considered the same as making contact with exposed energized conductors or circuit parts.

Fault Clearing Time
The arc duration is defined in ETAP as the Fault Clearing Time (FCT). This is the calculated time in seconds, which is needed by protective device to completely open and clear the arc fault (extinguish the arc).

Incident Energy
This is the calculated incident energy based on the system calculated parameters. The units for the incident energy are Cal/cm2. The incident energy is calculated using either the empirically derived IEEE 1584 2002 model or the Lee method (depending on the system voltage). The incident energy is used to determine the Hazard/Risk Category and the Flash Protection Boundary (ft.).

Level (NFPA 70E 2009)
The hazard/risk category (protective equipment class) is determined based on the system calculated incident energy for the bus. The possible levels are, 0,1,2,3 and 4. NFPA recommendations are used as a starting point for this sorting level system. The value may also be empty if the calculated value exceeds the maximum limit for level 4 of NFPA 70E 2009 (40 Cal/cm2), it is recommended not to work while the equipment is energized.