Relay Setting Calculation for Motors

The scope of this documents is to provide the relay setting schedule for the compressor motors and LV switchboard incomer for the Taweelah Power plant seawater intake Oil pollution Control System.

Equipment connected is:

Source	11 kV feeder in the client switchboard
MV Cable	11 kV 3C 240 sq. mm 1350m long
Transformer	1.5 MVA. 11 kV/433 V Z=6.62%
LV Switchboard incomer	2500A ACB Terasaki
Feeder from the LV Switchboard To power factor improvement Capacitor	Terasaki MCCB 630A
Feeder from the LV Switchboard To motor Star delta starter (5Nos.)	Terasaki MCCB 400A
LV motor Star-delta starter (5Nos.)	Klockner Moeller MCCB 400A
Compressor Motors (5Nos.)	140 kW, 415V as per data sheet

As a first step Fault calculations are done

Then the relay settings are done starting from the motor star delta feeder up to the incomer of the LV Switchboard.

The calculated settings are tabulated in a schedule and co-ordination curves demonstrating grading for the over current protection and earth fault are drawn, together with the protection SLD.

FAULT CURRENT CALCULATION

The switchboard fault level of the 11 kV feeder is 50 kA and the maximum 3 phase fault level as per client information is 40 kA and earth fault level is 1 kA.
In terms of MVA the 3 phase fault level is
$11kV \times 40 \times \sqrt{3} = 762.1$ MVA
This is the source fault level and in terms of 100 MVA the per unit impedance of the Source is
$100 / 762.1 = 0.1312$

The cable impedance is calculated as follows considering R and X values from cable catalogue. For 3C, 240sq mm R=0.0989 ohm / km and X=0.0722 ohm / km.
The value of X is considered for the fault level and R is ignored. For a length of 1350 m the reactance of cable X=0.0722x1.35=0.09747 ohms.

In per unit terms at 100 MVA base this is
$0.09747 \times 100 / 11^2 = 0.08$

Transformer % impedance at 1.5 MVA is 6.62%. In terms of 100 MVA the pu impedance is
$\frac{0.0662 \times 100}{1.5} = 4.41$
LV cable impedance from transformer to the switchboard is ignored due to the short length and large sized conductors.

Motor per unit impedance is calculated by considering the motor starting reluctance as Follows:
$\frac{0.96 \times 0.92 \times (100)}{0.14 \times 8} = 78.86$
Efficiency of 96%, power factor 0.92 and DOL starting ratio of 8 are considered as per the Motor data sheet.

Total impedance up to the switchboard bus is the sum of the p.u impedances of the source, cable and transformer that is

$Zs = 0.1312 + 0.08 + 4.41 = 4.6212$

Equivalent impedance of the 5 running motors is
$Zm = 78.86/5 = 15.772$

Resulting Positive sequence impedance is

$$Z = \frac{Zs \times Zm}{Zs+Zm} = \frac{4.6212 \times 15.772}{4.6212 + 15.772} = \frac{72.886}{20.39} = 3.574$$

The negative and zero sequence impedances are worked out as follows:

Source	Z1	= Z2
Cable	Z1	= Z2 and Z0 = 3xZ1
Transformer	Z1	= Z2 and Z0 = 0.9xZ1
Motor	Z1	= 0.73xZ2 and Z0 = 0.33xZ1

Hence negative seq. impedances is

Source side Zs = 0.1312 + 0.08 + 4.41 = 4.6212
Motors Zm = 0.73x78.86/5 = 11.514

Equivalent neg. seq. impedance = $\frac{4.6212 \times 11.514}{4.6212+11.514} = \frac{53.2085}{16.1352} = 3.298$

For the zero seq. impedance due to the delta primary, the source impedance will only be the transformer hence

Source side Zs=09x4.41 = 3.969
Motors Zm = 0.33x(78.86/5) = 5.2048
Equivalent zero seq. impedance = $\frac{3.969 \times 5.2048}{3.969+5.2048} = 2.252$

The source only contributes to the earth fault current as the motors are 3 ph (no neutral)

Hence the 3ph. fault level at the LV switchboard bus is

100 / 3.574 = 27.980 MVA ie $\frac{27.980}{0.415 \times \sqrt{3}} = 38.93$ kA with motor

100 / 4.6212 = 21.64 MVA ie $\frac{21.64}{0.415 \times \sqrt{3}} = 30.1$ kA without motor

and the L-G fault at the LV switchboard bus is

With the motor:
100 / (3.574 + 3.298 + 2.252) = 10.960 MVA $\frac{10.960}{0.415 \times \sqrt{3}} = 15.25$ kA

Without motor:
100 / (4.6212 + 3.298 + 2.252) = 9.83 MVA $\frac{9.83}{0.415 \times \sqrt{3}} = 13.67$ kA

OVERCURRENT RELAY SETTINGS

Star delta starter setting:

The starter is provided with Klockner Moeller MCCB of rating 400A.

Motor star delta starting current ratio is derived from the DOL current in the data sheet
Thus:

$$\frac{\text{DOL ratio}}{\sqrt{3}} \quad \text{ie} \quad 8/\sqrt{3} = 4.62$$

Hence starting current is 4.62 x 225 = 1039.5A

The run up time of the motor is assumed to be 8secs.
Using these values the starting curve of the motor is plotted.

Setting for thermal trip Ir.
Set at 1.25 times full load current
1.25 X 225 = 281 say 288A (nearest setting)
Time setting of 2 secs is set. This clears the starting current of the motor and the plotted curve is above the starting curve with adequate margin.

Setting for Magnetic Adjustment Im.
Range is 1.5 to 12 x Ir.
Choose a setting of 12 Ir, which is the maximum value and provides adequate margin above the starting current. This corresponds to 3456 A and is well below the bus short circuit rating

Setting of outgoing MCCB to motor starter:

MCCB rating is 400A and is of type XS400NJ

Setting for thermal trip Ir:
Motor full load current is 225A and the MCCB is set at approx. 30% margin which is
1.3 x 225 = 292.5 say 300A
Range is 0.63 to 1 x In where In = 400A. Set at the nearest the setting of 0.8 that provides 320A.
The standard curve is plotted and is above the motor starter curve with satisfactory margin.

Setting for Magnetic Adjustment Im:
Range is 5 to 10 X In
Choose a setting of 10 In which is the maximum value and provides adequate margin above the starting current. This corresponds to 4000 A and is well below the bus short circuit rating.

Setting of outgoing MCCB to Capacitor:

MCCB rating is 630A and is of type XS630NJ

Setting for the thermal trip Ir:
Capacitor rating is 250kVAR and the max current is 386 A and the MCCB is set at 30% margin which is
1.3 x 386 = 501 A
Range is 0.63 to 1 x I_n = 630A. For the required value of 501A, the nearest setting of Ir is 0.8 (504A)

Setting for Magnetic Adjustment Im:
Range is 5 to 10 x I_n
Choose a setting of 10 I_n which is the maximum value. This corresponds to 5000A and is well below the bus short circuit rating

The curve for this MCCB is also plotted.

Setting of the incoming breaker of the LV Switchboard.
The incoming circuit breaker is 2500 A ACB of type AR325S with over current protection OCR – General protection L

The total load on the LV switchboard is 752 kW including the 5 nos. 140 kW motors and the lighting + other loads

Total load is 752 kW

Full load current is $\frac{752}{(0.415 \times 0.9) \times \sqrt{3}} = 1163$ A

Considering a margin of 25% the incomer relay setting is to be1.25x1163 = 1454 A.

Settings:		
CT ratio I_n	0.5 to 1A	A setting of 0.63 is selected that provides 0.63 x 2500 = 1575A setting
Long time delay		
I_R	0.8 to 1 I_n	A setting of 0.95 is selected that provides a load setting of 0.95 x1575 = 1496 A which is above the current of 1454 A
t_R	0.5 to 30 s	The setting has to grade above the largest outgoing feeder which is the Capacitor feeder. A time setting of 10s is provided which provides the required grading.
Hot / cold mode		Cold mode is selected
Inst / MCR		Select MCR that will lock out the incomer for any fault

Instantaneous setting

Ii	2 to 16 I_n	set to NON

Short time delay

Isd	1 to 10 I_n	Not set choose NON
tsd	200 ms	Not applicable
I^2t	On/Off	Off

The over current protection release curve is plotted and it is found that adequate grading is available at all levels.

Details of the 11 kV breaker feeder is

CT ratio: 100/1
Relay type ITG 7371
Setting range: I> 0.7 to 2 In
Transformer FLC = $1500 / (11x\sqrt{3}) = 79$ A
Set I> at 1.5 In i.e 150 A

At the fault current of 30.1 kA the relay setting multiple is

$$\frac{30100x0.415}{100x11x1.5} = 7.57$$

Time of operation of the relay with time setting of 1.5 at this multiple from the graph is read as 2 sec.

Required time of operation is the time of operation of the downstream incomer relay + a discrimination of 0.35 s

$1+ 0.35 = 1.35$

The require time setting is $1.5x(1.35/2) = 1.01$. Choose 1.2 the nearest available higher setting.

The settings coordinate with the downstream incomer setting at the point of fault current but at lower currents the coordination is not available, therefore the setting is increased to 2.0 In

The instantaneous element I>> range is 5-20 I>

This is set at the fault current of 30.1 kA the setting required is

$$\frac{30100x0.415}{100x11x2} = 5.67$$

Choose a setting of 6 which is the nearest stop. (corresponds to 31.8 kA)

Recommended Settings are I> 2 tI> 1.2 and I>> 8

Earth fault setting

Earth fault setting for feeder to Motor Starter
ELR with Toroidal CT is used. Make - TemProtect Type – ELR-1.

Current setting range: 250 mA to 250 A
Set for 20% of Motor FLC of 225A 225 x 0.2 = 45A

Time delay = 20 ms to 5 sec
Set at max time of 5 sec to avoid any spurious tripping.

Incomer of LV Switchboard
Ground fault trip pick up current

I_g	0.1 to 1.0 I_{ct}	Set at 20% (i.e. 0.2 x 2500 = 500A) setting which provides a sensitive protection for pick up at low levels of earth fault and to be above the motor e/f setting.
t_g	100 to 2000ms	Set at a typical value of 200ms.
I^2t mode		Off

Earth fault relay for the Transformer Neutral
CT Ratio 250 / 1A

Earth fault current maximum value is 15.248 kA. Maximum value on secondary is 15250 /250 = 61
Setting Range Ie > 0.01 to 8 Set at 2.0 (500A)
To match the breaker curve downstream, EI curve is selected.

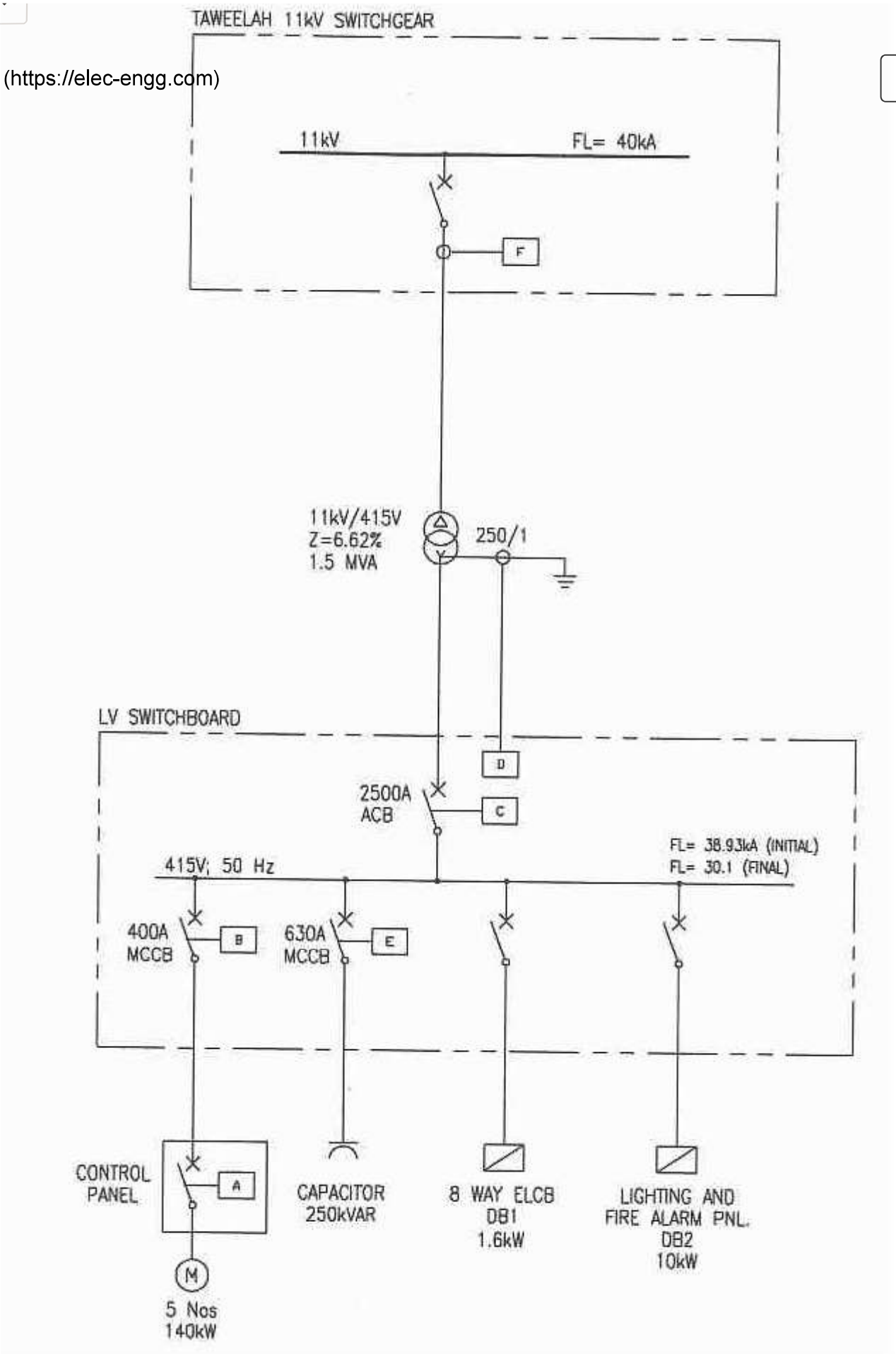
TMS range	0.025 to 1.5	Grading of 0.2s is achieved at 2000A i.e 8 times the CT primary current by choosing TMS of 0.075

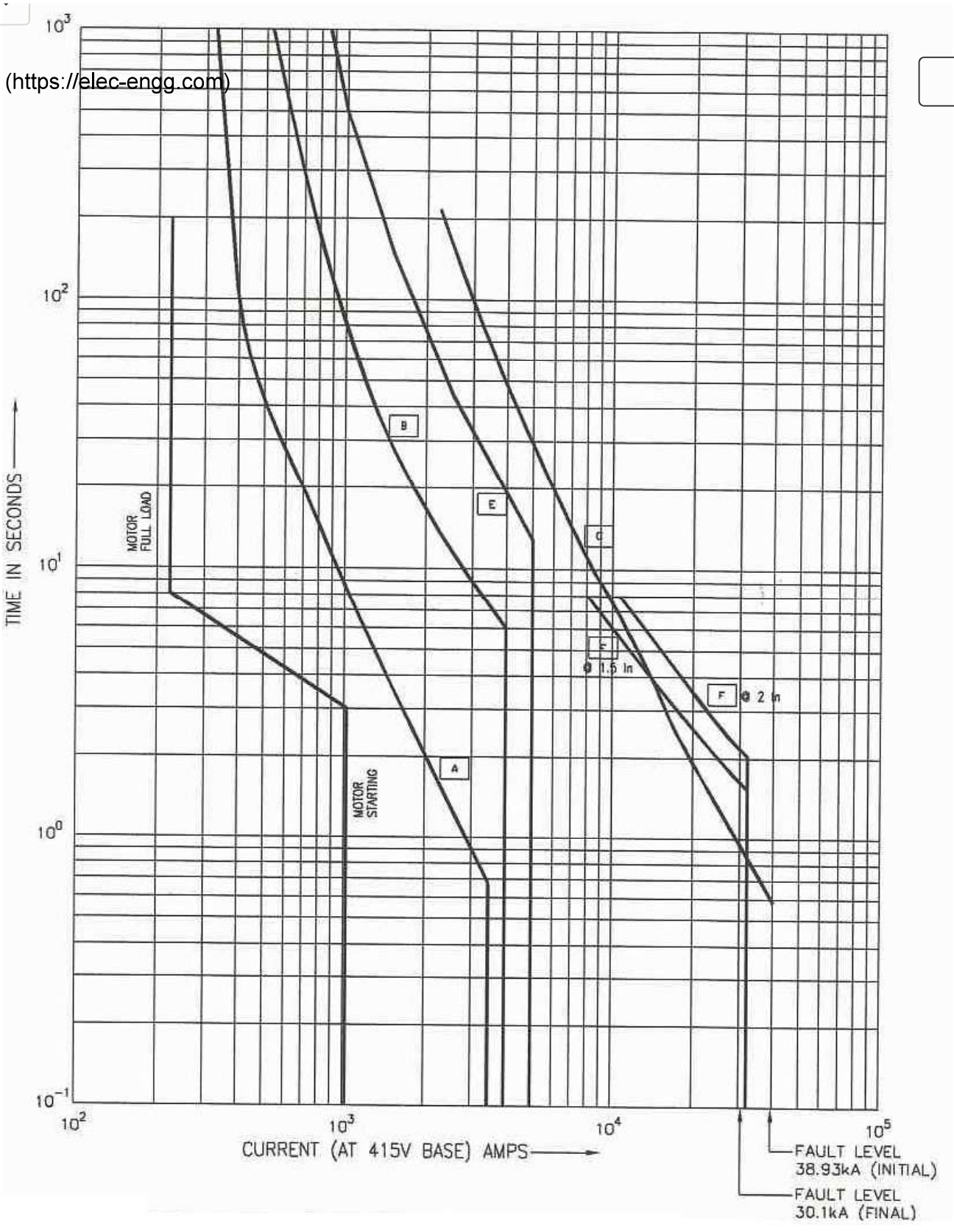
Instantaneous element of the relay is also set.

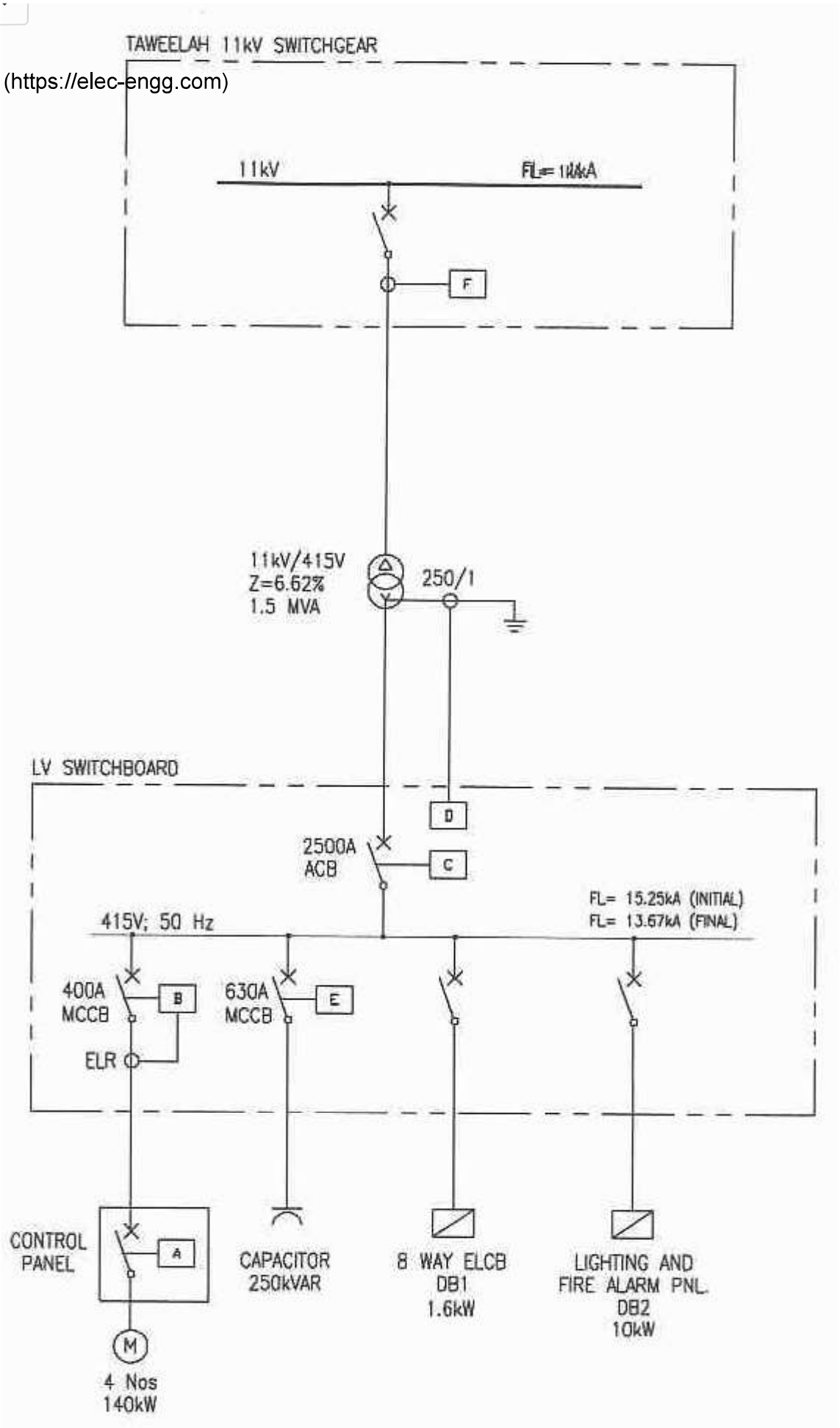
The range is Ie >>>0.01 to 8 and is set at the maximum value of 8 which is 2000A.
Co-ordination curve is plotted. It is seen that there is adequate margin at all levels.

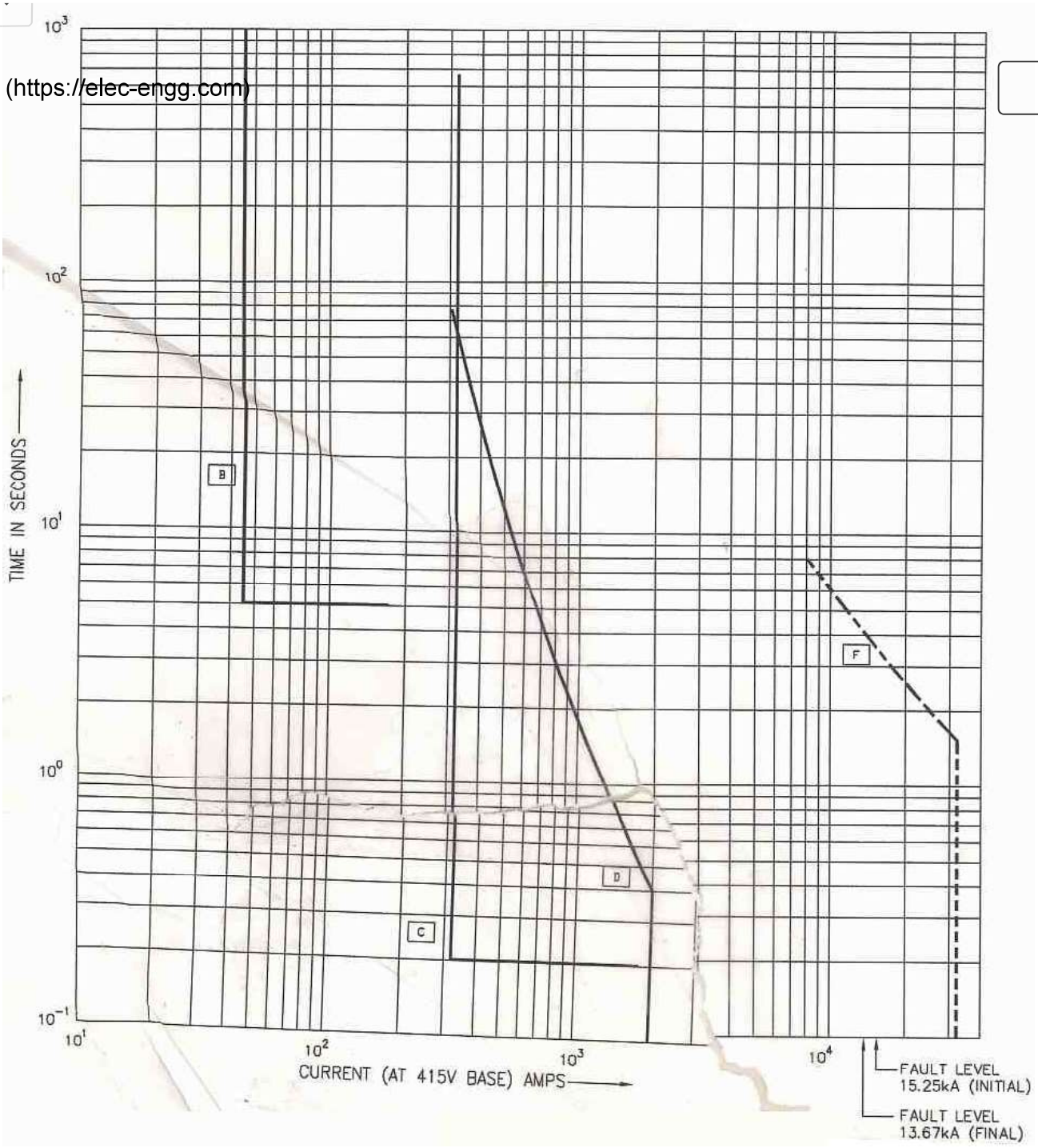
PANEL No.	CIRCUIT DESIGNATION	CT RATIO	RELAY CHARACTERISTICS				
			SERVICE	MAKE	MODEL	RANGE	SETTING
	415V LV SWITCHGEAR		RATED CURRENT CT SETTING (In)	TERASAKI	AP216S-AGR-22L-PG	0.5 – 1.0	0.63
	INCOMER PANEL		LONG TOME DELAY TRIP PICKUP CURRENT (CONTINUOUS) (I_R)			0.8 – 1.0	0.95
	AIR CIRCUIT BREAKER (ACB)		N-PHASE PROTECTION TRIP PICKUP CURRENT (CONTINUOUS) (I_N)			0.4 – 1.0 & NON	NON
	2500A		LONG TIME DELAY/N-PHASE PROTECTION TRIP TIMING (tR)			0.5 – 30 sec	10
			LONG TIME DELAY/N-PHASE PROTECTION TRIP MODE			HOT/COLD	COLD
			SHORT TIME DELAY TRIP PICKUP CURRENT (I_{sd})			1 – 10 & NON	NON
			SHORT TIME DELAY TRIP TIMING (t_{sd})			50 – 800 ms	N/A
			SHORT TIME DELAY TRIP I^2t MODE (I^2t t_{sd})			ON/OFF	OFF
			INSTANTANEOUS TRIP PICKUP CURRENT (I_i)			2 – 16 & NON	NON
			INST/MCR			SELECTABLE	MCR
			GROUND FAULT TRIP PICK UP CURRENT (I_g)			0.1 – 1.0 In	0.2
			GROUND FAULT TRIP TIMING (t_g)			100 – 2000 ms	200
			GROUND FAULT TRIP I^2t MODE (I^2t t_g)			ON/OFF	OFF
			PRETRIP ALARM PICKUP CURRENT (I_{pt})			0.75 – 1.0	0.95
			PRETRIP ALARM TIMING (t_{pt})			5 – 200 sec	5
	TRANSFORMER NEUTRAL	250/1	EARTH FAULT SETTING (Ie >)	ALSTOM	MICOM P120	0.01 – 8 Ion	0.125
	TO EARTH CIRCUIT		EARTH FAULT TMS			0.025 – 1.5	0.35
						CURVE	EI
			EARTH FAULT SETTING (Ie >>>)			0.01 – 8 Ion	8
						INST.	<30 msec FIXED

PANEL No.	CIRCUIT DESIGNATION	CT RATIO	RELAY CHARACTERISTICS					REMARKS
			SERVICE	MAKE	MODEL	RANGE	SETTING	
	MOTOR CONTROL PANEL		SETTING (Ir)	KLOCKNER MOELLER	NZM 10-400N/ZMM-400	200 – 400 A	288A	
	MCCB, 400A		SETTING (tr)			2 – 20 sec	2 sec	
			SETTING (Irm)			1.5 – 12 Ir	12 Ir	
	LV SWITCHBOARD MOTOR FEEDER		RATED CURRENT (In)	TERASAKI	XS 400NJ		400A	
	MCCB, 400A		THERMAL SETTING (Ir)			0.63 – 1 In	0.8	
			MAGNETIC INSTANTANEOUS SETTING (Im)			5 – 10 In	10	
			EARTH LEAKAGE RELAY	TERASAKI	TEMPROTECT ELR-1			
			CURRENT SETTING			0.25 – 250 A	45 A	
			TIME DELAY			20 ms – 5 sec	5 sec	
	LV SWITCHBOARD CAPACITOR FEEDER		RATED CURRENT (In)	TERASAKI	XS 630NJ		630A	
	MCCB, 630A		THERMAL SETTING (Ir)			0.63 – 1 In	0.8	
			MAGNETIC INSTANTANEOUS SETTING (Im)			5 – 10 In	10	
	11kV BREAKER FEEDER TO	100/1	CURRENT SETTIN (I>)	CEE	ITG7371	0.7 – 2 In	2	
	TRANSFORMER		TIME SETTING (t)			0.15 – 1.5	1.2	
			INSTANTANEOUS SETTING (I>>)			5 – 20 I>	6	


TAWEELAH 11kV SWITCHGEAR
11kV
FL= 40kA
F
11kV/415V
Z=6.62%
1.5 MVA
250/1
LV SWITCHBOARD
D
2500A
ACB
C
415V; 50 Hz
FL= 38.93kA (INITIAL)
FL= 30.1 (FINAL)
400A
MCCB
B
630A
MCCB
E
CONTROL
PANEL
A
M
5 Nos
140kW
CAPACITOR
250kVAR
8 WAY ELCB
DB1
1.6kW
LIGHTING AND
FIRE ALARM PNL.
DB2
10kW


TIME IN SECONDS
CURRENT (AT 415V BASE) AMPS
MOTOR FULL LOAD
MOTOR STARTING
A
B
C
D
E
F @ 1.5 In
F @ 2 In
FAULT LEVEL 38.93kA (INITIAL)
FAULT LEVEL 30.1kA (FINAL)


TAWEELAH 11kV SWITCHGEAR
11kV
FL= 16kA
F
11kV/415V
Z=6.62%
1.5 MVA
250/1
LV SWITCHBOARD
D
2500A
ACB
C
FL= 15.25kA (INITIAL)
FL= 13.67kA (FINAL)
415V; 50 Hz
400A
MCCB
B
630A
MCCB
E
ELR
CONTROL
PANEL
A
M
4 Nos
140kW
CAPACITOR
250kVAR
8 WAY ELCB
DB1
1.6kW
LIGHTING AND
FIRE ALARM PNL.
DB2
10kW



MOTOR PROTECTION RELAY SETTING CALCULATION FOR MOTORS

Protection Relay (https://elec-engg.com/category/protection-relay/)

Protection Engineer (https://elec-engg.com/author/engineer/)

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