The scope of this document 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 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

\[11kV \times 40 \times \sqrt{3} = 762.1 \text{ MVA}\]

This is the source fault level and in terms of 100 MVA the per unit impedance of the Source is

\[
\frac{100}{762.1} = 0.1312
\]

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 \(X=0.0722 \times 1.35=0.09747 \text{ ohms}\).

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 pu impedances of the source, cable and transformer that is

\[
Z_s = 0.1312 + 0.08 + 4.41 = 4.6212
\]

Equivalent impedance of the 5 running motors is

\[
Z_m = 78.86 / 5 = 15.772
\]

Resulting Positive sequence impedance is

\[
Z = \frac{Z_s \times Z_m}{Z_s + Z_m} = \frac{4.6212 \times 15.772}{4.6212 + 15.772} = \frac{72.886}{20.39} = 3.574
\]
The negative and zero sequence impedances are worked out as follows:

- Cable: $Z_1 = Z_2$ and $Z_0 = 3xZ_1$
- Transformer: $Z_1 = Z_2$ and $Z_0 = 0.9xZ_1$
- Motor: $Z_1 = 0.73xZ_2$ and $Z_0 = 0.33xZ_1$

Hence negative seq. impedances is

Source side $Z_s = 0.1312 + 0.08 + 4.41 = 4.6212$
Motors $Z_m = 0.73\times78.86/5 = 11.514$

Equivalent neg. seq. impedance $= 4.6212\times11.514 = 53.2085 = 3.298$
$4.6212 + 11.514 = 16.1352$

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

Source side $Z_s = 0.9\times4.41 = 3.969$
Motors $Z_m = 0.33\times78.86/5 = 5.2048$
Equivalent zero seq. impedance $= \frac{3.969\times5.2048}{3.969 + 5.2048} = 2.252$

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

\[
\frac{100}{3.574} = 27.980 \text{ MVA} \quad \text{ie} \quad \frac{27.980}{0.415\times\sqrt{3}} = 38.93 \text{ kA with motor}
\]

\[
\frac{100}{4.6212} = 21.64 \text{ MVA} \quad \text{ie} \quad \frac{21.64}{0.415\times\sqrt{3}} = 30.1 \text{ kA without motor}
\]

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

With the motor:

\[
\frac{100}{(3.574 + 3.298 + 2.252)} = 10.960 \text{ MVA} \quad \frac{10.960}{0.415\times\sqrt{3}} = 15.25 \text{ kA}
\]

Without motor:

\[
\frac{100}{(4.6212 + 3.298 + 2.252)} = 9.83 \text{ MVA} \quad \frac{9.83}{0.415\times\sqrt{3}} = 13.67 \text{ kA}
\]
OVERCURRENT RELAY SETTINGS

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:

\[
\frac{\text{DOL ratio}}{\sqrt{3}} = \frac{8}{\sqrt{3}} = 4.62
\]

Hence starting current is \(4.62 \times 225 = 1039.5\text{A}\)

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 \(\times\) 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 \(\times\) 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 \(\times\) 225 = 292.5 say 300A
Range is 0.63 to 1 \(\times\) 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 \(\times\) 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:

The MCCB is of type XS630NJ 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 be 1.25 x 1163 = 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 | 0.8 to 1 I_n | A setting of 0.95 is selected that provides a load setting of 0.95 x 1575 = 1496 A which is above the current of 1454 A
| I_t | 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

\[ I_{i} = 2 \text{ to } 16 \, I_{n} \quad \text{set to NON} \]

Short time delay

\[ I_{sd} = 1 \text{ to } 10 \, I_{n} \quad \text{Not set choose NON} \]

\[ t_{sd} = 200 \, \text{ms} \quad \text{Not applicable} \]

\[ I^{2}t \quad \text{On/Off} \quad \text{Off} \]

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: \( I_{>} = 0.7 \text{ to } 2 \, I_{n} \)
Transformer FLC = 1500 / (11 \times \sqrt{3}) = 79 \, A
Set \( I_{>} \) at 1.5 \( I_{n} \) i.e 150 \( A \)

At the fault current of 30.1 \( kA \) the relay setting multiple is

\[ \frac{30100 \times 0.415}{100 \times 11 \times 1.5} = 7.57 \]

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 1.5(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 \( I_{n} \)

The instantaneous element \( I_{>>} \) range is 5-20 \( I_{>} \)

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

\[ \frac{30100 \times 0.415}{100 \times 11 \times 2} = 5.67 \]

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

Recommended Settings are \( I_{>} \): 2 \( I_{i} \): 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  \[225 \times 0.2 = 45\text{A}\]

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
\[I_g = 0.1 \text{ to } 1.0 \times I_{nt}\]
Set at 20% (i.e. \[0.2 \times 2500 = 500\text{A}\]) setting which provides a sensitive protection for pick up at low levels of earth fault and to be above the motor e/f setting.

\[t_g = 100 \text{ to } 2000\text{ms}\]
Set at a typical value of 200ms.

\[I^2t\text{ mode} \quad \text{Off}\]

Earth fault relay for the Transformer Neutral
CT Ratio \[250 / 1\text{A}\]

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

TMS range \[0.025 \text{ to } 1.5\] 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 \[I_e >> 0.01 \text{ to } 8\] 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.
### Relay Characteristics

<table>
<thead>
<tr>
<th>Panel No.</th>
<th>Circuit Designation</th>
<th>CT Ratio</th>
<th>Service</th>
<th>Make</th>
<th>Model</th>
<th>Range</th>
<th>Setting</th>
<th>Remarks</th>
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### Transformer Neutral

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MOTOR PROTECTION  RELAY SETTING CALCULATION FOR MOTORS

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

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