**SMART POWER PLUS**

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# **MASTER TABLES**

## MFM READ PARAMETERS WITH TAGS

|  |  |  |  |
| --- | --- | --- | --- |
| MULTISPAN  Address list | Tags – use for ESP Code | Tag- use for WEB | Tag Description |
| 1 | KWH | P1 | TOTAL KWh ENERGY CONSUMPTION |
| 2 | KVAH | P2 | TOTAL KVAh ENERGY CONSUMPTION |
| 3 | KVARH | P3 | TOTAL KVArh ENERGY CONSUMPTION |
| 4 | VR | P4 | R-PHASE TO NEUTRAL VOLTAGE |
| 6 | VY | P5 | Y-PHASE TO NEUTRAL VOLTAGE |
| 8 | VB | P6 | B-PHASE TO NEUTRAL VOLTAGE |
| 10 | AVG\_VLN | P7 | AVERAGE PHASE TO NEUTRAL VOLTAGE |
| 12 | VRY | P8 | R TO Y PHASE VOLTAGE |
| 14 | VYB | P9 | Y TO B PHASE VOLTAGE |
| 16 | VBR | P10 | B TO R PHASE VOLTAGE |
| 18 | AVG\_VLL | P11 | PHASE TO PHASE VOLTAGE |
| 20 | IR | P12 | R-LINE CURRENT |
| 22 | IY | P13 | Y-LINE CURRENT |
| 24 | IB | P14 | B-LINE CURRENT |
| 26 | AVG\_I | P15 | AVERAGE LINE CURRENT |
| 28 | R\_PF | P16 | R-PHASE POWER FACTOR |
| 29 | Y\_PF | P17 | Y-PHASE POWER FACTOR |
| 30 | B\_PF | P18 | B-PHASE POWER FACTOR |
| 32 | AVG\_PF | P19 | AVERAGE PHASE POWER FACTOR |
| 33 | FREQUENCY | P20 | SYSTEM FREQUENCY |
| 34 | R\_KW | P21 | R-PHASE POWER (KW) |
| 36 | Y\_KW | P22 | Y-PHASE POWER (KW) |
| 38 | B\_KW | P23 | B-PHASE POWER (KW) |
| 40 | TOTAL\_KW | P24 | TOTAL POWER (KW) |
| 42 | R\_KVA | P25 | R-PHASE POWER (KVA) |
| 44 | Y\_KVA | P26 | Y-PHASE POWER (KVA) |
| 46 | B\_KVA | P27 | B-PHASE POWER (KVA) |
| 48 | TOTAL\_KVA | P28 | TOTAL POWER (KVA) |
| 50 | R\_KVAR | P29 | R-PHASE POWER (KVAr) |
| 52 | Y\_KVAR | P30 | R-PHASE POWER (KVAr) |
| 54 | B\_KVAR | P31 | R-PHASE POWER (KVAr) |
| 56 | TOTAL\_KVAR | P32 | TOTAL POWER (KVAr) |
| 84 | R\_THD-V | P33 | R\_Phase Voltage Harmonic Distortion % |
| 85 | Y\_THD-V | P34 | Y\_Phase Voltage Harmonic Distortion % |
| 86 | B\_THD-V | P35 | B\_Phase Voltage Harmonic Distortion % |
| 87 | R\_THD-I | P36 | R\_Phase Current Harmonic Distortion % |
| 88 | Y\_THD-I | P37 | Y\_Phase Current Harmonic Distortion % |
| 89 | B\_THD-I | P38 | B\_Phase Current Harmonic Distortion % |
|  | RSSI | P39 | Wi-Fi Signal Strength |

## DATA VALIDATION RULES TABLE

### HT DISTRIBUTION PANELS

HT Panel Data Validation Ranges (with ±15% buffer on critical thresholds)

|  |  |  |  |
| --- | --- | --- | --- |
| **TAGS** | **11 kV Range (Min–Max)** | **22 kV Range (Min–Max)** | **33 kV Range (Min–Max)** |
| VR | 9,350 – 12,650 V | 18,700 – 25,300 V | 28,050 – 37,950 V |
| VY | 9,350 – 12,650 V | 18,700 – 25,300 V | 28,050 – 37,950 V |
| VB | 9,350 – 12,650 V | 18,700 – 25,300 V | 28,050 – 37,950 V |
| AVG\_VLN | 9,350 – 12,650 V | 18,700 – 25,300 V | 28,050 – 37,950 V |
| VRY | 16,170 – 20,130 V | 32,340 – 40,260 V | 48,510 – 60,390 V |
| VYB | 16,170 – 20,130 V | 32,340 – 40,260 V | 48,510 – 60,390 V |
| VBR | 16,170 – 20,130 V | 32,340 – 40,260 V | 48,510 – 60,390 V |
| AVG\_VLL | 16,170 – 20,130 V | 32,340 – 40,260 V | 48,510 – 60,390 V |

Common Validation Ranges for All HT Panels (Non-voltage)

|  |  |  |
| --- | --- | --- |
| **TAGS** | **Range Start (Min)** | **Range End (Max)** |
| KWH | 0 | 999999 |
| KVAH | 0 | 999999 |
| KVARH | 0 | 999999 |
| IR | 0 | 3x of rated FLC (HT-User Config Page) |
| IY | 0 | 3x of rated FLC (HT-User Config Page) |
| IB | 0 | 3x of rated FLC (HT-User Config Page) |
| AVG\_I | 0 | 3x of rated FLC (HT-User Config Page) |
| R\_PF | 0.3000 | 1.15 |
| Y\_PF | 0.3000 | 1.15 |
| B\_PF | 0.3000 | 1.15 |
| AVG\_PF | 0.3000 | 1.15 |
| FREQUENCY | 40.8 | 58.7 |
| R\_KW | -50 | 2x of rated KW (User Config Page) |
| Y\_KW | -50 | 2x of rated KW (User Config Page) |
| B\_KW | -50 | 2x of rated KW (User Config Page) |
| TOTAL\_KW | -50 | 2x of rated KW (User Config Page) |
| R\_KVA | 0 | 2x of rated KVA (User Config Page) |
| Y\_KVA | 0 | 2x of rated KVA (User Config Page) |
| B\_KVA | 0 | 2x of rated KVA (User Config Page) |
| TOTAL\_KVA | 0 | 2x of rated KVAR (User Config Page) |
| R\_KVAR | -50 | 2x of rated KVAR (User Config Page) |
| Y\_KVAR | -50 | 2x of rated KVAR (User Config Page) |
| B\_KVAR | -50 | 2x of rated KVAR (User Config Page) |
| TOTAL\_KVAR | -50 | 2x of rated KVAR (User Config Page) |
| R\_THD-V | 0.00 | 35.00 |
| Y\_THD-V | 0.00 | 35.00 |
| B\_THD-V | 0.00 | 35.00 |
| R\_THD-I | 0.00 | 50.00 |
| Y\_THD-I | 0.00 | 50.00 |
| B\_THD-I | 0.00 | 50.00 |
| RSSI | -120 | -20 |

### LT DISTRIBUTION PANELS

**LT Panel Voltage Data Validation Ranges** With ±15% buffer over critical thresholds

|  |  |
| --- | --- |
| **TAGS** | **Min–Max Range (V)** |
| **VR** | **166 V – 529 V** |
| **VY** | **166 V – 529 V** |
| **VB** | **166 V – 529 V** |
| **AVG\_VLN** | **166 V – 529 V** |
| **VRY** | **289 V – 529 V** |
| **VYB** | **289 V – 529 V** |
| **VBR** | **289 V – 529 V** |
| **AVG\_VLL** | **289 V – 529 V** |

**LT Panel Current Data Validation Ranges**

|  |  |  |
| --- | --- | --- |
| **TAGS** | **Min–Max Range (A)** | **Logic / Notes** |
| **IR** | 0 – 869 A | 3x of rated FLC (LT-User Config Page) |
| **IY** | 0 – 869 A | 3x of rated FLC (LT-User Config Page) |
| **IB** | 0 – 869 A | 3x of rated FLC (LT-User Config Page) |
| **AVG\_I** | 0 – 869 A | 3x of rated FLC (LT-User Config Page) |

**LT Panel Frequency Validation**

|  |  |  |
| --- | --- | --- |
| **TAGS** | **Min–Max Range (Hz)** | **Logic / Notes** |
| **FREQUENCY** | 40.8 – 58.7 | Nominal = 50 Hz; ±3% = 48.5–51.5 Hz → Buffer ±15% = 40.8–58.7 Hz |

**Power Tags Validation Ranges**

|  |  |  |
| --- | --- | --- |
| **TAGS** | **Min** | **Max** |
| **R\_KW** | -50 | 2x Rated KW of Panel (LT-User Config page) |
| **Y\_KW** | -50 | 2x Rated KW of Panel (LT-User Config page) |
| **B\_KW** | -50 | 2x Rated KW of Panel (LT-User Config page) |
| **TOTAL\_KW** | -50 | 2x Rated KW of Panel (LT-User Config page) |
| **R\_KVA** | 0 | 2x Rated KVA of Panel (LT-User Config page) |
| **Y\_KVA** | 0 | 2x Rated KVA of Panel (LT-User Config page) |
| **B\_KVA** | 0 | 2x Rated KVA of Panel (LT-User Config page) |
| **TOTAL\_KVA** | 0 | 2x Rated KVA of Panel (LT-User Config page) |
| **R\_KVAR** | -50 | 2x Rated KVAR of Panel (LT-User Config page) |
| **Y\_KVAR** | -50 | 2x Rated KVAR of Panel (LT-User Config page) |
| **B\_KVAR** | -50 | 2x Rated KVAR of Panel (LT-User Config page) |
| **TOTAL\_KVAR** | -50 | 2x Rated KVAR of Panel (LT-User Config page) |

**LT Panel Energy Tags Validation Ranges**

|  |  |  |
| --- | --- | --- |
| **TAGS** | **Min** | **Max** |
| KWH | 0 | 999999 |
| KVAH | 0 | 999999 |
| KVARH | 0 | 999999 |

**LT Panel – Power Factor (PF) Validation Ranges**

|  |  |  |  |
| --- | --- | --- | --- |
| **TAGS** | **Min** | **Max** | **Logic / Remarks** |
| **R\_PF** | 0.3000 | 1.1500 | Accepts lagging (typical), leading (compensated), or PF faults in threshold window |
| **Y\_PF** | 0.3000 | 1.1500 | Same logic as R\_PF – avoids under-range/over-range MFM noise |
| **B\_PF** | 0.3000 | 1.1500 | Phase-level PF – includes PF dips due to capacitor fault/load imbalance |
| **AVG\_PF** | 0.3000 | 1.1500 | Used for incentive/penalty application – normalized across shift/day |

**Notes:**

* **<0.30** is considered invalid due to measurement noise, short interruptions, or CT/PT error.
* **>1.15** is rejected as **physically unrealistic**, even with high leading PF correction.
* Acceptable operating PF range (per **CEA Grid Code**, **MERC Case No. 322 of 2019**) is **0.95–1.00 lag**, but this validation range includes extended zones for penalty computation.

**LT Panel – THD Validation Ranges (Voltage & Current)**

|  |  |  |
| --- | --- | --- |
| **TAGS** | **Min** | **Max** |
| **R\_THD-V** | 0.00 | 35.00 |
| **Y\_THD-V** | 0.00 | 35.00 |
| **B\_THD-V** | 0.00 | 35.00 |
| **R\_THD-I** | 0.00 | 50.00 |
| **Y\_THD-I** | 0.00 | 50.00 |
| **B\_THD-I** | 0.00 | 50.00 |

### MCC PANELS

## DATA RANGE TABLE

### HT PANEL

#### VOLTAGE PARAMETERS

Table

|  |  |  |  |
| --- | --- | --- | --- |
| **KEY PARAMETER / TAG** | **ACCEPTABLE RANGE** | **WARNING RANGE** | **CRITICAL RANGE** |
| VRY / VYB / VBR (11 kV) (Tags: VRY, VYB, VBR) | 10.45 kV to 11.55 kV | 9.90 kV to 10.45 kV or 11.55 kV to 12.10 kV | < 9.90 kV or > 12.10 kV |
| VRY / VYB / VBR (22 kV) | 20.9 kV to 23.1 kV | 19.8 kV to 20.9 kV or 23.1 kV to 24.2 kV | < 19.8 kV or > 24.2 kV |
| VRY / VYB / VBR (33 kV) | 31.35 kV to 34.65 kV | 29.7 kV to 31.35 kV or 34.65 kV to 36.3 kV | < 29.7 kV or > 36.3 kV |
| VLL\_MAX\_DEV\_PERCENT (Max Deviation %) | ≤ 2% | > 2% up to 4% | > 4% |
| HT Voltage Imbalance % (VLL\_MAX\_DEV / V\_AVG \* 100) | ≤ 2% | > 2% up to 3% | > 3% |

#### CURRENT PARAMETERS

|  |  |  |  |
| --- | --- | --- | --- |
| **KEY PARAMETER / TAG** | **ACCEPTABLE RANGE** | **WARNING RANGE** | **CRITICAL RANGE** |
| I\_R / I\_Y / I\_B (Feeder Phase Currents) | 0% to 100% of feeder rated current | >100% up to 120% of rated current | >120% of rated current |
| I\_AVG (Average Current) | Same as individual phase (0% to 100% of rated) | Same as individual phase (>100% up to 120%) | Same as individual phase (>120%) |
| I\_MAX\_DEV\_PERCENT (Max Deviation %) | ≤10% of average current | >10% up to 20% of average current | >20% of average current |

#### FREQUENCY

|  |  |  |  |
| --- | --- | --- | --- |
| **KEY PARAMETER / TAG** | **ACCEPTABLE RANGE** | **WARNING RANGE** | **CRITICAL RANGE** |
| Frequency (Hz) | 49.5 Hz to 50.5 Hz | 48.5 Hz to 49.5 Hz or 50.5 Hz to 51.5 Hz | < 48.5 Hz or > 51.5 Hz |
| Max Frequency Deviation from 50 Hz | ≤ 0.5 Hz | > 0.5 Hz up to 1.5 Hz | > 1.5 Hz |

#### POWER CONSUMPTION

|  |  |  |  |
| --- | --- | --- | --- |
| **KEY PARAMETER / TAG** | **ACCEPTABLE RANGE** | **WARNING RANGE** | **CRITICAL RANGE** |
| Per-Phase Apparent Power (KVA\_R/Y/B) | ≤100% of rated per-phase capacity | >100% up to 110% of rated capacity | >110% of rated capacity |
| Per-Phase Active Power (KW\_R/Y/B) | -do- | -do- | -do- |
| Per-Phase Reactive Power (kVAr R/Y/B) | -do- | -do- | -do- |
| Total Apparent Power (kVA total) | ≤100% of rated capacity | >100% up to 110% | >110% |
| Total Active Power (kW total) | ≤100% of rated capacity | >100% up to 110% | >110% |
| Total Reactive Power (kVAr total) | ≤100% of rated capacity | >100% up to 110% | >110% |
| Cumulative Energy (kVAh / kWh / kVArh) | ≤ expected baseline (e.g. daily/monthly target) | >10% above expected | >20% above expected |

#### POWER FACTOR INCENTIVE & PENALTY TABLE

|  |  |  |  |
| --- | --- | --- | --- |
| **Key Parameter / Tag** | **Acceptable Range** | **Warning Range** | **Critical Range** |
| PF ≥ 0.995 | 3.5% incentive | — | — |
| PF 0.985 – 0.994 | 2.5% incentive | — | — |
| PF 0.975 – 0.984 | 1.5% incentive | — | — |
| PF 0.965 – 0.974 | 1.0% incentive | — | — |
| PF 0.955 – 0.964 | 0.5% incentive | — | — |
| PF 0.951 – 0.954 | No surcharge (incentive zone) | — | — |
| PF 0.900 – 0.950 | — | Warning Zone | — |
| PF 0.895 – 0.899 | — | — | 0% Penalty |
| PF 0.885 – 0.894 | — | — | 1.0% Penalty |
| PF 0.875 – 0.884 | — | — | 1.5% Penalty |
| PF 0.865 – 0.874 | — | — | 2.0% Penalty |
| PF 0.855 – 0.864 | — | — | 2.5% Penalty |
| PF 0.845 – 0.854 | — | — | 3.0% Penalty |
| PF 0.835 – 0.844 | — | — | 3.5% Penalty |
| PF 0.825 – 0.834 | — | — | 4.0% Penalty |
| PF 0.815 – 0.824 | — | — | 4.5% Penalty |
| PF 0.805 – 0.814 | — | — | 5.0% Penalty |
| PF < 0.805 | — | — | >5.0% Penalty (Utility Defined) |

# **HT DISTRIBUTION PANELS**

## **RMU PANAL**

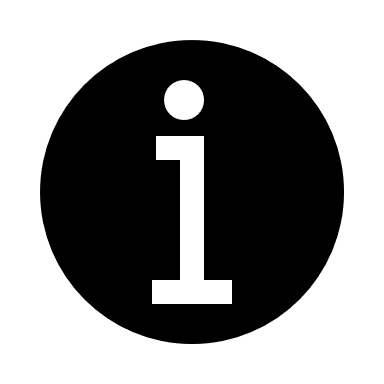
### A. REAL-TIME MONITORING(RTM) WEB PAGE

#### 1. RT - Line-to-Line Voltage (Tags: VRY, VYB, VBR)

##### Definition

1. Real-time measurement of the line-to-line voltages at the HT panel or RMU incomer: VRY (Red-Yellow), VYB (Yellow-Blue), VBR (Blue-Red). These voltages represent the phase-to-phase supply from the utility, typically 11 kV/22kV/33kV in Indian HT systems. Balanced, stable HT voltages are critical for the safe and efficient operation of downstream transformers, breakers, and connected machinery.
2. RT Reading from MFM+SPP with Tags VRY, VYB, VBR.
3. RMS values computed over each sampling interval as per IEC 61000-4-30 Class A methodology.

##### User Configuration Page

1. Need Toggle option to set Default Standards
2. Button Selection - Nominal voltage: 11 kV/22kV/33kV
3. Auto Select - Acceptable Range (): Up to (+5% or -5%) apply for   
   11 kV/22kV/33kV
4. Auto Select - Warning thresholds: (+5% to +10%) or (−5% to −10%) apply for 11kV/22kV/33kV, E.g., V > 11.55 kV or < 10.45 kV
5. Auto Select - Critical thresholds: (> +10%) or (< −10%) apply for   
   11 kV/22kV/33kV E.g., for 11 kV - V > 12.10 kV or < 9.90 kV
6. Toggle button for WhatsApp Alerts
7. Default Toggle for Alert Behaviour (Ref 1.1.19)
8. Help () & Pop-up message to conform
   1. IS 12360: Nominal system voltage 11 kV/22kV/33kV.
   2. MERC Standard of Performance, Regulation, 2005.

##### Acceptable Range

* 1. Based on user selected Voltage level – 11kV, 22kV, 33kV
  2. Standard As per IS 12360:1988, IEC 60038, and Indian utility norms.
  3. ±5% of nominal 11 kV/22kV/33kV
  4. 11kV ±5% → 10.45 kV to 11.55 kV.
  5. 22 kV ±5% → 20.9 kV to 23.1 kV.
  6. 33 kV ±5% → 31.35 kV to 34.65 kV.

##### Warning Range

1. Based on user selected Voltage level – 11kV, 22kV, 33kV
2. Standard As per IS 12360:1988 / IEC 60038 standard voltages for Indian HT systems
3. 11kV HT System
   1. Voltage between 11.55 kV to 12.10 kV (+5% to +10%)
   2. Voltage between 10.45 kV to 9.90 kV (−5% to −10%)
4. 22kV HT System
   1. Voltage between 23.1 kV to 24.2 kV (+5% to +10%)
   2. Voltage between 20.9 kV to 19.8 kV (−5% to −10%)
5. 33kV HT System
6. Voltage between 34.65 kV to 36.3 kV (+5% to +10%)
7. Voltage between 31.35 kV to 29.7 kV (−5% to −10%)

##### Critical Range

1. Based on user selected Voltage level – 11kV, 22kV, 33kV
2. IS 12360:1988 / IEC 60038 – Nominal system voltages with ±10% outer limit typically tolerated in emergency or abnormal grid conditions.
3. 11kV HT
   1. Voltage > 12.10 kV (> +10%)
   2. Voltage < 9.90 kV (< −10%)
4. 22kV HT
   1. Voltage > 24.2 kV (> +10%)
   2. Voltage < 19.8 kV (< −10%)
5. 33kV HT
   1. Voltage > 36.3 kV (> +10%)
   2. Voltage < 29.7 kV (< −10%)

##### Alert Behaviour

1. Based on SPP Device Payloads
2. Warning alert if any L-L voltage exceeds warning range for 2 consecutive payloads.
3. Critical alert if any L-L voltage exceeds critical range for 2 consecutive payloads.
4. Auto-reset once voltages within acceptable range in latest payload.
5. Alert Log page - Log event with
   1. Key Name
   2. Value
   3. Current Range (Warning / Critical)
   4. Acceptable Range Details
   5. Time Stamp
   6. Acknowledge Button
   7. If acknowledged – log Username – Highlight
6. MSG91 - WhatsApp Message Format for critical alert – “<Plant> <Location Tag> <Panel No. & Device Tag><Key><Value><” CRITICAL ALERT!! ”><Time Stamp>”

##### Widgets – Figma & UI/UX Design & Development

1. 3-phase polar chart - Tags VRY, VYB, VBR
2. 120deg each phase, Sequence – CW - VRY, VYB, VBR
3. V\_RY = Red; V\_YB = Yellow; V\_BR=Blue (Make a Standard)
4. Dotted Circle/shaded ring for all ranges (Acceptable – G; Warning – Y; Critical – R), (Make a Standard)
5. Polar Segment Stable: L-L voltages Acceptable Range (Make a Standard)
6. Polar Segment Ripples (polar origin to out)- every 3sec: L-L voltages Warning Range
7. Polar Segment Enlarge & Flash - every 2sec: L-L voltages Critical Range
8. When V\_AVG non-zero [Polar chart outer max – 12.0KV; inner min 9.0KV]
9. When V\_AVG = 0V - Panel Tripped [Polar chart/H Bar plot – Grey out & Tool Tip
10. Widget [RTW\_2] Standard
    1. Top left corner – widget label “3PH LINE to LINE VOLTAGE”
    2. Top right corner – Click Icon buttons to Navigate
       * Timeseries Data Table [TS/Key/value/Range Status/Std Range]
         + Dropdown for Latest records to show – 10, 30, 50.
         + Click Icon to Download in XLS/PDF with Date Range
       * Historical Plot
         + REF POINT 1.10
       * Alert Log Page
         + REF POINT 1.6
         + Dropdown for Latest Alert logs to show – 10, 30, 50.
         + Click Icon to Download in XLS/PDF with Date Range
       * Applicable Standard
         + REF POINT 1.12
       * IoT Device Status Icon
       * Device Config Page
       * RT Clock
       * Screen Enlarge
    * Real Time Values Display -
      + REF POINT 1.9

##### Tool Tip while Hover

* + 1. Format:
    2. Line 1 - <Panel Name & ID>: <Message>
    3. Line 2 – <TAG>: <Real Time Value> <Units>
    4. Line 3 - <Time Stamp>
    5. Healthy (logic: V\_AVG in AR)
    6. Warning (logic: V\_AVG in WR),
    7. Critical (logic: V\_AVG in CR)
    8. Feeder Trip (logic: V\_AVG ~ 0 volts)

##### RT Data Table / Card

1. RT VRY, VYB, VBR– Key, Value, AR/WR/CR Range Icon
2. RT – VLL\_MAX\_DEV, VLL\_MAX\_DEV\_PERCENT, V\_AVG – Key, Value, AR/WR/CR Range Icon

|  |  |  |
| --- | --- | --- |
| **KEY** | **VALUE** | **RANGE ICON** |
| VRY | 11.2 kV |  |
| VYB | 10.95 kV |  |
| VBR | * 1. V |  |
| **KEY** | **VALUE** | **RANGE ICON** |
| VLL\_MAX\_DEV | 158 V |  |
| VLL\_MAX\_DEV\_PERCENT | 1.2 % |  |
| V\_AVG | * 1. V |  |

##### 1. 10 Horizontal Bar Plot – Real Time

1. Right side of the card - Horizontal Bar Plot – Real Time
2. Bar for 1. VLL\_MAX\_DEV; 2. VLL\_MAX\_DEV\_PERCENT; 3. V\_AVG
3. Plot Horizontal bar with dynamic gradient colour change based on ranges (AR, WR, CR)
4. ToolTip while hovering

##### 1.11 Historical Chart Widget

1. Stacked Bar Plot VRY(Top), VYB(Middle), VBR(Bottom)
2. Dynamic Bar length based on Value
3. Apply similar logic REF POINT 1.7. c, e, f, g.
4. Date/Time Range selection tool: Dropdown - RT Stream, Current Shift so far, Current day so far, Current week so far, Current Month so far, Monthly, Quarterly, Custom Date Range (Shift: ALL/A/B/C), Custom date range with Time.
5. X-axis: Backend Logic for Auto Responsive scaled Time window
6. X- Axis: Responsive Zoom in/out Scale
7. Y-axis: Auto Responsive Avg values
8. Top Right Corner – Widget Label – “HT L-L VOLTAGE ANALYTICS PLOT”
9. Top - Date/Time Range selection tool & TS Display
10. Download Plot as PNG file

##### Key Insights

* Sustained over-voltage or under-voltage stresses transformer insulation and may accelerate failure.
* Voltage unbalance >2% significantly increases heating in motors and transformers (e.g. 2% unbalance ≈ 8–10% temperature rise in motors).
* HT voltage quality directly impacts the reliability of the entire downstream LV system.

##### Applicable Standards

* IS 12360: Nominal system voltage (11 kV / 22kV / 33kV ±5%)
* IEC 60038: Standard voltages
* IEC 61000-4-30: Measurement methodology for voltage monitoring

#### RT - Average Voltage (Tag: AVG\_VLL)

1. Apply the same settings as above
2. User Config page – User input / Default toggle – Apply similar logic as above
3. Display Card RT V\_AVG value
4. Historical Plot – Line graph overlaps on stacked bar plot of Voltages
5. Line graph – gradient colour change based on Range Status

#### 3. RT - Max Deviation & Max Deviation %

##### 3.1 Definition:

1. RMU Panel – Max Deviation from Average Line-to-Line Voltage
2. Tags: VLL\_MAX\_DEV, VLL\_MAX\_DEV\_PERCENT
3. Max Deviation is the maximum absolute difference between any one phase’s line-to-line voltage and the average of all three phase voltages.
4. Max Deviation % is calculated as:  
   (Max|V\_phase − V\_avg| ÷ V\_avg) × 100

// --- VLL Max Deviation ---

let VLL\_MAX\_DEV = Math.max(

Math.abs(event.VRY - event.AVG\_VLL),

Math.abs(event.VYB - event.AVG\_VLL),

Math.abs(event.VBR - event.AVG\_VLL)

);

let VLL\_MAX\_DEV\_PERCENT = (VLL\_MAX\_DEV / event.AVG\_VLL) \* 100;

1. This identifies voltage imbalance between phases, using the actual running average rather than a fixed nominal value.

##### 3.2 Acceptable Range:

1. Max Deviation % is less than or equal to 2% of average voltage (V\_AVG).
2. Max Dev Applicable for:  
   11 kV → Deviation ≤ 220 V  
   22 kV → Deviation ≤ 440 V  
   33 kV → Deviation ≤ 660 V
3. Deviation ≤2% indicates good balance and system health.

##### 3.3 Warning Range:

1. Max Deviation % greater than 2% and up to 4% of average voltage
2. Max Dev Applicable for:  
   11 kV → Deviation > 220 V up to 440 V  
   22 kV → Deviation > 440 V up to 880 V  
   33 kV → Deviation > 660 V up to 1,320 V
3. This suggests increasing imbalance and should be monitored

##### 3.4 Critical Range:

1. Max Deviation % greater than 4% of average voltage
2. 11 kV → Deviation > 440 V  
   22 kV → Deviation > 880 V  
   33 kV → Deviation > 1,320 V
3. High imbalance may result in overheating, malfunction, or phase-sensitive failures in motors and other 3-phase equipment

##### 3.5 Horizontal Bar Plot

1. Max Dev – Apply 1.10
2. Max Dev % - Apply 1.10

##### 3.6 Historical Plot

1. Max Dev – line graph over Max Dev % bar plot
2. Max Dev % - Bar plot
3. Include 2% and 4% reference lines for visualization of warning and critical levels
4. Mark periods where deviation entered warning or critical zones with timestamps

##### 3.7 Alert Behavior: Apply for all voltage levels (11kV, 22kV, 33kV)

1. A warning is triggered if Max Deviation exceeds 2% for more than 2 Payloads
2. A critical alarm is triggered immediately if deviation exceeds 4% for more than 2 Payloads
3. Auto-reset occurs when deviation drops below 2% and remains stable in latest Payload

## 4. RMU Voltage Imbalance %

##### 4.1 Definition

1. Voltage imbalance % (also called voltage unbalance) quantifies how unequal the phase-to-phase voltages (VRY, VYB, VBR) are at the RMU/HT incomer. A high imbalance stresses connected equipment, especially motors, transformers, and sensitive electronics, causing excess heating, reduced efficiency, vibration, and potential premature failure.

##### 4.2 Calculation

1. Simple Max Deviation Calculation Method (as per IS / IEC motor standards)
2. Perform this logic only when VRY, VYB, VBR non zero values
3. Voltage imbalance % = (Max deviation of any phase voltage from average) / Average voltage × 100
4. use Keys “V\_AVG” & VLL\_MAX\_DEV
5. Voltage imbalance % = (VLL\_MAX\_DEV)/ V\_AVG \* 100
6. Info: Average voltage = (VRY + VYB + VBR) / 3
7. Max deviation = largest absolute difference between any L-L voltage and the average

// --- RMU HT Voltage Imbalance ---

let V\_AVG = (event.VRY + event.VYB + event.VBR) / 3;

let VLL\_MAX\_DEV = Math.max(

Math.abs(event.VRY - V\_AVG),

Math.abs(event.VYB - V\_AVG),

Math.abs(event.VBR - V\_AVG)

);

let VOLTAGE\_IMBALANCE\_PERCENT = (VLL\_MAX\_DEV / V\_AVG) \* 100;

* 1. Example:

1. VRY = 11.2 kV, VYB = 10.8 kV, VBR = 11.0 kV, V\_AVG = 11.0 kV
2. Deviations: |11.2 - 11.0| = 0.2 kV, |10.8 - 11.0| = 0.2 kV, |11.0 - 11.0| = 0 kV
3. Max deviation = 0.2 kV
4. Voltage imbalance % = (0.2 / 11.0) × 100 = 1.82%
5. Apply the same logic for 22kV, 33kV.

##### 4.4 Acceptable Range (applicable for 11kV, 22kV, 33kV)

1. Voltage imbalance % ≤ 2% (per IS 12615 / IEC 60034-1 recommended limits for safe motor operation; good practice for RMU outgoing feeders to protect motors and transformers).

##### Warning Range (applicable for 11kV, 22kV, 33kV)

1. 2% up to 3% imbalance (risk of additional motor heating, reduced performance).

##### 4.6 Critical Range (applicable for 11kV, 22kV, 33kV)

1. 3% imbalance (high risk of motor overheating, transformer derating, possible failure of sensitive equipment).

##### 4.7 User Configuration Page – User Input Fields

1. Continue after
2. Default Toggle option - Max Dev % Warning threshold: Voltage imbalance ≤ 2%
3. Default Toggle option - Max Dev % Warning threshold: Voltage imbalance > 2%
4. Default Toggle option - Max Dev % Critical threshold: Voltage imbalance > 3%
5. Add Help button with ref to above
6. Default Toggle option similar to above

##### 4.8 Alert Behaviour (Based on SPP Payloads)

1. Warning alert if voltage imbalance exceeds 2% for 2 consecutive payloads.
2. Critical alert if voltage imbalance exceeds 3% for 2 consecutive payloads.
3. Auto-reset once imbalance returns within 2% in latest payload.

##### Historical Chart Design

1. Trend voltage imbalance & voltage imbalance % over time. Highlight yellow/red periods. Annotate significant events.
2. Apply similar logic as above
3. Widget Label – “HT VOLTAGE IMBALANCE ANALYTICS PLOT”

##### Key Insights for RMU & HT Equipment

1. Even 2% imbalance can cause 8–10% excess heating in motors (IS 12615 / IEC 60034-1).
2. Prolonged imbalance >3% risks damaging insulation and shortening transformer/motor life.
3. Voltage unbalance also increases neutral current in systems with neutral connection and can cause vibration in large motors.

##### Applicable Standards

1. IS 12615:2011 — Motor efficiency standards; recommends voltage imbalance ≤ 2% for safe motor operation
2. IEC 60034-1 — Rotating machines; voltage unbalance ≤ 2% for rated performance
3. IEC 61000-4-30 — Voltage unbalance measurement methodology (including symmetrical components)
4. IEEE 1159 — Recommended monitoring practices for PQ including voltage unbalance
5. IS 12360 / IEC 60038 — Nominal voltage reference (11 kV ±5% normal supply tolerance)

## Incoming 3ph line Currents, RMU Panel – 3 Phase Current (Feeder Load Current)

* + 1. RT - I\_R, I\_Y, I\_B – The below settings are for each Phase
       1. **Definition**:
* Measures the real-time current flowing through each phase of the RMU feeder. This is compared against the rated current of the feeder or CT configuration to assess load level and overload status.
* Typically used to monitor real-time feeder loading and detect overload conditions.
  + - 1. **Acceptable Range**:
* 0% to 100% of RMU feeder rated current
* All three phases should be roughly balanced
* Example: For a 630 A feeder, current up to 630 A is acceptable on each phase
  + - 1. **Warning Range**:
* Greater than 100% and up to approximately 120% of rated current
* This represents mild overload, which may be tolerated short-term depending on RMU design and protection settings
* Example: 630 A × 1.2 = 756 A – currents between 631 A and 756 A are in warning zone
  + - 1. **Critical Range**:
* Greater than 120% of rated current
* Example: Current exceeding 756 A on any phase is considered critical overload
* If sustained, this may trigger breaker trip or protection relay action
  + - 1. **Default Settings for User Device Configuration**:
* Device’s nominal current should be set equal to CT rating or feeder nameplate
* Default Warning Threshold: 100% of rated current
* Default Critical Threshold: 110–120% of rated current depending on equipment’s overload capacity
* Example: For 630 A feeder, set warning at 630 A, critical at 700–756 A
  + - 1. **Colour Coding (Dashboard Widget)**:
* Green: Load is less than or equal to 100% of rated current
* Yellow: Load between 100% and 120%
* Red: Load exceeds 120%
  + - 1. **Alert Behaviour** (Based on SPP Device Payloads)
* A warning alert is triggered if current exceeds 100% of rated load for more than 2 consecutive payloads
* A critical alarm is triggered if current exceeds 120% of rated load for more than 2 consecutive payloads
* Alarms auto-reset when current drops below 100% and remains within the acceptable range in the latest received payload
* Payloads to be received at a fixed interval of 30sec/1min/3min/5minutes as per setup (Based on Plan Subscription)
  + - 1. **Historical Chart Guidance**:
* Plot each phase current over time (I\_R, I\_Y, I\_B)
* Use horizontal reference line at rated current (100%)
* Indicate yellow band from 100–120% and red zone beyond 120%
* Mark alarm periods and annotate breaker trips if applicable
* Use visual stacking or overlay to identify phase overloading or imbalance
  + - 1. **Applicable Standards**:
* IS 13234 – Guidelines for overcurrent protection and distribution system monitoring
* IEC 60909 – Short-circuit current calculations and overload sizing
* IS 6600 / IEC 60076-7 – Overload tolerances in transformers and feeders
* IEC 60255 – Protection relay standards; long-time trip settings typically ~110–120% of rating
  + 1. RT - Average Current – Apply same as above
    2. RT - Max Deviation

**RMU Panel – 3 Phase Current Max Deviation / Max Deviation % (Relative to Average Current)**

* + - 1. **Definition**:
* Max Deviation refers to the maximum absolute difference between any one phase’s current and the average of the three phase currents.
* Max Deviation % is calculated as:  
  (|I\_phase − I\_avg| ÷ I\_avg) × 100
* This reflects current imbalance across the three phases in relation to the average load condition.
  + - 1. **Acceptable Range**:
* Max Deviation % is less than or equal to 10% of the average current
* Example: If average current is 500 A, each phase should be within ±50 A of that
  + - 1. **Warning Range**:
* Max Deviation % greater than 10% and up to 20% of average current
* Example: For 500 A average, a deviation between 51 A and 100 A is considered in the warning zone
  + - 1. **Critical Range**:
* Max Deviation % greater than 20% of average current
* Example: For 500 A average, deviation exceeding 100 A is critical and indicates serious current imbalance
  + - 1. **Default Settings for Device Configuration Page – User Input Fields**:
* Thresholds are based on percentage deviation from I\_avg
* Default Warning Threshold: 10%
* Default Critical Threshold: 20%
* These limits can be applied independently of CT rating since they are relative to the live measured average
  + - 1. **Colour Coding (Dashboard Widget)**:
* Green: Max Deviation ≤ 10% of average
* Yellow: Deviation between 10% and 20%
* Red: Deviation > 20%
  + - 1. **Alert Behaviour (Based on Payloads)**:
* A warning is triggered if Max Deviation % exceeds 10% for more than 2 consecutive payloads
* A critical alarm is triggered if Max Deviation % exceeds 20% for more than 2 consecutive payloads
* Auto-reset occurs when Max Deviation % falls below 10% and remains in that state in the latest received payload
* Include hysteresis logic to prevent toggling near boundary conditions
  + - 1. **Historical Chart Guidance**:
* Plot Max Deviation % over time
* Historical Plot - Shift/Day/Week/ Date Range
* Reference lines at 10% and 20% help visualize acceptable, warning, and critical imbalance levels
* Optional: Show each phase current as background to help correlate imbalance visually
* Highlight payloads where alert thresholds were crossed
  + - 1. **Applicable Standards**:
* IS 732:2019 – Code of practice for electrical wiring, recommends phase balance in distribution
* IEC 61000-4-30 – Standard for power quality measurement methods, includes unbalance computation
* IS 13234 and IEC 60255 – Protection coordination and relay logic, where imbalance may be tied to phase fault detection
  1. **Incoming System Frequency (Hz)**
     1. RT – Frequency value
        1. **Definition**:
* Measures the real-time system frequency from the grid or generator, typically expected to be close to 50.0 Hz in India.
* Frequency reflects load-generation balance; even small deviations indicate system stress or instability.
  + - 1. **Acceptable Range**:
* 49.5 Hz to 50.5 Hz
* This represents ±1% from nominal; considered stable for most grid and generator operations
  + - 1. **Warning Range**:
* Greater than ±1% deviation but within ±3%
* Frequency below 49.5 Hz or above 50.5 Hz, but still ≥48.5 Hz and ≤51.5 Hz
* Indicates minor under- or over-frequency condition
  + - 1. **Critical Range**:
* Less than 48.5 Hz or greater than 51.5 Hz
* Indicates major generation-load mismatch, risk of generator trip, load shedding, or power quality failure
  + - 1. **Default Settings for Device Configuration Page – User Input Fields**:
* Nominal Frequency: 50.0 Hz
* Warning Thresholds: 49.5 Hz (low), 50.5 Hz (high)
* Critical Thresholds: 48.5 Hz (low), 51.5 Hz (high)
  + - 1. **Colour Coding (Dashboard Widget)**:
* Green: 49.5–50.5 Hz
* Yellow: 48.5–49.5 Hz or 50.5–51.5 Hz
* Red: <48.5 Hz or >51.5 Hz
  + - 1. **Alert Behaviour (Based on Payloads)**:
* A warning is triggered if frequency goes outside 49.5–50.5 Hz for more than 2 consecutive payloads
* A critical alarm is triggered if frequency goes below 48.5 Hz or above 51.5 Hz for more than 2 payloads
* Auto-reset occurs when frequency returns to within 49.5–50.5 Hz in the latest payload
* Hysteresis logic should prevent alerts from toggling on small fluctuations near the boundaries
  + - 1. **Historical Chart Guidance**:
* Plot frequency trend over time with reference line at 50.0 Hz
* Shade 49.5–50.5 Hz as green band, 48.5–49.5 and 50.5–51.5 Hz as yellow
* Mark red excursions outside 48.5–51.5 Hz
* Annotate events such as frequency dips (e.g. “Grid under-frequency event”)
  + - 1. **Applicable Standards**:
* IS 12360:1988 – Specifies 50 Hz ±3% (48.5–51.5 Hz)
* Indian Electricity Grid Code – Tightens operational band (typically 49.90–50.05 Hz) for utilities
* ISO 8528-5 – Sets limits for generator frequency deviations (±1% steady state, ±5% transient)
  + 1. Max Deviation - Shift/Current Day
       1. **Definition**:
* Captures the largest deviation of frequency recorded during the shift or current day relative to nominal 50.0 Hz
* Used to analyze power quality and assess risk of under-frequency or over-frequency events
  + - 1. **Acceptable Range**:
* Max deviation within ±1% of nominal (i.e. ≤0.5 Hz deviation from 50.0 Hz)
* Example: Peak deviation between 49.5 Hz and 50.5 Hz
  + - 1. **Warning Range**:
* Deviation >0.5 Hz and ≤1.5 Hz from nominal (i.e. between 48.5–49.5 Hz or 50.5–51.5 Hz)
* Indicates frequency has left ideal zone at some point during the shift/day
  + - 1. **Critical Range**:
* Max deviation >1.5 Hz (i.e. frequency dropped below 48.5 Hz or exceeded 51.5 Hz at any time during the period)
* Represents major instability, likely requiring root cause investigation
  + - 1. **Default Settings for Device Configuration Page – User Input Fields**:
* Nominal Frequency: 50.0 Hz
* Warning Max Deviation: ±1.0 Hz
* Critical Max Deviation: ±1.5 Hz
  + - 1. **Colour Coding (Dashboard Widget)**:
* Green: Max deviation ≤0.5 Hz
* Yellow: >0.5 Hz to 1.5 Hz
* Red: >1.5 Hz
  + - 1. **Alert Behaviour (Based on Payloads)**:
* A warning is triggered if frequency deviation exceeds 0.5 Hz in any 2 or more payloads during the shift
* A critical alarm is triggered if deviation >1.5 Hz in 2 or more payloads
* Auto-reset once no payloads in the latest window show deviation >0.5 Hz
  + - 1. **Historical Chart Guidance**:
* Plot Max Deviation vs. time in shift-level summary charts
* Use 0.5 Hz and 1.5 Hz as reference bands
* Annotate key deviations with timestamp
* This metric is valuable for daily power quality health scoring
  + - 1. **Applicable Standards**:
* IS 12360:1988 – Nominal 50 Hz ±3%
* Indian Electricity Grid Code – Operational stability monitoring
* ISO 8528-5 – Transient and steady-state frequency deviation limits for generator systems
  1. **Incoming Power – Analysis will be based on user input data (Rated RMU Power rating)** 
     1. **Definition**:
* Monitors incoming Apparent Power (MVA), Active Power (MW), and Reactive Power (MVAr) for each phase.
* Analysis and thresholds are computed relative to the **user-entered rated power capacity** of the RMU or plant (entered in the device configuration page).
  + 1. **Default Settings for Device Configuration Page – User Input Fields**:
* Rated RMU capacity input: Text to enter a value in MVA (e.g. 2.0 MVA)
  + 1. Bar Plot - MVA, MW, MVAr – R, Y, B Phase - Shift/Current Day
       1. **Acceptable Range**:
* Power values per phase ≤100% of calculated rated capacity
* Example: If rated per-phase apparent power is 0.67 MVA (for 2 MVA total), then measured MVA\_R ≤ 0.67 MVA is acceptable
  + - 1. **Warning Range**:
* Per-phase power between 100% and 110% of rated values
* Indicates mild overloading, needs close monitoring
  + - 1. **Critical Range**:
* Power per phase >110% of rated values
* Could signal overload, incorrect load balancing, or impending trip
  + - 1. **Alert Behaviour (Based on Payloads)**:
* Warning alert if any phase exceeds 100% of rated value for more than 2 payloads
* Critical alert if any phase exceeds 110% for more than 2 payloads
* Auto-reset when values drop back below 100% in the latest payload
* Consider imbalance across R/Y/B as an additional metric
  + - 1. **Colour Coding (Dashboard Widget)**:
* Green: ≤100%
* Yellow: 100–110%
* Red: >110%
  + - 1. **Historical Chart Guidance**:
* Use bar plots showing MVA, MW, MVAr for R/Y/B phases over current shift
* Display rated capacity line as overlay
* Flag any exceedance in colour and label the alert payloads
* Tooltip should show exact % load per phase and power factor
  + - 1. **Applicable Standards**:
* IS 13234 – Overcurrent and power monitoring guidelines
* IEC 60255 – Threshold setting for protective functions
* IS 732:2019 – Balanced loading recommendation for phase power
  + 1. Total MVA, MW, MVAr - Shift/Current Day – Apply the same
    2. Historical Plot - Shift A, B, C/Day/Week/ Date Range
       1. **Reference Line**:
* Horizontal line at 100% of rated RMU capacity
* Optional second line at 110% for critical threshold visualization
  + - 1. **Event Markers**:
* Mark payloads where power exceeded thresholds
* Include tooltips for exact timestamp, value, and alert status
  + - 1. **Colour Zones**:
* Green zone up to 100%
* Yellow band from 100–110%
* Red zone beyond 110% capacity
  + - 1. **Applicable Standards**:
* IS 732 – Load profile analysis
* IEC 61850 – Time-series monitoring best practices
* ISO 50001 – Long-term energy performance tracking
  1. **Incoming Energy** 
     1. MVAh, MWh, MVArh – Total
        1. **Definition**:
* Tracks cumulative incoming energy consumption through the RMU over time.
* Includes Apparent Energy (MVAh), Active Energy (MWh), and Reactive Energy (MVArh).
* Used for energy billing, loss calculation, and overall plant consumption analysis.
  + - 1. **Settings (Defaults/User input) Required for Device Configuration Page – User Input Fields**:
  + Input – Previous Month Energy consumption value , or
  + Rated monthly energy budget or baseline (optional): in MWh, or
  + Rated shift wise energy budget or baseline (optional): in kWh
  + Rated energy charge per unit (Rs./kWh)
  + Optionally configure ToD slab references for analysis and visualization.
    - 1. **Acceptable Range**:
  + Total energy consumed within expected usage based on historical plant demand or monthly target
  + For example, if baseline is 120 MWh/month, then around 4 MWh/day is normal
    - 1. **Warning Range**:
  + Energy consumption exceeding average expected shift/day load by more than 10%
  + Example: If shift target is 1.5 MWh, any reading beyond 1.65 MWh triggers warning
    - 1. **Critical Range**:
  + Energy consumption overshoots target by more than 20%
  + Could indicate process inefficiency, abnormal load increase, or non-productive usage
    - 1. **Alert Behaviour (Based on SPP Payloads)**:
  + A warning is triggered if cumulative energy exceeds expected range by >10% in 2 or more payloads in the shift/day
  + A critical alert is triggered if deviation >20% in 2 or more payloads
  + Auto-reset when daily or shift-wise total returns below warning level in the latest payload
    - 1. **Colour Coding (Dashboard Widget)**:
  + Green: Consumption within baseline
  + Yellow: 10–20% above expected
  + Red: >20% above expected
    - 1. **Applicable Standards**:
  + IS 15959-2:2011 – Data acquisition for energy meters
  + CEA Metering Regulations – Energy accounting at feeder level
  + ISO 50001 – Energy baseline and performance monitoring
  + IS 12360 – Refers to standard system capacity ratings and integration
    1. Historical Plot - Shift A, B, C/Day/Week/ Date Range
       1. **Purpose**:
  + Visualize total energy inflow across various time ranges to analyze trends, peak usage, and inefficiencies
  + Useful for ToD comparison, billing audit, and consumption benchmarking
    - 1. **Design Features**:
  + Line or bar charts for each energy type: MVAh, MWh, MVArh
  + Overlay expected baseline as a reference line
  + Support selection of shift/day/week/date range filters
    - 1. **Reference Lines**:
  + User-defined baseline or auto-generated historical average
  + Separate lines for warning (110%) and critical (120%) benchmarks
    - 1. **Event Markers**:
  + Highlight segments exceeding alert thresholds
  + Annotate unusual spikes (e.g. “High Load during Shift B – 2.1 MWh”)
    - 1. **Colour Zones**:
  + Green for within target
  + Yellow for marginal overuse
  + Red for major excess energy draw
    - 1. **Applicable Standards**:
  + ISO 50001 – Energy tracking and performance comparison
  + IS 15959-2 – Historical data format and integrity
  + IEC 62053 – Energy metering equipment accuracy
  + IS 13234 – Energy audit and reporting practices
  1. **PF (Average / each Line)**
     1. Definition:
  + Power Factor (PF) is the ratio of active power (kW) to apparent power (kVA), and it reflects the efficiency of energy usage.
  + Measured at the RMU incoming feeder using MFM with CT/PT configuration.
  + A lagging PF is expected due to inductive loads; very low or very high (leading) PF is discouraged.
    - 1. Acceptable Range (Incentive Zone):
  + PF between 0.951 and 1.000 (lag or lead)
  + Indicates highly efficient system with minimal reactive power
  + Incentives applied as per MERC Order:
  + PF 0.955–0.964 → 0.5% rebate
  + PF 0.965–0.974 → 1.0% rebate
  + PF 0.975–0.984 → 1.5% rebate
  + PF 0.985–0.994 → 2.5% rebate
  + PF 0.995–1.000 → 3.5% rebate
  + Widget Colour: Green
  + Alert: No alert; system running efficiently
    - 1. Warning Range:
* PF between 0.900 and 0.950 lagging
* OR PF > 0.950 leading (Optional)
* Indicates moderate inefficiency or over-compensation
* Widget Colour: Yellow
* Alert Behaviour (Based on Payloads):
* Warning alert if PF stays in this range for more than 2 consecutive payloads
* Advisory to inspect capacitor bank settings
* Auto-reset when PF returns to > 0.951 lag in latest payload
  + - 1. Critical Range (Penalty Zone):
* PF < 0.900 (lagging or leading)
* Penalty slabs as per MERC Order:
* PF 0.895–0.900 → 0% penalty
* PF 0.885–0.894 → 1.0%
* PF 0.875–0.884 → 1.5%
* PF 0.865–0.874 → 2.0%
* PF 0.855–0.864 → 2.5%
* PF 0.845–0.854 → 3.0%
* PF 0.835–0.844 → 3.5%
* PF 0.825–0.834 → 4.0%
* PF 0.815–0.824 → 4.5%
* PF 0.805–0.814 → 5.0%
* Widget Colour: Red
* Alert Behaviour (Based on Payloads):
* Critical alert if PF is <0.900 (lag or lead) in more than 2 consecutive payloads
* Immediate notification to operator, log in event history
* Auto-reset if PF improves to > 0.900 and remains in latest payload
  + - 1. Default Settings for Device Configuration Page – User Input Fields:
* PF Target: 0.99 (lag)
* Warning Threshold: <0.95
* Critical Threshold: <0.90
* Optional Inputs: Utility-specific incentive/penalty %
  + - 1. Historical Chart Guidance:
* Plot average and phase-wise PF trend over time
* Display incentive and penalty bands as shaded zones
* Annotate PF correction events (sudden PF drops)

Use colour bands:

* Green: > 0.951
* Yellow: 0.900–0.950
* Red: <0.900 lag
  + - 1. Applicable Standards & References:
* CEA Grid Connectivity Regulations, 2007 – Minimum PF of 0.95 for bulk consumers
* IS 7752 – Practices for PF improvement
* MERC Case No. 322 of 2019 – Penalty structure for PF < 0.900
* MYT Order of MSEDCL FY 2020–21 to 2024–25 – Incentive structure for PF > 0.950
* Electricity Act, India – Penal provision for reactive energy draws from grid
  + 1. Real Time – R, Y, B Phase values – each phase (Data from MFM+IoT)
    2. Real Time – Avg PF (Data from MFM+IoT)
    3. Min PF – R, Y, B, Avg - Shift/Current Day/current week
    4. Max PF – R, Y, B, Avg - Shift/Current Day/current week
    5. PF Level with Incentive/Penalty % - Shift/Current Day
    6. Historical Plot - Shift A, B, C/Day/Week/ Date Range

## KPI’s ANALYTICS ENGINE

* 1. Real-Time Load % (8 Hrs Shift Interval)
  2. Average Load (MW, MVA)
  3. Maximum demand
  4. Load Factor Analysis
  5. ToD Energy Consumption Analysis
  6. PF Level Analysis
  7. V & I imbalance Analysis
  8. Average THD Analysis (If supported)
  9. Specific Energy Consumption (SEC) - If Production Output Provided
  10. Energy Cost Estimation (Only Approx. Energy Charges)
  11. EEPI – Enterprise Electricity Performance Index (Enterprise Score)
  12. Comparison Analytics – Data & Charts – Current Data with Historical Data

1. Load Factor
2. SPC
3. Energy Cost
4. Maximum Demand
5. PF Analysis

## **HT Panel**

## HT Panel – Real-Time Monitoring Web Page

**HT Panel (High Tension Panel) – Incoming HV Switchgear**

Parameters and thresholds are similar to RMU (since both handle HV supply), with focus on incoming power quality and protection:

* **Voltage (L-L):** Should be within acceptable HV range. **Green** if within ±5–6% of nominal (e.g. 33 kV ±6% = 31.0–34.98 kV). **Yellow** if deviation up to ±9–10%. **Red** if beyond (out of IS 12360 limits). Default alarm at ±6% (warn) and ±10% (crit). *Standard:* IS 12360 for voltage bands.
* **Current:** Each feeder/breaker’s phase current should not exceed 100% rated. Overload thresholds (100–120% yellow, >120% red) similar to RMU. The HT panel’s protection relay will trip in red zone. Default settings: warning at rating, alarm at 1.1× rating.
* **Frequency:** Grid frequency tolerance same as RMU (50 Hz ±3% max). HT panels often include under/over-frequency protection at ~47.5 Hz / 52 Hz. EMS thresholds: warn outside 49.5–50.5, critical beyond 48.5 or 51.5 Hz.
* **Power Factor:** If this panel is at service entrance, maintain PF ≥0.95 (green). Low PF alarms as per RMU. Likely an APFC (Automatic PF Correction) panel is connected; ensure PF stays in green. *Std:* CEA mandates ≥0.95.
* **Power (Active/Reactive):** Monitor kW, kVAr against contract demand or transformer capacity. Overload criteria same (avoid >100% continuously). Provide alarms if approaching sanctioned demand (to manage load).
* **Alarm/Reset Logic:** Similar to RMU – alarms for voltage, current, PF, etc., follow the same trigger delays and reset once back to normal. For an HT incomer, critical events (like OC, UV) may directly trip breakers via protection; the EMS alarm just records it.
* **Charting:** Use trends similar to RMU for V, I, PF, kW. Additionally, an HT panel’s dashboard often shows **demand trend** (15-min kW demand vs contract limit) – include a reference line for contract demand and mark peaks. Historical trending with event markers (e.g. “Capacitor bank switched on” or “Feeder tripped”) provides context.
* **Standards & References:** IS 12360 for HT voltage limits, IEEE 519/IS 1170 for harmonics (5% THD at 11 kV), CEA/State Grid Code for 3% max voltage unbalance, and Central Electricity Authority regulations for PF ≥0.95 at HT intake. These ensure the HT panel operates within BIS-recommended power quality and reliability criteria.
  1. **Voltage (R-Y, Y-B, B-R) – L-L**
     1. RT – Vry, Vyb, Vbr.
     2. RT – Average Voltage
     3. RT – Max Deviation
  2. **Line Current (R, Y, B)**
     1. RT – Ir, Iy, Ib
     2. RT – Average Current
     3. RT – Max Deviation
     4. Historical Plot – Shift A, B, C/Day/Week/ Date Range
  3. **Frequency (Hz)**
     1. RT – Frequency value
     2. Minimum – Shift/Current Day
     3. Maximum- Shift/Current Day
     4. Average – Shift/Current Day
     5. Max Deviation – Shift/Current Day
  4. **Power Factor (Average / Each Line)**
     1. RT – R, Y, B Phase values
     2. RT – Avg PF
     3. Max Deviation
     4. PF Level with Incentive/Penalty % - Shift/Current Day
     5. Incentive/Penalty charges calculation – Shift/Current Day
     6. Historical Plot – Shift A, B, C/Day/Week/ Date Range
     7. Min PF – R, Y, B, Avg – Shift/Current Day
     8. Max PF – R, Y, B, Avg – Shift/Current Day
  5. Apparent Power (kVA), Active Power (KW), Reactive Power (kVAr)
     1. RT – Bar Plot – R, Y, B Phase
     2. RT – Total
     3. Historical Plot – Shift A, B, C/Day/Week/ Date Range
  6. Energy Consumption with ToD Slots
     1. RT – Total – kWh, kVArh, kVAh
     2. Historical XY Plot – Shift A, B, C/Day/Week/ Date Range
  7. Maximum Demand
     1. kW, kVA, kVAr – Interval Shift / Day
  8. Voltage Harmonic Distortion – THD – V
     1. RT- THD – V %
     2. Avg
     3. Max Deviation
  9. Current Harmonic Distortion – THD – I
     1. RT- THD – I %
     2. Avg
     3. Max Deviation

Key Parameters from **HT Panel Annunciator** via RS485 (If Communication port available)

* 1. Overcurrent
  2. Earth fault
  3. Trip status
  4. Breaker open/close status
  5. Relay operated
  6. Over/Under voltage
  7. Over/Under frequency
  8. Phase failure or phase sequence issues
  9. Neutral displacement
  10. Buchholz relay trip (for transformers)
  11. Temperature alarms (transformer, Busbar, etc.)

## HT Panel – Derived KPI’s & Analytics

* + Real-Time Load %
  + Average Load (kW, kVA)
  + Maximum demand
  + Load Factor Analysis
  + Demand Factor (%)
  + Load Utilization (%)
  + Total Energy Inflow (kWh & kVAh)
  + ToD Energy Consumption Analysis
  + PF Level Analysis
  + V & I imbalance Analysis
  + Specific Energy Consumption (SEC) – If Production Output Provided
  + Transmission/Energy Loss Estimation (RMU-HT Panel)
  + Phase Reversal or Missing Phase Alerts
  + System Efficiency
  + Time Matrix (Idel / Run Time)
  + Energy Cost Estimation (Only Approx. Energy Charges)
  + Energy Balance (EnB) – (RMU-HT panel)
  + Average Voltage Harmonic Distortion – THD – V
  + Average Current Harmonic Distortion – THD – I
  + EEPI – Enterprise Electricity Performance Index (Enterprise Score)
  + Comparison Analytics – Data & Charts – Current Data with Historical Data

1. Load Factor
2. ToD Energy Consumption
3. Energy Charges
4. SEC
5. Energy Loss
6. System Efficiency
7. PF Levels

# **RTM LT DISTRIBUTION PANELS**

## **LT Incomer**

## LT Panels – Real-Time Monitoring Web Page

* 1. **3ph Voltages (L-L) - (Tags: VRY, VYB, VBR)**  
     Real-time measurement of voltage between R–Y, Y–B, and B–R phases – MFM Parameters
     1. **RT (Real Time) – Vry, Vyb, Vbr - VRY, VYB, VBR**
        1. **Acceptable Range**:  
           360 V to 440 V (for nominal 400 V system; ±10% as per IS 12360)
        2. **Warning Range**:  
           340 V – 359 V or 441 V – 460 V (moderate voltage deviation)
        3. **Critical Range**:  
           <340 V or >460 V (severe deviation from grid standard)
        4. <Figma – outer max – 460V; inner min 340V >
        5. **Default Settings for Device Configuration Page – User Input Fields**:
* Nominal voltage: 400 V
* Warning threshold: ±10%
* Critical threshold: ±15%
  + - 1. **Alert Behaviour (Based on Payloads)**:
* Warning if any phase voltage deviates from nominal by >10% for 2 consecutive payloads
* Critical alarm if deviation exceeds 15% for 2 payloads
* Auto-reset if voltages return within 10% range in latest payload
  + - 1. **Colour Coding (Widget)**:
* Green: 360–440 V
* Yellow: 340–359 V or 441–460 V
* Red: <340 V or >460 V
  + - 1. **Applicable Standards**:
* IS 12360:1988 – Voltage limits
* IEC 60038 – Standard voltages
* IEC 61000-4-30 – Voltage RMS measurement method (10/12 cycle)
  + 1. RT – Average Voltage - AVG\_VLL
* Definition: Arithmetic average of VRY, VYB, VBR.
  + - 1. Acceptable Range: 360 V to 440 V.
      2. Warning Range: 340 V – 359 V or 441 V – 460 V.
      3. Critical Range: Less than 340 V or more than 460 V.
      4. Default Settings for Device Configuration Page – User Input Fields:
* Nominal AVG\_VLL: 400 V
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if AVG\_VLL is outside 360–440 V for 2 payloads.
* Critical if outside 340–460 V for 2 payloads.
* Auto-reset if value returns to 360–440 V in the latest payload.
  + - 1. Colour Coding (Dashboard Widget): Same as 1.19.1
      2. Applicable Standards: Same as 1.19.1
    1. RT – Max Deviation – VLL\_MAX\_DEV

Definition: Maximum difference between any phase voltage and the average voltage.

* + - 1. Formula: MAX (|VRY – AVG\_VLL|, |VYB – AVG\_VLL|, |VBR – AVG\_VLL|)
      2. Acceptable Range: ≤ 10 V
      3. Warning Range: >10 V and ≤ 20 V
      4. Critical Range: >20 V
      5. Default Settings for Device Configuration Page – User Input Fields:
* Warning: 10–20 V
* Critical: >20 V
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if deviation >10 V for 2 payloads.
* Critical if >20 V for 2 payloads.
* Auto-reset if deviation is ≤10 V in the latest payload.
  + - 1. Applicable Standards:
* IEC 61000-4-30 – Power quality measurement
* IS 732:2019 – Voltage balance in LV systems
  + 1. RT – Max Deviation % - VLL\_MAX\_DEV\_PERCENT
* Definition: Max deviation of any phase voltage from average, expressed as percentage.
* Formula: (VLL\_MAX\_DEV ÷ AVG\_VLL) × 100
  + - 1. Acceptable Range: ≤ 2%
      2. Warning Range: >2% and ≤ 4%
      3. Critical Range: >4%
      4. Default Settings for Device Configuration Page – User Input Fields:
* Warning: >2%
* Critical: >4%
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if deviation % >2% for 2 payloads.
* Critical if >4% for 2 payloads.
* Auto-reset if deviation % drops to ≤2% in the latest payload.
  + - 1. Colour Coding (Dashboard Widget):
* Green: ≤2%
* Yellow: 2–4%
* Red: >4%
  + - 1. Applicable Standards:
* IEC 61000-4-30 – Voltage measurement and imbalance analysis
* EN 50160 – Utility supply balance guideline
  1. **3ph Voltages (L-N)**
     1. RT – Vrn, Vyn, Vbn- VR, VY, VB,

Definition: Real-time voltage values measured between each phase and neutral: R–N, Y–N, B–N.

* + - 1. Acceptable Range: 207 V to 253 V (for nominal 230 V system; ±10% as per IS 12360).
      2. Warning Range: 195 V – 206 V or 254 V – 265 V.
      3. Critical Range: Less than 195 V or more than 265 V.
      4. Default Settings for Device Configuration Page – User Input Fields:
* Nominal voltage: 230 V
* Warning threshold: ±10%
* Critical threshold: ±15%
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if any phase voltage is outside 207–253 V for more than 2 payloads.
* Critical if any phase voltage is outside 195–265 V for more than 2 payloads.
* Auto-reset if all voltages return within 207–253 V in the latest payload.
  + - 1. Colour Coding (Dashboard Widget):
* Green: 207–253 V
* Yellow: 195–206 V or 254–265 V
* Red: <195 V or >265 V
  + - 1. Applicable Standards:
* IS 12360:1988 – Voltage classification
* IEC 60038 – Standard voltages
* IEC 61000-4-30 – RMS voltage measurement method
  + 1. RT – Average Voltage AVG\_VLN
* Definition: Arithmetic average of VR, VY, VB.
  + - 1. Acceptable Range: 207 V to 253 V.
      2. Warning Range: 195 V – 206 V or 254 V – 265 V.
      3. Critical Range: Less than 195 V or more than 265 V.
      4. Default Settings for Device Configuration Page – User Input Fields:
* Nominal AVG\_VLN: 230 V
* Alert Behaviour (Based on SPP Payloads):
* Warning if AVG\_VLN is outside 207–253 V for 2 payloads.
* Critical if AVG\_VLN is outside 195–265 V for 2 payloads.
* Auto-reset if AVG\_VLN returns to 207–253 V in the latest payload.
  + - 1. Colour Coding (Dashboard Widget): Same as individual phase values.
      2. Applicable Standards: Same as 1.20.1
    1. RT – Max Deviation VLN\_MAX\_DEV
* Definition: Maximum difference between any single-phase L–N voltage and the average voltage.
* Formula: MAX (|VR – AVG\_VLN|, |VY – AVG\_VLN|, |VB – AVG\_VLN|)
  + - 1. Acceptable Range: ≤ 6 V
      2. Warning Range: >6 V and ≤ 12 V
      3. Critical Range: >12 V
      4. Default Settings for Device Configuration Page – User Input Fields:
* Warning: 6–12 V
* Critical: >12 V
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if deviation >6 V in 2 payloads.
* Critical if >12 V in 2 payloads.
* Auto-reset when deviation returns to ≤6 V in the latest payload.
  + - 1. Applicable Standards:
* IEC 61000-4-30 – Power quality measurement
* IS 732:2019 – Voltage balance in LV systems
  + 1. RT – Max Deviation % - VLN\_MAX\_DEV\_PERCENT
* Definition: Max deviation of any L–N voltage from the average, expressed as percentage.
* Formula: (VLN\_MAX\_DEV ÷ AVG\_VLN) × 100
  + - 1. Acceptable Range: ≤ 2%
      2. Warning Range: >2% and ≤ 4%
      3. Critical Range: >4%
      4. Default Settings for Device Configuration Page – User Input Fields:
* Warning: >2%
* Critical: >4%
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if deviation % >2% for 2 payloads.
* Critical if >4% for 2 payloads.
* Auto-reset when deviation % returns to ≤2% in the latest payload.
  + - 1. Colour Coding (Dashboard Widget):
* Green: ≤2%
* Yellow: 2–4%
* Red: >4%
  + - 1. Applicable Standards:
* IEC 61000-4-30 – Voltage measurement and imbalance
* EN 50160 – Voltage unbalance limits for public low voltage systems
  1. **3ph Currents (Line Current) - (Tags: IR, IY, IB)**
     1. RT – Ir, Iy, Ib

Definition: Real-time current values measured on R, Y, B phase lines from MFM via IoT.

* + - 1. Acceptable Range: 0% to 100% of feeder rated current.
      2. Warning Range: >100% to ≤120% of rated current (short-term overload).
      3. Critical Range: >120% of rated current (severe overload risk).
      4. Default Settings for Device Configuration Page – User Input Fields:
* Rated feeder current (e.g., 400 A, 630 A).
* Warning threshold: 100% of rated current.
* Critical threshold: 120% of rated current.
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if any phase current exceeds 100% for more than 2 payloads.
* Critical if any phase current exceeds 120% for more than 2 payloads.
* Auto-reset when current returns below 100% in latest payload.
  + - 1. Colour Coding (Dashboard Widget):
* Green: ≤100% of rated
* Yellow: 100–120%
* Red: >120%
  + - 1. Applicable Standards:
* IS 732:2019 – Safe wiring and loading guidelines
* IS 13234 – Distribution protection practice
* IEC 60909 – Overcurrent sizing and analysis
* IEC 60255 – Protection relay threshold definitions
  + 1. RT – Average Current (Reed from MFM + IoT)
* Definition: Average of Ir, Iy, Ib values.
  + - 1. Acceptable Range: 0% to 100% of feeder rating.
      2. Warning Range: >100% to 120% of rating.
      3. Critical Range: >120% of rating.
      4. Default Settings for Device Configuration Page – User Input Fields:
* Same as 1.21.1
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if AVG\_I exceeds 100% for more than 2 payloads.
* Critical if AVG\_I exceeds 120% for more than 2 payloads.
* Auto-reset if AVG\_I returns to ≤100% in latest payload.
  + - 1. Colour Coding (Dashboard Widget):
* Same as 1.21.1
  + - 1. Applicable Standards:
* Same as 1.21.1
  + 1. RT – Max Deviation
* Definition: Maximum deviation of any line current from the average current.
* Formula: MAX (|IR – AVG\_I|, |IY – AVG\_I|, |IB – AVG\_I|)
  + - 1. Acceptable Range: ≤10% of AVG\_I
      2. Warning Range: >10% to 20% of AVG\_I
      3. Critical Range: >20% of AVG\_I
      4. Default Settings for Device Configuration Page – User Input Fields:
* Warning: 10–20%
* Critical: >20%
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if deviation exceeds 10% for 2 payloads.
* Critical if deviation exceeds 20% for 2 payloads.
* Auto-reset when deviation returns to ≤10% in the latest payload.
  + - 1. Applicable Standards:
* IS 732:2019 – Load balance in 3-phase systems
* IEC 61000-4-30 – Current imbalance and deviation
  + 1. Historical Plot – Shift A, B, C/Day/Week/ Date Range
* Definition: Visualization of each phase current and average current over time.
* Plot Ir, Iy, Ib, and AVG\_I with reference line at 100% rated current.
* Highlight yellow region for 100–120% range and red region above 120%.
* Mark breaker trips or overload events with timestamp annotations.
* Provide comparative phase imbalance visualization (stacked or overlaid).
  + - 1. Applicable Standards:
* IEC 61850 – Time-series and event tagging
* IS 13234 – Event logging and alert recording
* ISO 50001 – Load profile tracking for energy management
  1. **System Frequency (Hz) - (Tag: FREQUENCY)**
     1. RT – Frequency value
* Definition: Real-time system frequency measured from the grid or DG source using MFM + IoT device.
  + - 1. Acceptable Range: 49.5 Hz to 50.5 Hz (±1% from nominal 50.0 Hz).
      2. Warning Range: 48.5 Hz – 49.4 Hz or 50.6 Hz – 51.5 Hz.
      3. Critical Range: Less than 48.5 Hz or more than 51.5 Hz.
      4. Default Settings for Device Configuration Page – User Input Fields:
* Nominal frequency: 50.0 Hz
* Warning thresholds: 49.5 Hz and 50.5 Hz
* Critical thresholds: 48.5 Hz and 51.5 Hz
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if frequency goes outside 49.5–50.5 Hz for more than 2 payloads.
* Critical alert if frequency goes beyond 48.5–51.5 Hz for more than 2 payloads.
* Auto-reset if frequency returns within 49.5–50.5 Hz in the latest payload.
  + - 1. Colour Coding (Dashboard Widget):
* Green: 49.5–50.5 Hz
* Yellow: 48.5–49.4 Hz or 50.6–51.5 Hz
* Red: <48.5 Hz or >51.5 Hz
  + - 1. Applicable Standards:
* IS 12360:1988 – Nominal frequency tolerance
* Indian Grid Code – Tight operational band under normal grid condition
* IEC 61000-4-30 – Frequency computation standard
* ISO 8528-5 – Generator frequency performance class
  + 1. Average – Shift/Current Day
* Definition: Average frequency calculated across all payloads in a shift or day.
  + - 1. Acceptable Range: 49.5–50.5 Hz
      2. Warning Range: Average within 48.5–49.4 Hz or 50.6–51.5 Hz
      3. Critical Range: Average outside 48.5–51.5 Hz
      4. Alert Behaviour (Based on SPP Payloads):
* Warning if average shift/day frequency is outside 49.5–50.5 Hz.
* Critical if average falls outside 48.5–51.5 Hz.
* Auto-reset when average returns within acceptable range in latest data cycle.
  + - 1. Applicable Standards:
* Same as 1.22.1
  + 1. Max Deviation – Shift/Current Day
* Definition: Highest absolute difference from 50.0 Hz recorded in the shift/day window.
* Formula: MAX(|FREQUENCY – 50.0 Hz|)
  + - 1. Acceptable Range: Deviation ≤ 0.5 Hz
      2. Warning Range: Deviation >0.5 Hz and ≤ 1.5 Hz
      3. Critical Range: Deviation >1.5 Hz
      4. Default Settings for Device Configuration Page – User Input Fields:
* Acceptable deviation: ≤ 0.5 Hz
* Warning: 0.6–1.5 Hz
* Critical: >1.5 Hz
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if deviation >0.5 Hz appears in more than 2 payloads.
* Critical if deviation >1.5 Hz appears in 2 or more payloads.
* Auto-reset if latest payloads show deviation within 0.5 Hz.
  + - 1. Applicable Standards:
* IS 12360, IEC 61000-4-30 – Frequency accuracy
* Indian Grid Code – Frequency stability margins
* ISO 8528-5 – Deviation limits for generator systems
  1. **Power Factor (Average / Each Line)**
     1. RT – R, Y, B Phase values
* Power Factor (PF) is the ratio of active power (kW) to apparent power (kVA), and it reflects the efficiency of energy usage.
* Measured at the LV Incomer using MFM with CT/PT configuration.
* A lagging PF is expected due to inductive loads; very low or very high (leading) PF is discouraged.
  + - 1. Acceptable Range (Incentive Zone):
* PF between 0.951 and 1.000 (lag or lead)
* Indicates highly efficient system with minimal reactive power
* Incentives applied as per MERC Order:
* PF 0.955–0.964 → 0.5% rebate
* PF 0.965–0.974 → 1.0% rebate
* PF 0.975–0.984 → 1.5% rebate
* PF 0.985–0.994 → 2.5% rebate
* PF 0.995–1.000 → 3.5% rebate
* Widget Colour: Green
* Alert: No alert; system running efficiently
  + - 1. Warning Range:
* PF between 0.900 and 0.950 lagging
* OR PF > 0.950 leading (Optional)
* Indicates moderate inefficiency or over-compensation
* Widget Colour: Yellow
* Alert Behaviour (Based on Payloads):
* Warning alert if PF stays in this range for more than 2 consecutive payloads
* Advisory to inspect capacitor bank settings
* Auto-reset when PF returns to >0.951 lag in latest payload
  + - 1. Critical Range (Penalty Zone):
* Same as 1.6.1.3
  + - 1. Default Settings for Device Configuration Page – User Input Fields:
* Same as 1.6.1.4
  + - 1. Historical Chart Guidance:
* Same as 1.6.1.5
  + - 1. Applicable Standards & References:
* Same as 1.6.1.6
  + 1. RT – Avg PF (Tag: AVG\_PF)
    2. RT – PF Level with Incentive/Penalty %
    3. Approx. Incentive/Penalty charges calculation – Shift/Current Day
    4. Average Incentive / Penalty % - Shift/Current Day
    5. Historical Plot – Shift A, B, C/Day/Week/ Date Range
    6. Min PF – R, Y, B, Avg
    7. Max PF – R, Y, B, Avg

1.23.2 Real-Time – R, Y, B Phase Values (Tags: R\_PF, Y\_PF, B\_PF)

* Real-time PF readings for each phase collected from MFM via IoT device
* Same PF thresholds and alert logic apply per phase individually
* Use for detecting phase-wise capacitor failures or load imbalance
* Display as separate indicators in dashboard and export to PF phase summary table

1.23.3 Real-Time – Avg PF (Tag: AVG\_PF)

* Average PF calculated in real-time as arithmetic mean or directly from MFM
* Used as main indicator for PF incentives, penalty alerts, and system efficiency
* Applies full logic from 1.23.1.1 to 1.23.1.3

1.23.4 Min PF – R, Y, B, Avg – Shift / Current Day / Week

* Backend-calculated lowest PF recorded per phase and average
* Flag if Avg PF <0.900 at any time (considered a critical PF event)
* Useful for shift-wise penalty trigger tracking and capacitor failure diagnostics

1.23.5 Max PF – R, Y, B, Avg – Shift / Current Day / Week

* Backend-calculated highest PF observed (lag or lead)
* High leading PF >0.995 may indicate overcompensation – advisory if repeated
* Store value for trendline max limits and for inverter/compensator sizing validation

1.23.6 PF Level with Incentive / Penalty % – Shift / Current Day

* Calculated based on shift/day Avg PF
* Mapped using MERC slab logic (refer 1.6.1.1 and 1.6.1.3)
* Displayed as overlay on PF widget or as numeric PF + % rebate/penalty
* Example: PF = 0.972 → 1.0% rebate | PF = 0.862 → 2.5% penalty

1.23.7 Historical Plot – Shift A, B, C / Day / Week / Date Range

* Same logic as 1.6.1.5
* Overlay actual PF vs. incentive/penalty bands
* Show capacitor ON/OFF events and PF dips in time window
* Plot both average PF and phase PF lines if available
  1. **Apparent Power (kVA), Active Power (KW), Reactive Power (kVAr)**
     1. RT – Bar Plot – R, Y, B Each Phase (Tags: R\_KVA, Y\_KVA, B\_KVA, R\_KW, Y\_KW, B\_KW, R\_KVAR, Y\_KVAR, B\_KVAR)
* Definition: Real-time phase-wise measurement of power values from MFM + IoT edge device.
* Display each parameter in bar chart format for R, Y, B phases.
* Used to detect phase loading imbalance, identify unbalanced kVAR draw or low kW efficiency.
  + 1. Acceptable Range: ≤100% of rated phase-wise transformer or breaker capacity.
    2. Warning Range: >100% and ≤110% of rated capacity.
    3. Critical Range: >110% of rated capacity.
    4. Default Settings for Device Configuration Page – User Input Fields:
* Rated kVA per phase – Text Field
* Rated PF to derive default rated kW and kVAR (e.g., 0.90 lag PF → 1000 kVA = 900 kW, 436 kVAR).
  + 1. Alert Behaviour (Based on SPP Payloads):
* Warning if any R, Y, B phase parameter exceeds 100% of rated for more than 2 payloads.
* Critical alert if any parameter exceeds 110% for more than 2 payloads.
* Auto-reset if phase power returns below 100% of rating in the latest payload.
  + 1. Colour Coding (Dashboard Widget):
* Green: ≤100%
* Yellow: 100–110%
* Red: >110%
  + 1. Applicable Standards:
* IS 732:2019 – Phase balance and power draw
* IS 13234 – Current-carrying system overload thresholds
* IEC 60255 – Device trip configuration via power thresholds
  + 1. RT – Total (Tags: TOTAL\_KVA, TOTAL\_KW, TOTAL\_KVAR)
* Definition: Sum of R, Y, B phase readings for apparent, active, and reactive power respectively.
* Used for assessing total plant demand vs. capacity.
  + 1. Acceptable Range: ≤100% of LV Incomer rated capacity (entered in device config).
    2. Warning Range: >100% and ≤110%
    3. Critical Range: >110%
    4. Default Settings for Device Configuration Page – User Input Fields:
* Rated Total Capacity: kVA (from transformer or incomer rating)
* Expected Rated PF: (e.g., 0.90)
  + 1. Alert Behaviour (Based on SPP Payloads):
* Warning if any total value exceeds 100% for more than 2 payloads.
* Critical if value exceeds 110% for more than 2 payloads.
* Auto-reset if power returns within 100% in latest payload.
  + 1. Colour Coding (Dashboard Widget):
* Same as 1.24.1
  + 1. Applicable Standards:
* IS 12360 – System voltage and apparent power class
* IS 13234 – Transformer utilization tracking
* IEC 60909 – System design power flow reference
* ISO 50001 – Real-time active/reactive demand management

1.24.3 Historical Plot – Shift A, B, C / Day / Week / Date Range

Definition: Line or stacked bar chart of real-time kVA, kW, kVAR plotted over the selected time window.

* Display total and/or per-phase values.
* Overlay 100% and 110% reference lines to indicate overloads.
* Annotate spike events, trip conditions, load drop-off points, etc.
* Optional: Correlate reactive power trends with capacitor bank operation.

Applicable Standards:

* ISO 50001 – Load profile reporting and optimization
* IEC 61850 – Historical data and event tag standard
* IS 13234 – Power overload and shift analysis practice
  1. **Energy Consumption with ToD Slots LV Incomer – Energy Consumption and ToD Energy/Cost Analysis**
     1. **RT – Energy Registers (Tags: KWH, KVAH, KVARH)**  
        Definition:  
        Total accumulated energy readings from the MFM via IoT –
* KWH: Active Energy (useful power consumption)
* KVAH: Apparent Energy (total supplied capacity)
* KVARH: Reactive Energy (non-working power flow)  
  Used for billing analysis, demand-side evaluation, and system efficiency scoring.
  + 1. Acceptable Range:  
       Values should increase progressively; daily/monthly targets defined by user-configured baseline.
    2. Default Settings for Device Configuration Page – User Input Fields:
* Monthly Energy Budget (kWh)
* Utility Contracted kVA Demand
* Unit Energy Rate (Rs./kWh)
* ToD time slab structure with energy multipliers
* Penalty for excess KVARH draw if PF < 0.90
  + 1. Alert Behaviour (Based on SPP Payloads):
* Warning if KWH exceeds daily baseline by 10% in more than 2 payloads
* Critical alert if daily KWH exceeds 20% over target
* Auto-reset when value returns below threshold in latest payload
  + 1. Colour Coding (Dashboard Widget):
* Green: Consumption within daily/shift target
* Yellow: 10–20% above
* Red: >20% above
  + 1. Applicable Standards:

• IS 15959-2 – Meter data exchange format

• CEA Metering Regulations – LV consumer metering

• ISO 50001 – Energy efficiency tracking

• IS 732 – Wiring system energy budgeting

* + 1. ToD Energy Consumption (Internal logic)

Definition:

* Calculation of energy consumed within each Time-of-Day slot as per utility billing structure.
* Time slots and multipliers are user-configurable (MSEDCL default used if not customized).

Example (MSEDCL):

* 22:00–06:00 → 0.85× (night rebate)
* 06:00–09:00 → 1.10×
* 09:00–18:00 → 1.00×
* 18:00–22:00 → 1.20× (peak)
* Total Energy and Cost = ∑ (KWH × applicable ToD multiplier)

Default Settings for Device Configuration Page – User Input Fields:

* Enable ToD Billing: Yes/No
* Define time slots and multipliers
* Base energy rate (Rs./kWh)

Alert Behaviour (Based on SPP Payloads):

* Warning if energy in peak slot > average by 10% for more than 2 payloads
* Critical if ToD peak slot overuse >20% or occurs in all 3 shifts
* Auto-reset when peak load drops to expected ratio in latest payload

Applicable Standards:

* MSEDCL MYT Order FY 2020–21 to 2024–25
* IS 15959 – Advanced metering with ToD support
* CEA Energy Accounting Guidelines
  + 1. Historical Plot – Shift A, B, C / Day / Week / Date Range

Definition:

* Time-based energy trend for each type – KWH, KVAH, KVARH – plotted over day/shift/week.
* Optional: Overlay ToD slot zones with different colors (peak, off-peak, night)
* Show comparative energy per shift/day, and overlay expected baseline for visual budget tracking.
* Display total energy consumed and estimated bill (if cost rate configured)
* Optionally show PF band and KVARH as a ratio to KWH to visualize inefficiency

Applicable Standards:

* ISO 50001 – Energy consumption reporting
* IS 15959 – Energy register trend formats
* BIS Grid Code – Real-time and historical tracking
  1. **Maximum Demand**
     1. kW, kVA, kVAr – Interval Shift / Day
* Definition: Maximum demand recorded for active power (kW), apparent power (kVA), and reactive power (kVAr) within configured demand integration period (typically 15 or 30 min) across shift/day.
  + - 1. Acceptable Range: Up to 100% of contract demand or rated capacity.
      2. Warning Range: >100% and ≤110% of contract demand or rated capacity.
      3. Critical Range: >110% of contract demand or rated capacity.
      4. Default Settings for Device Configuration Page – User Input Fields:
* Contract demand in kVA
* Integration period (default 30 min as per MERC/MSEDCL, optional 15 min)
* Rated transformer/incomer capacity
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if demand exceeds 100% for more than 2 payloads in the integration window.
* Critical if demand exceeds 110% for more than 2 payloads.
* Auto-reset if demand falls within acceptable limit in latest payload.
  + - 1. Colour Coding (Dashboard Widget):
* Green: ≤100%
* Yellow: 100–110%
* Red: >110%
  + - 1. Applicable Standards:
* IS 14697 – MD recording accuracy
* MERC Supply Code – Contract demand compliance
* ISO 50001 – Peak load tracking
* IEC 61850 – MD event timestamping
  + 1. Average MD
* Definition: Average of maximum demand values over selected shift/day (average of peak interval values).
  + - 1. Acceptable Range: ≤100% of contract demand.
      2. Warning Range: >100% and ≤110%.
      3. Critical Range: >110%.
      4. Default Settings for Device Configuration Page – User Input Fields:
* Same as 1.26.1
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if average MD exceeds 100% for 2 payloads.
* Critical if average MD exceeds 110% for 2 payloads.
* Auto-reset when average MD returns within 100% in latest payload.
  + - 1. Applicable Standards: Same as 1.26.1
    1. Max Deviation
* Definition: Largest absolute difference between current interval demand and average MD during shift/day.
  + - 1. Formula: MAX(|MD interval value – Average MD|)
      2. Acceptable Range: ≤5% of average MD.
      3. Warning Range: >5% and ≤10%.
      4. Critical Range: >10%.
      5. Default Settings for Device Configuration Page – User Input Fields:
* Warning: 5–10% deviation.
* Critical: >10% deviation.
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if deviation >5% for 2 payloads.
* Critical if deviation >10% for 2 payloads.
* Auto-reset if deviation returns within 5% in latest payload.
  + - 1. Applicable Standards:
* IS 14697 – Demand recording
* ISO 50001 – Load variance tracking
* MERC Supply Code – Demand limit monitoring
  1. **Voltage Harmonic Distortion – THD – V (Tags: R\_THD-V, Y\_THD-V, B\_THD-V)**
     1. RT- THD – V %
* Definition: Real-time total harmonic distortion of voltage measured on each phase as a percentage of the fundamental component.
  + - 1. Acceptable Range: ≤5% (per IEEE 519 / IEC 61000-2-2 for LV systems).
      2. Warning Range: >5% and ≤8%.
      3. Critical Range: >8%.
      4. Default Settings for Device Configuration Page – User Input Fields:
* Warning threshold: 5%
* Critical threshold: 8%
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if any phase THD-V exceeds 5% for 2 payloads.
* Critical if any phase THD-V exceeds 8% for 2 payloads.
* Auto-reset when THD-V returns within 5% in latest payload.
  + - 1. Colour Coding (Dashboard Widget):
* Green: ≤5%
* Yellow: >5% to 8%
* Red: >8%
  + - 1. Applicable Standards:
* IEEE 519 – Harmonic distortion limits
* IEC 61000-2-2 – Voltage quality public LV systems
* IEC 61000-4-30 – Harmonics measurement standard
  + 1. Avg
* Definition: Average THD-V across R, Y, B phases or over selected shift/day period.
  + - 1. Acceptable Range: ≤5%.
      2. Warning Range: >5% and ≤8%.
      3. Critical Range: >8%.
      4. Default Settings for Device Configuration Page – User Input Fields:
* Same as 1.27.1
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if average THD-V exceeds 5% for 2 payloads.
* Critical if average THD-V exceeds 8% for 2 payloads.
* Auto-reset if average THD-V returns within 5% in latest payload.
  + - 1. Applicable Standards: Same as 1.27.1
    1. Max Deviation
* Definition: Maximum difference between any individual phase THD-V and average THD-V during the shift/day.
* Formula: MAX(|R\_THD-V – AVG\_THD-V|, |Y\_THD-V – AVG\_THD-V|, |B\_THD-V – AVG\_THD-V|)
  + - 1. Acceptable Range: ≤1%
      2. Warning Range: >1% and ≤2%
      3. Critical Range: >2%
      4. Default Settings for Device Configuration Page – User Input Fields:
* Warning: 1–2% deviation
* Critical: >2% deviation
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if deviation >1% for 2 payloads.
* Critical if deviation >2% for 2 payloads.
* Auto-reset if deviation returns within 1% in latest payload.
  + - 1. Applicable Standards:
* IEC 61000-4-30 – Harmonic imbalance measurement
* IEEE 519 – System compatibility with harmonic sources
  1. **Current Harmonic Distortion – THD – I (Tags: R\_THD-I, Y\_THD-I, B\_THD-I)**
     1. RT- THD – I %
* Definition: Real-time total harmonic distortion of current measured on each phase as a percentage of the fundamental current component.
  + - 1. Acceptable Range: ≤20% (aligned with IEEE 519 guidance for typical LV systems at PCC).
      2. Warning Range: >20% and ≤50%.
      3. Critical Range: >50%.
      4. Default Settings for Device Configuration Page – User Input Fields:
* Warning threshold: 20%
* Critical threshold: 50%
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if any phase THD-I exceeds 20% for more than 2 payloads.
* Critical if any phase THD-I exceeds 50% for more than 2 payloads.
* Auto-reset when THD-I returns within 20% in latest payload.
  + - 1. Colour Coding (Dashboard Widget):
* Green: ≤20%
* Yellow: >20% to 50%
* Red: >50%
  + - 1. Applicable Standards:
* IEEE 519 – Harmonic current limits at PCC
* IEC 61000-4-30 – Harmonic current measurement
* IEC 61000-3-12 – Harmonic emission from equipment >16 A
  + 1. Avg
* Definition: Average of THD-I across R, Y, B phases or time-averaged over shift/day period.
  + - 1. Acceptable Range: ≤20%.
      2. Warning Range: >20% and ≤50%.
      3. Critical Range: >50%.
      4. Default Settings for Device Configuration Page – User Input Fields:
* Same as 1.28.1
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if average THD-I exceeds 20% for 2 payloads.
* Critical if average THD-I exceeds 50% for 2 payloads.
* Auto-reset if average THD-I returns within 20% in latest payload.
  + - 1. Applicable Standards: Same as 1.28.1
    1. Max Deviation
* Definition: Maximum absolute deviation of any phase THD-I from average THD-I in shift/day.
* Formula: MAX(|R\_THD-I – AVG\_THD-I|, |Y\_THD-I – AVG\_THD-I|, |B\_THD-I – AVG\_THD-I|)
  + - 1. Acceptable Range: ≤5% deviation.
      2. Warning Range: >5% and ≤10%.
      3. Critical Range: >10%.
      4. Default Settings for Device Configuration Page – User Input Fields:
* Warning: 5–10% deviation
* Critical: >10% deviation
  + - 1. Alert Behaviour (Based on SPP Payloads):
* Warning if deviation >5% for 2 payloads.
* Critical if deviation >10% for 2 payloads.
* Auto-reset when deviation returns within 5% in latest payload.
  + - 1. Applicable Standards:
* IEC 61000-4-30 – Imbalance and harmonic current tracking
* IEEE 519 – PCC current distortion compatibility

## LT Panels – Derived KPI’s & Analytics

* 1. Real-Time Load %
  2. Average Load (kW, kVA)
  3. Maximum demand
  4. Load Factor Analysis
  5. Demand Factor (%)
  6. Load Utilization (%)
  7. Transformer Efficiency
  8. Energy Loss across Transformer
  9. Transmission Losses (UG cables HT-LT Panel)
  10. Transformer Loading
  11. ToD Energy Consumption Analysis
  12. PF Level Analysis
  13. V & I imbalance Analysis
  14. Specific Energy Consumption (SEC)
  15. Energy Loss Estimation (HT-LT Panel)
  16. Phase Reversal or Missing Phase Alerts
  17. System Efficiency
  18. Time Matrix (Idel / Run Time)
  19. Energy Cost Estimation (Only Approx. Energy Charges)
  20. Energy Balance (EnB) – (HT-LT panel)
  21. Deviation from Baseline Consumption (ISO 50001 compliance)
  22. Average Voltage Harmonic Distortion – THD – V
  23. Average Current Harmonic Distortion – THD – I
  24. EEPI – Enterprise Electricity Performance Index (Enterprise Score)
  25. Comparison Analytics – Data & Charts – Current Data with Historical Data

1. Load Factor
2. Transformer Efficiency
3. Energy Losses
4. PF Level Analysis
5. SEC
6. Energy Cost

## **PCC Panels**

## A. PCC Panels – Real-Time Monitoring Web Page

**1.62 / 1.63 Harmonics (THD-V and THD-I)**  
Update: At PCC, apply stricter alerting logic for harmonics because this is the utility interface point.  
Recommended to issue advisory if THD-V >4% (instead of 5%) sustained at PCC to pre-empt PCC-level compliance violations.

**General note:**  
At PCC, it’s good practice to log and store PQ events (voltage dips, THD excursions, PF penalties) separately for compliance reporting.

**Summary:**  
Unless noted above, **all other indices (1.54 through 1.63)** follow **exactly the same logic, thresholds, colour coding, formulas, alerting, standards** as LV Incomer.

**1.54 PCC – 3 Phase Voltages (L-L)**  
**1.54.1 RT – Vry, Vyb, Vbr**  
Same as LT Incomer 1.19.1  
**1.54.2 RT – Average Voltage**  
Same as LT Incomer 1.19.2  
**1.54.3 RT – Max Deviation**  
Same as LT Incomer 1.19.3

**1.55 PCC – 3 Phase Voltages (L-N)**  
**1.55.1 RT – Vrn, Vyn, Vbn**  
Same as LT Incomer 1.20.1  
**1.55.2 RT – Average Voltage**  
Same as LT Incomer 1.20.2  
**1.55.3 RT – Max Deviation**  
Same as LT Incomer 1.20.3

**1.56 PCC – 3 Phase Currents (Line Current)**  
**1.56.1 RT – Ir, Iy, Ib**  
Same as LT Incomer 1.21.1  
**1.56.2 RT – Neutral Current (If supported)**

* Neutral current monitoring recommended for PCC.
* Acceptable Range: ≤30% of average phase current.
* Warning Range: >30% and ≤50%.
* Critical Range: >50%.
* Alert Behaviour (Based on SPP Payloads):
* Warning if neutral current exceeds 30% of average phase current for more than 2 payloads.
* Critical if exceeds 50% for more than 2 payloads.
* Auto-reset if neutral current returns within 30% in latest payload.
* Applicable Standards: IEC 60364, IEEE 519

**1.56.3 RT – Average Current**  
Same as LT Incomer 1.21.2  
**1.56.4 RT – Max Deviation**  
Same as LT Incomer 1.21.3  
**1.56.5 Historical Plot – Shift A, B, C / Day / Week / Date Range**  
Same as LT Incomer 1.21.4

**1.57 PCC – System Frequency (Hz)**  
**1.57.1 RT – Frequency value**  
Same as LT Incomer 1.22.1  
**1.57.2 Minimum – Shift / Current Day**  
Same as LT Incomer 1.22.2  
**1.57.3 Maximum – Shift / Current Day**  
Same as LT Incomer 1.22.3  
**1.57.4 Average – Shift / Current Day**  
Same as LT Incomer 1.22.2  
**1.57.5 Max Deviation – Shift / Current Day**  
Same as LT Incomer 1.22.3

**1.58 PCC – Power Factor (Average / Each Line)**  
**1.58.1 RT – PF\_R, PF\_Y, PF\_B Phase values**  
Same as LT Incomer 1.23.2  
**1.58.2 RT – Avg PF**  
Same as LT Incomer 1.23.3  
**1.58.3 Max Deviation**  
Same as LT Incomer 1.23.4  
**1.58.4 RT – PF Level with Incentive / Penalty %**  
Same as LT Incomer 1.23.6  
**1.58.5 Average Incentive / Penalty %**  
Same as LT Incomer 1.23.6  
**1.58.6 Approx. Incentive / Penalty charges calculation – Shift / Current Day**  
Enable calculation using actual kVAh, PF slab rate, and current utility ToD rates at PCC.  
Formula: (Base tariff × kVAh) ± (Incentive % / Penalty % × applicable energy portion).  
**1.58.7 Historical Plot – Shift A, B, C / Day / Week / Date Range**  
Same as LT Incomer 1.23.7  
**1.58.8 Min PF – R, Y, B, Avg**  
Same as LT Incomer 1.23.4  
**1.58.9 Max PF – R, Y, B, Avg**  
Same as LT Incomer 1.23.5

**1.59 PCC – Apparent Power (kVA), Active Power (kW), Reactive Power (kVAr)**  
**1.59.1 RT – Bar Plot – R, Y, B Phase**  
Same as LT Incomer 1.24.1  
**1.59.2 RT – Total**  
Same as LT Incomer 1.24.2  
**1.59.3 Historical Plot – Shift A, B, C / Day / Week / Date Range**  
Same as LT Incomer 1.24.3

**1.60 PCC – Energy Consumption with ToD Slots**  
**1.60.1 RT – Total – kWh, kVArh, kVAh**  
Same as LT Incomer 1.25.1 (ToD categorization mandatory at PCC for utility billing point).  
**1.60.2 Historical XY Plot – Shift A, B, C / Day / Week / Date Range**  
Same as LT Incomer 1.25.3

**1.61 PCC – Maximum Demand**  
**1.61.1 kW, kVA, kVAr – Interval Shift / Day**  
Same as LT Incomer 1.26.1  
**1.61.2 Average MD**  
Same as LT Incomer 1.26.2  
**1.61.3 Max Deviation**  
Same as LT Incomer 1.26.3

**1.62 PCC – Voltage Harmonic Distortion – THD-V**  
**1.62.1 RT – THD-V %**  
Apply stricter advisory alert at >4% sustained at PCC to preempt compliance issue.  
All other points same as LT Incomer 1.27.1  
**1.62.2 Avg**  
Same as LT Incomer 1.27.2  
**1.62.3 Max Deviation**  
Same as LT Incomer 1.27.3

**1.63 PCC – Current Harmonic Distortion – THD-I**  
**1.63.1 RT – THD-I %**  
Same as LT Incomer 1.28.1  
**1.63.2 Avg**  
Same as LT Incomer 1.28.2  
**1.63.3 Max Deviation**  
Same as LT Incomer 1.28.3

## B. PCC Panels – Derived KPI’s & Analytics

* 1. Real-Time Load %
  2. Average Load (kW, kVA)
  3. Maximum demand
  4. Load Factor Analysis
  5. Demand Factor (%)
  6. Load Utilization (%)
  7. Load Imbalance (%)
  8. Peak Load Usage Matrix (kW/KVA)
  9. Transmission/Energy Losses (UG cables LT-PCC Panel)
  10. Idle Load Detection
  11. ToD Energy Consumption Analysis
  12. PF Level Analysis
  13. V & I imbalance Analysis
  14. Specific Energy Consumption (SEC) – If Production Output Provided
  15. Phase Reversal or Missing Phase Alerts
  16. System Efficiency
  17. Time Matrix (Idel / Run Time)
  18. Energy Cost Estimation (Only Approx. Energy Charges)
  19. Energy Balance (EnB) – (HT-LT-PCC panel)
  20. Deviation from Baseline Consumption (ISO 50001 compliance)
  21. Average Voltage Harmonic Distortion – THD – V
  22. Average Current Harmonic Distortion – THD – I
  23. EEPI – Enterprise Electricity Performance Index (Enterprise Score)
  24. Comparison Analytics – Data & Charts – Current Data with Historical Data

1. Load Factor
2. Transmission/Energy Losses (UG cables LT-PCC Panel)
3. PF Level Analysis
4. System Efficiency
5. Energy Cost

# **MCC / ELECTRICAL MACHINES**

## **MCC Panel**

## MCC – Individual Electrical Machine - Real-Time Monitoring Web Page

* 1. **3ph Voltages (L-L)**
     1. RT – Vry, Vyb, Vbr.
        1. Definition
* Real-time measurement of the line-to-line voltages between Red-Yellow (VRY), Yellow-Blue (VYB), and Blue-Red (VBR) phases. These voltages represent the phase-to-phase supply feeding the motors and equipment from the MCC. Stable and balanced line voltages ensure motors operate efficiently and safely.
  + - 1. Acceptable Range
* Between 390 V and 440 V (±6% of nominal 415 V as per IS 12360 / IEC 60038).
* Voltage unbalance ≤ 2% as per IS 12615 / IEC 60034-1 recommended limits for motor protection.
  + - 1. Warning Range
* Voltage between 440 V to 457 V (+6% to +10%) or 390 V to 375 V (−6% to −10%).
* Voltage unbalance > 2% but ≤ 3%.
  + - 1. Critical Range
* Voltage > 457 V (> +10%) or < 375 V (< −10%).
* Voltage unbalance > 3% which may severely impact motor life and performance.
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Nominal Voltage: 415 V
* Warning Thresholds: >440 V or <390 V (voltage deviation); >2% unbalance
* Critical Thresholds: >457 V or <375 V (voltage deviation); >3% unbalance
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if any phase voltage exceeds warning range or unbalance > 2% in 2 consecutive payloads.
* Critical alert if any phase voltage exceeds critical range or unbalance > 3% in 2 consecutive payloads.
* Auto-reset occurs when all phase voltages return to within acceptable limits in the latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: All L-L voltages within ±6% of nominal and unbalance ≤ 2%.
* Yellow: Any L-L voltage deviation between 6%–10% or unbalance > 2% up to 3%.
* Red: Any L-L voltage deviation > 10% or unbalance > 3%.
  + - 1. Historical Chart Design
* Line graph showing VRY, VYB, VBR over time. Overlay nominal (415 V) and ±6% bands. Highlight periods in yellow or red where thresholds were exceeded. Annotate voltage unbalance excursions.
  + - 1. Applicable Standards
* IS 12360:1988 Nominal voltage for low voltage systems (415 V ±6% for LV 3 phase systems)
* IS 12615:2011 / IEC 60034-1: Voltage unbalance limits for motors (≤2% recommended for safe operation)
* IEC 61000-4-30: Methods for measuring supply voltage parameters and unbalance
* IEC 60038: Standard voltages
* IEEE 519: Guidelines on acceptable voltage quality for harmonic environments
  + 1. RT – Average Voltage
       1. Definition
* The average of the three line-to-line voltages (VRY, VYB, VBR) measured at the MCC incomer or outgoing feeders. This represents the general voltage level supplied by the MCC to connected equipment at a given instant. A stable average voltage close to the nominal value indicates good supply quality.
  + - 1. Calculation
* Average Voltage = (VRY + VYB + VBR) / 3
* Where VRY, VYB, VBR are real-time measured phase-to-phase voltages.
  + - 1. Acceptable Range
* Between 390 V and 440 V (±6% of 415 V nominal as per IS 12360 / IEC 60038).
  + - 1. Warning Range
* Between 375 V and 390 V (−6% to −10%) or 440 V to 457 V (+6% to +10%).
  + - 1. Critical Range
* Below 375 V (< −10%) or above 457 V (> +10%).
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Nominal Voltage: 415 V
* Warning Thresholds: Average voltage < 390 V or > 440 V
* Critical Thresholds: Average voltage < 375 V or > 457 V
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if average voltage is outside acceptable range but within warning range for 2 consecutive payloads.
* Critical alert if average voltage is outside critical range for 2 consecutive payloads.
* Auto-reset once average voltage returns within acceptable limits in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: Average voltage within ±6% of nominal.
* Yellow: Average voltage between ±6% and ±10% of nominal.
* Red: Average voltage beyond ±10% of nominal.
  + - 1. Historical Chart Design
* Plot average voltage trend over time. Overlay reference lines for 415 V, ±6% band, and ±10% band. Highlight warning periods (yellow) and critical periods (red).
  + - 1. Applicable Standards
* IS 12360:1988 Nominal voltage for LV systems (415 V ±6%)
* IEC 60038: Standard voltages (±10% supply limit in exceptional conditions)
* IEC 61000-4-30: Voltage monitoring methodology
  + 1. RT – Max Deviation
       1. Definition
* The maximum difference between any of the real-time measured line-to-line voltages (VRY, VYB, VBR) and the average voltage. It quantifies how much one phase-to-phase voltage deviates from the mean, reflecting voltage unbalance at the MCC. A low max deviation means the supply is symmetrical, while a high deviation signals potential stress on motors and equipment.
  + - 1. Calculation
* Max Deviation = Maximum absolute difference of any (VRY, VYB, VBR) from Average Voltage
* Deviation % = (Max Deviation / Average Voltage) × 100
  + - 1. Acceptable Range
* Voltage unbalance (deviation %) ≤ 2% (recommended by IS 12615 and IEC 60034-1 for motor safety and performance).
  + - 1. Warning Range
* Deviation % > 2% up to 3%.
  + - 1. Critical Range
* Deviation % > 3%.
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Nominal Voltage: 415 V
* Warning Threshold: Voltage unbalance > 2%
* Critical Threshold: Voltage unbalance > 3%
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if voltage unbalance exceeds 2% for 2 consecutive payloads.
* Critical alert if voltage unbalance exceeds 3% for 2 consecutive payloads.
* Auto-reset once voltage unbalance returns within 2% in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: Voltage unbalance ≤ 2%.
* Yellow: Voltage unbalance > 2% up to 3%.
* Red: Voltage unbalance > 3%.
  + - 1. Historical Chart Design
* Plot VRY, VYB, VBR and average voltage over time. Overlay deviation % trend line. Highlight time periods where unbalance exceeded thresholds in yellow or red.
  + - 1. Applicable Standards
* IS 12615:2011 / IEC 60034-1: Voltage unbalance ≤ 2% for motor performance
* IEC 61000-4-30: Methods for voltage unbalance measurement
* IS 12360:1988 Nominal voltage – base voltage for deviation calculation
  1. **3ph Voltages (L-N)**
     1. RT – Vrn, Vyn, Vbn.
        1. Definition
* Real-time measurement of the line-to-neutral voltages for each phase: Vrn (Red to Neutral), Vyn (Yellow to Neutral), and Vbn (Blue to Neutral). These voltages indicate the supply to single-phase loads and the health of the phase-to-neutral connections in the MCC. Balanced and stable L-N voltages are essential for reliable operation of single-phase motors, control circuits, and auxiliary equipment connected to the MCC.
  + - 1. Calculation
* Vrn, Vyn, Vbn are measured directly via potential transformers or direct voltage sensing.
* Each is computed as RMS value over a sampling window per IEC 61000-4-30 Class A methodology.
  + - 1. Acceptable Range
* Between 220 V and 240 V (−6% to +6% of nominal 230 V as per IS 12360 / IEC 60038 for L-N systems).
* Voltage unbalance ≤ 2% between phases recommended.
  + - 1. Warning Range
* Between 240 V to 253 V (+6% to +10%) or 220 V to 207 V (−6% to −10%).
* Voltage unbalance > 2% up to 3%.
  + - 1. Critical Range
* Above 253 V (> +10%) or below 207 V (< −10%).
* Voltage unbalance > 3%.
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Nominal L-N Voltage: 230 V
* Warning Thresholds: V < 220 V or > 240 V; unbalance > 2%
* Critical Thresholds: V < 207 V or > 253 V; unbalance > 3%
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if any L-N voltage is outside acceptable range or unbalance > 2% in 2 consecutive payloads.
* Critical alert if any L-N voltage is outside critical range or unbalance > 3% in 2 consecutive payloads.
* Auto-reset once voltages and unbalance return within acceptable limits in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: All L-N voltages within ±6% of nominal and unbalance ≤ 2%.
* Yellow: Any L-N voltage between ±6% and ±10% of nominal or unbalance > 2% up to 3%.
* Red: Any L-N voltage beyond ±10% of nominal or unbalance > 3%.
  + - 1. Historical Chart Design
* Plot Vrn, Vyn, Vbn over time with overlays for 230 V, ±6% band, and ±10% band. Highlight periods exceeding thresholds in yellow or red.
  + - 1. Applicable Standards
* IS 12360:1988 Nominal voltage for low voltage systems (230 V ±6%)
* IEC 60038: Standard voltages (230 V base for L-N systems)
* IS 12615:2011 / IEC 60034-1: Voltage unbalance ≤ 2% for motor safety
* IEC 61000-4-30: Voltage monitoring methodology
  + 1. RT – Average Voltage
       1. Same as 2.1.2
    2. RT – Max Deviation
       1. Definition
* The maximum difference between any real-time measured L-N voltage (Vrn, Vyn, Vbn) and the average of these voltages. It quantifies voltage unbalance at the L-N level. High deviation indicates supply asymmetry, which can stress single-phase equipment and control circuits connected to the MCC.
  + - 1. Calculation
* Max Deviation = Maximum absolute difference of any (Vrn, Vyn, Vbn) from Average Voltage
* Deviation % = (Max Deviation / Average Voltage) × 100
  + - 1. Acceptable Range
* Deviation % ≤ 2% (recommended limit for safe operation of motors and equipment as per IS 12615 / IEC 60034-1).
  + - 1. Warning Range
* Deviation % > 2% up to 3%.
  + - 1. Critical Range
* Deviation % > 3%.
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Nominal L-N Voltage: 230 V
* Warning Threshold: Voltage unbalance > 2%
* Critical Threshold: Voltage unbalance > 3%
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if voltage unbalance exceeds 2% for 2 consecutive payloads.
* Critical alert if voltage unbalance exceeds 3% for 2 consecutive payloads.
* Auto-reset once unbalance returns within 2% in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: Voltage unbalance ≤ 2%.
* Yellow: Voltage unbalance > 2% up to 3%.
* Red: Voltage unbalance > 3%.
  + - 1. Historical Chart Design
* Plot Vrn, Vyn, Vbn and average voltage over time. Overlay deviation % trend line. Highlight warning and critical periods with yellow and red markers.
  + - 1. Applicable Standards
* IS 12615:2011 / IEC 60034-1: Voltage unbalance ≤ 2% recommended
* IEC 61000-4-30: Methods for voltage unbalance measurement
* IS 12360:1988 / IEC 60038: Nominal voltage 230 V L-N
  1. **3ph Currents (Line Current)**
     1. RT – Ir, Iy, Ib
        1. Definition
* Real-time measurement of the line currents in the R, Y, B phases (IR, IY, IB) of the MCC. These values indicate the load on each phase at any moment. Balanced and appropriate line currents ensure that motors and connected loads operate within design limits and the MCC components (busbars, breakers, cables) are not overloaded.
  + - 1. Calculation
* IR, IY, IB are measured using CTs (Current Transformers) and computed as RMS values over a defined sampling window per IEC 61000-4-30.
* Each current reflects the actual phase load at the instant.
  + - 1. Acceptable Range
* IR, IY, IB ≤ 100% of rated feeder or MCC busbar current capacity.
* Current imbalance (max deviation % from average) ≤ 10% as good practice per IS 12615 / IEC 60034-1 for motor protection.
  + - 1. Warning Range
* IR, IY, or IB > 100% up to 110% of rated capacity.
* Current imbalance > 10% up to 15%.
  + - 1. Critical Range
* IR, IY, or IB > 110% of rated capacity.
* Current imbalance > 15%.
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Rated current (user input or default from CT/breaker size)
* Warning Thresholds: >100% rated current; imbalance >10%
* Critical Thresholds: >110% rated current; imbalance >15%
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if any phase current exceeds 100% rated or imbalance >10% in 2 consecutive payloads.
* Critical alert if any phase current exceeds 110% rated or imbalance >15% in 2 consecutive payloads.
* Auto-reset once all currents and imbalance return within acceptable limits in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: All currents ≤ 100% rated and imbalance ≤ 10%.
* Yellow: Any current > 100% up to 110% or imbalance >10% up to 15%.
* Red: Any current > 110% or imbalance > 15%.
  + - 1. Historical Chart Design
* Plot IR, IY, IB over time with overlay of rated current. Highlight overload or imbalance periods in yellow/red.
  + - 1. Applicable Standards
* IS 12615:2011 / IEC 60034-1: Current imbalance recommendations for motors
* IEC 61000-4-30: Current measurement methodology for power quality
* IS/IEC 60947-1: Rated current and overload handling for switchgear
  + 1. RT – Neutral Current (If supported)
       1. Definition
* Real-time measurement of the current flowing through the neutral conductor of the MCC, where applicable. In balanced three-phase systems without significant harmonic content or single-phase loads, the neutral current should ideally be near zero. In systems with unbalanced loads or high triplen harmonics (3rd, 9th, etc.), the neutral current can rise significantly and pose risks of overheating.
  + - 1. Calculation
* Neutral current is measured via a dedicated CT on the neutral conductor (if present).

Neutral Current = vector sum of IR, IY, IB (considering phase angles)

* + - 1. Acceptable Range
* ≤ 10% of the rated phase current (good practice for balanced systems per IEC 60364 / IS 3043).
  + - 1. Warning Range
* 10% up to 20% of rated phase current, indicating moderate imbalance or presence of triplen harmonics.
  + - 1. Critical Range
* 20% of rated phase current, indicating significant imbalance or harmonic pollution that could risk neutral overheating or voltage distortion.
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Neutral current monitoring: Enabled / Disabled (based on device support)
* Warning threshold: >10% of rated phase current
* Critical threshold: >20% of rated phase current
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if neutral current exceeds 10% of rated phase current for 2 consecutive payloads.
* Critical alert if neutral current exceeds 20% of rated phase current for 2 consecutive payloads.
* Auto-reset once neutral current returns within acceptable limits in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: Neutral current ≤10% of rated phase current
* Yellow: Neutral current >10% up to 20%
* Red: Neutral current >20%
  + - 1. Historical Chart Design
* Plot neutral current over time with overlays for warning and critical thresholds. Useful to correlate with load imbalance or harmonic events.
  + - 1. Applicable Standards
* IEC 60364 / IS 3043: Earthing and neutral current handling
* IS 12615 / IEC 60034-1: Related to current balance and system safety
* IEC 61000-4-30: Power quality measurement including neutral current
  + 1. RT – Average Current
       1. Definition  
          The arithmetic mean of the real-time measured phase currents (IR, IY, IB). Represents the overall load level on the MCC at any instant.

Calculation  
Average Current = (IR + IY + IB) / 3  
Remaining – Same as 2.3.1

* + 1. RT – Max Deviation
       1. Definition
* The maximum difference between any real-time measured phase current (IR, IY, IB) and the average current. This metric quantifies current imbalance at the MCC, which can indicate unequal load distribution across phases or issues such as a faulty motor or phase loss. Excessive imbalance stresses motors and increases neutral current, leading to overheating risks.
  + - 1. Calculation
* Max Deviation = Maximum absolute difference of any (IR, IY, IB) from Average Current
* Deviation % = (Max Deviation / Average Current) × 100
  + - 1. Acceptable Range
* Deviation % ≤ 10% (recommended as good practice for motor health per IS 12615 / IEC 60034-1).
  + - 1. Warning Range
* Deviation % > 10% up to 15%.
  + - 1. Critical Range
* Deviation % > 15%.
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Rated phase current (user input or derived from CT/breaker size)
* Warning threshold: Current imbalance > 10%
* Critical threshold: Current imbalance > 15%
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if current imbalance exceeds 10% for 2 consecutive payloads.
* Critical alert if current imbalance exceeds 15% for 2 consecutive payloads.
* Auto-reset once current imbalance returns within 10% in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: Current imbalance ≤ 10%
* Yellow: Current imbalance > 10% up to 15%
* Red: Current imbalance > 15%
  + - 1. Historical Chart Design
* Plot IR, IY, IB and average current over time. Overlay deviation % trend. Highlight warning and critical periods in yellow or red.
  + - 1. Applicable Standards
* IS 12615:2011 / IEC 60034-1: Motor operation voltage/current imbalance limits
* IEC 61000-4-30: Measurement methodology for current imbalance
  + 1. Historical Plot – Shift A, B, C/Day/Week/ Date Range
       1. Definition
* Historical trend chart of IR, IY, IB and average current over user-defined periods (shift, day, week, or custom date range). The chart provides a visual representation of load patterns, helping identify peak demand periods, load imbalance, and unusual load behaviors across phases.
  + - 1. Calculation
* Plot phase current values (IR, IY, IB) and average current at each sampling interval over time. Mark or shade areas where phase currents exceeded warning or critical thresholds or where imbalance exceeded set limits.
  + - 1. Acceptable Range
* Same as defined in 2.3.1 and 2.3.4:
* Phase currents ≤ 100% of rated
* Current imbalance ≤ 10%
  + - 1. Warning Range
* Same as defined in 2.3.1 and 2.3.4:
* Phase current >100% up to 110%
* Current imbalance >10% up to 15%
  + - 1. Critical Range
* Same as defined in 2.3.1 and 2.3.4:
* Phase current >110%
* Current imbalance >15%
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Same as defined in 2.3.1 and 2.3.4
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Same as defined in 2.3.1 and 2.3.4
  + - 1. Widget Colour Coding (Dashboard)
* Same as defined in 2.3.1 and 2.3.4
  + - 1. Historical Chart Design
* Line plot for IR, IY, IB and average current over the selected period. Overlay horizontal reference lines for rated current. Highlight overload or imbalance periods in yellow (warning) or red (critical). Allow zoom by shift, day, week, or custom date range for detailed analysis.
  + - 1. Applicable Standards
* IS 12615:2011 / IEC 60034-1: Motor safe operation current imbalance
* IEC 61000-4-30: Current measurement and data logging methodology
  1. **System Frequency (Hz)**
     1. RT – Frequency value
        1. Definition
* Real-time measurement of the system frequency supplied to the MCC. Frequency indicates the stability of the power system. Motors and connected equipment are designed to operate optimally at the nominal frequency (50 Hz in India). Deviations can affect motor speed, torque, and efficiency.
  + - 1. Calculation
* Frequency is measured by counting zero-crossings of the voltage waveform or using digital signal processing as per IEC 61000-4-30 Class A methods. Reported as RMS average over defined sampling windows (typically 200 ms or 10 cycles).
  + - 1. Acceptable Range
* 49.90 Hz to 50.05 Hz (Indian Electricity Grid Code for HT supply under normal conditions).
  + - 1. Warning Range
* 49.50 Hz to 49.89 Hz or 50.06 Hz to 50.50 Hz (minor grid stress zone).
  + - 1. Critical Range
* Below 49.50 Hz or above 50.50 Hz (severe grid imbalance, risk of load shedding or generator issues).
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Nominal frequency: 50 Hz
* Warning thresholds: <49.90 Hz or >50.05 Hz
* Critical thresholds: <49.50 Hz or >50.50 Hz
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if frequency exceeds warning range for 2 consecutive payloads.
* Critical alert if frequency exceeds critical range for 2 consecutive payloads.
* Auto-reset once frequency returns within acceptable range in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: Frequency between 49.90 Hz and 50.05 Hz
* Yellow: Frequency between 49.50–49.89 Hz or 50.06–50.50 Hz
* Red: Frequency below 49.50 Hz or above 50.50 Hz
  + - 1. Historical Chart Design
* Plot frequency over time. Overlay target band (50 Hz ± 0.05 Hz) and warning/critical bands. Highlight periods outside normal range with yellow or red markers.
  + - 1. Applicable Standards
* Indian Electricity Grid Code: 50 Hz nominal, tight frequency band requirements
* IEC 61000-4-30: Frequency measurement methodology
* IS 12360: Reference frequency for LV/MCC systems
  + 1. Max Deviation – Shift/Current Day
       1. Definition
* The maximum difference between the highest and lowest frequency values recorded during the shift or current day. This metric shows how much the supply frequency fluctuated over the period, reflecting grid stability and quality of power supplied to the MCC.
  + - 1. Calculation
* Max Deviation = Maximum frequency value during period − Minimum frequency value during period
  + - 1. Acceptable Range
* Max deviation ≤ 0.10 Hz (typical of a stable grid in India under normal conditions as per Indian Electricity Grid Code).
  + - 1. Warning Range
* Max deviation > 0.10 Hz up to 0.50 Hz (minor instability or load/generation imbalance).
  + - 1. Critical Range
* Max deviation > 0.50 Hz (significant grid disturbance, risk to motor and equipment performance).

Default Settings for Device Configuration Page – User Input Fields

* Nominal frequency: 50 Hz
* Warning threshold: Max deviation > 0.10 Hz
* Critical threshold: Max deviation > 0.50 Hz
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if max deviation exceeds 0.10 Hz for 2 consecutive payloads.
* Critical alert if max deviation exceeds 0.50 Hz for 2 consecutive payloads.
* Auto-reset once max deviation returns within 0.10 Hz in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: Max deviation ≤ 0.10 Hz
* Yellow: Max deviation > 0.10 Hz up to 0.50 Hz
* Red: Max deviation > 0.50 Hz
  + - 1. Historical Chart Design
* Plot frequency trend over shift/day. Mark min and max points and compute/display deviation. Highlight deviations outside acceptable range with yellow/red bands or markers.
  + - 1. Applicable Standards
* Indian Electricity Grid Code: Tight frequency control requirements
* IEC 61000-4-30: Methods for frequency deviation measurement
* IS 12360: Reference frequency 50 Hz
  1. **Power Factor (Average / Each Line)**
     1. RT – PF\_R, PF\_Y, \_PF\_B Phase values
        1. Definition
* Real-time measurement of power factor for each phase (R, Y, B) of the MCC. Power factor (PF) indicates the ratio of active power (kW) to apparent power (kVA) per phase and reflects the efficiency of electrical power use. Low PF signifies high reactive power draw, leading to higher losses and possible utility penalties.
  + - 1. Calculation
* PF\_R = kW\_R / kVA\_R
* PF\_Y = kW\_Y / kVA\_Y
* PF\_B = kW\_B / kVA\_B
* Computed as cos(Φ) where Φ = phase angle between voltage and current waveforms per IEC 61000-4-30.
  + - 1. Acceptable Range
* PF ≥ 0.951 lag or lead (MERC/MSEDCL incentive zone, eligible for rebates as per uploaded image).
* PF 0.955 to 0.964 → 0.5% incentive
* PF 0.965 to 0.974 → 1.0% incentive
* PF 0.975 to 0.984 → 1.5% incentive
* PF 0.985 to 0.994 → 2.5% incentive
* PF 0.995 to 1.000 → 3.5% incentive
  + - 1. Warning Range
* PF between 0.900 and 0.950 lag
* Optional caution: PF > 0.950 lead (over-compensation risk)
  + - 1. Critical Range
* PF < 0.900 lag or lead (MERC/MSEDCL penalty zone as per uploaded image)
* PF 0.895 to 0.900 → 0% penalty
* PF 0.885 to 0.894 → 1.0% penalty
* PF 0.875 to 0.884 → 1.5% penalty
* PF 0.865 to 0.874 → 2.0% penalty
* PF 0.855 to 0.864 → 2.5% penalty
* PF 0.845 to 0.854 → 3.0% penalty
* PF 0.835 to 0.844 → 3.5% penalty
* PF 0.825 to 0.834 → 4.0% penalty
* PF 0.815 to 0.824 → 4.5% penalty
* PF 0.805 to 0.814 → 5.0% penalty
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* PF target: 0.99 lag
* Warning threshold: PF < 0.95 lag or PF > 0.95 lead
* Critical threshold: PF < 0.90 lag
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if PF < 0.95 lag or PF > 0.95 lead in any phase for 2 consecutive payloads.
* Critical alert if PF < 0.90 lag or high leading PF for 2 consecutive payloads.
* Auto-reset when PF returns within acceptable limits in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: PF ≥ 0.951 lag or lead
* Yellow: PF 0.900–0.950 lag or > 0.950 lead
* Red: PF < 0.900 lag or excessive leading PF
  + - 1. Historical Chart Design
* Trend PF\_R, PF\_Y, PF\_B over time. Overlay incentive/penalty bands. Highlight periods with penalties or rebates. Annotate capacitor bank operations or PF correction events.
  + - 1. Applicable Standards
* IS 7752: Guide for power factor improvement
* CEA Grid Connectivity Regulations: Minimum PF ≥ 0.95 for bulk consumers
* MERC Order Case No. 322 of 2019: PF penalty structure
* MSEDCL MYT Order FY 2020-21 to FY 2024-25: PF incentive structure
* IEC 61000-4-30: PF measurement methodology
  + 1. RT – Avg PF
       1. Definition
* Real-time average power factor of the MCC, representing the overall ratio of active to apparent power across all phases. It reflects how efficiently the MCC uses power as a whole.
  + - 1. Calculation
* Avg PF = Total kW / Total kVA
  + - 1. Acceptable Range
* Same as 2.5.1 (PF ≥ 0.951 lag or lead eligible for incentives)
  + - 1. Warning Range
* Same as 2.5.1 (PF 0.900–0.950 lag or > 0.950 lead)
  + - 1. Critical Range
* Same as 2.5.1 (PF < 0.900 lag or lead)
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Same as 2.5.1
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Same as 2.5.1
  + - 1. Widget Colour Coding (Dashboard)
* Same as 2.5.1
  + - 1. Historical Chart Design
* Trend average PF over time. Mark incentive and penalty zones. Display approximate rebate or surcharge calculated from PF level.
  + - 1. Applicable Standards
* Same as 2.5.1
  + 1. Max Deviation & Max Deviation % on each phase and Average
       1. Definition
* Max Deviation represents the largest difference between any real-time measured phase PF (PF\_R, PF\_Y, PF\_B) and the average PF over a period (shift/day). Max Deviation % expresses this difference as a percentage of the average PF. This metric identifies how much individual phase power factor strayed from overall panel PF, helping detect unbalanced reactive loading, phase-wise correction issues, or failing compensation equipment.
  + - 1. Calculation
* Max Deviation = Maximum absolute value of (PF\_R − Avg PF, PF\_Y − Avg PF, PF\_B − Avg PF)
* Max Deviation % = (Max Deviation / Avg PF) × 100
  + - 1. Example
* If PF\_R = 0.96, PF\_Y = 0.92, PF\_B = 0.98
* Avg PF = (0.96 + 0.92 + 0.98)/3 = 0.953
* Max Deviation = |0.92 − 0.953| = 0.033
* Max Deviation % = (0.033 / 0.953) × 100 ≈ 3.5%
  + - 1. Acceptable Range
* Max Deviation % ≤ 2% (healthy phase PF balance, minimal phase-wise reactive mismatch).
  + - 1. Warning Range
* Max Deviation % > 2% up to 5% (indicates mild phase imbalance or unequal correction).
  + - 1. Critical Range
* Max Deviation % > 5% (significant imbalance; possible failure in phase-wise compensation or uneven load distribution).
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* PF target: 0.99 lag
* Warning threshold: Max Deviation % > 2%
* Critical threshold: Max Deviation % > 5%
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if Max Deviation % exceeds 2% for 2 consecutive payloads.
* Critical alert if Max Deviation % exceeds 5% for 2 consecutive payloads.
* Auto-reset once Max Deviation % returns within 2% in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: Max Deviation % ≤ 2%
* Yellow: Max Deviation % > 2% up to 5%
* Red: Max Deviation % > 5%
  + - 1. Historical Chart Design
* Plot PF\_R, PF\_Y, PF\_B and average PF over time. Overlay Max Deviation % trend line. Highlight periods with imbalance beyond thresholds using yellow or red shading.
  + - 1. Applicable Standards
* IS 7752: Guide for power factor improvement
* CEA Grid Connectivity Regulations: Focus on balanced PF contribution across phases
* IEC 61000-4-30: Methodology for accurate PF measurement
* MERC / MSEDCL Orders: Applicable for evaluating overall PF performance linked to incentives/penalties
  + 1. RT – PF Level with Incentive/Penalty %
       1. Definition
* This metric calculates the PF level category (Excellent, Very Good, Good, Neutral, Low, Very Low, Critical) and determines the applicable incentive or penalty percentage based on the average PF or phase PF values for the shift or day. It enables real-time cost monitoring linked to PF performance for the MCC.
  + - 1. Calculation Logic
* The power factor level and corresponding incentive/penalty % are determined using a defined logic, as below:

If PF > 0.99

→ Level: Excellent

→ Type: Incentive

→ Percent: +1.00% rebate

If PF > 0.98

→ Level: Very Good

→ Type: Incentive

→ Percent: +0.75% rebate

If PF > 0.95

→ Level: Good

→ Type: Incentive

→ Percent: +0.50% rebate

If PF ≥ 0.90

→ Level: Neutral

→ Type: None

→ Percent: 0.00%

If PF ≥ 0.85

→ Level: Low

→ Type: Penalty

→ Percent: −2.00% surcharge

If PF ≥ 0.80

→ Level: Very Low

→ Type: Penalty

→ Percent: −5.00% surcharge

If PF < 0.80

→ Level: Critical

→ Type: Penalty

→ Percent: −10.00% surcharge

* The above logic is applied independently to:

1. PF\_R → R\_PF\_INFO
2. PF\_Y → Y\_PF\_INFO
3. PF\_B → B\_PF\_INFO
4. Average PF → AVG\_PF\_INFO

Where each \*\_PF\_INFO includes level, type, percent.

Example

If average PF = 0.93

→ Level: Neutral

→ Type: None

→ Percent: 0%

If PF\_R = 0.88

→ Level: Low

→ Type: Penalty

→ Percent: −2%

If PF\_Y = 0.96

→ Level: Good

→ Type: Incentive

→ Percent: +0.5%

If PF\_B = 0.99

→ Level: Excellent

→ Type: Incentive

→ Percent: +1%

* + - 1. Default Settings for Device Configuration Page – User Input Fields
* PF target: 0.99 lag
* PF surcharge monitoring: Enabled
* PF incentive/penalty table: User editable or default as per logic above
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if PF level drops to Low (PF < 0.90) for 2 consecutive payloads.
* Critical alert if PF level drops to Very Low or Critical (PF < 0.85) for 2 consecutive payloads.
* Auto-reset once PF improves to Neutral or better in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: PF ≥ 0.951 (Good to Excellent, incentive zone)
* Yellow: PF 0.90–0.950 (Neutral zone)
* Red: PF < 0.90 (Penalty zone)
  + - 1. Historical Chart Design
* Plot average and phase-wise PF trends with overlay of incentive and penalty bands. Display applied percent rebate or surcharge at each interval. Annotate PF correction actions (e.g. capacitor bank switching).
  + - 1. Applicable Standards
* IS 7752: Guide for power factor improvement
* CEA Grid Connectivity Regulations: Minimum PF ≥ 0.95
* MERC Order Case No. 322 of 2019 / MSEDCL MYT Order: PF incentive/penalty structure
* IEC 61000-4-30: Methodology for PF measurement
  + 1. Historical Plot – Shift A, B, C/Day/Week/ Date Range
       1. Definition
* A historical trend graph showing the power factor (PF) values for each phase (PF\_R, PF\_Y, PF\_B) and average PF over the selected period (shift, day, week, or custom date range). The plot provides insight into how PF varied over time, highlights periods qualifying for incentives or penalties, and helps assess the effectiveness of PF correction equipment.
  + - 1. Calculation
* Plot PF\_R, PF\_Y, PF\_B, and average PF at each recorded interval. Overlay the incentive/penalty bands as horizontal zones (for example, >0.95 = green incentive zone, 0.90–0.95 = yellow neutral zone, <0.90 = red penalty zone). Annotate events like capacitor bank switching, major load changes, or PF correction activations where data is available.
  + - 1. Acceptable Range
* Average and phase PF values ≥ 0.951 (incentive zone).
  + - 1. Warning Range
* Average and phase PF values between 0.90 and 0.950 (neutral zone, no incentive or penalty).
  + - 1. Critical Range
* Average and phase PF values < 0.90 (penalty zone as per MERC / MSEDCL orders and uploaded images).
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Same PF bands and surcharge/incentive values as configured in 2.5.4.
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Same logic as 2.5.4, applied across historical data to flag intervals where sustained PF deterioration or improvement occurred.
  + - 1. Widget Colour Coding (Dashboard)
* Green band: PF ≥ 0.951 (incentive eligible)
* Yellow band: PF 0.90–0.950 (neutral, no surcharge or rebate)
* Red band: PF < 0.90 (penalty applicable)
  + - 1. Historical Chart Design
* Line plot for PF\_R, PF\_Y, PF\_B, and average PF over time. Highlight incentive zones (green shading), neutral zones (yellow shading), and penalty zones (red shading). Include optional bar or annotation for surcharge or incentive % at each interval. Provide selectable views: Shift-wise, daily, weekly, or custom date range.
  + - 1. Applicable Standards
* IS 7752: Guide for power factor improvement
* CEA Grid Connectivity Regulations: Power factor maintenance obligations
* MERC Order Case No. 322 of 2019: PF penalty rates
* MSEDCL MYT Order FY 2020-21 to FY 2024-25: PF incentive rates
* IEC 61000-4-30: Power quality measurement methodology
  1. **Apparent Power (kVA), Active Power (KW), Reactive Power (kVAr)**
     1. RT – R, Y, B each phase
        1. Definition
* Real-time measurement of the apparent power (kVA), active power (kW), and reactive power (kVAr) supplied by each phase (R, Y, B) of the MCC to electrical machines or motors.
* Active power (kW) reflects the real work done (e.g. shaft power, heat, lighting).
* Reactive power (kVAr) represents the energy exchanged between the source and inductive/capacitive elements (e.g. magnetization of motors).
* Apparent power (kVA) is the vector sum of active and reactive power and indicates total capacity drawn.
  + - 1. Calculation
* For each phase:
* kVA\_phase = V\_phase × I\_phase / 1000
* kW\_phase = kVA\_phase × PF\_phase
* kVAr\_phase = √ (kVA\_phase² - kW\_phase²)
* Where V\_phase and I\_phase are real-time phase voltage and current (RMS), PF\_phase is real-time phase power factor.
  + - 1. Acceptable Range
* kVA, kW, and kVAr per phase ≤ rated capacity of feeder, breaker, or motor (per IS/IEC nameplate or protection setting).
* Motor efficiency optimum when kW within 70%-90% rated motor load (IS 12615).
  + - 1. Warning Range
* Per phase kVA/kW between 100% and 110% rated capacity (overload margin typical for motors and feeders for short duration).
* kVAr unusually high compared to kW → possible power factor < 0.9 (reactive burden).
  + - 1. Critical Range
* Per phase kVA/kW > 110% rated (sustained overload, motor overheating risk).
* Excessive kVAr (PF < 0.85) indicating severe reactive draw.
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Rated kW/kVA per feeder or motor (user input or system default).
* Warning threshold: >100% rated kVA/kW
* Critical threshold: >110% rated kVA/kW
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if any phase kW or kVA >100% rated for 2 consecutive payloads.
* Critical alert if >110% rated for 2 consecutive payloads.
* Auto-reset when load returns within limits in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: kVA/kW ≤ 100% rated
* Yellow: >100% up to 110% rated
* Red: >110% rated
  + - 1. Historical Chart Design
* Bar or line plot per phase showing kW, kVAr, and kVA trends. Overlay rated capacity as reference line. Highlight overload periods (yellow/red).
  + - 1. Applicable Standards
* IS 12615: Motor efficiency and load guidelines
* IEC 60034-1: Rotating machinery load and capacity
* IS/IEC 60947-1: Switchgear rated load handling
* IEC 61000-4-30: Power quality power measurements
  + 1. RT – Total
       1. Definition

Real-time total apparent power (kVA), active power (kW), and reactive power (kVAr) drawn by the MCC panel across all phases combined. Indicates overall machine and panel loading.

* + - 1. Calculation

Total kVA = √3 × V\_L-L × I\_avg / 1000

Total kW = Σ(kW\_R + kW\_Y + kW\_B)

Total kVAr = Σ(kVAr\_R + kVAr\_Y + kVAr\_B)

* + - 1. Acceptable Range

Same as 2.6.1: total load ≤ rated MCC / transformer / contract demand capacity.

* + - 1. Warning Range

Total kVA/kW >100% up to 110% rated capacity.

* + - 1. Critical Range

Total kVA/kW >110% rated capacity.

* + - 1. Default Settings for Device Configuration Page – User Input Fields

Rated total kVA/kW (user input from system contract or MCC rating).

* + - 1. Alert Behaviour (Based on SPP Payloads)

Warning alert if total kVA/kW >100% rated for 2 consecutive payloads.

Critical alert if >110% rated for 2 consecutive payloads.

Auto-reset when load returns within limits in latest payload.

* + - 1. Widget Colour Coding (Dashboard)

Same as 2.6.1

* + - 1. Historical Chart Design

Plot total kVA, kW, kVAr trends over time. Overlay rated capacity lines. Highlight periods exceeding thresholds.

* + - 1. Applicable Standards

Same as 2.6.1

* + 1. Historical Plot – Shift A, B, C/Day/Week/ Date Range
       1. Definition
* Historical chart showing apparent power (kVA), active power (kW), and reactive power (kVAr) trends for the MCC across selected periods (shift, day, week, or custom date range). This plot helps analyze electrical machine loading, efficiency, and reactive burden over time.
  + - 1. Calculation

For each recorded interval:

* kVA = √3 × V\_L-L × I\_avg / 1000
* kW = Σ(kW\_R + kW\_Y + kW\_B)
* kVAr = Σ(kVAr\_R + kVAr\_Y + kVAr\_B)
  + - 1. Plot Design
* Display two bars side-by-side for each interval:
* Left bar = Total kVA (apparent power drawn)
* Right bar = Stacked bar:

1. Bottom segment = kW (useful active power)
2. Top segment = kVAr (wasteful reactive power)

* This arrangement allows immediate visual comparison of total power supplied (kVA) versus its breakdown into active and reactive components. A taller kVAr stack shows inefficiency and possible PF correction needs.
  + - 1. Acceptable Range
* Total kVA and kW ≤ rated capacity (MCC / machine / transformer)
* Active power ideally 70%–90% of rated machine load for optimal efficiency (IS 12615)
  + - 1. Warning Range
* kVA or kW >100% up to 110% rated
* Large kVAr portion (>25% of kVA)
  + - 1. Critical Range
* kVA or kW >110% rated
* Excessive kVAr burden (>40% of kVA, indicates very low PF or compensation failure)
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Rated kVA / kW capacity for MCC or machine
* Warning threshold for kVA/kW >100%
* Critical threshold for kVA/kW >110%
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if total kVA or kW >100% rated for 2 consecutive payloads or if reactive power >25% of kVA.
* Critical alert if total kVA or kW >110% rated or reactive power >40% of kVA for 2 consecutive payloads.
* Auto-reset once values return within limits in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: kVA and kW ≤ 100% rated, kVAr portion <25%
* Yellow: kVA/kW >100% up to 110% or kVAr 25%–40%
* Red: kVA/kW >110% or kVAr >40%
  + - 1. Historical Chart Notes
* Allow user to filter by shift, day, week, custom date.
* Enable tooltips showing exact kVA, kW, kVAr values and percentages.
* Optionally annotate capacitor bank operations or significant load events.
  + - 1. Applicable Standards
* IS 12615: Motor efficiency, loading, and reactive power guidelines
* IEC 60034-1: Rated performance limits of rotating machines
* IS/IEC 60947-1: Switchgear load handling
* IEC 61000-4-30: Power measurement methodologies
  1. **Energy Consumption with ToD Slots** 
     1. RT – Total & per phase – kWh, kVArh, kVAh
        1. Definition
* Real-time accumulated measurement of energy consumption by the MCC panel:
* kWh (kilowatt-hours): Active energy consumed by machines, representing useful work done.
* kVArh (kilovolt-ampere reactive hours): Reactive energy associated with inductive/capacitive loads, representing wasted or circulating power.
* kVAh (kilovolt-ampere hours): Apparent energy supplied, combining both active and reactive components.
* Values are provided both per phase (R, Y, B) and totalized across phases.
  + - 1. Calculation
* Per phase:
* kWh\_phase = ∫ (kW\_phase) dt
* kVArh\_phase = ∫ (kVAr\_phase) dt
* kVAh\_phase = ∫ (kVA\_phase) dt
  + - 1. Total:
* kWh\_total = Σ(kWh\_R + kWh\_Y + kWh\_B)
* kVArh\_total = Σ(kVArh\_R + kVArh\_Y + kVArh\_B)
* kVAh\_total = Σ(kVAh\_R + kVAh\_Y + kVAh\_B)
* Energy is integrated over time from real-time power values as per IEC 61000-4-30.
  + - 1. Acceptable Range
* Cumulative kWh, kVArh, and kVAh should align with expected machine duty cycles and rated capacities. For example, kWh reflecting machine load within 70%–90% of rated over typical shift.
  + - 1. Warning Range
* Energy accumulation rate indicates sustained load >100% rated machine capacity.
* High kVArh accumulation relative to kWh (>25%) — signals poor PF over time.
  + - 1. Critical Range
* Sustained load >110% rated capacity (from accumulated kWh trend).
* Very high kVArh (>40% of kVAh) — severe reactive burden.

Default Settings for Device Configuration Page – User Input Fields

* Rated kWh / kVAh consumption per shift/day (user input or calculated from machine capacity).
* Warning threshold: >100% expected energy use
* Critical threshold: >110% expected energy use
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if accumulated kWh or kVAh exceeds 100% of expected load for 2 consecutive payloads.
* Critical alert if exceeds 110% of expected load or kVArh exceeds 40% of kVAh for 2 consecutive payloads.
* Auto-reset once energy trends return within acceptable levels in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: Energy trends within expected capacity, kVArh <25% of kVAh
* Yellow: Slight overload or kVArh 25%–40% of kVAh
* Red: Overload >110% or kVArh >40% of kVAh
  + - 1. Historical Chart Design
* Plot cumulative kWh, kVArh, and kVAh over time. Allow per-phase or total view toggle. Optionally display kVArh as % of kVAh to visualize reactive burden.
  + - 1. Applicable Standards
* IS 12615: Energy efficiency and load guidelines for motors
* IEC 60034-1: Energy consumption standards for electrical machines
* IS/IEC 60947-1: Load and energy monitoring for switchgear
* IEC 61000-4-30: Energy measurement methodology
  + 1. Historical XY Plot – Shift A, B, C/Day/Week/ Date Range
       1. Definition
* A historical chart showing accumulated energy consumption trends for kWh, kVArh, and kVAh over selectable periods (shift, day, week, or custom date range). This plot provides insights into machine energy usage patterns, efficiency, and reactive power burden over time.
  + - 1. Calculation
* Cumulative kWh = ∫ active power (kW) dt
* Cumulative kVArh = ∫ reactive power (kVAr) dt
* Cumulative kVAh = ∫ apparent power (kVA) dt
* Data points plotted at each payload interval (e.g., 5-minute or 15-minute sampling).
  + - 1. Plot Design
* XY plot with time on X-axis and energy values on Y-axis.
  + - 1. Plot separate lines for:
* kWh (active energy, useful work)
* kVArh (reactive energy, wasted power)
* kVAh (total apparent energy drawn)
* Optionally display stacked or grouped bar sections for shift-wise totals.
* Allow toggling per phase or total energy view.
  + - 1. Acceptable Range
* Energy trends align with machine rated duty and load profile (70%–90% rated capacity as target).
  + - 1. Warning Range
* Accumulated energy reflects sustained load >100% rated capacity.
* kVArh exceeds 25% of kVAh (reactive burden).
  + - 1. Critical Range
* Accumulated energy reflects sustained load >110% rated capacity.
* kVArh exceeds 40% of kVAh (severe reactive burden).
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Rated daily/shift kWh, kVArh, kVAh (user input or computed from rated machine load and expected duty cycle).
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if energy accumulation rate indicates >100% rated capacity or kVArh >25% of kVAh for 2 payloads.
* Critical alert if >110% rated capacity or kVArh >40% of kVAh for 2 payloads.
* Auto-reset when energy accumulation trends return within limits.
  + - 1. Widget Colour Coding (Dashboard)
* Green: kWh, kVAh within expected capacity; kVArh <25% of kVAh
* Yellow: Slight overload or kVArh 25%–40%
* Red: Overload >110% or kVArh >40%
  + - 1. Historical Chart Design
* Clear time-based trends for energy consumption
* Highlight periods where thresholds were exceeded using colour bands
* Annotate load peaks or reactive spikes
* Allow drill-down: shift → day → week
  + - 1. Applicable Standards
* IS 12615: Motor energy efficiency and load guidance
* IEC 60034-1: Load and energy limits for electrical machines
* IS/IEC 60947-1: Load monitoring and protection
* IEC 61000-4-30: Energy measurement accuracy
  1. **Maximum Demand**
     1. Each Phase kW, kVA, kVAr – Interval 🡪Shift / Day
        1. Definition

Maximum Demand (MD) represents the highest average power recorded over a specified sliding interval (e.g. 15 or 30 minutes) during the selected period (shift, day, or week). It identifies the peak load conditions per phase, critical for managing demand charges, preventing overloading, and ensuring electrical machine and MCC safety.

* + - 1. Calculation

For each phase:

* MD kW\_phase = highest average active power over interval
* MD kVA\_phase = highest average apparent power over interval
* MD kVAr\_phase = highest average reactive power over interval
* These are typically computed as moving window averages (e.g. 15-minute blocks) over the period, as per utility metering standards.
  + - 1. Acceptable Range
* MD kW, kVA per phase ≤ rated capacity of MCC feeder, breaker, or machine.
* kVAr MD in proportion with machine design PF and compensation setup.
  + - 1. Warning Range
* MD kW or kVA >100% up to 110% of rated phase capacity.
  + - 1. Critical Range
* MD kW or kVA >110% of rated phase capacity — sustained peak demand condition, potential risk of overload, overheating, or breach of contract demand.
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Rated kW/kVA per phase (user input or system default from breaker/feeder/machine nameplate data).
* Warning threshold: MD >100% rated
* Critical threshold: MD >110% rated
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if MD exceeds 100% rated for 2 consecutive payloads.
* Critical alert if MD exceeds 110% rated for 2 consecutive payloads.
* Auto-reset once MD drops below thresholds in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: MD ≤100% rated phase capacity
* Yellow: MD >100% up to 110%
* Red: MD >110%
  + - 1. Historical Chart Design
* Bar or line plot showing MD kW, kVA, kVAr per phase over shift/day/week. Mark reference lines for rated capacity. Highlight intervals where thresholds were breached using yellow or red shading. Annotate key load events where available.
  + - 1. Applicable Standards
* IS 12615: Load handling and efficiency guidance for motors
* IEC 60034-1: Rated operational limits for rotating machines
* IS/IEC 60947-1: Switchgear and control gear rated capacity
* Utility metering standards for MD (e.g. as per contract demand and billing norms)
* IEC 61000-4-30: Power measurement methodology
  + 1. Total MD - Interval 🡪Shift / Day
       1. Definition
* Total Maximum Demand (MD) represents the highest average total load (kW, kVA, kVAr) drawn by the MCC across all phases over a specified sliding interval (e.g. 15 or 30 minutes) during a shift or day. It reflects the peak overall demand on the system, critical for managing demand charges, transformer loading, and ensuring protection coordination.
  + - 1. Calculation
* MD kW (total) = highest sliding interval average of Σ(kW\_R + kW\_Y + kW\_B)
* MD kVA (total) = highest sliding interval average of Σ(kVA\_R + kVA\_Y + kVA\_B)
* MD kVAr (total) = highest sliding interval average of Σ(kVAr\_R + kVAr\_Y + kVAr\_B)
* Sliding interval typically aligned with utility metering (15 or 30 minutes).
  + - 1. Acceptable Range
* MD kW and kVA ≤ rated MCC bus capacity, transformer capacity, or contract demand (if applicable).
  + - 1. Warning Range
* MD kW or kVA >100% up to 110% of rated capacity.
  + - 1. Critical Range
* MD kW or kVA >110% of rated capacity — sustained high peak load that may breach contract demand or overload supply equipment.
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* Rated total kW / kVA (user input or derived from MCC / transformer / contract capacity).
* Warning threshold: MD >100% rated
* Critical threshold: MD >110% rated
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if total MD exceeds 100% rated capacity for 2 consecutive payloads.
* Critical alert if total MD exceeds 110% rated capacity for 2 consecutive payloads.
* Auto-reset when MD returns within thresholds in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: MD ≤100% rated
* Yellow: MD >100% up to 110%
* Red: MD >110%
  + - 1. Historical Chart Design
* Plot total MD (kW, kVA, kVAr) trend over shift/day. Overlay rated capacity as reference line. Highlight yellow/red intervals where thresholds were breached. Annotate major load events or demand peaks if data available.
  + - 1. Applicable Standards
* IS 12615: Motor load guidelines
* IEC 60034-1: Rated operational limits for machines
* IS/IEC 60947-1: Switchgear rated load handling
* Utility demand metering standards (aligned with contract demand and penalty conditions)
* IEC 61000-4-30: Power measurement accuracy
  1. **Voltage Harmonic Distortion – THD – V**
     1. RT- THD – V %
        1. Definition
* Real-time measurement of Total Harmonic Distortion (THD) of the supply voltage at the MCC, expressed as a percentage of the fundamental voltage (50 Hz in India). THD–V % indicates the level of voltage waveform distortion caused by harmonics (e.g. 3rd, 5th, 7th harmonics) arising from non-linear loads or network conditions. Excessive THD–V can adversely affect electrical machines, leading to heating, torque pulsations, and premature failure.
  + - 1. Calculation
* THD–V % = (√(Σ Vn² for n ≥ 2)) / V1 × 100
* Where V1 = RMS value of fundamental voltage (50 Hz),
* Vn = RMS value of nth harmonic voltage
* Measured as per IEC 61000-4-30 (Class A power quality methodology).
  + - 1. Acceptable Range
* THD–V % ≤ 5% (recommended by IEEE 519 and IEC standards for LV systems supplying motors and sensitive equipment).
  + - 1. Warning Range
* THD–V % > 5% up to 8% (may begin to affect motor life, cause excess heating, and increase vibration).
  + - 1. Critical Range
* THD–V % > 8% (significant risk to motors: overheating, torque ripple, nuisance tripping, and accelerated insulation ageing).
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* THD–V target: ≤ 5%
* Warning threshold: >5% THD–V
* Critical threshold: >8% THD–V
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if THD–V exceeds 5% for 2 consecutive payloads.
* Critical alert if THD–V exceeds 8% for 2 consecutive payloads.
* Auto-reset once THD–V returns within acceptable limit in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: THD–V ≤ 5%
* Yellow: THD–V > 5% up to 8%
* Red: THD–V > 8%
  + - 1. Historical Chart Design
* Plot THD–V % trend over time. Highlight yellow/red periods when voltage distortion exceeded thresholds. Annotate major harmonic events if data available (e.g. large non-linear load start).
  + - 1. Key Insights for MCC & Electrical Machine Performance
* THD–V > 5% can cause additional losses in motors, raising operating temperature by ~10–15% (impacting life expectancy).
* THD–V > 8% can result in visible torque pulsations in motors, creating mechanical stress and potential alignment issues.
* Persistent high THD–V can degrade motor insulation faster, increasing maintenance costs and downtime.
* Harmonics can also interfere with control circuits, sensors, and protection devices connected to the MCC.
  + - 1. Applicable Standards
* IEEE 519: Recommended voltage THD limit ≤ 5% for LV systems
* IEC 61000-4-30: Methodology for THD measurement
* IS/IEC 60034-1: Motor performance tolerance with distorted supply
* IS 12615: Motor energy efficiency affected by harmonic distortion
  + 1. Avg THD–V %
       1. Definition
* The average Total Harmonic Distortion of voltage (THD–V %) over a selected period (e.g. shift, day, week). This metric reflects the sustained level of voltage waveform distortion experienced by the MCC and its connected machines during operations. It provides a clearer picture of ongoing power quality, beyond momentary disturbances.
  + - 1. Calculation
* Avg THD–V % = Mean of THD–V % values recorded at each payload interval during the selected period
* Where THD–V % at each point = (√(Σ Vn² for n ≥ 2)) / V1 × 100
  + - 1. Acceptable Range
* Avg THD–V % ≤ 5% (consistent with IEEE 519 and IEC recommendations for LV systems supplying motors and sensitive loads).
  + - 1. Warning Range
* Avg THD–V % > 5% up to 8% (indicates sustained exposure to distortion that may impact motor efficiency and reliability).
  + - 1. Critical Range
* Avg THD–V % > 8% (high risk of cumulative motor heating, torque instability, and premature failure).
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* THD–V target: ≤ 5%
* Warning threshold: Avg THD–V > 5%
* Critical threshold: Avg THD–V > 8%
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if average THD–V exceeds 5% over 2 or more consecutive payloads (sustained poor power quality).
* Critical alert if average THD–V exceeds 8% over 2 or more consecutive payloads.
* Auto-reset when average THD–V returns within acceptable range in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: Avg THD–V ≤ 5%
* Yellow: Avg THD–V > 5% up to 8%
* Red: Avg THD–V > 8%
  + - 1. Historical Chart Design
* Plot average THD–V % trend across shift, day, or week. Use colour shading to indicate warning or critical levels. Compare against target reference line (5% limit).
  + - 1. Key Insights for MCC & Electrical Machine Performance
* Sustained Avg THD–V > 5% increases core and copper losses in motors by 5–10%, reducing efficiency.
* Prolonged exposure above 8% can degrade insulation and bearings due to additional vibration from torque ripple.
* High Avg THD–V can result in frequent malfunctions of electronic controllers and protective relays.
  + - 1. Applicable Standards
* IEEE 519: Average voltage THD limit ≤ 5% for LV systems
* IEC 61000-4-30: Method for computing average THD
* IS/IEC 60034-1: Motor behaviour with harmonic-distorted supply
* IS 12615: Energy efficiency implications under harmonic distortion
  + 1. Max Deviation
       1. Definition
* The maximum deviation of voltage THD % recorded during a shift or day. It reflects the peak distortion event compared to the normal supply condition, highlighting the worst harmonic stress the MCC and connected machines experienced during the period.
  + - 1. Calculation
* Max Deviation THD–V % = Highest recorded THD–V % during the period − Average THD–V %
* Alternatively, Max THD–V % value itself can be tracked for direct comparison to thresholds.
  + - 1. Acceptable Range
* Max Deviation THD–V % ≤ 3% above average (consistent power quality, minor transients).
* Max THD–V ≤ 5% (IEEE 519 recommended limit for LV systems).
  + - 1. Warning Range
* Max Deviation THD–V % > 3% up to 6% above average
* Max THD–V > 5% up to 8%
  + - 1. Critical Range
* Max Deviation THD–V % > 6% above average
* Max THD–V > 8% (significant harmonic disturbance, risk to machine reliability).
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* THD–V target: ≤ 5%
* Warning threshold: Max Deviation > 3% from average or Max THD–V > 5%
* Critical threshold: Max Deviation > 6% from average or Max THD–V > 8%
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if max deviation exceeds 3% above average or Max THD–V > 5% in 2 consecutive payloads.
* Critical alert if max deviation exceeds 6% above average or Max THD–V > 8% in 2 consecutive payloads.
* Auto-reset when THD–V deviation or Max THD–V returns within thresholds in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: Max Deviation ≤ 3% above average or Max THD–V ≤ 5%
* Yellow: Max Deviation > 3% up to 6% or Max THD–V > 5% up to 8%
* Red: Max Deviation > 6% or Max THD–V > 8%
  + - 1. Historical Chart Design
* Plot Max THD–V events over time alongside average THD–V. Annotate spikes exceeding thresholds. Highlight with yellow or red markers depending on severity.
* Key Insights for MCC & Electrical Machine Performance
* Large deviation events indicate transients that could stress motor windings and cause vibration.
* Even brief THD–V spikes > 8% can trigger nuisance trips of sensitive drives or controllers.
* Frequent large deviations suggest need for harmonic mitigation (e.g. filters).
  + - 1. Applicable Standards
* IEEE 519: Max THD–V limit ≤ 5% recommended
* IEC 61000-4-30: Methods for recording max THD events
* IS/IEC 60034-1: Harmonic supply impact on motor performance
  1. **Current Harmonic Distortion – THD – I**
     1. RT- THD – I %
        1. Definition
* Real-time measurement of Total Harmonic Distortion of current (THD–I %) at the MCC. It represents the level of current waveform distortion caused by non-linear loads (such as VFDs, soft starters, rectifiers, LED lighting) connected to the MCC. Excessive THD–I % can lead to additional heating in motors, cables, transformers, and can reduce equipment life.
  + - 1. Calculation
* THD–I % = (√(Σ In² for n ≥ 2)) / I1 × 100
* Where I1 = RMS value of fundamental current (50 Hz),
* In = RMS value of nth harmonic current
* Measured using IEC 61000-4-30 Class A power quality monitoring method.
  + - 1. Acceptable Range
* THD–I % ≤ 8% (for strong systems with high short-circuit capacity as per IEEE 519 typical planning levels for industrial MCCs).
  + - 1. Warning Range
* THD–I % > 8% up to 15% (may cause elevated losses and heating).
  + - 1. Critical Range
* THD–I % > 15% (high risk of transformer overheating, excessive losses, nuisance tripping, neutral conductor overload where applicable).
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* THD–I target: ≤ 8%
* Warning threshold: >8% THD–I
* Critical threshold: >15% THD–I
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if THD–I exceeds 8% for 2 consecutive payloads.
* Critical alert if THD–I exceeds 15% for 2 consecutive payloads.
* Auto-reset once THD–I returns within acceptable limit in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: THD–I ≤ 8%
* Yellow: THD–I > 8% up to 15%
* Red: THD–I > 15%
  + - 1. Historical Chart Design
* Plot THD–I % trend over time. Highlight periods exceeding warning or critical thresholds in yellow/red. Annotate large load switch-on events or harmonic-producing equipment activity if data available.
  + - 1. Key Insights for MCC & Electrical Machine Performance
* THD–I > 8% increases I²R losses in cables and transformers, reducing efficiency and increasing operating costs.
* THD–I > 15% can cause thermal overload of neutral conductors (especially with triplen harmonics).
* Motors exposed to high THD–I supply currents may experience additional copper losses and vibration, shortening life.
* High THD–I may interfere with protection devices, causing false trips or failure to trip when required.
  + - 1. Applicable Standards
* IEEE 519: Recommended limits for current distortion at point of common coupling (≤8% for typical systems)
* IEC 61000-4-30: Power quality measurement standard
* IS 12615 / IEC 60034-1: Impact of supply current harmonics on motor life
  + 1. Avg THD – I %
       1. Definition
* The average Total Harmonic Distortion of current (THD–I %) over a selected period (shift, day, week). This metric indicates the sustained level of current waveform distortion affecting the MCC and its connected machines during operations. Average THD–I provides insight into the typical harmonic load profile rather than just transient peaks.
  + - 1. Calculation
* Avg THD–I % = Mean of THD–I % values recorded at each payload interval during the selected period
* Where THD–I % = (√(Σ In² for n ≥ 2)) / I1 × 100
  + - 1. Acceptable Range
* Avg THD–I % ≤ 8% (recommended planning level for LV industrial systems by IEEE 519).
  + - 1. Warning Range
* Avg THD–I % > 8% up to 15% (sustained harmonic current levels that can increase heating and losses).
  + - 1. Critical Range
* Avg THD–I % > 15% (indicates persistent high harmonic burden that can damage cables, transformers, and motors).
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* THD–I target: ≤ 8%
* Warning threshold: Avg THD–I > 8%
* Critical threshold: Avg THD–I > 15%
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if average THD–I exceeds 8% for 2 consecutive payloads.
* Critical alert if average THD–I exceeds 15% for 2 consecutive payloads.
* Auto-reset once average THD–I returns within acceptable range in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: Avg THD–I ≤ 8%
* Yellow: Avg THD–I > 8% up to 15%
* Red: Avg THD–I > 15%
  + - 1. Historical Chart Design
* Plot average THD–I % over time. Overlay yellow/red shading where sustained distortion exceeded thresholds. Provide option to correlate with equipment operation cycles (e.g. VFD operation periods).
  + - 1. Key Insights for MCC & Electrical Machine Performance
* High Avg THD–I % indicates persistent harmonic load, leading to continuous additional losses and transformer derating.
* Motors may operate hotter under sustained high THD–I, reducing insulation life.
* Long-term high Avg THD–I stresses protection devices, increasing risk of nuisance tripping or failure to operate.
* Persistent high harmonics can signal the need for harmonic filters or multi-pulse drive upgrades.
  + - 1. Applicable Standards
* IEEE 519: Recommended current distortion limits for sustained conditions
* IEC 61000-4-30: Average THD measurement methodology
* IS 12615 / IEC 60034-1: Motor performance impact of harmonics
  + 1. Max Deviation
       1. Definition
* The maximum deviation of current THD % recorded during a shift or day. It represents the peak distortion event relative to the average THD–I %, identifying the worst harmonic current stress that the MCC and connected machines experienced in the period.
  + - 1. Calculation
* Max Deviation THD–I % = Highest recorded THD–I % during the period − Average THD–I %
* Alternatively, track Max THD–I % as the absolute highest distortion event.
  + - 1. Acceptable Range
* Max Deviation THD–I % ≤ 5% above average (minor harmonic fluctuations typical in industrial settings).
* Max THD–I ≤ 8% (within IEEE 519 recommended planning level).
  + - 1. Warning Range
* Max Deviation THD–I % > 5% up to 10% above average
* Max THD–I > 8% up to 15%
  + - 1. Critical Range
* Max Deviation THD–I % > 10% above average
* Max THD–I > 15% (high distortion spike posing risk to MCC components and connected equipment).
  + - 1. Default Settings for Device Configuration Page – User Input Fields
* THD–I target: ≤ 8%
* Warning threshold: Max deviation > 5% above average or Max THD–I > 8%
* Critical threshold: Max deviation > 10% above average or Max THD–I > 15%
  + - 1. Alert Behaviour (Based on SPP Payloads)
* Warning alert if max deviation exceeds 5% above average or Max THD–I > 8% for 2 consecutive payloads.
* Critical alert if max deviation exceeds 10% above average or Max THD–I > 15% for 2 consecutive payloads.
* Auto-reset once deviation or Max THD–I returns within thresholds in latest payload.
  + - 1. Widget Colour Coding (Dashboard)
* Green: Max Deviation ≤ 5% above average or Max THD–I ≤ 8%
* Yellow: Max Deviation > 5% up to 10% or Max THD–I > 8% up to 15%
* Red: Max Deviation > 10% or Max THD–I > 15%
  + - 1. Historical Chart Design
* Plot Max THD–I % events over time alongside average THD–I %. Annotate periods where spikes exceeded thresholds. Highlight events in yellow or red based on severity.
  + - 1. Key Insights for MCC & Electrical Machine Performance
* Large Max Deviation THD–I % events can signal VFD switching issues, load imbalance, or sudden large non-linear load connection.
* High spikes contribute disproportionately to heating and stress on transformers, cables, and motor windings.
* Frequent large deviations may require review of harmonic mitigation (e.g. filter tuning, load sequencing).
  + - 1. Applicable Standards
* IEEE 519: Limits for short-term and individual harmonic distortion
* IEC 61000-4-30: Method for recording maximum harmonic events
* IS 12615 / IEC 60034-1: Motor performance under harmonic supply

## Individual Electrical Machine – Derived KPI’s & Analytics

* 1. Real-Time Machine Load %
  2. Machine Average Load (HP, kW, kVA)
  3. Machine Peak Load / demand
  4. Max Deviation Analysis
  5. Inrush Current Analysis
  6. Load vs Idle Current Analysis
  7. Load Imbalance (%)
  8. Machine Load Factor %
  9. Energy Losses Estimation (PCC-MCC Panel, MCC – Machine Terminal)
  10. Machine Losses Estimation
  11. Machine Energy Consumption Analysis – ToD / Shift
  12. Machine Energy Cost Estimation (Only Approx. Energy Charges)
  13. PF Level Analysis
  14. V & I unbalance Analysis
  15. Phase Reversal or Missing Phase Alerts
  16. Energy Balance (EnB) Analysis – (HT-LT-PCC-MCC- Machine)
  17. Deviation from Baseline Consumption (ISO 50001 compliance)
  18. Total Harmonic Distortion (THD- V & I)
  19. Average Voltage Harmonic Distortion – THD – V
  20. Average Current Harmonic Distortion – THD – I
  21. Machine Operating Time Matrix (Machine Off / No-Load/ Idle/ ¼th / Half / ¾th / Full Load) Analytics
  22. Duration and depth of voltage dips (Monitoring for voltage sags during machine startup or load switching)
  23. On-Off Cycles
  24. Sudden Load Surges
  25. EEPI – Enterprise Electricity Performance Index (Enterprise Score)
  26. Comparison Analytics – Data & Charts – Current Data with Historical Data
  27. Inrush Current Analysis
  28. Machine Efficiency %
  29. Energy Loss per Machine
  30. Total Harmonic Distortion (THD)
  31. V & I Unbalance
  32. Load factor %
  33. Load Imbalance (%)
  34. Machine Energy Consumption (kWh)
  35. Energy Charges
  36. Power Factor (PF) Analytics
  37. THD