BUS2000 Busbar Differential Protection System

Differential overcurrent system with percentage restraint protection
Typical Busbar Arrangements

- Single Busbar
- Double Busbar with Coupler
- Breaker and a Half
- Double Breaker
- Double Busbar with Transfer Bar
- Segregated Busbars with Coupler
Typical Single Busbar Arrangement
Typical Double Busbar with Coupler Arrangement
Typical Breaker and a Half Arrangement
Typical Double Breaker Busbar Arrangement
Typical Double Busbar with Transfer Bar

![Diagram of a typical double busbar with a transfer bar.](image)
Typical Segregated Busbar with Coupler
Types of Protection Schemes

– Low Impedance
– High Impedance
  • Medium Values
  • High Values
Low Impedance Protection

IDEAL CT’S

OVERCURRENT RELAY

\[ \Delta i = 0 \]
Saturation of the Auxiliary CTs

- A. Primary Fault Current
- B. Secondary Current from the Source CTs
- C. Secondary Current in the Faulty CT
- D. Differential Current
Low Impedance Protection
Current Detection + Second Criteria

– Time-delayed Overcurrent Relays
– Directional Overcurrent Relays
– Restraint Overcurrent relays
– CT Saturation Detectors
High Impedance Protection Scheme
High Impedance Protection

- $V_R = I_F \times (2R_L + R_S)$
- $V_{OP} > V_R$ Stability Criteria
- $V_S > V_{OP}$ Operation Criteria
- $TI_3$ Totally Saturated
- $R_S$ CT Secondary Winding R Value

WHERE:
- $R_L =$ CONNECTION WIRES RESISTANCE
- $I_F =$ SECONDARY RMS CURRENT VALUE IN $TI_3$
- $V_R =$ DIFFERENTIAL RELAY VOLTAGE
- $V_S =$ CT MINIMUM SATURATION VOLTAGE
- $V_{OP} =$ OPERATION VOLTAGE
Differential Overcurrent Relay with Percentage Restraint & Stabilizing Resistor

\[ I_{op} = \text{Operating current} \]
\[ I_{op} > I_d - K I_f \quad \text{Operating criteria} \]
\[ I_f = \text{Restraint current} \]
\[ I_{re} > R_{max} \frac{(1 - K)}{2K} \quad \text{Stability criteria} \]
\[ I_d = \text{Differential current} \]
\[ K = \text{Restraint percentage} \]
\[ R_{re} = \text{Stabilizing resistance} \]
\[ R_{max} = \text{Maximum secondary resistance of the saturated circuit} \]
BUS2000-External Fault
BUS2000-Internal Fault
BUS2000 - Differential Unit Block Diagram
BUS2000-Sensitivity Algorithm

WHERE:

\[ V_D = I_D \cdot N_{ED} \cdot R_D \]
\[ V_F = I_F \cdot N_{EF} \cdot R_F \]
\[ (V_D - K \cdot V_F) \sqrt{\frac{V_0}{2 \sin(90 - 9T)}} \geq V_0 \]

\[ I_D, N_{ED}, R_D, I_F, N_{EF}, R_F \geq \frac{V_0}{V^2 \sin(90 - 9T)} \]

**TRANSMITTERS RATIO**
**RESISTANCE ON SECONDARY TRANSMITTERS SIDE**
**DIFFERENTIAL VOLTAGE**
**RESTRAINT VOLTAGE**
**LEVEL DETECTOR VOLTAGE (DC)**
**DIFFERENTIAL CURRENT**
**ARITHMETIC SUM OF THE LINE CURRENTS**
**RESTRAINT PERCENTAGE**
**TIME**

\[ I_D - K I_F \geq V_0 \cdot \frac{1}{\sqrt{2 \sin(90 - 9T)}} \cdot \frac{1}{N.R} \]
BUS2000-Sensitivity Algorithm (2)

\[ I_D - KI_F \geq V_0 \cdot \frac{1}{\sqrt{2}} \cdot \frac{1}{\sin (90 - 9T)} \cdot \frac{1}{N \cdot R} \]

\[ V_0 = 0.137 \text{ (vDC)} \]

\[ T = 1.5 \text{ (ms)} \]

\[ N = 0.01 \]

\[ R = 100 \text{ (ohm)} \]

\[ I_D - KI_F \geq 0.1 \quad I_D \geq KI_F + 0.1 \]
BUS2000-Sensitivity Algorithm (3)

\[ I_D \geq K I_F + 0.1 \]

For internal fault: \( I_D = I_F \)

\[ I_D \geq \frac{0.1}{1-K} \]

<table>
<thead>
<tr>
<th>K</th>
<th>Sensitivity in Amps.</th>
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<tbody>
<tr>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>0.6</td>
<td>0.25</td>
</tr>
<tr>
<td>0.7</td>
<td>0.33</td>
</tr>
<tr>
<td>0.8</td>
<td>0.5</td>
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External Fault with CT Saturation
BUS2000-Stability Algorithm

\[ l_D = |l_{fault} - l_x | \]
\[ l_D \cdot R_E = l_x \cdot R_{\text{max}} \]

\[ l_{\text{max,up}} = l_D + l_0 \left( \frac{R_E}{R_{\text{max}}} \right) = l_D \left( 1 + \frac{R_E}{R_{\text{max}}} \right) \]

\[ l_{\text{max,down}} = l_D(1+ \frac{R_E}{R_{\text{max}}}) + l_0 \frac{R_E}{R_{\text{max}}} = l_D \left( 1 + 2 \frac{R_E}{R_{\text{max}}} \right) \]

The relay will trip if:
\[ l_D \geq K \cdot l_f + 0,1 \]
\[ l_0 \leq K \cdot l_0 \left( 1 + 2 \frac{R_E}{R_{\text{max}}} \right) + 0,1 \]
\[ l_D \left[ 1 - K \left( 1 + 2 \frac{R_E}{R_{\text{max}}} \right) \right] \geq 0,1 \]

The relay will not trip if:
\[ l_D \left[ 1 - K \left( 1 + 2 \frac{R_E}{R_{\text{max}}} \right) \right] < 0,1 \]

For more security we can say that the relay will not trip if:
\[ l_D \left[ 1 - K \left( 1 + 2 \frac{R_E}{R_{\text{max}}} \right) \right] < 0 \Rightarrow 1 - K \left( 1 + 2 \frac{R_E}{R_{\text{max}}} \right) < 0 \Rightarrow \]
\[ 1 < K \left( 1 + 2 \frac{R_E}{R_{\text{max}}} \right) \Rightarrow \]
\[ R_{\text{max}} < K \cdot R_{\text{max}} + 2 \cdot K \cdot R_E \Rightarrow \]
\[ R_E \geq \frac{R_{\text{max}} (1 - K)}{2K} \]
BUS2000-Stability Limit

\[ R_E > \frac{R_{\text{MAX}} (1 - K)}{2K} \]

<table>
<thead>
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<th>K</th>
<th>Minimum RE value to keep the stability criteria</th>
</tr>
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<tbody>
<tr>
<td>0.5</td>
<td>( \frac{R_{\text{MAX}}}{2} )</td>
</tr>
<tr>
<td>0.6</td>
<td>( \frac{R_{\text{MAX}}}{3} )</td>
</tr>
<tr>
<td>0.7</td>
<td>( \frac{R_{\text{MAX}}}{4.67} )</td>
</tr>
<tr>
<td>0.8</td>
<td>( \frac{R_{\text{MAX}}}{8} )</td>
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BUS2000-Operation Characteristic

Graph showing the relationship between normalized currents with different values of K, ranging from K=0.5 to K=0.8.
BUS2000-Auxiliary CT. Magnetizing Curve of the Secondary Side
BUS2000-Alarm Unit Block Diagram
Industrial Systems

Breaker Failure
Block Diagram
Numerical Monitoring Module

- Differential and Restraint Currents Metering Information
- Full Human-Machine Interface (Keypad + Graphic Display)
- IRIG-B Time Synchronization
- Alarm Treatment
- Differential Protection Outputs Status
Numerical Monitoring Module (cont)

– Oscillography Waveform Capture
– Event Record
– RS232 or fiber optics Communications
– Configurable I/O
– Undervoltage Supervision
BUS2000-Single Busbar (6 feeders) Differential Protection
BUS2000-Overcurrent and Breaker Failure (5 feeders) Protection
BUS2000-Test Rack
BUS2000-Numerical Monitoring Module
External Connections Diagram of Single Busbar BUS2000 System
BUS2000-Settings

– K for Sensitivity
– K and RE as low as possible
– RE for CT requirements for Overvoltage Conditions
Key Advantages

– Flexibility
– Independent settings for K and RE done in the field without any additional changes
– Wide Setting Range
– Suitable for all kinds of installations
– Measurement Units Supervision
– Current Circuits Supervision
Key Advantages (cont’d)

– Single-Three Phase Breaker Failure
– Test Rack Independent from the protection
– Easy Commissioning (accessible terminal blocks)
– Suitable for updating of old Substations
– Operating Principles well proven in the field
– Numerical Monitoring Module