Broken Rotor Bar Detection by Power and Current Based FFT Analysis

8 Series Mini Paper
The 869 protection relay provides FFT analysis in order to detect failure of the rotor bars. The feature is summarized as follows:

- Increased accuracy detection of cracked or Broken Rotor bars during runtime by an enhanced power based FFT detection. The combination of a voltage and current signature provides a more accurate detection compared to the typical current based algorithm.
- The 869 dynamically evaluates whether to utilize Power or Current based FFT based on the operating conditions.
- The Broken Rotor bar algorithm is automatically blocked during decaying voltage, low motor load, high current balance, motor starting etc. to ensure false alarms are minimized.

A defect in the rotor bar of an induction motor causes the modulation of the stator current. The impact of broken rotor bars to the stator current can be determined by analyzing in the frequency domain - this approach to detect rotor bar failures is typically called a Motor Current Signature Analysis (MCSA).

As mentioned above, there are two methods of detecting the Broken Rotor Bar component in the waveform signature that are implemented in 869 relay:

- **Power Based Coherent Demodulation**: This technique uses multiplication of voltage & current samples thereby shifting the fundamental to DC & fault frequency closer to the DC value. This method is automatically selected when the voltage is wired and the measurement is above the configured threshold.

- **Conventional current based FFT**: In the case when voltage is not available or voltage magnitude is lower than threshold setting value, the algorithm switches to analyzing the frequency spectrum from current samples only.

The spectral components due to broken rotor bars can be expressed as: \( fb = (1 \pm 2s)f_1 \). The lower component is due to broken bars, and upper one is due to a related speed oscillation. Since the broken rotor bar disturbances are of an “impulse nature”, the broken rotor bar spectral components can be expressed more accurately as:

\[
fs = (1 \pm 2k_s)f_1, \text{ where } k = 1, 2, 3...
\]

The amplitude of harmonic spectral components due to rotor bar defects, where \( k \geq 2 \), are dependent of the geometry of the fault. Their amplitude is significantly lower than the “main” sidebar component and can be ignored.

Below figure shows the frequency spectrum of a Motor with a Broken Rotor Bar:

*Note the waveform has been loaded into MatLab for analysis.*
Below are test results to illustrate the sweeping frequency window setting in an 869 relay to find the component level measured due to a single broken bar in a motor, at a given load:

<table>
<thead>
<tr>
<th>START OF BRB SIDEBAND (HZ)</th>
<th>END OF BRB SIDEBAND (HZ)</th>
<th>LOAD (XFLA)</th>
<th>COMPONENT LEVEL (DB)</th>
<th>COMPONENT FREQUENCY (HZ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>0.91</td>
<td>-76.9</td>
<td>51.29</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>0.92</td>
<td>-78.3</td>
<td>52.79</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>0.92</td>
<td>-82.8</td>
<td>54.01</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>0.93</td>
<td>-81.9</td>
<td>54.62</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>0.93</td>
<td>-56.0</td>
<td>55.85</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>0.95</td>
<td>-74.3</td>
<td>56.10</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>0.96</td>
<td>-79.4</td>
<td>57.20</td>
</tr>
</tbody>
</table>

In summary, the 869 offers current based analysis, but also a more advanced power based approach for broken Rotor Bar detection. A power based FFT algorithm provides the following benefits:

- Power based analysis shifts the fundamental frequency down to DC and the fault frequency to a lower value by multiplying by the voltage component thereby providing a sharper contrast in the fault signature. It also improves the detection accuracy as it is less affected by supply frequency variation or load deviation.

- Conventional current algorithms are prone to noise because of the leakage of the fundamental component and therefore, single frequency transformation doesn’t give accurate results, while Power based FFT algorithm gives sharper contrast. Shifting the spectrum by squaring the current alone can handle this but, makes detection more vulnerable to motor load variation.

- The 869 allows the user to specify the window for Broken Rotor Bar sideband detection to further narrow the analysis range.

The 869 provides comprehensive broken rotor bar detection allowing the operator to monitor the motor condition over time and take action before the motor is damaged and taken out of service.

The commissioning engineer identifies the component level of the healthy rotor during 869 installation and then configure the Broken Rotor Bar PKP level setting to be around 15 dB above it e.g., If the component level for healthy rotor is read as -70 dB, then the Broken Rotor Bar pickup level should be set at around -60 dB to detect cracked rotor and -55 dB to detect 1 Broken Bar.