Electric Motor Fault Frequencies: Vibration and Current Signature Lines

motor_fault_frequencies_a ver 1.0 by Tom Irvine

Notation

F_L line frequency or VFD output frequency (Hz), P number of poles, $p = P/2$ pole pairs, N running speed (rpm), N_b rotor bars (damper bars for a synchronous motor), N_s stator slots, f_c VFD carrier (switching) frequency (Hz).

Speed and slip

1. Synchronous speed $N_{sync} = \dfrac{120\,F_L}{P}$ rpm, $f_{sync} = \dfrac{2\,F_L}{P}$ Hz

2. Slip and running speed $s = \dfrac{N_{sync} - N}{N_{sync}}$, $1X = f_r = \dfrac{N}{60} = \dfrac{F_L(1-s)}{p}$

3. Slip frequency, rotor current $f_{slip} = f_{sync} - f_r$, $f_{rotor} = s\,F_L$

4. Pole pass frequency $F_P = P\,(f_{sync} - f_r) = 2\,s\,F_L$

Vibration spectrum

5. $1X,\ 2X$ $f_r,\ 2f_r$ unbalance; misalignment, looseness

6. Twice line frequency $2F_L$ stator faults, loose iron, soft foot, static eccentricity

7. Pole pass sidebands $f_r \pm F_P$ broken / cracked rotor bars [4]; $2F_L \pm F_P$ dynamic eccentricity [6]

8. Rotor bar pass $RBP = N_b f_r$, $RBP \pm 2F_L$, $2\,RBP$ loose rotor bars, air-gap forces [2, 4]

9. Stator slot pass $N_s f_r$, $N_s f_r \pm 2F_L$ stator slot / wedge problems (rarely dominant)

Stator current spectrum (MCSA)

10. Broken rotor bars $f_{bb} = F_L\,(1 \pm 2s)$ lower sideband is the main indicator [2]

11. Mixed eccentricity $f_{me} = F_L \pm f_r$ (also 1X load torque oscillation) [3]

12. Rotor slot harmonics $f_{ecc} = F_L \left[\dfrac{(N_b \pm n_d)(1-s)}{p} \pm n_w \right]$ [1]

$n_d = 0$: static (principal slot harmonics), $n_d = \pm 1$: dynamic eccentricity, $n_w = \pm 1$

Since $f_r = F_L(1-s)/p$, the slot harmonics equal $N_b f_r \pm F_L$ ($n_d = 0$) and $(N_b \pm 1) f_r \pm F_L$ ($n_d = \pm 1$). They appear only for some combinations of N_b and p; compare with a healthy baseline.

VFD carrier harmonics (sinusoidal PWM)

13. Carrier lines $mf_c + nF_L$: $m = 1, 3$ with $n = 0, \pm 2$; $m = 2$ with $n = \pm 1$ [5]

Current ripple, magnetic noise (whine) and vibration near these lines.

The sideband orders depend on the modulation scheme; PWM vibration has also been reported at $f_c \pm 3F_L$ [6].

Synchronous motor

$s = 0$, $f_r = f_{sync}$. Slip, pole pass, broken bar and slot harmonic lines are not listed; N_b is taken as damper (amortisseur) bars.

Units and notes

All inputs are frequencies (Hz), speed (rpm) or counts, so English and metric users get the same results.

CPM = 60× Hz. Order = f/f_r. Plot levels are schematic, not predicted amplitudes.

Lines at zero or negative frequency are dropped.

Fault interpretations are typical guidance from public summaries; confirm with trends, a baseline and other measurements.

References

[1] U. Ali, "Towards fault diagnosis in induction motor using fractional Fourier transform," arXiv:2412.18227 (2024), Eq. 2, citing Oumaamar et al., Mech. Syst. Signal Process. 84 (2017) and Hong et al., IEEE Trans. Power Electron. 27(5) (2012).

[2] arXiv:2412.18227, Eq. 1, $F_L(1 \pm 2ks)$, citing Trujillo-Guajardo et al., IEEE Trans. Instrum. Meas. 67(6), 2018; Reliabilityweb, "Diagnosing rotor bar issues with torque and current signature analysis" (example $F_L(1-2s)$, rotor bar pass = bars × rotational frequency).

[3] Pal and Mohanty, mixed eccentricity sidebands $F_L \pm kf_r$, $f_r = (1-s)F_L/p$ (public summary of the paper; check against the original).

[4] Vibration: Industrial Monitor Direct, "Detecting broken rotor bars using vibration analysis" ($F_P = 2sF_L$, $1X \pm F_P$); A. Doyle, Iris Power IRMC 2023.

[5] PWM carrier sidebands $f_c \pm 2F_L$, $f_c \pm 4F_L$: US patent literature (USPTO 12668228); Aalborg Univ. PWM radial force paper (vbn.aau.dk).

[6] PWM vibration at $f_c \pm 3F_L$: US patent literature (USPTO 10693410).

$2F_L \pm F_P$ for dynamic eccentricity: common vibration-chart guidance, not confirmed from a source here.

Formulas confirmed from the public sources above (Nov 2026). The fault interpretations are summarised from practitioner sources, not from a standard.