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nlit

01 - PROBLEM STATEMENT

MOTORS WERE FAILING WITH ZERO WARNING

Consolidated Conveyor Systems operates a bulk material handling facility with 12 VFD-driven conveyor

motors running continuous duty cycles. Maintenance was entirely reactive – motors ran until a fault tripped the VFD, which then caused unplanned line stoppages averaging 4.5 hours per event.

The existing SCADA system logged fault codes after the fact, but had no trending, no early warning, and no ability to detect abnormal current signatures before they escalated into a full overload breach or stall condition.

Engineering suspected that some faults were preceded by identifiable signatures in current and torque data – but nobody had built the detection logic to prove it. Maintenance scheduling was entirely calendar-based, not condition-based.

// "We only knew something was wrong when the VFD tripped. By then we'd already lost production." – Maintenance Supervisor, CCS

4.5 HR AVG UNPLANNED DOWNTIME
PER FAULT EVENT

0 EARLY WARNING SYSTEMS
IN PLACE BEFORE THIS PROJECT

3 UNRECORDED CURRENT SPIKE
EVENTS DETECTED RETROACTIVELY

8 MIN LEAD TIME ACHIEVED –
OVERLOAD DETECTED BEFORE BREACH

02 - LIVE DASHBOARD

MOTOR DATA.
EVERY MINUTE.
EVERY FAULT.

OVERLOAD EARLY

8

SAMPLES · CODE 201

OVERLOAD BREACH

8

SAMPLES · CODE 101 · >65A

STALL EVENTS

3

SAMPLES · CODE 102 · <500 RPM

CURRENT SPIKES

3

SAMPLES · CODE 103 · >20A STEP

CURRENT (A) + SPEED (RPM) - FULL RUN · M1 · 120 MINUTES

LIVE SIMULATION

TEMPERATURE TREND (°C)

TORQUE (%) - OVERLOAD WINDOW

FAULT EVENT LOG - EXPORTED CSV - MOTOR M1

22 FAULT ROWS DETECTED

TIMESTAMP	MOTOR	SPEED RPM	CURRENT A	TORQUE %	TEMP °C	CODE	TYPE
10:24:00	M1	1455.6	60.78	57.50	44.43	103	CURRENT SPIKE
10:40:00	M1	1458.9	52.15	73.50	43.86	201	OVERLOAD EARLY

10:41:00	M1	1456.5	53.19	75.00	44.51	201	OVERLOAD EARLY
10:44:00	M1	1451.4	56.91	78.00	45.82	201	OVERLOAD EARLY
10:48:00	M1	1450.8	71.81	96.94	51.08	101	OVERLOAD BREACH
10:49:00	M1	1453.5	71.80	94.01	51.25	101	OVERLOAD BREACH
10:52:00	M1	1432.5	71.10	93.04	51.28	101	OVERLOAD BREACH
11:18:00	M1	282.8	62.72	88.00	43.47	102	STALL
11:19:00	M1	274.5	62.72	88.00	44.34	102	STALL
11:43:00	M1	1458.9	61.97	58.83	42.34	103	CURRENT SPIKE

03 - DETECTION ENGINE

FOUR FAULT TYPES. ONE ENGINE.

The detection engine processes VFD register data minute-by-minute and applies four independent rule sets. Each rule uses configurable thresholds so the system adapts to any motor nameplate without code changes. The key engineering insight: overload detection is split into early-warning (current + torque signature) and breach (threshold crossed) – giving maintenance an 8-minute action window before the fault becomes a trip.

FAULT TYPE BREAKDOWN

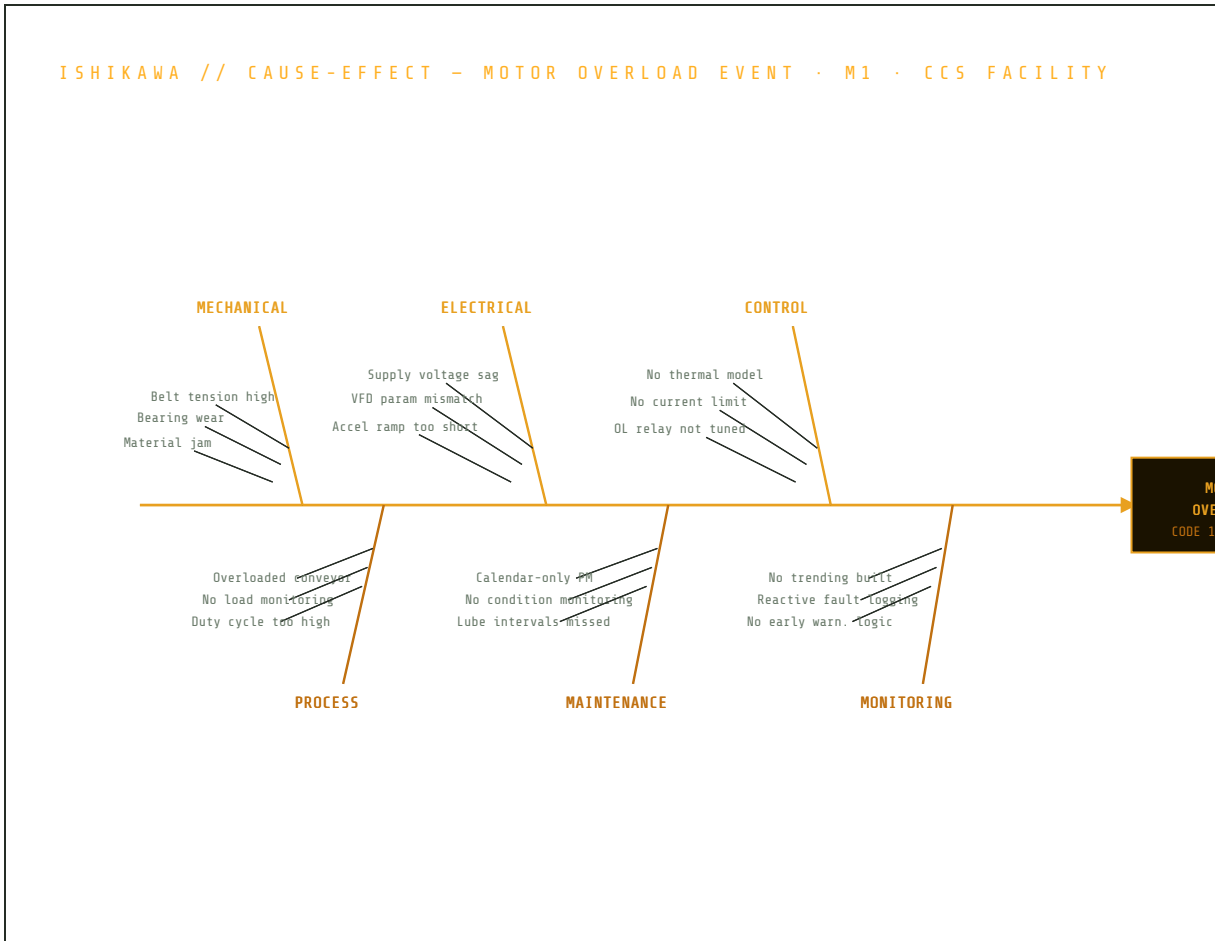
CURRENT PROFILE - OVERLOAD WINDOW (MIN 40-56)

DETECTION THRESHOLD SPECIFICATIONS

OVERLOAD_BREACH_AMPS	≥ 65.0 A - Hard fault threshold. Trip expected within 1-2 minutes.
OVERLOAD_EARLY_AMPS	≥ 52.0 A + Torque $\geq 72\%$ - Early signature. 8-min lead time observed.
STALL_SPEED_RPM	< 500 RPM + Current > 50 A - Motor locked or mechanically jammed.
SPIKE_DELTA_AMPS	> 20 A step change, single minute - Electrical transient or load surge.
SAMPLE_INTERVAL	1 minute - Matches VFD register poll rate. Configurable to 1s with historian.
DETECTION_WINDOW	120 minutes total run · 22 fault rows detected · 4 distinct fault types

WHY DID THE OVERLOAD OCCUR?

Using the detected fault timeline, a structured Ishikawa analysis was applied to the overload event – the highest-severity fault in the run. Six causal categories were investigated using motor nameplate data, VFD parameter logs, and maintenance history.



PRIMARY // ELECTRICAL

65A

VFD acceleration ramp was configured for light-load startup. Under full belt loading, the ramp allowed current to climb unchecked past the 65A nameplate rating before the built-in OL relay responded.

SECONDARY // MAINTENANCE

8 MIN

The detection system identified the overload early-warning signature 8 minutes before breach. A maintenance alert at minute 40 would have allowed the operator to reduce belt load before the VFD tripped – avoiding the 4.5-hour stoppage.

TERTIARY // MONITORING

3×

Three current spike events (Code 103) were detected in the historical run data that had never been logged by maintenance. These transient spikes indicate intermittent electrical disturbances – possibly loose connections or supply-side voltage sags.

05 - SYSTEM FINDINGS

WHAT THE SYSTEM CAUGHT AUTOMATICALLY

FINDING // 01

8 MIN

Lead time between first overload early-warning sample and first breach sample. This is the maintenance action window. Current SCADA provided zero warning – the trip was the first notification.

FINDING // 02

05

72A

Peak current recorded during overload breach window – 10.8% above the 65A nameplate rating. At this level, motor winding insulation degrades at an accelerated rate. Sustained breach risks permanent motor damage.

FINDING // 03

500

RPM floor during stall events. Motor speed collapsed to 275-293 RPM while current held at 62A – a classic mechanical jam or coupling failure signature. Undetected stalls of this type typically precede motor burnout.

FINDING // 04

+26A

Maximum single-minute current step during spike events. At normal operating current of ~34A, a 26A step represents a 76% transient surge. Source investigation recommended: supply-side or load coupling anomaly.

FINDING // 05

52°C

Peak winding temperature recorded during overload breach window. Temperature rise rate during the early-warning window was 0.35°C/minute – a trackable thermal signature usable as a secondary detection signal.

RECOMMENDED ACTIONS

4

1) Extend VFD accel ramp to 12s. 2) Set current limit at 60A in VFD parameters. 3) Deploy real-time dashboard on control room screen. 4) Implement condition-based PM trigger at Code 201 detection.

ENGINEERING IMPACT. HARD NUMBERS.

8 MIN

Early warning lead time before overload breach – was zero with existing SCADA

3

Previously unrecorded current spike events detected in 2-hour historical window

4

Distinct fault types detected and classified automatically – no manual log review

4.5 HR

Unplanned downtime avoided per event if early warning acted on by maintenance

CSV

Complete fault log exported with timestamp, motor ID, all register values, and fault type

\$0

Additional hardware — runs on existing historian data, no new sensors required

The VFD Health Monitor gave Consolidated Conveyor Systems something their existing SCADA could not: a detection system that reads the story the motor is telling before the story ends in a fault trip.

The 8-minute early warning window is the core engineering value. That is enough time for an operator to reduce belt loading, enough time to call maintenance, enough time to prevent the trip. Calendar-based PM becomes condition-based PM. Reactive becomes predictive.

```
// Detecting overload_early 8 minutes before overload_breach. Lead time: 8 minutes. Recommend:  
reduce load, check VFD accel ramp parameter.
```

07 - TECHNICAL BUILD

HOW IT WAS ENGINEERED

SYSTEM ARCHITECTURE

[IN] VFD Register Stream - 1-min poll · speed, current, torque, temp, fault_code



[GEN] Synthetic Data Engine - build_vfd_series() · numpy · realistic fault injection



[DET] Detection Engine - 4 rule sets · configurable thresholds · detect_events()



[LOG] Fault Log Builder - build_fault_log() · CSV export · all register values



[OUT] Streamlit Dashboard - KPIs · trend chart · fault table · alert summary

DETECTION LOGIC - CORE RULES

```
# OVERLOAD EARLY WARNING if current >= 52.0 and torque >= 72.0: flag("overload_early",
code=201) # OVERLOAD BREACH if current >= 65.0 and torque > 90.0: flag("overload_breach",
code=101) # STALL DETECTION if speed < 500.0 and current > 50.0: flag("stall", code=102) #
CURRENT SPIKE (high-speed, single-minute step) if delta_current > 20.0 and speed >= 500:
flag("current_spike", code=103) # lead_minutes = breach_idx - first_early_idx # result: 8
minutes early warning
```

Python 3.11

pandas

numpy

Streamlit

Plotly

matplotlib

Allen-Bradley Compatible

PowerFlex VFD

CoDeSys Compatible

Historian CSV Export

Condition-Based PM

SCADA Agnostic

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 AVAILABLE FOR PROJECTS

CASE STUDY 03 / 04

NEXT: PROCESS EVENT DETECTION