Power Quality Case Studies: Voltage Sag/Voltage Drop

Music City Power Quality Group Meeting
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Objectives-Case Study #1

- Describe the thought process behind solving a power quality issue while analyzing data in the order we received it.
- Discuss what to look for when control circuits are a possible cause of power quality problems.
- Discuss ESTOP circuits with ice cube relays.
- Identify whether a relay is AC or DC from an elementary diagram of a control circuit.

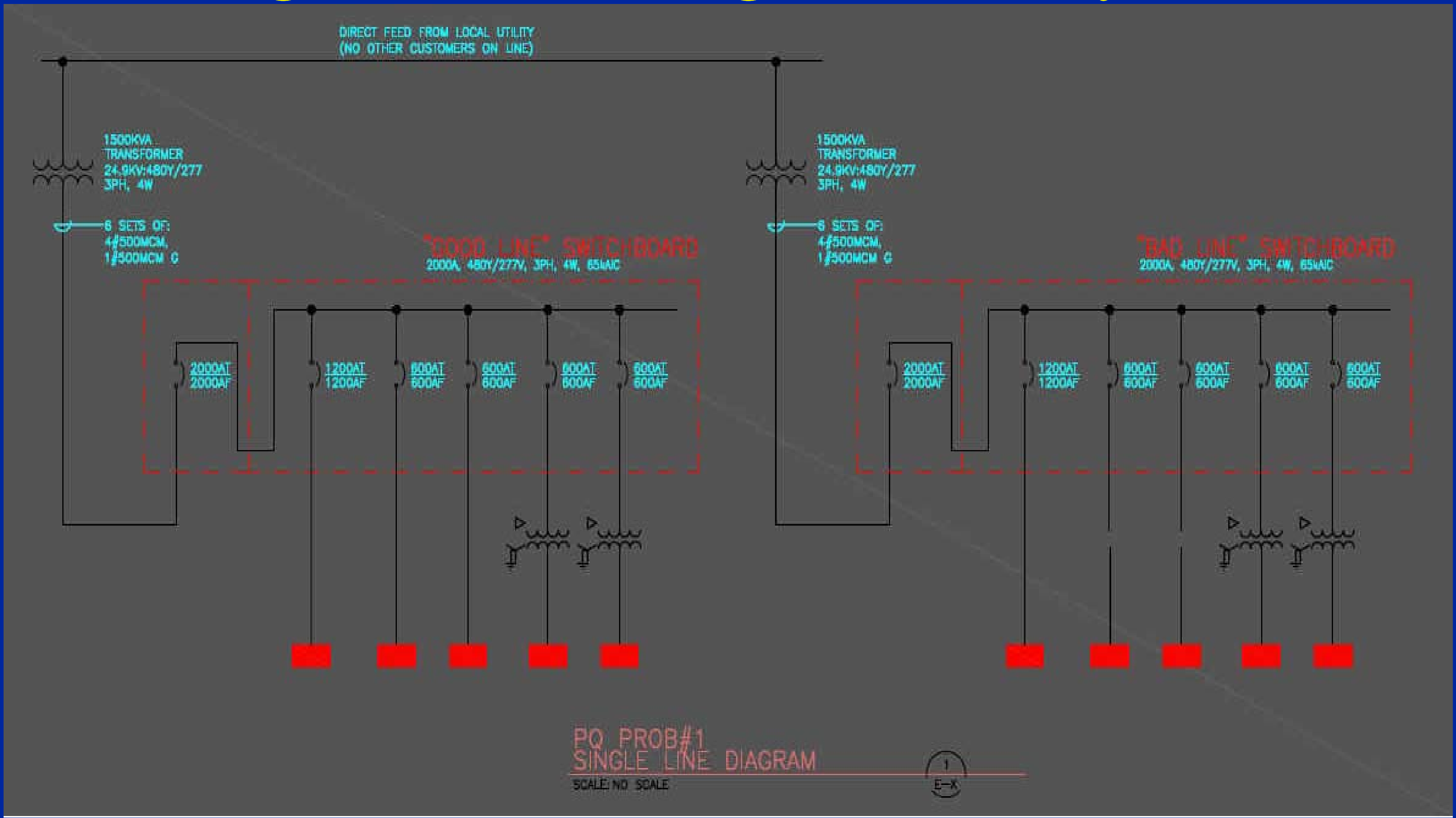
Problem #1 – Voltage Sag

- A large industrial customer has two “identical” process lines adjacent to each other in a manufacturing facility. The first process line (Good Line) is fed from a 1500kVA, 480Y/277V transformer and never has any issues where equipment drops out or loses power.
- The second process line (Bad Line) is fed from a second 1500kVA, 480Y/277V “identical” transformer. The Bad Line constantly loses power.
- “Losing power” is defined as the dropping out of the controls and motors involved with the second process line.
- Power loss causes the customer thousands of dollars of lost production each time it happens.

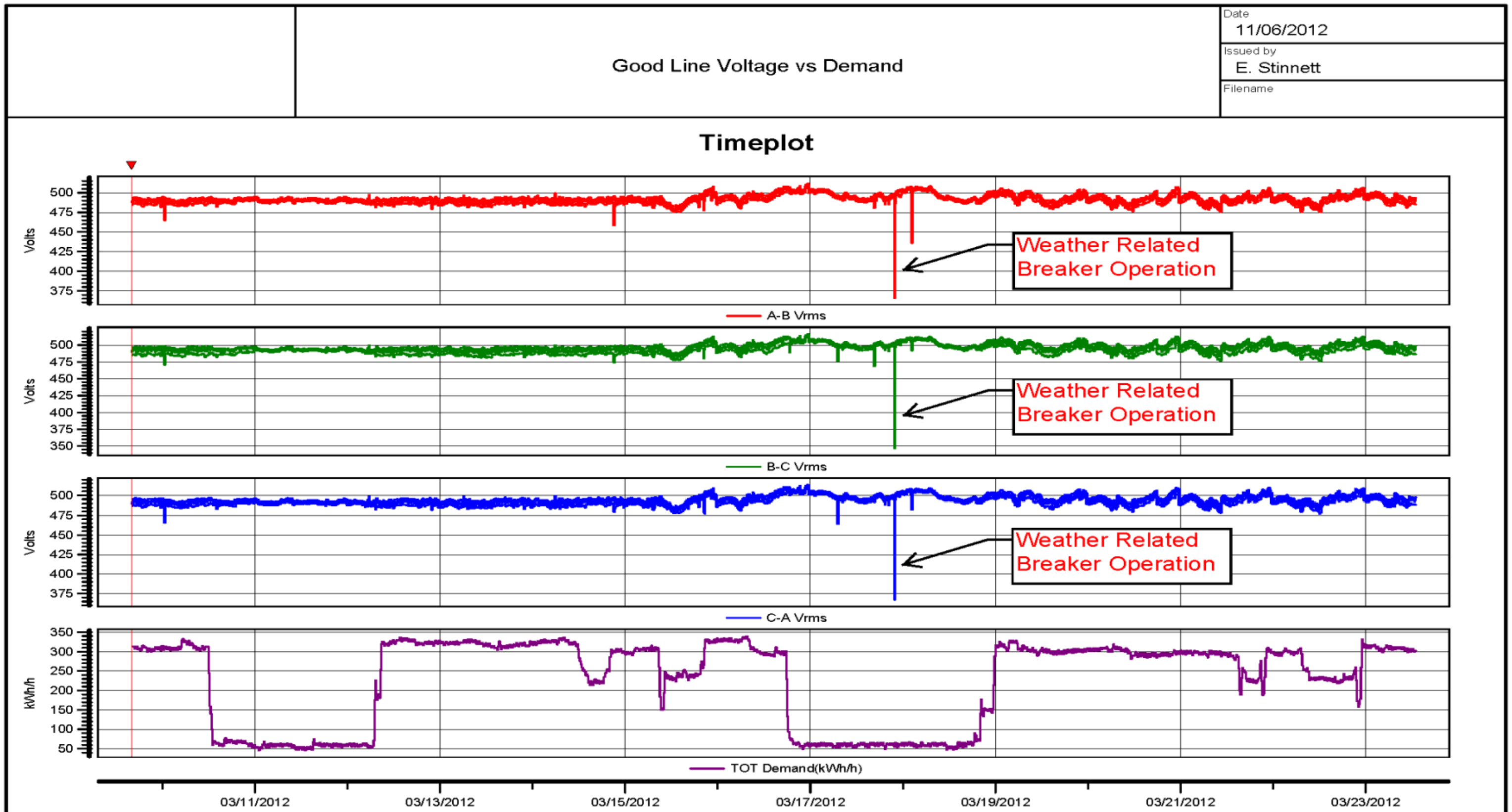
Initial Thoughts on Causes of the PQ Issues:

- **The problem must be because the utility transformer is defective.**
  - **The Bad Line transformer was replaced less than a year ago.**
  - **If the “identical” Good Line works fine with a duplicate transformer, the point of failure has to be the Bad Line transformer.**
- **There are issues with the incoming medium voltage feeder to the transformer in question.**
  - **Bad arrestor?**
  - **Tree trimming issues causing voltage sags?**

Single Line Diagram of System

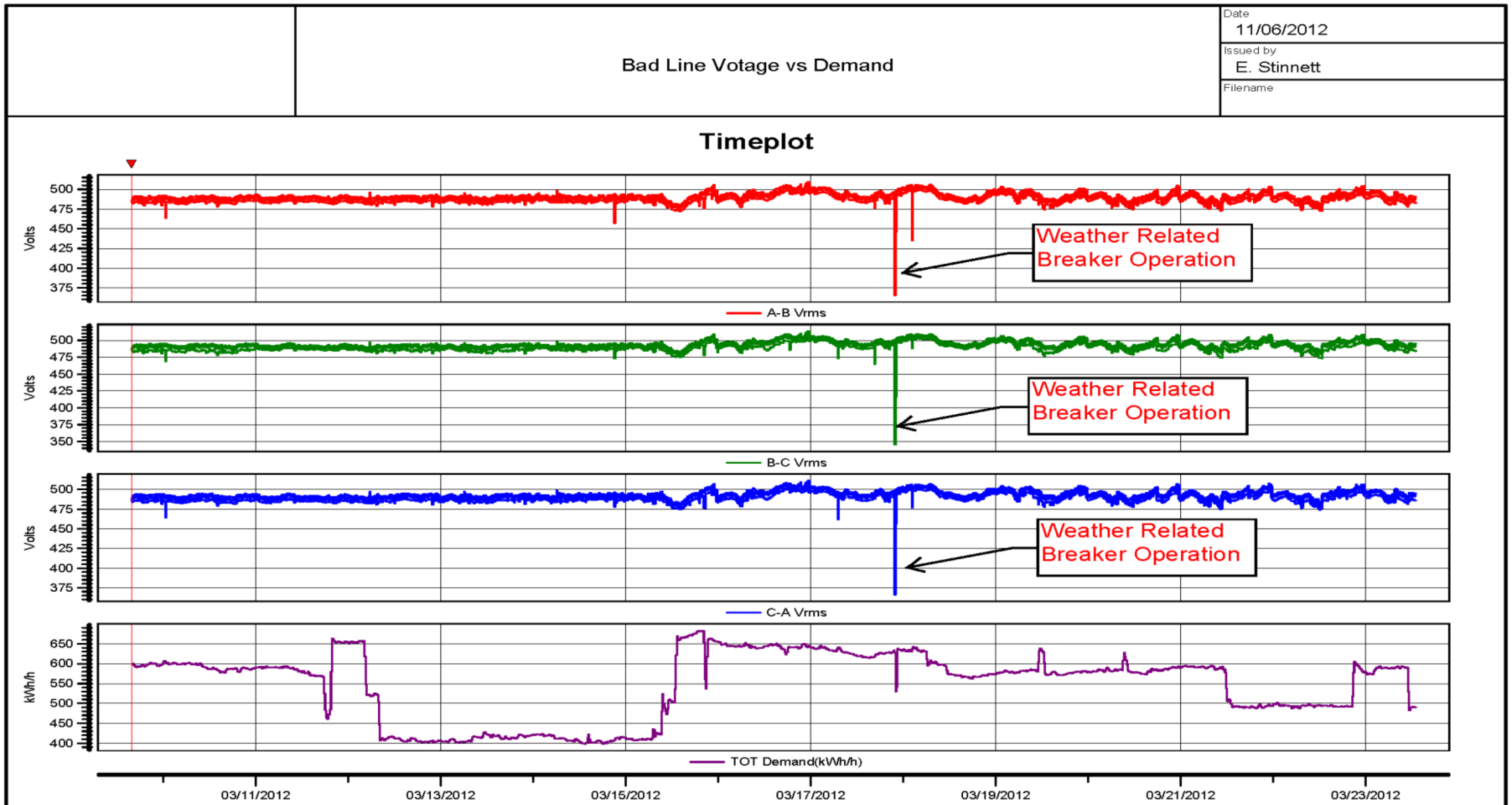


Step 1: Meter Incoming Utility (Good Line)



	Min	Max	Avg
A-BVrms	366.1	512.0	492.1
B-CVrms	346.6	516.3	495.9
C-AVrms	367.2	513.3	494.2
TOTDemand(kWh/h)	45.92	339.6	228.1

Step 1: Meter Incoming Utility (Bad Line)



	Min	Max	Avg
A-BVrms	365.3	509.6	489.7
B-CVrms	345.5	513.5	492.9
C-AVrms	366.2	510.7	491.7
TOTDemand(kWh/h)	398.4	682.7	547.8

Conclusions Post Metering

- We can most likely rule out utility line issues because both transformers are fed from the same utility feeder. A sag on the line is seen by both transformers.
- The Bad Line transformer seems to maintain a constant 480V voltage during the monitoring period. Voltage sags measured at the Bad Line were identical to those on the Good Line.
- Maybe both process lines are not identical. Solution to their problems might be traced to a point where both lines are different.
- Time to go into the plant a look at the layout of the two lines.

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Interior Layout of Both Lines

- Both lines are fed from separate switchboards.
- Both lines are majority conveyor loads (Motor loads) with some process loads to manufacture and move product.
- The control systems of both lines are separate and are comprised of several large PLC cabinets coupled with motor control cabinets.
  - These motor control cabinets house the overcurrent protection and contactors necessary to turn motors on and off.

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Interior Layout of both Lines

- The first difference between the two lines is noted:
  - The Good Line must be a couple of years newer than the Bad Line. How do I know this?
    - The Good Line is using Allen Bradley ControlLogix PLCs.
    - The Bad Line is using Allen Bradley SLC 500 PLCs.

New Information from Actual Operator of the Bad Line

- **When an outage occurs, the PLC and remote IO racks do not necessarily lose power.**
  - **Control screen is running when the operator shows up to restart the line.**
- ***All*** **of the motor loads do lose power or drop out.**
  - **This causes the operator to have to press an acknowledge button on his control screen.**
  - **Once the acknowledge has been pushed, the operator can then restart all of the motors to put the system back online.**
  - **Something must be dropping out the master control relays (MCR) within the motor panel.**

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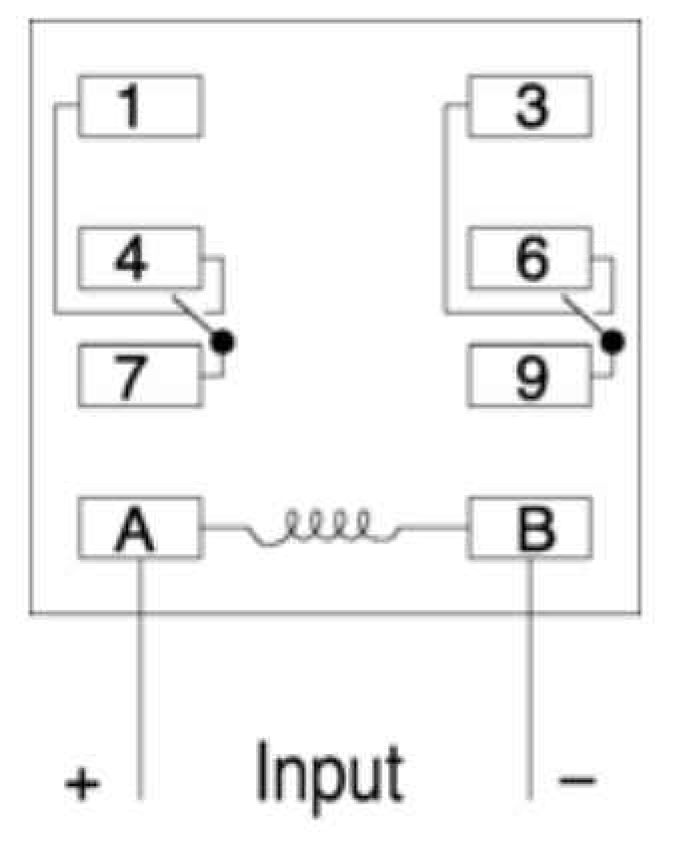
And the Weak Link Is…

- Emergency Stop (ESTOP) buttons or pull cords are circuits designed to shutdown lines or sections of lines anytime there is an emergency.
  - A relay within an ESTOP circuit is wired back to MCRs within motor panels. By pressing a button (usually a big red one) or by pulling a pull-cord, the hardwired circuit is broken and an ESTOP relay coil is de-energized.
  - Once the ESTOP coil is de-energized the MCR within a motor panel drops out and all of the motors on that circuit shut down instantly to prevent injury or damage to equipment.

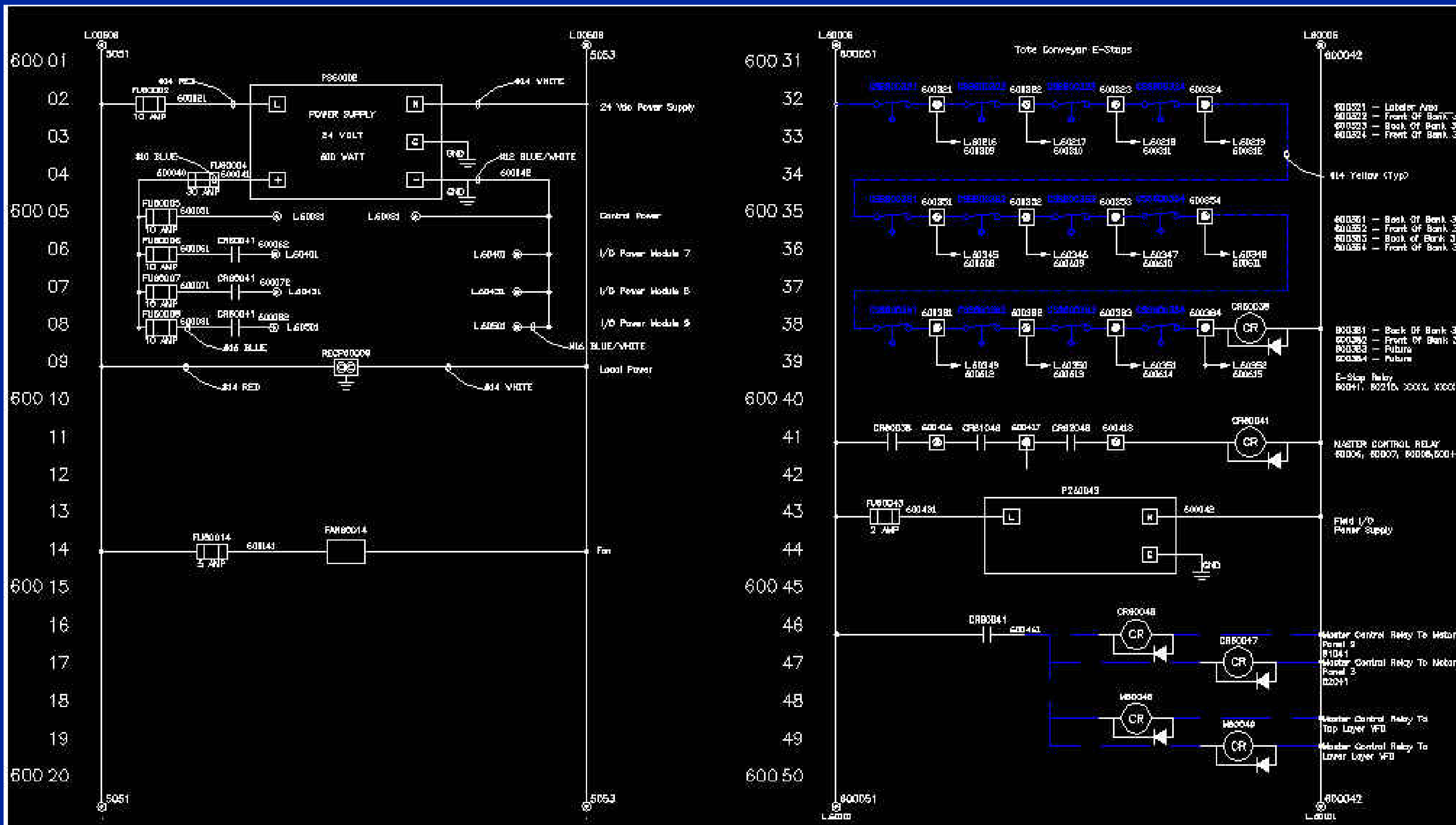
Relays



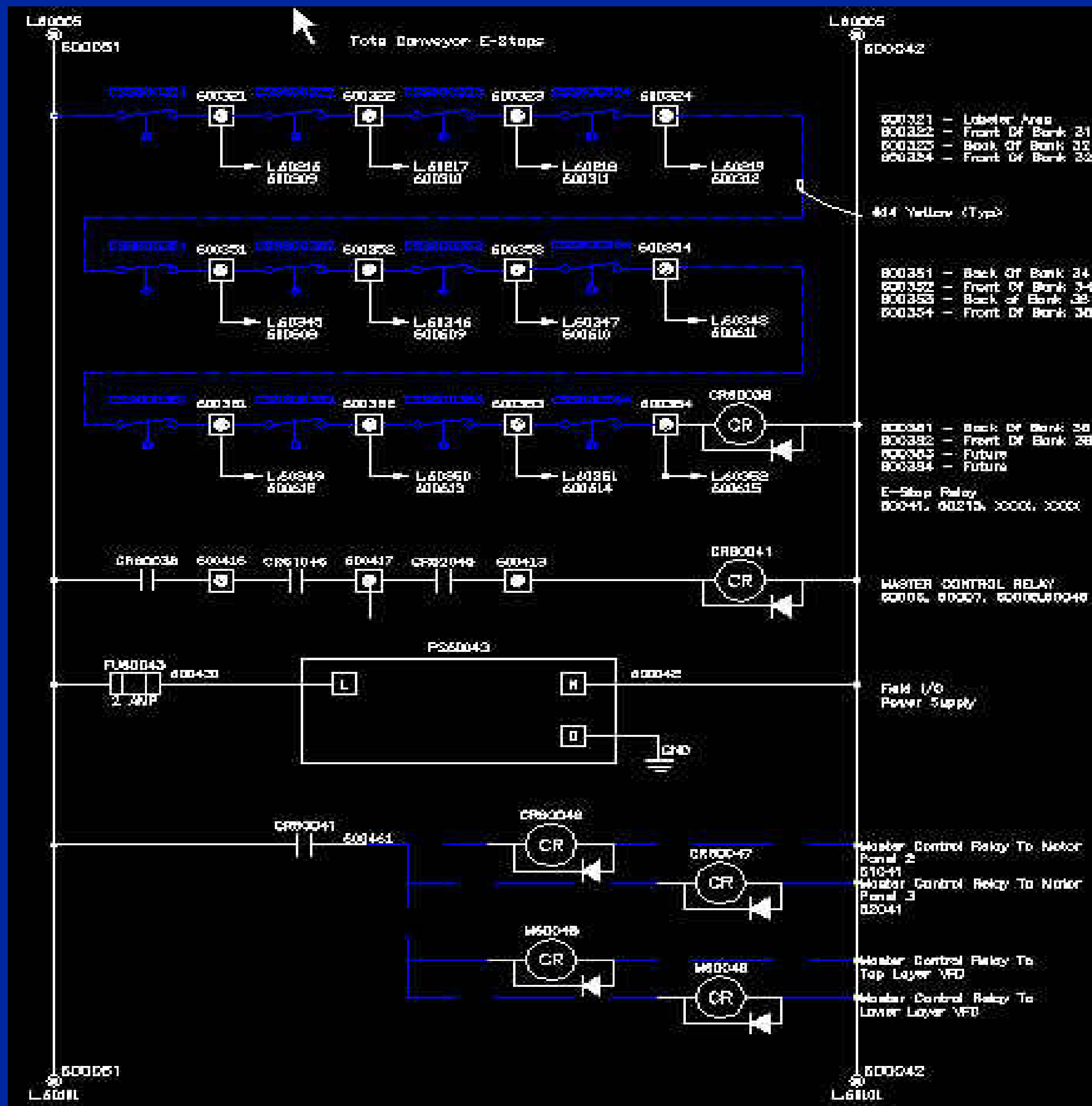
The Solution

- A comparison of ESTOP circuitry between the Good Line and the Bad Line showed that the Good Line was utilizing DC relays while the Bad Line was using AC relays for their ESTOP circuits.
- The AC E-Stop relays from the Bad Line were replaced with DC relays a month after study was done.
- Process outages due to momentary voltage sags have ceased even during summer storm months.

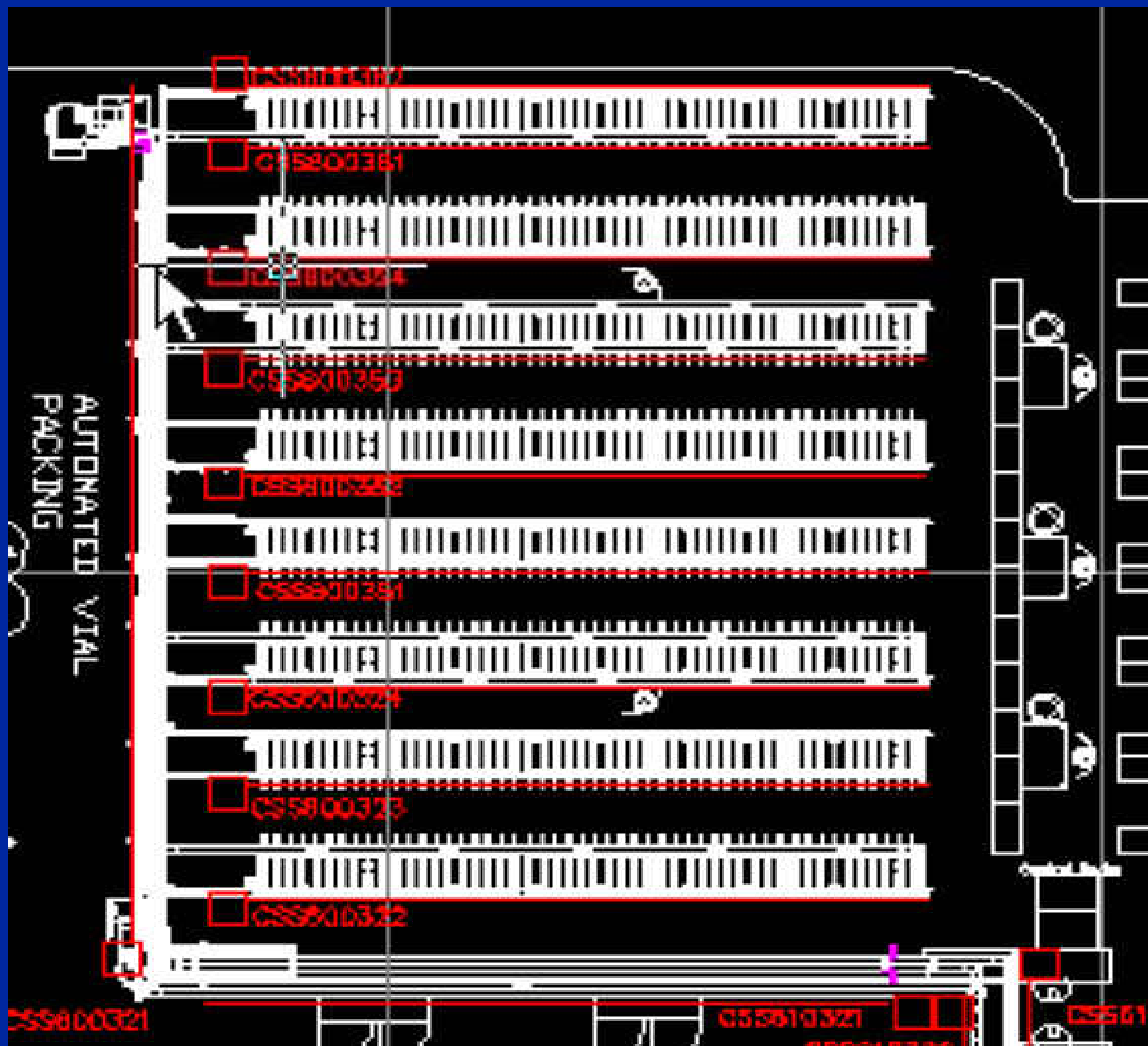
What does an ESTOP circuit look like?



What does an ESTOP circuit look like?



Where do you find the relays?



Conclusions

- **Be weary of "identical" systems.**
- **When groups of motors drop offline at the same time, try to identify whether they are controlled by a single Mater Control Relay.**
- **Master Control Relays are usually designed to drop out when E-Stop circuits lose power.**
- **Obtain Elementary or Riser diagrams when possible to trace controls circuits and locate AC relays.**

Questions?

Objectives-Case Study #2

- Present an obvious voltage drop issue feeding a motor with undersized wire.
- Look at the metered voltage and current data at both the motor terminals and the panel feeding the motor.
- Discuss NEC requirements for overload protection.
- Discuss NEC requirements for cable sizing.
- Discuss possible options other than resizing cable.

Problem #2 – Voltage Drop

- A small commercial customer owns a property that has several automatic gates.
- All of the gates work fine except for one that constantly trips its internal overload device.
- All of the circuits/gates/parts are identical (Awesome…Another "identical" system).
- All of the components of the gate have been changed out and replaced (motors, gears, breaker, etc) except for the feeder to the motor.
- Motor is a 1/2hp, 120V, with integral overload protection.
- Motor is fed by 550 ft of 2#8, #10G-1/2"C

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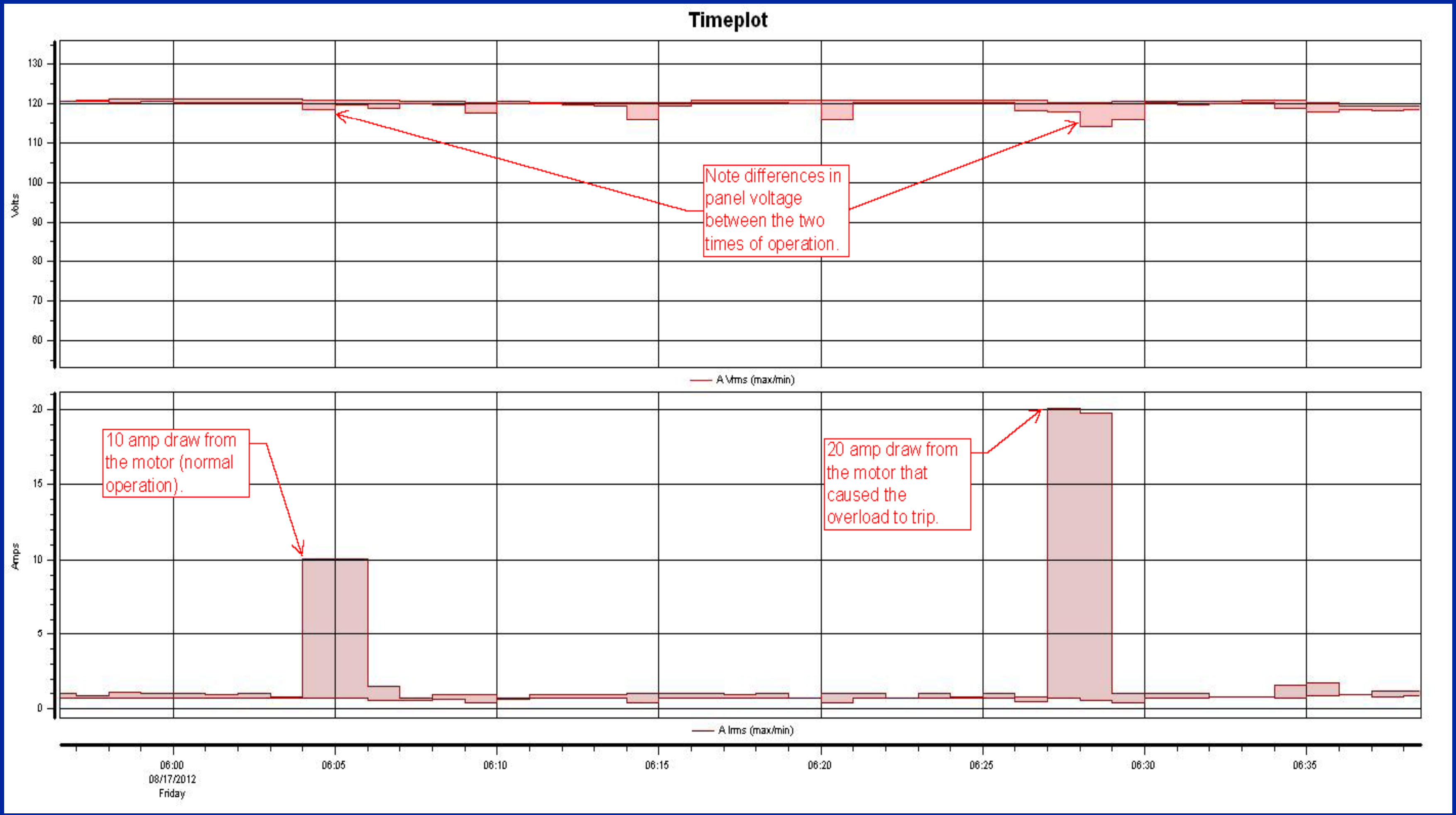
Initial Thoughts on Causes of the PQ Issues:

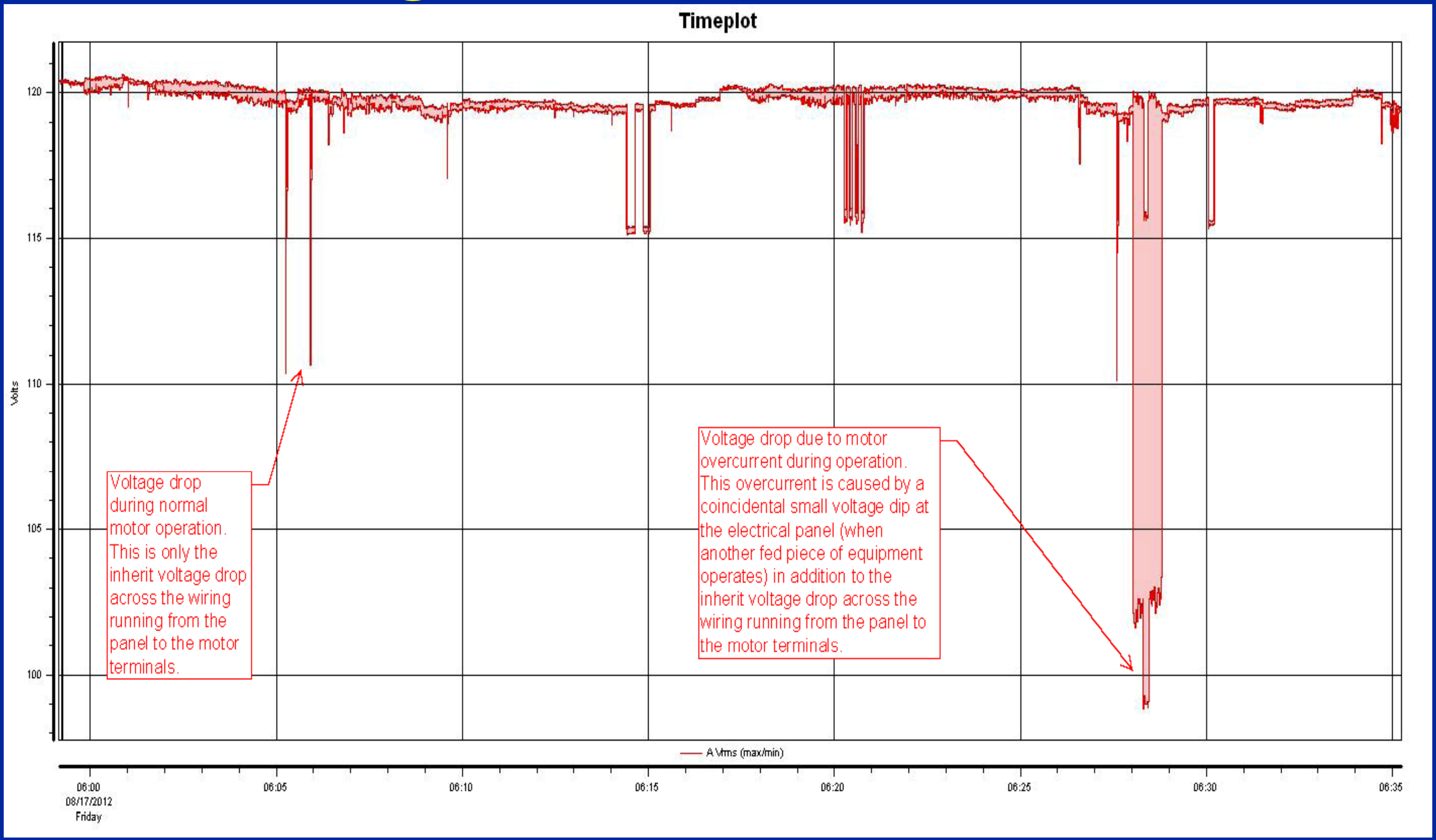
- **Motor/gate assembly is mechanically failing**
  - **Mechanical impedance of the motor shaft is increasing current draw**
- **Overloads are undersized**
- **Spikes from the utility are causing the overloads to trip**
- **Voltage Drop issues**

Diagram of System

Metered Data at Panel



Voltage at Motor Terminals



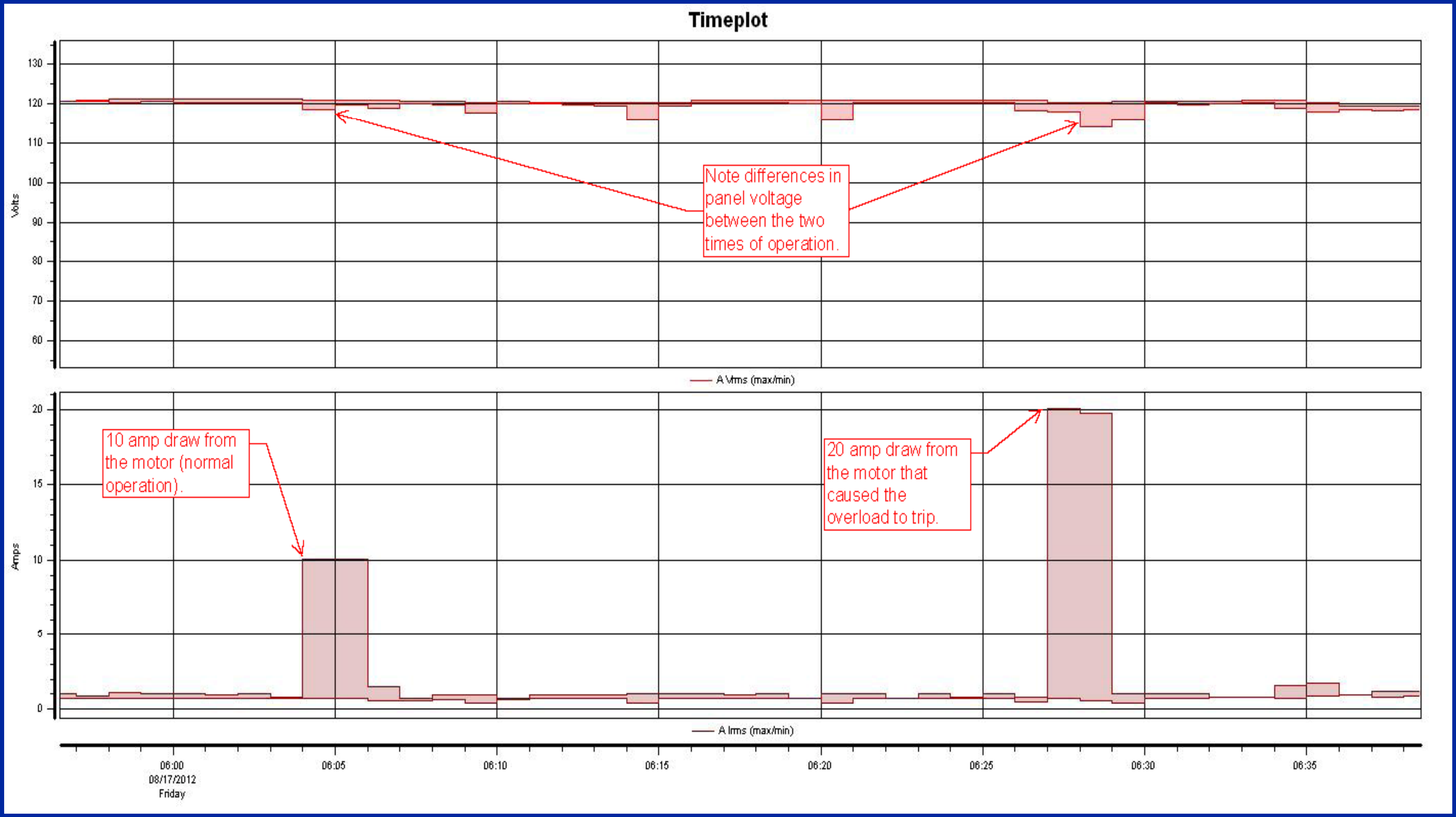
NEC Requirements for Overloads

- Article 430(A)(1) Separate Overload Device. A separate overload device that is responsive to motor current. This device shall be selected to trip or shall be rated at no more than the following percent of the motor nameplate full-load current rating:
  - Motors with a service factor 1.15 or greater: 125%
  - Motors with a temperature rise 40 deg C or Less: 125%
  - All other motors: 115%
- Article (B)(1)-Motors 1 hp and less refers back to 430(A)(1)
- We can assume the integral overloads are probably size to 115% FLA.

Overloads (Cont.)

- **Using motor full load values from NEC table 430.250, we can estimate what current trips the overload assuming it's sized at 115%:**
  - **FLA=9.8A at 115V**
  - **9.8A x 1.15% = 11.27A**
- **Our metered data explains why the overload works sometimes and trips at others.**

Metered Data at Panel



NEC Voltage Drop Recommendations

- NEC recommends no more than 3% voltage drop for either feeder circuits or branch circuits where the maximum total voltage drop on both feeders and branch circuits to the furthest device does not exceed 5%
- Voltage Drop Calculation for our circuit to the motor:
  - Vdrop = (2xLengthxResistancexI)/1000
  - Vdrop = (2x550ftx0.778x9.8A)/1000 = 8.39V
  - 8.39V/120V = 6.9% VD

What is the correct size?

- After substituting in the resistance values (Chapter 9, Table 8 in the NEC) for larger cables, we find that #4 AWG reduces the voltage drop to acceptable levels.
- Voltage Drop Calculation for our circuit to the motor:
  - Vdrop = (2xLengthxResistancexI)/1000
  - Vdrop = (2x550ftx0.308x9.8A)/1000 = 3.32V
  - 3.32V/120V = 2.76% VD

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Solutions?

- We can rip up 550’ of pavement to replace the #8 conductors with #4
  - This is because 2#4, #10G will not fit in ½”C per NEC.
- Use a Buck/Boost transformer
  - Need to consider if the contactor is rated to handle a 12% increase in voltage when motor is not running.
- Ask the manufacturer if the motor is dual rated for 240V
  - Need to consider whether the starter is rated for 240V.
- Use the existing #8 conductors to feed a 5 kVA 240:120 transformer set at the gate
  - 5000VA/240V = 20.8 Full load
  - 20.8 x 1.25 = 26A Needed Ampacity
  - #8, 60 deg C cable ampacity: 40A
  - 40A derated to 40 deg C ambient = 40Ax.82 = 32.8
  - 32.8A > 26A so we’re ok.

Solutions (Cont.)

- **New voltage drop calculation with 240V single phase transformer:**
  - **Vdrop = (2xLengthxResistancexI)/1000**
  - **Vdrop = (2x550ftx0.778x4.9A)/1000 = 4.19V**
  - **4.18V/240V = 1.7% VD**
- **Other Considerations:**
  - **Make sure there is space for a 2 pole breaker in the panel**
  - **Cost of pulling up cable versus cost of outdoor rated dry type transformer**

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Questions?