Why AC transformers "Complain" Noisily About DC Current

Ron Sharp

New Moraga Sub Bank #3

- 230kV/115kV
  - 1 phase auto
  - core form
  - 134MVA per phase

Pico Ct
51 Don Gabriel, orinda, ca
Donna Maria Way
Sager Ct
N
S
W
E
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Noise Complaints Begin

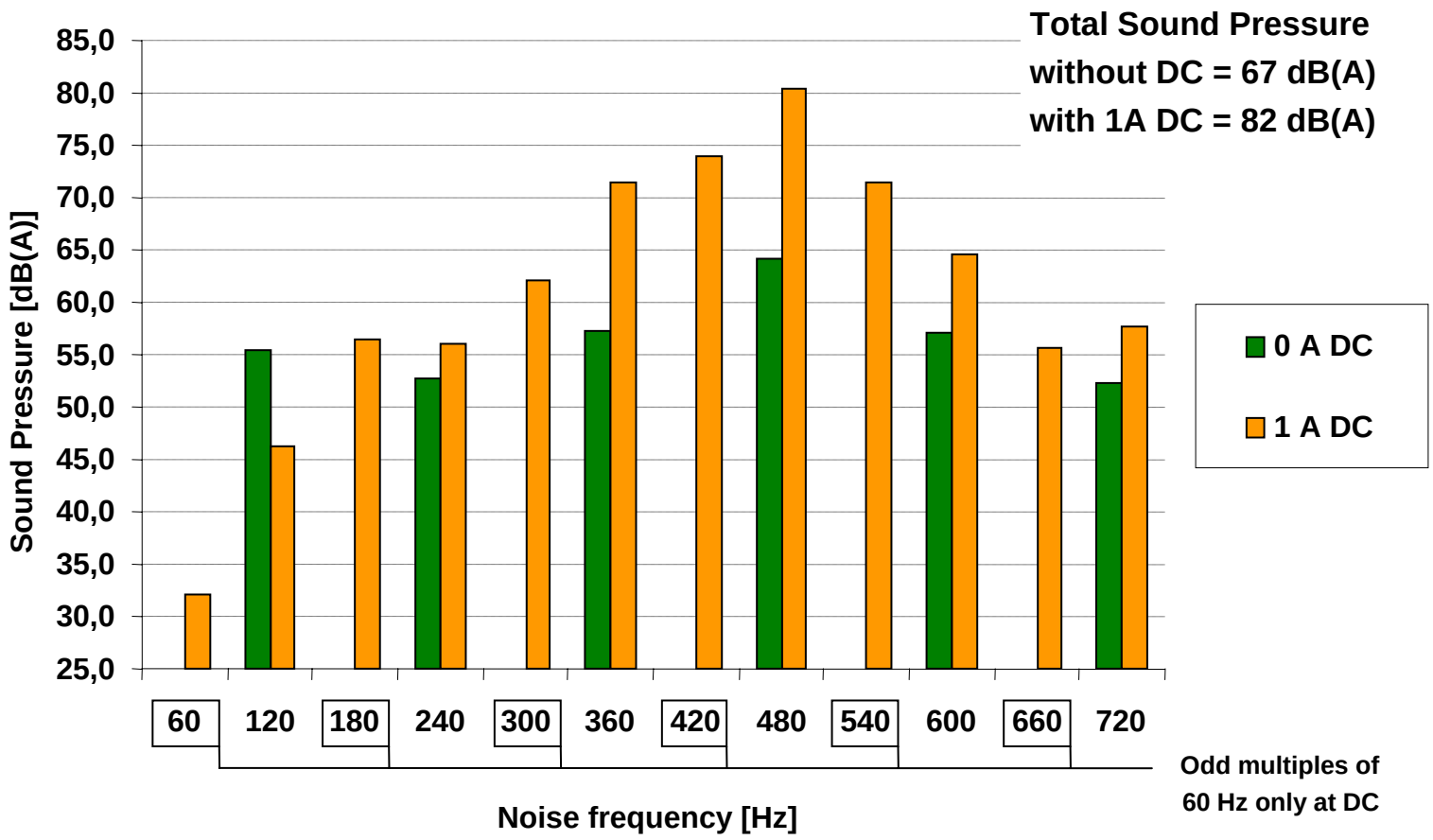
- November 2005 – Moraga Sub neighbors start complaining about noise from substation after Bank #3 was energized.
- PG&E measurements confirmed that Bank#3 was above specification.

Mysterious Noisy Transformer

- Not typical 120 Hz hum
- Bank #3 has "Buzz" at 300 Hz and higher
- Produces up to 85dB(A) and varies throughout day
- Transformer was designed to be 76dB(A) or less and stay out of saturation.
- Transformer at factory tested at 66dB(A) at .3 m distance w/o fans

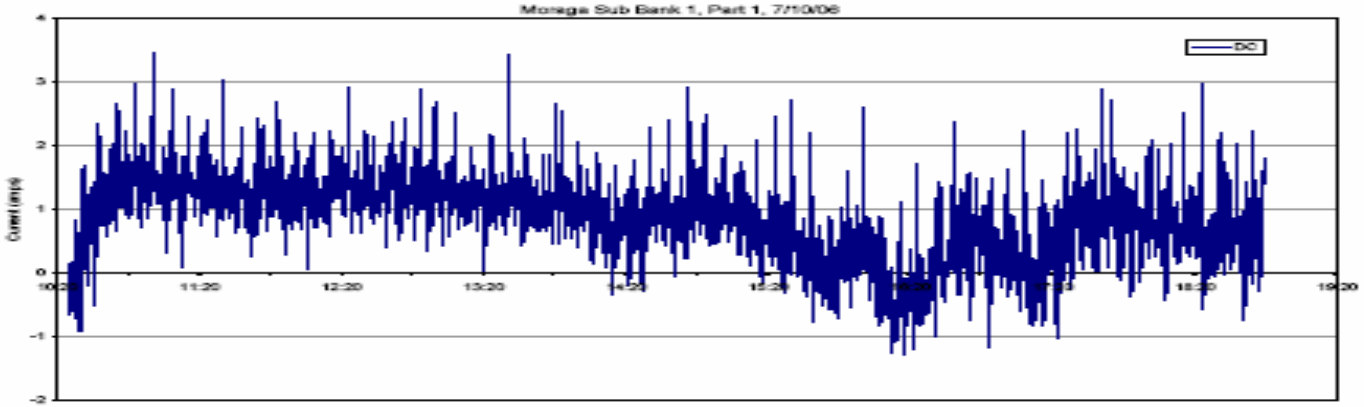
Sound Pressure Harmonics with and without DC Current

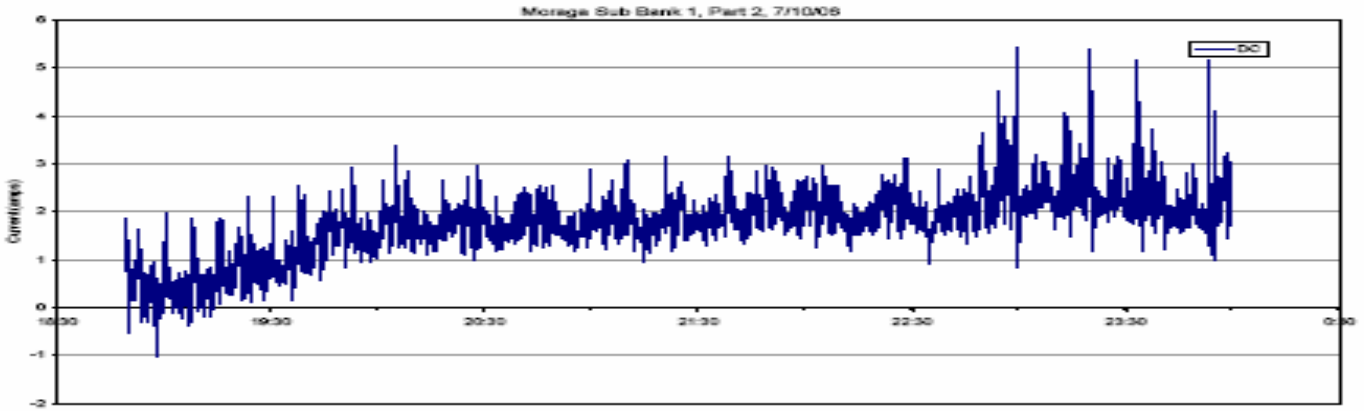
134 MVA Single Phase Transformer ($B_{\text{core rated AC}}$ = 1,73 T)

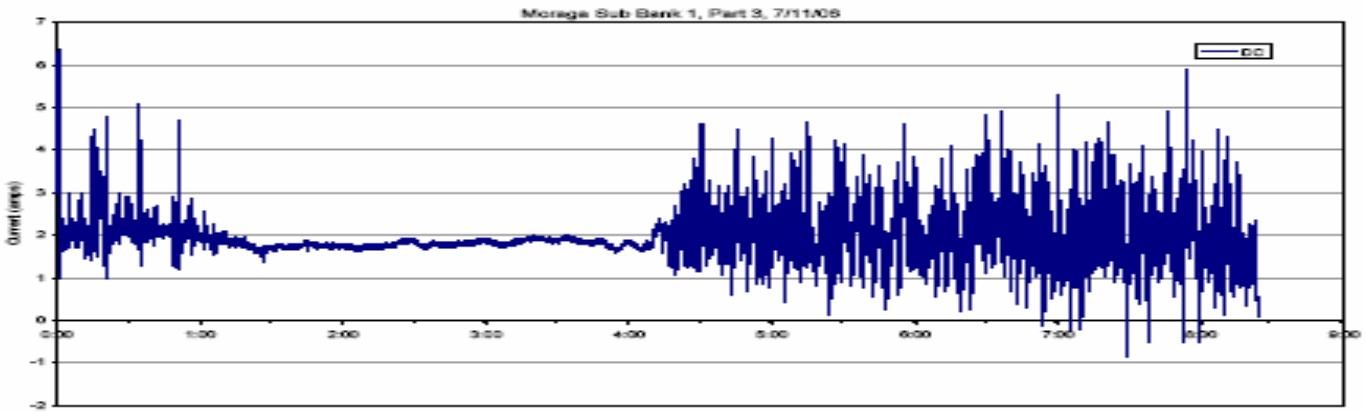


Investigation

- Raised Bk#3 NL taps
  - only slight sound reduction
- Field testing found low-level dc current from the system flowing through transformer neutral.
- Blocking dc current at neutral resulted in a short term (5 minutes) drop is noise (8-10dB(A))


Moraga Sub Bank 1, Part 1, 7/10/08
DC
Current (amps)
11:20
12:20
13:20


Moraga Sub Bank 1, Part 2, 7/10/08
DC
Current (amps)
19:30
20:30
21:30
22:30
23:30

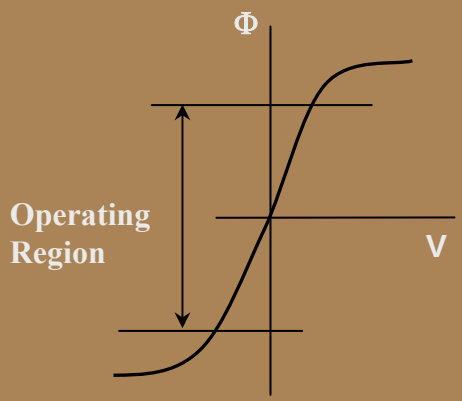

Moraga Sub Bank 1, Part 3, 7/11/08
DC
Current (amps)
1:00
2:00
3:00
4:00
5:00
6:00
7:00

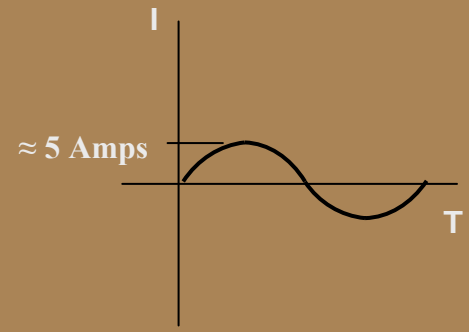
Hunting for the Solution

- We believed the high noise was being caused by DC current, but didn't know how to stop DC.
  - The dc current causes offset flux in the core and partial (1/2 cycle) saturation.
  - Same as GIC effect on transformers.
- Through switching tests, primary source of dc current was isolated to 115kV source.

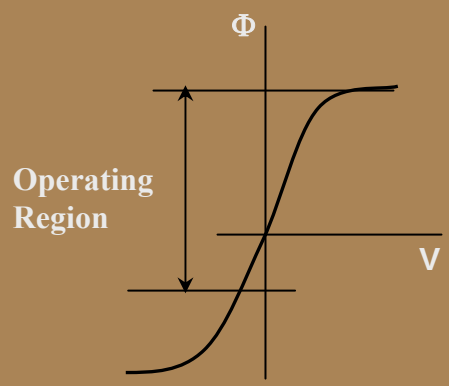
Transformer Operating Characteristics

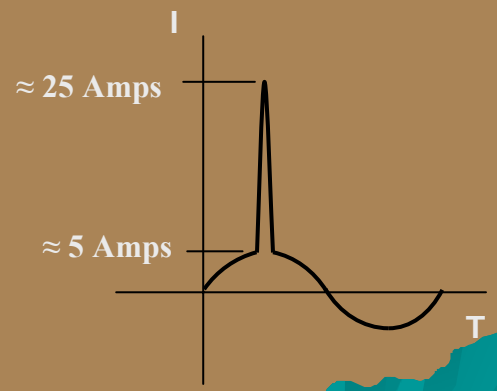
Xfmr Without DC





Xfmr With DC





Choices for Fixing Problem

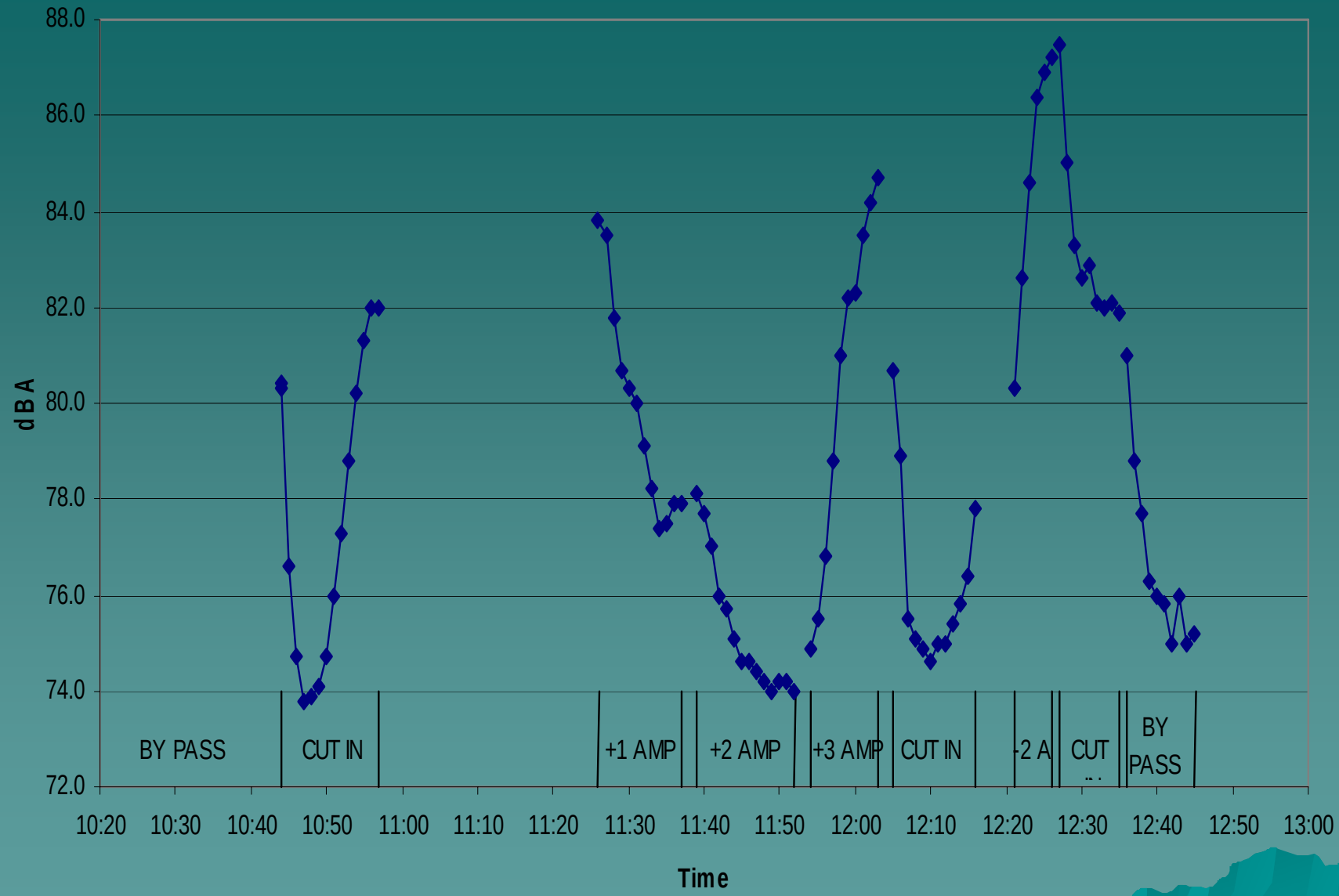
- Two Concerns:
  a) Noise in the neighborhood
  b) Possible loss of life for transformer from vibration

- 1) Build sound walls
- 2) Change out transformer
- 3) Active noise cancellation
- 4) Attempt to reverse saturation with active flux offset control

Short Term
Rented Sound Blankets

Help from up North

- Learned that Bonneville Power Administration (BPA) had dc caused transformer noise problem.
- Contacted them and learned of their method of dc injection to counter stray dc flow.
  - Applied at one location near Seattle on new 500/230kV transformer


88.0
86.0
84.0
82.0
80.0
78.0
76.0
74.0
72.0
dBA
BY PASS
CUT IN
+1 AMP
+2 AMP
+3 AMP
CUT IN
-2 A
CUT
BY PASS
10:20
10:30
10:40
10:50
11:00
11:10
11:20
11:30
11:40
11:50
12:00
12:10
12:20
12:30
12:40
12:50
13:00
Time

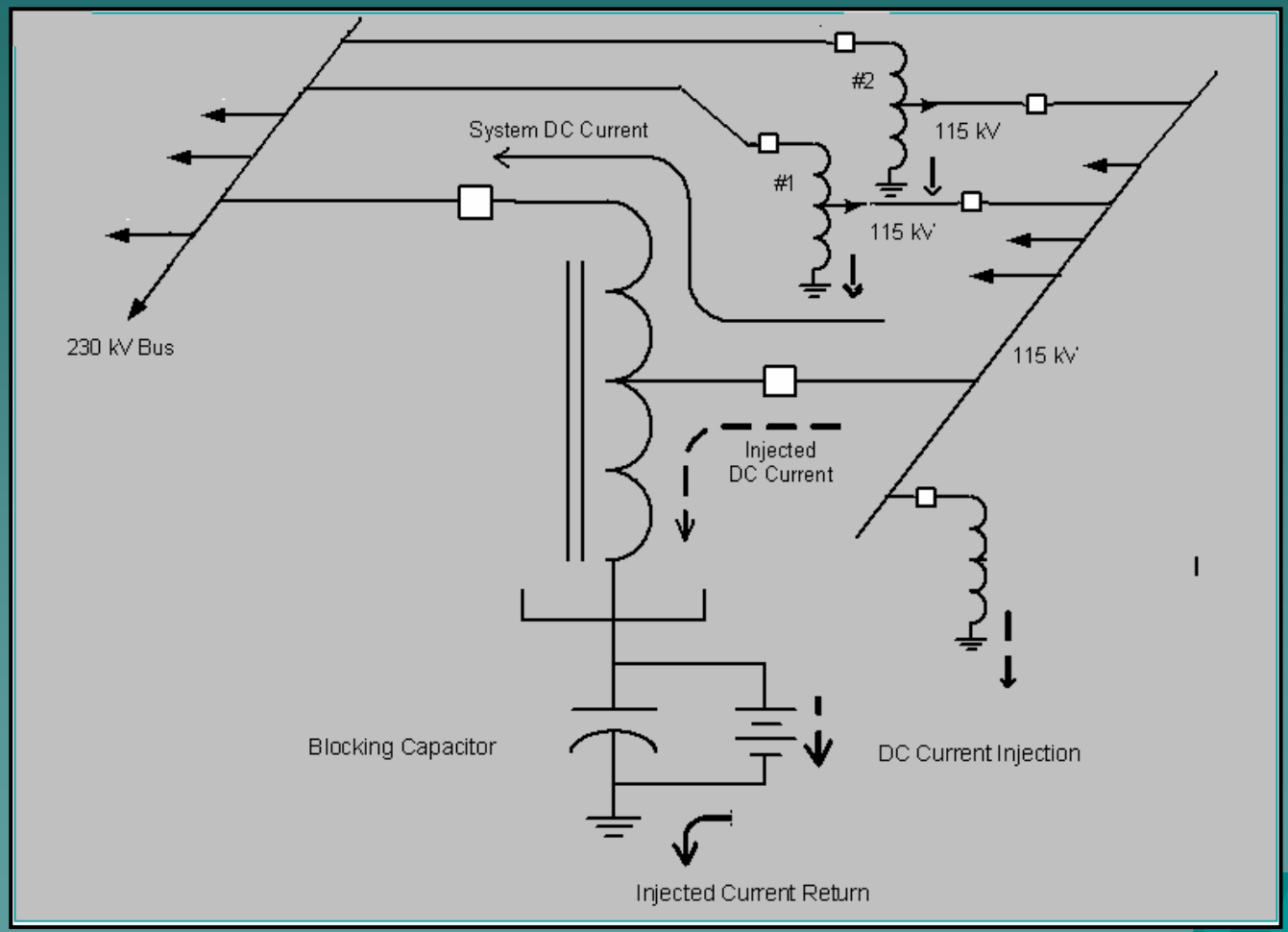
Flux Offset Controller

- Uses a low-ohm capacitor to pass ac current but block dc current in the neutral
- Detects when system dc current has caused offset flux to create transformer vibration
- Injects approx. 4 A dc current into neutral of bank and “pushes” flux back out of the saturation region
- Virtually all injected current is expected to stay in Moraga Substation and return to the controller via the ground mat.

Expected Impacts of FOC

- The injected dc current will add to the system dc current entering the Moraga 230kV and 115kV bus.
- The injected current returns to the FOC through the windings in banks 1, 2 and 5.
- Monitors for dc current have been installed in the neutrals of Banks 1, 2 and 5.
- Banks 1 and 2 are single phase autos and Bank 5 is a 3-phase, 3-leg, core-form and should not be affected by dc current.

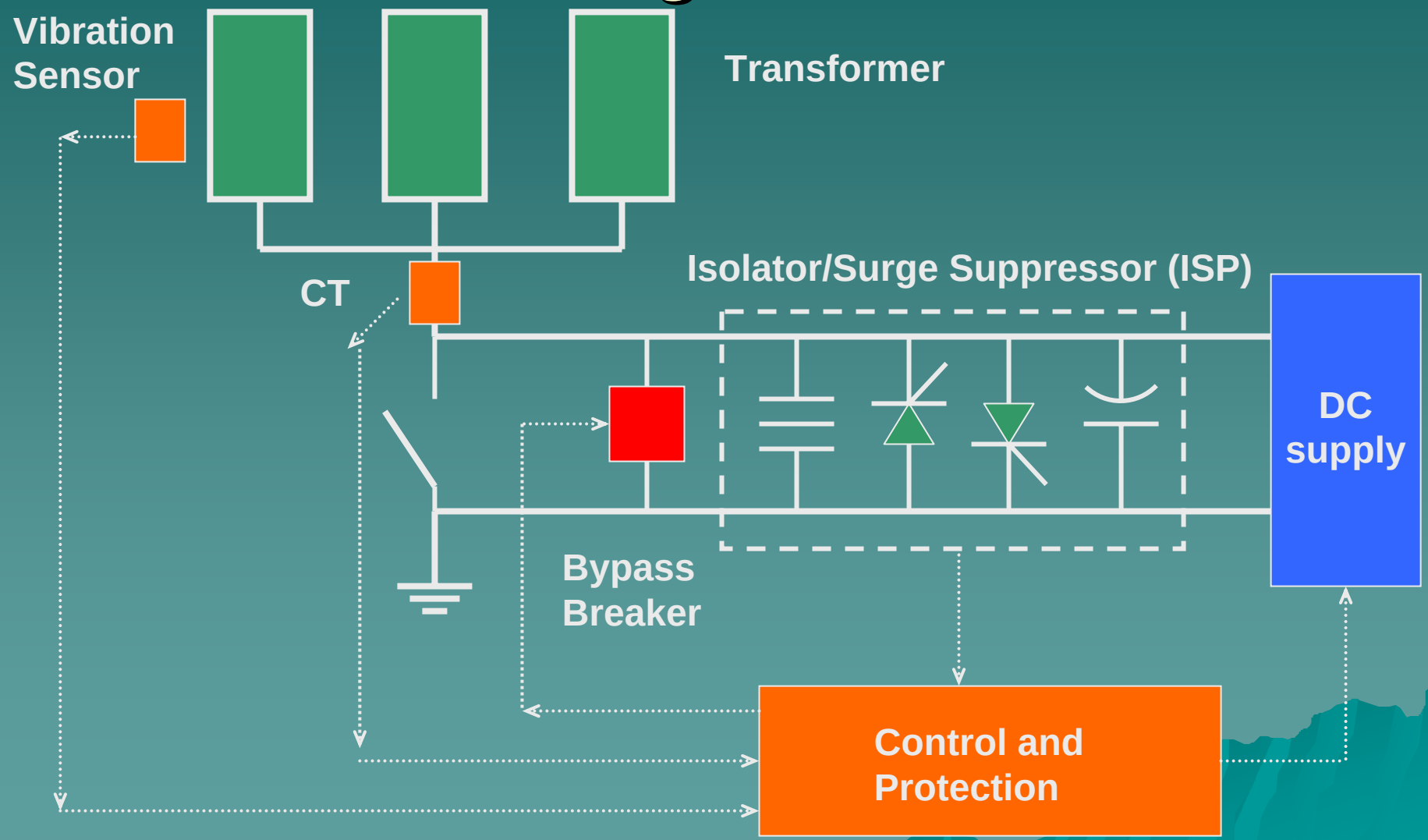
Moraga Substation Bk#3



Main FOC System Components

- **ISP** – Isolator / Surge Protector: Commercially available self-protected capacitor, 88 mΩ, 18 V breakover.
- **Power Supply** and Polarity-Switching 10 A max.Voltage or Current Controlled
- **Bypass Breaker**: Single-pole vacuum switches
- **Vibration Sensor**
- **Controls and Protection**: GE-N60 Programmable Relay

FOC Simplified One-Line Diagram

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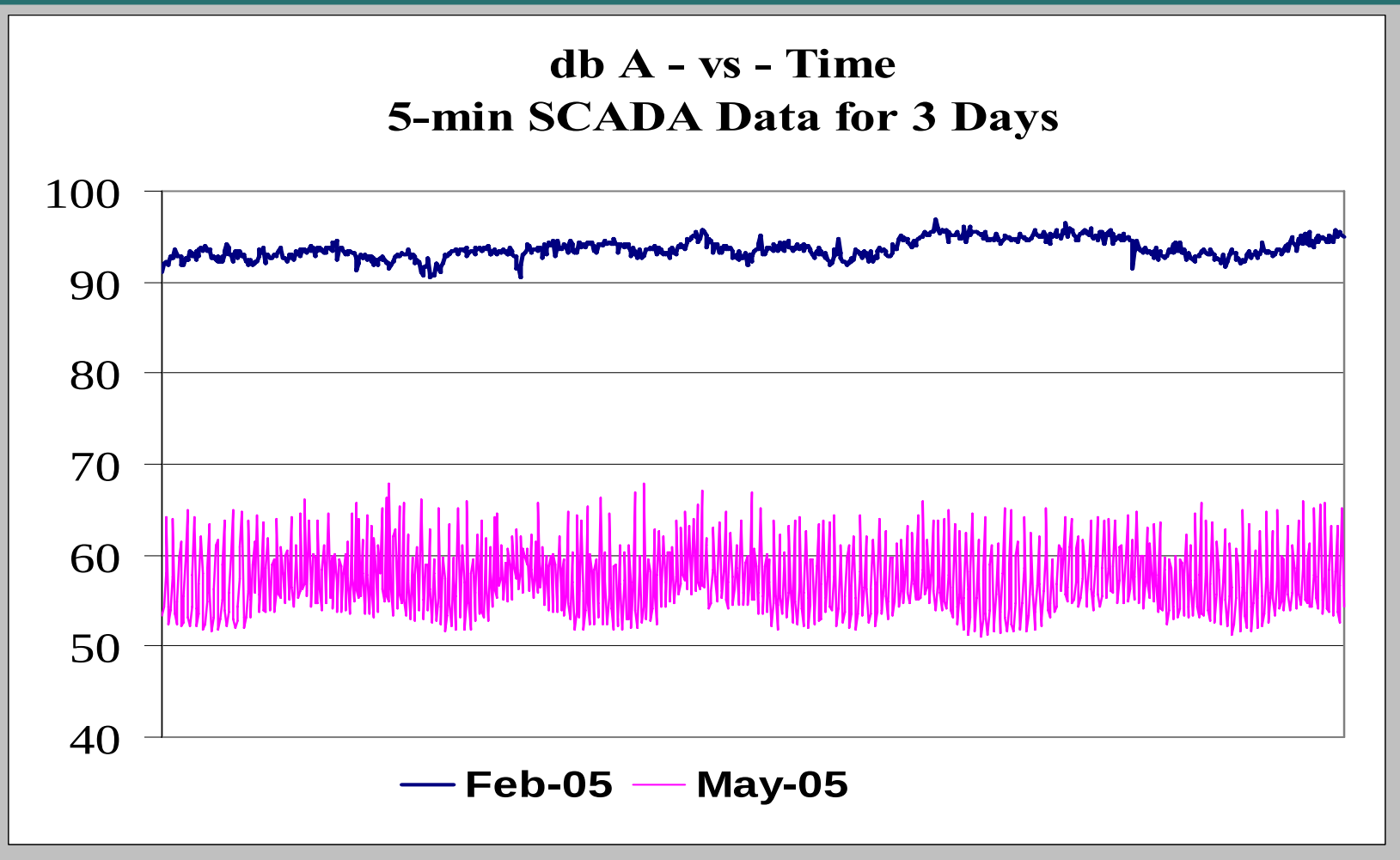
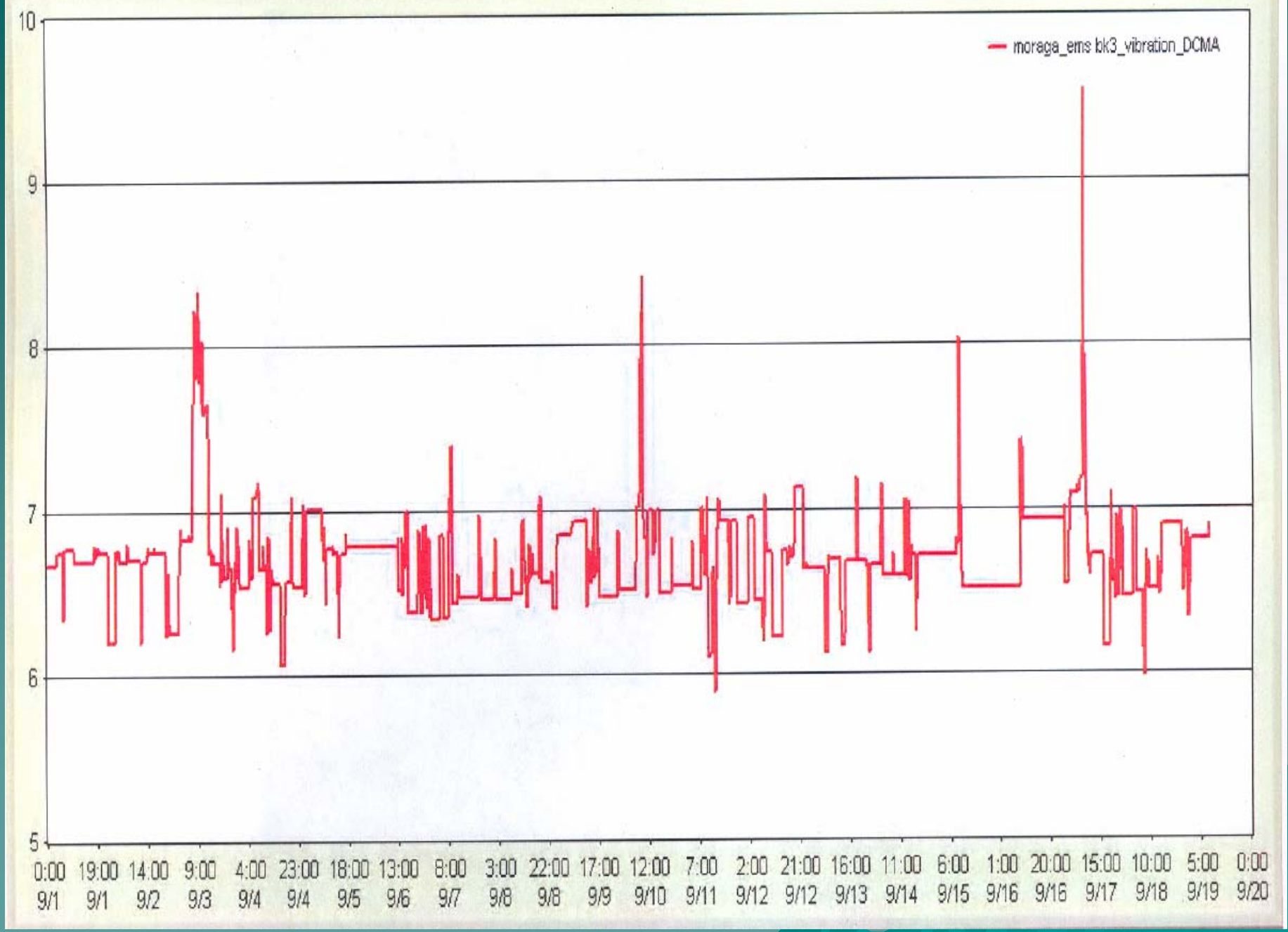
Sno-king Bank Vibration Before & After FOC




moraga_ems bk3_vibration_DCMA
10
9
8
7
6
5
0:00 9/1
19:00 9/1
14:00 9/2
9:00 9/3
4:00 9/4
23:00 9/4
18:00 9/5
13:00 9/6
8:00 9/7
3:00 9/8
22:00 9/8
17:00 9/9
12:00 9/10
7:00 9/11
2:00 9/12
21:00 9/12
16:00 9/13
11:00 9/14
6:00 9/15
1:00 9/16
20:00 9/16
15:00 9/17
10:00 9/18
5:00 9/19
0:00 9/20

What's next?

- To date, operational history looks very good.
- Modified controls for high system voltage.
- So far, no detectable effect on adjacent transformers or system.
- Try to find source
- Other banks?
- ~~~~ Thanks for listening! ~~~~~