IEEE BROADCAST TECHNOLOGY SOCIETY

Effective Monitoring and Protection systems for Multiplexed TV and Radio Facilities

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BTS IEEE Broadcast Technology Society

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AMERICAN TOWER®

IEEE

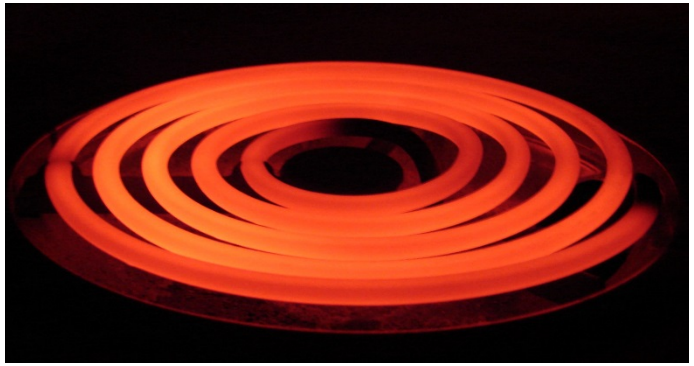
Why Monitor RF Systems?

- Protect large capital investment (typically $1 to $4 million per system)
- Keep stations on air
- Failure is rare BUT, stuff burns up!
- There is no way to predict when disaster will strike.
- Understand ongoing conditions/ help with P.M.
- Transmitters can’t be relied upon to protect the system

Why Monitor RF Systems?

Why Do RF Systems Fail?

- Contact = Heating = Insertion Loss
  - Series resistance that generates heat
  - Results from geometry and material design choices
  - Sets normal average power capacity
  - Loss is always there and becomes an issue when it rises above heat dissipation capabilities



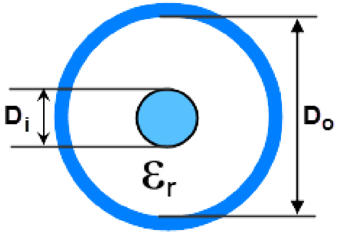
A 2 kW Element reaches 500 deg F in a matter of seconds, imagine what 50 kW does!

Why Do RF Systems Fail?

- Voltage Breakdown = Arcing
  - Voltage across gap exceeds allowable
  - Breakdown is dependent on:
    - Gas type: vacuum, dry air, nitrogen, etc
    - Pressure: capacity increases with pressure
    - Temperature: capacity decreases with temp
    - Humidity: capacity decreases with humidity
    - Altitude: capacity decreases with altitude
    - Geometry: Points decrease capacity
  - High Q (tuned) circuits have greatly increased voltages and are more susceptible to breakdown
  - Multi-channel (N) systems have peak voltage increase of N^2
  - Arcs don’t inherently cause damage if not sustained
  - Ionized air at arc reduces breakdown potential
  - Sustained arcs generate tremendous heat

What Happens Next?

- Physical properties or geometry changes



Coaxial Cable Cross-section

$$Z_O = \frac{138}{\sqrt{\varepsilon_r}} \log \frac{D}{d}$$

where : D = inside diameter of outer conductor
d = inside diameter of outer conductor
ε_r = relative permittivity of the dielectric

- Thermal runaway begins
- Carbon and molten Teflon land on other components and process accelerates
- VSWR changes

$\Gamma =$	$\frac{Zo - Z_L}{Zo + Z_L}$
VSWR =	$\frac{1 + \Gamma}{1 - \Gamma}$
RL (dB) =	-10 LOG $\lvert \Gamma \rvert^2$

Teflon melts at 600 deg F

Copper melts at 1900 deg F

How do we detect failures?

- Monitor VSWR for changes
  - Forward and reflected power sample[redacted]through directional couplers

$$\text{VSWR} = \frac{1+\sqrt{\dfrac{\text{REFLECTED POWER}}{\text{FORWARD POWER}}}}{1-\sqrt{\dfrac{\text{REFLECTED POWER}}{\text{FORWARD POWER}}}}$$

- Apply samples at various points throughout system to localize reflections
- Leads you to the scene of the crime!
- Some new sensors have ability to perform time domain

Power-ratio = 0.0199526

How to stop failures?

- Power MUST be removed at first signs of VSWR to prevent further damage
- Current transmitter foldback logic does NOT protect from damage
  - The reflected power for a 50kW transmitter in foldback is up to 50000*.01999= 1000 Watts max
  - The transmitter can thus deliver 1000 Watts forward and 1000 Watts reflected constantly
  - Logic needs to be changed to rely on VSWR as value to trip at
- Monitoring system interlocks must be hooked to RF mute
- Locate problems immediately through time domain and correct

Protection Systems Installed for American Tower

- Atlanta, GA Chester Avenue
- Atlanta, GA Briarcliff (VPT)
- Detroit, MI
- Miami, FL
- Boston, MA (VPT)
- Dallas, TX (VPT)
- Houston, TX (VPT)
- Oklahoma City, OK
- West Orange, NJ
- Richmond VA
- Knoxville TN
- Chicago, IL

VPT (Variable Polarization Technology) Dual Chain

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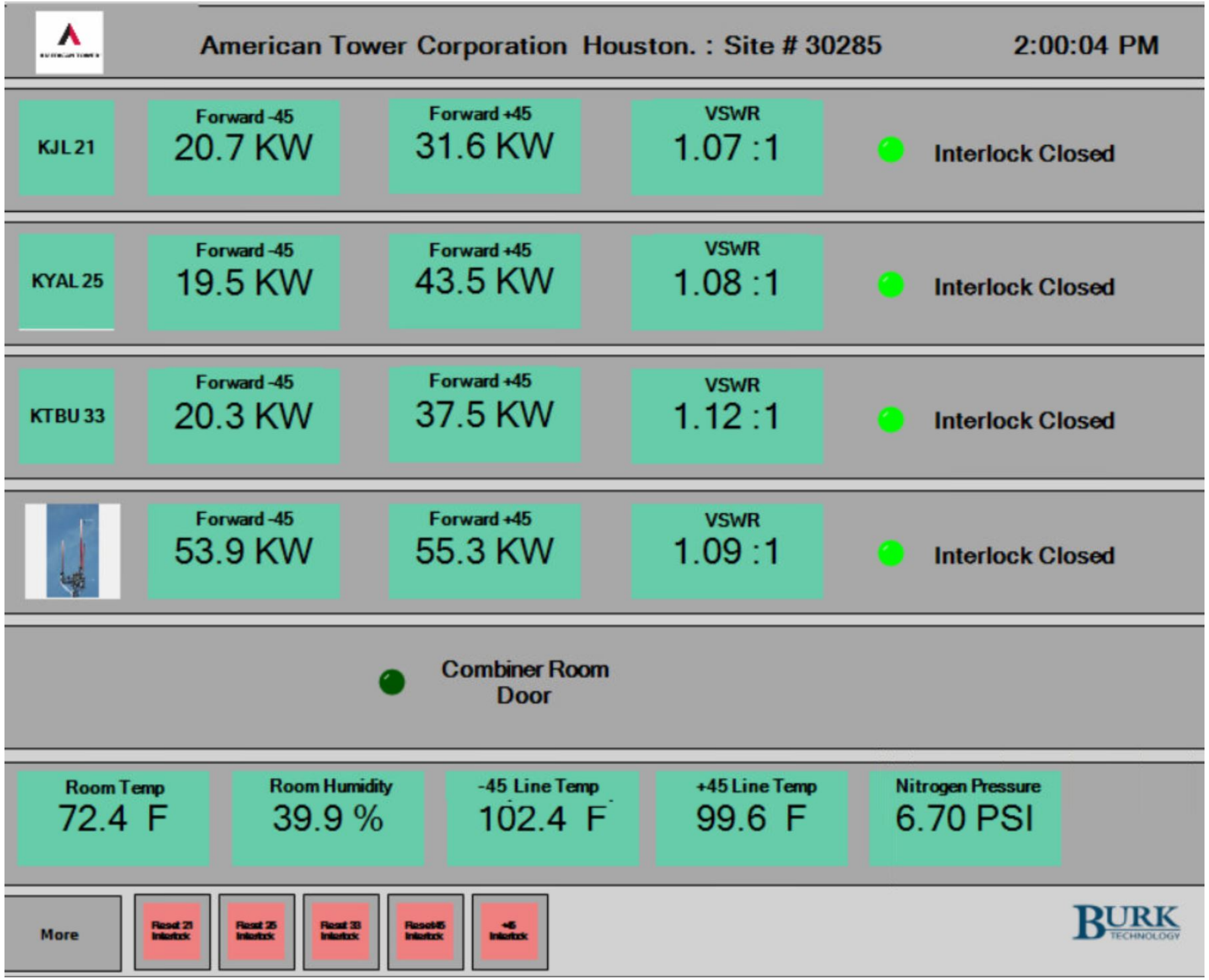
Houston RFS Combiner for American Tower Corporation (VPT)

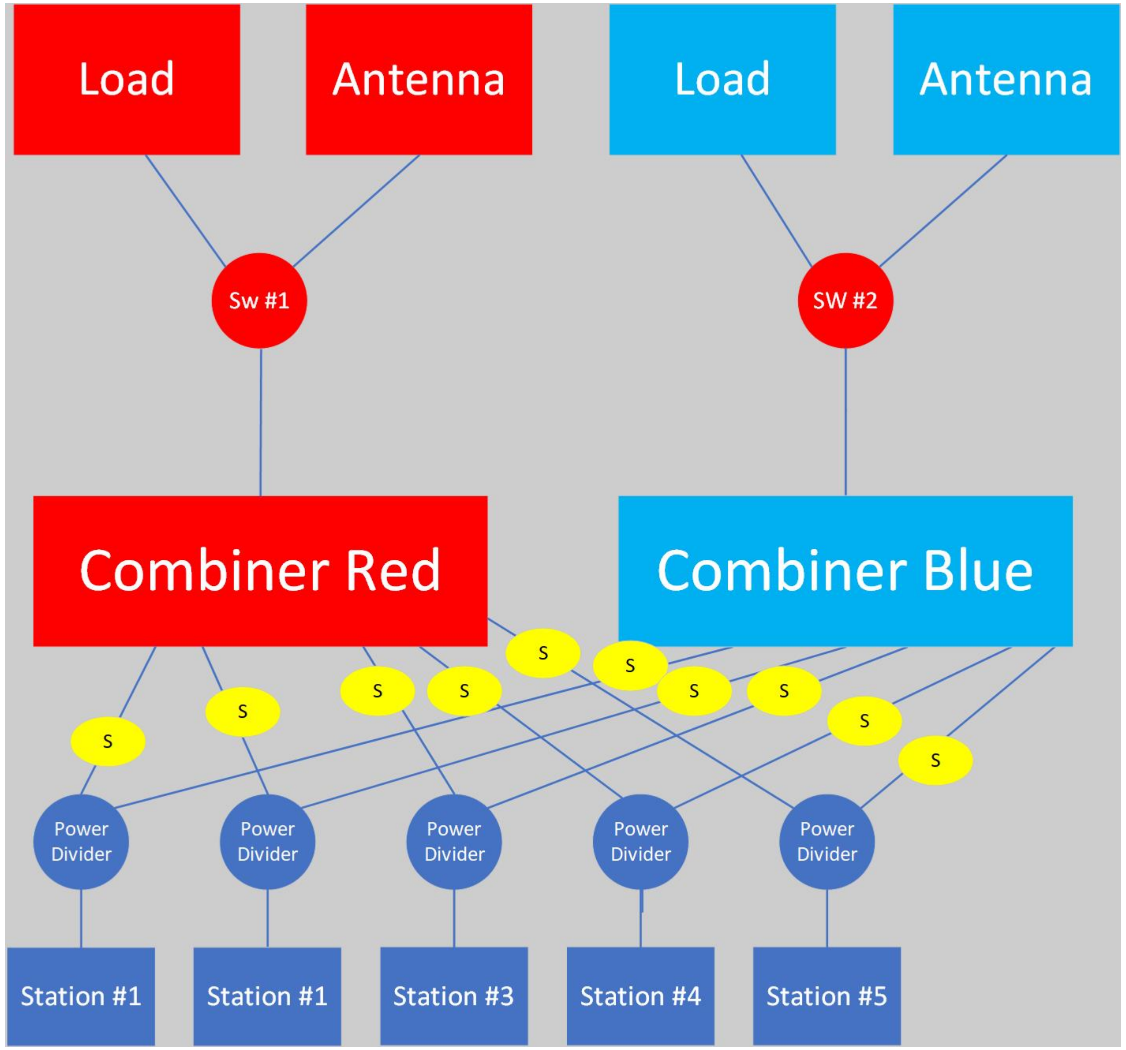


Computer Algorithms

- Trend Analysis
- Data Logging
- Coaxial and Waveguide Switch Interlocking and control
- Dummy load interlocking
- Real time web page generation for telemetry
- Heartbeat monitor
- Email/Text Message Notifications

Typical RF Sensor (indoor)

Typical VPT Combiner



Typical RF Sensor (Outdoor/Indoor)

With the DAC sensor the RL/VSWR (Voltage Standing Wave Ratio) can be determined at every pylon- or panel - antenna and splitter

The DAC sensor capture the PTx and the PRx values. The results are transmitted with one shielded cables to the Junction Box.

The sensor is:

- remotely powered, IP 66
- very high dynamic range
- broadband 50 - 860 MHz

A/D converter (16 bit for high resolution)

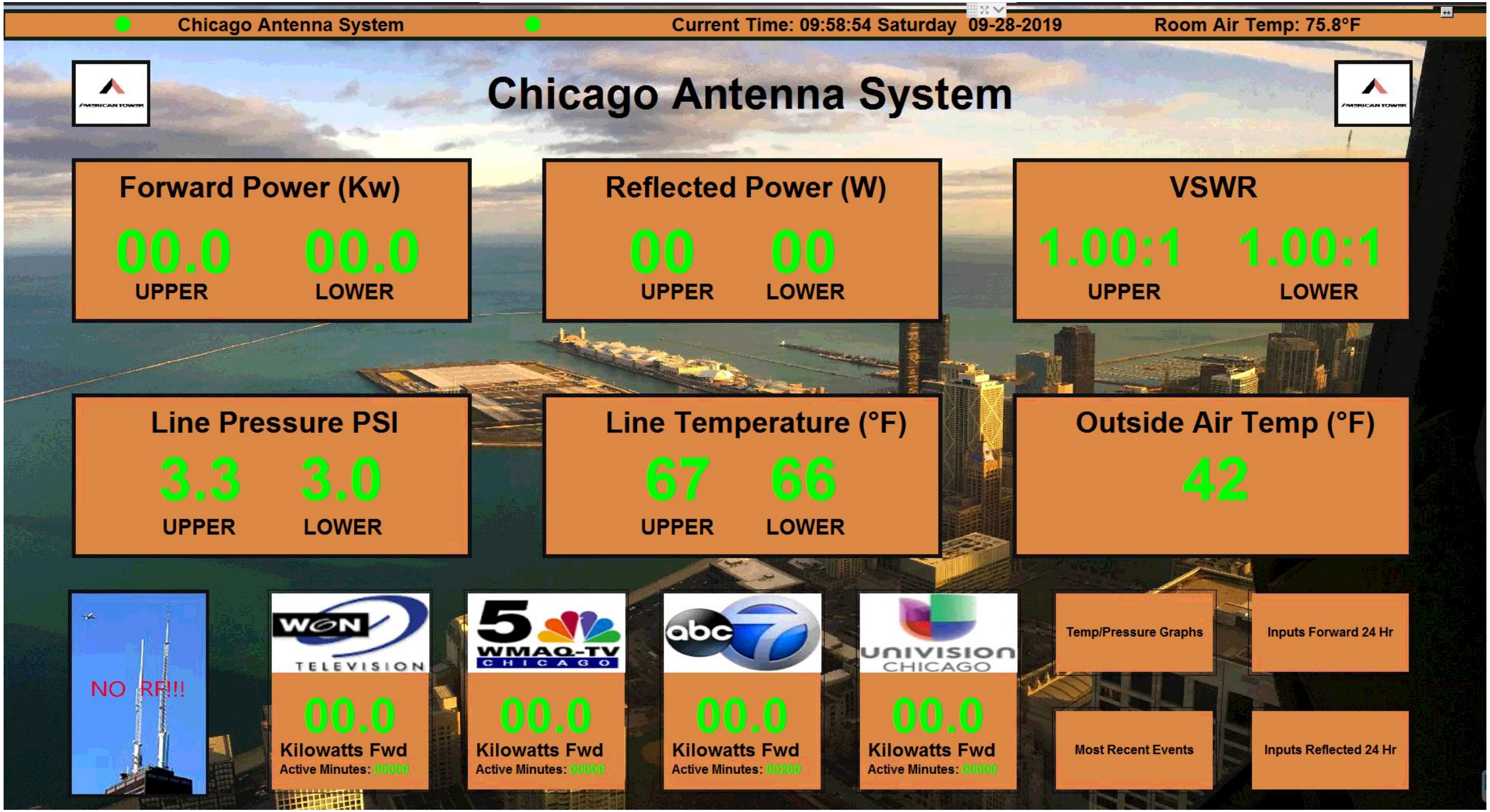
Example of thermal sensor on transmission line

Monitor Line Pressure

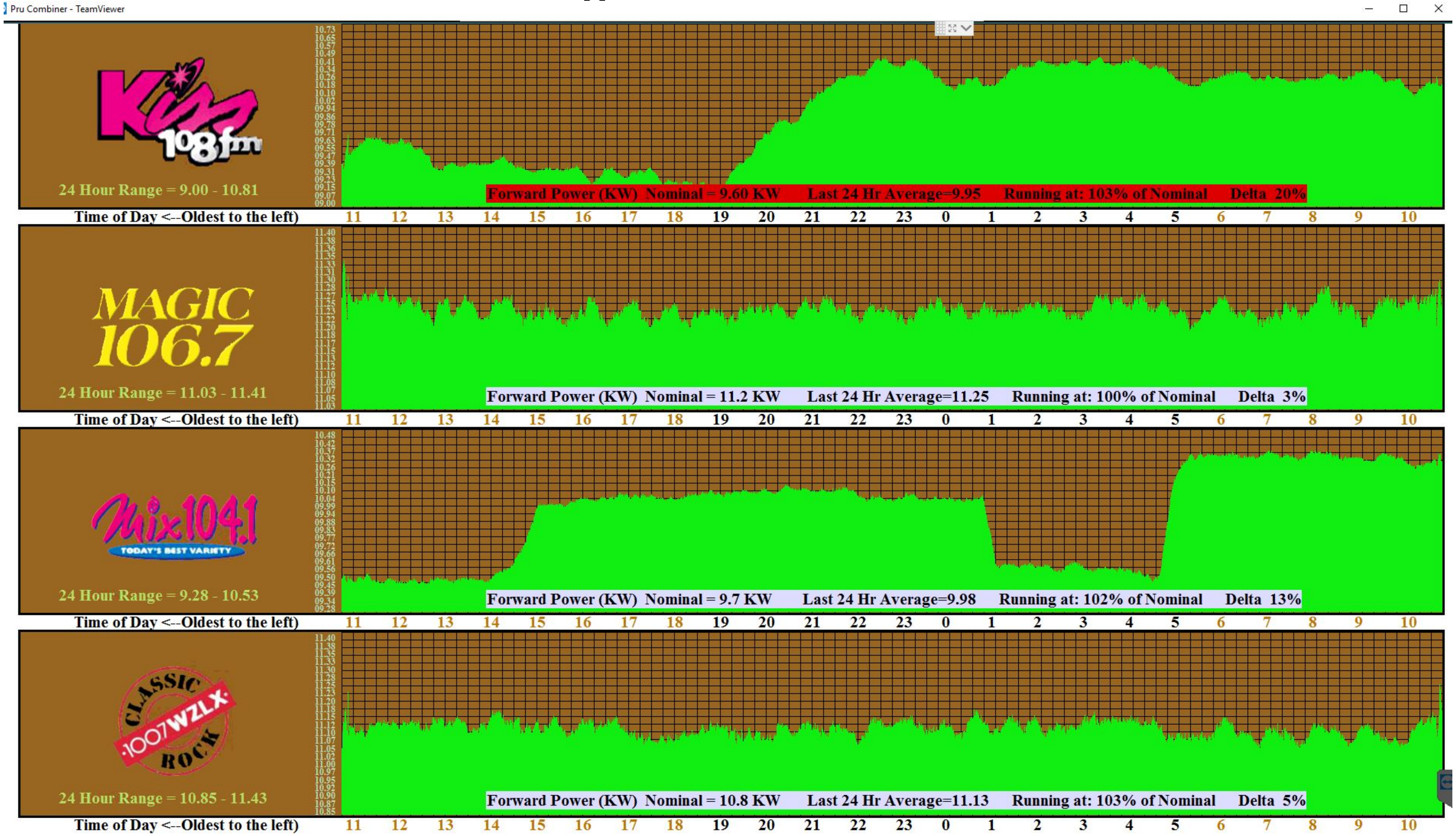
Example of Lockout/Tagout Key Switch

Clearly mark demarcation points for all stations to connect their interlocks to:

American Tower Chicago Aux Site Monitoring Screen



Prudential Building Boston 24 Hour Historical View



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Effective Multiplex Facility Program Management

- Require all stations to connect to[redacted]he interlocks
- Calibrate system at least annually (forward and reflected power)
- Require all stations to participate in annual interlock checks
- Have regular multiplex group meetings to discuss the operation of the facility, upgrades, tower and combiner inspections, room cleaning, business matters, etc.

Thank You!

Questions?