Voltage Transformer Failure Prediction With Synchrophasor Data

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Prevent equipment failure
Plan maintenance in advance

Voltage transformer
Potential impacts of failing voltage transformer

- Protection impacts
  - Improper relay operation
  - False alarms sent to SCADA
  - Misrepresentation of phase angle
  - Corrupted voltage measurements
  - Corrupted frequency signals
- Equipment/personnel impacts
  - Substation equipment damage
  - Personnel safety hazards

Existing detection methods

- Loss-of-potential logic in protective relays
- SCADA-based protection
SCADA misses information

- PMU real power
- SCADA real power

Power (kW)

Time

4:27:00
4:27:20
4:27:40

Synchrophasor system diagram

Substations
- DFR/PMU(s)
- Relay/PMU(s)

Secure network
- Grid operations environment
  - Operator web clients
  - Synchrophasor software
  - Synchrophasor software
  - Software platform
  - Server, Server, Server

- Engineering environment
  - Engineer web clients
  - Synchrophasor software
  - Synchrophasor software
  - Software platform
  - Server, Server, Server
Situational awareness software user interface

First voltage transformer failure

Repetitive C-phase voltage drops were detected for several weeks
First voltage transformer failure

Voltage (kV)

17:20 17:25 17:30 17:35 17:40

C-phase
B-phase
A-phase

First voltage transformer failure

Voltage (kV)

17:20 17:25 17:30 17:35 17:40

C-phase
B-phase
A-phase

Servicing C-phase PT fuse
First voltage transformer failure

Time
17:20 17:25 17:30 17:35 17:40

Voltage (kV)
7.6 7.4 7.2 C-phase
B-phase
A-phase

First voltage transformer failure

Time
17:20 17:25 17:30 17:35 17:40

Voltage (kV)
7.6 7.4 7.2 C-phase
B-phase
A-phase

Return to normal

Zoom
First voltage transformer failure

Zoom detail

~3%

Second voltage transformer failure
Second voltage transformer failure

- Repetitive C-phase voltage drops begin on August 1st.
- Service on August 6th.
Second voltage transformer failure

C-phase PT fuse failure

Second voltage transformer failure

C-phase PT fuse replacement
Second voltage transformer failure

![Graph showing voltage fluctuations over time](image)

New synchrophasor-based detection method

1. PMU measurements
2. Preprocessing
3. Failure detection
4. Postprocessing
5. Alarm
**Preprocessing**

\[ V_\phi \xrightarrow{\text{PU conversion}} \text{Median filter} \xrightarrow{\text{Interpolation}} V_{\phi, PP} \]

\[ \theta_\phi \xrightarrow{\text{Derivative}} \text{Median filter} \xrightarrow{\text{Interpolation}} \theta'_{\phi, PP} \]
The image contains a schematic diagram of a circuit, including voltage levels and failure detection logic. The diagram represents the flow of signals through various components such as LPF (IIR) and LPF (FIR) stages, with annotations for voltage levels like $V_{A,PP}$, $V_{B,PP}$, and $V_{C,PP}$. The output of the circuit is labeled as $D_A$, $D_B$, and $D_C$, with failure detection logic shown at the end of the circuit.
Failure detection
Failure detection

Postprocessing

\[ D_A \sum_{t-T}^t MAF + C_{TH} - T_P \quad \text{T_D} \quad \text{A-phase alarm} \]

\[ D_B \sum_{t-T}^t MAF + C_{TH} - T_P \quad \text{T_D} \quad \text{B-phase alarm} \]

\[ D_C \sum_{t-T}^t MAF + C_{TH} - T_P \quad \text{T_D} \quad \text{C-phase alarm} \]
Postprocessing
Results for second voltage transformer failure

![Graph showing voltage magnitude over time for different phases. The graph includes markers for VA, VB, VC, DA, DB, and DC. The time scale ranges from day 27 to day 04, with a y-axis representing magnitude in pu (per unit).]
Questions?