Shorted Winding Assessment of Turboalternators

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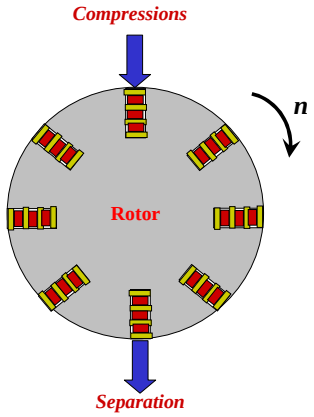
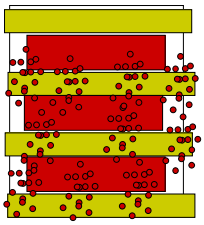


Pounding of the Copper Conductors



Pounding of the Copper Conductors

- Results in the accumulation of copper powder within slots.
- When the machine is energized, the copper dust can cause arcing between turns.
- Over time, a full short between turns may occur.
- Broken rotor conductors and water intrusion may also cause shorted turns.
- In many instances, the rotor short turns are speed dependent

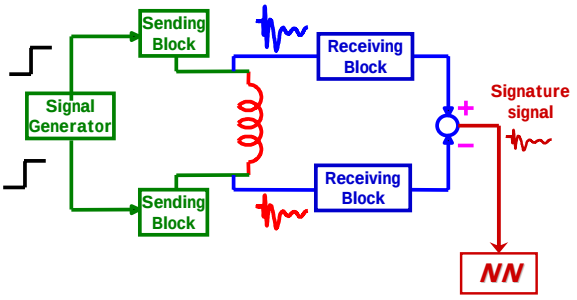
Challenges to Shorted Turns Detection

- Intermittent shorts
- Hard to detect
- Periodic maintenance is expensive
- Elusive general solution

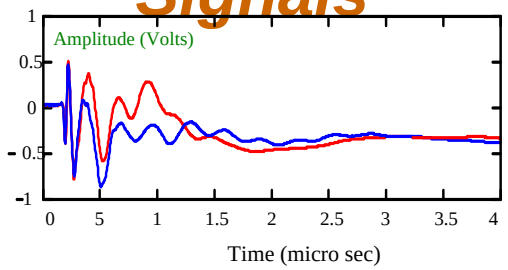
Existing Techniques

- Pickup coils for direct Measurement of Air/Gas-Gap Magnetic Flux Using Slot Probes
- Vibrations Monitoring
- Synchronous Generator Capability Curves
- Timed maintenance

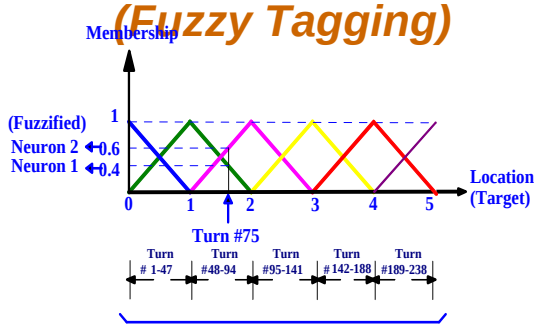
Signature Signal



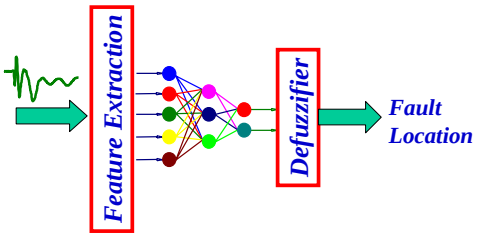
Signature Signals



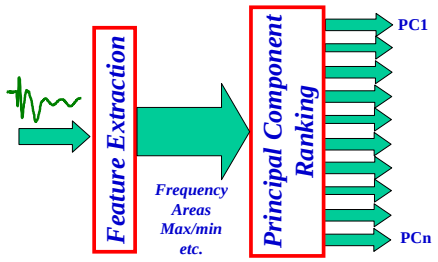
Short Localization (Fuzzy Tagging)



General Localization



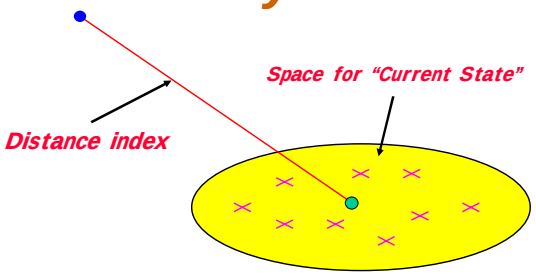
Principal Components



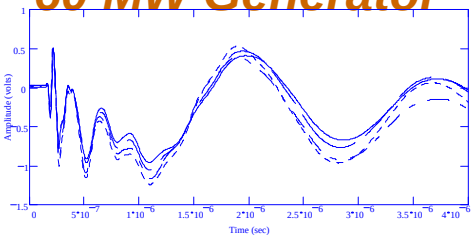
Operational Rotor

- **Problem:** Localizing a short by NN requires data for shorted and healthy rotors.
- **Solutions:**
  - → Create a short to train the NN
    - Not possible
    - Not feasible
  - → Develop a base case
    - New machines
    - Status of Existing machine
    - Novelty filter

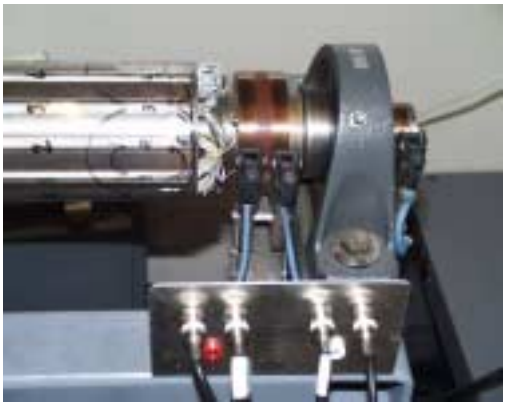
Novelty Filter

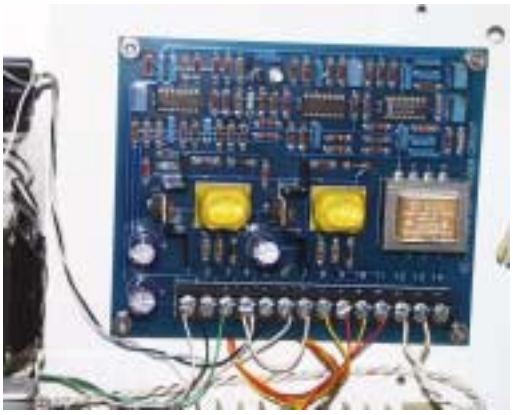


Clustering Signature Signals: Data from 60 MW Generator

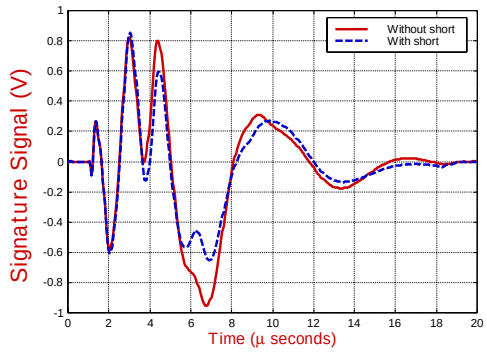


Setup for Lab Test

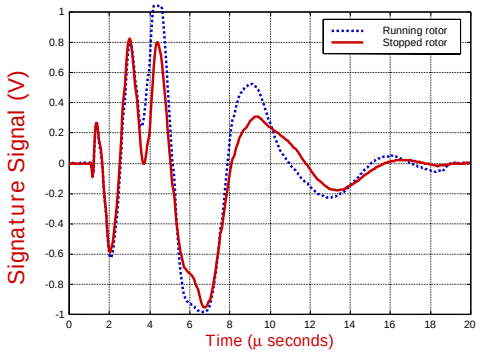




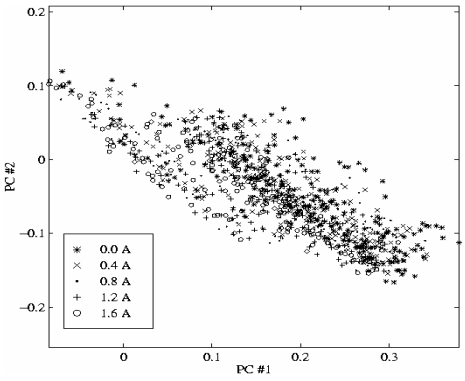
Signature Signal with/out shorts



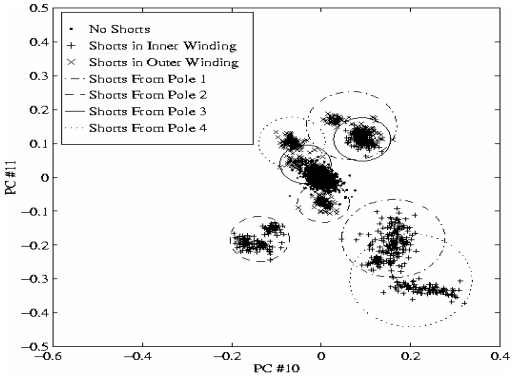
Signature Signal: speed dependency

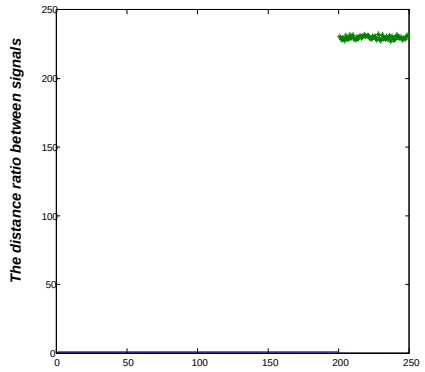


Clustering of Healthy Data: Various Excitations



Clustering After Shorts





Lab Test: Effect of Speed

Rotor speed →	Stopped	30-60 rpm	1800 rpm
False Alarm rate α	0.0	0.0	0.4
Detection rate β	100.0	100.0	91.0

Lab Test: Comparisons

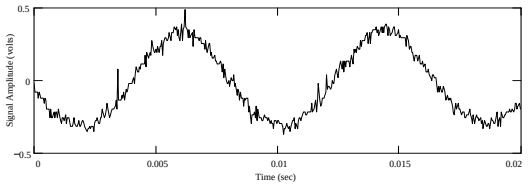
Detection Method	Stopped Rotor		Turning-Gear		Full Speed Rotor	
	α %	**β %**	**α %**	**β %**	**α %**	**β %**
Spherical	0.0	83.8	0.0	85.3	0.0	65.0
Min-Max	63.6	100	32.9	100	0.8	92.8
Nearest Neighbor	56.2	100	0.0	100	0.1	79.3
Elliptical	0.0	100	0.0	100	0.4	91.0

false alarm rate, α detection probability, β

Field Test

- Southern California Edison Company
  - Unexcited Machine (60 MW rotor)
    - Fault is introduced
  - Excited Machine (60 MW rotor at Highgrove Power Station)
    - Fault cannot be introduced
    - Brush noise exists
    - Rotational noise – mechanical vibration
    - Electromagnetic noise
    - dc isolation
    - Fail safe operation

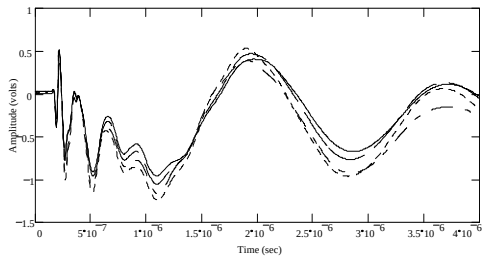
Brush Noise: 60 MW Excited Rotor



Field Test Results: Unexcited Machine

Test Results	
Percentage of Accurate Identification of Coil	100%
Maximum error in short localization	± 7 turns (± 3%)

Field Test Results: Excited Machine



SCE 60 MW Steam Turbine at Highgrove Station

Conclusions

- A system has been developed to detect and localize a short in the rotor windings of a turboalternator.
- The circuits floats on any applicable DC or AC voltage so that testing can be performed on-line for excited windings.

Conclusions

- The system does not require installation of any hardware inside the machine.
- The system is capable of handling variations in the signature signals due to several factors such as machine temperature, speed, excitation current, and brush noise.