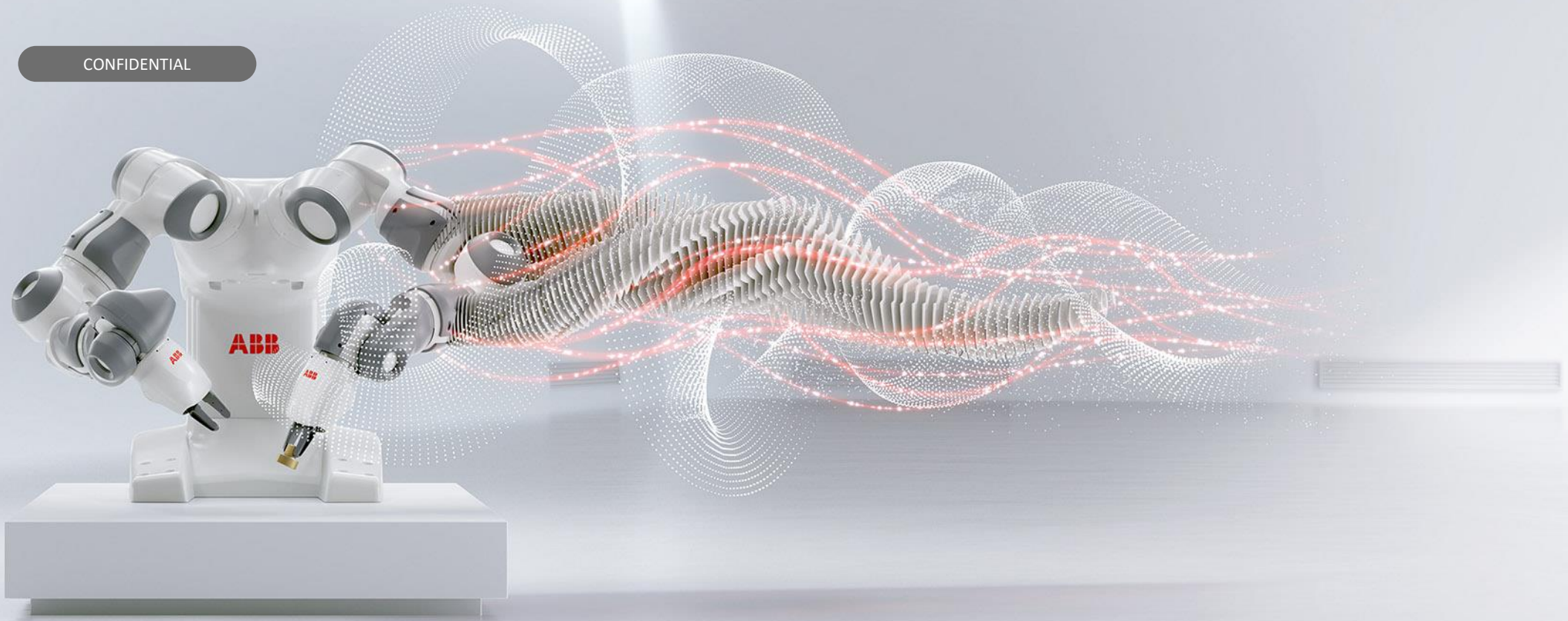
CONFIDENTIAL



DEC 2023

Non-invasive generator diagnosis: A model-based evaluation

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Non-invasive generator diagnosis

A model-based idea evaluation

Hydro-generator

https://www.hydroreview.com/technology-and-equipment/generators-and-electrical-components/a-retrospective-on-generator-failures/#gref

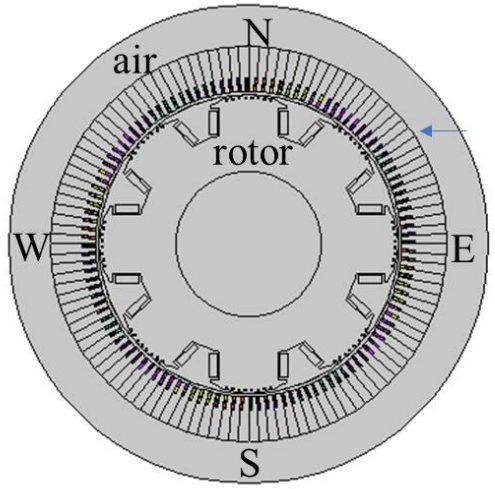
blic/645e395f8666430ab3979260d8fc8981/3BUS094951_A_Hydro%20power_Governor%20b

A Retrospective on Generator Failures (hydroreview.com)

Generator diagnosis essential to prevent loss in efficiency, catastrophic failure

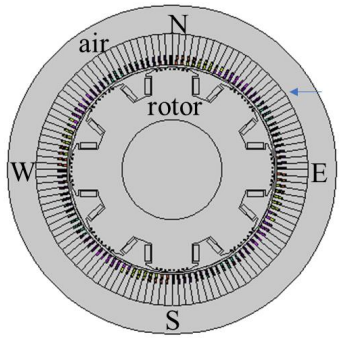
- Defects
  - Rotor eccentricity: static/dynamic
  - Stator short circuiting, Rotor electrical imbalance
- Motor current/magnetic signature methods can diagnose defects. Difficult to identify specific defect
- Proposed idea: Multiple non-invasive magnetic flux sensors

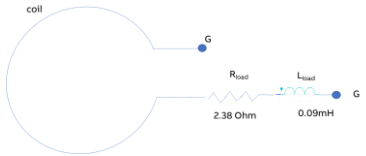
- Non-invasive flux sensors: feasible safe
- Multiple sensors: Identifying defect



Non-invasive generator diagnosis

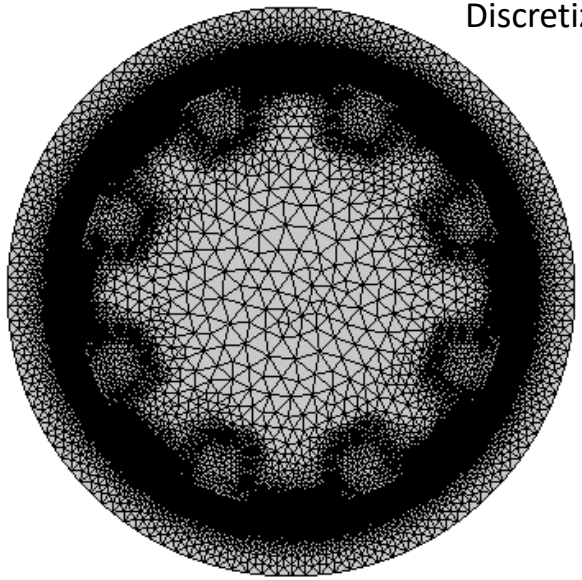
A model-based idea evaluation

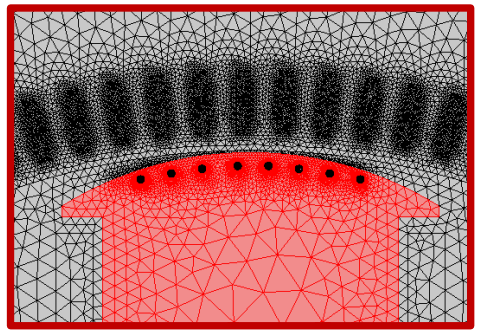




Closed circuit

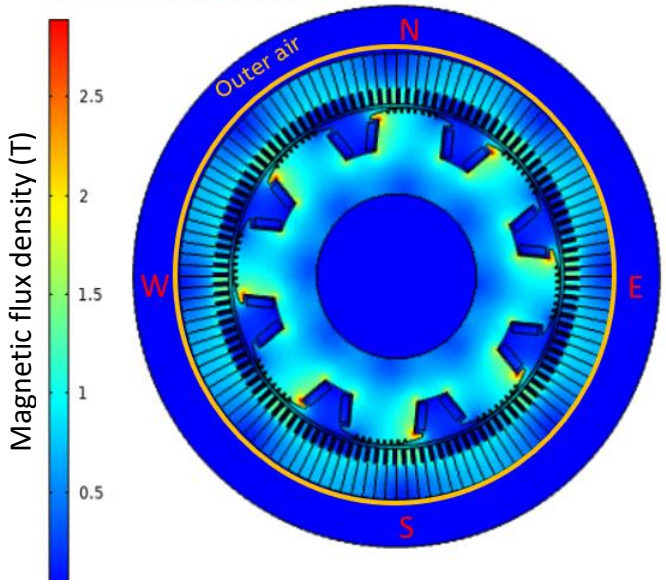
Discretization





Critical zones: Well-resolved

Non-invasive sensors: N, S, E, W



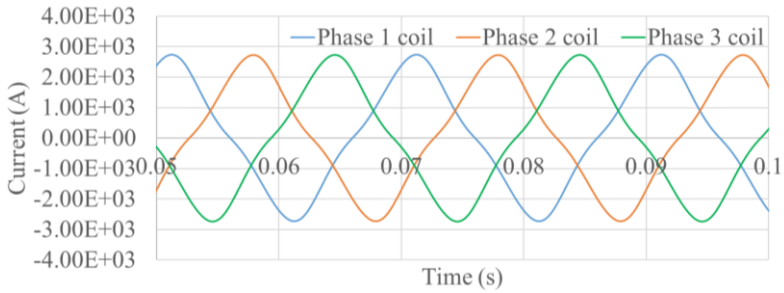
Ampere's law

$$\nabla \times H = J \qquad H = B/\mu$$

$$B = \nabla \times A$$

$$J = \delta E$$

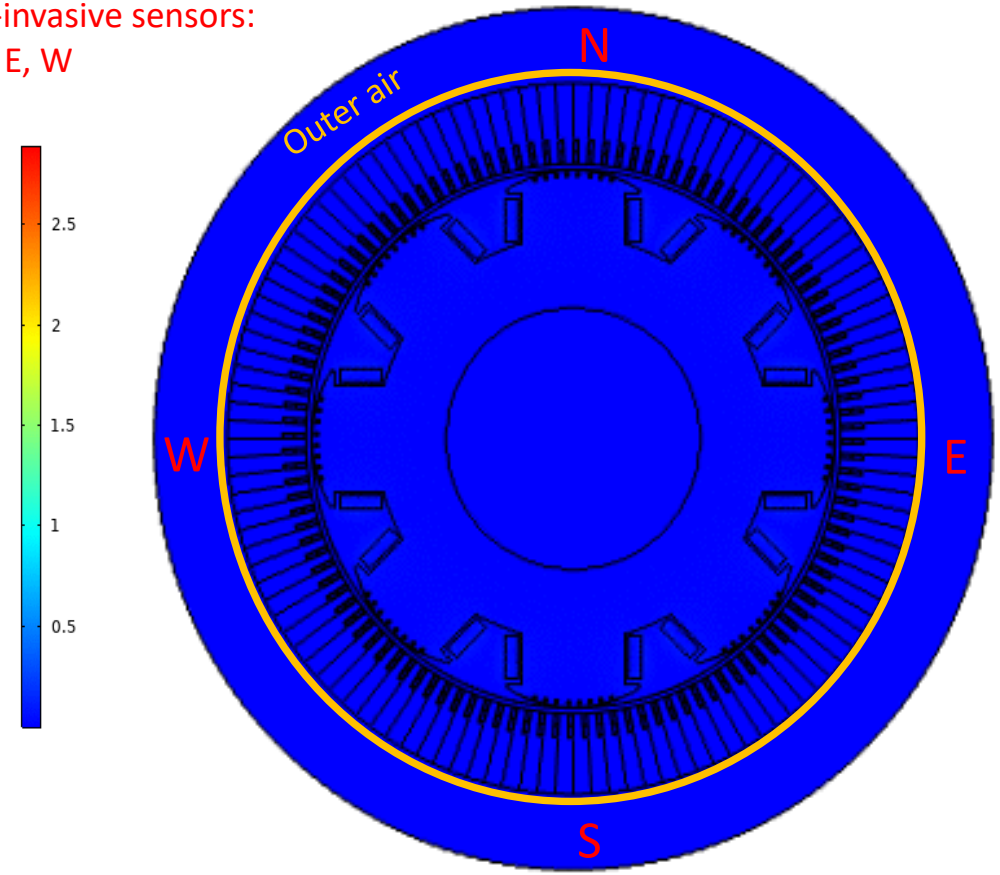
- Solved for stationary and rotating domains
- Solves external magnetic flux



Non-invasive generator diagnosis

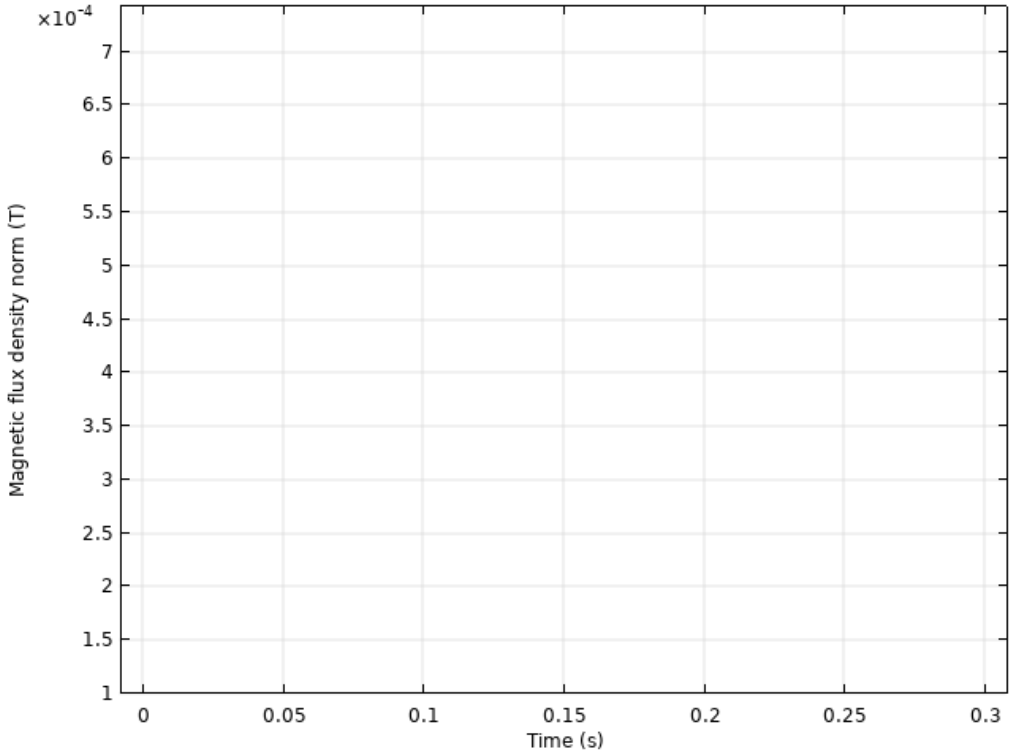
A model-based idea evaluation

Non-invasive sensors:
N, S, E, W



Finite element electromagnetic model, to demonstrate proof-of-concept

Defect free performance
All sensors exhibit similar flux profile



Non-invasive generator diagnosis

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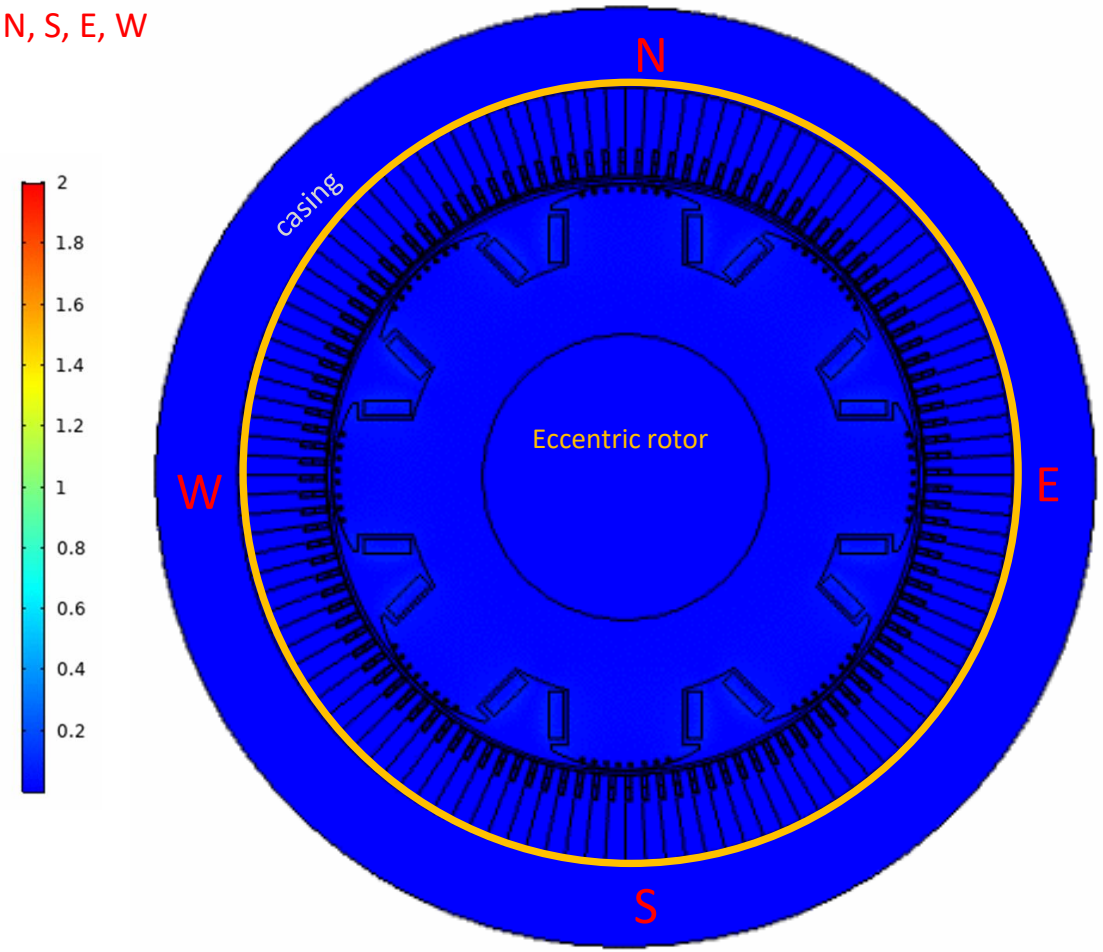
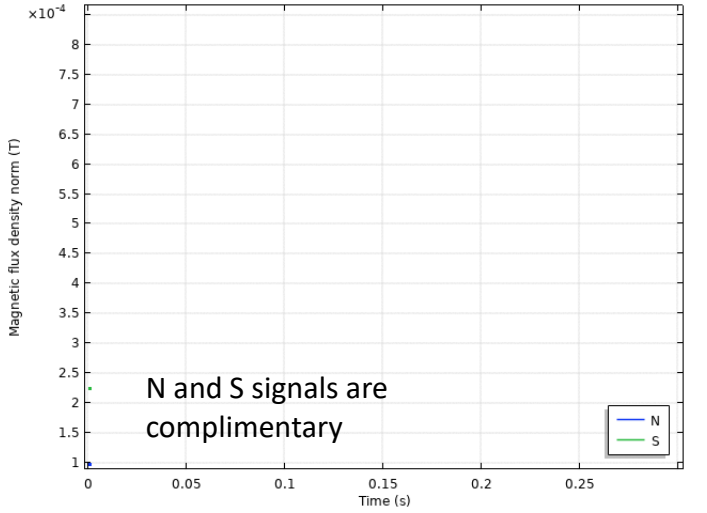
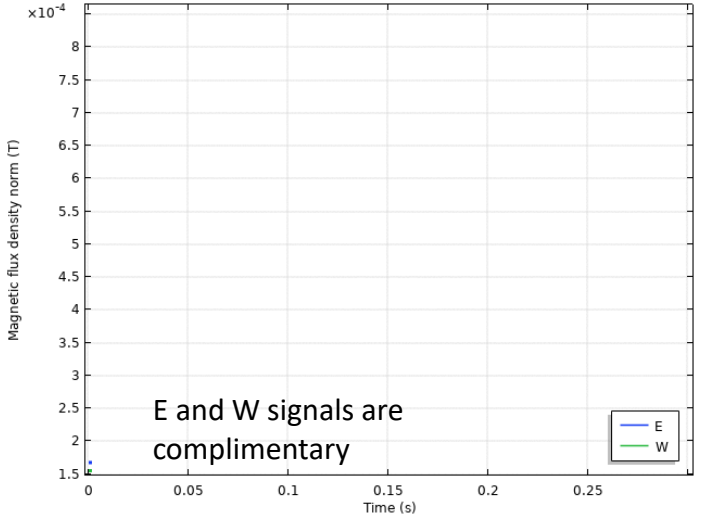
Non-invasive sensors:
N, S, E, W







Characteristic of rotor eccentricity

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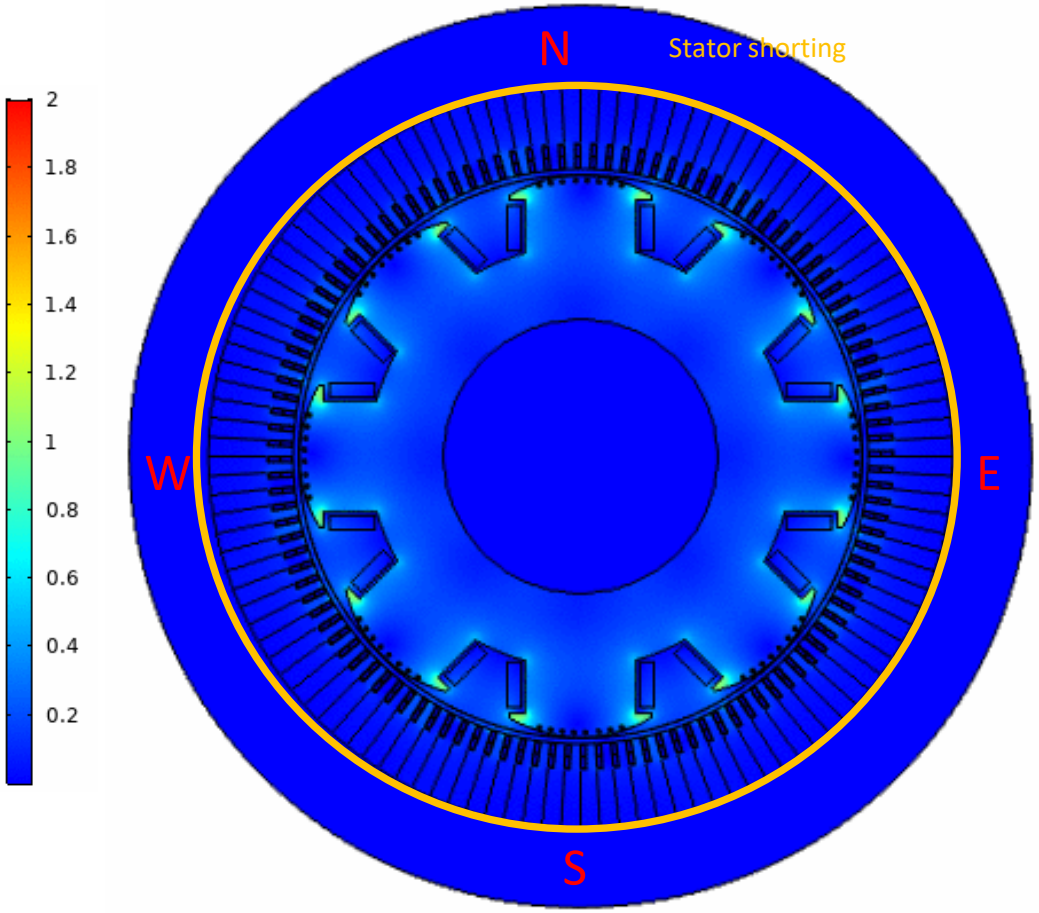
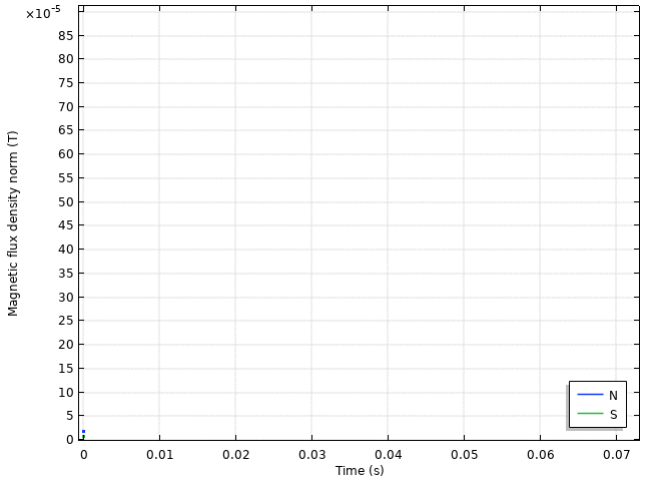
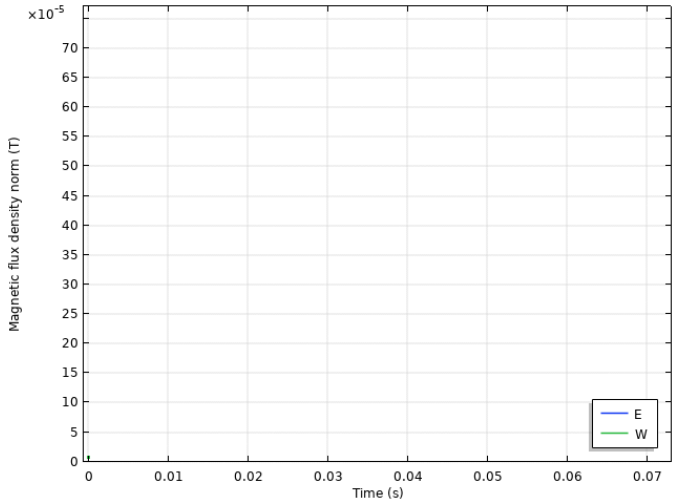
Non-invasive sensors:
N, S, E, W





High flux values at N



Characteristic of stator shorting

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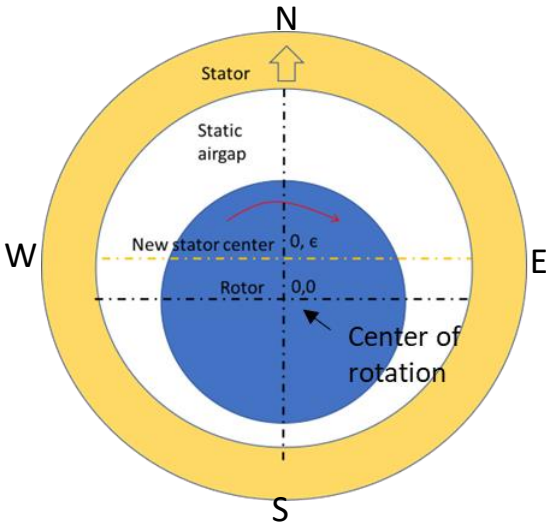
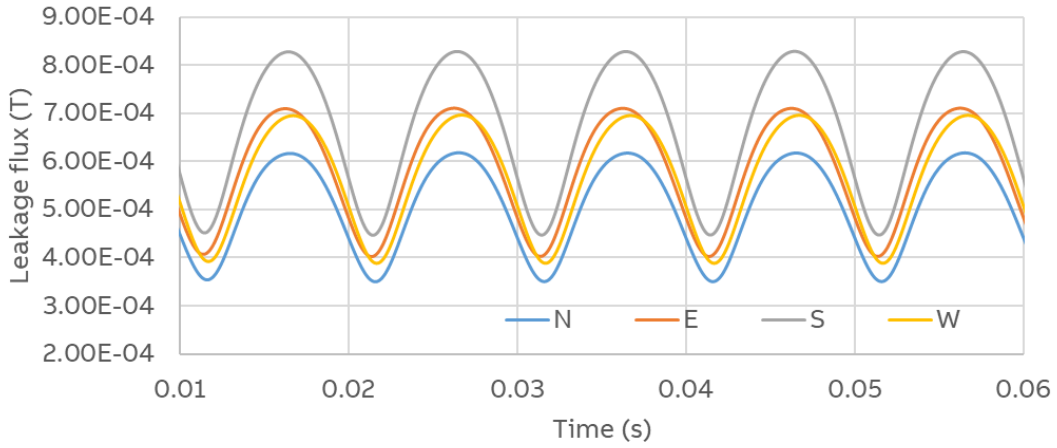
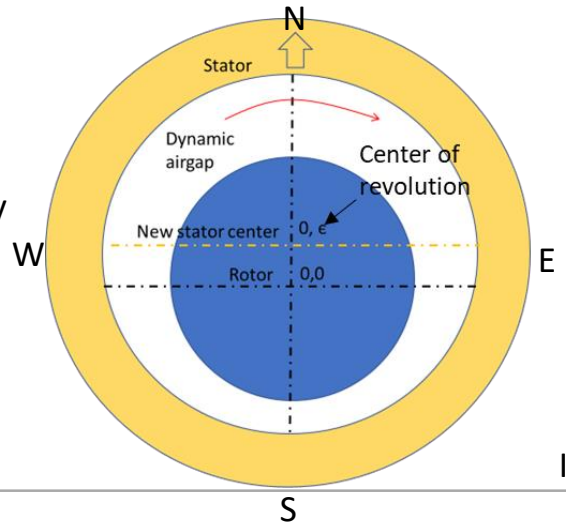
Static eccentricity

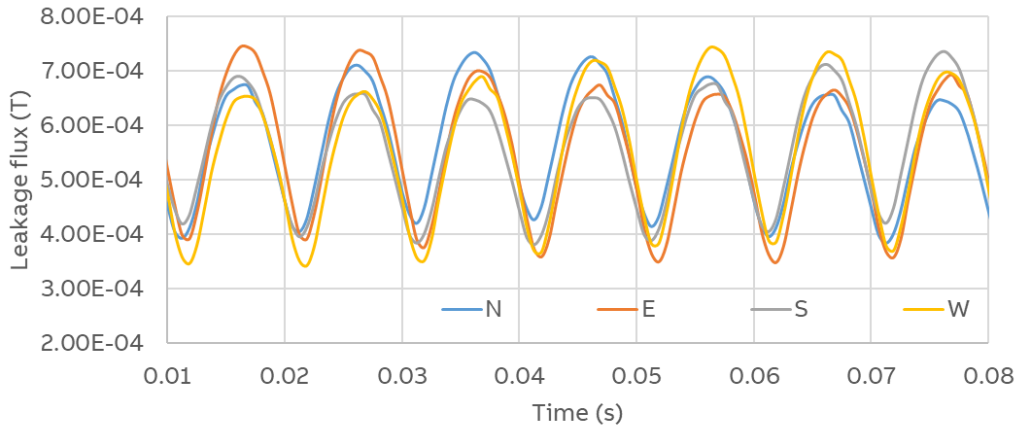




- ***Constant imbalance*** *in each sensor*
- *At any instant* ***average peak is constant***

Dynamic eccentricity





- *Imbalance* ***changes with time***
- *At any instant* ***average peak height is constant***

Identification of specific mechanical defects

Non-invasive generator diagnosis

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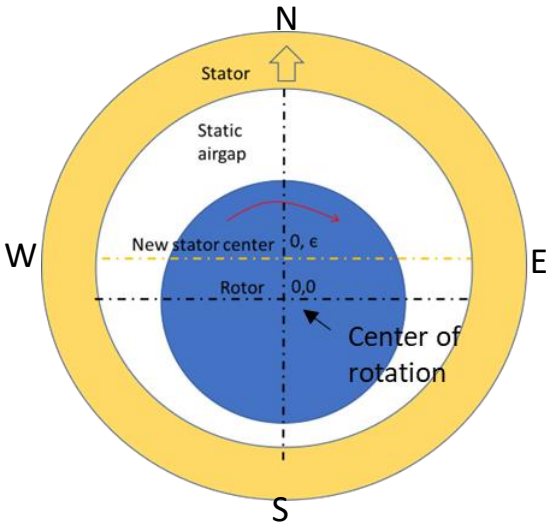
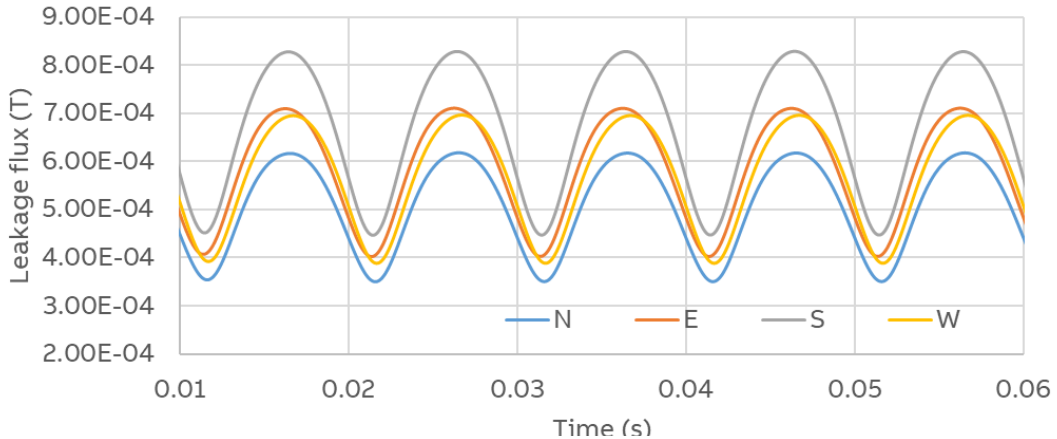
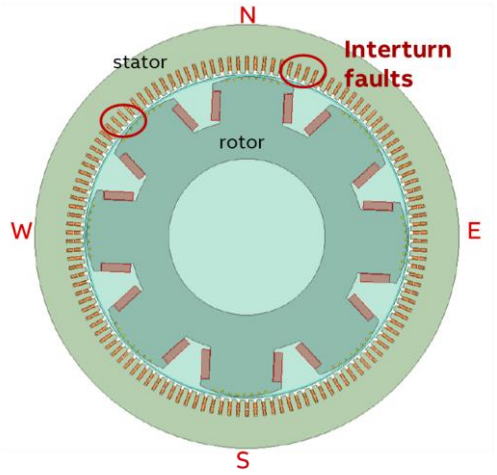
Static eccentricity

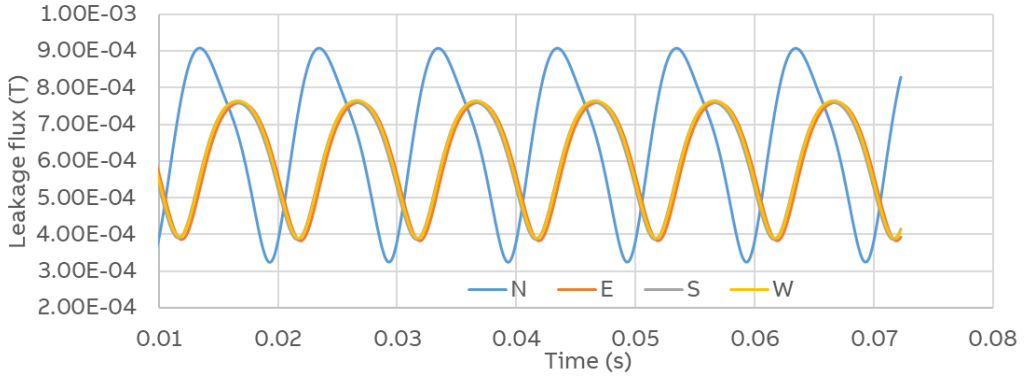




- *Constant imbalance in **each sensor***
- *At any instant average peak **is constant***

Stator electrical fault



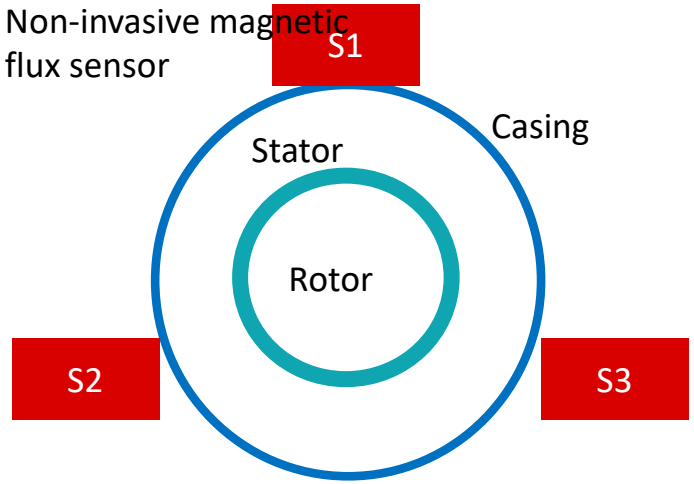


- *Constant imbalance in **one or more sensor***
- *At any instant average peak is **not constant***

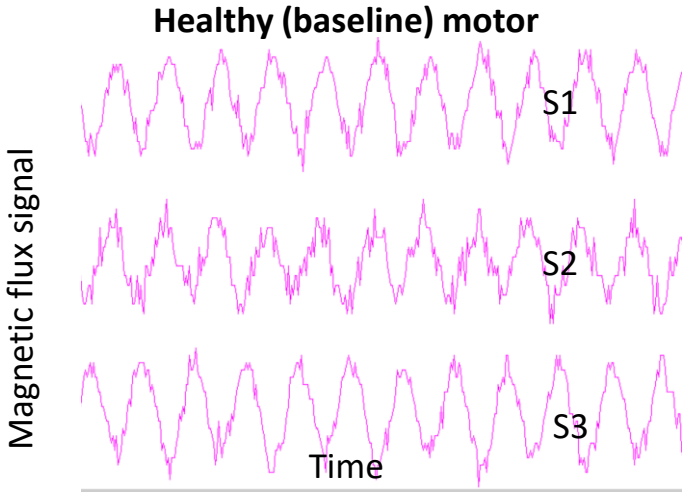
Distinguishing mechanical from electrical defects

Experimental Verification of Idea

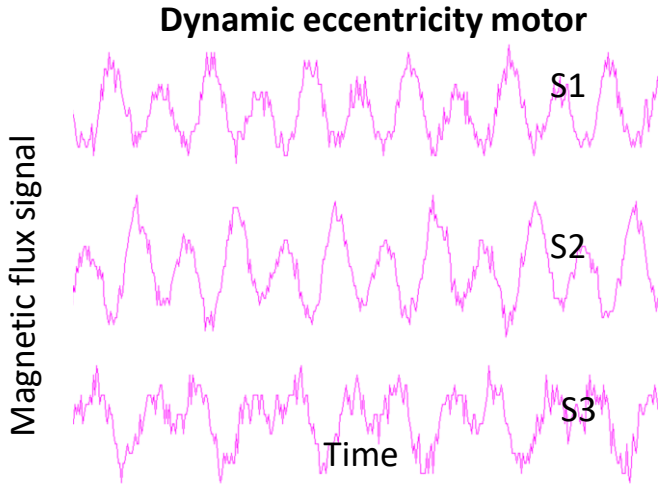
Using motor as testing device



Testing motor

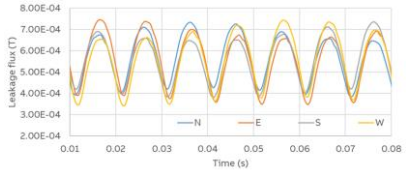


- Peaks of every sensor of similar height with respect to time
- Phase difference of 120 degrees between adjacent sensors



- Peak of each sensor of varying alternately
- Phase difference of 120 degrees between adjacent similar peaks

In agreement with model



Tests build confidence in modeling approach, ability to detect and specify defect

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Conclusion……

- COMSOL multiphysics model: Useful tool in developing advanced diagnostics, obtaining proof-of-concept.
- Using multiple non-invasive sensors specific defects can be identified.
- Study encourages leveraging technology to machines of various sizes and configurations.


ABB