Vector Magnetic Circuit Theory and Its Applications

SPEAKER

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About The Speaker:

Peng Han:

Peng Han (Senior Member, IEEE) is an Application Engineering Manager at Ansys, specializing in low-frequency electromagnetic products. With a Ph.D. from Southeast University, his expertise includes electric machines, power electronics, and renewable energy. He has held research roles, received IEEE awards, and delivered tutorials at major conferences.

Ming Cheng:

Ming Cheng (Fellow, IEEE, IET) is an Endowed Chair Professor at Southeast University, China, and Director of the Research Center for Wind Power Generation. His research focuses on electrical machines, EV motor drives, and renewable energy. He has authored over 500 papers, 7 books, and holds 150+ patents. A former IEEE IAS Distinguished Lecturer, he has received numerous awards, including the IET Achievement Award and SAE Environmental Excellence in Transportation Award.

ABSTRACT

Magnetic equivalent circuits, or magnetic circuits for simplicity, have long been widely used to understand and analyze electromagnetic devices, such as electric machines, inductors, transformers, etc. The traditional magnetic circuit theory from textbooks relying on the only magnetic circuit element -- magnetic reluctance, has been found facing significant challenges in modeling coupled electromagnetic phenomena at high frequencies (several kHz to hundreds of MHz) with high fidelity, such as the phase difference between magnetomotive force (MMF) and magnetic flux, eddy current reaction and eddy current losses, as well as the magnetic hysteresis, in ac magnetic circuits. By introducing two more magnetic circuit elements, one for the eddy effect and the other for magnetic hysteresis, the magnetic circuit becomes closer to the electric circuit counterpart, and the same electromagnetic power can be calculated from the perspective of magnetic circuit, which has never been successful before.

The extended magnetic circuit theory, termed as “vector magnetic circuit theory” in the literature, makes it possible to understand electromagnetic phenomena from the magnetic circuit perspective and improve electromagnetic component designs by optimizing the placement and size of the two new magnetic circuit elements. Several examples will be provided to show the additional insights obtained from the vector magnetic circuit theory.

The short course will cover:

1. Historical overview of magnetic circuits
2. Introducing two more magnetic circuit elements

2.1 “Magductance” – a new magnetic circuit element characterizing eddy current

2.2 “Hysteretance” – a new magnetic circuit element characterizing magnetic hysteresis

2.2 Consistency with Maxwell’s equations

2.3 Electromagnetic power calculation from the perspective of magnetic circuit

3. Applications and FEA validations

3.1 Analyzing induction machines

3.2 Solving magnetic equivalent circuit/network taking into account eddy effect

3.3 Optimizing magnetic cores for inductors/transformers

3.4 Interpreting Meissner effect in superconductors

3.5 Designing motor control considering eddy-current reaction

4. Conclusions and outlook