

DL: Abstracts of Talks and Tutorials

Talks

Talk 1: Transformer Engineering for Future Power System

Abstract: Power systems are undergoing significant changes these days and some of the major characteristics of future power systems would be the deployment of both AC and DC technologies at transmission and distribution levels, significant penetration of renewable and distributed energy sources, widespread application of efficient and green technologies, and effective use of smart and artificial intelligence-based solutions. Accordingly, transformers need to be specified, designed, operated, and monitored to enable their cost-effective operation, control, and asset management. Increasing numbers of transformers are being manufactured these days with environment-friendly ester oils. Power electronic converters will be used in applications involving solid-state transformers, static tap changers, and phase-shifting transformers. Low-loss magnetic materials will make transformers efficient, particularly at the distribution level. Miniaturized sensors are expected to enhance transformer diagnostics capabilities. Three-dimensional field computations will become essential for the design and optimization of transformers. The talk will highlight futuristic nanotechnology-based applications in transformers at the end.

Talk 2: Insights into Design of Transformers

Abstract: This talk covers broad rules and guidelines for the design of transformers. In addition to describing important design principles and operational aspects, intricate considerations while choosing materials and types of magnetic circuits and windings are elaborated. Conflicting requirements while choosing various design parameters are highlighted. Advanced numerical tools like the Finite Element Method need to be routinely used these days for estimating performance parameters accurately and for reliability enhancement. Insulation design and optimization can be tricky and the issues thereof are highlighted. Ensuring adequate short-circuit strength is an important design aspect that requires the deployment of complementary manufacturing practices. Power and distribution systems are increasingly becoming complex, and transformers need to be designed accordingly. The talk will end by enumerating challenges in transformer engineering, which include the requirements to make transformers green and efficient in emerging smart grids with increasing penetration of renewable energy sources.

Talk 3: Applications and Design of Magnetic Devices for High-Frequency Power Electronics Circuits

Abstract: Magnetic components like inductors and transformers are essential parts of power electronic circuits. They are used for galvanic isolation, voltage transformation, filters, etc. The size and overall dimensions of the circuit depend on how efficiently these components are designed

and manufactured. The main requirements in designing these components are low losses and high power density with compact dimensions. Selection of core geometry and its magnetic material with desirable saturation magnetic flux density is the most important design step. Hysteresis, eddy, and anomalous components make the total magnetic loss. Skin and proximity losses in windings can become critical at high frequencies. To overcome these challenges, relevant electromagnetic concepts including the theory of eddy currents need to be properly understood. This talk focuses on such fundamental aspects in addition to the design of magnetic circuits and coils for high-frequency applications. Finally, steps in the design of a high-frequency inductor are elaborated.

Talk 4: Transformer System Interactions and Modeling

Abstract: Transformers are important components of power systems which often become vulnerable to transient overvoltages. Steeply increasing voltage transients associated with gas-insulated substations can be detrimental to bushing and windings. Transformers are also affected by many steady-state operating conditions like unbalanced operations, harmonics, and ferroresonances. In addition, several unexpected phenomena or failures involving transformers are reported in the literature due to their interactions with connected power networks. For analyzing these interactions and suitably designing transformers, accurate modeling of magnetic circuits and windings is essential. Frequency-dependent properties of their materials need to be taken into account if required. Depending upon the frequency region of interest, models can be conveniently simplified to reduce computational efforts. In this talk, a few case studies on the modeling of transformers for analyzing their different system interactions are presented.

Talk 5: Frequency Response Analysis of Transformers: Basics and Diagnostics

Abstract: Transformer windings may get deformed or displaced due to short circuits, transport-induced stresses, and aging. Frequency Response Analysis (FRA) is a popular technique for deformation diagnostics of transformers. After explaining the causes and failure mechanisms leading to deformation/ displacement, the basics of FRA including a description of the nature of response in various frequency regions are covered in the talk. Reasons for the complex nature of the frequency response are enumerated using simple circuit theory. Parametric analysis is done to explain the influence of various geometrical and material parameters on the frequency response. This talk will help practicing engineers and researchers to clearly understand the art and science of deformation diagnostics. A few case studies will also be presented at the end.

Talk 6: Basics of Finite Element Method

Abstract: Finite Element Method (FEM) is a numerical technique to solve partial differential equations. Design, optimization, and analysis of electrical machines and equipment can be done by solving partial differential equations (PDEs) derived from Maxwell's equations. Solving these equations analytically for practical geometries is not straightforward. FEM has emerged as the most preferred tool by researchers and industry professionals for solving complex problems which

may involve nonlinearity, anisotropy, heterogeneity, three-dimensional structures, and coupled fields. Many commercial FEM software programs are available; however, users tend to use them without properly understanding background concepts. The purpose of this talk is to give exposure to the governing principles of the method so that commercial programs can be used effectively and with confidence. A step-by-step procedure of FEM is described for a simple example. A few case studies will also be presented highlighting the capabilities of FEM in solving real-life problems.

Talk 7: Electromagnetics Made Easy

Abstract: Electromagnetics is one of the foundational subjects of electrical and electronics engineering disciplines. However, complex mathematical concepts tend to make the subject difficult-to-understand for students and difficult-to-teach for teachers. Practicing engineers also face difficulties when they encounter electromagnetic theory while working on a product or system. It is generally difficult for beginners to visualize fields in space. This talk elaborates on a few topics, which are generally not well understood, using alternative descriptions and circuit components like capacitors and inductors, without going deep into mathematics. Participants will be able to consolidate their understanding of Maxwell's equations during the talk. A few concepts will also be explained using a web portal, Virtual Electromagnetics Laboratory, developed in the Electrical Engineering Department, IIT Bombay.

Talk 8: Energy Transition in India - Challenges and Opportunities

In light of the growing concerns about greenhouse gas emissions and climate change, the need for an energy transition from fossil to non-fossil-based sources for a carbon-neutral economy is inevitable. This talk focuses on the existing challenges in India's pathway to energy transition and identifies research opportunities and some new paradigms to address them. India has set ambitious goals toward achieving carbon neutrality, and as part of that, in the past few years, the country has made great strides toward increasing the share of renewable energy sources in its energy mix. In India, solar and wind sources account for the majority of installed renewable energy capacity. This increased share presents certain challenges for a 100% renewable grid, such as intermittency, grid integration, oversized power system networks, recyclability, etc. The hydrogen economy is a promising option to cater to the energy demands of the country. However, the production and storage challenges of green hydrogen would be the roadblocks. Solar fuels – chemicals produced directly from the energy of sunlight – have the potential to address some of the aforementioned challenges and can be a significant part of the power to X (PtX) economy. Energy storage technologies attract a lot of research attention as they form an integral part of the emerging power and distribution systems. Despite all the challenges, India's transition to a carbon-neutral economy should be achievable with a carefully planned roadmap.

Talk 9: Effective Technical Communication

Abstract: Technical communication is an integral part of research activities in academics. It ought to be effective to convey one's research and development work through various forms of communication, viz. books, technical articles, patents, reports, and blogs. Oral skills are very important while delivering lectures and presentations, participating in group discussions, facing interviews, etc. Technical communication is effective when it is clear, concise, non-repetitive, understandable, reproducible, and novel/ practically relevant. Correct grammar, right formatting, and proper data representation are also essential ingredients of good communication. After explaining the above aspects, DOs and DONTs in technical paper writing will be elaborated in this talk, including ethical publishing practices. In the end, the virtues of excellent research work are enumerated.

Tutorials

Tutorial 1: Transformers - Design Principles and Advanced FEM Analysis

Duration: 6 hrs

Abstract: This tutorial starts with a typical design procedure of a power transformer (3-phase, 31.5 MVA, 132/33 kV), which covers broad electrical aspects involved in its design. In addition to describing important principles and operational aspects, a step-by-step design procedure is elaborated starting with magnetic circuit followed by windings and insulation. After evaluating the leakage reactance by an approximate analytical formula, the losses in core, LV and HV windings and the parameters of the equivalent circuit of the transformer are determined. Subsequently, conflicting requirements for various engineering aspects (electromagnetic, thermal, mechanical) of design are enumerated. Limits on design variables imposed by temperature rise considerations, manufacturing processes, and transport restrictions are highlighted. Some of the performance figures like eddy and stray losses in windings and structural parts cannot be accurately determined by analytical formulae, necessitating the use of the Finite Element Method (FEM) for the purpose. Similarly, for determining response to transient overvoltages involving very high frequencies, detailed modeling of windings is essential. The equivalent circuit parameters for accurate transient analysis can be calculated using FEM. The basics of FEM formulations useful for the design and analysis of transformers will be covered. Many complex phenomena in transformers involve interactions between electromagnetic fields and connected circuits and/or other physical fields (thermal, mechanical, fluid, and acoustic). A few case studies will be presented at the end which use coupled field computations in solving challenging problems encountered while designing and analyzing transformers.

Schedule:

Session	Duration	Title of the session
1	0.0 hr to 2.0 hr	Design of a 31.5 MVA, 132/33 kV transformer
2	2.0 hr to 2.5 hr	Design considerations for magnetic circuit
3	2.5 hr to 3.0 hr	Eddy and stray losses
4	3.0 hr to 3.5 hr	Short circuit strength of windings
5	4.0 hr to 4.5 hr	Surge performance
6	4.5 hr to 5.0 hr	Insulation design
7	5.0 hr to 6.0 hr	Coupled field computations

Tutorial 2: Revisiting Electromagnetic Concepts Relevant to Power Equipment and Systems
Duration: 3 hrs

Abstract: Electromagnetics is one of the fundamental subjects of electrical and electronics engineering. However, undergraduate students and practicing engineers face difficulty in understanding the subject because of the associated complex mathematical theory. If corresponding physics and applications are not explained properly or adequately, the subject does not enthuse students as well as working professionals. Understanding its many concepts and principles starting with Maxwell's equations is essential while designing power equipment and analyzing complex phenomena involving power networks. This tutorial is split into two parts. The first part elaborates on Maxwell's equations, Lorentz force, and continuity equation. Basics of vector calculus, static and time-varying fields, and electromagnetic radiation are covered. Their relevance to Power Engineering will be emphasized. Virtual Electromagnetics Laboratory has been developed at Electrical Engineering Department, IIT Bombay, using JAVA-based applets and FEM to explain subtle concepts effectively. A few examples from this web portal will be used to make the first session interactive and to give hands-on experience to participants. The second part covers the biological effects of electromagnetic fields, the theory of eddy currents, skin and proximity effects, electromagnetic shielding, frequency-dependent material parameters, and the design of magnetic devices for high-frequency power electronic applications.

Schedule:

Session	Duration	Title of the session
1	0 to 1.5 hr	Principles of Electromagnetics
2	1.5 hr to 3.0 hr	Electromagnetic Theory and Concepts Relevant to Power Equipment and Systems

Tutorial 3: Hysteresis Phenomena in Transformers and Rotating Machines: Physics and Modeling

Duration: 3 hrs

Abstract: The magnetization process in magnetic materials affects the performance of electrical machines and transformers. The energy spent during the process of magnetization can be termed as hysteresis loss. For proper optimization of design, an accurate hysteresis model is essential. The magnetization process of a material can be represented in terms of its hysteresis loop and the loop area gives the total material losses which include three components: static hysteresis loss, eddy current loss, and anomalous loss. The last two components together make frequency-dependent dynamic losses. Understanding the physics behind the process and applying proper hysteresis formalism in numerical analysis is important for the accurate modeling of magnetic circuits in transformers and electrical machines.

This tutorial starts with the classification of magnetic materials based on their characteristics. The magnetization phenomenon, involving reversible and irreversible magnetization processes, is explained in terms of domain theory. The influence of time-varying fields, direction of magnetization, and thermal and mechanical stresses on the core loss components is elaborated. In the second part of the tutorial, two popular hysteresis models, the Preisach and Jiles-Atherton (JA) models, used in numerical analysis are discussed in detail, along with their comparison, advantages, and disadvantages. The implementation of the JA model in a coupled circuit-FEM formulation for a three-phase transformer will be demonstrated. Along with these models, there are some curve-fitting approaches based on mathematical functions like polynomials, tan hyperbolic functions, exponentials, etc. In the second session, mathematical formulations based on these methods will be elaborated.

Schedule:

Session	Duration	Title of the session
1	0 to 1.5 hr	Classification of magnetic materials and factors influencing magnetic performance of transformers and rotating machines
2	1.5 hr to 3.0 hr	Preisach and JA based hysteresis formalisms and implementation of the JA model in numerical analysis