Title of the Tutorial: **High Performance Control of Induction and Synchronous Motor Drives**

Abstract:

Modern high power drives employ ac motors with high performance control to achieve good control over torque and speed. Field oriented control, which was initially suggested by Blaschke in 1969, has been very widely applied for induction motor drives. Field oriented control (also known as vector control) requires coordinate transformation from a rotating reference frame to the stationary reference frame, and is therefore, computationally intensive. Direct torque and flux control (DTFC) of induction motor aims at the control of torque and flux of an induction motor without going for coordinate transformation. One of the high power applications of induction motor is electric traction where the direct torque and flux control of induction motor drive can be used. The induction motor can be supplied from a multilevel inverter to facilitate higher power applications. Although induction motors are extensively used in medium and higher power applications, wound field synchronous motors are attractive for very high power applications due to their high voltage design economy, rugged construction due to increased air gap and possibility of operation at unity power factor. For very high power and low speed applications ranging from a few 10's of MW to a few 100's of MW, wound field synchronous motor fed from naturally commutated cycloconverter is an appropriate choice. The present tutorial gives an overview of high performance control of induction and synchronous motors starting from field oriented control and finally culminating with two high power applications, namely direct torque and flux control of induction motor for traction application and cyclconverter-fed vector controlled synchronous motor drive for rolling mill application.

Initially, the basics of field oriented control and direct torque and flux control of induction motor are reviewed. Subsequently, a three-level neutral point clamped (NPC) front-end ac-dc converter supplying a three-level inverter fed induction motor drive operating under Direct Torque and Flux Control (DTFC) is presented. The three-level ac-dc converter draws sinusoidal ac current from the supply and keeps the dc-link voltage constant. Hysteresis current controller is used for current control of the front-end converter because of its simplicity, easy implementation. A diode clamped multilevel inverter is used for driving induction motor operating under DTFC scheme. The overall system has been simulated. A laboratory prototype of the drive system has been developed and tested. In the proposed drive system, the DTFC principle can be applied to the entire speed range. Simulation and experimental results of three-level converter-inverter system are presented to demonstrate the effectiveness of the drive system.

Cyclconverter-fed wound field synchronous motor drives are attractive for very high power and low speed applications such as steel rolling mills, cement kilns, mine winders, etc. The armature of the synchronous motor is supplied from a 6-pulse non-circulating current cycloconverter. Field oriented control or vector control of synchronous motor results in good torque and speed response. Vector control with stator-flux orientation in a synchronous motor aims at an independent control of stator flux and stator current similar to that of a separately excited dc machine. In a special case where an orthogonal relationship is maintained between the stator current and stator flux, unity displacement factor condition is obtained, leading to optimum dimensioning of the cycloconverter system. Control of synchronous motor in stator

flux coordinate requires both variation of stator current and field current to maintain unity displacement power factor condition. Usually, the field time constant is much higher than the armature time constant. Hence, a component of the armature current in phase with the stator flux is supplied in the transient condition to maintain the stator flux constant. The field is supplied from a 6-pulse converter. The steady- state displacement factor of the motor is decided by the displacement angle controller. In the lightly loaded condition, the displacement angle controller gives a lagging angle command, maintaining the continuity of current and, thus, avoiding unwanted torque ripples. Beyond 20% of the full load, the displacement angle controller gives zero angle lag command, restoring the orthogonality between the stator current and the flux. The closed-loop speed control of the entire drive system has been digitally simulated and experimentally realized in the laboratory. The simulation and experimental results are presented to validate the closed-loop control performance of the drive system.

Speaker's biodata:

Prof. Shyama Prasad Das received the B.Tech. (with honors) degree in Electrical Engineering, the M.Tech. degree in 'Machine Drive and Power Electronics' and the Ph.D. degree from the Indian Institute of Technology, Kharagpur, India, in 1990, 1992, and 1997, respectively.
From 1997 to 2023, he was on the faculty of Electrical Engineering, IIT Kanpur. He is currently a visiting Professor in the School of Electrical and Computer Sciences, IIT Bhubaneswar. His research interests include power electronics, high performance industrial drives, power quality conditioners, and microprocessor-based control and instrumentation. He received Indian National Academy of Engineering (INAE) young engineer award in 2003. He has developed one web-based course and two video courses under NPTEL. He has received a number of letters from Director, IIT Kanpur regarding his excellent teaching performance. He is a Senior Member of IEEE (USA) and a Fellow of Institute of Electronics and Telecom Engineers (IETE), India.

Target audience:

1. Postgraduate students in Electrical Engineering
2. Practicing Engineers in Electrical Engineering working in electric drives area in general and automotive sector in particular.