Static Converters with Innovative Control Structures and Logics for Advanced Industrial Drives and Generation and Storage Systems

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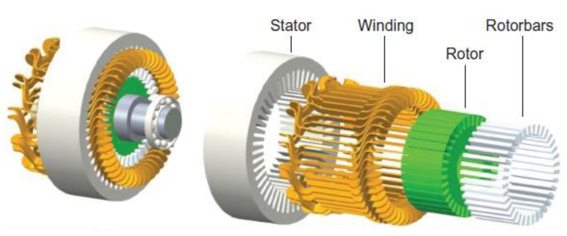
Abstract

Industrial drives are at the core of modern manufacturing, seamlessly transforming electrical energy into mechanical power. This intricate interplay between the electrical and mechanical domains is essential for a wide range of industrial processes. Our research focuses on optimizing both aspects, addressing issues of efficiency and performance.

Motor Side

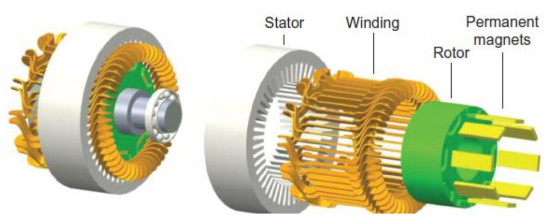
In today's industrial landscape, electric motors are widely used in various applications. The two most common motor types found in industrial, residential, commercial, and transportation applications are induction motors and permanent magnet motors.

Induction Motors



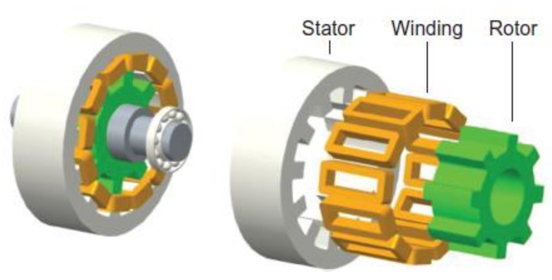
- **Pros:** Robust, Reliable, Simple
- **Cons:** Lower Efficiency

Permanent Magnet Motors



- **Pros:** High Efficiency, Controllability
- **Cons:** Rare-Earth Material Dependenc

While induction and permanent magnet motors are presently dominating the market, switched reluctance motors (SRMs) are emerging as strong contenders for the future of electric motor technology.

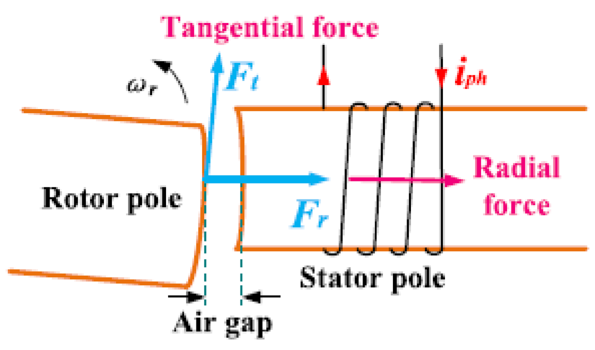


Advantages of SRMs over Traditional Motor Types:

- Simple and Low-Cost Construction
- High-Speed and High-Temperature Operation
- Efficiency Over Various Speeds
- Extremely Robust Rotor Construction
- Easier Fault-Tolerant Operation

Challenges of SRMs:

- Torque Ripple
- Acoustic Noise/Vibration



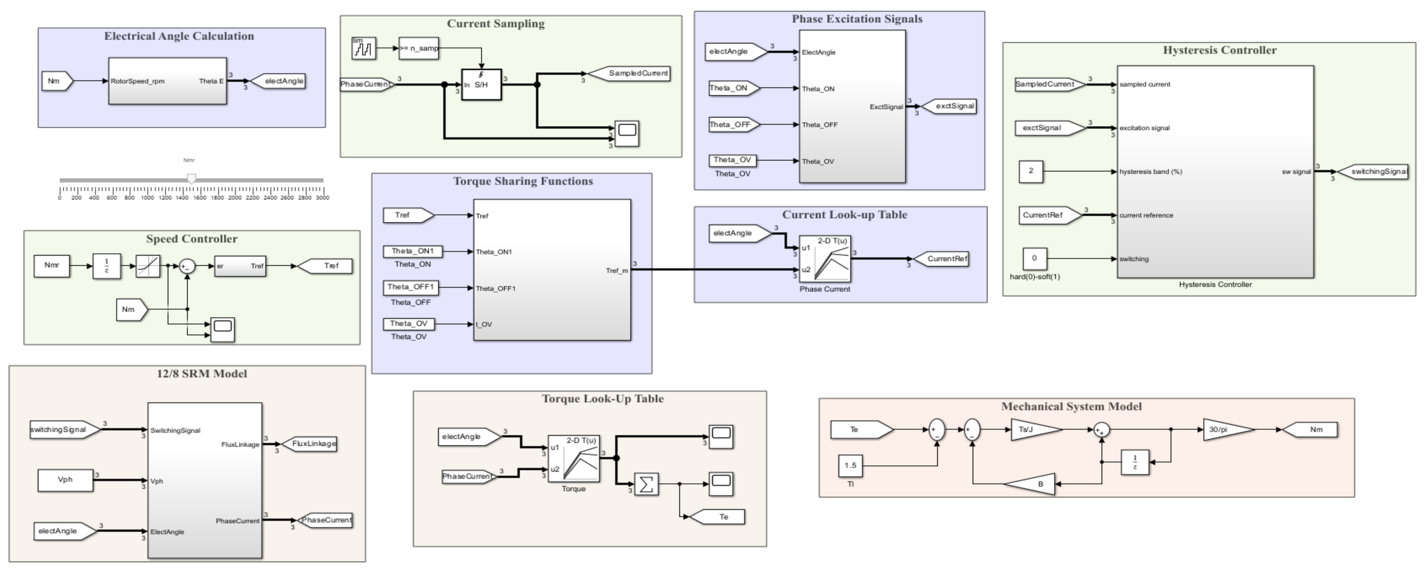
Understanding Torque Ripples and Acoustic Noise/Vibration in SRMs: The electromagnetic attraction force features two components: tangential and radial. The tangential force contributes to the output torque and its variation causes the torque ripple; both forces determine frame deformation leading to vibration and acoustic noise.

Multiple methods have been proposed in the literature to confront the challenges associated with SRMs to mitigate torque ripple and acoustic noise/vibration; our current study is mainly focused on the former.

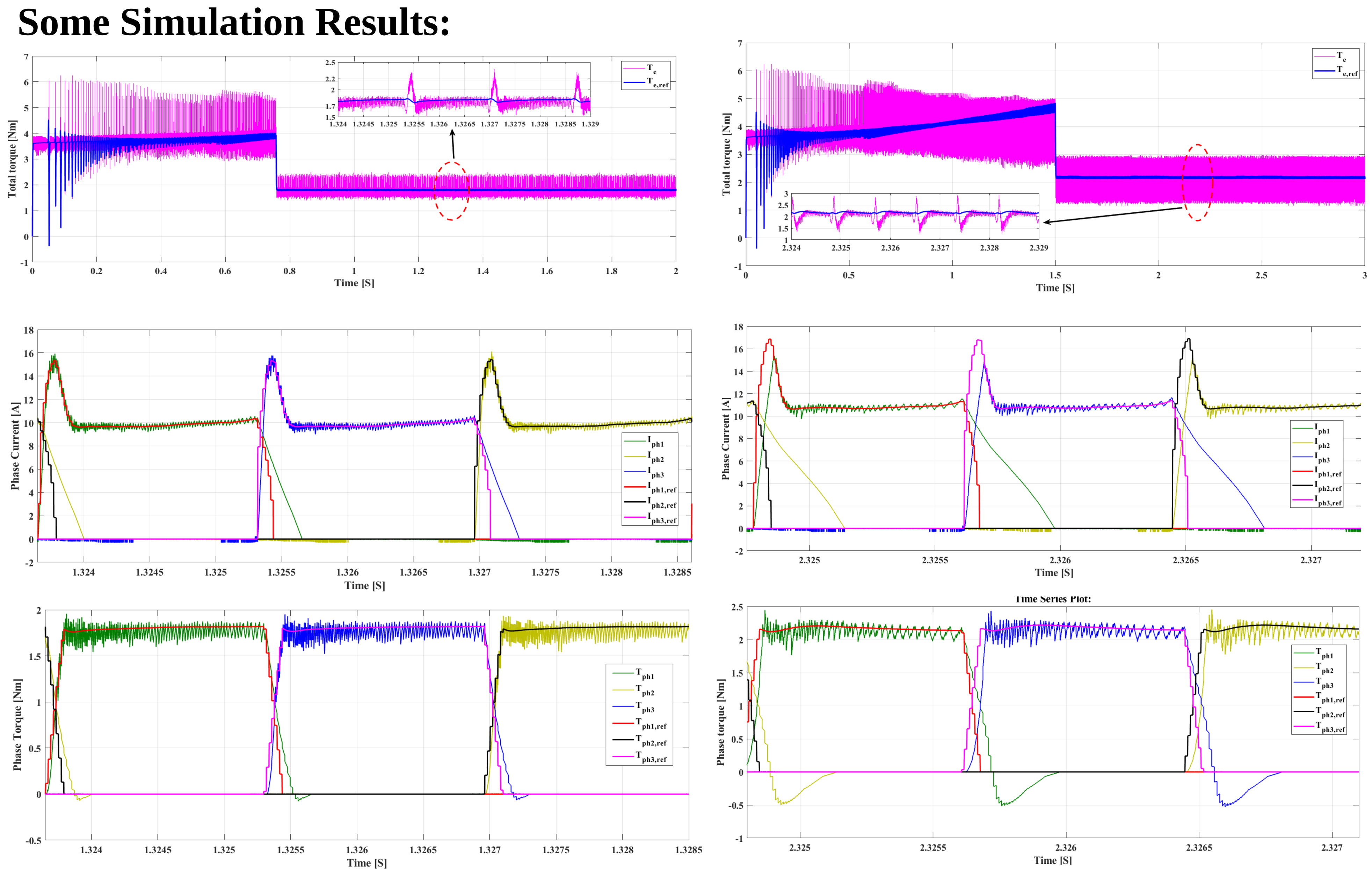
Mitigation Techniques for Torque Ripple:

Method	Advantages	Disadvantages
Current and Angle Modulations	Enhanced efficiency, torque-speed, and reduced torque ripple.	Limited current and torque control; significant memory requirement.
Average Torque Control (ATC) and Direct Torque Control (DTC)	Direct control reduces torque ripple as desired.	Requires prior knowledge of machine parameters
Torque Sharing Function (TSF) Based Control	**Smoothly controlled torque waveforms over a wide speed range.**	**Requires prior knowledge of machine parameters**
Feedback Linearization Control	Reduces torque ripple, ensures no nonlinear feedback, and decouples currents.	Lacks adaptability to uncertain parameter changes; complex linearization.
Iterative Learning Control	Enables perfect current tracking without system parameter identification.	Complex learning control with iteration restrictions and transient performance limitations.
Intelligent Control	Strong self-learning, adaptive, and reduces torque ripple without system reliance.	Complex learning control with iteration restrictions and transient performance limitations.

For investigating the challenges confronting SRMs, particularly focusing on torque ripple, we developed a **dynamic model for a classical 12/8 SRM drive system** using MATLAB/Simulink.



Some Simulation Results:



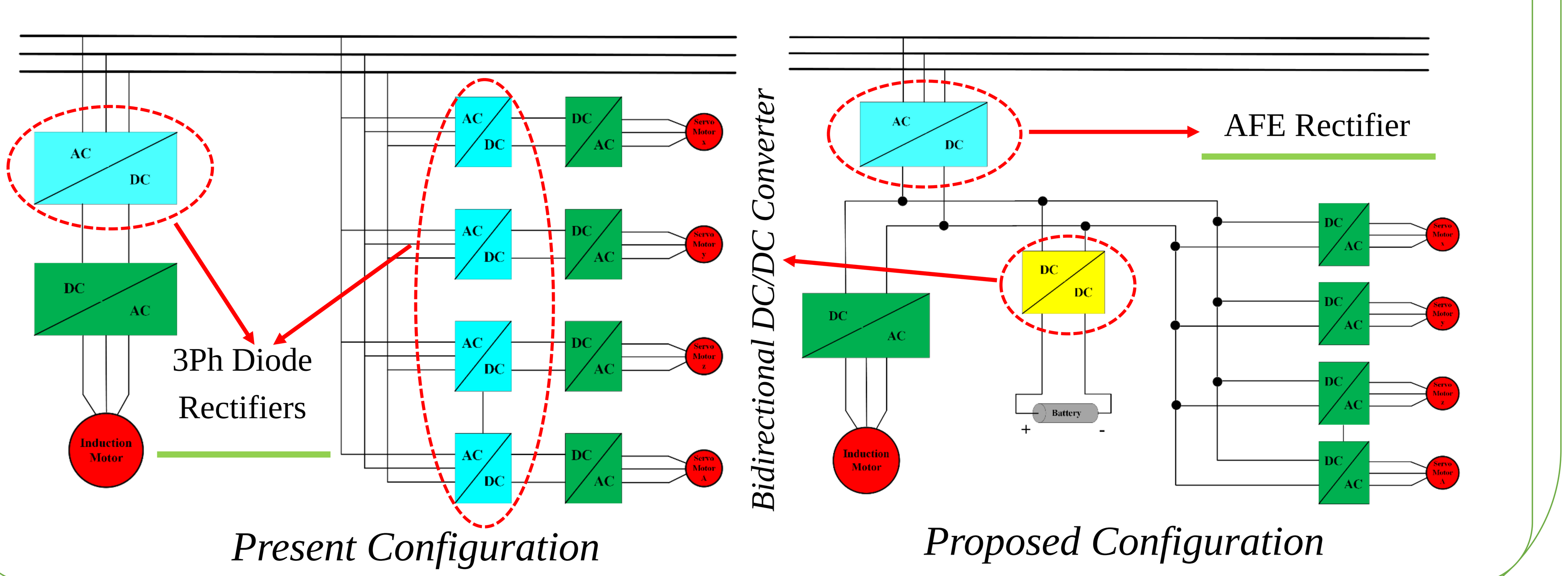
Comparing low speed (left) to high speed (right) operation, current control becomes less effective thus producing larger torque ripple

Converter Side

The enhancement of power infrastructure, particularly in grid-connected converters, is vital for contemporary industrial systems. It must meet key criteria such as **harmonic pollution reduction**, **bidirectional power flow capability**, **enhanced power quality**, and **dynamic response** for optimal reliability and operation.

Case Study: In the facilities of Compolab, our primary sponsor, we examine a cutting machine utilizing five dedicated diode rectifiers for individual motor power supply. While traditionally functional, this setup lacks energy recovery capability and power quality is also low.

Proposed upgrade: Replacing the rectifiers with a single reversible AC/DC converter (Active Front End) providing a shared DC bus for the inverters of the different motor drives, and also incorporating a battery system to provide UPS functionality for sparing costs and damages due to short supply interruptions. These enhancements fulfill criteria for an advanced connection to the grid, reducing harmonic pollution, correcting power factor, enabling regenerative capability, boosting system efficiency, and ensuring reliability during power interruptions.



Ongoing Activities:

- Completion of literature review
- Study of advanced smart torque sharing strategies
- Investigation of innovative designs for SRM aimed to improve controllability
- Investigation of integrated structures for power conversion system
- Familiarization with microcontrollers for real-time control of converters