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Torque Sharing Function Optimization for Extended Speed Range Control in Switched Reluctance Motor Drive

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Introduction

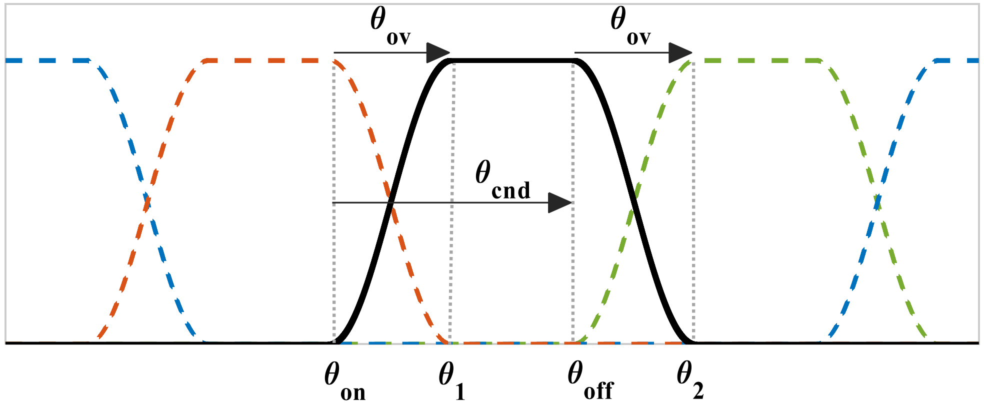
- Amongst all other types of electrical motors, the SRMs are the simplest in the structure. Where they have no windings nor permanent magnets in the rotor.
- They can offer a reliable, low-cost, less maintenance, and extended-speed range drives. These great features made them optimal candidates to be adopted in electric vehicles applications.
- However, due to the salient nature of both the stator and the rotor, their magnetic characteristics are nonlinear function of rotor position.
- A major blocking factor of wider usage of SRM drives is the significant ripple in the motor torque specially at high-speed ranges.

Introduction

- Many strategies based on control techniques have been proposed to reduce the torque ripple of SRMs.
- One of the most effective strategies is based on **t**orque **s**haring **f**unction (TSF).
- TSF is an efficient torque ripple minimization approach in switched reluctance motor (SRM) drives but it work only at low and medium speed ranges.
- In this paper an optimized TSF is presented to enhance the torque profile of SRM over an extended speed range.
- Another attention towards minimizing the RMS value of the phase current is also achieved and therefore, motor efficiency is improved.

Torque Sharing Function

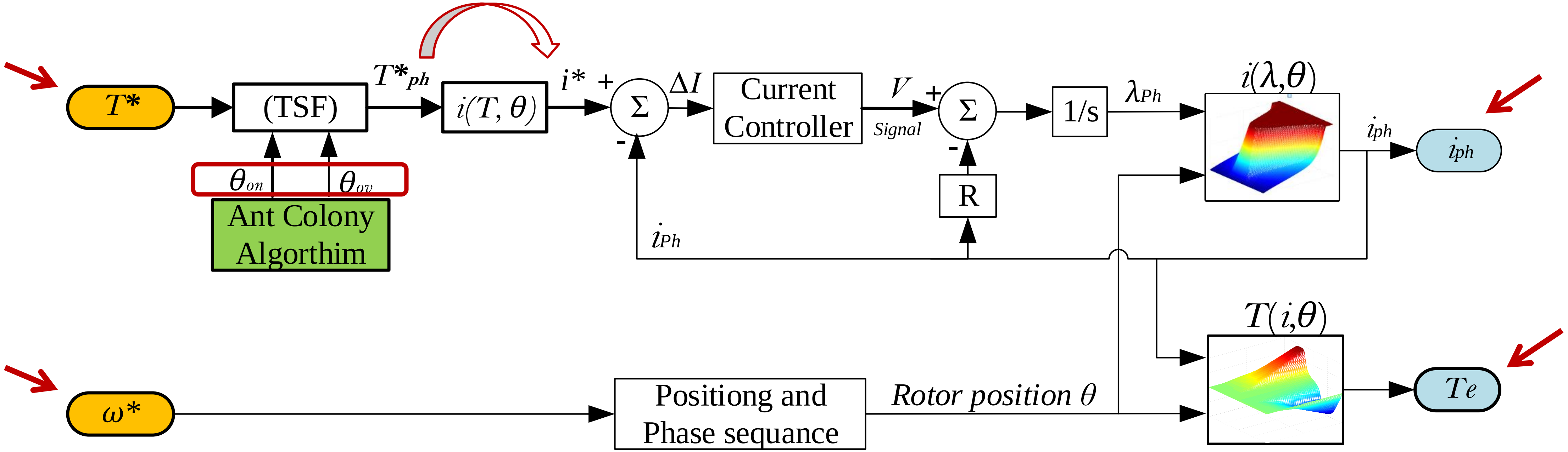
- TSF intelligently divides a commanded reference torque between all the phases of the machine in such away the summation of the torques set up by each phase will add up to a total constant torque.
- The typical sinusoidal TSF for four phase SRM is shown below:



- The above TSF can be modified by optimally selecting the turn-on and the overlap angels.

SRM Modelling Based on TSF

- In this way the commanded torque is controlled indirectly by controlling the current.



The Optimization Problem Formulation

The formulation of the optimization problem is as shown:

Minimize:

$$F = w_1 \left(T_{max} - T_{min}\right) + w_2\left(I_{rms}\right)$$

Subjected to:

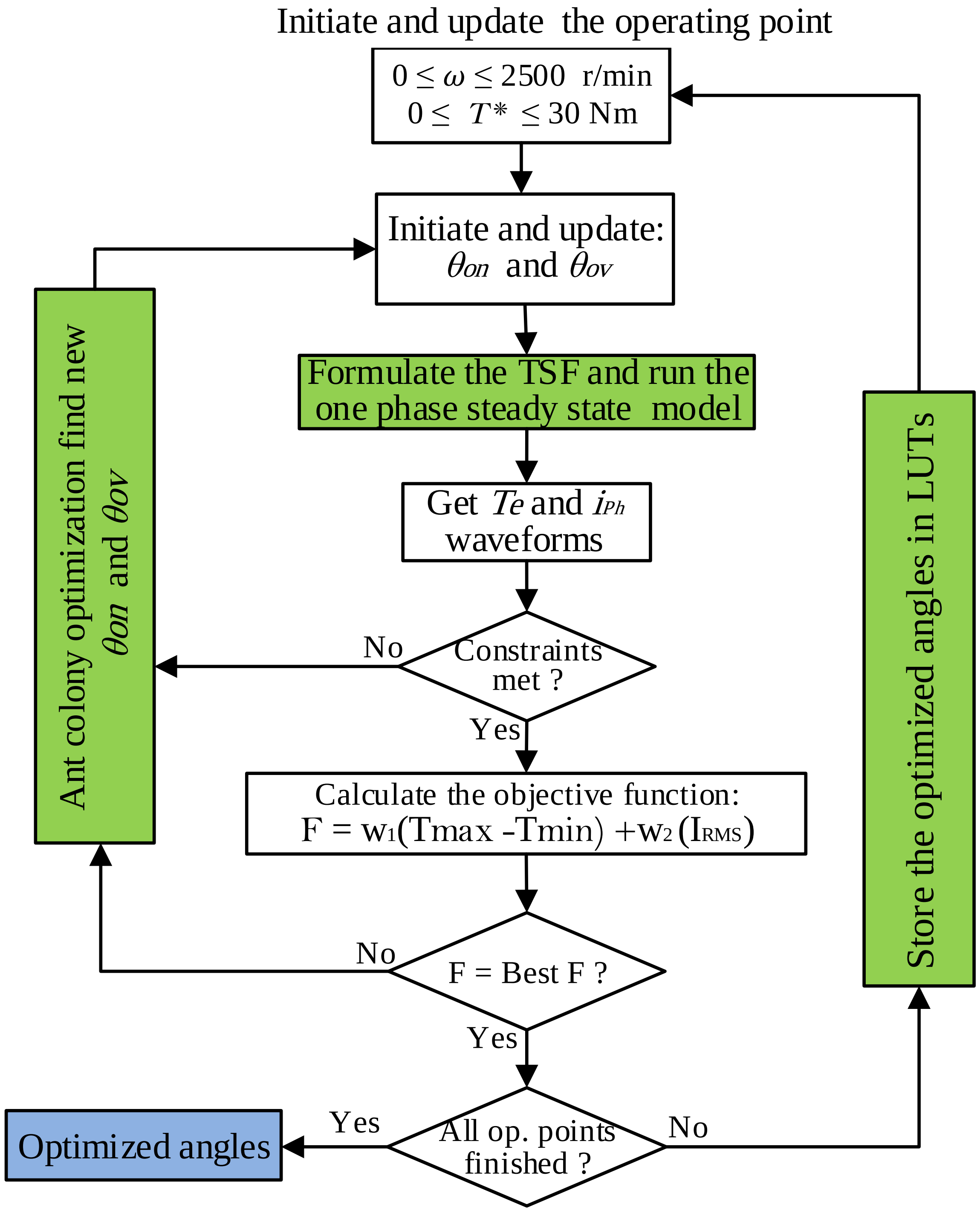
$$T_{ave} = \sigma\, T^*$$

Where,

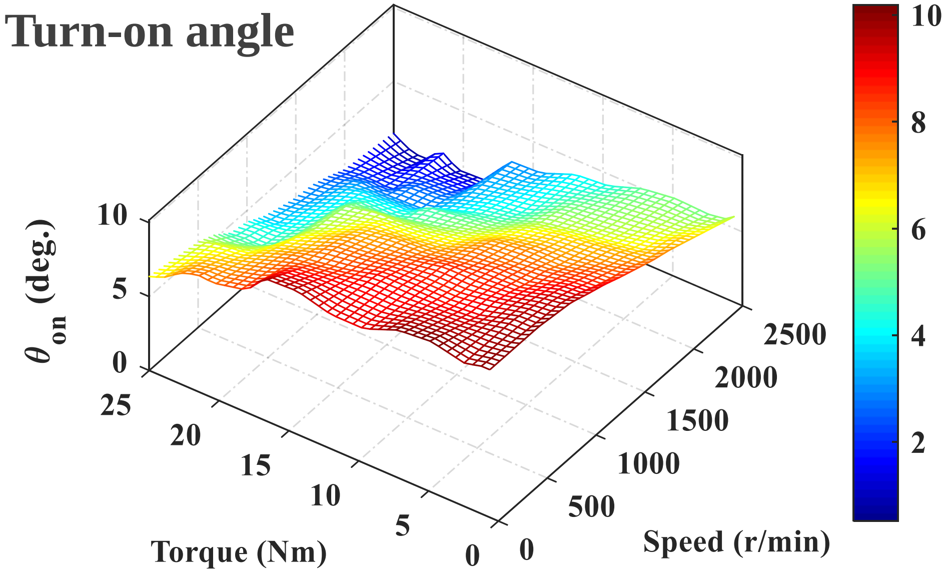
$\left(T_{max} - T_{min}\right)$ is the net torque ripple, I_{rms} is the RMS value of the phase current.

w_1, w_2 are weighting factors, σ is a scaling factor.

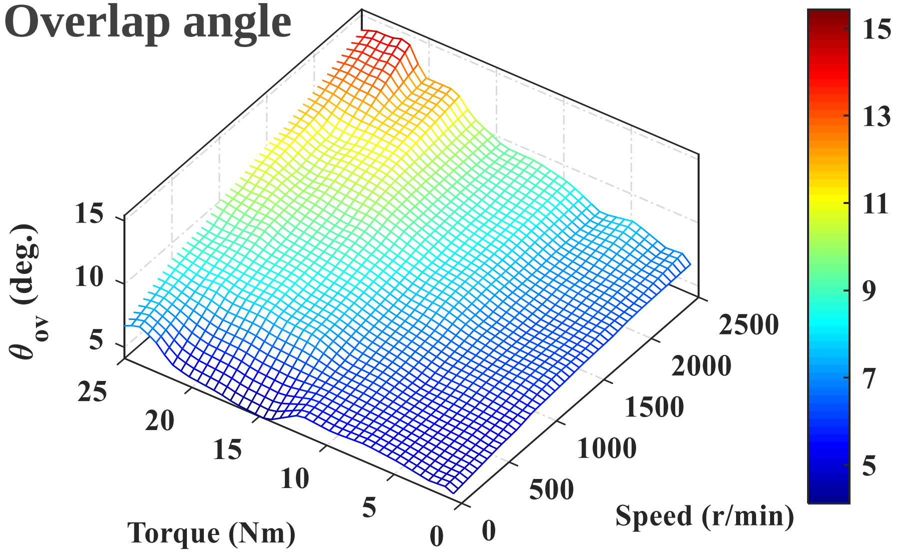
The Optimization Flow Chart



- **Turn-on angle**



- **Overlap angle**

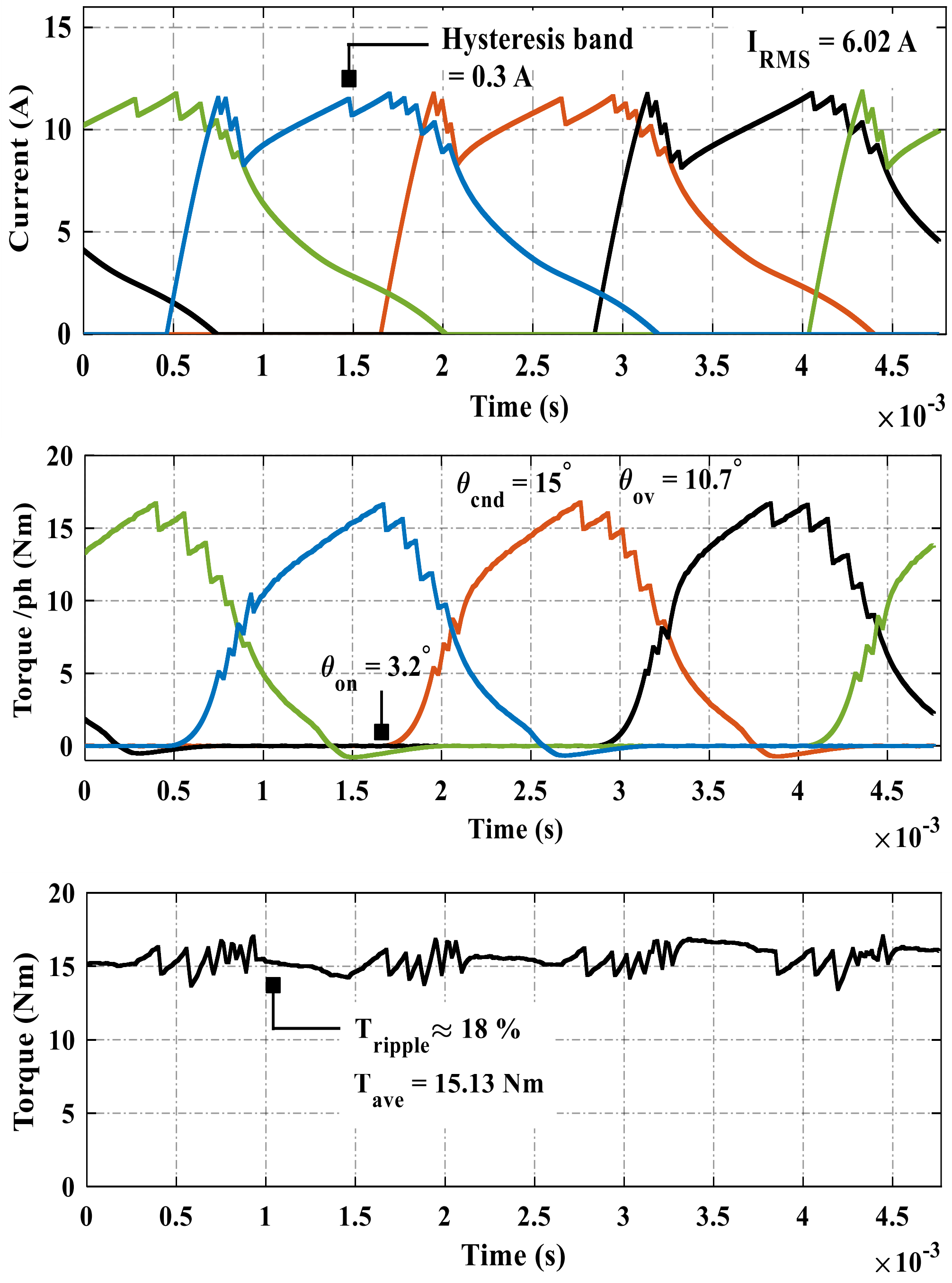


Optimization Problem Results

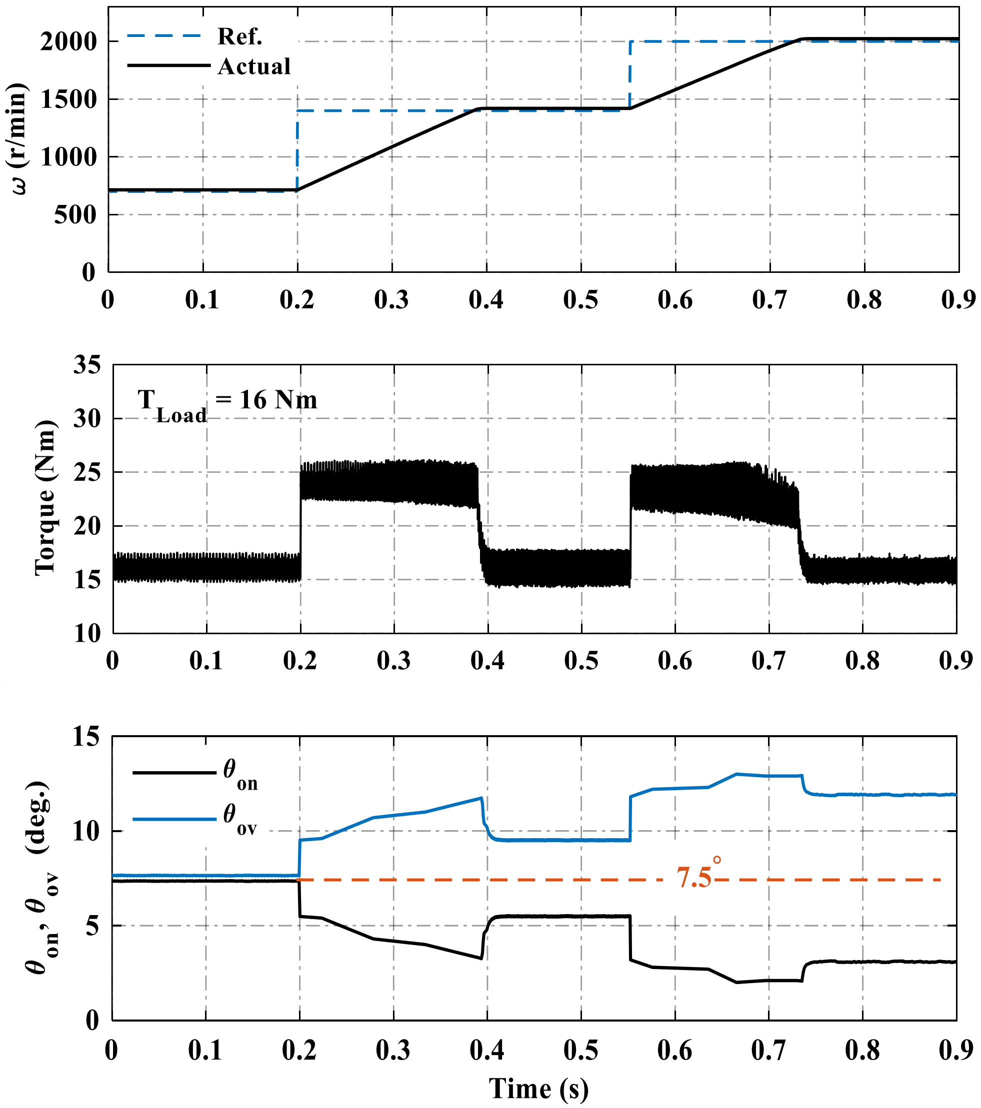
- The optimized switch-on and overlap angles for each combination of speed and torque commands are shown to the left.
- It can be clearly seen that as the speed increase the turn-on angle advances while, the overlap angle increase.
- The overlap angle can be approximated by mirroring θ_{on} around 7.5°, which is nothing but half the conduction angle.

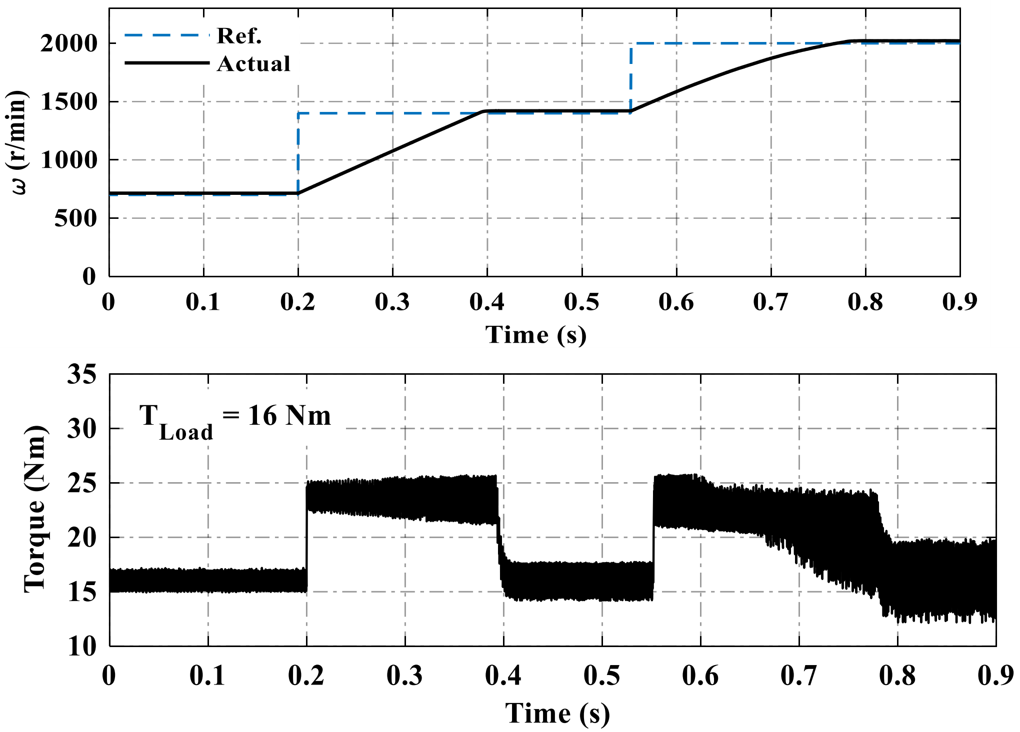
Simulation Results
(Steady State Performance)

The phase current, phase torque (TSF) and the total torque at 2100 r/min speed and 12 A ref. current are shown below:



Simulation Results (Dynamic Performance)





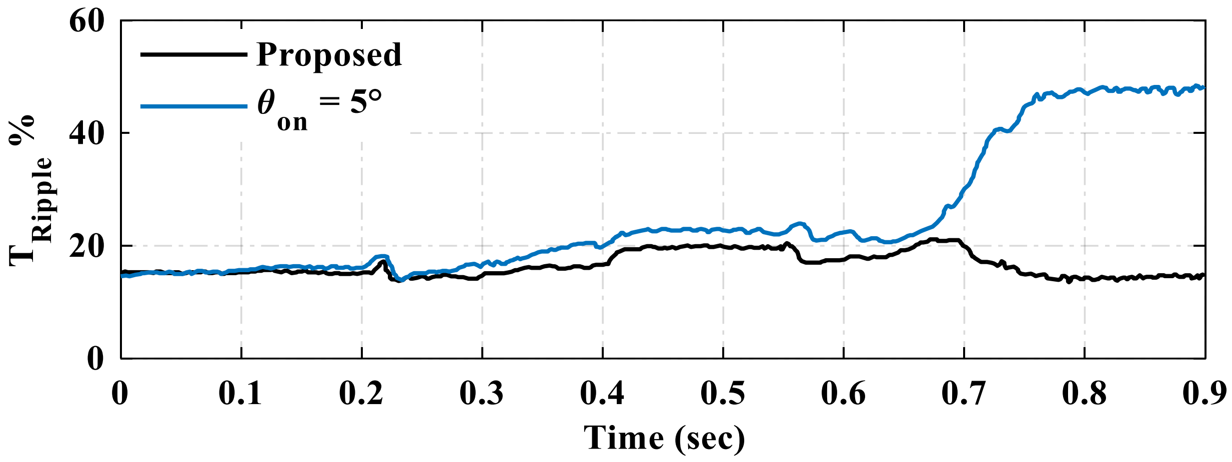
The dynamic torque waveform and the variation of θ_{on} and θ_{ov} obtained from the closed-loop speed controller at different speed.

Left side: Proposed controller,

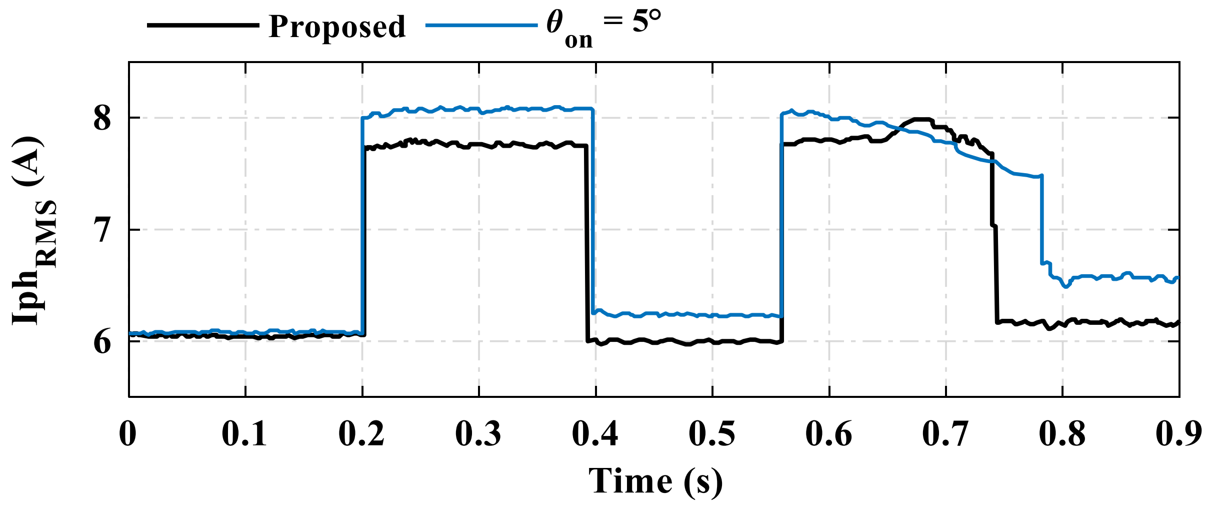
Right side: Constant turn-on angle controller

Comparative Analysis

A comparison between the on-line calculated torque ripple and the rms phase current when using the proposed controller and the fixed angle controller.



Torque Ripple %



RMS phase current

Conclusions

- Torque sharing function is very efficient technique to solve the problem of torque ripple in SRMs specialty at low-speed ranges.
- To extend the speed range of SRMs drives based on TSF, its very necessary to optimize the switch-on and the overlap angles
- A modified version of the ant colony algorithm is employed to optimally select both angles, then the overlap angle is approximated by mirroring the switch-on angle around half the conduction angle.
- The focus is to reduce the torque ripple at high-speed ranges as its basic requirement for electric vehicle application moreover, another attention towards minimizing the RMS value of the phase current is achieved by forming multi-objective function.

Thank You

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