ADVANCED ELECTRICAL DRIVES MINI PROJECT

Operating Trajectories for the Control of Permanent Magnet Synchronous Machines

Report by RANDOM GROUP 15
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28.06.2023

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1.1 a: MTPA for the Base speed operation: When operating along the MTPA trajectory, the magnetic field produced by the permanent magnets in the machine is utilized efficiently, resulting in a high torque generation for a given amount of current. This is especially advantageous in base speed operation, where the machine operates within its rated speed range.This also ensures the maximum torque output , and enhances the efficiency of the machine.
MTPF for field weakening operation: As the speed of the PMSM increases beyond the rated speed, it becomes impractical to follow the maximum torque per Ampere trajectory due to limitations in the magnetic flux generated by the permanent magnet. At the higher speeds, a machine would be generating the larger back emf, and as a result, the resultant flux would be reduced, and thus the machine can't produce the high torque. To maintain the torque output, Machine tends to reduce the magnetic flux. This reduction in the magnetic flux won't allow a machine to follow the MTPA, and A machine needs to compromise and choose the MTPF trajectory by reducing the torque output, which further enables it to extend the speed range. It also prevents the high current draw and overheating to follow the MTPA trajectory, and thus it is always beneficial to follow the MTPF trajectory when operating in the field weakening operation to extend the speed range by compromising some torque output considering the restrictions on the Magnetic flux.
For the Permanent magnet synchronous machine, to ensure the high efficiency, high torque output and enhance the speed range, it is always beneficial to operate the PMSM along the maximum Torque per Ampere trajectory in the base speed operation, and maximum Torque per flux trajectory in the Field weakening operation.

1.1 b: The function '**calc_reference_currents(Te,ωs)**' calculates the reference currents for the specific torque and the target speed values.We have added the matlab code for that in a matlab(.m) file.
E.g. in a code, this is tested with, [i_sd_ref, i_sq_ref] = calc_reference_currents(70,1500)

1.1 c: Challenges:
To Understand the concept of controlling a salient SM well enough to develop and implement a Matlab script for controlling the Machine.
To Find a sufficient way for the implementation for Matlab to do the heavy lifting of the calculation
Solutions: We spent a considerable amount understanding the concepts, and then splitting the tasks into the subtasks and then we created a code that is understandable and easy to follow.

1.2 a: The function '**plot_current_trajectory(70,5236)**' plots the i_sdq for the speed range 0-50000 rpm or 0-5236 rad/sec.
1.2 b:The function '**plot_torque_over_speed_map(70,5236)**' plots the T_m for the speed range 0-50000 rpm or 0-5236 rad/sec.

1.2 c: It is computed from the MATLAB code, and The maximum speed for base speed operation with the reference torque 70 NM is **2933 rpm.**

1.2 d:It is computed from the MATLAB code, and The maximum speed for the reference torque 70 NM is **4687 rpm.**

1.3 a: The operation at the short circuit current is not safe as it would lead to the excessive current through the circuitry causing the damage to an inverter and the protective devices by overheating.
1.3 b: The function ‘**plot_current_trajectory(70,5236)**’ plots the i_sdq for the speed range 0-50000 rpm or 0-5236 rad/sec with the updated short circuit current of i_max=400 A.

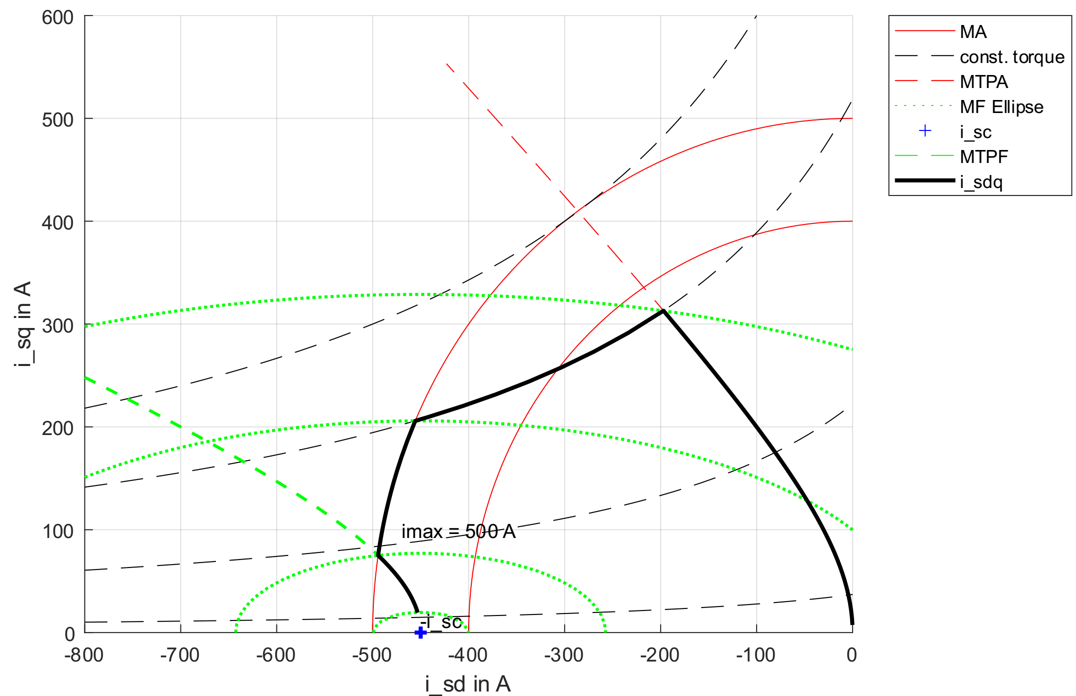
1.3 c: The function ‘**plot_torque_over_speed_map(70,5236)**’ plots the T_m for the speed range 0-50000 rpm or 0-5236 rad/sec with the updated short circuit current of i_max=400 A. From these two plots we can conclude that the passive cooling led short circuit current restrictions would cause the reduction in the maximum speed of base speed operation, and there is significant reduction in the torque generated as well in the field weakening operation.

Contributions:
Károly Farkas: Writing MATLAB script, plotting, writing report
Mayur Waghchoure: Report Writing and Code Debugging
Qihao Zhang: Writing part MATLAB script and report

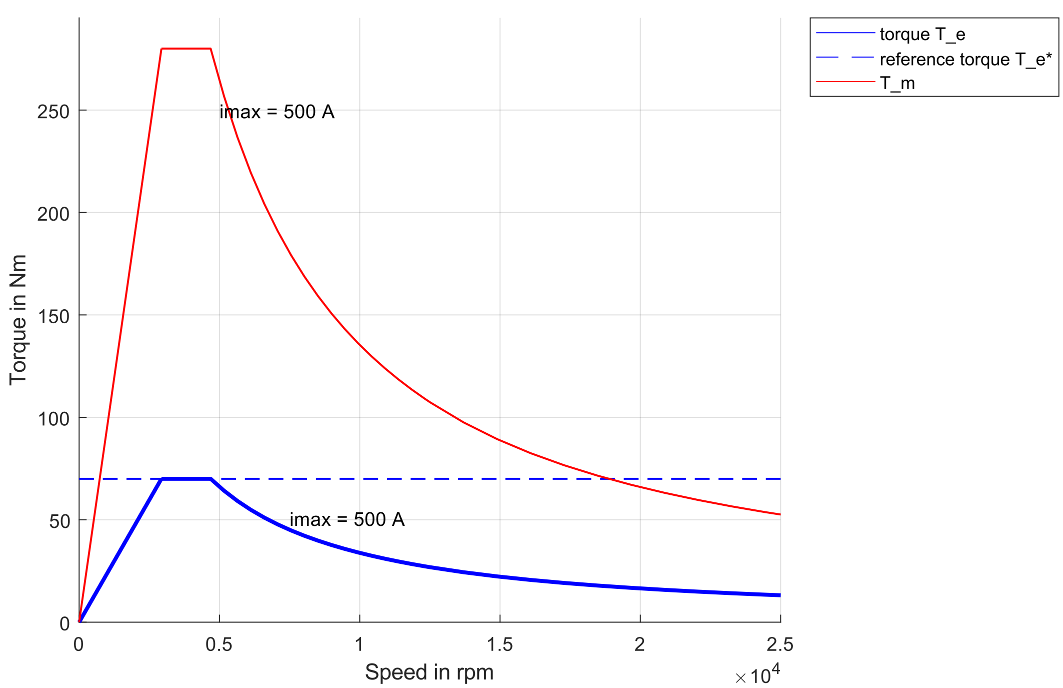
Appendix:

Plots:

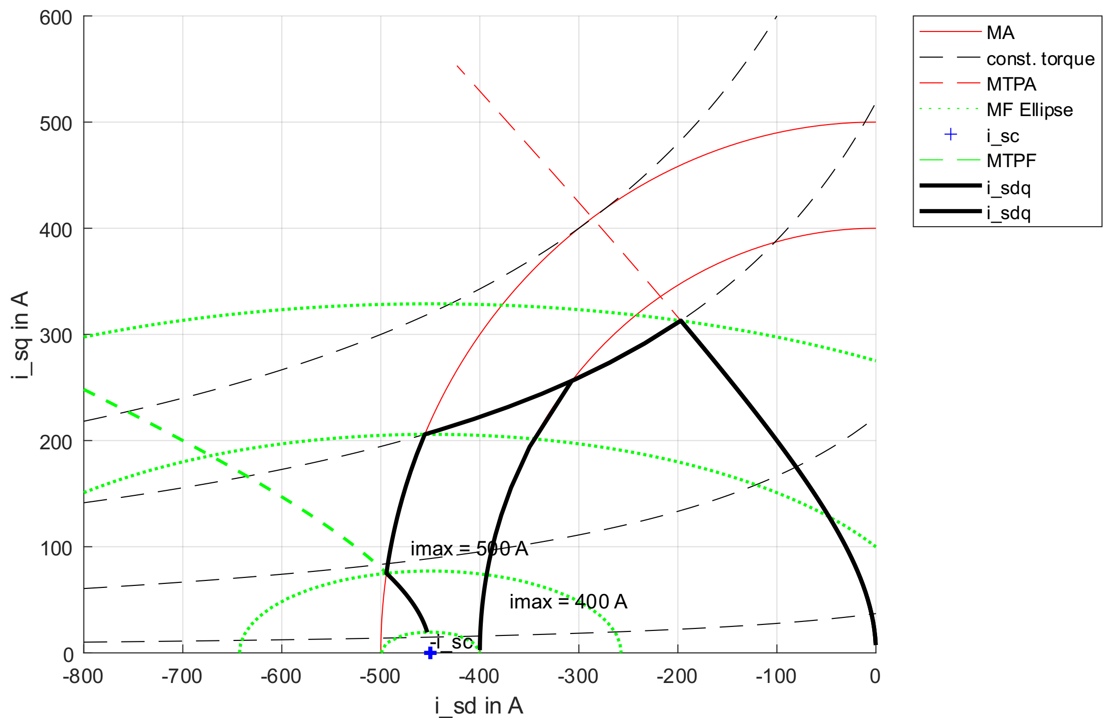
1.2 a: Current Trajectory for T_e* = 70 Nm and i_max = 500 A.



1.2 b: T_e and T_m for n = 0 … 50000 rpm with i_max = 500 A.



1.3 b: Current trajectories for T_e* = 70 Nm for i_max = 400A and i_max = 500 A.



1.3 c: T_e and T_m for n = 0 … 50000 rpm with i_max = 400 A and i_max = 500 A.