Application of High Performance Research Computing to Parametric Design and Analysis of Electric Machines

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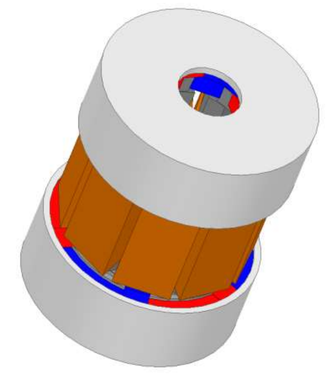
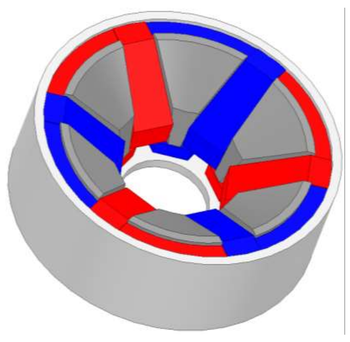
Background

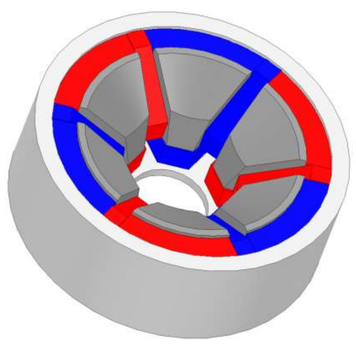
- Use ANSYS Maxwell for finite element analysis (FEA) simulations of electromagnetic devices.
  - Motors and generators
  - Magnetic couplings and magnetic gears
- Evaluate voltages, currents, torques, forces, magnetic fields, and losses.
- Extensive simulations required for a thorough characterization of design and performance trends.
- Certain machine topologies, such as the one shown to the right, require computationally intensive high resolution 3D models.
- Use High Performance Research Computing (HPRC) Linux clusters for the parallel simulation of numerous cases.



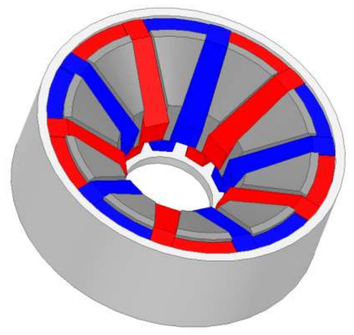
Full Model



Base Motor Template



Different Magnet Thickness



Different Pole Pairs

Workflow

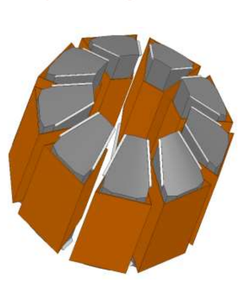
Sim_Num	PP	Stator_L1	Housing_T	Stator_Cap_H	Stator_Cap_T	AG	AG2
		mm	mm	mm	mm	mm	mm
1	3	123	4.5	4	4	1.15	1.6
2	3	123	4.5	4	6	1.15	1.6
3	3	123	4.5	4	8	1.15	1.6
4	3	123	4.5	6	6	1.15	1.6
5	3	123	4.5	6	8	1.15	1.6
6	3	123	4.5	8	8	1.15	1.6
7	3	123	4.5	4	4	1	1
8	3	123	4.5	4	6	1	1
9	3	123	4.5	4	8	1	1
10	3	123	4.5	6	6	1	1

MATLAB

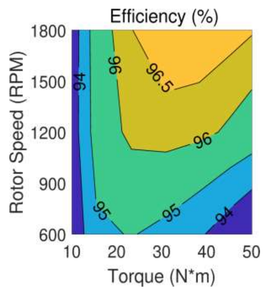
High Performance Research Computing Cluster

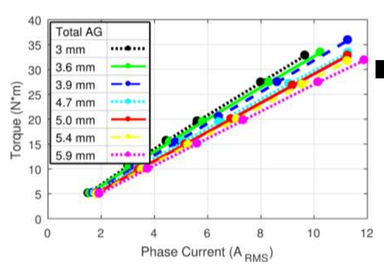
ANSYS

ANSYS Maxwell



MATLAB





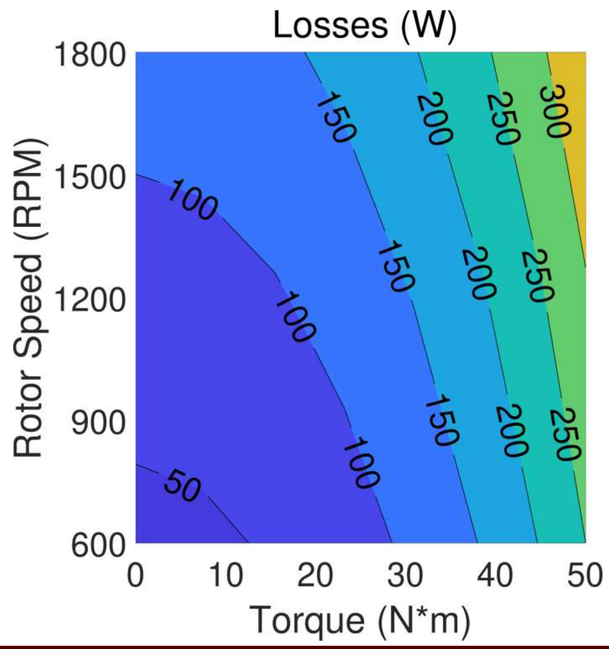
- On a local workstation, the user:
  - Creates a parametric model template in ANSYS Maxwell.
  - Enters the desired simulation parameter value combinations (designs) in a spreadsheet.
- On a local workstation, a Matlab script:
  - Copies and modifies the ANSYS Maxwell template to create simulation files based on the designs specified in the spreadsheet.
  - Uses scp to move the simulation files to a directory on the Linux cluster.
  - Creates simulation job (.slurm) files
- On the Linux cluster, a bash script:
  - Submits simulation job (.slurm) files for corresponding Maxwell files
- On a local workstation, a Matlab script:
  - Automatically periodically polls the cluster to download any new simulated ANSYS Maxwell files.
- On a local workstation, the user:
  - Processes and plots the results using Matlab data analysis and visualization scripts.

Results

Comparison of Design Study Run Times
Local Machine vs. HPRC Cluster

	Local Machine	HPRC Cluster
Average Run Time per Case	13 Hours	13 hours
Total Number of Cases	1500	1500
Cases Running in Parallel	2	100
Total Time	9750 Hours (Est.) (1.13 Years)	195 Hours (~8 Days)

- Losses map is drawn against variation of operating conditions.
- Motor parameters are then chosen based on analysis of simulation results.
- Use of HPRC's resources enabled higher resolution parametric analysis and detailed performance optimization, which would not be practical otherwise.
- Reduced total losses by 21%.



Conclusions

- Used HPRC resources to conduct extensive parametric analysis and optimization of electrical motor and magnetic gear topologies.
- Certain topologies required the use of computationally intensive 3D finite element models.
- Large numbers of cases can be evaluated in parallel on HPRC's Linux cluster, resulting in a significantly faster optimization process.
- HPRC resources enabled a more thorough optimization process.
  - Used higher fidelity models.
  - Evaluated more parametric design variations.

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