Application of High Performance Research Computing to Parametric Design of Magnetic Gears Using a Genetic Algorithm

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Use ANSYS Maxwell for finite element analysis (FEA) simulations of electromagnetic devices.
- Motors and Generators
- Magnetic couplings and magnetic gears
- Evaluate, torques, forces, magnetic fields, and losses.

Extensive simulations required for a thorough characterization of design and performance trends.
Magnetic gears have significant end effects which require computationally intensive high resolution 3D models to accurately assess.
Use open source GOSET genetic algorithm optimization tool for Matlab.
Use High Performance Research Computing (HPRC) Linux clusters for the parallel simulation of numerous cases.
Use HPRC’s resources to perform 36 multi-objective optimizations at 6 different permanent magnet temperatures.

On a local workstation, the user:
- Creates a parameterized model template in ANSYS Maxwell.
- Enters the desired initial population simulation parameter values and ranges in a spreadsheet in Excel.

On a local workstation, a Matlab script:
- Copies and modifies the template to create ANSYS Maxwell files for the individuals of that generation.
- Uses scp to move the simulation files to a directory on the Linux cluster.
- Creates simulation job (.slurm and .LSF) files which include instructions for the Linux cluster to solve the ANSYS Maxwell files and export the relevant data into .csv files.

On the Linux cluster, a bash script:
- Submits simulation job (.slurm and .LSF) files for corresponding Maxwell files.
- Automatically periodically polls the cluster to download any new .csv files.
- Calculates fitness of designs.
- Passes the calculated fitness and parameters of the designs through the open source GOSET genetic algorithm, which creates the next parameters for the next generation of designs.
- Automatically repeats this process for each generation.

On a local workstation, the user:
- Post-processes and plots the results using Matlab data analysis and visualization scripts.

Comparison of Design Study Run Times

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<tr>
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<th>Local Machine</th>
<th>HPRC Cluster</th>
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<tbody>
<tr>
<td>Average Run Time per Case</td>
<td>~15.8 minutes</td>
<td>~15.8 minutes</td>
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<tr>
<td>Total Number of Cases</td>
<td>106,992</td>
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<tr>
<td>Cases Running in Parallel</td>
<td>2</td>
<td>Up to 300</td>
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<tr>
<td>Total Time (~1.61 Years)</td>
<td>~14100 Hours</td>
<td>~570 Hours</td>
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Magnetic gear parameters are chosen based on analysis of genetic algorithm’s final generation simulation results.
Unique magnet material design combinations.

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Conclusions

- Used HPRC resources to conduct extensive parametric analysis and optimization of electrical motor and magnetic gear topologies.
- Large numbers of cases can be evaluated in parallel on HPRC’s Linux cluster, resulting in a significantly faster optimization process.
- This process can be automated to require minimal human oversight.