1. Introduction

We proposed new conceptual designs for 1 MW marine current turbine generator (MCTG) concerning two topologies using permanent magnets (PMs) and high temperature superconducting (HTS) windings for field poles. The design starts from analytical equations and is then optimized based on 3D FEM simulation, where good agreements are achieved. The influence of number of poles and the confinement of outer diameter, etc., on the generator performance are clarified. Finally, the results indicates HTS topology is lighter in weight and higher in efficiency at 1 MW class.

2. Initial Design Conditions

Extractable energy: \( P = \frac{1}{2} \rho A T V^3 C P \) (1)

Tip speed ratio: \( \lambda = \frac{V}{r_b \omega} \) (2)

Table I. Design Conditions of 1 MW 3-Phase MCTG

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output power (kW)</td>
<td>1000</td>
</tr>
<tr>
<td>Rated current speed (m/s)</td>
<td>2.5</td>
</tr>
<tr>
<td>Rated speed (RPM)</td>
<td>16</td>
</tr>
<tr>
<td>Turbine outer diameter (m)</td>
<td>18</td>
</tr>
<tr>
<td>Generator outer diameter (m)</td>
<td>4 ± 0.1</td>
</tr>
<tr>
<td>Terminal voltage (V)</td>
<td>660</td>
</tr>
<tr>
<td>Power factor</td>
<td>1</td>
</tr>
</tbody>
</table>

3. Conceptual Structure

![Fig. 1. Rim-driven generator @OpenHydro.](http://www.openhydro.com/)

**Features:**
- Direct-driven PM synchronous generator
- Weight: ~ 850 tons (turbine 350 ~ 400 t, subsea gravity base 400 ~ 450 t)

**Objective:**
- To fully utilize the space of open-center.
- Introduce HTS technology into machine design.

4. Electrical Design Algorithm

Induced magnetomotive force per phase:
\[ V_{phase} = 4.44 k f N \Phi_{Armature} \] (3)

Key parameter: Magnetic flux leakage coefficient, \( \sigma \)
\[ \sigma_1 = \frac{\Phi_{Field}}{\Phi_{Armature}} \] (4)
\[ \sigma_2 = \frac{\Phi_{Air-gap}}{\Phi_{Armature}} \] (5)

5. Comparisons for PM and HTS Topologies

- 1. Design conditions based on marine current
- 2. One pole magnetic flux & armature structure
- 3. Outer diameter confinement with \( e_{1, x} \) and \( e_{2, x} \)
- 4. Armature winding parameters and leakage reactance
- 5. MMF under load and no-load condition
- 6. Considerations and determination of PM and HTS
- 7. Best individual for 3D simulation

6. Design Results and Conclusions

**New parametric sweep with**
\[ \sigma_{1,n} \cdot \sigma_{2,n} \]

**Final results**

- Yes

![Fig. 3. The determination of operating point of the PM with varied thickness.](

![Fig. 4. Performance of HTS wires under external field at 77 K.](

![Fig. 5. Key parameters variation of PM topology as a function of the number of poles.](

![Fig. 6. Key parameters variation of HTS topology as a function of the number of poles.](

![Fig. 7. 3D simulation of one field pole for PM topology.](

![Fig. 8. 3D simulation of one field pole for HTS topology.](

![Fig. 9. 3D simulation of one field pole for HTS topology.](

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**Comparative Study of 1 MW PM and HTS Synchronous Generators for Marine Current Turbine**

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