

The background features several large, overlapping, semi-transparent swirls in shades of purple, green, and blue. Scattered throughout are numerous small, yellow, triangular shapes, some pointing towards the center and others pointing outwards, creating a dynamic and energetic feel.

“Developments of Rare-Earth-Free-Motors for HEV and EV”

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Background

In recent years, motor need is increasing for Hybrid Electric Vehicle.

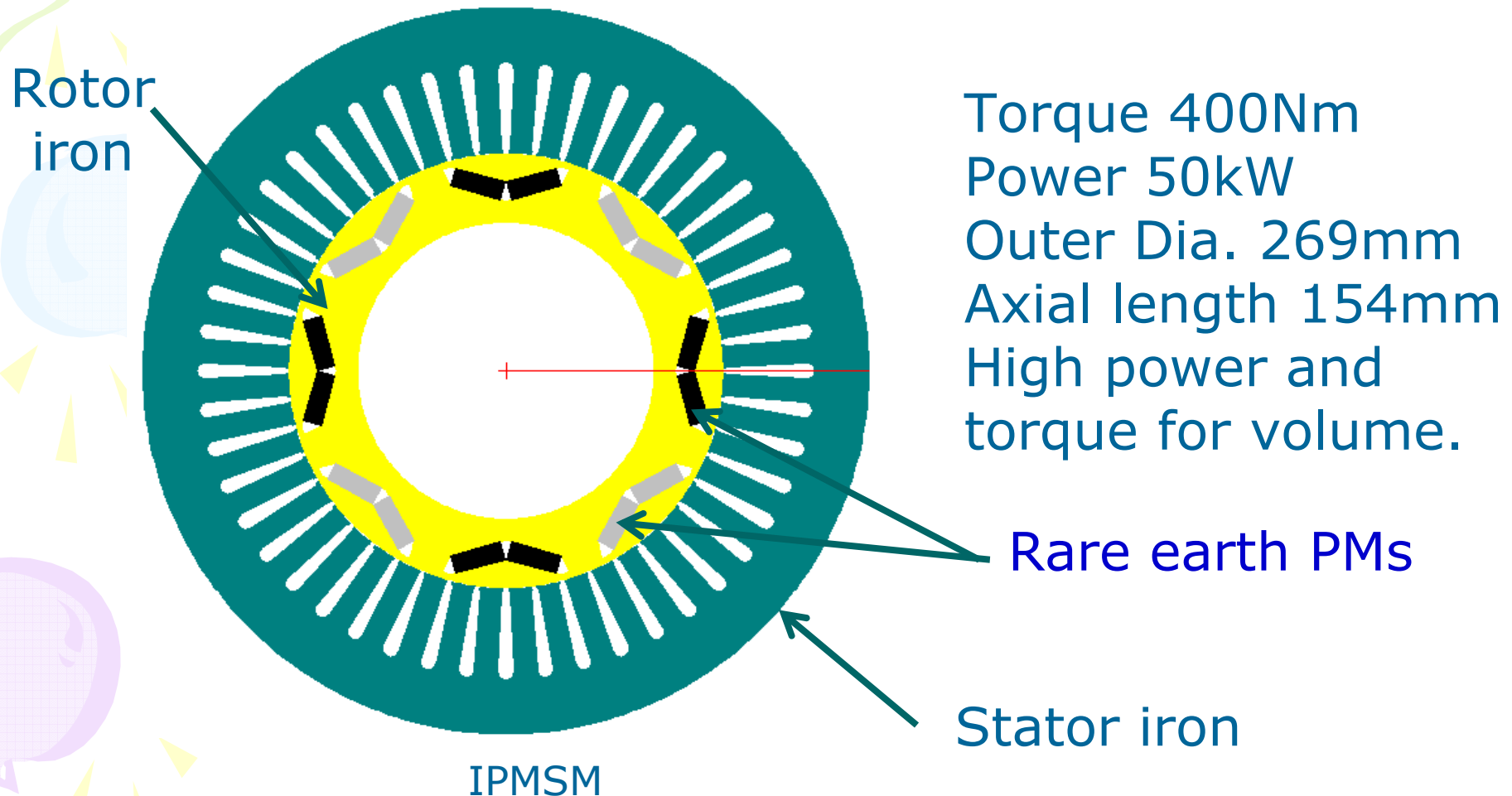
The demands of HEV

- **High torque density**
- **High efficiency**
- **Low cost**

IPM motor is most popular motor for HEV and EV. **However, IPM motor** contains permanent magnet with **rare earth** such as **Neodymium and Dysprosium.**

Cross section of HEV IPM motor

About 1kg of NdFeB PM is used. A half of material cost is PM.



Motivation of NEDO projects

- **Rare-Earth-Free electric motors** are strongly demanded for mass production HEVs and EVs.
- NEDO has started rare-earth-free-motor projects 3 years ago.
- The rare-earth-free motors must have
 1. Competitive size
 2. Competitive power density
 3. Competitive efficiency
 4. **but no rare-earth permanent magnet**with respect to the rare-earth(NdFeB) IPM motors employed in HEVs and EVs. Thus, the targets are very challenging. Rare-earth-free motors are a new generation motor of post NeFeB IPM motors.

Switched Reluctance Motor Project

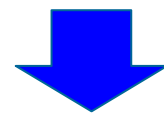
target: 2nd generation Prius

The advantages of SRM

No permanent magnet
No rare earth material
Low cost
**Robust in high temperature
or high rotational speed**

The problems of SRM

- I Low torque density**
- II Low efficiency**
- III Unique inverter circuit**
- IV High noise and vibration**



**All these problems are
needed to be solved**

In this project, the **problems I and II** have been investigated. The target also includes **competitive torque density** with respect to the NeFeB IPM motor in the best seller HEV.

Principle of SRM

SRM is rotated by reluctance torque only.

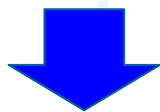
Reluctance torque is made by the difference of reluctance between aligned position and unaligned position.

SRM rotating process

Provide current to winding A



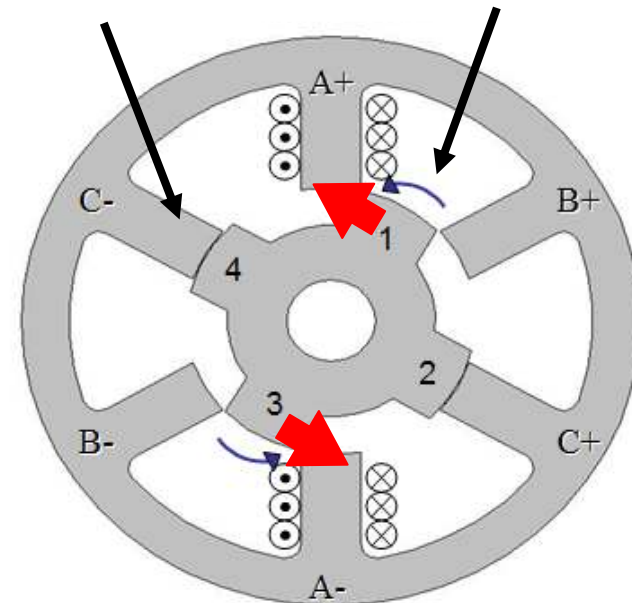
Rotor rotates from unaligned position to aligned position.



Current Phase is changed.

Aligned position

Unaligned position



Technical improvements of the SRM

A competitive SRM has been designed with respect to the IPMSM employed in 2nd generation HEV. To achieve high torque density and efficiency, the main keys are

- (i) Machine design with increased number of poles. 12/18
- (ii) Low loss iron (high silicon steel) is selected.
- (iii) Rapid analysis software is selected for optimization.

Three test machines have been built.



Stator and rotor laminations of a test machine



The outer diameter is 269mm, i.e., the target value.

Stator core, windings and frame



Rotor core and shaft



SRM project summary

- SR motor has been developed in the same outer diameter and axial length.
- Developed SR motor is found to have competitive **power** and **efficiency** as well as **torque density**.
- The **operating area** of SR motor is found to be competitive to the IPMSM. High efficiency area is larger than that of the IPMSM.
- Now developed motor has been installed in a converted EV for further tests.