E-core Transverse Flux Machine (ETFM)

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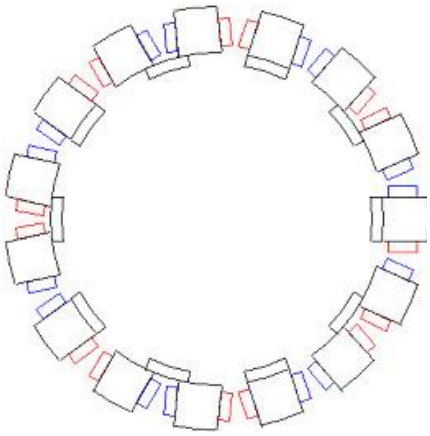
General description of the ETFM

The E-core Transverse Flux Machine (ETFM) is a new mechanical design of the Switched Reluctance Machine (SRM). The new design is patented by Aalborg University, Institute of Energy Technology in Denmark, and is developed by ePower Technology ApS.

The ETFM is a transverse flux machine, which means the flux is running in the axial direction, in contrast to traditional switched reluctance machines, where the flux runs radial. The stator and rotor poles are constructed of traditional EI-cores, which are well-known from transformers. The stator poles consist of the E-cores and the rotor poles consist of the I-cores. Due to the transverse flux path, the stator poles are operated locally and the space in the center of the machine is "free".

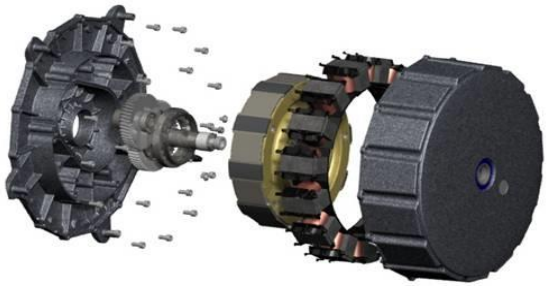


Cross sectional view of the ETFM

The segmental construction of the ETFM makes it possible to make the pole configuration almost free. The SRM has some fixed pole configurations, like 6/4, 12/8, 18/12 for three phase machines. Any combination in between are impossible because of the flux path. The ETFM has both the traditional pole configuration, but also some uneven numbers, like the 15/10 shown in the figure. This flexible pole configuration makes it very easy to design the machine for any application.

The ETFM is operated exactly like the traditional switched reluctance machine. The reluctance principle of the switched reluctance motor was discovered in 1838, but the motor could not realize its full potential until the modern era of power electronics and FEM. Especially in the late 1980s and in the 1990s has the switched reluctance motor become interesting, due to the development of MOSFETS and IGBT's.

The ETFM can operate in all four quadrants depending on the topology of the power electronic converter. ePower has developed a power electronic converters for 1-6 phased models in the voltage range 24-48V which are commonly used in automotive. The power stage consists of three asymmetrical H-bridges, one for each phase, which makes four quadrant operations possible. The power stage has also a brake chopper circuit for dumping excessive energy during deceleration or generator operation.



Exploded view of the ETFM

The potential of the ETFM is very interesting, because the new mechanical design makes it possible to integrate the ETFM in applications, where the axial length of the machine must be short. An example is the indoor cycle, eTenzor, developed by AWS Technology. The ETFM, with integrated gearbox, is placed directly between the pedals, which make the design homogeneous.

The key features of the ETFM are:

- **Robustness** – The ETFM is simple in structure and the machine is fault tolerant, due to the separated phase-windings. No windings or magnets on the rotor.
- **Starting Torque** – The ETFM provides a high starting torque, up to 3-4 times nominal.
- **Low speed** – Maintain full rated torque down to zero speed.
- **Gearbox** – A gearbox can be integrated in the machine without increasing the physical size.
- **Shape** – The ETFM has a short axial length, approximately the width of the E-cores
- **Low Inertia at large diameter** – The Transverse flux principle makes it possible to keep the moment of inertia low at large rotor diameter. Perfect for direct drive start/stop applications.
- Possibly **no cogging torque** from zero speed and maximal torque. Perfect for direct drive precision applications.
- **No magnetic losses** at high speed with no load (free wheel) keep high efficiency at low torque.
- N**o magnets** - no rare earth materials used.
- **Low maintenance costs.**

3 phases ETFM generator

This model is optimized for the Synergy Indoor bike. It is constructed with internal gearbox a short axial length, so it fit between the pedals in the bike. The focus in the development was on strong mechanical construction, high power, outdoor bike feeling and cost effective.

Motor phases:	3
Stator pole configuration	15 pole pairs
Rotor pole configuration	10 poles
Speed range, internal	200 to 1500 RPM
Speed range, external	30 to 200 RPM
Load range, internal	0-11 Nm
Load range, external	0-80 Nm
Generator power (Continuous)	600W
Generator power (Peak)	1000W
Internal gear box ratio	1:7,31

Motor controller:
Cost effective dedicated motor controller for the Synergy Indoor bike, with build in outdoor bike feeling emulation

Other features:
Internal fly wheel, Inertia for bike feeling.
Build in free wheel, designed up to 150 kg persons
Low cost internal encoder feedback

5 phases ETFM motor/generator

This model is optimized for the gym80 4E strength test and training equipment. The focus in the development was on 4 quadrant control, high peak torque, high speed range and most of all low torque ripple and low hearable noise.

Motor phases:	5
Stator pole configuration	15 pole pairs
Rotor pole configuration	12 poles
Speed range, internal	-1500 to 1500 RPM
Speed range, external	-200 to 200 RPM
Load range, internal	0-20 Nm
Load range, external	0-146 Nm
Generator power (Continuous)	800W
Generator power (Peak)	2000W
Motor power (Continuous)	600W
Motor power (Peak)	1300W
Internal gear box ratio	1:7,31

Motor controller:
Full 4 quadrant motor general purpose motor controller, controlled by LabVIEW

Other features:
High precision internal encoder, with resolution of 0,018 degree of the motor shaft
Lightweight rotor for high speed adoption
Low torque ripple