Advances in Permanent Magnet Motors

Induction

Permanent Magnet

Surface-Mounted

Embedded

Inserted

Efficiency

Cost

John Petro  Motor Summit 2018 International, Zurich, Switzerland

November 2018
Innovation continues at an encouraging pace

- Overall market
- Line-start Permanent Magnet motors (LSPM)
- Motor design advances
- Improvements in materials
- Conclusions
Current Industry Status

- All motor types are improving
  - Induction – IE4 and possibly IE5 with copper rotor
  - Synchronous reluctance – IE4 and higher with PM magnet assist
  - Switched reluctance – lower material and drive costs and line-start versions, vibration still limiting issue
- PM motors still achieve the highest efficiencies
- Cost and complexity limit high efficiency motor usage and are often due to drive electronics
- Line operation could solve cost and complexity
The Problem for Line-Start PM Motors

- Limited options for AC line-operated PM motors
- PM AC line operation often accomplished by
  - AC line drive – drive costs about same as motor cost
  - DC low voltage drive – low cost drives are available, but conversion of line AC to low voltage DC cost is still high (> 3-5 US cents/watt)
  - Induction line start often has oscillations at startup
- Electronics are often less reliable than the motor
- Single phase power is often utilized for smaller motors
The MGT Line-Start Dual Rotor Motor

- Outer rotor starts as quickly as induction rotor
- Inner rotor coupled as magnetic clutch

Additional bearings
Startup Issues with LSPM Motors

- Motor startup is a challenging issue

Standard LSPM

MGT Inc. dual rotor start
Large Inertia Startup (~100 x rotor inertia)

- Startup time about 8 seconds
Large Efficiency Gains are Possible

- PM motors can greatly increase small motor efficiency
MGT Motor Efficiency

- As efficient as best commercially available drive operated PM motors
- More efficient when drive losses are considered
- Efficiency gains of 10 % to > 20 % over existing induction motors!
- Only additional costs are bearings and magnets
- Future work
  - Reduce magnet costs with use of ferrite
  - Develop single phase version
Additional PM Motor Advantages

• Induction motors are less efficient at < 1800 rpm
• PM motors with higher pole counts can operate efficiently at lower speeds
• This enables direct drive low speed operation and can eliminate gearing losses
Commercially Available Motor Improvements

- Efficiencies and range still improving

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<th>HP</th>
<th>600 RPM</th>
<th>900 RPM</th>
<th>1200 RPM</th>
<th>1800 RPM</th>
<th>2400 RPM</th>
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NovaMAX motor 182/184 Frame
NovaMAX motor 213/215 Frame
Motor Design Developments

- Interior PM designs (IPM) improving
  - Driven by automotive traction motors
  - Reduced volumes of magnet material
  - Major reductions in cost
- Hairpin winding technology
- PM-assisted synchronous reluctance motors
- Ferrite PM flux concentration in motor designs
- Line-start PM-assisted switched reluctance
New Magnet Developments

- New ferrite materials becoming available
  - Higher coercivity – more available motor power
  - Positive temperature coefficient – no demagnetization at cold temperatures
- Low rare earth formulations
- Substitution of lower cost rare earth elements
- Oriented molded magnets at > 20 MGO*
- Samarium iron nitride commercially available
  - Moldable and oriented in thin slots
  - Flexible magnetic orientations

*) MGO: Mega Gauss Oersted - the standard measurement for magnet performance
Conclusions

MGT line start motor has good performance

- Smooth AC line start with any inertia
- High efficiency and load stable
- Low cost, standard manufacturing techniques

<table>
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<tr>
<th>DR-LSPM Operating point</th>
<th>Load Torque (Nm)</th>
<th>Line to Line Voltage (Vrms)</th>
<th>Phase Current (Ams)</th>
<th>Power Factor (PF)</th>
<th>RPM (rpm)</th>
<th>Input Power (W)</th>
<th>Output Power (W)</th>
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John Petro
Zurich, Switzerland
November 2018
Conclusions

- World needs more efficient motors
- PM motors can provide efficiency gains
- AC line operation is key
- Motor designer challenge
  - Explore all options for line-start PM motors
  - Investigate use of ferrite with flux-concentration
  - Look at lower speed, direct drive applications
  - Look at other motor types - LS Synchronous Reluctance (SRM)
Thank you !!!

Questions?

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