Saving Energy, Materials, Size and Cost: Electronically Commutated IPM motors

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The continual improvements in both Power Electronics and Digital Signal Processing as well as the changing economics of the materials used in motors and rising energy costs is signaling a change in how we use and deploy motors and their controllers. The size and cost of electronics has continued to shrink, while the efficiencies and reliability have improved. The cost of copper[i] and steel have significantly increased while the cost of magnetic material has simultaneously reduced. The economics of electronically commutated IPM motors are resulting in faster initial payback and continued savings both for the user and for the infrastructure.

In the United States, 70% of the total electricity produced is consumed by motors. Motors smaller than one horsepower represent 9% of motor power usage, or 6.3% of the total electricity produced. US Government figures[ii] indicate an overall average cost of electricity of 10.63 cents per kWh, varying from 5.8 cents in West Virginia to 14.5 cents in California, 19 cents in New York, and 32.6 cents in Hawaii. In addition to just the cost of energy, there are also Federal Mandates[iii] to increase motor efficiencies.

The goal of reducing energy usage is aided by the use of high efficiency motors, but it does not end there. System efficiencies are often reduced by 1) not operating the motor near its highest efficiency point, 2) over sizing the motor with respect to the load and then using dampers etc. to reduce the motor output to that which is required, and 3) using constant output motors with variable loads.

- Driving forces
  - Reduce Energy use
  - 70% US electric used by motors
  - 9% of motors (6.3% of electric) by motors < 1HP
  - Cost of energy & Energy independence
  - Cost of Pollution
  - Availability of energy (more power plants)
  - Federal Mandate
    - AC induction motors
    - Future – expect more to come.
- Initial response and Unintended Consequences
  - Improvements to Induction motors
    - Reduce squirrel cage losses
    - Reduce stator copper losses
  - Consequences
    - More copper and Aluminum use
    - More rapid acceleration at power up due to lower loss
      - High turn-on surge of high efficiency motors
      - More stress on mechanical components
      - Stress on power system at power on
    - Need to add soft-start control

- System Efficiency
    - Optimal vs. real life
        - Optimal Efficiency point of Motor
            - Speed and torque point
            - Power factor over line voltage
        - Multiple margins add up to oversized motor
            - Margins for installation variables
            - Margins for power line voltage
            - Variable loads
            - Matching the Motor Output to load requirements
                - Shedding extra load (dampers)
                - Varying motor speed
                    - Greatly reduces efficiency for induction motors
- Permanent Magnet vs. Induction Motors
    - Power to produce reacting magnetic field
    - Material usage
    - Size
    - Weight
    - Speed control / regulation
    - Efficiency
- Face mounted vs. Indirect PM motors
    - Wider efficient operation range of IPM
        - Field weakening
        - Emulation of DC series wound motor speed-torque characteristics
- Controlling the motion
    - Variable speed drives
        - Induction vs. PM
    - Stepper motors
    - Full Servo
        - 4 quadrant including stopped
    - Interior mount PM (IPM) field weakening to more resemble DC series motors Wide constant power range
    - High pole count + servo allows direct drive applications
- Pay back time for upgrading
    - Direct energy usage
    - Reduced need for gear heads and their maintenance
    - Multiplier by air conditioning costs for many factory floor applications
    - Reduced noise – reduced system cost
    - Improved performance -> improved final product
    - Less wear and tear from startups
    - Longer life due to lower temperatures
    - Improved power factor
    - Less weight/size for PM motors
- Battery powered / mobile
    - More efficiency -> longer life or smaller batteries
    - Smaller size and weight further improves efficiency
    - 4 quadrant allows regenerative braking
    - IPM allows traction friendly torque curve approximating DC series motor

        - Very high torque at lower speeds transitioning to constant power
    - IPM with field weakening provides wide high efficiency speed range

[i] http://www.metalprices.com/FreeSite/metals/cu/cu.asp

[ii] http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html

[iii] http://www.eia.doe.gov/oiaf/aeo/leg_reg.html