Green Power Solutions

AC vs DC Motor Drives for Heavy Duty Application

Jorge Eduardo Haros Villanueva

AMI Automation

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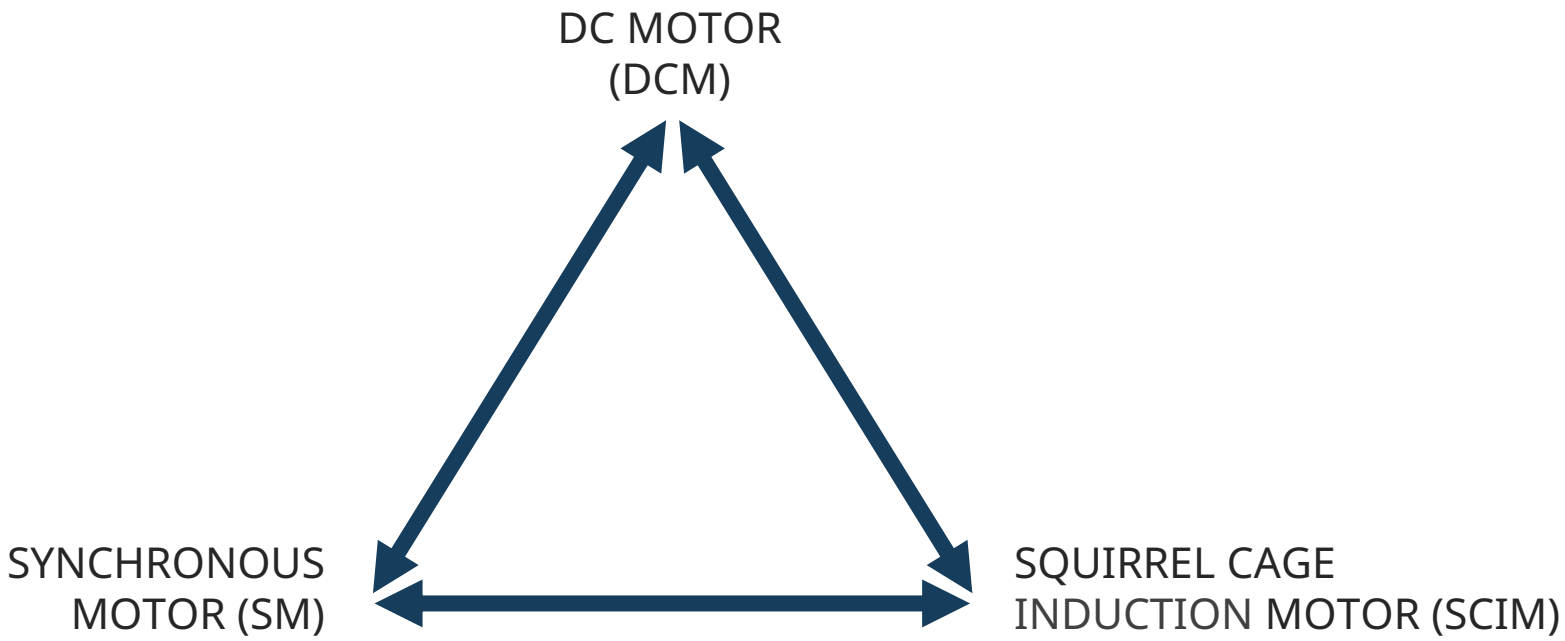
COMPARISON OF MOTORS



COMPARISON OF MOTORS

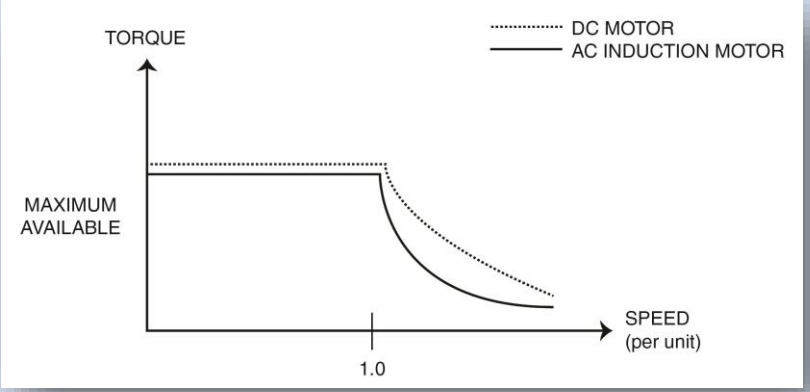
- DC motors (DCM) with the Variable Voltage method have been applied in almost all main and auxiliary Drive applications throughout the industry for decades.
- In recent years, Vector Control AC Drives with Motors (SM) and (SCIM) have been developed for practically all applications.
- The application of DC Motors (DCM) has decreased dramatically.

COMPARISON OF MOTORS

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
STRUCTURE	The commutator and the brushes transfer current to the armature windings located in the rotor. Field windings in the stator.	The Armature Windings are in the stator and the Field windings in the rotor. Slip rings with brushes transfer current to the field winding.	The primary winding is in the stator. There are NO isolated windings in the rotor; it only consists of copper or aluminum bars and short circuit rings. The Primary current produces both the flow and the Torque current.

COMPARISON OF MOTORS

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
EXTENDED SPEED RANGE TOP-BASE	5:1 is Possible Over Load is reduced by only 25% in a range of 3:1	3:1 Maximum 2:1 Typical Similar to DCM	4:1 Maximun 2:1 Típical but special Over Load is reduced by 50% Very low RPM Base Speed causes significant increse in motor current in



COMPARISON OF MOTORS

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
SPEED RANGE	100-2400 RPM Operate at 0 RPM continuously requires Special Motor and ventilation.	Range Similar to DCM It is not recommended to operate at Hi speeds.	100-7000 RPM Operating at 0 RPM continuously requires Special Motor even without ventilation.

COMPARISON OF MOTORS

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
ENCLOSURE	They are usually Open Machines DP. 97% require forced ventilation. TE machines are available with Heat Exchanger.	Similar to DCM	TE machines are common. Easier Cooling DP Machines also available.

COMPARISON OF MOTORS

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
EFFICIENCY (Eff)	$Prq = \frac{\text{Motor kW}}{\text{Motor Eff.}}$ Motor Eff. for HSM FM (100-500 rpm) = 90%-92% Motor Eff. for HSM RM (30-60rpm) = 88%-91%	$Prq = \frac{\text{Motor kW}}{\text{Motor Eff.}}$ Power Factor (PF) = 1 Motor Eff. For HSM FM (100-500 rpm) = 94%-97% Motor Eff. For HSM RM (30-60rpm) = 92%-95% Lowest Power Requirement	$Prq = \frac{\text{Motor kW}}{\text{Motor Eff. x PF}} \times \frac{\text{Term Volt at Top Spd}}{\text{Term Volt at Base Spd}}$ Power Factor (PF) = 0.75 -0.9 Motor Eff. For HSM FM (100-500 rpm) = 93%-96% Motor Eff. For HSM RM (30-60rpm) = 90%-94%

COMPARISON OF MOTORS

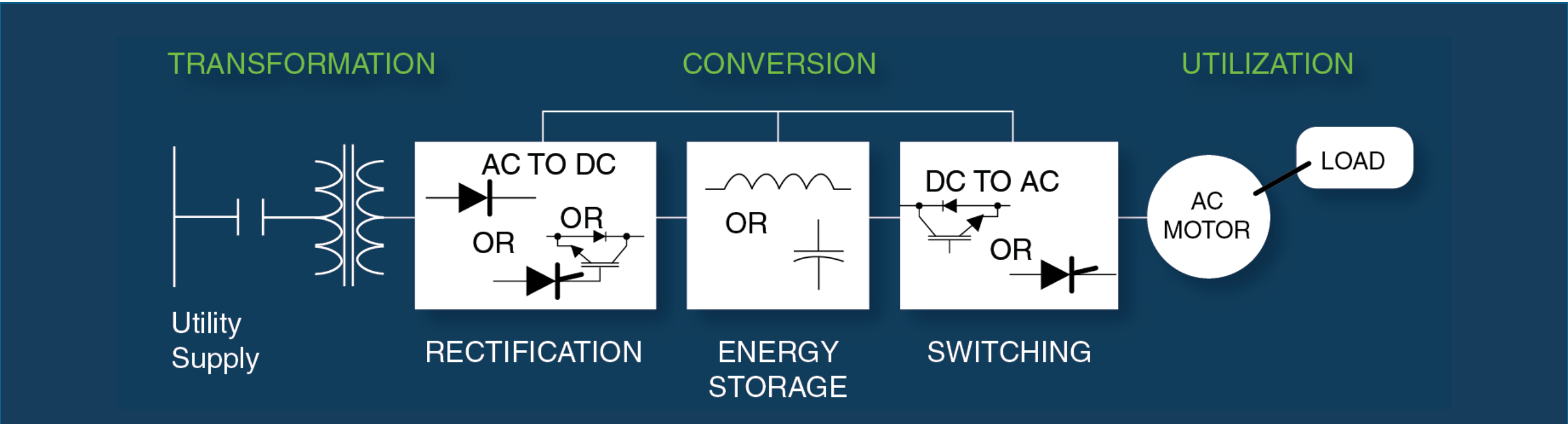
	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
MAINTENANCE	Many brushes create a high maintainability and require the change of brushes. It is also required to keep the surface of the commutator in good condition for proper operation.	Requires Brushes but they are only 10% of a DCM. Because there is no switching the life of the brushes in greater than a DCM. Resulting in Less Maintenance.	No brushes and no rotor windings mean very low maintenance. Very Robust.

COMPARISON OF MOTORS

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
MAINTENANCE	Large Machines are made with Split Stator	Large Machines are normally made with a solid stator. Rotor weigh can be 2X DCM	Not very common with pedestal bearings.

COMPARISON OF DRIVES

- AC Drivers can have more than Double Components than a DC Similar.
- In DC Reversible is Equal to Regenerative (96%) DC.
- Requires Switches / Contactors to operate Regenerating.



COMPARISON OF DRIVES

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
VOLTAGE AND CURRENT REQUIREMENTS	Voltage <1000 V Rare cases up to 1200 V Low voltages result in high armature currents.	Voltage <3300 V Rare cases <6600 V Due to FP = 1 of the Motor, the Armature current is the lowest. However, the Field current is considerable.	Voltage <33000 V Rare cases <6600 V Due to the FP <= .8 of the Armature Running Motor it is the highest that SM.

COMPARISON OF DRIVES

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
EFFICIENCY (Eff)	Drive Eff. 99-99.5% Air Cooled Lowest Power Requirement	Drive Eff. 94-96% Water Cooled	Similar lo SM but with higher current requiremt due to the Motor PF Air/Water Cooled

COMPARISON OF DRIVES

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
— SENSORS	Requires Over-speed Protection. It can Operate without a Speed Sensor even in torque regulation or zero speed regulation applications.	Always requires Sensors: • Speed • Position	Requires Speed Sensor: • Regulating Torque around zero speed. • High Starting Torque> 150% • Wide Speed range

COMPARISON OF DRIVES

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
SPEED RESPONSE MOTOR CONNECTED TO DRIVE SHAFT.	Less than 20 *radians/sec.	In HSM can be up to 30-40 *radians/sec. Depending on the drive shaft condition: Preferable that 1st natural frequency >approx. 17 Hz and $\frac{1/3 < GD^2 \text{ (motor)} < 3}{GD^2 \text{ (load)}}$	In CM Can be up to 60 *radians/sec. Depending on the drive shaft condition: Preferable that 1st natural frequency > approx. 20 Hz and $\frac{1/3 < GD^2 \text{ (motor)} < 3}{GD^2 \text{ (load)}}$
APPLICATION	Rolling mill Main Drives and Auxiliary Drives.	HSM Roughing Mill. Finish Mill. Plate Mill. Steckel Mill. Larger Section Mill. Other large scale Main Drives.	Mill Auxiliary Motors. Table Motors. Coiler Mandrel. Shear. Other medium size main Drives such as cold Mill Main Drives and Reel and Rod, Bar, and Wire mills.

COMPARISON OF DRIVES

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
MOMENT OF INERTIA GD2	D2L (Diameter may be big).	D2L (Diameter can be smaller and length longer).	D2L (Diameter can be smaller and length longer).
1ST NATURAL FREQUENCY IN DRIVING SHAFT	Low	High	High
DRIVE SYSTEM	Thyristor Variable Voltage System. IGBT Variable Voltage for Small Size	3-Level PWM Inverter or Cycloconverter.	3-Level PWM Inverter (2-Level PWM Inverter for auxiliary drives).
TYPICAL APPLICATION	Very small to large.	3000 kW and higher (can be very high).	Very small to medium size (<7000kW).

DRIVES SUMMARY

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
NEGATIVE FEATURES	1. Low Power factor Operation < 0.8 2. Highest THD. Comply with IEEE519 requires additional filtering. 3. Higher KVA Required 1.2 KVA /HP 4. The use of DC Circuit Breaker is mandatory in Hi Performance Applications	1. Drive efficiency is low 2. Mainly Water cooled drives available 3. Field Power Supply Requires Heavy Overload 4. Additional Safety Requirement in Medium Voltage Applications 5. Complex Speed/Position Sensor is required 6. Power Device Failures often cause collateral Damage 7. Early Maturity Problem due to the Technology Racing in Power Semiconductors	1. Drive efficiency is low. Using low RPM Motors just make this problem worse 2. Additional Safety Requirement in Medium Voltage Applications 3. Complex Control algorithms. 4. Power Device Failures often cause collateral Damage 5. Early Maturity Problem due to the Technology Racing in Power Semiconductors

DRIVES SUMMARY

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
POSITIVE FEATURES	1. Proven Reliable Operation. Units with 40+ year 2. SCRs are relatively easy to upgrade 3. Highest Eff Power Conversion System 4. Normally Maintenance Friendly 5. Smallest Foot Print/KW	1. Unity PF or leading 2. Normally Comply with IEEE 519 3. No Special Breakers are required 4. High performance speed control response compared to DCM. 5. Cyclones hold similar characteristics of DCM Drives	1. Unity PF or leading 2. Normally Comply with IEEE 519 3. No Special Breakers are required

MOTORS SUMMARY

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
NEGATIVE FEATURES	1. Motor efficiency is low. 2. Motor voltage comparably low and armature current comparably high. 3. Main circuit equipment (circuit breaker, inductor, DC contactor, and copper bus) very expensive. 4. Armature current cannot change quickly because of commutator (di/dt x Δi is limited) 5. Motor capacity limitation of power, top speed, and base to top speed ratio. May require multiple motors for an application. kW x rpm (top) x rpm (base) rpm (base) M Constant <$6x10^6$	1. Torque is reduced at very low speed when using inverter drives. 2. Proven Life Expectancy below 20 Years vs 40+ years in DCM	1. Higher incoming kVA requirements compared to synchronous motor. 2. Very Hi Motor current in low Base Speed Motors. 3. Proven Life Expectancy below 20 Years vs 40+ years in DCM

MOTOR SUMMARY

	DC MOTORS (DCM)	SYNCHRONOUS MOTOR (SM)	SQUIRREL CAGE INDUCTION MOTOR (SCIM)
POSITIVE FEATURES	1. Motor speed varies with terminal voltage (easy to control). 2. Armature current proportional to torque. 3. Motor torque created quickly in response to load. 4. Proven Life Expectancy of 40+ Years	1. Fewer Brushes (less maintenance). 2. High motor efficiency. 3. Minimum motor input power required. 4. High performance speed control response compared to DCM.	1. No brushes (low maintenance, very robust). 2. High performance speed control response compared to DCM. 3. Mass produced (very popular), so price is lowest for smallest to medium size applications.

CONCLUSIONS

- AC Drives will eventually replace DC in its entirety?
- New and more robust Power components will eventually match the SCRs in reliability?
- SM or SCIM will ever match DCM reliability?