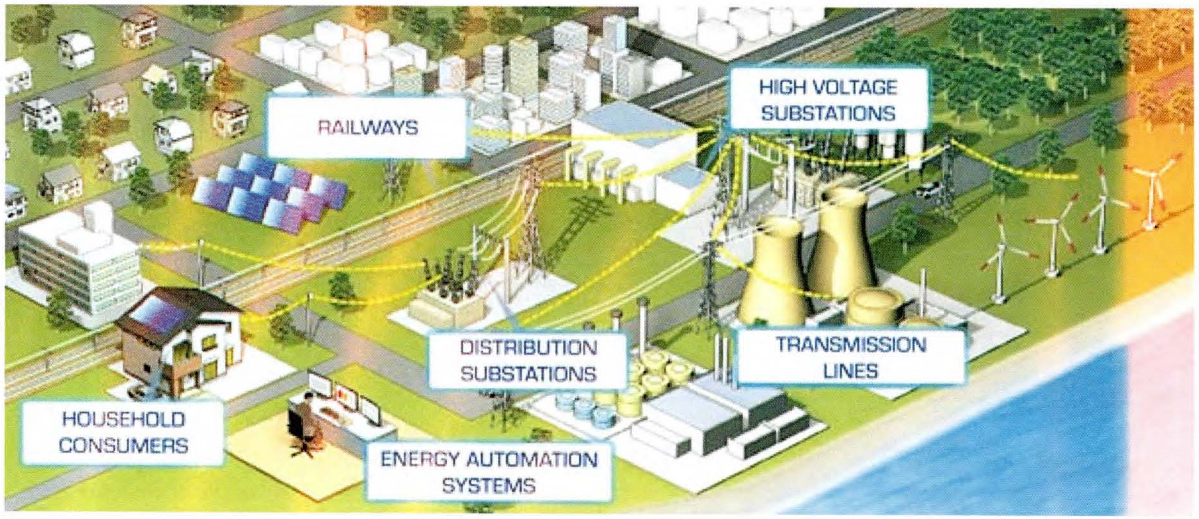
The Global Drive for Efficiency

Enhancing the world's transfer of energy

Manufacturers face new challenges in supplying integrated solutions for energy transmission, distribution, and smart communities to power plants, factories, transportation systems, and residential homes.



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Leading Innovation >>>

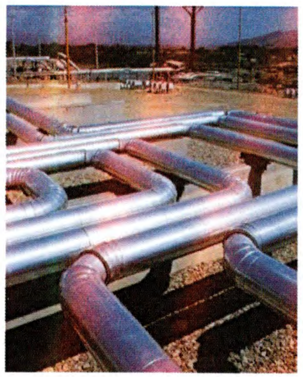
The Global Drive for Efficiency

Optimizing System Efficiency

Motors & Drives

Electric power flows from the Power Systems, T&D, Power Electronics Converters to the Motor & Drives

Motors & Drives Systems use more than 40% of all the electric energy produced to run a wide range of industrial applications.



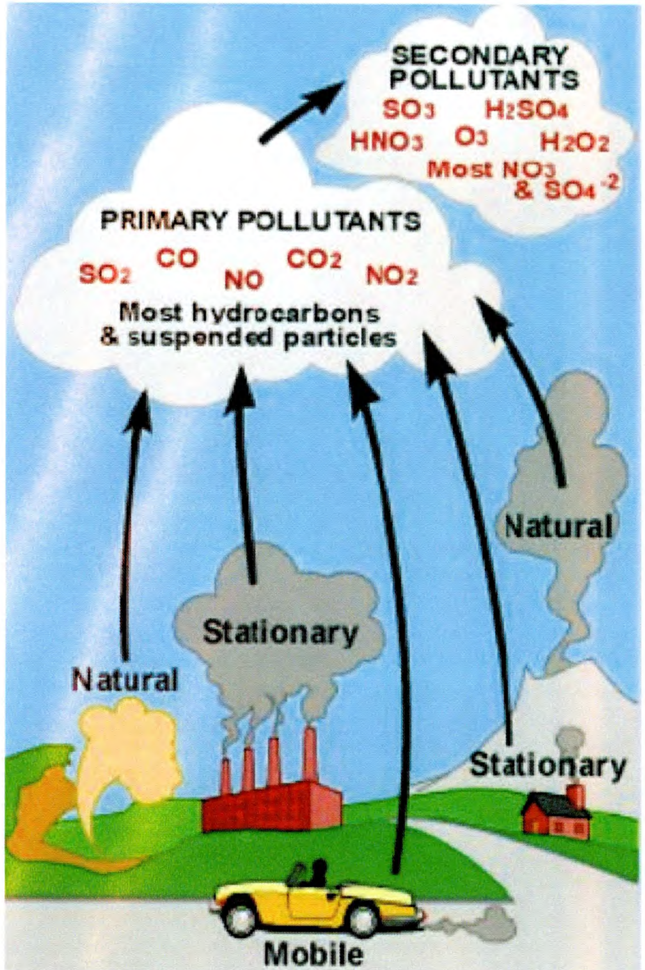
The Global Drive for Efficiency

Enhancing the Environment

- **Reduce carbon emissions**

Electric Motors account for more than 40% of the world's 16,000 TWh electrical consumption, thus 6 billion tons $CO_{2\,eq}$ emission

Stringent Efficiency Standards and Regulations, and reducing CO_2 Major opportunities for Motors & Drives (ASDs) .



Common Sense; lets look at we have done in the past.

Here is an example of how variable speed can effect system operation.

While going to work, your highest speed was 55mph. Would you accelerate to 100mph, and set your cruise control? Then control your actual speed by applying varying amounts of brake pressure?

Common Sense; A Better Idea

Our cars are a form of variable speed drive. The throttle (or cruise control) determines the speed of the car.

This is not how we operate pumps and fans. We turn on an electric motor at say 1750 rpm, and then govern the flow through the pipes or ducts by opening and closing valves or dampers.

Can you imagine the wear and tear on your vehicle, the fuel mileage, and not to mention how strong your leg would get?

"Seems the onboard computer analyzed your driving patterns and determined it was best for all not to start the engine."

How affinity laws relate to energy savings

There are occasions when you might want to permanently change the amount of fluid or air you're pumping. There are four ways you could do this:

- **Regulate the discharge of the pump.**
- **Change the speed of the pump.**
- **Change the diameter of the impeller.**
- **Purchase a new pump**

Of the four methods the middle two are the only sensible ones. In the following paragraphs we'll learn what happens when we change the pump speed, and as you would guess, other characteristics of the pump are going to change along with speed.

As an example:

If you wanted to reduce the speed of a pump to 50%

New speed/old speed = 1750/3500 = 0.5

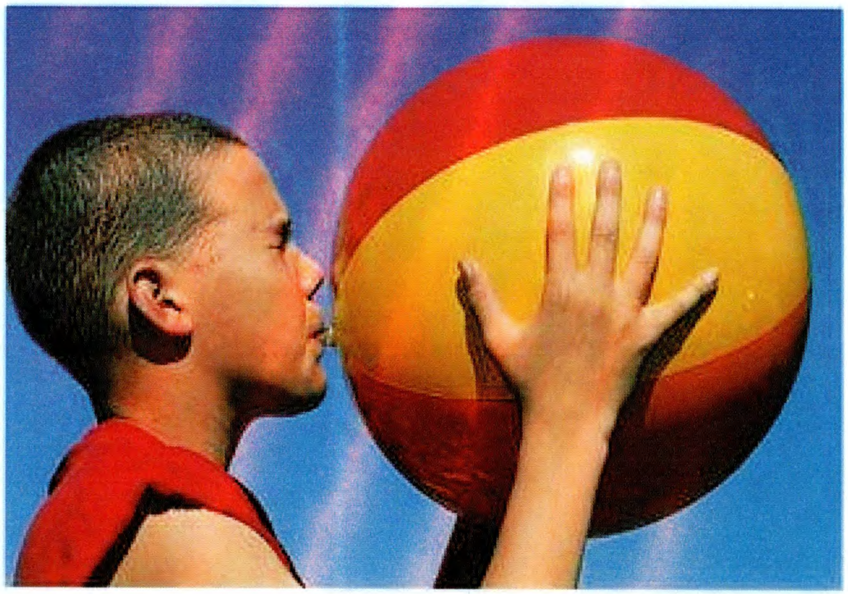
The capacity, or amount of fluid you're pumping, varies **directly** with this number.

Example: 100 GPM x 0.5 = **50 GPM**

As an example:

The head varies by the **square** of the number.

Example : a 50 foot head x 0.25 *(0.5)*(0.5)* = **12.5 foot head**

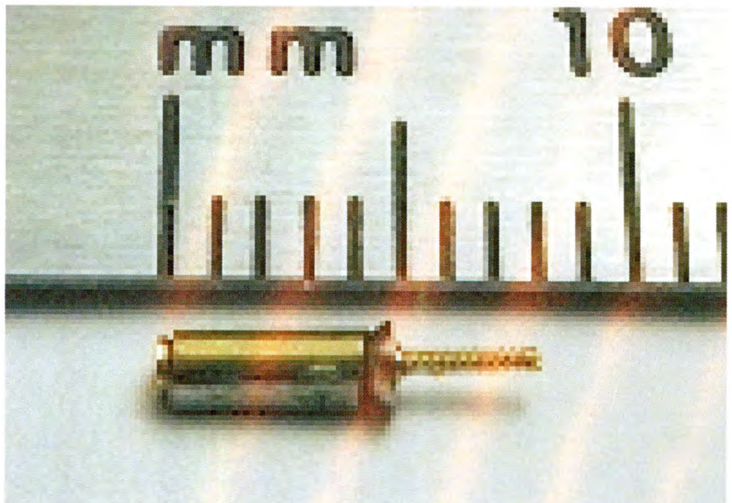


As an example:

The Horsepower required changes by the **cube** of the number.

Example : a 72 Horsepower motor was required to drive the pump at 3500 rpm.. How much is required now that you are going to 1750 rpm?

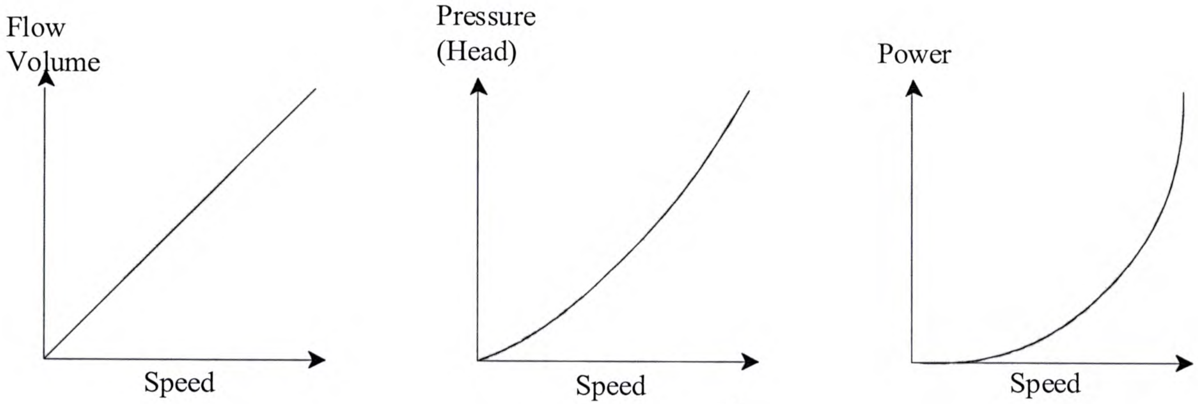
Example: 72 x 0.125 *(0.5)*(0.5)*(0.5)* = **9 Horsepower** is now required.



Loads and Load Characteristics

AFFINITY LAWS

Centrifugal Loads [Fans, Pumps (no static head), etc.]



$$\frac{Q_2}{Q_1} = \frac{N_2}{N_1} \qquad \frac{P_2}{P_1} = \left(\frac{N_2}{N_1}\right)^2 \qquad \frac{HP_2}{HP_1} = \left(\frac{N_2}{N_1}\right)^3$$

Where:

N = Fan or Pump Speed

Q = Flow (CFM)

P = Pressure (Static inches of water or feet of head)

HP = Horsepower

Loads and Load Characteristics

Inherent Power Savings

A **10%** reduction in speed reduces electrical consumption over **25%** while reducing flow only **10%**

Numeric Description of the Affinity Laws		
Speed	**Flow**	**Required Power**
100%	100%	100%
90%	90%	73%
80%	80%	50%
70%	70%	34%
60%	60%	22%
50%	50%	13%
40%	40%	6%
30%	30%	3%

The Global Drive for Efficiency

ASDs on IM motor applications

About 40% of Induction Motor (IM) applications use an ASD (Drive) when variable speed is needed

On Centrifugal loads ASDs can save as much as 50% of energy used, if the speed of a fan or pump is reduced from 100% to 80%

But what is the additional energy savings if new Permanent Magnet (PM) motor technology is used?

Efficiency and Energy Savings comparison

PM motor technology vs. IM motor

- ✓ How much more energy could be saved in an ASD application if a Permanent Magnet Motor were used?
- ✓ The presentation will show test results and an efficiency comparison of a PMM to an IE3 class IM.
- ✓ Motor drive system efficiency is evaluated for constant and variable torque applications.
- ✓ Both motors will be tested in a laboratory. Full and partial loads will be applied by a dynamometer.
- ✓ The Motors efficiency is calculated based on measured torque, speed and kilowatt input for various loads and speeds.
- ✓ Energy savings, cost savings and reduced carbon footprint are illustrated for both motor drive systems.

TEST MOTORS

IM vs PM motor

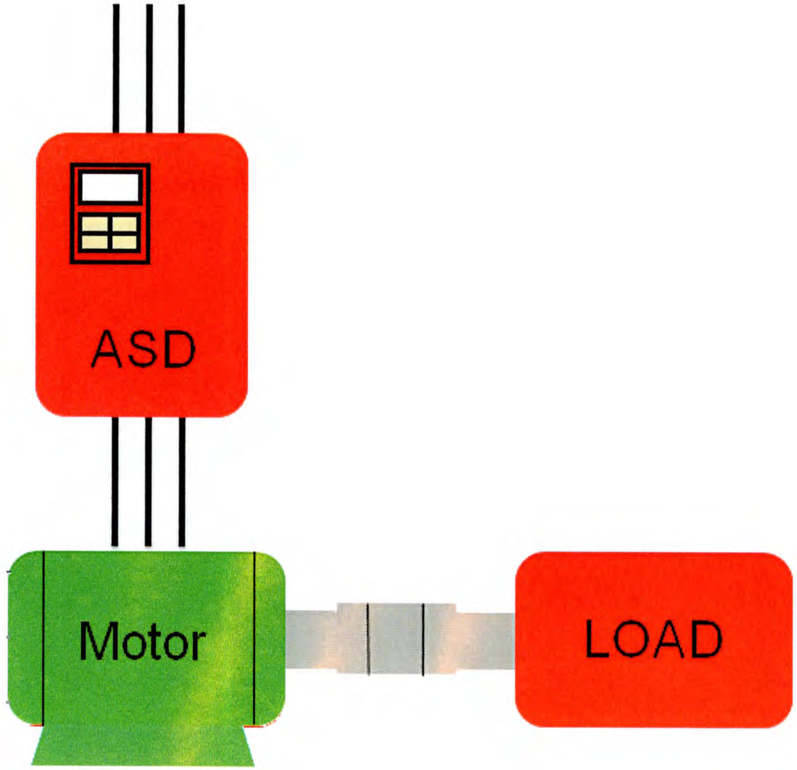
- **The motors to be compared:**

TEST MOTORS	PM: Ultra Prem. Ef. IE5	IM: NEMA Prem. Ef. (IE3)
Rated Power	7.5 kW	10 HP
RPM	1800	1760
Torque	40 Nm	29.4 lb-ft
Efficiency	94 %	91.7 %
Rated Current	12 A	12.3 A

- **IE3 = Premium Efficiency; IE4 = Super Premium Eff. IE5 = Ultra Premium Efficiency; IE6 = …, run out of names?**

TEST SET UP

IM vs PM motor



- **ASDs impact motor efficiency (η_M)**

TEST POINTS

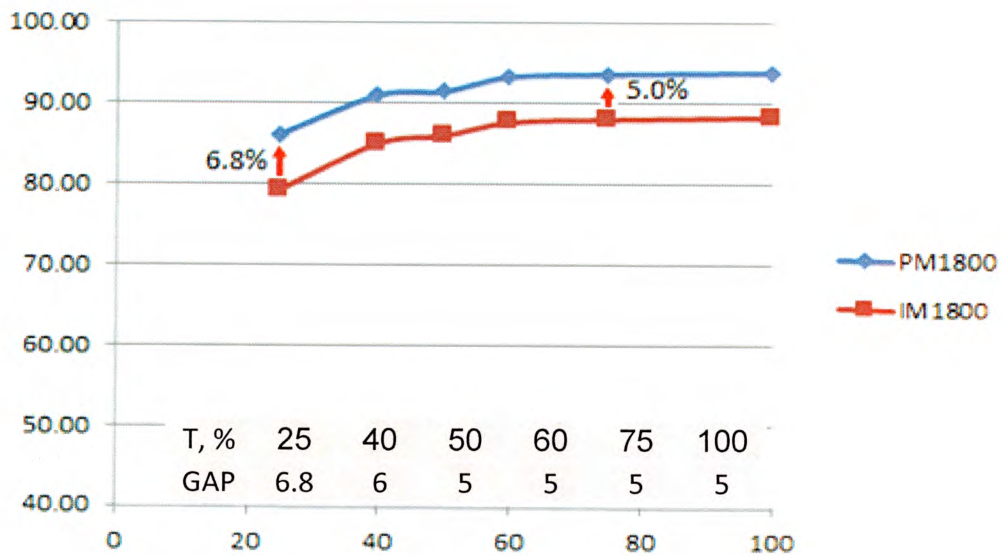
Motor Loading Points

LOAD	25%	40%	50%	60%	75%	100%
100% speed			(50,100)		(75,100)	**(100,100)***
75% speed						
60% speed						
50% speed						
40% speed						
25% speed						

- Note*: The IM motor efficiency given on its nameplate is at Rated Torque and Rated Speed (100%,100% point) and it is for sine power. In our case the IM and PM motor are ASD-fed.

TEST RESULTS

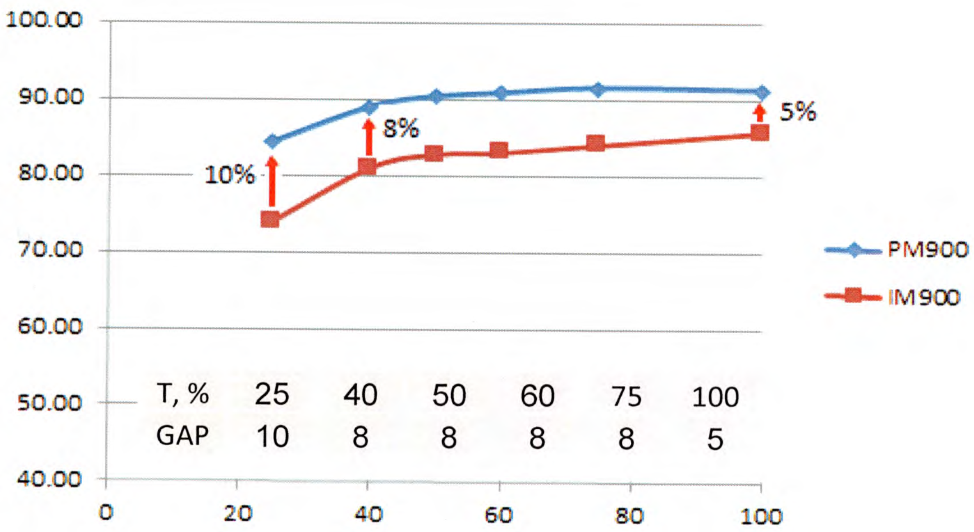
Motors Efficiency at Full Speed: IM vs PM



- The gap between the efficiency lines is relatively constant (5%)
- At about 40% load it slightly widens (6.8% at 25% load)

TEST RESULTS

Motors Efficiency at Half Speed

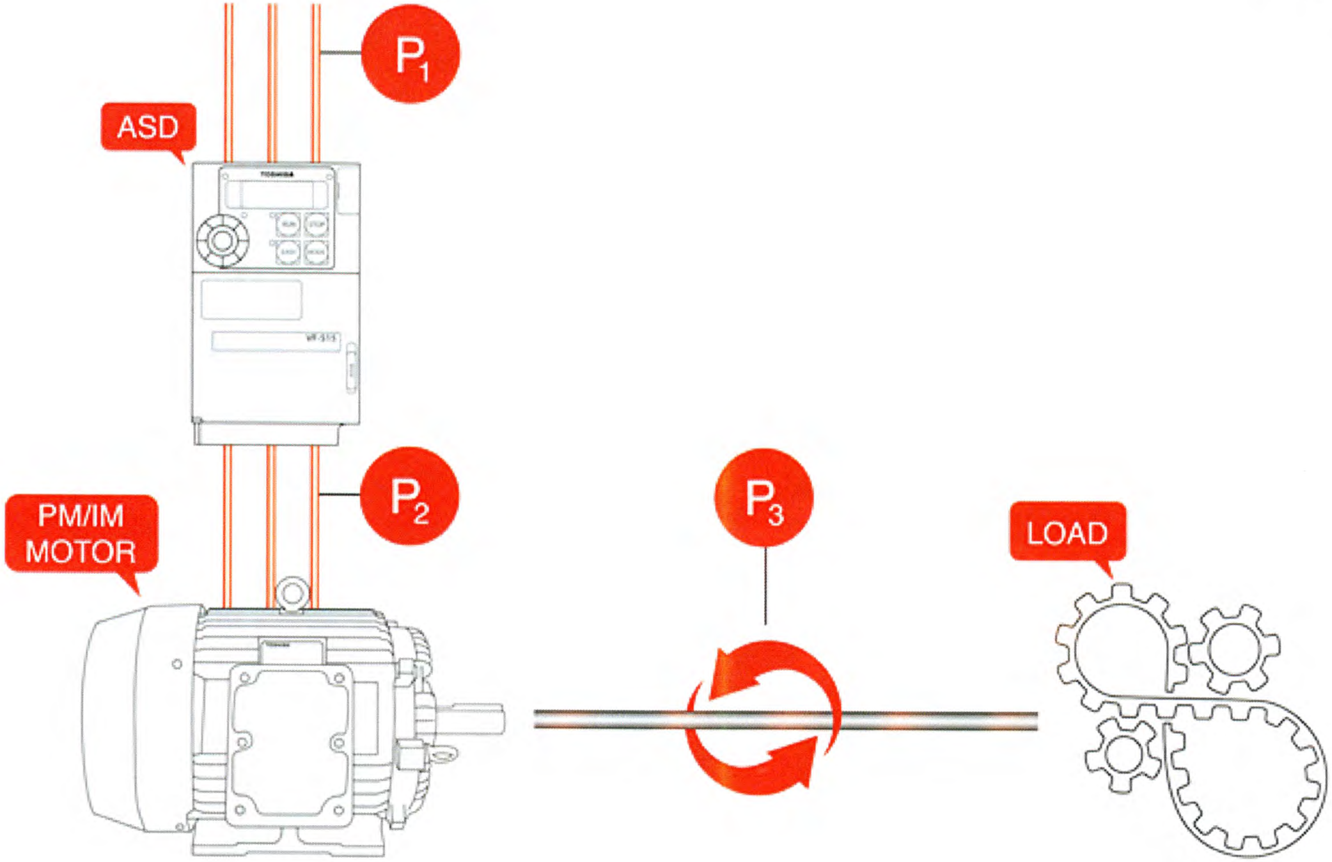


- **The PM motor (blue line) shows almost same efficiency level as at full speed (about 1% less)**
- **The IM efficiency (red line) drops off and the 5% gap quickly gets wider 8% and 10% at 25% load**

ENERGY SAVINGS

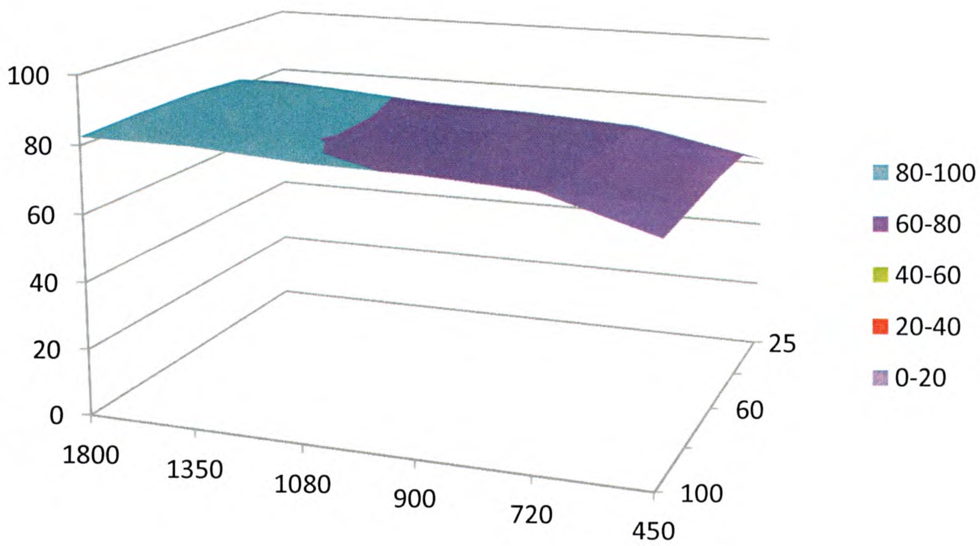
SYSTEM EFFICIENCY (ASD + MOTOR)

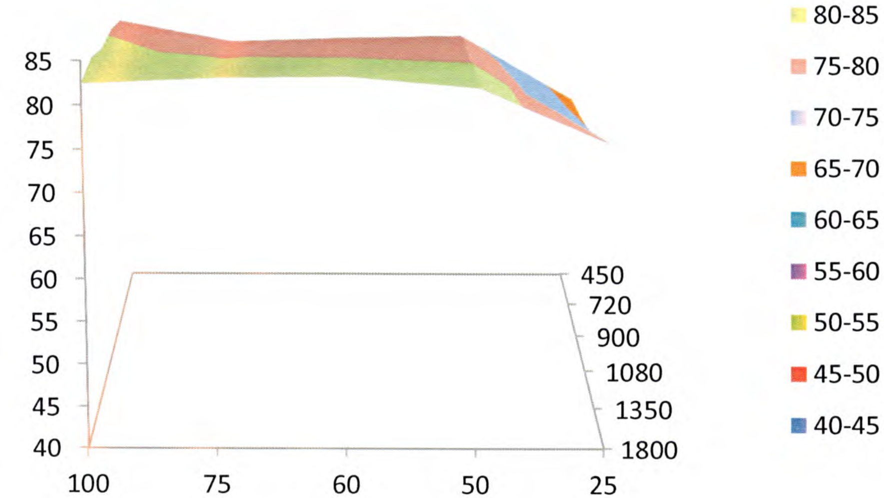
$$\eta_a = SYS_{IM} = \frac{P_{3a}}{P_{1a}} \qquad \eta_b = SYS_{PM} = \frac{P_{3b}}{P_{1b}}$$



SYSTEM EFFICIENCY 3D-PLOTS

IM System (IM motor +ASD)

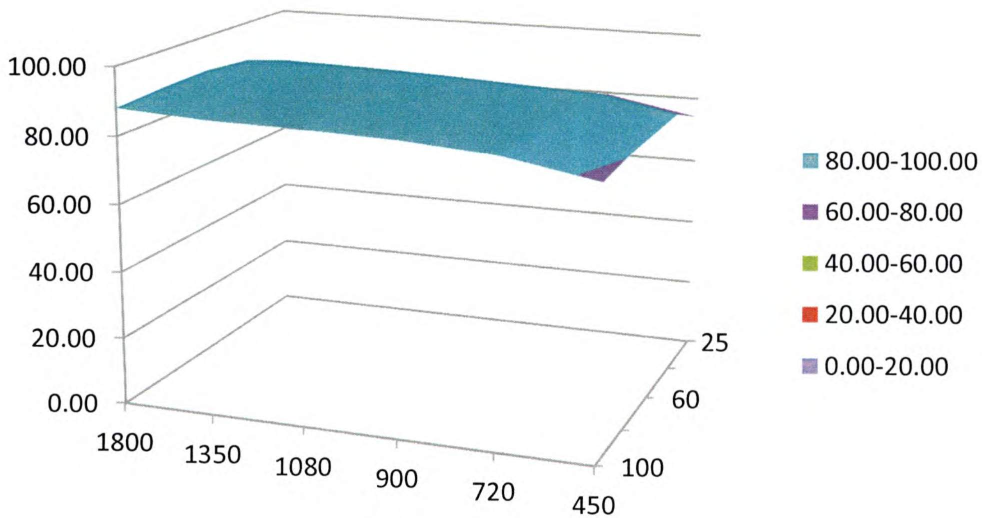


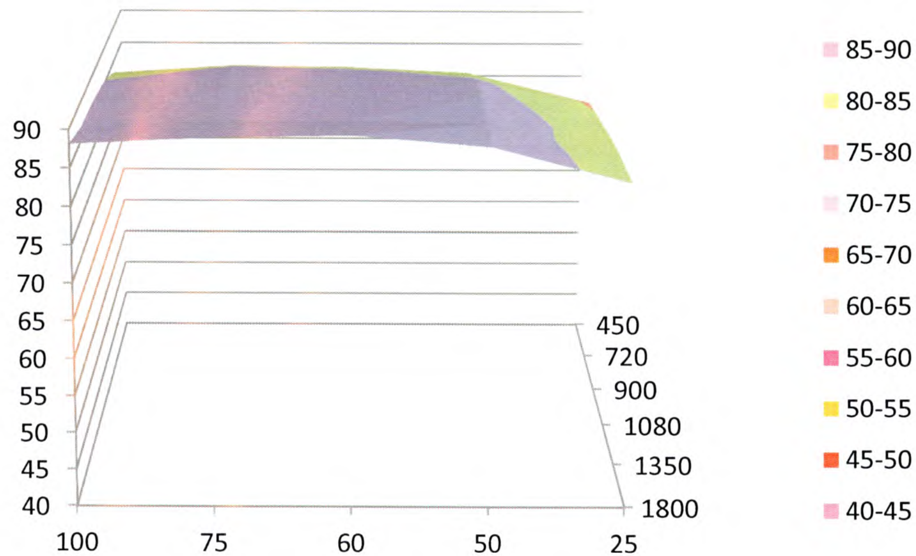


The IM System shows efficiencies between 85-80% in about ½ of the speed-torque operational range

BEST EFFICIENCY AT ANY POINT

PM System (PM motor +Drive)





The PM motor system keeps higher efficiency (between 90-85%) throughout most of the operational range

Energy Savings

CT and VT Application

- $Esav(\eta_h, P_h) = \sum_{h=1}^{8760} P_{SHAFT}\left(\frac{1}{\eta_{ah}} - \frac{1}{\eta_{bh}} \right)$

Efficiency $\eta_h = f\ (\omega, T)$

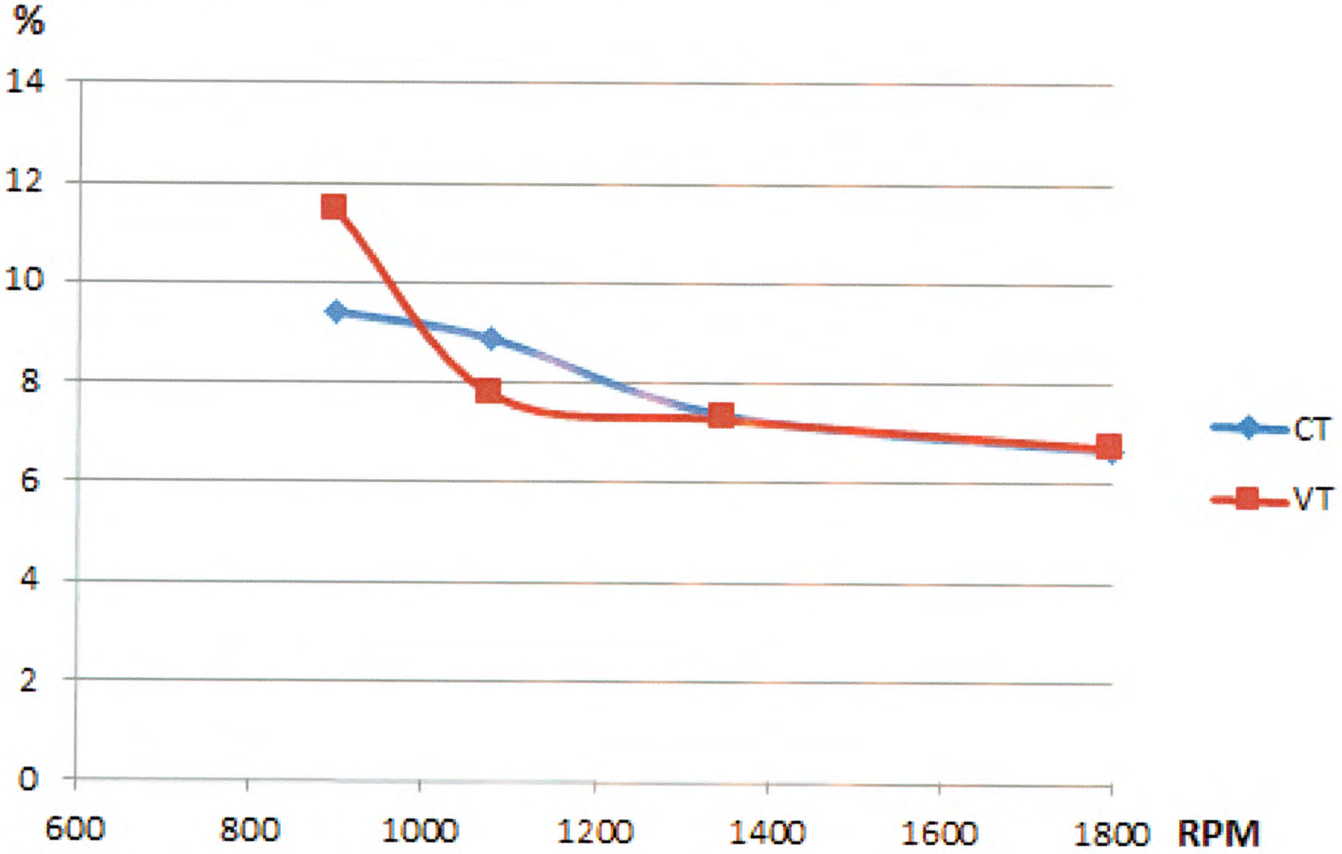
Annual Load Profile $\sum_{h=1}^{8760}$

a) for a typical Constant Torque (CT) application

b) for a typical Variable Torque (VT) application

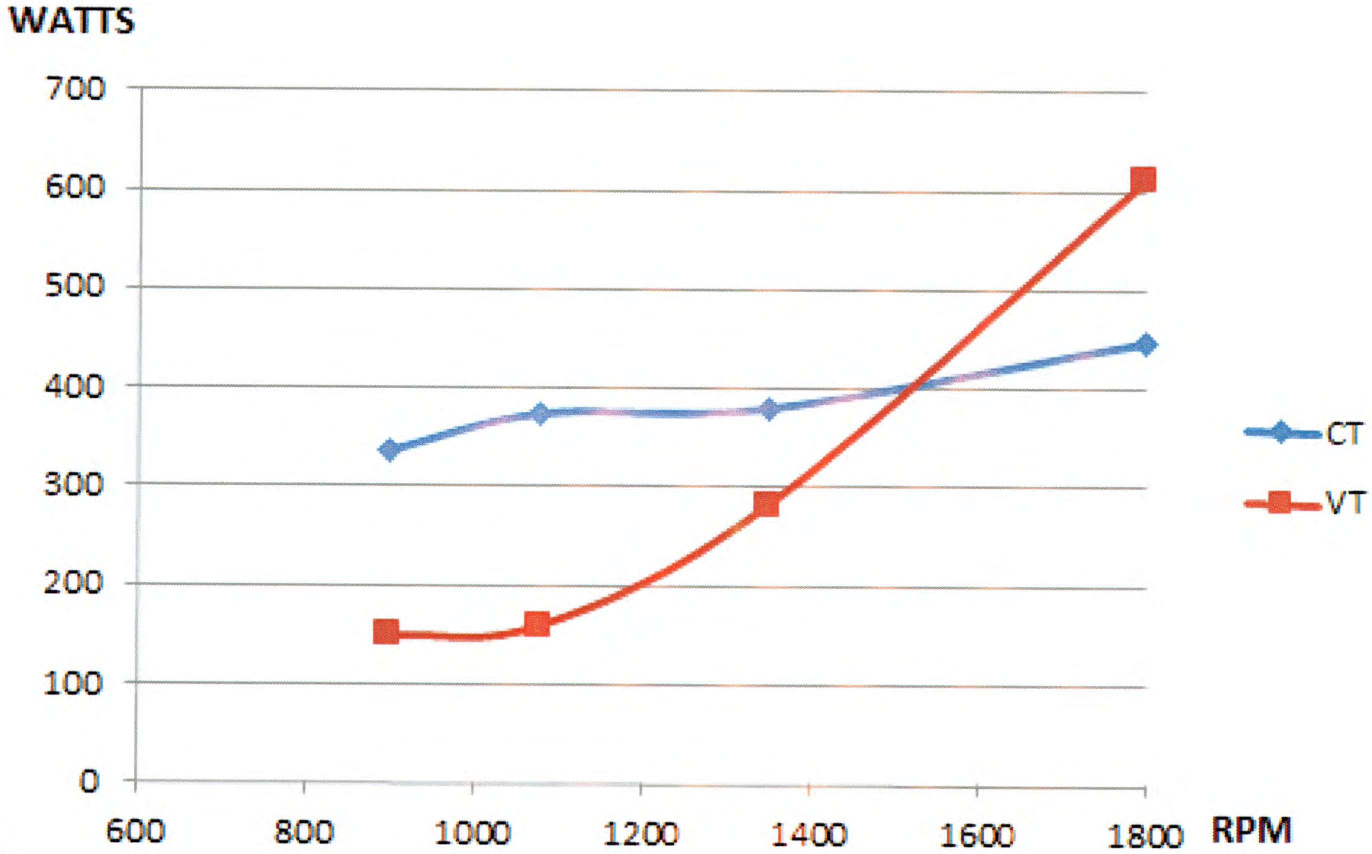
Energy Savings

- **12% and higher of saved Watts in VT applications that run at half speed or lower** [CT75]



Energy Savings

- **The saved Watts absolute value shows that constant torque (CT) applications can yield higher savings especially at lower speeds.**



CT=75%

Annual Savings , ROI and CO_2 reduction

CT and VT Applications

	CT LOAD	VT LOAD
SAVED kWh/year	3284	3373
SAVED $/year	328.4	337.3
PM PREMIUM $	100	100
% SAVINGS	7.44	8.31
ROI	111 days	108 days
CO2 REDUCTION	1.72 Tons CO2	1.77 Tons CO2

- **Savings are estimated at CT =75% Load, ten cents/kWh and a typical load/speed profile for a pump(VT) and a conveyor (CT) Load.**

The Global Drive for Efficiency

Optimizing System Efficiency

Conclusions

Tested PM technology vs IM-System (motor + drive):

- 6% higher efficiency at full speed and 10% at half speed
- 7-8% savings on average thru the operational range
- 4 months ROI
- The lower the load or speed the higher the percent energy savings and superior system performance
- Shift from energy efficient components to system efficiency for specific applications

The Global Drive for Efficiency

Optimizing Motors & Drives System Efficiency

THANK YOU!

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LOW VOLTAGE MOTORS & DRIVES

Permanent Magnet Motor Drive System

MEETS OR EXCEEDS IE4 EFFICIENCY LEVELS

Toshiba's permanent magnet (PM) motor drive system is a highly efficient motor and drive solution ideal for maximizing energy cost savings. Permanent magnet motor technology offers the highest motor efficiencies, power density, torque output, and speed accuracy on the market. Toshiba's Tosh-ECO® PM motor paired with Toshiba's state-of-the-art AS3® or S15 adjustable speed drive offers on average 7% efficiency improvement when compared to an induction motor drive system.

High-End Application	Precisely metered torque, speed, and position are obtainable with Toshiba's Tosh-ECO PM motor when paired with a Toshiba ASD
Systematic Control	Can operate as an open-loop system in mid-range performance applications requiring speed and torque control
Protection	Provides a reduction in risk of high-current demagnetization with over-current protection
Compact Design	Delivers high power efficiency and power density levels allowing for a compact and lightweight solution
Energy Savings	Maximize energy cost savings by pairing Toshiba's Tosh-ECO PM motor with a AS3 or S15 drive
AS3 Drive	Designed with an emphasis on built-in communications, it allows end-users to access real-time data and refined controls
S15 Drive	Compact and high performing ASD, capable of controlling a wide range of variable and constant torque applications

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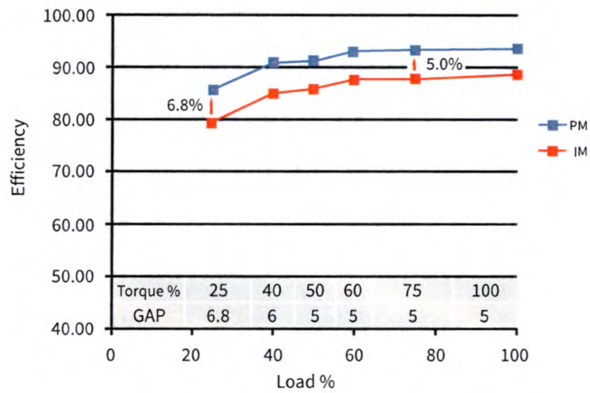
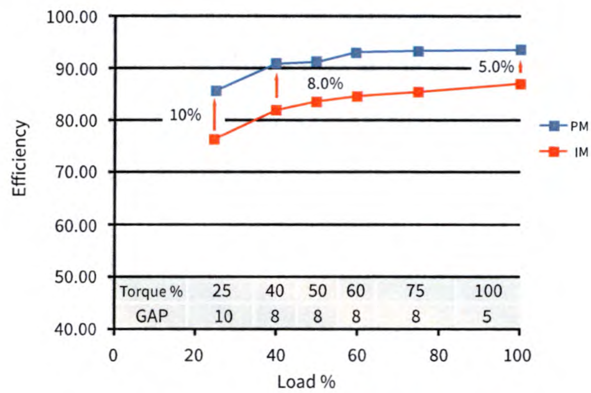
SUPER PREMIUM EFFICIENCY WITH TOSH-ECO PM MOTOR

Toshiba's Tosh-ECO PM motor provides a higher efficiency across all operating conditions when compared to an induction motor. The Tosh-ECO PM motor maintains nearly the same efficiency at half speed and full speed, while the induction motor's efficiency drops at full load operation.



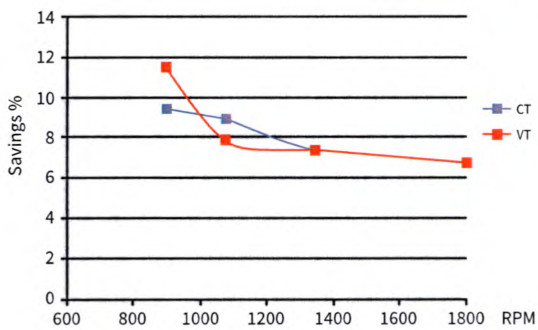
Motors Efficiency at Full Speed:
Induction Motor vs. Permanent Magnet Motor



Motors Efficiency at Half Speed:
Induction Motor vs. Permanent Magnet Motor

GREATER POWER SAVINGS WITH THE TOSH-ECO PM MOTOR

Toshiba's Tosh-ECO PM motor yields greater power savings, compared to induction motors, especially on lower speed conditions for constant torque applications. Additional power savings of up to 9.5% for constant torque and up to 12% for variable torque loads can be achieved by using a permanent magnet motor drive system. (Test Results Based on 7.5 kW Motor-Drive System)



PERMANENT MAGNET MOTORS: A SMART DECISION

On average, the ROI for selecting a permanent magnet motor over an induction motor is less than four months. With the life of a motor reaching 20 years, permanent magnet motors provide substantial savings.

Annual Savings with a PM Motor	Constant Torque Load	Variable Torque Load
Energy Savings	7.44%	8.31%
Return on Investment	111 Days	108 Days
CO^2 Reduction	1.72 Tons CO^2	1.77 Tons CO^2

*Annual savings calculated based on typical constant torque and variable torque load profiles, estimated at 8,568 operation hours, 10 cents/kWh. The carbon footprint (CO^2) reduction is calculated at 0.525 kgCO^2.

INDUSTRIES SERVED

- Water & Wastewater
- Mining & Minerals
- Oil & Gas

APPLICATIONS

- Pumps
- Fans
- Compressors
- Centrifuges
- Conveyors
- Mixers

DRIVE APPLICATIONS

- Constant Power Output in Field Weakened Range for Variable Torque Operation
- Overspeed Conditions
- Precision Speed Control Without Requiring an Encoder
- Full Torque Across the Rated Speed Range
- Suitable for Shaft Grounding and Bearing Protection
- Bi-Directional Designs
- Exclusively Operated on an ASD

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PM+ASD SYSTEM

3 THREE YEAR WARRANTY

TOSH-ECO PM MOTOR

Power	.55 to 315 kW
Speed	1800, 3600, & 4500 RPM
Voltage	400 V
Service Factor	1.0
Enclosure	Totally Enclosed Fan Cooled
Frame Size	71 - 315 per IEC 60072
Ingress Protection	IP55
Insulation	Class F - Random Wound
Vibration	Grade A, Balanced with Half Key per ISO 8821
Environment	Severe Duty
Efficiency	Meets or Exceeds IE4 Efficiency Levels (As Defined by IEC60034-30-1)
Energy Savings	5-8% Typical Average Efficiency Improvement vs. Induction Motor
Operation	Suitable for High Speed Operation Up to 20% Above Rated Speed at Constant Power (Beyond NEMA Max Overspeed)

CONSTRUCTION

Frame	Aluminum Frame 71 - 132; Cast Iron Frame 160 - 315; Interchangeability/Drop-In Replacement with IEC Metric Frame Induction Motor Counterparts
Paint	Severe Duty, Corrosion Resistant Resin Primer Paint, with an Acrylic Enamel Finish (RAL 6012). Surpasses 96 Hour Salt Spray Test
Shaft Seals	Shaft V-Ring Protection System
Lifting	Eye Bolt or Cast in Lifting Mechanism for Frames >90L
Mounting	Suitable for Horizontal Mounting; All Mounting Orientations for <160 Frame; IEC Mounting and Flanges with Removable Feet
Fan Cover	Fabricated Steel
Conduit Box	Top Mount with Rotatable 90° Increments and 2 Ground Provisions (One Plastic Cable Gland & Plug)

INSULATION SYSTEM

Temperature Rise	Class B Rise @ 1.0 SF
Thermal Protection	Thermistor PTC Rated for 135°C for 160-315 Frames (Quantity 3, Single-Phase)

	AS3 DRIVE		S15 DRIVE			
Voltage	230 V	460 V	Single-Phase 230 V	230 V	460 V	600 V
Horsepower	1 to 100 HP ND (0.5 to 75HP HD)	1 to 500 HP ND (0.5 to 450 HP HD)	0.25 to 3 HP	0.5 to 20 HP	0.5 to 20 HP	2 to 20 HP
Overload Current Rating	120% for One Minute ND (150% for One Minute HD)		150% for One Minute			
Enclosure	NEMA 1 up to Frame A5 Built-In; NEMA 1 with Optional Conduit Box Frame A6 and above; NEMA 3R and Type 12/IP55 Enclosures Available		NEMA 1			
Ambient Temperature	-10°C to +50°C (60°C with Derate)		-10°C to +50°C (60°C with Derate)			
Terminal Strip I/O	Eight Digital Inputs, Three Digital Outputs (One Form C, Two Form A Relays), Three Analog Inputs (0 to 10 VDC, -10 to +10 VDC, 0 to 20 mADC), Two Analog Outputs (0 to 10 VDC or 0 to 20 mADC), STO (Safe Torque Off)		Six Digital Inputs, Three Digital Outputs (One Form C Relay, One Form A Relay, One Open Collector Output), Three Analog Inputs (0 to 10 VDC, -10 to +10 VDC, 0 to 20 mADC), One Analog Output (0 to 10 VDC or 0 to 20 mADC), STO (Safe Torque Off)			
Display	Advanced Full-English LCD Display		Seven-Segment LED Display			

ND - Normal Duty
HD - Heavy Duty

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