



Ansaldo Sistemi Industriali

RESULTS TO THE POWER OF THREE

***20 Years of High-Speed Adjustable-Speed  
Electric drive Motor Systems: Case Studies,  
Reliability, Energy Savings, Opportunities***

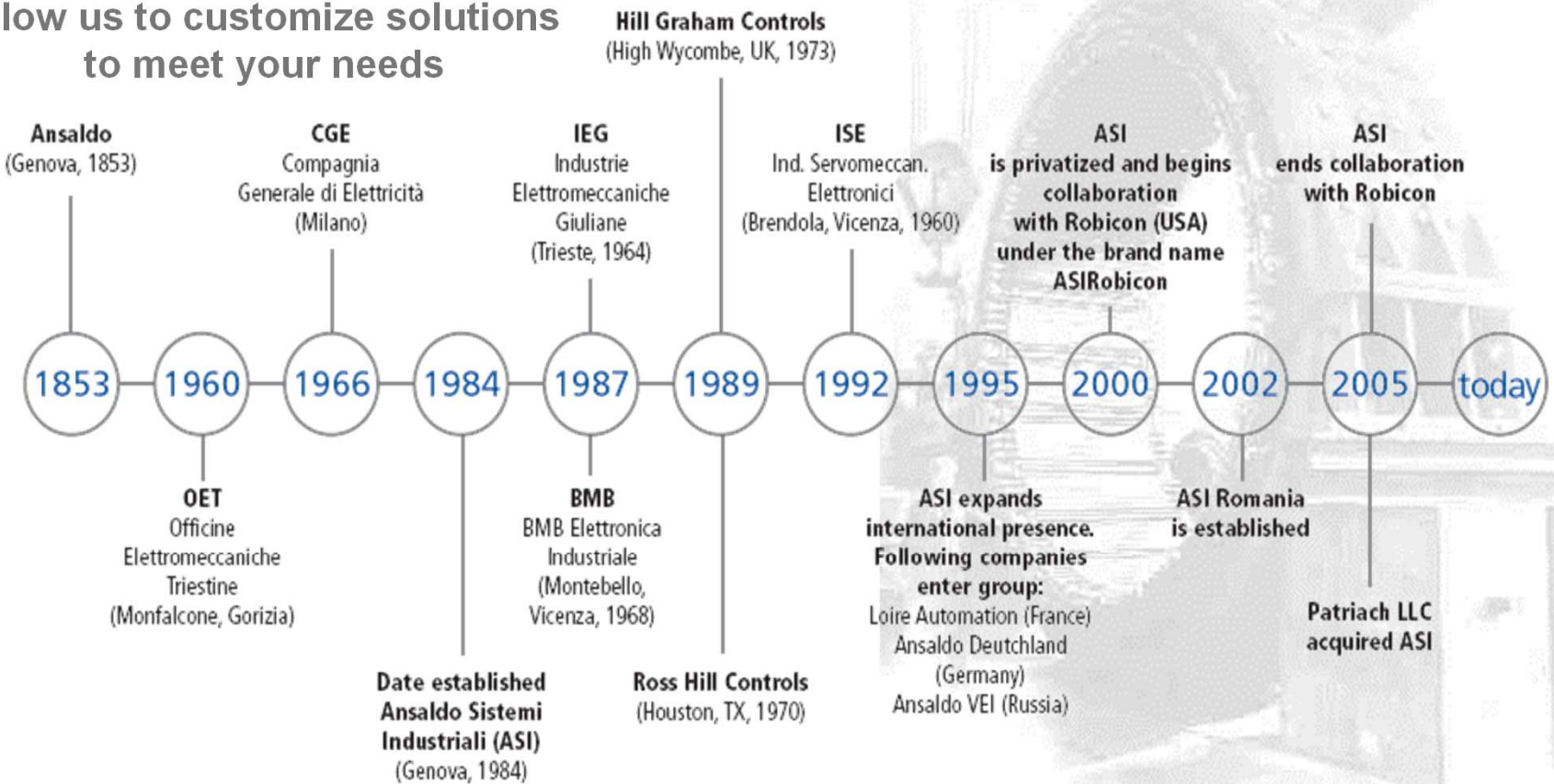
***Anselectric LLC***

***2011 Gas/Electric Partnership Conference XIX***

***Houston, Texas - February 9-10<sup>th</sup>, 2011***



With over a century of experience, our domain expertise & systems know-how allow us to customize solutions to meet your needs





100 %

Hveasi Holding B.V.  
Amersfoort  
The Netherlands

100 %

Ansaldo Sistemi Industriali SpA  
Milan  
Italy

Principal Partner, **Ms. Lynn Tilton**

### About Patriarch

Patriarch LLC is an Investment fund with approximately 6 billion USD in assets under its management.

Patriarch provides portfolio management services to 8 closed funds and one private equity fund. Funds include credit lines

and equity positions in more than 65 companies.

***On July 31st 2005 Patriarch Partners purchased 100 % shares of ASI Robicon SpA's holding company Hveasi Holding BV***

***May 2006, ASI Robicon SpA changed its name to Ansaldo Sistemi Industriali SpA***



Dusseldorf, DE  
Metal Systems  
Sales & Service  
Integration



Roche-Moliere, FR  
Metal Systems  
Sales & Service  
Integration



Genoa, Italy  
Metals – Flat products  
Artics Platform Develop.  
Marine Systems



Montebello, Italy  
AC & DC LV Drives  
Metals – Long products  
Ropeway transportation  
System Integration  
System Automation



Monfalcone, Italy  
AC & DC Motors  
Generators  
Special Machines



Milan, Italy  
MV Drives  
Drive systems  
Power Supply

**Other subsidiaries**

- Beijing, China**  
ASI Industrial Systems
- Moscow, Russia**  
Ansaldo-VEI
- Houston, USA**  
Anselectric LLC
- Romania**  
Ansaldo Sistemi Industriali



Ansaldo Sistemi Industriali

RESULTS TO THE POWER OF THREE

## Monfalcone Manufacturing Facility



Total Area : 90,000 m<sup>2</sup>  
Buildings : 38,000 m<sup>2</sup> + ...

N. employees : 495  
288 Blue Collars / 207 White Collars  
ISO9001:2000 & ISO14001 certified

+ 5,000 additional m<sup>2</sup> in progress





## High-Speed Adjustable-Speed References

End User, Location	Qty	Coupled Machine	[kW]	[rpm]	[V]	Commissioning
TRANSCO -USA	2	Centr. compressor	5220	3200/5500	4600	1991
PGT-PG&E, CA-USA	2	Centr. compressor	6570	4200+5200	5500	1993
TRANSCO -USA	2	Centr. compressor	8955	5800/7300	7800	1993
TENNECO GAS TN-USA	2	Centr. compressor	5000	4000/6000	4530	1994
TRANSCO -USA	2	Centr. compressor	5220	3200/5500	4600	1994
TENNECO TX-USA	1	Centr. compressor	9550	5800/7800	10500	1995
CHEVRON, CA-USA	3	Centr. compressor	2610	8350/11130	2800	1996
OLEODUCTO CENTRAL S.S., Colombia	4	Centr. pump	7460	3000/3960+4180	6600	1998
PETROCANADA, Canada	1	Centr. compressor	11200	4100/4500+5000	2x4400	1998
ANSALDO TRASPORTI, Italy	1	Test room gen.	400	2660+6000	340	1999
GENERAL ELECTRIC, France	1	Test room bench	1440	100/2400+5750	580	2001
GENERAL ELECTRIC, France	1	Test room bench	1800	100/3000+5800	580	2003
GENERAL ELECTRIC, Italy	1	Test room bench	34200	1500/3000+3300	3200	2006
MINISTERO DIFESA / NAVARM, Italy	1	Gas turbine gen.	2000	5490/6300	2x1200	2008
QATARGAS, Qatar	13	Centr. compressor + gas turbine gen.	45000	2880/3000+3060	4x7200	≥2008
RASGAS, Qatar	7	Centr. compressor + gas turbine gen.	45000	2880/3000+3060	4x7200	≥2009
HITACHI, Japan	1	Centr. compressor	1330	0+13300	5320	2009
SHANXI INSTITUTE, China	2	Centr. compressor	2x5000	5000/13000	6000	2010
RETE FERROVIARIA ITALIANA, Italy	2	Test Room gen.	2320	0/1500+4500	2810	2010
MINISTERO DIFESA / NAVARM, Italy	1	Gas turbine gen.	1700	19000/22500	4x620	2011



Q.ty / Model - Type : 3 / **HSCR 450 Y 2** – *induction motor*  
Rated power : 2610 kW (3500 HP) @ 11130 rpm  
Ratings : : 2.8 kV / 135 A / 186 Hz  
Speed range : constant torque @ 8350 to 11130 rpm  
Mounting / Cooling : IM 7313 / IC 86W (TEWAC forced ventilated )  
Type of protection : pressurised Ex-p, for installation in hazardous area  
Class I, Division 2, groups B & D  
Coupled machine : centrifugal compressor  
Location / Customer : El Segundo, CA, USA / Chevron  
Commissioning year : 1996

**Key technical features :**

- flexible grooved one-piece steel-forged solid rotor with stainless-steel alloy retaining rings and **aluminum fabricated cage**
- pedestal tilting pad bearings with forced oil lubrication
- API Std. 541
- system back-to-back load tested
- thyristor CSI driven
- *“Development of an 11,000 rpm, 3,500 hp Induction Motor and Adjustable Speed Drive for Refinery Service”  
B.M. Wood, C.L. Olsen, G.D. Hartzo, J.C. Rama, F.R. Szenasi, IEEE/PCIC 1995,*
- mass 9000 kg
- **uninterrupted operation since 1995** : 93°C hot spot, < 0.09 in/s / 0.48 mils p-p radial, < 0.13 in/s axial, critical speeds 2200 and 6800 rpm

**Running 24/7  
99.9% Availability  
Vibration level unchanged  
in 16 years**



**Running 24/7**  
**99.9% Availability**  
**Vibration level unchanged**  
**in 13 years**

**Key technical features :**

- flexible grooved cylindrical one-piece steel-forged solid rotor with stainless-steel alloy retaining rings
- **only 2 pedestal tilting pad bearings** with forced oil lubrication and **outboard** brushless induction exciter and rotating rectifier
- API Std. 546
- thyristor LCI driven
- 45000 kg
- **uninterrupted operation since 1998** : 53 K hot spot, 0.69 mils p-p radial, critical speed 2400 rpm

Q.ty / Model – Type : 1 / **MSCR 900 Y 2** – *synchronous motor*  
Rated power : 11200 kW (15000 HP) @ 4500 rpm  
Ratings : 2x4.4 kV / 2 x 850 A - 75 Hz – *dual winding*  
Speed range : constant torque @ 4100 to 4500 rpm /  
constant power @ 4500 to 5000 rpm  
Mounting / Cooling : IM 7211 / IC 86W (TEWAC forced ventilated )  
Type of protection : pressurised Ex-p, for installation in hazardous area  
Class I, Division 2, group D  
Coupled machine : centrifugal compressor  
Location / Customer : Empress, AB, Canada / Petrocanada, Calgary  
Commissioning year : 1998





Q.ty / Model – Type	: 2 / <b>HSCR 500 Y 2</b> – <i>induction motor</i>
Rated power	: 2 x 5000 kW @ 13000 rpm – <i>mechanical tandem</i>
Ratings	: 6000 V - 135 A - 217 Hz
Speed range	: constant torque @ 5000 to 13000 rpm
Mounting / Cooling	: IM 7314 / IC 86W (TEWAC forced ventilated )
Coupled machine	: test bench centrifugal machines
Location / Customer	: Shanxi, China / Shanxi Institute
Commissioning year	: 2010

### Key technical features :

- **tandem assembly** with flexible coupling
- flexible grooved one-piece steel-forged solid rotor with stainless-steel alloy retaining rings and aluminum fabricated cage
- pedestal tilting pad bearings with forced oil lubrication,
- IEC Std.
- VSI PWM IGBT driven
- mass 12000 kg
- tandem system no-load tested
- since commissioned : 43 K hot spot, < 0.89 mils p-p radial, critical speeds 3200, 8200, 14200 rpm (< 1.5 mils p-p)





### Key technical features :

- ✓ VSI type
- ✓ IGBT based
- ✓ PWM controlled
- ✓ 4,16 up to 7,2 kV
- ✓ 250 Hz, extended range up to 330 Hz
- ✓ air cooling (TH)  $\leq 3000$  kVA / water cooling (NH)  $\leq 18700$  kVA
- ✓ higher power on request for water cooling (NH)
- ✓ diode front-end, multipulse (power factor  $\geq 0,96$ )
- ✓ input transformer integrated or close to the electric cabinet
- ✓ induction or synchronous motor control
- ✓ centrifugal loads (pumps, compressors, fans), revamping of existing motor, high-speed applications, ...





Q.ty / Model - Type	: 1 / <b>HSCR 450 Y 2</b> – <i>induction motor</i>
Rated power	: 1330 kW @ 13300 rpm
Ratings	: 6000 V - 213 A - 217 Hz
Speed range	: constant torque @ 0 to 13300 rpm
Mounting / Cooling	: IM 1001 / IC 86W (TEWAC)
Coupled machine	: test bench centrifugal machines
Location / Customer	: Hitachi Test Room, Japan / Hitachi
Commissioning year	: 2009

**Key technical features :**

- **active magnetic bearings**
- flexible grooved one-piece steel-forged solid rotor with stainless-steel alloy retaining rings and aluminum fabricated cage
- IEC Std.
- VSI PWM IGBT driven
- mass *7500 kg*
- system no-load tested
- since commissioned : 52 K hottest, radial < 1.60 mils p-p



- Q.ty / Model - Type : 20 / **MGSCR 1120 Z4** –  
*synchronous motor-generator*
- Rated power : 45000 kW @ 3000 rpm
- Ratings : 4 x 7200 V - 917 A - 100 Hz
- Speed range : quadratic torque @ 2880 to 3000 rpm  
constant power 3000 to 3060 rpm
- Mounting / Cooling : IM 7316 / IC 81W (TEWAC self  
ventilated )
- Coupled machine : LNG refrigeration string gas turbine  
and centrifugal compressor
- Location / Customer : Ras Laffan, Qatar / GE Oil&Gas for  
QatarGas - RasGas
- Commissioning years : since 2008



**Key technical features :**

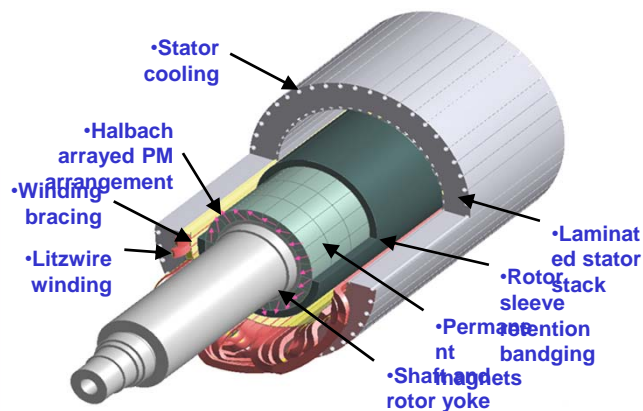
- starter and motor and/or generator machine with double shaft-end
- 4 pole / 100 Hz (no twice-line frequency)
- flexible grooved cylindrical one-piece steel-forged solid rotor with stainless-steel alloy retaining rings
- 4 form-wound stator winding x 4 VSI PWM IGBT converter supply
- 3 of 4 fault tolerance @ continuous operation and +33% peak capability @ full-pressure restart
- 150 MW drive-through capability
- lateral rotordynamics
- 2 pedestal tilting pad bearings with forced oil lubrication
- brushless induction exciter with rotating rectifier
- IEC Std.
- back-to-back and string tested @ full load
- < 1% p-p torque ripple (PWM, 4 pole with reduced bearing span no twice-line frequency)
- 100,000 kg mass
- *“Design, Manufacture and Test Campaign of the World’s Largest LNG Refrigeration Compression String” R. Salisbury, P. Rasmussen, T. Griffith, A. Fibbi, 36th Turbomachinery Symposium, LNG Journal July-August 2007,*
- *“Design and testing of a 45-MW 100-Hz Quadruple-Star Synchronous Motor for a Liquefied Natural Gas Turbo-Compressor Drive” A. Tessarolo, G. Zocco, C. Tonello, IEEE Transactions on Industry Applications (coming soon)*
- Since early commissioning in 2008 : 59 K hottest, 98.1%  $\eta$ , radial < 1.0 mils p-p, critical speeds 1850 and 4000 rpm



Q.ty / Model - Type	: 1 / <b>PMUHS 280 L4 – PM generator</b>
Rated power	: 1700 kVA @ 22500 rpm
Ratings	: 4 x 620 V - 396 A - 750 Hz
Speed range	: 19000 ÷ 22500 rpm
Mounting / Cooling	: IM 1001 / water jacket + forced ventilation
Coupled machine	: high-efficiency gas turbine
Customer	: Ministero Difesa / NAVARM - RasGas
Commissioning year	: 2010

**Key technical features :**

- Permanent Magnet Rotor
- 4 pole / 750 Hz w low-loss stator laminations
- 4 litzwire stator winding vs 4 chopping rectifiers
- flexible one-piece steel-forged solid SPM rotor w carbon fiber bandaging
- shield-mounted tilting pad brgs w forced oil lubrication
- system full-load tested : 96.0%  $\eta$ , temperature < B
- mass 2000 kg





### **Key technical features :**

- ✓ Trapezoidal slotless Halbach configuration
- ✓ Rotor sleeve retention bandaging
- ✓ Active magnetic bearings
- ✓ speed > 15000 rpm
- ✓  $\eta > 98.5\%$
- ✓ Maximum fatigue and thermal reliability
- ✓ NdFeB or SmCo permanet magnets
- ✓ MTBF = 20 years (motor) or 100000 h (mag brgs drive)
- ✓ MTTR = 24 h (motor replacement) or 0.5÷1.0 h (magnetic bearing drive)

