DC-AC Converters

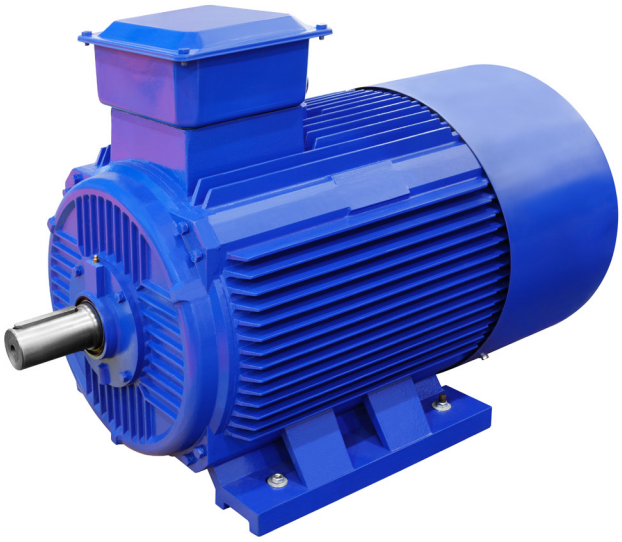
FOR SUBMARINES

Nöjdhs

DC-AC Converters in submarines

In a conventional submarine the energy source is batteries. Because of this the classic drive for propulsion and auxiliary machinery is the DC- motor (Direct Current) together with necessary equipment for start and speed control. The DC-motor is equipped with brushes and commutator. These need maintenance which can be rather complicated in a submarine.

In the industry we use 3-phase AC (Alternating Current) for the power supply, and for drives the basic rule since many years is: "Use the 3-phase induction motor". The induction motor, or as it sometimes is called the squirrel cage motor, has no electric connection between the stator and the rotor. That means that the induction motor needs a minimum of maintenance.



Example of a standard 3-phase induction motor.

The development of power electronic components has given possibilities to design different converters with high efficiency and low electrical noise emission. One of the possibilities is making a 3-phase AC (Alternating Current) from DC. That means that today you can design a drive using the induction motor even if you have a DC network. The normally used name for a DC/AC-converter is in fact inverter. However, using the first name gives less misunderstandings.

The first DC/AC-converter in a Swedish submarine was installed in1987 feeding a cooling water pump. Since then we have delivered a large number of DC/AC converters to Swedish and foreign navy submarines.

DC-AC Converters installed in a submarine.

Installed drives

In the Swedish and foreign submarines you find the DC/AC-converter in use for:

- Air compressors
- Freon compressors
- Hydraulic pumps
- Weight compensation system
- Different cooling pumps
- Different fans

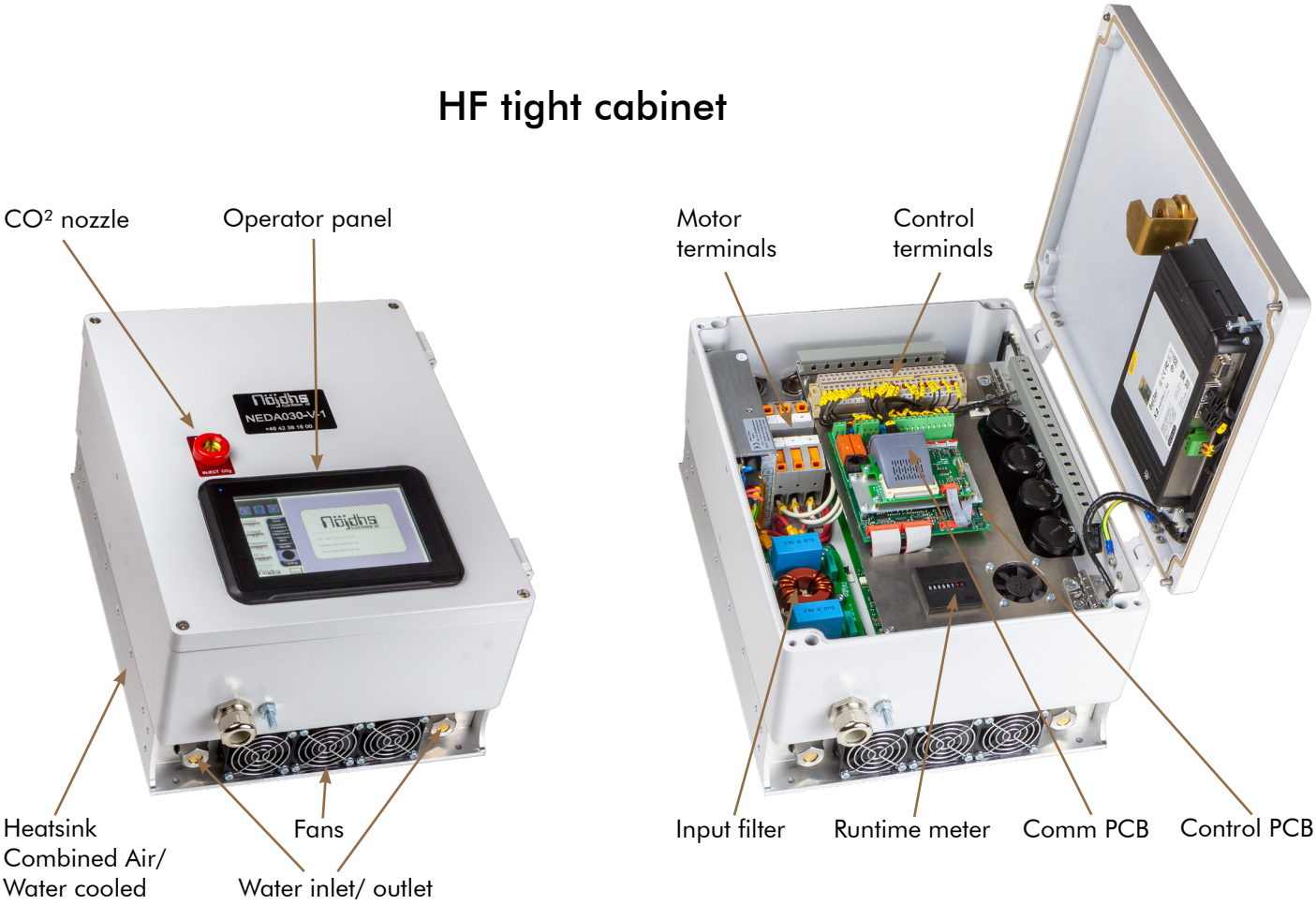
The battery voltage in a submarine.

In a traditional submarine the battery voltage will fluctuate depending on the charge of the battery. Depending on submarine class, the battery voltage can be for instance 200-300 V DC, 300-450V DC or 550-900V DC. The DC voltage is an important parameter for the design of the drive. With 200 V DC the maximum possible AC voltage is 140V AC.

Power electronic components

The development of power electronic components is fast, and this contributes to the improvement of properties for power converters. Power transistors are in motor control applications mostly switched with frequencies lower than 100 kHz, usually in the range 1-20 kHz. The most common power transistor for motor applications is the IGBT (Insulated Gate Bipolar Transistor).

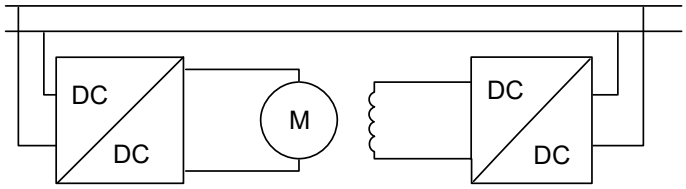
HF tight cabinet



DC-AC Converters in submarines

The DC-motor and DC-drive

Just a few words about the DC-drive as this was traditionally used for propulsion and other large motors in submarines. The principle diagram shows that for an optimal drive both the armature (rotor) and the excitation winding (stator) must be fed by their own converter. In a submarine these must be DC/DC-converters. To get the highest motor efficiency it is necessary to control both the armature and excitation voltage. This can be made manually or automatically.



DC-network for instance 300-450 V

The induction motor

The induction motor has only one winding (a 3-phase winding), that means that the armature and excitation winding is the same. The winding is placed in the stator, and there is no connection between the rotor and the stator. Compared to a DC motor the induction motor has smaller dimensions and lower weight, which is important in a submarine. A comparison is made in the table below.

Comparison between DC-and 3-phase induction motor

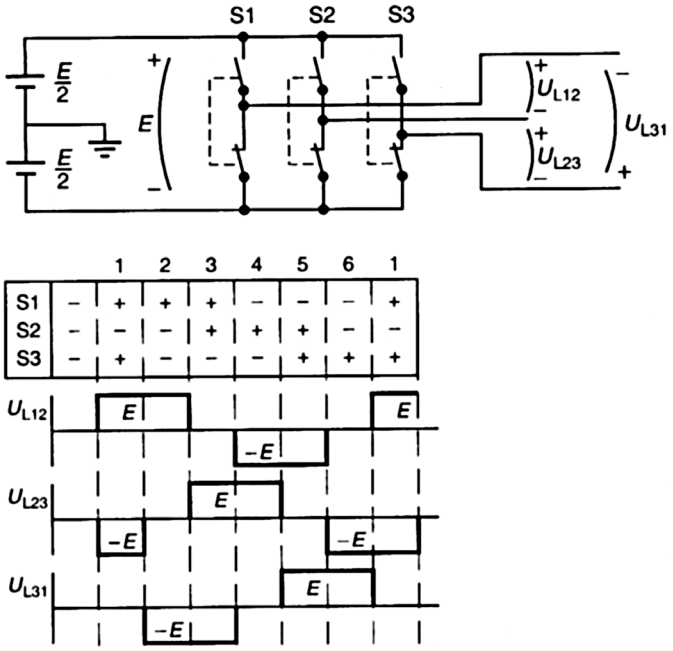
Comparable motors:	DC-motor Separate excitation		AC-motor Squirrel cage	
	M1	M2	M3	M4
Shaft power	54 kW	7,1 kW	55 kW	7,5 kW
Speed	1400 rpm	1570 rpm	1460 rpm	1430 rpm
Torque	370 Nm	43,5 Nm	360 Nm	50 Nm
Efficiency	0,86	0,75	0,91	0,87
Mass	460 kg	108 kg	320 kg	50 kg
Protection	IP23	IP23	IP55	IP55
Rotor connections	Brushes and laminated commutator. Sparks.		None No sparks	
Windings	Rotor and excitations with different voltages. Commutating winding etc.		One three-phase winding. One three-phase voltage.	

DC/AC-converter type PWM

The diagram shows how six switches, synchronised two and two, make 3-phase AC from DC.

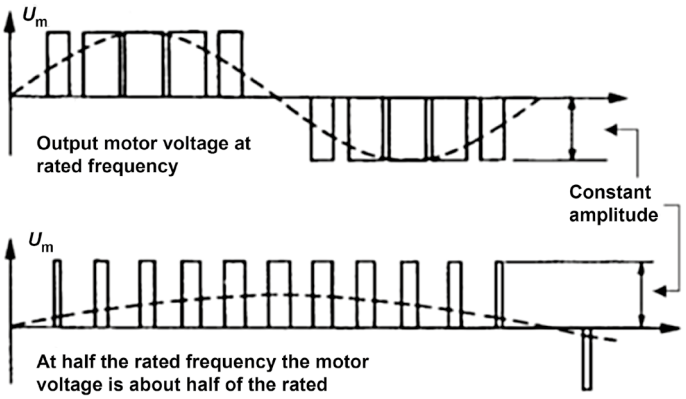
The switches are of course electronic components and to make the current commutation possible when the load has inductance, each transistor has an anti-parallel diode.

In order to get a more sinusoidal motor current the switching of the voltage is Pulse Width Modulated (PWM). Depending the size of the converter the PWM-frequency mostly is in the range 2-10 kHz. Higher frequency gives higher switching losses (lower efficiency) but also lower harmonics.

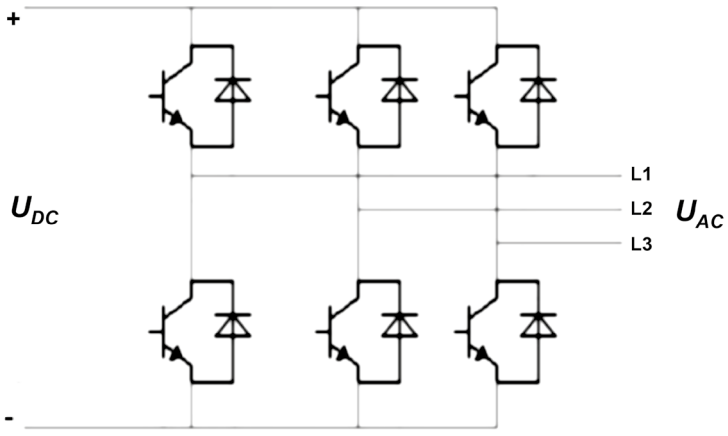


DC becomes 3-phase AC.

NEDA074-V



Principle of the PWM voltage



Main circuit for DC/AC-converter with transistors as main components. The antiparallel diodes make inductive load possible.

DC-AC Converters in submarines

The DC/AC-drive

The converter is mounted in a special HF tight cabinet. The protection class is IP 54.

The main parts of the converter are DC-filter, inrush current limitation, capacitor bank, IGBT bridge with driver, a control logic with DSP and control unit from which the settings can be made. The settings can also be made by computer.

The DC/AC-drive can be connected with conventional cable to the DC network and to the AC motor with a screened cable.

In the intervals 300-450 V DC and 550-900 V DC standard motors for 230 V respectively 400 V AC can be used with the same ratings as when connected to 230 V or 400 V AC network.

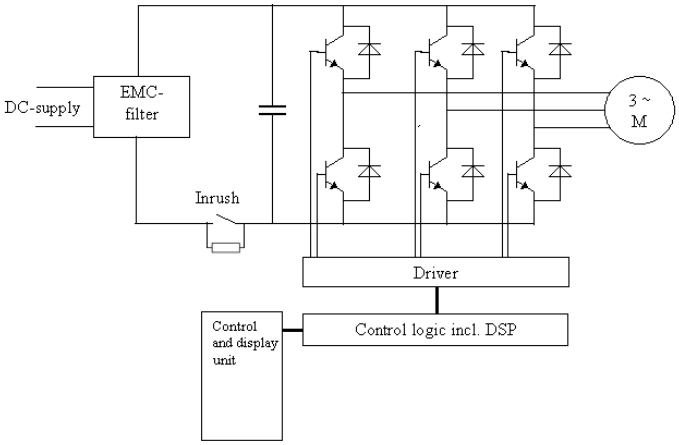
If the converter is connected to a submarine battery with voltage 200-300 V DC, maximum voltage from the drive will be in the range 140-210 V AC. This problem can be solved in different ways.

One way is to order a motor with special winding for instance 133 V, 50 Hz and then set the converter to 133 V, 50 Hz. Independent of the battery voltage, the output voltage from the converter will be constant 133 V AC at 50 Hz.

Another way is to use a standard motor and a transformer 133/400 V or 133/230 V between the converter and the motor.

A third option (and often the best) is to use an oversized standard 230 V motor. At low battery voltage the drive will not be able to supply the nominal motor voltage. However, as the motor is oversized, it can still deliver the required power at a higher current.
In the Swedish submarines both the transformer solution and the solution with oversized motor has been used without problems.

The DC/AC converter make it possible to control the speed of the motor across the full range and to adjust acceleration and deceleration time. Noise problems can be minimized by avoiding certain speeds. The converter also has a built-in soft start, no high start current and built-in overload protection.



Block diagram for the DC/AC Drive. Programming can be made from the control unit or from a PC.

NEDA074-V

DC/AC Converter type NEDA-V

NEDA-V is the fifth generation of DC/AC Converters. The name NEDA is coming from Nöjdhs Elektronik DC AC Converter. NEDA-V is designed to meet military requiremnets for degree of protection, shock resistance and EMC. It is possible to monitor and control the NEDA-V either locally or by remote control. Ethernet connection makes it possible to connect the NEDA-V to a Ship Control and Monitoring system.





General Technical data	NEDA018-V	NEDA030-V	NEDA074-V	NEDA146-V	NEDA210-V
DC Supply	180-700 V	180-700 V	180-700 V	180-700 V	180-700 V
Motor Power (50/60Hz)	<5.5 kW	<8 kW	<22 kW	<45 kW	<65 kW
I_n RMS	18 A	30 A	74 A	146 A	210 A
$I_{60\ sec}$ RMS	21.6 A	36 A	89 A	175 A	252 A
$T_{ambient}$	0-45°C	0-45°C	0-45°C	0-45°C	0-45°C
Degree of protection	IP54	IP54	IP54	IP54	IP54
Shock resistance	15g 20 ms	15g 20 ms	15g 20 ms	15g 20 ms	15g 20 ms
EMC	Corresponding to MilStd461	Corresponding to MilStd461	Corresponding to MilStd461	Corresponding to MilStd461	Corresponding to MilStd461
Dimensions excl. fittings					
Lenght	404 mm	404 mm	600 mm	1360 mm	1360 mm
Width	313	313 mm	380 mm	600 mm	600 mm
Height	208	208 mm	297 mm	382 mm	382 mm
Weight	25 kg	26 kg	39 kg	227 kg	237 kg

The DC/AC Converters could be configured to suit various applications upon request.
Please contact us for more details.

About us

Nöjdhs Elektronik AB and Nojdhs Underwater Technology PTE LTD belongs to the group TN Development AB. Included in the group TN Development AB is also Milab Microphones AB.

Nöjdhs Elektronik AB was founded in 1985 by Thomas Nöjdh, who has a background in the Swedish Navy and in Kockums AB´s submarine electrical design department. Nöjdhs Elektronik AB were one of the first companies in Sweden to use a PC-controlled milling machine for fast production of prototype PCBs.

The company has grown steadily, from 6 employees in 1990 to today's 35 employees divided on two locations, Singapore and Sweden.

Our customers are found mainly in the defence and in the industry. Defence related assignments, particularly in the underwater sector have helped us establish a special competence within this area. Defence projects have also set the standard for the quality and reliability of our products.

We provide customer specific designed solutions and production of electrical and electronic systems. We are specialised in rugged design for use in submarines, naval ships or other demanding environmental circumstances.

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