Electrical auxiliary propulsion

A simple means of improving a vessel's operational performance is to install an electrical auxiliary propulsion system. In this system, the electrical motor is included into the shaft line of the main propulsion engine running the controllable pitch propeller (CPP). On vessels where the space between the shaft line bearing or support and the reduction gear is limited, similar results can be achieved by installing the electrical motor onto the reduction gearbox (when this is made physically possible in the gearbox).

Electrical auxiliary propulsion (EAP) is fed from an auxiliary generator or from some other energy source, such as a battery. The EAP mode is utilized when the main propulsion engine is not connected to the propeller shaft. Slow speed operation is possible without the main propulsion motors. Best performance is reached if the CPP curve can be modified for this new use and best blade angle practices are designed for electrical auxiliary and main mechanical modes individually.

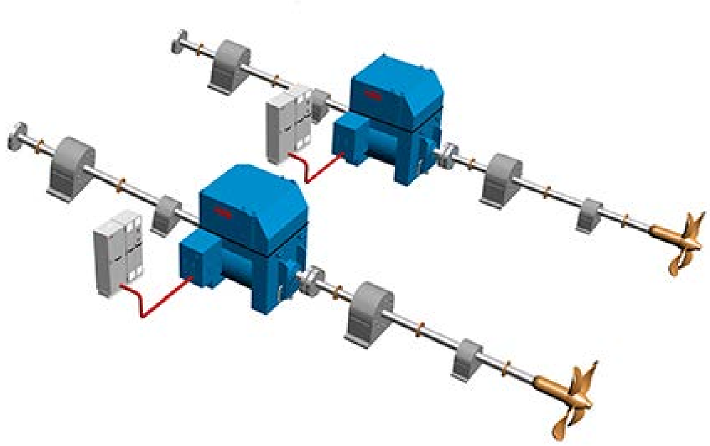

Figure 1: Overall principle of the shaft-installed electrical auxiliary propulsion system. The propulsion drive including the brake resistor (A) is fed from the auxiliary generator. The feeder may require a transformer to match the voltages. The drive feeds the auxiliary propulsion motor (B) when the main propulsion engine is disconnected from the shaft.

If there is room available between the gearbox and the propeller shaft support bearings in propeller shaft installations, one robust option for fuel savings is to consider adding the propulsion electrical motor into the shaft line itself. In such installations, the electrical motor is a part of the shaft, connected to it from both ends. ABB has pre-designed a few options from its proven standard motor portfolio to be available for new building and retrofitting purposes.

Figure 2: Four different motor sizes from ABB's AMI motor family are pre-designed to meet the typical requirements of electrical auxiliary propulsion motors. The special features of such motors are as follows:

- IM1002, shaft end available on both ends of the motor.
- Increased shaft diameter.
- Maximized torque carrying capability of the shaft (double key on both cylindrical shaft ends).
- Bearing solutions allowing ±8mm axial tolerance.
- Fan cooling for slow RPMs.

In normal operation, the vessel utilizes the main propulsion engine as before, but now through the electrical auxiliary propulsion motor. In this operation, the EAP motor rotates freely as a part of the shaft, not providing power into the system. When operated with the main engine, the EAP motor's interference to the system consist mainly of minor additional rolling losses of the EAP motor bearings and the rotating mass of the EAP motor's rotor. These factors need to be taken into account when calculating shaft forces and vibrations. To avoid thrust loading of the EAP motor bearings from the propeller shaft, the axial tolerance of the EAP bearings is designed to be wider than in the thrust bearing of the shaft line.

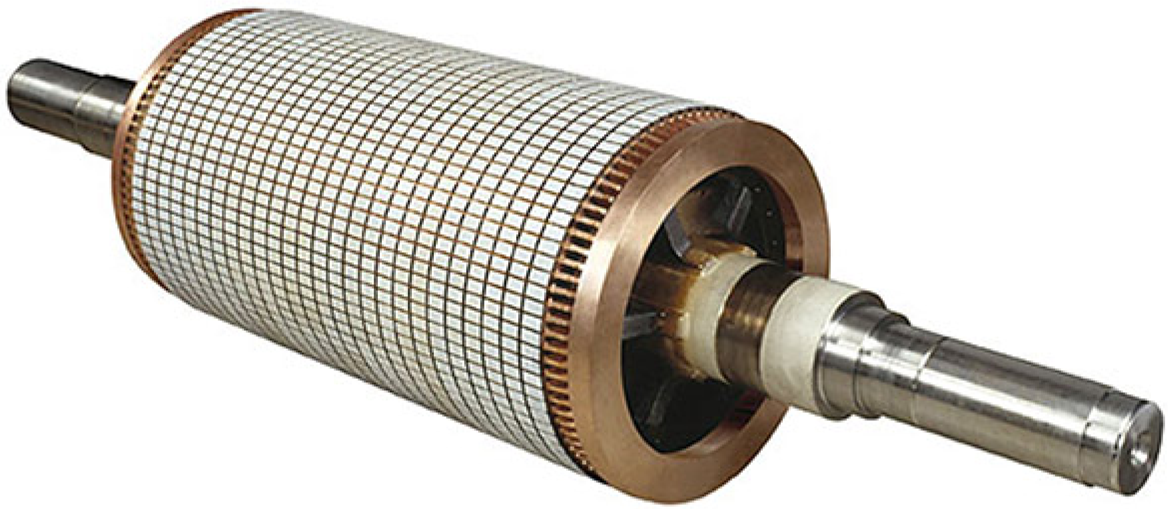

Figure 3: The rotor structure of the induction motor is simple and robust.

When the main propulsion engine is not utilized and the clutch is open, the EAP motor can be driven in the EAP mode by utilizing the same input reference signals as used by the main engine or by utilizing an additional dedicated reference signal. In this mode, the EAP motor is controlled by an EAP drive that provides a smooth slow speed operation range without main engine losses. The drive is fed from the electrical network (or from battery) and it includes the needed protection against blackouts and other damages to the equipment.

Even though the specific fuel oil consumption (SFOC) is normally higher for auxiliary engines and induction motor efficiency is not very good at low speeds, EAP still presents remarkable potential for fuel savings. This is due to the fact that the total consumption of auxiliary engines (total direct fuel consumption + engine auxiliaries' fuel consumption) is typically much less than the total consumption of the main propulsion engines. From the fuel savings perspective, this option becomes especially interesting when auxiliary engines are running during normal operation and there is room to increase their load by addition from EAP.

Direct electrical auxiliary propulsion	Shaft diameter [mm]	Maximum transfer torque through motor [kNm] with / without key	Shaft height (shaft middle from the bottom) [mm]
Direct EAP 400	110	30 / 30	400
Direct EAP 450	125	45 / 62	450
Direct EAP 500	140	52 / 90	500
Direct EAP 560	180	105 / 165	560

Direct electrical auxiliary propulsion	Forged shaft material [mm]	Motor shaft length [mm]	Minimum speed without forced lubrication *
Direct EAP 400	42Crmo4 or similar	2420	110
Direct EAP 450	42Crmo4 or similar	2620	70
Direct EAP 500	42Crmo4 or similar	3000	60
Direct EAP 560	42Crmo4 or similar	3550	110

* forced lubrication is an available option

Motor performance must be evaluated in the speed range defined by the main engine inefficiency. The basic philosophy of auxiliary propulsion is to operate in the propeller speed areas where the use of main propulsion is not efficient.

Below is a table showing motor performances in a 180 rpm situation, which represents an example operation point of 5-6 knots. Each evaluation should include the estimation of the needed propeller speed in the target slow speed operation of the vessel. Theoretically, the auxiliary propulsion motor efficiency improves while the motor speed increases, and therefore it is recommended that the propeller pitch/power curve is re-designed for the EAP mode taking into account also the propeller and propulsion efficiencies.

Direct electrical auxiliary propulsion	Available power in 180 RPM / 660 VAC [kW]	Torque rating of motor [kNm]	Motor efficiency at 180 RPM [%]
Direct EAP 400	110	5.8	87.8**
Direct EAP 450	230	12.1	88.7**
Direct EAP 500	350	18.5	91.7**
Direct EAP 560	420	32.8	90.7**

**Guidance value. To be verified for each supply individually

More power may be taken from the motor by increasing the revolutions. This results in more current via the supplying drive and the motor winding. Therefore, the EAP drive selection should mainly be made based on the current rating of the motor.

The EAP drive, which is a standard ABB ACS800 low voltage drive, needs to be equipped with special software that is suitable for EAP use or with a propulsion control unit for more complex installations. The drive technology is selected according to the network parameters:

- either with diode supply and brake resistor, when network braking of regenerative is not chosen due to low network load and harmonics are tolerated / filtering is possible
- or with low harmonics active front-end and feed transformer (this transformer is always needed for high frequency interference isolation)

High speed electrical auxiliary propulsion

When the size and weight of the installation are critical design factors, electrical auxiliary propulsion can be implemented with a high-speed induction motor that is connected to the reduction gear (in case there is an input possibility).

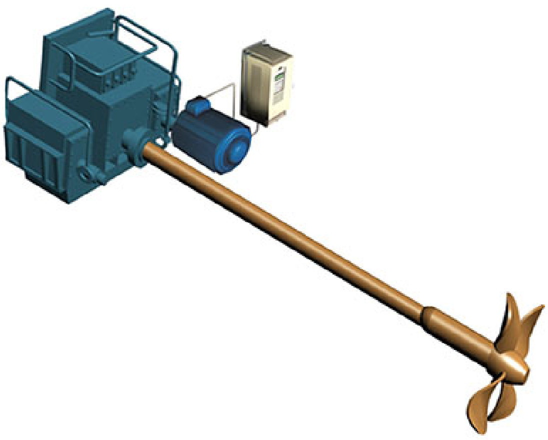

Figure 4: Overall principle of the gear-installed electrical auxiliary propulsion system. The propulsion drive including the brake resistor (C) is fed from the auxiliary generator (D). The drive feeds the auxiliary propulsion motor (B) when the main propulsion engine is clutched from the shaft. The gear ratio of the reduction gear (A) allows for smaller and lighter motor sizes than possible in direct installations.

In small vessels where geared electrical auxiliary propulsion is often the only possibility for efficiency updates, the most demanding design challenge is typically the auxiliary power source. If there is room for a new power source to be installed and its weight is tolerated, high speed EAP components are often easier to fit in.

In normal operation, the vessel utilizes the main propulsion engine as before. In this operation, the EAP motor, which is a standard ABB motor, rotates freely as a part of the shaft, not providing power into the system. When operated with the main engine, the EAP motor's interference to the system consists mainly of minor additional gear and rolling losses. Also the EAP motor's weight and vibrations need to be taken into account when designing the system update. To minimize mechanical stress to the system, the first option is to consider installation where the motor is flange-connected to the gear and supported from the motor foot. The code for this type of installation is IM2001, but evaluation of the installation also requires support from the gear manufacturers who are the experts with their own designs.

When the main propulsion engine is not utilized and the clutch is open, the EAP motor can be driven. The same input reference signals as used by the main engine or an additional dedicated reference signal can be used. In this mode, the EAP motor is controlled by the EAP drive, which provides a smooth slow-speed operation range without main engine losses. The drive is fed from the electrical network (or from battery) and it includes the needed protection against blackouts and other damages to the equipment.

Even though the specific fuel oil consumption (SFOC) is normally higher for auxiliary engines, EAP still presents remarkable potential for fuel savings and plenty of comfort benefits. The slow speed solution greatly improves the induction motor efficiency and often covers also additional gear losses. The fact that the total consumption of auxiliary engines (total direct fuel consumption + engine auxiliaries' fuel consumption) is typically much less than the total consumption of the main propulsion engines makes the EAP saving potential interesting.

The high-speed electrical auxiliary propulsion system is a combination of standard, robust ABB motors and the EAP drive, also a standard ABB ACS800 low-voltage drive that is equipped with special software, suitable for EAP use.

The following pre-designed high-speed electrical auxiliary propulsion systems are available:

High speed electrical auxiliary propulsion	Available power in 1800 RPM / 400VAC [kW]	Torque rating of motor, cylindrical shaft end with key [Nm]	Motor efficiency at 1800 RPM [%]
High speed EAP 50	50	350 (shaft Ø60mm)	94.3*
High speed EAP 100	100	668 (shaft Ø65mm)	95.5*
High speed EAP 150	150	990 (shaft Ø65mm)	96.1*
High speed EAP 200	200	1230 (shaft Ø65mm)	96.3*

*Guidance value. To be verified for each supply individually

High speed electrical auxiliary propulsion	Motor weight [kg]	Motor dimensions [mm]	Connection flange diameters [mm]
High speed EAP 50	500	L: 875 (+fan 300) ** H: 605	Ø Inner 450, outer 550 8 * Ø19 (45°, 500mm)
High speed EAP 100	950	L: 1204 (+fan 300) ** H: 852	Ø Inner 550, outer 660 8 * Ø23 (45°, 600mm)
High speed EAP 150	1000	L: 1315 (+fan 300) ** H: 852	Ø Inner 550, outer 660 8 * Ø23 (45°, 600mm)
High speed EAP 200	1160	L: 1315 (+fan 300) ** H: 852	Ø Inner 550, outer 660 8 * Ø23 (45°, 600mm)

** Fan is needed for zero speed cooling

High speed electrical auxiliary propulsion	Drive weight + brake resistor weight [kg]	Drive dimensions + brake resistor dimensions [mm]	Drive type
High speed EAP 50	34 + 14	H: 739 W: 265 D: 286 H: 600 W: 300 D: 345	ABB ACS800-01-70
High speed EAP 100	67 + 25	H: 880 W: 300 D: 399 H: 1320 W: 300 D: 345	ABB ACS800-01-120
High speed EAP 150	400 + 30	H: 2130 W: 830 D: 646 H: 1320 W: 300 D: 345	ABB ACS800-02/07-210
High speed EAP 200	500 + 30	H: 2130 W: 830 D: 646 H: 1320 W: 300 D: 345	ABB ACS800-02/07-260

Benefits to the vessel owner

- New operational mode for the vessel.
- Fuel savings.
- Reduced noise and vibration in low speed operations.
- Increased comfort.
- Increased redundancy.
- New fueling and energy generation options.
- Standard and proven products, supported worldwide.

Benefits to the shipyard / designer

- Simple installation.
- Reduced gear stress (in case of shaft line installation).

- Risk reducing by gear output removed (in case of shaft line installation).
- Gear/support for motor (sensible) installation not needed (in case of shaft line installation).
- Ready design options available.
- Slow speed noise targets can be described without main propulsion engines.

Savings and payback time

Consider electrical auxiliary propulsion if your vessel operates in slow speeds (0-6 kn) and utilizes CPP propulsion with main propulsion engines. Electrical auxiliary propulsion enables you to fully change your operations to be much more economical. The payback time of such savings is typically very short, but the change requires project-specific evaluation.