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Turnkey ready modular electrical propulsion systems for low and high-power commercial applications

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Executive Summary

The Torqeedo GmbH supplies integrated electric propulsion solutions since 2005. In 2016 Torqeedo introduced a modular, high-power electric drive system with a dedicated power and energy management for commercial and recreational vessels with a power up to 100 kW. Since then, the request in power and energy is continuously increasing. It turns out that this modular concept with proven, off-the-shelf components in connection with a multi-system approach is suitable for creating a distributed, redundant electric drive system with scaling up to 800 kW and 4000 kWh energy per drive train.

Keywords: Electric Ships & Airplanes, Drive & Propulsion Systems, Energy management, Energy storage systems, Retrofitting EVs

1 Introduction

"DEEP BLUE Hybrid" is a high-power electric drive system for commercial and recreational vessels, which is a fully integrated propulsion and energy management system developed and manufactured by Torqeedo since 2016. Since then, the DEEP BLUE system controls, monitors and integrates the ship's propulsion systems, electric battery systems, charging system, electric power take ins (ICE Gensets, Fuel Cell Power System incl. tank system), electric power take offs (Bow Thruster, Windlass, Winches, Hotel loads, Air-condition system) and more. It represents an optimum in terms of cost, necessary performance, maintainability and reliability due to industrialized development and testing standards.

The energy & power management system is a fully integrated concept covering functions for basic to advanced plants for all types of hybrid energy source and consumer arrangements.

The integration concept makes it easy to adapt the system to any propulsion and battery plant, ensuring an efficient control concept both operational and cost-wise. Applying the DEEP BLUE redundancy concept ensures a high level of availability and safety.

The DEEP BLUE Hybrid was originally designed for vessels with a propulsion system scaling up to 100 kW and 200 kWh energy per drive train. Approximately 200x DEEP BLUE systems and DEEP BLUE Hybrid systems have been successfully integrated in new-built and converted passenger ships in the past years. Based on this experience, it is obvious to transfer this technically and commercially successful solution concept to higher power and larger energy storage systems.

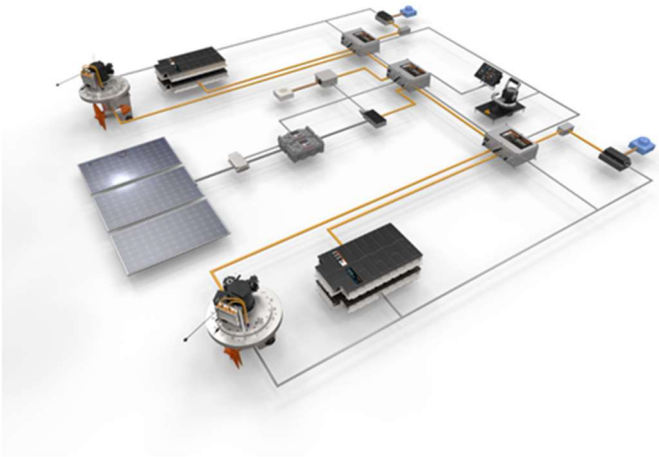

Figure 1: Todays modular architecture of the Torqeedo "DEEP BLUE Hybrid" system

Since the request for power and full system provision is permanently rising Torqeedo is further developing the modular propulsion system kit. This paper describes the Torqeedo concept of extending the current modular architecture with proven, off-the-shelf components in connection with a multi-system approach. This multi-system approach is suitable for creating a distributed, redundant electric drive system with scaling up to 800 kW and 4000 kWh energy per drive train.

2 Current Solution

When defining the basic system architecture of the system, three main goals are implemented by Torqeedo:

a. Flexibility: Support for a wide range of different system configurations consisting of motor(s), battery(ies), AC/DC converter(s) etc., also keeping in mind easy integration of future components.

b. Scalability: Possibility to design larger scale systems with multiple motors, large battery banks, multiple house load supplies etc.; options for extension of existing systems at a later stage.

c. Redundancy: Implementation of redundant subsystems, that can either work jointly as a complete system or – in case of failure or emergency – also act as an independent unit with basic functionality.

To fulfill these three goals, the DEEP BLUE Hybrid is based on a Connection Box with three level controller architecture [1]:

a. The Device Control Unit (DCU), which is installed up to five times in one Connection Box. It is designed to detect the connected device(s) and implement basic low-level controlling and safety features.

b. The Box Control Unit (BCU) acts as box-master, enumerates and monitors logical and abstracted devices and if at least one device of class battery, motor and throttle is found, it provides features for basic propulsion operation.

c. The System Control Unit (SCU), which also controls abstracted devices of all other classes like shore power charger, DCDC converter, DCAC inverter, generator, solar charger, and low voltage battery.

The current selection includes multiple high efficiency electric drivetrain options, a set of high energy density long lifetime automotive high-voltage batteries, AC shore power chargers, DC/AC converters, 24V low voltage batteries, solar charge controllers and a powerful bi-directional DC/DC converter for high voltage/low voltage energy transfer.

All components are waterproof and tested by Torqeedo for marine use on component and system level. The system itself is a fully integrated propulsion and energy management solution. This results in a large portfolio showed in Figure 2:

Figure 2: Torqeedo's System Portfolio

3 Scaling of the current solution

The projects implemented by Torqeedo to date have been characterized by a ratio of drive power in kW to stored energy in kWh of 1:1 for planning hulls, parallel hybrid drives and auxiliary drives and more than 1:3 for ships primarily used for commercial purposes. In the case of the latter, displacement hulls are in the foreground.

The premise for growth both in performance and energy of the drive train is therefore the evolutionary development of the previous basic system while maintaining the control and communication dynamics, and else the continued use of basic system components used successfully in many completed projects.

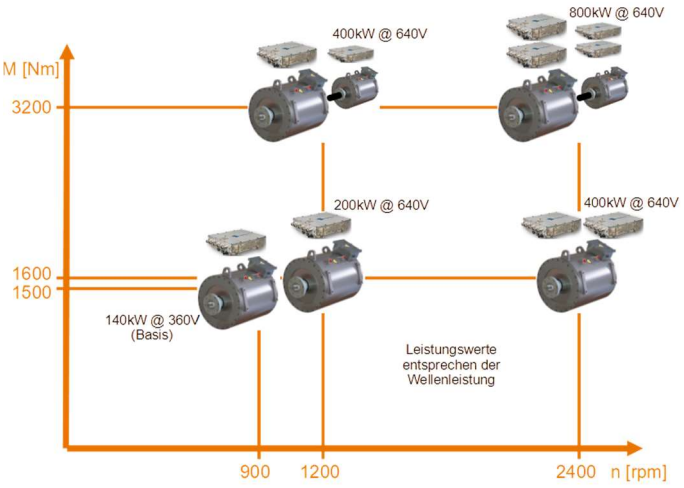

Figure 3: The Torqeedo Motor Matrix

Ongoing developments are preparing the system for quadrupling power, based on a stacked motor solution for increased torque and based on doubled battery voltage for increased speed.

Torqeedo follows an approach of parallel operation of sub-motors with speed control. This will partially add redundancy to single line shaft propulsion applications. Herewith, applications for 800 kW shaft power per line shaft can be addressed.

The battery voltage is increased by connecting battery units in series. When battery units are connected in series, energy balancing of the individual battery units is required.

Furthermore, creating redundancy between multiple energy sources is a key element for increasing operational readiness in maritime applications. This is typically achieved by galvanically isolating battery units, which are then electrically coupled via DCDCs. In ships with numerous energy consumers beyond the propulsion, this can lead to large energy content differences during operation. The high DCDC power required for balancing the energy content typically results in limited energy efficiency and high costs. Therefore, it makes sense to explore more technically efficient methods for balancing the energy of the battery units.

Today, the simplest method for balancing battery units is to activate multiple independent loads assigned to the individual battery units, such as battery heating systems or ventilation units. Alternatively, active balancing of energy content can be achieved by sequentially connecting individual battery units to a DC charging system.

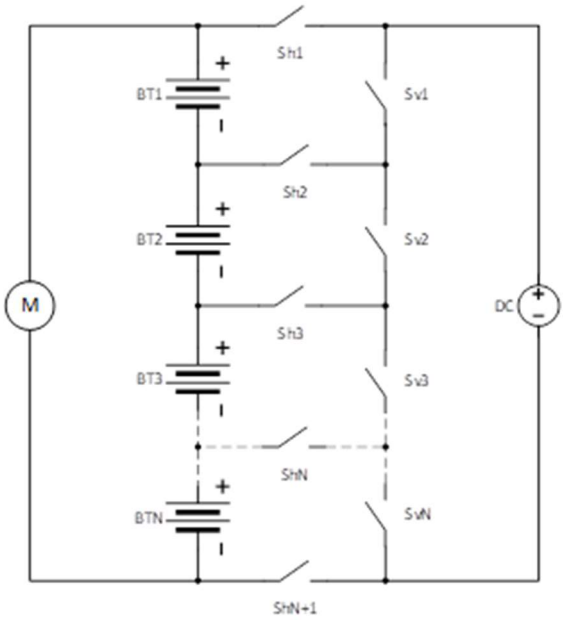

Figure 4: Switch Matrice for Battery Balancing

There are several approaches to the topologies of switch matrices for the series connection of N batteries.

A simplification of the series connection of two batteries with integrated balancing circuit used by Torqeedo is shown in Figure 5.

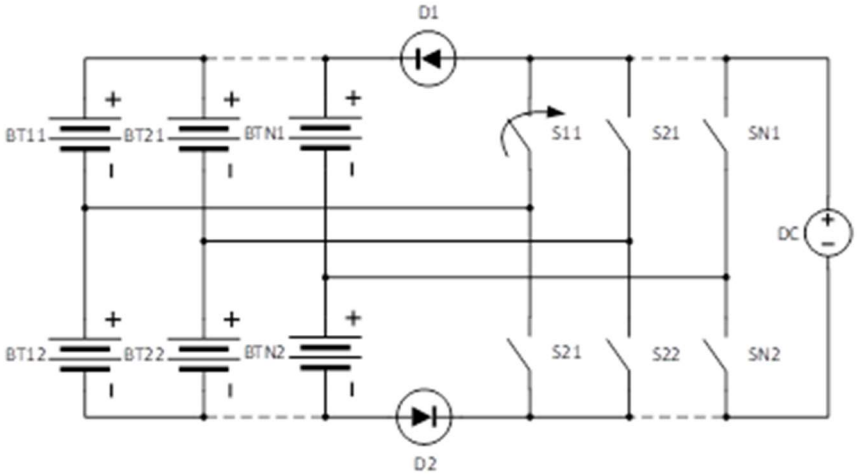

Figure 5: Use of current source to balance series connection of two batteries

The battery balancing measures presented can be integrated into the drive system with little effort.

Hence Torqeedo is providing an industrialized serial product to the market for high power applications at lowest possible costs. This is being achieved with the use of industrialized components for motors, inverters or batteries available in high quality and quantity. Such are marinized and integrated into Torqeedo's proprietary control and management system. With this system Torqeedo supports the increase of water bound mobility significantly and helps fleet operators and ship owners to equip each ship with the best solution based on a high quality, reliable and scalable modular system.

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5 References

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6 Presenter Biography

Alfons Doerr (Torqeedo GmbH) studied physics in Konstanz and Kiel. He received his doctorate from the University of Kiel and initially worked on the topic of vehicle safety at Continental AG and Robert Bosch GmbH. In 2009, he began to work on the topic of lithium-ion battery storage for automotive applications at SB Limotive Co.Ltd., a joint venture of Samsung SDI and Robert Bosch GmbH. Since 2022 he is responsible for system development for marine propulsion and energy management systems at Torqeedo GmbH.