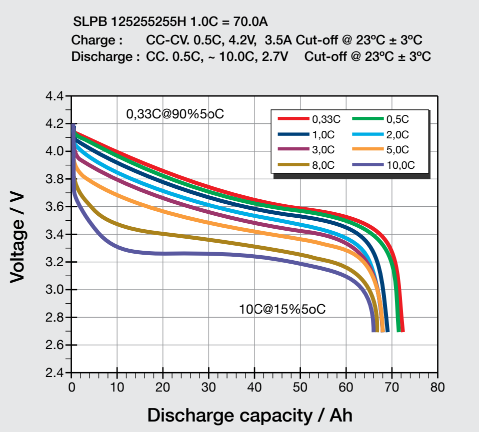
Batteries installation and load sharing in hybrid power plants

FRANK WENDT – Facing a growing demand for higher power plant efficiency, reduced fuel consumption and lower emission levels, the marine market is evaluating concepts based on the use of hybrid power plant with energy storage systems. Given the availability of high power and energy dense batteries, such systems are now being considered as a possible additional and/or alternative power source to diesel generator sets for shipboard electrical power plant. Load sharing has to be controlled, especially when the battery system is operating in parallel with other power sources, and this article describes a load sharing method which allows a direct connection of the battery with a DC-link system.

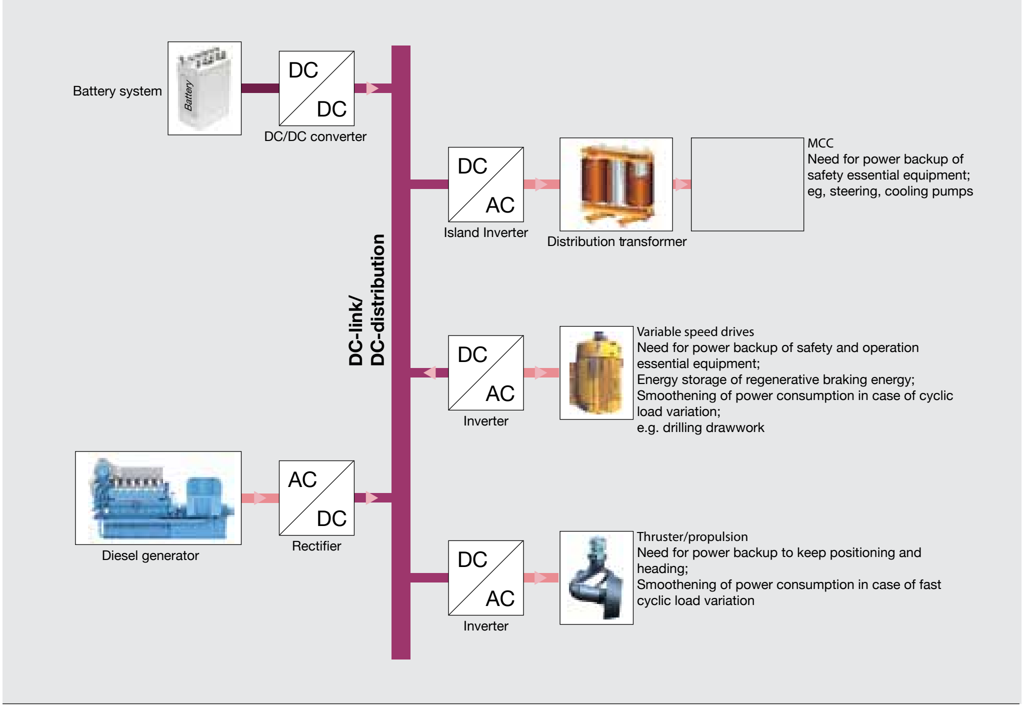
1 Cell performance of lithium Ion battery (Corvus Energy)



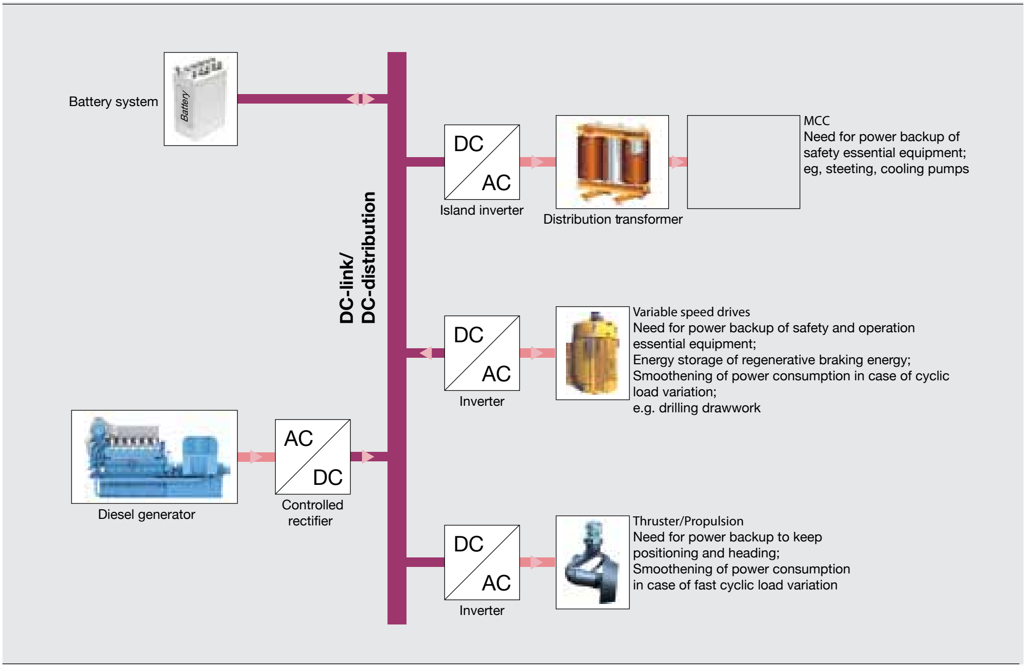
When using a battery-based energy storage system in a diesel-electric power plant, load sharing between the battery system and diesel generator(s) has to be controllable. The battery system can be connected either to the common DC bus in a multi-drive variable speed drive system or directly into a DC grid power distribution system.

The voltage at the batteries' terminals varies with their state of charge (SoC) and the charge or discharge current. The variation in voltage depends on the battery chemistry and, for a lithium ion cell, can be up to 20-25 percent between a typical operation point 0.33C@90 percent SoC and 10C@15 percent SoC, C being the rated discharge current (Figure 1). Furthermore, unlike other power sources such as diesel generators, there is no way of controlling a battery that enables direct power sharing.

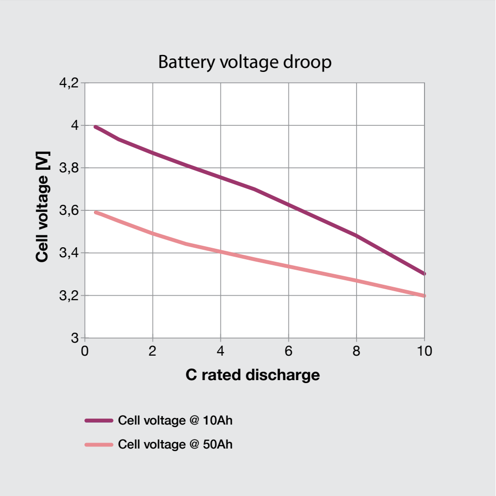
2 Battery system connected through a DC/DC converter to DC-link)



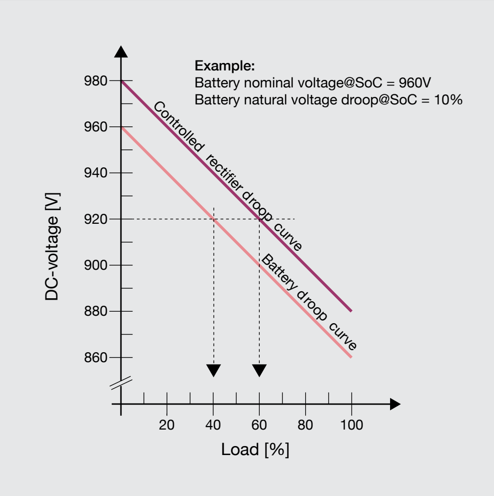
3 Battery system directly connected to DC-link



4 Battery voltage droop



5 Voltage droop based load sharing

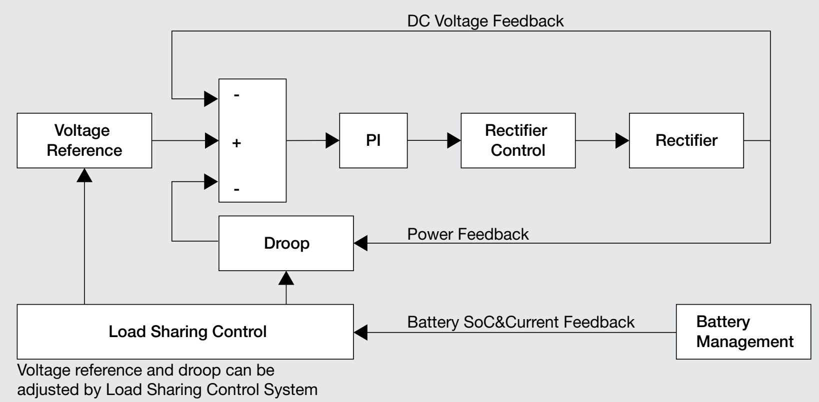


The marine market is evaluating concepts based on the use of hybrid power plant with energy storage systems.

The main power consumers in a diesel-electric power plant are usually variable speed drive (VSD) systems, including, for example, propulsion thrusters and cargo and drilling drives. Modern VSDs are based on voltage source converter technology which uses a relatively constant DC voltage intermediate circuit. To guarantee full performance of the VSD, the DC link voltage has to stay above certain defined levels.

When using batteries as part of the power source for VSD systems, the voltage variation of the battery can be compensated for through the use of DC/DC converters, which boost the changing battery voltage level up to the required DC link voltage. The DC/DC converter also enables the control of direct power load sharing between the battery system and diesel generator (Figure 2). In high power battery energy storage systems, however, the DC/DC converter contributes significantly to the size and cost of the overall battery energy storage system and can cause additional losses.

An alternative configuration is to connect the battery directly to the DC link (Figure 3). In such a system the battery voltage determines the DC-link voltage and all power consumers have to be rated according to the variation of the DC link voltage. This mainly affects the current and voltage rating of the power components in the system, as these must be able to convert or produce the required power at both maximum and minimum voltage levels. Load sharing between the battery system and the diesel generator(s), as well



as battery charging/discharging, has to be controlled by the AC/DC rectifier unit(s), which feed power into the DC link system. In applications with a high C-rate discharge current, the natural droop of the battery voltage can be used for load sharing between a diesel generator set and the battery. The voltage droop (cell voltage versus discharge current) is relatively linear, but changes with the SoC of the battery (Figure 4). Voltage droop based load sharing is an effective and robust method for parallel operating power sources. With the DC voltage common for both the battery and rectifier, each unit supplies the amount of power, which corresponds to its applied droop curve. As the load on the DC link increases, the DC-voltage drops.

By implementing a voltage droop control algorithm in the rectifier control system, the output voltage of the rectifier can be adjusted to control both the power flow in the battery and the AC/DC rectifier and consequently between the battery and diesel-generator (Figure 5). The natural droop curve of the battery is only quasi-static and changes with the SoC. With current and SoC feedback from the battery management controller, a load sharing controller can adjust the voltage reference and droop curve settings of the droop controller in the controlled rectifier. By adjusting the voltage reference and droop curve setting in the droop controller, not only can the load sharing between the battery and diesel generator be controlled, but also the battery charging.

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