Shipboard Power System as a Microgrid

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1. Introduction

IEEE Std 2030.7 defines a microgrid as:

> "A group of interconnected loads and distributed energy resources with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid and can connect and disconnect from the grid to enable it to operate in both grid-connected or island modes."

Distributed energy resources (DER) are further defined as:

> "Sources and groups of sources of electric power that are not directly connected to the bulk power system; they include both generators and energy storage technologies capable of exporting power."

When a microgrid is electrically connected to the grid it is in the "Steady state connected" mode. When a microgrid is operating disconnected from the grid it is in the "Steady state islanded" mode. Transition modes include "Unplanned islanding", "Planned islanding", "Black start", and "Reconnect."

Shipboard power systems are inherently "A group of interconnected loads and distributed energy resources with clearly defined electrical boundaries that acts as a single controllable entity." Many ships however, cannot connect to the grid; therefore, they do not completely fulfill the definition of a microgrid. On the other hand, due to environmental regulations in many ports of the world, commercial ships are increasingly employing "cold-ironing" by providing shore connection systems. Naval ships historically have provided shore connection systems (otherwise known as "shore power") because these ships regularly spend extended periods of time in port. By drawing power from the grid while in port, the ship's prime movers may be turned off.

Ships that can interconnect their shipboard power system with the grid fulfill the definition of a microgrid. However, virtually all of these ships do not usually operate their onboard generator sets in parallel with the grid; other than for short periods of time, the onboard loads are typically powered by either the shore connection system, or the onboard generator sets, but not both.

While the analogy of shipboard power systems with microgrids is not complete for the "steady-state connected" mode, it is nearly complete for the "steady-state islanded" mode. DERs onboard ship typically consist of the diesel and gas turbine generator sets.

Few ships currently employ bulk energy storage which are featured prominently in terrestrial microgrids. Furthermore, the shipboard DERs can operate between their minimum and maximum power ratings independent of time of day. Terrestrial DERs often include sources such as wind and solar installations which depend on weather conditions and time of day. Shipboard power systems do have “defined electrical boundaries that acts as a single controllable entity” in common with terrestrial power systems. In the “steady-state islanded” mode, the control of shipboard power systems and terrestrial microgrids must address many of the same issues. The two predominant issues are limited inertia of the electrical systems, and limited generation capacity.

2. Limited Inertia Systems

Within an electrical power system, inertia is the amount of stored energy that can be rapidly applied to maintain voltage and frequency during transients induced by changes in load. Rotating machines, such as generators, store energy in the spinning of their rotors; power electronics store energy in dc link capacitance. During transients, generators will tend to speed up or slow down depending on the control algorithms of the prime mover and on the amount of mechanical inertia in their rotors. While power electronics can maintain frequency during a transient, the dc link capacitance may discharge and limit the inverter output voltage.

The overall grid is assumed to be an “infinite bus” in that nothing that a load does is assumed to change the frequency of the grid; and voltage transients are purely local. In islanded microgrids and shipboard power systems, large load changes can cause transient responses in the system voltage and frequency. If sources are paralleled the combined transient responses of the sources may lead to overloading a source to an extent that it drops offline. The design of microgrids and shipboard power systems should ensure the power system can respond to likely transients in a manner that power quality standards are maintained.

3. Limited Generation Capacity

Both islanded microgrids and shipboard power systems must address ramifications of limited generation capacity. The amount of real and reactive power consumed at any instance must be nearly balanced by the amount of real and reactive power produced. Any differences result in voltage or frequency deviations. Unlike the grid where real power is scheduled and reactive power is a function of network topology and characteristics, in islanded microgrids and shipboard power systems, sources implement techniques for real and reactive power sharing. These techniques may be as simple as voltage and frequency droop, or may involve the exchange of control signals.

Energy storage is often used in islanded microgrids to augment generation when the total load exceeds generation. This energy storage is recharged during periods where generation capacity exceeds total load.

Some shipboard systems employ energy storage as the primary source of power. For example, electric ferries use a large battery system to power both propulsion and ship service loads; the batteries are recharged at each stop of the ferry.

If there is a significant deficiency of generation capacity, both islanded microgrids and shipboard systems generally employ load management techniques such as load shedding to reduce the overall load to below the existing generation capacity.

4. Interconnecting with the Grid

As stated earlier, most microgrids and some shipboard power systems have the ability to interconnect with the grid. For most microgrids, the "steady state connected" mode is the usual mode of operation. For most shipboard power systems, the "steady state islanded" mode is the usual mode of operation.

In terrestrial microgrids, DER operation is integrated with grid operation when in the "steady state connected" mode. Any excess power generated by the DER can be provided to the grid, and the grid can provide power if the DER generation is not sufficient.

For most shipboard power systems, operating with the onboard generator sets paralleled with the grid is either not done, or done for only a short period of time while transferring load to/from the onboard generator sets from/to the grid. Often the onboard generator sets are not paralleled at all with the grid; the onboard generator set breakers are opened before the shore connection breakers are closed when transferring power to the grid and the shore connection breakers are opened before the onboard generator set breakers are closed when transferring power back to the ship's onboard generator sets. Additional details are provided by Sulligio et al. (2015) and Doerry, Islam, and Prousalidis (2025).

5. Concluding Thoughts

A considerable amount of research is being invested in microgrids. While the analogy of a microgrid to a shipboard power system is not perfect, the design of shipboard power systems can leverage many of the concepts, techniques, hardware, and software that the commercial industry has developed to support microgrids. It would be wise to keep abreast of industry advances in microgrid technology.

6. References

Doerry, Norbert, Mohammed M. Islam, John Prousalidis, *Design of Shipboard Power System Grounding / Earthing* , IEEE Press - Wiley, January 2025, ISBN-10 1119933080 ISBN-13 978-1119933083

Sulligoi, Giorgio, Daniele Bosich, Roberto Pelaschiar, Gennaro Lipardi, and Fabio Tosato, "Shore-to-Ship Power," in Proceedings of the IEEE, vol. 103, no. 12, 2381-2400 Dec. 2015.

IEEE Std 2030.7, IEEE Standard for the Specification of Microgrid Controllers