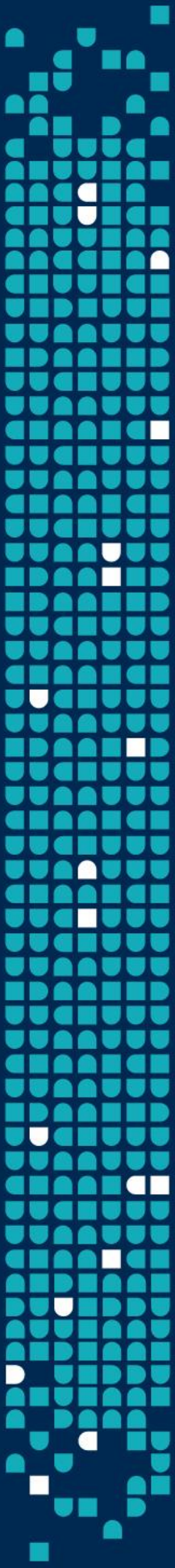
Off-Grid Power Systems: Using The Adptative Power Setpoint to Integrate Several Power Sources

Stéphan Landry P.Eng.
September 2016



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Executive Summary

Generating electricity using off-grid systems in remote areas is expensive and involves significant procurement and operational challenges. Optimizing the use of energy sources reduces fuel consumption, which has a direct impact on the environment.

The adaptive power setpoint should be an integral part of smart grids. It allows for the addition of off-grid storage systems as well as several power sources, including renewable ones, without compromising system reliability and stability. This logic can be part of the real-time management strategy for the power sources of off-grid systems, including microgrids, to reduce construction and operational costs since the various sources are operated concurrently to optimum effect.

This logic has been successfully applied to several off-grid systems in order to incorporate highspeed generators as alternative energy sources. For example, the adaptive power setpoint was used to integrate three diesel generators to a system powered by a liquid natural gas (LNG) generating station. It was also used to facilitate the addition of a 3 MW wind turbine to the offgrid system of a major mining site.

An adaptive power setpoint can be used for different system configurations and grid conditions in order to meet user needs while optimizing the use of various power generation sources with an off-grid system.

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Business Challenge

Off-grid systems are used to supply power to communities and industries in remote areas without access to public utility grids. Access to these sites is often limited, which complicates fuel procurement. Diesel generators are usually the main source of power. As a result, energy costs are high and power sources must be optimally managed to ensure operational efficiency and reliability. In northern regions, fuel can only be procured during a short period of the year, which in turn requires the installation of a sizeable fuel storage system. The cost of fuel for one year of operation is usually over 50% of the cost **to build the generating station.**

To improve the energy efficiency of these grids and limit investment costs, several power sources can be used simultaneously. For example, low-speed generators (e.g., 720 RPM) are much more reliable and efficient, but are also larger and more costly than those operating at higher speeds (e.g., 1,800 RPM). Unlike low-speed generators that can run continuously at 100% of their nominal capacity, high-speed generators cannot operate continuously beyond 70% of their nominal capacity. Moreover, diesel motors are generally more efficient when operated at over 80% of their nominal capacity.

Low-speed generators are typically used for a site's main generating station, whereas highspeed generators are used as auxiliary generating stations for peak management and when a low-speed generator is down or unavailable.

However, running high-speed generators concurrently with low-speed ones using conventional load-sharing loops means exceeding the continuous capacity of the high-speed generators, which is 70% according to the ISO-8528-1 Standard.

Is there a load-sharing system that can adapt to different types of generators or power generation sources that operate concurrently? This document introduces the adaptive power setpoint, a control mode that optimizes the use of various power generation sources with an offgrid system.

Description of the Solution

As previously mentioned, it is impossible to operate high-speed generators concurrently with low-speed generators using conventional load-sharing loops without exceeding the continuous capacity of the high-speed generators, which is 70% according to ISO-8528-1 Standard. The adaptive power setpoint is designed to circumvent this problem by applying optimal power setpoints to control high-speed generators, which keeps these generators within their continuous operating limits while maintaining low-speed generators within their optimal operating range. The adaptive power setpoint also allows high-speed generator spinning reserves to be used when required to support the system during temporary events, like load pickups or loss of generation, thus ensuring operational stability of the system.

When high-speed generators are independent from other generation sources, they are operated in isochronous mode (constant frequency at any load level) or in droop mode (frequency that varies by load level) to ensure the system's operational stability. The control system can also use a logic that reflects grid configuration to manage the operating modes.

The advanced control algorithm for the adaptive power setpoint can be added to a programmable logic controller (PLC), and the logic must be designed and optimized for the needs and configuration of each system. The main generating station is usually operated in isochronous mode with a digital or analog load-sharing loop, which distributes the load optimally without affecting frequency control, at any load level, while high-speed generators are used as an auxiliary or backup power source.

The figure below illustrates the adaptive power setpoint logic that was implemented for a backup generating station consisting of 1,800 RPM Caterpillar high-speed generators and operated as auxiliary power sources at the main generating station, which consisted of 900 RPM EMD generating units. In this application, the load level of the high-speed generators quickly increases as the load level of the main generating station exceeds 88% in order to support additional power demand or the loss of a generator at the main generating station. When generator output at the main generating station drops below 70%, the generators at the auxiliary generating station reduce their output to ensure optimal operation of the generating units at the main generating station

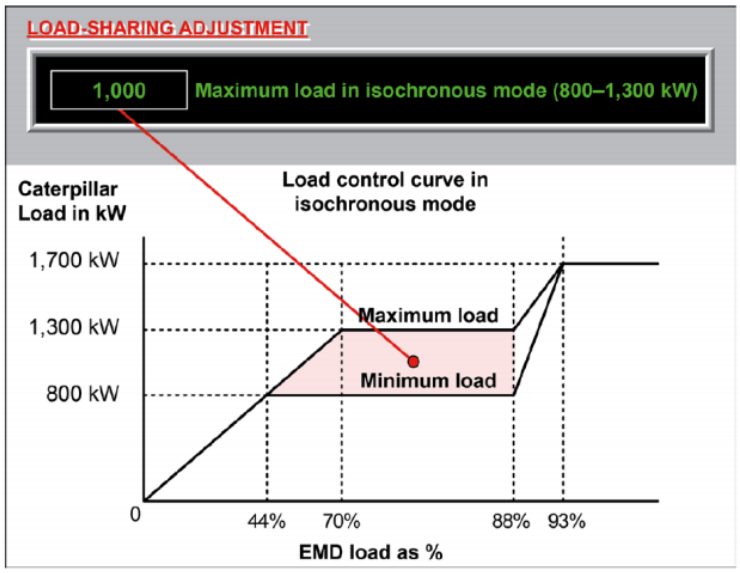

Figure 1: Power setpoint of high-speed generators based on the load of low-speed generators

There are many benefits to applying the adaptive power setpoint to an off-grid system, including reduced construction costs, lower operating costs and improved operational reliability.

An adaptive power setpoint reduces construction costs by:

- Using high-speed generators, which are much less expensive than low-speed generators.

Benefits of the Solution

An adaptive power setpoint lowers operating costs by:

- Optimizing the use of low-speed generators to supply the main system load. For example, over 95% of the power supplied to the system comes from low-speed generators.
- More effectively integrating renewable power sources like wind turbines because the setpoint can adapt to variations in wind power while keeping generators at the main generating station within their optimal operating range. Renewable energy sources are used to reduce fuel consumption as well as the environmental impacts of diesel generating stations.
- Optimizing the heat recovered from the main generators, which can be used to heat buildings at a northern site. For a diesel generator, the available thermal energy is roughly equal to its electrical output.

An adaptive power setpoint increases system reliability by:

- Making efficient use of the spinning reserve, i.e., the full capacity of high-speed generators, when necessary, such as when a generator at the main generating station fails or to meet additional power demand.
- Ensuring the stability of an off-grid system composed of several electrical generating sites that are kilometres apart. This strategy has been used to distribute loads by radio communication between two generating stations 3 km apart. One generating station operates in isochronous mode, while the other operates in adaptive power setpoint mode.
- Using generators from various manufacturers with different speed control systems that cannot be on the same load-sharing loop.
- Integrating power generation sources with different response times while ensuring appropriate system stability.

High-speed generators are often used during site construction and can be recycled as emergency generating units or as auxiliary power sources. It is worthwhile to keep this equipment and make it part of the permanent power system—a strategy that reduces the cost of building a generating station. For example, the savings for a 20 MW generating station can easily reach $10 million if these generators are used for system redundancy.

The adaptive power setpoint can also be used to control a storage system for an off-grid system. Additionally, this logic can be used beneficially to connect power sources to a public utility system, for example, for peak demand management.

Conclusion

The adaptive power setpoint has been applied successfully to a number of industrial off-grid systems ranging from 2 to 30 MW in output. This advanced control logic made it easier to add a 3 MW wind turbine to a major mining site in Nunavik, reducing annual diesel consumption by over 2,000,000 L.

Similarly, the adaptive power setpoint was used to add three high-speed diesel generators to a system with a main generating station operating with liquid natural gas (LNG) generators. It also optimized generator heat recovery at a main generating station. This logic can be part of the control strategy for smart grids and can be used to integrate storage systems on off-grid systems, including microgrids.

About the Author

Stéphan Landry, P. Eng.
Electrical Engineer
stephan.landry@bba.ca

Stéphan Landry is an Electrical Engineer with over 25 years of experience in high-, medium- and low-voltage power systems in the energy, mining, and oil and gas sectors, as well as in the pulp and paper industry, data centres and airports. He is recognized for his expertise in off-grid and emergency power systems. His versatility, overall vision and vast field experience acquired during years of performance testing and commissioning are a significant asset in performing feasibility studies, master plans and system design.

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