DYNAPOWER

POWERING A CLEANER PLANET™

ENERGY STORAGE MICROGRIDS

Energy Storage Microgrid Benefits

Microgrids are an increasingly attractive alternative to the traditional centralized grid system due to an increased focus on grid resiliency and the proliferation of Distributed Energy Resources (DER). Microgrids are small collections of loads controlled locally by a limited number of DERs, as opposed to large centralized power systems which are operated and controlled from a centralized authority. Large centralized power systems maintain system stability through top down control and the aggregated inertia of the system.

The centralized grid model worked well until the proliferation of DER such as solar, wind, etc. High penetration of grid-connected DER have made the system complicated to control from a centralized authority. Microgrids can help to simplify this by breaking the problem up into discrete components. These discrete components can then be controlled as a microgrid independent of the larger grid.

Controlling the system in this way helps to improve grid resiliency by reducing the impact of faults to finite areas on the grid. Microgrids allow faults to be isolated on one section without impacting the ability of other surrounding microgrids to continue operation. For this reason, ongrid/offgrid microgrids are extremely valuable, especially for critical power systems.

Microgrid energy storage allows operators to actively balance energy on the grid by alternately injecting and absorbing excess power. The method and speed for how the power balance is controlled is the key to microgrid stability.

Challenges to Microgrid Stability

The main challenge of microgrid control is stable operation of what is an inherently low inertia system. While the inertia in the rotors of large synchronous generation slows the rate of frequency change in the large centralized generators, microgrids largely driven by power electronic devices have no inertia. The rate of frequency change will be dependent on the ability of the power electronics to respond to frequency and voltage deviations. Thanks to Dynapower's patented control technology, all Dynapower PCS can quickly and reliably respond to these fluctuations.

Dynapower PCS have years of experience in reliable islanded (offgrid) operation. Our industry-leading speed of response provided by the Dynapower PCS controller maintains microgrid voltage and frequency while minimizing deviations through various microgrid conditions.

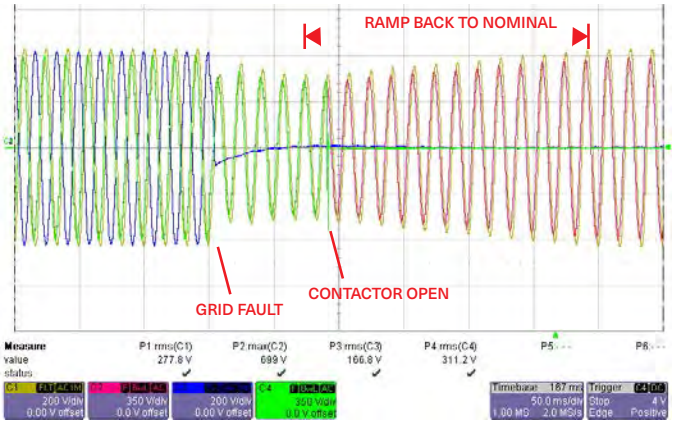

Figure 1: Dynapower's proprietary Dynamic TransferTM from grid tied to islanded microgrid.

Dynapower's Self-Healing Microgrid

Microgrid reliability is impacted not only by the energy storage PCS' ability to maintain a stable power balance between the microgrid's generation and load but also by it's ability to react appropriately to system faults. Faults need to be isolated from the rest of the system to maintain overall operation of the remainder of the systems. Isolation is typically provided by overcurrent protection devices (OCPD) such as breakers and fuses, however these OCPDs rely on an adequate amount of fault current to be provided by the systems sources to trip the OCPD and isolate the fault.

Dynapower PCS are designed to provide fault current in accordance with their overload capability when operating in microgrid mode. When the microgrid's load OCPDs are coordinated with the overload capability of the PCS, the PCS will be able to provide enough fault current to isolate the system fault. Isolation of the fault enables the microgrid to "self-heal" and continue reliable operation.

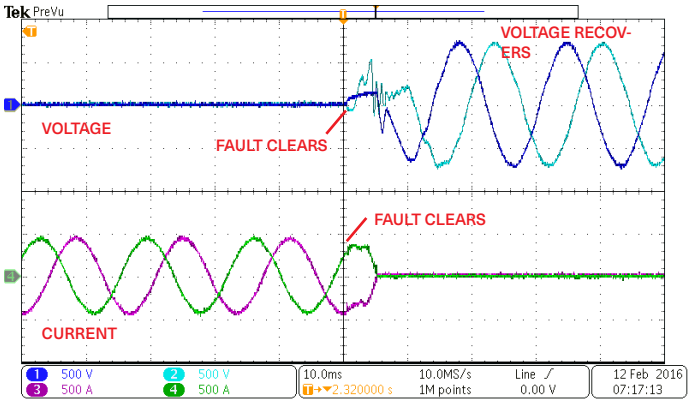

Figure 2: Example of Dynapower's "self-healing" microgrid capabilities.

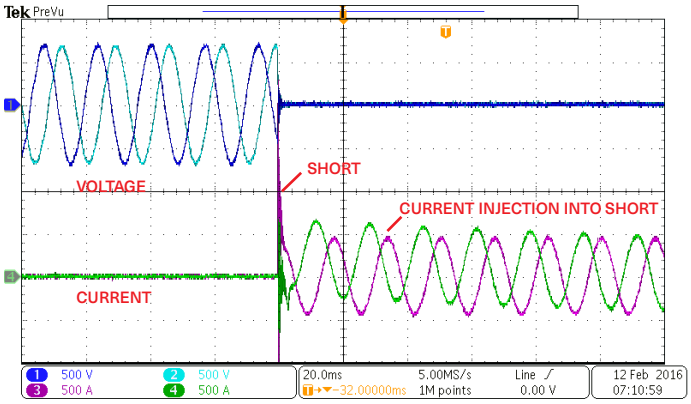

Figure 3: Example of a Dynapower Inverter supplying fault current into microgrid fault.

Step Changes

Step changes in the load in both the positive and negative directions need to be immediately responded to, to maintain system voltage and frequency stability. In a traditional centralized grid, voltage and frequency is maintained through inherent inertia in the synchronous generation and very small load steps relative to the overall size of the centralized generator. In a microgrid enabled by power electronics, there is low inherent inertia in the system and the load steps can be very high relative to the power electronic enabled DER.

Dynapower's Microgrid mode features high speed controls that are capable of servicing load steps of up to 100% rated power in under 8ms. The high speed of response enables the Dynapower PCS to maintain stable operation of the microgrid through controlled injection and absorption of Real and Reactive current, minimizing the impact seen by the microgrid system loads.

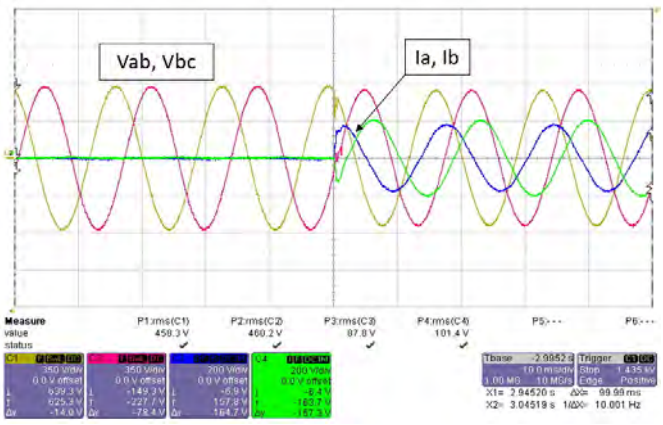

Figure 4: Example of Dynapower PCS step response.

Load Imbalance

PCS used for grid-tied energy storage are typically sized and controlled for balanced three-phase operation. While this is desirable in grid-tied operation in microgrid operation the use of single phase loads will require the PCS to provide unbalance current to maintain system stability. Dynapower PCS are capable of supplying up to 100% phase current imbalance. This results in the PCS being able to support one phase of the system being loaded up to 100% of its rating while the other 2 phases are unloaded.

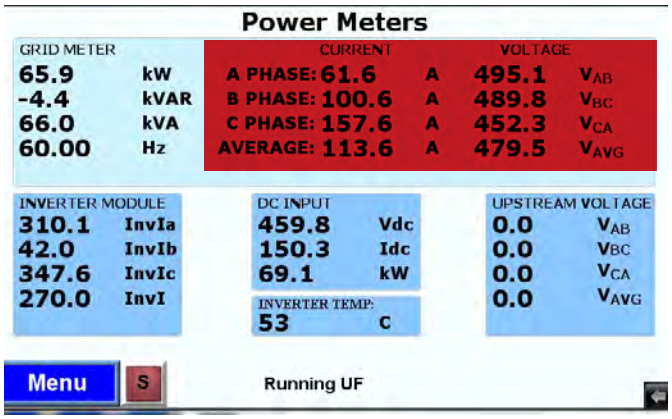

Figure 5: Example of load imbalance (in red).

Managing Inrush Currents

Upon startup the magnetizing currents seen by transformers and motor loads can be many multiple times the steady state load of the motor or transformer. In microgrid mode the power electronic enabled DER will be required to provide the high initial current from these loads. PCS not sized to support this high current requirement will not be capable of starting a microgrid with this common type of load.

Dynapower's patented Black Start capability, enables Dynapower PCS to support high startup currents to start a microgrid after a blackout. To do so, Dynapower's Black Start ramps the microgrid voltage and frequency to mitigate the high inrush magnetizing currents. This soft start of the system means the inverter will not have to be sized to support the high inrush currents, while still enabling the microgrid system to start the microgrid. By using settable ramping limits Dynapower PCS can Black Start any type of transformer load, making it distinctive in the marketplace and providing unique value to microgrid operators.

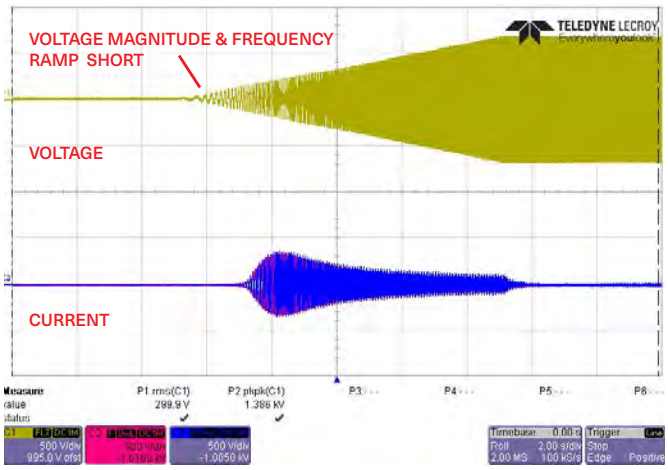

Figure 6: Example of Dynapower's proprietary Dynamic Transfer from grid tied to islanded microgrid.

Control of Multiple DER

Control of a small microgrid with a single PCS is simple with one system supplying power and controlling the voltage and frequency of the microgrid. As microgrids grow larger, a single system may not be large enough to fully service the load of the microgrid and will require multiple power electronic enabled DER.

With multiple DER deployed on the same microgrid these power electronic devices must communicate reliably and efficiently so the multiple DER systems can work together to maintain overall voltage and frequency stability of the microgrid.

Coordination of these DER resources needs to be done fast, to maintain system stability while limiting the amount of communication infrastructure to minimize overall system cost.

Dynapower PCS can be configured to run microgrids with multiple parallel Dynapower PCS as well as other forms of DER. Unit to unit communication for load sharing is accomplished with frequency and voltage droop on the microgrid system minimizing any need for unit to unit communication infrastructure. This balanced control through Dynapower PCS not only ensures the reliable operation of micogrids with multiple DERs, it reduces costs for microgrid installers and increases reliability for systems owners.

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