

LABORATORY SCALE MICROGRID TEST BED – PART I HARDWARE IMPLEMENTATION

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A microgrid is essentially an active distribution network encompassing different distributed energy resources (DER) and various loads at distribution voltage level. From an operational point of view, DERs need to be equipped with power electronic interfaces for control, to provide the required flexibility which ensures its operation as a single aggregated system and to maintain the specified power quality. This control flexibility would allow the microgrid to present itself to the main utility power system as a single controlled unit that meets local energy need for reliability. The main advantage of a microgrid is that it is treated as a controlled entity within the power system. It can be operated as a single aggregated load or a source.

A significant aspect that needs to be considered for power system planning and operation, is that reliability is challenged more in a microgrid environment. This is because: (1) renewable energy resources usually have low capacity factors as well as low correlation with the load profile; (2) there is a mismatch between forecast generation and the actual value generated; (3) transmission and distribution congestion are also critical. In order to participate in the power market in a cost effective way, load management and demand response on the customer side is necessary. While DERs provide a relatively clean power supply to end-users, a seamless integration of the DERs and the utility grid also becomes important. More important is the fact that when faults take place in a microgrid, a proper scheme of protection and control is necessary to ensure the safety of both users and the utility providers. These operational scenarios and more could be evaluated on a test-bed before implementation in a real-life microgrid network. A single line diagram for the laboratory scale microgrid test-bed implemented at Penn State Harrisburg is shown in Figure 1.

The Microgrid test bed is based on IEEE 1547 which serves as an interconnection standard. This standard focuses on the technical specifications for and testing of the interconnection itself. It provides requirements relevant to the performance, operation, testing, safety considerations and maintenance of the interconnections. It includes general requirements, response to abnormal conditions, power quality, islanding and test specifications and requirement for design, production, installation evaluation, commissioning and periodic tests. The stated requirements are universally needed for the interconnection of a distributed resource, including synchronous machines, induction machines and power inverters/converters and would be sufficient for most installations. These criteria and requirements are applicable to all DER technologies with aggregate capacity of 10MVA or less at the point of common coupling, interconnected to electric power systems at the typical primary and /or secondary distribution voltage. By developing a test bed based on the norms of IEEE 1547, efforts can be made to study the impact of interconnecting DER with the electrical grid. Certain technical specifications like voltage and frequency regulation, clearing of faults, etc. could be studied with the aid of this test-bed. These are the key goals for developing such a test-bed in the research laboratory, though on a smaller scale

The following areas of research are targeted with the test bed setup:

1. Integration of distributed energy sources, including renewable resources such as wind, solar, fuel cells, etc. in power generation and their control structure.
2. Intelligent protection schemes and their application in detecting, mitigating and preventing cascading outages, islanding situations and total grid blackout occurrences.
3. Creating new microgrid solutions for residential and industrial applications.
4. Intelligent real time demand side management based on renewable energy uncertainty.

The total power capability of the test bed is over 12kW from AC, renewable and storage capability. This test-bed uses laboratory scale components in addition to industrial grade hardware to model the realistic behavior of a large power system. The architecture of the test-bed is an excellent base, not

only for innovative research ideas, but also for teaching general power system concepts. This test-bed is especially important given the possibility of the addition of more renewable resources. The architecture proposed serves to meet several essential criteria of a microgrid with the following specifications:

1. Voltage regulation, ANSI C 84.1-1995 Range A. i.e. at $120V \pm 5\%$.
2. Frequency of operation of the microgrid within 60.5 Hz to 59.3Hz.
3. Synchronization with the following conditions: $\Delta f = 0.3$ Hz, $\Delta V = 10\%$ and $\Delta \phi = \pm 20\%$
4. Islanding: Normal operation of the microgrid remains undisturbed at times when the microgrid islands itself from the Utility. The microgrid should have ability to maintain voltage and frequency within the norms, at times when it is operating in an islanded mode.
5. Protection: Faults that occur within a microgrid has to be cleared within the microgrid itself and faults that occur outside the microgrid should not affect the operating units within a microgrid.

SINGLE LINE DIAGRAM
PENN STATE HARRISBURG MICROGRID TEST BED

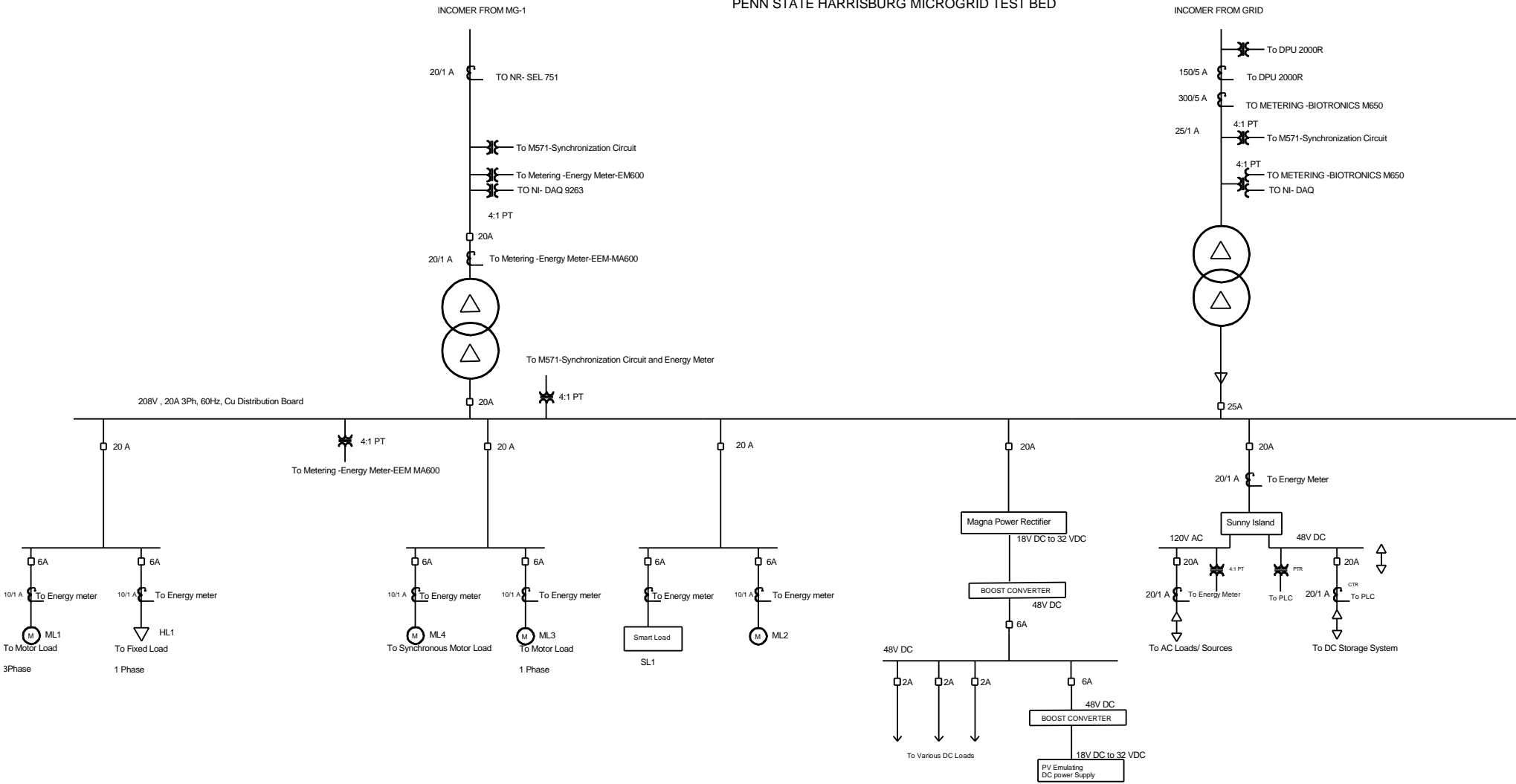


Figure 1. Microgrid Test Bed Single Line Diagram

Microgrid Test Bed at PPL Power Lab, Penn State Harrisburg



Figure 2. Microgrid Control Center



Figure 3. Right View of Microgrid Test Bed

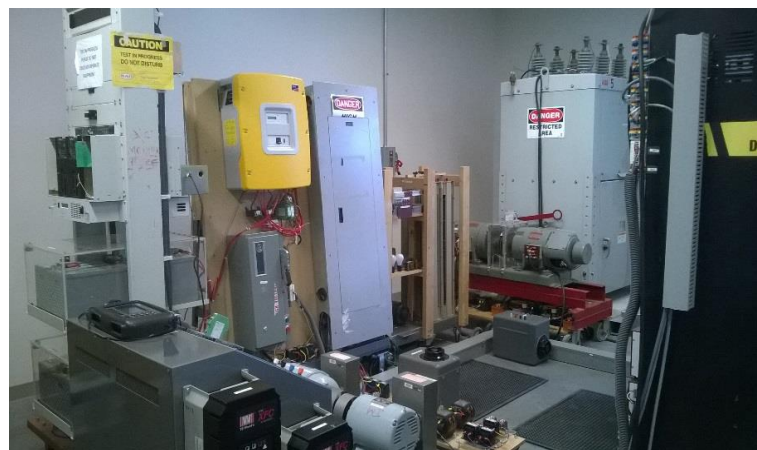


Figure 4. Left View of Microgrid Test Bed