Developing Benchmark Models for Studying the Integration of Distributed Energy Resources

Kai Strunz
SESAME Laboratory, Department of Electrical Engineering
University of Washington, Seattle, WA 98195-2500, USA

Abstract— **The widespread use of distributed energy resources (DER) relies on methods and techniques aimed at facilitating the network integration of DER. In this context a methodology for the evaluation of the quality and relative merits of these methods and techniques is missing. CIGRE Task Force C6.04.02, which is affiliated with CIGRE Study Committee C6, has addressed this problem. A set of resource and network benchmarks is proposed in order to model a wide spectrum of real-world DER integration problems and to create and evaluate solutions to these problems. In the present paper, the development of these benchmarks is introduced.**

Index Terms— **Benchmarking, distributed generation, distributed energy resources, power system modeling, power system simulation.**

I. Introduction

Due to the strong growth of market share of distributed energy resources (DER), today's electric power system of centrally located generation, transmission networks and distribution networks is expected to evolve into an infrastructure where small-scale distributed energy resources and loads, connected through local microgrids, are common. The success of such drastic transformation will heavily rely on the availability of methods and techniques that enable the economic, robust, and environmentally responsible integration of DER. Due to the importance of DER, industry, universities, and research institutes all over the world are actively engaged in research and development. What is missing, however, are accepted platforms that allow for the studying and testing of the methods and techniques resulting from this research and development. This problem is dealt with by CIGRE Task Force (TF) C6.04.02. It is the vocation of this TF to establish a common basis in the form of benchmark systems for DER integration studies.

II. Methodology

The CIGRE HVDC benchmark model, which is aimed at creating a common reference for HVDC control studies, was discussed in [1]. While the topology of an HVDC system is quite well defined, distributed energy systems are more diverse. For studies of distributed energy systems it is therefore not possible to define one single benchmark that fits all needs. To cover the spectrum of DER studies in a collectively exhaustive and mutually exclusive manner, a DER benchmarking methodology that comprises a set of benchmark configurations was developed.

Central to the methodology is the hierarchical structure of four levels depicted in Fig. 1. There is a generalization-specialization hierarchy between any two levels. Starting from the highest level, the electric power system, specializations are carried out until levels of detail that are of interest for DER benchmarking are reached. At the same time it is made sure that at any one level the entries are mutually exclusive and collectively exhaustive.

The electric power system is described by the underlying network and the resources connected to its nodes. A resource node is by itself an interesting candidate for a benchmark since many of the techniques for the integration of DER rely on source side control and power electronic conversion. Further specialization is needed for the network. It can be distinguished between transmission and distribution networks. The latter can vary significantly in their characteristics depending on whether rural or urban types are considered. Together, low-voltage (LV) urban distribution, medium-voltage (MV) rural distribution, and high-voltage (HV) transmission networks represent a suitable set of candidates for DER benchmarking.

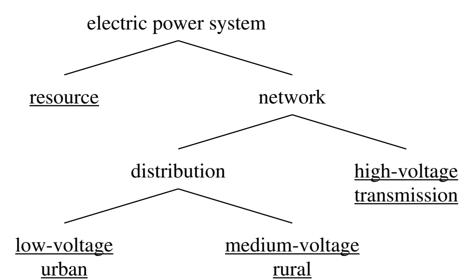

Fig. 1. Hierarchy with DER benchmark systems underlined

III. DER Benchmark Systems

In what follows, the individual DER benchmark systems and their applications are discussed.

A. DER Benchmark Resource

The benchmark resource is depicted in Fig. 2. It comprises one AC bus to which at least one DER module and a grid equivalent are connected. The DER module is of the topology introduced in [2]. Over a DC bus, source, diverse but complementary types of storage, and local load modules are connected to a DC/AC interface module. The storage modules are of particular interest when the sources are of stochastic input. The access-oriented storage is suitable for the compensation of fast power fluctuations. Examples of instantiations of the access-oriented storage are the flywheel or the super capacitor. The capacity-oriented storage is well-suited for storing large amounts of energy. Examples of instantiations are battery or hydrogen storage systems. It can be seen that switches have been inserted to enable the study of different configurations. If for example the study of storage and local loads on the DC bus is not desired, then switches S1, S2, and S3 are opened.

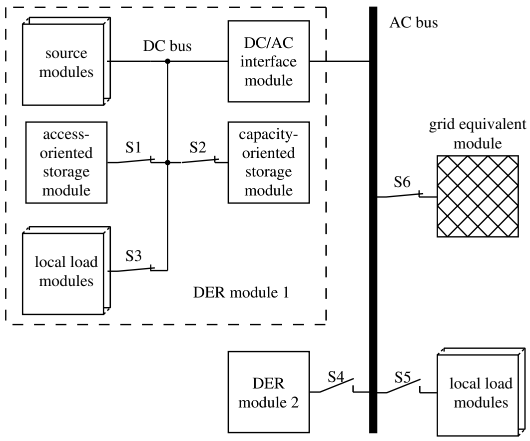

Fig. 2. DER benchmark resource

While this benchmark is suitable for the study of controls and power electronic conversion of a single DER source, it is also possible to study the interaction with another DER source. This is achieved by closing switch S4. An example for a study of interaction between DER sources is for example given in [3].

B. DER Benchmark Networks

As discussed above, three benchmark networks are established in order to deal with studies that are mainly concerned with the network side of DER integration. These studies include but are not limited to the analysis of the impact of diverse DER on the power flow, voltage profile, stability, power quality, reliability, as well as the application of methods and techniques of energy management, control, and protection.

As an example of a benchmark network, the topology of the DER medium-voltage rural distribution benchmark network is shown in Fig. 3. This benchmark is derived from a test network presented in [4]. At all nodes, loads are connected. DER can be added at any node. Two subnetworks can be recognized. Subnetwork 1 has rural character and supplies a small town and the surrounding rural area. Subnetwork 2 is added by closing switch S2. Closing both switches S1 and S2 allows the optional study of an MVDC coupler.

The other two DER benchmark networks deal with the integration of DER in transmission and low-voltage urban distribution networks, respectively. The DER high-voltage transmission benchmark network serves mainly studies of integration of wind farms. The DER low-voltage urban distribution benchmark network, which is discussed in [5], is suitable for the study of integration of DER at lower power levels.

In order to support a wide use of the benchmark networks, the associated parameters will be provided in the per unit system together with suggested base values for different geographic regions. Further regional adaptations are made based on feeder characteristics. For example, for the European version of the DER low-voltage urban distribution benchmark network, three-phase feeders are assumed in residential areas. For the North American version, however, single-phase configurations are assumed for the same feeder.

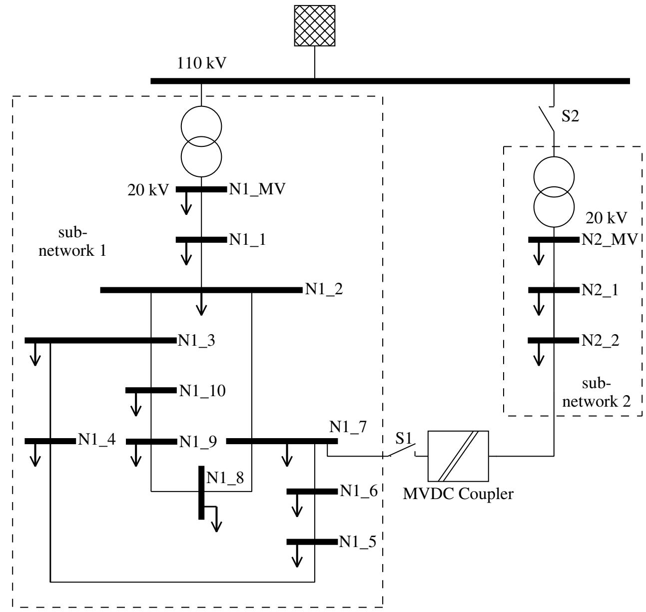

Fig. 3. DER medium-voltage rural distribution benchmark network, modified from [4]

IV. Conclusions and Outlook

This short paper can only give a brief overview of the activities of Task Force C6.04.02. A detailed report on the results will be published in the form of a brochure. This brochure will contain a thorough description of all benchmarks and discuss the applications of the latter.

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References

[1] Working Group 14.02 (Control in HVDC Systems) of Study Committee 14. The CIGRE HVDC benchmark model — a new proposal with revised parameters. *ELECTRA*, (157):60–66, December 1994.

[2] K. Strunz and E. K. Brock. Hybrid plant of renewable stochastic source and multi-level storage for emission-free deterministic power generation. In *CIGRE/IEEE PES International Symposium on Quality and Security of Electric Power Delivery Systems*, Montreal, Canada, October 2003.

[3] S. Barsali, M. Ceraolo, P. Pelacchi, and D. Poli. Control techniques of dispersed generators to improve the continuity of electricity supply. In *IEEE Power Engineering Society Winter Meeting*, New York, USA, January 2002.

[4] B. Buchholz, H. Frey, N. Lewald, T. Stephanblome, and Z. Styczynski. Advanced planning and operation of dispersed generation ensuring power quality, security and efficiency in distribution systems. In *CIGRE 2004 Session*, Paris, France, August/September 2004.

[5] S. Papathanassiou, N. Hatziargyriou, and K. Strunz. A benchmark low voltage microgrid network. In *CIGRE Symposium on Power Systems with Dispersed Generation*, Athens, Greece, April 2005.