Benchmark Systems for Network Integration of Renewable and Distributed Energy Resources

Members

Convener Kai Strunz (DE), Ehsan Abbasi (DE), Chad Abbey (CA), Christophe Andrieu (FR), Udaya Annakkage (CA), Stefano Barsali (IT), Ryan C. Campbell (US), Robert Fletcher (US), Feng Gao (CN), Trevor Gaunt (ZA), Ani Gole (CA), Nikos Hatziargyriou (GR), Reza Iravani (CA), Géza Joos (CA), Hiroo Konishi (JP), Maren Kuschke (DE), Erkki Lakervi (FI), Chen-Ching Liu (US), Jean Mahseredjian (CA), Farid Mosallat (CA), Dharshana Muthumuni (CA), Antje Orths (DK), Stavros Papathanassiou (GR), Krzysztof Rudion (DE), Zbigniew Styczynski (DE),Suresh C. Verma (JP)

Introduction

Renewable and Distributed Energy Resources (DER) as well as smart grid technologies are key drivers in the future development of an efficient electric power system. The successful transition relies on the availability of methods and techniques that support the integration of DER. Missing in this context was an accepted platform that supports the analysis and testing of those methods and techniques. TF C6.04.02 has recognized this problem and proposes a common platform as the basis for DER integration studies with international reach.

Scope and Methodology

Establishing a common basis for testing DER integration poses a challenge resulting from the diversity of distributed energy systems. TF C6.04.02 addressed this problem by developing a structured set of benchmarks that cover the spectrum of DER integration issues in a mutually exclusive and collectively exhaustive manner. Following the hierarchy developed in Figure 1, an electric power system consists of nodes with resources including DER and the interconnecting network. A nodal resource is by itself an interesting candidate for a benchmark since many techniques for the integration of DER rely on source-side control and power electronic conversion. On the network side, transmission and distribution networks are distinguished. Distribution networks heavily vary depending on whether medium or low voltage levels are considered. Together, the underlined ends of the tree-like hierarchy of Figure 1 represent a suitable set of candidates for developing benchmark systems for integration of renewable and distributed energy resources.

Description of the TB

Following the introduction in Chapter 1, the DER benchmark modeling methodology is introduced in Chapter 2. An overview of the scope of application of the benchmarks for practical studies is given in Chapter 3. For clarity, the applications are categorized into the following classes: operation and control, planning and design, power quality, protection, and stability. Within these classes, the scope is elaborated further. In Chapter 4, the so-called resource benchmark aimed at the study of source-side solutions to DER network integration is introduced. The high voltage (HV) transmission network benchmark for wind farm integration is developed in Chapter 5. The medium voltage (MV) distribution network benchmark for DER integration is described in Chapter 6. The low voltage (LV) distribution network benchmark is discussed in Chapter 7. In Chapter 8, case studies are performed. The appendix is devoted to more in-depth background information.

For each benchmark, European and North American versions were developed. The European design of three-phase delta-connected MV distribution systems of typically 11 kV or 20 kV was originally developed and popular for servicing dense urban loads in the cities of Europe. In contrast, North America has utilized a three-phase four-wire distribution MV system of typically 12.47 kV or 24 kV and was first designed to serve widely spaced rural farms. These differences have been accounted for in the development of the benchmarks. As an example, the topology of the European version of the MV distribution network benchmark is shown in Figure 2. Framed by dashed lines are Feeders 1 and 2. Feeder 1 represents an •••

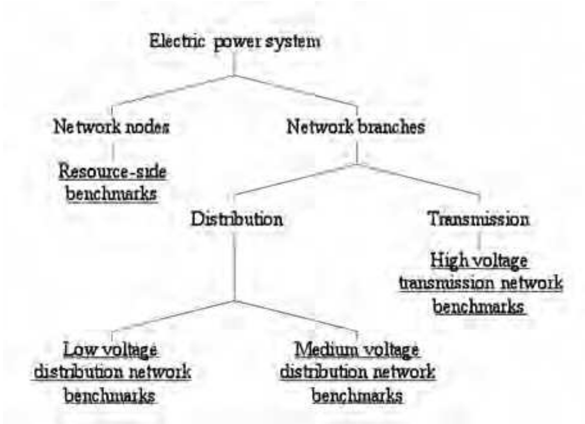

Figure 1: Hierarchy for identifying DER integration benchmarks

urban area. Feeder 2 with the longer distances between the nodes indicates a rural area. Both feeders operate at 20 kV and are fed via separate transformers from the 110 kV sub-transmission system. Either feeder alone or both feeders can be used for studies of DER integration. Further variety can be introduced by means of configuration switches S1, S2, and S3. If these switches are open, then both feeders are radial. Closing S2 and S3 in feeder 1 creates a loop or mesh. With the given location of S1, it can either be assumed that both feeders are fed by the same substation or by different substations. Closing S1 interconnects the two feeders through a distribution line.

After describing the topology, the Technical Brochure (TB) gives details on geometries of overhead lines and underground cables using figures and tables. The equations relating the geometries and the parameters are explained. Furthermore, conductors, transformers, and loads are specified in detail. After offering these details, an extra section is devoted on how to customize the parameters for other network conditions. Thus, it is possible to take the parameters as they are readily listed or to adapt them according to study needs.

The strict hierarchy of Fig. 1 supports the combination of the benchmarks. The primary sub-transmission HV system shown at the top of the MV distribution network benchmark in Figure 2 gives the possibility to connect with the HV transmission network benchmark. The load points in turn allow for connection to the LV distribution network benchmarks. The European version of the LV distribution network benchmark is shown in Figure 3. Residential, industrial, and commercial feeders are distinguished. As for the MV level, comprehensive details on all parameters and pathways for customization are given in the TB. The North American version of the LV distribution network benchmark differs significantly for its usage of •••

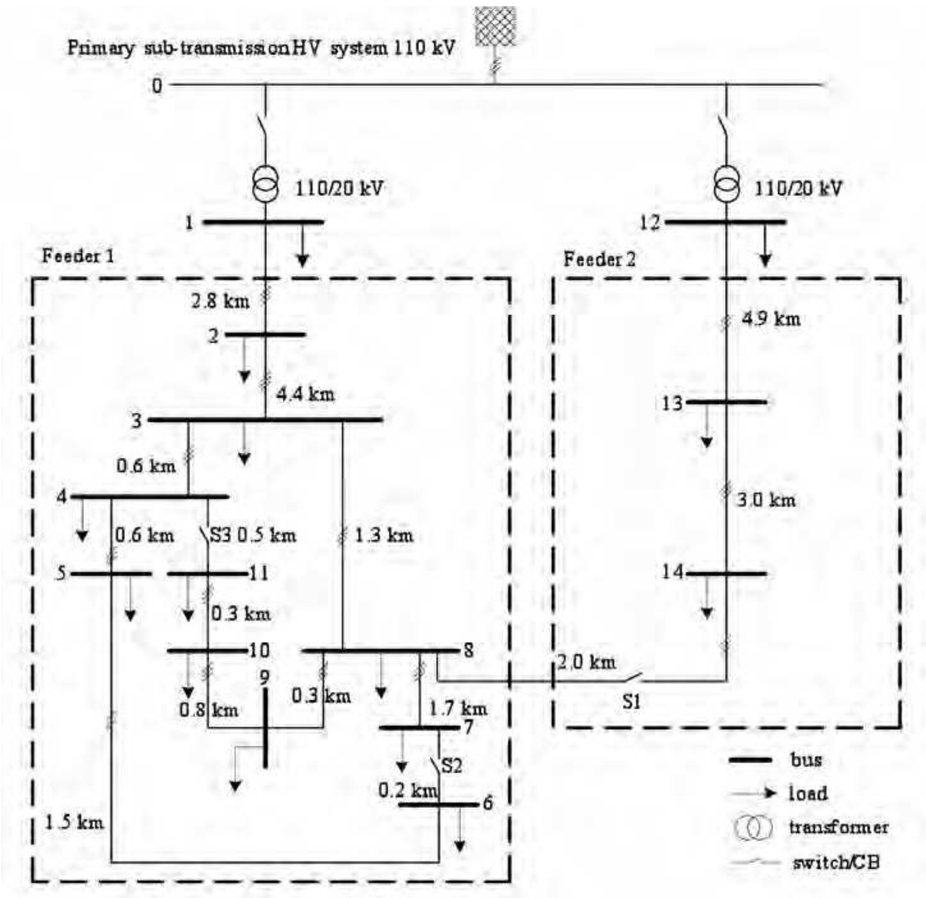

Figure 2: Topology of European MV distribution network benchmark

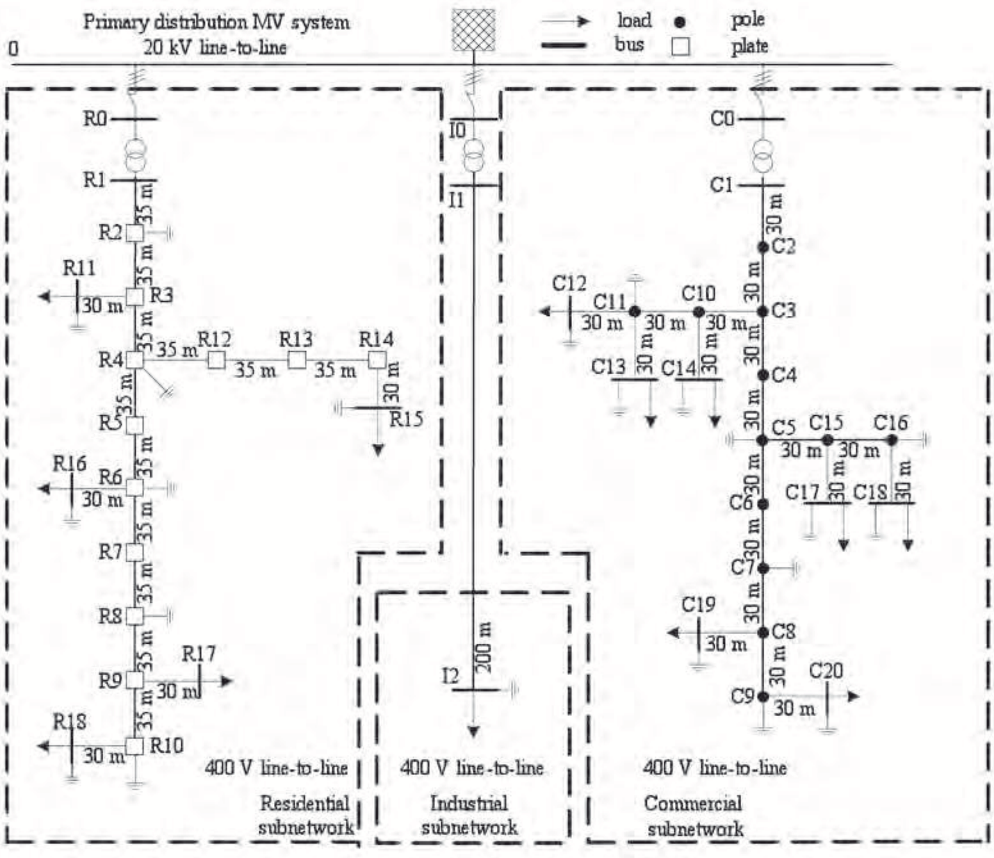

Figure 3: Topology of European LV distribution benchmark network

single-phase networks and the way customers are connected. The differences are accounted for and are specified.

Conclusions

Beyond the presentation of the whole suite of benchmark systems from the high voltage to the low voltage level, the TB covers the application of the benchmarks for practical studies. The examples include the co-ordinated control of distributed energy storage, fault-ride-through testing, energy management evaluation, power electronic converter control testing, planned islanded operation, and power flow analysis. Different types of modeling and simulation tools were used for those studies.

The application of the benchmark systems goes far beyond the examples given above. Early users praise the modularity of the methodology allowing the connection, the comprehensiveness of the given data, the guidance offering flexibility of customization, and the adaptation to the different situations of Europe and North America. These hallmarks make the benchmarks valuable assets for the entire community interested in the network integration of renewable and distributed energy resources. ■