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Communication for battery energy storage systems compliant with IEC 61850

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ABSTRACT

This paper examines the development and implementation of a communication structure for battery energy storage systems based on the standard IEC 61850 to ensure efficient and reliable operation. It explores this standard's capability to define suitable data exchange with battery energy storage systems and the feasibility of implementation in the field. It also analyzes the extent to which standard IEC 61850′s information model and defined interfaces suffice to ensure communication that enables full integration of a battery energy storage system in an electrical (smart) grid. A data model compliant with the standard is developed and subsequently tested in prototype implementation among a control center, photovoltaic system and battery energy storage system.

1. Introduction

The decentralization and increase of system components and their functions in the electrical grid necessitates coordinating a multitude of actors [1–3]. The continuous exchange of extensive information is essential to ensuring stable grid operation [4–6]. Since the communication protocols employed at present are often no longer up to the job, they either have to be modified or replaced [7,8]. The differences in proprietary protocols make it necessary to configure and operate gateways, which is time-consuming, costs money and increases the complexity of a communication system [9,10] and raises the need to apply more innovative standards like IEC 61850. This standards also ensures a higher level of interoperability among intelligent electronic devices (IEDs) and their interchangeability [11–14] (See Fig. 1).

Communication with a battery energy storage system or BESS that is compliant with this protocol is not yet state-of-the-art but will be necessary in the future [15–17]. The steady growth of (private) photovoltaic (PV) systems in recent years makes the idea of a BESS interesting since PV systems' production of electricity is highly volatile [18,19]. Large quantities of generated electricity can be stored and retrieved anytime too little power is produced [20]. Such a scenario can only be implemented when data is exchanged properly among a BESS, PV system and control system [21].

First, applicable communication standards are investigated and especially the usage of IEC 61850 as the most innovative standard for power system communication is analyzed according to the needs for BESS (Section II). Based on relevant use cases (Section III), described in this paper, the necessary data exchange model is compared with the capabilities of the IEC 61850 standard. Necessary future extensions to that standard are derived from this analyzes (Section IV).

To show, that the developed concepts are working, a proof-of-concept is performed, realizing a chosen concept with a real BESS (Section V). The findings are shown in Section VI

The results and conclusions are summarized in Section VII.

2. Basics and state-of-the-art

2.1. Smart grid

Since definitions of "smart grid" often focus on different factors, none is standard [22]. All existing definitions stress the integration of different components, e.g. renewable generation structures, storage systems and loads, in the existing electrical grid and their interconnection by means of information and communications technologies. The number of PV systems has grown steadily in recent years, primarily among private residences. Wind farms, especially off-shore wind farms, have also grown dramatically in number [23]. Development toward a distributed generation structure will continue in the future [24]. Such a grid structure and enabled demand management necessitate control of the electrical grid and remote monitoring and control of systems [25]. A smart grid can thus be described as an electrical grid that allows the integration renewable energies, thus ensuring high security of supply for demand in the grid [26].

Moreover, smart grids employ so-called intelligent electronic

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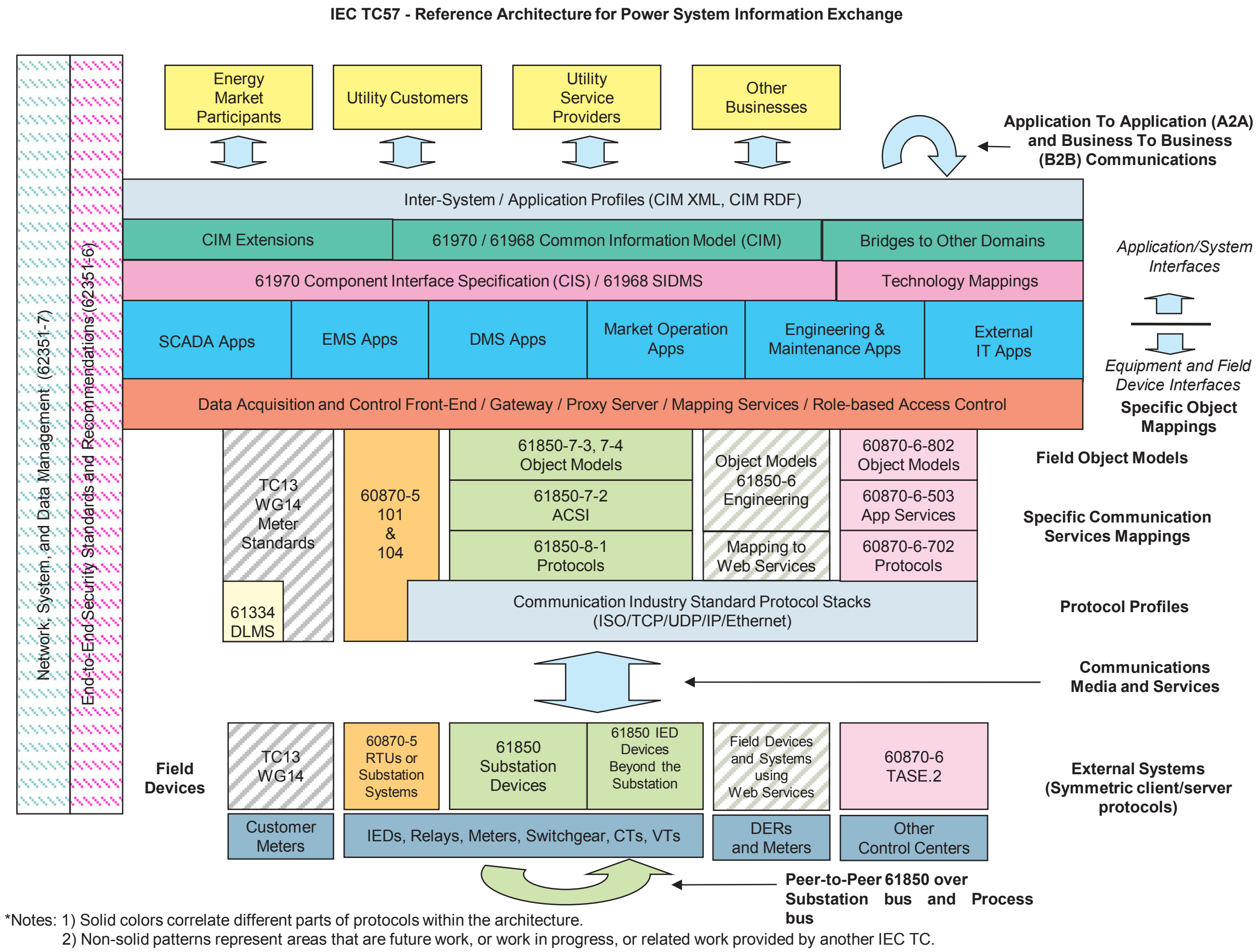

Fig. 1. Current reference architecture for power system information exchange [33].

devices or IEDs [28]. These electronic devices use microprocessors to perform different calculations and not only interface with different communications technologies but also store data such as measurements locally [29]. Regardless of their size and capacity, distributed energy resources (DER) such as BESS are normally also equipped with an IED for control and monitoring [30]. In this paper, a BESS consists of an actual energy storage system, electronic monitoring equipment (battery management system) and hardware and software for grid communication.

A smart grid therefore consists of different distributed systems, controllable IEDs and control structures, and communications technologies that exchange data and information. Communication protocols defined in pertinent standards are essential to enabling the requisite information exchange. IEC 61850, presented in Fig. 4, is one such standard developed for future tasks in electrical grids.

2.2. IEC 61850

Development of the series of IEC 61850 standards “Communication Networks and Systems in Substations” commenced in 1995. Going into effect in 2004, they are intended to supersede proprietary signal-oriented protocols and the standard IEC 60870 in particular in substation automation and to improve interoperability among different manufacturers’ devices [27].

The series of IEC 61850 standards not only specifies a communication protocol but also defines a generic object data model, a description language for the configuration of IEDs, and other information models [28]. Since object-orientation was relied on here for the first time and the semantics of the respective data is specified, the data model is distinctive and something not found in prevalent protocols. Thus not only number codes and values but also the specific meaning are transmitted [29]. Unlike object-orientation found in object-oriented programming (OOP), the data are organized in tree structures, which, in turn, produce a tree data model.

Standard IEC 61850′s information exchange chiefly builds upon a well-defined information model, which can be considered the heart of the standard IEC 61850. It defines information and semantics regardless of the concrete implementation [30,31]. Concrete objects are inferred or instantiated from this generic model depending on the project plan. Objects and thus different devices and IEDs are also described with the description language SCL defined in the standard [32].

The data model is organized hierarchically out of logical devices (LD), logical nodes (LN), data objects (DO) and data attributes (DA), as in Fig. 2. A physical device (IED) can operate as server and as client. IEDs exchange data and call services reciprocally, depending on their use. Communication is thus peer-to-peer. An IED can have several LDs, which, in turn, consist of several LNs that constitute the containers for functional data. LNs encapsulate the different functions and contain essential data according to function. These DOs, in turn, are grouped into common data classes (CDCs), which contain the different attributes. The attributes contained by a CDC are additionally divided into functional groups (functional constraints), e.g. status information (ST) or configuration (CF). Since they contain the individual standard data and semantics, CDCs are especially important for interoperability. Finally, the attributes encapsulate the actual data points, basic data types, and settings and controls [31].