Assessment of a MACsec-based security system for use in critical Infrastructure Communication

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***Abstract*—Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet.**

***Index Terms*—MACsec, IEC61850, IEC62351, GOOSE, Secure Communication**

I. Introduction

Companies that are classified as critical infrastructure as for example water supply facilities, power plants and their corresponding distribution systems, can constitute a vulnerability which may be exploited to disrupt the supply of basic resources to entire countries. For this reason, laws such as the Network and Information Security Act (NIS-2) [1] of the European Union or the IT Act 2.0 [9] of the German Federal Office for Information Security (BSI) demand a unified level of cybersecurity for these entities. In these regulations, the councils prescribe that the companies will be required to implement security features to detect and prevent intrusions, as well as remove faults caused through intrusion attempts during system runtime. [9, §11 (1d)] Additionally the extension of this paragraph dictates, that these companies are obliged to provide proof of compliance with the safety requirements in a two year period. [9, §11 (1e)] This decision is intended to ensure the future working of the security systems with respect to adapting changes of the latest technologies.

This paper evaluates the currently established implementation of protection systems securing communication in Substation Automation Systems (SASs) and thereby provides a brief overview of the communication standard used in these facilities. Following this we propose a Media Access Control Security (MACsec) based security system with the security goals set for these applications. The further course of the paper is structured as follows: Chapter III displays relevant information presented by related works assessing the current state of technology in this topic. Chapter II-A provides a general overview of the IEC 61850 communication standard and the associated IEC 62351 safety standard with special focus placed on the different message types and their respective protection. Chapter IV explains the test setup used to measure the efficiency of the MACsec-based security system. Lastly the data gathered from this is then evaluated in chapter V.

II. Background

A. Overview of the IEC 61850 Standard

Among other standards used for communication is industrial applications, power systems primarily utilize the IEC 61850 standard [3], which is published and maintained by the International Electrotechnical Comission (IEC) [5]. This standard specifies the transmission of diagnostical information, measurement values or control signals among devices structured in a three level architecture [7], as displayed in Figure 1. The major advantage here consists of the object-oriented data structure defined in this standard, which makes the integration of various components developted by different vendors possible [2, p. 5643].

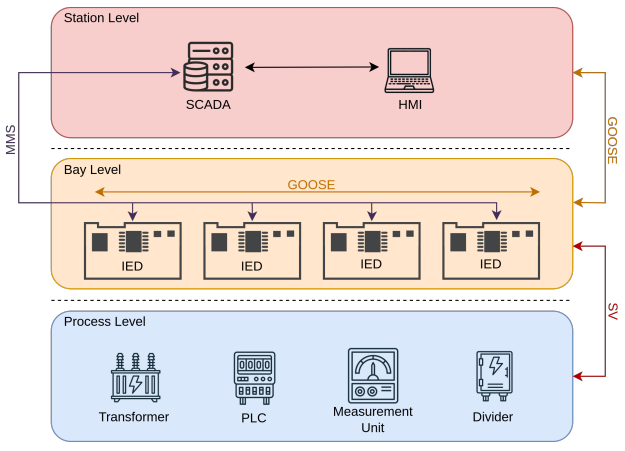

Fig. 1. Overview of the three architecture levels in IEC 61850 [7]

At the lowest point, the process level contains devices tasked with the actual power management. Examples for these are: transformers, circuit breakers, Programmable Logic

Controllers (PLCs) and measurement units [7]. Upon configuration, Process Level components periodically publish measurement information to the subscribing communication partner in the Bay Level via Sampled-Value (SV) packages [8].

The devices located in the Station Level

B. Fundamentals of the MACsec Security Standard

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III. Related Works

To assess the operating principal of a MACsec-based security system in IEC 61850 compliant communication it is necessary to understand both the working method of the communication inside a substation as well as the corresponding functionality of the MACsec security standard. The following related works display these important aspects and are therefore relevant for the implementation of an experimental set up for MACsec secured industrial communication.

Mackiewicz [5] describes the overall usage of the IEC 61850 protocol by displaying key features as well as the general aspects of IEC 61850 compliant communication. Since this standard represents a core part of the communication inside of power grid systems, it is vital to understand the corresponding aspects such as communication paths, model structures or data addressing in order to design a representative test environment.

Hussain *et al.* [2] published a paper assessing the IEC 62351 standard and its security mechanisms towards IEC 61850 compliant messaging. The publication initially describes the basic values and security goals of the safety standard and, building on this, which attacks can potentially be carried out on IEC 1850 messages to manipulate the internal workings of a SAS. At this point the paper primarily focuses on the Ethernet-based message types Generic Object Oriented Substation Event (GOOSE) and Sampled Values (SV) and the associated decision not to encrypt them due to strict time delivery requirements.

Moreira *et al.* [6] evaluate various approaches to introduce cyber security in SASs. Initially, a brief outline of the communication structures in substations is presented. Building on this, various established security approaches are explained and evaluated based on the protection objectives of the IEC 62351 standard. The authors also point out possible implementation problems, such as incompatibilities between the security systems and the communication protocols or the handling of redundant packets inside ring-topology networks. In the further course of the paper, they present the idea of MACsec based communication security in SASs and the and the associated advantages and challenges that arise with it.

Lackorzynski *et al.* [4] proposed modifications of the IEEE 802.1AE standard to improve MACsec for usage in industrial applications. In particular, the fragmentation of Ethernet frames was considered. This procedure is necessary, if messages exceed the Maximum Transmission Unit (MTU) and are thus possibly discarded by the recipient of the message. The presented implementation ensures this parameter and spits messages into multiple frames, if it is exceeded. Additionally the authors discuss the usage of different cipher suits instead of the `AES-GCM 128/256` specified in the MACsec standard. The evaluation of their study shows that the ChaCha20-Poly1305 cipher is a promising alternative for industrial applications.

Building on the findings of Moreira [6] and Lackorzynski [4] we formulate the evaluation of MACsec carried out for use in substations and other power systems based on the IEC 61850 standard. Along with this, we discuss the advantages and disadvantages of MACsec in comparison with the security goals of the IEC 62351 standard based on our findings.

IV. Implementation

V. Evaluation

VI. Conclusion

References

[1] Council of European Union. *Directive (EU) 2022/2555 of the European Parliament and of the Council of 14 December 2022 on measures for a high common level of cybersecurity across the Union, amending Regulation (EU) No 910/2014 and Directive (EU) 2018/1972, and repealing Directive (EU) 2016/1148 (NIS 2 Directive)*. L 333, p. 80. Dec. 2022.

[2] S. M. Suhail Hussain, Taha Selim Ustun, and Akhtar Kalam. "A review of IEC 62351 security mechanisms for IEC 61850 message exchanges". In: *IEEE Transactions on Industrial Informatics* 16.9 (2019), pp. 5643–5654.

[3] *IEC 61850:2023 SER Series – Communication networks and systems for power utility automation – ALL PARTS*. International Standard. Geneva, CH: International Electrotechnical Comission, 2023.

[4] Tim Lackorzynski et al. "Enabling and optimizing MACsec for industrial environments". In: *IEEE Transactions on Industrial Informatics* 17.11 (2020), pp. 7599–7606.

[5] Ralph E Mackiewicz. "Overview of IEC 61850 and Benefits". In: *2006 IEEE Power Engineering Society General Meeting*. IEEE. 2006, 8–pp.

[6] Naiara Moreira et al. "Cyber-security in substation automation systems". In: *Renewable and Sustainable Energy Reviews* 54 (2016), pp. 1552–1562.

[7] SGRWin - Network Solutions Suite. *Basic understanding of IEC 61850*. https://www.sgrwin.com/goose-mms-and-sv-protocols/. Accessed: 2024-04-30.

[8] Typhoon HIL Inc. *IEC 61850 Sampled Values protocol*. https://www.typhoon-hil.com/documentation/typhoon-hil-software-manual/References/iec_61850_sampled_values_protocol.html. Accessed: 2024-04-30.

[9] "Zweites Gesetz zur Erhöhung der Sicherheit informationstechnischer Systeme*". In: *Bundesgesetzblatt, ausgegeben zu Bonn* (2021). Teil I Nr. 25, pp. 1122–1138.