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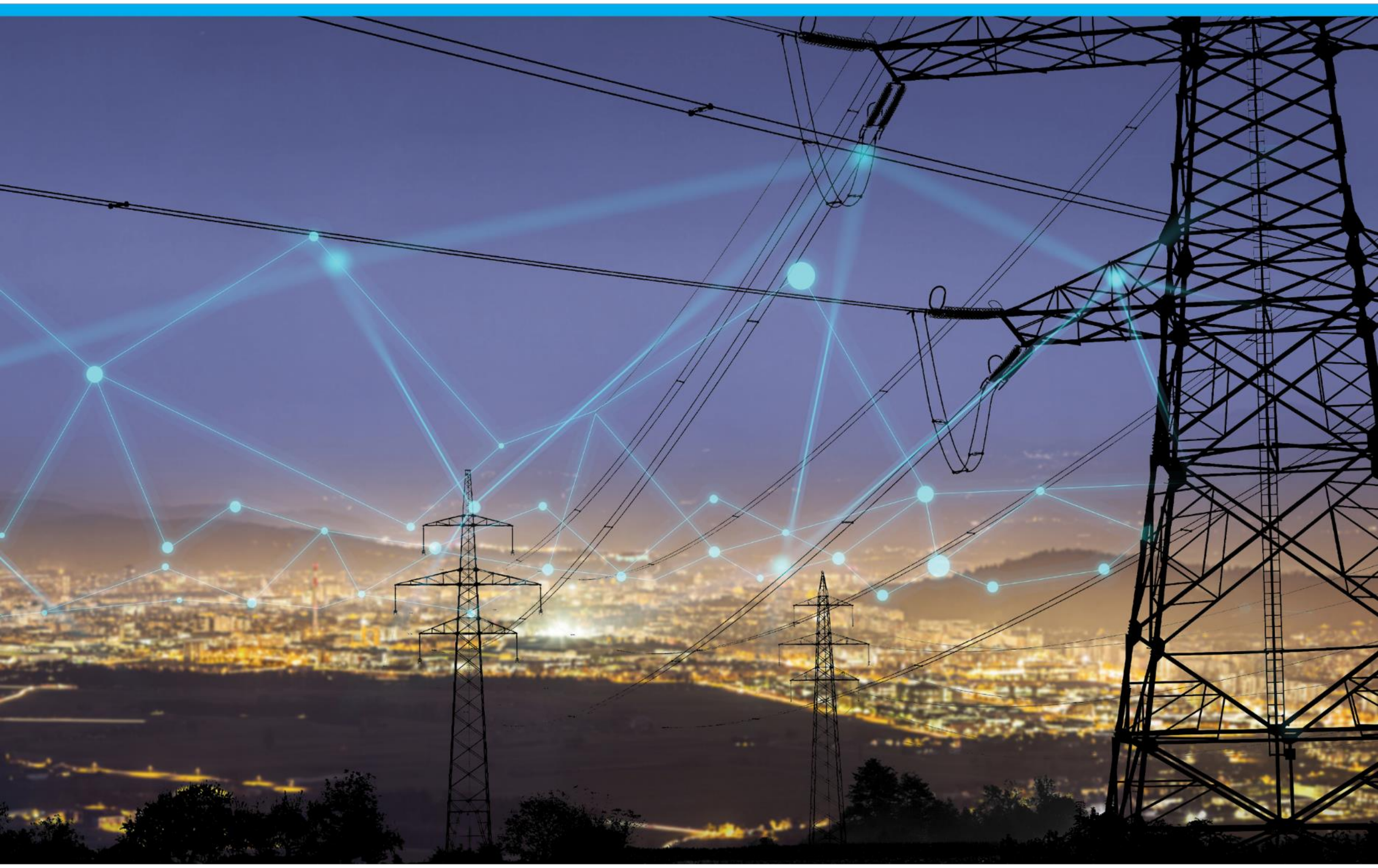
ELECTRIC POWER RESEARCH INSTITUTE



SMART GRID INTEROPERABILITY STANDARDS ADOPTION IN SOUTHEAST ASIA

Gap Analyses for Indonesia, Malaysia, Philippines, Thailand, and Vietnam

Disclaimer

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List of Acronyms

ADR	Auto-Demand Response
AHRI	Air-Conditioning, Heating, & Refrigeration Institute
ANSI	American National Standards Institute
ASEAN	Association of Southeast Asian Nations
CEE	Consortium of Energy Efficiency
COSEM	Companion Specification for Energy Metering
CTA	Consumer Technology Association
DER	Distributed Energy Resource
DLMS	Device Language Message Specification
DOE	U.S. Department of Energy
DR	Demand Response
Asia EDGE	Asia Enhancing Development and Growth through Energy
EN	European Standard
EPRI	Electric Power Research Institute
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IS	Indian Standard
ISO	International Standards Organization
ITA	U.S. International Trade Administration
ITU	International Telecommunications Union
kV	Kilovolt
NERC	North American Electric Reliability Cooperation
NIST	National Institute of Standards and Technology
OBIS	Object Identification System
SDO	Standards Development Organization
WTO	World Trade Organization

Background and Objective of Study

Policymakers and grid operators around the world have long envisioned the benefits of creating a "smart grid"; an electrification system that harnesses the power of sensors, information communications technology, software, and analytics to increase the efficiency, reliability, and resiliency of the grid. Smart grid interoperability standards are tools that drive value by enabling technologies from different vendors across grid domains to interact. The U.S. government has taken steps to build a solid framework and roadmap for deploying smart grid interoperability standards by working with stakeholders and partners from across industry, government, and academia. This work is vital to modernize the grid and reduce the level of current greenhouse gas (GHG) emissions due to inefficient grid systems.

The transition to a carbonless future will require expertise and investments to increase grid modernization and resiliency, both in the United States and abroad. To succeed, grid operators will need to overcome complex technical challenges, such as incorporating more intermittent sources of energy (e.g., solar and wind) connecting disparate renewable energy sources to cities and population centers, ensuring interoperability, and strengthening the grid to withstand the threats posed by climate change.

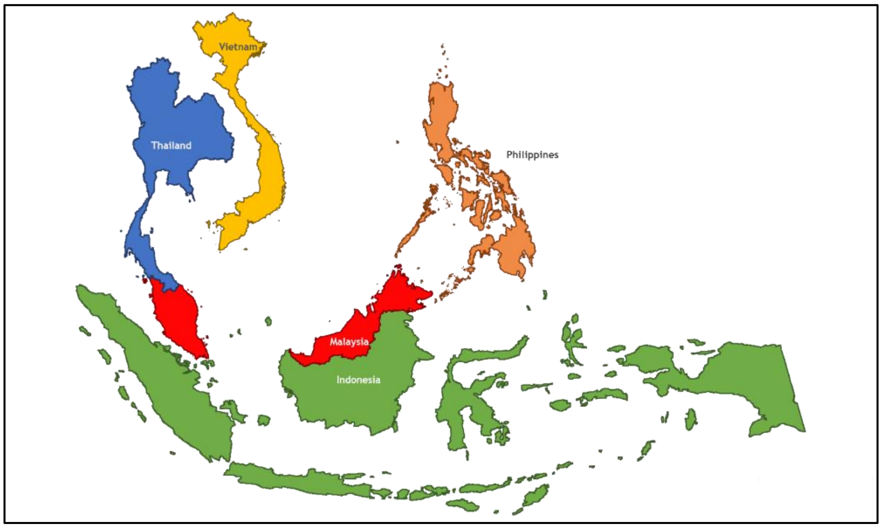

Figure 1: Target ASEAN countries

Southeast Asian nations are rapidly evaluating their current electricity generation capacity and grid systems to mitigate and adapt to the worst impacts of climate change. According to Fitch Solutions[1], the five Southeast Asian markets of Indonesia, Malaysia, Philippines, Thailand, and Vietnam are expected to add over 50 gigawatts (GW) of generation capacity and spend upwards of $100 billion on grid upgrades and new power transmission and distribution networks by 2030. This grid modernization effort creates new commercial opportunities for U.S. exporters and service providers. It also creates opportunities for U.S. Standards Development Organizations (SDOs) and U.S. Government to share best practices with Southeast Asian policy leaders and practitioners to improve the region's ability to consistently provide its citizens with safe, reliable, and affordable access to electric power.

To support this broader effort, this study aims to:

1) Provide gap analyses of the current state of smart grid interoperability standards adopted in Indonesia, Malaysia, Philippines, Thailand, and Vietnam in relation to the full list of standards enumerated in the *NIST Smart Grid Interoperability Standards Framework*,
2) Offer practical tools and case studies to help Southeast Asian policymakers address climate-related challenges and modernize their grids based on global best practices and standards.

This study complements other U.S. initiatives, resources, and pre-existing workstreams such as the NIST Smart Grid Program and the Asia Enhancing Development and Growth through Energy (EDGE) initiative. The findings will also inform ITA's future standards work in the region and will be shared to support interagency partners working on energy standards, including the Department of State, Department of Energy, the U.S. Agency for International Development, and the U.S. Trade and Development Agency.

[1] Figure calculated from Fitch Solutions' Q3 2021 *Power Reports* for Indonesia, Malaysia, Philippines, Thailand and Vietnam. www.fitchsolutions.com

Approach

The approach to the study was comprised of four primary tasks as described below and summarized in **Figure 2**.

1. **Compile a Comprehensive List of Smart Grid Interoperability Standards.** The project team reviewed existing U.S. Government resources and reports in order to compile a comprehensive list of smart grid interoperability standards. The main reference document used in this study was the National Institute of Standards and Technology's (NIST) *Framework and Roadmap for Smart Grid Interoperability Standards, Release 4.0* (Framework)[2]. The Framework provides a useful conceptual model for smart grid applications by categorizing functions within various domains and subdomains. The Framework builds upon a dataset of 240 individual standards found in the *Review of Smart Grid Standards for Testing and Certification Landscape Analysis*, which served as the baseline list of standards for this project.[3]

2. **Conduct a Gap Analysis of Smart Grid Interoperability Standards in Indonesia, Malaysia, Philippines, Thailand, and Vietnam.** The project team conducted stakeholder outreach and open-source research on grid interoperability standards in Indonesia, Malaysia, Philippines, Thailand, and Vietnam. Using the NIST framework as the baseline, a gap analysis was conducted for each market to find evidence if any standards from that baseline are formally codified as mandatory standards by the relevant country grid authorities, as well as to identify standards that are being deployed in a voluntary capacity within the country by industry.

3. **Analyze Data and Present Results.** The project team analyzed the data from the gap analysis and documented findings and conclusions. The purpose of this section is to inform policymakers and private industry of the general landscape of smart grid interoperability standards within the target markets, as well as providing a more holistic regional snapshot. The section also identifies lessons learned and areas that could be strengthened by future research.

4. **Identify Priority Standards and Draft Case Studies.** Using insights from the gap analysis, the project team identified five standards in specific smart grid domains that have been successfully adopted in the United States but which are either excluded in the target markets or exist non-preferentially in tandem with other standards. The purpose of these case studies is to inform policymakers in the respective markets how adopting smart grid interoperability standards can drive performance and increase net benefit to governments, system operators, utilities, and customers. The case studies are informed by the gap analyses and particularly emphasize emerging standards families put forth by U.S.-domiciled SDOs or those more commonly associated with the U.S. grid. This is done to provide insight into how the successful deployment of these standards in the U.S. has improved grid performance and driven customer value.

Figure 2: Summary of Study Approach

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[2] https://www.nist.gov/publications/nist-framework-and-roadmap-smart-grid-interoperability-standards-release-40
[3] https://data.nist.gov/od/id/8697BBCF15D113AEE05324570681C74F2061

Comprehensive List of Smart Grid Interoperability Standards

This study reviewed existing literature by the National Institute of Standards and Technology (NIST), specifically the *Framework and Roadmap for Smart Grid Interoperability Standards, Release 4.0 (Appendix J)*[4], and the *Review of Smart Grid Standards for Testing and Certification Landscape Analysis*[5] documents, along with the Catalog of Standards[6] maintained by the Smart Electric Power Alliance (SEPA), combined with additional outreach to relevant experts. The NIST Framework consists of 240 standards that have been developed by the 21 organizations shown in **Table 1**.

Table 1: Organizations included in smart grid interoperability standards review

SDOs	Alliances/Professional Associations	Government Agencies
• American National Standards Institute (ANSI)[7,8] • International Electrotechnical Commission (IEC)[9] • Institute of Electrical and Electronics Engineers (IEEE)[10] • Internet Engineering Task Force (IETF)[11] • International Standards Organization (ISO)[12] • International Telecommunications Union (ITU)[13] • National Electrical Manufacturers Association (NEMA)[14] • North American Energy Standards Board (NAESB)[15] • Society of Automotive Engineers (SAE)[16]	• American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE)[17] • Consumer Energy Alliance (CEA)[18] • Customer Electronics Design and Installation Association (CEDIA)[19] • Multispeak[20] • North American Electric Reliability Corporation (NERC)[21] • OPC Foundation[22] • Open Geospatial Consortium (OGC)[23] • Organization for the Advancement of Structured Information Standards (OASIS)[24] • Open ADR Alliance[25] • UCA International User's Group (UCAIUG)[26]	• National Institute of Standards and Technology (NIST)[27] • U.S. Department of Homeland Security (DHS)[28]

[4] https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1108r4.pdf
[5] https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.2042.pdf
[6] http://gridstandardsmap.com/
[7] https://www.ansi.org/
[8] The American National Standards Institute is technically not a Standards Development Organization. ANSI oversees standards and conformity assessment activities in the United States while coordinating U.S. industry positions in major global and regional standards accreditation organizations like the IEC, ISO, etc. For the purposes of this study, ANSI is included as an SDO for its role as an accreditor American National Standards, such as ANSI C12- Code for Electric Metering.
[9] https://www.iec.ch
[10] https://www.ieee.org
[11] https://www.ietf.org
[12] https://www.iso.org
[13] https://www.itu.int
[14] https://www.nema.org
[15] https://www.naesb.org
[16] https://www.sae.org
[17] https://www.ashrae.org
[18] https://consumerenergyalliance.org
[19] https://cedia.net
[20] https://www.multispeak.org
[21] https://www.nerc.com
[22] https://opcfoundation.org
[23] https://www.ogc.org/
[24] https://www.oasis-open.org
[25] https://www.openadr.org
[26] https://www.ucaiug.org
[27] https://www.nist.gov
[28] https://www.dhs.gov

Background on Standards Development Entities

Organizations that create the standards and technical specifications necessary for the interoperability of smart grid technologies fall into two main categories: 1) formal standards development organizations (SDOs) and 2) professional associations and industry alliances that develop standards or technical specifications.

Standards Development Organizations (SDOs)

A Standards Development Organization (SDO) is an organization whose primary activities are developing, coordinating, promulgating, revising, or otherwise producing technical standards. In general terms, the committee members doing the actual development work are bound by anti-trust laws and are limited from engaging in anti-competitive behavior such as market division and pricing discussions.

In the United States, SDOs are accredited by the American National Standards Institute (ANSI)[29] and must meet certain essential requirements for their standards development processes. For example, under ANSI's requirements, accredited SDOs should balance the interests of three categories: producer, user, and general interest. For balloting purposes, no single category can exceed forty (40) percent of eligible voters. While ANSI does not develop standards itself, standards developed in compliance with ANSI's essential requirements may be published by ANSI, either as a co-branded standard (e.g., ANSI/ASHRAE 135, ANSI/CEA 852, etc.) or simply as an ANSI standard (e.g., ANSI C12).

Alliances & Professional Associations

Associations and alliances are groups of entities and individuals that recognize the value of a particular technology and form a formal "interest group" to promote the codification of the design and marketing of that technology. As both are multi-party by nature, the difference between an alliance and an SDO lies within both the governing rules of these organizations and in their finished work products. Since any number of interested parties can form an alliance, the rules under which they operate vary widely. Also, since alliances are not required to have balanced memberships, or in some cases are not required to follow certain anti-trust regulations, their work products must be submitted to an SDO in order to become true *de jure* standards (as discussed further below). In addition, one of the primary goals of most alliance efforts is to prove demonstrable product interoperability within the framework of a defined certification program.

Government Agencies

Some government agencies are also involved in the development of the standards highlighted in the comprehensive list. U.S. federal agencies are encouraged to participate in the development of standards used by industry and adopt them for their own purposes (e.g., regulatory, procurement, etc.) rather than develop government-unique standards. For government adoption, these standards must meet certain criteria including openness, balance of interests, and consensus-based decision-making.

When appropriate, government agencies publish guideline documents on the implementation of technologies. For example, the National Institute of Standards and Technology (NIST) has four interagency reports (referred to as NISTIR) on the list that provide guidelines for cyber security and the adoption of telecommunication technologies for smart grid applications. The Department of Homeland Security also has guideline documents relating to cyber security included on the list.[30]

De Facto vs De Jure Standards

The different structures of these organizations have a major impact on the types of "standards" they produce. Standards produced by SDOs are referred to as *de jure* standards – those that are codified in a manner similar to a law. Standards produced by alliances and professional associations are generally considered *de facto* "standards". A *de facto* "standard" has enough commonality among enough producers to consider the product / approach / protocol a "standard". Given the careful attention to balloting balance, open rules, and open participation, *de jure* standards may be adopted in place of laws in certain jurisdictions.

Occasionally, *de facto* "standards" become *de jure* standards after working through the more formalized process of an SDO. For example, Open ADR was a specification developed by the Lawrence Berkeley National Lab but has recently been adopted by the IEC.[31] Several of the standards reviewed by the project team started as *de facto* "standards" promoted by an alliance or association and then became *de jure* standards after being accredited by an SDO. In several cases, a standard that has been developed by one SDO is also adopted by another SDO. For example, ANSI/CEA 709.1-D-2014 has also been adopted by the ISO and IEC under ISO/IEC 14908-1:2012.

Mandatory vs. Voluntary Standards

Most countries have their own national standards-making bodies. These organizations typically:

1) publish, and may write, their own national standards
2) represent their country in regional and international standard-setting fora
3) hold a reference library of national, regional, and international standards
4) sell copies of standards
5) offer conformity assessment services such as accreditation, certification, or other commercial activities

[29] https://www.ansi.org
[30] The technical guidance issued by NIST and DHS are referenced in this section mainly because they fall within the list of standards cited in the NIST Framework, which served as the guiding list of standards for the gap analyses. The team did not presume nor expect that technical guidance issued by U.S. federal government agencies would hold any authority within the five respective countries, but they are included for illustrative purposes.
[31] https://www.openadr.org/assets/docs/openadr_primer.pdf

The use of standards may be voluntary, or the standards may be referenced in regulation, therefore making them legally mandatory within a jurisdiction. World Trade Organization (WTO) rules require governments to base their national regulations on international standards produced in accordance with certain principles, such as openness, transparency, balance, etc. Notable SDOs that develop international standards include ISO, IEC, many ANSI-accredited SDOs, and IEEE. Because of these rules and the general globalization of trade, national standards bodies are increasingly adopting or otherwise using international standards wherever possible.[32]

The relevant standards bodies for the five target ASEAN countries are listed below:

- Bureau of Philippine Standards[33]
- National Standardization Agency of Indonesia[34]
- Department of Standards Malaysia[35]
- Thailand Industrial Standards Institute[36]
- Vietnam Directorate for Standards, Metrology, and Quality[37]

Families of Standards

The NIST Framework classifies eight smart grid interoperability domains: information model, communication protocol, physical performance, test method, communication mapping, model mapping, guideline and practice, and cybersecurity. The project team specifically focused on standards that address the information model, communication protocol, and physical performance domains. This study focused on the 167 standards germane to these three domains (out of the 240 standards in all eight interoperability domains.)

Within the 167 standards, there are 59 standard families that have been developed by 17 different organizations. An example of a family of standards are the ANSI C12 standards for electric metering. The comprehensive list includes eight standards[38] that are associated with ANSI C12: C12.1-2008, C12.1-2014, C12.18-2006, C12.19-2008, C12.19-2012, C12.20-2015, C12.21-2006, and C12.22-2012. Each standard describes a different aspect of electric metering, but they are collectively referred to as ANSI C12. Similarly, the IEC 61850 family of standards has 34 separate standards included in the comprehensive list.

Figure 3 shows the breakdown of the 59 standards families by organizational share. The IEC has the most standards families included on the list followed by the IEEE and ANSI. **Table 2** outlines the other standards organizations whose standards comprise the list and includes their respective share.

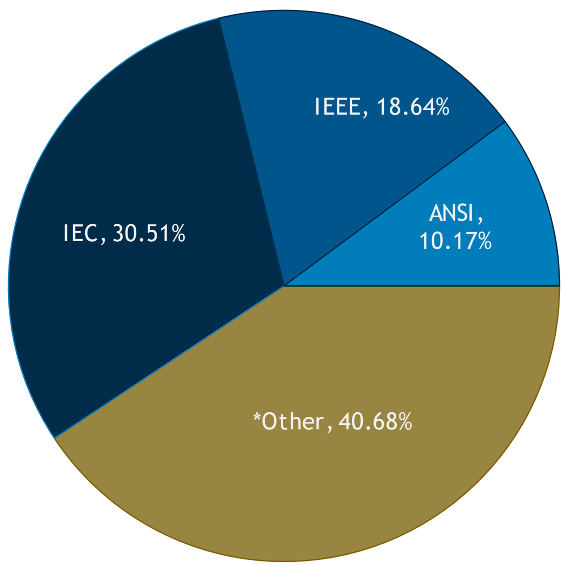


Figure 3: Share of standards families included in the comprehensive list of standards by source

[32] https://www.iso.org/sites/ConsumersStandards/1_standards.html
[33] http://www.bps.dti.gov.ph/
[34] https://www.bsn.go.id/
[35] https://www.jsm.gov.my/
[36] https://www.tisi.go.th/home/en
[37] https://tcvn.gov.vn/
[38] There are more than 8 standards in the ANSI C12 family, but NIST included only 8 of the standards on the list included in the *Framework and Roadmap for Smart Grid Interoperability Standards, Release 4.0*

Table 2: Other organizations whose standards are included in smart grid interoperability standards review

Organization Name	Share of List
ISO/IEC	5.08%
ITU	5.08%
NISTIR	5.08%
OASIS	5.08%
SAE	5.08%
NCS	1.69%
IETF	1.69%
ISO	1.69%
MultiSpeak	1.69%
NAESB	1.69%
NEMA	1.69%
OGC	1.69%
OPC	1.69%
OpenADR	1.69%

Gap Analysis of Smart Grid Interoperability Standards in Indonesia, Malaysia, Philippines, Thailand, and Vietnam

The first step in this task was to identify the standards that have been adopted within each of the five target ASEAN countries. To accomplish this task, the project team pursued several approaches. First, the team engaged U.S. manufacturers with sales and operations within the region to obtain insights on standards adoption within the five markets. A summary of this feedback indicated that a strong IEC culture exists within the region, with confirmation that utilities from all five markets to varying degrees accept standards developed by the IEC. Furthermore, one industry representative referred to an "IEC culture" that exists in these countries where IEC standards are taught in schools and are well-established in utility procurement specifications. While the project team reached out to several electric utilities in the target countries, this outreach did not yield useful feedback on general standards adoption practices or on the adoption of specific standards.

This limited feedback is in part due to the ongoing COVID-19 pandemic, as many utilities in the region are experiencing significant operational challenges and staffing constraints. Some of the feedback gathered suggests the limited capacity of regional electric utilities to engage in this extra-programmatic research. Another reason is that the scope of the project deliverable is inherently broad and crosses multiple domains within an individual utility. Likewise, engaging with local utilities across multiple geographies experiencing travel freezes and lockdowns is challenging. As a follow-on to this report, further research and projects focused on specific electric utilities could yield great value from both a technological and commercial perspective. Such research could increase the utility's awareness of interoperability gaps and add value by providing greater visibility into the universe of vendor options.

The team received a greater response from representatives of national standards accrediting organizations and regulatory bodies. For example, across all five countries, the IEC National Committees are affiliated with their respective country standards accrediting bodies, which in all cases are government agencies (unlike in the United States, whose accrediting body ANSI is a non-governmental entity). In these cases, the team worked with U.S. Foreign Commercial Service staff to facilitate requests for documentation assistance and with country resources. This method was particularly successful in returning grid code documentation from each country.[39]

Due to the challenge of uncovering accepted standards deployed across the five countries, the project team relied primarily on open-source research via the websites of each country's standards organization. All 59 standard families included in the comprehensive spreadsheet were individually searched for by country. The databases for Malaysia[40] and Thailand[41] included both general and mandatory standards while those for Indonesia[42], the Philippines[43], and Vietnam[44] offered only general standards. The project team also conducted open-source research of each of the 59 standard families within the countries to identify whitepapers, utility reports, or reputable news articles on the standard family's deployment within each market (see Appendix A). Despite the constraints of the COVID-19 induced virtual environment, the project team made significant efforts to validate all open-source research and consult with appropriate subject-matter experts where possible.

[39] A grid code is a technical specification which defines the parameters for a facility to connect to a public electrical grid while ensuring safe and proper functioning. The facility can be a generating plant, consumer or another network. In these cases, the project team had greater success in uncovering accepted standards.
[40] "Malaysian Standards Online", https://msonline.jsm.gov.my/ Accessed 23 Aug 2021.
[41] "List of TIS standards.". Appdb.Tisi.Go.Th, 2021, http://appdb.tisi.go.th/tis_dev/p3_tis/p3tis.php. Accessed 23 Aug 2021.
[42] "Pemesanan Online :: Bsn.Go.Id". Pesta.Bsn.Go.Id, 2021, https://pesta.bsn.go.id/produk. Accessed 23 Aug 2021.
[43] "Booklibrary Manager | ". Bps.Dti.Gov.Ph, 2021, http://www.bps.dti.gov.ph/index.php/component/booklibrary/115/show_search?Itemid=115. Accessed 23 Aug 2021.
[44] " TCVN | DIRECTORATE FOR STANDARDS, METROLOGY AND QUALITY – STAMEQ ". Tracuu.Tcvn.Vn, 2021, http://tracuu.tcvn.vn/sdomain/front/tieu-chuan-viet-nam. Accessed 23 Aug 2021.

Findings and Conclusions of the Gap Analysis

The results of the gap analysis were recorded in the spreadsheet provided in **Appendix A**. Each country's acceptance of a standard is denoted in one of three ways:

- **Mandatory standards,** per grid code or country standards body
- **Non-Mandatory standards,** generally listed by the country standards body
- **Standards** listed in a utility report, article, white paper, etc. describing the use or certification of a standard in the given country

Figure 4 through **Figure 7** below summarize the findings of the gap analysis. **Figure 4** shows the number of identified standards families accepted by each of the five target ASEAN member countries by the type of acceptance as described above. **Figure 5** through **Figure 7** shows the number of identified standards families accepted by each country organized by SDO. Each figure lists the type of acceptance.

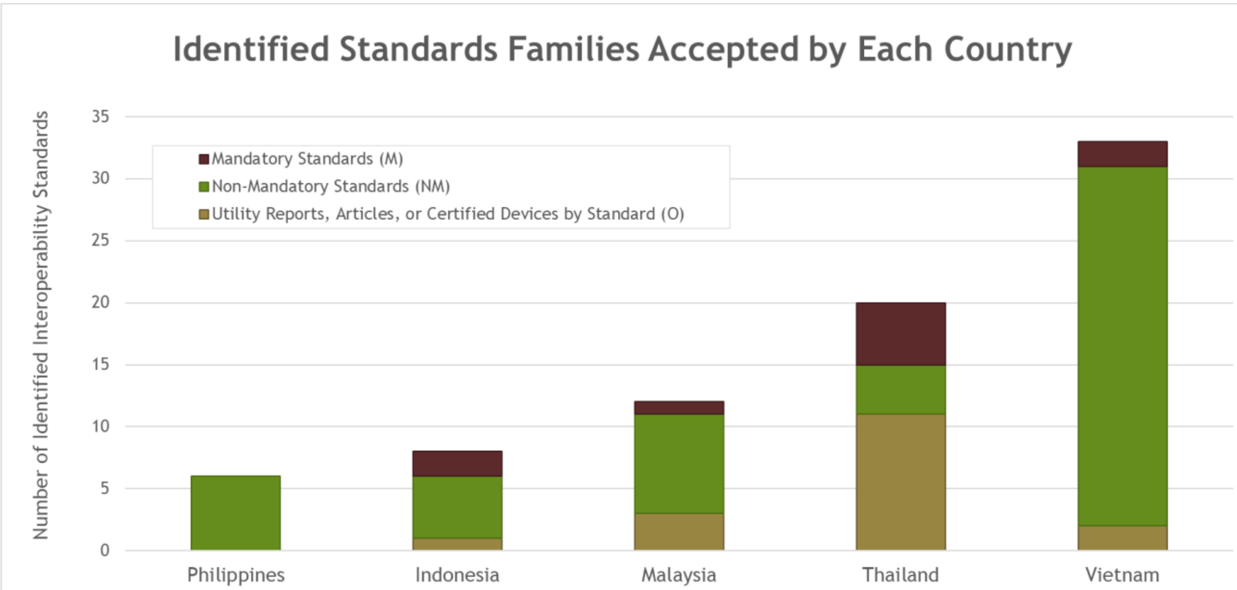


Figure 4: Identified standard families accepted by each country by type of acceptance

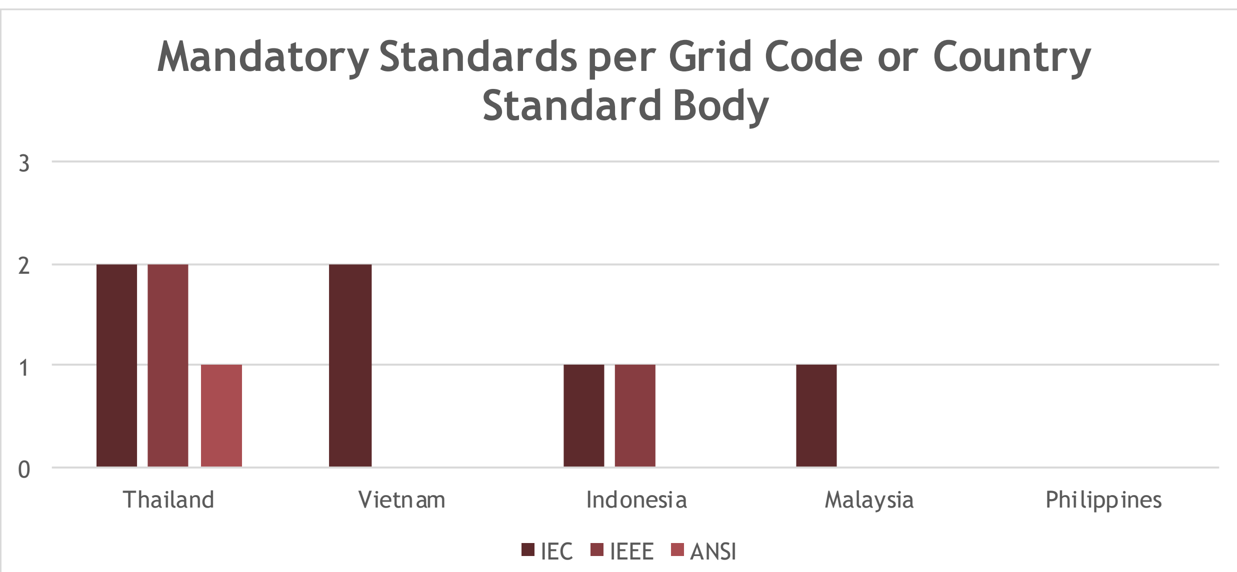


Figure 5: Identified mandatory standards by country

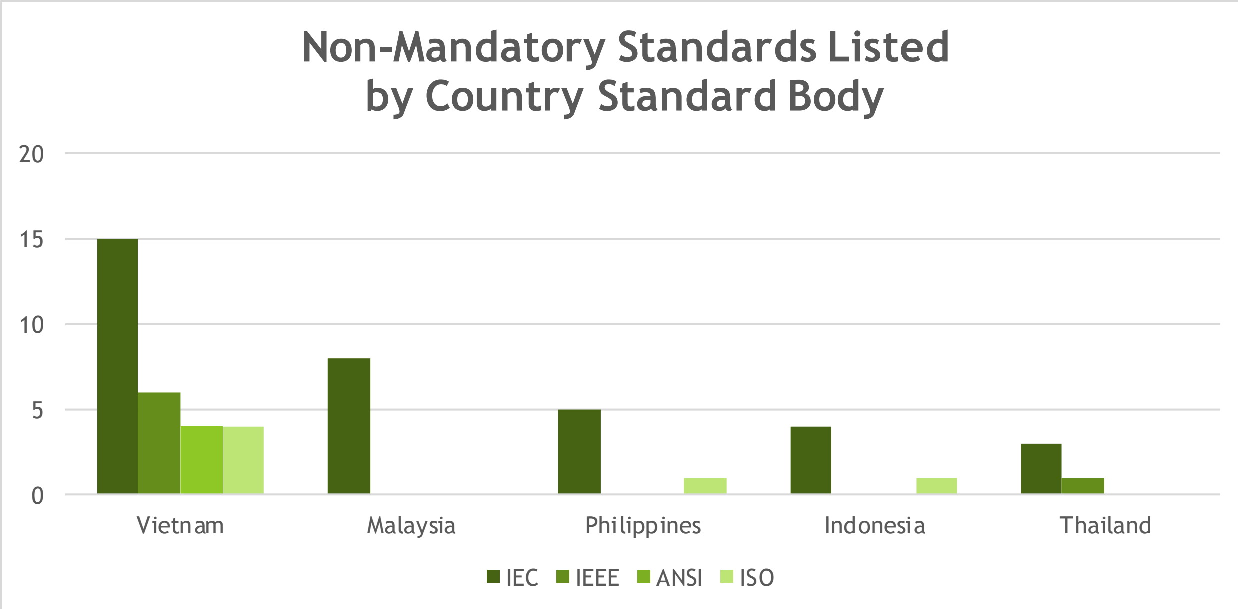


Figure 6: Identified non-mandatory standards by country

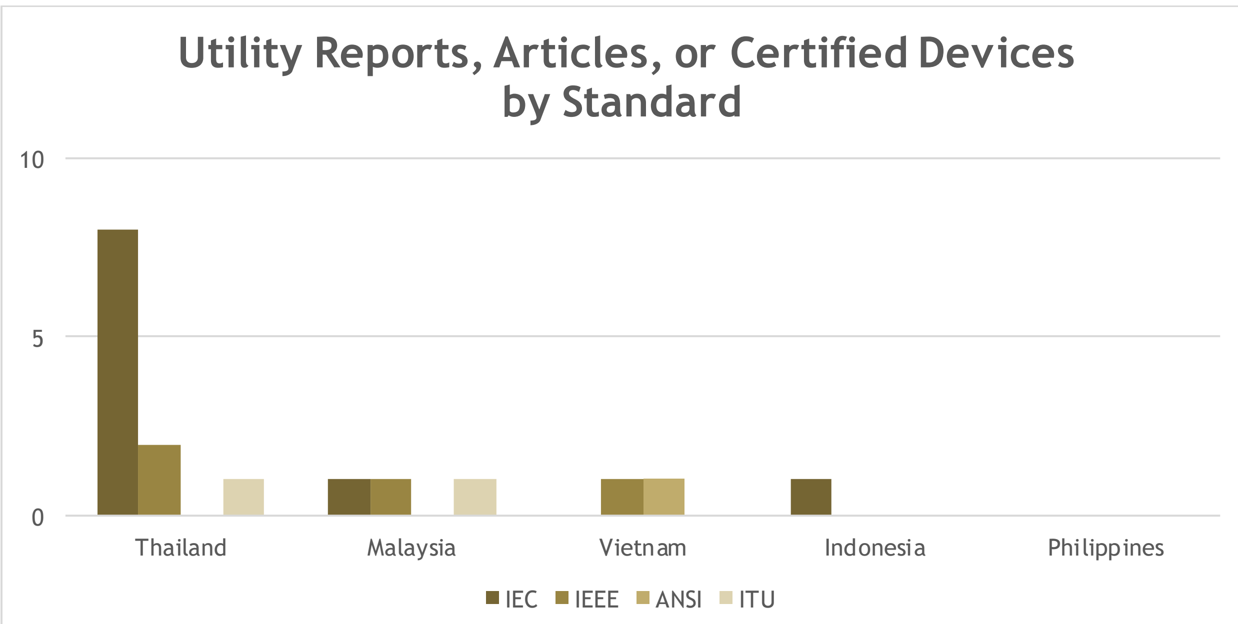


Figure 7: Identified standards per reports, articles, or devices by country

The data from the gap analysis generally supports the position that IEC and ISO standards are well established in all five countries. Additional significant findings from the gap analysis include:

- The national standards bodies in all five countries appear to only accept *de jure* standards produced by international SDOs
- Indonesia, Malaysia, and the Philippines showed evidence of accepting ISO and IEC standards but were not found to support the relevant ANSI or IEEE standards families
- Thailand and Vietnam were found to accept a mixture of the relevant ANSI, IEEE, ISO, and IEC smart grid interoperability standards
- Only Thailand was found to reference the relevant ANSI and IEEE standards as mandatory standards
- Four of the 59 identified standards families were found to be accepted or validated in all 5 countries
    - IEC 61000 – Electromagnetic compatibility
    - IEC 61850 – Power system automation
    - IEC 61851 – Electric vehicle charging
    - IEC 62053 – Electric metering

- Two additional standards were found to be accepted or validated in all of the countries besides Indonesia:
    - IEC 60870 – Systems for telecontrol (supervisory control and data acquisition)
    - IEC 62056 – Electricity metering data exchange

These findings tend to support the feedback that the project team received from equipment manufacturers on the adoption of standards within the five target countries. Interviewees referred to an IEC culture that exists in these countries where IEC standards are taught in schools and are well-established in utility procurement specifications. As a result, emerging technologies and concepts such as storage, distributed generation, and demand response present the best opportunity for the five countries to adopt standards from U.S. domiciled SDOs and those associated with the U.S. grid rather than standards that exist in tandem with well-established IEC standards.

Identify Priority Standards and Draft Case Studies

PThe final phase of the study identified five standards families for case studies. These are standards that are 1) more commonly associated with U.S. grid; and 2) are either not currently accepted in the targeted countries or exist non-preferentially in these markets in tandem with other standards. The case studies highlight how these standards were adopted successfully in the United States and other markets with the help of U.S. vendors and service providers.

The project team established two additional guidelines for identifying priority standards for case studies. First, the team avoided selecting grid standards that exist in tandem with mature, well-established IEC standards. For example, if a utility has adopted IEC 61850 as a design standard for all of their power substations, it would be difficult and highly impractical for it to transition to a different standard. Second, the team attempted to focus on grid standards that did not have a comparable IEC equivalent. Using these criteria, the team targeted emerging energy storage, electric vehicle, and advanced metering standards as priorities.

The priority standards selected for case studies are:

- IEEE 1547-2018, Interconnection and Interoperability of DER with Associated Electric Power Systems Interfaces
- IEEE 2030.5, Smart Energy Profile Application Protocol
- OpenADR 2.0, Open Automated Demand Response
- ANSI/CTA-2045, Modular communications interface for energy management
- DLMS/COSEM (IEC 62056), Electricity metering data exchange

Case studies include the following information:

- the standard’s background and description
- an understanding of the current situation in the five ASEAN countries
- the advantage of adopting the standard
- other known competing standards
- examples of adoption of the standard
- other industry cases studies related to the standard

The five case studies are included in **Appendix B**.

Appendix A: Comprehensive Gap Analysis Spreadsheet

Appendix A provides a concise list of standards and their adoption category. *For a complete list of standards and their corresponding reference materials, scroll to the end of Appendix A and double-click on the embedded image to open a Microsoft Excel spreadsheet containing the complete dataset.*

	Standard Classification Categories
X	**Mandatory Standards**, found in the Grid Code or Country Standard Body
X	**General Standard**, listed by Country Standard Body
X	**Standard** cited unofficially by Utility Reports, Articles, or Certified Devices

Standard Organization	Acronym	Standard Family	Indonesia	Malaysia	Philippines	Thailand	Vietnam
American National Standards Institute	ANSI	ANSI C12				X	X
American National Standards Institute / American Society of Heating, Refrigerating and Air-Conditioning Engineers	ANSI	ANSI/ASHRAE 135					X
American National Standards Institute / American Society of Heating, Refrigerating and Air-Conditioning Engineers	ANSI	ANSI/ASHRAE 201					X
American National Standards Institute / American Society of Heating, Refrigerating and Air-Conditioning Engineers	ANSI	ANSI/CEA 709					X
American National Standards Institute / Consumer Electronics Association	ANSI	ANSI/CEA 852					X
American National Standards Institute / Consumer Technology Association	ANSI	CTA 2045					
The Department of Homeland Security	DHS	DHS National Communications System (NCS)					
International Electrotechnical Commission	IEC	IEC 60255		X		X	X
International Electrotechnical Commission	IEC	IEC 60870		X	X	X	X

Standard Organization	Acronym	Standard Family	Indonesia	Malaysia	Philippines	Thailand	Vietnam
International Electrotechnical Commission	IEC	IEC 61000	X	X	X	X	X
International Electrotechnical Commission	IEC	IEC 61334		X		X	X
International Electrotechnical Commission	IEC	IEC 61850	X	X	X	X	X
International Electrotechnical Commission	IEC	IEC 61851	X	X	X	X	X
International Electrotechnical Commission	IEC	IEC 61869				X	X
International Electrotechnical Commission	IEC	IEC 61968	X			X	X
International Electrotechnical Commission	IEC	IEC 61970		X		X	X
International Electrotechnical Commission	IEC	IEC 62053	X	X	X	X	X
International Electrotechnical Commission	IEC	IEC 62054		X			X
International Electrotechnical Commission	IEC	IEC 62056 (DLMS/COSEM)*	X	X		X	X
International Electrotechnical Commission	IEC	IEC 62282				X	X
International Electrotechnical Commission	IEC	IEC 62325					X
International Electrotechnical Commission	IEC	IEC 62357				X	

Standard Organization	Acronym	Standard Family	Indonesia	Malaysia	Philippines	Thailand	Vietnam
International Electrotechnical Commission	IEC	IEC 62541					X
Institute of Electrical and Electronics Engineering	IEEE	IEEE 1377					
Institute of Electrical and Electronics Engineering	IEEE	IEEE 1451				X	
Institute of Electrical and Electronics Engineering	IEEE	IEEE 1547	X			X	X
Institute of Electrical and Electronics Engineering	IEEE	IEEE 1588				X	X
Institute of Electrical and Electronics Engineering	IEEE	IEEE 1686					
Institute of Electrical and Electronics Engineering	IEEE	IEEE 1701					X
Institute of Electrical and Electronics Engineering	IEEE	IEEE 1702					
Institute of Electrical and Electronics Engineering	IEEE	IEEE 1815					X
Institute of Electrical and Electronics Engineering	IEEE	IEEE 1901				X	X
Institute of Electrical and Electronics Engineering	IEEE	IEEE 2030					X
Institute of Electrical and Electronics Engineering	IEEE	IEEE C37				X	X
Internet Engineering Task Force	IETF	IETF RFC-6272					

Standard Organization	Acronym	Standard Family	Indonesia	Malaysia	Philippines	Thailand	Vietnam
International Electrotechnical Commission	IEC	IEC 62689					X
International Organization for Standardization	ISO	ISO 15118	X		X		X
International Organization for Standardization / International Electrotechnical Commission	ISO/IEC	ISO/IEC 10192 (CTA-2045)*					X
International Organization for Standardization / International Electrotechnical Commission	ISO/IEC	ISO/IEC 14908					X
International Organization for Standardization / International Electrotechnical Commission	ISO/IEC	ISO/IEC 15067					X
International Telecommunication Union	ITU	ITU T-G.9903				X	
International Telecommunication Union	ITU	ITU T-G.9960					
International Telecommunication Union	ITU	ITU T-G.9972					
National Rural Electric Cooperative Association	N/A	MultiSpeak Security					
North American Energy Standard	NAESB	NAESB					
National Electrical Manufacturers Association	NEMA	NEMA SG-AMI 1					
National Institute of Standards and Technology Interagency/Internal Report	NISTIR	NISTIR 7761					

Standard Organization	Acronym	Standard Family	Indonesia	Malaysia	Philippines	Thailand	Vietnam
National Institute of Standards and Technology Interagency/Internal Report	NISTIR	NISTIR 7862					
National Institute of Standards and Technology Interagency/Internal Report	NISTIR	NISTIR 7943					
Organization for the Advancement of Structured Information Standards	OASIS	OASIS EI					
Organization for the Advancement of Structured Information Standards	OASIS	OASIS EMIX					
Organization for the Advancement of Structured Information Standards	OASIS	OASIS WS Calendar					
Open Geospatial Consortium	OGC	OGC-GML					
OPC Foundation, Scottsdale AZ USA	OPC	OPC-UA					
Open Automated Demand Response Alliance	OpenADR	OpenADR 2.0					
International Electrotechnical Commission	IEC	IEC 62746 (OpenADR 2.0B)*					X
Society of Automotive Engineers	SAE	SAE J1772					
Society of Automotive Engineers	SAE	SAE J2836					
Society of Automotive Engineers	SAE	SAE J2847					

For complete dataset, view the attached "*Dataset on Smart Grid Interoperability Standards Adoption in Southeast Asia.xlsx*" file that is included in this PDF. (NOTE: readers must download the PDF file and view it with an appropriate reading software to access the attachment).

Appendix B: Case Studies

IEEE 1547-2018 - IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

IEEE 2030.5 - IEEE Standard for Smart Energy Profile Application Protocol

Open Automated Demand Response, OpenADR 2.0 International Electrotechnical Commission (IEC) 62746-10-1:2018

ANSI/CTA-2045, Modular communications interface for energy management, formerly known as ANSI/CEA-2045

DLMS/COSEM (IEC 62056-5-3) - Electricity metering data exchange - The DLMS/COSEM suite - Part 5-3: DLMS/COSEM application layer

IEEE 1547-2018 Case Study

Transmission | Distribution | DER / DER Field Device | Photovoltaic Systems / Distribution Generation | Energy Storage | Customers

Name of Standard or Standard family

IEEE 1547-2018 - IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

Background of Standard

The primary interconnection standard for Distributed Energy Resources (DER) in North America, IEEE Std 1547TM (abbreviated 'IEEE 1547' throughout this case study), has been under revision for several years. Originally developed in 2003 assuming a low penetration of DER, the voluntary standard has been broadly referenced in the United States to specify grid-connected DER capabilities and performance. When utilities connect new DER with the grid, the DER must follow requirements to ensure the safe and reliable operation of the grid. North American grid codes refer to the IEEE 1547-2018 family of standards for technical requirements and the testing of those requirements.

Description of Standard

Renewable generation/DER introduces variability into electric grids. New smart distributed energy resources can help mitigate potential issues through enabling flexible operations that allow them to adjust behavior based on manual, control signals, or autonomous algorithms. Requirements for these features are defined in IEEE 1547-2018.

The 2018 revision to IEEE 1547 introduced a paradigm shift in the expectations for DER. While IEEE 1547-2013 required that DER disconnect from the grid if grid conditions went outside of tolerance, IEEE 1547-2018 recognizes DER as an important resource in maintaining grid stability that must remain connected in some conditions to support the grid using smart inverter functions. Because this required dynamic control of DERs and therefore communications capabilities, the standard defines both functional and communications requirements. Many of these requirements had not previously been implemented in any grid code in the world.

While IEEE 1547-2018 is relatively new, adoption in the United States is expected to increase significantly. Major manufacturers have committed to implementing the required features and major testing organizations (e.g., UL) are implementing tests to validate that requirements have been met. Deadlines for implementation are due in 2022 or later based on jurisdiction.

Current Situation of ASEAN Countries (Indonesia, Malaysia, Philippines, Thailand, Vietnam)

The ASEAN Member States have committed to meeting a target of 23 percent renewable energy in total primary energy demand by 2025.[45] They can meet this target by connecting large-scale renewable resources (hydro, solar, wind, etc.) to the transmission system or by connecting smaller DER to the distribution system.

Table 3 below shows the share of photovoltaic (PV) generation in total generation capacity in 2019, the share of residential and commercial installed PV generation in total PV generation in 2019, and the compound annual growth rate of residential and commercial PV generation from 2016 to 2019. PV as a share of total generation capacity ranges from a low of 0.2 percent (Indonesia) to a high of 10 percent (Vietnam) across the five countries. The share of residential and commercial installed PV generation in total PV generation gives a sense of the amount of DER in each country. This ranges from a high of 35.4 percent (Indonesia) to a low of 6.8 percent (Vietnam). The compound annual growth rate provides insight into DER growth in each country. Growth in the five target ASEAN countries ranges from 1.3 percent (Indonesia) to 255 percent in Vietnam.

[45] Arboleya, L., Kristiansen, R. "Southeast Asia can reach clean energy targets b investing in transmission." IEA. February 5, 2021. https://www.iea.org/commentaries/southeast-asia-can-reach-clean-energy-targets-by-investing-in-transmission.

Table 3: Photovoltaic Adoptions Trends in the Five Target ASEAN Countries[46]

Country	Share of Photovoltaic Generation in Total Generation Capacity in 2019 (%)	Share of Residential and Commercial Installed Photovoltaics Generation in Total Photovoltaic Generation in 2019 (%)	Compound Annual Growth Rate of Residential and Commercial Photovoltaic Generation from 2016 to 2019 (%)
Indonesia	0.2	35.4	13.1
Malaysia	3.0	26.7	36.8
Philippines	3.9	8.5	18
Thailand	7.3	13.0	35.9
Vietnam	10.0	6.8	255

As the power capacity of the Southeast Asia region expands with large-scale renewables, smart inverters will be added to the grid. Implementing a grid interconnection standard like IEEE 1547-2018 could help modernize grid stability and increase interoperability with harmonized communication efforts at a large scale.

The gap analysis identified that Thailand and Vietnam are the only countries in the target ASEAN countries that support the IEEE 1547-2018 standard. Regulation of the Metropolitan Electricity Authority of Thailand mentions "IEEE 1547" along with other standards like IEC 61727, IEC 62116, and AS 4777.3 as part of their Power System Network Connection Code. However, it seems that a specific standard has yet to be fully adopted. The national standards of Vietnam issued by the Vietnam Standard and Quality Institute have on record "IEEE 1547", Standard for Interconnecting Distributed Resources with Electric Power Systems in its catalogs of standards.

Advantages of Adopting this Standard

If adopted, IEEE 1547-2018 would ensure that DER installed today have the ability to provide new flexible, grid-interactive features. The timeline for the adoption of each feature would depend on local penetration levels, regulatory environments, customer programs, and other local factors. IEEE 1547-2018 was the first to embrace smart inverter functionality and includes requirements for interoperability and the capability to communicate.

[46] BloombergNEF, *Historic Generation*. https://www.bnef.com/interactive-datasets/2d5d59acd9000011?data-hub=7&tab=Generation%20(historic)&view=f1972ee2-50d3-4426-99a8-6ea3717e2695 [bnef.com] Accessed September 1, 2021.

Other Known Competing Standards

Table 4: List of Interconnection standards for DER[47]

Country	Standard ID	Year	Title	Scope of Application
Australia / New Zealand	AS 4777-1 [6]	2016	Grid connection of energy systems via inverters Part 1: Installation requirements	Inverters ≤200 kVA at Low voltage
Australia / New Zealand	AS 4777-2	2015	Grid connection of energy systems via inverters Part 2: Inverter requirements	Inverters at low voltage
Europe	CLC/TC 50549-1	2019	Requirements for generating plants to be connected in parallel with distribution networks—Part 1: Connection to an LV distribution network—Generating plants up to and including Type B	Generating plants up to and including Type B at LV network
Europe	EN 50438	2013	Requirements for micro-generating plants to be connected in parallel with public low-voltage distribution networks	Micro-generating plants ≤16 A per phase at public LV distribution networks 230/400 V
Germany	BDEW	2008	Generating Plants Connected to the Medium-Voltage Network	Generating Plants at MV and LV
Germany	VDE-AR-N 4105	2011	Power generation systems are connected to the low-voltage distribution network. Technical minimum requirements for the connection to and parallel operation with low-voltage distribution networks	Power generation systems ≤100 kVA connected to low voltage
India	Gazette of India. Part III-Sec. 4	2014	Technical Standards for Connectivity of the Distributed Generation Resources	DER connected to the electricity system
International	IEC/IEEE/PAS 63547	2011	Interconnecting distributed resources with electric power systems	DER ≤10 MVA
Italy	CEI 0-21	2019	Reference technical rules for the connection of active and passive users to the LV electrical Utilities	Active and Passive Users at distribution systems <1 kV (LV)
People's Republic of China	GB-T 19964	2012	Technical requirements for connecting photovoltaic power station to power system	PV connected at HV, MV, and LV
Spain	UNE 206007-1	2013	Requirements for connecting to the power system. Part 1: Grid-connected inverters	Inverters connected to a public distribution network
U.K.	G 59	2014	Recommendations for the connection of generating plant to the distribution systems of licensed distribution network operators	Generating plants <17 kW per phase or <50 kW three-phase at the distribution system
U.K.	G 83	2012	Recommendations for the Connection of Type Tested Small-scale Embedded Generators (Up to 16 A per Phase) in Parallel with Low-Voltage Distribution Systems	Small-Scale embedded Generators ≤16 A per phase at low-voltage distribution networks 230/400 V
United States	UL 1741	2005	Inverters, Converters, Controllers, and Interconnection System Equipment for Use with Distributed Energy Resources	DER connected to electric power systems

[47] Rebollal, D., Carpintero-Rentería, M., Santos-Martín, D. and Chinchilla, M. Rebollal, David et al. "Microgrid And Distributed Energy Resources Standards And Guidelines Review: Grid Connection And Operation Technical Requirements". Energies, vol 14, no. 3, 2021, p. 523. MDPI AG, doi:10.3390/en14030523. Accessed 17 Aug 2021.

Adoption and Case Studies of Standard

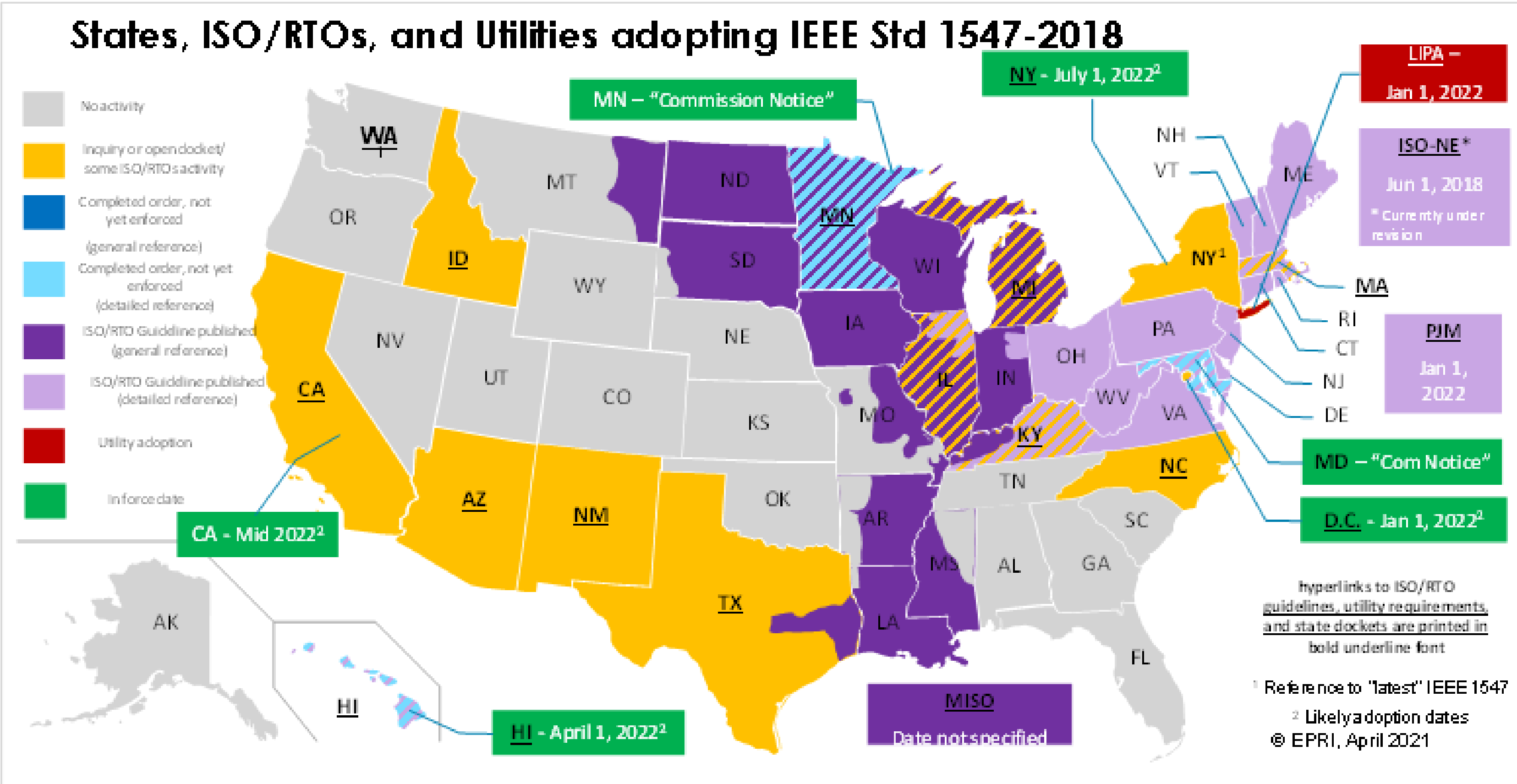
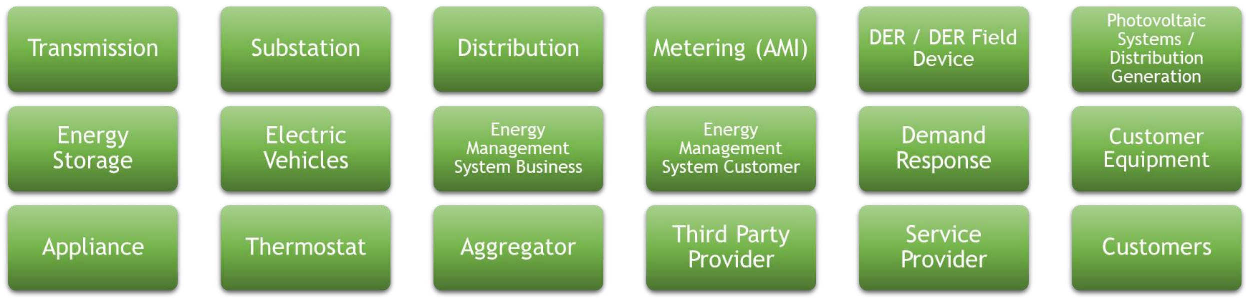


Figure 8: Adoption of IEEE 1547-2018[48]

[48] Boemer, Jens, Cordova, Jose; "EPRI's Role and Contribution on DER and IBR-related Industry Standards", EPRI Integrated Modeling and Analysis Tech Talks – 2021, slide 15, August 2021

IEEE 2030.5 Case Study



Name of Standard or Standard Family

IEEE 2030.5 - IEEE Standard for Smart Energy Profile Application Protocol.

Background of Standard

IEEE 2030.5 is an application layer specification formerly referred to as SEP 2.0 (Smart Energy Profile 2.0). It was developed as a communication protocol to securely integrate consumer's smart devices into the smart grid including smart loads, electric vehicles, and distributed energy resources (DER). IEEE 2030.5 was recently revised to include the necessary DER functions to meet the requirements of grid codes like Hawaiian Rule 14H, California Rule 21, and the proposed revision to IEEE 1547.

Description of Standard

IEEE 2030.5 has a dedicated function set for the management of different types of DER including solar, energy storage, demand response, group management, and electric vehicles. The mechanisms for exchanging application messages, the exact messages exchanged including error messages, and the security features used to protect the application messages are defined in this standard. IEEE 2030.5 uses a client-server network architecture. The server hosts the necessary DER resources (e.g., volt/var curve) for clients which are accessed through methods called "polling" and "subscription/notification".

Current Situation of ASEAN Countries (Indonesia, Malaysia, Philippines, Thailand, Vietnam)

The current situation is similar to that of IEEE 1547-2018. **Table 5** below gives a sense for the amount of DER and its growth rate in the five countries. It shows the share of photovoltaic (PV) generation in total generation capacity in 2019, the share of residential and commercial installed PV generation in total PV generation in 2019, and the compound annual growth rate of residential and commercial PV generation from 2016 to 2019.

This data indicates that Vietnam and Thailand, in particular, may be in a position where the adoption of the IEEE 2030. standard would be beneficial.

Table 5: Photovoltaic Adoptions Trends in the Five Target ASEAN Countries[49]

Country	Share of Photovoltaic Generation in Total Generation Capacity in 2019 (%)	Share of Residential and Commercial Installed Photovoltaics Generation in Total Photovoltaic Generation in 2019 (%)	Compound Annual Growth Rate of Residential and Commercial Photovoltaic Generation from 2016 to 2019 (%)
Indonesia	0.2	35.4	13.1
Malaysia	3.0	26.7	36.8
Philippines	3.9	8.5	18
Thailand	7.3	13.0	35.9
Vietnam	10.0	6.8	255

[49] BloombergNEF, *Historic Generation*, accessed September 1, 2021. https://www.bnef.com/interactive-datasets/2d5d59acd9000011?data-hub=7&tab=Generation%20(historic)&view=f1972ee2-50d3-4426-99a8-6ea3717e2695 [bnef.com]

As large-scale renewables require the power capacity of the Southeast Asia region to expand, smart inverters and electrical vehicle fleets will be added to the grid. Implementing a communication standard like IEEE 2030.5 could help modernize grid stability and increase interoperability with harmonized communication efforts at a large scale. The gap analysis identified Vietnam as the only target country that references the IEEE 2030 standard.

Advantages of Adopting this Standard

The protocol reduces communications architectural challenges by using the widely used Internet Protocol (IP) at the internet layer and supporting a variety of protocols at the physical layer (including Ethernet, Wi-Fi, powerline communications, and different low power radio technologies). IEEE 2030.5 has dedicated function sets that support DER including smart inverters and energy storage, load control devices like thermostats, plug-in electric vehicles, pool pumps and water heaters, energy management systems like home energy management systems, building energy management systems, aggregators cloud servers, measurement devices like smart meters, etc. A complete implementation of an IEEE 2030.5 communication stack also includes all the mandated cybersecurity features in the standard which ensures all transactions between clients and servers to be secured using HTTP over Transport Layer Security.

Other Known Competing Standards

IEEE 2030.5 has a dedicated function set for the management of DER including solar and energy storage systems. Its information model is derived from IEC 61850-7-420 and the Common Functions for Smart Inverter (EPRI 3002008217, 2017[50]).

Adoption and Case Studies of Standard

The standard was recently revised to include the necessary DER functions to meet the requirements of grid codes like Hawaiian Rule 14H, California Rule 21, and the proposed revision to IEEE 1547. The SunSpec Alliance lists more than 92 CSIP certified IEEE 2030.5 products varying from a server, aggregator, and client devices on its website.[51]

Additional examples of adoption include the following:

Smart Inverters

- IEEE 2030.5 is more prevalent in the solar photovoltaic market with requirements for IEEE 2030.5 in both California Rule 21 and IEEE 1547-2018.

Electric Vehicles

- There are limited products on the market today for the electric vehicle sector, but vehicle manufacturers are currently running pilot programs focused on the curtailment of electric vehicles and vehicle-to-grid capabilities particularly around electric buses.[52]

Additional insight can be found in the QualityLogic Case Study – Standardization and Integration Consulting and Test Services, Accelerating Interoperability of a Transactive Energy System in the PNW Regional Smart Grid Demonstration Project.[53]

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[50] "EPRI Home". Epri.Com, 2021, https://www.epri.com/research/products/000000003002008217. Accessed 20 Aug 2021.
[51] "Certified Registry - Sunspec Alliance". Sunspec Alliance, 2019, https://sunspec.org/certified-registry/. Accessed 19 Aug 2021.
[52] https://distributechplus.com/adoption-of-electric-vehicles-into-utility-operational-landscape-a-use-case-for-vehicle-to-grid-v2g-in-grid-management-systems-using-ieee-2030-5/
[53] Qualitylogic.Com, 2021, https://www.qualitylogic.com/wp-content/uploads/2017/01/QL_CaseStudy_PNWSGDP.pdf. Accessed 19 Aug 2021.

OpenADR 2.0 Case Study

Distribution | Service Provider | Customers

Name of Standard or Standard Family

Open Automated Demand Response, OpenADR 2.0 International Electrotechnical Commission (IEC) 62746-10-1:2018

Background of Standard

OpenADR 2.0 (OpenADR), is an international standard adopted by the IEC as standard 62746-10-1:2018, Systems Interface Between Customer Energy Management System and the Power Management System - Part 10-1: Open Automated Demand Response. OpenADR was originally developed by OASIS Standards Development Organization (SDO) through research that included utilities and industry stakeholders to automate and standardize demand response (DR) communications between power system operators or independent system operators and electric customers.[54]

Description of Standard

OpenADR is a bi-directional application-layer standard for managing and automating distributed energy resources (DER) for demand response (DR) programs. The current version can support a wide range of DR programs, as well as many common DER operations such as power, voltage, and frequency management. The standard defines grid signals or events to direct or motivate desired resource behaviors, expressing the requests in grid operational terms (such as absolute or relative power levels) or as descriptions of the state of the grid (using qualitative levels or energy prices, for example). Both telemetry and history reports can be created and exchanged to enable visibility and performance monitoring.

The central idea of OpenADR is an "event," described by a signal or a data model, a start time, and a duration. Events can be divided into "intervals" and any number of intervals may be included in a single event (the sum of the duration of the intervals must equal the duration of the overall event) across the DR program participants. Depending on the DR program design, an event can be communicated well in advance of its start time to give a resource time to prepare for it (such as by precooling a building or by suitably adjusting an industrial process). After an event is created, it can subsequently be modified or canceled. Event recipients can also communicate a decision to opt out of participation in the event (if that is allowed by the DR program in which they are enrolled). OpenADR is usually used to control resources (aggregations of many customer devices or individual devices).

Due to the richness (and resulting potential complexity) of the customer-side implementations of the full standard (known as "Profile B"), a simplified version (called "Profile A") is available for use by customer devices with limited computing power or network capacity. In Profile A, all events use a four-level qualitative signal, as grid-state indicators, and customer response. Each level may be interpreted differently and customized, depending on the definition in the DR program by the service provider. OpenADR is different from interconnection-related standards those required for inverter-based DERs (e.g., solar and energy storage) as it does not directly control the asset. It is instead used to provide an ability for the DERs to determine the response based on grid requests.

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[54] "Harmonized Information and Communications for Distributed Energy Resources: Preliminary Guide for Grid Operators and Standards Organizations." EPRI, Palo Alto, CA: 2021. 3002020093.

Current Situation of ASEAN Countries (Indonesia, Malaysia, Philippines, Thailand, Vietnam)

The ASEAN Member States' electrical demand is one of the fastest-growing regions in the world. Demand has grown by more than 6 percent annually over the past 20 years on average, driven by the growing ownership of household appliances and an increase in the consumption of goods and services. Demand response can be used to offset or shift loads during peak times thus deferring or avoiding the construction of a new line. **Table 6** shows the electricity consumption in 2019 and the 10-year annual growth rate for the five countries[55].

Table 6: Electricity Consumption and Annual Growth Rate

Country	2019 Electricity Consumption (TWh)	Annual Growth Rate 2009 – 2019 (%)
Thailand	183	3.0
Indonesia	281	6.6
Vietnam	259	12.6
Malaysia	162	4.0
Philippines	100	5.4

Demand response can also provide load balancing which can be valuable as the amount of variable generation increases. **Table 7** shows the amount of photovoltaic and wind resources in each of the 5 ASEAN countries in 2019 and the annual growth rate from 2016 to 2019[56]. The Electricity Generating Authority of Thailand (EGAT) announced in June 2021 that it is undertaking a demand response demonstration project to optimize the supply and demand balance of the Thai grid.[57]

Table 7: Wind and Photovoltaic Generation and Annual Growth Rate

Country	2019 Wind and Photovoltaic Generation (MW)	Annual Growth Rate 2016 – 2019 (%)
Thailand	4454	25
Indonesia	304	46
Vietnam	5848	226
Malaysia	1113	52
Philippines	1416	5

This data suggests that Vietnam, Malaysia, and Thailand, in particular, may be interested in investigating demand response.

Advantages of Adopting this Standard

The OpenADR Alliance, a non-profit member-based organization, manages OpenADR adoption and runs the official certification program for OpenADR products.[58] To help companies develop OpenADR 2.0-compliant products, the OpenADR Alliance provides a tool for common certification testing. Automating the demand through standardized DR programs can lead to a higher level of customer participation. ASEAN Member States can adopt this strategy to cost-effectively address the demand growth.

Other Known Competing Standards

There are no competing standards that are known at this time.

[55] Source: Our World in Data, https://ourworldindata.org
[56] BloombergNEF, *Historic Generation*, accessed September 1, 2021. https://www.bnef.com/interactive-datasets/2d5d59acd9000011?data-hub=7&tab=Generation%20(historic)&view=f1972ee2-50d3-4426-99a8-6ea3717e2695 [bnef.com]
[57] https://www.smart-energy.com/industry-sectors/energy-grid-management/egat-to-pilot-flexibility-in-thailand/
[58] "Home". Openadr.Org, 2021, *https://www.openadr.org/*. Accessed 20 Aug 2021.

Adoption and Further Case Studies of Standard

The OpenADR Alliance lists more than 200 certified products on its website which support either utility- or customer-side implementations of OpenADR profiles (Profile A and Profile B). The adoption of OpenADR is expected to grow as it plays a critical role in interfacing with new DER and new energy markets including dynamic pricing, transactive energy, and transactive load management.[59]

Openadr.org has three case studies with a variety of technologies involving energy management systems and electric vehicle fleets.

Warehousing, "Energy Management Success Story - Railex®"

Openadr.Org, 2021, https://www.openadr.org/assets/docs/cppcasestudiesrailex_v5_wcag_rmt.pdf. Accessed 3 Aug 2021.

Southern California Edison, "Energy Management Success Story – Nordstrom"

Openadr.Org, 2021, https://www.openadr.org/assets/docs/nordstromcasestudy.pdf. Accessed 3 Aug 2021.

FleetCarma, "It's Easy To Include Electric Vehicle Smart Charging in Automated Demand Response Programs"

Openadr.Org, 2021, https://www.openadr.org/assets/FleetCarma_OpenADR%20Case%20Study.pdf. Accessed 3 Aug 2021.

[59] "Transactive Incentive-signals to Manage Energy-consumption (TIME): The System- and MarketBased Transactive Load Management (TLM)." EPRI, Palo Alto, CA: 2017. 3002012290

ANSI/CTA-2045 Case Study

Electric Vehicles | Energy Management System Customer | Customer Equipment | Appliance | Thermostat | Demand Response

Name of Standard or Standard family

ANSI/CTA-2045, Modular communications interface for energy management, formerly known as ANSI/CEA-2045.

Background

ANSI/CTA-2045 is an American National Standard Institute (ANSI) and Consumer Technology Association (CTA) “modular communications port” standard that defines interface requirements for (1) the DER (typically load) and (2) a communication module to plug into and communicate with the resource. Adopted by the IEC as an international standard, International Organization for Standardization / International Electrotechnical Commission 10192:2017, Home electronic system (HES) interfaces — Part 3: Modular communications interface for energy management.

Description of Standard

The ANSI/CTA-2045 standard defines the physical communication ports, the interface module, the message exchange between the module and the end device. The ANSI/CTA-2045 module referred to as a “Universal Communication Module” provides the means of communication networks to be bridged to DER through an ANSI/CTA-2045 port. The ANSI/CTA-2045 end device is equipped with an ANSI/CTA-2045 port which allows users to supply grid services or functionality to the device. Compatible end devices could consist of electric vehicle supply equipment, water heaters, thermostats, mini-split heating, ventilation, and air conditioning systems, packaged terminal air conditioner systems, and variable speed pool pumps.

The ANSI/CTA-2045 standard focuses on information exchange between the module and the DER. The standard is intended to provide a means by which DER manufacturers can reduce the risk of embedding a network technology into their products that may change over the product lifespan. It’s important to note that the ANSI/CTA-2045 standard does not specify or presume anything about this communications network. In practice, communication modules have been built to bridge ANSI/CTA-2045 resources to networks such as Wi-Fi, Cellular, and AMI that transport application-layer protocols including OpenADR, DNP3 (IEEE 1815), or a third-party specific protocol.

The ANSI/CTA-2045 standard defines message types and commands of functions like load shed, critical peak, grid emergency, end shed, relative price, time remaining in price period, customer override, sleep/wake, and operational state. The functional response of a smart grid end device when it receives these commands is not strictly defined in the standard. Also, the ANSI/CTA-2045 standard is not a demand response program, however, it enables demand response features and functionalities for grid services at the device level.

Current Situation of ASEAN Member Countries (Indonesia, Malaysia, Philippines, Thailand, Vietnam)

The current situation is similar to that of Open ADR. Electricity demand is growing in all five target ASEAN Member Countries as is the amount of DER. **Table 8** below shows the growth rate in electricity consumption from 2009 to 2019 and the annual growth rate in residential and commercial DER from 2016 to 2019.

Table 8: Annual Growth Rate for Electricity Consumption and Wind and Photovoltaic Generation

Country	Annual Growth Rate in Electricity Consumption 2009 – 2019 (%)[60]	Annual Growth Rate in Wind and Photovoltaic Generation 2016 – 2019 [61](%)
Thailand	3.0	25
Indonesia	6.6	46
Vietnam	12.6	226
Malaysia	4.0	52
Philippines	5.4	5

As Southeast Asia continues to experience economic growth, demand from utilities rises. Implementing a demand response program using technologies like ANSI/CTA-2045 could help offset or shift loads during peak times. The research conducted from the gap analysis identified that Vietnam is the only country in the target ASEAN countries that support the ISO/IEC 10192-2017, which is the IEC adopted standard to ANSI/CTA-2045. Further studies or research could help identify target end devices for benefiting a demand response program.

Advantages of Adopting this Standard

As communications and technology advance, the device assets that are already in the field could become obsolete over time as technology evolves. With ANSI/CTA-2045, the old asset could be upgraded to a new UCM module at the interface level to keep assets from becoming obsolete. This allows older assets to stay in the DR program without having to replace the entire asset. The standard uniformed type of messages and commands for each device to enable grid functions for utility use cases and benefits. The standard also provides a common language amongst manufacturers. This allows any device equipped with an ANSI/CTA-2045 port to participate in any DR Program regardless of the manufacturer or vendor of the device. The ANSI/CTA-2045 standard ensures open access, which can encourage competition and innovation.

Other Known Competing Standards

No other competing standards exist or are known.

[60] Source: Our World in Data, https://ourworldindata.org

[61] BloombergNEF, *Historic Generation*, accessed September 1, 2021. https://www.bnef.com/interactive-datasets/2d5d59acd9000011?data-hub=7&tab=Generation%20(historic)&view=f1972ee2-50d3-4426-99a8-6ea3717e2695__[bnef.com]

Adoption and Case Studies of Standard

Over the last few years, the U.S. industry has created new state regulations, standards, and specifications to advance the adoption and use of DER for grid services. Some examples are listed in **Table 9**.

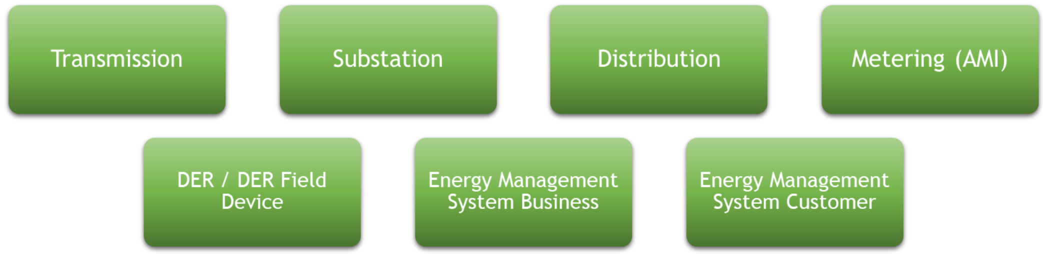
Table 9: Examples of state regulations, standards, and specifications to advance the adoption and use of DER for grid services

Release / Publication Date	Entity / Source	Title	Type
May 2016	Northwest Energy Efficiency Alliance	Advanced Water Heater Specification	Specification
March 2018	Consortium of Energy Efficiency	CEE Residential Water Heating Specification	Specification
January 2019	Air-Conditioning, Heating, & Refrigeration Institute	AHRI 1380 (I-P) Demand Response through Variable Capacity HVAC Systems in Residential and Small Commercial Applications	Standard
April 2019	Environmental Protection Agency's ENERGY STAR® Program	ENERGY STAR® Program Requirements Product Specification for Residential Water Heaters Eligibility Criteria Version 3.3 Draft 2	Specification
May 2019	Washington State	House Bill 1444 APPLIANCE EFFICIENCY STANDARDS	State Law
March 2020	Oregon	Executive Order 20-04	State Law
June 2020	NEEA	Residential Water Heaters Advanced Water Heating Specification Version 7.0	Specification
July 2020	Oregon	2020 Standards Final Rules Summary (CTA-2045 requirements for electric water heaters take effect 1/1/2022)	State Law
May 2021	California	Express Terms, 2022 Energy Code, Title 24 Parts 1 and 6	State Law
In-progress	American Heating and Air Conditioning Institute, AHRI	AHRI 1430 Standard for Demand Response for Electric Water Heaters	Standard

Table 10: ANSI/CTA-2045 Case Studies

Release / Publication Date	Entity / Source	Title
December 2019	U.S. Department of Energy	Heat Pump Water Heaters Achieve Significant Peak Reduction and Energy Savings
November 2018	Bonneville Power Administration	CTA-2045 Water Heater Demonstration Report
June 2018	National Rural Electric Cooperative Association (NRECA)	Standardized Communications for Demand Response
April 2017	Peak Load Management Alliance	Field Test Results of the Consumer Technology Association's CTA-2045 Demand Response Standard
February 2016	Portland General Electric	CTA-2045 Enables Low-Cost Grid-Interactive Water Heaters

DLMS/COSEM (IEC 62056-5-3) Case Study



Name of Standard or Standard Family

DLMS/COSEM (IEC 62056-5-3) - Electricity metering data exchange - The DLMS/COSEM suite - Part 5-3: DLMS/COSEM application layer

Background of Standard

The DLMS/COSEM protocol is developed by the DLMS Users Association, which then feeds this work to the IEC for standardization as the IEC 62056 series of standards. The DLMS Users Association is a membership organization that also maintains a conforman ce testing and certification program. The DLMS/COSEM is Device Language Message Specification (DLMS) and Companion Specification for Energy Metering (COSEM). Together, these two pieces describe both an object model (COSEM) and the communications protocol to interact with these objects. In the COSEM context, "object" is intended in the sense of a software object that is commonly used in the computer programming paradigm called "object-oriented programming (OOP)."

Description of Standard

DLMS/COSEM specifies the data model, the messaging protocol, and media-specific communication profiles. DLMS/COSEM are the generic terms used by the DLMS Users Association to refer to both the application layer (DLMS) and the object model (COSEM) as well as the object mappings (OBIS codes). Generally, the DLMS Users Association tends to work out the details of the protocol and then bring it to technical committee (TC) 13, working group (WG) 14 for standardization as part of the IEC 62056 series.

Current Situation of ASEAN Countries (Indonesia, Malaysia, Philippines, Thailand, Vietnam)

Table 11 below summarizes the current status of advanced metering infrastructure deployment in the five target ASEAN countries. Deployment ranges from being partially complete (Ho Chi Minh City Power Corp. in Vietnam[62] and TNB in Malaysia[63]) to just beginning (Meralco in the Philippines[64]). PLN in Indonesia recently announced its plans to implement AMI over the next several years[65] while PEA and MEA in Thailand are evaluating the results of their AMI pilot projects[66].

Table 11: Current Status of Advanced Metering Infrastructure deployment in five target ASEAN countries

Country	Currently Implementing Smart Meters	Have Announced Plans to Implement Smart Meters	Conducting Smart Meter Pilot Projects
Vietnam			
Philippines			
Thailand			
Malaysia			
Indonesia			

Implementing an advanced metering infrastructure can provide automated billing, meter reading, and security of investment for purchasers and suppliers, reducing costs and risks over time. The research conducted from the gap analysis identified that Indonesia, Malaysia, and Vietnam include DLMS/COSEM (IEC 62056-5-3) as part of their standard catalog within each country's

[62] https://vietnamnews.vn/society/793097/evnhcmc-to-complete-installation-of-electronic-meters-for-all-customers-next-year.html
[63] https://www.theedgemarkets.com/article/tnb-expects-more-600000-new-smart-meter-users-yearend
[64] https://news.abs-cbn.com/business/09/01/20/meralco-hastens-rollout-of-smart-meters-to-prevent-bill-shock
[65] https://www.thejakartapost.com/news/2020/06/17/pln-to-install-79-million-smart-meters-in-indonesia-after-billing-fiasco.html
[66] https://www.smart-energy.com/industry-sectors/smart-meters/thailand-lessons-from-a-116000-smart-meter-rollout/

standard body. Provincial Electricity Authority of Thailand, specification no. RMTR-033/2560 references DLMS/COSEM (IEC 62056) in their technical specification, division of smart meters and accessories, 1c.10 Communication Protocol.[67]

Advantages of Adopting this Standard

Application-layer protocol is used to support a domain-specific application using a high-level protocol— that is, one that is above the Transport layer in the Open Systems Interconnection (OSI) model. Using a standard application layer protocol promotes interoperability among devices, allows the use of different underlying transport and network layer protocols as matched appropriately to the particular usage, environment, and requirements. It makes the system more flexible to modify or update over time than a system that uses a non-standard application layer protocol. DLMS/COSEM includes robust security mechanisms, an intuitive and thorough object model for metering, and is a mature and well-tested protocol that has been used successfully throughout the world for decades.

Other Known Competing Standards

M-Bus (EN 13757) is most often used in conjunction with DLMS/COSEM, and so can be thought of as more of a compliment than a competitor standard. The US national committee recently accepted DLMS/COSEM as a national standard alongside the existing ANSI C12 series of protocols. Unlike the ANSI C12 series of protocols, there is a robust testing and certification program for DLMS/COSEM and the security mechanisms available within DLMS/COSEM are more advanced than those of the ANSI standards.

- EN 13757-1 Communication systems for meters - Part 1: Data exchange[68]
- ANSI C12. Smart Grid Meter Package[69]
    - ANSI C12.18-2006, (R2016) Protocol Specification for Type 2 Optical Port
    - ANSI C12.19-2012, American National Standard for Utility Industry End Device Data Tables
    - ANSI C12.22-2012 (R2020), Protocol Specification for Interfacing To Data Communication Networks

[67] Bidding.Pea.Co.Th, 2021, https://bidding.pea.co.th/sites/default/files/tor/2021-03/5802d7ac-07d2-4f7e-967a-7a055ce64105/DOC120321-12032021151606.pdf Accessed 19 Aug 2021.
[68] Standards, E. Standards, European. "EN 13757-1". *Https://Www.En-Standard.Eu*, 2021, https://www.en-standard.eu/csn-en-13757-1-communication-systems-for-meters-part-1-data-exchange/. Accessed 19 Aug 2021.
[69] "ANSI C12. Smart Grid Meter Package". Webstore.Ansi.Org, 2021, https://webstore.ansi.org/Standards/NEMA/ANSIC12SmartGridMeterPackage. Accessed 19 Aug 2021.

Adoption and Case Studies of Standard

DLMS/COSEM is used in more than 60 countries and implemented by over 150 vendors in 1,000+ certified device types. It offers solutions for communication with almost any constrained and non-constrained smart device, over any network.[70] The DLMS Users Association maintains a conformance testing and certification program. Their website currently lists over 1,000 certified products from dozens of companies distributed throughout the world.[71]

The largest utilities in France and Spain have standardized on DLMS/COSEM and have developed Companion Specifications to meet their requirements. A DLMS/COSEM Companion Specification is the equivalent to a profile in some other standards; that is, it is a selection of a subset of options within the standard to facilitate interoperability. Several open-source implementations exist, but most appear to be the head-end side rather than the meter side[72][73][74].

The Bureau of Indian Standards adopted DLMS/COSEM as a national standard (IS 15959) in 2011. Prior to 2011, the use of disparate protocols (e.g. ANSI C12.18, DLMS/COSEM, IEC 61107, etc.) and other proprietary standards made it difficult for utilities to standardize on equipment and inhibited Indian meter manufacturers' global competitiveness.[75] The adoption of the national standard in 2011 provided utilities with more options for metering devices and increased Indian companies' national and international competitiveness. For example, Indian companies Kalkitech and Nekstron now offer DLMS/COSEM software as a significant portion of their product portfolios.

Utilities in many other countries have also standardized their use of DLMS/COSEM for electricity metering. They include Enel (Italy), Iberdrola (Spain), Endessa (Spain), EDF (France), Eskom (South Africa), and most recently and in progress, is Avangrid (US).[76]

[70] "List Of Members | Dlms". Dlms.Com, 2021, https://www.dlms.com/the-association/structure/list-of-members. Accessed 19 Aug 2021.
[71] "List Of Certified Equipment | Dlms". Dlms.Com, 2021, https://www.dlms.com/certification-scheme/certificates-list. Accessed 19 Aug 2021.
[72] MeterLinq. 2014. Open Source DLMS/COSEM is available. 5 9. http://www.meterling.com/en/blog/open-source-dlmscosemdownloading-freely/. Accessed 8 26, 2018.
[73] Gurux. 2018. Open Source. Accessed 8 26, 2018. http://www.gurux.fi/OpenSource.
[74] "Github - Meterkit/Cosemlib: C++ Client/Server DLMS/Cosem Library". Github, 2021, https://github.com/meterkit/cosemlib. Accessed 19 Aug 2021.
[75] "Adoption of an international energy meter protocol in India."Smart Energy International. 2008. https://www.smart-energy.com/regional-news/asia/adoption-of-an-international-energy-meter-protocol-in-india/. Accessed 19 Aug 2021.
[76] Urrutia, Iker et al. "Interoperability Strategy For An AMI Deployment In The US". AIM, 2019, p., https://www.cired-repository.org/handle/20.500.12455/40. Accessed 19 Aug 2021.