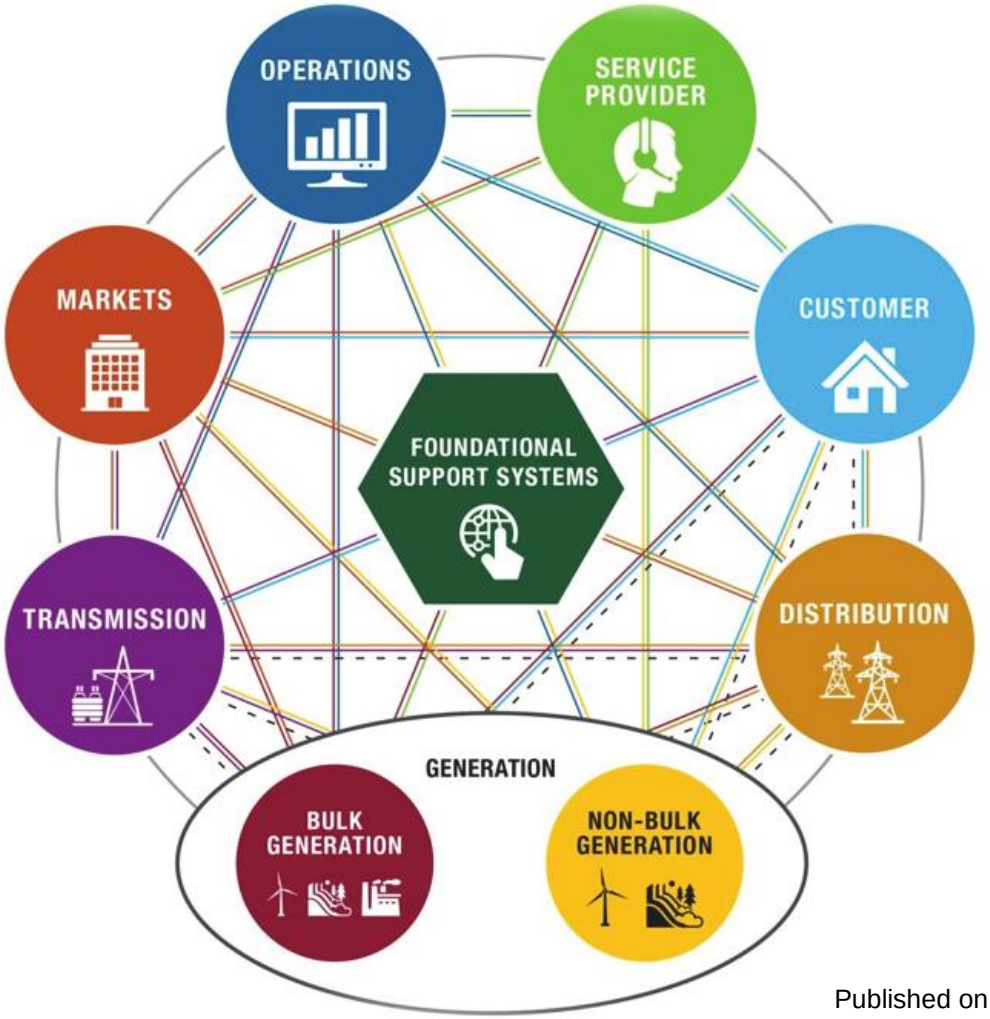
IEEE Smart Grid Survey Structure of Emerging Technologies

White Paper #1 - Draft

Topic: Overview - Scope, Goals, Challenges, Tasks and Guiding Principles

Authored by: IEEE Smart Grid R&D Committee Members



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IEEE Smart Grid Initiative brings together IEEE's broad array of technical societies and organizations through collaboration to encourage the successful rollout of technologically advanced, environment-friendly and secure smart-grid networks around the world. As a professional community and leading provider of globally recognized Smart Grid information, IEEE Smart Grid Initiative is intended to organize, coordinate, leverage and build upon the strength of various entities within IEEE with Smart Grid expertise and interest. Additional information on IEEE Smart Grid can be found at http://smartgrid.ieee.org.

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1. INTRODUCTION

Smart Grid deployment is a reality on the international landscape. But the Smart Grid is a revolutionary undertaking—entailing new communications-and-control capabilities, energy sources, energy transfer models and adherence to cross-disciplinary regulatory structures. Success of the Smart Grid demands objective collaboration, integration, and interoperability among a vast array of disciplines, including computational and communications control systems for generation, transmission, distribution, customer, operations, markets, service providers and regulatory authorizes.

IEEE is well-positioned to assume the critical unifying role in the Smart Grid movement for a variety of reasons. IEEE is an international non-profit organization with a high degree of involvement in research and development. It has a diversity of global expertise across both established and emerging technologies, rich programs, proven standards and a lifecycle of related processes that promote technology adoption and open and build global markets. Finally, IEEE brings objective coordination among the huge cast of public and private organizations that contribute to smart grid development.

IEEE Smart Grid Initiative was conceptualized and led under the direction of Wanda Reder, former President of the IEEE Power & Energy Society, as a New Initiative in IEEE Future Directions Committee (FDC) in 2011.

The IEEE FDC, in association with Societies, Councils, and Organizational Units (OUs), anticipates and determines the direction of existing, new, and emerging technologies and related issues, and spearheads their development. Taking a holistic view, the FDC emphasizes new, emerging technical areas and drives them to maturity within the IEEE infrastructure. Additionally, the FDC serves as a liaison to and fosters cooperative efforts among Societies, Councils, and industry to develop new products and services in emerging topics.

In November 2013, after two years as an incubation project of FDC, IEEE voted to graduate IEEE Smart Grid from the IEEE FDC to a fully functioning program of IEEE. It was agreed that the IEEE Power & Energy Society would become the new administrator of the Initiative and continue and grow upon its momentum, beginning in January 2014.

Currently, the IEEE Smart Grid Initiative is an all-IEEE-wide collaborative with 14 partner organizational units including:

1. IEEE Communications Society
2. IEEE Computer Society
3. IEEE Control Systems Society
4. IEEE Dielectrics and Electrical Insulation Society
5. IEEE Industrial Applications Society
6. IEEE Industry Electronics Society
7. IEEE Instrumentation & Measurement Society
8. IEEE Power Electronics Society

9. IEEE Power & Energy Society
10. IEEE Reliability Society
11. IEEE Signal Processing Society
12. IEEE Standards Association
13. IEEE Systems, Man, and Cybernetics Society
14. IEEE Vehicular Technology Society

Each of the societies appoints volunteer representatives to serve in the standing committees of the IEEE Smart Grid Initiative:

1. Marketing Committee
2. Publications Committee
3. Education Committee
4. Research and Development (R&D) Committee
5. Policy Technical Support Committee
6. Technical Activities Committee

Volunteers from each of the OUs comprise of experts from government, industry, academia, and research institutions, all reflecting the multi-dimensional aspects of the Smart Grid arena.

2. IEEE Smart Grid R&D White Paper Series

This white paper is the first in a series of white papers developed by the IEEE Smart Grid R&D Committee. The intent of the series is to provide a concise view into the thought process and the mechanism employed by the R&D committee in its independent survey of Smart Grid emerging technologies.

The *IEEE Smart Grid Survey Structure Emerging Technologies White Paper Series* will comprise of the following white papers:

1. Introduction to the R&D Committee: This white paper provides the motivation, philosophy, and structure of the R&D committee in its survey of emerging technologies.
2. Process, Synopsis of Collation of Topics, Relational Database and Parking Lot White paper: This white paper will provide a cohesive presentation of the:
    a) Selection, collation, and categorization of the individual topics,
    b) Details of the selection process in order for the readers to understand how the topics are categorized into their respective domains,
    c) Thinking behind the initiation of creating a relational database, and
    d) Concept of the “Parking Lot” will also be explained in the paper.
3. A sub-series of topic-specific white papers will highlight important areas of research that are not yet explicitly represented within the IEEE Smart Grid Domains and Sub-domains categorization that is employed in the initial R&D committee effort. Topics will include: :
    a) Controls Systems
    b) Power Electronics
    c) Industry Applications
    d) Big Data Analytics

3. The Research and Development Committee of IEEE Smart Grid

The Smart Grid R&D committee has the mission of collecting, collating, organizing, and cataloguing research and development topics as the technology associated with the Smart Grid evolution.

Beyond the initial task of collecting the potential technologies generated by the practitioners, one of the most important tasks for the R&D committee is to map out the relationships between the topics: tracking the enabling technologies which necessarily precede each topic as well as the enabled technologies which succeed the topic. This task is necessary in order to present to the R&D community a useful roadmap that can track advanced research and development in both a very high level and in granular form accordingly. The audience for this work is the practicing innovator and researcher, legislative and policy making bodies, interested observers with a good technical background in search of inspiration or who have an idea looking for a niche.

3.1 Scope

By definition, the scope of the IEEE Smart Grid R&D Committee is to:

- Engage in identifying emerging pivotal R&D areas in the Smart Grid related domain and engage the broader IEEE societies in all pertinent areas for collaboration.
- Support and collaborate with public/private enterprises to assess priority areas and disseminate Smart Grid and sustainable energy research and implementation strategies.

3.2 Goals

The goals of the R&D committee are multifaceted. They are directed by the acknowledgment that the basis of the IEEE Smart Grid Initiative is to build a clear R&D picture of both what exists in the state-of-the-art and what is necessary in the future to implement the Smart Grid as envisioned by the global community for both the practitioners, as well as, the researchers so that they can push forward with their work in clarity. The global approach is important in order to deliver on the promise of a global vision of the Smart Grid.

The IEEE Smart Grid R&D Goals include:

1. Evaluation of existing Smart Grid and related technology road maps from the following organizations:
   a) IEEE Standards Association
   b) National Institute of Standards and Testing (NIST)
   c) Smart Grid Interoperability Panel (SGIP)
   d) United States Department of Energy (DOE)
   e) Electric Power Research Institute (EPRI)
   f) European, African, Asian, and Micronesian entities that deal with the Smart Grid concept and development.

2. Solicitation of Smart Grid related R&D ideas from each of the IEEE Organizational Units and establish communications each.

3. Surveying the R&D activities of all IEEE OUs involved in Smart Grid activities and collaborate – particularly in the areas of: Technical Activities, Emerging Technologies, and Standards – and liaise with representatives from each OU.

4. Helping the OUs identify and promote their interest areas within Smart Grid R&D. We should also focus, at least partially, on identifying critical legislation changes in Grid Codes, since Grid Codes defines rules for the power system operation. Unfortunately, they are still written more for conventional way of power system operation and do not leave a space for Smart Grid development.

5. Initiation of collaborations amongst the OUs where there are gaps – identify a research direction/need – identify opportunities to collaborate and fill gaps.

6. Creation of a database with the state of the art visual representation technology to represent the complex inter-relationships and geography inherent in the Smart Grid concept in a clear and concise manner.

3.3 Challenges

The definition of the Smart Grid is abstract and ever-changing. It is difficult to create salient structures at present without compromising future vision. The committee faces the challenge to keep the structure elaboration process flexible.

The concept of the Smart Grid is all-encompassing; it is tangentially related to every single innovative idea in power systems, communications, controls, measurement, sensors, automotive, renewable energy, and innumerable as yet unidentified areas of innovation. The committee is challenged to maintain a broader focus in order to maintain the scope of the Smart Grid concept.

The skeletal structure of the Smart Grid, as envisioned presently begins with the traditional electric power grid structure; as such, the focus has been on topic areas that have deep roots in the historical electric power generation, transmission, distribution, and metering world. Yet, the Smart Grid, as a concept, promises to have an expansive and almost limitless scope. The committee is challenged to use the existing guidelines while still seeking to grow the concept organically.

3.4 Tasks

Initial collection of topics comes through solicitation and collating of topics from many sources. These topics are filtered so that the R&D topics can be sorted into Domains, Sub-domains, and Focus areas as defined by the National Institute of Standards and Technology (NIST).

Tasks of the IEEE Smart Grid R&D Committee are to:

- Identify the emerging pivotal R&D areas in the Smart Grid related domain,
- Engage the broader IEEE societies in all pertinent areas for collaboration, and
- Support and collaborate with public/private enterprises to assess priority areas and disseminate Smart Grid and sustainable energy research and implementation strategies.

Broken down further, the tasks are to:

- Generate an existing list of R&D topics already being undertaken by industry, legislation, academia, and private enterprise.
- Generate a list of R&D topics that have been recognized as necessary areas of research
- Categorize them into the NIST defined Domains and Subdomains bailiwicks without forcing orphan topics into awkward subdomain definitions.
- Create a list of R&D topics that are enabling technologies necessary to implement the vision of the Smart Grid, even though the definition is amorphous and ever changing.
- Create a list of R&D topics which will necessarily enhance the smart grid or will depend on the smart grid in order to exist, from a long term future perspective.
- Create a big picture view of research and separate them out into the following: what exists now, what needs to be done in the short term, and what must be done to ensure a future and the long term future.

4. GUIDING PRINCIPLES

One guiding principle is a paraphrase of the Occam's Razor that has been often attributed to Albert Einstein: *"Everything should be kept as simple as possible, but no simpler."*

- Simplicity allows easier comprehension and integration of the vast structure which describes the reality of the Smart Grid R&D landscape.
- Oversimplified structures of the Smart Grid R&D obfuscate the underlying interconnectedness of the topics and the subject of the Smart Grid.
- Constantly challenge the complexity and simplicity imposed on the information.

Another principle is to maintain the relational links between topics, even across the walls of the domains, sub-domains, and Focus Area. This can be achieved by:

- Keeping the vision in mind and make the vision broad in order to be inclusive of future topics as yet undiscovered.
- Keeping the structure flexible in order to accommodate future research and development results.

5. PROCESS

The transitory nature of the R&D Committee's research and development renders a need to develop a cogent organizational system that allows efficient and effective processing of existing research topics into the IEEE Smart Grid Domains, Sub-Domains and Focus Areas bailiwick. This process requires collection, categorization and collation into an imposed structure that will allow for organic growth and evolution within the changing landscape of the Smart Grid R&D world.

The first task for the R&D committee is to:

(1) Collect, categorize, and collate the existing R&D topics into the pre-defined IEEE Smart Grid Domains, Sub-Domains and Focus Areas,
(2) Identify topics that may not fit an existing IEEE Smart Grid, Domain, Sub-Domain or Focus Area, and
(3) Identify topics that belong to other research domains and can be brought up or merged into the IEEE Smart Grid Domains, Sub-Domains or Focus Areas.

The R&D committee will then take those topics which already fall into the existing categories and expand their attributes in order to account for:

- The OUs which are most closely associated with the topics, as there are usually more than one OU associated with most topics.
- The IEEE Smart Grid Domains, Sub-domains and Focus Areas these topics fall under
- The preceding technology which necessarily spawned this technology.
- The succeeding topics which depend on this technology topic to succeed before they can start evolving.

This list will be the first milestone of the R&D committee's work. It will be passed on to the IEEE Technical Activities Committee for their consideration in their work tracking the progress of the topics, acting as conduit to the industry for introduction of these nascent technologies into the marketplace, and identifying potential areas for standard making work. This list will also serve as the initial test records for a relational database that will be the deliverable for this phase of the R&D committee's work.

5.1 Parking Lot

The term "Parking Lot" is used in the R&D committee to define those topics that all have agreed belongs in the future of Smart Grid but does not fit comfortably in the existing IEEE Smart Grid Domains, Sub-domains and Focus Areas.

Keeping in mind that as the R&D committee is completing its identification and categorization work, it is also indirectly charged with prognosticating the future direction of the Smart Grid technology; a daunting and perhaps foolhardy exercise.

It is also a fool's errand to assume that the original structural definition – as passed on to the Smart Grid R&D committee by NIST and embodied in the Domains, Sub-Domains, and Focus Areas – is the definitive structure of the future direction of Smart Grid research and development which forces the committee to indiscriminately crowbar future topics into an aging, unnatural, and predetermined niche.

The committee has agreed to err on the side of caution by placing potential topics that are unnatural fits into the "Parking Lot". These are topics which may be orphaned by technological evolution, topics which seemingly fits into many different existing niches, or topics that are so

new that there are no existing definitions within the structure to accommodate them. These topics will be examined and categorized by the committee as more research results and other newer topics evolve. The new information will, we hope, clarify and broaden the structure and help clarify the riddle of the topic identity and allow the committee to best categorizes the topic under the most logical branch of the Domains, Sub-domains and Focus Areas research tree.

One other aspect of the parking lot is that the committee also feels free to create additional structures that are new to the NIST structure, as well as reshuffle the existing structure. This decision was made based on the previous logic: that the initial definitions of the IEEE Smart Grid Domains, Sub-domains and Focus Areas are not written with the prescience to predict future innovations; the structure may therefore be lacking in potential structures which are much more logical. Once again, the committee will examine the topics with a detail oriented vision from a high altitude view in order to accommodate the breadth and depth of the Smart Grid, as it evolves through innovation.

Rest assured that great patience will be exercised as the topics and examined and re-examined. No changes will be made before it is time. The committee must ensure that the R&D community is not led astray by the committee's rashness and impatience.

6. Relational Database

Through the collation process, the R&D Committee identifies many research areas. These areas may have names that mean different things to different research fields, or may be closely related even though they are being developed in different IEEE societies. The goal of collating the data from the different IEEE OU's and national documents is to cross reference this information in a relational database.

A relational database is a digital database whose organization is based on the relational model of data. The intent is to create pathways between records which reflect the relationship between each of the entries so that simple queries by the user can uncover the hidden relationships between topics and in so doing, relating disparate topics to one another. This is very useful for connecting a large number of topics that reside under a very large umbrella, such as the R&D topics within the broad scope of the Smart Grid.

The ultimate plan for the relational database is to create a web based database that is available to the general research public so that they can track their own research as well as educate themselves on the vast expanses of the Smart Grid and the deep depths of the research work already underway.

The initial relational database is being worked on concomitantly with the topic generation effort. The committee's intent is to create a first attempt at a small scale relational database using a limited list of the topics already unearthed by the committee, thereby giving form and function to the nascent relational database; the committee is well aware of the importance of doing no

harm and not overstepping potential boundaries by assuming too much about the future structure of the Smart Grid, this is the reason why the relational database is based on existing R&D topics. There will be further work on the relational database as the R&D information structure grows.

Once the initial list has been compiled and categorized, that portion of the work will become the domain of the IEEE Smart Grid Technical Activities Committee for upkeep and maintenance. The relational database, when it is up and running will also be given to the Technical Activities committee for upkeep and maintenance. The R&D committee will be then freed to continue to collect long term type of possible R&D topics as well as work in categorizing those topics residing in the Parking Lot.

7. REFERENCES

- IEEE Grid Vision 2050 Reference Model
- IEEE Grid Vision 2050 Roadmap
- IEEE Grid Vision 2050
- IEEE Vision for Smart Grid Controls: 2030 and Beyond
- IEEE Vision for Smart Grid Communications: 2030 and Beyond Reference Model
- IEEE Vision for Smart Grid Communications: 2030 and Beyond
- IEEE Vision for Smart Grid Communications: 2030 and Beyond Roadmap
- IEEE Smart Vision for Computing: 2030 and Beyond
- IEEE Vision for Smart Grid Controls: 2030 and Beyond Reference Model
- IEEE Vision for Smart Grid Controls: 2030 and Beyond Roadmap
- IEEE Smart Grid Vision for Vehicular Technology: 2030 and Beyond