Y9.ET2.2: FAWG System Level Architecture and Metrics

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1. **Project Goals**

   The FREEDM Architecture Working Group (FAWG) develops artifacts that document the most current design architecture of the FREEDM System. Given the wide scope of the Center's research, and the many researchers of different backgrounds that are involved, it became difficult for the entire research team to keep abreast of all of the developed components and technologies. At the same time, an understanding of the entire system architecture is important for both the researchers and the students involved in the research. To address this issue, the FAWG develops and disseminates centralized resources that provide the necessary information about the FREEDM System architecture design. The expected deliverables are: (1) reference document that is agnostic to hardware, software, network, and embedded systems architectures, and (2) to use this architecture to elicit subsystem requirements and interface specifications.

2. **Role in Support of Strategic Plan**

   The primary output is a living article elicited from interviews from each subthrust. All future development must reference the architecture. The architecture provides a critical reference for system development, ensuring the common understanding of FREEDM functionality across all aspects of the Center. The architecture, coupled with the Use Cases, provides the input to a distributed smart grid reference standard that could be used worldwide.

3. **Fundamental Research, Technological Barriers and Methodologies**

   The primary barrier in the FAWG has been to extract the relevant information form the ongoing research and present it in a form that allows reproducing the system. To help formalize the process, the team has developed use cases, which provide a good starting point for further driving system engineering practices and tools throughout the engineering development and system integration process.

4. **Achievements**

   The primary objective of this research is to develop a document of the whole system architecture with distinguished hardware/software components, which have multiple levels of detail, and a hierarchical structure.

   Development of the Shared Web Portal for FAWG Documentation: To document and share the developed artifacts, the team has developed a website that documents all aspects of the FREEDM Systems Design. The basic design of the website was developed last year. This year, the team has continued to populate the website, and organize the information provided by subthrust leaders. The information was purposely presented at a high level, with references to team publications that provide a deep technical dive into the design of a particular aspect of the system. The development of the shared web portal is ongoing, and will continue beyond the graduation of the Center. The team plans to actively manage the website until graduation, at which point the PIs involved in the projects will be expected to continue using and updating this resource.

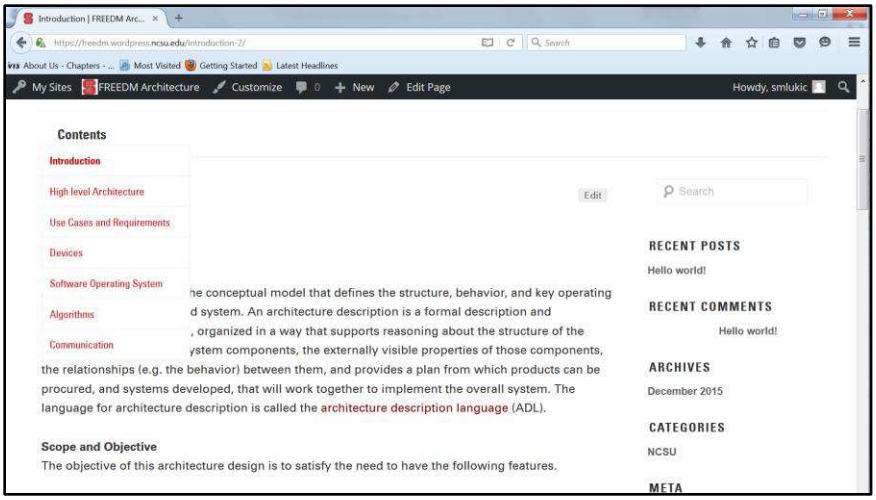

Figure 1: Screenshot of the FREEDM FAWG Website with the pull-down menu visible [1].

The sections of the website, and the general architecture has been defined last year. This year, we continue the efforts to complete each section with the most current implementation of the system feature. As a reminder, the main sections of the web portal are defined below:

1. **Introduction:** This section describes the scope and objectives of the FAWG initiative, our approach towards the case and how the website fits into this mission.
2. **High-level Architecture:** This section discusses the high-level architecture of the FREEDM system where different levels of operation and control are classified and discussed. Schematics and complete architecture diagrams are shown, defining the Categorization of Levels in the architecture as the Energy Cell (level 1) where the coordination of the load, generation and storage is discussed for power balance; Single SST (level 2) where the interaction of a single SST with medium voltage FREEDM system is described; the FREEDM System (level 3) where the interaction strategy of multiple SSTs and FIDs in a FREEDM system is described; and multiple FREEDM Systems (level 4) interconnected to form a medium-voltage distribution system is managed.
3. **Use Cases and Requirements**: This section describes the eight Use Cases defined in FREEDM. These Use Cases have been defined in earlier years through the System Engineering efforts in the Center. This section of the website describes the interactions between FREEDM systems components under each Use Case. The abstract architecture diagram which is built using an extension of the SYSML's class diagram serves as the reference for how the Use Cases are described, and how the interaction between the components takes place.
4. **Devices**: This section describes the components unique to the FREEDM center: the solid state transformer, the fault isolation device, the distributed energy storage device, and the distributed renewable energy resources. The components' desired functionality, interaction with other sub-systems, and implemented controllers are described.
5. **Software Operating System:** This section describes the FREEDM distributed grid intelligence architecture, as well as the FREEDM Supervisory Control and Data Acquisition (SCADA) implementation.
6. **Algorithms:** This section describes the main FREEDM algorithms: Intelligent Energy Management (IEM), Intelligent Power Management (IPM), and Intelligent Fault Management (IFM)
7. **Communications**: This section defines the information exchange requirements, methods of communication and selected communication protocols.
8. **Glossary of terms**.

Development of Git Repositories for GEH Implementation:

As the FREEDM Systems Center reaches graduation, the center will continue to move its technologies towards the demonstration plane, and towards system demonstrations. To support this move towards the demonstration plane, FAWG team has focused on documenting the architecture and the technologies that are part of the FREEDM Green Energy Hub (GEH) testbed, which serves as the hardware implementation of the FREEDM system. To do this, the team has dedicated a section of the Website to documenting the architecture of the GEH at a high level. The website defines the operation and the functions of the sub-systems that make up the GEH Testbed.

Beyond the high-level description of the system, the team is developing a Git repository of the algorithms that run the systems and sub-systems of the GEH Testbed. These repositories allow the FREEDM Center researchers and others to replicate sub-systems that are in use in the FREEDM GEH testbed. Importantly, having a centralized repository ensures that various researchers can contribute algorithms and functions to the GEH without having to develop the backbone of basic functionalities that are already available. By using the features of the Git repository, different branches can implement different variants of the same component. Figure 2 shows a screenshot of the GitHub repository in development.

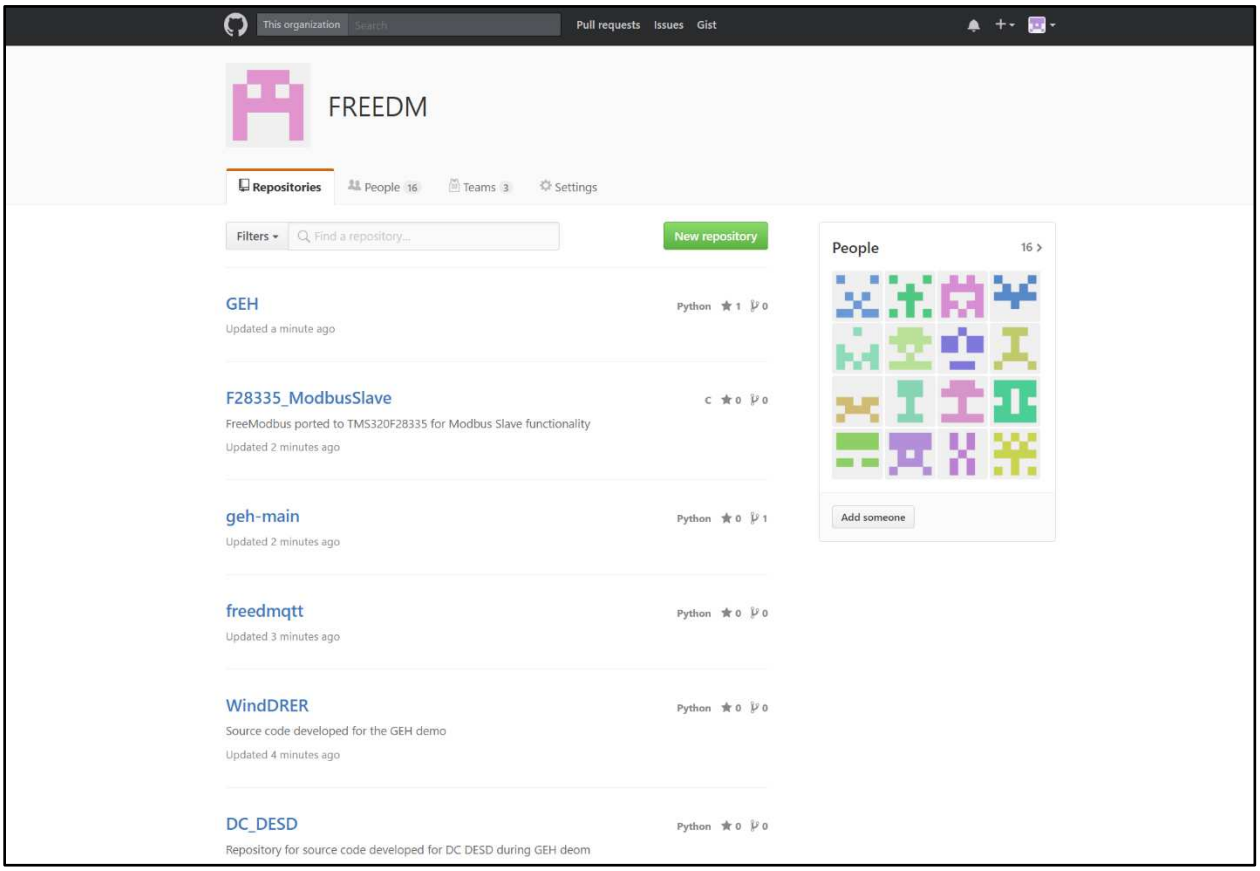

Figure 2: Screenshot of the Git Repositories in Development [2].

5. Other Relevant Work Being Conducted Within and Outside of the ERC

As with any engineered system, there is a need to document the system architecture so that future developments are made in a systematic manner, and so that other individuals and entities can be

educated on the current system architecture. Therefore, the FAWG efforts provide a common reference platform for all center investigators and advisory members. Parallels to the FAWG effort can be found for any engineered system of similar complexity.

6. Milestones and Deliverables

Complete development, documentation and wiki webpages of all the Use Cases.
Complete compilation of all algorithms that are currently in use in the GEH testbed.

7. Plans for Next Five Years

FAWG efforts will continue beyond the NSF funding period, since it is important to continue to update the system architecture as the FREEDM system continues to evolve. Future FAWG activities will use the developed documentation framework; specifically, the Website and the Git repository will be continuously updates as the system evolves.

8. Member Company Benefits

No member companies are related to this project.

9. References

[1]. https://freedm.wordpress.ncsu.edu/
[2]. https://github.ncsu.edu/