A NEW DIRECTION FOR BATTERY AND ENERGY STORAGE STANDARDS DEVELOPMENT

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Abstract

In 1964, Bob Dylan released a song with the lyric, "Your old road is rapidly agin'; so get out of the new one if you can't lend your hand; for the times, they are a changin'." The IEEE Power and Energy Society recognizes the truth of that statement for the power and energy industry. As a result, the IEEE Stationary Battery Committee has been reorganized to address the current needs of its Society members. This paper will explain the rationale behind that decision, discuss its scope and organizational structure, and outline what it sees as its future objectives.

Introduction

On January 8, 1982, a consent decree was concluded that mandated the end of AT&T as we knew it then.[1] This led to the wide-scale deregulation of the telephone industry. The seeds of electric deregulation – letting free market principles dictate prices – began in 1995 when Congress passed legislation that allowed deregulation of the wholesale power market in Texas[2]. This led the states of California with the passage of Assembly Bill 1890 in August of 1996[3], and Texas when Governor George Bush signed Senate Bill 7 on June 18, 1999[4] to deregulate not only the generation of electric power, but the retail purchasing of electricity. Pennsylvania and a few other states also passed legislation allowing deregulation during this period[5], but California and Texas were the two largest states to implement it and gain its large-scale notoriety.

However, it was the advances in technology that underlay and really allowed the deregulatory forces in both telecommunications and electric power generation to gain the steam that has created the market situation we see today.

In 1973, a Motorola researcher made the historic call to Dr. Joel Engel at the Bell Labs using a hand-held mobile phone[6]. This led to advances in decentralizing telecommunications with the creation of remote cell towers, mobile switching centers, distributed switching offices and other outside plant applications.

A similar transition is taking place within the electric utility industry. Wind and solar farms have led to the generation of electricity using renewable energy. We are now talking about distributed generation resources (DER) not only utilizing renewables, but also energy storage devices. The Smart Grid, the Intelligent Grid, the manufacture of electric and natural gas vehicles and the Internet of Things (IoT) have introduced new requirements for the grid that cannot be met simply with traditional or legacy bulk power generation.

As a result, demands for frequency regulation, load balancing and load shifting, peak shaving, and on-demand electricity have introduced the expanded demands for energy storage.

Battcon Emphasis on Energy Storage Systems (ESS)

Interestingly, Energy Storage is not a new topic at Battcon Conferences. With access to the archives containing all Battcon conference papers beginning in 1997, it should be noted there have been 83 papers given on various aspects of energy storage. Table 1 provides a summary of a cursory review of the archives. It counts only papers that have a reference to some part of energy storage in their title, and does not include any reference to papers that might have had an indirect reference to ESS within the text of a paper not titled for energy storage. However, where reference is made in a paper to more than one ESS topic, all references are counted.

BATTCON PAPERS ON ENERGY STORAGE TOPICS - 1997-2015										
Year	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
ESS General					4	2		2		2
Advanced Lead-Acid										2
LI-Ion[1]						2		3	3	
Sodium[2]							1			
Redox Vanadium Flow Batteries										
Nickel Metal Hydride									2	
Fuel Cells							3		2	
Ultra-Capacitors						1		4		1
Flywheels		1					1			
Thermal										
Advance Compressed Air (CAES)									1	
ESS Testing and Maintenance	1									
Utility (Grid) Scale ESS										
Renewables	1					2	1			
Electric Vehicles										
IEEE SBC Papers								1		
TOTALS	**2**	**1**	**0**	**0**	**4**	**7**	**6**	**10**	**8**	**5**
Year	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**TOTALS**
ESS General				2	1			1		**14**
Advanced Lead-Acid			1						1	**4**
LI-Ion[1]	5	3	1	2	2	3		3	2	**29**
Sodium[2]				1	1	1		1	1	**6**
Redox Vanadium Flow Batteries			1							**1**
Nickel Metal Hydride				1		1	1			**5**
Fuel Cells	4	2					1		1	**13**
Ultra-Capacitors				1						**7**
Flywheels										**2**
Thermal										**0**
Advance Compressed Air										**1**
ESS Testing									1	**2**
Utility (Grid) Scale ESS									1	**1**
Renewables	1		1		1		2			**9**
Electric Vehicles						1				**1**
IEEE SBC Papers								2		**3**
TOTALS	**10**	**5**	**4**	**7**	**5**	**6**	**4**	**7**	**7**	**98**
1	Includes all Li-Ion technologies									
2	Includes all Sodium technologies									

Table 1. ESS subjects addressed in Battcon papers, 1997-2015

A Short History of Energy Storage

A Brief Selective Overview

Energy Storage per se is not really new. Lead-acid batteries have always been an electrical storage device beginning in 1859 with Gaston Planté's first lead-acid battery. Pumped Hydro Storage, one of the earliest forms of electrical energy storage was developed in Europe in the late 1800's. In 1882 the first hydropower plant to serve private and commercial customers was opened in Wisconsin in the USA[7]. Today, Advanced Pumped Hydro Storage can handle 1000's of megawatts of electrical storage as evidenced at the Bath County Hydro Storage generating plant in Bath County Virginia (see Figure 1).

Figure 2-2 | Pumped Hydro Storage *(Vattenfall, IEC MSB/EES Workshop, 2011)*

[4] The largest PHS plant in the world, with 2100 MW peak power, is the Bath County hydroelectric pumped storage plant located in Virginia, USA [bat85].

[5] Adjustable-speed machines are now being used to improve efficiency.

Figure 1: Largest Pumped Hydro Storage plant in the world now upgraded to 3003KW, Bath County, Virginia

(Photo is from a presentation previously given by the author at an IEEE Stationary Battery Committee meeting.)

Types and features of energy storage systems

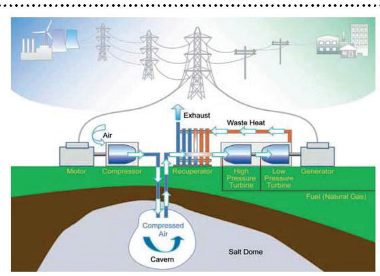

Figure 2-3 | Underground CAES [rid11]

Figure 2. Configuration for a CAES Plant

Compressed Air Energy Storage (CAES) is another energy storage device that is not really new. The world's first compressed air storage power station, located in Bremen, Germany, was put into operation in 1978. It can supply 290MW of peak power with a total volume of 11 million cubic feet stored at pressures up to 1000 psi in two salt caverns approximately 2500 feet below the surface[8]. The first US CAES plant was commissioned in 1991. Called the McIntosh project in Andalusia, Alabama, it is a 110 MW unit operated by the Alabama Electric Cooperative (AEC)[9].

One of the earliest attempts at a US based battery energy storage system (BESS) was actually a 2-year pilot project conducted at the Southern California Edison Chino generating station. It housed 8,256 cells of a lead-acid battery. It was designed to provide 10MW of power over a 4-hour period, and began operation in August of 1988[10].

Energy Storage Technologies

As you can see, batteries are not the only form of energy storage being used or considered today. There are basically four major categories of ESS devices:

1. Electrochemical energy storage devices
2. Mechanical energy storage devices
3. Thermal energy storage devices
4. Chemical energy storage devices

Table 2 lists some of the major technologies associated with each category. Since many governmentally sponsored and university research and development efforts are underway, other technologies may present themselves as candidates for ESS inclusion in the future. This list is a representative list of the major technologies under consideration at the present time.

Electrochemical Technologies	Mechanical Technologies	Electrical
Lead-Acid (LA)	Pumped Hydro Systems (PHS)	Double-layer Capacitor (DLC)
Nickel Cadmium (NiCd)	Compressed Air Energy (CAES)	Superconducting Magnetic Coil (SMES)
Nickel Metal Hydride (NiMH)	Flywheel (FES)	
Lithium-Ion[1]		
Sodium[2]	**Thermal Technologies**	**Chemical**
Redox Flow Battery[3]	Molten Salt	Synthetic Natural Gas (SNG)
Hybrid Flow Battery[4]	Advanced-Adiabatic Compressed Air (AA-CES)	Hydrogen Fuel Cell[5]
Fuel Cell (FC)[5]		

[1] includes all lithium types, e.g. lithium metal polymer, lithium phosphate, etc.
[2] Includes all sodium types, e.g. sodium sulphur, sodium metal halide (Zebra), etc.
[3] Includes Zinc bromide and Vanadium
[4] Includes hybrid membrane and hybrid vanadium and DLC.
[5] Fuel Cells are Electrochemical or Chemical depending upon composition

Table 2. Energy Storage Categories and Major Technologies

The New Dimension for Energy Storage

Electrical Energy Storage (ESS) has taken on a new dimension in recent times due to the demands on the utility grid as described above. It has been said that the utility electric grid is the largest Just-in-Time (JIT) supply system in the world. The difficulty is that the grid has no capacity to store the energy generated on the grid. As a result, grid operators are constantly balancing the energy needs of consumers (both residential and commercial) with the generation resources they control[11]. Thus, "the entire electric grid operates without any inventory of the product it supplies"[12].

Energy applications that can benefit from Energy Storage Systems, therefore, include peak shaving, load-leveling, transmission and distribution upgrade deferral, renewable generation shifting, energy arbitrage, frequency and voltage regulation, power quality issues, renewable generation smoothing, ramp-rate control and trackside regulation for electric rail operations[13].

The Department of Energy website at http://www.energystorageexchange.org/projects lists 1358 ESS projects worldwide. Of these, 639 have been verified as valid ESS projects. The remaining 719 noted in red are in various stages of validation.[14]

IEEE Power and Energy Society (IEEE PES) and the Energy Storage and Stationary Battery Committee

The Need for Re-structuring

The Power and Energy Society recognized that they had not visited the structure of the Technical Committees within its jurisdiction for over a decade. As a result, the Joint Technical Council of the IEEE PES scheduled a retreat in November 2012 in Orlando FL to identify gaps where key technologies or issues were not being covered adequately.

At its conclusion five (5) key objectives were prioritized; chief among them was looking at the technical committee structure and determining what should be done.

The IEEE PES Society is now composed of 17 Committees (see Table 3 for a complete list of the current committees). This was the result of a restructuring from 21 Committees originally. You will note that the Stationary Battery Committee has been renamed the IEEE Energy Storage and Stationary Battery Committee and carries the acronym ESSB. Again, this was part of a Society-wide restructuring that grew out of the original retreat in 2012, followed by several recurring planning and town hall meetings.

The proposed reorganization was posted on several IEEE websites and society member public comments were solicited. At the Joint Technical Committee Meeting held in Memphis during the second week of January 2016, the JTCM made its final recommendations, which were then given to the IEEE PES Executive Committee, and on Thursday, January 14, 2016, the IEEE Board of Governors approved the restructuring and the 17 resulting Committees and 3 PES Coordinating Committees became operational[15]

Analytics Methods for Power Systems Committee Electric Machinery Committee Energy Development and Power Generation Committee Energy Storage and Stationary Battery Committee Insulated Conductors Committee Nuclear Power Engineering Committee Power System Communications and Cybersecurity Committee Power System Dynamic Performance Committee Power System Instrumentation and Measurements Committee	Power System Operations, Planning and Economics Committee Power System Relaying and Control Committee Smart Buildings, Loads and Customer Systems Committee Substations Committee Surge Protective Devices Committee Switchgear Committee Transformers Committee Transmission and Distribution Committee

Table 3. List of Restructured Technical Committees approved by the IEEE PES Board of Governors

The Scope of the ESSB

The first order of business was to establish a scope that outlines the intent and purpose for the ESSB. While not radically different than the scope previously published for the Stationary Battery Committee, it encompasses the following three purposes::

1. Provide a means for the IEEE PES (and affected industries) to develop and publish standards that define recommended industry practices for the health, safety, performance and maintenance of the integrated parts of stationary battery and energy storage in both static and renewable states.

2. Conduct technical sessions and webinars; publish articles, papers and technical reports; and participate in forums and conferences to inform the industry of milestone progress as the Electrical Energy Storage (EES) industry evolves.
3. Aggressively engage participants involved in the EES industry to join the ESSB Committee, and its subcommittees and working groups, to accomplish the development of standards, guides, best practices and technical papers and reports.

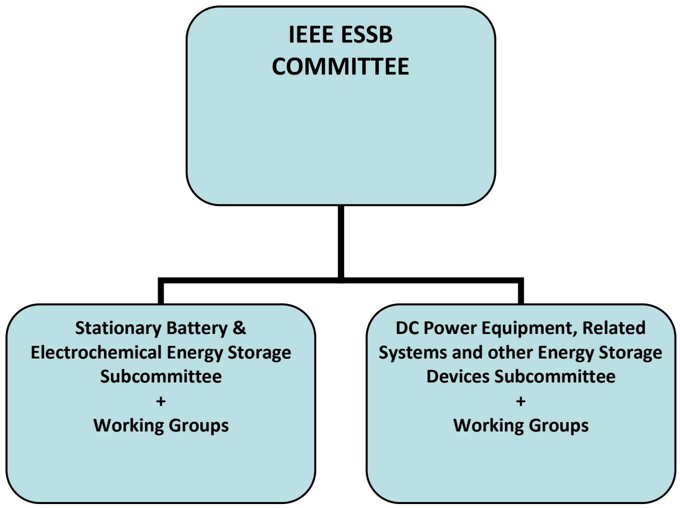

Figure 3 – Organizational Chart of the IEEE ESSB

The Committee Structure

The Energy Storage Committee will be composed of two subcommittees initially:

The reasoning behind this approach is that the Energy Storage part of the Committee is in its embryonic form. The two subcommittees will divide the existing Working Groups. The Committee has chosen three officers while the subcommittees will be run by two officers each. Each Working Group contains at least a Chair and a Secretary.

The longer term goal is to expand the working subcommittees into at least three. When this occurs, the other energy storage devices will become a separate subcommittee to engage in the writing of standards (best practices and guidelines) for the technologies that are not electrochemical in nature.

The current officers of the Committee and the Subcommittees are listed in the References section of the paper. The current allocation of the Working Groups is also listed in the References section.

The Makeup of the Stationary Battery and Electrochemical Energy Storage Subcommittee

This subcommittee will continue to write standards for lead-acid and Ni-Cd batteries, but will also develop standards for other electrochemical EES technologies. It is currently working on standards (again, best practices) for both Lithium and Sodium based batteries. The other technologies the subcommittee envisions developing standards for are shown below:

- ✓ Flow Batteries
- ✓ Metal Air Batteries
- ✓ Electric Double Layer Capacitors
- ✓ Fuel Cells (??)
- ✓ Other relevant electrochemical technologies

The Makeup of the DC Power Equipment, Related Systems and other Energy Storage Devices Subcommittee

This subcommittee is inheriting Working Groups that did reside with the Stationary Battery Committee but under the new restructuring will function as part of this subcommittee. It is envisioned that within the next two to three years this subcommittee will be divided into two subcommittees:

- The DC Power Equipment and Related Systems Subcommittee
- Mechanical and Other Energy Storage Devices Subcommittee

Currently, this subcommittee will continue working on standards (best practices and guidelines) that deal with DC systems design, chargers and rectification, ventilation and thermal management, as well as battery and energy management monitoring and control systems.

It is envisioned that in the future, working groups will be established to write standards (best practices and guidelines) for:

- ✓ Flywheels
- ✓ Water based Thermal
- ✓ Gas and Heat Thermal
- ✓ Pumped Hydro
- ✓ Compressed Air
- ✓ Magnetic Coils

ESSB Special Coordination and/or Task Forces

Finally, the Energy Storage and Stationary Battery Committee will retain four (4) Task forces or Coordinating Groups:

1. Fire Safety Standards and Safety Codes Coordination Task Force (NFPA, UL, NEC, etc.)
2. NERC Task Force
3. Safety Data Sheets Task Force

Conclusion

In the words that begin in the Abstract, "the times are a changin" is really true in more than one respect. An evolution is certainly occurring within the electric utility industry. Distributed Generation and "the Smart Grid" with all its connotations are a reality.

A push by both federal and state governments to find renewable energy sources is not going away. In fact, on February 16, 2016, 17 governors from the states of California, Connecticut, Delaware, Hawaii, Iowa, Massachusetts, Michigan, Minnesota, Nevada, New Hampshire, New York, Oregon, Pennsylvania, Rhode Island, Vermont, Virginia and Washington, signed a "Governor's Accord for a New Energy Future"[16].

This is being driven by the desire to reduce CO_2 emissions as much as practically possible and provide more efficient and reliable energy. This can be accomplished with the use of renewables and taking advantage of the ability to distribute the generation of energy by employing principles of the smart grid. This in turn leads to the need to provide short term, medium term and long term energy solutions. And, of course, this is where the technologies of energy storage come into play.

Please understand, there is no magic bullet that can satisfy the demands of the evolving grid infrastructure, nor will one technology offer a complete solution. I think the following chart explains the paradigm that is driving the changes we are experiencing:

Objectives (Goals)

- Reduce CO_2 Emissions
- Provide More Efficient/Reliable Energy
- Meet Needs of the new Drivers

Drivers

- Renewable Energies
- Distributed Generation
- Smart Grid
- Micro Grid

Market Needs

- Short Term but Instant Storage
- Medium Term Storage
- Long Term Storage
- Dispersed (Distributed) Storage

Technical and Practical Implications

- Batteries will play a Large Role
- Other EES Alternatives based on Lifetime Costs

The Suggested Path Forward

- Standards/Guidelines are Essential
- R&D Incentives are Valid
- A Cohesive National Policy is needed

Table 4: Paradigm chart as presented by the author at the ESSB/SBC Town Hall Meeting held during the IEEE General Meeting in Denver, July 2015.

The IEEE Power and Energy Society Joint Technical Council understands that for us to make a significant and lasting contribution to the forward looking efforts of batteries and energy storage, it is important that we draw professionals from all of the following areas: [1] battery and energy storage users, [2] battery and energy storage manufacturers, [3] engineering consultants and battery and energy subject matter experts, [4] installation and testing technicians as well as contractors, [5] academics, [6] government individuals involved with research and development of ESS technologies and [7] any other interested individuals who would like to help in the development of these standards, best practices and guidelines as well as contributing knowledge, experience and expertise through publication of papers and giving presentations.

We welcome that participation.

Bibliography

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16 "Governors' Accord for a New Energy Future," Signed by 17 Governors on February 16, reported by Robert Walton, Utility Dive, February 18, 2016.

References

Officers of the ESSB and its Two Subcommittees

Chair	Chris Searles
Vice-Chair	Curtis Ashton
Secretary	Bill Cantor
Treasurer	TBD

Task Forces under ESSB

Officers of the Stationary Battery and Electrochemical Energy Storage Subcommittee

Chair	Rick Tressler (through December 2016)
Vice-Chair/ Secretary	Kurt Uhlir

Working Groups of the Stationary Battery and Electrochemical Energy Storage Subcommittee

IEEE 450- VLA Maintenance and Testing
IEEE 484-VLA Battery Installation
IEEE 485-VLA Battery Sizing
IEEE 535-Nuclear Battery Qualification
IEEE 1106-NiCd Installation, Maintenance & Testing
IEEE 1115-NiCd Battery Sizing
IEEE 1881-Stationary Battery Glossary
IEEE 1184-UPS Batteries
IEEE 1187-VRLA Installation
IEEE 1188-VRLA Maintenance and Testing
IEEE 1189-Battery Selection
IEEE 1660-Batteries Used in Cycling Service
IEEE 1679.1-Lithium Batteries
IEEE 1679.2-Sodium Batteries
IEEE 1625-Batteries in Portable Computing
IEEE 1725-Batteries in Cell Phones
Nuclear Working Group [no IEEE number assigned]

Note: Please see IEEE ESSB website for Complete Names of Working Group documents

Officers of the DC Power Equipment, Related Systems and other Energy Storage Devices Subcommittee

Chair	Steve Vechy (Through December 2017)
Vice-Chair/Secretary	TBD

Working Groups of the DC Power Equipment, Related Systems and other Energy Storage Devices Subcommittee

IEEE 946-DC Systems Design
IEEE 1375-Battery Protection
IEEE 1491-Battery Monitoring
IEEE 1578-Battery Spill Containment
IEEE 1635-Battery Ventilation and Thermal Mgmt.
IEEE 1657-Battery Technician Qualification
IEEE 1679-Emerging Technologies (General)
IEEE 2405-Battery Chargers

Note: Please see IEEE ESSB website for Complete Names of Working Group documents