STABALID

STAtionary Batteries LI-ion safe Deployment

Verneuil-en-Halatte, November 20, 2014

Report title:	D4.2 Proposal for a harmonized environmental regulatory framework for European regulations on Li-ion stationary battery system				
Costumer:	European Commission				
Project title:	STABALID - STAtionary Batteries LI-ion safe Deployment	**Customer order Nr.:**	Grant Agreement: 308896		
		Internal project Nr.:	12076		
		Project start:	01/10/2012		
		Project end:	31/03/2015		
Subproject:		**Applicable codes/standards:**			
Workpackage:	WP4	**Date of order acceptance:**	10/10/2012		
Task:	T4.2	**Date of completion:**			
Additional contract info:	Project website: www.stabalid.eu-vri.eu				
Participants / Distribution:	**Participants in the activity:**	**Distribution (list):**			
	SAFT, EDP, INERIS, EU-VRI	Stabalid Team			
Document data:	**Author(s):**	Michel DEMISSY			
	Doc. Nr.:		**Version:** 1	**Date:**	20/11/2014
	Pages:	35	**Annexes:**		
	Status:	Final	**Confidentiality:**	PU	
	Keywords:	Li-Ion System, Regulations, Standards, Guidelines			

Approved by:	**Task Leader:**	Amandine LECOCQ	**Yes/No:**	Yes
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The rapid development of large capacity renewable energy (RE) generation brings many challenges to power grid and the impacts are extending from local areas to the entire power system. RE generation becomes more and more often the selected power technology to diversify the energy mix and reduce CO_2 emissions.

The capacity of wind power is planned to reach 230 GW in Europe, 200 GW in China and 150 GW in United States in 2020. According to International Energy Agency (IEA) expectations, the plans for the deployment of wind power in the future are 400 GW in Europe in 2030, 300 GW in United States in 2030, 1000 GW in China in 2050.

In Europe wind power is expected to meet 16 % of the total electricity demand by 2020 and 33 % by 2030.

The global photo-voltaic (PV) cumulative installed capacity is somewhat lower but will reach 290 GW in 2017 and will also increase. In Europe it is expected that the PV could provide up to 10 % of the total electricity demand by 2030.

As integrating more large capacity RE into the grid brings variability and uncertainty, there is a need to provide more flexibility and improve the efficiency of power systems for constantly balancing generation and load. Flexibility in particular can be achieved from electrical energy storages (EES) that can act as either generation or load. Different technologies of EES can be used.

Generally, energy storage technologies with the highest power densities tend to have the lower energy densities; they can discharge enormous amounts of power, but only for a short time. Likewise, technologies with the highest energy densities tend to have lower power densities; they can discharge energy for a long time, but cannot provide massive amounts of power immediately.

Among the electrical energy storages, some have medium discharge time and are able to produce discharge for minutes to hours, and have an energy to power ratio of between 1 and 10. This category is dominated by batteries, namely lead acid (LA), lithium ion (Li-ion), and sodium sulphur (NaS), though flywheels may also be used. Medium discharge time resources are useful for power quality and reliability, power balancing and load following, reserves, consumer-side time-shifting, and generation-side output smoothing. Moreover, specific batteries may be designed so as to optimize the power density or energy density. As such, it is relevant to address both the uncontrollable variability and partial unpredictability that RE generation brings to the grid.

The conjunction of the development of renewable energy and the need of their association with EES is largely responsible for the strong deployment expected of EES in the near future.

This report identifies relevant existing regulations and standards for deployment of secondary batteries used as stationary battery systems. This means that the battery is regarded as a whole and not only by considering the safety of its elementary components. The first section proposes a review of the existing regulations. The second section focuses on available standards. The third part is dedicated to an identification of technical contents that should be useful to gather in a specific standards or regulations to improve the installation safety of large EES.

2 Relevant European regulations for installation of large Li-ion stationary batteries [3]

2.1 *Introduction*

In the United States the storage facilities are recognized as a management tool in distribution networks, which promotes investment in storage technologies, improving network.

In Europe, there are large disparities between countries: specific regulation for storing energy in Austria with an exemption from network access fees, exemption of access fees for any new installation of stationary storage also in Germany, etc. In a more general way, it remains considerable uncertainty in Europe on the issue of "ownership" of storage between the producer, the network manager or even the consumer: is a storage facility a production device ? or a network device as a transformer ? or a complement installed by the consumer as a generator? This uncertainty is an important obstacle to the development of the market.

In France, Article 6 of the New Organization of Electricity Market (NOME) law (for opening the electricity market) requires the alternative suppliers of electricity to prove that they are able to ensure the consumption of their customers during peak periods.

To do this, they can:

- have their own production capacity (e.g. combined-cycle natural gas) or use EES time shifting;
- Or, have virtual peaking capacity by subscribing a contract of power production from a producer;
- Or, to prove they can activate, if necessary, withdrawal capacity (that is to say it can reduce its electricity demand peak) by contracting with consumers.

This obligation should help to the birth of an EES market.

Overall, both legislative and economic channels could combine to allow the progressive development of massive energy storage. The regulation is imposing storage obligations on intermittent energies producers like in Japan or in France for island areas. Alternatively, the economic way with the emergence of business models can allow the arrival of dedicated industrial players as it has been the case in the natural gas industry. In this scheme, additional services would be provided: secure energy supply, smoothing peak, economic infrastructure optimization, autonomy, etc. They would ensure the profitability of storage facilities.

In this context where neither the legal nor the economics drivers are established it is expected that few regulations take into account the implementation of EES.

In the task D4.1, a survey has been carried out to identify the regulations in force on Li-ion stationary battery systems in different countries of Europe, both for accident prevention and mitigation, and for environmental impact in the framework of the Directive 2010/75/EC on industrial emissions (integrated pollution prevention and control). Moreover, the regulatory context related to Li-ion batteries for stationary applications has been compared in Europe and in Japan. Data collected in this work are summarized in table 1.

Seveso Directive 96/82/EC on the control of major-accident hazards	
Battery Directive 2006/66/EC about recycling or end of life	
Occupation health and safety Directive 89/391/EEC on OSH "Framework Directive"	
EIA Directive 2014/52/EU on "Environmental Impact Assessment"	
SEA Directive 2001/42/EC on "Strategic Environmental Assessment"	
Law of 19th July 1976 on "installations classées pour la protection de l'environnement " (more specifically Article L511-1 to L-517-2 of Environmental Code)	
Fire protection law (Japanese law)	

Table 1: Main regulations mentioned in the overview study task 4.1

2.2 *Seveso directive 2012/18/EU*

A new Directive on the control of major accident hazards involving dangerous substances (known as "Seveso III") was published on 24 July 2012 and will be written into domestic legislation which will come into force on 1 June 2015. It will amend and subsequently repeal the Seveso II Directive.

It strengthens a number of areas such as public access to information and standards of inspection and will continue to ensure a high level of protection to human health and the environment from major accidents involving dangerous substances.

This Directive lays down rules for the prevention of major accidents which involve dangerous substances, and the limitation of their consequences for human health and for the environment, with a view to ensuring a high level of protection throughout the Union in a consistent and effective manner.

The main objective is to reduce the possibility for a dangerous substance, to cause a release of matter or energy that could create a major accident under both normal and abnormal conditions which can reasonably be foreseen. For that, a risk analysis must be performed and the assessment shall take into account the following characteristics:

- (a) the physical form of the dangerous substance under normal processing or handling conditions or in an unplanned loss of containment;
- (b) the inherent properties of the dangerous substance, in particular those related to dispersive behaviour in a major- accident scenario, such as molecular mass and saturated vapour pressure;
- (c) the maximum concentration of the substances in the case of mixtures.

Otherwise, to improve the risk management provisions, the Directive provides the followings items:

- the containment and generic packing of the dangerous substance should, if appropriate, be taken into account;
- general obligations of the operator that need to prove he takes measures to avoid major accident or to mitigate their consequences;
- a Competent Authority (in charge of the implementation of the directive) is defined;
- declaration to list dangerous substances, processes and main risks have to be notified to the Authority;
- major-accident prevention policy is a document of guidelines produced by the operator;
- domino effects is treated (concept of interactions between different companies on a same site)
- safety report available (technical demonstration of risk evaluation and adequate measures)
- management of change in case of modification of an installation, an establishment or a storage facility;
- emergency plans (internal in charge of the operator and external in charge of the authority);

- land-use planning (keeping safe distances from the dwellings);
- information to the public ;
- public consultation and participation in decision-making;
- information to be supplied by the operator and actions to be taken following a major accident are defined;
- action to be taken by the competent authority following a major accident are defined;
- prohibition of use (if insufficient measures are taken);
- inspections (by competent authority).

In order to prove that everything was done to prevent major accidents, the operator should provide to the competent authority the relevant pieces of information in the form of a safety report. This will be used to prepare emergency plans and response measures too.

That safety report should contain details on the concerned facilities including: i) the dangerous substances present, ii) the process equipment and operational details, iii) risk analysis and possible major accident scenarios. The safety report should also contain the prevention and intervention measures and the safety management system, in order:

- to prevent and reduce the risk of major accidents,
- and to enable the necessary actions to be taken to limit the impacts of any incident.

Last update to the Seveso Directive refers to the Globally Harmonized System of Classification and Labeling of Chemicals or GHS as an agreed upon system created by the United Nations. The risk analysis study (figure 1) is at the center of the safety report and must assess the EES from the point of view of safety on the full value chain, from the early design phases, construction and commissioning, operational use over lifetime and at the end of life, recycling or second life issues

The following issues could be addressed:

- Main risks related to the identified use cases
- Guidelines for risk analysis and "tolerable risk" definition.
- Technical contents and results to produce in the safety report.

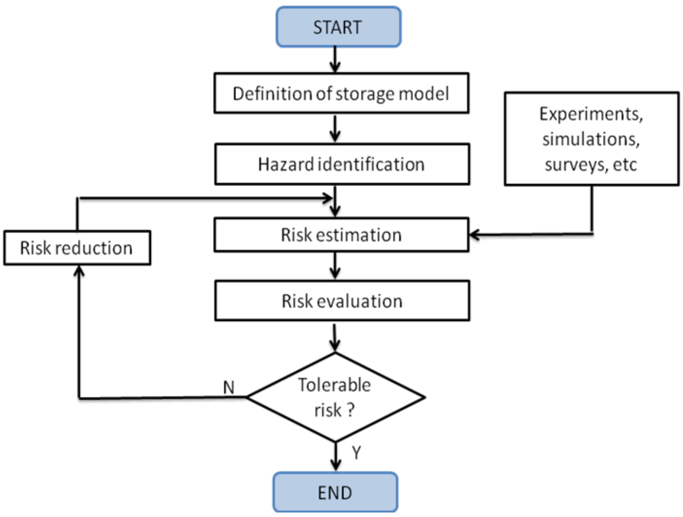


Figure 1: Iterative checking sequence in general risk assessment procedure

2.3 *Environmental impact assessment directive 2014/92/EU*

The Directive 2011/92/EU of 13 December 2011 concerns the assessment of the effects of certain public and private projects on the environment. This text is amended by the Directive 2014/92/EU in order to strengthen the quality of the environmental impact assessment procedure.

Before consent is given by the competent authority, projects likely to have significant effects on the environment by virtue, inter alia, of their nature, size or location are made subject to an assessment with regard to their effects. Those projects of concern are defined.

In the list of projects subjected to the directive, the electrochemical storage by secondary battery types are not listed. The closer item mentioned concerns the "Industrial installations for the production of electricity".

2.4 *Battery directive 2006/66/EC*

The Directive on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC is dated 2006/09/06. The primary objective of this text is to minimise the negative impact of batteries and accumulators and waste batteries and accumulators on the environment, thus contributing to the protection, preservation and improvement of the quality of the environment.

The scope includes industrial and automotive batteries and batteries used in connection with solar panel, photo-voltaic, and other renewable energy applications, so we can consider that this directive applies to larger storage of Li-Ion batteries.

Requirements essentially focus on collections schemes and on waste treatment:

- member States shall ensure that producers of industrial batteries and accumulators, or third parties acting on their behalf, shall not refuse to take back waste industrial batteries and accumulators from end-users, regardless of chemical composition and origin. Independent third parties may also collect industrial batteries and accumulators.
- Producers or third parties set up schemes using best available techniques, in terms of the protection of health and the environment, to provide for the treatment and recycling of waste batteries and accumulators;
- Member States shall prohibit the disposal in landfills or by incineration of waste industrial and automotive batteries and accumulators. However, residues of any batteries and accumulators that have undergone both treatment and recycling may be disposed of in landfills or by incineration.

2.5 *Occupation health and safety Directive 89/391/EEC*

This Directive is of general concern: the employer shall have a duty to ensure the safety and health of workers in every aspect related to the work. This is mainly done by the following principles of prevention:

- avoiding risks;
- evaluating the risks which cannot be avoided:
  - combating the risks at source;
  - adapting the work to the individual, especially regarding the design of work places, the choice of work equipment and the choice of working and production methods, with a view, in particular, to alleviating monotonous work and work at a predetermined work-rate and to reducing their effect on health.
- adapting to technical progress;
- replacing the dangerous by the non-dangerous or the less dangerous;
- developing a coherent overall prevention policy which covers technology, organization of work, working conditions, social relationships and the influence of factors related to the working environment;
- giving collective protective measures priority over individual protective measures;
- giving appropriate instructions to the workers.

In the case of electrochemical storages, electrical, mechanical, temperature, fire hazards have to be avoided.

2.6 *Risks related to chemical agent at work – Directive 98/24/CE*

As electrochemical products are necessarily chemical agents, the workers in charge of commissioning, maintenance or decommissioning are concerned with the scope of this directive.

Risks to the health and safety of workers at work involving hazardous chemical agents shall be eliminated or reduced to a minimum by:

- the design and organisation of systems of work at the workplace,
- the provision of suitable equipment for work with chemical agents and maintenance procedures which ensure the health and safety of workers at work,
- reducing to a minimum the number of workers exposed or likely to be exposed,
- reducing to a minimum the duration and intensity of exposure,
- appropriate hygiene measures,
- reducing the quantity of chemical agents present at the workplace to the minimum required for the type of work concerned,
- suitable working procedures including arrangements for the safe handling, storage and transport within the workplace of hazardous chemical agents and waste containing such chemical agents.

2.7 *Directive 2006/95/EC on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits*

This Directive applies to all electrical equipment designed for use with a voltage rating of between 50 and 1000 V for alternating current and between 75 and 1500 V for direct current. Voltage ratings refer to the voltage of the electrical input or output, not to voltages that may appear inside the equipment. Following discussions with Member States the Commission has taken the position that the term "designed for use with a voltage range" shall be understood as equipment having either a rated input voltage or a rated output voltage inside this voltage range. Internally there may be higher voltages.

Battery operated equipment outside the voltage rating is obviously outside the scope of the Low Voltage Directive (LVD). Nevertheless, any accompanying battery-charger as well as equipment with integrated power supply unit within the voltage ranges of the Directive are in the scope of the LVD. This applies also, in the case of battery operated equipment with supply voltage rating under 50 V AC and 75 V DC, for their accompanying power supply unit (e.g. Notebooks).

The Directive covers all risks arising from the use of electrical equipment, including not just electrical ones but also mechanical, chemical (such as, in particular, emission of aggressive substances) and all other risks. The Directive also covers health aspects of noise and vibrations, and ergonomic aspects as far as ergonomic requirements are necessary to protect against hazards in the sense of the Directive. Article 2 and Annex I lay down eleven "safety objectives", which represent the essential requirements of this Directive.

It should be noted that electromagnetic compatibility (emission and immunity) aspects, except in so far as they deal with safety, are excluded from the scope of this Directive and are separately regulated under Directive 2004/108/EC

2.8 *Directive 2004/108/EC on the approximation of the laws of the Member States relating to electromagnetic compatibility*

The EMC Directive first limits electromagnetic emissions of equipment in order to ensure that, when used as intended, such equipment does not disturb radio and telecommunication as well as other equipment. The Directive also governs the immunity of such equipment to interference and seeks to ensure that this equipment is not disturbed by radio emissions when used as intended.

3 Codes and regulations applicable in other regions (international perspective)

3.1 *Codes and regulations applicable in US*[4]

If the system is to be located in the USA, the codes affecting energy storage systems include electrical installation codes such as the National Fire Protection Association (NFPA) 70 National Electrical Code (NEC) or the IEEE C2 National Electrical Safety Code (NESC) depending upon whether or not the energy storage systems are utility systems. Both of these codes contain energy storage sections, but other areas of the codes including wiring methods, grounding criteria, signage, enclosures, etc. impact energy storage system safety. Local electrical codes will typically adopt some version of the NEC as part of their codes with what they feel may be necessary modifications specific to their location. Building and fire codes may adopt some version of the International Code Council (ICC) codes, which may impact an energy storage system. Because energy storage systems contain electronics that can have electromagnetic interference, there are Federal Communications Commission (FCC) regulations that would apply to ensure that energy storage systems are not unintended radiators. Energy storage systems, depending upon their technology, may also be affected by regulations addressing hazardous materials such as Pipeline and Hazardous Materials Safety Administration (PHMSA) transport regulations for lithium ion batteries or the Environmental Protection Agency (EPA) or local material recycling regulations such as those for lead acid batteries and control of hazardous wastes or other materials that are utilized by the system. Local building and fire codes will also impact energy storage system, so it is important to know which local codes apply to the system. Building codes include requirements for battery rooms, spill containment, and fire protection for areas containing energy storage. The table 2 below outlines some applications codes and standards which may affect the energy storage system.

Table 2: Some codes that may affect energy storage systems in US

Code/Regulation	Title	Impact
NFPA 70	National Electrical Code (NEC)	Basis for many local building electrical codes
IEEE C2	National Electrical Safety Code (NESC)	Electrical Code for utilities
ICC IFC	ICC International Fire Code	Used in many local building fire codes
49CFR173.185 (PHMSA)	Code of Federal Regulations - Part 173, Section 173.185 - Lithium cells and batteries.	Transport of systems that use lithium ion batteries
47CFR15.109 (FCC)	Code of Federal Regulations - Part 15, Section 15.109 Radiated Emissions limits	System needs to meet FCC criteria for emissions
29CFR1910 Occupational Safety and Health Administration (OSHA)	Code of Federal Regulations – Part 1910, Occupational Safety and Health Standards	Regulations regarding workplace safety

3.2 *Codes and regulations applicable in Japan* [5]

After the great east Japan earthquake, the Government of Japan is now redesigning the energy policy. In this policy, battery storage is a core technology under the current tight electricity supply and demand situation. It can help the electric load leveling and can promote the use of distributed power sources systems in smarts grids.

The storage battery industry is expected to be a growth sector with a potential for market expansion. To help this development, the Japan government intend to accelerate sophistication, cost reduction and wide spread use of battery storage. In this way research, development and commissioning of large scale demonstrators are supported.

It is also interesting to note that regulations are also being eased for expanding markets for batteries. Some procedures have been simplified or removed for promoting batteries (deregulation). When approval is required the application is done by power companies for their procurement with limited involvement of battery manufacturers.

Type	**Regulations**		**Governing Organization**
Guideline (Technical Requirement)	Technical requirements guideline of grid interconnection to secure electricity quality (2004, revised in 2013)		Ministry of Economy, Trade and Industry (METI)
	Grid Interconnection Code (JEAC 9701-2006) (superseded by JEAC 9701-2012.)		Japan Electric Association (JEA)
Law	Electricity Business Act	Required approval for large electricity storage system more than 80,000kWh	Ministry of Economy, Trade and Industry(METI)
	Fire Service Act	Dangerous material for more than 1,000ℓ organic electrolyte solution	Fire and Disaster Management Agency,
	Fire Prevention Ordinance	Required approval for large battery (4,800Ah/cell)	Ministry of Internal Affairs and Communications
	Building Standards Act	Construction application for building regarding to fire prevention property	Ministry of Land, Infrastructure, Transport and Tourism

Table 3 : Some codes that may affect energy storage systems in Japan

4 Relevant standards

4.1 *Existing standards on safety testing of li-ion batteries* [6]

The STABALID document D1-2 on « Identification of relevant protocols for safety testing » identifies standards and testing protocols designed to assess a battery's ability to withstand certain types of abuse conditions. Tests considered have been classified in different categories :

- electrical tests,
- mechanical tests,
- environmental tests,
- additional specialized tests.

Emphasis is placed on the lack of an internal short circuit test designed for execution without risks to laboratory personnel.

There are a number of standardized tests procedures that evaluate the safety and abuse tolerance of tests and batteries. Some are Industry standards (UL, NEMA, SAE, IEEE, BATSO, TELCORDIA, JIS, SBA, INERIS) and others are International standards (UN, IEC, ISO).

The STABALID document gives an overview comparisons of tests conditions between these standards.

Some standards such as the IEC 60896-11, IEC 60896-21 and IEC 60896-22 include both performance and safety criteria of lead acid batteries.

Most of these standards are based on a "test only" approach, but this approach is incomplete when evaluating the safety of the system. It is important to have some level of minimum safety construction through the use of Failure Mode and Effects Analysis (FMEA) and a review of the parts of the system to ensure they are going to function as anticipated. Electrical spacings criteria, for example, are critical to ensure that insulation levels are adequate, and tests such as the dielectric voltage withstand are the final check of the system insulation.

4.2 *UN Li battery transport requirements* [7]

Nearly all lithium batteries are required to pass section 38.3 of the UN Manual of Tests and Criteria (UN Transportation Testing).

Tests 1-8 of this specification are following:

T1 – Altitude Simulation (Primary and Secondary Cells and Batteries)
T2 – Thermal Test (Primary and Secondary Cells and Batteries)
T3 – Vibration (Primary and Secondary Cells and Batteries)
T4 – Shock (Primary and Secondary Cells and Batteries)
T5 – External Short Circuit (Primary and Secondary Cells and Batteries)
T6 – Impact (Primary and Secondary Cells)
T7 – Overcharge (Secondary Batteries)
T8 – Forced Discharge (Primary and Secondary Cells)

A short description of the tests is given in figures 2 and 3.

Overview of Transport Requirements

T1-T5 conducted in order

Test	Method Summary	Pass/fail
T1 Altitude Simulation	11.6 kPa for 6 h, ambient temp	nf, nl, nv, nd, nr, ocv ≥ 90%
T2 Thermal	72 ± 2 °C to -40 ± 2 °C, hold temp for 6 h, 10 cycles, 24 h at ambient temp	nf, nl, nv, nd, nr, ocv ≥ 90%
T3 Vibration	sinusoidal WF w log, 7 Hz→200Hz→7Hz in 15 min, 12 cycle for 3 h for 3 mutually ⊥ dir. 0.8 mm amp, Large Bat – 0.2 g peak accel, Small Bat and Cells – 0.8 g peak acc.	nf, nl, nv, nd, nr, ocv ≥ 90%
T4 Shock	half-sine, Large Cell and Bat: Peak accel 150 gn, pulse 6 msecs; Small Cell and Bat: Peak accel of 50 gn, pulse 11 msecs	nf, nl, nv, nd, nr, ocv ≥ 90%
T5 External Short Circuit	55 ± 2 °C , ≤ 0.1Ω, 1 h or until case returns to 55°C temp, Check results for 6 h	nf, nr, nd,170°C
Conditioning: Cells and small batteries: 1st cycle and 50 cycles; Large batteries: 1st cycle and 25 cycles		

Figure 2: T1-T5 UN test description

Overview of Transport Requirements

Test	Method Summary	Pass/fail
T6 Impact / Crush Cell Conditioning: 1st cycle, 50% SOC	a) Impact for cylindrical ≥ 20 mm diameter only; 9.1 kg kg mass dropped 61 cm onto 15.8 mm diameter bar across cell; b) Crush for other than cylindrical with diameter ≥ 20 mm cells; 13 kN flat plate crush at 1.5 cm/s rate until: - force reached, or - 100 mV OCV drop, or - 50% deformation. Check results for 6 h	nf, nd, 170°C
T7 Overcharge Battery Conditioning: Small: 1st cycle and 50 cycle Large: 1st cycle and 25 cycles	CC at $2I_{Cmax}$, Bat ≤ 18 V: CV = 2 x V_{Cmax} or 22 V; Bat > 18 V:CV = 1.2 x V_{cmax}, Check results for 7 days	nf, nd, 170°C
T8 Forced Discharge Cell Conditioning: 1st cycle and 50 cycles	connect resistive load in series with test cell, cell forced discharged for time equal to rated capacity ÷ initial test current. Check results for 7 days	nf, nd

6

Figure 3 : T8-T8 UN test description

It is also indicated that required tests are adapted to what is shipped as stipulated in the table 4:

What is shipped?	Required Tests
Cells (single cell batteries considered a cell)	T1, T2, T3, T4, T5, T6 and T8
Batteries (w/wo tested cells & oc protection)	T1, T2, T3, T4, T5, T7
Battery Assembly ≤ 6200 Wh (w tested batteries & if not provided with a monitoring system to prevent oc, od, sc, and oh)	T3, T4, T5 and T7
Component Cell (only shipped as a component in a battery)	T6, T8
Secondary single cell battery with overcharge protection	T7 (in addition to cell tests)

Table 4 : Test definition depending on the component type considered

4.3 *Existing standards that address hazard based assessment*

When analyzing an energy storage system's safety, a hazards based assessment approach should be taken. Potential hazards associated with energy storage systems include potential fires and explosions, electric shock hazards, physical hazards to those persons that may be in proximity to the system, hazardous materials that may be contained or that could vent from the system such as flammable or toxic fluids, hazardous electrolyte leakage, etc.
Energy storage systems can be complex, and ensuring safety requires an understanding of both:

- the system -- how the parts of the system interact in order to keep the system operating within safe boundaries, and
- the application -- the intended environment to which the system will be exposed.

Reviewing the system in a step by step, organized fashion will help to ensure that all impacts to safety have been considered.

In order to analyze any energy storage system, it is important to have a process for identifying potential safety hazards, categorizing their impact to safety and evaluating the methods inherent in the system for mitigating these hazards. This process is often referred to as a Failure Modes and Effects Analysis or FMEA. There are several different procedures for conducting this analysis and standards have been developed for guidance including IEC 60812 and the functional safety standard series International Electrotechnical Commission (IEC) 61508, Society of Automotive Engineers (SAE) J1739, and the US Department of Defense military standard, MIL-STD-1629A.

Another methodology which assists in the evaluating of specific faults is the Fault Tree Analysis (FTA), as outlined in IEC 61025. The results of an FTA analysis can then be used to build the FMEA. If electronics and/or software have been identified as critical to the safety of the energy storage system, then they should be evaluated for functional safety, and an appropriate safety integrity level (SIL) or equivalent should be determined for the controls (IEC 61511-3 : 2003 - Functional safety –Safety instrumented systems for the process industry sector – Part 3 Guidance for the determination of the required safety integrity levels).

The purpose of IEC 61882 is to describe the principles and procedures of another available tool which is the Hazards and Operability (HAZOP) study. This approach can also be useful to assess the safety of a stationary storage system. HAZOP is a structured and systematic technique for examining a defined system with the objective of identifying potential hazards and identify potential operability problems. An important benefit of HAZOP studies is that the resulting knowledge is of great assistance in determining appropriate remedial measures.

4.4 *Standards evaluating the safety of energy storage systems* [4]

There are published safety standards that can be used to evaluate the safety of energy storage systems. The standards are often divided into technology specific and/or application specific.

For battery energy storage systems, many of these standards specifically address more traditional technologies such as lead acid or NiCd chemistries. Some of these published documents are in the form of guides or recommended practices rather than standards such as the Institute of Electrical and Electronics Engineers (IEEE) 1375, IEEE Guide for the Protection of Stationary Battery Systems, but they contain useful information for determining the safety of the system. At the international level, there are often technology specific standards for nickel and lead acid technologies such as the IEC 62845-2, Safety Requirements for Secondary Batteries and Battery Installations – Part 2: Stationary Batteries. There are IEC safety standards under development that address lithium ion technologies. These standards are IEC CD 62619, Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications (not published) and IEC NP 62897, Stationary Energy Storage Systems with Lithium Batteries – Safety Requirements. Note that IEC 62219 address cells and the battery interaction with the Battery Management System (BMS).

Some standards such as American National Standard's Institute (ANSI) UL 1973, Standard for Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications are not technology specific and cover any number of battery chemistries as well as electrochemical capacitors (i.e. ultracapacitors).

Some applications have their own standards that must be applied. Telcordia GR-3150-CORE, Generic Requirements for Secondary Non-aqueous Lithium Batteries, which includes both performance and safety requirements for lithium ion battery systems used for telecom applications. The new work item proposal IEC NP 62897 scope is safety of lithium-ion battery systems for residential applications.

Another standard under development that is not technology specific but is application specific is UL Subject 9540, Safety for Energy Storage Systems and Equipment. This document will cover various types of energy storage systems including batteries, but will be specific to utility grid interactive systems. This scope is also that of IEC TC120 dealing with "Standardization in the field of grid integrated Electrical Energy Storage (EES) Systems". For the purpose of TC 120, "grid" includes:

a) transmission grids
b) distribution grids
c) commercial grids
d) industrial grids
e) residential grids
f) islanded grids

and will prepare normative documents to define unit parameters, testing methods, planning and installation, guide for environmental issues and system safety aspects.

To sum up, when determining which standard would apply, the technology of the system and the intended application will affect which standard or similar document would apply. Some are intended for specific countries and others are written as international standards. Table 5 summarizes standards addressing stationary battery safety with mention of the discussed criteria (a cross in the column means that the standard is technical (Tech.) or application (Appl.) or location (Locat.) dependant).

Standard N°	Title	Tech.	Appl.	Locat.
ATIS-0600330	Valve-regulated lead-acid batteries used in the telecommunications environment	X	X	X
Telcordia GR-3020-CORE	Nickel cadmium batteries in the outside plant	X	X	X
Telcordia GR-3150-CORE	Generic requirements for secondary non-aqueous lithium batteries	X	X	X
Telcordia GR-4228-CORE	VRLA battery string certification levels based on requirements for safety and performance	X	X	X
UL 810A	Electrochemical Capacitors	X		X
UL 1973	Batteries for use in Light Electric Rail (LER) and Stationary Applications			X
UL Subject 9540	Standard for Safety for Energy Storage Systems and Equipment (under development)		X	X
IEEE 1375	Guide for the Protection of Stationary Battery Systems	X		
IEEE 1679	Recommended Practice for the Characterization and Evaluation of Emerging Energy Storage Technologies in Stationary Applications			
IEC 60896-11	Stationary lead-acid batteries - Part 11: Vented types - General requirements and methods of tests	X		
IEC 60896-21	Stationary lead-acid batteries –Part 21: Valve regulated types –Methods of test	X		
IEC 60896-22	Stationary lead-acid batteries Part 22: Valve regulated types – Requirements	X		
IEC 62485-2	Safety requirements for secondary batteries and battery installations – Part 2: Stationary batteries	X		
IEC CD 62619	Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for secondary lithium cells and batteries, for use in industrial applications (under development)	X		
IEC NP 62897	Stationary Energy Storage Systems with Lithium Batteries – Safety Requirements (under development)	X	X	
CENELEC EN 50272-1	Safety Requirements for Secondary Batteries and Battery Installations Part 1: General safety information	X		X
CENELEC EN 50272-2	Safety Requirements for Secondary Batteries and Battery Installations Part 2: Stationary Batteries	X		X

Table 5 : Stationary Battery and Energy Storage Standards that Address Stationary Battery Safety.

The figure 4 gives a comparison of the safety tests proposed in three of these standards.

Standard	Short circuit	Overcharge	Over discharge	Imbalanced Charge	Dielectric Voltage Withstand	Continuity	Temperature	Failure of Thermal Stability System	Temperature Cycling	Vibration	Shock	Drop	Enclosure Tests	Water Exposure	External Fire	Internal Fire
UL 1973	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tel-cordia GR-3150-CORE	X	X	X	-	-	X	X	-	X	X	X	X	X	X	X	-
IEC CD 62619 (SBA S1101)	X	X	X	-	-	-	-	X	┤	-	-	X	-	-	-	X

Figure 4: Safety tests proposed in UL 1973, Telcordia GR-3150-CORE et IEC CD 62619 standards

5 Safety recommendations for stationary storage

As previously discussed different sources of information are available in standards and regulations (figure 5). Few of them allow to directly assess EES Safety, but some standards of this type are under construction as:

1/ UL Subject 9540 (draft), outline of investigation for Safety Storage Systems and Equipment. It may become an ANSI standard for both the USA and Canada.

2/ IEC Technical Specification 62937 in preparation is about “Safety Considerations related to the Installation of Grid integrated Electrical Energy Storage (EES) Systems”.

3/ IEC 62897 (Approved New Work) concerns the “Stationary Energy Storage Systems with Lithium Batteries - Safety Requirements”. STABALID aims to address this standard.

The two first standards cited (UL 9540 and IEC 62937) address different storage technologies including batteries but also chemical or mechanical or thermal energy storages.

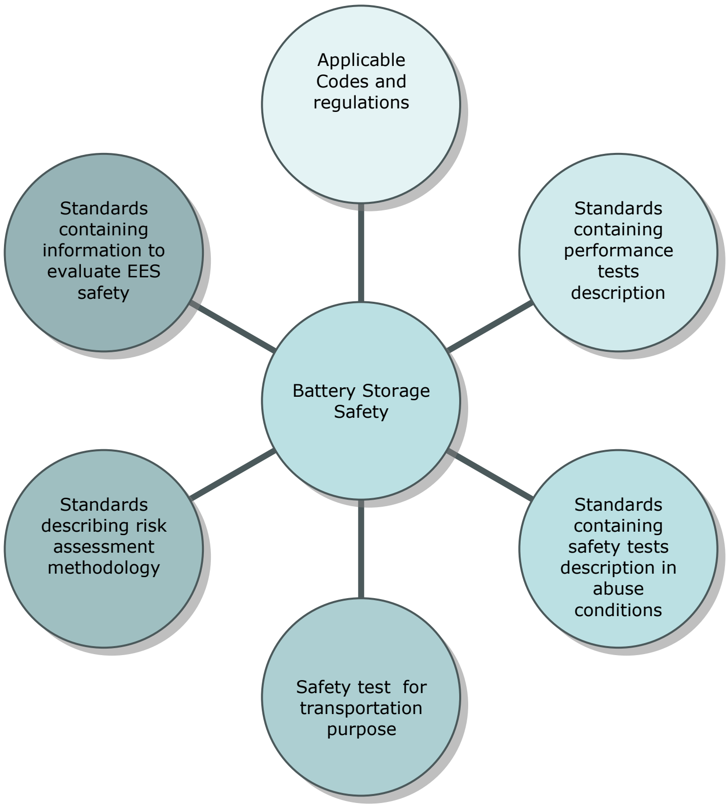


Figure 5 : Standards related to Stationary Battery safety, current landscape

Table 6 summarizes the specifications given in UL 9540 distributed in four parts about construction recommendations, performance verification, markings and instructions. The “construction” section provides practical guidelines to ensure both occupational safety and environmental safety.

Section	Issues discussed
Construction	
Non-Metallic materials	mechanical strength, electrical insulation, gaskets and seals
Metallic Parts Resistance to Corrosion	Guidance on methods to achieve corrosion protection
Enclosures and guarding of hazardous parts	Resistance to possible physical abuses. Designed to prevent inadvertent access to hazardous parts. Rated to the level of exposure to water
Walk in systems (protection, procedures for access, inside conditions)	Procedure for access. Ease of access(voltage parts, ventilation, lighting)
Wiring and electrical supply connections	Wiring insulation, connection, routing. Lightning surges.
General electrical service equipment	Fuses, disconnection, power transformers
Electrical spacings and separation circuit	Physical distance between electrical circuits
Insulation levels and protective grounding	Insulation recommendations and grounding methods
Safety analysis and control systems	FMEA – SIL level
Remote controls	Safety requirements
Communication systems	Communication protocols between storage and grid
Heating and cooling systems	Safety shutdown upon failure of the thermal management system
Piping systems, Pressure vessels, fuel and other fluid supply connections and controls	Compliance to applicable codes.
Containment of moving parts	Safety enclosure
Hazardous liquid spill containment	Liquid spill containements; means of neutralization
Combustible concentrations	Flammable atmosphere ventilation – Electrical compartment safety
Fire detection and suppression	Fire risk assessment
Utility grid interaction	Interconnection performance
Energy storage System technology	electrochemical, chemical, mechanical, thermal

Performance	
Electrical tests	Check of operating temperatures. Dielectic voltage withstand test to evaluate electrical spacing and insulation. Grounding and bonding test. Insulation resistance measurement.
Mechanical tests	Over speed test or faulted securement test or blocked rotor test to see if containment means can contain the parts. Leakage test on hazardous fluid containments. Strength test for fuel cells
Environmental tests	Exposure to special environments (salt fog, seismic ratings …) Manufacturing and production tests
Markings	Marking recommendations
Instructions	For installation and decommissioning at the end of the life, operation and maintenance

Table 6 : Draft content of UL 9540

The Technical Committee IEC TC 120 is working on the same objectives. TC 120 scope is given on figure 6.

TC 120 Scope

1. Standardization in the field of grid integrated EES Systems.
- TC 120 focuses on system aspects on EES Systems rather than energy storage devices.
- TC 120 investigates system aspects and the need for new standards for EES Systems.
2. For the purpose of TC120, "grid" includes :
a) transmission grids
b) distribution grids
c) commercial grids
d) industrial grids
e) residential grids
f) islanded grids
It is also confirmed that TC120 can include "smart grid." Storage in railway systems is considered if it contributes as an EES System to the grid.
Note:
grid: electricity supply network (ISO/IEC 15067-3)
smart grid: electric power system that utilizes information exchange and control technologies, distributed computing and associated sensors and actuators, for purposes such as:
- to integrate the behaviour and actions of the network users and other stakeholders
- to efficiently deliver sustainable, economic and secure electricity supplies (IEV 617-04-13)
3. EES includes any type of grid-connected energy storages which can both store electrical energy from a grid or any other source and provide electrical energy to a grid.
TC120 includes Chemical ES as one of the ESs.
Thermal storage is included in the scope, only from the electricity exchange point of view.
Unidirectional energy storages such as UPS are not included in the scope of TC 120.
Note : The importance of discussing what is to be done for the thermal energy storage in the Gap Analysis (by PT or CAG to be established) was acknowledged, considering TC 117 and other TC/SC work.
4. The scope of TC 120 is to prepare normative documents dealing with the system aspects of electrical energy storage.
For example, TC 120 deals with defining unit parameters, testing methods, planning and installation, guide for environmental issues and system safety aspects.

Figure 6 : IEC TC 120 scope

The related IEC technical specification TS 62937 in preparation will follow the IEC Guide 104 on "the preparation of safety publications and the use of basic safety publications and group safety publications" and especially its check-list basis given in Annex A and summarized in table 7. Figure 7 gives the layout synoptic of the TS with three main issues relative to: types of risks, risk analysis and abuse testing and preventives measures.

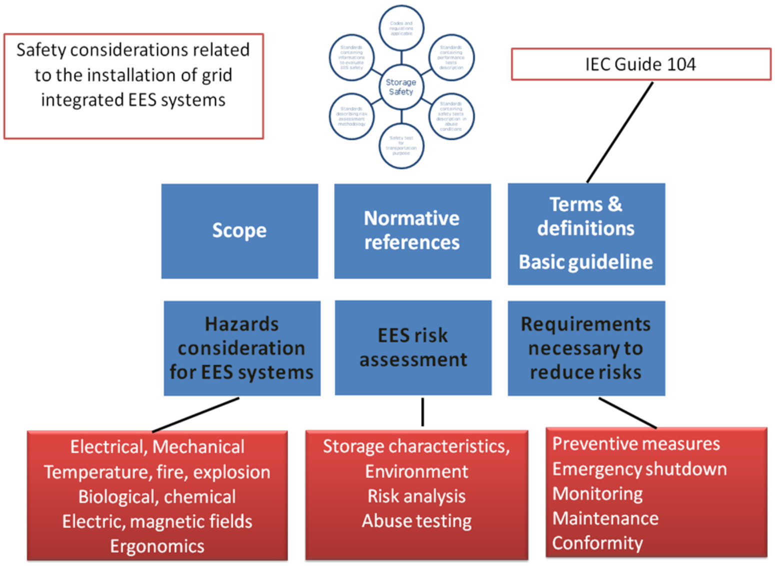


Figure 7 : IEC TS 62937 structure in discussion.

Section	Issues discussed
Safety integration	Equipment shall be designed and manufactured so that adequate protection is afforded in normal condition and in single fault condition. Take into account situations of normal use and situations of reasonably foreseeable misuse.
Protection against electrical hazards	accessible conductive parts of equipment shall not be hazardous live protective measures to keep good insulation adequate protection against : – leakage current; – energy supply; – stored charges; – arcs; – electric shock; – burns.
Protection against mechanical hazards	Watch internal forces arising from : – instability; – break-down during operation; – falling or ejected objects; – inadequate surfaces, edges or corners; – moving parts, especially where there may be variations in the rotational speed of parts; – vibration; – improper fitting of parts.
Protection against other hazards	- Explosion - Hazards arising from electric, magnetic and electromagnetic fields, other ionizing and non-ionising radiations

	- Electric, magnetic or electromagnetic disturbances - Optical radiations - Fire - Temperature - Acoustic noise - Biological and chemicals effects - Emissions, production and/or use of hazardous substances (e.g. gases, liquids,dusts, mists, vapour) - Unattended operations - Connection to and interruption from power supply - Combination of equipments - Implosion - Hygiene conditions - Ergonomics
Functional safety and reliability	Equipment shall be designed and constructed to be safe and reliable so as to prevent hazards arising,
Information requirements	Markings and instructions

Table 7 : IEC Guide 104, safety aspects relating to electrical equipment

6 Feedback related to large scale battery storage accidents

As they are quite new, only few accidents on large scale battery storages are reported.

On November 26, 2012, around 17:30 in Flagstaff, United States, a Li-ion storage system stationary 1.5 MWh caught fire. The fire, initially reported as transformer fire is finally identified as a fire in the storage system Li-ion. The fire crew waited until the site operator APS (Arizona Public Service Company) has cut off all power source to extinguish the fire with water within 30 minutes. The fire did not spread to the related site facilities. Surveillance teams took turns all night.

On September 21, 2011, 2 MW NAS storage caught fire and burnt several days in Joso, Japan. NGK manufacturer ask its customers to stop their facilities during investigations. The NGK report on "Cause of NAS Battery Fire Incident, Safety Enhancement Measures and Resumption of Operations" is given in annex 1.

The main report conclusions are given hereinafter and can be taken into account when defining preventions measures.

- One battery cell faulty had a breach and leaked hot molted material.
- This material caused a short between battery cells in an adjoining block.
- Because there was no fuse installed a short-circuit current flows continuously and emitted heat which destroyed other battery cells and cause the fire.

These observations emphasizes the need for the considered technology :

- to prevent short circuit between blocks (combination of cell in serie and parallel) to implement sufficient number of fuses.
- To prevent short circuits to add insulation boards in battery assembly.
- To add anti-fire boards between modules to stop fire propagation to the whole battery.
- To develop fire fighting strategy and means to assist fire crew.

These conclusions could be keep in mind when analyzing the safety of all types of large scale battery storages.

7 Guidelines to ensure adequate safety in large battery storage implementation

7.1 *The current landscape*

The review of different codes regulation and standards made in this report shows that a lot of provisions on safety are available but scattered in many texts.

Some standards contain safety tests description, some performance tests description. They could be of general use or dedicated to specific battery technologies.

Moreover the UN Recommendations on the Transport of Dangerous Goods (Rev.18) gives, in part 3, special provisions applicable to certain articles or substances and consider cells and batteries containing lithium.

As the energy storage systems shall be provided with a safety analysis such as a failure mode and effects analysis (FMEA) that identifies critical safety components and circuits of the systems, the reference to standards describing risk assessment methodology and SIL levels is important.

In Europe and in different countries some regulations could be applicable. These regulations can contain energy storage sections or not. Certain provisions can impact energy storage safety. Codes affecting energy storage systems are mainly relative to :

- Electrical installation,
- Electromagnetic interferences,
- Hazardous materials,
- Environmental protection,
- Recycling.
- Occupational safety.

In this landscape it could be interesting to define specific provisions dedicated to large scale battery storage independently of their technology. We found two standards of that type under construction:

- UL Subject 9540 (draft), outline of investigation for Safety Storage Systems and Equipment.
- IEC Technical Specification 62937 about “Safety Considerations related to the Installation of Grid integrated Electrical Energy Storage (EES) Systems”.

It should be noted that both are relative to all types of storage including batteries.

Last, as the number of large storages in the world are still low, we have only few experience on incidents or accidents. This is the reason why all information of this type should be carefully collected and exploited.

7.2 The market perspectives

In 2011, the electrochemical storage capacity installed in the world was divided as follows : 400 MW of NAS batteries, 45 MW of Li-Ion batteries, 45 MW of Lead acid batteries and 40 MW of Ni-Cd batteries. An interactive database created by the DOE (Department of Energy) in the United States identifies the projects and sites of energy storage connected to the grid at global scale. This data base is accessible and regularly updated[1]. In August 2014, the data analysis shows that the Li-Ion technology is getting widely deployed with 225 projects identified (advertised or operational). The number of projects (57) under construction shows the potential of this technology. The NAS batteries follow with 36 projects and more than 200 systems installed in Japan. Figure 8 compares both technologies in regard to the power classification of the systems.

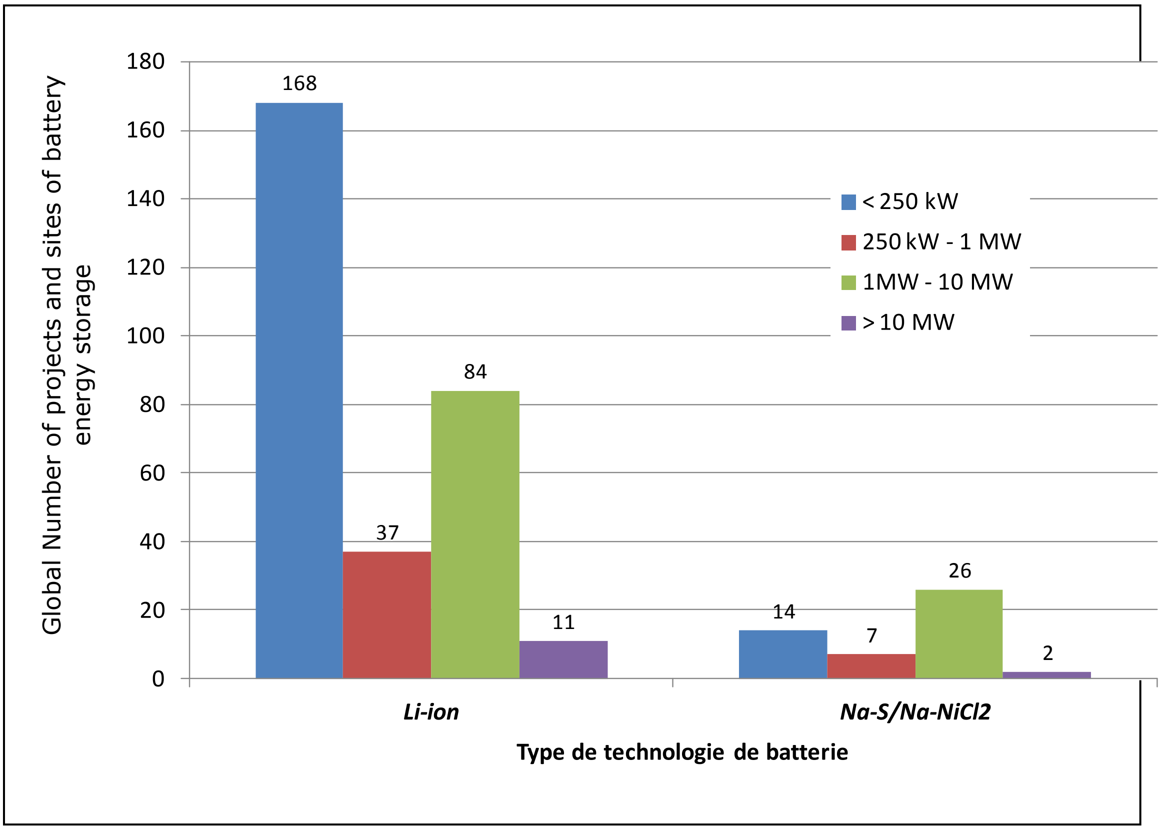


Figure 8: Comparison of the Li-ion and NAS technologies deployment

The French network on electrochemical energy storage RS2E consider that "with the massive use of renewable energies and the aggressive penetration of electromotive transportation, our extensive reliance on battery technology will only become greater with time, leading to a market of staggering proportions". The figure 9 illustrates this message.

[1] http://www.energystorageexchange.org/

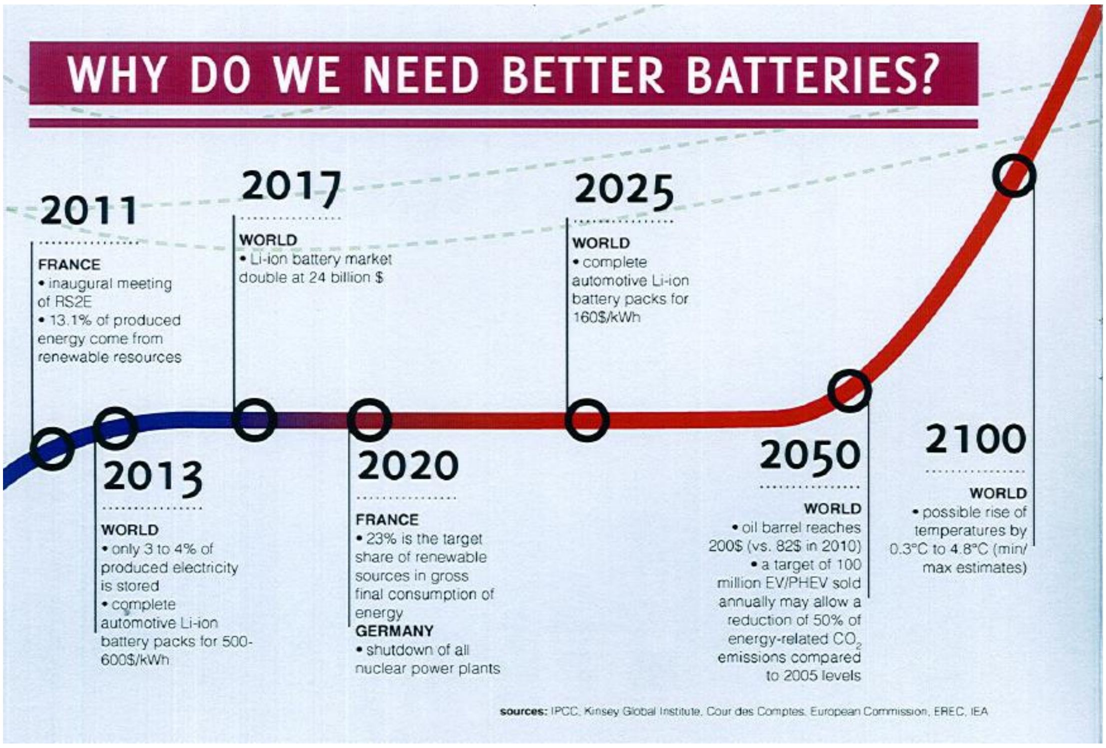


Figure 9 : Perspective of market evolution

7.3 *Main issues to ensure a better safety of batteries storages*

7.3.1 *Prevention of major accidents*

In Europe, the Seveso Directive (last issue published on 2012, July 24th, in the Official Journal of the European Union) deals with the prevention and control of major accident hazards involving dangerous substances to limit their possible consequences on human health and the environment. These dangerous substances might result from particular industrial activities. One should consider that the large electrochemical storages are part of them.

The question of the need to apply the directive to stationary storage arises. It is a fact that in some cases the total mass of hazardous products can exceeds the classifying thresholds. But it is important to consider that the mass is strongly decoupled in numbers of cells and modules such that the propagation of accidental effects is more difficult. So we consider that ***the specificity of these facilities must be taken into account by the Seveso Directive*** and by the National Regulations implementing the Directive.

However, in order to prove that everything was done to prevent major accidents***, the operator should provide to the competent authority the relevant pieces of information in the form of a safety report****.* ***This will be used to prepare emergency plans and response measures too.*** This point of the Directive can be kept in mind to consider specific situation in regard of storage type and of geographical location of the premises with possible occurrence of natural disasters.

7.3.2 *Occupational safety*

Occupational safety is related to the safety of people working in the facility. A large electrochemical storage could be seen as a quite "passive" facility with no on site people available for facility operation. Staff is involved in installation, commissioning, maintenance and end of life operations. ***These issues required adapted safety measures as:***

- ***protection against electrical hazards;***
- ***protection against mechanical hazards;***
- ***protection against others hazards (fire, explosion, emission of hazardous substances that may be toxic, corrosives …)***

7.3.3 *Risk analysis and safety testing*

Risk analysis can lead to the definition of the most relevant accident scenarios to quantify the consequences. However, some tests should be performed before proceeding to the risk analysis work.

Firstly, ***the system must reach the expected performances*** "in normal conditions of use" and it may be necessary to demonstrate its conformance with existing specifications. This can be achieved through applying design rules, performing calculations/simulations or by appropriate testing. For example, the electrical cycling performances or the compliance of acceptable temperature range of operation of all components and system are features that must be checked by means of tests.

Secondly ***the system's response to some abuse conditions should be evaluated***. For a stationary system, we can assume that these conditions should entail both internal and external disorders including natural hazards interactions. Thus, the behavior in the event of lightning, earthquake, flooding should be considered. In the same way the external aggressions (fire, violent shock) that the system can undergo have to be studied and modeled by representative tests.

Stationary systems being potentially fairly large, ***it may be necessary to determine what elements should be tested separately***. For example in case of a battery storage the EES includes the storage unit itself (cells arranged in modules) and the substation (BMS, transformer, switch...) sometimes kept in a separate house.

7.3.4 *Mitigation measures*

As resulting from risk analysis conclusions, the necessary measures must be taken to prevent accidents and limit their consequences. This means that for all the scenarios for which the probability and/or the severity of consequences is too high, measures of risk reduction must be proposed. Therefore the recommendations to prevent or mitigate accidental must be provided.

The NAS battery feedback shows that it *is* ***necessary to codify the means of intervention to be implemented in case of accident and to have emergency stop procedures*** with grid decoupling.

As the facility is generally remotely controlled, the monitoring of all parameters useful for the safety management must be defined.

7.3.5 *Identification of opportunities to develop new Codes, Standards, Regulations (CSR)*

An inventory of Safety-related Codes and standards for Energy Storage Systems has been published in September 2014. This document [8] lists a large numbers of the current CSR's relevant to energy storage application which have been classified in sections as shown on figure 10.

Figure 10 : Inventory of CSR related to ESS safety.

Moreover the document reports "important lessons" learned from developers who have gone through deployment activities. The purpose of this information in to provide some insight into the CSR that have been applied in approving ESS installation and the processes associated with requesting and securing those approvals.

In conclusion the author develop ***the idea that where there are no CSR defining criteria and where there are no logical CSR to locate them or where there are a myriad of different CSR that each address a part of ESS, that could be better combined into one document***. This could be the objective of the IEC TC 120 standardization effort started in 2013 (figure 6).

7.3.6 *Third party accredited Certification*

Increased uniformity in assessment and ***approval of ESS technology can be facilitated through the use of accredited third parties*** who would issue reports on findings for acceptability consideration by competent authority. To facilitate the uniformity and acceptability of those reports the development of an auditing framework and of acceptance criteria could be undertaken.

7.3.7 *Link with the Industrial Emission Directive and the BREF on Energy Efficiency*

When examining the existing BREF documents, the only one that includes some considerations on energy storage is the BREF on Energy Efficiency[2]. However, the technology considered to store energy in this BREF is the Compressed Air Systems in relation with the use of pneumatic tools. No other energy storage technology is included in this BREF whereas there are many electrical energy storage systems that can be classified into mechanical electrochemical, chemical electrical and thermal energy storage systems as shown in figure 11.

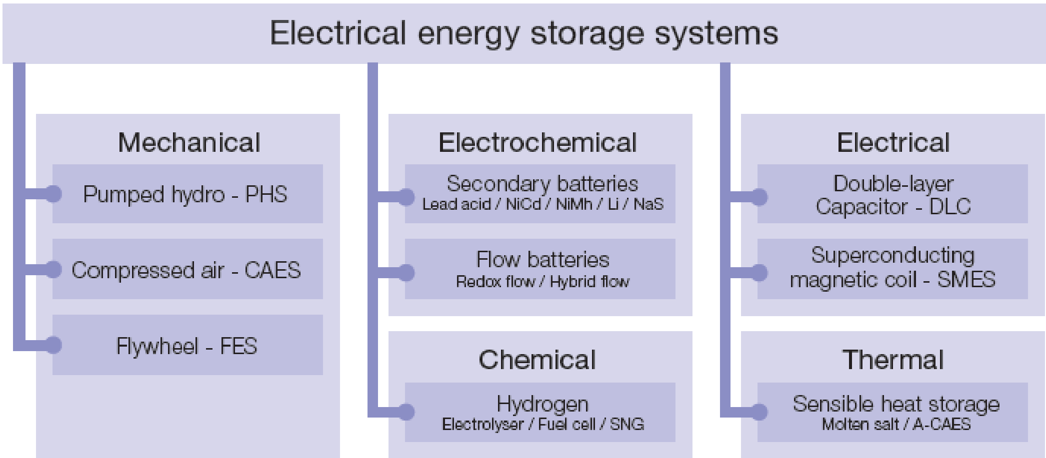


Figure 11: Classification of electrical energy storage systems according to energy form

2 http://eippcb.jrc.ec.europa.eu/reference/BREF/ENE_Adopted_02-2009.pdf

The paragraph 7.1.1.2.1 of the BREF on Energy Efficiency indicates that "*The most important forms encountered in thermodynamic applications are: internal, kinetic and potential energy. Other forms of energy such as magnetic, electric, and surface tension effects are significant only in some specialized cases and will not be considered here".*

Consequently, two possibilities can be proposed:

- the electrochemical energy storage systems can be included into the Energy Efficiency BREF. However, the others electrical energy storage systems may also be considered in this BREF,
- a dedicated BREF on electrical energy storage systems can be developed as part of the grids where they efficiently deliver sustainable, economics and secure electricity supplies.

The outline related to the electrochemical energy storage systems (EESS) that could be integrated in a BREF is proposed hereinafter:

- inventory and assessment of electrochemical energy storage systems: the aim of this step is to establish an inventory of the different electrochemical energy storage systems with the key operating characteristics (the inventory may contain EESS technology, energy density, power density, capacity, cycle life, operating hours/years, maintenance, issues specific to EESS…),
- recommendations for the EESS selection which depends on the system, applications requirements, technical characteristics of the EESS,…
- information on maintenance needs (frequency, signs which indicate that a maintenance is required, actions needed, etc),
- EESS safety aspects: collection of data related to EESS safety,
- if the BREF targeted is Energy Efficiency, data on achieved environmental benefits, applicability and economics of EESS should be collected.

Based on the above collected data, best available techniques (BAT) will be defined.

8 References

[1] IEC White paper, “Electrical Energy Storage”, December 2011.

[2] IEC White paper, “Grid integration of large-capacity Renewable Energy sources and use of large-capacity Electrical Energy Storage”, October 2012.

[3] Stabalid report D4.1 B. Caillard, O. Salvi; “Overview of regulations in force in Europe and Japan on Li-ion stationary battery system”.

[4] Laurie Florence (UL); “Stationary Battery Standards: current landscape and what’s coming soon” Battcon 2014 Conference, Boca Raton, FL, Proceedings 14-1;14-5.

[5] Tetsuji Tomita (IEEJapan); “Policies and Regulations for Electricity Storage in Japan”; IRENA International Energy Storage Policy and Regulation Workshop; 27 March 2014, Düsseldorf, Germany.

[6] Stabalid report D1.2; J.M. Bodet; “Identification of relevant existing protocols for safety testing”.

[7] Laurie Florence (UL); “UN Lithium Battery Transport Tests & UL Battery Safety Standards – Status Update” NTSB presentation, april 2013.

[8] DR Conover; “Inventory of Safety-related Codes and Standards for Energy Storage Systems”;Pacific Northwest National Laboratory –PNNL-23618- September 2014.

ANNEX 1

Cause of NAS Battery Fire Incident, Safety Enhancement Measures and Resumption of Operations

NGK INSULATORS, LTD. has announced the cause of the fire that occurred on September 21, 2011 involving the NAS (sodium-sulfur) batteries for electricity storage that it has manufactured. NGK also announced safety enhancement measures and the resumption of factory operations.

NGK has worked to find the cause of the incident and implement countermeasures since it happened. Recently, a third-party investigation committee, with Japan's Hazardous Materials Safety Techniques Association serving as secretariat, reviewed the cause of the fire and containment measures, and judged that the details regarding both were reasonable and appropriate.

Based on the results of this investigation, NGK decided to voluntarily implement safety enhancement measures, including a monitoring system, under the guidance of the Fire and Disaster Management Agency.

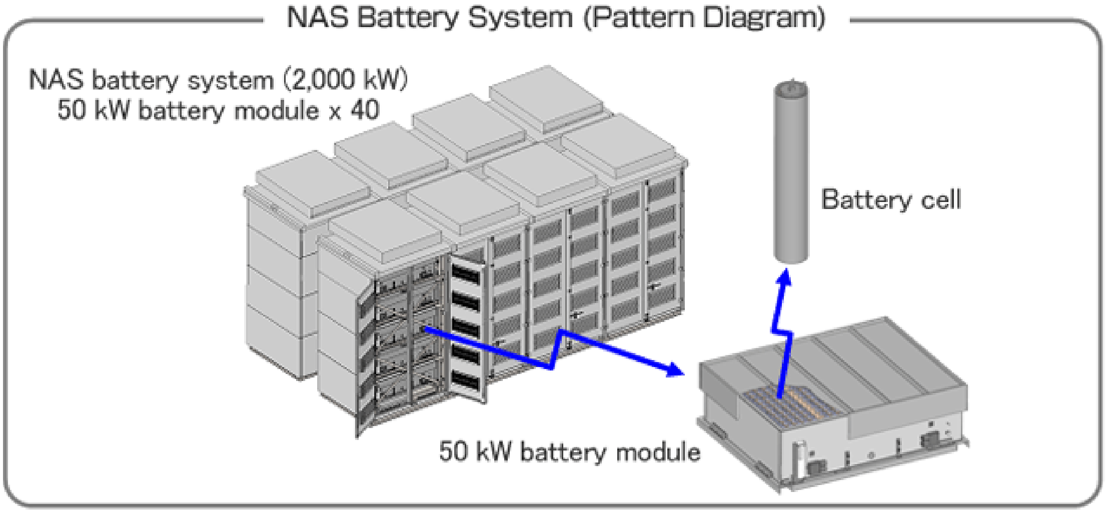
By implementing these safety enhancement measures, customers can be assured of their using NAS batteries with even greater peace of mind because the batteries now have more safety features than previous ones.

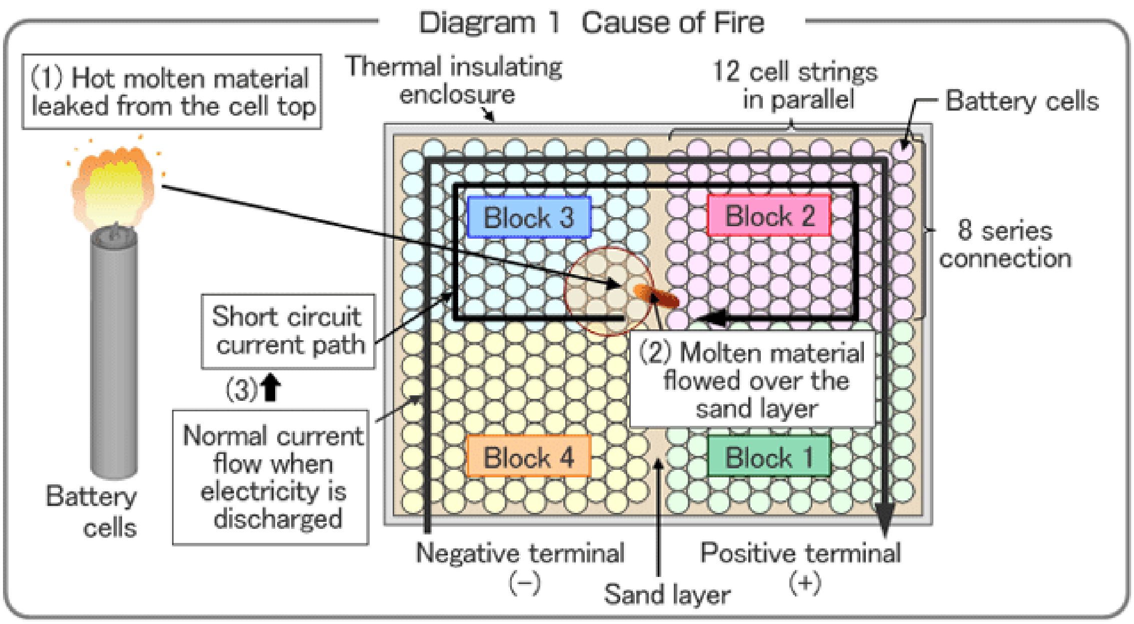
Up until now, NGK has asked almost all customers to suspend using NAS batteries or to restrict their usage. NGK is working so that these batteries can be re-used after quickly implementing safety enhancement measures according to installation conditions, while following the guidance of the fire authorities having jurisdiction in the installation locations.

The main details of the cause of the fire and safety enhancement measures are as follows:

1. Cause of Fire (Refer to Diagram 1)

1. (1) The NAS battery system is made up of 40 battery modules. In one of these modular batteries, which are made up of 384 battery cells, 1 battery cell was faulty. That battery cell had a breach and leaked hot molten material.
2. (2) This molten material flowed over the sand filler portion between blocks inside the battery module, causing a short between battery cells in an adjoining block.
3. (3) Because there was no fuse installed between the battery cells that shorted, the short circuit current flowed continuously and emitted heat, which destroyed a number of other battery cells, which in turn caught on fire. This fire spread to the whole battery module in question.
4. (4)The combustion of the particular battery module released flames and hot molten material that melted battery cell casings inside battery modules installed above and below, causing the fire to spread further.

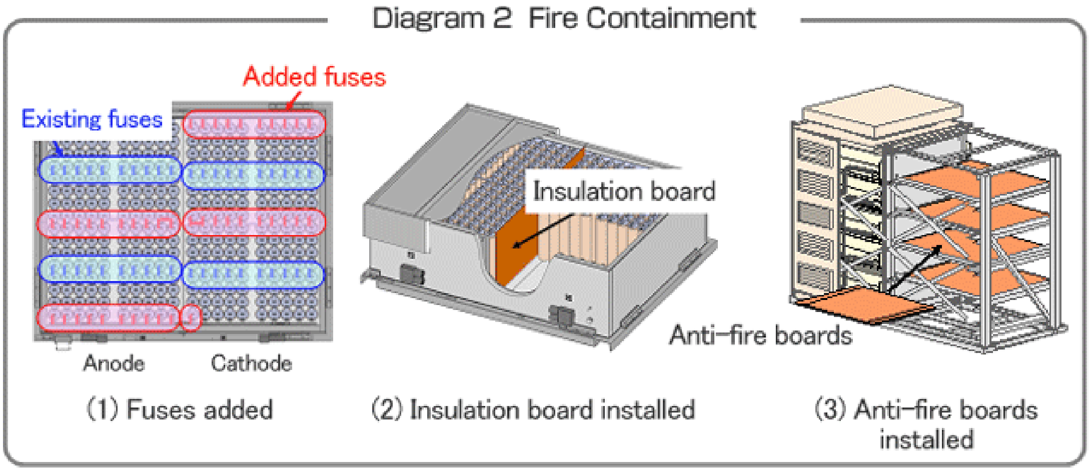




2. Safety Enhancement Measures

1) Measures to prevent the spread of fire in modular batteries (Refer to Diagram 2.)

1. (1) Fuses will be added between battery cells in modular batteries to prevent a short circuit current from causing a fire.
2. (2) Insulation boards will be placed between blocks in battery modules to prevent leaking molten materials from causing a short circuit.
3. (3) Anti-fire boards will be placed between battery modules above and below to prevent fire from spreading to other battery modules.



2) Other safety enhancement measures

1. (1) The monitoring system will be strengthened to enable quick fire detection.
2. (2) Fire extinguishers and fire-prevention equipment will be installed and a fire-fighting structure put in place in preparedness for a fire.
3. (3) A fire evacuation route will be developed and a guidance system put in place in preparedness for a fire.

Since the fire incident, NGK has suspended operations at its NAS battery factory in Komaki City, Aichi Prefecture, Japan. However, operations will resume at this facility from June 2012 now that the cause of the fire has been investigated and safety enhancement measures devised.

For the time being, the plant will put priority on reforming NAS batteries that continue to be used by customers. However, NGK plans to commence production of new batteries in the second half of the current fiscal year, which starts on October 1, 2012.

NGK deeply regrets any worry or inconvenience that may have caused to customers and other concerned parties by the fire incident.

Global demand for large-capacity electricity storage batteries has continued to increase, driven mainly by the utilization of renewable energy, smart grids, and government energy policy reviews.

Looking ahead, NGK will work to implement safety enhancement measures and raise quality further as it works on customer service, while expanding business in NAS batteries, which have garnered high marks for their large capacity and highly efficient electrical storage capacity.