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International Electrotechnical Commission Standards Development for Energy Storage System Safety

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Outline

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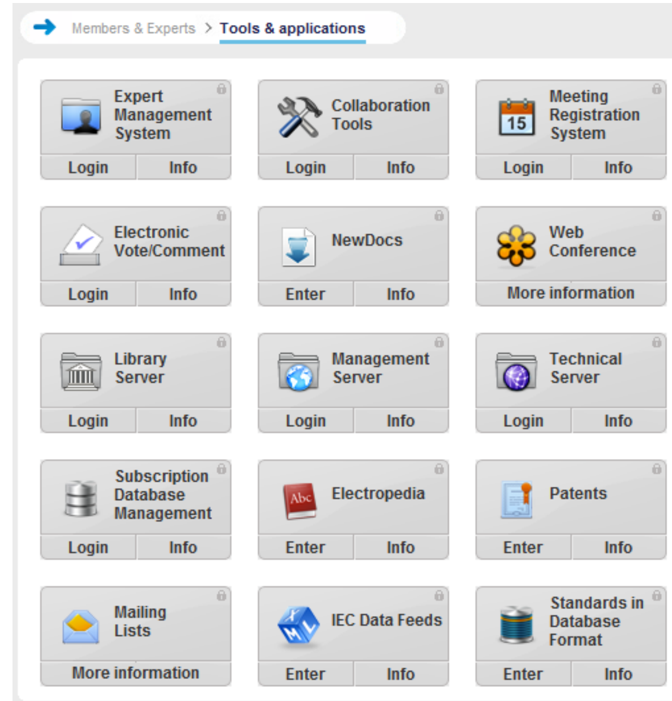
- What is IEC?
  - How can you get involved?
- How does IEC work?
- Why is IEC relevant?
- What are the various ESS and Battery Safety Standards developed?
  - IEC TC120 Energy Storage System
    - Description of overall effort
    - Focus on safety
  - TC21/JWG105 Flow Battery safety
  - Various TC21 efforts on cells and module safety
  - Next steps and vision

What is International Electrotechnical Commission (IEC)

- Develops standards for “all electrical, electronic and related technologies”
- IEC home page: www.iec.ch
- Experts Management System
- Collaboration Tools Suite
- Meeting Registration System
- Voting & Commenting
- New Docs / MyNewDocs
- Web Conferencing
- Technical Information Services and Support (tiss@iec.ch)



Most of the text is from Slide from Damien Lee presentation at TC 120 meeting, 2013-12-12, Frankfurt, Germany, with some information from http://www.iec.ch/about/?ref=menu

IEC – how does it work?

- "One of three global sister organizations (IEC, ISO, ITU)"
- IEC cooperates with ISO or ITU via joint committees to ensure compatibility
- Each IEC standard is developed by working groups in a technical committee (TC)
- Each country has its own technical advisory group (TAG) associated with a TC
- The US TAG is overseen by NEMA
- Any individual can join the US TAG by paying annual dues ($250/TAG)
- Each Tag has a Secretary and Head of Delegation
- At the IEC level, there is a Secretary and Chairperson.
- The working group leads are assigned by consensus among member countries
- The working group develops committee drafts (CDs) that are put up for comments
- Each member country submits its comments through its TAG.
- The working group lead consolidates comments and decides which are accepted
- The CD is then subject to voting (CDV) by all member countries
- Based on consensus, the draft is then published as a standards or rejected for further revisions
- This process can take up to 5 years

IEC – Relevance and next steps

- International standards can become trade barriers
  - Adversely impact US interests
  - Provide entry into global markets for products from other countries that may not comply with US standards/metrics
- IEC makes concerted effort to avoid doing duplicative work
- The DOE-sponsored performance protocol was used as basis of WG2 TC120 work on ESS Performance
  - Efforts ongoing to include latest revision of Protocol into TC120 (WG3 – examples of various applications in the Appendix)
- Poor adoption rate in the US for IEC standards
  - We continue to rely on US codes and standards
  - By actively engaging in IEC TC WGs, the US can ensure its interests are well represented

IEC TC 120

- TC120 **Develops an ESS standard for performance, grid integration, safety and environment**

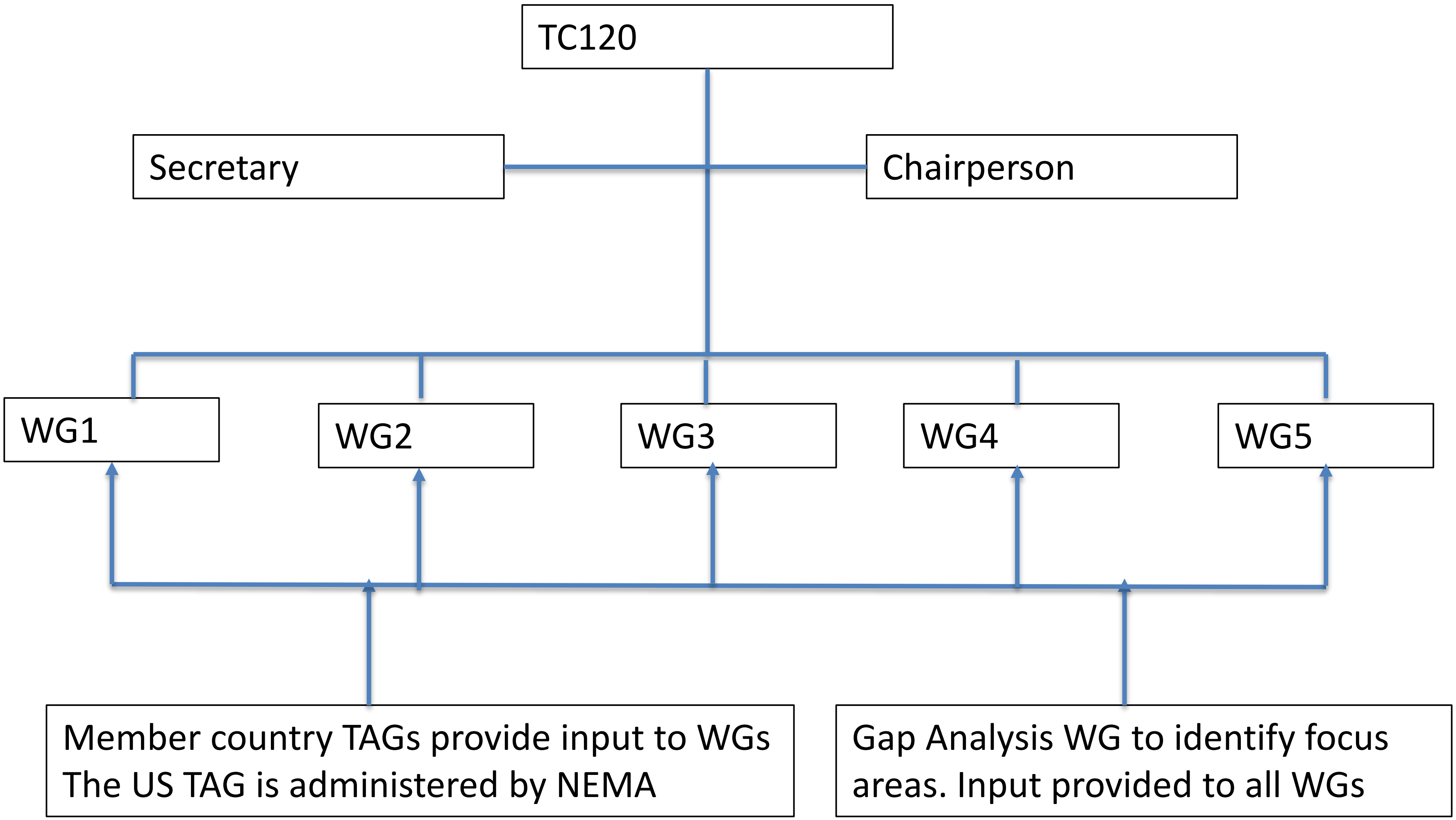
- **Scope "Electrical Energy Storage (EES) Systems are becoming key components of the grid. TC 120 describes and defines system aspects of EES systems which are grid connected AND operated as both an energy source and sink with respect to the grid." Grid includes utility, commercial/industrial and residential.**

- **Principles:**
  - **No duplication of existing IEC TC activities**
  - **Establish liaisons with appropriate TCs Perform gap analysis to determine gaps in ESS storage standards**
  - **Consider storage as a black box – don't go inside - concept adopted from DOE-OE protocol.**

TC120

- WG1 – Terms and definitions
  - define terms applicable to electrical energy storage systems
- WG2 – Unit parameters and test methods
  - Unit parameters – energy capacity, input/output power, SOC range
  - Performance test – accuracy, round trip efficiency, response time
  - Categorizing the EES systems applications – peak shaving/shifting, Ancillary service (frequency regulation), renewable integration
- WG3 – Planning and installation of ESS
  - Electrical properties of grid operation
  - Monitoring and measurement
  - Operation and maintenance
- WG4 – Environmental
  - Ensure environmental hazards are reduced to tolerable level for utility, commercial/industrial or residential use.
  - General requirements include normative documents for the harmful materials in the ESS, recycling and greenhouse effects. Specific requirements include documents for electrical, mechanical and surrounding conditions.
- WG5 – Safety
  - Implement safety measures and study potential risks in relation to the technologies used and their locations.
  - Prepare normative documents dealing with risks, recommendations to mitigate bad outcomes from an accident, and suggested scale for testing the storage

TC120 Structure



Liaisons with other IEC TCs

- TC8: Systems aspects for electrical energy supply
- TC21: Secondary cells and batteries
- SC21A : Secondary cells & batteries containing alkaline or other non-acid electrolytes
- TC22: Power electronic systems and equipment
- TC57: Power systems management & associated information exchange
- TC 82: Solar photovoltaic energy systems
- TC 88: Wind turbines
- TC 105: Fuel cell technologies
- TC 117: Solar thermal electric plants

IEC TC120 Safety

- Draft Technical Specification (DTS) ready for voting
- Several safety related terms added to Terms and Definitions:
  - Explosion hazard
  - Failure mode
  - Fire hazard
  - Protective subsystem
  - Protective measure
  - Reasonably foreseeable misuse
  - Risk
  - Risk analysis
  - Risk assessment
  - Risk evaluation
  - Safety
  - Thermal hazard
  - Tolerable risk

IEC TC120 Safety - Approach

- Identify hazards
- Perform risk analysis
- Develop risk mitigation measures

IEC TC120 Safety – identify hazards

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- Electrical – burns, fires and injuries from arc flash, explosion from static electricity build-up in the presence of flammable substances
- Mechanical – ejected parts from equipment hitting the individual. Results in abrasions, lacerations, contusions.
- Explosion – deflagration and detonation
  - Physical such as Boiling Liquid Expanding Vapor Explosion leads to tank rupture
  - Chemical from thermal runaway of exothermic reactions, fuel/air mixtures, dust particles/air – the latter two need an ignition source
- Electromagnetic – can cause electrical arcs
- Fire
- High temperature
- Chemical
- Unsuitable working conditions

TC 120 – Information needed for ESS risk assessment

- General characteristics – Battery type, rated power &energy, rated life, safety measures, operating parameters, known hazards
- Specific characteristics associated with various types of energy storage
- Type of grid– transmission, distribution, commercial, industrial, residential, islanded
- Application type – peak shaving, load levelling, frequency regulation, renewable firming, backup
- Location of storage – outdoor or indoor, enclosed or not, underground
- Unintended access by people, moving objects, extreme weather, lightning, flooding
- Unattended operation
- Unintentional islanding

TC120 – Risk analysis

- Hazard impact considered across the life cycle (cradle to grave)
- Poor protection devices – cannot interrupt high current
- Ineffective malfunction detection
- System control malfunction
- Aux subsystem malfunction
- Proper safety policies in place
- Assessment of risk from serious hazards such as fire, explosion, high speed projectiles, toxic gas release
- Maintenance
- System level – FMEA, FMECA, FTA, HAZOP

TC120 – Risk mitigation

- After identification of risk, consider if risk is tolerable. If not, mitigate
  - Control and monitoring
  - Prevention
  - Mitigation
  - Plant Emergency Response
  - Area Emergency Response
- Preventive measures
  - Against damage to nearby locations
    - ESS should have a safety related system independent and separated from ESS control subsystem
  - Against damage to workers and other residents
    - Electrical hazards
      - Guard against accidental contact by fending, guarding etc.
      - Appropriate PPE
      - Protection measures against arc flash and shock
      - Detection of Earth fault, over/under voltage, current and temperature
      - Lightning protection
      - Electrostatic dissipation
      - Fusing

TC 120 – Risk mitigation continued

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- Preventive measures
  - Against damage to workers and other residents
    - Mechanical hazards
      - Enclosure structural requirements
      - Safety interlock to control access to an otherwise moving part
      - Stop motion of a moving part
      - Stabilize the equipment
    - Explosion
      - Prevention – reduce explosive atmospheres, avoid ignition source
      - Protection – isolation, venting, suppression and containment
    - Electric, magnetic and electromagnetic fields
      - IEC 61000 series relevant to immunity against these hazards
      - Single component EMC immunity confirmed
      - System interactions should be considered along with EMC disturbances in the environment
    - Other hazards – fire, temperature, chemical, unsuitable work environment, hazardous emissions and leaks
- Over current protection design

TC 120 – Risk mitigation continued

- System disconnection and shutdown
  - Regular maintenance
  - Subsystem/component malfunction
  - External constraints
  - System upgrades
  - End of service life
- Circuit opening done at different points
  - PCC
  - At transformer level
  - Switching device
  - Storage subsystem
  - Auxiliary subsystem
- Grid-disconnected state – ESS disconnected from grid
- Stopped state – DC storage not connected to PCS – the system shutdown command places ESS in this state
  - Part of Auxiliary subsystem remains powered
- Partial disconnection – when only parts of the ESS need to be shutdown
- Emergency shutdown Preventive maintenance staff training

TC 120 – Risk mitigation continued

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- Safety design should be incorporated cradle to grave – as new components introduced or application changes
  - Not possible to do certain safety tests on entire system. Hence component testing critical.
- Testing to validate subsystem compatibility and safety
  - Auxiliary system malfunction
  - ESS control system malfunction
  - ESS internal and external communication malfunction
- Guidelines and manuals

TC 120 – main risks of batteries

- Cell failure due to overcharge, overdischarge, external or internal short-circuit, temperature rise, loss of containment.
- Propagation to neighboring cells
- Insufficient heat dissipation
- External mechanical effects
- Accidental heat flux exposure
- Cell venting
- All of the above lead to thermal runaway resulting in
  - Cell explosion
  - Chemicals emissions
  - Release of hot, flammable, corrosive gas, liquid
  - Fire

Flow Battery Safety IEC TC21 JWG7 21/901/CD IEC 62932-2-2

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- Lots of similarities with IEC TC120
- Several normative references cited
- Risk analysis procedure described (For FMEA and FTA, IEC 60812 and 61025 used as guidance)
- Safety requirements and protective measures
  - Risk information – includes safety data sheer and user manual
  - Electrical hazards
    - Shock
    - Short circuits
    - Ground faults
  - Gas hazards
  - Ventilation – natural, forced
  - Fluid hazards
    - Acid or alkali
      - Ensure good sealing
      - Material containing fluid stable
    - Leakage detection – shutdown pumps when leak detected
    - Specific information related to emergency measures

Flow Battery Safety IEC TC21 JWG7 21/901/CD IEC 62932-2-2

- Mechanical hazards
- Operational hazards
  - Improper integration of subcomponents
  - Start operation done only after safeguards in place with suitable interlocks for proper sequence during start
  - Emergency shutdown – triggered by protection system or manual
  - Remote monitoring and control
  - Suitable protection devices to detect abnormal situations and intitate emergency stop
- Proper nameplate and safety information
- Transport – national and international regulation. For example, fluids shall be emptied out of stacks to avoid short circuit
- Regular inspection
- Verification tests for safety
  - External short circuit
  - Tanks and stacks have sufficient electrical resistance to avoid earth grounding fault
  - Standard operation of charge or discharge
  - Emergency stop

IEC TC 21 62485-1 Safety requirements for secondary batteries and battery installations – Part 1: general safety information

- Nominal voltage up to 1500 V DC
- Addresses basic safety requirements for parts 2, 3 and 4
- Part 2 - safety needs for stationary batteries with aqueous electrolyte
- Part 3 – safety needs for Traction batteries with aqueous electrolyte
- Part 4 – safety needs for batteries used in portable applications
- Normative references
  - IEC 60364-4-41 Protection for safety for electrical installations of buildings
  - IEC 61429:1996 + A11:1998 Marking with international recycling symbol ISO 7000-1135
- Terms and definitions
- Technical characteristics of various batteries
- Application type
  - Telecommunications
  - UPS
  - PV solar
  - Forklift
  - Mining
  - Ships, railways

IEC TC 21 62485-1 Safety requirements for secondary batteries and battery installations – Part 1: general safety information

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- Switch mode operation – One power source feeds load, and another charges battery. When DC1 fails, battery connected to load
- Parallel mode operation – DC power source, battery and load connected in parallel
- Superimposed AC ripple current during charge or discharge causes additional heating
- Measures for protection against shock
- Disconnection and separation
- Commissioning - Delivery condition, electrolyte filling
- Voltage, current, SOC range and temperature limits
- External short circuit
- Explosion hazards
- Electrolyte hazards
- Marking, labeling
- Transport and storage
- Disposal and environmental aspects

Example of IEC work on DC cells and batteries

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- TC21/JWG82 – Secondary Cells and Batteries for Renewable Energy Storage. General Requirements and Methods of Test – Part 2: On-grid applications
- Methods of test for performance and endurance
- Accelerated degradation using pulsed cycling (frequency regulation), constant power cycling (peak shaving) described
- Round trip efficiency over 840 pulse cycles calculated
- Data tracked throughout the cycling to determine efficiency change with degradation
- Waste heat generation determined

IEC TC21 – 62660-3 Li-ion cells (cell blocks) for electric propulsion – Part 3: Safety

- Test procedures for safety
- Normative references
  - IEC 62133 safety requirements for portable alkaline or non-acid sealed cells
  - IEC 62619 safety requirements for secondary lithium cells and batteries, for use in industrial applications (under development)
  - IEC 62660-2 Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 2: 69 Reliability and abuse testing
  - ISO 12405-3: (2nd Edition, under development), Electrically propelled road vehicles - Test specification for lithium-ion battery packs and systems - Part 3: Safety performance requirements
  - Terms and definitions
  - Test conditions/measurement– voltage, current, temperature, capacity, power measured with proper tolerance

IEC TC21 – 62660-3 Li-ion cells (cell blocks) for electric propulsion – Part 3: Safety

- Mechanical
  - Vibration - in accordance with 6.1.1.1 of IEC 62660-2.
  - Mechanical shock - in accordance with 6.1.2.1 of IEC 62660-2.
  - Crush – new procedure developed. 100% SOC for BEV and 80% SOC for HEV. Use semi-circular bar for crushing a cylindrical cell, and a hemisphere 15 cm in diameter to crush prismatic cell. Force released when voltage drops by 33% or > 15% deformation occurs. Monitor for 24h or till cell temperature declines by 80% of the maximum temperature rise, whichever is sooner. No fire or explosion.
  - Thermal test
    - High temperature endurance (130 deg C) for 30 min. Turn off heat and monitor of 6h in oven – no fire or explosion
    - Temperature cycling – in accordance with 6.2.2.1.1 of IEC 62660-2. No leakage, venting, rupture, fire or explosion
  - Electrical tests
    - External short circuit - in accordance with 6.3.1.1 of IEC 62660-2. No fire or explosion
    - Overcharge from 100% SOC at 1C for BEV and 5C for HEV till voltage is 1.2 times Vmax, or amount of charge reaches 130% SOC, whichever comes first. No fire or explosion.
    - Forced discharge from 0% SOC at 1C till cell V is < 0.75 of nominal voltage or cell discharged for 30 min, whichever is sooner. No leakage, venting, rupture, fire or explosion.
    - Internal short circuit - in accordance with 8.3.9 of IEC 62133 or IEC 62619 (under development) or ISO 12405-3 (under development).

IEC TC21 – 62660-3 Li-ion cells (cell blocks) for electric propulsion – Part 3: Safety

- Operating range of cells for safe use
  - Charge – I, V as f(temperature)
  - Discharge – I,V as f(temperature)
- 21/857/DC provides alternative test methods for internal short circuit test
- IEC 62619 provides detailed description for safety test procedures for lithium batteries for industrial applications

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IEC TC120, TC21, TC21 JWG 105 working groups