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Vinoski & Associates, Inc.

USA & London UK

POWER GENERATION

Renewables, BESS, Wind, Solar, Hydrogen

Latent Defect Design Reviews, Root Cause Investigations, Insurance claim Support

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Power Generation

- Our Core remains Large Combustion Turbines, *(especially Hydrogen-mixed fuel failures and accelerated degradation)*, Steam Turbines, Generators, Balance of Plant Equipment.
- Structural Steel – Boilers/HRSG, Buildings, geothermal and solar-thermal.
- Steam Turbine, Boiler, HRSG, and Coal Handling Corrosion
- Insurers using VAI to review the local in-country engineering reports
  - (1) to locate root cause,
  - (2) identify extent of damage) and
  - (3) to help train local engineering companies the art and sciences of failure analysis and claim support. This support is worldwide and quite effective.

Renewables/Alternatives

- The exchange of one form of a pollutant or toxin for a different pollutant or toxin.
  - The statement above impacts disposal options
  - Ethanol in petro/gasoline CO reduced and exchanged for formaldehyde creation
  - Coal to Gas. High pH ash (non-carcinogenic) for NOx a Low pH acid that drives cancer.
  - Photovoltaic and Batteries an exchange of Abiotic Oil for Toxic Compounds

Solar and Photovoltaic

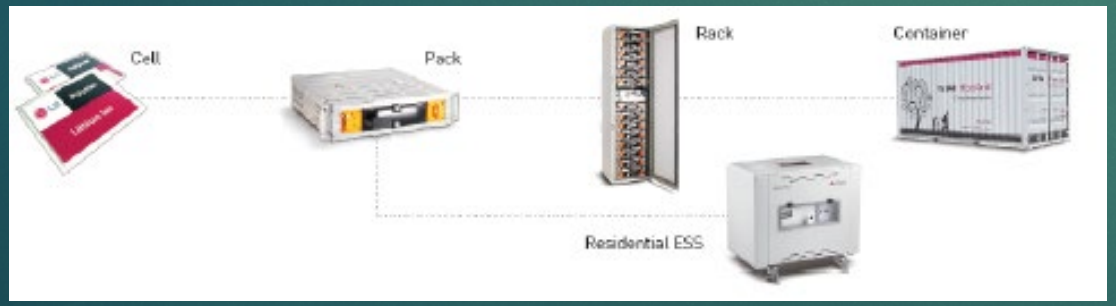
- Whether solar thermal or pure photovoltaic – we have manufacturing and operations experience since 1984
- This includes the "renewed" interest in Fuel Cell technology.
  - Our 40-year history with design, manufacturing, transportation, and operational risks/problems will be of benefit.
- Invertor damage, repairs, rebuilds of "obsolete" units, etc.

Wind Turbine

- Blade design deficiencies
- Tower oscillations, strengths & weaknesses and civil foundation issues.
- Lightning & Grounding deficiencies and errors in standards and warranty provisions.
- O&M short-falls,
- Invertor, generator, transformer, wiring, and electrical issues.
- Main shaft bearing wear and gearbox wear / damage.

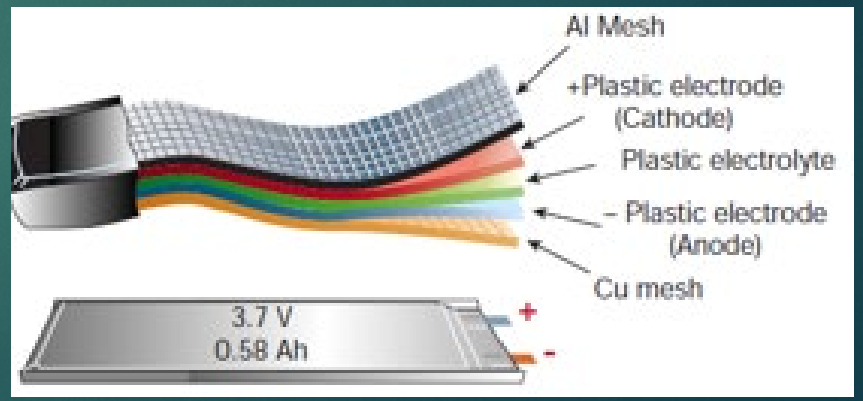
Battery Energy Storage

- The wave of the future. 100% Battery "supply" is this 50% or 200%
- Shutting down large generator stations that used to sink Peak Loads
- Green Energy does not push or pull VARS
- Battery Technology has been around for a hundred years
- Lithium-Ion compounds have high energy density, easily released.
  - Fire systems cause more fires. Disposal, recycling, and reuse?



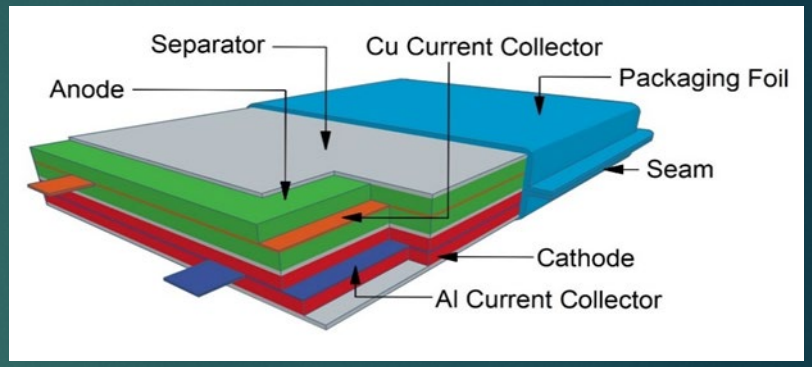
Li-ion compounds

- In the 1980's Westinghouse tested and experimented with a dozen types of Lithium compounds.
  - Many problems were encountered related to manufacturing, production, mass production, stacking, embrittlement, loading, unloading, life expectancies and more importantly – disposal.
  - Many concerns remain.
  - Power Contracts exceed life expectations.
  - Now designated as toxins.



Design Features.

- BESS Location and Grounding.
- Types of Li compounds:
  - LiNi0.8Co0.15Al0.05O2; LiNi1/3Mn1/3Co1/3O2; LiNi0.4Mn0.4Co0.2O2
  - LiNi0.5Mn0.3Co0.2O2, LiNi0.6Mn0.2Co0.2O2, LiNi0.8Mn0.1Co0.1O2
  - LiMn2O4, LiNi0.5Mn1.5O4, Li1.15Ni0.15Mn0.55Co0.15O1.7, LiFePO4, LiC6
- Various charging rates, no intermixing.
- Various discharging rates, current carrying capacities.
- Various crystallographic densities.
- Compound binders vary and must be pure as with porosity



Cost Information

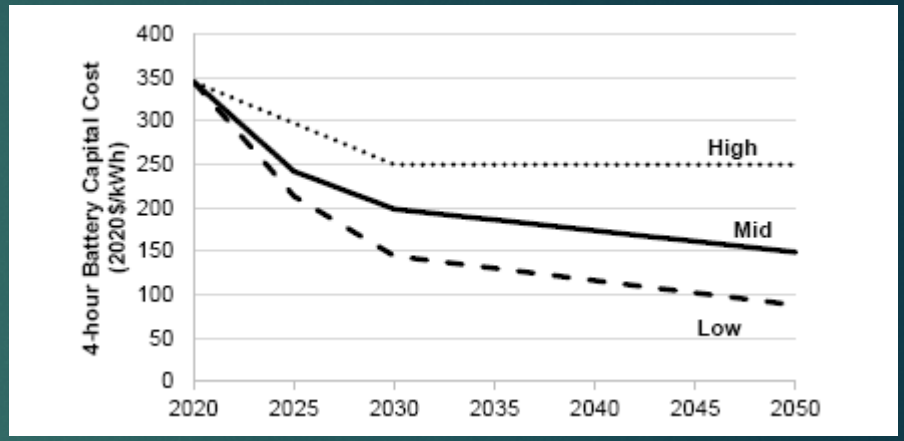
- Costs vary grossly.
  - Cost of raw materials, cost of cells, cost of modules, total costs.
  - Cost vary by lithium compound used.
  - Lithium mining is not yet monopolized but China controls the largest mines. China and South Korea control production. Not a green process at all.
- VAI is tracking over 1,800 BESS, they keep growing.
- VAI has been very successful at turning Insurance Claim Losses back to Manufacture's Warranty Claims direct to South Korea & China.
  - Why should the insurance market pay for latent design defects?
- Replacement costs up 132%.
- Entombment vs Recycling (Wording! - long term liability: cradle to grave).

Latent Design Defects

- Li-ion compounds are not always homogenous mixes. They can have contamination and voids that affect the cells internal resistivity.
  - Ohm's Law still important when charging or discharging
  - $\Delta V_b = V - I*R_{cr}$ whereby V_b is the battery cell voltage and R_{cr} in the resistance across the cells compound.
- Transportation damage can occur.
- Controls systems must be state of the art. Terabytes of scanning diagnostics are critical at the cell level.
- Voltage state, charging rates, and discharging rates must be controlled. Average module voltage metering does not work.
- Grounding Loops: Can increase the bias of the electronics. Raising charging limits above safe threshold.
- Grounding grid design and proper earthing and grounding validation.
- Design Life: 2,400 to 7,000 cycles. Years are short. Decay is important.

Pricing

- Pricing reductions predicted: No True.
  - The National Renewable Energy Laboratory is guessing there will be future price reductions.
  - If there are any price reductions those "savings" will be offset by disposal costs.
- Claim losses include fire, water, smoke, damages; module & cell level inspections and testing;
  - 100% loss. Claims range from 25% to 300% of total construction
- Replacement of ancillary/auxiliary equipment and controls, battery cost are sometimes covered by OEM warranty provisions; not transportation, disposal/recylcing.
  - Remediation
  - Containment during transportation – use of coffins.
  - Toxic gases, requiring SCUBA gear for inspections
  - Where did the damaged units end up? Document it.



BESS Fire

- Fire or Thermal Event? - BOTH.
- Two deaths and one missing Operator.
- Li-ion Compound suspected (V=IR) but the controls for this system were because it provided DC directly as an output.
  - The lack of inverters were considered to have lowered the risk?
  - Inverter work to homogenize the module cluster outputs and work as an isolator between the source and the load. These designs are proposed here in the USA and Europe but carry new risks.
- Risks include application/use, quality controls, battery management and control systems, module gaps/insulation, fire protection/extinguishing – meaning Speed and Ability to quench at the cell level.

USA – multiple losses

- Fire or Thermal Event? - BOTH.
- Extended Drainage, Poor Controls, Poor Battery Management Software/Controls.
- Voltage metering discrepancies
- Startup Procedure issues.
- Inexperience

Construction & Contract Considerations

- Is the site new BESS site or a brownfield site (old warehouse, steam turbine deck, or shopping mall? Site specific grounding issues.
- Is the BESS located indoors, in the basement, adjacent to occupied buildings?
- Technical Audit of design documents, battery management systems, battery protection, and the fire protection systems – exposes **many** weaknesses.
- Review of Purchase Contracts, Warrantees, & Guarantees lessen claims losses.
- In a loss event, warranties cover the battery losses, some cover the container losses, some do not. These systems have many inverters, communications modules, data loggers, supercomputers, etc.
- Construction records, commissioning records, and sign-offs are extremely valuable, especially when the EPC firm is not experienced.
- Subrogation. Possible, but warranty first, then pick out aggressive attorneys.

Example of Claim Creep

- We use an 80-point Q&A/Investigative Process.
- We use competitive EPC Bidding and Life-cycle Maintenance costing
- Quick on-site evaluation of Direct Damage 300 modules. Months later after extensive engineering costs the insured's engineer also say 300 modules
- Actual damage $9.4, Expect $13.7. Risk of recovery creep $9+$8 = $17 million
  - Battery testing, disposal. Throw out everything in question/ "no warranty"
- BESS recovery efforts include upgrades, redesigns, & maintenance.
- Types of upgrades to expect:
  - Waterproofing of racks, we have seen up to $13million in adders.
  - Rerouting and waterproofing of electric, cables, wiring up to $10 million.
  - Balance of plant changes to improve maintenance and repairs up to $14.8 million
  - EPC – complete management of repairs, recovery, upgrades, redesigns. $28 million
- Consider site presence, engineers, and clerk of the works.
- Overseeing re-design efforts is vital.

WIND

- Common problems
  - Assembly of the nacelle (techs are constantly dropping washers, nuts, and bolts in the open top transformers.
  - Transformers have mechanic welds that separate and failure causing a drastic increase in current density. This can be determined on the first visit once the nacelle is on the ground.
  - Medium Voltage Bridge incorrectly wired. Relay protection not set up.
  - Not one wind farm has adequate relay protection.
  - Circulating currents and lightning protection systems are the major cause of bearing damage. Rarely does a wind farm monitor key bearing dynamics that tell them "CHANGE OUT THE BEARING". This causes 90% of the gearbox damages.
  - Blading is getting larger and mechanical fastening is not capable of the loading. VAI's Sam DelaTorre recent patent on measuring fiberglass thickness to strength a Shear Tester.
  - Wind LPS systems barely address resistivity, let alone inductive/impedance. Lightning calculations on the design show greater weaknesses.

Hydrogen

- We have extensive design and testing experience on various turbines with a few manufacturers, Siemens, MHI, GE, Westinghouse, etc.
- We have H-technology test rig, rainbow, thermal-mechanical first stage blade testing experience.
- Hydrogen burners – require a new design. Hydrogen Fuel Cells have unique issues. Design, development, and experimentation started decades ago 1980's.
- The 7HA.03 and other turbines are being designed to use hydrogen and some plants are built.
  - These will be test sites (R&D) for some time.
    - Failure modes have been roughly identified by the DOE and DOD.
    - Failure modes may not look like they are design related but there are many differences in the combustion dynamics of using Hydrogen in part or in full.
    - Partial fuel mixes are problematic.

Hydrogen Risk Areas

- Flame Stability and length – length will be more problematic.
  - Fuel nozzles are different and controlled differently.
  - Flame temperature is higher NOx increases – causing other changes.
  - Burner flashback controls must change.
  - Hydrogen flame velocity is much faster than natural gas.
  - Purge and explosion control changes must be made and managed.
  - The thermo-acoustic amplitudes and frequencies are very different.
- Hydrogen embrittlement is coming back, as the H2 migrates through the materials. This is temperature driven so it will affect some piping.
- Fuel Handling. Very small molecule – better at escaping than Harry Houdini. Colorless and odorless, flame is not visible so new sensors to eyeball the flame.
- Fire protection will be different and more complicated to detect hydrogen flames.

Hydrogen fueled turbines

- Expect to see Diffusion-type Combustor designs.
- Post combustion Hydrogen has a high moisture content in the exhaust gases. Expect to see heat transfer issues to HGP components, HRSG, and other exhaust components.
  - Hot Corrosion Components and failure modes have been identified.
- Supply. Where's it all coming from.
  - Current hydrogen electrolysers (another area our chemical engineers are studying) cannot produce but 3% of the hydrogen supply expectations. More on electrolyser risks and O&M later.
    - There have been supply limitations in the 50hz and 60hz markets
    - There will be changes to storage, transportation, and liquification.
      - Changes are being made to the cryogenic tanks, pumps, components. It takes a lot of energy to liquify hydrogen. We look to the problems and changes made at the world's largest storage sites. An 850,000 gallon tank or 3.2 million liters gets consumed in 8 hours in a 432 MW 7HA.03 Gas Turbine.

Hot Gas Path Components

- Materials have been changed to accommodate the elevated temperatures. Expect to see and not see (internal) high temperature oxidation and corrosion.
  - Multi-color infrared Pyrometers and Laser Absorption Devices – working.
  - There are changes to Cooling, Sealing, and Purge Flow. – This will cause mechanical damages and require slight control changes.
- Combustor/Combustion
  - High flame speeds – this alters the damage we will see if not designed properly.
  - H_2N_2 can reach 3,000°F.. HIGHLY subject to gas-supply constituents!
    - Can require physical changes to the fuel nozzles and pre-mixers.
    - Materials changes will also be required – many test components using zirconia. Other alloys are being used, better at higher temperatures but other characteristics are marginal.
- Promises. Cooling flows must be reduced to obtain the heat rates. There are several changes to the cooling flow schemes, a few changes to the seal designs, and blading cooling internals are highly-sophisticated.

Impact on Traditional T-G Sets

- Renewable energy cannot meet or displace the massive generators of yesteryear. These behemoths could absorb and push VARS. They could easily absorb heat in off balance matches between the grid and consumers.
  - Renewables cannot.
  - All traditional Turbine Generator sets are now being used for "load-following" or filling the gap.
    - This changes the dynamic loading on generators from one form to another thereby accelerating the mean time between failures.
    - Singular Angular Ball Thrust Bearing Turbines cannot endure or are not made for load-following. Large units with inter-coolers have mechanical and thermal inertia loading issues that result in failures.
    - Duplex Angular Ball Thrust Bearing Turbines work well except for when placed in a load-following mode, the lubrication system do not work. This can be fixed quickly.
- No one is maintaining coal equipment. Causing delays to increase B.I.
- Transformer losses need to be addressed damage events are on the rise due to a lack of maintenance. They all can be repaired and quicker that manufacturing new units. We have four transformer experts experienced at repairing all sorts of damages

Experts

- Walt Vinoski – Siemens-Westinghouse & MHI CTG, Steam Turbine & General Power plant, FEMA
- David Kalmanovitch (UK-based) – Metallurgist, Turbine Hot Gas Path and Boiler corrosion expert
- Paul Markham (UK-based) Power Engineer, conventional turbine-generators, renewables
- Georg Nauman – design, fire/water piping, structural, modeling, loading.
- Wendall Moulder – Nuclear, Power, Gas/LNG Startup Boiler Expert. UK, South Africa, Mexico, Canada, Indonesia, Thailand, and Singapore.
- R. "Bucky" Croushore. Civil Engineer – Power plant structural steel. Bridge damages repairs, designs, and claims reviews.
- Dudley Green – GE Combustion Turbine expert, general steam turbine expert
- Mike McNeil – Electrical Engineer – Apparatus, Root Cause Analysis protocols, Fault Tree Analysis, Life-cycle Planning
- Rick O'Mahony – Electrical, Generator designer/repairs, switchgear, transformers, and grounding. Wind Turbine experienced
- Jack Bahnak – Electrical, Transformers, Electrical apparatus, turbines, wind turbines, & Product Liability Testing
- Kim Eiss – electrical generator expert
- Rick Johnston – Chemical Eng. Layer bonding and defect issues
- Dr. Fuchs (USA), Dr. Kalmanovitch (London), - Materials, bonding, manufacturing.
- Helmut Nauman – Steam and gas turbine designer
- Robert Shallenberger, materials engineer – quality controls
- Dr. Uman – Earth grounding and lightning expert
- Mark Bennett – Startup and O&M expert for coal and combustion turbines.
- Joe Jaskulski – certified fire inspector
- Dick Johnston – GE & P&W aero derivative turbine design engineer
- Ralph Leidy. Powerplant O&M Expert, Turbine Machinery Operations, and Maintenance expertise.
- Justin Jeffcoat. Crane, rigging, and lifting expert.
- Gene Borrows – Wind and power plant startup and construction manager.
- Robert Bizzak. NRC designer, piping and rupture expert.
- Various Controls Experts, Process Engineers, Civil Engineers, and Construction/O&M Experts