CleanTech Strategies

Improving Reliability of TMCES Systems

Dave Ridley, EE
CleanTech Strategies LLC
dave.ridley@cleantechstrategies.us

CTS Partners

CleanTech Strategies

Pacific Northwest NATIONAL LABORATORY

NATIONAL ENERGY TECHNOLOGY LABORATORY

OAK RIDGE National Laboratory

Sandia National Laboratories

Argonne NATIONAL LABORATORY

INL Idaho National Laboratory

bci BATTERY COUNCIL INTERNATIONAL SINCE 1924

EPRI ELECTRIC POWER RESEARCH INSTITUTE

NY BES+ NEW YORK BATTERY AND ENERGY STORAGE TECHNOLOGY CONSORTIUM

NAATBatt INTERNATIONAL

IEEE Advancing Technology for Humanity

CTS TMCES Clients: ARES & EarthEn

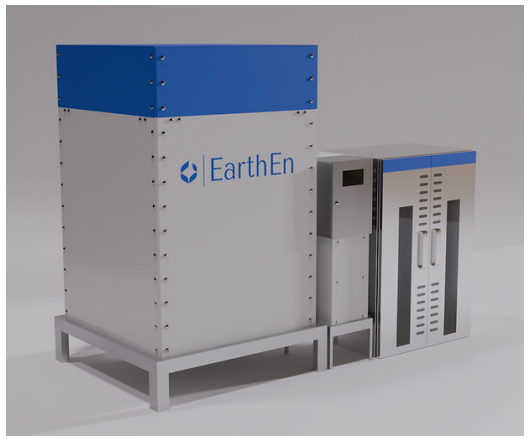
CleanTech Strategies

ares

https://aresnorthamerica.com/

EarthEn

POWERED BY: GRID8



https://www.earthen.energy/

Know your customer:
Uptime is a key stakeholder requirement

CleanTech Strategies

Uptime	Downtime/year	Resource Examples
< 1x9	Multiple months	Coal, Geothermal, Biomass, Hydro
1x9	1 month	Nuclear, Wind, Natural Gas
2x9's	3 days	Solar, BESS
3x9's	8 hours	US Electric Grid
5x9's	5 minutes	Data Center, Telecom, Hospital
> 5x9's	None	Airplanes, Satellites, Military

An uptime calculation is crucial to any energy storage system design

CleanTech Strategies

- MTBF =
  - Mean Time Between Failures
- MTTR =
  - Mean Time To Repair
- Component uptime =
  - (MTBF – MTTR) / MTBF
- Module uptime =
  - Π(component uptimes)

Component	MTBF	MTTR	Uptime
Compressor	50,000 h	168 h	99.664%
Turbine	50,000 h	168 h	99.664%
Cooling fan	25,000 h	48 h	99.808%
Aux power supply	70,000 h	48 h	99.931%
Controller	200,000 h	48 h	99.976%
		Module Uptime =	**99.047%**

Any component that can take down part of the system shall be included

CleanTech Strategies

Power path

transformers, inverters, power meters

Switchgear

circuit breakers, fuses, contactors, protection relays

Instrumentation

temperature, pressure, level, flow, voltage, current

Safety

leak detection, fire detection, limit switches, interlocks

Thermal

cooling fans, freeze protection, chillers, coolant pumps

Control

various levels of controllers, communication gear

Mechanics

gear boxes, motors, bearings, valves, slip rings

Target module uptime depends on module size relative to project size

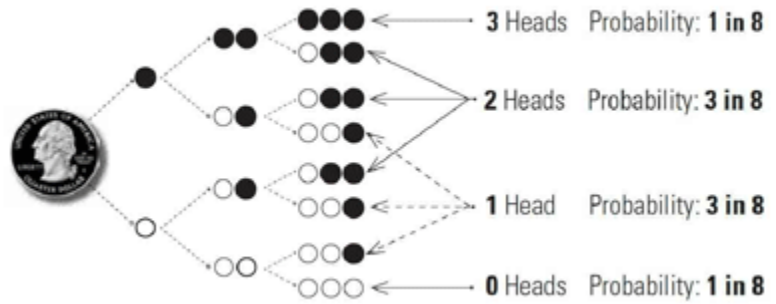
CleanTech Strategies

- Larger module size or fewer modules per project necessitates a higher target module uptime
- Pilot projects can present reliability challenges as they are often sub-scale

Component	MTBF	MTTR	Uptime
Compressor	50,000 h	168 h	99.664%
Turbine	50,000 h	168 h	99.664%
Cooling fan	25,000 h	48 h	99.808%
Aux power supply	70,000 h	48 h	99.931%
Module controller	200,000 h	48 h	99.976%
Various sensors	50,000 h	168 h	99.664%
Safety interlocks	50,000 h	168 h	99.664%
Power electronics	50,000 h	336 h	99.328%
Transformer	500,000 h	672 h	99.866%
Switchgear	500,000 h	672 h	99.866%
Protection relay	500,000 h	168 h	99.966%
Power meter	500,000 h	168 h	99.966%
Site controller	200,000 h	48 h	99.976%
Market gateway	200,000 h	48 h	99.976%
		Module Uptime =	**97.346%**

Uptime requirements can significantly impact system level cost

- Module uptime = 97%
- N+m uptime calculation uses the binomial distribution
- Nameplate (N) = 10 modules
- 2x redundant modules (m) required to achieve 2x9's at the system level
  - **20% Overbuild**



Nameplate (N)	Redundant (m)	Total (N+m)	Uptime
10	0	10	76%
10	1	11	96%
10	**2**	**12**	**99.00%**
10	3	13	99.9%
10	4	14	99.99%
10	5	15	99.999%

Many ways to improve uptime beyond paying for high reliability components

CleanTech Strategies

System Engineering Principle	Examples
Fault tolerant design	• Utilize redundant communication network topologies • Implement redundant higher-level controls • Redundant components for critical devices
Detect hidden failures	• Monitor component degradation and detect trends • Sense ground isolation resistance or ground leakage • Detect welded contactors during open/close sequences
Optimize MTTR	• Simplify component replacement procedures • Quick component access with standard tools • Connectorized components and segmented LOTO
Design to “Fail ON”	• Sensors with error or internal fault detection • Enable signals can fail on if protection fails off • Continue ops for non-safety critical component failures

Takeaways

1. System design starts with uptime analysis

- Modeling enables quantifiable trade-offs for architectural decision making

2. Uptime directly impacts the bottom line

- Architectural – overbuild cost, failure capacity impact, failure urgency
- Contractual – uptime violations, downtime loss of revenue
- Maintenance – anticipate costs accurately, minimize site activity
- Reputational – performance warranty, reference customers, industry stigma

3. Build N+m architectures that are serviceable

- Concurrent maintainability eliminates the emergency from failures