Advanced Energy Storage System for Utilities:

Case of Korea Electric Power

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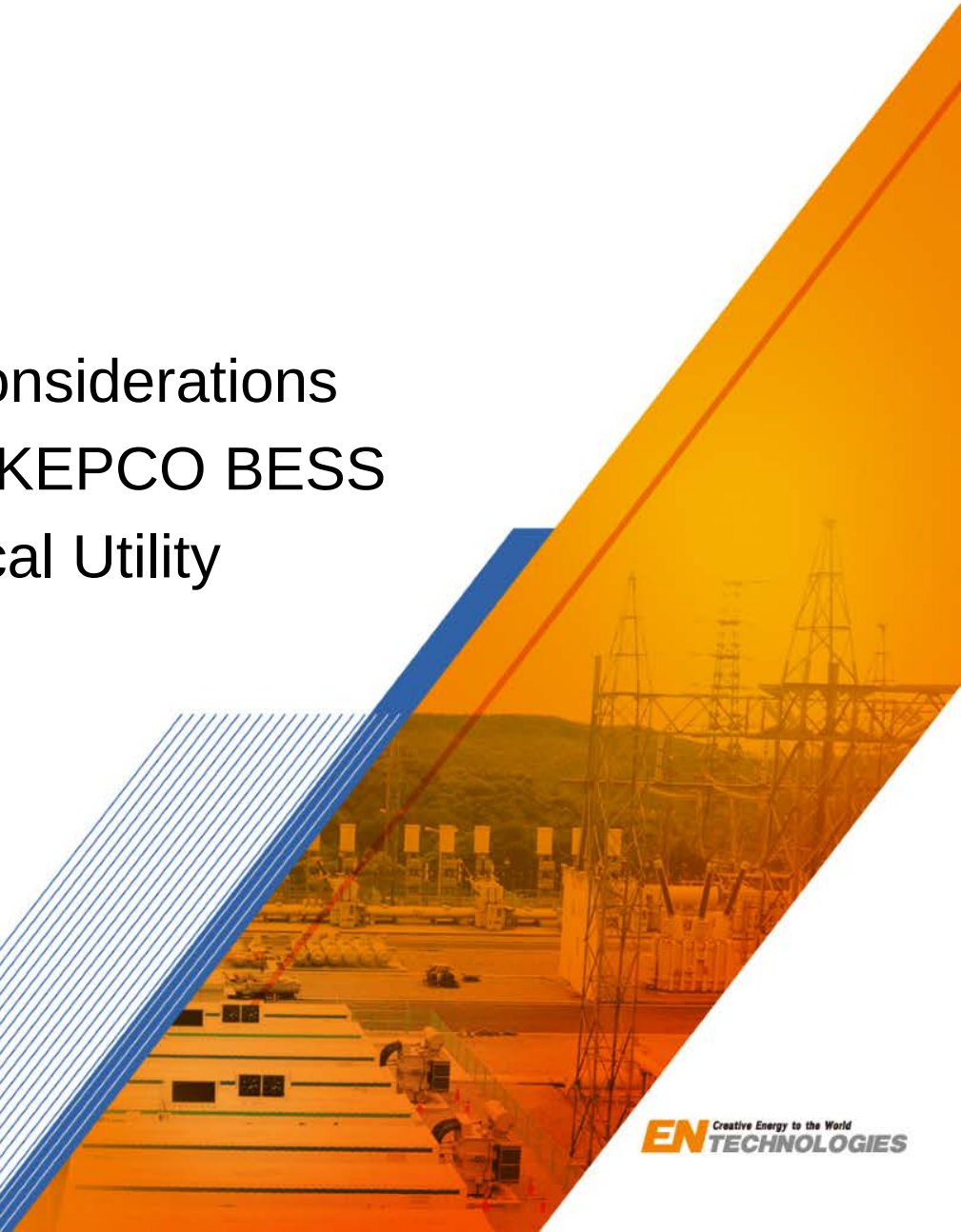
Agenda

- Why Energy Storage?
- KEPCO BESS Project
- BESS Benefits and Considerations
- Economic Analysis of KEPCO BESS
- Considerations for Local Utility



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Advanced Energy Storage System for Utilities

Why Energy Storage?

- Electricity Supply must equal Demand at all times
  - Battery Energy Storage System (BESS) can provide support during generation surplus or shortfall.
- Frequency Regulation
  - BESS can support to correct small changes in frequency to remain within thin tolerance band

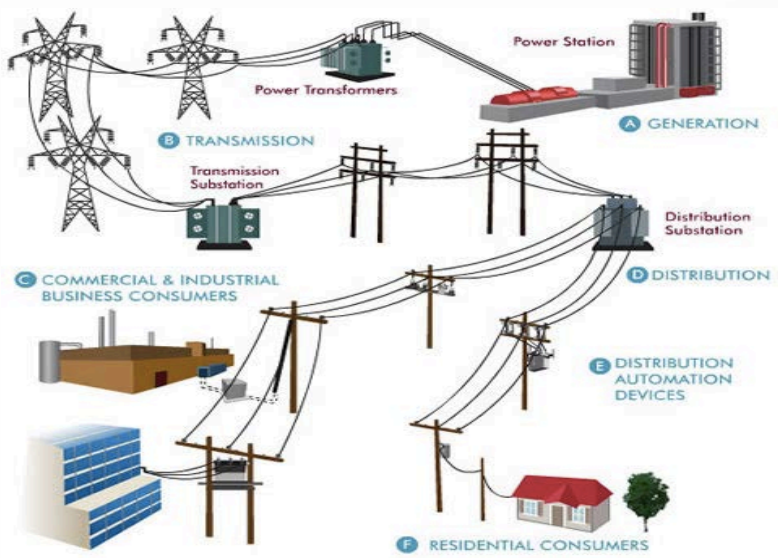

Figure (left): Electrical System Network *is composed of generating power assets, transmission and distribution infrastructure, and end customers. A core tenet of this complex operation is that power generation should equal customer demand in near real time. This leads to substantial network supply-demand fine-tuning known as frequency regulation, and stress points in the distribution and generation infrastructure during peak periods of demand. Significant cost is incurred by operators in the maintaining this balance.*

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Why Energy Storage? cont.

- Peak Demand & Spinning Reserves
  - KEPCO operates most units at 95% of capacity for reserves. BESS could be used for peak shaving and sudden changes in demand and allow large units to run at 100% capacity.
- Peak vs. Capacity Build
  - On average, KEPCO only uses 60% of available capacity. BESS would reduce amount of units constructed to only meet peak demand.

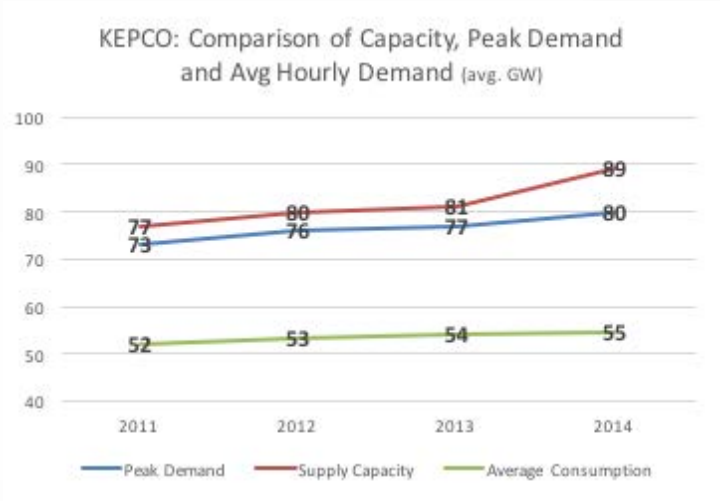

***Figure (left)**: KEPCO average hourly demand was approx. 60% of capacity; and 68% of peak demand*

Source: KEPCO Annual Report 2014

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Genesis of KEPCO BESS Project

- Advances in lithium-ion battery technology led Korean Electric Power Corporation (KEPCO) to design and implement large-scale storage project
- KEPCO maintains approx. 1,000 MW in reserves and wants to use energy storage to replace as much as half or 500 MW of reserves
- Number of hurdles existed to start project
  - Regulatory Approval
  - Operational and Financial Viability

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Genesis of KEPCO BESS Project

- Hurdle #1 – Regulatory Approval
  - Korean generation assets are independently operated (as a whole assets are majority owned by KEPCO), distribution assets are largely in the hands of KEPCO.
  - Korea Power Exchange (KPX) is the main regulatory arm between generation and distribution capacity
  - KPX initially took position that BESS was generating asset, therefore KEPCO could not own or operate the BESS as a distribution company.
  - Eventually differences were worked out and regulations were adjusted to account for the new technology

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Genesis of KEPCO BESS Project, cont.

- Hurdle #2 – Operational and Financial Viability
  - Government, majority stakeholder of KEPCO, insisted the project be funded on its own by KEPCO
  - Little precedent in other countries for using BESS for frequency regulation
  - KEPCO initiated USD$30M feasibility trial for testing BESS
  - Jeju Island Test Project
    - 4 MW / 8 MWh BESS
    - Applications tested: peak shaving, wind renewable power smoothing, and frequency regulation
    - Trial was completed in 2013 and demonstrated the operational improvements and financial viability of BESS
- Alignment of the government's national interest
  - Cost-savings and compelling capital returns for the national utility
  - The development of a leading edge eco-system for energy storage
  - The prospect of Korea leading international development of BESS for frequency regulation through technology transfer, licensing, and exports

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KEPCO BESS Project

- KEPCO began implementation of BESS project in Dec 2014
- First stage was 52 MW for testing and confirmation of technology
- After confirmation of system capability in May 2015, KEPCO installed an additional 184 MW of BESS capacity
- KEPCO worked with multiple technology partners for the design and integration of the system
  - Specific attention to the power conversion of the battery systems and their linkage to the energy power management system of KEPCO

Figure (left): *KEPCO deployment of BESS at the Shin-Yongin substation where 16 MW system designed and implemented by EN Technologies is installed.*

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KEPCO BESS Project, cont.

- BESS Architecture – Composed of three core components
  - Frequency Regulation Controller – measures constantly in near real-time the frequency of the system at a given point on the grid and provides instructions for charging and discharging of the storage system
  - Power Conditioning System (PCS) – receives signals from the Frequency Control and communicates with the battery system on the extent of charges or discharges and also converts the DC→AC or vice-versa
  - Battery Management System – system operates in real-time with discharge/charge/hold decisions being made every four seconds, system also tracks the state of charge of all battery systems on the grid. Also constantly monitors temperature to guard against overcharging.

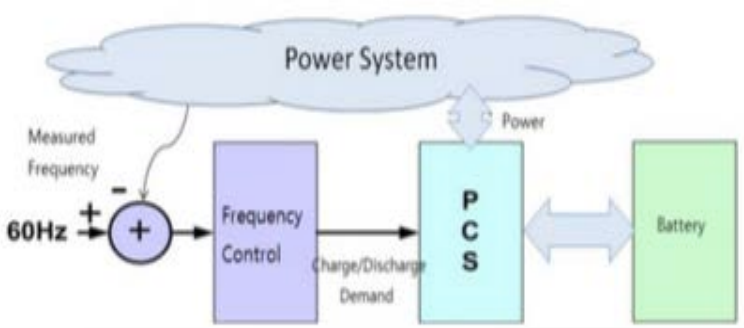

Figure (left): *The KEPCO BESS system architecturally consists of three main components: frequency control, power conversion and battery storage.*

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KEPCO BESS Project, cont.

- National Roll-Out of BESS
  - System is modular in nature, each BESS unit comprised of a 4 MW PCS together with 1 MWh battery system. Enables each unit to discharge 4 MW for a maximum of 15 minutes

Figure (left): *The map shows the current deployment of the BESS in Korea. The black stars represent BESS systems already implemented and the red stars represent BESS that is scheduled for installation in December of this year.*

Phase 1 involved the deployment of 52 MW at two sub-stations one hour outside of Seoul, while Phase 2 totals 184 MW at seven substations and eight sites spread through the country. Phase 2 installation was completed in January 2016.

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BESS Benefits and Considerations

- Cost Reduction
  - KEPCO is able to reduce its spinning reserve needs through BESS adoption
  - Normal spinning reserve requirement of 5% could be cut by as much as half
- Power Quality
  - BESS is able to respond in milliseconds to frequency regulation requirement, typical reserves can take as much as 15 seconds to 15 minutes

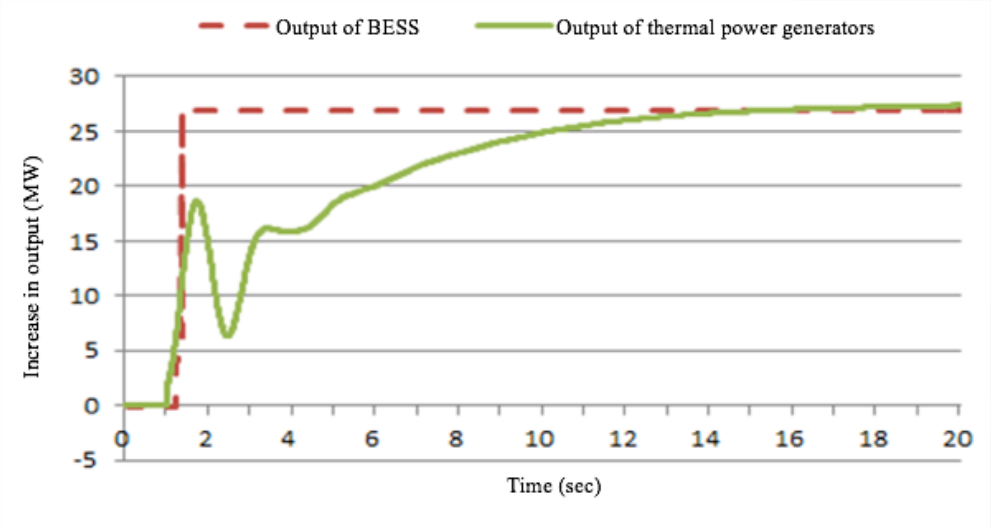

Figure: Test comparison of frequency regulation through BESS and the output of thermal power generation*. The BESS was able to output greater than 25 MW of power within 1/10 of a second, while thermal power generation took 12 seconds to reach this level. The current method results in material lags in a utilities ability to control frequency in real time.*

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BESS Benefits and Considerations, cont.

- Environmental and Trade Impact
  - Currently KEPCO uses mostly thermal coal as spinning reserve. Korea is largely an energy importer, a greater use of BESS will reduce imports helping to improve the trade balance
- BESS Costs
  - Lithium-ion costs have been dropping 10-15% per year, cost today is roughly one half the cost in 2012. Analysts predict it could go as low as sub-USD$200/kWh by 2020.
- Safety
  - There have been incidents of fires bursting out from over-heated lithium-ion batteries. Technology has improved significantly, including better chemistry (more gel-like rather than liquid), better temperature sensing, and safety systems to guard against over-heating

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Economic Analysis for KEPCO BESS

- Analysis based on KESRI study performed following completion of Phase 1 of the Project (52 MW, completed in May 2015)
- Key Assumptions
  - Capital costs of 500 MW approx. US$542M, conservative view, expected to decrease
  - Payment savings based on what KEPCO will no longer need to pay generators for 5% of capacity held back for reserve purposes
  - Expected life of batteries 10 years, other components have 20+ year life
- Projected IRR: 33% (7 Years), 38% (10 years)

KEPCO BESS IRR										
USD MN	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Investment - BESS	-542									
Payment Savings		281	281	281	281	281	281	281	281	281
O&M Costs		-63	-63	-63	-63	-63	-63	-63	-63	-63
Gross Cash Flow	-542	218	218	218	218	218	218	218	218	218
Cumulative Gross CF	-542	-324	-106	112	330	548	765	983	1201	1419
IRR --10 Year	38%									
IRR --7 Years	33%									

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Considerations for Local Utility

- KEPCO project demonstrates large-scale lithium-ion based energy storage system are commercially viable for core utility requirements including frequency regulation, peak demand management and power back-up
- Same benefits could apply to utilities in other countries
  - Reduction of costs, especially in frequency regulation and peak demand management, Korean project demonstrated BESS can be substantially more cost-effective than traditional spinning reserves
  - A more responsive grid that adapts quickly to sudden changes in supply or demand.
  - More efficient use of generation assets by moving away from legacy-based spinning and other reserve systems. Less “wear and tear” on generating assets and higher capacity factors of existing assets.
  - Can also be used to help utilities help defer transmission or distribution line investments through peak reduction, improve power quality for value customers and integrate renewables more easily onto the local grid

Questions?

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Thank You
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