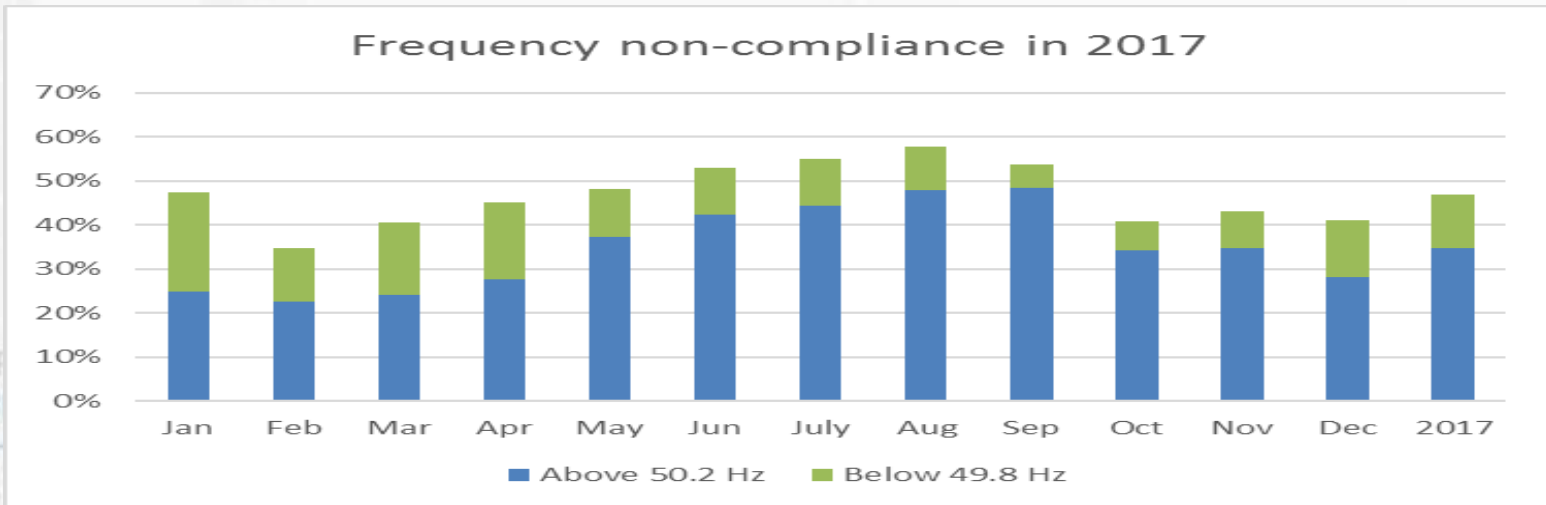
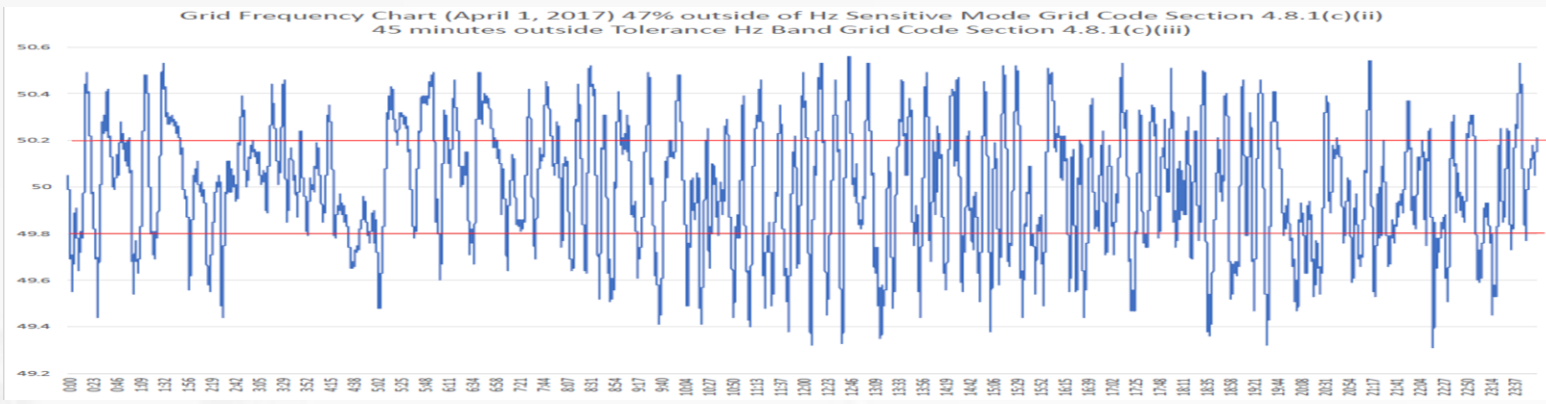




Frequency noncompliance in Pakistan

Frequent frequency noncompliance. Load shedding is the current method for load-frequency control.





Battery Energy Storage System (BESS) for Frequency Regulations

Advantages of BESS for frequency regulations

Type	Response time	To full output
Enhanced frequency reserve via BESS	subsecond	subsecond
Primary reserve via FGMO*	5-10 s	30-60 s
Secondary reserve via AGC**	30-60 s	5 m
Contingency reserve	10-15 m	30 m

- Rapidly decreasing cost of battery
- BESS has been proven for frequency regulation in many countries including UK, USA, Australia, Korea and Germany

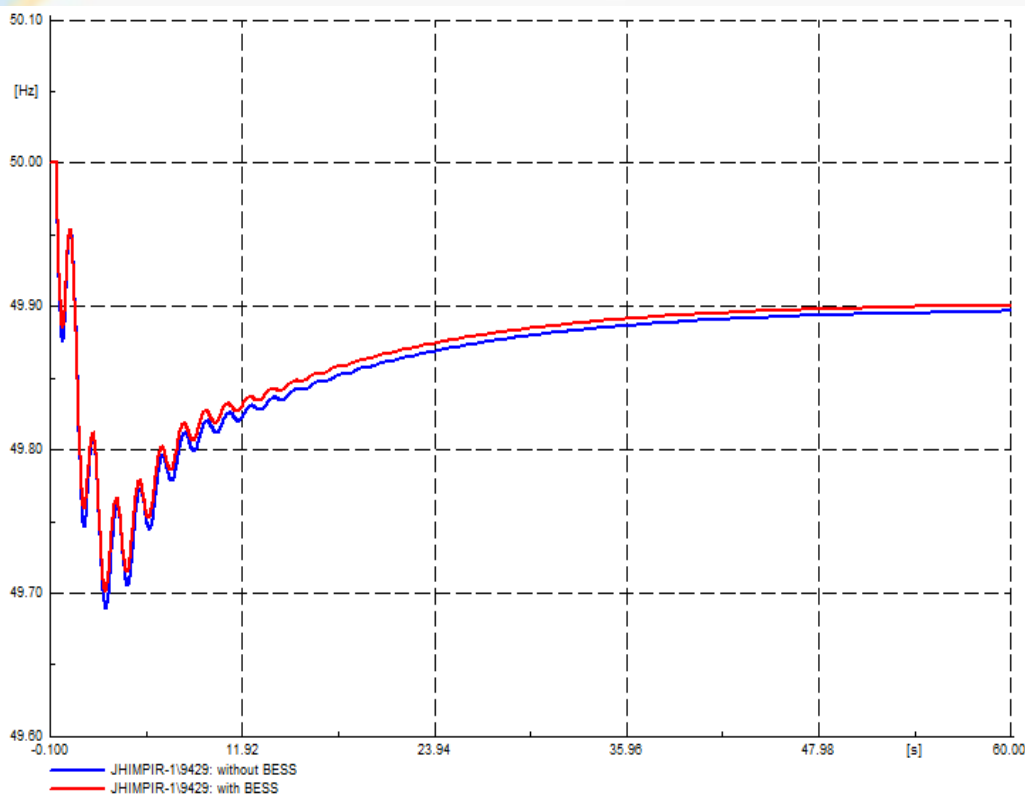


Pilot BESS in Pakistan

- ✓ Why: Frequency compliance is the mandatory of NTDC and wind farm IPPs, per Grid Code.
- ✓ Where: NTDC's existing 220 kV *Jhimpir-1* substation. Sufficient space and close to Jhimpir cluster wind farms.
- ✓ What: Lithium- titanium-oxide battery energy storage system **20MW/5MWh (4C)**:
 - i) EPC+OM (2 years) through contractor;
 - ii) capacity building by consultant including:
 - Preparation of energy system storage roadmap
 - recommendations on grid code revision and development of ancillary services market
- ✓ How: One component of ADB's 2nd Power Transmission Enhancement Investment Program- Tranche 3:
 - i) \$4 mil grant from HLTF (\$3 mil for EPC, \$1 mil for capacity building), and around \$3 mil from Tranche 3
 - ii) Tranche 3 (\$280 mil ADB loan+\$4 mil grant) approved in June 2018



Pilot BESS in Pakistan

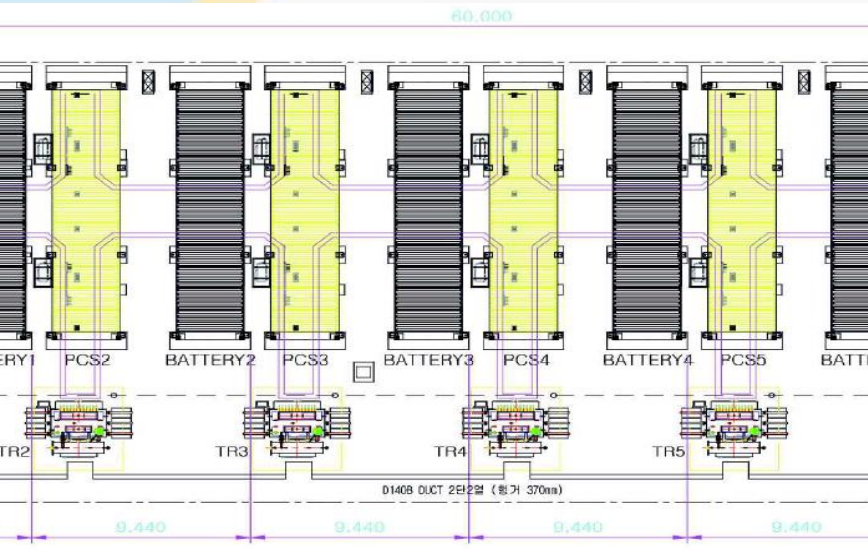


The simulations show that after the loss of a 660 MW generation unit, the BESS (20MW/5MWh) results in:

- ✓ a reduction in the post-contingency frequency dip of 0.019 Hz at the bottom (at 3.5 secs) and 0.007 Hz at steady-state (after 60 secs)
- ✓ a general improvement in post-contingency voltage profiles in the HESCO region



Pilot BESS in Pakistan



The BESS supplements the load frequency function of the SCADA system being upgraded under Tranche 2



Pilot BESS in Pakistan

Milestone	Date
PC-1 Approved by CDWP (Central Development Working Party)	May 2018
Loan/grant Negotiations	May 2018
Location finalized (220 kV substation)	May 2018
Loan Approval by ADB	June 2018
Bidding Docs finalized	Q4 2018
EPC + O&M Contract Award	Q2 2019
Construction starts	Q2 2019
Commissioning	Q4 2019
EPC + O&M contract ends	Q4 2021