



# MMC HVDC Technology in China

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**NR ELECTRIC CO., LTD.**

# Business Scope of NREC



Protection, Automation & Control (PAC)	<ul style="list-style-type: none"><li>• Protection &amp; Control</li><li>• Substation Automation</li><li>• Digital Substation</li><li>• Phasor Measurement</li></ul>	<ul style="list-style-type: none"><li>• Disturbance Recorder</li><li>• Power Stability Control</li><li>• EMS / DMS</li></ul>
HVDC & FACTS	<ul style="list-style-type: none"><li>• LCC-HVDC</li><li>• VSC-HVDC</li><li>• SVC</li><li>• STATCOM</li></ul>	<ul style="list-style-type: none"><li>• FSC / TSCS</li><li>• UPFC</li><li>• CSR / MCR</li><li>• DC De-Icer</li></ul>
Renewable & Microgrid	<ul style="list-style-type: none"><li>• SCADA</li><li>• Power Forecaster</li><li>• PV Inverter</li><li>• SFC / LCI</li></ul>	<ul style="list-style-type: none"><li>• Microgrid Controller</li><li>• PMS / EMS</li><li>• BESS</li></ul>
Engineering & Services	<ul style="list-style-type: none"><li>• Turnkey Solution</li><li>• Analysis &amp; Simulation</li><li>• Setting</li><li>• Engineering &amp; Design</li></ul>	<ul style="list-style-type: none"><li>• Operation &amp; Maintenance</li><li>• Training</li></ul>

- 1 HVDC Development in China
- 2 Case Studies
- 3 A Glance at STATCOM Applications
- 4 Conclusion

- Three applied HVDC: LCC, VSC, MVDC
- LCC-HVDC application
  - Long distance bulk power transmission
  - Asynchronous grid Interconnection



- Technical advantages

- Increase transmission efficiency over long distance
- Interconnect asynchronous grids
- Control bidirectional power flow
- Perform firewall to AC faults at different locations
- Enhance power grid stability

- Economic advantages

- Reduce cost of transmission line over 500-700km
- Narrow down rights-of-way of overhead line



- VSC-HVDC application
  - Power supply to passive grid
  - City center in-feed
  - Bulk power evacuation
  - Asynchronous grid Interconnection
  - Off shore wind farm connection
  - Power from shore



- VSC-MVDC application

- DC power sources and DC loads Interconnection
- Power flow balance; Renewable power penetration
- Reactive power support; AC faults isolation



- HVDC becomes backbone of power grid
  - LCC-HVDC: 36 links  
50kV-1100kV, 50MW-12GW
  - VSC-HVDC: 9 links, 30kV-800kV,  
18MW-5000MW
  - VSC-MVDC: 4 links, 8kV-10kV,  
20MW-32MW

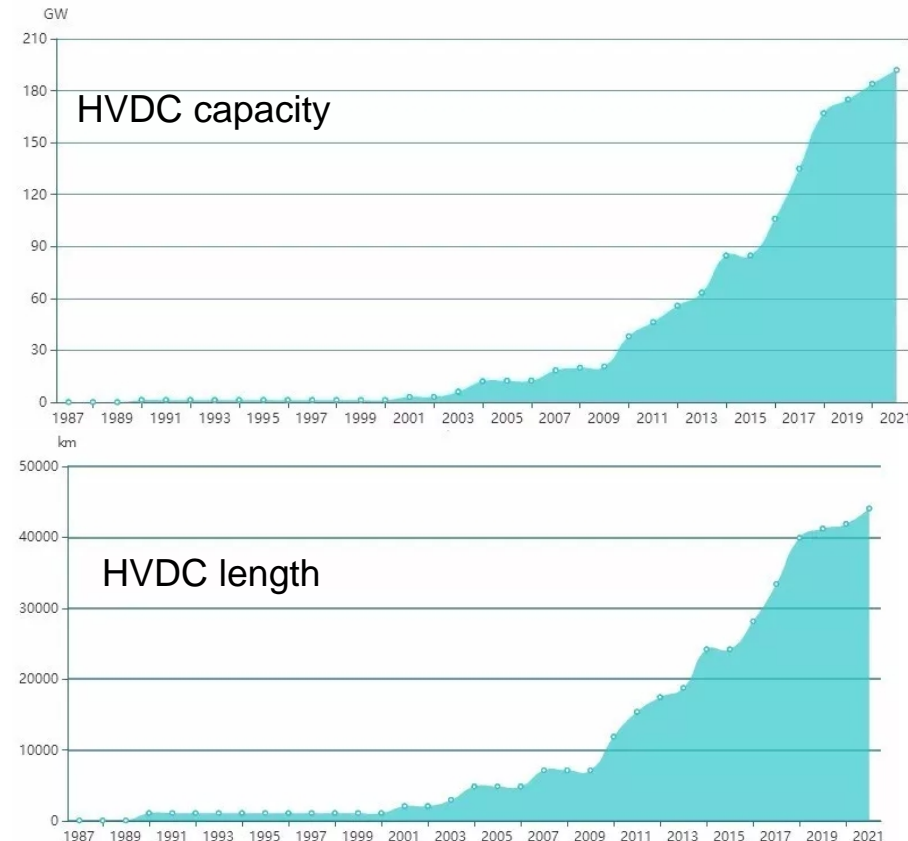


$\pm 800\text{kV}$  Linyi station

# HVDC Links in China

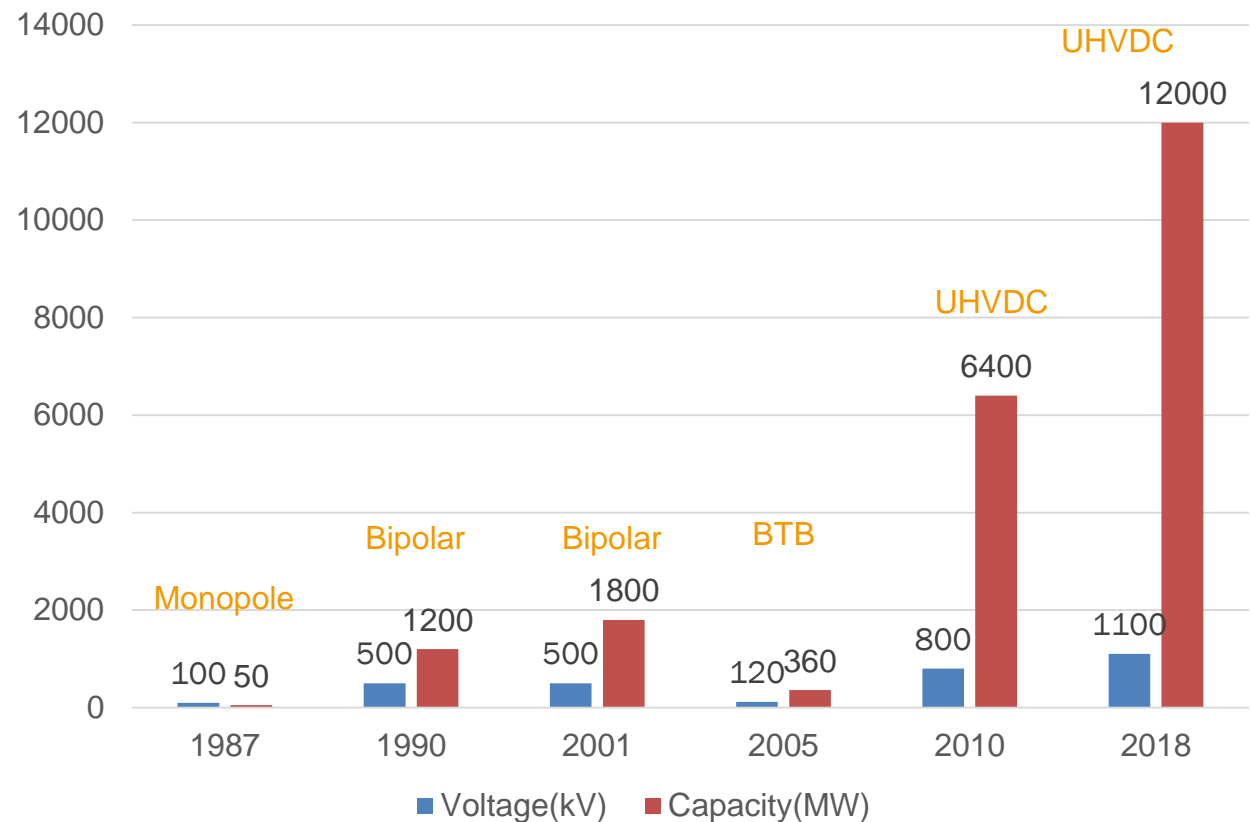


- 45 HVDC links in total (except MVDC) and 39 in operation till 2018
- Total transmission capacity is 167GW and transmission length is 39900 km until 2018
- Total transmission capacity will grow up to 192GW and total transmission length grows to 44000 km till 2021

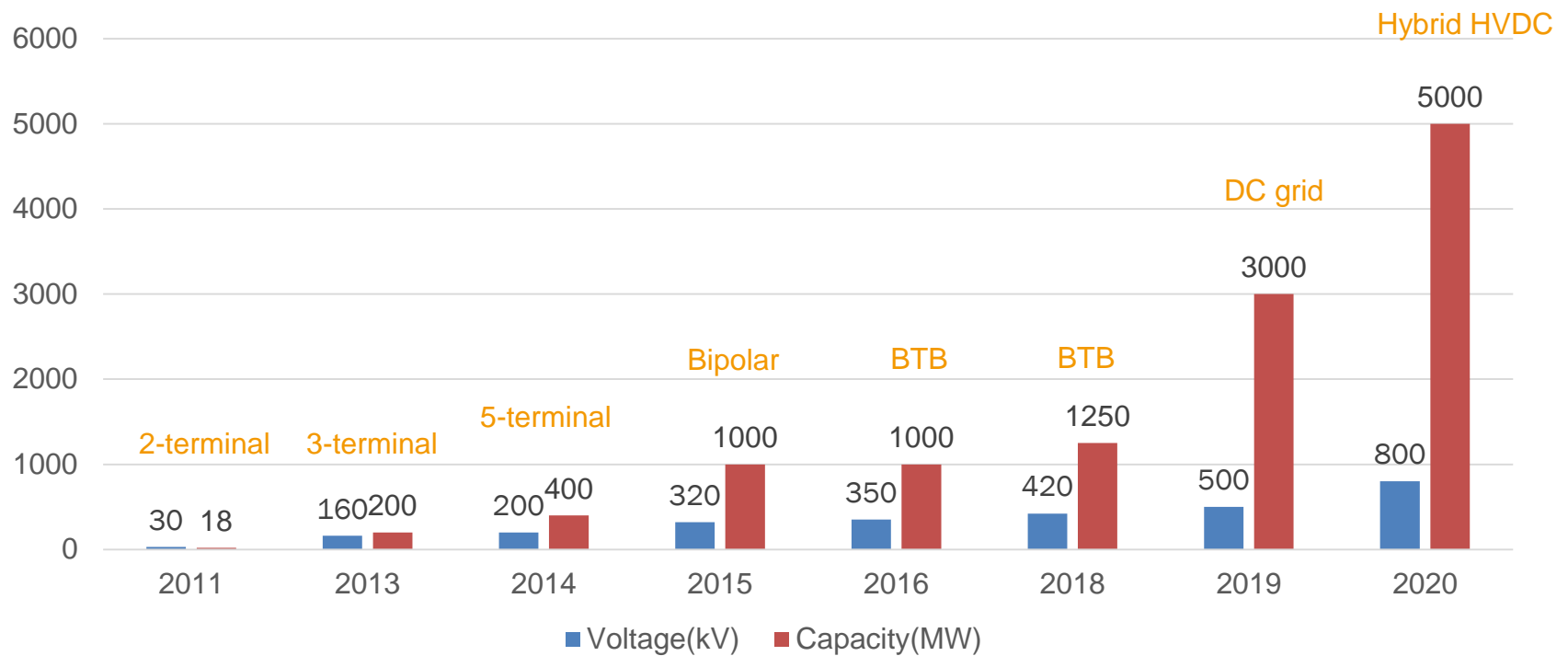


# LCC-HVDC Development

- Before 1990: exploration stage, 2 HVDC links
- 1991-2000: stagnation stage, No HVDC built
- 2001-2010: developing stage, 14 projects
- 2011-present: developing stage, 20 projects



# VSC-HVDC Development



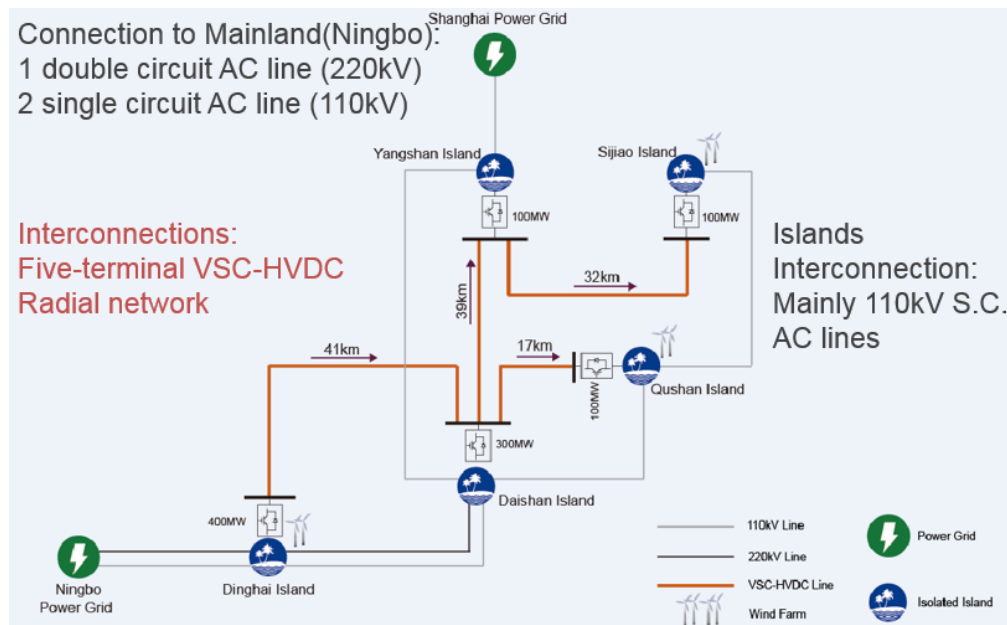
Indicate the maximum VSC converter in multi-terminal, DC grid or hybrid link

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# ±200kV Zhoushan 5-Terminal VSC-HVDC

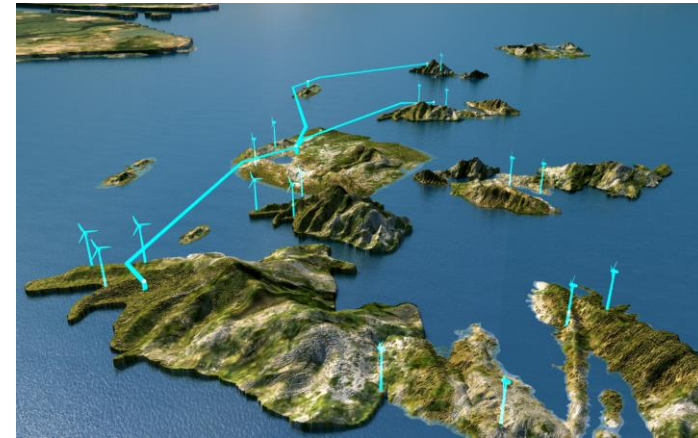


- Supply power to weak island grids for enhancing power security
- Service in 2014



Converter Station	Transmission Capacity (MW)
Dinghai	400
Daishan	300
Qushan	100
Yangshan	100
Sijiao	100

- Power security enhancement of regional grid
  - 400MW power gap by 2020
  - Islands were interconnected by single AC feeders only
- Effective multi terminal operation
- Wind energy connection
  - Wind farms in Dinghai, Qushan and Sijiao
- Black start
- Better power quality by providing reactive power support



Sijiao station

- Barriers

- Coordinate control and protection scheme
- Various operation modes
- Development of converters

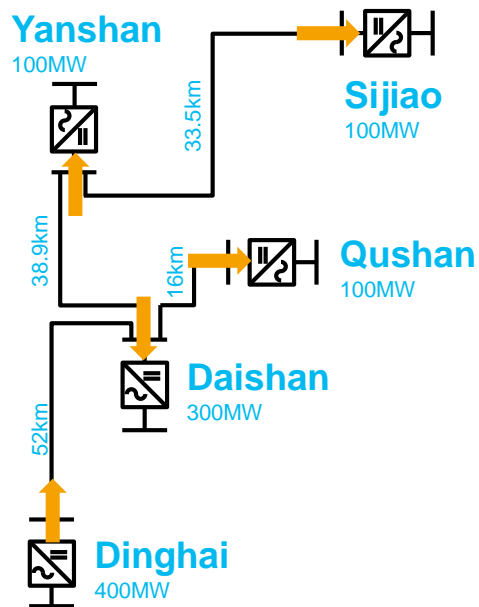
- Measures

- DC voltage deviation control and proper protection zones
- Proper various operation modes control
- Reliable converters with low failure rate



400MW converters

# Operation Mode of 5-Terminal VSC-HVDC

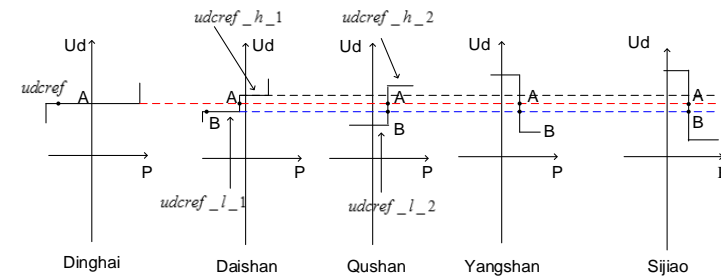


**26** operation modes are designed for Zhoushan 5-Terminal VSC-HVDC :

5 terminal	1
4 terminal	5
3 terminal	10
2 terminal	9
STATCOM	Each station



- Coordinate control
  - Master-slave with communications;  
DC voltage deviation control without communications
- AC faults ride through
- Island mode control
- Black start



DC voltage deviation control

## Site commissioning

Coordinate control test; Protection test

Redundancy switchover test; Stable state performance test

Operation configuration switchover test; Auxiliary control test

Dynamic state performance test

Black-start test

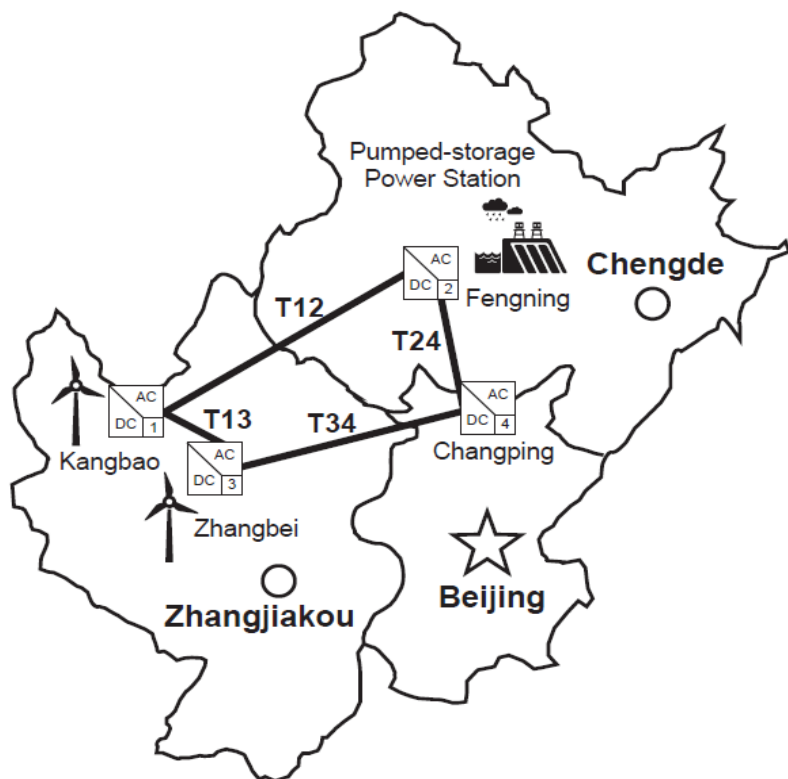
Island mode test

Overload test

Disturbance test

# ±500kV Zhangbei DC Grid

- Under site commissioning



## Technical Data

AC Voltage Level	500kV
AC Frequency	50Hz
DC Voltage Level	±500kV
Power Rating	3000MW/Zhangbei station 3000MW/Beijing station 1500MW/Fengning station 1500MW/Kangbao station
Converter	Bipolar with half-bridge MMC

- Bulk renewable power evacuation from weak AC grids
  - No reactive power demand from AC grid
  - Immunity to synchronous instability due to unstable renewable power
  - Flexible power distribution within DC grid
- Skeleton for future extended DC grid



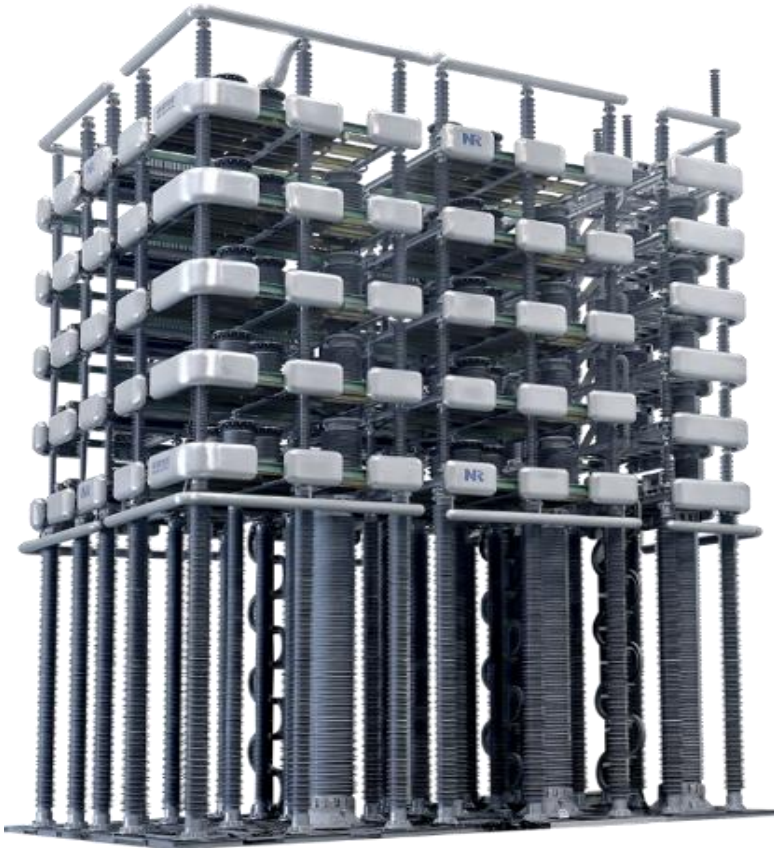
Zhangbei area

## ● Barriers

- DC faults clearance and fast recovery of healthy system
- Development of 500kV/3000MW converters and 500kV DC breakers
- Coordinate control of DC grid
- Islanded grid connection

## ● Measures

- Fast DC line faults detection and selection; fault clearance by DC breaker within 6ms; system fast recovery strategy in case of transient faults
- Type testing of 3000MW converters and 500kV DC breakers
- Master-slave control and DC voltage deviation slope control
- Proper U/f control strategy



500kV hybrid DC breaker	
Rated Voltage	500KV
Rated Current	3KA
Breaking Current	25KA
Breaking Time	<3ms

# ±800kV Wudongde Hybrid DC Link



Source: B4-120, CIGRE 2018

Technical Data	
AC Voltage Level	500kV
AC Frequency	50Hz
DC Voltage Level	±800kV
Power Rating	8000MW/Yunnan station 5000MW/Guangdong station 3000MW/Guangxi station
OHL Length	Yun-Guangxi 932km Guangxi-Guangdong 557km
Converter	Bipolar with MMC

- Bulk hydro power transmission to load centers
- Immunity to commutation failure caused by multi in feed of LCC inverter stations
  - 8 LCC inverters are already located within a  $200\text{km} \times 200\text{km}$  area in Guangdong
  - One more LCC inverter has high risk of suffering multi-commutation failures, so hybrid type is deployed



Construction started

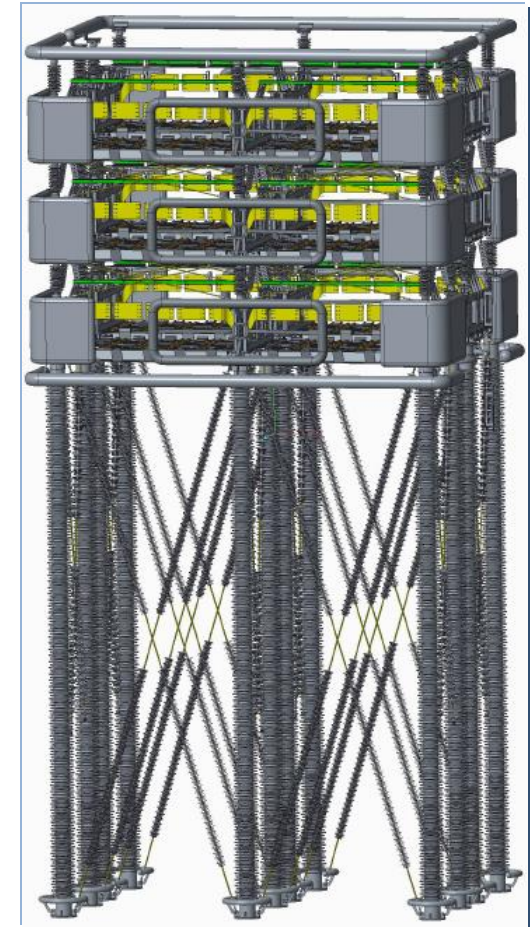
## ● Barriers

- Control and protection philosophy compliance with different characteristics of LCC and VSC
- Development of 800kV VSC converters
- DC faults clearance strategy

## ● Measures

- Coordinate control and protection technology for hybrid UHVDC
- Development and testing of 800kV VSC converters
- DC faults clearance by hybrid converters with full-bridge and half-bridge modules

- Development and testing of 800kV hybrid full-bridge and half-bridge VSC converters
  - Full-bridge and half-bridge modules development and testing
  - Compatibility design of VBC(valve base control )
  - Compatibility valve tower structure design
  - Insulation design and testing



800kV converter

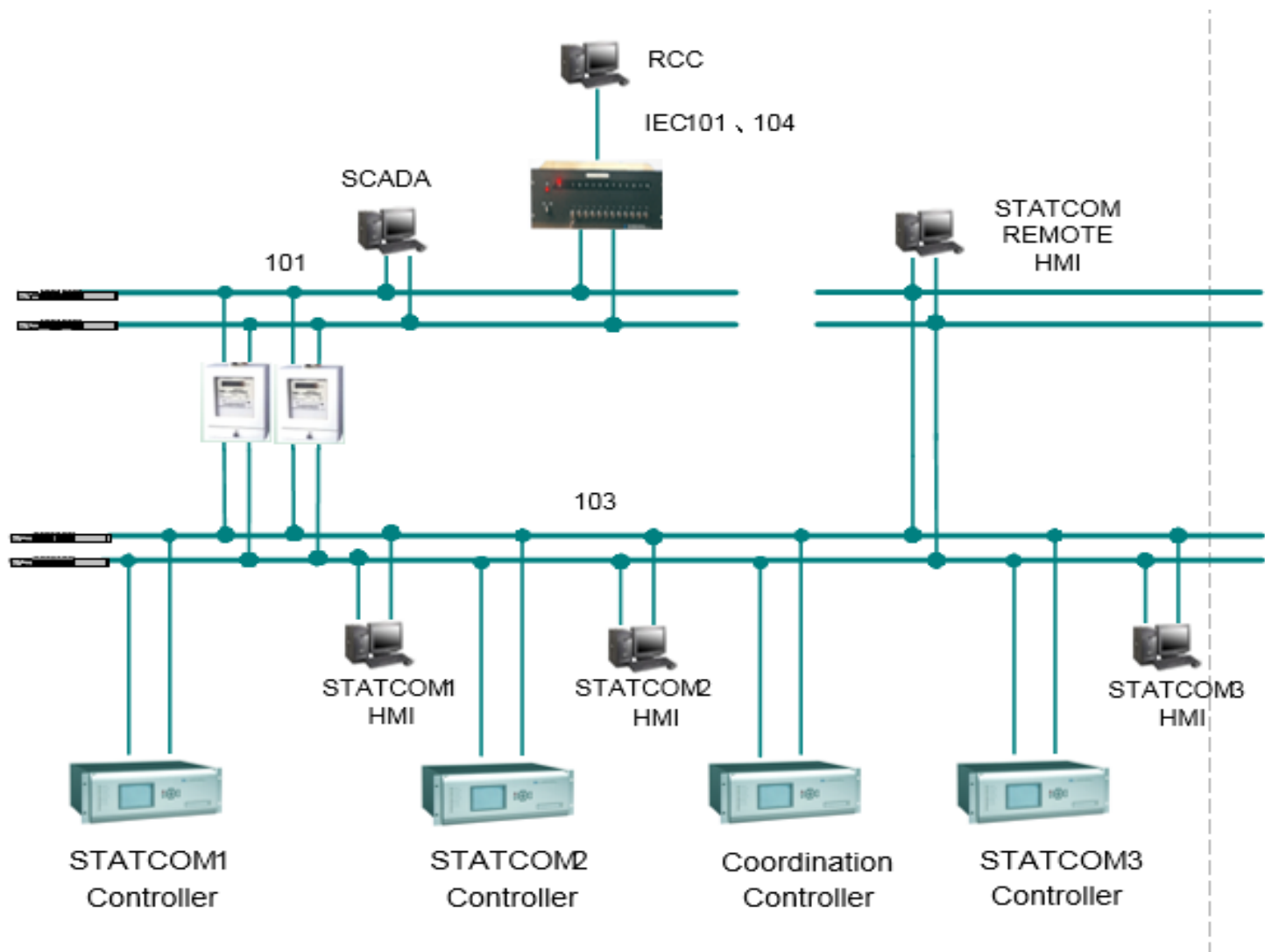
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# Wujiang 300MVar STATCOM

- Put into service in 2018
  - Coordinate control of 3 units
  - 1.5 p.u. 5s over current capability

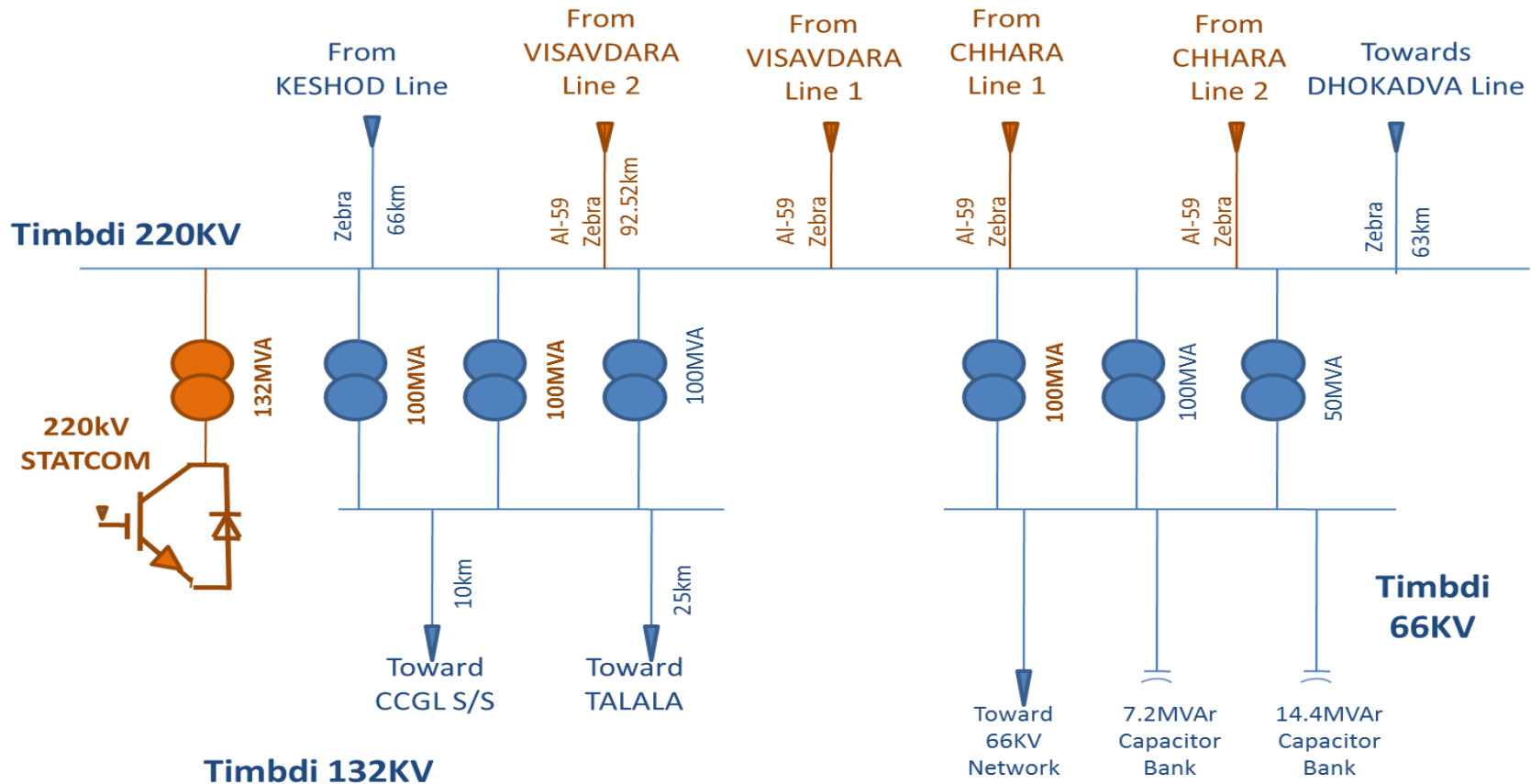


# Wujiang 300MVar STATCOM



## India GETCO weak AC network with potential risk of voltage instability

- Big voltage fluctuation
- Potential voltage instability in case of heavy loading with induction motor



# India GETCO 120Mvar STATCOM



**EPC contract in association with local construction partner STELMEC**  
**Be in service on March 2019**



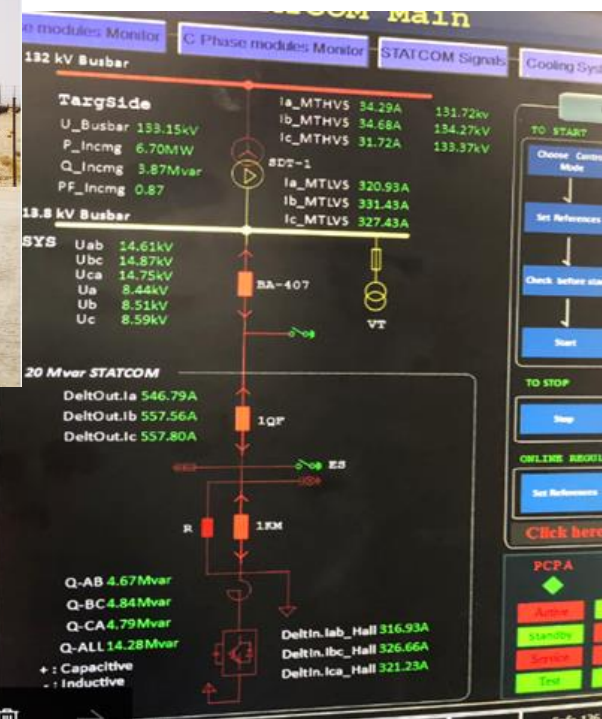
**Valve Tower (factory view)**



**Coupling Reactor**

- Put into service in Layla and Summan areas in 2018, 20MVar each
  - Low voltage in summer due to heavy A.C. loads
  - STATCOM acts to regulate voltage and can quickly inject reactive power and support voltage recovery during and after network fault
  - Proper system design considering harsh operating environment , very high temperature up to 55°C and sand storm

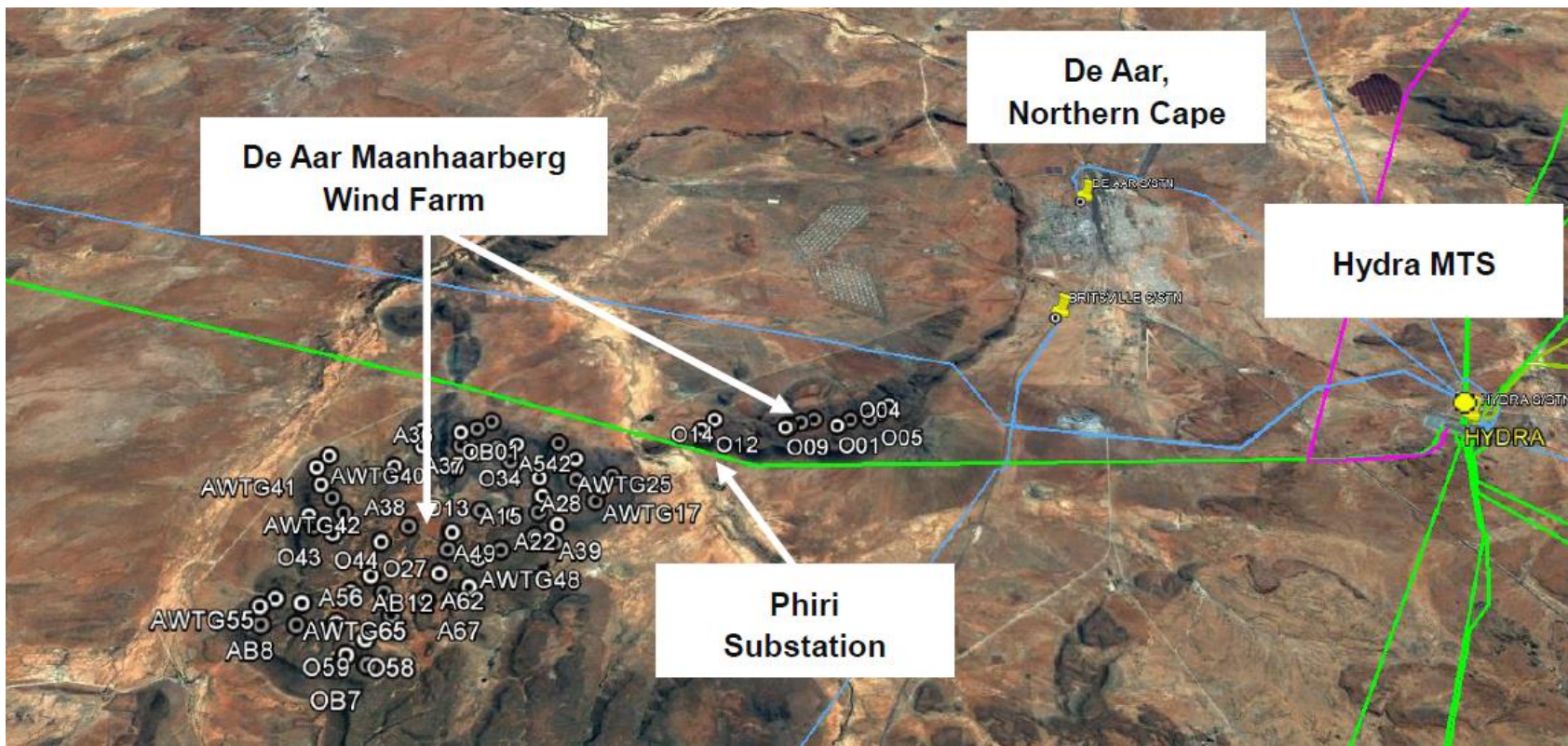
# Saudi Arabian National Grid Mobile STATCOM





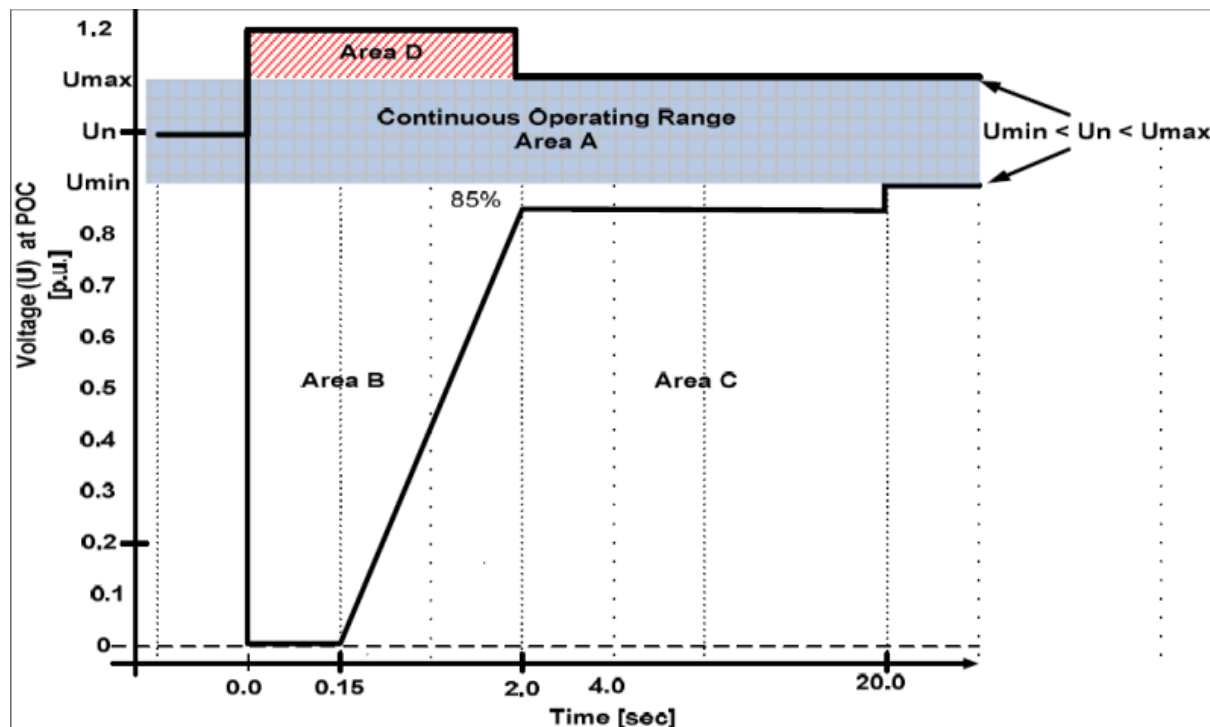
## Mulilo De Aar Wind Power in South Africa

- access to power grid for installed wind power at size of 244.5MW
- voltage support along with reactive power compensation targeting to 132kV
- voltage ride-through requirement
- power quality improvement at connection point



## Grid code

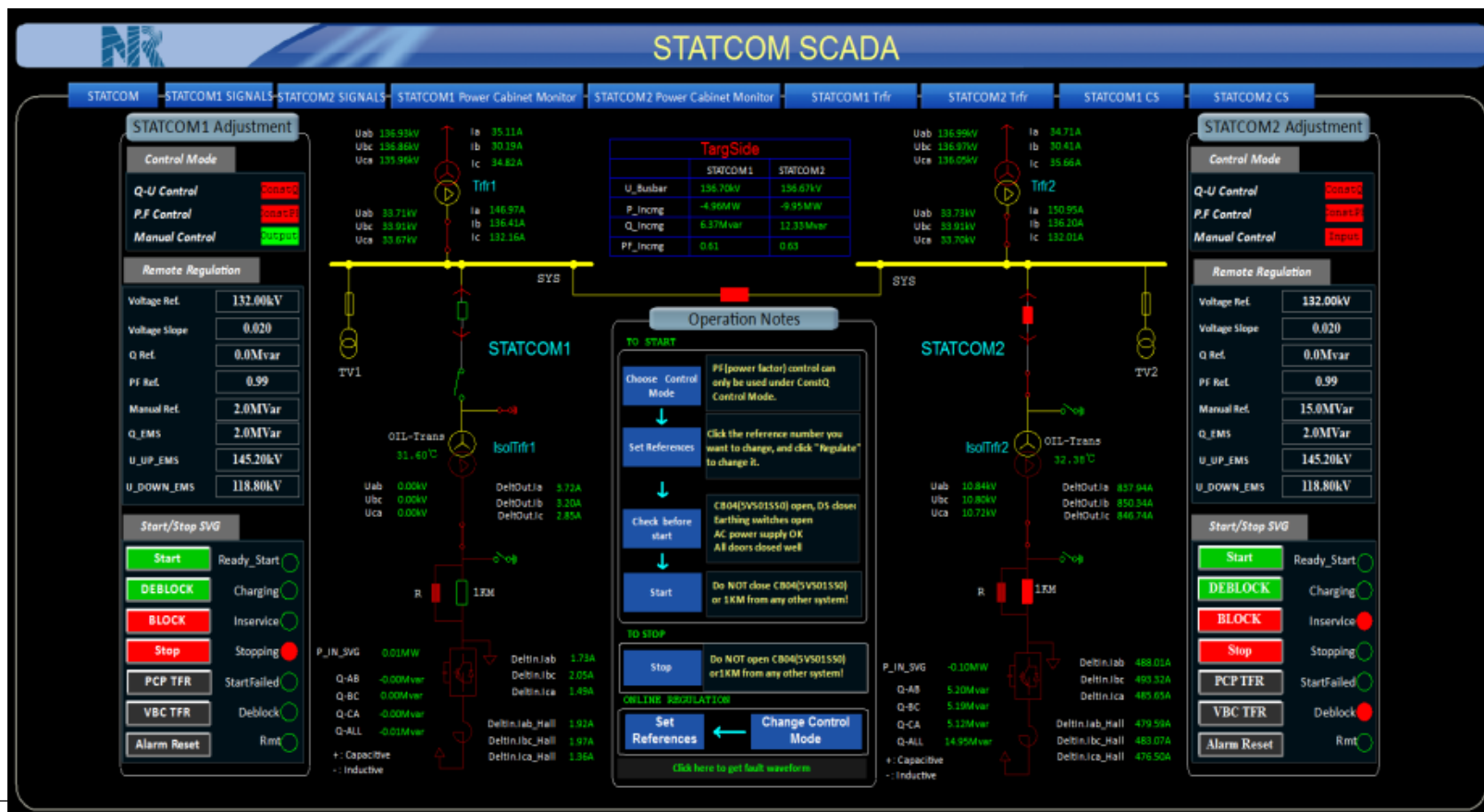
- Voltage regulation
- Power factor
- LVRT and HVRT
- Even if some wind turbine has some variable reactive power capabilities, wind farms can not provide enough dynamic reactive power



# STATCOM for Wind Farm

## STATCOM configuration

- 4(14Mvar and 18Mvar, 21Mvar and 24Mvar) sets of container type of STATCOM rated at 33kV, each one for each busbar
- delta-connected circuit, air/water cooling system



# STATCOM for Wind Farm

## STATCOM's Site Picture



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- LCC-HVDC takes critical role in power transmission and VSC becomes more competitive because of technical maturity and cost reduce of semiconductor
- The first DC grid is under site commissioning and expected to have a leap of development in near future
- Hybrid HVDC is a proper solution to resolve multi in-feed LCC inverters commutation failure
- MVDC and PET also make distribution networks more flexible and resilient
- STATCOM is widely applied to provide support to grid and improve power quality

# Thanks

[www.nrec.com](http://www.nrec.com)