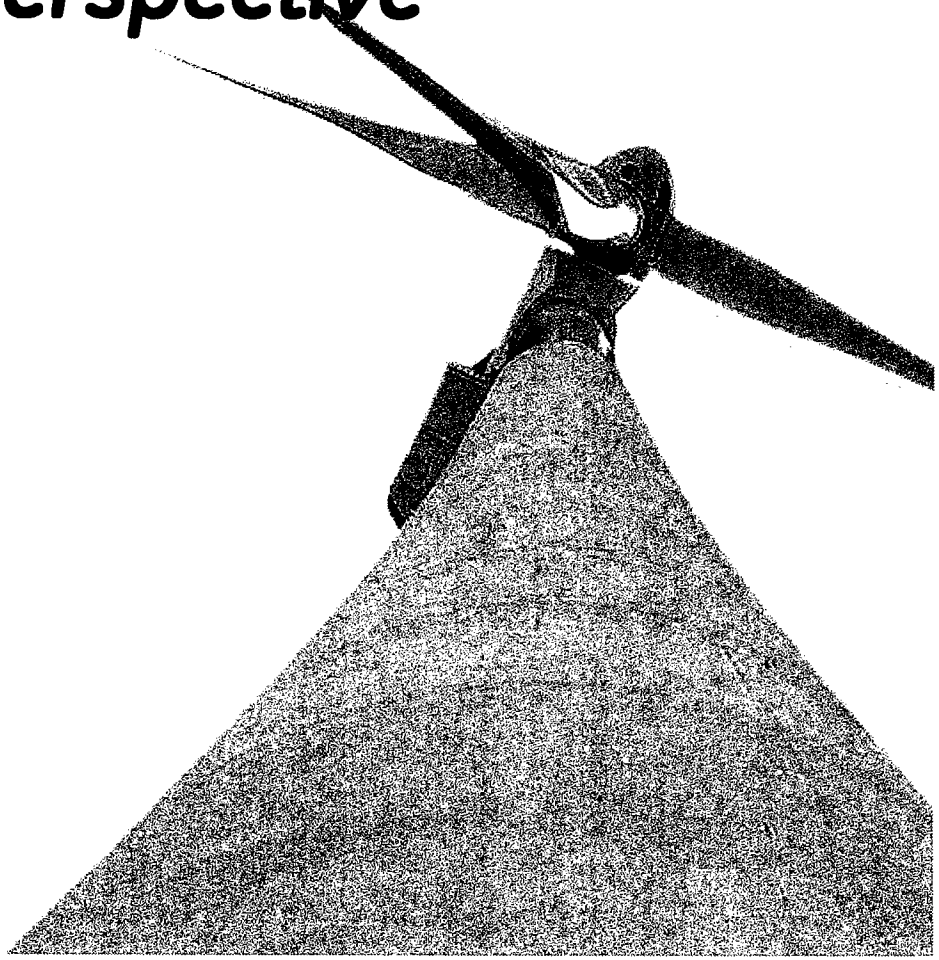
GE Energy

Achieving India's Wind Power Goal from a Grid Interconnection Perspective

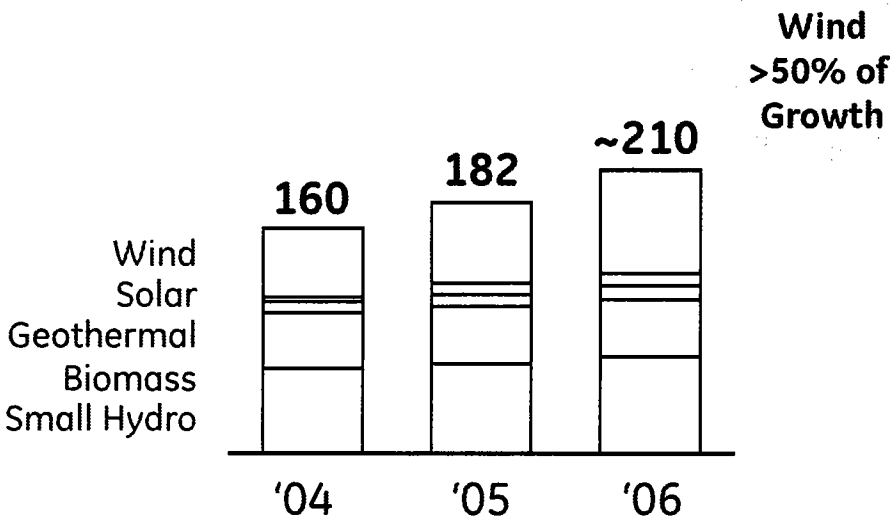


Dillip Guru
GE Energy
04th Aug 2008
Chandigarh

GE imagination at work

Growing renewables demand …

Global renewable Installed capacity (GWs)

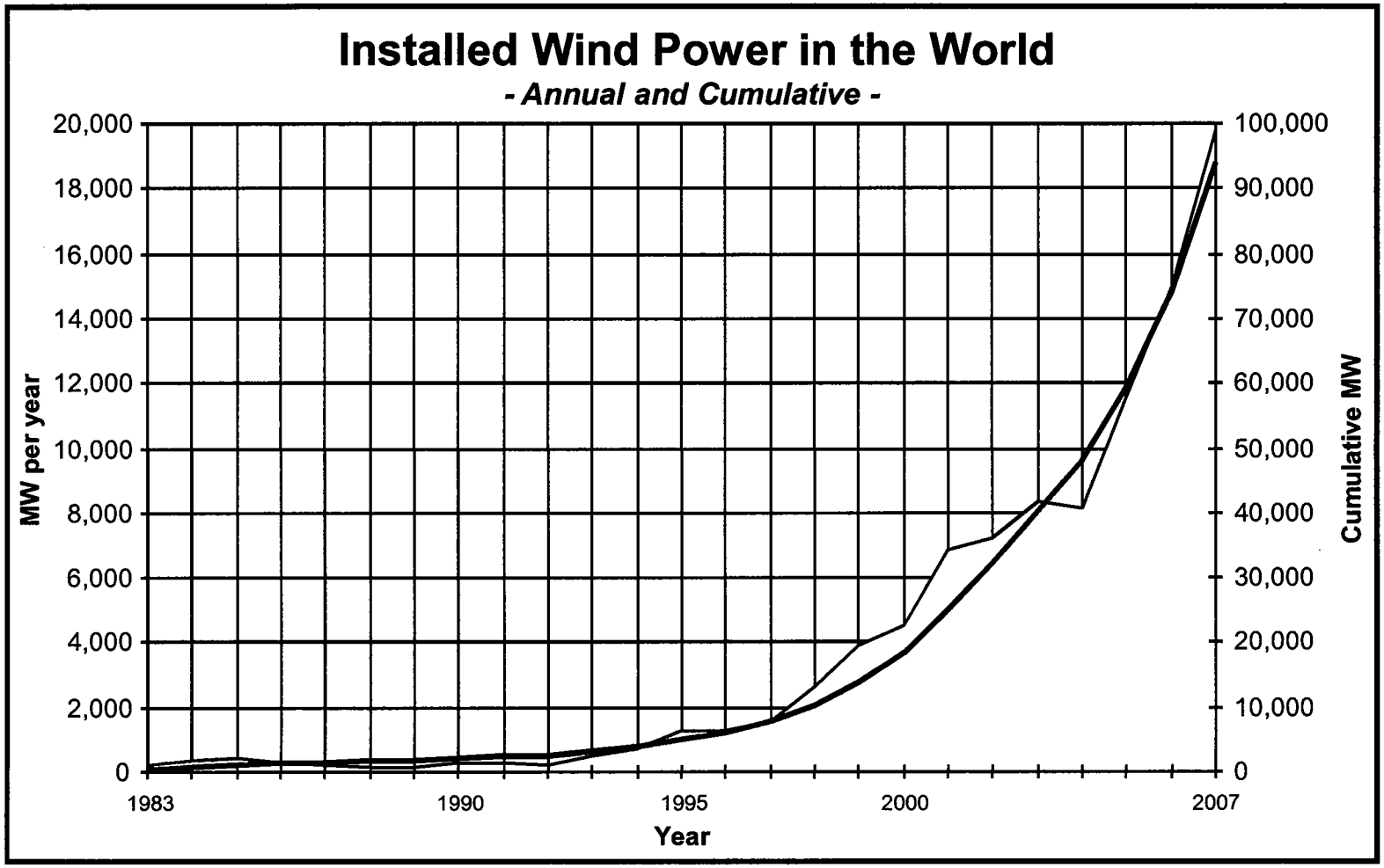


Source: REN21 2006 update + GE est (2/07)

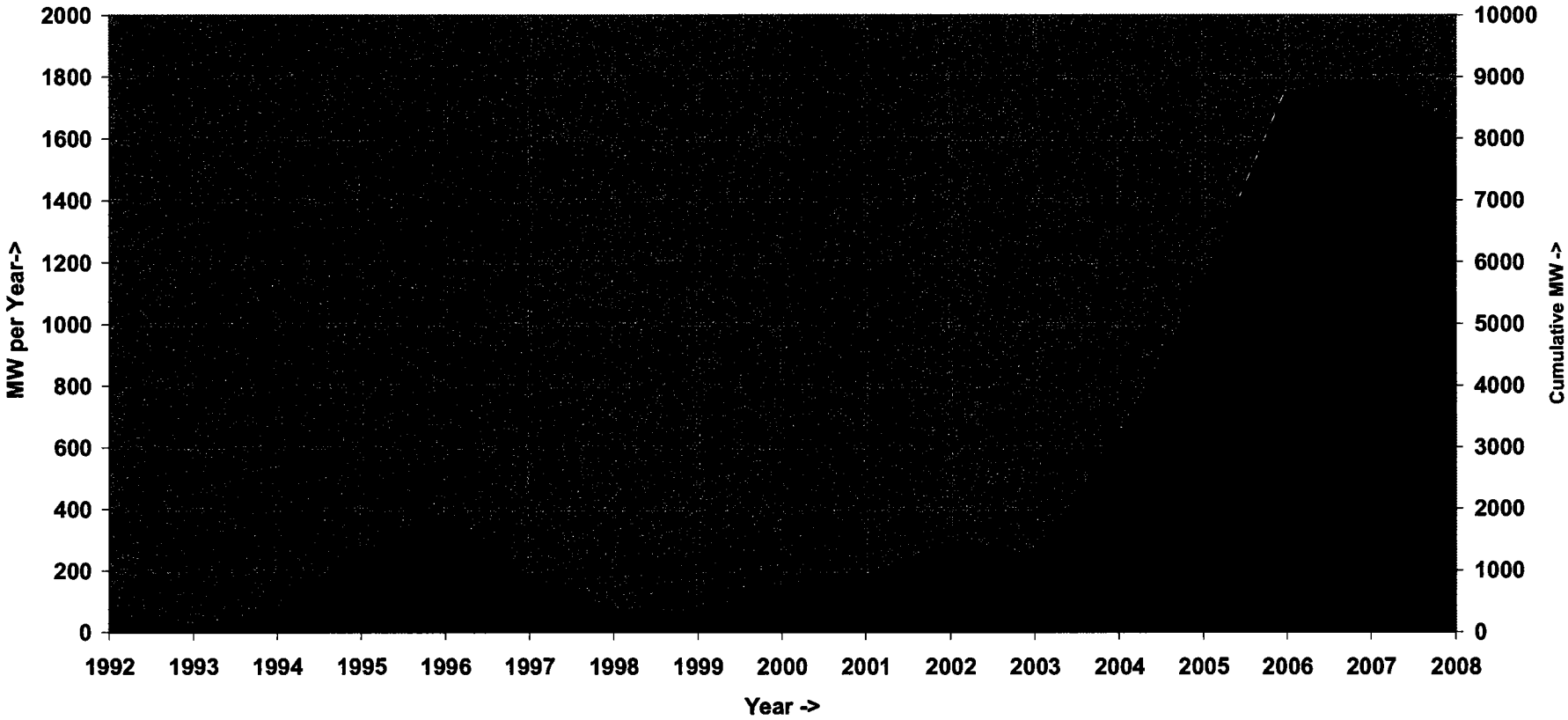
Aggressive global targets

- ✓ 50 countries installing wind power
- ✓ 38 countries with renewable targets
- ✓ 29 US states with RPS goals
- ✓ US … 20% Wind '30
- ✓ EU … 22% Renewables '10
- ✓ China … 8 % by '20
- ✓ India … 40 GW Wind '22

World requiring renewable energy solutions


Installed Wind Power in the World
- Annual and Cumulative -
MW per year
Cumulative MW
Year
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
1983
1990
1995
2000
2007

India Wind Power (MW) Installed Capacity

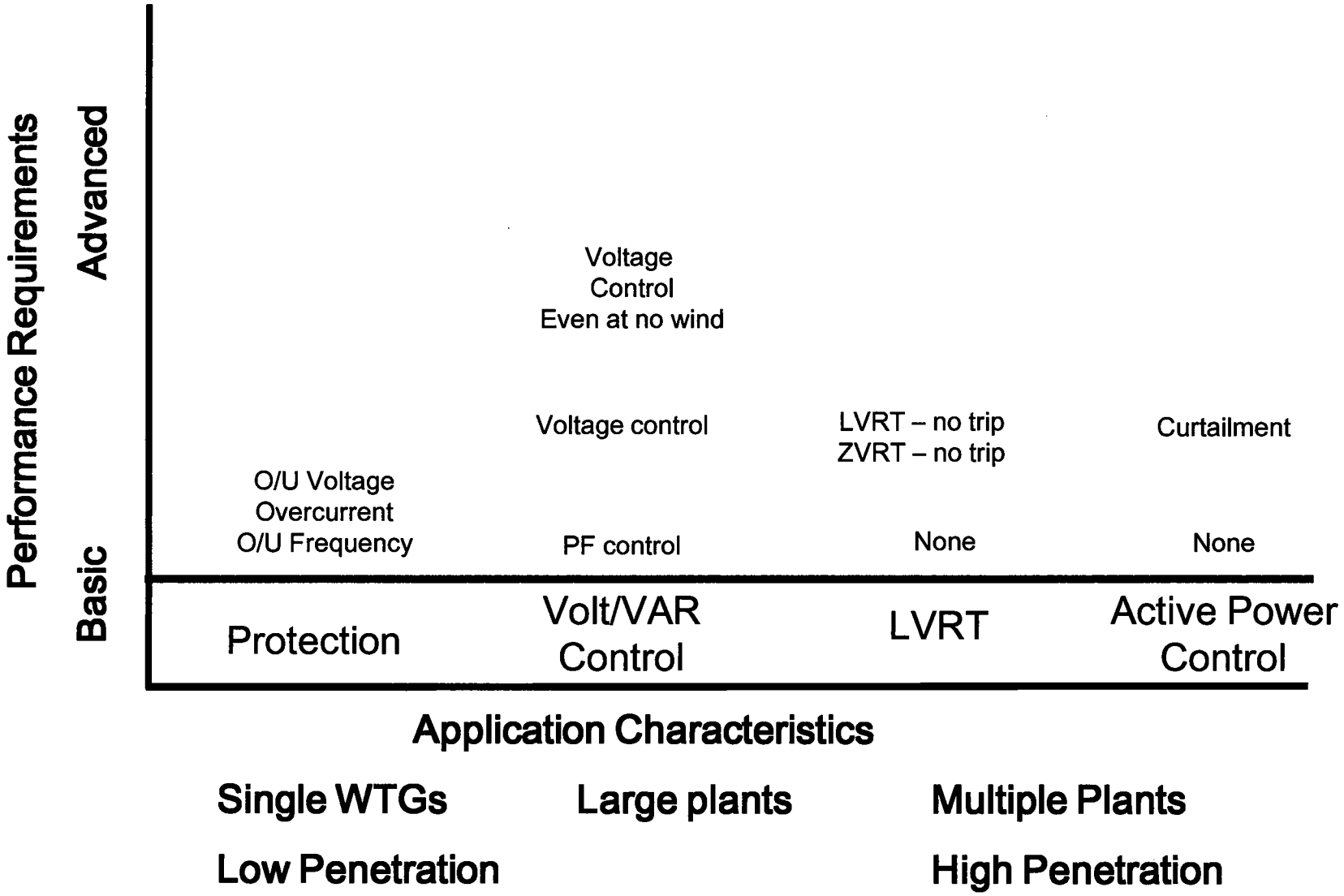


Not wind farms any more ….. Wind Power Plants

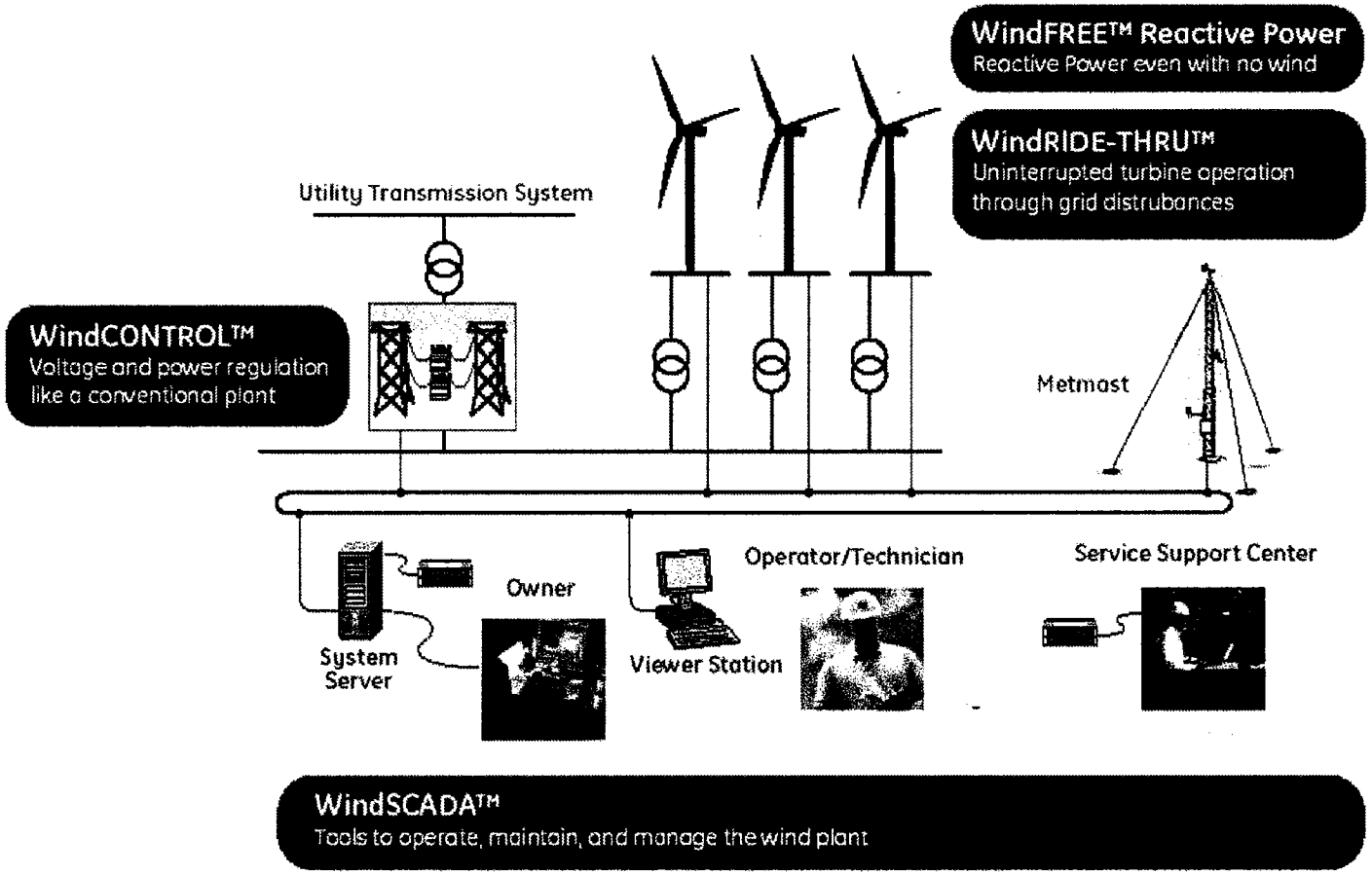
Lessons from Europe... on How does India successfully achieve 40 GW Wind?

- Europe has pioneered high penetration of wind power
- Grid operation problems have increased as wind penetration has increased
  - ✓Large voltage variations
  - ✓Loss of large blocks of wind generation after grid faults
  - ✓Uncontrollable power from wind turbines
- European grids developed grid codes to require voltage regulation, LVRT, reactive power control ... *(grid-friendly features)*
  - ✓Many problems still exist, because large numbers of existing turbines do not meet new requirements
- India has the opportunity to avoid the problems experienced in Europe
  - ✓Install wind turbines with grid friendly performance features that regulate voltage, ride-through faults, and control power output

Grid requirements with evolution of larger wind plants



Grid Friendly Wind Power Plant

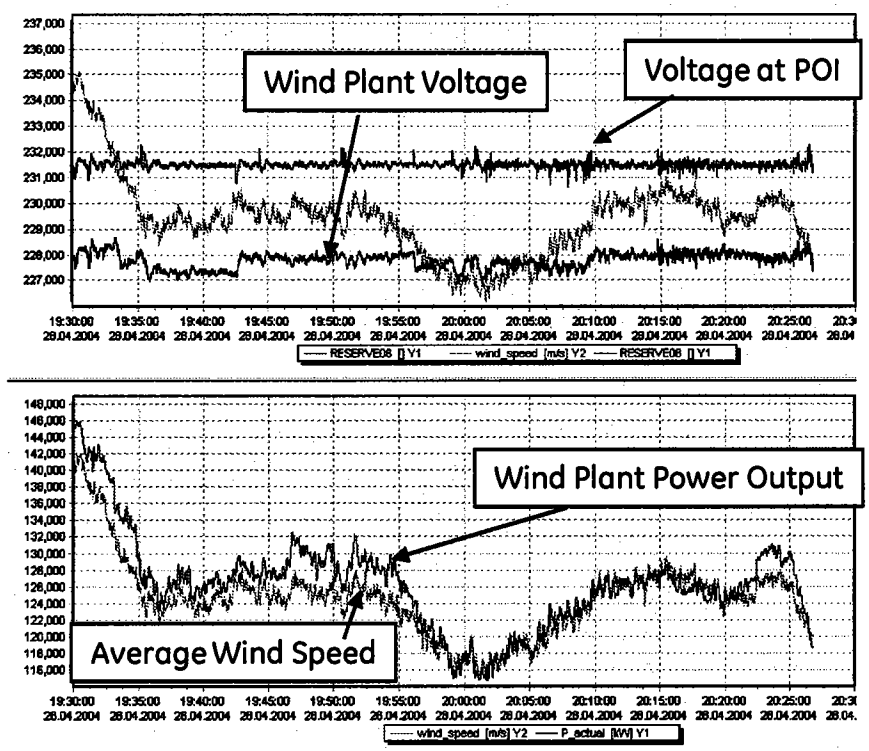


Avoids grid operation problems when wind penetration increases

Voltage Control

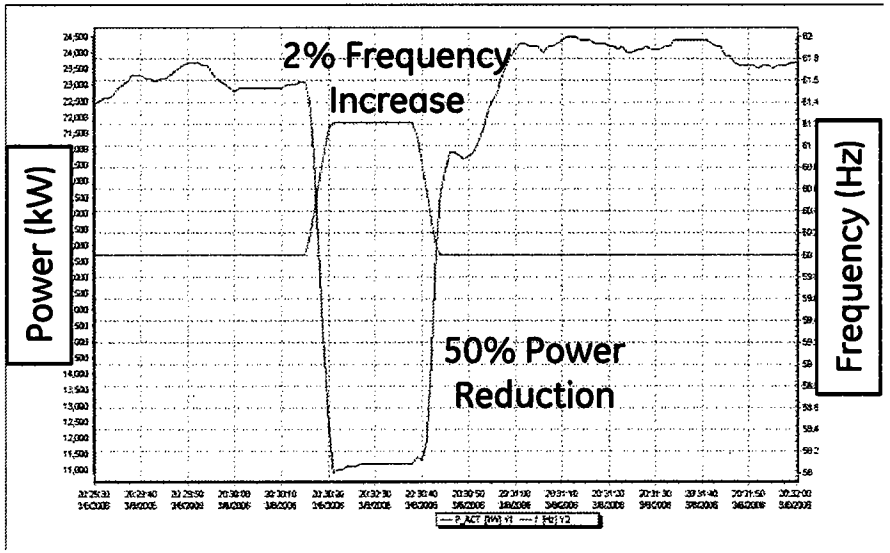
- Regulates Grid Voltage at Point of Interconnection
- Minimizes Grid Voltage Fluctuations Even Under Varying Wind Conditions
- Regulates Total Wind Plant Reactive Power through Control of Individual Turbines

Actual measurements from a 162 MW wind plant

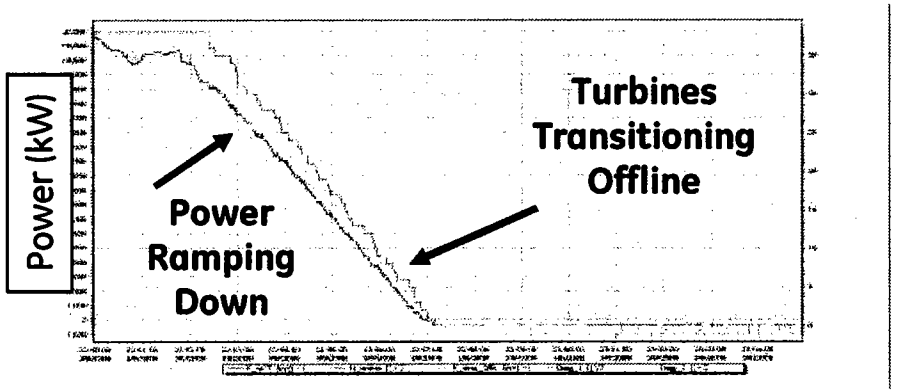


Active Power Control

- Provides Power-Frequency or Governor Droop Functions - Over-frequency response helps to regulate system frequency and does not require reducing normal plant output
- Regulates/Limits the rate of change in power under varying wind conditions
- Manages Power Ramp rates with Startup/ Shutdown turbine sequencer

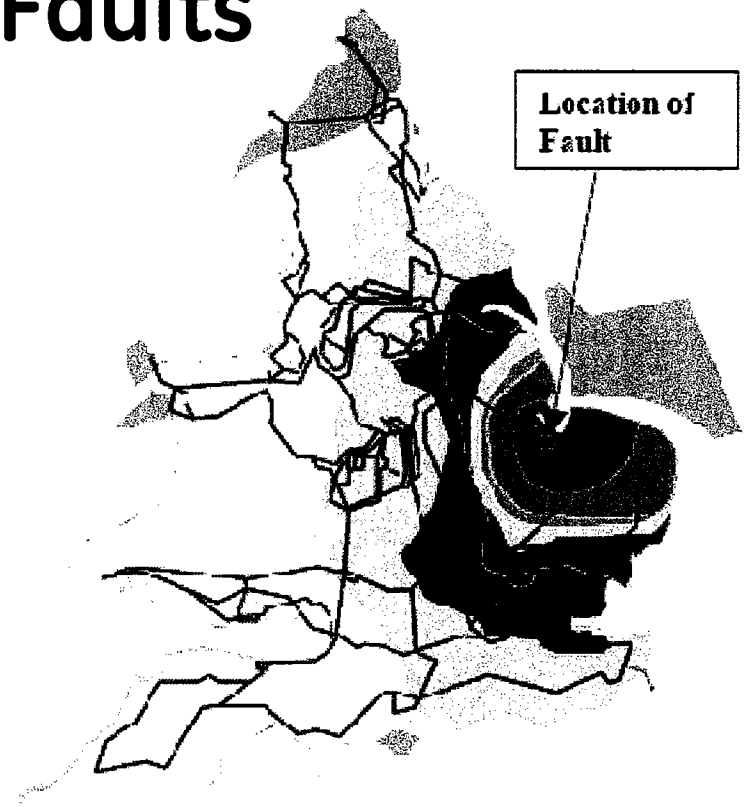


Over-frequency Droop Response



Response During Grid Faults

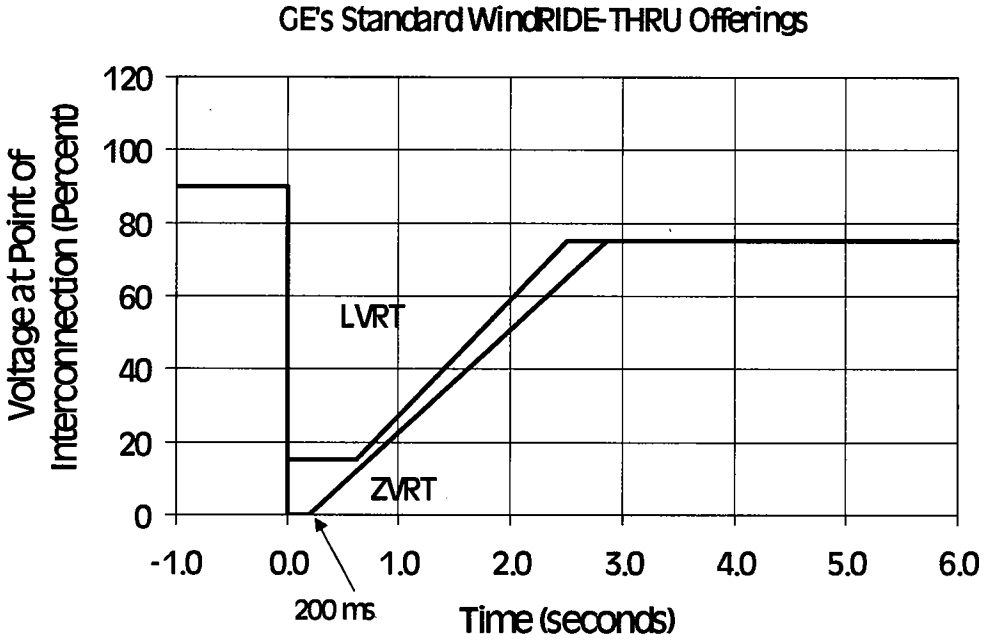
- Conventional wind turbines trip off line when bus voltage is depressed
- This causes a single-contingency event to immediately degrade to a double-contingency (loss of transmission line and loss of generation)

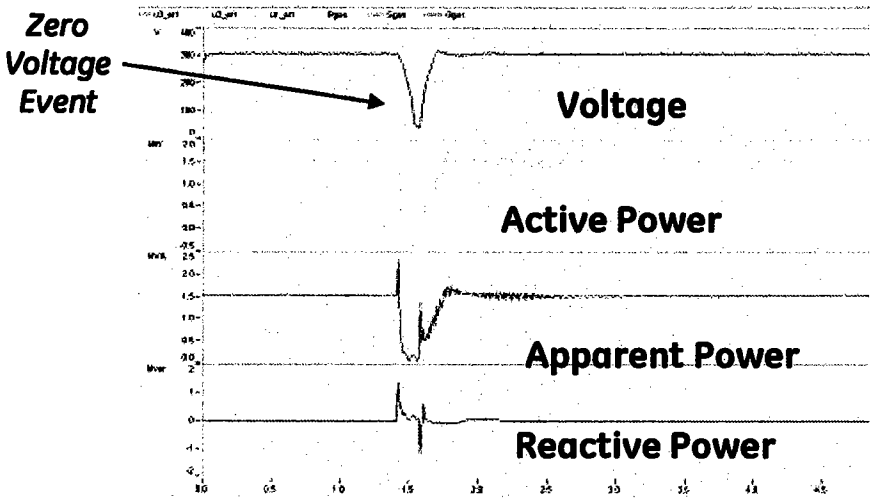


Source: paper by A.Johnson of National Grid, 5th International Workshop on Large-scale Integration of Wind Power and Transmission Network for Offshore Wind Farms, 2005

Ride-Thru Capabilities

- Remains on-line and feeds reactive power through system disturbances
- Meets present and emerging grid requirement with Low/Zero Voltage Ride Through (LVRT/ZVRT) capability
- Meets transmission reliability standards similar to thermal generators

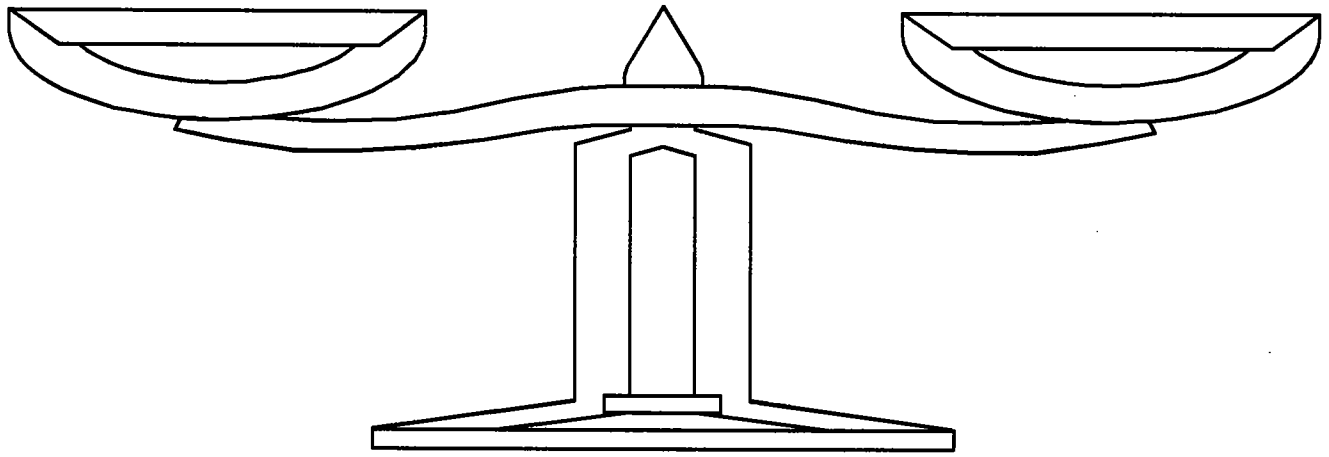




Grid Code Development

<u>Tight</u>
More Expensive Equipment
Reduced Efficiency

<u>Loose</u>
Compromised System
Reliability



Grid Code Functional Specifications

Grid Codes should be no more specific than they need to be to avoid over-designed equipment and reduced efficiency of wind generation, but should be specific enough for adequate system reliability and stability

Global Grid Codes Examples

❑ Europe

- **Germany, Denmark, Ireland**
  - ✓ LVRT: Required
  - ✓ Reactive Power Control : Required
  - ✓ Active Power Control: required
- **Great Britain - GCRP**
  - ✓ LVRT: Required
  - ✓ Reactive Power (±0.95) and dynamic reactive power support: Required
  - ✓ Active Power Control and Frequency Response : required

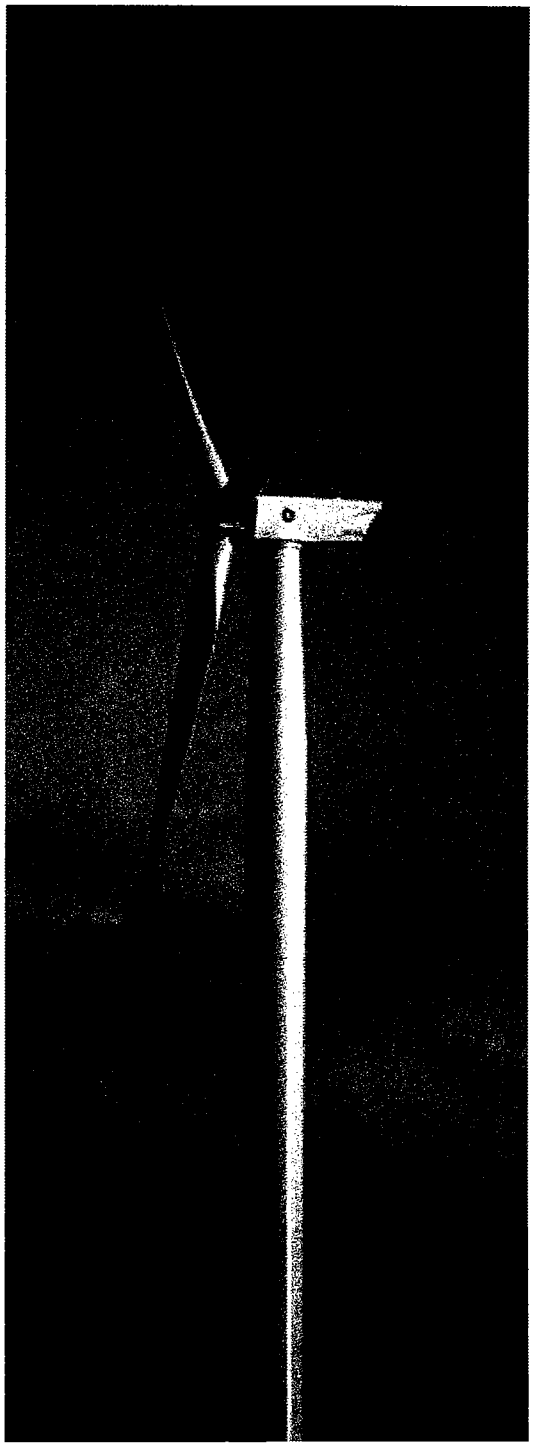
❑ North America

- **Canada – CanWEA**
  - ✓LVRT: mandatory
  - ✓Reactive Power: +0.9/-0.95
- **United States - FERC**
  - ✓LVRT: mandatory
  - ✓Reactive Power (±0.95) and dynamic voltage support: if study shows required

Summary

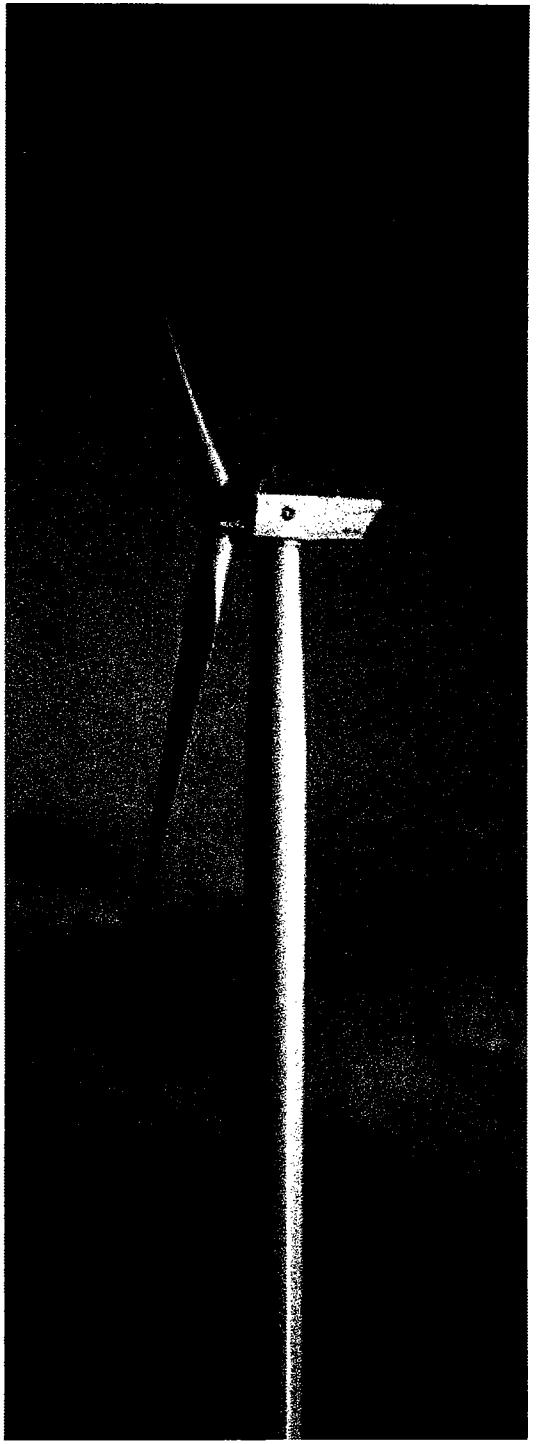
- ✓ Reactive Power drawl should be incentivized /dis-incentivized based on local voltage
- ✓ Generators should be able to ride through transient faults
- ✓ Active Power Control based on system frequency

Thank U



GE imagination at work

Achieving India's Renewable Energy Goals . . . . .



GE is Committed to Technologies that:

- —Reduce the Cost of Wind Energy
- —Address Grid Operation and Reliability Concerns
- —Increase Capability of Power Grids to Achieve High Levels of Wind Penetration

GE is Committed Long Term... ecomagination

GE imagination at work

Evolution of Indian Power System over last decade

- ❑ Unbundling of SEBs
- ❑ Grid code
- ❑ ABT
- ❑ Open Access
- ❑ Power Exchange

Objective : To supply quality power reliably & cost effectively

Every stake holders must participate in maintaining system reliability…