TU Delft Delft University of Technology

EMT RTDS Modelling and Control of a 20-MW DC Wind Power Generator Integrated with an Electrolyser

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UGM RTDS USER'S GROUP MEETING

2024 EUROPE USER'S GROUP MEETING
DELFT, NETHERLANDS

RTDS Technologies AMETEK

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The research work shown in this presentation has received funding from Shell Global Solutions International B.V. It reflects only the authors' views, and the above indicated organization is not responsible for any use that may be made of the information it contains in.

Outline of the Presentation

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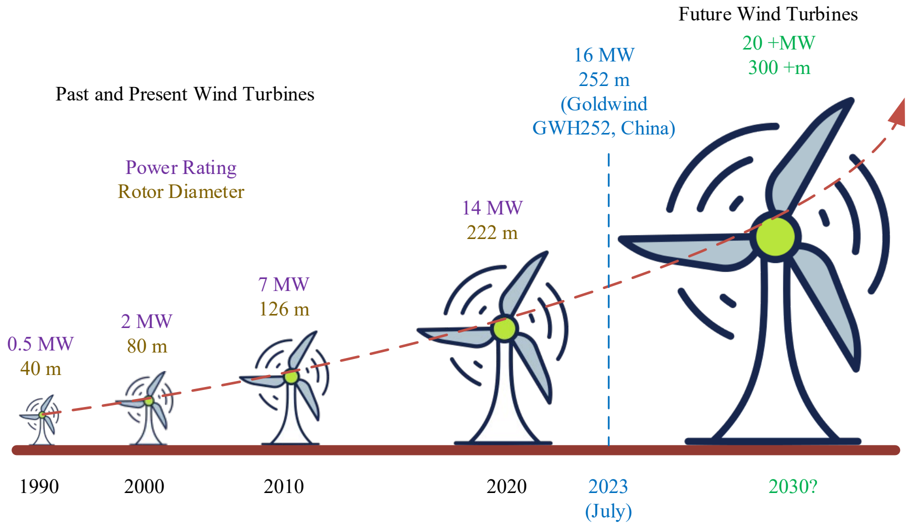
2. Wind Energy System Configuration
3. Wind Energy System Controls
4. RSCAD Models Overview and Simulation
5. Electrolyzer Integration
6. Electrolyzer Controls
7. RSCAD Model with Complete System Simulation
8. Conclusion

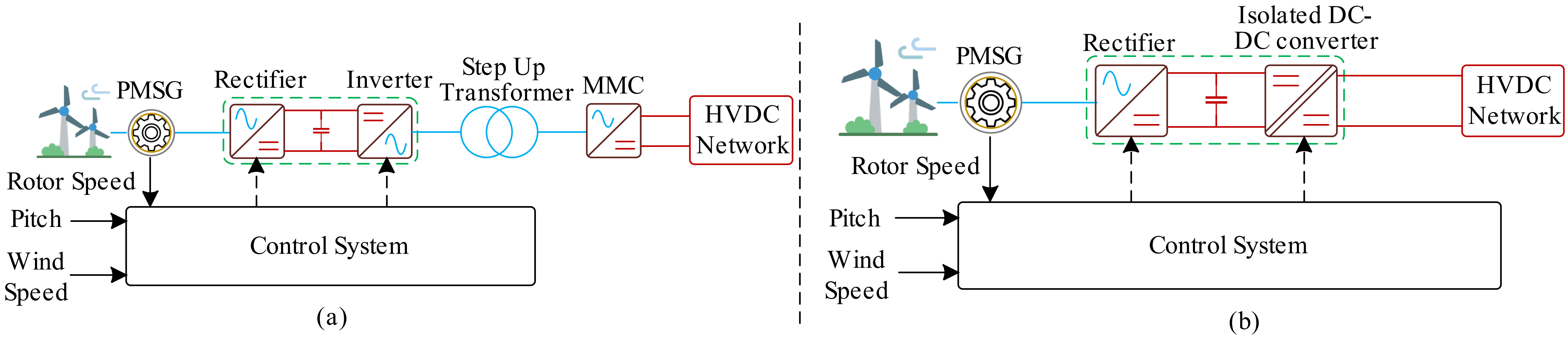
Motivation and Objective

- Motivation
  - High potential of wind energy
  - Growing demand for large-scale renewable energy systems (voltage and power)
  - Importance of efficient wind energy generation with P2G
- Objective
  - Design and analyze an EMT model for a 20 MW DC wind generator in HVDC networks with P2G integration



Manufacturer	Model	Rating	Deployment	Plant/Location
Dongfang Electric Corporation	DEW-18 MW-260	18MW	June 2024	Shantou City, China
Mingyang Wind Power	MySE 16.0-260	16 MW	July 2023	Fujian, China
Goldwind	GWH252-16MW	16 MW	June 2023	Fujian, China
Siemens Gamesa	SG 14-222 DD	14.7 MW	April 2024	Moray West, Scotland
GE Wind Energy	Haliade-X	13 MW	August 2023	Dogger Bank A, Dogger Bank B, (United Kingdom)
Mingyang Wind Power	MySE 12-242	12 MW	August 2023	Qingzhou 4, China
Siemens Gamesa	SG 11.0-200 DD	11 MW	April 2022	Hollandse Kust Zuid (Netherlands)
MHI-Vestas	V164-10	10 MW	June 2023	Seagreen, United Kingdom

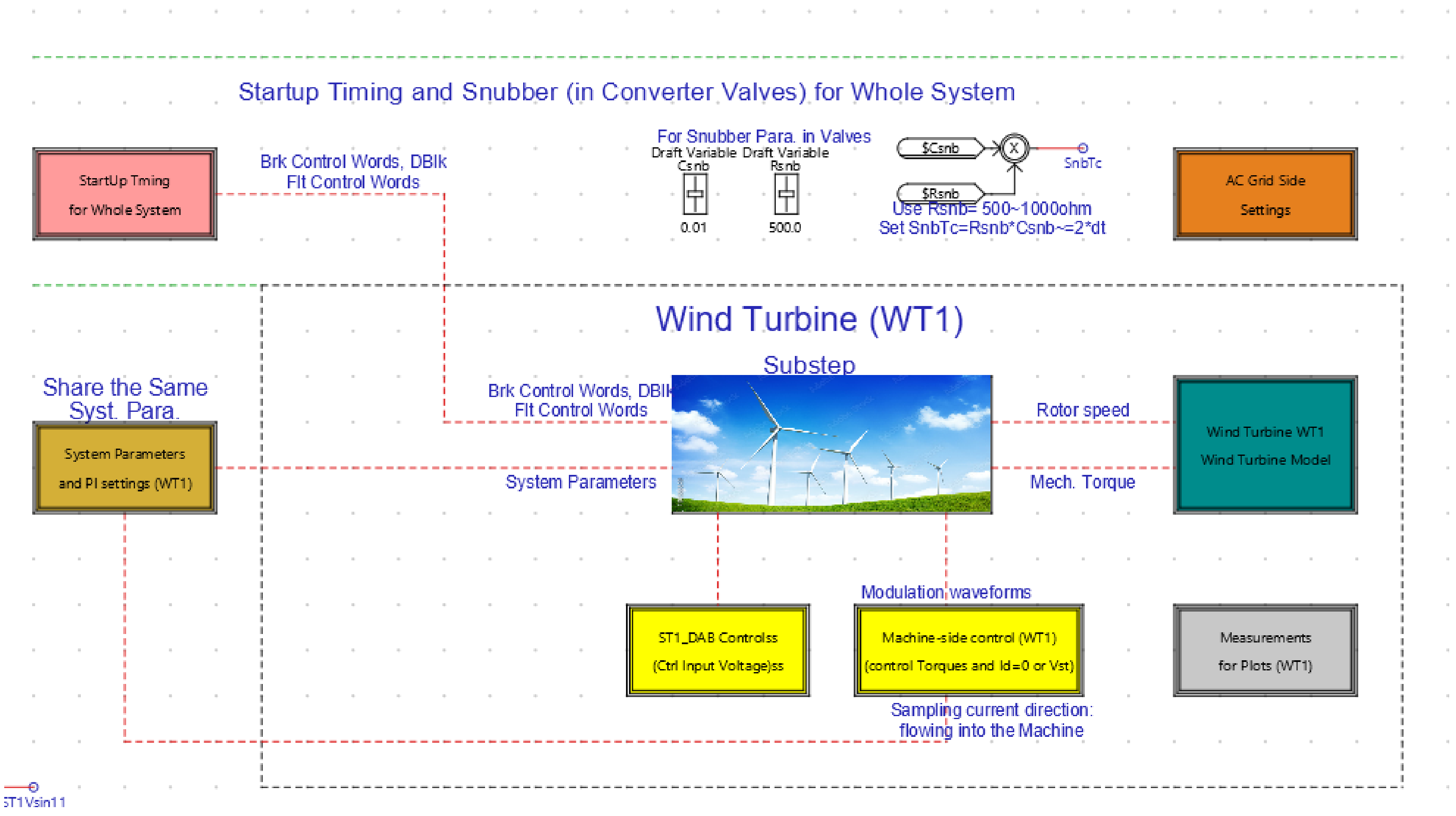
System Configuration for Power Delivery



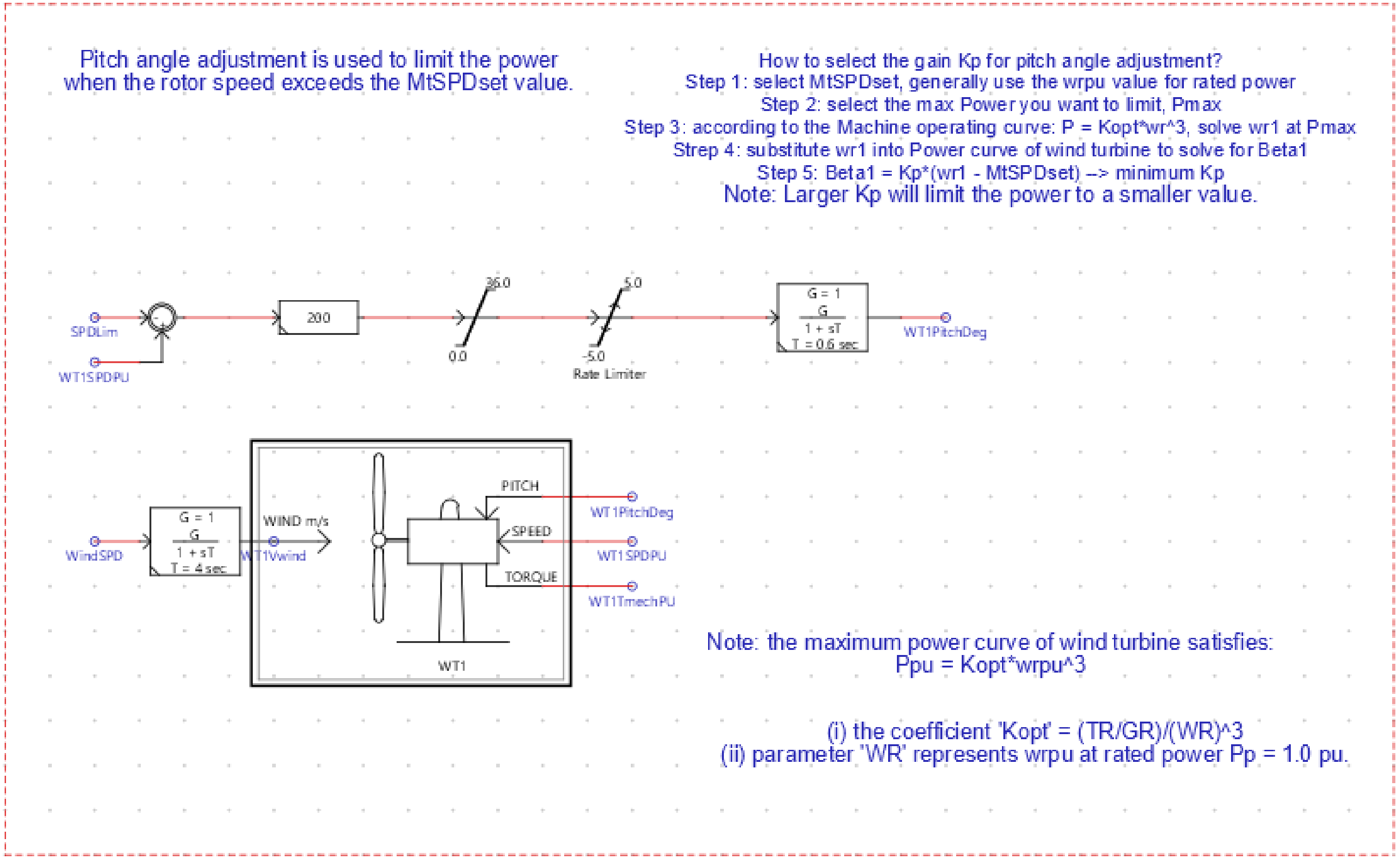
- AC-DC-AC back-to-back system
- Multiple power conversion stages
- Bulky and heavy step-up transformer

- Isolated DC-DC converter used as the GSC
- Reduction of power conversion stages

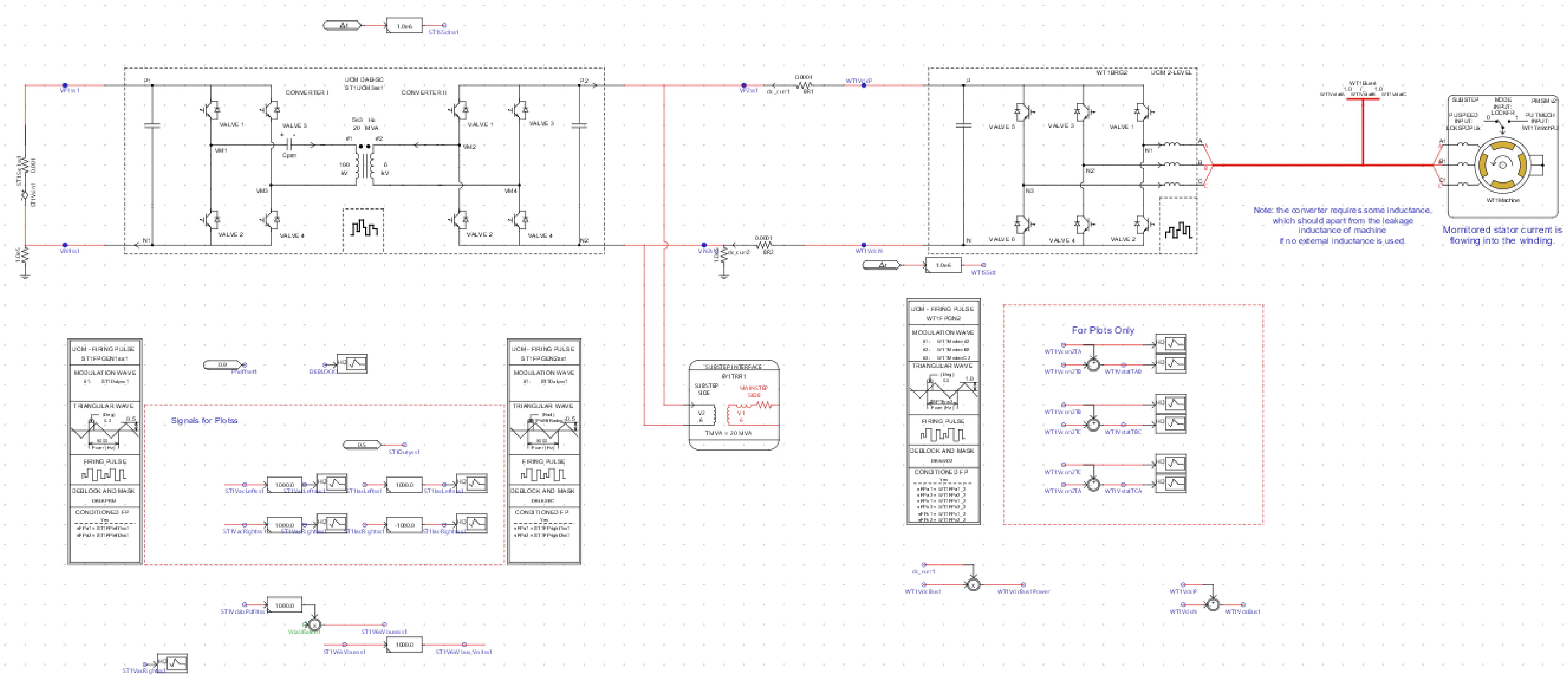
RSCAD Model Overview



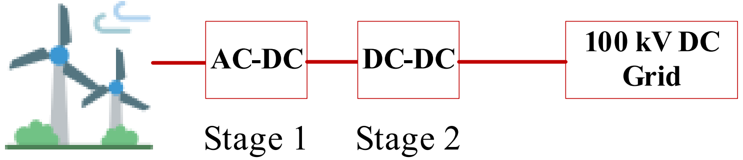
Wind Turbine in RSCAD



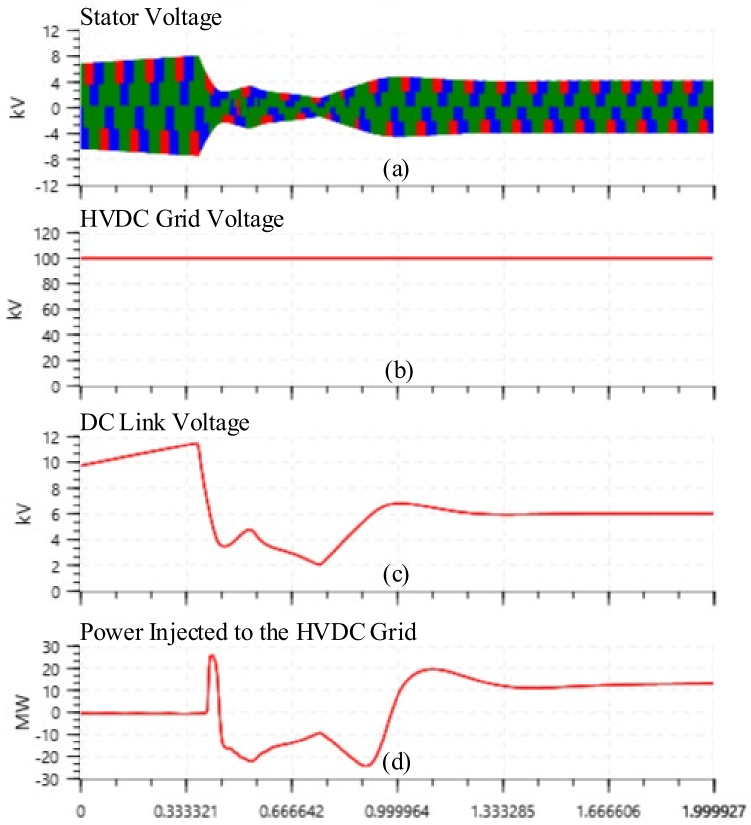
Power Conversion in RSCAD

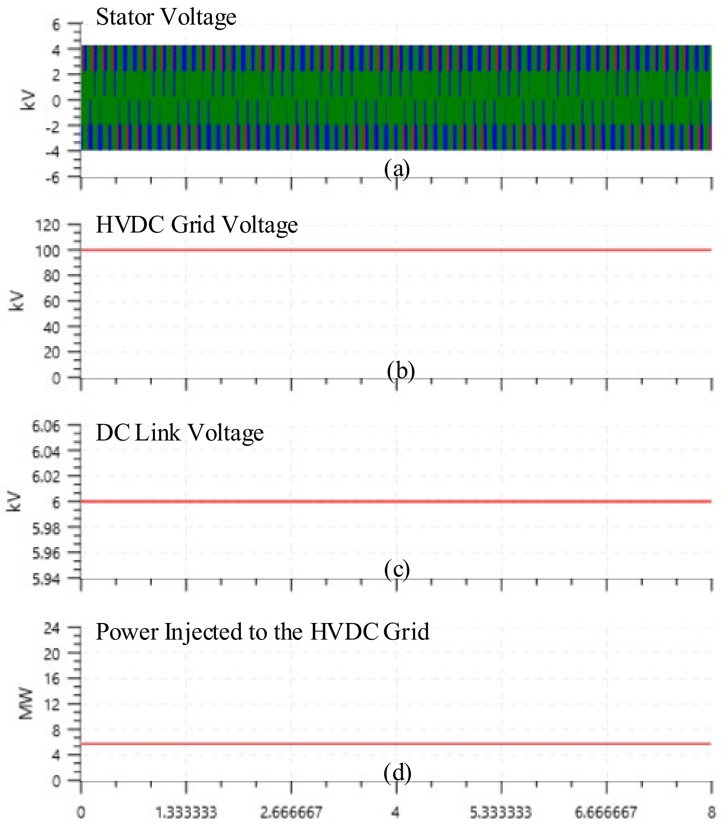


Simulation at Rated Conditions

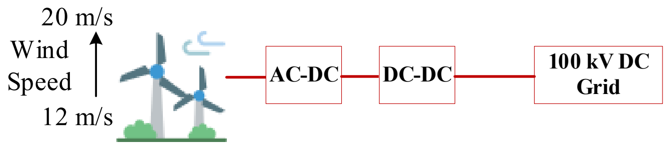


- Operational Sequence
  - MSC is turned on first
  - GSC (isolated DC-DC converter) is turned on next
- System Behavior
  - Initial oscillation observed
  - DC link voltage stabilizes to 6 kV
  - Power injected stabilizes to 20 MW.



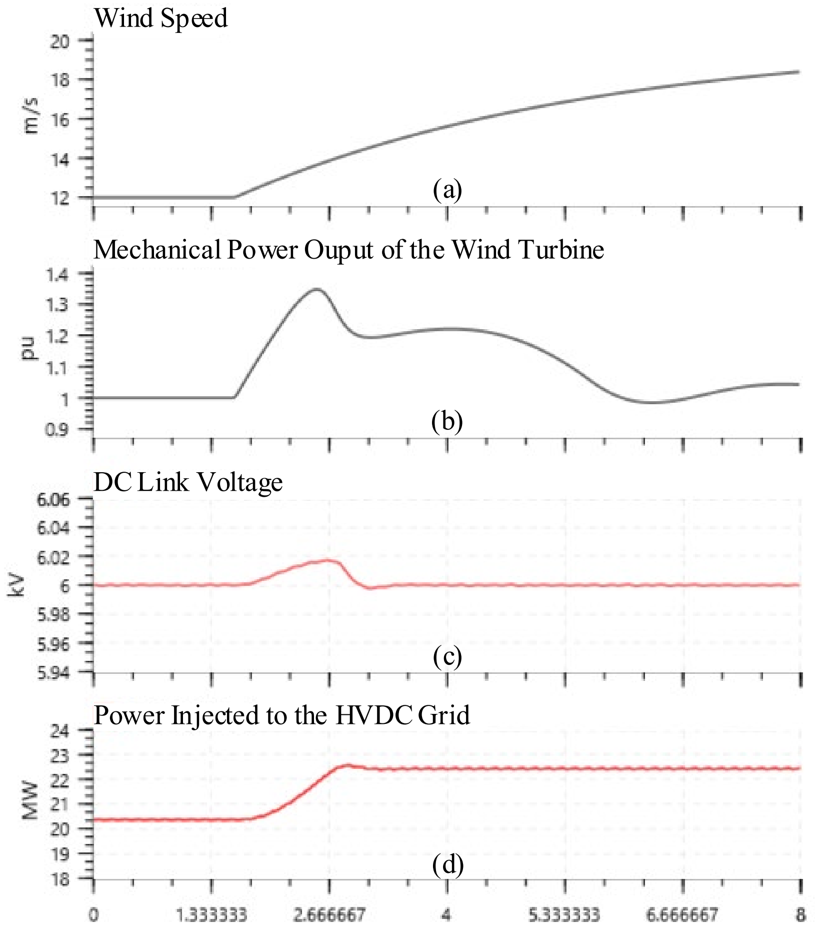


Simulation Results for Increase in Wind Speed

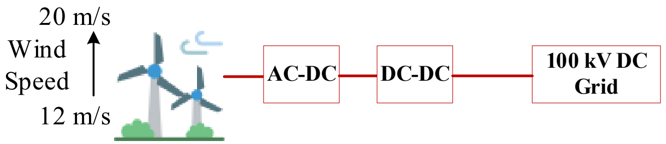


- Test Condition
  - Wind speed change from 12 m/s to 20 m/s.
- System Behavior
  - Increased wind speed leads to increased mechanical power output of the wind turbine.
  - Corresponding increase in power injected to the HVDC grid.
  - Converter maintains DC link voltage constant at 6 kV.

Validates the operation of the proposed system under varying wind speeds.



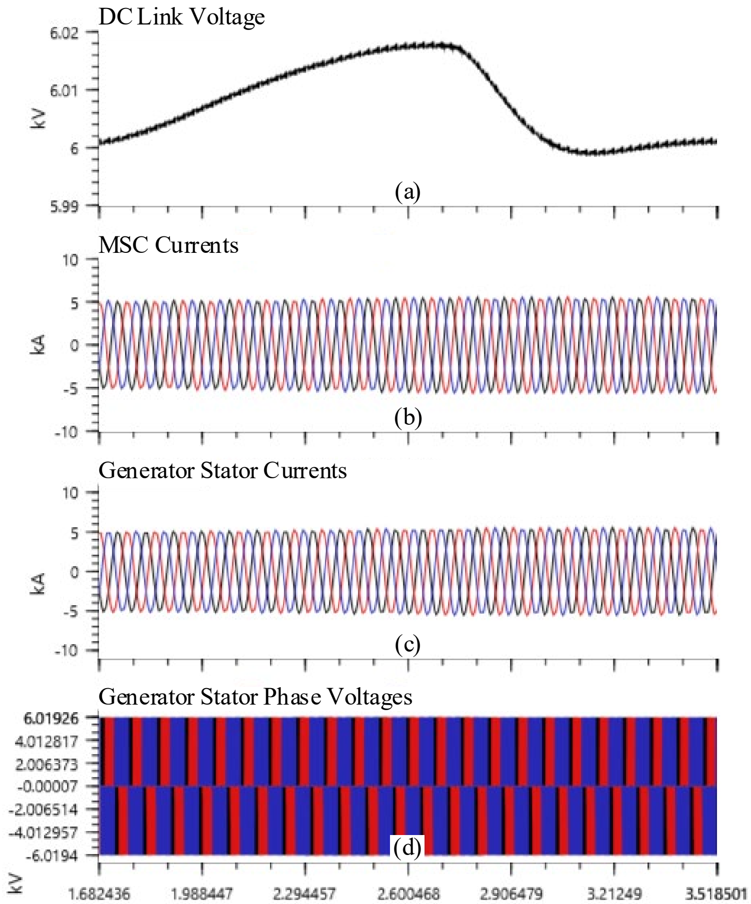
Waveforms During Increase in Wind Speed



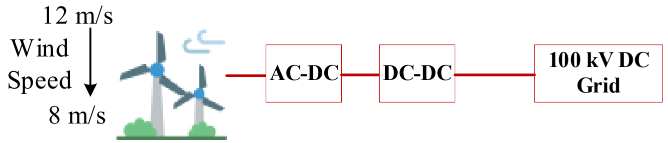
- DC link voltage quickly settles to the reference with a slight momentary deviation
- MSC converter currents show an increase
- Generator stator winding currents show an increase
- PMSG stator winding voltages remain unchanged despite the increase in wind speed

AC and DC voltages are maintained

Increased current leads to increased power injection to the HVDC grid.

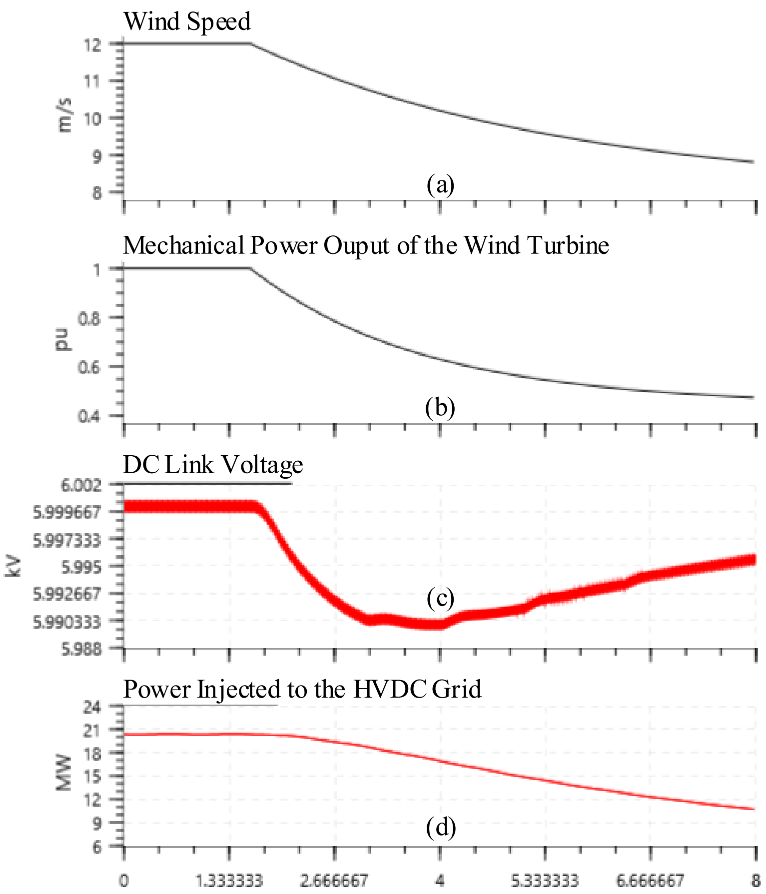


Simulation Results for Decrease in Wind Speed

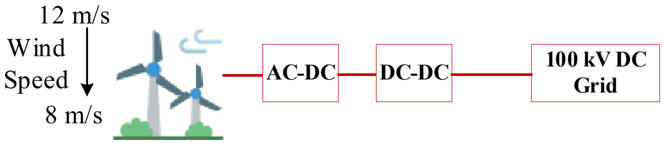


- Wind speed is decreased from 12 m/s to 8 m/s.
- Mechanical Power Decreases as wind speed decreases
- Electrical Power Injection Decreases correspondingly
- Power injected to the grid decreases to 5.7 MW
- Isolated DC-DC converter maintains it at 6 kV

Validates the correctness of the developed model under varying wind speeds



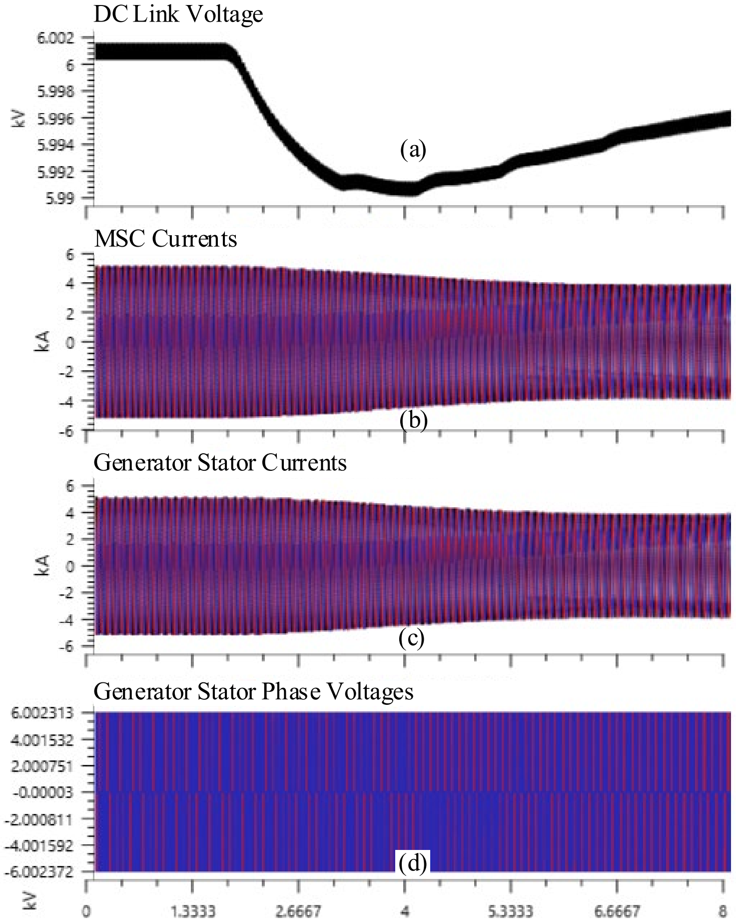
Waveforms During Increase in Wind Speed



- DC link voltage quickly settles to the reference with a slight momentary deviation
- MSC converter currents decrease
- Generator stator winding currents show a decrease
- PMSG stator winding voltages remain unchanged despite the increase in wind speed

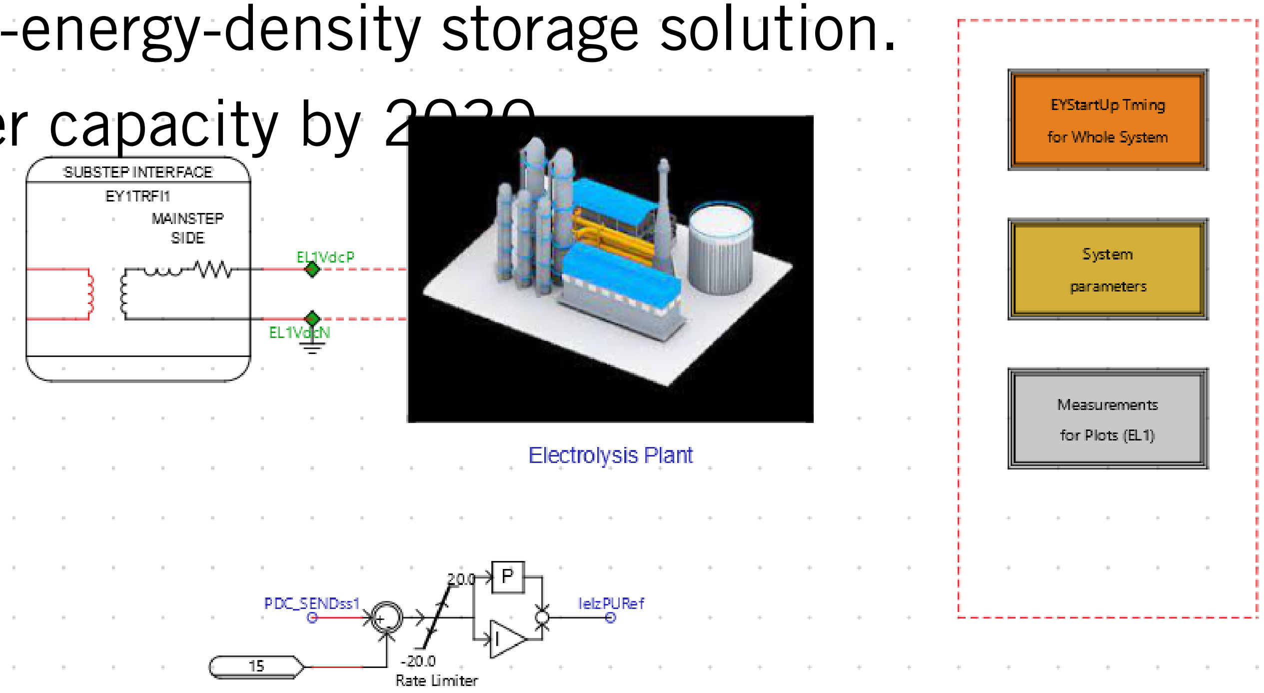
AC and DC voltages are maintained

Decreased current leads to reduced power injection to the HVDC grid.

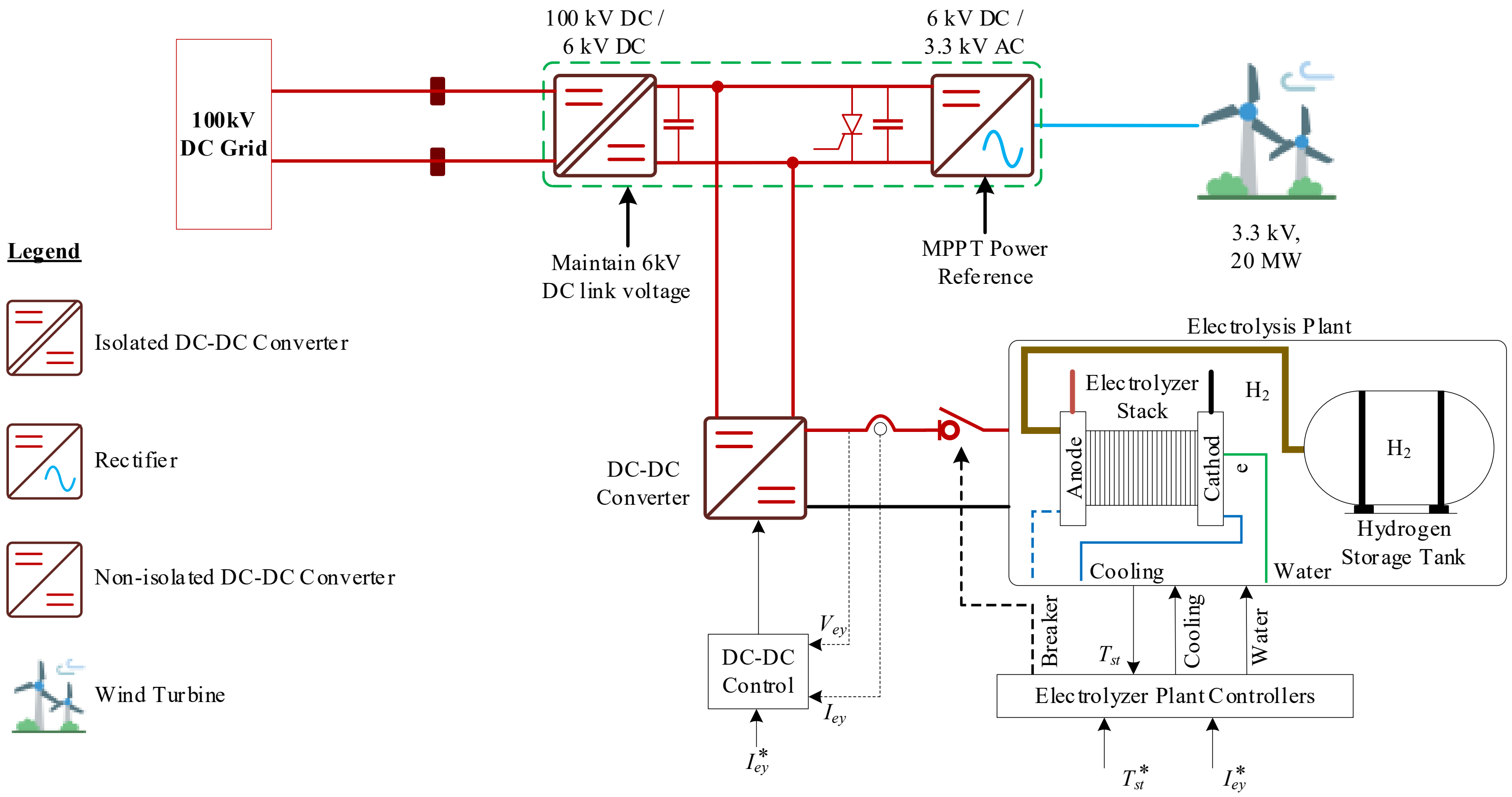


Electrolyzer Integration

- Intermittent nature of renewable energy → Storage Required
- Lithium-ion batteries → issues like cycle life, fire safety, and limited raw materials
- Hydrogen emerging as a cleaner, high-energy-density storage solution.
- Europe targeting 40 GW of electrolyzer capacity by 2030.

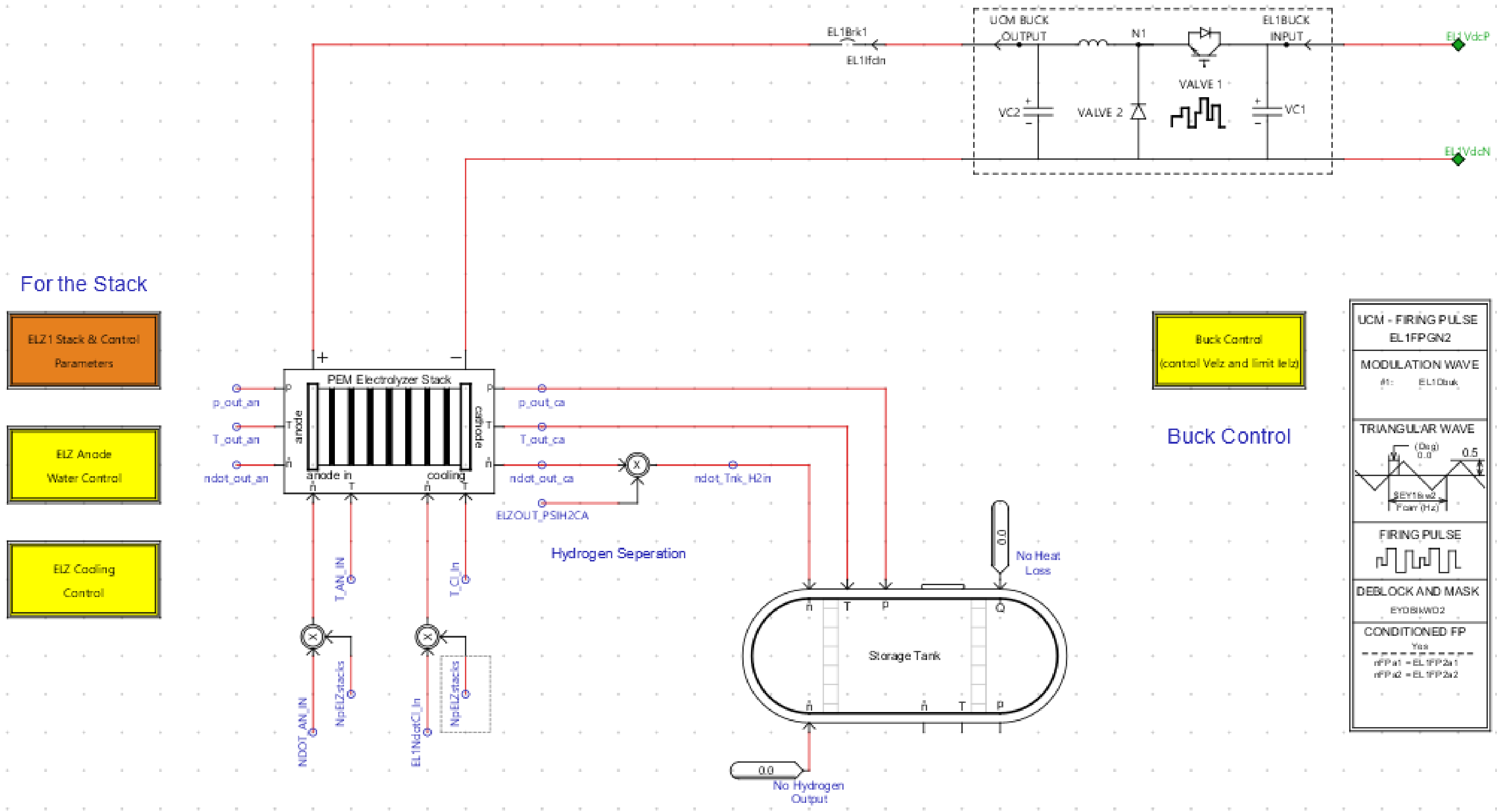


Electrolyzer Integration



- Operation with 7 MW Electrolyzer and 20 MW wind turbine

Electrolyzer Configuration in RSCAD



Electrolyzer Modes of Operation

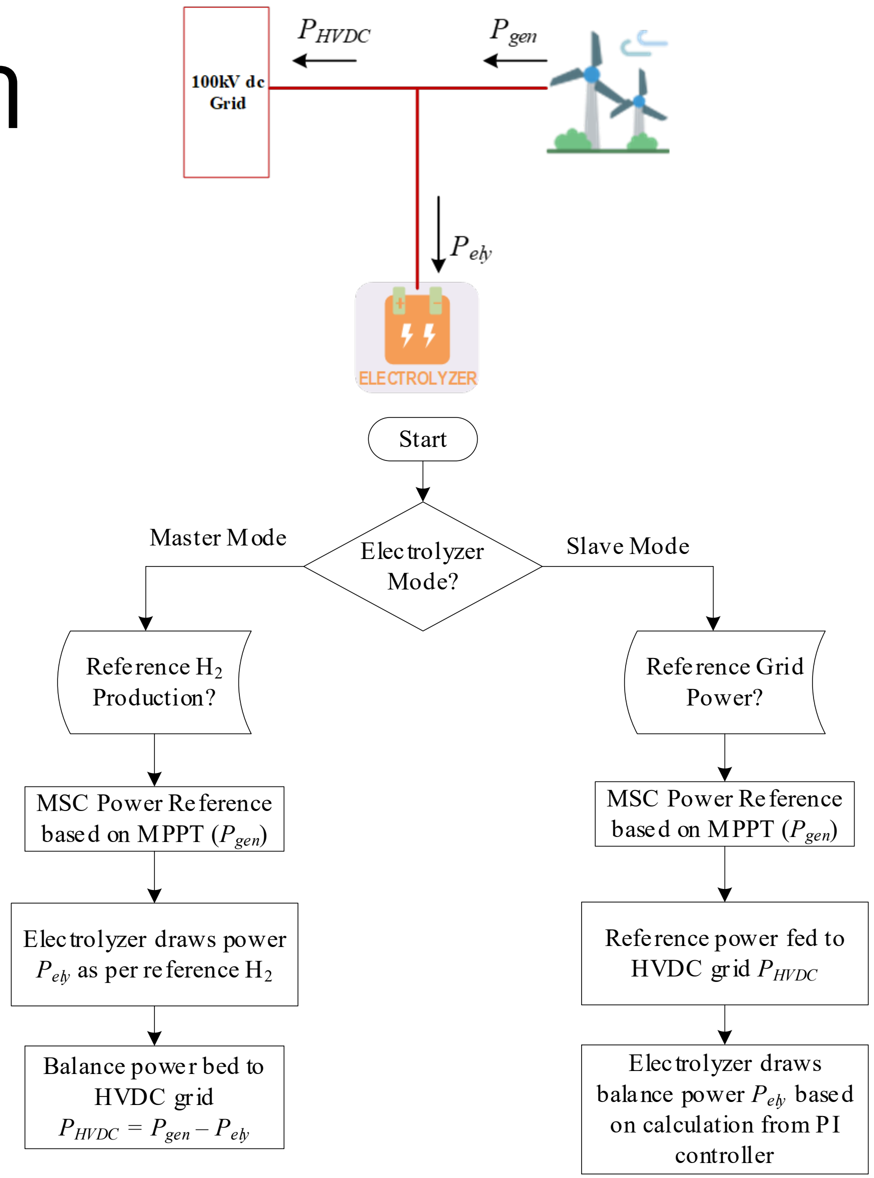
Electrolyzer model has H2 control and I control

- Master Mode (H2 Control)
  - Priority to H2 production
  - Balance power fed to grid

$$P_{HVDC} = P_{gen} - P_{ely}$$

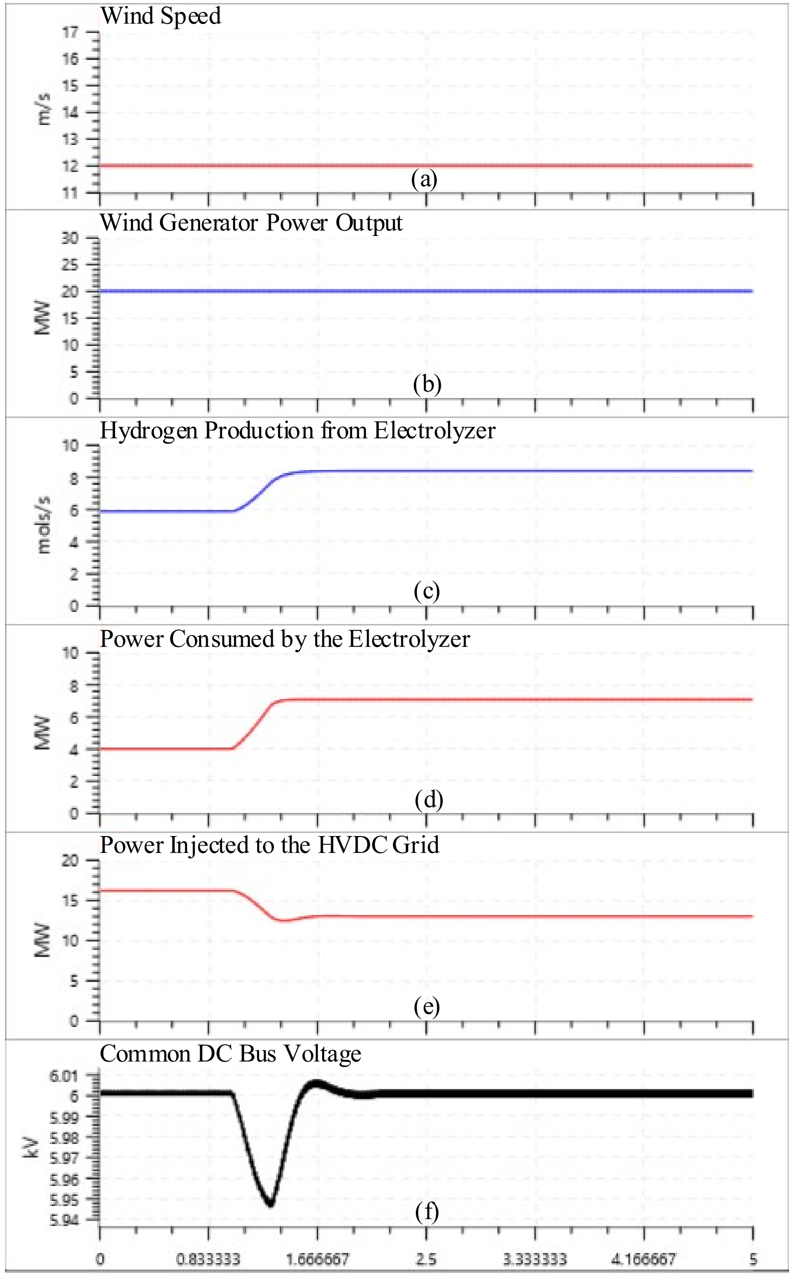
- Slave Mode (I Control)
  - Priority to grid injection
  - Electrolyzer current reference based on balance power

$$P_{ely} = P_{gen} - P_{HVDC}$$



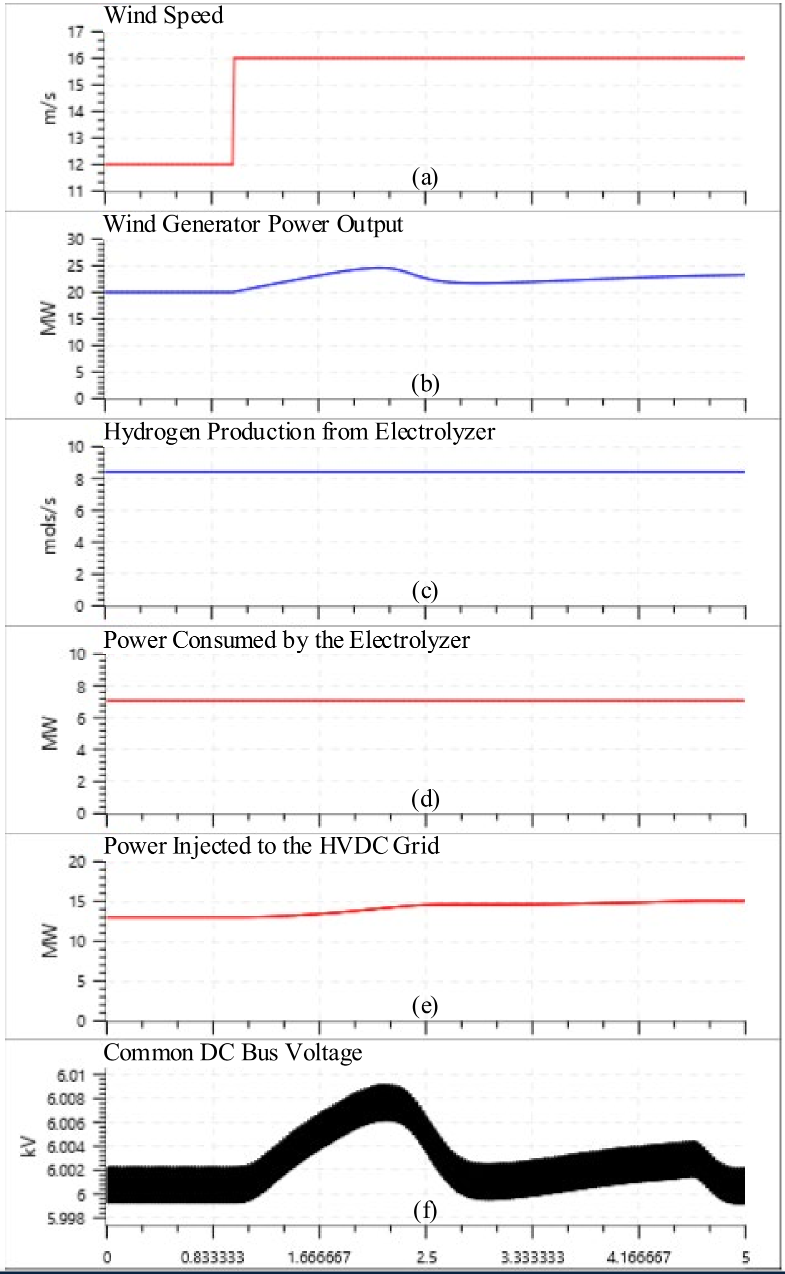
Simulation Results – H2 Reference Change (Master Mode)

- Wind speed remains constant at 12 m/s – constant power generation
- Hydrogen production increases from 6.5 moles/s to 8.5 moles/s
- Electrolyzer power consumption increases from 5MW to 7 MW
- Power injected to the HVDC grid decreases from 15 MW to 13 MW
- Negligible oscillation is observed in the common DC bus voltage of the wind turbine



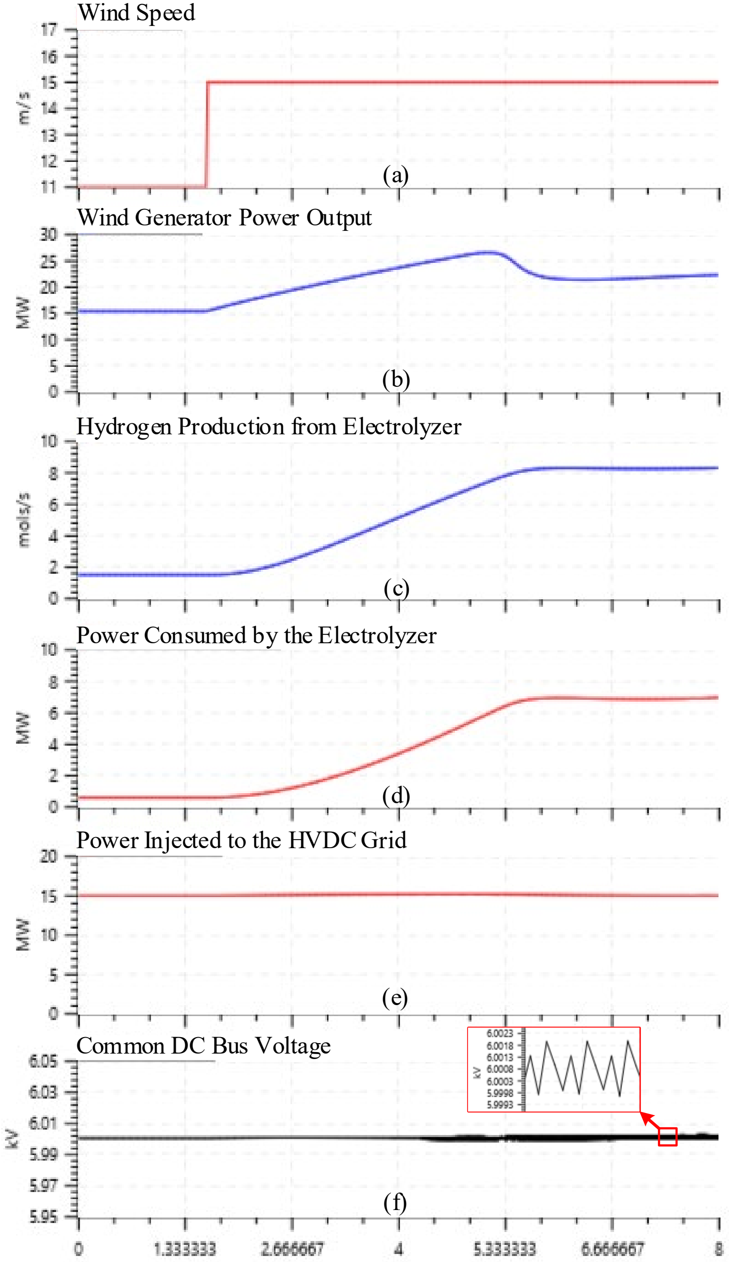
Simulation Results – Wind Speed Change (Master Mode)

- Wind speed increases from 12 m/s to 16 m/s
- Corresponding rise in power generation from 20 MW to 22 MW
- Hydrogen production remains constant at 8.5 moles/s
- Power consumed by the electrolyzer also constant at 7 MW
- Increased power generation leads to higher power injected to the HVDC grid – 13 MW to 15 MW
- Negligible oscillation is observed in the common DC bus voltage



Simulation Results – (Slave Mode)

- Wind speed increases from 11 to 15 m/s, power generation from 15 to 22 MW
- Hydrogen production increases from 6.5 moles/s to 8.5 moles/s
- Electrolyzer power consumption increases
- Power injected to the HVDC grid constant at 15 MW
- Negligible oscillation is observed in the common DC bus voltage of the wind turbine



Conclusions

- Summary
  - Developed an EMT model of a 20 MW wind generator for HVDC networks.
  - Integration of in-turbine Electrolyzer with H2 and Ielz controls
  - Proposed system uses an isolated DC-DC converter after AC-DC conversion.
  - Reduced system size, weight, and cost by eliminating additional components.
- Key Benefits
  - Enhanced efficiency by reducing power conversion stages.
  - Suitable for large-scale offshore wind energy projects.
- Future Work
  - Develop a HVDC network with multiple wind generating systems.
  - Aim to transmit power in the GW range from offshore to shore.
- Implications
  - Potential to significantly impact the scalability and efficiency of offshore wind farms with power to gas.

Thank You!