NIST/DOE Workshop on Medium-Voltage Wide-Bandgap Power Electronics for Advanced Distribution Grids

# Medium Voltage grid interfaces and interconnection equipment

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# Summary

- Wind farm interconnection issues and requirements
- DER interconnection issues and requirements
- Microgrid operation, interconnection requirements and controller features
- Power electronic interfaces – an enabler for deployment and operation

# Transmission wind farm interconnection issues

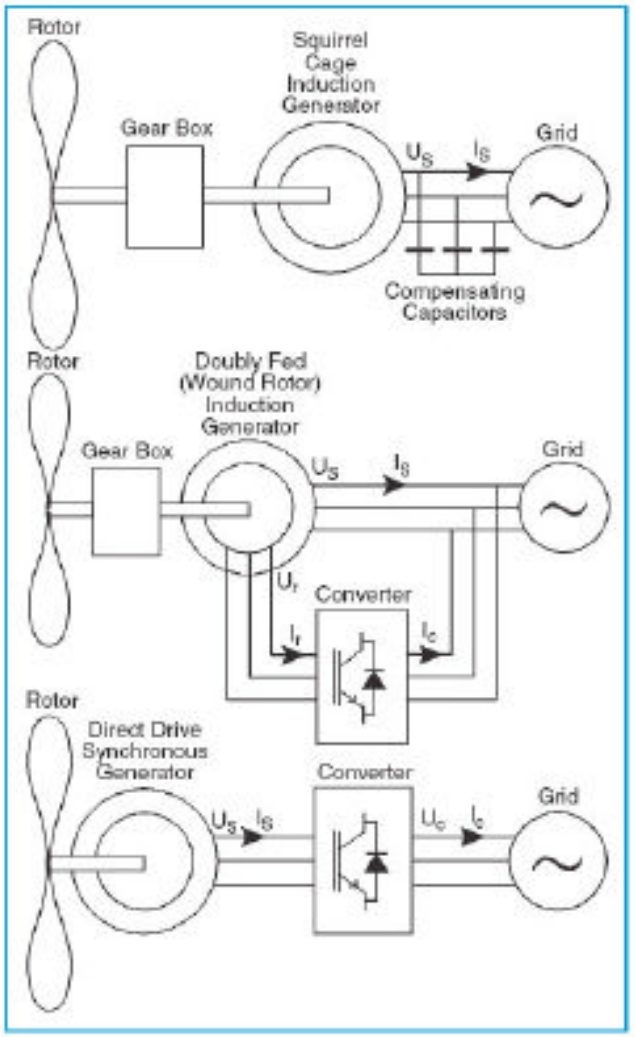
- Given that
  - Renewable resources produce variable and intermittent power and are not dispatchable
  - Conventional generators have features that define the way generation dispatch is carried out and transmission assets are used and optimized
  - High penetration of wind energy displaces/replaces conventional (synchronous generator based) production
- It is reasonable, in the framework of the existing electric grid, to expect that wind farms must:
  - Reproduce the features of conventional generators, notably inertial response
  - Use power electronic interface flexibility and dynamic response to support the grid, by means of its fast real and reactive power control

# Large wind generator plants – past and future

Past

Present

Future




690 VAC

690 VAC

690 VAC,
or potentially
High Voltage,
AC or DC

- *Large transmission-level plants required for cost parity*
- *Power electronics drive needed to meet grid requirements*

# Wind farm interconnection requirements – typical

- Response to disturbances on the grid, including loss of grid – voltage/grid support and low voltage ride through
- Voltage regulation, reactive power and power factor
- Frequency support under faults – inertial response
- Equipment protection – voltage and frequency ranges
- Ramp rates – maximum up and down ramps
- Power system oscillations damping – power system stabilizer functions
- Real power limitation under abnormal conditions – power curtailment

# Distribution interconnection issues for DER

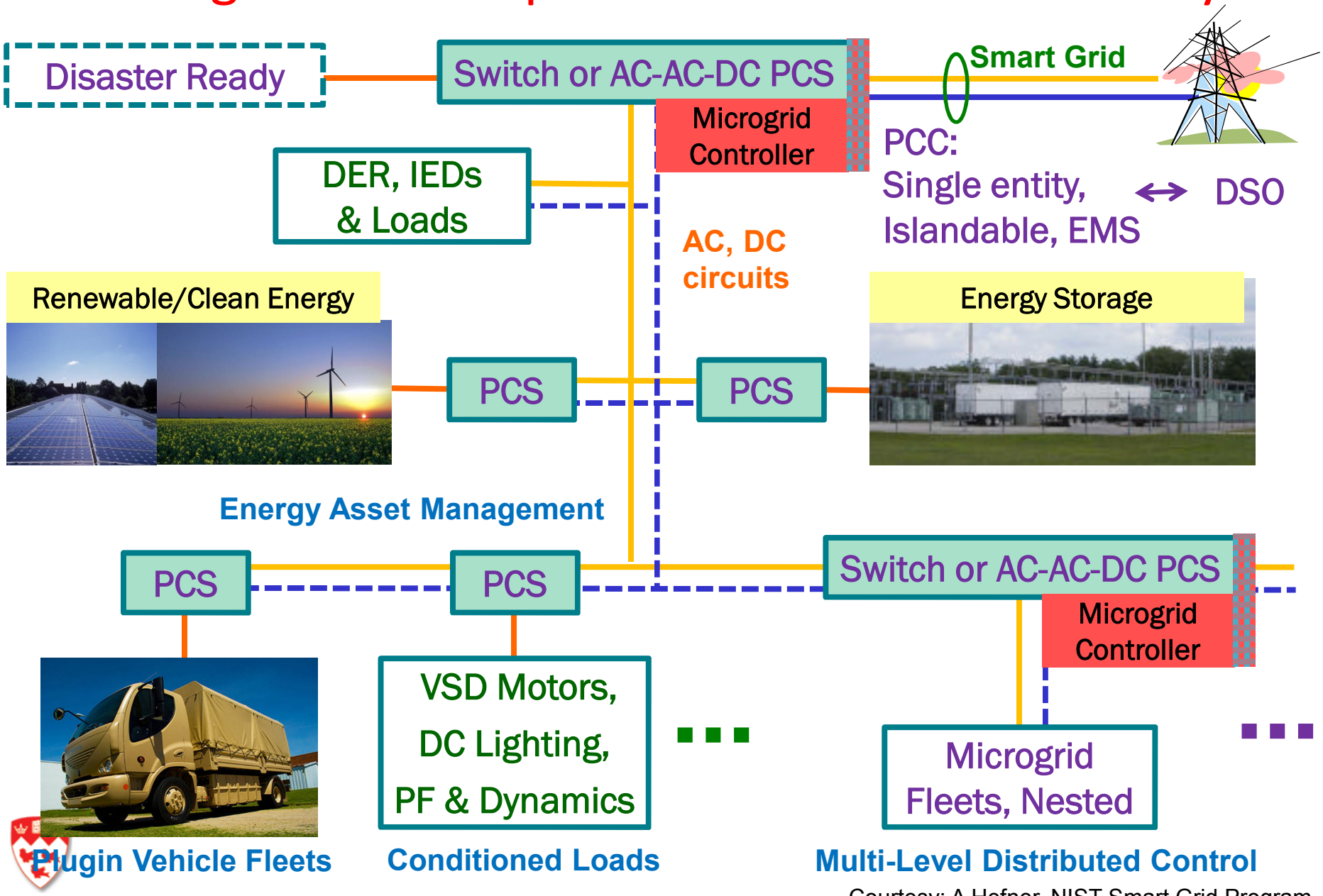
- Synchronization
- Voltage regulation
- Islanding and reclosing, islanding detection
- Power and power factor ranges/control
- Response to voltage disturbances – voltage support
- Response to frequency disturbances
- Grid support, low voltage ride through, tripping ranges
- Protection – overcurrent, other functions
- Power quality – harmonic distortion, voltage sags
- Grounding

# Smart inverter functions – control – P-Q dispatch

Facilitate DER interconnection and integration

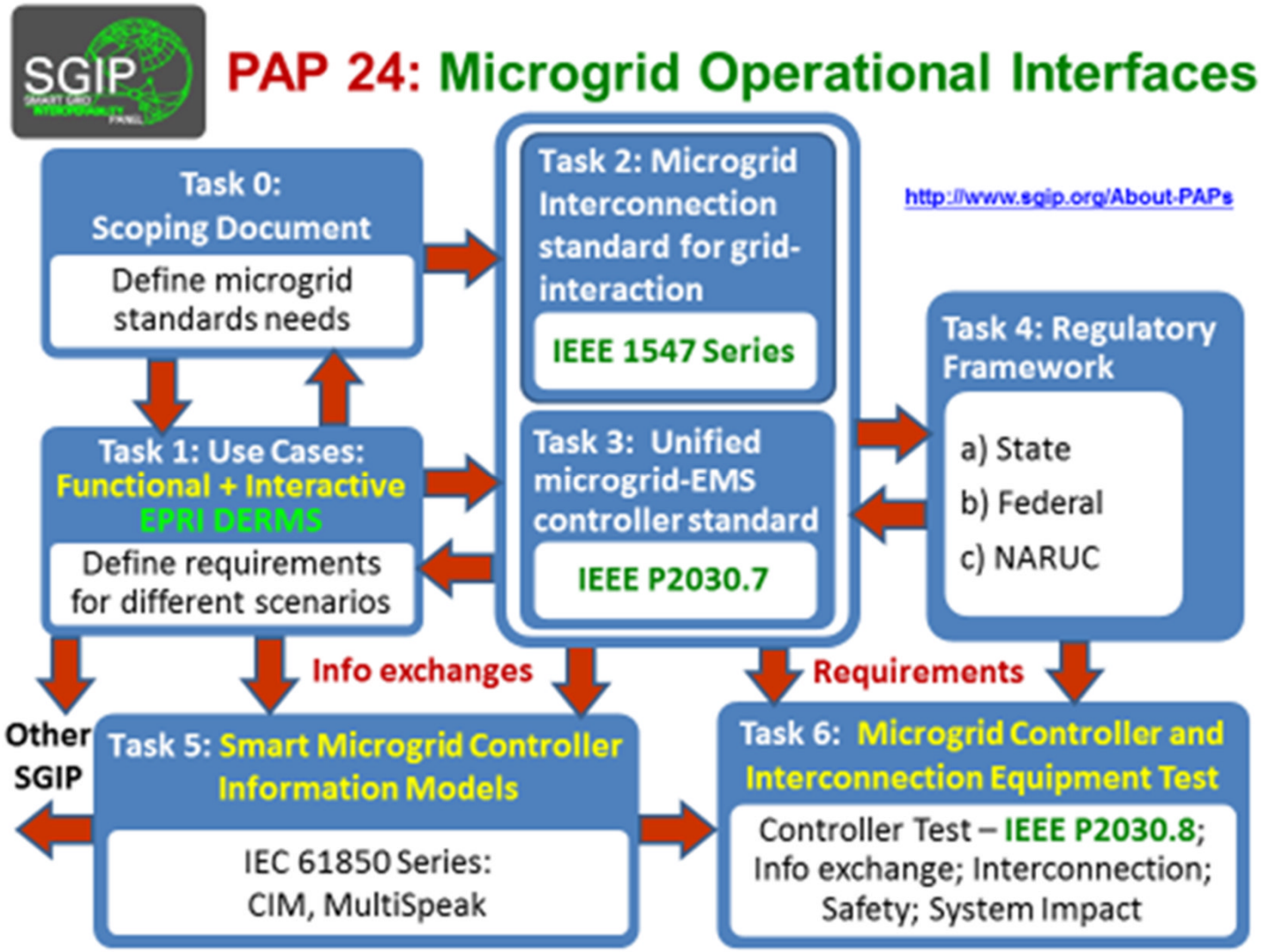
- Voltage/reactive power function – voltage support
- Voltage/power function – grid support – bidirectional option
- Frequency/power function – grid support
- Voltage ride through – configurable ranges
- Dynamic reactive current/power – voltage support function
- Peak power limiting – applicable to battery storage
- Power smoothing – controlled within a range of variations
  - Note 1: Needed function must be identified, required features selected, and controller implementation defined
  - Note 2: Possibility of operating in the 4 quadrants of the P-Q plane with storage

# Microgrids enable pervasive DER and resiliency




Courtesy: A Hefner, NIST Smart Grid Program

# NIST/SGIP Microgrid standards coordination



# Microgrid operating requirements

- Microgrid – role, structure and configuration
  - Integration of DER, including generation based on renewables
  - Integration of electric energy storage
  - Integration of controllable loads, and hybrid loads (EV)
- Interconnection requirements – external to the microgrid
  - Control/limit the energy exchange with the distribution grid
  - Manage the energy exchange to an pre-agreed level
  - Present a neutral operation to the distribution grid
  - Provide ancillary services to the distribution grid as negotiated
- Operational requirements – internal to the microgrid
  - Balancing renewable generation variability, meeting load requirements
  - Providing resiliency to the customers
  - Enabling high renewable DER penetration levels
  - Meeting distribution utility interconnection requirements
  - Meeting the needs of local customers in terms of power quality

# Microgrid interconnection requirements

2 basic functional requirements – work carried out in P2030.7

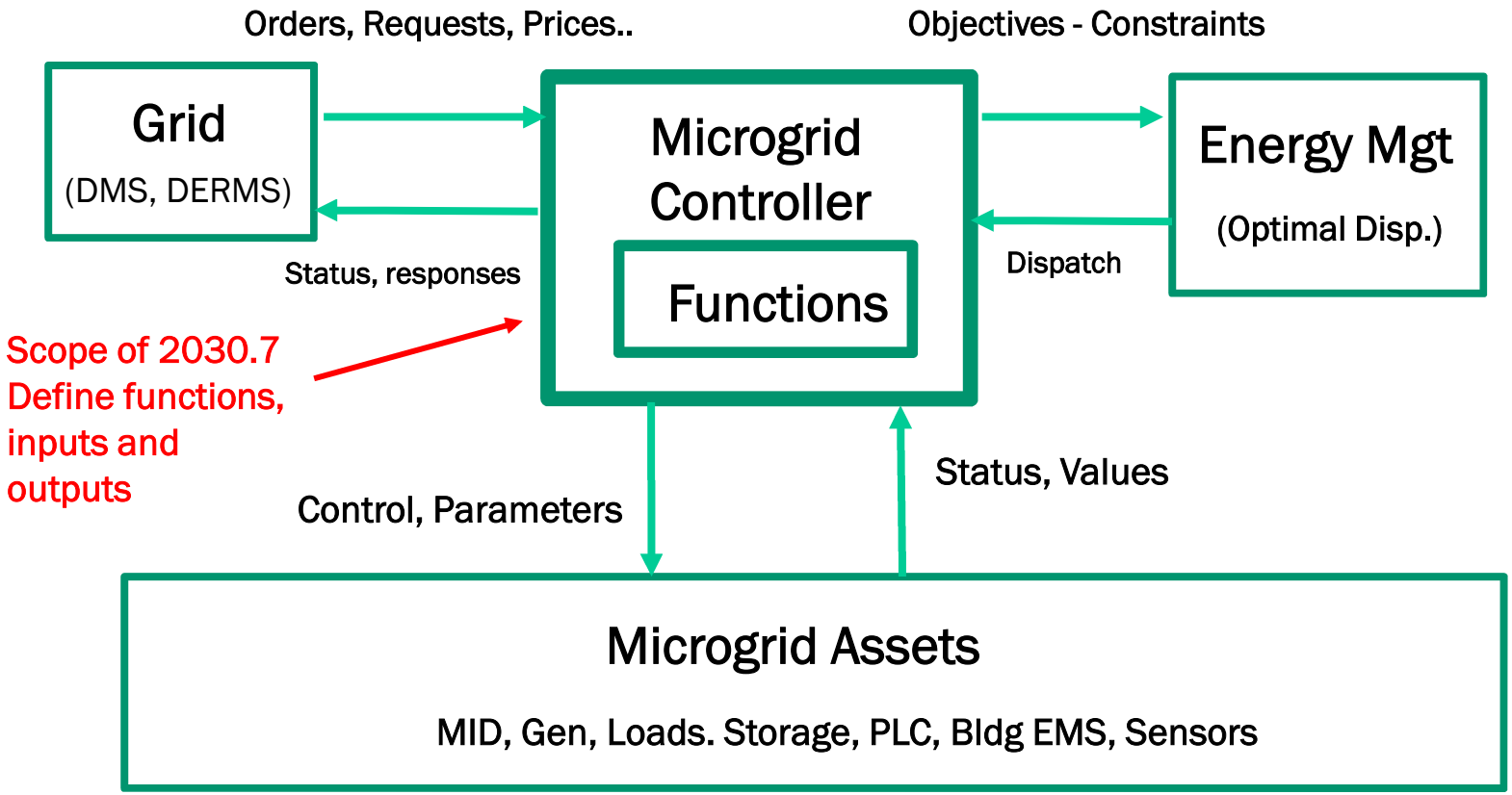
- Transitions (abnormal/fault operation) – capability to island when required, while maintaining microgrid internal operation within voltage and frequency limits during transitions, with minimum load disruption and stabilization to the new operating point in a specified time
- Dispatch (normal operation) – capability to maintain operation within voltage and frequency limits in islanded mode and grid connected modes – provide gird support and ancillary services to the distribution grid as required

# Microgrid function implementation

2 basic functional requirements – equipment/systems required

- Transitions – from grid connection to islanded modes and reconnection
  - Islanding detection
  - Microgrid Interface Device (MID) – Interface with the grid, for disconnection and isolation, and for reconnection
  - Microgrid controller – implementing centralized or decentralized control making use of intelligent DER functions for the transition period
- MID implementation options
  - Mechanical switch, contactor, breaker
  - Power electronics converter or switch, hybrid switch
- Dispatch
  - Microgrid controller – implementing centralized or decentralized control, making use of intelligent DER functions for normal mode
  - Power electronic MID control for continuous grid interface exchanges

# Microgrid controller framework – P2030.7 proposal



# Microgrid/DER power electronic interface enablers

- Local DER power electronic interfaces – control
  - Implementation of smart inverter grid-support functions
  - Controllable DER – storage devices
  - Managing local grid perturbations
  - Aggregation of DER for ancillary services provision
- Power electronic interfaces – microgrid to grid interconnection
  - Controlled power exchanges
  - Isolates the microgrid from the grid perturbations
  - Allows a controlled connection and disconnection (islanding)
  - Reconfigurable converter structures - flexible and multiple functions
  - Implementable using MV power converters – benefits

# Microgrid deployment enablers

- Power electronic equipment
  - Grid interface inverter robustness – handling harsh environments (temperature and humidity), improvement in overload capabilities, robust operation under faults (remaining connected)
  - Grid interface inverter flexibility – smart inverter functions, grid support
  - Grid interface inverter functionality – integrated storage
- Operations
  - Protection system design – integrated protection layer, adaptive protection (grid connected and islanded operation)
  - Microgrid controller implementation – centralized control, decentralized control (fall back)
  - Communication infrastructure