Digital Twins for the Future Power System - Summary

1. Why Digital Twins (DTs) for Power Systems?

- The energy transition demands decentralized, renewable, and intelligent energy systems.
- Traditional models can't keep up with real-time optimization and flexibility needs.
- Digital Twins offer:
  - Real-time monitoring and prediction
  - Enhanced system resilience and control
  - Integration of distributed energy resources (DERs), prosumers, and storage

2. Key Components of a Digital Twin System (DTS)

- Physical Asset: Real-world system (e.g., turbine, battery)
- Virtual Model: Simulated version using physics- or data-driven approaches
- Data: Real-time measurements and historical logs
- Services: Functions like condition monitoring, control, predictions
- Connections: Two-way communication and control loops

3. Enabling Technologies

- Data Acquisition: SCADA, PMUs for real-time grid info
- Modeling: Combines white/grey/black box models; uses ML and system identification
- Communication: 5G/6G for low-latency and high-throughput
- Computing: Cloud + Edge computing for distributed, fast analytics
- Data Analysis: AI/ML for predictive maintenance, optimization

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4. System of Digital Twin Systems (SDTS)

- Hierarchy: Component -> Unit -> Plant -> Grid
- Horizontal Integration: Communication between similar levels
- Vertical Integration: Coordination across levels
- Modularity: Easy to scale and plug-in new assets
- Framework: Open-source, cloud-based platform

5. Application Scenarios

1. Economic Dispatch
   - Probabilistic forecasting and bidding
   - Setpoints passed from grid-level DT to plant DTs

2. Load-Aware Wind Farm Control
   - DTs monitor turbine fatigue and coordinate for longevity
   - Adjust operation dynamically based on flow conditions

3. Fault-Tolerant Control
   - DTs detect partial converter faults
   - Local control adapts in real-time to maintain operation

Vision Forward

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- Unified framework enabling:
  - Autonomous system management
  - Data-driven control
  - Scalable and secure operations
- Target: A System of Digital Twin Systems for optimized, decentralized energy systems.