Measurement and Control in Smart Grid Using the NI Technology

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Contents:

• Introduction

• Smart Grid Issues

• Role of NI Technologies

• Case Study

• Conclusions
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Introduction

• **Smart Grid:**
  Electric Power Grid That is ‘Smart’
  ‘Smart’ = Uses *Computer, Communication, Sensing* and *Control*

• **Why ‘Smart’:**
  - Reliability
  - Cost Minimization to Consumers
  - Interconnection of New Generating Sources
Introduction

• Extant of Control Systems in Power Grid:
  - Temporal Scale
  - Geographical Scale
  - Device Level
  - Power System Wide Control
  - Utility Pricing
  - Demand Response
Introduction

Table: Time Scale Nature of Smart Grid

<table>
<thead>
<tr>
<th>Operation</th>
<th>Time frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switching Over-Voltages</td>
<td>milli Seconds</td>
</tr>
<tr>
<td>Fault Protection</td>
<td>100 milli Seconds Or A Few Cycles</td>
</tr>
<tr>
<td>Stability</td>
<td>1 Second</td>
</tr>
<tr>
<td>State Measurement And Estimation</td>
<td>Steady-State/Ongoing</td>
</tr>
<tr>
<td>Load Management</td>
<td>1 Hour</td>
</tr>
<tr>
<td>Expansion Planning</td>
<td>Years</td>
</tr>
</tbody>
</table>
Introduction

• Control Systems On Various Scales
  - Theory Exists: Theory Of Time Scales (Still Developing)

• Hybrid Control Systems
  - Issues In Theory And Implementation
Introduction

Table: Trait Comparison Of Traditional And Smart Grid

<table>
<thead>
<tr>
<th>Trait</th>
<th>Traditional Grid</th>
<th>Smart Grid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>Centralized</td>
<td>Distributed</td>
</tr>
<tr>
<td>Switching</td>
<td>Electromechanical</td>
<td>Solid State</td>
</tr>
<tr>
<td>Failures And Blackouts</td>
<td>Yes</td>
<td>No/Less (Islanding)</td>
</tr>
<tr>
<td>Real-Time Monitoring</td>
<td>No</td>
<td>Yes And Very Extensive</td>
</tr>
<tr>
<td>Reaction Time</td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td>Restoration</td>
<td>Manual</td>
<td>Automatic/Self-Healing</td>
</tr>
<tr>
<td>Communication</td>
<td>One-Way</td>
<td>Two-Way</td>
</tr>
<tr>
<td>Energy Storage</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Grid-wide control</td>
<td>Utility</td>
<td>Utility + Customer</td>
</tr>
</tbody>
</table>
Introduction

• Control Problem:

□ Control And Manage A Heterogeneous, Geographically Widely Dispersed But Interconnected System

□ Control This System Optimally
Introduction

• Measurement Problem:

- **Measure** Variables Of Interest Spread Over A Geographically Wide Area In Real-time
- If Measurements Are Not Available Then **Estimate**
- Grid Model Is Needed
Introduction

• Why Difficult?

- Electric Power Network + Network Of Sensing + Communication + Control
  = *Complex Dynamical Network*

- Non-Linear

- Geographically Dispersed

- Interaction Between Components And Human Owners
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• **Smart Grid Issues**

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Smart Grid Issues:

• Power Grid Backbone:
  - Strong And Smart
  - Efficient Integration Of Intermittent Sources
  - Connectivity For Transportation
Smart Grid Issues: Demand Response

• How Does The Grid Respond When Demand Goes High?
• Reduce Peak To Average Load Ratio
• Demand Response Management
• Shift Usage To Off-Peak Hours
Smart Grid Issues

• Micro-Grid:

  ❑ A Group Of Distributed Energy Sources And Inter-Connected Loads

  ❑ Clearly Defined Electrical Boundaries

  ❑ Single Controllable Entity With Respect To Grid
Smart Grid Issues

• Distributed Generation (DG):

- Different Energy Resources Combined To Form An Energy System
- Meet The Demand Of Consumers At Local Level
- Supports Needs Where Utility Infrastructure May Not Be Enhanced
Smart Grid Issues

• Micro-Grid Islanding:

- Connect And Disconnect From The Grid
- Connect = Grid-connected Mode
- Disconnect = Island Mode
- Connect/Disconnect Should Be Fast And Accurate
Smart Grid Issues

• Micro-Grid Islanding:
  - Connect / Disconnect Through A Single Connection
  - Point Of Common Coupling (PCC)
  - Bi-Directional Energy Flow
Smart Grid Issues

Fig: Concept of a Micro-grid
Smart Grid Issues

• Micro-Grid Challenge:
  - Interconnection Of DGs
  - Integration With Power Grid
  - Generation Of Different Rating And Characteristics
  - Wind vs Solar: Intermittency vs Availability
Smart Grid Issues

• Micro-Grid Challenge:
  - Sensing: Power And Power Quality Parameters, State Estimation
  - Communication: Equipment
  - Control System (Centralized Vs Distributed)
Smart Grid Issues: Measurement And State Estimation

State Estimation Must Be Real-Time

Grid Model + State Estimation / Partial Observation

Data From Geographically Dispersed Entities
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Role of NI Technologies

• Smart Grid Enabling Technology To Be Successful:
  ➢ Lots And Lots Of *Real-Time Processing Power*
  ➢ Reliable *Interfacing*
  ➢ Seamless *Integration*
Role of NI Technologies

- Smart Grid Enabling Technology To Be Successful:
  - Lots And Lots Of *Real-Time Processing Power*
  - Reliable *Interfacing*
  - Seamless *Integration*
Role of NI Technologies

- Real-Time Processing Power
Role of NI Technologies: Micro-Grid Utility Integration
Role of NI Technologies
Role of NI Technologies: Measurement and State Estimation

State Estimation

Must Be

Real-Time

Grid Model + State Estimation /Partial Observation

Data From Geographically Dispersed Entities
Role of NI Technologies: Measurement and State Estimation

State Estimation

*Must Be*

*Real-Time*

Data From Geographically Dispersed Entities
Role of NI Technologies: Demand Response

• Change Homes To Active Nodes Of Smart Network

• **Interoperability** Of Smart Homes With The Network

• **Two Interconnected Devices:**
  - Device For Smart Load Controlling
  - Smart Meter
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FE&EE: Involvement in Smart Grid Related Issues

- “Identification of Suitable Technologies for the Implementation of Smart Grid Infrastructure”, MS Thesis
- “Impact on the PV System: Climatic and Technical Variables”, MS Thesis
- “State Estimation Technique for Impedance Matching in Distribution feeder Reconfiguration”, PhD Thesis
Case Study:

• “Identification of Suitable Technologies for the Implementation of Smart Grid Infrastructure”, MS Thesis

• “Impact on the PV System: Climatic and Technical Variables”, MS Thesis

• “State Estimation Technique for Impedance Matching in Distribution Feeder Reconfiguration”, PhD Thesis


Case Study:

- Pakistan
  - Energy Crisis (Apart From Of Course Other Crisis)
  - Huge Solar Potential
  - 5kWh/msq/day
  - Increasing Trend Towards Solar
Case Study:

- **PV Module**
  - Characterization With Respect To Technical/Climatic Variables
  - Enhanced Simulation Model: **LabVIEW**
  - Three Variables: Temperature, Irradiance And **Angle**
  - Experimentation In Real Time: Courtesy Of **NI**
Case Study: Experimental Setup
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Conclusions

- Smart Grid Global Market by 2020: $400 Billion
- Smart Meters Globally by 2020: 800 Million
- US Smart Grid Annual Benefits by 2019: $130 Billion
- Needs RT- Processing, Interfacing, Integration
- Role For NI Products
Thank You!