Distributed Power Flow Control Using Smart Wires for Energy Routing

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Project Objective and Differentiation

Objective:
- Develop a distributed approach to power flow control
- Implement Smart Wires, a combination of PowerLine Guardians installed on transmission lines, a master controller managing the devices, and an ecosystem of power system tools

Differentiation:
- Low cost via mass manufacturer, electrically/physically floating, use of COTS components
- Reliability by distribution and elimination of single point of failure
- Definition of product and testing requirements in collaboration with utilities (NEETRAC Smart Wire Focused Initiative)
Project Challenges and Metrics

Challenges:
- Distributed solutions require robust hardware and communications
- Existing simulation tools to date are unable to demonstrate full capabilities of the devices
- Disconnect between project timeline and utility adoption process

Key Metrics:
- 50 μH injection per PowerLine Guardian at rated current
- <150 lbs. per PowerLine Guardian
- Fault rating of 63 kA for 30 cycles
- <5% PowerLine Guardian failure rate after 3 months of test bed operation
- Development of a suite of simulation tools
- Simulation results demonstrating a >30% improvement in ATC using Smart Wires
Tool Development

Collaboration with Key Partners led to Robust Tool Development

1. **Integrated PowerLine Guardians into PowerWorld Simulator**
   Power flow, contingency analysis, OPF, SCOPF, and ATC algorithms and tested on >10,000 bus balanced networks

2. **Incorporated PowerLine Guardians into EDD’s DEW**
   Power flow and optimal planning algorithms and tested on >7,000 bus unbalanced networks

3. **Developed distributed CSCOPF**
   Compatible with PowerLine Guardians and able to solve >100 bus systems

4. **Developed probabilistic state estimator**
   Compatible with PowerLine Guardians able to solve >100 bus system
Simulations Results – Increase Transfer Capacity

PowerLine Guardians dramatically increase transfer capacity in PJM

• Reduces the need for expensive capacity payments.
• Prior to PowerLine Guardian deployment, PJM capacity auctions cleared in the West at ~$10/kW and in the East as high as $90/kW for the year.
• Derived savings assume:
  • Auction clearing prices are unchanged
  • Ignores energy savings which would reduce payback period

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**Project Contributions**

- **Manufacture of power flow controllers** that exceeded utility-specified requirements
- **Deployment and multi-year operation** of 100 power flow controllers on the TVA transmission grid

**Overall Project Accomplishments**

- **Development of simulation tools** to assess the impact of PowerLine Guardians
- **Creation of methodologies** for planning and operating a system with ubiquitous distributed power flow controller
- **Plan for integration** into the broader utility ecosystem (EMS, IT, cybersecurity, planning, operations, asset management)
Remaining Challenges

- **Further tool development:**
  - Planning horizon – SCUC integration and additional planning tools
  - Operational horizon – state estimator, RTCA, SCUC, SCOPF tools

- **Exhaustive testing** to ensure tools are robust under all expected conditions (i.e. high penetration of PowerLine Guardians)

- **Adoption** of new tools
Technology-to-Market

Objective: Sell the vision of the dynamic grid

Target audience:
- Utilities: assess the value of the dynamic grid and deploy Smart Wires as a building block of the dynamic grid
- Regulators/ISOs/stakeholders: support the dynamic grid vision

Major developments since last meeting:
- New customer: EirGrid
- Follow-up order: Southern Company
- Design and installation of Generation 2 devices
- Successful round of fund raising
Post ARPA-E Goals & Risks

Goals:

- Increase adoption of distributed power flow control
- Expand product line (Router family)
- Integrate into major EMS and MMS platforms
- Develop SCUC and long-term planning tools incorporating all power flow controllers – Energy Exemplar partnership

Risks:

- Timeline for adoption of new technologies and business practices in the utility sector
- Misalignment of incentives in the transmission sector
Conclusions

- Developed and deployed power flow controllers exceeding utility requirements for the transmission system
- Developed an ecosystem of power system tools to support technology adoption
- Continued commercial success with 3 customers and robust sales pipeline for 2015
- Continued stakeholder engagement to drive large-scale adoption