To Err is Human: Grid Automation and Operator Performance

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Introduction: Sandia's Focus on Energy Security

- Energy security is central to Sandia's mission and is a cross-cutting capability
- Reliability and resilience of the electric grid is becoming a high-priority area for Sandia and supported by a diverse portfolio of capabilities and expertise:
  - Power systems engineering
  - Complex systems and resilience modeling
  - Critical-infrastructure protection
  - Human reliability and human factors research
- Cross-disciplinary work encouraged
- Ideal platform to investigate the human dimension of grid resilience

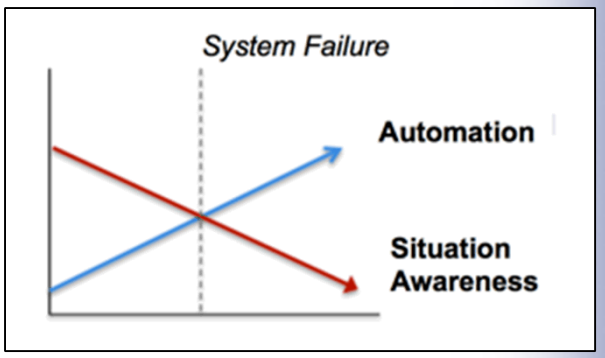
Human Dimension Is Essential to Grid Modernization

- Grid architecture is rapid transforming: smarter and more decentralized

- This transformation to a “smart grid” is enabled by advanced automation; one goal is self-healing

- But the grid will remain a human-in-the-loop critical infrastructure for the foreseeable future

Human Dimension Is Also Critical to Grid Resilience



- Automation introduces risk: inverse correlation with situational awareness

- Humans are most prone to error, bias and misjudgment during critical incidents

- Bad things can happen when human operators lose control

Manhattan, 2003

So California, 2009

"Structurally sound aircraft plummet to earth, ships run aground in calm seas, industrial machines run awry…*all because of incompatibilities between the way things are designed and the way people perceive, think, and act.*" **- Steven Casey, 1993**

Important to Get Automation Right

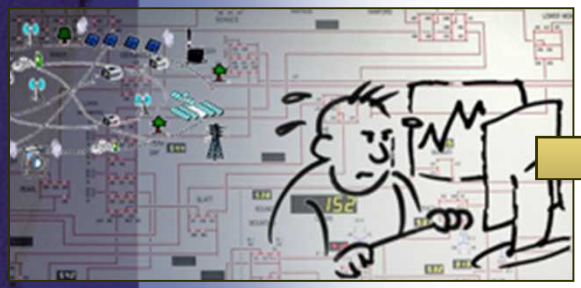
"We saw in our own testing that human drivers can't always be trusted to dip in and out of driving when the car is encouraging them to sit back and relax." Chris Urmson, Google.

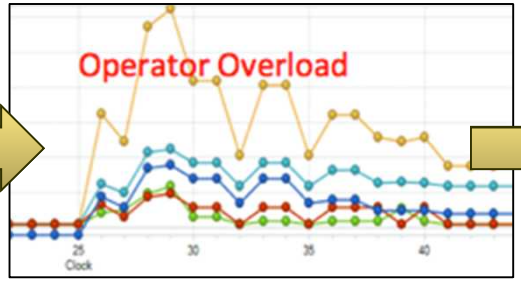

TECHNICAL GLITCH!
HUMAN ERROR!

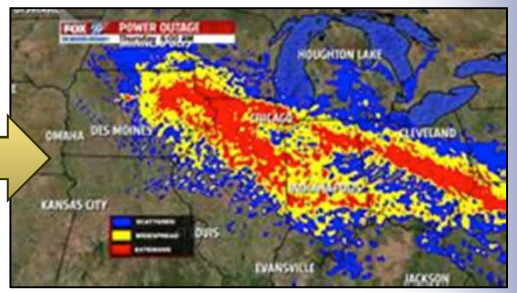
"Improving Grid Resilience (through) Informed Decision-making," or IGRID Project

Pilot Study with Three Objectives:

1) Identify causal relationships between automated technologies and grid operator performance;
2) Develop measures of human performance as a function of automation; and
3) Instantiate the impact of 1) and 2) on grid performance through the development of a cause-effect model







"…new data-visualization methods and tools to improve decision making by system operators" is key DOE objective." -- DOE Grid Modernization Roadmap

Three-Way Partnership

Partner	Objectives	Technical Contributions
Sandia US DOE National Laboratory and major research institution in the field of energy	To understand the human dimension of grid resilience in order to increase the security and reliability of our nation's rapidly transforming distribution grid.	Expertise in multiple areas: • Human Reliability and Human Factors Research • Power Systems Engineering • Computational Modeling • Complex Systems and Resilience
Green Mountain Power Leader in grid modernization; active promoter of distributed e resources. Rolling out sensors, autor reclosers, switchgear…	To 1) increase their confidence in new technologies (safety and reliability), 2) better understand the ROI; 3) demonstrate impact on grid performance; and 4) improve operator training and effectiveness.	Access: • Operators and GMP management • Network and SCADA data Technical Assistance • Scenario development and experimental support
Oracle Developer of an advanced distribution management system (MS). Called Network MS, or NMS, th support automation cap including FLISR.	To obtain data that will 1) help improve the usability of their Network Management System (NMS) software; 2) quantify the benefits of automation, measured in customer minutes interrupted (CMI); 3) expand their market share.	Technical Assistance: • Reproduced the GMP network • Re-created scenarios in their simulation • Contributed to exp. design • Conducted training sessions

Three-Part Technical Approach

- Part 1: Observational and cognitive studies*:*
  -- Direct viewing of GMP operators in real time
  -- Applied Cognitive Task Analysis
- -- Defined expertise in this domain.

- **Part 2: Experimental studies of GMP operators**
  -- Conducted on Oracle training simulator
  -- Operators asked to complete multiple outage scenarios with and without the aid of automation.
  -- Restoration times and customer outages carefully measured

- Part 3: Development of a grid performance model, populated with both historical outage data and experimental data.

The IGRID Experiment: Three Hypotheses

1. Experts will be faster than non-experts to complete the scenarios, that is to appropriately restore power to all customers, regardless of complexity or automated condition.

2. Restoration will be faster with the aid of automation than without automation, regardless of expertise.

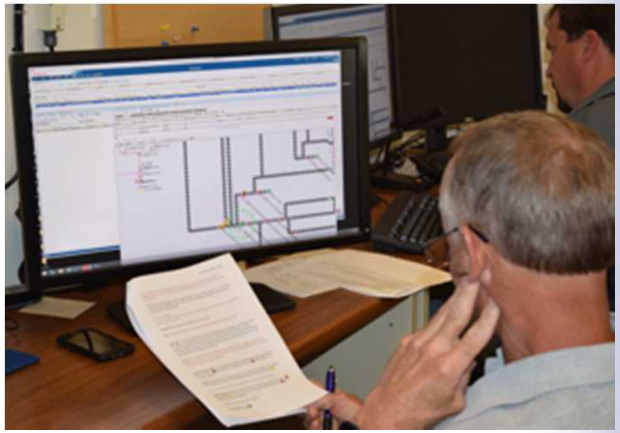
3. Experts will make fewer decision errors than non-experts.

4. Faster restoration will result in a measurable drop in Customer Minutes Interrupted (CMI.)

5. With increasing complexity, dependence on FLISR automation results in lack of situational awareness and an increase in errors and CMI.

Scenario-Based Experimental Methodology

No	Level of Difficulty	FLISR-Enabled
1	low	no
2	low	yes
3	medium	no
4	medium	yes
5	high	no

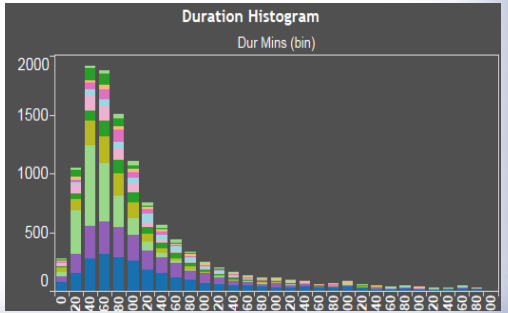


Five Outage Scenarios

-- Scenarios presented to operator on the NMS training simulator
-- Operator instructed to restore outages as safely and efficiently as possible
-- Collected data on every operator action; not only what he did but how long each action took
-- Four sources of data: NMS, Snag-It, observational notes, stopwatches.
-- Conducted post-experiment interviews

What We Hoped to Learn

- The circumstances under which automation either enhances or hinders grid restoration
- Whether the definitions of novice and expert remain intact under increasing levels of automation. Consider the following:
  - -- "The best decisions are derived between the ears of an experienced operator." (GMP)
  - – "Operational efficiencies in the 21st century will be defined by the efficiency with which a person clicks a mouse." (Oracle)
- The degree to which automation, coupled with operator expertise, reduces CMI.



What We *Have* Learned So Far (Preliminary Observations)

Expertise

Our most-expert operator was the slowest. Experience or lack of proficiency?

Situational Awareness

Under simulated conditions, evidence suggests that situational awareness may be diminished: Operators were "racing the clock," making decisions onscreen before interacting with the field crew.

Critical Thinking Skills

Less apt to be reflective. Had a tendency to "go rogue," as in, open/close switches to explore the consequences.

Trust in Automation

Vast majority of operators like the automation; see it as the future. But think trust will be an issue.

IGRID: Platform for Further Investigation

Goal is to expand our work and our operator pool to draw more definitive conclusions regarding the interactions of operators and automation (e.g., SA, trust, critical thinking skills, expertise, proficiency)

Extensible IGRID methodology allows us to investigate other grid vulnerabilities/challenges:

- Cyberattacks (e.g., intrusion detection)
- Extreme weather events
- Blue-sky events
- High-penetration of intermittent renewables

Why This Field of Research Matters:

- Research on the human dimension of grid resilience has not kept pace with technological advances: vulnerabilities and opportunities exist in this space that are not well understood

- Opportunities Are Many:
  - Strategic system planning that considers grid behavior as a function of operator behavior
  - Training and hiring of operators: need to reduce operational vulnerabilities and maintain operator performance as automation increases
  - Development and deployment of more effective human-machine interfaces and real-time decision-support tools
  - Justification of investing in automation/making the case to regulators

- Can Inform, and be integrated with, other grid resilience efforts

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Questions?

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