Life Lessons and Reflections from a 42+ Year Career at a Dense Urban Utility

Presenter: Pat Duggan
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Smart Grid Educational Series Webinar for November 2013
my own experience and history...

Patrick M Duggan Enterprises, Inc
Some front end personal perspectives...
Not about me, but about some incredible people I worked with

• My career aspirations in 1968:
  • Prior summers- Test Bureau (2) & Inside Plant
  • I’ll just stay a few years for advanced degree
  • “Don’t get sick son… they don’t like that.”
  • 1968 Strike- East River Control Room
  • “50 Year” men… great teachers… including teaching humility
    – An INCREDI BLY GREAT first boss (and many others)
    – A non-malicious yeller with a Very Big Heart
    – AEP move to Columbus
    – A “Chief-of-the-Boat”
    – And so very many other bosses, co-workers and friends that I respect
      and enjoyed working with… quite a few that are very very special to me.
Con Edison Overview  *statistics approximate unless identified w/date

- **Customers** (meters) 3,300,000
- **Peak Demand** 13,322 Megawatts (MW) at 5 p.m. (July. 2013)
- **Avg System Density** 19.8 MW/mi²
- **Urban Territory** Manhattan
  - Urban Area 23 mi²
  - Urban Demand 5,437 MW (July 2005)
  - Urban Density 221 MW/mi² up to 2,000 MW/mi²
- **Con Edison fault currents**
  - 345kV & 138kV systems = 63,000 amps
  - 13kV system = 20,000 to 40,000 amps

Service Territory

Entire System: 660 mi²
New York City & Westchester Country
What is Dense Urban?

- Very high reliability and customer service expectations
- High load densities
- selected N-2 design requirements
- High fault currents
- High load growth
- Urban area & community issues
  - Traffic restrictions
  - Noise restrictions
  - Environmental impacts
  - Impacts of Outages
  - Public Perceptions
  - Real Estate Prices & Availabilities
  - Costs of doing business in NYC
Some other urban issues...

• Telephone Lines (Judge Green, route insurance, green death, SOCCSX, relay protection failures, common carrier credibility???)

• Rats, road salt and MOISTURE (embedded failures?)

• Environmental Issues
  – Lost Tools we didn’t know would hurt us (asbestos, lead, PCBs)
  – Underground infrastructure multiplies the problem (muck & leakage)
  – New massive loads (to prevent storm runoff from overwhelming sewage treatment)

• Interference Costs (water tunnels & mains, sewers, roadwork, subways, communications + steam, gas & oil lines)

• Street settling and undermining impacts on infrastructure
Footprint of Current Substation Design

Con Edison Distribution (138kV / 13.8kV) Substation example

Design:
- 5 transformers
- Supply 250 MW

Footprint:
- 25,000 to 40,000 ft.²

Height:
- 40 ft. to 60 ft.
  (4 “stories”)
New York City
Some emerging general utility issues

- Interdependencies
  - Communication
  - More Regionalized Fuel (+regional & price diversity + seasonal gas diversion for heating in the northeast)

- Wide Area Monitoring (a necessity whether we reach out to more remote assets, or try to monitor and manage a substantial future penetration of distributed assets)

- The distribution system will be much more volatile; a challenge to distinguish load changes and trends from distributed resource remaining availabilities

- Ubiquitous GPS applications (Solar Storms> not just GIC but communication disruptions, the ACE Satellite & EPRI/NASA early warnings & commercialization of space missions)

- Phasor Time stamps

- Situational Awareness (of an evolving system that can fragment)
Some more personal perspectives...

• Sea of Desks → Cubicles → Open Offices → Computers → Laptops → PDAs → SmartPhones → Notebooks

• System versus Discipline Engineers

• Suits vs. White Collars vs. Blue Collars
  – Cross-Discipline Training (now includes IT & Cyber)
  – Don’t wear 3 piece suits to Construction sites (regulators)
  – Incredible value of “hands on” and empirical knowledge
  – Treating everyone the same as you’d like to be treated (respect, kindness, concern for their job & real concern for personal problems, well being and advancement)
  – Gate-keepers (secretaries, self-secretaries and executive assistants)

• SYNERGIES (S/Ss are a “test bed” for distribution)
All utilities are different not easier... just Different CHALLENGES

Service Territory Characteristics

- Weather (frequencies and severities of temperature, humidity, lightning, wind, hurricane, tornado, flooding, icing)
- Geography, terrain, trees, other hazards (e.g. earthquakes)
- Access to water (Southwest, Lake Meade)
- Latitude (GIC susceptibility)
- Alternative fuels (e.g. gas curtailment for home heating)
- Load Density vs. Drive Time
- Congestion (above & below ground)
- Real Estate (cost, availability, rezoning)
- Cost of Doing Business
- Work Restrictions (traffic, noise, holiday truck restrictions)
All utilities are different (continued)...

Grid Characteristics

- Transmission & Generation Access
- Generation capacity (rich/poor vs load)
- Overhead, underground, network, radial, N-1, N-2
- Fault Current (too high, not enough for protection)
- Infrastructure condition (not age!), ratings and adequacy for load
- R-O-W access and expandability
- Eastern Interconnect vs. looser western grid (data at the plug vs. “it’s all over by then”- need for communication infrastructure)
All utilities are different (continued)...

Operational Characteristics

- Capacitive (overhead) or Inductive (underground)
- Voltage Regulation
- Impedance of Xfmrs
- Series Reactors
- Types of protection (e.g. distance relaying vs phone lines)
- Pre-tripping
- Separate overlay networks & normally open bus ties
- Communication dependencies (solar flare impacts on GPS, communication & time stamps)
- Break-Before-Make or vice versa
- Special Protection Schemes
- Market congestion
- Impacts of contingencies (after N-1; N-2 = N-1)
All utilities are different (continued)...

Economic Characteristics

• Generation Regulated/Deregulated/Divested
• Rates (Demand, Time-of-Day, DeCoupled)
• Economic development &/or Vertical Growth
• Joint planning with municipality
• Interference costs
• Market rules
• Current relationship with Regulator
All utilities are different (continued)...

Customer Characteristics

- Structures (1 family, multi-family, high rise commercial or residential, industrial)

- Demands for Reliability (financial centers, hospitals, mass transit, production lines, other public infrastructures like water delivery)

- Loss of Customers (Katrina, Detroit, DC System in NYC prior to retirement)

- Customer Expectations

- Distributed Generation
All utilities are different (continued)...

Load Characteristics

- Residential, Industrial, Office
- Particular Loads (arc furnaces, server farms, future super computers)
- Winter -, Summer- Daily- Peaks
- Load Types (A/C penetration & humidity, rolling peaks)
- Load Growth
- Penetration Rates & Characteristics for new loads (Flat Screen TV, TV Top appliances, PEVs, Vampire Loads)
- Privacy
- Electric Permits (Degree of Detail- e.g. PEVs)
- Critical Loads
- Needs for Resiliency
All utilities are different (continued)...

Regulatory Situation

- Current Issues with your Regulator
- Rate Cases
- Rate Base
- Performance Based Rates
- Penalties
All utilities are different (continued)...

Neighboring Utilities

- Generation (rich/poor)
- Load (rich/poor)
- Type of protection (distance relaying e.g. August 2003)
- Are you a Path for someone else? [Utility A (gen rich) - YOU - Utility B (load rich)]
- Are you subject to Loop Flows that impact your Operation?
Examples of operational CONFLICTS between Utilities

- TVA “almost” Blackout
- August 2003 blackout “oversimplified”
- CA lack of generation assets
- CT-LI Long Island Sound Neptune Cable
- Mid-West Wind vs East Cost Offshore wind
- FCC Broadband & Sharing Emergency Spectrum
- NY Energy Highway Plan? (Quebec vs western NY wind)
World Energy Perspective
Energy efficiency policies: what works and what does not

Report from World Energy Council (WEC) and France's energy and environment agency, ADEME

The energy efficiency report recommends nine core policy proposals that will help to embed efficiency within the future development agenda:

• Energy prices should reflect real costs of supply and thus ensure consumers get the right price signals.

• Consumers need information to be able to make informed decisions.

• Smart billing represents a significant potential of energy savings.

• Innovative financing tools are needed to support investments by consumers.

• The quality of energy-efficient equipment and services should be verified.

• Regulations should be properly enforced and regularly strengthened.

• Consumer behavior should be examined and addressed, especially in terms of growing reliance on ICTs (information & communication technologies).

• It is necessary to monitor the trends in energy efficiency to be able to evaluate the real impact of energy-efficiency policies.

• International and regional cooperation in support of energy efficiency should be enhanced.
The Limits of Efficiency as THE ONLY Solution

- I personally believe energy efficiency will be a one time “belt tightening” followed in the best case by a reduction in the rate of future load growth.

- If you ask most people, they will likely tell you that they try to conserve energy (e.g. lights & thermostats) …. BUT…
  - Bigger “instant on” TVs (old TVs migrate to other rooms like refrigerators)
  - Multiple TV sets may be on, so we know everything that is going on minute by minute & room to room (IPad is a new portable TV)
  - TV top 7x24 appliances to record store & replay TV we would have missed
  - Multiple mobile communication and entertainment devices that require charging, and in many cases additionally add to the growing collection of “vampire loads”
  - More & more “baby boomers” retired and home all day
Has the last new high penetration load type been invented???? PROBABLY NOT

Just look at a short list so far…Sewing Machines, Irons, Electric cars, Washing machines, Dryers, refrigerators, Radio, Electric blankets, Electric Trolleys, Traffic Lights and Road Lighting, Telephones, Advertising Lighting, Elevators, Escalators, TV, Air conditioners, Flood lights and stadium lighting, Pagers, Swimming pool pumps and heaters, Hair Dryers, Vacuums, Dehumidifiers, Air Cleaners, Video games, Personal computers, Printers and scanners, DVRs, Personal Digital Computers, Portable phones, Cable Boxes, Cell Phones, Laptops, Heat Pumps, Instant on TVs, IPods, IPads, Flat Screen TVs, Apple TV, Hybrids and PEVs…

WHAT DID I MISS… AND WHAT’S NEXT???
How about a few of the new or recently emerging very large electrical loads:

- The Digital Grid (e.g. relays used to be powered by CTs & PTs)
- The Smart Grid itself
- Temporary feeds for cruise ships (medium sized towns) when docked
- Increases in Train loads (due to increases in weight for safety)
- Server Farms for the Internet
- Massive pumps to prevent sewer runoff from overwhelming waste treatment systems

and some potential future loads:

- Advanced lower temperature heat pumps
- Cooling systems for supercomputers
- Food irradiation at supermarkets
- Air and water disinfection where large crowds congregate
...But what if we really got serious about energy efficiency?

Jevons Dismal Theorem, also referred to as Jevons Paradox was first developed by William Stanley Jevons in 1865, as a element of his evaluation of the economic impacts on the use of coal in England. The Theorem at its core proposes that an increase in efficiency of use of a resource does not in fact preserve the resource, but leads to increased use of the resource instead of a reduced use. It has proven to apply to many other cases and is now a generally accepted phenomenon not just for coal, but for food production, the continually expanding use of electricity itself and can most recently be seen in the proliferation of LED lighting in places like YIELD traffic signs and Pier number signs on NYC’s West Side highway. (The history and many more illustrative examples of this principle can be found in The Myth of Resource Efficiency: The Jevons Paradox (Earthscan Research Editions John M. Polimeni (Author), Kozo Mayumi (Author), Mario Giampietro (Author), Blake Alcott (Author)).
Energy Storage - The Missing Application

• Frequency, Voltage, VAR Regulation (e.g. for intermittent or volatile gen, loads or load pockets)

• System Peak Capacity/Demand Management

• Spinning Reserve

• Feeder capacity support (voltage sag mitigation &/or feeding from both ends to delay/avoid feeder upgrade)

• Substation capacity support (xfmrs, bkrs, buses, fault duties, real estate)

• Community Energy Storage (matched with distribution xfmrs)

Needs to be Cost & Footprint Effective for Urban Load Centers
So what does that mean for the Smart Grid?... more a journey than a universal definition

• Each utility (and regulator) will look at Smart Grid solutions through the prism of their own problems and concerns

• Starting points are individual utility business case driven

• DEMOs verify feasibilities, but only sustained business value supports rollouts

• A good place to look for guidance is in the various responses made to the New York State PSC, who essentially asked all utilities and interested parties, "how can we do this cost effectively?".

(I like the Con Edison of NY responses, in particular... having been a minor contributor to it.)
Smarter more flexible grid

• Functional needs:
  – Building substations that use all of our equipment more effectively
  – Sharing capacity wherever it is needed
  – Replacing infrastructure as it ages "just in time"
  – Better asset utilization (sharing N-2 redundancy))
  – Power Xfmr sharing
  – Load transfers
  – Submersible fast transfer switches (load Xfrs between substations)
  – Innovative infrastructures & smart charging stations to deal with EV mobility
  – Fault current limiters
    • superconductors - recovery time
    • DGs - availability to serve peak
Information makes it work

• Communication and control of equipment in the field
• Real time fault locating (reducing momentary outages)
• Real time outage identification
• Condition based monitoring to minimize expensive in-service failures & unplanned outages
• Selected communication path redundancies
• Layered cybersecurity (i.e. focused where needed) particularly for legacy critical cyber assets
• Data use driven communication priorities & timeliness
• Mitigation of “burst data” and encryption burdens
• Model transfer capabilities (e.g. LIPA EMS to Transmission Planning model xfrs)
INTEROPERABILITY makes it survivable

- Lower risk of technology obsolescence for utilities
- Supports economies of scale
- Reduced complexity for customer purchase decisions
- Security related benefits (e.g. less one off patches VS “false security by obscurity”)
- More standard customer data retrieval interfaces
- Ease of interconnection today (right now)
- Reduced “life cycle” costs as supporting software is modified and expanded over time (ability to incorporate functionality & performance advances)
- Options for “best of breed” versus “fork-lift” replacements
- Ease of communication across traditional grid “silos” (more sophisticated and broad based analytical tools)
- Simulation, modeling and machine learning across traditional grid “silos”
- Ease of sharing less costly follow-on applications between utilities
- Ease of evolution, integration and synergies over time
In Summary- The grid is becoming more complex and less forgiving...

- Existing Grid has very limited communication dependencies

- Local zonal relay protection (one case where silos work very well and relatively failsafe design is possible)

- WAMs- Wide Area Measurement Systems (a necessity whether we reach out to remote FACTs devices, or try to monitor and manage a significant future penetration of distributed assets)

- Managing failures will be a challenge (wide area = no "fail safe" state; interpreting between events, sensor failures, communication failures)

- Machine learning will be needed to interpret data and turn it into understandable, prioritized, timely information

- Interoperability, cybersecurity and privacy for the smart grid
Existing Grid has very limited communication dependencies

- Local zonal relay protection (one case where silos work very well and relatively failsafe design is possible)
- Managing failures will be a challenge (wide area = no "fail safe" state; interpreting between events, sensor failures, communication failures)
- Machine learning will be needed to interpret data and turn it into understandable, prioritized, timely information… a distribution “State Estimator”? 
So What is the biggest thickest BRICK WALL for dense urban utilities
Significant Issues relative to fault currents

Sources of Fault Current

• High load density = high required capacity
• Parallel systems (e.g. N-2 redundancies)
• New transmission sources (National Interest Electric Transmission Corridors, Remote Renewables to load centers)
• New IPPs
• New distributed generators
• Future technologies (energy storage, PEVs, has the last new load type been invented?, electricity as an alternate urban fuel, etc.)
• More realistic calculations:
  – motor contributions, DC offsets, actual voltages and transformer tap positions (vs. nominal)
  – demonstrated by oscillograph readings

INCREASED LOAD = INCREASED CAPACITY = INCREASED FAULT CURRENTS
Why they are of concern to Con Edison?

• Circuit breaker interruption ratings

• Impracticality of just continuing breaker replacements
  
  • **bracing** (Ckt Bkrs, Swgr & Bus & other equipment)
  
  • increased forces and thermal stress
  
  • adequacy & safety of grounding
  
  • “through-fault” & contingent damage impacts on even broader vicinities of “nearby” equipment

• Even if damage is not immediate there is accumulated damage & loss of life

• Stresses and shocks to distribution components may already contribute to moisture entry & be embedded in current failure rates
What is the linkage between fault currents and the application of DGs?

- PSC mandates Con Edison support for DG interconnections
- Fault Duties versus Breaker Ratings prevent DG interconnection in significant portions of Manhattan
- Ongoing distribution voltage level substation breaker uprate programs have cost as much as $20M/year… and do not permanently solve the problem
- Solutions like explosive fuses would make DGs unavailable to serve peak demand following a nearby external fault (involving other equipment) until the fuses can be safely removed and replaced immediately
- Fault current limiters (of lower ratings could allow DGs to “ride through” faults and remain available to serve peak load immediately following external faults... Greatly improving their usefulness and business case
Other things I didn’t have time to talk about...

- Complexities and conflicts within Grid Optimization
- FCL details, issues, benefits and alternatives
- Smart Grid challenges, applications and benefits
- PEV & charger challenges
- Future R&D Needs
- The necessity of engagement
- Honest Brokers
- Personal Engagement tips
- Industry Information Sources
- Power Factor Mitigation? (distributed renewables hogging unity PF)
- An infinite number of war stories
Thank you !!!

• Any questions?...

Pat Duggan
patmduggan@gmail.com