# Today’s Agenda

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TODAY’S GOAL

- Begin conversations about EUI
- Learn about EUI efficiency projects
  - Around the country – Ron Schoff, EPRI
  - Here in MN – Lisa Severson, Minnkota
- Set up discussions for future meetings about policy barriers/issues concerning EUI efficiency
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Definition of EUI

- Infrastructure is any equipment or facilities owned by a utility used to deliver electric energy to consumers
- Generation, Transmission, Distribution
- Everything upstream of the meter
- Also called supply-side
Projects owned by a utility that:

- Replace or modify existing infrastructure to conserve energy
- Conserve energy by recovering waste heat from infrastructure
An estimated 12-15% of the nation’s electricity production is consumed by generation auxiliary loads, transmission and distribution losses, and substation consumption.
Current CIP EUI Policy

- MN Next Generation Energy Act (2007) established conservation as a resource
- NGEA specifically allows utilities to count infrastructure conservation savings*

*Minnesota Statute Section 216B.241, Subd.1c(d). Infrastructure savings count after 1% minimum goal is met AND must result in efficiency greater than would have occurred through normal maintenance activity
- Can include utility-owned buildings
- Must result in efficiency greater than would have occurred through “normal maintenance activity”
- Only count beyond minimum 1% savings
- Non-TRM measures require approval
- Can carry over savings for 5 years
Example EUI Technologies

- High efficiency transformers
- Low-loss conductors
- Generation heat rate improvements
- Conservation Voltage Reduction
- Varied measures at utility-owned facilities
High Efficiency Distribution Transformer Exceeds NEMA Premium Efficiency rating

Photo from Hammond Power Solutions
Low-loss conductors can improve distribution and transmission efficiency

Photo from General Cable
Controls strategies like Conservation Voltage Reduction can achieve energy savings.
Example EUI Technologies (cont.)

- Substation waste heat recovery
- Upgrade to HVDC transmission lines
- Accelerated maintenance activities
- Advanced systems controls (for example enabling load leveling, dispatch priorities, or demand response)
HVDC Transmission Line
Lower losses than typical high-voltage AC lines

Photo from Great River Energy
Projects underway are aimed at addressing technical and policy uncertainty.

Develop as a tool for post-“low-hanging fruit” phase of the energy efficiency movement.
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EUI Efforts in Minnesota

- TRM Measure Development
  - Completed 2016
- Potential Study
  - Underway - to be completed 2017
- Policy Review (includes today’s meeting)
  - Underway – to be completed 2018

Several EUI Measures developed in 2016

• Generation Heat Rate Improvements
• Conservation Voltage Reduction (CVR)
• High Efficiency Transformers

Annual kWh Savings (Ref. 1)

\[
= 8,766 \times \left( \left( \frac{\text{Load}_{\text{peak}}}{\text{FLC}_{\text{base}}} \right)^2 \times \text{FLL}_{\text{base}} \times \text{LossFactor} + \text{NLL}_{\text{base}} \right) - \left( \left( \frac{\text{Load}_{\text{peak}}}{\text{FLC}_{\text{ee}}} \right)^2 \times \text{FLL}_{\text{ee}} \times \text{LossFactor} + \text{NLL}_{\text{ee}} \right)
\]

Peak kW Savings

\[
= \left( \left( \frac{\text{Load}_{\text{peak}}}{\text{FLC}_{\text{base}}} \right)^2 \times \text{FLL}_{\text{base}} + \text{NLL}_{\text{base}} \right) - \left( \left( \frac{\text{Load}_{\text{peak}}}{\text{FLC}_{\text{ee}}} \right)^2 \times \text{FLL}_{\text{ee}} + \text{NLL}_{\text{ee}} \right)
\]
Estimate the potential for improving efficiency and reducing carbon emissions related to Electric Utility Infrastructure in Minnesota

- Develop models and collect all data required to populate them – your organization may be able to help
- Present potential with recommendations to effectively prioritize implementation of EUI efficiency projects

https://www.mncee.org/mnsupplystudy/about/
Overview of EUI Policy Review

- Project Goals:
  - Understand existing policies concerning EUI
  - Examine (dis)incentives to improve EUI efficiency
  - Recommend policy changes or clarifications to leverage EUI efficiency to meet MN goals

- Conduct 4 public stakeholder meetings (Today is #1)
- Develop roadmap to increase EUI efficiency
- Funding from DOE grant
- Minnesota is leading the country
Policy Review Project Team

Study lead
Collect data
Produce deliverables

Stakeholder engagement
Coordination across ongoing EUI projects
Stakeholder Meeting Topics

- Meeting 1 – 7/28/2017 - EUI Technologies
- Meeting 2 – 10/20/2017 – EUI Policies
- Meeting 3 – Late 2017 – EUI Financing
- Meeting 4 – TBD – Comprehensive EUI Landscape in Minnesota
EUI Policy Review Outcomes

- Inform participants
- Facilitate discussion
- Solicit ideas
- Provide specific recommendations to create a roadmap to driving EUI efficiency deployment

You (stakeholders) can shape EUI policy
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Electric Infrastructure Technologies for Energy Conservation

Ronald L. Schoff
Senior Program Manager, Technology Innovation

Minnesota EUI Statewide Energy Efficiency Policy Review

July 28, 2017
Intro to EPRI

**BORN IN A BLACKOUT**

Founded in 1972 as an independent, nonprofit center for public interest energy and environmental research

New York City, The Great Northeast Blackout, 1965

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**EPRI’S VALUE**

To provide value to the public, our members, and the electricity sector

**THOUGHT LEADERSHIP**

**INDUSTRY EXPERTISE**

**COLLABORATIVE MODEL**

---

**OUR MEMBERS...**

- 450+ participants in more than 30 countries
- EPRI members generate approximately 90% of the electricity in the United States
- International funding – nearly 25% of EPRI’s research, development, and demonstrations
Customers at the center

Flexible central generation, storage, new loads, active customers and better forecasts balance variable generation

Physical connections augmented by secure data and communications

Implements Reliability

Promotes Efficiency

Expands Customer Choice

For more information visit http://ien.epri.com
Energy and Natural Resource Systems are Integrated to Provide Reliable, Safe, Affordable Cleaner Energy and Expanded Customer Choice
Why Do We Need an Integrated Energy Network?

Integration enables quick assessment, containment, and rapid response.

Digitalization of energy provides both near-term and unforeseeable opportunities.

Integration makes possible a wide array of efficient, affordable, cleaner energy options.

For more information visit [http://ien.epri.com](http://ien.epri.com)
Research Imperatives to Support IEN Pathways

Producing Cleaner Energy
- Next-Generation Renewables
- Advanced Nuclear Energy Systems
- Novel Fossil Cycles with CCUS
- Efficient Electrification

Integrating Energy Resources
- Energy Storage
- Grid Modernization
- Water-Energy Nexus
- Cross-Cutting Technologies

Supporting Science & Technology R&D

Next-Generation Renewables
Advanced Nuclear Energy Systems
Novel Fossil Cycles with CCUS
Efficient Electrification
Energy Storage
Grid Modernization
Water-Energy Nexus
Cross-Cutting Technologies
Cross-Cutting Technologies

- Materials
- Nondestructive Evaluation
- Robotics & Unmanned Aerial Systems
- Sensors
- Data Science & Analytics
- Cyber Security
- Communications
- Modeling & Analysis
Today’s Focus is on Infrastructure

- EPRI’s energy efficiency research covers both the supply and demand side of the electricity sector.
- Significant opportunities for demand-side efficiency improvement exist and can be discussed in another forum.
- The focus today will be on the opportunities to reduce energy use through investments in the electric power supply infrastructure.
Heat Rate Improvement

- Since the mid-1960’s, the average heat rates of coal-fired power plants in the United States have gradually increased due to:
  - Reduced maintenance and upkeep
  - Additional cycling
  - Added pollution controls
  - Decreasing coal quality
- A portion of efficiency loss is potentially recoverable if the correct processes, procedures, and resources are applied and maintained
- Reducing power plant heat rate reduces fuel consumption and costs and reduces CO$_2$ and all other emissions
EPRI Technical Assessments and Case Studies

- EPRI has conducted general technical assessments and site-specific case studies evaluating heat rate improvement potential of different activities.
- Activities can be both capital investments in equipment modifications and changes in operations and maintenance approaches.

Heat rate improvement potential is plant-specific and will require a site-specific assessment – improvement ranges and costs listed here are for general example purposes only.
Assessment of Hypothetical 500-MW Coal Plant

Capital projects:
- Turbine steam seal upgrades
- Turbine section replacements
- Intelligent soot-blowing systems
- Automated boiler drains
- Coal drying systems
- Air heater baskets
- Combustion optimization

- Not all projects generate net benefits with a positive payback
- Heat rate reductions range from 0.10% to 2.50%
- Project positive net benefits range from $30,000/year to $2.9 million/year

Maintenance projects:
- Replacing feed pump turbine steam seals
- Repairing steam and water leaks
- Boiler chemical cleaning
- Repairing boiler air in-leakage
- Cleaning air preheater coils
- Repairing condensate pumps
- Repairing flue gas desulfurization systems

- Heat rate reductions range from 0.03% to 1.50%
- Maintenance annual benefit-cost ratios range from about 1X to more than 100X

Five Site-Specific Case Studies

- **Common issues include:**
  - Combustion problems and high air heater/stack exit gas temperatures
  - Limited heat rate information availability
  - Need for heat rate awareness training, including controllable losses understanding
  - Need for unit and equipment performance testing
  - Feedwater heater train performance problems
  - Need for soot-blowing optimization

- **Common recommendations:**
  - Make heat rate information readily available to more plant personnel (50-150 Btu/kWh)
  - Provide heat rate awareness training to operations staff (50-100 Btu/kWh)
  - Improve utilization of controllable losses information by operations staff (75-100 Btu/kWh)
  - Initiate a routine testing program (75-200 Btu/kWh)
  - Increase routine feedwater heater performance monitoring (30-60 Btu/kWh)
  - Optimize soot-blower operation (70 Btu/kWh)

Unit heat rate improved at four of the five plants with performance improvements ranging from 3-5%.

Low Load and Load Following Impacts on Heat Rate

- Multiple causes:
  - Higher excess combustion air
  - Lower furnace heat absorption
  - Less efficient pumps, motors, compressors
  - Increased steam attenuator flows
  - Lower steam temperatures, turbine efficiency

- Highly site specific

- Need to differentiate between heat rate at steady state low load versus transient loads
Options for Improving Heat Rate with Flexible Operations

- Sliding pressure operation
- Variable-speed drives
- Optimized control schemes and operation of:
  - Boiler draft system fans
  - Pulverizers and firing systems
  - Air quality control systems
  - Cooling water pumps and tower fans
- Minimized flow, pressure, and temperature oscillations
- Performance monitoring

Operational Awareness and Heat Rate Improvement Programs

- Heat Rate Improvement Programs
  - Provide information for decision making
    - Maintenance actions, operational adjustments, and/or physical modifications
  - Create a culture centered on improving plant performance
    - Sharing performance data with the entire plant staff strengthens understanding of how each individual may contribute
  - Mean heat rate improvement of >4% could be achieved at existing plants by implementing an effective heat rate improvement program based on a 1983 utility survey covering 129 fossil generation units

- Remote Monitoring Centers
  - Track and improve equipment reliability
  - Monitor thermal performance and heat rate
  - Heat rate improvements in the range of 2.5-4% attributed to actions resulting from remote monitoring centers

I4Gen Digital Technologies and Implementation Suite

**Insight** through the **Integration** of **Information** for **Intelligent** Generation

**Objectives and Scope**
- Holistic approach to create a digitally connected and dynamic power plant
  - Project 1: I4Gen Working Group
  - Project 2: I4Gen Data Analytics
  - Project 3: I4Gen Case Studies

**Value**
- Performance and reliability benefit for equipment, plants, and fleet
- Workforce efficiency and effectiveness
- Cost reductions and reduced down time
- Manage and control dynamic plant operations

Unique by being an open collaborative project

Intelligent Generation is the dynamic optimization of a plant for a given set of complex objectives
Key Starting Points – I4Gen Supplemental Project

- Platform to manage competing objectives and increase effectiveness is worthwhile
- Plant data and information are valuable
- Connected digital assets is a key enabler
- Embedding intelligence and developing intuitive interaction are important for usability
- Stakeholder feedback is critical
- Path forward is an evolution in deploying current work, applying development efforts and reducing novel technology to practice

I4Gen is targeting the adoption of tools, techniques and enabling technologies to dynamically optimize a plant for a given set of complex objectives
I4Gen Application Areas

- Low-cost Sensor Technologies and New Measurement Capabilities
- Data Analytics, Integration and Visualization
- Advanced Controls and Automation
- Monitoring and Diagnostics
- Digital Worker Technologies
Drivers and Targeted Benefits for I4Gen

Drivers
- Flexible and diverse generation
- Plant Performance (RAM)
- Changing workforce
- Cost competitiveness
- Data & information hold value
- Grid modernization
- Customer engagement

Benefits
- Increase efficiency, availability & reliability
- Improve maintenance & outage planning
- Higher levels of worker effectiveness
- Increase equipment reliability
- O&M cost management
- Enhance decision-making and analysis
- Ability to forecast and proactive responses/actions
- Integration with grid
- Manage complexity with advanced power systems/cycles
Use Case Options: Integrating Digital Worker into O&M

- Identify opportunities to streamline O&M work activities and data capture using mobile/digital technology
- Identify appropriate hardware/software and initiate pilot project
- Evaluate effectiveness through key metrics and make recommendations for enterprise implementation
- Use cases could include electronic work management, equipment inspections and lockout/tagout, location and equipment identification technology, field access to equipment data, etc.
Transmission & Distribution Efficiency Improvement

- Losses in the transmission and distribution grid can be on the order of 5-10%.
- Losses are due to a number of causes and depend on unique network situations; solutions are often site/circumstance specific.
- Efficiency improvement solutions can be:
  - **Passive** – installing new equipment with design or material composition that will reduce losses.
  - **Active** – enabling operators to operate the system in a way that reduces losses through control decision mechanisms, communication and control of equipment, and in some cases coordination with neighboring systems.
  - **Planning and management** – enabling construction and operation of a system in ways that reduce losses.
Transmission Systems

- Research focuses on CO$_2$ reductions in two ways:
  - Efficiency improvements of transmission systems to reduce losses
  - Increased line and system utilization to maximize integration of renewables

- Reduce system losses: coordination of Volt/Var control, voltage upgrades, and loss minimization optimization

- Reduce line and equipment losses: advanced conductors and low-loss substation equipment

- Increase line and system utilization: dynamic ratings and smart transmission control
Demonstration Project Highlights

- **Extra-High Voltage (EHV) overlay**: improves efficiency of the interconnected system by unloading underlying lower-voltage, higher-loss transmission system

- **Substation/Transformer Efficiency**: 15-20% reduction in auxiliary power with improvements ranging from replacing lighting to more complex options such as replacing pumps and transformers

- **Transmission Line Efficiency**: trapezoidal wire conductor can provide 15-20% efficiency improvement over a comparably sized conductor

- **System Loss Reduction**: computational tool for day-ahead optimal scheduling of active and reactive power resources, loss savings at different hours during a full day period range from 0.5% to almost 4%

- **Increase Line/System Utilization**: reconductoring a few miles of existing line with high-temperature low-sag (HTLS) conductor shows a significant benefit in improving asset utilization

Day-ahead reactive power and voltage optimization tool

Functional Diagram

- **Benefits**
  - Provide guidance to the operators to optimize the use of reactive power resources and voltage scheduling
  - 24-hour schedule for system operators to support their decision making over the course of the day
  - Reduced active losses: estimated 0.5-5% (average 2%)
  - Reduced reactive power losses
Voltage Control Optimization to Improve Transmission Efficiency

**Objective:** assess the potential benefits and applicability of near-real-time optimization of voltage control to reduce transmission losses, and to improve overall reactive support

**Approach**
- Winter Peak Day (2)
- 60% Peak Day (2)
- 70% Peak Day (2)
- 50% Peak Day (2)
- Summer Peak Day (2)

**Cases analyzed**
- Winter Peak Day (2)
- 60% Peak Day (2)
- 70% Peak Day (2)
- 50% Peak Day (2)
- Summer Peak Day (2)
Voltage Control Optimization to Improve Transmission Efficiency

- Present operating voltage target schedules are shown to be close to the real-time operating conditions
- Important benefits from optimizing voltages for real-time conditions
- Need for further investigation:
  - impact of instruments inaccuracies
  - Additional burden to generator for more frequent communication
Reduction of Substation Auxiliary Power

Objective

- Investigate where and how energy is being used within the substation premises
- Comprehensive assessment of energy usage: measure energy consumption of selected substation components for 12-month period
- Investigate options to reduce energy consumption of substation auxiliary system
- Quantify impact on carbon emissions
- Assess benefits and savings
Reduction of Substation Auxiliary Power

Main Findings

- In-city and suburban substations were analyzed
- Potential energy savings:
  - 17-20% if several energy efficiency improvement measures are implemented
- Saving measures:
  - HVAC, lighting, cooling pumps, transformer pumps, station service transformer
- In one utility system: Potential $2.4M/year or 10,257 MWh if applied throughout all substation facilities
Transmission Loss Reduction from Trapezoidal Conductors

- **Background and Objective**
  - Age-Based In-Kind Replacement plan: Re-conductor 1,000 miles of 138 kV and 345 kV lines in the New York system
  - Evaluate the benefits of using ACSR/TW conductor

- **Approach**
  - Loss evaluation based on historic data of selected lines
  - Economic benefits from demand and energy loss reduction, and potential CO\(_2\) emission reduction
  - Incremental cost of TW considered in economic analysis

- **Results**
  - Solution cost effective for most of the lines
  - Savings: 38 GWh/yr, 8.6 MW at peak load, CO\(_2\): 17,000 ton/yr
  - Levelized benefits: $2.4M/year
  - Incremental Cost to install TW conductor: $12.5 million
Potential Benefits from Dynamical Thermal Rating

Background and Objective
- Dynamic thermal rating technology installed at two 230 kV lines
- Evaluate potential benefits to improve wind integration

Approach
- Evaluate wind curtailment reduction due to increased transmission capacity permitted by DTR

Findings
- 1.7 GWh/yr curtailment reduction for existing wind generation
  - 45 Gwh/yr with additional 215 MW of wind generation
Finding from other cases studies and research

- Voltage upgrade of transmission lines:
  - may have significant impact on losses
  - very case specific

- High efficient transformers:
  - 0.15% of efficiency improvement, may results in energy and emission savings ranging from 18% to more than 35%

- Use of High-Temperature, Low-Sag (HTLS):
  - Valid solution to increase transmission capacity due to N-1 condition

- Shield wire loss reduction
  - Shield loss 1-3% conductor losses
Transmission Efficiency and Utilization Takeaways

- High-efficiency equipment is an important contributor to overall system efficiency, but replacement for efficiency alone is seldom justified
  - The opportunity arises when replacement is needed
- Increased utilization and loss reduction may result in conflicting objectives
  - Some technologies, such as dynamic thermal rating and advanced conductors, may have negligible or negative impact on reduction of resistive loss but increase transmission system utilization
- Advances in technology are required to achieve further efficiency gains
  - Technologies such as high-temperature superconducting (HTS) and advanced monitoring and control to support a smarter transmission system are key strategic technology-development pathways
Distribution Systems

- Distribution system losses can be addressed at the distribution line, at the transformer, and at the system level.
- Modeling results show that the majority of losses are in primary line losses and transformer losses.
- Loss reduction techniques evaluated include:
  - Voltage reduction
  - Phase balancing
  - Var (reactive power) optimization
  - Additional voltage regulators
  - Re-conductoring
  - Transformer replacements
Distribution Modeling Results

- The optimal efficiency improvement approach is circuit-dependent.
- Voltage optimization provided the most energy reduction by improving end-use efficiency as well as reducing no-load losses and provided benefit on almost all circuits.
- Circuits that showed the most improvements with voltage optimization had sufficient voltage margin already existing in the feeder.
- When applicable, re-conductoring and ideal var control resulted in the greatest reduction in losses.
- Additional improvement is possible by flattening voltage profiles by phase balancing, circuit reconfigurations, or with additional voltage regulators or capacitors.

Continue the Discussion

EPRI website: www.epri.com
EPRI Journal: eprijournal.com
Twitter: @EPRINews

Visit our incubatenergy.org and follow the conversation on Twitter & LinkedIn

Subscribe to our Podcast on iTunes

Contact Ron Schoff with any questions: rschoff@epri.com, @ronschoff33
Together...Shaping the Future of Electricity
COFFEE BREAK
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Minnkota Power Cooperative

- Wholesale electric generation and transmission cooperative formed in 1940
- 11 member-owner cooperative
  - 3 in ND, 8 in MN
- 12 municipals – Northern Municipal Power Agency
- Serve 35,000 square miles in 33 counties
- About 150,000 consumer accounts
- Milton R. Young Station
  - Primary Generation Source
Minnkota Power Cooperative

- Beltrami Electric
  Bemidji, MN
- Cass County Electric
  Fargo, ND
- Cavalier Rural Electric
  Langdon, ND
- Clearwater-Polk Electric
  Bagley, MN
- Nodak Electric
  Grand Forks, ND
- North Star Electric
  Baudette, MN
- PKM Electric
  Warren, MN
- Red Lake Electric
  Red Lake Falls, MN
- Red River Valley Co-op Power
  Halstad, MN
- Roseau Electric
  Roseau, MN
- Wild Rice Electric
  Mahnomen, MN
Participating Municipals

12 municipals
10 in NW Minnesota
  • 2 NE North Dakota
Minnkota is the operating agent

Northern Municipal Power Agency

Bagley, MN
Baudette, MN
Fosston, MN
Grafton, ND
Halstad, MN
Hawley, MN
Park River, ND
Roseau, MN
Stephen, MN
Thief River Falls, MN
Warren, MN
Warroad, MN
### 2017 Joint System Resources

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<th>Type</th>
<th>Quantity</th>
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<td>Young 1</td>
<td>Coal</td>
<td>250</td>
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<tr>
<td>Young 2</td>
<td>Coal</td>
<td>355</td>
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<tr>
<td>Coyote</td>
<td>Coal</td>
<td>128</td>
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<td>Hydro</td>
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<td>Wind</td>
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<tr>
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<td></td>
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<td><strong>1,335</strong></td>
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3,340 Miles of Transmission Lines
Substations

- 251 substations
  - 46 Transmission
  - 205 Distribution
Minnkota developed a program with the MN cooperatives and municipals

The program is called PowerSavers
- Contains a variety of rebates that include both residential and business customers
- [http://www.minnkota.com/powersavers.html](http://www.minnkota.com/powersavers.html)
- Saved over 150 million kWh’s
Infrastructure Projects (Supply Side)

- Referred to as Electric Utility Infrastructure (EUI) projects in CIP language
- Potential to count the savings that result from qualified improvements
  - Generation
  - Transmission
  - Distribution infrastructure
  - Conservation measures at its own facilities
These projects must be pre-approved by the Division of Energy Resources (DER)

Energy savings can be carried over for five years

Key to approval is to be able to prove that the option chosen is above and beyond the normal course of operations and maintenance
Key Component
- Must achieve at least one percent savings through conservation improvements on the end-use side before supply side savings can be used

Legislative Change in early 2016
- Eliminated the minimum one percent requirement
- However, language change in statue wasn’t clear therefore change did not take place
Replacement of HP/IP turbine motor in 2009

• New rotor generated and additional 17MW of electric energy with the same steam flow and fuel burned
• Resulted in 18,763,920 kWh savings
Transformer Optimization Tap Project

- Changed tap settings on the transformers connected to the 345kV line
- Raised the operating voltage of the 345kV line by roughly two percent from Coyote to Maple River
- 6,247,000 kWh savings – Alternative portion of the project
- 8,720,000 kWh savings – Accelerated portion of the project
Center to Grand Forks Conductor Upgrade

• Updated to larger conductor to minimize line loss over the lifetime of the CGF line
• Energy savings estimated at 15,433,005 kWh
Young 2 Generator Step-up (GSU) – located at the power plant

- Install a new GSU transformer and keep existing transformer as backup
- Increases voltage from the generator to make it suitable for transmission
- Energy savings estimated at 1,745,989 kWh savings
Summary of Projects

- Replacement of HP/IP turbine rotor
  - All 18,763,920 kWh savings have been claimed
    - 2010 - 3,752,784
    - 2011 - 6,842,985
    - 2012 - 4,563,780
    - 2013 - 3,604,371
Summary of Projects

- Transformer Tap Optimization Alternative Project
  - 3,297,600 remaining KWh savings to claim
    - 1,249,400 in 2014
    - 1,700,000 in 2015
    - No supply side savings need to be claimed in 2016
Summary of Projects

- Transformer Tap Optimization Acceleration Project
  - 8,720,000 remaining kWh savings to claim
- Center to Grand Forks Conductor Upgrade
  - 15,433,005 remaining kWh savings to claim
Summary of Projects

- Young 2 GSU (Generator Step-up)
  - 1,745,989 remaining kWh savings to claim
- Total of 29,196,594 kWh savings left to claim
Communication with engineers that work on the infrastructure projects

- Get in front of them and remind them to think outside the box
- Find the ones that like this sort of projects
  - Before you know it, they will be coming to you with ideas
Lessons Learned

- Make sure the option chosen is above and beyond the normal course of operations and maintenance
- Provide detailed information about the project
Minnkota Power Cooperative Proposal
for CIP Energy Savings Credit

The following proposal is submitted by Minnkota Power Cooperative, Inc. (MPC) as an application for an energy savings credit for the Transformer Tap Optimization Electric Utility Infrastructure Project which increases energy efficiency greater than what would have occurred through normal maintenance activities. Upon approval of this project, these savings will be applied to the PowerSavers energy savings goal after the one percent from energy conservation improvements on the end use side has been met, in accordance with the statute of Minnesota.

Submitted to: State of Minnesota, Division of Energy Resources
Conservation Improvement Program

Project: Transformer Tap Optimization

Submitted by: Minnkota Power Cooperative, Inc.
Aaron Vander Voorst, Electrical Engineer

April 17, 2013

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Lessons Learned

Background

MPC will acquire increasing shares of the power output from the Milton K. Young II generator near Center, ND as part of an arrangement with Minnesota Power. In exchange, MPC will sell the Square Butte DC transmission line to Minnesota Power. This deal was made to secure MPC’s baseload power supply into the future. MPC wishes to reduce the DC line’s power demand and deliver it to their service territory in northern MN. In order to make room for the new wind generation on the Square Butte DC line, MPC will inject power from Young II onto the AC transmission system at Square Butte. The power will be delivered to MPC’s service territory in northwestern MN and northwest MN across the ND power system. To facilitate this additional transfer of power, MPC is building a new 345 kV transmission line from Center to Grand Forks (hereinafter the CBF line). The CBF line is expected to be completed in early 2018.

In order to connect the CBF line to the power grid and to deliver the Young II generation over the AC system, MPC was required to not a system impact study to identify constraints which would prevent interconnection of the new line and the changed injection point of Young II. The system impact study report (hereinafter the CBF study) identified undervoltage issues along the existing Coyote – Center – Jamestown – Buffalo – Maple River 345 kV line (MPC System Study 2-1), which stretches approximately 245 miles from the Coyote plant near Bismarck, ND to the Red River Valley, terminating at the Maple River substation near Fergus, ND. The Coyote – Maple River 345 kV line is currently the only 345 kV line between central and eastern ND and is the primary path for MPC’s baseload generation to Marcellus’ load in northwestern MN. The CBF line will provide a second high-impedance path to MPC’s load in northwestern MN. The voltage constraints identified in the CBF study were required to be mitigated at the time the CBF line was energized, which also marked the transition of Young II injection onto the AC system. The CBF study utilized capacitors to improve the voltage performance and mitigate violations (MPC System Study 2-1).

1 The CBF project team at MPC selected an alternative mitigation for the new transmission line to reduce losses. The loss reduction created by that project has been approved for credit under the ND GIP program.

CIP Project Introduction

MPC performed an additional study in order to identify alternative solutions to mitigate the voltage constraints along the Coyote – Maple River 345 kV line and to look for additional efficiencies in the system losses (MPC Optimization Study). The optimization study evaluated the adjustment of tap settings on the 345 kV transformers connected to the Coyote – Maple River 345 kV line. The hypothesis for the study was that the tap settings could be optimized in such a way as to not only mitigate the voltage constraints observed in the CBF study, but also to reduce system losses more effectively that if capacitors were used. If the hypothesis could be proven, the voltage constraints which prevented the CBF project from proceeding could be mitigated and a greater system loss benefits could be realized than would have been achieved by using capacitors (MPC Optimization Study 2-4).

The optimization study showed that a single step-increase on taps of the 345 kV windings of each transformer along the Coyote – Maple River 345 kV line resulted in a roughly 2.5% voltage increase across the entire 345 kV line without impacting the voltage of the lines connected to the secondary or tertiary winding of those transformers, thus proving the hypothesis of the study (MPC Optimization Study 2-4). When the CBF study was reviewed with the adjusted transformer taps, the voltage constraint was successfully mitigated (MPC System Study Addendum 7-1). Knowing that the pre-approval for allowable system performance had been met, the focus turned to the potential for power loss reduction. The increase in operating voltage along the Coyote – Maple River 345 kV line due to the transformer tap changes was shown to reduce losses for regional power transfer from central ND to the Red River Valley, which straddles the ND/MN state line. The benefits to system losses were recorded in the optimization study report and are repeated in Table 1 below (MPC Optimization Study 3-9).

Because the transformer tap changes provided benefits to system issues following the addition of the CBF line, the optimization study also reviewed performance of the transformer tap changes prior to the addition of the CBF line. The study determined that the same set of tap changes would be acceptable for near-term system operation and beneficial for reducing losses (MPC Optimization Study 3-11). Therefore, MPC decided to proceed with the changes prior to the requirement of having them in place by the completion of the CBF line.

The transformer tap changes were implemented shortly after the draft optimization study report was reviewed by the affected neighboring transmission owners. The tap changes were completed on May 10th, 2012. Due to the short period of time between the completion of the study and the actual system changes being implemented, it was not possible to submit this proposal prior to the implementation of the changes to the system.

The following sections provide more detail regarding theory and calculations which further explain and quantify the loss savings realized through the transformer tap adjustments which would not have been realized through other mitigation techniques. The acceleration of the project for system loss benefits is also considered.
Lessons Learned

Theory

Although the actual loss savings calculation is more complex and will be considered in a later section, the conceptual theory behind the loss reductions which are realized by changing the transformer taps requires only the foundational electrical formulae for current, voltage, resistance, and power flow.

Consider a singlewire carrying electricity. The power flowing through that wire is equal to the product of voltage and current, \( P = IV \). By substituting (1) into (3) (voltage is equal to the product of current and resistance, or \( V = IR \) into the power equation), we obtain the formulation for real power loss, \( P_{\text{loss}} = IR \).

As described above, when the transformer tap changes were implemented, the operating voltage of the entire 345 kV line increased by approximately 2.5%. Assuming the power on the line remains constant, an increase in voltage results in a proportional increase in current. This 2.5% voltage increase results in the current being increased approximately 2.14% of the original current. Replacing the reduced current into the power loss equation, we see that the current is squared. Therefore, the power loss on the line will be reduced by approximately 95.2% of the original power loss, roughly a 9% reduction in power losses on the line.

Pre-CGF Loss Savings - Project Acceleration

As noted above, the CGF line is scheduled to be completed in early 2018. Consequently, the voltage mitigation was not needed until that time. Because the potential for savings in system losses was recognized, however, the transformer taps were changed at the earliest possible opportunity (completed May 19, 2013, as mentioned above). Therefore, system loss savings have been and will continue to be achieved until the CGF line is completed. The entire completion schedule is for the transformer tap changes. The full system loss savings are available for CGF during this time, as calculated below.

Using the data found in the optimization study (see Table 1), a best fit curve was generated using linear regression tools (see Figure 1).

Figure 1: Best Fit Loss Savings Curve, Pre-CGF

Tap Change Loss Savings Trend (Pre-CGF)

Because some historical data is available for the pre-CGF timeframe, actual data will be used as part of the proposal. The remaining period prior to the CGF line will be estimated to account for known system changes.

Historical Loss Savings (Pre-CGF)

Historical flow data (hourly average) on the Center - Jamestown 345 kV line was acquired from the time the tap changes were completed through the first quarter of 2013. The best fit curve was applied to the historical data to determine historical loss savings. See Figure 2 (2012 data) and Figure 3 (first quarter data).
Lessons Learned

Figure 2: 1st Quarter 2013 Historical Flows and System Loss Savings

Estimated Future Loss Savings (Pre-CGF)

Due to the avogadro and system-wide losses noted above, a reliable future loss savings calculation cannot be obtained by extrapolating historical data. Therefore, a similar approach will be taken as in the CGF proposal for an alternative conductor on the CGF line (Property 8), which calculates annual loss savings using expected future flow on the CGF line and extrapolated savings over the course of a year, and then discounted for outage time using a WPL load factor.

The models used in the optimization study were re-calculated to obtain a summer and winter load factor, as this load factor accurately reflects system baseline for 2013 (MPP Optimization Study 2013-14). Load factor data was reduced to winter levels and wind in MP was set to 40%. With these changes, the load factor for the CGF conductor project was calculated as: Average CGF Load Factor Summer: 49%, CGF Load Factor Winter: 37%, A load factor.

Table 3: Estimated 2013 Summer/November CGF System Loss Savings (Pre-CGF)

<table>
<thead>
<tr>
<th>Season</th>
<th>CGF 12 MV Base Load</th>
<th>Year Loss Savings</th>
<th>Day Load Factor</th>
<th>kWh Loss Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>340 MW</td>
<td>865 kWh</td>
<td>0.9</td>
<td>4,750,000 kWh</td>
</tr>
<tr>
<td>Winter</td>
<td>454 MW</td>
<td>1,071 kWh</td>
<td>0.9</td>
<td>1,520,000 kWh</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>9,271 kWh</td>
<td></td>
<td>6,270,000 kWh</td>
</tr>
</tbody>
</table>

Although this estimate is slightly higher than was seen in the historical evaluations above, this is not unreasonable due to the extended plant outage and wind farm additions which took place during the period in which the historical data was collected. As a reliability check, the cruise flows identified in the table can be compared with the data February-March flows obtained in Figure 3, which represent a generally intact system. The 340 and 454 MW cruise values in the table correspond well with the historical flows shown.

Therefore, the estimated total system loss savings realized by changing the transformer taps is 6,270,000 kWh during the last three quarters of 2013.

If the CGF line is not completed on January 1st, 2014, as it is estimated to be, the pre-CGF estimated loss savings can be projected forward or backward by the number of days between January 1st and the completion of the CGF line using the winter calculations above.
Lessons Learned

Summary
System issues were reduced beyond the scope of normal maintenance activities in two ways through the optimization of the tap settings on transformers connected to the Cayote–Maple Ever 345 kV line. First, the project schedule was accelerated by approximately 6 months in order to capture lost benefits prior to the need for voltage measurement. Second, using the transformer tap settings provided a uniform voltage increase across the Cayote–Maple Ever 345 kV line instead of a localized voltage increase provided by a capacitor. This uniform voltage increase resulted in a greater reduction in system losses than the addition of a capacitor.

The cost of the transformer tap changes was primarily labor, including an extensive study effort and the need to obtain the necessary rezoning of the transformer tap settings. As such, it is not possible to estimate the project cost.

The energy savings created by reducing system issues through the optimization of transformer tap settings on the Cayote–Maple Ever 345 kV line are summarized in Table 1. Minn Kota Power Cooperative, Inc. respectfully submits this report as an application for credit towards the Conservation Improvement Program (CIP) requirements as mandated by the state of Minnesota.

<table>
<thead>
<tr>
<th>Year</th>
<th>Savings Created Through</th>
<th>CIP Year</th>
<th>Loss Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>Project Acceleration</td>
<td>3,000,000</td>
<td>3,000,000</td>
</tr>
<tr>
<td>2013</td>
<td>Project Acceleration</td>
<td>3,000,000</td>
<td>3,000,000</td>
</tr>
<tr>
<td>2014</td>
<td>Alternative Mitigation</td>
<td>6,244,000</td>
<td>6,244,000</td>
</tr>
<tr>
<td>2015</td>
<td>Alternative Mitigation</td>
<td>6,244,000</td>
<td>6,244,000</td>
</tr>
<tr>
<td>Annual</td>
<td>Alternative Mitigation</td>
<td>6,244,000</td>
<td>6,244,000</td>
</tr>
</tbody>
</table>
Lessons Learned

- These projects must be pre-approved by the DER
  - Can present problems if they aren’t able to approve projects in a reasonable amount of time
- Personally haven’t had any issues
  - Potential to become a problem as more projects come in for approval
  - Detailed reports require a lot of time for evaluation
Summary

- Infrastructure projects have all been approved to date
- Minnkota has claimed over 21 million kWhs
- Remaining 29 million kWhs left to claim
Summary

- The process has worked for us
- Unfortunately the engineer that worked on these types projects has left Minnkota
  - Search continues for his replacement
**Today’s Agenda**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meeting kick-off</td>
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<td>Utility Infrastructure Efficiency 101: What is it?</td>
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<td>Lisa Severson, Minnkota – Example Projects in Minnesota</td>
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<tr>
<td>Group Discussion</td>
<td></td>
</tr>
<tr>
<td>Preview of Stakeholder Meeting #2 – Policy Issues</td>
<td></td>
</tr>
</tbody>
</table>
GROUP DISCUSSIONS

- Have you heard of EUI before?
- Has your organization considered implementing EUI projects?
- Are there major reasons your organization would NOT consider EUI?
- How to promote EUI as a CIP tool?
# Today’s Agenda

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</tr>
</tbody>
</table>
Save the date – 10/20/2017

Topic: EUI Policy Issues

More national and local expert speakers

Opportunity to help shape MN EUI Policy
EUI savings have been available to claim for ~10 years, but few projects submitted.

- Identified a list of possible barriers for consideration and future discussion (some listed on the handout provided).
Homework for Meeting #2

- Talk to people in your organization to get an idea of EUI implementation awareness and likelihood of implementation
- Specifically – think about barriers to EUI implementation
- Extra credit – solutions to EUI barriers
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Adam Zoet  
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651-539-1798

Project Website: https://www.mncee.org/mnsupplystudy/home/