

Duquesne Light Company Transmission Planning Criteria

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Duquesne Light Company's Comprehensive Transmission Reliability Plan, July 2005

Duquesne Light Company's Strategic Transmission Plan, December 2005

Duquesne Light Company's FERC Form 715 Annual Transmission Planning and Evaluation Report, March 2007

Overview

Duquesne Light Company defines its bulk electric transmission system as facilities with voltages of 69 kV and above that meet the FERC seven-factor test. This includes transformers with low-side voltages of 69 kV and 138 kV and lines with voltages of 69 kV, 138 kV, and 345 kV. The transmission system consists of over 670 circuit-miles of overhead and underground transmission lines.

The transmission located within the Duquesne zone adheres to the requirements of NERC, Federal and Pennsylvania State standards.

NERC Reliability Criteria

Duquesne Light operates and plans its system in conformance with NERC Reliability Standards as a registered Transmission Planner. A complete list of these approved standards can be found at http://www.nerc.com/files/Reliability_Standards_Complete_Set_2009Feb25.pdf.

Long Term Planning

Internally, Duquesne Light Company produces an annual 5-year minimum Transmission Assessment of its local facilities to ensure ongoing adequate delivery service to retail customers in Duquesne's service territory in accordance with Duquesne's local reliability standards and distribution service restoration policies. The results of this assessment, coupled with actual System Operations feedback and contingency overload analysis conducted by PJM are used to identify planning recommendations for system upgrades and reinforcements.

All transmission capacity problems and other concerns are initially identified from actual System Operations information and engineering studies. In addition, the latest available summer peak load data, acquired from Duquesne System Operations SCADA, is used to verify results. Bulk supply station load data for the forward-looking 5-year horizon is then obtained from the Distribution Planning Engineers. This data is entered into an updated load flow database along with proposed new stations to evaluate future system problems. The resulting facility loading (both pre and post-contingency) is compared to documented Duquesne Light Company transmission facility ratings to determine overloads, problems, and other identified concerns.

In preparing development plans, the transmission system is studied using summer peak loads forecasted for the near-term and long-term periods. First, the system is reviewed using a base case scenario with all facilities in service to simulate normal operating conditions. Next, global single contingency testing is performed against the base case. This testing simulates the loss of a single transmission facility, including generating units (NERC Category B contingencies).

Duquesne also performs global double contingency testing as well as studies additional NERC Category C contingencies that are not covered by the global double contingency analysis. NERC Category C contingencies include, but are not limited to, double circuit tower line contingencies,

breaker or protection failure contingencies, and bus section contingencies. Finally, NERC Category D contingencies are reviewed using the base case. NERC Category D contingencies include, but are not limited to, such severe events as loss of all transmission lines on a common right-of-way, loss of a substation (one voltage level plus transformers), and loss of all generating units at a station.

Of particular importance to Duquesne is the system's ability to withstand the loss of generators during non-shoulder months. Two generating stations, five units, support both the load and the voltage in the eastern portion of the system. Both near and long-term assessments are made with and without the generation from these stations.

In addition to load carrying capability, opportunities to reduce operating and maintenance expenditures or to improve utilization of the transmission system are studied/explored. For example, where existing major facilities are obsolete and known to require high and expensive maintenance, options are evaluated to reduce or eliminate those costs. In addition, opportunities to simplify and/or standardize the transmission system are explored as well as opportunities to evaluate the intelligence and protection of the electric grid. Furthermore, obstacles that result from planning a transmission system in an urban area must be mitigated in most cases through costly underground construction.

Solutions to identify transmission system problems and concerns are determined only after applying the various planning criteria, evaluating all practical alternatives, and selecting the most cost effective solutions. Duquesne evaluates the solutions through its Business Plan process. The resulting plan is treated as a dynamic document and subsequently reviewed, revised, expanded, and amended as additional issues and/or changes in existing issues arise.

Projects identified through this planning process are introduced into the PJM Regional Transmission Expansion Plan under provisions of the Plan.

Regional Transmission Expansion Plan

Duquesne became a member of the PJM Interconnection on January 1, 2005. PJM is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia. PJM now functionally operates the Duquesne Light transmission system on a minute-to-minute basis. In the Transmission Planning department, engineers study the system in the same fashion that PJM operates it. That is, following a single contingency, the current system becomes the new system normal condition and it must be able to withstand the loss of another transmission element.

As a member of PJM Interconnection, LLC (PJM), Duquesne adheres to PJM planning criteria. PJM's planning criteria can be found at: <http://www.pjm.com/planning/planning-criteria/pjm-planning-criteria.aspx>.

The Regional Transmission Plan (RTEP) Process follows a set of established business rules that lead to the publication of a Plan for the enhancement and expansion of transmission facilities. These business rules are summarized below.

The process develops a coordinated expansion plan as a result of the need for additional transfer capability associated with criteria violations identified using PJM planning criteria or through the applicable regional reliability council assessments, load forecasts, generation additions and transmission additions or transmission or distribution system upgrades by transmission owners themselves.

PJM notifies the Transmission Expansion Advisory Committee (TEAC) regarding initiation of the study process. The TEAC notifies PJM of any additional transmission considerations to be included. PJM consults with the TEAC to prepare a Scope and Procedure. The Scope includes identification of system limitations; proposes mitigating actions/system expansion alternatives; evaluates proposed enhancements; estimates associated expansion costs and proposed cost allocation; and assesses compliance with established reliability criteria. Transmission Owners supply PJM with the necessary transmission system modeling data.

Upon completion of its studies and analyses, PJM prepares a recommended enhancement and expansion plan and forwards it to the TEAC for review. The plan also includes allocations for assignment of cost. PJM will propose transmission enhancements if market forces do not provide system solutions to resolve congestion which cannot be hedged.

Any transmission owner and other participants on the TEAC may offer an alternative plan that PJM will evaluate. If PJM does not accept such alternative, the Transmission Owner may submit it for alternative dispute resolution.

The PJM Board of Managers has the authority for approval of the final Regional Transmission Expansion Plan, including any alternatives. Transmission Owners shall construct and own or finance the transmission facility enhancements or expansions specified in the Regional Transmission Expansion Plan (subject to requirements of applicable law, regulation actions, land acquisition requirements, financing, cost recovery, etc.).

Regional Planning Process Drivers

A number of factors within the RTEP Process drive the results in each RTEP and, thus, also have a bearing on the facility enhancement recommendations put forth. These factors encompass a range of planning perspectives and inputs, including:

The Reliability Council Assessments – a forward-looking assessment performed to assure compliance with NERC and applicable regional reliability council reliability standards, as appropriate.

PJM Transmission Adequacy Assessment – a forward looking assessment to assure that the transmission system is adequate to the task of reliably delivering aggregate PJM capacity resources to aggregate PJM load.

PJM Annual Report on Operations – an assessment of the previous year’s operational performance to assure that any bulk power system operational conditions which have emerged, e.g., congestion, are adequately considered going forward.

PJM Load Serving Entity (LSE) submitted capacity plans.

Generator and Transmission Interconnection requests – submitted by the developers of new generating sources and new merchant transmission facilities, these requests seek interconnection with the PJM bulk power transmission system (or seek needed enhancements as the result of increases in existing generating resources).

Transmission Owner submitted transmission development plans.

Interregional transmission development plans – the transmission expansion plans of those power systems adjoining PJM, and in some cases, beyond.

Long-term Firm Transmission Service Requests.

Transmission solutions developed for cost-effective relief of unhedgeable congestion.

PJM Transmission Expansion Advisory Committee (TEAC) – input from broad stakeholder representation.

The cumulative effect of these drivers on the bulk power system is analyzed to develop a Regional Transmission Expansion Plan which recommends specific transmission facility enhancements and expansion on a reliable, economic and environmentally sensitive basis.

ReliabilityFirst, ECAR Reliability Criteria & ECAR Document 1

Duquesne Light, as a former member of the East Central Area Reliability Coordination Agreement (ECAR), adheres to and plans the utility system in accordance with the ECAR guidelines. These ECAR guidelines are contained in ECAR Documents No.1 through 16. Until such time as ReliabilityFirst develops its own planning criteria, the legacy ECAR criteria, procedures, and protocols still apply to Duquesne Light facilities.

A list of approved ReliabilityFirst standards can be found at:
<http://www.rfirst.org/Standards/ApprovedStandards.aspx>.

As a result, Duquesne Light adheres to the reliability criteria defined by ECAR in Document 1, *Reliability Criteria for Evaluation and Simulated Testing of the ECAR Bulk Electric Systems*.

This document sets forth the standards that the former ECAR Transmission Providers are required to comply with (along with some recommended guidelines) in conducting simulated testing and system performance evaluations of former ECAR transmission systems. The standards cover the areas of system performance, reliability assessment, and system data modeling. Bulk Electric Systems must be planned to withstand the more probable forced and maintenance outage contingencies at projected demand and firm electricity transfer levels. Requirements include:

1. Individual systems shall be planned such that with all transmission facilities in service and with normal (pre-contingency) operating procedures in effect, the network can deliver generator unit output to meet projected demands and provide contracted firm transmission services.

Transmission Providers shall ensure that transmission system performance with respect to:

- a. Line and equipment loadings shall be within normal ratings.
- b. Voltage levels shall be maintained within normal limits.
- c. Stability of the network shall be maintained.
- d. No unplanned loss of load, generation or contracted firm power transfers shall occur.

2. Individual systems shall be planned such that the network can be operated to supply projected demands and contracted firm transmission services with any single outage of a transmission line, transformer, special control device or generator due either to a forced outage or the failure of a primary protective device or special protective scheme. The transmission systems shall also be capable of accommodating bulk facility maintenance outages scheduled prior to such contingencies. Transmission Providers shall ensure that transmission system performance with respect to:

- a. Line and equipment loadings shall be within applicable ratings.
- b. Voltage levels shall be maintained within applicable limits.
- c. Stability of the network shall be maintained.
- d. Planned or controlled interruption of generators or electric supply to radial customers or some local network customers, connected to or supplied by the faulted component or by the affected area, is permitted as long as it does not impact the overall security of the interconnected transmission systems. No unplanned loss of load, generation or contracted firm power transfers shall occur.

3. Individual systems shall be planned such that the network can be operated to supply projected demands and contracted firm transmission services with contingencies such as the loss of a bus section, breaker failure, double circuit tower outage or the delayed clearing of a single line to ground fault of a generator, bus section, or transmission element. Such contingencies can result in the outage of more than one element or facility. The controlled interruption of demand, the planned removal of generators, or the curtailment of contracted firm power transfers is permitted.

Transmission Providers shall ensure that transmission system performance with respect to:

- a. Line and equipment loadings shall be within applicable ratings after all manual and automatic intervention has been completed. Intervention may include opening of transmission lines and transformers.
- b. Voltage levels shall be maintained within applicable limits after all manual and automatic intervention has been completed. Intervention may include opening of transmission lines and transformers.

- c. Stability of the network shall be maintained.
- d. Planned outages of load or generation are permitted, and contracted firm power transfers may be curtailed.
- e. Cascading shall not occur.

4. The transmission systems shall also be capable of accommodating facility maintenance outages, scheduled prior to such contingencies. Transmission Providers shall ensure that transmission system performance with respect to:

- a. Stability of the network shall be maintained.
- b. Planned outages of load or generation are permitted, and contracted firm power transfers may be curtailed in the analysis. Line and equipment loadings shall be within applicable ratings after all manual and automatic intervention has been completed. Intervention may include opening of transmission lines and transformers.
- c. Voltage levels shall be maintained within applicable limits after all manual and automatic intervention has been completed. Intervention may include opening of transmission lines and transformers.
- d. Cascading shall not occur.

5. Individual systems shall be planned such that Cascading shall not result from the condition of a single outage of a transmission line, transformer, special control device or generator due either to a forced outage or the failure of a primary protective device or special protective scheme, followed by a second single outage. Before or after the second contingency, the controlled interruption of demand, the planned removal of generators, manual intervention or the curtailment of contracted firm power is permitted.

Seasonal Assessments/Operations

Duquesne performs seasonal engineering assessments in addition to testing the adequacy of its transmission system for known, short-term conditions. Duquesne Light prepares an individual company assessment of the Duquesne zone bulk electric system for the up-coming peak load period. This assessment includes the effect of known, planned, and forced outages on overall system performance. The results of the study were previously presented formally to other ECAR companies as part of ECAR's overall peer review and readiness program.

As part of Duquesne's assessment and using the same method as the near-term studies, the Siemens PSS/E Load Flow program is used to perform both a thermal and voltage analysis of the transmission system. Duquesne reviews the system using a base case scenario with all facilities in service to simulate normal operating conditions. Next, global single contingency testing is performed, simulating the loss of a single transmission facility, including generating units. Duquesne also performs global double contingency testing as well as studies additional NERC Category C contingencies that are not covered by the global double contingency analysis. NERC Category C contingencies include, but are not limited to, double circuit tower line contingencies, breaker or protection failure contingencies, and bus section contingencies. Finally, NERC Category D contingencies are reviewed. Again, these contingencies include, but are not limited to, such severe events as loss of all transmission lines on a common right-of-way, loss of a substation, and loss of all generating units at a station.

Engineers in Transmission Planning seek operator input to identify operational issues that may not appear in long-range planning studies. For example, Duquesne assessments include stressed conditions when either one or both of the eastern generating stations are out-of-service.

State Estimation and Contingency Analysis

Post-contingency voltage constraints can limit the amount of energy that can be imported from and through portions of the PJM RTO. The PJM EMS performs automated online full AC security analysis transfer studies to determine Transfer Limits for the use in real-time operation. The PJM Transfer Limit Calculator (TLC) simulates worse case transfers, with the simulation starting point being the most recent State Estimator solution. The TLC executes in the PJM EMS approximately every five minutes automatically recommending updated Transfer Limits to the PJM Dispatcher. The TLC determines a collapse point for each interface.

The PJM RTO Bulk Power Electric Supply System is operated so that loading on all PJM Monitored Bulk Power Transmission Facilities are within normal continuous ratings, and so that immediately following any single facility malfunction or failure, the loading on all remaining facilities can be expected to be within emergency ratings. This principle requires that actions should be taken before a malfunction or failure occurs in order to control post-contingency loading on a pre-contingency basis. Some examples of possible pre-contingency actions include pre-arranged approved switching, use of approved special purpose relays, Phase Angle Regulator tap adjustments (PARs), redispatch, and transaction curtailment. These actions can be used pre-contingency to control post-contingency operation so as not to exceed emergency ratings. These pre-contingency options are simulated by PJM's Operations Planning Department when they perform the day-ahead analysis of the system. Following any malfunction or failure, all remaining facilities or procedures of PJM are utilized, as required or as practical, to restore PJM RTO conditions within 15 minutes to a level that restores operation within normal ratings and protects against the consequences of the next malfunction or failure. Transmission overloads, both actual and post-contingency, are corrected within this time requirement. PJM uses the following techniques to control contingency or system violations:

- adjusting PARs
- switching reactive devices in/out of service or adjusting generator MVAR output
- switching transmission facilities in/out of service
- adjusting generation MW output via redispatch
- adjusting imports/exports
- issuing a TLR (Transmission Loading Relief)

PJM will operate the facilities that are under PJM's operational control such that no PJM monitored facility will violate normal voltage limits on a continuous basis and that no monitored facility will violate emergency voltage limits following any simulated facility malfunction or failure.

PJM is responsible for the overall coordination of the bulk power voltage scheduling. In general, since voltage schedules have a significant effect on local voltages PJM authorizes the Local

Transmission Control Center to establish and adjust voltage schedules. Whenever the generator or the LCC desired voltage schedule impacts the overall PJM economic/reliable operation then PJM shall exercise its operational control and direct changes to the generation voltage/reactive schedules, capacitor/reactor schedule/status, and transformer LTC operation for the overall reliable/economic operation of PJM.

Stability Limits

The PJM RTO established stability limits for preventing electrical separation of a generating unit or a portion of the PJM RTO. PJM recognizes three types of stability:

- *Steady State Stability* – A gradual slow change to generation that is balanced by load.
- *Transient Stability* – The ability of a generating unit or a group of generating units to maintain synchronism following a relatively severe and sudden system disturbance. The first few cycles are the most critical time period.
- *Dynamic Stability* – The ability of a generating unit or a group of generating units to damp oscillations caused by relatively minor disturbances through the action of properly tuned control systems.

PJM will operate the facilities that are under PJM operational control such that the PJM system will maintain angular and voltage stability following any single facility malfunction or failure. In general, stability is not a limiting constraint on the PJM RTO.

Load Forecasting

The future equipment loading is determined by an analysis of historical and projected circuit loads. In order to allow adequate construction time for new projects or system upgrades, load forecasting is essential in anticipating future overloads on existing facilities. This way, relief projects are scheduled prior to actual occurrence of such overloads. This helps to minimize loss of life of equipment as a result of any anticipated overloads. As part of the continuing data collection, records of current and historical loads on individual circuits are maintained. Utilizing these data projections of future circuit loads are made based on historical trends adjusted for expected area changes, new customers or changes in existing customers and expected future area rate of growth. The forecasts are also normalized for abnormal weather conditions. Finally, these individual forecasts are adjusted (when loading coincident with the system peak is desired) so that in the aggregate these forecasts are consistent with the company's system forecast.

Additional Duquesne Planning Criteria

In addition to the NERC and ReliabilityFirst (former ECAR) reliability criteria, the general transmission planning philosophy of Duquesne Light is that the bulk power system shall be able to withstand any single contingency with all facilities remaining within appropriate emergency ratings and no loss of firm customer load. To determine the adequacy and needs of the

transmission system, the following criteria are applied as a screen to determine potential problem areas, which do not satisfy this planning philosophy:

Based on peak load conditions with all firm transactions modeled and all generation available and economically dispatched,

- all facilities should be within normal ratings with all facilities in service
- all facilities should be within emergency ratings (4 hr. overhead conductors, 24 hr. underground cable and transformers) for any single contingency including generator outages.

In addition to adhering to both NERC and Reliability *First* (former ECAR) planning criteria, Duquesne Light has used good utility practice in order to develop internal planning criteria. In order to ensure reliable service to transmission substation, the Transmission Planning department has developed guidelines, outlined in the *Transmission Supply to Bulk Stations*, which stipulate that once a bulk power substation exceeds or is projected to exceed 100 MVA (approximately 22,000 customers), the station will require three transmission sources. This practice ensures continuous reliable service during routine maintenance scenarios as well as single contingency events.

Duquesne Light's transmission system is also required to be reviewed and modified in order to reliably support and supply its distribution load. Transmission projects can arise from efforts to accommodate load growth, back-up capacity needs of the underlying electrical system, or to expand the intelligence of the electric grid. Furthermore, the use of transmission to replace antiquated system designs where substations rely solely on subtransmission support is considered. Opportunities to reduce inventory, maintenance, and problems created by load growth in areas of marginal capacity are analyzed when applicable. In planning the transmission system, Duquesne also endeavors to diversify sources of supply, wherever possible, so that no one substation is the sole source of supply to Duquesne's load centers.

More stringent reliability guidelines are appropriate to address the needs of a major city. The City of Pittsburgh and its major load centers supporting its urban population and its critical services and infrastructure utilized by the surrounding tri-state area require reliability standards for transmission service more stringent than NERC criteria alone provides. The Duquesne Light transmission system relies on underground cables to supply the City of Pittsburgh. Some of these cables may share a common trench or a common return pipe. Outages of these common facilities are simulated and transmission solutions are developed so that no loss of load results. Underground cable outages could be long in nature and therefore, the remainder of the system should continue to operate reliably and within its normal rating limits following such events. As a result, Duquesne Light will advocate transmission solutions so that no loss of load occurs following an N-2 contingency supporting the City of Pittsburgh. This internal criterion is more stringent than the reliability standard TPL-003 (Category C3).

Additionally, as stated above, the Duquesne Light transmission system relies on the support of two generating stations, five units, in the eastern portion of its system. Four of the units in one station share a single scrubber. Therefore, all four units are modeled out-of-service as a single

contingency, in addition to single unit contingencies. Although this has a lower probability of occurrence when compared to a typical single contingency, the transmission system should not have any facility above normal rating limits nor loss of load following this event, but allowing for redispatch and manual system adjustments. This internal criterion is more stringent than the standard TPL-004 (Category D10).

The Duquesne Light transmission system should also be able to withstand the next contingency without any facility above normal rating limits and without loss of load following an outage of the other eastern generating station, which consists of one large unit. This internal criterion is more stringent than the standards TPL-003 (Category C3).

In screening for potential cascading events, Duquesne Light uses the method of removing all facilities loaded above 130% of their emergency rating and removing all units with bus voltages below their minimum acceptable operating voltages. The power flow is then re-solved and the process repeated until either no facility is loaded above 130% and no generating bus voltage is below its acceptable level, or the case does not solve. The cascading analysis considers facilities on neighboring systems. Although Duquesne Light has not encountered any cascading events that would negatively impact the PJM bulk electric system, cascading analyses can reveal potential opportunities to upgrade facilities within Duquesne in order to prevent loss of load, under stressed system conditions such as loss of multiple generators or tower-line contingencies.