Impact of Weather Uncertainty and Transmission Outages on Economic Project Evaluations

Version 3.0

Document Revisions

Date	Version	Description	Author(s)
8/28/2017	1.0	First draft	Tim McGinnis, Sandeep Borkar
11/7/2017	2.0	Clarify use of outage sensitivity along with weather scenario. Updated outage statistics.	Sandeep Borkar
6/25/2018	3.0	Updated outage statistics	Sandeep Borkar

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1. Background

ERCOT uses production cost (PC) savings as the metric to measure the economic (societal) benefits[1] of a transmission project. The PC savings are determined by simulating future system conditions by using an 8760-hour PC simulation. ERCOT has evaluated the impact of weather uncertainties and the impact of including transmission outages in the PC simulations. This document describes each problem statement and presents a methodology that will be used to address it.

2. Impact of weather uncertainties

2.1. Problem Statement

The Nodal Protocol Section 3.11.2(5) states that PC simulations shall be based on 'expected ERCOT system Load over the planning horizon'. Traditionally, the economic planning models used input data based on only one weather scenario. However, Texas can experience a range of weather conditions from year to year and only studying one weather year may not accurately reflect the expected economic benefit of a transmission project which will be in service for many decades with a variety of weather conditions across the life of the facilities. The new methodology builds upon the prior practice by choosing three different weather years which are selected after a careful consideration of not only demand but also wind and solar generation profiles.

2.2. Methodology

The new methodology builds on the existing practice to determine the PC savings of a transmission project. The new methodology now includes averaging of PC savings based on multiple weather scenarios. Here is an overview of the updated procedure:

1. Identify a region or a binding constraint that might benefit from an economic transmission project.
2. Test the effectiveness of the transmission project in reducing the system-wide PC. This evaluation is done by determining the PC savings with input data based on one weather scenario modeled in the base and change. The base PC savings to capital cost ratio (B/C ratio) for the transmission project is thus calculated using the PC savings and the first-year revenue requirement of the project. The weather scenario selected for this base simulation should represent near historic averages in terms of system peak demand, system energy, wind energy, and solar energy if possible.

[1] ERCOT's economic criteria can be found in Protocol Section 3.11.2 (5).

3. If the B/C ratio for the transmission project is within +/- 5% of the economic criteria[1], determine PC savings under two additional weather scenarios. These scenarios should be selected based on the guidelines set in section 2.3 of this document. Determine PC savings under a range of selected weather scenarios.
4. Average the three PC savings and obtain an average PC savings to capital cost ratio for the project being studied.

$$Weather - averaged\ PC\ Savings = \frac{\sum_{i-1}^{3} PC\ Savings_i}{3}$$

Figure 1: Calculating the weather-averaged PC Savings

5. If a project has an overall PC savings to capital cost ratio that meets the economic criteria, then the project can be approved as an economic project after considering other projects and factors as necessary.

2.3. Weather selection criteria

At least once every two years, the forecasted load, and wind, and solar profiles (existing) will be analyzed to help choose weather scenarios that should be included in economic analysis. This data should be forecasted for a future year based on multiple years of historical weather. The table should include demand energy, peak load, and wind and solar capacity factors.

The number of weather scenarios selected for use in economic studies should consider the benefit of determining additional PC savings to capital cost ratios as well as the resources required. Resources required to run multiple weather scenarios include the number of days to complete a study, the number of employee hours performing study work, and hard drive space for storing the output data.

The recommendation for which weather scenarios to include in economic studies should be based on the table of forecasted data. Here is an example table of weather scenario data that has been sorted by demand energy and where the 2010, 2009, and 2007 weather scenarios have been selected for use in economic studies.

Table 1: Weather Scenario Data for the Year 2022 (based on 2016 LTLF)

2022 Input Data						
Weather Scenario	**Demand Energy (GWh)**	**Peak Load (MW)**	**Wind Energy (GWh)**	**Wind Capacity Factor (%)**	**Solar Energy (GWh)**	**Solar Capacity Factor (%)**
2011 Weather Scenario	407,971	82,503	84,519	41.6%	5,570	35.0%
2010 Weather Scenario	398,172	79,302	81,232	40.0%	5,427	34.1%
2014 Weather Scenario	393,996	75,920	80,944	39.9%	5,198	32.6%
2013 Weather Scenario	393,897	78,325	79,134	39.0%	5,179	32.5%
2015 Weather Scenario	393,492	78,778	79,143	39.0%	5,008	31.4%
2009 Weather Scenario	392,508	77,751	79,356	39.1%	5,282	33.1%
2005 Weather Scenario	391,881	75,264	74,089	36.5%	5,387	33.8%
2006 Weather Scenario	391,520	76,557	78,957	38.9%	5,387	33.8%
2012 Weather Scenario	391,310	80,352	80,418	39.6%	5,284	33.2%
2008 Weather Scenario	390,552	75,733	85,155	41.9%	5,420	34.0%
2003 Weather Scenario	387,175	80,168	74,790	36.8%	5,356	33.6%
2007 Weather Scenario	384,733	76,430	73,291	36.1%	5,253	33.0%
2004 Weather Scenario	382,914	74,072	76,470	37.7%	5,065	31.8%

To aid in the selection of weather scenarios, the weather scenarios should be ranked by four metrics: demand energy, peak load, wind capacity factor, and solar capacity factor. If one weather scenario is to be selected, a weather scenario ranked near the middle for each of the four metrics should be selected. The weather scenario selected for the base simulation should represent near historic averages in terms of system peak demand, system energy, wind energy, and solar energy if possible. The other weather scenarios selected for analysis should include a range of the other metrics, including values that are lower and higher than the base scenario. Before using the selected weather scenarios in the economic models, ERCOT should solicit a stakeholder review of the recommended weather scenarios.

Table 2: Weather Scenarios Ranked by Demand Energy, Peak Load, and Wind and Solar Capacity Factors

	Ranks				
Weather Scenario	Demand Energy (GWh)	Peak Load (MW)	Wind Capacity Factor (%)	Solar Capacity Factor (%)	Avg Rank
2011 Weather Scenario	1	1	2	1	1.25
2010 Weather Scenario	2	4	3	2	2.75
2014 Weather Scenario	3	10	4	10	6.75
2013 Weather Scenario	4	6	8	11	7.25
2015 Weather Scenario	5	5	7	13	7.50
2009 Weather Scenario	6	7	6	8	6.75
2005 Weather Scenario	7	12	12	4	8.75
2006 Weather Scenario	8	8	9	5	7.50
2012 Weather Scenario	9	2	5	7	5.75
2008 Weather Scenario	10	11	1	3	6.25
2003 Weather Scenario	11	3	11	6	7.75
2007 Weather Scenario	12	9	13	9	10.75
2004 Weather Scenario	13	13	10	12	12.00

2.4. Application and limitation

The above approach provides a general explanation of how weather scenarios are expected to be used in economic analysis. However, each study scope that is published by ERCOT and reviewed by the stakeholders will contain the details of how weather scenarios will be used in that particular study.

3. Impact of transmission outages

3.1. Problem Statement

Traditionally the economic planning methodology used only known transmission outages applicable to the study period. However, information about such long term transmission outages is rarely available with certainty and these do not present a realistic range of outages that may impact the system. Per the Nodal protocol section 3.11.2(5) *"This market simulation is intended to provide a reasonable representation of how the ERCOT System is expected to be operated over the simulated time period."* Given the fact that transmission outages, both planned and forced, are a fact-of-life for any transmission system, it is imperative that there is a way to include the impact of such outages in PC simulations. It is also imperative for the new methodology to acknowledge the uncertainty around the duration and scheduling of outages over the study horizon.

The objective of this white paper is to outline the methodology used to incorporate transmission outages in economic transmission planning.

3.2. Methodology

The new methodology builds on the existing practice to determine the PC savings of a transmission project. Figure 2 below describes the new process.

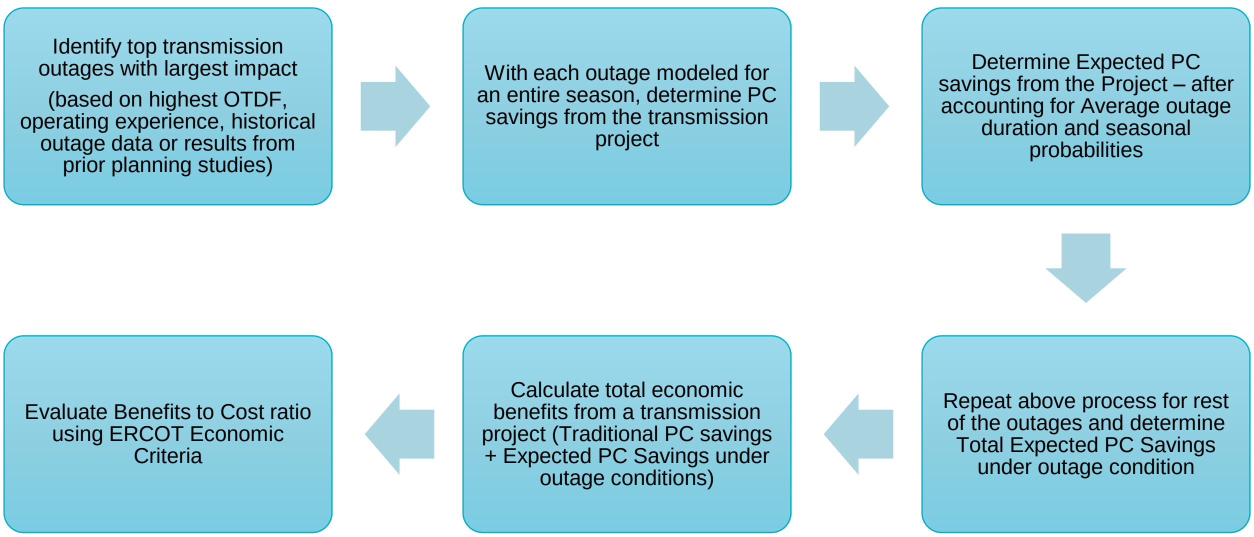

Figure 2: New methodology to determine Total PC savings under outage conditions

1. Identify a region or a binding constraint that may benefit from an economic transmission project.
2. Design a transmission project and test the effectiveness of the same in reducing the system-wide PC. This is done by determining the PC savings with no transmission outages modeled in the base or the change case and comparing it to the first-year revenue requirement of the project. These are the base PC savings from the transmission projects.
3. Identify top outages that may impact congestion in the region. These outages are selected based on operational experience, historical observation, or findings from recent planning studies.
4. Model each outage with a duration of entire season (spring, summer, winter, and fall) in independent PC simulations. These runs will provide the new base production costs under outage conditions (4 PC simulations per outage, one for each season)

5. Using models from step 4, determine the PC savings resulting from the transmission project under outage conditions. (4 independent PC savings per outage, one for each season)
6. Repeat steps 4 and 5 to determine savings under rest of the outages.
7. Calculate the Annual expected PC savings for the entire year and the PC savings with outages as shown in Figure 3.
8. This can be used to determine additional PC savings related to outages delivered by the new transmission project as explained further in section 4.

$$PC\ Savings_{base\ year\ with\ outages} = Annual\ PC\ Savings_{base\ year} \times \left[1 - \sum_{out=i}^{n} pr(out)_{annual}\right] + Annual\ Expected\ PC\ Savings_{Out}$$

Where,

$$Annual\ Expected\ PC\ Savings_{out} = \sum_{Out=i}^{n} \sum_{Season=1}^{4} PC\ Savings_{Season-outage} \times pr(out)_{Season}$$

$and\ n = \#\ of\ outages$

Where,

$$pr(out) = \frac{\#\ of\ occurences\ per\ period\ \times average\ duration\ per\ occurence}{\#\ of\ circuits \times \#\ of\ hours\ in\ the\ period}$$

Figure 3: Calculating the PC Savings under outage conditions[i]

3.3. Outage Statistics

Outage statistics used in this methodology were derived using ERCOT Outage Scheduler data. This statistics are based on 345-kV and 138-kV transmission outage data from 2011 through 2017. Both forced and planned[2] outages, as long as they were at least two hour long, were included in this analysis. The seasons are defined as Spring: March, April, May; Summer: June, July, August; Fall: September, October, and November and; Winter: December, January, and February. The following tables show the seasonal and annual probabilities of outages based on the calculations seen in Figure 3.

[2] Planned outages are included in this analysis because this is an annual production cost simulation and it is expected that planned transmission outages will get scheduled at different times throughout the year. Additionally, outage records related model management activities were ignored for this analysis.

Table 3: Probability of transmission outages

Equipment type	Fall	Spring	Summer	Winter	Annual
Circuits (345-kV)	0.059	0.027	0.009	0.021	0.028
Circuits (138-kV)	0.037	0.011	0.004	0.010	0.015
Transformer (345-kV)	0.038	0.025	0.007	0.043	0.029

3.4. Application and limitation

The methodology achieves the objective of capturing the true savings from a transmission project and will be used to evaluate societal benefits of a transmission project. Additionally, it could also be used to evaluate relative merits of alternative options of a reliability-driven project.

However, the analysis is resource intensive in nature. Close to 40 PC simulations (4 seasons X 2 cases X 5 outages) may be required as a result of this methodology, assuming five outages are analyzed.

The PC savings identified using the above methodology will be less than the actual PC savings as it does not take into account all possible outages on the system. The above approach continues to remain conservative as it assumes that each outage happens independent of others with no overlap. The issue of probability of a double-circuit outage also remains to be addressed. Until better double-circuit outage statistics can be established the methodology will continue to be based on single-circuit outages.

4. Methodology example

While both analyses can be performed independent of each other, there are times when a project evaluation could benefit from an analysis that includes both the weather scenarios and transmission outage sensitivities. This section provides an example for a sample project evaluation. For an economic project being evaluated:

1. Determine base PC savings and calculate the base B/C[3] ratio. This analysis is performed using the base weather year of 2009.
2. If the B/C ratio is within +/- 5% of the economic criteria[4] then this analysis could benefit from determining weather-averaged savings from additional weather

[3] B/C stands for Benefit-to-Cost ratio where Benefits are PC savings from a transmission project being evaluated and cost is the Capital cost of constructing such a project.
[4] 15% for 2017

scenarios. If the above condition is met, determine the average B/C ratio using the three weather years.

3. If the weather-averaged B/C Ratio is more than the -5% threshold but below the B/C criteria then determine additional PC savings due to Transmission Outages. The PC simulations using transmission outages is performed using the base weather year of 2009. These simulations are used to determine the additional PC savings under outage conditions as explained earlier. Note that transmission outage analysis could be performed independently and in that instance the above criteria mentioned above may not apply. The additional PC savings under outage conditions are calculated as follows:

$$Additional\ PC\ savings\ under\ outage\ conditions = PC\ Savings_{base\ year\ with\ outages} - Annual\ PC\ Savings_{base\ year}$$

Figure 4: Calculating the Additional PC Savings under outage conditions

4. Determine the Total PC savings using the weather-averaged PC savings from step 2 and additional PC savings under outages from step 4 as follows:

$$Total\ PC\ Savings = Weather - averaged\ PC\ savings + Additional\ PC\ savings\ under\ outage\ conditions$$

Figure 5: Calculating the Total PC Savings with weather scenarios and outage consideration

5. If the Total B/C ratio is larger than the threshold set by ERCOT economic criteria then the project will be approved.

The following flowchart provides additional details regarding this process.

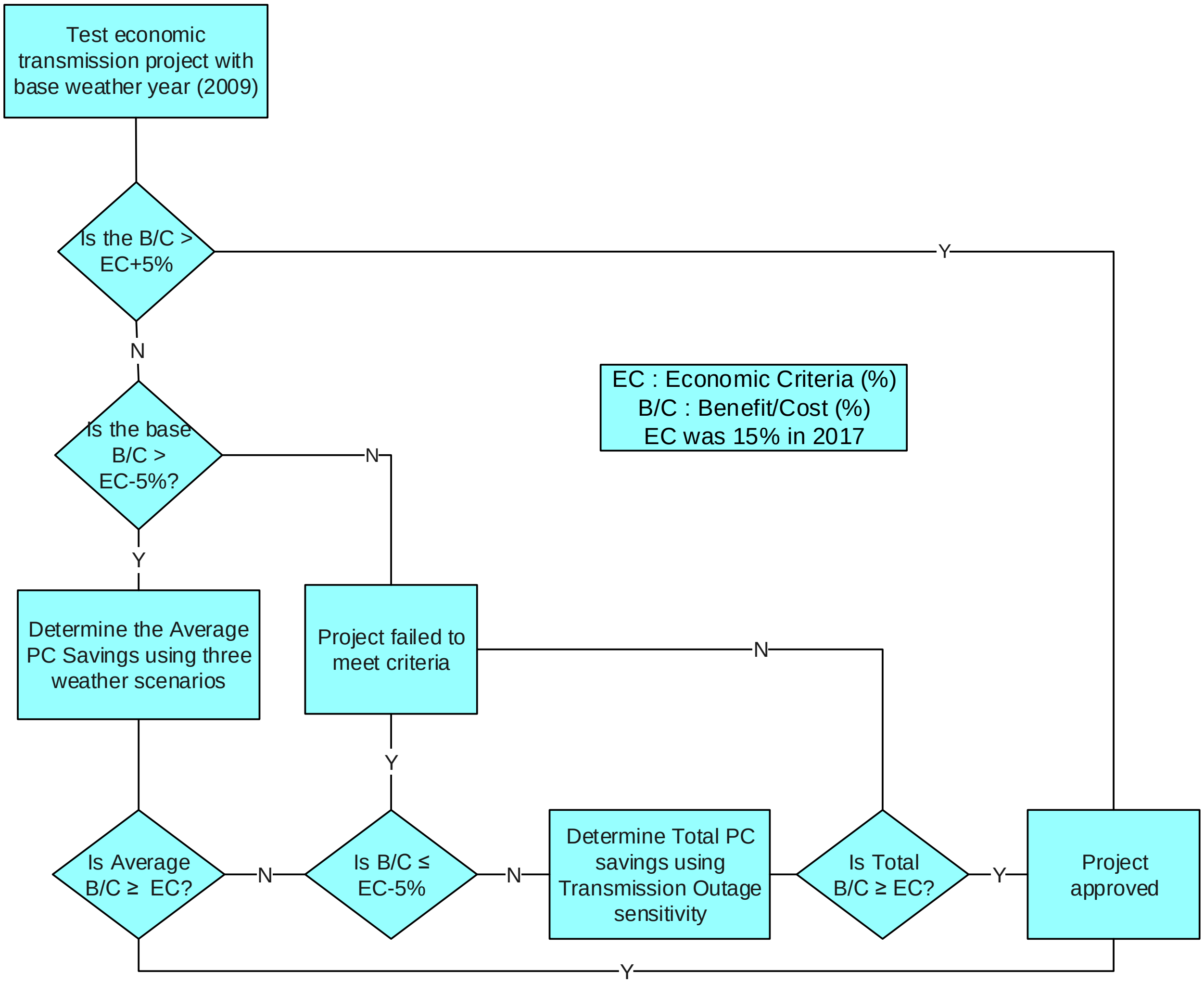

Figure 4: Economic project evaluation (example)

5. Appendix

A list of past stakeholder presentations about these topics.

- Transmission Outage update at March 2017 PLWG - http://www.ercot.com/content/wcm/key_documents_lists/113016/PLWG_TransmissionOutageEconomicAnalysis_posting.pptx
- Weather Scenarios Update at May 2017 PLWG - http://www.ercot.com/content/wcm/key_documents_lists/113024/Weather_Sensitivities_5-4-2017__002_.pptx
- Weather Scenarios Update at July 2017 CMWG - http://www.ercot.com/content/wcm/key_documents_lists/123595/Weather_Scenarios_6-29-2017.pptx
- Update on economic transmission plannign practicies at the August 2017 RPG meeing - http://www.ercot.com/content/wcm/key_documents_lists/108880/EconomicTransmissionPlanningPractices.pptx

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[i] The annual expected savings calculation explained in detail:
The objective of the methodology is to determine the total PC savings from a transmission project. This total PC savings has two components. First is the traditional PC savings under normal system conditions (no transmission outages) and second is the additional PC savings under outage conditions. The calculation for the PC savings under outage conditions have to accommodate the uncertainty around outages viz. uncertainty around outage occurrence and also around duration of each occurrence. These uncertainties are handled by making PC simulations with a base assumption that the outage is taken for an entire season and the savings from a project under such conditions are de-weighted using the probability of that outage in the season under study. This seasonal approach is used to acknowledge the fact that planned outages are seasonal in nature. The probability of outage incorporates both average duration and the frequency of outages in that season. Repeating this step for all seasons and outages gives us a probability-weighted additional PC savings from the transmission project. The traditional PC savings are based on a simulation for all 8760 hours. These savings are de-weighted to represent the savings from the hours were all the studied outages were in service.