

Approaches to Generation Dispatch in Transmission Planning

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SUMMARY

A critical factor affecting transmission system development is the assumed location and size of generating units. The representation of generation in a planning model depends both on what generation is included and the output of these generators. The matter as to *what* generation is included in the model depends on the treatment of the generation in the generation queue. The *output* of the generators is set by the assumed generation dispatch.

With transmission plans being developed five and ten years into the future the treatment of the generation queue is an important variable. There are at least three general types of generation dispatch used in transmission planning—economic dispatch, stressed dispatch, and flat dispatch. Each will result in a different pattern of generation and subsequent transmission loadings. These different transmission loadings can affect what transmission improvements are needed.

The paper discusses the generator queue and dispatch practices of four systems: The PJM Interconnection; The California ISO; The Electric Reliability Council of Texas; and The Alberta Electric System Operator.

A portion of the PJM transmission system is used to demonstrate the potential impact of different assumptions regarding generation dispatch.

The pros and cons of different approaches are also discussed

KEYWORDS

Transmission planning, generation dispatch options, transmission planning assumptions, transmission planning in market environments.

1. Generation dispatch and transmission planning

A critical factor affecting transmission system development is the assumed location and size of generating units. The need for transmission expansion is determined by the patterns and amounts of power flowing between generators and loads together with the topology of the transmission network. And while load growth is an important factor affecting transmission requirements, the location and size of generation is usually more important. Load tends to grow in a diffuse pattern across wide geographic areas. Generation, in contrast, is concentrated at specific locations and often in very large sizes.

In open markets generation ownership is usually independent of transmission ownership. Generator owners are generally free to propose new generation locations, sizes, and fuel types. Generator owners are also generally free to upgrade, de-rate, or retire existing generators. These uncertainties regarding generation are challenging for transmission planners.

Generation, then, is probably the most important driver for most transmission additions. Yet there is a range of practices in the way transmission planners include generation in their planning studies. These different practices can result in identifying different transmission problems and, thus, different solutions.

The representation of generation in a planning model depends both on what generation is included and the output of these generators. The matter as to *what* generation is included in the model depends on the treatment of the generation in the generation queue—the chronological list of generators requesting connection to the system. The *output* of the generators is set by the assumed generation dispatch.

In the following sections examples will be discussed for these systems:

- The PJM Interconnection (PJM)—145,000 MW peak load;
- The California Independent System Operator (CAISO)—49,000 MW;
- The Electric Reliability Council of Texas (ERCOT)—65,000 MW; and
- The Alberta Electric System Operator (AESO)—8,200 MW.

2. Impacts of generation queue assumptions

With transmission plans being developed five and ten years into the future the treatment of the generation queue can be an important variable. A 50,000 MW system with 2% growth will need about 6,000 MW of new generation in five years and 12,500 MW in ten years.¹ The type and location assumed for this future

1. This assumes 2% annual growth plus 15% reserves and no retirement of existing generation.

generation will have an important impact on future transmission needs. And yet there is a large amount of uncertainty regarding the generation in the generation queue. This uncertainty falls into three groups:

1. The first uncertainty group is linked to the lead-times of new generation. Simple-cycle combustion turbines take less time to license and build than combined-cycle units; these take less time than conventional steam units and, even more so for large coal or nuclear units. These differences mean that new nuclear and coal generators must be planned and committed for construction much farther in advance than the other types. The combined effect is that there will likely be a higher proportion of base-load (nuclear and coal) units than the other types included in the later years of the queue.
2. The second uncertainty group is how many of the generators in the queue will actually be built. There is often a marked fall-off in the amount of generation that is proposed to the amount that is actually built. In the PJM system it is only about 10% —less than 15% of the generation that is studied for interconnections actually enters the generation queue; and only about 75% of the generation in the queue is actually built.²
3. The third uncertainty group is which existing generators will retire. Generally generators need to give no more than 2-3 years advance notice of their plans to retire any specific unit. This usually means that, beyond 3 years in the future, there will be unannounced retirements that are not being planned for.

The treatment of generation in the queue in regard to transmission planning is somewhat different among North American systems. The normal progress of a new generation project begins with a press release or public announcement; this is followed by a request for a connection study; if the study result is favorable, then a connection agreement is executed; regulatory approval is requested; and, finally construction begins. The inclusion of the generation in the various stages of the generation queue is shown in Table 1.

2. When measured in MW of installed capacity.

Table 1: Inclusion of the generation queue in transmission planning

	Generator status					
	Under construction	Executed connection agreement	Regulatory approval	Completed connection study	Filed study application	Press release/ announced
PJM	√	√				
CAISO five-year	√					
CAISO ten-year	√	√	√	†	†	†
ERCOT	√	√		‡	‡	‡
AESO	√	√	√	◇	◇	◇

Notes:

- † Only if additional generation is required to achieve an acceptable initial power flow case.
- ‡ Because some generation will need to be developed in order to serve the 10-year load forecasted, the characteristics of additional future generation are selected to match the assumptions of different scenarios.
- ◇ The AESO evaluates transmission plans for several generation expansion scenarios to satisfy the Provincial Energy Strategy that sets out the government’s integrated vision for the continuing development of the province’s energy resources.

The general pattern is to only include generators from the queue that are reasonably certain of being built and available—those under construction or with executed connection contracts.

3. Approaches to generation dispatch in transmission planning

It is common for the predominant generation of any area to be located near predominant fuel sources or their delivery points. Hydro-electric generation must be located where there is both water and elevation; coal plants are located near coals mines or near major transportation hubs; nearly all thermal generation must be located near a water source sufficient for cooling; and major natural-gas generation must be located near high capacity pipelines. All of these tend to be geographic factors that make certain locations either required (e.g. hydro) or much more practical than others. And generally, large coal or nuclear units are not located near population centers.

These geographic factors tend to result in one or just a few predominant patterns of power flow. The transmission system has been developed over the years, and often decades, to support this pattern of power flow. The existing system may be said to have a bias in favor of these patterns, however, since there has been only limited construction of new transmission in North America during the last 20 years, the predominant patterns have often stressed the transmission system to be at or near its thermal or voltage limits.

Introducing markets changed the whole enterprise of generation and transmission planning. Generation proposed for the predominant areas must compete with other types of generation planned for other locations. An economic dispatch that favors the existing patterns will tend to favor new generation proposed for the predominant location(s).

There are at least three general types of generation dispatch used in transmission planning—economic dispatch, stressed dispatch, and flat dispatch. Each will result in a different pattern of generation and subsequent transmission loadings. These different transmission loadings can affect what transmission improvements are needed. For all three of these types of generation dispatches the transmission is then subject to the various contingency analyses called for in the respective system's planning criteria.

3.1 Economic dispatch

In evaluating transmission needs, many planners assume an economic dispatch for peak load conditions as the basis for their plans. (Other load conditions may also be considered each with their own economic dispatch.) This approach, and its variations, is perhaps the most obvious. This approach, however, can bias transmission plans in favor of large base-load generators with their high availability and low operating costs.

3.1.1 CAISO economic dispatch

The CAISO uses a form of economic dispatch in its economic planning (congestion) assessment. This assessment assumes a normal (50/50% probability) load forecast for the CAISO area. The generation is dispatched using a Security-Constrained Unit Commitment (SCUC) and Security-Constrained Economic Dispatch (SCED).

Purpose of this study is to identify where congestion may occur and how long it may last. This information is then used in a cost-benefit analysis to find the most cost-effective alternative to mitigate congestion.

The CAISO also uses a stressed dispatch as discussed in §3.2.3, below.

3.1.2 AESO economic dispatch

The AESO plans the Alberta transmission system so that, on an annual basis, at least 95% of all anticipated in-merit electric energy can be traded when operating under abnormal operating conditions. In determining transmission system adequacy, generation is dispatched according to the forecast merit order for the period of study. Non-dispatchable generation such as wind or run of river hydro is assumed at its minimum or maximum seasonal output whichever is more onerous.

3.1.3 ERCOT economic dispatch

ERCOT uses a form of economic dispatch in planning and evaluating overall transmission system reliability. This assessment assumes a 50/50 load forecast with a generation dispatch that simulates Security-Constrained Unit Commitment (SCUC) and Security-Constrained Economic Dispatch (SCED). The purpose of this study is to identify transmission criteria violations across the state.

A stressed dispatch is used to evaluate the transmission capability to serve the four largest metropolitan areas discussed §3.2.4, below.

3.2 Stressed dispatch

The North American Electric Reliability Organization (NERC) planning standards require that studies “cover critical system conditions and study years as deemed appropriate by the responsible entity.”³ Utilities and ISOs have generally interpreted this to mean some sort of ‘stressed’ system conditions. The nature of what makes up the stressing conditions varies. The ‘stress’ may simulated by the outage a specific large generator, conditions that stress certain critical transmission lines, or the absence of critical imports from outside the area. In recent years, stressed conditions have been included in planning to represent the vagaries of wind and solar generation.

Stressed dispatch is the one most commonly used by systems in North America.

3.2.1 TO stressed dispatch

The impact of different approaches on the loading of a particular 500 kV transmission line in the PJM area will be discussed in §4, below. The critical overload on this line is the result of a form of stressed dispatch that is used by the Transmission owner (TO) of the overloaded line. The case is a hybrid of a flat dispatch under stressed conditions.

The case is based on serving the 50/50 peak load from all generation dispatched to the same proportionate output level—about 0.85—what is being called a flat dispatch in this paper. It is then assumed that the largest unit in the local load area is out of service. All generation output in the PJM system is then increased slightly to make up for the generation lost.⁴ The system is then evaluated for all single contingencies.

3. See NERC, “Reliability Standards for the Bulk Electric Systems of North America,” January 1, 2007, §R1.3.1 of TPL-001, §R1.3.2 of TPL-002 and TPL-003.

4. The generating capacity in the PJM area totals about 170,000 MW, so an increase for the loss of 740 MW is only about 0.4% of the capacity.

3.2.2 PJM stressed dispatch

The stressed condition described above is used by the TO of the overloaded line. The responsible ISO, PJM, uses a different stress test that resulted in slightly lower loading.

The relevant PJM stressed dispatch test is called the Load Deliverability Test.⁵ This test “determines that the physical capability of the transmission network has been found adequate to have capacity delivered on a firm basis under specified terms and conditions.” This test assumes a high load conditions (90/10) in the load area being tested, 50/50 load conditions in the rest of the system, and a high level of generator unit unavailability (once in 25 years) in the load area being tested. The generation outside the load area being tested is adjusted so that any overloads are mitigated or are reduced to the lowest level possible.

PJM also uses a form of flat dispatch that is discussed in §3.3.1, below.

3.2.3 CAISO stressed dispatch

The CAISO’s stressed dispatch test is not as complex or explicit as with that of PJM. The CAISO, in practice, assumes stressed conditions in evaluating and developing its transmission study plans. It should be noted that California does not have enough in-state generation to meet its peak load, so import levels are a critically important variable.

Three general generation dispatches were used in developing the CAISO’s *2010 Transmission Study Plan*:

1. Reliability planning assessment—assumes 50/50 peak load conditions with high, but not necessarily maximum, import flows to each of the 12 major load areas, representing a stressed system operating condition.
2. Local reliability assessment— assumes 90/10 peak load conditions of each of the 12 major load areas. Reliability Must-Run (RMR) units are dispatched to their minimum levels. Market units in the areas are dispatched at or close to their P_{\max} levels or as needed to simulate the most critical conditions. Qualifying Facilities (QFs) and self-generating units are modeled according to their historical output.
3. Economic planning (congestion) assessment—uses a form of economic dispatch and is discussed in §3.1.1, above.

5. These analyses are described in Appendix E of PJM Manual 14B, *Generation and Transmission Interconnection Planning*.

3.2.4 ERCOT stressed dispatch

The ERCOT system uses two generation dispatch approaches in developing its transmission plans. A stressed dispatch is used to evaluate the four major load areas in the state—Dallas/Fort Worth, Houston, Austin/San Antonio, and Corpus Christi. Each area is modeled with 50/50 peak load forecast and with greatly reduced generation in each metropolitan area.

The generation outside the area being studied is economically dispatched as described in §3.1.3, above.

3.3 Flat dispatch

In a flat dispatch all the generation in an area is dispatched to the same proportionate output level. A flat dispatch develops plans using an ‘unbiased’ dispatch that treats all generation equally regardless of generating production costs or location. While being inherently ‘fair’ to all generators, such a dispatch is unrealistic in that it will almost certainly never occur in actual operation.

3.3.1 PJM flat dispatch

Transmission planning in PJM includes three parts:

1. The load deliverability test (stressed dispatch) discussed above in §3.2.2;
2. A generation deliverability test (another form of stressed dispatch) not discussed here; and
3. The regional transmission expansion plan (RTEP) process.

It is the third of these parts—the RTEP—that uses a flat dispatch. During the RTEP process, power flow and other bases cases are developed for various load levels and years. These cases are based on a 50/50 load forecast with all generation dispatched to the same level in proportion to their rated capability. So if the system had a peak load of 170,000 MW and 195,000 MW of generation capability, each generator would be dispatched to 87.2% (170/195) of its capability.

The cases developed by the RTEP process are also used by PJM to check compliance with the NERC reliability standards. The PJM staff checks these cases for compliance under single and multiple contingencies.

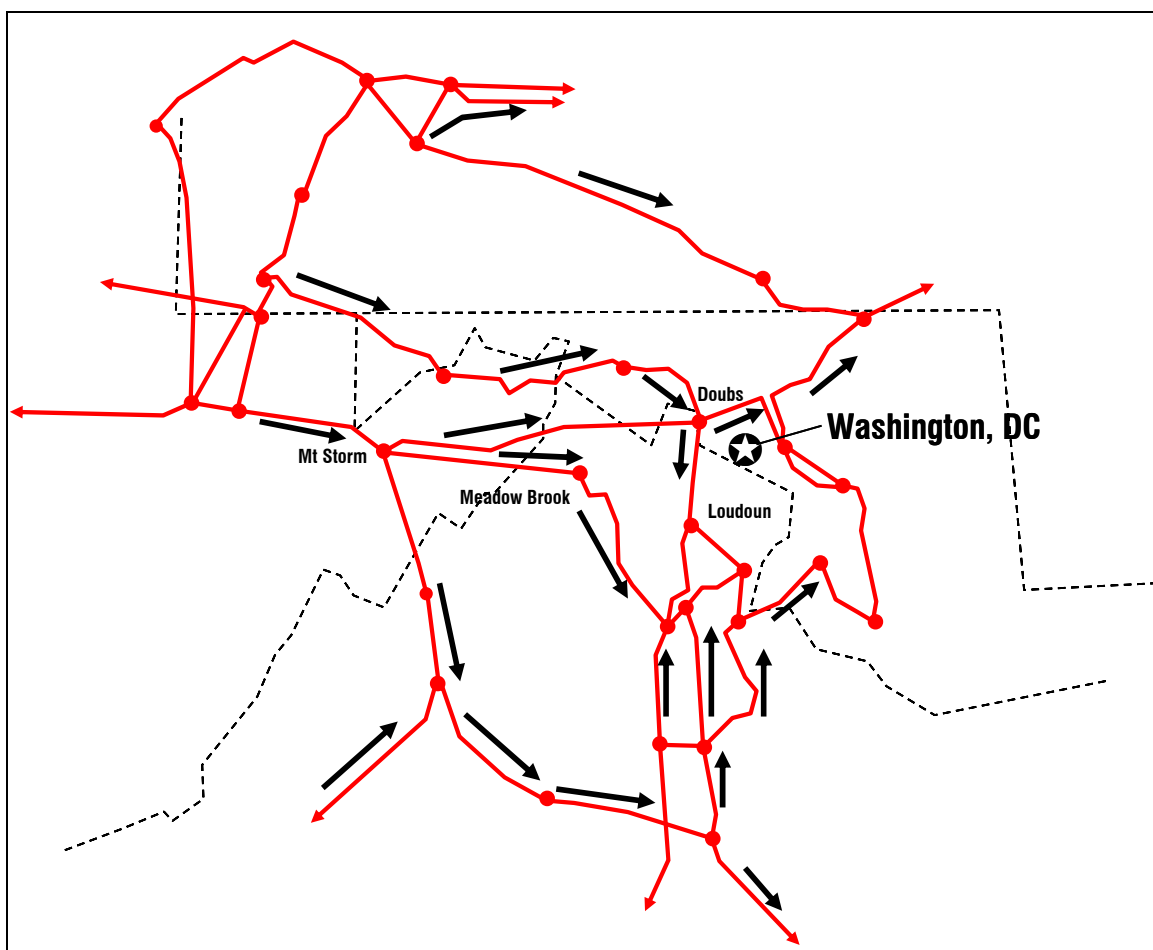
The two PJM stressed dispatch cases (load deliverability and generation deliverability tests) are more severe tests of the transmission system than the flat dispatch cases. Generally the tests of the RTEP flat dispatch cases and do not produce new or more severe criteria violations than were found with the two deliverability tests.

The RTEP cases are also used for other analyses by PJM, the member systems, and other stakeholders. It was such an RTEP case that was the starting point for the TO stressed case discussed in §3.2.1, above.

4. Impact of generation dispatch approaches

To demonstrate the potential impact of different assumptions regarding generation dispatch we will use a portion of the PJM transmission system as shown in Figure 1.⁶ The area shown includes portions of Pennsylvania, Maryland, Virginia, West Virginia, and the District of Columbia. The area is about 400 km from east to west and 300 km from north to south.

Figure 1: Eastern PJM—basic power flow pattern

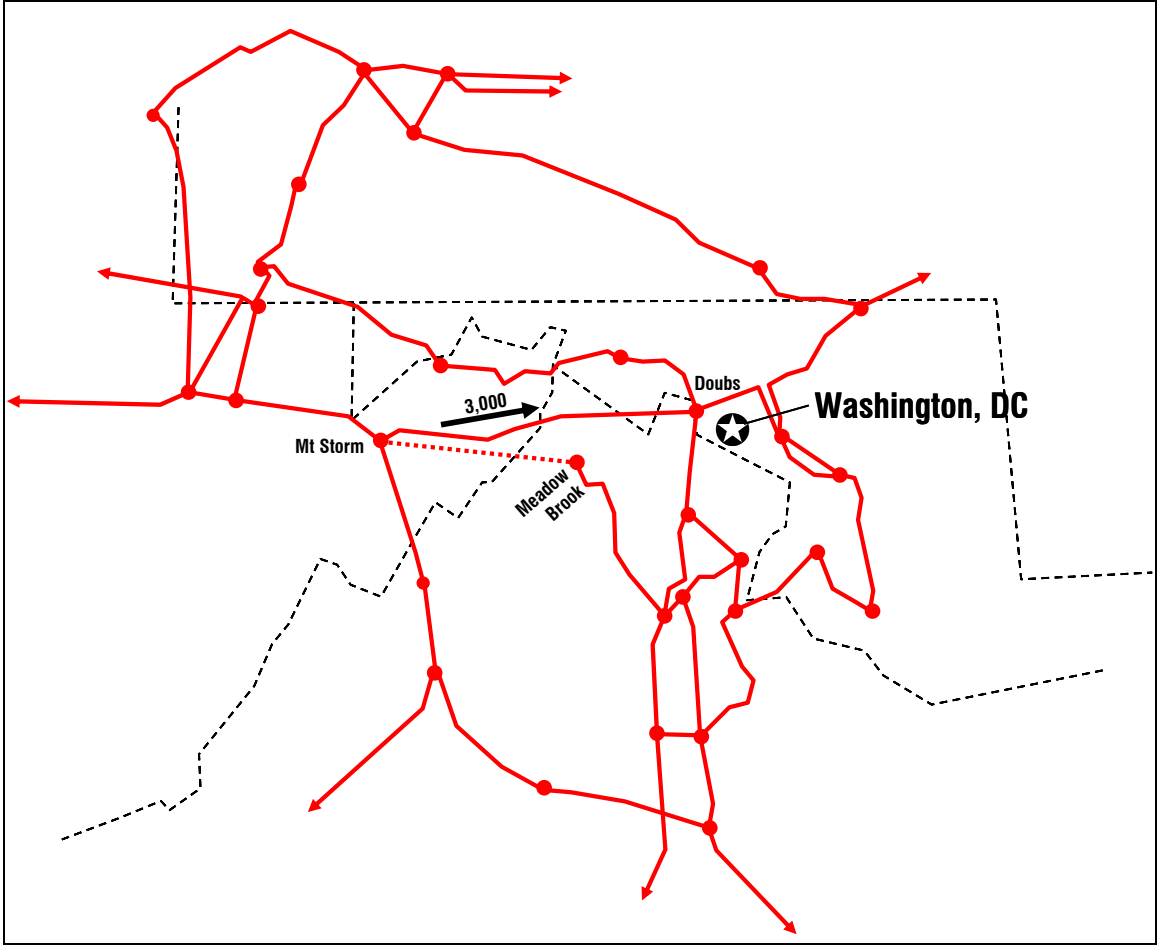


The figure shows the basic power flow pattern of the area. Power generally flows from west to east. Much of the power is delivered to the area around the Loudoun substation (center of the figure) in Northern Virginia, however, large amounts of power also flow to the area east of the figure.

6. This system was the subject of regulatory hearings before the Virginia Commerce Commission in the winter and spring of 2008. The results described at those hearings were used as the basis for the examples presented here.

The example will focus on the impact of various generation dispatch assumptions on the contingency loading of the Mt. Storm – Doubs 500 kV transmission line. While there are several contingencies that can cause criteria violations, this discussion will focus on one of the worst—the loss of the parallel Mt. Storm – Meadow Brook 500 kV line—as shown in Figure 2. In this case the loading of the Mt. Storm – Doubs 500 kV line is 3,000 MVA; 123% of the line’s 2,440 MVA limit. Under these conditions the line would be overloaded by 560 MVA.

Figure 2: Worst contingency overload of Mt. Storm – Doubs



The incremental impact of different generation dispatch options in comparison to the loading shown in Figure 2 is shown in Table 2, below.

Table 2: Impact of different iso assumptions on Mt. Storm–Doubs loading

	Mt. Storm – Doubs overload	Comment
Stressed dispatch examples		
Local TO	560	Based on serving the 50/50% peak load with a flat dispatch and assuming the largest unit in the local load area is out of service.
PJM load deliverability	500	This is a stressed case for delivery to the Washington, DC area, but with the most beneficial dispatch of generation outside the area.
CAISO stressed	~500-550	The two CAISO stressed methods are very similar to the TO and PJM approaches.
ERCOT	~550	The test is very similar to that used by the TO.
Economic dispatch examples		
CAISO economic	>1,200	An economic dispatch would significantly increase low-cost generation west of Mt. Storm–Doubs.
AESO	>1,200	An economic dispatch would significantly increase low-cost generation west of Mt. Storm–Doubs.
Flat dispatch examples		
PJM flat	~500	Restoring the largest generating unit reduces the overload

While a certain amount of engineering judgment was used in completing Table 2, the results of most of the various methods are likely to be very close to those determined by the TO and PJM. Cases where economic dispatch is used would significantly increase the overload on the Mt. Storm–Doubs line.

5. Pros and cons of different approaches

It should be clear that a planner can get a wide range of transmission planning results depending on what generation—new and existing—is assumed to be in service and how it is dispatched. In setting the generation dispatch assumptions used for transmission planning under market conditions the regional planner must use caution so as to be transparent, predictable, and unbiased.

Rules must be established regarding these assumptions so that:

- Results can be justified by the planner and replicated by various stakeholders;
- Participants are prevented from picking generation dispatch assumptions to evaluate the transmission system that benefits them;
- Participants will be discouraged from ‘gaming’ the system; and

- Studies will produce consistent results that can be confirmed and replicated by outside parties.

5.1 Pros and cons of generator queue approaches

Clearly there must be a consistent and reasonable standard used to decide what generation from the generator queue should be included for study. Including all proposed generation is one extreme, while including only that generation that is under construction would be the other extreme.

As shown in Table 1 above, the systems discussed here are reasonably consistent in this regard. Generators under construction or with executed transmission connection contracts are included. Less certain generation is included only by a few of these system, and then only under certain special conditions. This approach limits the amounts and types of generation that will be included in studies, especially beyond a five-year planning horizon.

On the other hand, to include all proposed generation or even all generation that had completed or filed for a connection study would be an invitation to manipulation and gaming by generation developers. If all generation filing for a connection study were included in evaluating the example system, generators in the east could proposed far more generation than they could possibly built so as to discourage any new west-east transmission from being built. Then when all the generation didn't materialize, the lack of transmission would cause congestion prices to rise and profit the eastern generators.

The situation would quickly escalate as western generators countered with their own fanciful proposals to balance out those being made for the east. Chaos would ensue.

5.2 Pros and cons of generation dispatch options

Each of the three dispatch patterns discussed above present advantages and disadvantages.

5.2.1 Economic dispatch

An economic dispatch might seem to be the most logical choice as it most closely matches the approach generally used when utilities were vertically integrated and before competition and market designs were introduced. An economic dispatch will tend to favor existing low-cost generation and existing power flow patterns to the disadvantage of generation alternatives located closer to load centers. Such an assumption could well bias transmission plans in favor of certain generators or technologies over others.

In the example system presented in §4, large coal units built near coal mines are located west of the affected line and tend to increase its loading. An economic dispatch assumption would justify additional transmission so that this energy could be delivered. New transmission facilities would likely provide ‘spare’ capacity that could allow new coal generation to be built without having to pay for expensive transmission upgrades. This new coal generation would, then, become part of the base system that would likely justify future transmission additions based on economic dispatch assumptions in future studies.

5.2.2 Stressed dispatch

Stressed dispatch in various forms is the most commonly applied among the systems discussed here. The idea is to stress the transmission system significantly in a reasonable and realistic way. The challenge is in establishing clear procedures for developing these stressed cases while allowing some flexibility to include system conditions that are of reasonable concern to system operators and planners. Otherwise, affected parties can argue for changes in the assumptions that will favor their particular situation or project.

5.2.3 Flat dispatch

A flat dispatch is, in one way, the most unbiased assumption. No generator is favored over any other as they are all dispatched to the percentage of their individual capabilities. At the same time, a flat dispatch is the most unnatural—the one that is least likely to actually occur in any realistic operation. On the other hand, this is the dispatch that is the easiest to explain and replicate by all parties, it has the appearance of fairness.

6. Conclusions

In general, the only generators that should be included from the queue are those that are reasonably certain of being built and available—those under construction or with executed connection contracts. Systems that are experiencing higher growth rates will have to include additional generation. For these systems the most-certain generation will probably not be enough to meet load growth beyond about five years into the future. In these cases, it would seem best to develop several scenarios that would establish conceptual plans for different generation expansion patterns.

In regard to generation dispatch, some form of stressed dispatch seems best. The challenge is to define what conditions qualify as ‘stressed’. The approach should be transparent, predictable, and unbiased.

Using an economic dispatch tends to pick winners and losers among generators depending on what assumptions are made regarding variable operating costs, fuel

costs, heat rates, et cetera. It will also open many issues for debate regarding data and assumptions.

The flat dispatch, while being the 'fairest', is also clearly unrealistic. It can be useful, however, as a starting point for analyses by various stakeholders, as is done by PJM.

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