Market Efficiency 2014/2015 Long Term Order 1000: Optimal Capacitors Configuration

Background

The PJM Order 1000 Long Term Market Efficiency proposal window solicited stakeholder proposals for market efficiency projects that could relieve future PJM simulated market congestion. Proposals were submitted to address congestion in many different regions of PJM. In particular, 41 separate projects were submitted to relieve congestion associated with PJM IROL (Interconnected Reliability Operating Limit) reactive interfaces. Specifically, these projects were targeted to reduce congestion on either the APSOUTH or AEP-DOM reactive interfaces. The allowed flow on the PJM reactive interfaces correlate to power flows beyond which voltage violations may occur. These allowed flows, or limits, were separately determined based on an AC voltage stability analysis.

Scope

PJM conducted a thorough analysis on the 41 proposed projects directed to relieving congestion on the PJM reactive interfaces. Of the 41 projects proposed to address the reactive interface congestion, 6 projects provided the most benefits. Many of these projects provided area reactive support through distributed capacitor installations. Through this analysis, PJM discovered that the projects that included reactive support and in particular inclusions of capacitors were most beneficial from a theoretical standpoint. The results indicated that multiple capacitors would provide the greatest benefits from a cost to benefit standpoint and a congestion reduction standpoint. The benefits were mainly realized because the PJM Power Systems Voltage Stability (PV) analysis showed an increase of ratings particularly on the AP-South interface. However, the PV analysis is a theoretical analysis based on planned data and it relies on input assumptions that might not always be representative of actual operations. In particular, the analysis showed that several thousand MVARs of capacitors would be beneficial to include in the RTEP. However, an inclusion of several thousand MVARs of capacitors is not practical in Operations. In other words, the addition of capacitors can help to maintain system voltages during heavy transfers however the addition of too many capacitors in a local area could create operational problems. In fact, many existing in-service capacitors already cannot be turned on because of operational issues such as high voltages. To ensure that the best solution was found, PJM Markets, Planning, and Operations collaborated to select the optimal set of capacitors from those that were submitted in the proposal window. The main goal was to make sure that any of the proposed capacitor projects (or combination of multiple projects) do not harm the system and provide some operational benefits.

Analysis Overview

The determination of the optimal capacitor configuration involved using historical analysis, EMS TLC analysis, and QV analysis. Many of the proposed capacitor locations were already in areas with existing capacitors or SVCs. In addition, some proposed capacitor locations overlapped with approved RTEP reliability projects.

Table 1 below summarizes the existing capacitors/SVCs that are located in close proximity to the proposed capacitors. From the table, it is obvious that there are already a significant number of existing capacitors/SVCs in close proximity to proposed projects.

Table 1: Proposed and Existing Capacitors/SVCs

Project	Bus	Size (MVAR)	Existing Area Capacitors/SVCs (at sub or one substation away)	Total nearby (MVAR)
9A	Dooms Substation	175	Dooms 138 MVar cap, Dooms 70 Mvar SVC, Valley 150 Mvar cap	358
	Lexington Substation	175		
	Brambleton Substation	350	Mosby 290 Mvar cap, Mosby 250 Mvar SVC1, Mosby 250 Mvar SVC2, Goose Creek 100 Mvar cap1, Goose Creek 100 Mvar cap2, Loudoun 147 Mvar cap1, Loudoun 150 Mvar cap3, Ashburn 178 Mvar cap, Pleasant View 138 Mvar cap	1603
	Ashburn Substation	350	Ashburn 178 Mvar cap, Pleasant View 138 Mvar cap	316
	Jackson's Ferry Substation	250		
	Broadford Substation	250		
Total 9A		**1550**		**2277**
6C	Dooms Substation	300	Dooms 138 MVar cap, Dooms 70 Mvar SVC, Valley 150 Mvar cap	358
	Shelhorn substation	300		
	Morrisville substation	300	Morrisville 300Mvar cap, Loudoun 147 Mvar cap1, Loudoun 150 Mvar cap3	597
	Liberty substation	150		
	Cannon Branch	150		
Total 6C		**1200**		**955**
17A	Cochran Mill	600	Pleasant View 138 Mvar cap, Loudoun 147 Mvar cap1, Loudoun 150 Mvar cap3	435
Total 17A		**600**		**435**
Total		**3350**		**3667**

* *1. The nearby capacitors/SVCs are at the substation or substation away.*
2. Only the significant capacitors are included in the list – the smaller capacitors are omitted.

PJM Operations selected some historical periods when AP-South congestion was higher and applied the proposed capacitors to see if they will be beneficial. The study was focused on determining the point of saturation, the point when there were too many capacitors. Also, to avoid high voltages, various scenarios were studied with different capacitors. It was found that placing the proposed capacitors in service sequentially produced some inconsistent results due to very high voltages. Consequently, some existing capacitors were left in or out of service. In addition to the analysis done by PJM Operations, PJM Planning completed an optimal

MVAR location study using QV analysis. Note that this QV analysis looks at dynamic reactive injections so the results may not be directly comparable in all instances to static capacitor injections.

PJM historical analysis showed that since January 2013, 89% of the AP South congestion hours have been driven by either loss of Bedington – Black Oak 500 kV or Black Oak – Hatfield 500 kV, with congestion due to loss of Bedington – Black Oak occurring with more than twice the frequency of loss of Black Oak – Hatfield.

As a result, using the 2019 RTEP Summer Peak base case, PJM Planning performed a QV analysis for the AP South interface for loss of Bedington – Black Oak at a transfer level of about 700 MW beyond the voltage collapse point to determine how much dynamic reactive injections substations in the vicinity of the interface would be required to remedy the voltage collapse. Over 200 substations were examined and ranked from lowest MVAR injection required to highest MVAR injection required. Only 71 substations were able to provide voltage relief at the transfer level tested.

Solution

Based on the PJM analysis, a capacitor configuration that provides high market congestion benefits, high reliability, and allows for optimal operational impact was selected as solution.

The recommended locations are depicted in the Figure 2, and consist of new capacitor installations of 175 MVAR, 175 MVAR, 300 MVAR, and 150 MVAR at the existing Brambleton, Ashburn, Shelhorn, and Liberty substations, respectively.

These upgrades to existing equipment will be designated to the incumbent transmission owner.

Figure 2: Market Efficiency Optimal Capacitor Configuration