OFFICIAL
EXHIBITS

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EXHIBIT NO. 6
4-14-15 AT
DATE REPORTER

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**VERIFIED DIRECT TESTIMONY**

**OF**

**DONALD E. MARTIN**

**ON BEHALF OF**

**INDIANAPOLIS POWER & LIGHT COMPANY**

**CAUSE NO. 44540**

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**INCLUDING ATTACHMENT DEM-1**

**VERIFIED DIRECT TESTIMONY OF DONALD MARTIN**
**ON BEHALF OF**
**INDIANAPOLIS POWER & LIGHT COMPANY**

**Q1. Please state your name, title and business address.**

A1. My name is Donald E. Martin. I am an Executive Consultant with ABB Power Systems Consulting ("ABB"). My business address is 940 Main Campus Drive, Suite 300, Raleigh, North Carolina 27606.

**Q2. How long have you held your current position?**

A2. I have been in my current position with ABB for 13 years.

**Q3. What position did you hold prior to your present position?**

A3. Previously, I held the position of Manager of System Control and Stability with ABB for 18 years.

**Q4. What positions did you hold prior to joining ABB?**

A4. I held the position Director of the System Engineering Division for Western Area Power Administration's Boulder City Area Office from 1975-1983. Prior to that position I worked in system planning and system protection for Arizona Public Service.

**Q5. What are your professional qualifications?**

A5. I hold the degrees of Bachelor of Science and Master of Science in Electrical Engineering. I am a professional registered Electrical Engineer in the State of Nevada and the State of Maine.

**Q6. Have you previously testified before the Indiana Utility Regulatory Commission ("IURC" or "Commission") or any other regulatory bodies?**

A6. I submitted direct testimony on behalf of IPL in Cause No. 44339. I have testified before the Maine Public Utilities Commission and the Alberta Utilities Commission.

**Q7. What is the purpose of your testimony?**

A7. Indianapolis Power & Light Company ("IPL") engaged ABB to conduct an import and voltage stability study to evaluate system performance assuming the retirement of Eagle Valley Units 1-6, Harding Street (Stout) Units 3-4 and unavailability of HS-7 (also known as Stout Unit 7). The purpose of my testimony is to present the results of ABB's import and voltage stability study with these units' retirement and unavailability.

**Q8. Does your testimony include any attachments?**

A8. Yes. My testimony includes Attachment DEM-1, which is a copy of the ABB report titled "IPL Import and Voltage Stability Study, Sensitivity Analysis for Retirement of Eagle Valley Units 1-6 and Harding Street Units 3-4 and Unavailability of Stout 7".

**Q9. Was the attachment identified above prepared or assembled by you or under your direction or supervision?**

A9. Yes.

**Q10. What is the purpose of conducting an import and voltage stability study?**

A10. The purpose of this analysis was to evaluate transmission system performance assuming the retirement of Eagle Valley Units 1-6, Harding Street (Stout) Units 3-4 and unavailability of HS-7 (also known as Stout Unit 7).

**Q11. What system performance criteria were used in preparation of the power transfer study?**

A11. The system performance criteria used in the power transfer study consisted of the use of North American Electric Reliability Corporation ("NERC") reliability standards and IPL transmission planning criteria as used by the Midcontinent Independent System Operator ("MISO") for its study process.

**Q12. What import and voltage stability study did ABB prepare for IPL?**

A12. ABB performed an import and voltage stability study for IPL for evaluating the system upgrades that would be needed to meet system performance requirements after Eagle Valley Units 1-6 and Harding Street Units 3-4 retired and assuming the unavailability of HS-7. Based on the system performance criteria, IPL and ABB worked together to develop any necessary least cost transmission solutions. The solutions needed to meet the criteria include substation upgrades, transmission line upgrades, and reactive power equipment. These solutions were tested by ABB to insure that the system met the criteria without HS-7 and mitigated any conditions that do not meet the system performance criteria. Solutions for mitigating thermal overloads involved replacement of terminal equipment on affected facilities and/or new and upgraded transmission lines and/or transformers. Mitigation of low voltages was in the form of shunt capacitor additions and other Flexible AC Transmission System ("FACTS") devices. The final list of upgrades for meeting system performance was reviewed by IPL in order to determine the feasibility of each upgrade such as right-of-way considerations and availability of space in the substations to minimize the cost of each project.

**Q13. What types of problems occur if system performance criteria are not met?**

A13. Typical import and voltage stability study deficiencies include overloaded transmission facilities and bus voltages outside the design criteria.

**Q14. What was the methodology used in the import and voltage stability study?**

A14. As described in the ABB report titled "IPL Import and Voltage Stability Study, Sensitivity Analysis for Retirement of Eagle Valley Units 1-6 and Harding Street Units 3-4 and Unavailability of Stout 7" (Attachment DEM-1), the techniques to analyze the system performance were steady-state power flow simulations and reactive power reserve level analysis of the interconnected power grid. These simulations were done with a Base Case and the Gap Year case (with existing IPL Eagle Valley Units 1-6 and Harding Street Units 3-4 retired and unavailability of Harding Street Unit 7) with no contingencies, single contingencies, and selected multiple contingencies. The Gap Year referred to in the study is the time period between when Eagle Valley Units 3 through 6 are shutdown in April 2016 and when the new Eagle Valley CCGT goes on line in May 2017. The Power System Simulator for Engineering ("PSS/E") with its AC contingency calculator ("ACCC") contingency analysis tool were used in this study to run detailed power flow simulations. A summary of the transmission constraints was provided in the Import and Voltage Stability Study Report with a list of voltage and branch loading deviations from the criteria. This list included the percent deviation, contingency description, overloaded element description, rating, etc. The PSS/E power flow simulation module was used to analyze system reactive power reserve levels under critical contingency conditions. This study determined the requirements for reactive power support needed to maintain a comparable dynamic reactive resource as provided by the Base Case. IPL and ABB worked together to develop any necessary least cost transmission solutions. These solutions were tested by ABB to fix the criteria deviations if there were any. The system intact and contingency analysis was repeated with the transmission solutions included to ensure that the criteria were met.

**Q15. Please describe the results of the import and voltage stability study set forth in Attachment DEM-1.**

A15. The results of the import and voltage stability study quantify the system upgrades and additions for the system performance to meet the criteria along with the financial investment required to implement the system upgrades and additions identified by the study.

**Q16. Please summarize the results of the import and voltage stability study set forth in Attachment DEM-1.**

A16. The summary results of the import and voltage stability study in terms of costs of upgrades to be compliant with requirements are listed in Table 1 below. These costs are for the upgrades and additions that are needed to maintain system performance within the criteria if HS-7 (also known as Stout Unit 7) is unavailable. ABB developed these costs from several sources and compared them. Sources were internal to ABB, but previous MISO and IPL projects were also reviewed. The substation additions were based only on the equipment that needed to be installed at the substation and did not necessarily include any costs of rerouting lines if this were determined to be required. The Static Var Compensator ("SVC") estimate was for a complete turnkey delivery but this does not include any environmental, licensing, land, or IPL management and oversight costs.

| Proposed By | TABLE 1<br>Proposed Upgrades | Estimated Cost ABB ($) |
|---|---|---|
| This Study | Guion: 345 kV ring bus with 2-345 kV breakers | $3,933,333 |
| This Study | Rockville: 1-345 kV and 1-138 kV breakers | $3,466,667 |
| This Study | Southeast: +300/-100 MVA 138 kV SVC | $22,100,000 |
| This Study | Southwest: 75-100 MVar Switched Shunt | $1,457,143 |
| This Study | Francis Creek – Petersburg 345 kV line Rating upgrade to 1195 MVA completed in Q4,2013 | $0 |
| This Study | Guion – Whitestown 345 kV line Rating to 1195 MVA completed in Q2,2014 | $0 |
| **Total** | | **$30,957,143** |

**Q17. Does this conclude your prefiled direct testimony?**

A17. Yes

## VERIFICATION

I, Donald Martin, Executive Consultant with ABB Power Systems Consulting, affirm under penalties of perjury that the foregoing representations are true and correct to the best of my knowledge, information and belief.

Donald E. Martin

Donald Martin

Dated: October 15, 2014

# IPL IMPORT AND VOLTAGE STABILITY STUDY

## Sensitivity Analysis for Retirement of Eagle Valley Units 1-6 and Harding Street Units 3-4 and Unavailability of Stout 7

## FINAL REPORT

July 23, 2014

**SUBMITTED TO:**
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## Table of Contents

# 1 Introduction

**Indianapolis Power & Light Company (IPL)** commissioned ABB Inc., to perform an IPL Import and Voltage Stability Study to identify system performance following the retirement of generation due to Environmental Protection Agency requirements.

The purpose of this analysis was to evaluate system performance assuming the retirement of Eagle Valley Units 1-6, Harding Street (Stout) Units 3-4 and unavailability of Stout Unit 7. The design criteria for import capability in peak load conditions consists of taking the largest unit connected to the 138 kV system being out-of-service for any given generation retirement scenario. Based on this criteria, Stout CT #6 (153 MW) would be the next largest unit. Since this case is evaluated in other studies, Stout Units 5 and 6 (208 MW total) were selected to meet the design criteria. The proposed transmission solutions improve import capability and voltage stability to reliably serve IPL load and must to be installed by the retirement dates of the generation to meet Environmental Protection Agency (EPA) requirements.

# 2 Model Development and Study Methodology

## 2.1 Model Development

<u>BASE_SP</u>

Based on the MTEP12 summer peak power flow case for 2017, the following changes were made to develop the summer peak base case:

- Reflect any other IPL generation, transmission, and load updated information
- Reflect PJM RTEP approved transmission projects close to study areas
- Include detailed IPL 34.5 kV network and 13.8 kV capacitor banks.
- Scale up IPL load to summer peak level – 3200 MW
- Update the sizes of IPL existing 138 kV MSC banks:
  - Castleton 138 kV – reduced from 150MVar to 100 MVar
  - Pike 138 kV – reduced from 150MVar to 100 MVar
  - North 138 kV – 100MVar, no change

  Total IPL 138 kV MSC banks is **300 MVar**.

Table 2-1 shows the case summary in IPL area.

**Table 2-1 IPL Case Summary – Base_SP**

| Type | | Amount (MW) |
|---|---|---|
| **Generation** | Georgetown 1-4 | 319 |
| | Petersburg 1-4 | 1710 |
| | Eagle Valley 2-6 | 291 |
| | Stout 3-7 | 665 |
| | Stout CT 4-6 | 306 |
| | **Total** | 3291 |
| **Import from Tie Line** | | 13 |
| **Total Load** | | 3200 |
| **Total Losses** | | 94 |
| **To Line Shunt** | | 9 |

<u>GP_SP</u>

Based on case **BASE_SP**, the following changes were made to develop the summer peak Gap Year Case:

- Model the retirement of the following units:
  - Eagle Valley (Pritchard) Units 1-6 (291 MW)
  - Stout Units 3-4 (40.2 MW)
- Model the unavailability of Stout 7 (416.3 MW)

Total 747.5 MW generation were turned off. In order to keep the generation and load balance, Petersburg plant generation was increased to its maximum (additional 5.7 MW). And the generation in the following neighbor areas were scaled up by 741.8 MW:

- Area 205 (AEP)
- Area 207 (HE)
- Area 208 (DEI)
- Area 210 (SIGE)

Table 2-2 shows the case summary in IPL area.

**Table 2-2 IPL Case Summary – GP_SP**

| Type | | Amount (MW) |
|---|---|---|
| **Generation** | Georgetown 1-4 | 319 |
| | Petersburg 1-4 | 1716 |
| | Stout 5-6 | 208 |
| | Stout CT 4-6 | 306 |
| | **Total** | 2549 |
| **Import from Tie Line** | | 762 |
| **Total Load** | | 3200 |
| **Total Losses** | | 102 |
| **To Line Shunt** | | 9 |

**GP_SP_U2**

Based on case **GP_SP**, the following system upgrades were added to the summer peak Gap Year Case. These system upgrades are identified by previous studies:

- Hanna: Upgrade Hanna East 345/138 kV auto transformer to 500MVA and add 2-345 kV breakers
- Thompson: Move the existing Hanna East 275 MVA 345/138 kV auto transformer to Thompson substation and add 1-345 kV and 2-138 kV breakers

**GP_SP_A1_U2**

Based on the Gap Year case with system upgrades GP_SP_U2, the following changes were made to develop sensitivity case A1:

- Turn off Stout steam units 5 and 6*
- Redispatch by scaling up generation in neighboring areas
- Add 300 MVar SVC at Southwest 138 kV
- Add 300 MVar SVC at Southeast 138 kV

Add 75 MVar switched capacitors at Southwest 138 kV (due to generator retirements, IPL local voltages drop below 0.95 pu under system-intact (N-0) conditions; these capacitors were added in order to bring system voltages to above 0.95 pu under system intact conditions)

* Stout 5&6 is switched off to follow the IPL Transmission Planning Criteria #9: Import capability at peak load conditions is evaluated with the assumption that the largest base load unit at 138 kV is out-of-service.

The two SVCs are set to regulate their respective 138 kV bus voltages. Under system intact conditions (N-0) conditions, the output of each SVC is 0 MVar. This design was implemented in order to allow the SVCs to preserve their MVar capability for supporting system voltages following disturbances.

Table 2-3 shows the case summary in IPL area.

**Table 2-3 IPL Case Summary – GP_SP_A1_U2**

| Type | | Amount (MW) |
|---|---|---|
| **Generation** | Georgetown 1-4 | 319 |
| | Petersburg 1-4 | 1716 |
| | Stout CT 4-6 | 306 |
| | **Total** | 2341 |
| **Import from Tie Line** | | 972 |
| **Total Load** | | 3200 |
| **Total Losses** | | 104 |
| **Total Line Shunt** | | 9 |

## 2.2 Study Methodology

Power flow analysis was performed for GP_SP_A1_U2 study cases developed in Section 2.1. All IPL Category B and C contingencies are studied for the study case. IPL control area 138 kV and above system was monitored. Steady state criteria in Table 2-4 and Table 2-5 was used for this study to flag thermal and voltage violations. LTC transformers, switched shunts and phase angle regulators are modeled as regulating pre-contingency and non-regulating post-contingency (SVCs are allowed to regulate). Voltage criteria for IPL Category C contingency is >0.90 pu and <1.05 pu. In this study, IPL 138 kV buses voltage below 0.95 pu following Category C contingency are also flagged as violations and are mitigated by system upgrades. This plan will help to provide more reactive reserves for IPL 138 kV system in the steady-state condition in order to use the reserves during dynamic events.

Transmission upgrades and reactive compensation solutions were developed to fix the criteria violations if any. System intact and contingency analyses are repeated with the solutions included. All the studied contingencies as well as any additional contingencies that may result because of the new network configuration were simulated. The evaluation summarized the improvements as well as any possible adverse impacts associated with the proposed solutions.

**Table 2-4 Study Criteria for Thermal Violations**

| | |
|---|---|
| **Flow** | Loading > 100% of Rate A for System Intact Conditions<br>Loading > 100% of Rate B for Contingency Conditions |
| **Flow Contingency Change** | Loading with contingency - Loading without contingency > 1 MVA |

| | |
|---|---|
| **TDF** | (Loading with Generation Turned off - Loading for Base Case)/Turned off Generation > 4% |

**Table 2-5 Study Criteria for Voltage Violations**

| | |
|---|---|
| **IPL Category B Contingency** | <0.95 pu or >1.05 pu |
| **IPL Category C Contingency** | <0.90 pu or >1.05 pu |
| **IPL Category C3 Contingency** | <0.90 pu or >1.10 pu |
| **Voltage Contingency Change** | abs(Voltage with contingency - Voltage without contingency) > 0.005pu |

# 3 Import Study and Steady State Voltage Stability Study Results

## 3.1 Case GP_SP_A1_U2 Evaluation

Power flow simulations with no contingency, IPL Category B and C contingencies were performed for Case GP_SP_A1_U2. Results are compared with the Base Case (Base_SP) results to identify significant adverse system impacts by the generator retirements (Eagle Valley 1-6, Stout 3 and 4), unavailability of Stout 7 and Stout 5 and 6 off-line.

**System Intact Conditions**

There are no thermal or voltage violations for Case GP_SP_A1_U2 under system intact conditions.

**Contingency Conditions**

**Table 3-1**Table 3-1 and Table 3-2 show thermal violations and voltage violations under contingency conditions. If there is more than one contingency that results in violations on the same transmission facility, only the most-limiting contingency (contingency that results in the worst loading or voltage violation) is shown in the tables. All the contingency violations are included in Appendix K. Table 3-3 shows associated contingency descriptions.

**Table 3-1 Thermal Violations for Case GP_SP_A1_U2 Contingency Conditions**

| FROM NO. | FROM NAME | FROM KV | TO NO. | TO NAME | TO KV | CK ID | AREA | ZONE | CONTINGENCY ID | RATING (MVA) | Base_SD (pu) | GP_SP_A1_U2 (pu) | Diff (pu) | TDF (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18 | X16HANNA | 138.0 | 254658 | 16SE | 138.0 | 26 | 216 | 1216 | C1_106 | 478 | 0.413 | 1.048 | 0.635 | 32% |
| 254521 | 16FRANCS | 345.0 | 254529 | 16PETE | 345.0 | 13 | 216 | 1216 | C2_N04 | 956 | | 1.028 | | |
| 254523 | 16GUION | 345.0 | 249529 | 08WHITST | 345.0 | 9 | 216 | 1216 | C2_127 | 956 | 0.708 | 1.029 | 0.321 | 32% |
| 254523 | 16GUION | 345.0 | 254601 | 16GUION | 138.0 | N | 216 | 1216 | C2_109 | 500 | 0.858 | 1.083 | 0.224 | 12% |
| 254524 | 16HANNA | 345.0 | 254605 | 16HANNA | 138.0 | E | 216 | 1216 | C2_N02 | 500 | | 1.032 | | |
| 254534 | 16STOUT | 345.0 | 3WNDTR | 90156A | WND 1 | 1 | 216 | 1216 | C2_111 | 500 | 0.718 | 1.180 | 0.462 | 24% |
| 254591 | 16FVE_T | 138.0 | 249677 | 08SPTBK1 | 138.0 | 9 | 216 | 1216 | C2_110 | 287 | 0.374 | 1.095 | 0.722 | 22% |

* Some contingencies are defined for the Gap Case only, not valid for the Base Case. Those invalid sections are highlighted by gray.

**Table 3-2 Voltage Violations for Case GP_SP_A1_U2 Contingency Conditions**

| NUMBER | NAME | KV | AREA | ZONE | CONTINGENCY ID | Base_SD (pu) | GP_SP_A1_U2 (pu) | Diff (pu) |
|---|---|---|---|---|---|---|---|---|
| 254568 | 16BRIDGEPORT | 138 | 216 | 1216 | B2_133 | 0.956 | 0.948 | 0.007 |
| 254572 | 16CAMBY | 138 | 216 | 1216 | C2_N08 | | 0.920 | |
| 254576 | 16CNTRTN | 138 | 216 | 1216 | C1_012 | 1.015 | 0.949 | 0.066 |
| 254593 | 16FRANK | 138 | 216 | 1216 | C2_113 | 0.991 | 0.949 | 0.042 |
| 254600 | 16GLENS | 138 | 216 | 1216 | C1_012 | 0.987 | 0.915 | 0.073 |
| 254607 | 16HEARTCROSS | 138 | 216 | 1216 | C2_N08 | | 0.931 | |
| 254608 | 16HRTCRSTAP | 138 | 216 | 1216 | C2_N08 | | 0.931 | |
| 254626 | 16MOORSV | 138 | 216 | 1216 | C2_N08 | | 0.925 | |
| 254627 | 16MULLNX | 138 | 216 | 1216 | C1_012 | 0.994 | 0.923 | 0.071 |
| 254641 | 16PRITCH | 138 | 216 | 1216 | C1_012 | 1.015 | 0.949 | 0.066 |
| 254672 | 16THOMPS | 138 | 216 | 1216 | C2_N08 | | 0.920 | |
| 254677 | 16UNITED | 138 | 216 | 1216 | B2_133 | 0.956 | 0.949 | 0.007 |

**Table 3-3 Contingency Descriptions Contingencies Cause the Worst Violations**

| CONTINGENCY ID | CONTINGENCY DESCRIPTION |
|---|---|
| B2_133 | LINE 16BRIDGEPORT 138.0 TO 16ROCKVL 138.0 CIRCUIT 33 |
| C1_012 | STOUT PLANT SOUTH 138KV EAST BUS |
| C1_106 | HANNA SUBSTATION 345KV WEST BUS |
| C2_109 | GUION SUBSTATION 345KV BREAKER #20 FAILURE |
| C2_110 | GUION SUBSTATION 345KV BREAKER #21 FAILURE |
| C2_111 | HANNA SUBSTATION 138KV BREAKER #1 FAILURE |
| C2_113 | HANNA SUBSTATION 138KV BREAKER #4 FAILURE |
| C2_127 | THOMPSON SUBSTATION 345KV BREAKER #4 FAILURE |
| C2_N02 | HANNA SUBSTATION 345KV BREAKER #26 FAILURE |
| C2_N04 | THOMPSON SUBSTATION 345KV BREAKER #5 FAILURE |
| C2_N08 | THOMPSON SUBSTATION 138KV BREAKER #2N FAILURE |

The following thermal violations are detected under contingency conditions:

- The Hanna – Southeast 138 kV line is overloaded following the loss of the Hanna substation 345 kV west bus.
- The Frances Creek – Petersburg 345 kV line is overloaded following failure of breaker #5 at the Thompson 345 kV substation.
- The Guion – Whitestown 345 kV line is overloaded following failure of breaker #4 at the Thompson 345 kV substation.
- The Guion 345/138 kV transformer is overloaded following failure of breaker #20 at the Guion 345 kV substation.
- The Hanna 345/138 kV east transformer is overloaded following failure of breaker #26 at the Hanna 345 kV substation.
- The Stout 345/138 kV transformer is overloaded following failure of breaker #1 at the Hanna 138 kV substation.
- The Five Points - 085PTBK1 138 kV line is overloaded following failure of breaker #21 at the Guion 345 kV substation.

The following critical contingencies cause voltage violations in IPL system:

- Contingency on the Bridgeport – Rockville 138 kV line
- Contingency on the Stout plant south 138 kV east bus
- Contingency on the Hanna substation 138 kV breaker #4 failure
- Contingency on the Thompson substation 138 kV breaker #2N failure

Transmission upgrades are needed to mitigate above thermal and voltage violations.

### 3.2 Additional Transmission Solutions

Based on the thermal and voltage violations detected and shown in Section 3.1, IPL developed various transmission solution options. These were reviewed and tested to determine their effectiveness in mitigating the violations. The additional transmission solutions listed below are all needed.

- Hanna: 138 kV breaker and a half 3-bay bus design ( this upgrade resulted in changes to the contingency deck)
- Guion: 345 kV ring bus with 2-345 kV breakers (this upgrade resulted in changes to the contingency deck)
- Rockville: 1-345 kV and 1-138 kV breakers (this upgrade resulted in changes to the contingency deck)
- Southport: 100 MVar Switched Shunt
- Francis Creek – Petersburg 345 kV line: Rating upgrade to 1195 MVA completed Q3, 2013
- Guion – Whitestown 345 kV line: Rating upgrade to 1195 MVA completed Q2, 2014

### 3.3 Case GP_SP_A1_U3 Evaluation

The transmission solutions listed in Section 3.2 were included in Case GP_SP_A1_U2 to create Case GP_SP_A1_U3. Power flow analysis was performed on Case GP_SP_A1_U3 based on the methodology described in Section 2.2. Results are compared with the Base Case to verify the effectiveness of the upgrades in resolving the violations.

There are no thermal or voltage violations under system intact conditions.

Table 3-4 and Table 3-5 show the worst thermal and voltage violations under contingency case conditions. All the contingency violations are included in Appendix K. Table 3-6 shows associated contingency descriptions.

**Table 3-4 Thermal Violations for Case GP_SP_A1_U3 Contingency Conditions**

| FROM NO. | FROM NAME | FROM KV | TO NO. | TO NAME | TO KV | CK ID | AREA | ZONE | CONTINGENCY ID | RATING (MVA) | Base_SD (pu) | GP_SP_A1_U2 (pu) | Diff (pu) | TDF (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 254523 | 16GUION | 345.0 | 254601 | 16GUION | 138.0 | N | 216 | 1216 | C2_109 | 500 | 0.858 | 1.056 | 0.198 | 10% |
| 254524 | 16HANNA | 345.0 | 254605 | 16HANNA | 138.0 | E | 216 | 1216 | C2_N02 | 500 | | 1.079 | | |
| 254534 | 16STOUT | 345.0 | 3WNDTR | 90156A | WND 1 | 1 | 216 | 1216 | C2_N05 | 500 | | 1.139 | | |

* Some contingencies are defined for the Gap Year Case only, not valid for the Base Case. Those invalid sections are highlighted by gray

Based on information provided by IPL, above overloads are mitigated by operating procedures and no additional transmission upgrades are needed.

**Table 3-5 Voltage Violations for Case GP_SP_A1_U3 Contingency Conditions**

| NUMBER | NAME | KV | AREA | ZONE | CONTINGENCY ID | Base_SD (pu) | GP_SP_A1_U2 (pu) | Diff (pu) |
|---|---|---|---|---|---|---|---|---|
| 254600 | 16GLENS | 138 | 216 | 1216 | C1_012 | 0.987 | 0.929 | 0.058 |
| 254627 | 16MULLNX | 138 | 216 | 1216 | C1_012 | 0.994 | 0.937 | 0.057 |
| 254572 | 16CAMBY | 138 | 216 | 1216 | C1_118 | 0.987 | 0.937 | 0.051 |
| 254626 | 16MOORSV | 138 | 216 | 1216 | C1_118 | 0.991 | 0.941 | 0.050 |
| 254607 | 16HEARTCROSS | 138 | 216 | 1216 | C1_118 | 0.996 | 0.946 | 0.049 |
| 254608 | 16HRTCRSTAP | 138 | 216 | 1216 | C1_118 | 0.996 | 0.947 | 0.049 |
| 254672 | 16THOMPS | 138 | 216 | 1216 | C2_N08 | | 0.933 | |

Table 3-5 shows that post-contingency voltages following certain Category C1 and C2 contingencies are as low as 0.93 pu, which are in violation of the 0.95 pu low voltage criteria to maintain reactive reserves. Additional reactive support is required to improve IPL system voltage above criteria.

**Table 3-6 Contingency Descriptions Contingencies Cause the Worst Violations**

| CONTINGENCY ID | CONTINGENCY DESCRIPTION |
|---|---|
| C1_012 | STOUT PLANT SOUTH 138KV EAST BUS |
| C1_118 | THOMPSON SUBSTATION 138KV WEST BUS |
| C2_N08 | THOMPSON SUBSTATION 138KV BREAKER #2N FAILURE |
| C2_109 | GUION SUBSTATION 345KV BREAKER #20 FAILURE |
| C2_N02 | HANNA SUBSTATION 345KV BREAKER #26 FAILURE |
| C2_N05 | THOMPSON SUBSTATION 345KV BREAKER #2 FAILURE |

## 3.4 Additional Reactive Support in Steady-State Conditions

One way of improving post-contingency voltages is to raise system voltages under system intact conditions. This can be done by providing additional switched capacitors (over and above existing capacitors and the 75 MVar of capacitors at Southwest 138 kV). Another option is to change the voltage schedule of the SVCs such that they generate MVar under system intact conditions (this plan however reduces the amount of reactive support that can be provided by the SVCs following contingencies). For the purposes of this analysis, the voltage schedule of the SVCs is changed such that each SVC generates 100 MVar under system intact conditions (200 MVar is available for post-contingency reactive power support).

The case with above SVC adjustments is called GP_SP_A1_U3_R1. Contingencies that resulted in post-contingency voltage violations on previous Case GP_SP_A1_U3 were tested.
Table 3-7 shows the voltage violations under contingency conditions. Table 3-8 shows associated contingency descriptions.

**Table 3-7 Voltage Violations for Case GP_SP_A1_U3_R1 Contingency Conditions**

| BUS | | | AREA | ZONE | CONTINGENCY | VOLTAGE |
|---|---|---|---|---|---|---|
| 254600 | 16GLENS | 138 | 216 | 1216 | C1_012 | 0.946 |
| 254600 | 16GLENS | 138 | 216 | 1216 | C2_061 | 0.946 |
| 254600 | 16GLENS | 138 | 216 | 1216 | C2_064 | 0.946 |

**Table 3-8 Contingency Descriptions**

| CONTINGENCY ID | CONTINGENCY DESCRIPTION |
|---|---|
| C1_012 | STOUT PLANT SOUTH 138KV EAST BUS |
| C2_061 | STOUT SOUTH PLANT 138KV BREAKER #2C FAILURE |
| C2_064 | STOUT SOUTH PLANT 138KV BREAKER #3C FAILURE |

Based on information provided by IPL, the above voltage violations are acceptable (voltages are reasonably close to 0.95 pu) and no additional Steady-State reactive support is needed.

## 3.5 IPL System Reactive Power Reserve Levels

IPL reactive power reserve levels under different system conditions are analyzed for the following study cases to evaluate the reactive supports requirements:

- Base_SP – Summer peak base case
- GP_SP_A1_U3_R1 – Gap year case with 300 MVar SVC at Southwest 138 kV bus and 300 MVar SVC at Southeast 138 kV bus
- GP_SP_A1_U3_R2 – Gap year case with 300 MVar SVC at Southwest 138 kV bus and 100 MVar switched capacitor at Southeast 138 kV bus

IPL reactive power reserve levels are shown in Figure 3-1. IPL 138kV reactive power reserve levels are shown in Figure 3-2. Table 3-9 shows the contingency descriptions.

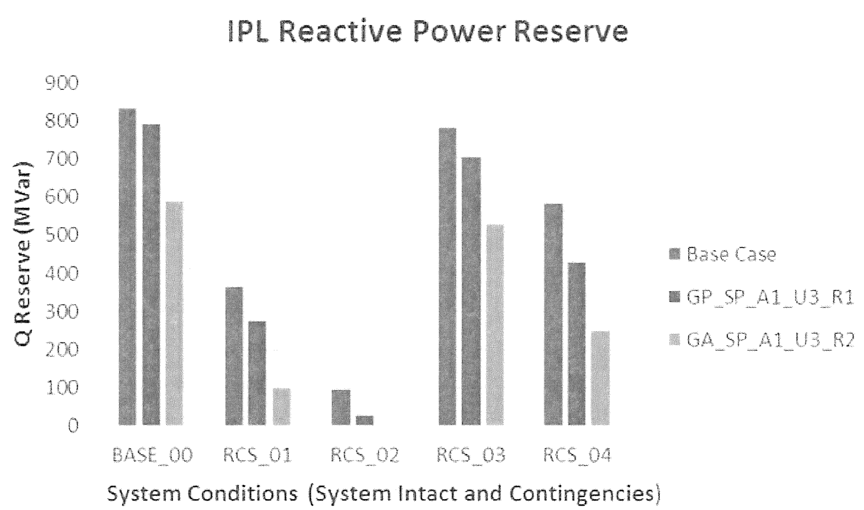


**Figure 3-1 IPL Reactive Power Reserve Level**

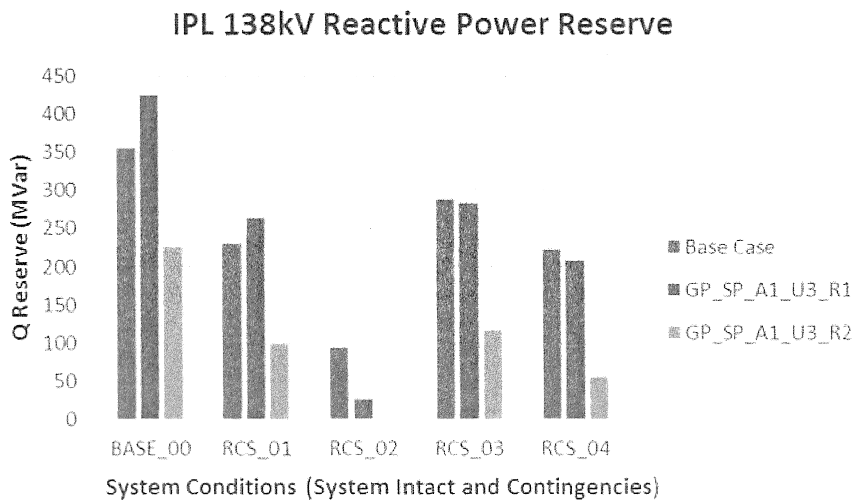


**Figure 3-2 IPL 138kV Reactive Power Reserve Level**

**Table 3-9 Contingency Descriptions**

| ID | Description |
|---|---|
| RCS_01 | Loss of AEP 765KV Rockport-Jefferson Line |
| RCS_02 | Loss of AEP 765KV Rockport-Jefferson and DEK 345 kV Cayuga-Nucor Lines |
| RCS_03 | Loss of IPL 345 kV Petersburg-Thompson Line |
| RCS_04 | Loss of Duke 345 kV Cayuga-Nucor Line |

Under the system conditions with retirement of Eagle Valley Units 1-6 and Harding Street Units 3-4 and unavailability of Stout 7, Case GP_SP_A1_U3_R1 with two 300 MVar SVCs (one at Southwest 138 kV bus, one at Southeast 138 kV bus) provides similar reactive reserve levels as the Base Case. Replacing 300 MVar SVC at Southeast 138 kV bus by 100 MVar switched capacitor, the reactive reserve levels shown in Case GP_SP_A1_U3_R2 are 200 MVar less than shown in Case GP_SP_A1_U3_R1.

Based on the discussion with IPL, in order to provide an equivalent reactive power source to dynamic capabilities of a CCGT, a static VAR compensator ("SVC") was considered as the reactive compensation solution to produce a comparable dynamic reactive resource to the Base Case.

In order to produce a comparable dynamic reactive resource to the Base Case, 300 MVar SVC at Southeast 138 kV bus is recommended with retirement of Eagle Valley Units 1-6 and Harding Street Units 3-4 and unavailability of Stout 7.

# 4 Summary

This study shows the results of an evaluation of system performance assuming the retirement of Eagle Valley Units 1-6, Harding Street (Stout) Units 3-4 and unavailability of Stout Unit 7. The design criteria for import capability in peak load conditions consists of taking the largest unit at 138 kV out-of-service for any given generation retirement scenario. Based on this criteria, Stout CT #6 (153 MW) would be the next largest unit. Since this case is evaluated in other studies, Stout Units 5 and 6 (208 MW total) were selected to meet the design criteria. The proposed transmission solutions improve import capability and voltage stability to reliably serve IPL load and must to be installed by the retirement dates of the generation to meet Environmental Protection Agency (EPA) requirements.

The study case was developed with additional Reactive Supports. Table 4-1 shows the summary of this study case.

**Table 4-1 Study Cases Summary**

| Case | Generator | | | Reactive Supports (MVar) | | |
|---|---|---|---|---|---|---|
| | Eagle Valley 1-6 | Stout 3-6 | Stout 7 | Southwest | | Southeast |
| | | | | Cap | SVC | SVC |
| GP_SP_A1_U2 | Off | Off | Off | 75 | 300 | 300 |

## 4.1 Import Capability Results

Power flow analysis was performed for this study case. An overall summary of the violations in this case is shown beginning in Tables 3-1 and 3-2. The following additional transmission solutions were identified for this study cases:

- Hanna: 138 kV breaker and a half 3-bay bus design (this upgrade resulted in changes to the contingency deck)
- Guion: 345 kV ring bus with 2-345 kV breakers (this upgrade resulted in changes to the contingency deck)
- Rockville: 1-345 kV and 1-138 kV breakers (this upgrade resulted in changes to the contingency deck)
- Southport: 100 MVar Switched Shunt
- Francis Creek – Petersburg 345 kV line: Rating upgrade to 1195 MVA completed Q4, 2013
- Guion – Whitestown 345 kV line: Rating to 1195 MVA completed Q2, 2014

In order to improve post-contingency voltages, system voltages under system intact conditions are raised by changing the voltage schedule of the SVC such that they generate more MVar under system intact conditions.

Table 4-2 shows the steady-state output and dynamic reserve levels for each of the studied SVCs. As a result of this analysis, the post contingency voltages are improved and no additional reactive support is proposed for steady state conditions.

**Table 4-2 Steady-State Output and Dynamic Reserve for Reactive Supports**

| Case | Reactive Supports (MVar) | | | | |
|---|---|---|---|---|---|
| | Southwest Cap Steady-State | Southwest SVC | | Southeast SVC | |
| | | Steady-State Output | Dynamic Reserve | Steady-State Output | Dynamic Reserve |
| GP_SP_A1_U2 | 75 | 100 | 200 | 100 | 200 |

IPL reactive power reserve levels under different system conditions are analyzed for the following study cases to evaluate the reactive supports requirements:

- Base_SP – Summer peak base case
- GP_SP_A1_U3_R1 – Gap year case with 300 MVar SVC at Southwest 138 kV bus and 300 MVar SVC at Southeast 138 kV bus
- GP_SP_A1_U3_R2 – Gap year case with 300 MVar SVC at Southwest 138 kV bus and 100 MVar switched capacitor at Southeast 138 kV bus

In order to produce a comparable dynamic reactive resource to the Base Case, 300 MVar SVC at Southeast 138 kV bus is recommended with retirement of Eagle Valley Units 1-6 and Harding Street Units 3-4 and unavailability of Stout 7.

## 4.2 Proposed Solutions and Cost Estimate

**Transmission Solutions Proposed in Previous Studies**

The following transmission solutions are proposed for import capability and voltage stability associated with the retirement of Eagle Valley Units 1-6 and Harding Street Units 3-4:

- Hanna: Upgrade Hanna East 345/138 kV auto transformer to 500MVA and add 2-345 kV breakers
- Thompson: Move the existing Hanna East 275 MVA 345/138 kV auto transformer to Thompson substation and add 1-345 kV and 2-138 kV breakers
- Hanna: 138 kV breaker and a half 3-bay bus design
- Southport Substation: 100 MVar MSC bank
- Glens Valley Distribution: 3.6-12 MVar MSC banks
- Southwest: New +300/-100 MVA 138 kV SVC or equivalent STATCOM
- RCCS operation of most MSC banks during mid to high system loading from summer to early fall is proposed to help to improve voltage recovery.

**Additional Transmission Solutions Proposed by this Study**

Based on the results of this study, the following additional solutions are proposed for the unavailability of Harding Street Unit 7:

- Guion: 345 kV ring bus with 2-345 kV breakers (this upgrade resulted in changes to the contingency deck)
- Rockville: 1-345 kV and 1-138 kV breakers (this upgrade resulted in changes to the contingency deck)
- Southeast: New +300/-100 MVA 138 kV SVC or equivalent STATCOM
- Southwest Substation: 75 MVar MSC bank
- Francis Creek – Petersburg 345 kV line: Rating upgrade to 1195 MVA completed in Q4,2013
- Guion – Whitestown 345 kV line: Rating to 1195 MVA completed in Q2,2014

The estimated cost of these upgrades is shown in Table 4-3. ABB developed these costs from several sources and compared them. Sources were internal to ABB, but also MISO, and previous IPL projects were reviewed. The substation additions were based on the equipment that needed to be installed at the substation and did not necessarily include any costs of rerouting lines if this was required. The SVC estimate was for a complete turnkey delivery but this does not include any environmental, licensing, land, or IPL management and oversight costs.

**Table 4-3 Estimated Cost for Proposed Upgrades**

| Proposed By | Proposed Upgrades | Estimated Cost ABB ($) |
|---|---|---|
| This Study | Guion: 345 kV ring bus with 2-345 kV breakers | $3,933,333 |
| This Study | Rockville: 1-345 kV and 1-138 kV breakers | $3,466,667 |
| This Study | Southeast: +300/-100 MVA 138 kV SVC | $22,100,000 |
| This Study | Southwest: 75-100 MVar Switched Shunt | $1,457,143 |
| This Study | Francis Creek – Petersburg 345 kV line<br>Rating upgrade to 1195 MVA completed in Q4,2013 | $0 |
| This Study | Guion – Whitestown 345 kV line<br>Rating to 1195 MVA completed in Q2,2014 | $0 |
| **Total** | | **$30,957,143** |