An Evaluation of Transfer Capability Limitations and Solutions for South Mississippi Electric Power Association

Nathan L Brown

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AN EVALUATION OF TRANSFER CAPABILITY LIMITATIONS AND SOLUTIONS FOR SOUTH MISSISSIPPI ELECTRIC POWER ASSOCIATION

By

Nathan L. Brown

A Thesis
Submitted to the Faculty of Mississippi State University in Partial Fulfillment of the Requirements for the Degree of Master of Science in the Department of Electrical and Computer Engineering

Mississippi State, Mississippi
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AN EVALUATION OF TRANSFER CAPABILITY LIMITATIONS AND SOLUTIONS FOR SOUTH MISSISSIPPI ELECTRIC POWER ASSOCIATION

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Historically, transmission transfer capability between transmission systems was typically assumed based on the thermal limits of specific transmission paths. Because electric transmission systems are becoming more and more heavily loaded, accurately evaluating transfer capability between transmission systems and maintaining minimum levels of transfer capability has become increasingly important.

This Thesis evaluates the transfer capability needs and limitations of a specific small electric utility. Identified are various analysis tools and evaluation methods used to determine transfer capability. Two specific evaluation methods are analyzed and compared to determine the best method of determining transfer capability. Various solutions, including upgrading existing or installing new transmission interconnections, are identified and evaluated to determine the best overall solution to achieve and maintain the utility’s desired transfer capability level.
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>ii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>v</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>viii</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II. OVERVIEW OF SMEPA</td>
<td>5</td>
</tr>
<tr>
<td>- SMEPA Control Area</td>
<td>5</td>
</tr>
<tr>
<td>- SMEPA Load in the MPCo Area</td>
<td>6</td>
</tr>
<tr>
<td>- SMEPA Load in the EMI Area</td>
<td>8</td>
</tr>
<tr>
<td>- SMEPA Interconnections with AEC</td>
<td>10</td>
</tr>
<tr>
<td>III. EVALUATION METHODS</td>
<td>12</td>
</tr>
<tr>
<td>- Creation of Models</td>
<td>12</td>
</tr>
<tr>
<td>- Analysis Tools and Solution Techniques</td>
<td>14</td>
</tr>
<tr>
<td>- Power System Simulator (PSS/E) Software</td>
<td>14</td>
</tr>
<tr>
<td>- Managing and Utilizing System Transmission (MUST) Software</td>
<td>21</td>
</tr>
<tr>
<td>IV. EVALUATION PROCEDURE</td>
<td>23</td>
</tr>
<tr>
<td>- Transmission System Evaluation</td>
<td>23</td>
</tr>
<tr>
<td>- Transfer Capability</td>
<td>25</td>
</tr>
<tr>
<td>- Transfer Capability Evaluation Procedure</td>
<td>25</td>
</tr>
<tr>
<td>V. EVALUATION OF TRANSFER CAPABILITY</td>
<td>34</td>
</tr>
<tr>
<td>- Evaluation of Existing SMEPA Transfer Capability</td>
<td>35</td>
</tr>
<tr>
<td>- Transfer Capability Between SMEPA and Southern Company</td>
<td>35</td>
</tr>
<tr>
<td>- Transfer Capability Between SMEPA and Entergy</td>
<td>37</td>
</tr>
<tr>
<td>- Transfer Capability Between SMEPA and AEC</td>
<td>39</td>
</tr>
<tr>
<td>- Identifying Potential Interconnections</td>
<td>41</td>
</tr>
</tbody>
</table>
CHAPTER Page

Potential Interconnections Between SMEPA and MPCo ......................... 41
Clarke 230/161kV Interconnection ....................................................... 41
Jasper 230/161kV Interconnection ....................................................... 43
Jones 230/161kV Interconnection ......................................................... 45
Lumberton 230/161kV Interconnection ............................................... 46
Morrow 230/161kV Interconnection ..................................................... 48

Potential Interconnections Between SMEPA and EMI ......................... 50
Rankin 230kV Interconnection ............................................................. 50
Salem 161/115kV Interconnection ....................................................... 52
Silver Creek 161/115kV Interconnection ............................................ 54
South Walthall 500/161kV Interconnection ........................................ 55

Potential Interconnections Between SMEPA and TVA ........................ 57

VI. DISCUSSION OF RESULTS ............................................................... 61
Importing with the Existing Interconnections ...................................... 61
Exporting with the Existing Interconnections ...................................... 63
Interconnection Evaluation ................................................................. 64
SMEPA Import ..................................................................................... 64
SMEPA Export .................................................................................... 67

VII. CONCLUSIONS .............................................................................. 73
REFERENCES ....................................................................................... 77

APPENDIX

A. SYSTEM MAPS ................................................................................. 79
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Comparison of MUST and PSS/E results utilizing both the Reduced Load and Emergency Dispatch methods of evaluating the flow on the Purvis 230/161kV Transformer</td>
<td>30</td>
</tr>
<tr>
<td>2. Comparison of Reduced Load and Emergency Dispatch methods using MUST and PSS/E to evaluate the flow on the Purvis 230/161kV Transformer</td>
<td>31</td>
</tr>
<tr>
<td>3. Results of MUST transfer capability comparison of three evaluation methods</td>
<td>32</td>
</tr>
<tr>
<td>4. Transmission upgrades required to achieve 300 MW import FCITC from Southern Company through the study period</td>
<td>36</td>
</tr>
<tr>
<td>5. Transmission upgrades required to achieve 300 MW export FCITC to Southern Company through the study period</td>
<td>37</td>
</tr>
<tr>
<td>6. Transmission upgrades required to achieve 300 MW import FCITC from Entergy for the study period</td>
<td>38</td>
</tr>
<tr>
<td>7. Transmission upgrades required to achieve 300 MW export FCITC to Entergy through the study period</td>
<td>39</td>
</tr>
<tr>
<td>8. Transmission upgrades required to achieve 300 MW import FCITC from AEC through the study period</td>
<td>40</td>
</tr>
<tr>
<td>9. Transmission upgrades required to achieve 300 MW import FCITC from Southern with the Clarke 230/161kV interconnection through the study period</td>
<td>42</td>
</tr>
<tr>
<td>10. Transmission upgrades required to achieve 300 MW import FCITC from Southern with the Jasper 230/161kV interconnection through the study period</td>
<td>44</td>
</tr>
<tr>
<td>11. Transmission upgrades required to achieve 300 MW import FCITC from Southern with the Jones 230/161kV interconnection through the study period</td>
<td>46</td>
</tr>
</tbody>
</table>
Table      Page

12. Transmission upgrades required to achieve 300 MW import FCITC from Southern with the Lumberton 230/161kV interconnection through the study period. ................................................................. 47

13. Transmission upgrades required to achieve 300 MW export FCITC to Southern with the Lumberton 230/161kV interconnection through the study period. 48

14. Transmission upgrades required to achieve 300 MW import FCITC from Southern with the Morrow 230/161kV interconnection through the study period. ................................................................. 49

15. Transmission upgrades required to achieve 300 MW import FCITC from Entergy with the Rankin 230kV interconnection through the study period. ........ 51

16. Transmission upgrades required to achieve 300 MW import FCITC from Entergy with the Salem 161/115kV interconnection through the study period. .... 53

17. Transmission upgrades required to achieve 300 MW import FCITC from Entergy with the Silver Creek 161/115kV interconnection through the study period. ................................................................. 55

18. Transmission upgrades required to achieve 300 MW import FCITC from Entergy with the South Walthall 500/161kV interconnection through the study period. ................................................................. 56

19. Transmission upgrades required to achieve 300 MW import FCITC from TVA with the Lake 161kV interconnection through the study period................. 59

20. Transmission upgrades required to achieve 300 MW export FCITC to TVA with the Lake 161 kV interconnection through the study period...................... 60

21. Resulting import FCITC to SMEPA with 250MVA Waynesboro 230/161kV transformer. ........................................................................................................ 62

22. Resulting export FCITC from SMEPA with 300MVA Purvis 230/161kV transformers and upgraded Morrow to Purvis 161kV lines......................... 63

23. Evaluation of the MVA flow impacts of each SMEPA/MPCo interconnection to the Waynesboro 230/161kV transformer for a 300MW import from Southern Company......................................................... 65
24. Evaluation of the MVA flow impacts of each SMEPA/EMI interconnection to the Waynesboro 230/161kV transformer for a 300MW import from Entergy.. 66

25. Resulting import FCITC values assuming the Waynesboro 230/161kV transformer is the limiting element. ................................................................. 67

26. Resulting export FCITC values of potential SMEPA/MPCo interconnections assuming the Purvis 230/161kV transformer is the limiting element......... 67

27. Resulting export FCITC values of potential SMEPA/EMI interconnections assuming the Purvis 230/161kV transformer is the limiting element........ 69
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.1</td>
<td>Combined SMEPA and MPCo Transmission Systems</td>
<td>80</td>
</tr>
<tr>
<td>A.2</td>
<td>Clarke 230/161kV Interconnection</td>
<td>81</td>
</tr>
<tr>
<td>A.3</td>
<td>Jasper 230/161kV Interconnection</td>
<td>82</td>
</tr>
<tr>
<td>A.4</td>
<td>Jones 230/161kV Interconnection</td>
<td>83</td>
</tr>
<tr>
<td>A.5</td>
<td>Lumberton 230/161kV Interconnection</td>
<td>84</td>
</tr>
<tr>
<td>A.6</td>
<td>Morrow 230/161kV Interconnection</td>
<td>85</td>
</tr>
<tr>
<td>A.7</td>
<td>Combined SMEPA and EMI Transmission Systems</td>
<td>86</td>
</tr>
<tr>
<td>A.8</td>
<td>Rankin 230kV Interconnection</td>
<td>87</td>
</tr>
<tr>
<td>A.9</td>
<td>Salem 161/115kV Interconnection</td>
<td>88</td>
</tr>
<tr>
<td>A.10</td>
<td>Silver Creek 161/115kV Interconnection</td>
<td>89</td>
</tr>
<tr>
<td>A.11</td>
<td>South Walthall 500/161kV Interconnection</td>
<td>90</td>
</tr>
<tr>
<td>A.12</td>
<td>Lake 161kV Interconnection</td>
<td>91</td>
</tr>
</tbody>
</table>
CHAPTER I
INTRODUCTION

South Mississippi Electric Power Association (SMEPA) is a non-profit electric
generation and transmission cooperative serving the wholesale power requirements of its
eleven member distribution cooperatives. The SMEPA member distribution cooperatives
serve approximately 350,000 retail customers throughout the state of Mississippi.

Because SMEPA’s member distribution cooperatives are located throughout the
state of Mississippi, SMEPA has portions of its load served from three different
transmission systems located within three different control areas, SMEPA, Southern
Company, and Entergy. In the SMEPA and Entergy control areas, SMEPA owns
generation facilities and has generation responsibilities for its load. Therefore, SMEPA
must maintain the ability to transmit power from one control area to another in order to
maintain reliable, economic service to the member distribution cooperative load.

The purposes of this research are to evaluate the existing transfer capability of the
SMEPA transmission system, to determine the transfer capability needed to allow reliable
and economic operation of SMEPA’s generation and transmission system, and to
evaluate potential new transmission interconnections to help meet future transfer
capability needs. As discussed previously, because SMEPA has load in three separate
control areas with varying contractual responsibilities in each control area, adequate transfer capability is required to serve SMEPA's load economically and reliably.

Transfer capability is the measure of the ability of interconnected electric systems to move or transfer electric power reliably from one area to another area by way of all transmission lines between those areas under specified system conditions. An area is an individual utility, control area, power pool, sub-region, region, regional transmission organization (RTO), or a portion thereof that is comprised of a specified configuration of generation stations, substations, and internally connected transmission lines. The transmission paths between areas may represent one or more transmission lines or interconnections [1].

The determination of transfer capability between specified areas is performed using computer simulation techniques to evaluate the operation of the interconnected transmission systems under a specific set of assumed operating conditions [2]. Each simulation represents a set of system operating conditions that may not be valid in all cases. These system conditions include generation dispatch, system loading, planned system outages, and power transfers into or across the interconnected transmission system. Therefore, any major changes to the assumed system operating conditions can drastically change the calculated transfer capability.

To determine transfer capability, generation or load in the exporting area is adjusted so as to create an excess of generation, while generation or load in the importing area is adjusted so as to create a generation deficiency, thereby automatically creating a power transfer between the exporting and importing areas. These differential adjustments
resulting in excess generation are increased until a specified test level is achieved or until equipment or system limits are reached, taking into account the most critical single contingency outage condition. A single contingency outage is the sudden, unexpected outage or failure of a system facility or element. The transfer capability limit is the transfer level at which a system or equipment limit is reached, as a result of a single contingency outage, and cannot be removed as a limit by implementation of an operating procedure. An operating procedure is a set of policies, practices, or system adjustments that may be automatically or manually implemented by a system operator within a specified time frame to maintain the operational integrity of the interconnected electric systems [1].

To determine transfer capability in the opposite direction, the generation or load adjustments are reversed forcing generation to flow in the opposite direction. Because the generation dispatch, load distribution, and limiting facilities are different, the transfer capability is rarely the same for both directions.

Chapter II presents an overview of SMEPA, which includes details of SMEPA’s generation and transmission facilities and the contractual arrangements between SMEPA and neighboring utilities to serve load within the Entergy and Southern Company control areas. Chapter III discusses the creation of the base case models used for the evaluation and discusses the analysis tools and solution techniques used to evaluate the base case and interconnection models. Chapter IV presents two different methods commonly used to evaluate transfer capability and performs a comparison of these two methods to determine which method produces the best results.
In Chapter V, the transfer capability for the existing SMEPA system is evaluated. In addition, transfer capability is evaluated for each potential transmission interconnection. A discussion of the results of each evaluation is presented in Chapter VI.

In this chapter, the potential interconnections that produce a significant increase in transfer capability will be compared to upgrading SMEPA’s existing interconnections on a reliability, feasibility, and economic basis. Chapter VII discusses the conclusions of the evaluations, including the recommended solutions to achieve the desired transfer capability. In addition, Chapter VII discusses the advantages and disadvantages of the solution techniques and evaluation methods discussed in Chapters III and IV.
CHAPTER II
OVERVIEW OF SMEPA

SMEPA owns and operates a bulk transmission system consisting of 45 miles of 230kV transmission lines and 345 miles of 161kV transmission lines. In addition, SMEPA operates a looped sub-transmission system consisting of 892 miles of 69kV lines. The SMEPA transmission system primarily serves the area in Mississippi east of Interstate 55, south of Interstate 20, and north of Interstate 10. Using these transmission facilities, SMEPA operates a NERC (North American Electric Reliability Council) control area that provides wholesale electric service to four of its eleven member distribution cooperatives with a combined 2001 coincident peak load of 546MW. The SMEPA transmission facilities interconnect with the transmission facilities of Entergy Mississippi, Incorporated (EMI), Mississippi Power Company (MPCo), and Alabama Electric Cooperative (AEC). The transmission facilities of EMI are located within the Entergy control area and the transmission facilities of MPCo are located within the Southern Company control area. AEC operates its own control area.

SMEPA Control Area

Within the SMEPA control area, SMEPA owns and operates two major generation facilities, Plant Morrow and Plant Moselle. Plant Morrow, located in Lamar County Mississippi, is a 400MW coal-fired steam plant consisting of two 200MW units that are connected to SMEPA’s 161kV transmission system. Plant Moselle, located in
Jones County Mississippi, is a 260MW natural gas or oil-fired plant consisting of three 59MW steam units and one 83MW combustion turbine. The three 59MW units are connected to SMEPA’s 69kV transmission system and the 83MW unit is connected to SMEPA’s 161kV transmission system.

In addition, SMEPA owns and operates two peaking turbines, Benndale and Paulding. Paulding is a 20MW oil-fired combustion turbine located in Jasper County Mississippi. Benndale is a 16MW natural gas-fired combustion turbine located in George County Mississippi. These units are unmanned and operated remotely from SMEPA’s Control Center located in Hattiesburg, Mississippi.

Generation expansion plans for the SMEPA control area include the addition of a second 83MW natural gas-fired combustion turbine that will connect to SMEPA’s 161kV transmission system at Moselle. Additional plans include the addition of three 47.5MW natural gas-fired combustion turbines at a new site in Smith County Mississippi. This new generation facility, named “Sylvarena Generation Facility,” will be connected to the SMEPA 69kV transmission system. The transmission upgrades associated with the addition of the Sylvarena Generation Facility include the reconstruction of four 69kV lines with 795ACSR construction. These facilities are being insulated for future conversion to 161kV operation.

**SMEPA Load in the MPCo Area**

The SMEPA and MPCo transmission facilities are directly interconnected through a single 230/161kV interconnection located in Purvis, Mississippi. At Purvis, SMEPA
owns two 168MVA, 230/161kV transformers that connect SMEPA’s 161kV transmission system to the MPCo 230kV transmission system.

SMEPA has contractual arrangements with MPCo to provide all-requirements service to Coast Electric Power Association, the non-SMEPA area of Singing River Electric Power Association, and specific delivery points of Dixie Electric Power Association and Pearl River Valley Electric Power Association. For delivery points within the MPCo area, SMEPA builds all new transmission tap facilities from the MPCo transmission system to the member cooperative delivery points. The generation requirements for the majority of the cooperative delivery points in the MPCo service area are provided by all-requirements contracts, with the exception of the Southeastern Power Administration (SEPA) generation, which is delivered directly to SMEPA delivery points in the MPCo area. The newest MPCo service area delivery points are served via all-requirements, market-based contracts. Currently, the amount of load served by the market-based contracts is approximately 130MW with a projected peak load of approximately 200MW in 2006. Under the market-based contracts, MPCo currently provides generation and transmission service with the cost of generation based on a five-year market projection. SMEPA periodically evaluates the potential of serving the market-based loads in the MPCo area from generation within the SMEPA control area. Having this flexibility requires transfer capability between the SMEPA and Southern Company control areas. Depending on future conditions, it may become more economical for SMEPA to serve these loads from SMEPA generation in the SMEPA control area or generation (purchased or owned) within the Southern Company control
area. In either case, adequate transfer capability must be available to serve the SMEPA load in the MPCo area.

In addition to the all-requirements and market-based contracts with MPCo, SMEPA also has a protective capacity contract (ProCap) with MPCo that provides 200MW of operating reserve to SMEPA in the event of a SMEPA generation emergency. Therefore, SMEPA must maintain a minimum import capability of 200MW from the Southern Company control area to ensure reliability of this resource.

**SMEPA Load in the EMI Area**

SMEPA’s transmission facilities are directly connected to the EMI transmission facilities through a single 161/115 kV interconnection located in Magee, Mississippi. At Magee, SMEPA owns two 150MVA, 161/115kV transformers that connect SMEPA’s 161kV transmission system to the Entergy 115kV transmission system.

SMEPA presently purchases transmission service from EMI for its member cooperatives located in the western portion of the state of Mississippi. Unlike service in the MPCo area, SMEPA has generation responsibilities in addition to building transmission tap facilities to serve member cooperatives’ delivery points in the EMI area. Using the EMI transmission system, SMEPA provides wholesale electric service to Coahoma Electric Power Association, Delta Electric Power Association, Twin County Electric Power Association, Yazoo Valley Electric Power Association, Southwest Mississippi Electric Power Association, Magnolia Electric Power Association, and portions of Southern Pine Electric Power Association with a 2001 coincident peak load of 581MW.
SMEPA generation resources in the EMI area include 10% ownership of the Grand Gulf Nuclear Station located in Claiborne County Mississippi. In addition, SMEPA has long-term power purchase contracts with Louisiana Generating (formerly Cajun Electric Cooperative) for 75MW, Aquila Power Marketing for the purchase of the output of Batesville Unit # 3, approximately 280MW, and with SEPA for 51MW. These power purchase contracts have long-term transmission service reservations for delivery of the power to SMEPA load in the EMI area. Generation expansion plans for the EMI area include the construction of a 249MW natural gas-fired generation station consisting of three 83MW simple-cycle combustion turbines in Jefferson Davis County Mississippi. This new generation facility, named “Silver Creek Generation Facility”, will be connected to the EMI 115kV transmission system at EMI’s existing Silver Creek substation.

SMEPA load in the EMI area is served under a Grandfathered Agreement with Entergy. A Grandfathered Agreement is any existing contract or agreement that was executed prior to the issuance of Order No. 888 on April 24, 1996 by the Federal Energy Regulatory Commission (FERC). Under this agreement, SMEPA has contractual rights to the single SMEPA/Entergy interconnection at Magee. Currently under the contract, SMEPA is awarded transfer capability for this interface based on the contract path rating of 300MW. The contract path or transmission path methodology assumes flow capability across specific transmission facilities with the path limit typically being the thermal rating of the facilities. Currently, transfer capability is available in either direction (from SMEPA to Entergy or Entergy to SMEPA), depending on scheduling needs. Without the
Grandfathered Agreement, transfer capability between SMEPA and Entergy would be determined on a flow basis.

The addition of Batesville Unit #3 (BU3) to SMEPA's EMI area generation resources further increases the need to maintain the 300MW contract path rating of the SMEPA/Entergy interface. The output of BU3 when operating at full-load is approximately 280MW. This generation resource has been identified by SMEPA as a network resource for the SMEPA load within the EMI area. As a network resource, Entergy allows SMEPA to redispatch its EMI area generation resources, including BU3, to relieve system constraints that otherwise would result in the loss of generation. When needed to redispatch, SMEPA has three options, replace the power with other SMEPA owned generating resources within EMI, purchase capacity for delivery to SMEPA load within the EMI area, or utilize the transfer capability between SMEPA and Entergy to schedule generation resources from within the SMEPA control area. Therefore, in order to maintain the flexibility to dispatch generation in both areas economically and reliably, SMEPA must maintain a minimum of 300MW of transfer capability between SMEPA and Entergy.

SMEPA Interconnections with AEC

In addition to the transmission interconnections with MPCo and EMI, SMEPA has two 230kV interconnections with AEC, one at Waynesboro, Mississippi and one at Benndale, Mississippi. At Waynesboro, SMEPA owns one 150MVA, 161/230kV transformer and approximately 18 miles of 230kV transmission line that connects the SMEPA transmission system to the AEC transmission system. At Benndale, SMEPA
owns two 150MVA, 161/230kV transformers and approximately 27 miles of 230kV transmission line that connects the SMEPA transmission system to the AEC transmission system.

In past studies, imports from neighboring utilities to the SMEPA control area have been limited by the rating of the Waynesboro 161/230kV interconnection. Also, exports from the SMEPA control area to neighboring utilities have been limited by the rating of one of the Purvis 161/230kV transformers.

Because SMEPA has load in three separate control areas, Entergy, SMEPA, and Southern Company, maintaining adequate transfer capability is required to ensure reliable, economic service to the SMEPA member distribution cooperatives. The goal is to achieve and maintain a minimum of 300MW of transfer capability between the SMEPA and Entergy control areas and between the SMEPA and Southern Company control areas.

Chapter III discusses the base case model development. In addition, the analysis tools used to perform the evaluation, and the solution techniques used by these analysis tools are discussed.
CHAPTER III
EVALUATION METHODS

This chapter discusses the methods used to create the base case and interconnection models. In addition, this chapter includes a detailed discussion of the solution tools used to perform the evaluations and the solution techniques used by these solution tools.

Creation of Models

SMEPA is a member of the Southeastern Electric Reliability Council (SERC). As a SERC member, SMEPA participates in the VST (VACAR-Southern-TVA-Entergy) modeling process, which includes both loadflow and dynamics modeling processes for the sub-regions of SERC. The completed VST models are provided to the North American Electric Reliability Council (NERC) in Power Technologies, Incorporated Power Systems Simulator software (PSS/E) format. The NERC Multi-regional Modeling Working Group (MMWG) and System Dynamics Database Working Group (SDDWG) incorporate these models with models from other regional reliability councils to create the NERC models.

The loadflow models used for the SMEPA transfer capability evaluation were provided by each neighboring utility. In addition to including the detailed modeling data of each neighboring utility, each model includes the detailed outer world modeling data created using the VST modeling process. These models were updated to include the most
up-to-date SMEPA modeling data with the resulting models used as the base case models for the evaluation.

In order to include the SMEPA modeling data in the neighboring utility models, the existing SMEPA data included in the models was removed using the PSS/E activity PURG. Activity PURG is the equipment removal activity of PSS/E, which allows removal of a single element or an entire subsystem of elements.

SMEPA maintains and periodically updates internal transmission models with the latest projected transmission configuration, load distribution, and generation dispatch data. Data from these models was incorporated into the working models using PSS/E activity RDCH, which is the bulk power flow data input and modification activity. The resulting working models were solved using PSS/E activity FNSL and saved. A detailed discussion of the solution techniques used by activity FNSL is presented in the next section. These working case models were compared to the SMEPA internal models using the PSS/E activity DIFF, which provides a tabular comparison of solution results of two separate loadflow evaluations. The resulting saved case models were used as the base case models, from which all other models used in the evaluation were created. The base case models used in the evaluation include the 2005 summer, 2007 summer, 2007 winter, and 2009 summer. Base case models were created for three SERC sub-regions, Entergy, Southern, and TVA. From these base case models, the specific models of each potential interconnection were created for each load level. Therefore, the study period for the evaluation begins in the summer of 2005 and ends in the summer of 2009.
Analysis Tools and Solution Techniques

The tools used to evaluate the base case and interconnection models include Power Technologies Managing and Utilizing System Transmission (MUST) and PSS/E software. These software packages are recognized as the industry standard power system analysis tools. Various solution techniques are available for use with each of these software packages. Many of these techniques will be used to evaluate the base case and interconnection models.

Power System Simulator (PSS/E) Software

The first step in the evaluation process is to perform a contingency analysis of each model to determine system constraints. These evaluations are performed using activity ACCC, which is the network contingency calculation activity of PSS/E. Prior to evaluating the models with ACCC, a distribution factor file (DFAX) must be created [3]. Activity DFAX reads a set of user defined linear network analysis data files and reflects their contents in a distribution factor data file. These user defined data files include the subsystem description file that is used by ACCC to define subsystems within each model for evaluation, a contingency file that defines the transmission outages to be evaluated, and a monitor file that specifies the elements to be monitored for overloads and voltage excursions during the contingency evaluation. Activity DFAX verifies that each bus is connected to a swing bus through the in-service AC network, it reads the data input files, it derives the line outage distribution factors from the linearized network
model and it and creates the distribution factor data file for use as input to ACCC and TLTG [3].

Activity ACCC requires as part of its input the distribution factor data file created using activity DFAX. The distribution factor data file is used by ACCC to calculate a full AC power flow solution for each contingency specified in the distribution factor data file. The AC solution performed by activity ACCC uses the same fixed-slope decoupled Newton-Raphson iterative solution algorithm as does the solution activity FDNS [3].

Activity FDNS uses a fixed-slope decoupled Newton-Raphson iterative algorithm to solve for bus voltages required to satisfy the bus boundary conditions of a loadflow model. The fixed-slope decoupled Newton-Raphson solution technique is similar to the fast-decoupled Newton-Raphson solution technique. The fast-decoupled Newton-Raphson solution technique is a modified version of the standard fully coupled Newton-Raphson solution technique, in which each iteration is made up of a pair of “half iterations” with the first half iteration calculating new voltage phase angles with the voltage magnitudes held constant and the second half iteration calculating new voltage magnitudes with the voltage phase angles held constant. Therefore, the fast-decoupled Newton-Raphson solution technique separates the real power-angle calculation from the reactive power-voltage adjustment [3].

The fast-decoupled Newton-Raphson method uses an approximation of the Jacobian matrix which is insensitive to bus voltages. Therefore, the real-power angle matrix remains fixed throughout the solution. The reactive-power matrix changes only when generator busses switch between VAR limited and voltage regulating boundary
conditions. The advantages of the fast-decoupled Newton-Raphson method include less sensitivity to poor initial voltage estimates and reduced time per iteration as compared to the fully coupled Newton-Raphson method [3].

The fully coupled Newton-Raphson technique, which is utilized by activity FNSL, is an iterative technique used to solve a specified number of non-linear equations with an equal number of unknowns. The basic equation for the Newton-Raphson solution is shown in Equation 3.1.

\[ \mathbf{x}^{(i)} = \mathbf{x}^{(0)} - \frac{\mathbf{f}(\mathbf{x}^{(0)})}{\mathbf{f}'(\mathbf{x}^{(0)})} \]  

The step-by-step application of the Newton-Raphson method includes choosing an initial value for \( \mathbf{x}^{(0)} \), calculating \( \mathbf{f}(\mathbf{x}^{(0)}) \), evaluating the derivative of \( \mathbf{f}(\mathbf{x}) \) at \( \mathbf{x} = \mathbf{x}^{(0)} \), calculating \( \mathbf{x}^{(1)} \), setting \( \mathbf{x}^{(0)} = \mathbf{x}^{(1)} \), and recalculating \( \mathbf{f}(\mathbf{x}^{(0)}) \). This procedure is repeated until the calculated value of \( \mathbf{f}(\mathbf{x}^{(0)}) \) is less than the specified solution tolerance [4]. The fixed-slope Newton-Raphson solution technique bounds the values of \( \mathbf{x}^{(0)} \) in Equation 3.1 to minimize the possibility of overshooting the solution between iterations, further improving the probability of achieving convergence.

When applying the Newton-Raphson technique to a power flow problem, the function \( \mathbf{f}(\mathbf{x}) \) in Equation 3.1 is replaced by the equation for power injection expressed at each bus as shown in Equation 3.2.

\[ P_i + jQ_i = V_i^2 Y_{ii} + \sum_{k=1}^{n} Y_{ik} V_i V_k^* \]  

Equation 3.2 can be broken down into real and imaginary parts and can be rewritten as shown in Equation 3.3 and 3.4.
\[ P_{Ti} = P_{Gi} - P_{Li} = \sum_{k=1}^{n} V_i V_{ik} \cos(\delta_i - \delta_k - \gamma_{ik}) \quad (3.3) \]

\[ Q_{Ti} = Q_{Gi} - Q_{Li} = \sum_{k=1}^{n} V_i V_{ik} \sin(\delta_i - \delta_k - \gamma_{ik}) \quad (3.4) \]

The magnitude of \( P_T \) and \( Q_T \) are functions of the voltage magnitude and phase angle (\( \delta \)) at each bus. From Equations 3.3 and 3.4, the Jacobian matrix is formed. The Jacobian matrix is a square matrix used to compute the numerical value of partial derivatives based on variations in power, voltage magnitude, and angle. Elements of the Jacobian matrix related to the slack bus and voltage-controlled busses can be removed because the voltage at these busses is specified [5]. Therefore, incorporating the Jacobian matrix into the Newton-Raphson equation produces the equation shown in Equation 3.5.

\[ \begin{bmatrix} \Delta P_1 \\ \vdots \\ \Delta P_n \\ \Delta Q_1 \\ \vdots \\ \Delta Q_n \end{bmatrix} = \begin{bmatrix} \frac{\partial P_1}{\partial \delta_1} & \ldots & \frac{\partial P_1}{\partial \delta_n} & \frac{\partial P_1}{\partial V_1} & \ldots & \frac{\partial P_1}{\partial V_n} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial \delta_1} & \ldots & \frac{\partial P_n}{\partial \delta_n} & \frac{\partial P_n}{\partial V_1} & \ldots & \frac{\partial P_n}{\partial V_n} \\ \frac{\partial Q_1}{\partial \delta_1} & \ldots & \frac{\partial Q_1}{\partial \delta_n} & \frac{\partial Q_1}{\partial V_1} & \ldots & \frac{\partial Q_1}{\partial V_n} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial Q_n}{\partial \delta_1} & \ldots & \frac{\partial Q_n}{\partial \delta_n} & \frac{\partial Q_n}{\partial V_1} & \ldots & \frac{\partial Q_n}{\partial V_n} \end{bmatrix} \begin{bmatrix} \Delta \delta_1 \\ \vdots \\ \Delta \delta_n \\ \Delta V_1 \\ \vdots \\ \Delta V_n \end{bmatrix} \quad (3.5) \]

From Equation 3.5, new values of \( \delta_i \), \( \delta_k \), \( V_i \), and \( V_k \), can be determined assuming initial starting values for \( \delta_i \), \( \delta_k \), \( V_i \), and \( V_k \). The resulting values can be incorporated into Equations 3.3 and 3.4 and new values of \( \delta_i \), \( \delta_k \), \( V_i \), and \( V_k \), can be calculated. This process continues until the solution tolerance applied to the quantities in either column of the matrix in Equation 3.5 is satisfied. To achieve convergence, the initial assumptions of
voltage magnitude and angle must be reasonable. Typically, the starting voltage is assumed to be $1.0 \angle 0^\circ$ pu, which is commonly referred to as a “flat start.” The fully coupled Newton-Raphson solution works well and was the preferred solution technique until the advent of the fast-decoupled technique in the early 1970’s [6].

The fast-decoupled technique incorporates many additional simplifying assumptions. These are shown in Equations 3.6, 3.7, 3.8, and 3.9.

$$
\cos (\delta_i - \delta_k - \gamma_{ik}) \approx 1.0 \\
G_{ik} \sin (\delta_i - \delta_k - \gamma_{ik}) \ll B_{ik} \\
Q_i \ll B_{ik} \\
G_{ii} \approx 0
$$

The modified Jacobian matrices are identified as $J'$ and $J''$. Other simplifications include removing terms from $J'$ such as shunt reactances and off-nominal in-phase transformer taps that largely influence VAR flows and removing the phase angle shifting influences in $J''$ of phase-shifting transformers. The resulting fast-decoupled Newton-Raphson power flow equations are shown in Equations 3.10 and 3.11.

$$
\left[ \begin{array}{c} \frac{\Delta P}{V} \\ \frac{\Delta Q}{V} \end{array} \right] = [J'][\Delta \delta] \\
\left[ \begin{array}{c} \frac{\Delta P}{V} \\ \frac{\Delta Q}{V} \end{array} \right] = [J''][\Delta V]
$$

In Equation 3.10, the $J'$ matrix is evaluated at $\delta = 0$ and the line charging term $B_{kk}$ is removed. In Equation 3.11, the $J''$ matrix is evaluated neglecting the contribution of the series resistance [6].
As with the fully coupled Newton-Raphson solution, the references to the swing bus and voltage-controlled busses can be removed from Equations 3.10 and 3.11 because these values are specified. Equations 3.10 and 3.11 can be used to solve iteratively for the solution. Since the J matrices remain constant through the iteration process, they can be inverted at the beginning of the solution process, saved, and stored for the next iteration. As with the fully coupled Newton-Raphson method, this process continues until the solution tolerance is reached [6].

Activity ACCC can be used to evaluate quickly a large number of contingencies in specified areas. Once these contingencies have been evaluated, ACCC provides an output report that identifies overloaded base case and contingency elements and the resulting bus voltages that are not within a user defined voltage range.

For comparison of two ACCC simulations, SMEPA uses an Excel spreadsheet that compares the ACCC output files and sorts the output based on user defined criteria. For instance, the Excel spreadsheet will provide output of contingency problems that were identified specifically in one case that are not present in the comparison case. In addition, the spreadsheet will list contingency problems identified in both cases and list these contingency problems based on percentage differences in MVA loading or resulting voltage. If the percent difference is input as zero, the spreadsheet lists all contingencies present in both cases.

In addition to using PTI's MUST software to evaluate the various models for transfer capability, activity TLTG was used on certain case evaluations as a comparison tool to verify the output of MUST. Activity TLTG is the transmission interchange limit
analysis activity of PSS/E. Activity TLTG is a predecessor to PTI's MUST software.

As with activity ACCC, activity TLTG requires as part of its input a distribution factor
data file, created using activity DFAX, as described above. Based on the subsystem,
contingency, and monitor file data requirements, activity TLTG estimates the import or
export limits of a specified sub-system using a linearized network model. These estimates
are determined using DC loadflow techniques that assume constant bus voltage
magnitude and transmission line losses as a branch is placed in or out of service. The
advantage of the DC solution technique is that it is substantially faster than a full AC
loadflow solution. The power equation for the DC case is expressed as shown in Equation
3.12.

\[ P_i = V_i + \sum_{k=1}^{n} Y_{ik} V_k \]  \hspace{1cm} (3.12)

Incorporating Equation 3.12 into the Newton-Raphson equations results in the equation
shown in Equation 3.13.

\[ \Delta P_i = \sum_{k=1}^{n} \frac{\partial P_i}{\partial V_k} \Delta V_k \]  \hspace{1cm} (3.13)

Writing Equation 3.13 in matrix notation results in the equations shown in Equations 3.14
and 3.15.

\[
\begin{bmatrix}
\Delta P_1 \\
\vdots \\
\Delta P_n
\end{bmatrix} =
\begin{bmatrix}
\frac{\partial P_1}{\partial V_1} & \cdots & \frac{\partial P_1}{\partial V_n} \\
\vdots & \ddots & \vdots \\
\frac{\partial P_n}{\partial V_1} & \cdots & \frac{\partial P_n}{\partial V_n}
\end{bmatrix}
\begin{bmatrix}
\Delta V_1 \\
\vdots \\
\Delta V_n
\end{bmatrix}
\]  \hspace{1cm} (3.14)
\[ V_i^{\text{new}} = V_i^{\text{old}} - [J]^{-1}[\Delta P] \] (3.15)

From Equation 3.15, values of \( V_i^{\text{new}} \) can be determined assuming initial starting values for \( V_i^{\text{old}} \). The resulting values can be incorporated into Equation 3.12 and new values of \( P_i \) can be calculated. This process continues until the solution tolerance applied to the quantities in either column of the matrix is satisfied [7].

For activity TLTG evaluations, the DC loadflow technique is applied to user defined import and export systems in which the total generation is decreased for import and increased for export. Power transfer distribution factors for each subsystem element are determined and reported in the output data. The maximum study transfer is extrapolated subject to the constraint that no monitored element exceeds its rating by a specified percentage [3].

Managing and Utilizing System Transmission (MUST) Software

PTI’s MUST software was developed in 1996 with cooperation with the VACAR Companies, Virginia Power, Duke Power, Carolina Power and Light, Santee Cooper, and South Carolina Electric and Gas (SCEG). The original purposes for developing the MUST software were to provide a tool to assist transmission operators to understand transaction patterns and their effect on the transmission system, to understand and justify transmission transfer capability limits, and to provide a faster means to perform transfer limit calculations. MUST is capable of performing a linear DC transfer limit analysis, an AC based transfer limit analysis, an evaluation of parallel transfers, a generation sensitivity analysis, and determining the worst-case generation dispatch for a transfer [9].
MUST uses the same DC loadflow techniques as described for PSS/E activity TLTG. The initial base case flows are determined using AC or DC solution techniques. As with activity TLTG, MUST determines transfer limits based on thermal overloads. Typically, the MW flows are within a few percent of AC loadflow results, with extreme deviations within five percent. In addition, MUST features AC analysis tools that utilize either the fast-decoupled Newton-Raphson or the full Newton-Raphson solution technique to refine further the results of the transfer limit analysis. Typically, the first few transfer limits identified using the DC loadflow techniques are verified using AC analysis techniques [8].
CHAPTER IV

EVALUATION PROCEDURE

As a member of SERC, SMEPA is required to meet minimum guidelines as specified in the NERC and SERC Planning and Operating Standards. The SERC Principles and Guides for Reliability in System Planning states that “the purpose of SERC is to augment the reliability of the bulk power supply in the areas served by the SERC member systems” [10]. What follows in this chapter is a discussion of the evaluation techniques used to evaluate the base case models and models including the potential transmission interconnections.

Transmission System Evaluation

Section III of the SERC Principles and Guides for Reliability in System Planning document states “transmission systems should be capable of delivering generator unit output to meet projected customer demands during normal and probable contingency conditions” [10]. In compliance with these guidelines, the evaluation of the base case models and the interconnection models was evaluated using the PSS/E activity ACCC.

ACCC can be used to evaluate base case and single contingency outage conditions under normal base case generation dispatch conditions for the SMEPA system and the neighboring utility system under study. In addition, facilities in all neighboring systems, AEC, Entergy, TVA, SMEPA, and Southern Company, were monitored to
highlight existing base case problems or to highlight problems created by the addition of a potential transmission interconnection.

The base case models were evaluated under normal and single contingency outage conditions to identify the limitations of each transmission system. In each evaluation, multiple transmission facilities were identified as overloaded in the base case or as a result of a single contingency outage. The addition of new transmission interconnections can worsen, improve, or simply not have any effect on these existing problems. Therefore, the comparison evaluations must be performed to identify existing system constraints that were impacted by the addition of the transmission interconnection under study.

The base case models and each specific interconnection model were evaluated using activity ACCC. The ACCC output file for a specific interconnection model was compared to its corresponding base case model using SMEPA’s ACCC comparison spreadsheet. The comparison spreadsheet identifies transmission constraints that exist in either the base case model or in the interconnection model. The resulting output files list the constraints identified with each associated model in tabular format.

Constraints that exist in each model are compared to determine if the addition of the interconnection improves or deteriorates the existing transmission constraints. For example, if a transmission line is overloaded in the base case and the addition of an interconnection increased or reduced this overload by a specified percentage, this constraint is listed as appearing in both cases. Constraints that exist only in the base case
or the comparison case are also identified and listed in tabular format. The specified percentage used for comparison of all transmission evaluations was three percent.

**Transfer Capability**

Section III of the SERC Principles and Guides for Reliability in System Planning document states “transmission interconnections between electric systems should have sufficient capability to accommodate projected electricity transfers while not burdening neighboring electric systems” [10]. Therefore, evaluation of transfer capability between areas must monitor the effects of the transfer on the neighboring electric systems to ensure that neighboring electric systems are not burdened.

As part of each transfer capability evaluation, single contingency evaluations were performed for every transmission element with a voltage rating of 115kV or above within the import and export systems. For example, evaluation of transfer capability between SMEPA and Entergy requires performing a single contingency outage evaluation of each element rated 115kV or above within the SMEPA and Entergy control areas. In addition, transmission elements of all neighboring utilities (AEC, Entergy, Southern Company, TVA, and SMEPA) with a voltage rating of 115kV and above must be monitored during the single contingency evaluation to identify potential transmission constraints.

**Transfer Capability Evaluation Procedure**

According to the July 11, 1999 revision of the SERC ATC Coordination Procedures, transfer capability is calculated by the “emergency demand” scenario, which
is essentially simulating a generation emergency in an importing area as a result of the loss of a large generator or multiple generators in which the exporting system is relied upon to increase its generation to supplement the loss of generation in the importing system [11]. In SMEPA’s case, simulating the loss of the largest generation unit would limit the import test limit to 200MW. To provide the necessary flexibility to serve load in the EMI area, SMEPA desires to maintain a minimum transfer capability, import and export, of 300MW between SMEPA and Entergy. Therefore, in order to evaluate a 300MW import test level realistically, SMEPA’s generation emergency assumes the loss of one Morrow unit, 200MW, one Moselle unit, 59MW, and one Sylvarena unit, 43MW, for a total of 302MW.

Determining the proper method of evaluating export transfer capability for the SMEPA system is somewhat more complex due to the small size of the SMEPA control area. One method currently used by one particular utility is to perform a load reduction in the exporting area equivalent to the generation export test level. For the remaining discussion, this method will be referred to as the “Reduced Load” method. For large utilities in the Southeast, using 10 to 15 percent load reduction to simulate transfers is realistic. However, for small utilities, particularly in SMEPA’s case, this technique raises some concerns. For the SMEPA control area, assuming a 300MW export test level requires a load reduction of approximately 43 percent. The Reduced Load method will be further evaluated and compared with other methods of determining transfer capability discussed later in this chapter.
One advantage of the Reduced Load method is that the base case generation dispatch is maintained and many studies can be performed between multiple control areas without requiring the base case to be modified by scaling load and determining new generation dispatch for each exporting area. One potential disadvantage is that the transmission system is relieved of its responsibility to serve its full native load requirements while providing for the transfer, which may result in increased error.

For example, using MUST to evaluate a 300MW transfer from SMEPA to Entergy with the Reduced Load method produces a transfer limit of 118.9MW, as will be shown later. The limiting element for the transfer is one of the Purvis 230/161kV interconnection transformers as a result of the contingency involving the loss of the adjacent transformer. Modifying the 2005 summer peak model by reducing the load by 118.9MW and adding a base transfer from SMEPA to Entergy of 118.9MW results in a flow on the Purvis 230/161kV transformer of 168.6MVA (168MVA Rating), with the adjacent transformer out of service. Therefore, the Reduced Load method produces a realistic result for a transfer of 118.6MW. Typically, transfer capability as calculated with MUST or PSS/E activity TLTG is rounded down to the nearest 10 MW to account for any errors associated with the calculation.

The method for calculating transfer capability as specified in the SERC ATC Coordination Procedures is commonly referred to as the Emergency Dispatch method. For this method, an emergency situation is simulated in which critical generation facilities within the importing system are lost. The exporting system increases generation at actual physical generation facilities and attempts to reproduce accurately the expected
generation availability and generation level. For generation-limited areas, the procedures allow for up to a 10% reduction in system load to obtain a realistic test level. In addition, the procedures state that “special” circumstances may dictate a load reduction greater than this, but it should be done with care [11].

In the 2005 summer peak base case model, the SMEPA control area load is 697MW. With the base case generation dispatch, there is approximately 164MW of generation available within the SMEPA control area for export. Therefore, to provide 300MW of available generation for a 300MW export requires a reduction in system load of approximately 19 percent. The SERC ATC Coordination Procedures allow for a 10 percent reduction in load to achieve a transfer, with larger amounts of load reduction allowed in “special” circumstances, if the reduction is “done with care” [11]. Therefore, in order to verify that the Reduced Load and the Emergency Dispatch methods produce realistic results for the SMEPA system, these methods will be compared at various transfer levels to evaluate the accuracy of both.

In this comparison, the MUST results were compared to PSS/E analysis in which the flow on the limiting element identified using MUST, the Purvis 230/161kV transformer, is used as the comparison element. In PSS/E, the Reduced Load model was evaluated at the 0, 50, 100, 150, 200, 250, and 300MW transfer levels. For each case, the system load was reduced by the transfer level and the base case system net interchange modified to reflect the transfer. The resulting model was evaluated with the contingency element, the adjacent Purvis 230/161kV transformer, out-of-service. The resulting flow on the remaining Purvis 230/161kV transformer was used to compare against the MUST
results for the same method. The Reduced Load method assumes a constant generation dispatch at all levels of the transfer.

For the Emergency Dispatch method, all available generation was utilized as a contribution to the 300MW test level. The remaining generation needed for the 300MW test level was obtained by reducing the base case system load by 19 percent. Using PSS/E, the Emergency Dispatch method was evaluated at the 0, 50, 100, 150, 200, 250, and 300MW transfer levels by changing the system net interchange to reflect each level. For the 50, 100, and 150MW test levels, available generation in the model was dispatched on an economic basis. A reduction in system load was required to achieve the 200, 250, and 300MW test levels. At these test levels, all SMEPA generation was on-line and operating at full load. The resulting model was evaluated with the contingency element, the adjacent Purvis 230/161kV transformer, out-of-service. The resulting flow on the remaining Purvis 230/161kV transformer was used to compare against the MUST results for the same method. The results of the comparison are shown in Table 1. The MUST values were calculated by multiplying the outage transfer distribution factor (OTDF), as determined by MUST, by the transfer level, and subtracting the MUST determined pre-shift flows. The OTDF is the ratio of the post-contingency change in MW flow on a monitored element to the change in MW transfer [8]. The results of this evaluation are also shown in Table 1.
Table 1. Comparison of MUST and PSS/E results utilizing both the Reduced Load and Emergency Dispatch methods of evaluating the flow on the Purvis 230/161kV Transformer.

<table>
<thead>
<tr>
<th>Transfer Test Level (MW)</th>
<th>Resulting Flow on Purvis 230/161 kV Interconnection Transformer</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reduced Load (MW)</td>
<td>MUST</td>
</tr>
<tr>
<td>0</td>
<td>121.7</td>
<td>121.4</td>
</tr>
<tr>
<td>50</td>
<td>141.2</td>
<td>140.5</td>
</tr>
<tr>
<td>100</td>
<td>160.7</td>
<td>160.0</td>
</tr>
<tr>
<td>150</td>
<td>180.2</td>
<td>179.6</td>
</tr>
<tr>
<td>200</td>
<td>199.6</td>
<td>199.2</td>
</tr>
<tr>
<td>250</td>
<td>219.1</td>
<td>220.2</td>
</tr>
<tr>
<td>300</td>
<td>238.6</td>
<td>239.7</td>
</tr>
</tbody>
</table>

As shown in Table 1, MUST and PSS/E produced similar results, typically within 1.0 percent of each other, with the average percent error between the MUST and PSS/E results for the Reduced Load method less than 0.4 percent. For the Emergency Dispatch method, the average percent error between MUST and PSS/E is less than 0.5 percent. Therefore, MUST provides a good representation of each of the transfer capability methods.

Table 2 displays the differences between the two methods as compared by MUST and PSS/E. The average difference between the two methods, as evaluated with MUST, is approximately 1.2 percent. The average difference between the two methods as compared by PSS/E is less than 1 percent with the largest difference of 1.83 percent occurring at the 300MW test level. Therefore, the Reduced Load method provides a good representation of transfer capability for the SMEPA transmission system.
Table 2. Comparison of Reduced Load and Emergency Dispatch methods using MUST and PSS/E to evaluate the flow on the Purvis 230/161kV Transformer.

<table>
<thead>
<tr>
<th>Transfer Test Level (MW)</th>
<th>Resulting Flow on Purvis 230/161 kV Interconnection Transformer</th>
<th>MUST Comparison of Methods (MW)</th>
<th>PSS/E Comparison of Methods (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RL</td>
<td>ED</td>
<td>% Difference</td>
</tr>
<tr>
<td>0</td>
<td>121.7</td>
<td>121.7</td>
<td>0.00</td>
</tr>
<tr>
<td>50</td>
<td>141.2</td>
<td>140.1</td>
<td>0.77</td>
</tr>
<tr>
<td>100</td>
<td>160.7</td>
<td>158.5</td>
<td>1.37</td>
</tr>
<tr>
<td>150</td>
<td>180.2</td>
<td>177.0</td>
<td>1.78</td>
</tr>
<tr>
<td>200</td>
<td>199.6</td>
<td>196.4</td>
<td>1.65</td>
</tr>
<tr>
<td>250</td>
<td>219.1</td>
<td>216.9</td>
<td>1.03</td>
</tr>
<tr>
<td>300</td>
<td>238.6</td>
<td>234.4</td>
<td>1.80</td>
</tr>
</tbody>
</table>

One question concerning the Emergency Dispatch method is how to model the generation dispatch properly in the reduced load case, used by MUST. For the SMEPA case, it is assumed that the reduced load model generation dispatch will be based on economics. Exports from the SMEPA control area are typically limited by one of the Purvis 230/161kV interconnection transformers with the contingency element being the adjacent transformer. The Purvis interconnection is located 4.6 miles from Plant Morrow, therefore, the dispatch of Plant Morrow greatly affects SMEPA’s First Contingency Incremental Transfer Capability (FCITC). FCITC is the amount of electric power, incremental above normal base transfers, which can be transferred over the interconnected transmission system in a reliable manner. [8]

One assumption is to use the “scale all generation” option of MUST that essentially modifies the generation dispatch based on a specific generator’s share of the total generation in the area [9]. Using the “scale all generation” approach, Plant Morrow...
is dispatched below full load at approximately 300MW. With this generation dispatch and using MUST to evaluate a 300MW transfer from SMEPA to Entergy with the Emergency Dispatch method, a transfer limit of 154.2MW is produced, as shown in Table 3, with the limiting element being one of the two Purvis 230/161kV interconnection transformers as a result of the contingency involving the loss of the adjacent transformer.

Another assumption is that the generation dispatch in the reduced load model used as the base case for the Emergency Dispatch method is based on economics. For this case, Plant Morrow will be dispatched at full load, 400MW. With Plant Morrow dispatched at full load, evaluating the 300MW SMEPA to Entergy transfer produces a transfer limit of 123.4MW, as shown in Table 3. For this case, the limiting element is as it was previously, one of the Purvis 230/161kV interconnection transformers as a result of the contingency involving the loss of the adjacent transformer. Therefore, in the SMEPA case, the SMEPA export FCITC changed by 30MW based on how Plant Morrow was dispatched in the base case. However, in order to achieve a 150MW transfer capability level, SMEPA would have to be willing to operate Plant Morrow at a reduced load level.

Table 3. Results of MUST transfer capability comparison of three evaluation methods.

<table>
<thead>
<tr>
<th>Transfer Capability Evaluation Method</th>
<th>Transfer Limit (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced Load with Economic Dispatch</td>
<td>118.9</td>
</tr>
<tr>
<td>Emergency Dispatch with Economic Dispatch</td>
<td>123.4</td>
</tr>
<tr>
<td>Emergency Dispatch with Non-Economic Dispatch</td>
<td>154.2</td>
</tr>
</tbody>
</table>
The conclusion of the comparison between the Reduced Load and the Emergency Dispatch methods of calculating transfer capability is that the Reduced Load model provides an adequate approximation of actual transfer capability for the SMEPA transmission system and is, therefore, the method of choice for the evaluation. Unlike the Emergency Dispatch method, the Reduced Load method maintains the base case generation dispatch throughout the incremental transfer capability evaluation. The Emergency Dispatch method also provides a good representation of transfer capability, however, based on the results of the evaluation, this method is more subject to error as a result of the assumptions used to determine the generation dispatch of the reduced load model.

The choice of evaluation method depends greatly on the study system. For the SMEPA transmission system, export transfer capability from the SMEPA control area to neighboring utilities is greatly impacted based on the generation dispatch of a major generation facility located near a limiting element. For this reason, the Reduced Load method provides the best results for the SMEPA transmission system.

The Reduced Load method of evaluating transfer capability may not be the preferred method for all transmission systems. For example, evaluation of a transmission system with a large load near a limiting element with the Reduced Load method could produce unrealistic results. Therefore, the method of choice depends greatly on the transmission system being evaluated.
CHAPTER V
EVALUATION OF TRANSFER CAPABILITY

The purposes of this chapter are to evaluate the transfer capability of SMEPA’s existing transmission system, to evaluate potential upgrades to SMEPA’s transmission system to achieve the desired transfer capability level, and to evaluate potential new transmission interconnections with neighboring utilities to determine the best solution for SMEPA to achieve and maintain the desired transfer capability level. The base case models used for the evaluations include the 2005 summer, 2007 summer, 2007 winter, and 2009 summer load levels. The study period for the evaluations begins with the 2005 summer and extends through the 2009 summer.

In this chapter, tables will be used to identify the limiting transmission elements requiring upgrade for the specific case being evaluated to achieve the 300MW FCITC level through the study period. Identified in each table are the load level (year and season) at which the limit first occurs, the FCITC level at which the limit occurs, the limiting element, the owner of the limiting element, the existing MVA rating of the limiting element, and the rating of the limiting element required to achieve a 300MW FCITC level through the study period. Transfer capability values as calculated with MUST were rounded down to the nearest 10 MW to account for potential errors associated with the DC solution techniques.
Evaluation of Existing SMEPA Transfer Capability

Evaluations were performed on each base case model to determine transfer capability between SMEPA and each neighboring utility. To perform the evaluation, MUST software was used to simulate imports and exports of 300MW between SMEPA and the SMEPA neighboring utilities.

For each evaluation, imports to SMEPA assume the loss of one Plant Morrow unit (200MW), one Moselle unit (59MW), and one Sylvarena unit (43MW) for a total simulation of 302MW. Exporting from the SMEPA control area assumes the SMEPA area load will be reduced by 300MW. For the neighboring systems, exports from neighboring systems assume a reduction in system load equivalent to the transfer. Imports to neighboring systems assume a worst-case generation reduction.

Transfer Capability Between SMEPA and Southern Company

The evaluation of transfer capability for a 300MW import from Southern Company produces a FCITC of 0MW for the 2005 summer. The limiting element is identified as SMEPA’s Waynesboro 230/161kV transformer, which has a 150MVA rating. Achieving the import test level through the study period requires upgrade of this facility to a minimum of 202MVA. The next limiting element is AEC’s McIntosh 230/115kV transformer. Table 4 identifies the additional facilities requiring upgrade to achieve a 300MW import FCITC level through the study period.
Table 4. Transmission upgrades required to achieve 300 MW import FCITC from Southern Company through the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating Required (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>0</td>
<td>Waynesboro 230/161 kV XFMR</td>
<td>SMEPA</td>
<td>150</td>
<td>202</td>
</tr>
<tr>
<td>2005 S</td>
<td>200</td>
<td>McIntosh 230/115 kV XFMR</td>
<td>AEC</td>
<td>150</td>
<td>162</td>
</tr>
<tr>
<td>2005 S</td>
<td>250</td>
<td>Highway 53 to Saucier 115 kV Line</td>
<td>MPCo</td>
<td>107</td>
<td>110</td>
</tr>
</tbody>
</table>

As shown in Table 4, there are three limiting elements, all of which first occur in the 2005 summer that limit SMEPA’s import FCITC from Southern Company. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

The evaluation of transfer capability for a 300MW export from SMEPA to Southern Company produces a FCITC of 120MW for the 2005 summer case. The limiting element is the Purvis 230/161kV transformer during a contingency involving the loss of the adjacent 230/161kV transformer. The next limiting element is the MPCo Lumberton to Hurricane Creek 115kV line. Table 5 identifies the additional facilities requiring upgrade to achieve a transfer capability of 300MW through the study period.
Table 5. Transmission upgrades required to achieve 300 MW export FCITC to Southern Company through the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating Required (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>120</td>
<td>Purvis 230/161 kV Transformer</td>
<td>SMEPA</td>
<td>168</td>
<td>235</td>
</tr>
<tr>
<td>2005 S</td>
<td>150</td>
<td>Lumberton to Hurricane Creek 115 kV Line</td>
<td>MPCo</td>
<td>107</td>
<td>114</td>
</tr>
<tr>
<td>2005 S</td>
<td>250</td>
<td>Hurricane Creek to Wiggins 115 kV Line</td>
<td>MPCo</td>
<td>99</td>
<td>107</td>
</tr>
</tbody>
</table>

As shown in Table 5, three limiting elements are identified, all of which first occur in the 2005 summer that limit SMEPA’s export FCITC to Southern Company. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

Transfer Capability Between SMEPA and Entergy

Evaluations of a 300MW transfer from Entergy to SMEPA produces a FCITC of 50MW for the 2005 summer case. The limiting element is identified as the Waynesboro 230/161kV interconnection transformer, which has a rating of 150MVA. The rating of this facility required to achieve a 300MW import transfer capability level through the study period is 204MVA. The next limiting element for the 2005 summer is the AEC McIntosh 230/115kV transformer, which occurs at the 300MW test level. Table 6 identifies the additional facilities requiring upgrade to achieve a 300MW import FCITC through the study period.
Table 6. Transmission upgrades required to achieve 300 MW import FCITC from Entergy for the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating Required (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>50</td>
<td>Waynesboro 230/161 kV XFMR</td>
<td>SMEPA</td>
<td>150</td>
<td>204</td>
</tr>
<tr>
<td>2007 S</td>
<td>240</td>
<td>McIntosh 230/115 kV XFMR</td>
<td>AEC</td>
<td>150</td>
<td>170</td>
</tr>
<tr>
<td>2009 S</td>
<td>0</td>
<td>Silver Creek to New Hebron 115kV</td>
<td>EMI</td>
<td>161</td>
<td>180</td>
</tr>
<tr>
<td>2009 S</td>
<td>70</td>
<td>Magee to New Hebron 115kV</td>
<td>EMI</td>
<td>161</td>
<td>175</td>
</tr>
</tbody>
</table>

As shown in Table 6, four limiting elements are identified at various load levels that limit SMEPA’s import FCITC from Entergy. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

Evaluations of a 300MW export from SMEPA to Entergy produces a FCITC of 110MW, for the 2005 summer case. The limiting element is the Purvis 230/161kV transformer during a contingency involving the loss of the adjacent 230/161kV transformer. The rating of this facility required to achieve the 300MW export FCITC through the study period is 235MVA. The next limiting element is SMEPA’s Purvis to Morrow 161kV line, which occurs beyond the test limit at the 340MW test level. Table 7 identifies the additional facilities requiring upgrade to achieve a 300MW export FCITC through the study period.
Table 7. Transmission upgrades required to achieve 300 MW export FCITC to Entergy through the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating Required (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>110</td>
<td>Purvis 230/161 kV Transformer</td>
<td>SMEPA</td>
<td>168</td>
<td>235</td>
</tr>
<tr>
<td>2007 W</td>
<td>230</td>
<td>Purvis to Morrow 161kV</td>
<td>SMEPA</td>
<td>296</td>
<td>331</td>
</tr>
</tbody>
</table>

As shown in Table 7, two limiting elements are identified at various load levels that limit SMEPA’s export FCITC to Entergy. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

Transfer Capability Between SMEPA and AEC

Evaluation of a 300MW transfer from AEC to SMEPA produces a FCITC of 0MW for the 2005 summer case. The limiting element is identified as the Waynesboro 230/161kV interconnection transformer, which has a rating of 150MVA. The rating of this facility required to achieve the 300MW import FCITC through the study period is 230MVA. The next limiting element is the AEC McIntosh 230/115kV transformer, which is a limit at the 170MW test level in the summer of 2005. Table 8 identifies the additional facilities that require upgrade to achieve an import FCITC of 300MW through the study period.
Table 8. Transmission upgrades required to achieve 300 MW import FCITC from AEC through the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating Required (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>0</td>
<td>Waynesboro 230/161 kV XFMR</td>
<td>SMEPA</td>
<td>150</td>
<td>230</td>
</tr>
<tr>
<td>2005 S</td>
<td>170</td>
<td>McIntosh 230/115 kV XFMR</td>
<td>AEC</td>
<td>150</td>
<td>177</td>
</tr>
</tbody>
</table>

As shown in Table 8, two limiting elements are identified, both of which first occur in the 2005 summer that limit SMEPA’s import FCITC from AEC. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

Evaluations of a 300MW export from SMEPA to AEC produce a FCITC of 140MW in the 2005 summer case. The limiting element is the Purvis 230/161kV transformer during a contingency involving the loss of the adjacent 230/161kV transformer. The rating of this facility required to achieve the 300MW export FCITC through the study period is 248MVA. The next limiting element is SMEPA’s Purvis to Morrow 161kV line, which occurs beyond the test level at 380MW in summer 2005.

In every base case model evaluated, the transformation facilities at SMEPA’s Waynesboro and Purvis interconnections are the limiting elements to SMEPA’s import and export transfer capability. Therefore, upgrades to these facilities may be required in lieu of or in conjunction with additional transmission interconnections to achieve and maintain the desired transfer capability between SMEPA and its neighboring utilities.
Identifying Potential Interconnections

In order to achieve and maintain adequate transfer capability to serve the SMEPA load growth in the SMEPA, MPCo, and EMI areas, additional transmission interconnections between SMEPA and its neighboring utilities may be required. One purpose of this research is to identify potential transmission interconnections with SMEPA neighboring utilities and evaluate those potential interconnections to identify the best and most economical solution to provide the necessary transfer capability needed to serve SMEPA’s projected total system load.

Potential Interconnections Between SMEPA and MPCo

The SMEPA transmission system is located in the southeastern portion of Mississippi, along with the transmission system of MPCo. The SMEPA and MPCo transmission systems overlap each other with exception of the Meridian area and the three coastal counties of Mississippi. SMEPA and MPCo have one existing transmission interconnection located in Purvis, Mississippi. A map showing the combined transmission systems of SMEPA and MPCo is shown in the Appendix in Figure A.1. Described further in this chapter are five potential transmission interconnections between SMEPA and MPCo that could be implemented to ensure adequate transfer capability exists to serve SMEPA’s system load.

Clarke 230/161kV Interconnection

The proposed Clarke 230/161kV interconnection assumes connection of existing SMEPA and MPCo transmission facilities located in southwest Clarke County
Mississippi. The proposal for the Clarke 230/161kV interconnection includes tapping SMEPA’s Waynesboro to Missionary 161kV line and interconnecting with MPCo’s Laurel East to Sykes 230kV line, through two 230/161kV, 150MVA transformers. A combined SMEPA/MPCo map of this interconnection is shown in the Appendix in Figure A.2. The estimated cost of facilities to install the Clarke 230/161kV interconnection is $9,300,000. This cost estimate does not include costs to upgrade facilities listed below as limiting elements to FCITC.

Evaluation of the Clarke 230/161kV interconnection with ACCC as compared to the base case shows that the addition of this interconnection increases the flow on the Waynesboro 230/161kV interconnection by approximately 19 percent. Otherwise, no additional transmission limitations are identified based on contingency analysis.

The increase in flow on the Waynesboro 230/161kV interconnection worsens SMEPA’s ability to import from Southern Company. The Waynesboro 230/161kV transformer is overloaded in the base case and therefore the import capability from Southern Company to SMEPA is 0MW. Table 9 shows the transmission facilities needing upgrade to achieve the 300MW import FCITC level through the study period.

Table 9. Transmission upgrades required to achieve 300 MW import FCITC from Southern with the Clarke 230/161kV interconnection through the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating Required (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>0</td>
<td>Waynesboro 230/161kV XFMR</td>
<td>SMEPA</td>
<td>150</td>
<td>228</td>
</tr>
<tr>
<td>2005 S</td>
<td>230</td>
<td>McIntosh 230/115kV XFMR</td>
<td>AEC</td>
<td>150</td>
<td>165</td>
</tr>
<tr>
<td>2005 S</td>
<td>260</td>
<td>Highway 53 to Saucier 115kV</td>
<td>MPCo</td>
<td>107</td>
<td>110</td>
</tr>
</tbody>
</table>
As shown in Table 9, three limiting elements are identified, all of which first occur in the 2005 summer that limit SMEPA’s import FCITC from Southern Company. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

The addition of the Clarke interconnection improves SMEPA’s ability to export power to Southern Company. SMEPA’s Purvis 230/161kV interconnection transformer becomes overloaded for an export in excess of 250MW, in the 2005 summer case. The minimum rating of this facility required to achieve the 300MW test level is 182MVA in 2005 and 208MVA in 2009.

Jasper 230/161kV Interconnection

The proposed Jasper 230/161kV interconnection assumes connection of existing SMEPA and MPCo facilities located in eastern Jasper County Mississippi. The proposal for the Jasper interconnection includes tapping SMEPA’s Waynesboro to Missionary 161kV line and interconnecting with MPCo’s Laurel East to Meridian Northeast 230kV line through two 230/161kV, 150MVA transformers. A combined SMEPA/MPCo map of this interconnection is shown in the Appendix in Figure A.3. The estimated cost to install the Jasper 230/161kV interconnection is $9,300,000. This cost estimate does not include costs to upgrade facilities listed below as limiting elements to FCITC.

Evaluation of the Jasper 230/161kV interconnection with ACCC as compared to the base case shows that the addition of this interconnection increases the flow on the Waynesboro 230/161kV interconnection by approximately 17 percent. Otherwise, no additional transmission limitations are identified based on contingency analysis.
The increase in flow on the Waynesboro 230/161kV interconnection worsens SMEPA’s ability to import from Southern Company as compared to the existing system. The Waynesboro 230/161kV transformer is overloaded in the base case and therefore the import FCITC from Southern Company to SMEPA is 0MW. Table 10 shows the transmission facilities needing upgrade to achieve the 300MW import FCITC level through the study period.

Table 10. Transmission upgrades required to achieve 300 MW import FCITC from Southern with the Jasper 230/161kV interconnection through the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating Required (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>0</td>
<td>Waynesboro 230/161 kV XFMR</td>
<td>SMEPA</td>
<td>150</td>
<td>239</td>
</tr>
<tr>
<td>2005 S</td>
<td>230</td>
<td>McIntosh 230/115 kV XFMR</td>
<td>AEC</td>
<td>150</td>
<td>166</td>
</tr>
<tr>
<td>2005 S</td>
<td>250</td>
<td>Highway 53 to Saucier 115 kV Line</td>
<td>MPCo</td>
<td>107</td>
<td>110</td>
</tr>
</tbody>
</table>

As shown in Table 10, three limiting elements are identified, all of which first occur in the 2005 summer that limit SMEPA’s import FCITC from Southern Company. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

The addition of the Jasper 230/161kV interconnection improves SMEPA’s ability to export power from SMEPA to Southern Company. SMEPA’s Purvis 230/161kV interconnection transformer becomes overloaded for an export in excess of 240MW in the 2005 summer case. The minimum rating of this facility required to achieve the 300MW export test level is 185MVA in 2005 and 212MVA in 2009.
Jones 230/161kV Interconnection

The proposed Jones 230/161kV interconnection assumes connection of existing SMEPA and MPCo transmission facilities located in south Jones County Mississippi. The proposal for the Jones interconnection includes tapping SMEPA’s Plant Moselle to Hintonville 161kV line and interconnecting it with MPCo’s Hattiesburg Southwest to Laurel East 230kV line through two 230/161kV, 150MVA transformers. A combined SMEPA/MPCo map of this interconnection is shown in the Appendix in Figure A.4. The estimated cost to install the Jones 230/161kV interconnection is $9,300,000. This cost estimate does not include costs to upgrade facilities listed below as limiting elements to FCITC.

Evaluation of the Jones 230/161kV interconnection with ACCC as compared to the base case shows that the addition of this interconnection increases the flow on the Waynesboro 230/161kV interconnection by approximately 5 percent. Otherwise, no additional transmission limitations are identified based on contingency analysis.

The increase in flow on the Waynesboro 230/161kV interconnection slightly worsens SMEPA’s ability to import from Southern Company as compared to the existing system. The Waynesboro 230/161kV transformer is overloaded in the base case and therefore the import FCITC from Southern Company to SMEPA is 0MW. Table 11 shows the transmission facilities needing upgrade to achieve the 300MW import FCITC level through the study period.
Table 11. Transmission upgrades required to achieve 300 MW import FCITC from Southern with the Jones 230/161kV interconnection through the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>0</td>
<td>Waynesboro 230/161 kV XFMR</td>
<td>SMEPA</td>
<td>150</td>
<td>221</td>
</tr>
<tr>
<td>2005 S</td>
<td>230</td>
<td>McIntosh 230/115 kV XFMR</td>
<td>AEC</td>
<td>150</td>
<td>168</td>
</tr>
<tr>
<td>2005 S</td>
<td>250</td>
<td>Highway 53 to Saucier 115 kV Line</td>
<td>MPCo</td>
<td>107</td>
<td>110</td>
</tr>
</tbody>
</table>

As shown in Table 11, three limiting elements are identified, all of which first occur in the 2005 summer that limit SMEPA’s import FCITC from Southern Company. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

The addition of the Jones 230/161kV interconnection increases SMEPA’s ability to export power to Southern Company. For the 2005 load level, the FCITC from SMEPA to Southern Company is 350MW. SMEPA’s Purvis 230/161kV interconnection transformer becomes overloaded for an export in excess of 280MW in 2009. The minimum rating of this facility required to achieve the 2009 test level of 300MW is 173MVA.

**Lumberton 230/161kV Interconnection**

The proposed Lumberton 230/161kV interconnection assumes connection of existing SMEPA and MPCo transmission facilities located in Lamar and Forrest counties of Mississippi. The proposal for the Lumberton interconnection includes tapping MPCo’s Purvis to Hurricane Creek 230kV line, installing two 230/161kV, 150MVA transformers, and building approximately four miles of new 161kV line to SMEPA’s existing
Lumberton 161/69kV substation. A combined SMEPA/MPCo map of this interconnection is shown in the Appendix in Figure A.5. The estimated cost to install the Lumberton 230/161kV interconnection is $9,580,000. This cost estimate does not include costs to upgrade facilities listed below as limiting elements to FCITC.

Evaluation of the Lumberton 230/161kV interconnection with ACCC as compared to the base case shows that the addition of this interconnection has little effect on existing transmission facilities in the SMEPA or Southern Company areas. The import FCITC from Southern Company to SMEPA including the facility ratings required to achieve the 300MW import FCITC level through the study period is shown in Table 12.

Table 12. Transmission upgrades required to achieve 300 MW import FCITC from Southern with the Lumberton 230/161kV interconnection through the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating Required (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>0</td>
<td>Waynesboro 230/161 kV XFMR</td>
<td>SMEPA</td>
<td>150</td>
<td>214</td>
</tr>
<tr>
<td>2005 S</td>
<td>230</td>
<td>McIntosh 230/115 kV XFMR</td>
<td>AEC</td>
<td>150</td>
<td>166</td>
</tr>
<tr>
<td>2005 S</td>
<td>250</td>
<td>Highway 53 to Saucier 115 kV Line</td>
<td>MPCo</td>
<td>107</td>
<td>110</td>
</tr>
</tbody>
</table>

As shown in Table 12, three limiting elements are identified, all of which first occur in the 2005 summer that limit SMEPA’s import FCITC from Southern Company. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

The addition of the Lumberton 230/161kV interconnection improves SMEPA’s ability to export power to Southern Company. MPCo’s Lumberton to Hurricane Creek
115kV line becomes overloaded for an export from SMEPA in excess of 150MW. The export FCITC to Southern Company from SMEPA including the facility ratings required to achieve the 300MW import FCITC level through the study period is shown in Table 13.

Table 13. Transmission upgrades required to achieve 300 MW export FCITC to Southern with the Lumberton 230/161kV interconnection through the study period

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating Required (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005S</td>
<td>150</td>
<td>Lumberton to Hurricane Creek 115 kV</td>
<td>MPCo</td>
<td>107</td>
<td>115</td>
</tr>
<tr>
<td>2005 S</td>
<td>200</td>
<td>Purvis 230/161 kV XFMR</td>
<td>SMEPA</td>
<td>168</td>
<td>214</td>
</tr>
<tr>
<td>2005 S</td>
<td>240</td>
<td>Hurricane Creek to Wiggins 115 kV</td>
<td>MPCo</td>
<td>99</td>
<td>108</td>
</tr>
</tbody>
</table>

As shown in Table 13, three limiting elements are identified, all of which first occur in the 2005 summer that limit SMEPA’s export FCITC to Southern Company. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

Morrow 230/161kV Interconnection

The proposed Morrow 230/161kV interconnection assumes connection of existing SMEPA and MPCo transmission facilities located in eastern Lamar County Mississippi. The proposal for the Morrow interconnection includes tapping of SMEPA’s Plant Morrow to Columbia and Plant Morrow to Plant Moselle 161kV lines and interconnecting with the MPCo Hattiesburg Southwest to Bogalusa 230kV line, through two 230/161kV, 150MVA transformers. A combined SMEPA/MPCo map of this
interconnection is shown in the Appendix in Figure A.6. The estimated cost to install the Morrow 230/161kV interconnection is $10,900,000. This cost estimate does not include costs to upgrade facilities listed below as limiting elements to FCITC.

Evaluation of the Morrow 230/161kV interconnection with ACCC as compared to the base case shows that the addition of this interconnection has little effect on existing transmission facilities in the SMEPA or Southern Company areas. The import FCITC from Southern Company to SMEPA including the facility ratings required to achieve the 300MW import FCITC level through the study period is shown in Table 14.

Table 14. Transmission upgrades required to achieve 300 MW import FCITC from Southern with the Morrow 230/161kV interconnection through the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating Required (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>0</td>
<td>Waynesboro 230/161 kV XFMR</td>
<td>SMEPA</td>
<td>150</td>
<td>218</td>
</tr>
<tr>
<td>2005 S</td>
<td>230</td>
<td>McIntosh 230/115 kV XFMR</td>
<td>AEC</td>
<td>150</td>
<td>168</td>
</tr>
<tr>
<td>2005 S</td>
<td>250</td>
<td>Highway 53 to Saucier 115 kV Line</td>
<td>MPCo</td>
<td>107</td>
<td>110</td>
</tr>
</tbody>
</table>

As shown in Table 14, three limiting elements are identified, all of which first occur in the 2005 summer that limit SMEPA’s import FCITC from Southern Company. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

The addition of the Morrow 230/161kV interconnection increases SMEPA’s ability to export power from SMEPA to Southern Company. For the 2005 load level, the FCITC from SMEPA to Southern Company is 360MW. SMEPA’s Purvis 230/161kV interconnection transformer becomes overloaded for an export in excess of 270MW in
2009. The minimum rating of this facility required to achieve the 2009 test level of 300MW is 173MVA.

Potential Interconnections Between SMEPA and EMI

The EMI transmission system is located on the western side of the SMEPA transmission system, primarily serving areas west of Interstate 55 in Mississippi. SMEPA has one existing transmission interconnection with EMI located at Magee, Mississippi. A map of the combined SMEPA and EMI transmission system is shown in the Appendix in Figure A.7.

The models used for the evaluation of the potential EMI interconnections have multiple transmission elements that are identified as overloaded in the base case. According to the Entergy transmission planning staff, these facilities are in the current planning process and have already been or are scheduled to be upgraded by the summer of 2005. Therefore, these facilities are not considered as limits in the evaluation of each transmission interconnection. Described in this chapter are four potential transmission interconnections between SMEPA and EMI that could be implemented to ensure that adequate transfer capability exists to serve SMEPA’s system load.

Rankin 230kV Interconnection

The proposed Rankin 230kV interconnection assumes connection of SMEPA’s transmission facilities located in Scott County Mississippi to existing EMI transmission facilities located in Rankin County Mississippi. The proposed interconnection requires the construction of approximately 28 miles of new 230kV line between SMEPA’s
Homewood 161/69kV substation and EMI’s Rankin 230kV substation and installing two 230/161kV, 150MVA transformers at SMEPA’s Homewood 161/69kV substation. In addition, the proposed Rankin Interconnection assumes completion of the Missionary to Sylvarena Generation 161kV line and the completion of the Sylvarena Generation to Homewood 161kV line. A combined SMEPA/EMI map of this interconnection is shown in the Appendix in Figure A.8. The estimated cost of the facilities required to install this interconnection is $18,260,000. This cost estimate does not include costs to upgrade facilities listed below as limiting elements to FCITC.

Evaluation of the Rankin 230kV interconnection with ACCC as compared to the base case shows that the addition of this interconnection has little effect on existing transmission facilities in the SMEPA or Entergy areas. The comparison identifies two EMI 115kV lines that are slightly overloaded in the 2009 Rankin 230kV interconnection model. The import FCITC from Entergy to SMEPA including the facility ratings required to achieve the 300MW import FCITC level through the study period is shown in Table 15.

Table 15. Transmission upgrades required to achieve 300 MW import FCITC from Entergy with the Rankin 230kV interconnection through the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating Required (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>60</td>
<td>Waynesboro 230/161 kV XFM</td>
<td>SMEPA</td>
<td>150</td>
<td>193</td>
</tr>
<tr>
<td>2007 S</td>
<td>230</td>
<td>McIntosh 230/115 kV XFM</td>
<td>AEC</td>
<td>150</td>
<td>152</td>
</tr>
<tr>
<td>2009 S</td>
<td>0</td>
<td>Silver Creek to New Hebron 115 kV</td>
<td>EMI</td>
<td>161</td>
<td>179</td>
</tr>
<tr>
<td>2009 S</td>
<td>0</td>
<td>Magee to New Hebron 115 kV</td>
<td>EMI</td>
<td>161</td>
<td>173</td>
</tr>
</tbody>
</table>
As shown in Table 15, four limiting elements are identified that first occur at various load levels that limit SMEPA’s import FCITC from Entergy. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

The addition of the Rankin 230kV interconnection improves SMEPA’s ability to export power to Entergy. The limiting element is one of the Purvis 230/161kV transformers in the summer of 2005. The Purvis transformer is the limiting element up to the export test limit of 300MW in 2009. The rating required for this facility to achieve the export FCITC level through the study period is 267MVA.

Salem 161/115kV Interconnection

The proposal for the Salem 161/115kV interconnection includes connection of existing SMEPA transmission facilities located in Marion County Mississippi to existing EMI transmission facilities located in Walthall County Mississippi. The proposal includes tapping EMI’s Tylertown to Silver Creek 115kV line, installing two 161/115kV, 150MVA transformers, building approximately 12.5 miles of new 115kV line to Jayess, and building approximately 20 miles of new 161kV line to SMEPA’s Columbia 161/69kV substation. A combined SMEPA/EMI map of this interconnection is shown in the Appendix in Figure A.9. The estimated cost of the facilities required to install this interconnection is $15,675,000. This cost estimate does not include costs to upgrade facilities listed below as limiting elements to FCITC.

Evaluation of the Salem 161/115kV interconnection with ACCC as compared to the base case shows that the addition of the Salem 161/115kV interconnection reduces
existing base case contingency problems associated with the EMI Kentwood to Amite, Kentwood to Colonial Pipeline, Amite to Independence, and Hazelhurst to James Road 115kV lines. The addition of the Salem interconnection requires upgrade to the Entergy Bogalusa to Dexter, Bogalusa to Franklin, Elton to Southwest Jackson, Elton to Byram, and Jackson to Ray Braswell 115kV lines.

The addition of the Salem 161/115kV interconnection slightly decreases the flow on the SMEPA limiting element to import capability from Entergy. The FCITC from Entergy to SMEPA is 0MW and is limited by the Bogalusa to Dexter 115kV line. The import FCITC from Entergy to SMEPA including the facility ratings required to achieve the 300MW import FCITC level through the study period is shown in Table 16.

Table 16. Transmission upgrades required to achieve 300 MW import FCITC from Entergy with the Salem 161/115kV interconnection through the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating Required (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>0</td>
<td>Bogalusa to Dexter 115 kV</td>
<td>EMI</td>
<td>80</td>
<td>116</td>
</tr>
<tr>
<td>2005 S</td>
<td>0</td>
<td>Vaughn to West Brookhaven 115 kV</td>
<td>EMI</td>
<td>161</td>
<td>171</td>
</tr>
<tr>
<td>2005 S</td>
<td>70</td>
<td>Waynesboro 230/161 kV XFMR</td>
<td>SMEPA</td>
<td>150</td>
<td>190</td>
</tr>
<tr>
<td>2005 S</td>
<td>270</td>
<td>Kentwood to Amite 115 kV</td>
<td>EMI</td>
<td>80</td>
<td>82</td>
</tr>
<tr>
<td>2007 S</td>
<td>290</td>
<td>McIntosh 230/115 kV XFMR</td>
<td>AEC</td>
<td>150</td>
<td>151</td>
</tr>
<tr>
<td>2009 S</td>
<td>0</td>
<td>Silver Creek to New Hebron 115 kV</td>
<td>EMI</td>
<td>161</td>
<td>179</td>
</tr>
<tr>
<td>2009 S</td>
<td>0</td>
<td>Magee to New Hebron 115 kV</td>
<td>EMI</td>
<td>161</td>
<td>174</td>
</tr>
</tbody>
</table>

As shown in Table 16, seven limiting elements first occurring at various load levels are identified that limit SMEPA’s import FCITC from Entergy. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.
The addition of the Salem 161/115kV interconnection improves SMEPA’s ability to export power to Entergy. The FCITC from SMEPA to Entergy is 140MW in 2005 with the limiting element being one of the Purvis 230/161kV transformers. The Purvis transformer is the limiting element up to the export test limit of 300MW in 2009. The rating required for this facility required to achieve the export test limit through 2009 is 266MVA.

**Silver Creek 161/115kV Interconnection**

The proposal for the Silver Creek 161/115kV interconnection includes tapping SMEPA’s Columbia to Magee 161kV line and building approximately 15 miles of 161kV line to SMEPA's Silver Creek Generation Facility, which is under construction in Jefferson Davis County, Mississippi. At Silver Creek, SMEPA has, under construction, a 249MW generation facility that will be connected to the EMI 115kV transmission system at the existing EMI Silver Creek substation, located in Lawrence County, Mississippi. A combined SMEPA/EMI map of this interconnection is shown in the Appendix in Figure A.10. The estimated cost of the facilities required to install this interconnection is $11,350,000. This cost estimate does not include costs to upgrade facilities listed below as limiting elements to FCITC.

Evaluation of the Silver Creek 161/115kV interconnection with ACCC as compared to the base case shows that the addition of the interconnection requires upgrade to Entergy’s Bogalusa to Dexter, Kentwood to Amite, and Kentwood to Colonial Pipeline 115kV lines. The FCITC from Entergy to SMEPA is 0MW and is limited by the EMI Ray Braswell 500/230kV transformer. The import FCITC from Entergy to SMEPA
including the facility ratings required to achieve the 300MW import FCITC level through the study period is shown in Table 17.

Table 17. Transmission upgrades required to achieve 300 MW import FCITC from Entergy with the Silver Creek 161/115kV interconnection through the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating Required (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>0</td>
<td>Ray Braswell 500/230kV XFMR</td>
<td>EMI</td>
<td>560</td>
<td>686</td>
</tr>
<tr>
<td>2005 S</td>
<td>0</td>
<td>Ray Braswell 500/115kV XFMR</td>
<td>EMI</td>
<td>560</td>
<td>647</td>
</tr>
<tr>
<td>2005 S</td>
<td>0</td>
<td>Bogalusa to Dexter 115 kV</td>
<td>EMI</td>
<td>80</td>
<td>111</td>
</tr>
<tr>
<td>2005 S</td>
<td>80</td>
<td>Waynesboro 230/161 kV XFMR</td>
<td>SMEPA</td>
<td>150</td>
<td>195</td>
</tr>
</tbody>
</table>

As shown in Table 17, four limiting elements are identified, all of which first occur in the 2005 summer that limit SMEPA’s import FCITC from Entergy. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

The addition of the Silver Creek 161/115kV interconnection has no apparent effect on SMEPA’s ability to export power to Entergy. The FCITC from SMEPA to Entergy is 100MW in 2005 with the limiting element being one of the Purvis 230/161kV transformers. The Purvis transformer is the limiting element up to the export test limit of 300MW in 2009. The rating required for this facility to achieve the export test limit through 2009 is 300MVA.

**South Walthall 500/161kV Interconnection**

The proposal for the South Walthall 500/161kV interconnection includes connection of SMEPA’s existing 161kV transmission facilities in Marion County.
Mississippi to existing EMI 500kV transmission facilities in south Walthall County Mississippi. The proposal includes tapping Entergy’s Franklin to Bogalusa 500kV line, installing two 500/161kV, 500MVA transformers, and building approximately 30 miles of 161kV line to SMEPA’s Columbia 161/69kV substation. A combined SMEPA/EMI map of this interconnection is shown in the Appendix in Figure A.11. The estimated cost of the facilities required to install this interconnection is $24,300,000. This cost estimate does not include costs to upgrade facilities listed below as limiting elements to FCITC.

Evaluation of the South Walthall 500/161kV interconnection with ACCC as compared to the base case shows that the addition of the interconnection requires upgrades to both SMEPA 230/161kV Purvis transformers and Entergy’s Bogalusa to Dexter 115kV line. The addition of the South Walthall 500/161kV interconnection provides a significant increase in import transfer capability from Entergy. The FCITC from Entergy to SMEPA is 150MW and is limited by SMEPA’s Waynesboro 230/161kV transformer. The import FCITC from Entergy to SMEPA including the facility ratings required to achieve the 300MW import FCITC level through the study period are shown in Table 18.

Table 18. Transmission upgrades required to achieve 300 MW import FCITC from Entergy with the South Walthall 500/161kV interconnection through the study period.
As shown in Table 18, three limiting elements occurring at two different load levels are identified that limit SMEPA’s import FCITC from Entergy. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

The addition of the South Walthall 500/161kV interconnection reduces SMEPA’s ability to export power to Entergy. The FCITC from SMEPA to Entergy is 0MW in 2005 with the limiting element being one of the Purvis 230/161kV transformers. The Purvis 230/161kV transformer is the limiting element up to the export test limit of 300MW in 2009. The rating for this facility required to achieve the 300MW export test limit through 2009 is 292MVA.

Potential Interconnection Between SMEPA and TVA

The TVA transmission system is located north of the SMEPA transmission system, essentially serving the areas north of Interstate 20 and east of Interstate 55 in Mississippi. SMEPA does not currently have any transmission interconnections with TVA. However, TVA has under construction a new 161kV line from Sebastopol to Lake, Mississippi. SMEPA serves a member cooperative delivery point from its 69kV transmission facilities at Lake. Because the transmission facilities of the two utilities will be located in close proximity of each other, SMEPA and TVA believe that a potential interconnection should be evaluated. Therefore, the Lake 161kV interconnection will be included with the transmission interconnections being evaluated.

The proposal for the Lake 161kV interconnection assumes connection of the proposed TVA Lake 161kV substation to SMEPA’s Homewood 161kV substation,
through a new 18 mile, 161kV line. Evaluation of the proposed Lake interconnection assumes completion of SMEPA’s Missionary to Sylvarena Generation and Sylvarena Generation to Homewood 161kV lines. A combined SMEPA/MPCo map highlighting the location of this interconnection is shown in the Appendix in Figure A.12. The estimated cost of the facilities required to install this interconnection is $12,960,000. This cost estimate does not include costs to upgrade facilities listed below as limiting elements to FCITC.

Evaluation of the Lake 161kV interconnection with ACCC as compared to the base case shows that the addition of the interconnection requires upgrades to SMEPA’s Waynesboro 230/161kV transformer due to contingency constraints. Evaluation of SMEPA import capability from TVA with the proposed Lake 161kV interconnection results in an import FCITC of 0MW, for the 2005 summer case. The limiting element is SMEPA’s Waynesboro 230/161kV transformer. Upgrading this facility to achieve the test limit through the study period requires upgrade of the transformer, which is currently rated at 150MVA to achieve a rating of 219MVA. The next limiting element is the AEC McIntosh 230/115kV transformer, which limits the FCITC to 220MW in the 2007 summer case. Upgrading this facility to achieve the test limit through the study period requires upgrade of this transformer, which is currently rated at 150MVA to achieve a rating of 162MVA. The import FCITC from TVA to SMEPA including the facility ratings required to achieve the 300MW import test level through the study period are shown in Table 19.
Table 19. Transmission upgrades required to achieve 300 MW import FCITC from TVA with the Lake 161kV interconnection through the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating Required (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>0</td>
<td>Waynesboro 230/161 kV XFMR</td>
<td>SMEPA</td>
<td>150</td>
<td>219</td>
</tr>
<tr>
<td>2007 S</td>
<td>220</td>
<td>McIntosh 230/115 kV XFMR</td>
<td>AEC</td>
<td>150</td>
<td>162</td>
</tr>
</tbody>
</table>

As shown in Table 19, two limiting elements are identified first occurring at different load levels that limit SMEPA’s import FCITC from TVA. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.

Evaluation of SMEPA export capability to TVA with the proposed Lake 161kV interconnection provides an export FCITC of 180MW, with the limiting element being one of the Purvis 230/161kV transformers. Upgrading this facility to achieve the test limit through the study period requires upgrade of the transformer to achieve a rating of 229MVA (168MVA Rating). The FCITC in 2009 is 0MW and is limited by the TVA East Point 500/161kV transformer. Upgrading this facility to achieve the test limit through the study period requires upgrade of the transformer, which is currently rated at 750MVA to achieve a rating of 786MVA. The export FCITC to TVA from SMEPA including the facility ratings required to achieve the 300MW import test level through the study period is shown in Table 20.
Table 20. Transmission upgrades required to achieve 300 MW export FCITC to TVA with the Lake 161 kV interconnection through the study period.

<table>
<thead>
<tr>
<th>Load Level</th>
<th>FCITC (MW)</th>
<th>Limiting Element</th>
<th>Facility Owner</th>
<th>Rating (MVA)</th>
<th>2009 Rating (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 S</td>
<td>180</td>
<td>Purvis 230/161 kV XFMR</td>
<td>SMEPA</td>
<td>168</td>
<td>229</td>
</tr>
<tr>
<td>2009 S</td>
<td>0</td>
<td>East Point 500/230kV XFMR</td>
<td>TVA</td>
<td>750</td>
<td>786</td>
</tr>
</tbody>
</table>

As shown in Table 20, two limiting elements are identified first occurring at different load levels that limit SMEPA’s export FCITC to TVA. These limiting elements must be upgraded to achieve the desired transfer capability through the study period.
CHAPTER VI

DISCUSSION OF RESULTS

In every base case and interconnection model evaluated, the Waynesboro 230/161kV transformer is the SMEPA limiting element to import FCITC from AEC, Entergy, and Southern. In addition, the Purvis 230/161kV transformers are the SMEPA limiting elements to export FCITC to AEC, Entergy, and Southern as a result of a contingency involving the loss of the adjacent transformer. Therefore increasing SMEPA’s transfer capability requires upgrading these existing facilities or installing new transmission interconnections that reduce the flow on these existing limiting facilities.

Importing with the Existing Interconnections

The Waynesboro 230/161kV interconnection substation is designed for future expansion with existing provisions for a second 230/161kV transformer. Currently, there is one 230/161kV, 150MVA transformer at Waynesboro. The existing substation facilities will support a larger transformer with a rating up to 300MVA.

One solution to increase SMEPA’s import transfer capability is to install a second 150MVA, 230/161kV transformer at Waynesboro. Evaluation of this solution shows that adding a second 150MVA transformer increases the SMEPA import FCITC to approximately 100MW, in the 2005 summer case. For this case, the limiting element is one of the Waynesboro 230/161kV transformers during the outage of the adjacent transformer. However, this solution does not produce the desired import FCITC to
SMEPA from its neighboring utilities. Another solution to increase SMEPA’s import transfer capability is to upgrade the Waynesboro 230/161kV transformer capacity from 150MVA to 250MVA. This solution was evaluated to determine the resulting import FCITC from each neighboring utility. The results of this evaluation are shown in Table 21.

Table 21. Resulting import FCITC to SMEPA with 250MVA Waynesboro 230/161kV transformer.

<table>
<thead>
<tr>
<th>Time Frame</th>
<th>Import FCITC from AEC (MW)</th>
<th>Import FCITC from Entergy (MW)</th>
<th>Import FCITC from Southern Company (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 Summer</td>
<td>170</td>
<td>300</td>
<td>200</td>
</tr>
<tr>
<td>2007 Summer</td>
<td>130</td>
<td>240</td>
<td>150</td>
</tr>
<tr>
<td>2007 Winter</td>
<td>290</td>
<td>350</td>
<td>330</td>
</tr>
<tr>
<td>2009 Summer</td>
<td>120</td>
<td>0</td>
<td>140</td>
</tr>
</tbody>
</table>

For each case in Table 21, with the exception of the import from Entergy in the summer of 2009, the first limiting element to import FCITC is the AEC McIntosh 230/161kV transformer. In addition, the MPCo Highway 53 to Saucier 115kV line limits import FCITC from Southern Company to 250MVA in the summer of 2005. The EMI Silver Creek to New Hebron and Magee to New Hebron 115kV lines limit import FCITC from Entergy to 0MW in the summer of 2009. Therefore, upgrades to these facilities are required in addition to upgrading the Waynesboro 230/161kV transformer capacity in order to maintain an import FCITC of 300MW. Based on the evaluations, replacing the existing Waynesboro 230/161kV, 150 MVA transformer with a 250MVA transformer will remove SMEPA’s limiting elements to import FCITC from each neighboring utility.
through the study period. The total estimated cost of this solution is $13,700,000. This cost estimate includes costs to upgrade the transmission facilities of AEC, EMI, MPCo, and SMEPA required to achieve the 300MW import FCITC through the study period.

**Exporting with the Existing Interconnections**

The Purvis 230/161kV interconnection substation is expansion limited making the installation of a third 230/161kV, 168MVA transformer difficult. Currently, there are two 230/161kV, 168MVA transformers at Purvis. The existing substation facilities are capable of supporting larger transformers up to a maximum of 400MVA.

One possible solution is to replace the existing Purvis 230/161kV, 168MVA transformers with 300MVA transformers. This solution will remove the Purvis 230/161kV transformers as the limiting elements to export FCITC through the study period. However, in addition to replacing the Purvis 230/161kV transformers, achieving the desired 300MW export FCITC level requires upgrading both SMEPA Purvis to Morrow 161kV lines which are currently rated at 296MVA to achieve a minimum rating of 331MVA. Replacing both the Purvis 230/161kV transformers and rebuilding both Purvis to Morrow 161kV lines results in the FCITC export values shown in Table 22.

Table 22. Resulting export FCITC from SMEPA with 300MVA Purvis 230/161kV transformers and upgraded Morrow to Purvis 161kV lines.

<table>
<thead>
<tr>
<th>Time Frame</th>
<th>Export FCITC to AEC (MW)</th>
<th>Export FCITC to Entergy (MW)</th>
<th>Export FCITC to Southern Company (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 Summer</td>
<td>460</td>
<td>430</td>
<td>150</td>
</tr>
<tr>
<td>2007 Summer</td>
<td>480</td>
<td>450</td>
<td>260</td>
</tr>
<tr>
<td>2007/2008 Winter</td>
<td>360</td>
<td>450</td>
<td>310</td>
</tr>
<tr>
<td>2009 Summer</td>
<td>430</td>
<td>380</td>
<td>160</td>
</tr>
</tbody>
</table>
The FCITC export to Southern Company for the 2005, 2007, and 2009 summers is limited by the MPCo Hurricane Creek to Wiggins 115kV line. Therefore, an upgrade to the Hurricane Creek to Wiggins 115kV line is required to achieve the desired export transfer capability to each neighboring utility through the study period. Upgrading the Purvis 230/161kV transformers and both Purvis to Morrow 161kV lines, removes the SMEPA limiting elements to export FCITC throughout the study period. The estimated cost to upgrade the export FCITC limiting facilities throughout the study period is $7,700,000. This cost estimate includes costs to upgrade the MPCo and SMEPA transmission facilities required to achieve the 300MW export FCITC through the study period.

**Interconnection Evaluation**

As part of this study, ten potential transmission interconnections between SMEPA and its neighboring utilities were evaluated. The results of the evaluations show that none of these potential transmission interconnections provide a significant increase in SMEPA import transfer capability.

**SMEPA Import**

Because the Waynesboro 230/161kV transformer is overloaded in the base case and in most of the interconnection models, comparing each interconnection to the base case model based on the resulting increase in transfer capability produces unusable results. Typically, the import FCITC is 0MW because the potential interconnections have a minimal flow impact to the Waynesboro 230/161kV transformer.
Therefore, in order to evaluate and compare the potential interconnections, each was evaluated based on its impact to the flow on the Waynesboro 230/161kV transformer. Table 23 shows the MVA flow impact that each potential SMEPA/MPCo interconnection has on the Waynesboro 230/161kV transformer when evaluating a 300MW import from Southern Company, as compared to the base case.

Table 23. Evaluation of the MVA flow impacts of each SMEPA/MPCo interconnection to the Waynesboro 230/161kV transformer for a 300MW import from Southern Company.

<table>
<thead>
<tr>
<th>Time Frame</th>
<th>Clarke IC (%)</th>
<th>Jasper IC (%)</th>
<th>Jones IC (%)</th>
<th>Lumberton IC (%)</th>
<th>Morrow IC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 Summer</td>
<td>12.9</td>
<td>10.9</td>
<td>1.5</td>
<td>-1.5</td>
<td>0.5</td>
</tr>
<tr>
<td>2007 Summer</td>
<td>11.1</td>
<td>9.3</td>
<td>0.9</td>
<td>-1.4</td>
<td>0.0</td>
</tr>
<tr>
<td>2007 Winter</td>
<td>17.4</td>
<td>15.2</td>
<td>1.6</td>
<td>-1.6</td>
<td>0.0</td>
</tr>
<tr>
<td>2009 Summer</td>
<td>12.0</td>
<td>10.1</td>
<td>1.8</td>
<td>-1.4</td>
<td>0.5</td>
</tr>
</tbody>
</table>

As shown in Table 23, of the five SMEPA/MPCo interconnections evaluated, only the Lumberton 230/161kV interconnection provides a reduction in flow on the Waynesboro 230/161kV transformer when importing from Southern Company. However, with this reduction in flow, the import FCITC from Southern to SMEPA is 0MW for all load levels with the exception of the 2007 winter case. For the 2007 winter, the FCITC from Southern to SMEPA is 40MW. Therefore, none of the SMEPA/MPCo interconnections will be considered as solutions to import FCITC limitations from Southern Company.

Because the Waynesboro 230/161kV transformer is overloaded in the base case and in most of the interconnection models, comparing each interconnection to the base
case model based on the resulting increase in transfer capability produces unusable results. Therefore, in order to evaluate and compare the potential interconnections, each was evaluated based on its impact to the flow on the Waynesboro 230/161kV transformer. Table 24 shows the MVA flow impact that each potential SMEPA/EMI interconnection has on the Waynesboro 230/161kV transformer, as compared to the base case.

Table 24. Evaluation of the MVA flow impacts of each SMEPA/EMI interconnection to the Waynesboro 230/161kV transformer for a 300MW import from Entergy.

<table>
<thead>
<tr>
<th>Time Frame</th>
<th>Rankin IC (%)</th>
<th>Salem IC (%)</th>
<th>Silver Creek IC (%)</th>
<th>South Walthall IC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 Summer</td>
<td>-6.0</td>
<td>-3.3</td>
<td>-3.3</td>
<td>-11.4</td>
</tr>
<tr>
<td>2007 Summer</td>
<td>-4.8</td>
<td>-5.8</td>
<td>-7.7</td>
<td>-9.6</td>
</tr>
<tr>
<td>2007 Winter</td>
<td>-4.7</td>
<td>-2.6</td>
<td>-1.0</td>
<td>-9.9</td>
</tr>
<tr>
<td>2009 Summer</td>
<td>-5.4</td>
<td>-6.9</td>
<td>-4.4</td>
<td>-9.8</td>
</tr>
</tbody>
</table>

As shown in Table 24, each EMI interconnection slightly reduces the flow on the Waynesboro 230/161kV transformer. However, the slight reduction in flow on the Waynesboro 230/161kV transformer is not sufficient to achieve the desired import FCITC level.

The resulting FCITC values for each potential SMEPA/EMI interconnection are shown in Table 25. As shown in Table 25, none of the interconnections evaluated produces a sufficient increase in import FCITC to achieve the desired import level without requiring upgrades to the existing Waynesboro 230/161kV transformer.
Evaluation of an import from TVA to SMEPA with the Lake 161kV interconnection shows that installing this interconnection provides a reduction in MVA flow on the Waynesboro 230/161kV transformer of an average of 1.9% throughout the study period, as compared to the base case. However, with this reduction in flow, the resulting import FCITC is 0MW for every time frame with the exception of the 2007 winter. For the 2007 winter, the import FCITC from TVA to SMEPA is 40MW.

SMEPA Export

Each potential SMEPA/MPCo interconnection was evaluated based on its impact on export FCITC from SMEPA to Southern Company. Table 26 shows each potential SMEPA/MPCo interconnection and its resulting SMEPA export FCITC.

Table 26. Resulting export FCITC values of potential SMEPA/MPCo interconnections assuming the Purvis 230/161kV transformer is the limiting element.
As shown in Table 26, the Jones and Morrow 230/161kV interconnections produce the most significant increase in export FCITC from SMEPA to Southern Company. Both exceed the desired export FCITC level through the 2007 winter. Beginning in the 2009 summer, the Purvis 230/161kV transformers are the limiting elements to export FCITC. The estimated cost to install the Jones 230/161kV interconnection is $9,300,000 and the estimated cost to install the Morrow 230/161kV interconnection is $10,900,000. These cost estimates include costs for the facilities required to interconnect and do not include costs to upgrade existing transmission facilities due to transfer capability limits.

For both the Jones 230/161kV and the Morrow 230/161kV interconnections, the Purvis 230/161kV transformers will require upgrade by the 2009 summer load level to maintain the export FCITC level from SMEPA to Southern. In addition, Southern Company’s McGraw 500/230kV transformer becomes overloaded in the 2009 summer base case. Further evaluation will be required by Southern Company to determine the solution and estimated cost to upgrade this limiting element.

Table 27 shows each potential SMEPA/EMI interconnection and its resulting export FCITC from SMEPA to Entergy. As shown in Table 27, the Rankin 230kV and the Salem 161/115kV interconnections provide some increase in export FCITC from SMEPA to Entergy. However, the results do not produce the desired export limit from SMEPA to Entergy at any time through the study period.
Table 27. Resulting export FCITC values of potential SMEPA/EMI interconnections assuming the Purvis 230/161kV transformer is the limiting element.

<table>
<thead>
<tr>
<th>Time Frame</th>
<th>Base Case (MW)</th>
<th>Rankin IC (MW)</th>
<th>Salem IC (MW)</th>
<th>Silver Creek IC (MW)</th>
<th>South Walthall IC (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 Summer</td>
<td>110</td>
<td>140</td>
<td>140</td>
<td>100</td>
<td>0</td>
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<tr>
<td>2007 Summer</td>
<td>100</td>
<td>130</td>
<td>130</td>
<td>70</td>
<td>0</td>
</tr>
<tr>
<td>2007 Winter</td>
<td>20</td>
<td>10</td>
<td>50</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>2009 Summer</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Evaluation of export transfer capability from SMEPA to TVA with the Lake 161kV interconnection produces an export FCITC from SMEPA to TVA of 180MW in the 2005 summer, 210 MW in the 2007 summer, 0MW in the 2007 winter, and 60MW in the 2009 summer models. The limiting elements for each load level are the Purvis 230/161kV transformers with the exception of the 2009 summer case. In the 2009 summer case, the limiting element to export FCITC is TVA’s East Point 500/115kV transformer.

The proposal for the Lake 161kV interconnection includes the construction of a single 161kV line interconnecting the SMEPA and TVA transmission systems. The calculated FCITC values discussed above are valid only when the 161kV interconnection line is not the contingency element. Therefore, FCITC would be available for each summer season with the provision that the radial 161kV line is in service.

Of the ten potential interconnections evaluated, six produced minimal increases in import transfer capability from neighboring utilities to SMEPA. However, none of these produced increases in import capability of significant amounts to justify the cost of adding the interconnection. Throughout the evaluation process, the Waynesboro
230/161kV transformer has been the primary limiting element to SMEPA import transfer capability. Of the potential transmission interconnections evaluated, none were identified as the economic alternative to increase SMEPA’s import transfer capability from neighboring utilities.

The solution that produced the best overall results is to replace the existing Waynesboro 230/161kV, 150MVA transformer with a 250MVA transformer. This solution will remove the SMEPA limiting element to import capability from neighboring utilities throughout the study period. Additional facilities requiring upgrade include AEC’s McIntosh 230/115kV transformer, MPCo’s Highway 53 to Saucier 115kV line, EMI’s Silver Creek to New Hebron 115kV line, and EMI’s Magee to New Hebron 115kV line. The total estimated cost to upgrade these transmission facilities is $13,700,000.

Eight of the ten interconnections evaluated produced an increase in export transfer capability from SMEPA to its neighboring utilities. Of these, two potential interconnections were identified that, if implemented, could significantly increase SMEPA’s export transfer capability to neighboring utilities. These two interconnections are the Jones 230/161kV and the Morrow 230/161kV.

The addition of the Jones 230/161kV interconnection increases SMEPA’s export transfer capability to Southern Company above the desired 300MW level through the 2007 winter load level. Beyond the 2007 winter requires upgrade to the Purvis 230/161kV transformers. The total estimated cost for the Jones 230/161kV interconnection to achieve the desired export transfer capability from SMEPA to
Southern Company through the study period is $12,300,000. This estimate includes the cost to install the interconnection and replace the Purvis 230/161kV transformers.

The addition of the Morrow 230/161kV interconnection increases SMEPA’s export transfer capability to Southern Company above the desired 300MW level through the 2007 winter load level. Maintaining the desired export transfer capability level from SMEPA to Southern Company beyond the 2007 winter load level requires upgrade to the Purvis 230/161kV transformers. The total estimated cost for the Morrow 230/161kV interconnection to achieve the desired export transfer capability from SMEPA to Southern Company through the study period is $13,900,000. This estimate includes the cost to install the interconnection and to replace the Purvis 230/161kV transformers.

The primary limiting element to SMEPA export transfer capability to neighboring utilities is one of the Purvis 230/161kV transformers as a result of the outage of the adjacent transformer. One solution is to replace the existing Purvis 230/161, 168MVA transformers with 300MVA transformers. This solution removes the Purvis 230/161kV transformers as the limiting elements to export FCITC from SMEPA to neighboring utilities through the study period. In addition to replacing the Purvis 230/161kV transformers, achieving the desired 300MW export FCITC level requires upgrading both SMEPA Purvis to Morrow 161kV lines and the MPCo Hurricane Creek to Wiggins 115kV line. The estimated cost to upgrade these facilities is $7,700,000. This estimate includes replacing the existing Purvis 230/161kV, 168MVA transformers with 300MVA transformers, rebuilding both SMEPA Purvis to Morrow 161kV lines, and rebuilding MPCo’s Hurricane Creek to Wiggins 115kV line.
Achieving the desired export transfer capability level from SMEPA to its neighboring utilities can be accomplished by upgrading the existing Purvis 230/161kV interconnection, installing the Jones 230/161kV interconnection, or installing the Morrow 230/161kV interconnection. However, because the Jones and Morrow interconnections require upgrade to the existing Purvis 230/161kV interconnection by the summer of 2009, the obvious solution is to proceed with the upgrade to the Purvis 230/161kV interconnection and reevaluate the Jones and Morrow 230/161kV interconnections when the need for additional transfer capability arises.
CHAPTER VII
CONCLUSIONS

The analysis tools used to perform the evaluations include PTI’s PSS/E and MUST software. The primary PSS/E activity used was activity ACCC, which is the network contingency calculation activity of PSS/E. Activity ACCC is used to perform a single contingency outage evaluation quickly in specified areas. Activity ACCC uses a fixed-slope Newton-Raphson iterative algorithm which uses an approximation of the Jacobian matrix that is insensitive to bus voltages. The advantages of this solution technique are that it is less sensitive to poor initial voltage estimates and it has a reduced time per iteration as compared to the fully coupled Newton-Raphson solution.

PTI’s MUST software uses DC solution techniques to estimate import or export limits of a specified system using a linearized network model. These estimates are determined using DC loadflow techniques that assume constant bus voltage magnitude and transmission line losses. The advantage of this solution technique is that it is substantially faster than an AC loadflow solution.

A comparison of MUST results and a full AC solution was performed to determine the difference between the MUST results and the PSS/E results for two different evaluation techniques. In each application, the MUST and PSS/E results were typically within 1 percent of each other.
Two different evaluation techniques were used to evaluate the base case and interconnection models. These are the Reduced Load and the Emergency Dispatch methods. The Emergency Dispatch method is specified in the SERC ATC Coordination Procedures [11]. The Reduced Load method is used by one SMEPA neighboring utility to calculate transfer capability. As part of the evaluation, these two methods were compared at different load levels to determine which method produced the best results. The MUST results of each method were compared to the PSS/E results. The comparison of the two methods using MUST shows the results of the Reduced Load method are approximately 1.80 percent higher than the Emergency Dispatch method at the 300MW test level. For the PSS/E case, the difference was approximately the same with the Reduced Load method being approximately 1.83 percent higher at the 300MW test level. Therefore the results produced by MUST and PSS/E are approximately the same.

The purposes of this research were to evaluate the existing transfer capability of the SMEPA transmission system, to determine the transfer capability needed to allow reliable and economic operation of SMEPA’s generation and transmission system, and to evaluate potential new interconnections to help meet future transfer capability needs. As part of the evaluation, solutions were identified to upgrade two of SMEPA’s four existing transmission interconnections to allow SMEPA to import and export power between each neighboring control area through the study period. The desired transfer level for SMEPA was determined to be 300MW for each neighboring utility. This transfer capability level is consistent with the existing contract path rating of the Magee 161/115kV interconnection between SMEPA and EMI.
Of the ten potential interconnections evaluated, six produced minimal increases in import transfer capability. However, none of these produced increases in import capability of significant amounts to justify the cost of adding the interconnection. Upgrading the existing Waynesboro 230/161kV interconnection provides the best and most economical solution to achieve the desired 300MW import transfer capability level to SMEPA from its neighboring utilities. Therefore, the recommended solution is to replace the existing Waynesboro 230/161kV, 150MVA transformer with a 250MVA transformer. Implementing this solution requires working with each neighboring utility to further evaluate the limiting elements identified for imports to SMEPA.

Eight of the ten interconnections evaluated produced an increase in export transfer capability. Of these, two potential interconnections were identified that, if implemented, could significantly increase SMEPA’s export transfer capability. These two interconnections are the Jones 230/161kV and the Morrow 230/161kV. However, both require upgrade to the Purvis 230/161kV transformers by the summer of 2009. Upgrading the existing Purvis 230/161kV interconnection transformers provides the best and most economical solution to achieve the desired 300MW export transfer capability level. Therefore, the recommended solution is to replace the existing Purvis 230/161kV, 168MVA transformers with two 230/161kV, 300MVA transformers.

Should system conditions change or should SMEPA need additional export transfer capability in the future, the Jones and Morrow 230/161kV transmission interconnections between SMEPA and MPCo should be evaluated further. Evaluations of
transfer capability beyond the summer 2009 load level will likely require the installation of new transmission interconnections.

Depending on future needs as determined by SMEPA and TVA, the Lake 161kV interconnection could provide benefits that should be evaluated further. While this interconnection will not produce a significant increase in SMEPA transfer capability, it could provide future benefits to SMEPA and TVA. In addition, should any large loads materialize in the vicinity of Lake, this transmission interconnection could be implemented to strengthen the transmission systems in this area.

Therefore, the results of the evaluations performed for this research show that the best and most economical solution for SMEPA to achieve and maintain its desired transfer capability with each neighboring utility through the study period is to upgrade the existing transmission interconnection facilities at Waynesboro and Purvis. Should additional export transfer capability from SMEPA to its neighboring utilities be required in the future, the Morrow and Jones 230/161kV interconnections should be further evaluated.
REFERENCES


APPENDIX A

SYSTEM MAPS
Figure A.1. Combined SMEPA and MPCo Transmission Systems
Figure A.2. Clarke 230/161kV Interconnection
Figure A.4. Jones 230/161KV Interconnection
Figure A.6. Morrow 230/161KV Interconnection
Figure A.7. Combined SMEPA and EMI Transmission Systems
Figure A.8. Rankin 230kV Interconnection
Figure A.9. Salem 161/115kV Interconnection
Figure A.10. Silver Creek 161/115kV Interconnection
Figure A.12. Lake 161kV Interconnection (TVA)