



January 12, 2018

Ms. Kavita Kale
Michigan Public Service Commission
7109 W. Saginaw Hwy.
P. O. Box 30221
Lansing, MI 48909

Via E-filing

RE: MPSC Case No. U-18419

Dear Ms. Kale:

The following is attached for paperless electronic filing:

Direct Testimony of Josh Berkow on behalf of the Michigan Environmental
Council

Exhibits MEC-88 and MEC-89

Proof of Service

Sincerely,

Christopher M. Bzdok
chris@envlaw.com

xc: Parties to Case No. U-18419, ALJ Suzanne D. Sonneborn
James Clift, MEC

STATE OF MICHIGAN

BEFORE THE MICHIGAN PUBLIC SERVICE COMMISSION

In the matter of the Application of
DTE ELECTRIC COMPANY for approval
of Certificates of Necessity pursuant to MCL
460.6s, as amended, in connection with the
addition of a natural gas combined cycle
generating facility to its generation fleet and for
related accounting and ratemaking
authorizations

U-18419

ALJ Suzanne D. Sonneborn

DIRECT TESTIMONY OF JOSH BERKOW

ON BEHALF OF MICHIGAN ENVIRONMENTAL COUNCIL

January 12, 2018

1 **Q. What is your name & business address?**

2 A. I am Josh Berkow, employed by RINA Consulting as a Principal Power Systems
3 Engineering Consultant. My business address is 705 South Main St, Suite 260, Plymouth,
4 MI 48170.

5 **Q. Have you testified before the Michigan Public Service Commission before?**

6 A. No.

7 **Q. Please describe RINA Consulting.**

8 A. RINA Consulting is the engineering consultancy division of RINA, a global corporation
9 that provides engineering and consultancy services, as well as testing, inspection, and
10 certification.

11 RINA Consulting is the result of the integration of a number of internationally respected
12 companies including D'Appolonia, Centro Sviluppo Materiali, Edif ERA (ERA
13 Technology), G.E.T., Logmarin Advisors, OST Energy, Polaris, SC Sembenelli
14 Consulting, and Seatech. RINA Consulting brings together a rich heritage of engineering
15 consultancy expertise into one unique organization. RINA Consulting provides a wide
16 range of traditional and innovative services to critical industry sectors, including Oil &
17 Gas, Power, and Renewables. RINA consulting has over 1,700 professionals worldwide.

18 **Q. What is your experience with power systems?**

19 A. I have been involved with power systems for over 10 years. I have worked for power
20 plant developers creating and managing interconnection requests, as well as providing
21 engineering support for renewable project development. This work has required my
22 observation and involvement in transmission planning in ERCOT, MISO, NYISO, PJM,
23 SERC, SPP, and WECC. Prior to joining RINA, I worked for 4 ½ years for the consulting

1 company HDR in Ann Arbor as a substation project engineer and assistant project
2 manager, assisting both the substation design and transmission studies group. Because of
3 all this work, I am very familiar with the MISO and Michigan transmission systems.

4 **Q. What is your educational background?**

5 A. I am an electrical engineer with a BS and MS in Electrical Engineering from State
6 University of New York at Buffalo. My resume and CV are attached as Exhibit MEC-88.

7 **Q. Are you sponsoring any exhibits?**

8 A. Yes.

- 9 • Exhibit MEC-88 Resume of Josh Berkow
- 10 • Exhibit MEC-89 Transmission Alternatives Analysis

11 **Q. What is the purpose of your testimony?**

12 A. The purpose of my testimony is to provide the Commission with information regarding
13 electric transmission options for DTE relevant to its Integrated Resource Plan (IRP) and
14 Certificate of Necessity (CON) application. Specifically, as presented in the report
15 attached as Exhibit MEC-89, with upgrades identified in the report, the transmission
16 system may accommodate the import of 1500 MW of capacity from Ontario into
17 southeast Michigan after the retirement of several DTE generating units.

18 **Q. What role did you have in the drafting of the Transmission Alternatives Analysis
19 presented in Exhibit MEC-89?**

20 A. I am the primary author of the report. The modeling and analysis in the report was
21 undertaken at my direction.

1 **Q. Please include any pertinent background information to your findings below.**

2 A. Additional information to assist in the understanding of the findings in Exhibit MEC-89
3 are provided below.

4 • Per the Lake Erie Loop Flow Mitigation report from New York Independent System
5 Operator (NYISO), dated November 2008, “The bulk power transmission facilities
6 that surround Lake Erie have been subject to unpredictable and volatile loop flows for
7 more than 40 years.” These “Loop flows” are interchangeably referred to as Lake Erie
8 Loop flow or Lake Erie Circulation flow.

9 • Per the Lake Erie Loop Flow Mitigation report, Loop flows occur when the physical
10 flow of electric power does not correspond to the scheduled flow of power. Absent
11 any control devices, physical flow of power follows the path of least impedance
12 through the transmission system. Lake Erie Loop flow contributed to increased
13 transmission congestion, which resulted in increased wholesale electricity costs.

14 • The entities impacted by Lake Erie Loop flow are the New York Independent System
15 Operator (NYISO), Independent Electricity System Operator (IESO), Midcontinent
16 Independent System Operator (MISO), and PJM Interconnection, LLC (PJM). To
17 limit Lake Erie Loop Flow between Michigan and Ontario, Phase Angle Regulators
18 (PARs) have been installed at the interfaces between these control areas between
19 2003 and 2012. PARs have been installed at the following interfaces around Lake
20 Erie.

PAR Location	Interface
Waldwick	PJM-NYISO
Linden and Hudson	PJM-NYISO
Ramapo	PJM-NYISO
St. Lawrence	NYISO-IESO
IESO-Minnesota Power	IESO-MISO

IESO-Manitoba Hydro	IESO-MISO
Lambton	MISO-IESO
Bunce Creek	MISO-IESO
Keith	MISO-IESO

1
2 • PARs, also called Phase Shifting Transformers, are a special type of power
3 transformer whose primary purpose is to control the flow of power, rather than
4 changing the system voltage. Per IEEE Standard C57.135, a PAR has two effects on
5 power flow. First the connection of the windings in the PAR causes a shift in the
6 voltage phase angle. This change in phase angle causes a change in flow of power
7 through the PAR. Second, the windings in the PAR introduce an additional
8 impedance into the transmission system, which changes the flow of power through
9 the transmission system.

10 **Q. Please summarize your findings below.**

11 A. My findings are summarized as follows, and fully described in the report “Transmission
12 Alternatives Analysis” which is attached as Exhibit MEC-89.

- 13 • The current transmission interface between Michigan and Ontario (IESO) is currently
14 controlled by the PARs at Lambton, Bunce Creek, and Keith Substations.
- 15 • It is possible that the PARs could change their operation to increase import capability
16 of power from IESO into Michigan; however, additional analysis by ITC (the owner
17 of the PARs on the United States side) and MISO would need to be performed to
18 verify. Absent this analysis, we assumed a new HVDC converter station could be
19 built, to import 1,500 MW of capacity from Ontario into Michigan.
- 20 • RINA performed steady state power flow analysis to determine if the additional
21 imports were feasible. Two transmission upgrades, one in Michigan and one in
22 Ontario, were identified by this analysis. The Ontario upgrade may be unnecessary

1 depending on how the generators in Ontario are dispatched. RINA did not adjust how
2 the generators in Ontario were dispatched, as the source of electric power was not
3 identified for this study. A change in output of the generators in Ontario will change
4 how power flows across the IESO system. This change, once determined, may
5 preclude the need for transmission upgrades in Ontario.

- 6 • Total cost of the HVDC converter station and transmission upgrades is roughly \$320
7 million. A detailed breakdown of estimated costs is provided in Exhibit MEC-89. If
8 the PARs are able to be used to their rated capacity, and the Ontario system is able to
9 be dispatched to avoid the transmission upgrade, total cost would be just \$15 million
10 for the Michigan transmission upgrades.

11 **Q. How did you perform your modeling?**

12 A. RINA performed its modeling using Siemens PTI PSS/E version 33. This software was
13 used to perform steady state power flow analysis, which is a numerical analysis to
14 determine the parameters of the AC power system under unchanging conditions. We used
15 the MISO 2015 MTEP Summer 2025 case. We assumed the DTE plants shown in the
16 table below are retired by 2025. The Lambton PARs are bypassed in this study and a
17 1500MW HVDC converter station is installed between Lambton and St. Clair.

Plant Name	MW Impact
River Rouge 3	234 MW
St. Clair 1-4, 6, & 7	1215 MW
Trenton 9	430 MW
Belle River 1 & 2	998 MW

18

1 **Q. Does this conclude your testimony?**

2 A. Yes.



RINA Consulting: Summary CV

Josh Berkow, PE – Principal Power Systems Engineering Consultant

Profile

Mr. Berkow holds an MS in Electrical Engineering and is a licensed professional engineer. He has worked for independent power producers, utility consultants, and research laboratories. He has experience in the planning, development, engineering, procurement, project management, cost estimation, and construction of wind plants, PV plants, battery storage systems, substations, and transmission lines.

Employment History

2016 to present – Principal Power Systems Engineering Consultant at RINA Consulting.
2012 to 2016 – Project Engineer / APM at HDR.
2011 to 2012 – Utility Development Engineer at SunEdison.
2010 to 2011 – Engineering Manager at Axio Power.
2009 to 2010 – Project Engineer at Apex Wind Energy & Axio Power.
2007 to 2009 – Project Engineer at BQ Energy.
2005 to 2007 – Researcher at Energy Systems Institute – University at Buffalo.

Selected Project Experience

Engineering Manager and Project Engineer for over 100MW of solar PV and 500MW of wind power projects in the USA. The role included providing preliminary designs, scopes of work, design reviews, interconnection agreements, interconnection evaluation bidding power purchase agreements, equipment selection, and contractor selection. The projects included solar PV on municipal landfills, solar PV & wind with battery storage, wind on municipal landfills, and offshore wind in the Great Lakes.

Owner's Engineer for multiple battery energy storage projects in the USA. The role included technology selection, EPC contract reviews, warranty and performance guaranty reviews, design review, control system review, cost estimation, and off-take market evaluations. Battery technologies included lithium ion, lead acid, sodium sulfur, and vanadium redox.

High Voltage Engineer for multiple combustion power plant projects in the USA. The role included preparation of EPC specifications for high voltage substations, preliminary design of plant and interconnection substations, and preliminary routing of generation tie lines. Projects included 1-on-1 and 2-on-1 natural gas combined cycle plants, landfill gas generators, and waste-to-energy plants for utilities and IPPs.

Planning Engineer for the development of

multiple independent transmission projects in the Mid-Continent ISO to improve reliability to municipal electric companies. The role involved reviewing the configuration of the area transmission system, validating the power flow model against the actual system configuration, interpreting power flow model results, and cost estimation for the project and system upgrades.

Lead Engineer & Project Manager for over 13 greenfield substations, including multiple executed through EPC Contracts. The role involved physical design, P&C design, procurement, and construction management of the substations while coordinating the site civil and structural design. Projects included some in complex terrain and at high altitude.

Interconnection Engineer for a solar PV development program in California. The role involved the review of FERC Form 715 data, CPUC filings, and FERC filings to determine optimal places to construct PV facilities with minimal interconnection cost. This project was an interdisciplinary effort with GIS analysts and environmental engineers.

Lead Engineer responsible for the specification and procurement of a harmonic snubber for a 20MW solar PV project. Mr. Berkow lead a design team to create the physical layout, control system design, and technical specifications based on an owner-provided harmonics study.

Consulting Engineer responsible for analysis of interconnection requirements and compliance for PV systems in Puerto Rico, Panama, and Mexico

Design Manager responsible for the engineering, procurement, and construction of multiple transmission and distribution substations to serve growing load due to oil extraction in the Bakken oil field. Mr. Berkow managed multiple simultaneous projects working with an interdisciplinary design team to deliver the projects on time and on budget.

Lead Engineer responsible for the addition of a temporary 230kV line terminal to an existing 115kV ring bus substation. Mr. Berkow was responsible for the design, specification, procurement, and construction management of the substation. The project utilized wood pole construction to expedite construction and minimize costs for the short life of the line terminal.

Nationality / Languages

USA / English

Qualifications

Bachelor of Science: Electrical Engineering, University at Buffalo, 2005.

Master of Science: Electrical Engineering, University at Buffalo, 2008

Professional Engineer P.E. Electrical Engineering, New York State, 2011.

Key Skills

Electrical Design, Physical Design, Design Review, Project Management, Specifications, Cost Estimation, Independent Engineering, Power System Planning, Battery Storage System Selection

Sectors

Solar PV Power, Wind Energy, Battery Energy Storage, Substations, Transmission Planning

Confidentiality

Certain details have been omitted from the adjacent experience list for reasons of client confidentiality



Transmission Alternatives Analysis

MISO-IESO HVDC Link
Case U-18419

Client: Michigan Environmental Council

January 2018

V1.0



Disclaimer

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Executive Summary

The Michigan Environmental Council (the Client) is studying transmission-based alternatives to new generation in Michigan. To that end, the Client has engaged RINA Consulting, Inc (RINA) to perform load flow studies to assess the ability of the transmission system to accommodate a transfer of 1500MW from Ontario into Michigan. The interface between Ontario and Michigan is currently controlled by Phase Angle Regulators (PARs) at Lambton, Keith, and Bunce Creek Substations. The Lambton PARs are bypassed in this study and a 1500MW HVDC converter station is installed between Lambton and St. Clair. This study does not address whether the existing PARs have the capability to import the required energy across the interface. While the system planning models indicate adequate capacity on the existing PARs, detailed modelling by MISO, ITC, and IESO would determine if that was feasible.

The transmission system analysis was performed in Siemens PTI PSS/E software utilizing the MISO 2015 MTEP Summer 2025 case. Proposed generator retirements in DTE's 2017 IRP were included in the study. No projects from the transmission and generation interconnection queues were included. No modifications were made to the generator dispatch in the model, as the source of energy from Ontario has not yet been identified.

The simulation results show two upgrades required to accommodate this project. One of these could potentially be addressed through dispatch and ancillary services. Cost estimates for the new equipment and for mitigating the overloads are presented in the report.



1 Introduction

RINA Consulting, Inc (RINA) has worked on behalf of the Michigan Environmental Council (the Client) to analyze transmission-based alternatives to provide 1500MW of additional capacity to southeast Michigan. This study analyzes the addition of a 1500MW HVDC converter between Load Zone 7 (LS-7) of the Midcontinent Independent System Operator (MISO) and Ontario's Independent Electricity System Operator (IESO).

Flow is currently limited by Phase Angle Regulators (PARs) at Lambton, Keith, and Bunce Creek Substations. While the MISO 2015 MTEP Summer 2025 planning model indicates the PARs have sufficient capacity to deliver 1500MW, a transient analysis by MISO, ITC, and IESO would be needed to analyze that scenario in detail. Instead this study analyzes a proposed HVDC converter station located between the Lambton and St. Clair substations.

The study has two components:

- An assessment of thermal constraints associated with the transfer of 1500MW between IESO and MISO
- An estimate of capital costs required for the new facilities and any associated upgrades.

For purposes of this study, thermal constraints are any operating restrictions imposed upon elements of the transmission system which may include: transformers, transmission lines, substation components, or other items. The available information on the transmission system does not detail whether an operating restriction is due to an actual capacity limit or due to a subcomponent. Any thermal constraints are assumed to require a complete replacement of the constrained element.



2 Methodology

This section describes the methodology used for analyzing the MISO LS-7 transmission system and estimating upgrade costs.

2.1 Transmission Analysis Methodology

System models were requested from FERC and were modified as needed to create the following scenarios:

- Base Case Scenario: MISO MTEP 2015 approved 2025 Summer Peak Case, as submitted to FERC, unchanged for this analysis
- HVDC Case Scenario: Base Case with proposed DTE plant retirements and added 1500MW HVDC converter station

No additional projects in the generation interconnection or transmission queues in MISO or IESO were added to the Base Case or HVDC Case scenarios. No changes were made to the generator dispatch other than the proposed retirements. Proposed generator retirements are identified in DTE’s 2017 IRP, Table 2.4-1 and are presented below. All generators were modelled as retired in 2025 regardless of the actual planned retirement date. This represents a worst-case scenario for 2025. No MTEP model for the years 2029 or 2030 was available to RINA at the time of this report.

Table 1: DTE Plant Retirements

Plant Name	MW Impact
River Rouge 3	234 MW
St. Clair 1-4, 6, & 7	1215 MW
Trenton 9	430 MW
Belle River 1 & 2	998 MW

The HVDC Case was modelled with a new HVDC converter station located near the St. Clair power plant as shown in the power flow single line below. The existing PARs at the Hydro One’s Lambton Substation were bypassed in the model, meaning they were deactivated. The Lambton substation has existing bypass switches for this purpose. With the HVDC converter in place, the PARs at Lambton would not be needed. Whether they would be removed or left in place for contingencies is out of the scope of this study. The existing PARs at Hydro One’s Keith Substation and ITC’s Bunce Creek Substation were not modified.



Figure 1: Base Case MISO-IESO Interface at St. Clair

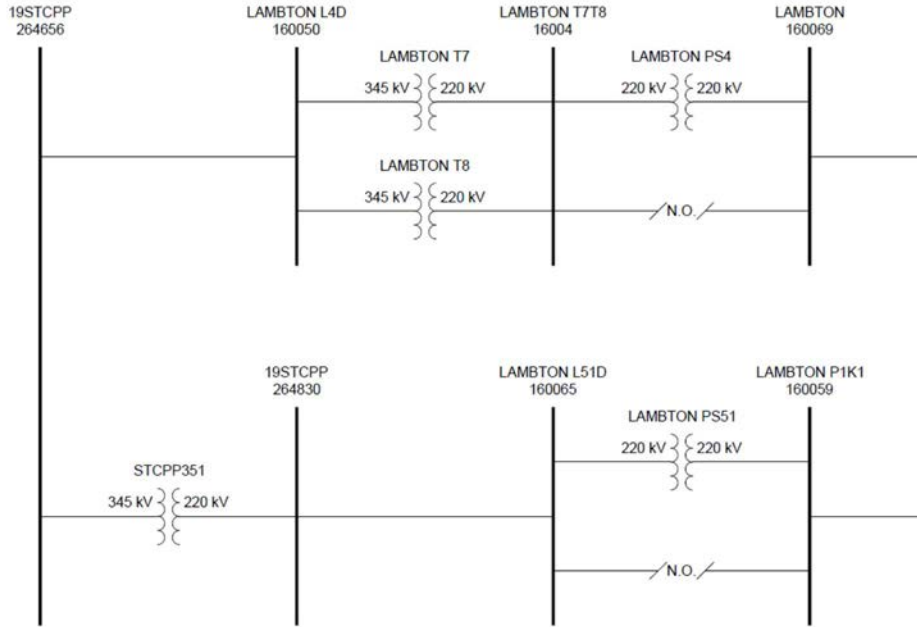
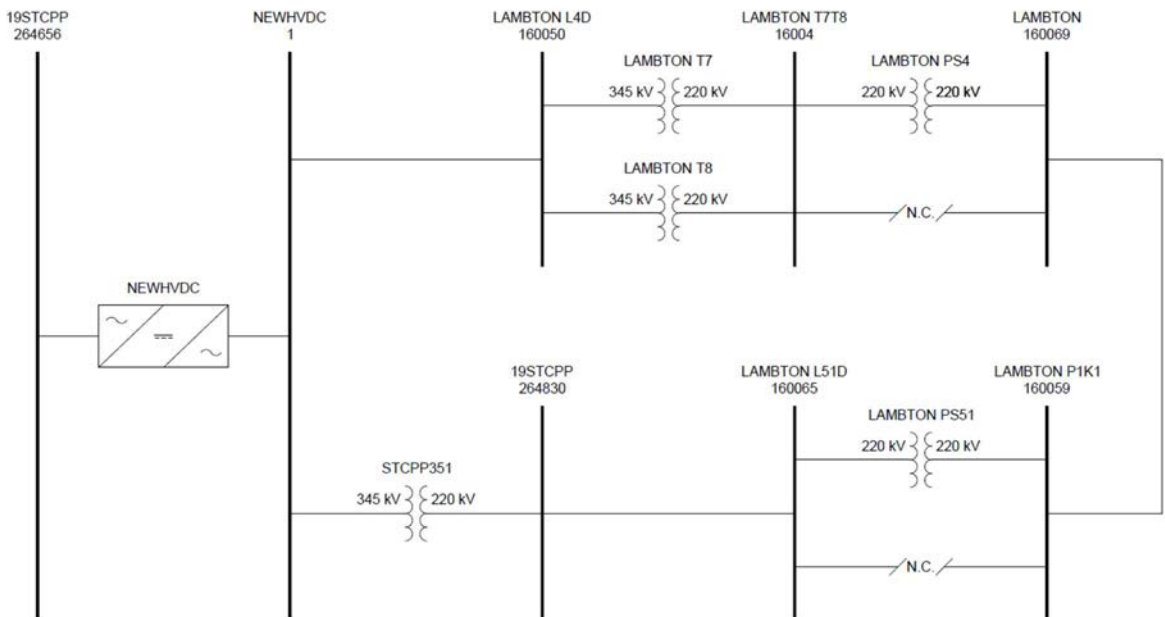


Figure 2: HVDC Case MISO-IESO Interface at St. Clair



RINA performed a steady state load flow analysis on the Base Case and HVDC Case using Siemens PTI PSS/E. The HVDC converter was dispatched incrementally up to 1500MW. The analysis was performed under system intact (N-0) and emergency (N-1) conditions to identify



thermal constraints. If any element’s ratings were violated in Base Case and the HVDC Case, it is recognized as a Pre-existing Overload. If any element’s ratings were violated only in the HVDC Case, it is recognized as a New Overload. The study evaluated contingencies on all elements $\geq 100\text{kV}$ (including transformers where one winding $\geq 100\text{kV}$) within 5 busses of the St. Clair Power Plant, and monitored overloads on all elements $\geq 100\text{kV}$. Cost of upgrades are estimated and allocated to the project if the following criteria are met. As elements may be overloaded by different contingencies, only the most severe overload was recorded.

- System Intact (N-0)
 - All transmission elements loaded over 100% of Normal Operation Rating A where
 - Element is located within the MISO footprint
 - Change in flow $> 5\text{MW}$ or 20% of element rating
- Emergency (N-1)
 - All transmission elements loaded over 100% of Emergency Operation Rating B where
 - Element is located within the MISO footprint
 - Change in flow $> 5\text{MW}$ or 20% of element rating

In addition to the load flow analysis, RINA also inspected the Base Case to determine the ratings of the existing PARs at the MISO-IESO interface. The purpose of this inspection is a high-level determination as to the sufficiency of the existing PARs to import energy into Michigan.

2.2 Costing Methodology

RINA uses two methodologies for estimating the costs of transmission system facilities. For transmission lines < 10 miles and substations that are part of the proposed project, RINA relies upon the past experience of its engineering professionals to estimate costs. For transmission lines > 10 miles or substations not part of the proposed project, RINA relies upon the Cost Estimation data presented to the MISO Economic Planning Users Group on February 13, 2017. All costs are assumed to be $\pm 20\%$

In RINA’s opinion, there are too few HVDC converter stations constructed to build any reliable general indices of construction costs. For this purpose RINA relied on public filings made by Lake Erie Connector to the National Energy Board of Canada. RINA has assumed the following general conditions apply to cost estimates in this report.

Table 2: Construction Cost Estimate General Conditions

Item	Quantity
Engineering	8%
Land Acquisition	0%
Construction Management	5%
EPC Fee	10%
AFUDC	7.5%
Owner’s Internal Costs	10%
Contingency	15%



3 Findings

3.1 Transmission Analysis

Analysis of the transmission system with a new transfer of 1500MW from IESO to MISO was performed. Analysis was performed for both System Intact (N-0) and Emergency (N-1) conditions.

3.1.1 System Intact

The table below identifies one overload attributable to the project in the System Intact scenario. The transmission line between IESO Hawthorne Substation and IESO Raisin Substation was overloaded and may need to be upgraded to accommodate the additional flow from IESO to MISO. As the preferred source of energy in IESO has not been identified, flows across the IESO system are subject to change. RINA expects this overload will be mitigated once the source of energy is determined, and the IESO system is economically dispatched to accommodate the transfer of power into Michigan. As this cannot be determined prior to identifying the energy source, RINA has included costs for this upgrade in the report, even though the upgrade may ultimately not be required.

Table 3: System Intact Overloads

From	To	Voltage	Rating	MVA	%	Length
154050 - HAWTHORNE_TS	155114 - *RAISIN_R_J24	220	514.4	559.7	101.1	67.3 mi

3.1.2 Emergency Conditions

The table below identifies one overload attributable to the project in the Emergency N-1 scenario. The transmission line between ITC Bismarck and ITC Golf is overloaded due to a nearby contingency and needs to be upgraded.

Table 4: Emergency N-1 Overloads

From	To	Voltage	Rating	MVA	%	Length
264788 - 19BISMARCK1	265023 - *19GOLF2	120	214	217.6	110.4	14.37 mi

Several other overloads were identified, but were rejected for inclusion in this study for various reasons, as outlined below.

Table 5: Ignored Contingencies

Contingency	Cause	Mitigation / Reason for Exclusion
NEWHVDC – LAMBTON L4D	Outage of one of the lines between IESO and the HVDC	HVDC will be curtailed to half output due to loss of one of the lines, reducing flows



Contingency	Cause	Mitigation / Reason for Exclusion
NEWHVDC – 19STCPP	Outage of one of the lines between IESO and the HVDC	HVDC will be curtailed to half output due to loss of one of the lines, reducing flows
LAMBTON_T7T8 – LAMBTON_P2K2	Outage of one of the lines between IESO and the HVDC	HVDC will be curtailed to half output due to loss of one of the lines, reducing flows
LAMBTON_L51D - LAMBTON_PHJ	Outage of one of the lines between IESO and the HVDC	HVDC will be curtailed to half output due to loss of one of the lines, reducing flows
LAMBTON_L51D – 19STCPP	Outage of one of the lines between IESO and the HVDC	HVDC will be curtailed to half output due to loss of one of the lines, reducing flows
LAMBTON_L4D – LAMBTON T8	Outage of one of the lines between IESO and the HVDC	HVDC will be curtailed to half output due to loss of one of the lines, reducing flows
NP_COCHRANE XFMR	Outage of the HVDC	NP_Chocrane is an IESO slack bus. This overload will be mitigated in real time through dispatch of ancillary services

3.2 Review of Existing PARs

The MISO 2015 MTEP Summer 2025 planning model indicates there are two (2) 845MVA, one (1) 481MVA, and one (1) 675MVA PAR at the southeast Michigan MISO-IESO interface. While this indicates adequate existing capacity to deliver 1500MW, a transient analysis by MISO, ITC, and IESO would be needed to analyze that scenario in detail. Details of the PAR control scheme, and any operating constraints placed upon the PARs for inter-regional coordination may not be represented in the MTEP study model. RINA recommends that further analysis be performed by MISO, ITC, and IESO to determine the feasibility of utilizing the existing PARs.

3.3 Upgrade Costs

RINA has assumed complete replacement of the overloaded lines is required at a cost of \$1,048,715 per mile. As stated previously, the overload of Hawthorne – Raisin may be mitigated once generator dispatch is taken into consideration.

**Table 6: System Upgrades Opinion of Probable Cost**

Description	Cost
Replace Hawthorne – Raisin 220kV	\$70,578,520
Replace Bismarck – Golf 120kV	\$15,070,035
Total	\$85,648,555
+20%	\$102,778,266
-20%	\$68,518,844

The cost of the new HVDC converter station is presented in the following table. RINA has made the following assumptions as part of the cost estimate:

- A new 345kV 6-Breaker Ring Bus Substation will be constructed between the Belle River and St. Clair Power Plants.
- The substation will be rigid-bus and low profile.
- The existing St. Clair – Lambton transmission lines will be re-routed to the new substation.
- Two new transmission lines will be constructed from the new substation to the St. Clair substation. Existing poles and conductor will be re-used to the extent possible.
- All new transmission towers will be steel monopoles except where crossing existing transmission lines.
- The transmission lines between the new substation and Lambton Substation will be operated at 220kV.
- The transmission lines between the new substation and St. Clair substation will be operated at 345kV.
- The existing 345 – 220kV transformer at St. Clair substation will be re-located to the new substation.
- A new 1500MW HVDC converter station will be installed at the new substation.
- All land and rights-of-way are currently owned or controlled by DTE and no acquisition costs will be required.

Table 7: HVDC Converter Opinion of Probable Cost

Description	Cost
New HVDC Converter Station	\$211,127,127
New 345kV Switchyard	\$15,201,760
New / Modified Transmission Lines	\$9,010,425
Total	\$235,339,312
+20%	\$282,407,174
-20%	\$188,271,450



4 Conclusion

This study has identified that an import of 1500MW is possible across the MISO-IESO interface into southeast Michigan with an HVDC converter station. Two upgrades to the existing system may be required, though it may be possible to address these through system dispatch. Future studies may identify additional upgrades to support transient stability.

The existing PARs at the MISO-IESO interface may be capable of importing the energy, but additional study by the transmission owners and operators would be required to determine this conclusively.

RINA estimates upgrade costs of \$235.3MM to install and integrate an HVDC converter station into the system, and \$85.6MM additional transmission upgrades. These estimates are +/-20%.



Appendices

A. Complete List of Overloads – HVDC N-1 Case

Table 8: Complete Overloads List – HVDC N-1

From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT	Cont. No.	RATING	MW	Mvar	MVA	%	Zone
1	NEWHVDC	345	160050	*LAMBTON_L4D	345	1	13	1188	-1540.2	48	1541	125.3	ITCT
1	NEWHVDC	345	160050	*LAMBTON_L4D	345	1	39	1188	-1540.2	48	1541	125.3	ITCT
1	NEWHVDC	345	160050	*LAMBTON_L4D	345	1	77	1188	-1540.2	48.3	1541	125.3	ITCT
1	NEWHVDC	345	264830	*19STCPP	220	1	40	1316	-1540.2	-194.2	1552.4	118	ITCT
160064	*LAMBTON_T7T8	220	160069	LAMBTON_P2K2	220	1	13	999	-1543.4	-217.5	1558.6	149	IESO
160064	*LAMBTON_T7T8	220	160069	LAMBTON_P2K2	220	1	39	999	-1543.4	-217.5	1558.6	149	IESO
160064	*LAMBTON_T7T8	220	160069	LAMBTON_P2K2	220	1	77	999	-1543.4	-217.3	1558.6	149	IESO
160065	*LAMBTON_L51D	220	160191	LAMBTON_PHJ	220	1	40	999	-1546.8	-302.1	1576	153.9	IESO
160065	LAMBTON_L51D	220	264830	*19STCPP	220	1	40	1037	1540.2	194.2	1552.4	148.2	ITCT
264788	19BISMARCK1	120	265023	*19GOLF2	120	1	38	214	217.4	8.7	217.6	110.4	ITCT
264788	19BISMARCK1	120	265023	*19GOLF2	120	1	75	214	202.5	2.4	202.5	101.5	ITCT
152396	*NP_COCHRANE	118.05	152910	NP_COCHRANE	27.6	T1	HVDC	12	-12.5	8.3	15	124.7	IESO
152396	*NP_COCHRANE	118.05	152910	NP_COCHRANE	27.6	T1	4	12	-12.5	8.1	14.9	123.9	IESO
152396	*NP_COCHRANE	118.05	152910	NP_COCHRANE	27.6	T1	14	12	-12.5	8.1	14.9	123.9	IESO
152396	*NP_COCHRANE	118.05	152910	NP_COCHRANE	27.6	T1	18	12	-12.5	8.1	14.9	123.9	IESO
152396	*NP_COCHRANE	118.05	152910	NP_COCHRANE	27.6	T1	39	12	-12.5	8.1	14.9	123.9	IESO
152396	*NP_COCHRANE	118.05	152910	NP_COCHRANE	27.6	T1	40	12	-12.5	8.1	14.9	123.9	IESO
152396	*NP_COCHRANE	118.05	152910	NP_COCHRANE	27.6	T1	42	12	-12.5	8.1	14.9	123.9	IESO
152396	*NP_COCHRANE	118.05	152910	NP_COCHRANE	27.6	T1	87	12	-12.5	8.1	14.9	123.9	IESO
160050	*LAMBTON_L4D	345	3WND TR	LAMBTON T8	WND 1	T8	13	733.4	-767.1	26.2	767.5	104.7	IESO
160050	*LAMBTON_L4D	345	3WND TR	LAMBTON T8	WND 1	T8	39	733.4	-767.1	26.2	767.5	104.7	IESO
160050	*LAMBTON_L4D	345	3WND TR	LAMBTON T8	WND 1	T8	77	733.4	-767.1	26.3	767.5	104.7	IESO



B. Contingency List

Table 9: Contingency List

Cont. No.	From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT
HVDC	Outage of HVDC Link						
1	264656	19STCPP	345	264664	19STEPH	345	2
3	264656	19STCPP	345	264857	19SC7	18	1
4	264656	19STCPP	345	264863	19SC6	120	1
6	264580	19JEWEL	345	264656	19STCPP	345	1
7	264604	19BLRPP	345	264656	19STCPP	345	1
8	264664	19STEPH	345	264722	19BISMK	345	1
9	264664	19STEPH	345	264752	19CANIF	345	1
10	264664	19STEPH	345	264763	19STEPH	230	4
11	264580	19JEWEL	345	264664	19STEPH	345	1
12	264663	19STEPH	120	264664	19STEPH	345	1
13	160065	LAMBTON_L51D	220	264830	19STCPP	220	1
14	264858	19SC6	18	264863	19SC6	120	1
15	160050	LAMBTON_L4D	345	160064	LAMBTON_T7T8	220	
16	264580	19JEWEL	345	264722	19BISMK	345	1
17	264580	19JEWEL	345	264888	19LENOX	345	1
18	264580	19JEWEL	345	264750	19JEWEL3	230	3
19	264580	19JEWEL	345	264841	19JEWEL1	230	1
20	256026	18THETFD	345	264580	19JEWEL	345	1
21	264604	19BLRPP	345	264635	19PONTC	345	1
22	264604	19BLRPP	345	264746	19FITZ	345	1
23	264604	19BLRPP	345	264755	19BLRPPP	345	1
24	264604	19BLRPP	345	264888	19LENOX	345	1
25	264604	19BLRPP	345	264855	19BLRP1	26	1
26	264604	19BLRPP	345	264856	19BLRP2	26	1
27	264722	19BISMK	345	264723	19BISMK	230	3
28	264722	19BISMK	345	264788	19BISMARCK1	120	1
29	264730	19CANIFP	120	264752	19CANIF	345	1
30	264626	19NEAST	230	264763	19STEPH	230	1
31	264663	19STEPH	120	264814	19AGSTTP	120	1
32	264663	19STEPH	120	264979	19ERIN3	120	3
33	264663	19STEPH	120	265047	19CTL10-1	120	1
34	264663	19STEPH	120	265048	19CTL10-2	120	2
35	264663	19STEPH	120	265102	19BISMARCK2	120	2
36	264663	19STEPH	120	268730	STEPH	24	1
37	264518	19BECK1	120	264663	19STEPH	120	1
38	264535	19BENSN	120	264663	19STEPH	120	1
39	160065	LAMBTON_L51D	220	160191	LAMBTON_PHJ	220	1



Cont. No.	From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT
40	160064	LAMBTON_T7T8	220	160069	LAMBTON_P2K2	220	1
41	264749	19LENOX1	120	264888	19LENOX	345	1
42	264750	19JEWEL3	230	264760	19STERL	230	1
43	264841	19JEWEL1	230	264842	19SPKNE	230	1
44	256026	18THETFD	345	256500	18MURPHY	345	1
45	256026	18THETFD	345	265075	19BAUER	345	1
46	256006	18GOSS	345	256026	18THETFD	345	1
47	256007	18HAMPTN	345	256026	18THETFD	345	1
48	256026	18THETFD	345	256307	18THTFD3	138	
49	256026	18THETFD	345	256308	18THTFD4	138	
50	264635	19PONTC	345	264636	19PLACD	345	1
51	264635	19PONTC	345	264697	19WIXOM	345	1
52	264635	19PONTC	345	264746	19FITZ	345	1
53	264635	19PONTC	345	264805	19BFOOT	345	1
54	264635	19PONTC	345	265075	19BAUER	345	1
55	264635	19PONTC	345	264638	19PONTC3	120	3
56	264635	19PONTC	345	264766	19PONTIAC	230	5
57	264634	19PONTC1	120	264635	19PONTC	345	1
58	264746	19FITZ	345	264805	19BFOOT	345	1
59	264746	19FITZ	345	265228	19FITZ	120	1
60	264706	19GRNEC	345	264746	19FITZ	345	1
61	264723	19BISMCK	230	264724	19REDRN	230	1
62	264788	19BISMARCK1	120	265023	19GOLF2	120	1
63	264788	19BISMARCK1	120	265102	19BISMARCK2	120	Z1
64	264600	19MALTA1	120	264788	19BISMARCK1	120	1
65	264538	19CANIF	120	264730	19CANIFP	120	1
66	264625	19NEAST	120	264626	19NEAST	230	1
67	264814	19AGSTTP	120	264815	19AGSTA2	120	1
68	264814	19AGSTTP	120	264972	19LENOX3	120	1
69	264979	19ERIN3	120	268586	ERIN	41.57	3
70	264977	19ERIN12	120	264979	19ERIN3	120	Z1
71	264978	19ERIN2	120	265047	19CTL10-1	120	1
72	264977	19ERIN12	120	265048	19CTL10-2	120	2
73	264704	19MALTATP2	120	265102	19BISMARCK2	120	1
74	264518	19BECK1	120	265100	19BECK2	120	Z1
75	264535	19BENSN	120	264597	19MACOMB3	120	1
76	264535	19BENSN	120	265067	19BENSON	120	1
77	160059	LAMBTON_P1K1	220	160191	LAMBTON_PHJ	220	1
78	160069	LAMBTON_P2K2	220	160091	LYNWOOD_JL28	220	1
79	160069	LAMBTON_P2K2	220	160108	GREEN_ELCTRJ	220	1
80	160069	LAMBTON_P2K2	220	160127	LONGWOODJL26	220	1
81	160069	LAMBTON_P2K2	220	160147	GREENFD_IF38	220	1



RINA CONSULTING

Cont. No.	From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT
82	160069	LAMBTON_P2K2	220	160154	N_MOORE_JL27	220	1
83	160069	LAMBTON_P2K2	220	160704	LAMBTON_GS-3	24	T3
84	160069	LAMBTON_P2K2	220	160705	LAMBTON_GS-4	24	T4
85	264749	19LENOX1	120	264971	19LENOX2	120	Z1
86	264749	19LENOX1	120	265177	19GRAYLING1T	120	1
87	264665	19STERL1	120	264760	19STERL	230	1
88	264842	19SPKNE	230	264924	19SPKNE2	120	1
89	256025	18NLSNRD	345	256500	18MURPHY	345	1
90	256027	18TITBAW	345	256500	18MURPHY	345	2
91	256499	18MURPHY	138	256500	18MURPHY	345	3
92	265075	19BAUER	345	265195	19RINGLE	345	1
93	265075	19BAUER	345	265199	19GRASSMERE	345	1
94	256007	18HAMPTN	345	265075	19BAUER	345	1
95	256015	18MANNGT	345	265075	19BAUER	345	1
96	256006	18GOSS	345	256573	18SLATE	345	1
97	256006	18GOSS	345	256155	18GOSS	138	
98	256007	18HAMPTN	345	256008	18KARN3	345	3
99	256007	18HAMPTN	345	256009	18KARN4	345	4
100	256007	18HAMPTN	345	256027	18TITBAW	345	1
101	256286	18THETFD	138	256307	18THTFD3	138	3
102	256286	18THETFD	138	256308	18THTFD4	138	4
103	264636	19PLACD	345	264697	19WIXOM	345	1
104	264636	19PLACD	345	265021	19PLACD2	120	2
105	264636	19PLACD	345	265022	19PLACD4	120	4
106	264697	19WIXOM	345	264785	19QUATP	345	1
107	264697	19WIXOM	345	264884	19WIXOM	230	1
108	264692	19WAYNE	345	264697	19WIXOM	345	1
109	264696	19WIXOM1	120	264697	19WIXOM	345	1
110	264598	19MADRDR	345	264805	19BFOOT	345	1
111	264638	19PONTC3	120	264834	19GDNGS2	120	1
112	264638	19PONTC3	120	264940	19PONTC2	120	1
113	264638	19PONTC3	120	265175	19ORTNVLTP	120	1
114	264765	19BLMFD	230	264766	19PONTIAC	230	1
115	264634	19PONTC1	120	264794	19JSLYN	120	1
116	264634	19PONTC1	120	264940	19PONTC2	120	Z1
117	264556	19BURNS2	120	265228	19FITZ	120	1
118	265172	19RUDYTP	120	265228	19FITZ	120	1
119	264706	19GRNEC	345	264758	19GRNECP	345	1
120	264706	19GRNEC	345	265076	19RAPSON	345	2
121	264706	19GRNEC	345	265077	19BANNER	345	1
122	264706	19GRNEC	345	264865	19GRNEC	26	1
123	264567	19GRNEC	120	264706	19GRNEC	345	1



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Cont. No.	From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT
124	264724	19REDRN	230	264976	19REDRN3	120	1
125	265023	19GOLF2	120	265024	19GOLF3	120	Z1
126	265023	19GOLF2	120	265150	19MACOMB1	120	2
127	264538	19CANIF	120	264544	19CORTL	120	1
128	264538	19CANIF	120	264609	19MACK	120	1
129	264538	19CANIF	120	264623	19NEASTS	120	1
130	264538	19CANIF	120	264983	19BRSTL4	120	1
131	264538	19CANIF	120	265118	19SATURN2	120	1
132	264625	19NEAST	120	264773	19RAMVL2	120	1
133	264625	19NEAST	120	264894	19NEAS23	120	1
134	264625	19NEAST	120	265035	19CTL151	120	1
135	264625	19NEAST	120	265037	19CTL152	120	1
136	264623	19NEASTS	120	264625	19NEAST	120	1
137	264507	19NEAST	24	264625	19NEAST	120	1
138	264681	19VICTR	120	264972	19LENOX3	120	1
139	264971	19LENOX2	120	264972	19LENOX3	120	Z1
140	264554	19ERIN1	120	268586	ERIN	41.57	1
141	264978	19ERIN2	120	268586	ERIN	41.57	2
142	264977	19ERIN12	120	264978	19ERIN2	120	Z1
143	264554	19ERIN1	120	264977	19ERIN12	120	Z1
144	264704	19MALTATP2	120	265103	19MALTA2	120	1
145	264704	19MALTATP2	120	265177	19GRAYLING1T	120	1
146	264607	19MEDNA	120	265100	19BECK2	120	1
147	264597	19MACOMB3	120	265150	19MACOMB1	120	Z1
148	264597	19MACOMB3	120	265151	19MACOMB5	120	Z1
149	160059	LAMBTON_P1K1	220	160099	E_LK_STCLR_J	220	1
150	160059	LAMBTON_P1K1	220	160120	TALFORD_JL23	220	1
151	160059	LAMBTON_P1K1	220	160126	LONGWOODJL24	220	1
152	160059	LAMBTON_P1K1	220	160146	GREENFD_IF37	220	1
153	160059	LAMBTON_P1K1	220	160153	N_MOORE_JL25	220	1
154	160059	LAMBTON_P1K1	220	160638	LAMBTON_D	27.6	T5
155	160059	LAMBTON_P1K1	220	160696	LAMBTON_Y	27.6	T6
156	160091	LYNWOOD_JL28	220	160108	GREEN_ELCTRJ	220	1
157	160055	CHATHAM_SS	220	160091	LYNWOOD_JL28	220	1
158	160085	KENT_TS_L28C	220	160091	LYNWOOD_JL28	220	1
159	160108	GREEN_ELCTRJ	220	160109	GREEN_ELCTRN	220	1
160	160127	LONGWOODJL26	220	160129	LONGWD_DSN26	220	1
161	160062	LONGWOOD_TS	220	160127	LONGWOODJL26	220	1
162	160145	GREENFLD_L38	220	160147	GREENFD_IF38	220	1
163	160142	NOVA_SS_JL27	220	160154	N_MOORE_JL27	220	1
164	160152	N_MOORE_L27V	220	160154	N_MOORE_JL27	220	1
165	264652	19GRAYLING2T	120	264971	19LENOX2	120	1



Cont. No.	From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT
166	264960	19STC12	120	264971	19LENOX2	120	1
167	264568	19GRAYLING1	120	265177	19GRAYLING1T	120	1
168	264826	19AGSTA1	120	265177	19GRAYLING1T	120	1
169	264665	19STERL1	120	264936	19STERL2	120	Z1
170	264665	19STERL1	120	268731	STERL	41.57	1
171	264617	19MUSTG1	120	264665	19STERL1	120	1
172	264924	19SPKNE2	120	264925	19SPKNE3	120	Z1
173	264661	19SPKNE1	120	264924	19SPKNE2	120	Z1
174	256025	18NLSNRD	345	256029	18VERGEN	345	1
175	256025	18NLSNRD	345	256030	18RENAIS	345	1
176	256025	18NLSNRD	345	256573	18SLATE	345	1
177	256010	18KENOWA	345	256025	18NLSNRD	345	1
178	256005	18GALGRT	345	256027	18TITBAW	345	1
179	256015	18MANNGT	345	256027	18TITBAW	345	1
180	256016	18MCV	345	256027	18TITBAW	345	1
181	256027	18TITBAW	345	256290	18TITBAW	138	
182	256169	18HSC	138	256499	18MURPHY	138	1
183	256193	18LAWNDL	138	256499	18MURPHY	138	1
184	256290	18TITBAW	138	256499	18MURPHY	138	1
185	256494	18ORR RD	138	256499	18MURPHY	138	1
186	265195	19RINGLE	345	265196	19CROSSWINDS	345	1
187	265190	19STEIN	345	265195	19RINGLE	345	1
188	265199	19GRASSMERE	345	268837	PINNIBOGG	120	1
189	265076	19RAPSON	345	265199	19GRASSMERE	345	1
190	256014	18MANING	345	256015	18MANNGT	345	1
191	256573	18SLATE	345	256574	18BEEBE	345	1
192	256155	18GOSS	138	256244	18PASDNJ	138	1
193	256115	18CORNELLB	138	256155	18GOSS	138	1
194	256151	18DUFLDJ	138	256155	18GOSS	138	1
195	256008	18KARN3	345	256329	18KARN3	26	3
196	256009	18KARN4	345	256330	18KARN4	26	4
197	256286	18THETFD	138	256312	18WEDCKB	138	1
198	256286	18THETFD	138	256565	18DORTW	138	1
199	256286	18THETFD	138	256665	18HEMPHILLB	138	1
200	256286	18THETFD	138	256375	18THTFD5	13.8	5
201	256286	18THETFD	138	256412	18THTFD1	13.8	61
202	256286	18THETFD	138	256413	18THTFD2	13.8	62
203	256051	18AT-K-T	138	256286	18THETFD	138	1
204	256121	DELANEY	138	256286	18THETFD	138	1
205	256126	18DORTB	138	256286	18THETFD	138	2
206	256286	18THETFD	138	256416	18THETF78	13.8	
207	264632	19PLACD1	120	265021	19PLACD2	120	Z1



Cont. No.	From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT
208	264509	19PLACD	41.57	265021	19PLACD2	120	2
209	265022	19PLACD4	120	265139	19DURANT2	120	1
210	264632	19PLACD1	120	265022	19PLACD4	120	Z1
211	264785	19QUATP	345	264786	19QUAKR	345	1
212	264692	19WAYNE	345	264785	19QUATP	345	1
213	264884	19WIXOM	230	264885	19QUAKR	230	1
214	264884	19WIXOM	230	264886	19CVTRY	230	1
215	264692	19WAYNE	345	264707	19BNSTNS	345	2
216	264692	19WAYNE	345	264737	19BNSTNN	345	1
217	264692	19WAYNE	345	265009	19WAYNE3	120	3
218	264599	19MAJTC	345	264692	19WAYNE	345	1
219	264612	19MON12	345	264692	19WAYNE	345	1
220	264688	19WAYNE	230	264692	19WAYNE	345	4
221	264691	19WAYNE2	120	264692	19WAYNE	345	1
222	264696	19WIXOM1	120	264942	19WIXOM3	120	Z1
223	264515	19AKRON	120	264696	19WIXOM1	120	1
224	264598	19MADRD	345	264599	19MAJTC	345	1
225	264596	19MADRD	120	264598	19MADRD	345	1
226	264834	19GDNGS2	120	264938	19WALTN2	120	1
227	264903	19CLRDT1	120	264940	19PONTC2	120	1
228	265175	19ORTNVLTP	120	268846	ORTVL	120	1
229	265110	19STRATFORD2	120	265175	19ORTNVLTP	120	1
230	264765	19BLMFD	230	264921	19BLMFD3	120	1
231	264683	19WALTN1	120	264794	19JSLYN	120	1
232	264520	19ADAMS	120	264556	19BURNS2	120	1
233	265172	19RUDYTP	120	268822	RUDY	120	1
234	264536	19BUNCE1	120	265172	19RUDYTP	120	1
235	265076	19RAPSON	345	265077	19BANNER	345	1
236	265076	19RAPSON	345	265190	19STEIN	345	1
237	265076	19RAPSON	345	265086	19RAPSON	120	2
238	265077	19BANNER	345	265088	19BANNER	120	1
239	264567	19GRNEC	120	264713	19KILGORE1	120	1
240	264567	19GRNEC	120	264721	19BENET	120	1
241	264976	19REDRN3	120	268703	REDRN	41.57	3
242	264975	19REDRN2	120	264976	19REDRN3	120	Z1
243	264533	19GOLF1	120	265024	19GOLF3	120	Z1
244	264739	19HOUSTONTP2	120	265024	19GOLF3	120	1
245	265150	19MACOMB1	120	268638	MACMB	41.57	1
246	264544	19CORTL	120	264608	19MIDTN	120	1
247	264544	19CORTL	120	264686	19WARENS	120	1
248	264544	19CORTL	120	268568	CORTL	24	1
249	264609	19MACK	120	264623	19NEASTS	120	1



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Cont. No.	From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT
250	264609	19MACK	120	264791	19MOPAR	120	1
251	264609	19MACK	120	268637	MACK	24	1
252	264555	19VOYAG	120	264609	19MACK	120	1
253	264982	19BRSTL3	120	264983	19BRSTL4	120	Z1
254	264566	19SATURN1	120	265118	19SATURN2	120	Z1
255	264655	19SKYLK1	120	264773	19RAMVL2	120	1
256	264772	19RAMVL1	120	264894	19NEAS23	120	1
257	265034	19CTL141	120	265035	19CTL151	120	1
258	265036	19CTL142	120	265037	19CTL152	120	1
259	264681	19VICTR	120	264829	19JACOB	120	1
260	264681	19VICTR	120	268747	VICTR	41.57	1
261	264554	19ERIN1	120	264607	19MEDNA	120	1
262	264607	19MEDNA	120	268643	MEDNA	41.57	1
263	265151	19MACOMB5	120	268638	MACMB	41.57	2
264	264533	19GOLF1	120	265151	19MACOMB5	120	1
265	160099	E_LK_STCLR_J	220	160100	E_LK_STCLAIR	220	1
266	160092	LYNWOOD_JL29	220	160099	E_LK_STCLR_J	220	1
267	160063	SCOTT_TS	220	160120	TALFORD_JL23	220	1
268	160077	DUPONT_JL23N	220	160120	TALFORD_JL23	220	1
269	160126	LONGWOODJL24	220	160128	LONGWD_DSN24	220	1
270	160062	LONGWOOD_TS	220	160126	LONGWOODJL24	220	1
271	160144	GREENFLD_L37	220	160146	GREENFD_IF37	220	1
272	160153	N_MOORE_JL25	220	160160	N_CHEM_SSL25	220	1
273	160151	N_MOORE_L25V	220	160153	N_MOORE_JL25	220	1
274	160055	CHATHAM_SS	220	160092	LYNWOOD_JL29	220	1
275	160055	CHATHAM_SS	220	160105	RWEC_J_C23Z	220	1
276	160055	CHATHAM_SS	220	160110	SANDWCH_JC21	220	1
277	160055	CHATHAM_SS	220	160111	SANDWCH_JC22	220	1
278	160055	CHATHAM_SS	220	160167	KEPA_WF_JC24	220	1
279	160055	CHATHAM_SS	220	160188	C31_SKWP_CMS	220	1
280	160055	CHATHAM_SS	220	160199	DUART_JW44LC	220	1
281	160055	CHATHAM_SS	220	160416	LEAMINGJCT21	220	1
282	160055	CHATHAM_SS	220	160417	LEAMINGJCT22	220	1
283	160051	ERIEAU_WF_J	220	160055	CHATHAM_SS	220	1
284	160085	KENT_TS_L28C	220	160618	KENT_TS_EZ	27.6	T4
285	160085	KENT_TS_L28C	220	160635	KENT_TS_B	27.6	
286	160109	GREEN_ELCTRN	220	160600	GREEN_ELC_G1	18	T1
287	160109	GREEN_ELCTRN	220	160601	GREEN_ELC_G1	13.8	
288	160129	LONGWD_DSN26	220	160650	LONGWOOD_J	27.6	13
289	160062	LONGWOOD_TS	220	160074	COWAL_JW44LC	220	1
290	160062	LONGWOOD_TS	220	160075	COWAL_JW45LS	220	1
291	160062	LONGWOOD_TS	220	160130	BUCH_J_W42L	220	1



Cont. No.	From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT
292	160062	LONGWOOD_TS	220	160131	BUCH_J_W43L	220	1
293	160000	LONGWOOD_TS	500	160062	LONGWOOD_TS	220	
294	160145	GREENFLD_L38	220	160728	GREENFLD_GS2	18	T2
295	160145	GREENFLD_L38	220	160729	GREENFLD_GS3	18	T3
296	160142	NOVA_SS_JL27	220	160150	N_CORUNN_L27	220	1
297	160142	NOVA_SS_JL27	220	160156	N_CHEM_SSL27	220	1
298	160152	N_MOORE_L27V	220	160656	NOVA_MOORE	13.8	T1
299	264652	19GRAYLING2T	120	264771	19MALTA3	120	1
300	264652	19GRAYLING2T	120	265096	19GRAYLING2	120	1
301	264960	19STC12	120	264961	19STC10	120	Z1
302	264720	19REMER2	120	264960	19STC12	120	2
303	264959	19STC13	120	264960	19STC12	120	1
304	264936	19STERL2	120	264937	19STERL3	120	Z1
305	264936	19STERL2	120	268731	STERL	41.57	2
306	264715	19ALPHA	120	264936	19STERL2	120	1
307	264937	19STERL3	120	268731	STERL	41.57	3
308	264565	19GENDY	120	264617	19MUSTG1	120	1
309	264925	19SPKNE3	120	268716	SPKNE	41.57	2
310	264905	19TINKNT	120	264925	19SPKNE3	120	1
311	264661	19SPKNE1	120	264674	19SENECA1	120	1
312	264520	19ADAMS	120	264661	19SPKNE1	120	1
313	256004	18GAINES	345	256029	18VERGEN	345	1
314	256029	18VERGEN	345	256298	18VERGEN	138	
315	256030	18RENAIS	345	256351	18RENAS1	18	1
316	256010	18KENOWA	345	256013	18LUDNGT	345	1
317	256005	18GALGRT	345	256012	18LVNSTN	345	1
318	256003	18GALAGR	345	256005	18GALGRT	345	1
319	256016	18MCV	345	256216	18MCV1	138	
320	256290	18TITBAW	138	256304	WACKERLY 1	138	1
321	256087	18BULLOCKB	138	256290	18TITBAW	138	1
322	256169	18HSC	138	256290	18TITBAW	138	1
323	256169	18HSC	138	259217	SARATOGA	46	
324	256193	18LAWNDL	138	256491	18GEDDEJ	138	1
325	256193	18LAWNDL	138	258728	LAWNDALE E	46	
326	256169	18HSC	138	256494	18ORR RD	138	1
327	265196	19CROSSWINDS	345	265197	19CROSSWINDS	34.5	1
328	268837	PINNIBOGG	120	268838	ECHOPARKHI	120	1
329	256014	18MANING	345	256208	18MANING	138	
330	256574	18BEEBE	345	256575	18BEEBE	34.5	1
331	256244	18PASDNJ	138	256565	18DORTW	138	1
332	256069	BENNINGTN	138	256115	18CORNELLB	138	1
333	256312	18WEDCKB	138	256355	18WEDCK7	18	7



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Cont. No.	From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT
334	256052	BANGOR	138	256312	18WEDCKB	138	1
335	256312	18WEDCKB	138	256336	18WEDCK	23	
336	256126	18DORTB	138	256565	18DORTW	138	Z1
337	256565	18DORTW	138	258453	DORT G	46	
338	256166	18HEMPHILLW	138	256665	18HEMPHILLB	138	Z1
339	256051	18AT-K-T	138	256186	18KARNW	138	1
340	256121	DELANEY	138	256166	18HEMPHILLW	138	1
341	256121	DELANEY	138	258435	DELANEY	46	
342	256126	18DORTB	138	256168	18ROEDLJ	138	1
343	256112	18COLEJ	138	256126	18DORTB	138	1
344	256126	18DORTB	138	258456	DORT T	46	
345	264632	19PLACD1	120	264633	19PROUD	120	1
346	264509	19PLACD	41.57	264632	19PLACD1	120	1
347	264781	19DURANT1	120	265139	19DURANT2	120	Z1
348	264885	19QUAKR	230	264929	19QUAKR3	120	1
349	264886	19CVTRY	230	264887	19CODY	230	1
350	264707	19BNSTNS	345	264736	19BNSTNS	230	3
351	264612	19MON12	345	264707	19BNSTNS	345	1
352	264737	19BNSTNN	345	264998	19BNSTN2	120	1
353	264613	19MON34	345	264737	19BNSTNN	345	2
354	264619	19NBURG1	120	265009	19WAYNE3	120	1
355	238889	02LEMOYN	345	264599	19MAJTC	345	1
356	238563	02BAY SH	345	264612	19MON12	345	1
357	264688	19WAYNE	230	264731	19HINES	230	1
358	264691	19WAYNE2	120	264733	19KOPPERNKTP	120	1
359	264942	19WIXOM3	120	264943	19HANCK2	120	1
360	264515	19AKRON	120	264668	19SNSET	120	1
361	264596	19MADRD	120	264800	19COLFX	120	1
362	264938	19WALTN2	120	264939	19WALTN3	120	Z1
363	264683	19WALTN1	120	264938	19WALTN2	120	Z1
364	264700	19SUNBIRD1	120	264903	19CLRDT1	120	1
365	264666	19STRATFORD1	120	265110	19STRATFORD2	120	Z1
366	264921	19BLMFD3	120	264923	19BLMFD5	120	Z1
367	264693	19WHELRL1	120	264921	19BLMFD3	120	1
368	264611	19MONTC	120	264683	19WALTN1	120	1
369	264536	19BUNCE1	120	264776	19MOHIC1	120	1
370	265086	19RAPSON	120	265163	19MINDEN	120	1
371	264622	19SEASD	120	265086	19RAPSON	120	1
372	264658	19SANDU	120	265088	19BANNER	120	1
373	264713	19KILGORE1	120	265154	19KILGORE2	120	Z1
374	264721	19BENET	120	268524	BENET	41.57	1
375	264639	19REDRN1	120	268703	REDRN	41.57	1



Cont. No.	From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT
376	264975	19REDRN2	120	268703	REDRN	41.57	2
377	264639	19REDRN1	120	264975	19REDRN2	120	Z1
378	264667	19SKYLK2	120	264975	19REDRN2	120	1
379	264533	19GOLF1	120	264779	19BOYNE1	120	1
380	264739	19HOUSTONTP2	120	264959	19STC13	120	1
381	264739	19HOUSTONTP2	120	265152	19HOUSTON2	120	1
382	264608	19MIDTN	120	265224	19STONEPOOL	120	1
383	264561	19FRISB	120	264608	19MIDTN	120	1
384	264686	19WARENS	120	265042	19CTL7	120	1
385	264684	19WAREN	120	264686	19WARENS	120	1
386	264791	19MOPAR	120	264980	19ESSX7	120	1
387	264555	19VOYAG	120	265148	19ESSEX4	120	1
388	264530	19BRSTL1	120	264982	19BRSTL3	120	Z1
389	264561	19FRISB	120	264566	19SATURN1	120	1
390	264591	19LOGAN2	120	264655	19SKYLK1	120	1
391	264772	19RAMVL1	120	264837	19PLUTO	120	1
392	265034	19CTL141	120	265179	19FERNDALE1	120	1
393	264748	19L-N-NW	120	265036	19CTL142	120	1
394	264661	19SPKNE1	120	268716	SPKNE	41.57	1
395	256010	18KENOWA	345	256029	18VERGEN	345	1
396	256019	18PALISD	345	256029	18VERGEN	345	1
397	256030	18RENAIS	345	256352	18RENAS2	18	2
398	256030	18RENAIS	345	256353	18RENAS3	18	3
399	256030	18RENAIS	345	256354	18RENAS4	18	4
400	256010	18KENOWA	345	256024	18TALLMG	345	1
401	256010	18KENOWA	345	256588	18HAYES	345	1
402	256016	18MCV	345	256337	18MCVST1	22	20
403	256016	18MCV	345	256217	18MCV2	138	
404	256290	18TITBAW	138	256542	18REDSTONE	138	1
405	256290	18TITBAW	138	259407	BISLAND 2	138	1
406	256193	18LAWNDL	138	259404	BAY RD 2	138	1
407	256193	18LAWNDL	138	258729	LAWNDALE W	46	
408	256494	18ORR RD	138	258055	YATES 2	138	1
409	256494	18ORR RD	138	258175	YATES 1	138	1
410	256494	18ORR RD	138	259318	YORK 1	138	1
411	256494	18ORR RD	138	259319	YORK 2	138	1
412	265190	19STEIN	345	265200	19PHEASANTRN	345	1
413	264829	19JACOB	120	264957	19STC7	120	1
414	160100	E_LK_STCLAIR	220	160863	E_LK_STCLAIR	34.5	T1
415	160063	SCOTT_TS	220	160089	LUCASVIL_J21	220	1
416	160063	SCOTT_TS	220	160204	SCOTT_TS_KP	118.05	
417	160077	DUPONT_JL23N	220	160079	DUP_ST_CLR23	220	1



Cont. No.	From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT
418	160128	LONGWD_DSN24	220	160675	LONGWOOD_Q	27.6	14
419	160105	RWEC_J_C23Z	220	160106	RWEC_WF_C23Z	220	1
420	160110	SANDWCH_JC21	220	160416	LEAMINGJCT21	220	1
421	160111	SANDWCH_JC22	220	160417	LEAMINGJCT22	220	1
422	160167	KEPA_WF_JC24	220	160168	PT_ALMA_CSS	220	1
423	160049	DUART_W44LC	220	160199	DUART_JW44LC	220	1
424	160416	LEAMINGJCT21	220	160418	LEAMINGTC21J	220	1
425	160417	LEAMINGJCT22	220	160419	LEAMINGTC22J	220	1
426	160051	ERIEAU_WF_J	220	160052	ERIEAU_WF	220	1
427	160074	COWAL_JW44LC	220	160134	BUCH_J_W44LC	220	1
428	160075	COWAL_JW45LS	220	160078	DUART_JW45LS	220	1
429	160130	BUCH_J_W42L	220	160132	BUCH_DSN_W42	220	1
430	160054	BUCHANAN_TS	220	160130	BUCH_J_W42L	220	1
431	160131	BUCH_J_W43L	220	160133	BUCH_DSN_W43	220	1
432	160054	BUCHANAN_TS	220	160131	BUCH_J_W43L	220	1
433	158007	NANTICOKE_TS	500	160000	LONGWOOD_TS	500	1
434	160150	N_CORUNN_L27	220	160655	NOVA_CORUNNA	13.8	T2
435	160156	N_CHEM_SSL27	220	160161	N_CHEM_SSV43	220	1
436	160151	N_MOORE_L25V	220	160656	NOVA_MOORE	13.8	T2
437	264961	19STC10	120	264962	19STC6	120	Z1
438	264798	19CRBNT	120	264961	19STC10	120	1
439	264720	19REMER2	120	264820	19DEAN12	120	1
440	264627	19MUSTG2	120	264937	19STERL3	120	1
441	264560	19BRONC	120	264715	19ALPHA	120	1
442	264710	19TINKN2	120	264905	19TINKNT	120	1
443	264674	19SENECA1	120	265068	19SENECA2	120	Z1
444	264542	19CHTNT1	120	264639	19REDRN1	120	1
445	264667	19SKYLK2	120	264837	19PLUTO	120	1
446	264779	19BOYNE1	120	265112	19BOYNE2	120	Z1
447	264779	19BOYNE1	120	268574	BOYNE	41.57	1
448	264958	19STC11	120	264959	19STC13	120	Z1
449	256244	18PASDNJ	138	258131	PASADENA	138	1
450	256115	18CORNELLB	138	256563	18CORNELLW	138	Z1
451	256115	18CORNELLB	138	258126	OWOSSO	138	1
452	256151	18DUFOLDJ	138	256266	18STACYJ	138	1
453	256151	18DUFOLDJ	138	258076	DUFFIELD	138	1
454	256176	BRITTRDGE 1	138	256312	18WEDCKB	138	1
455	256312	18WEDCKB	138	259178	WEADOCK E	46	
456	256149	18GARFIELDB	138	256565	18DORTW	138	1
457	256234	18NEFRDJ	138	256665	18HEMPHILLB	138	1
458	256245	18PORTRJ	138	256665	18HEMPHILLB	138	1
459	256284	18HEMPH T4 H	138	256665	18HEMPHILLB	138	1



Cont. No.	From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT
460	256051	18AT-K-T	138	264705	19ATLAN	138	1
461	264530	19BRSTL1	120	264561	19FRISB	120	1
462	264980	19ESSX7	120	264981	19ESSEX5	120	Z1
463	264553	19ESSEX6	120	264980	19ESSX7	120	Z1
464	264553	19ESSEX6	120	265148	19ESSEX4	120	Z1
465	265179	19FERNDALE1	120	265180	19FERNDALE2	120	Z1
466	264748	19L-N-NW	120	264970	19LINCN3	120	1
467	256004	18GAINES	345	256022	18ROSVLT	345	1
468	256004	18GAINES	345	256147	18GAINES	138	
469	256019	18PALISD	345	256022	18ROSVLT	345	1
470	247803	05SEGRETO	345	256019	18PALISD	345	1
471	256298	18VERGEN	138	256322	18LOWELJ	138	1
472	256013	18LUDNGT	345	256020	18PERMQT	345	1
473	256024	18TALLMG	345	256588	18HAYES	345	1
474	256000	18ARGNTA	345	256024	18TALLMG	345	1
475	256024	18TALLMG	345	256281	18TALLMG	138	
476	256000	18ARGNTA	345	256588	18HAYES	345	1
477	256588	18HAYES	345	256589	18HAYES	138	
478	256012	18LVNSTN	345	256201	18LVNSTN	138	
479	256003	18GALAGR	345	256148	18GALAGR	138	
480	256216	18MCV1	138	256394	18MCVG9	13.8	9
481	256217	18MCV2	138	256388	18MCVG3	13.8	3
482	256304	WACKERLY 1	138	259425	WACKERLY 2	138	Z1
483	256304	WACKERLY 1	138	259158	WACKERLY S	46	
484	256542	18REDSTONE	138	256543	18GRATIOT	138	1
485	256066	18REGAL	138	256542	18REDSTONE	138	1
486	256129	BISLAND 1	138	259407	BISLAND 2	138	Z1
487	256087	18BULLOCKB	138	256134	18EDNVLJ	138	1
488	256087	18BULLOCKB	138	258324	BULLOCK E	46	
489	256491	18GEDDEJ	138	256562	18CLAREMONTW	138	1
490	256060	BAY RD 1	138	259404	BAY RD 2	138	Z1
491	268838	ECHOPARKHI	120	268839	ECHOPARKLO	34.5	1
492	264542	19CHTNT1	120	264926	19CHTNT2	120	Z1
493	264542	19CHTNT1	120	265053	19CTL52	120	1
494	264542	19CHTNT1	120	268567	CHTNT	41.57	1
495	264810	19HOUSTONTP1	120	265112	19BOYNE2	120	1
496	264810	19HOUSTONTP1	120	264958	19STC11	120	1
497	264957	19STC7	120	264958	19STC11	120	Z1
498	264862	19SC1	15.5	264958	19STC11	120	1
499	256208	18MANING	138	256554	18TSCOLA BAY	138	1
500	256186	18KARNW	138	256208	18MANING	138	1
501	258131	PASADENA	138	258932	PASADENA 1	46	



Cont. No.	From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT
502	256047	18BLUWRJ	138	256563	18CORNELLW	138	1
503	256563	18CORNELLW	138	258410	CORNELL	46	
504	258126	OWOSSO	138	258917	OWOSSO 2	46	
505	256266	18STACYJ	138	258156	STACEY	138	1
506	256070	BEVERIDGE W	138	256266	18STACYJ	138	1
507	256052	BANGOR	138	256225	MONITOR	138	1
508	256176	BRITTRDGE 1	138	256177	BRITTRDGE 2	138	Z1
509	256149	18GARFIELDB	138	256166	18HEMPHILLW	138	1
510	256166	18HEMPHILLW	138	258627	HEMPHILL E	46	
511	256234	18NEFRDJ	138	256321	18WILRDJ	138	1
512	256284	18HEMPH T4 H	138	256327	18HEMPH T4 L	120	
513	256186	18KARNW	138	256361	18KARN1A	16	
514	264705	19ATLAN	138	265283	19ATLANTA1	120	1
515	256168	18ROEDLJ	138	256313	18WEDCKW	138	1
516	264926	19CHTNT2	120	264927	19CHTNT3	120	Z1
517	264926	19CHTNT2	120	268567	CHTNT	41.57	2
518	264816	19WHITR2	120	265053	19CTL52	120	1
519	264927	19CHTNT3	120	268567	CHTNT	41.57	3
520	264927	19CHTNT3	120	265045	19CTL51	120	1
521	264590	19LOGAN1	120	264927	19CHTNT3	120	1
522	264577	19FMTEC2	120	264816	19WHITR2	120	1
523	264589	19LINCN1	120	265045	19CTL51	120	1
524	264590	19LOGAN1	120	264670	19VNDYK1	120	1
525	264577	19FMTEC2	120	264965	19TROY3	120	1
526	264589	19LINCN1	120	264969	19LINCN2	120	Z1
527	264589	19LINCN1	120	265180	19FERNDALE2	120	1
528	264589	19LINCN1	120	268572	LINCN	24	1
529	264565	19GENDY	120	264670	19VNDYK1	120	1
530	264965	19TROY3	120	268740	TROY	41.57	3
531	264592	19LNGLAKETP2	120	264965	19TROY3	120	1
532	264964	19TROY2	120	264965	19TROY3	120	Z1
533	264969	19LINCN2	120	264970	19LINCN3	120	Z1
534	264969	19LINCN2	120	268572	LINCN	24	2
535	264970	19LINCN3	120	268572	LINCN	24	3
536	264677	19TROY1	120	268740	TROY	41.57	1
537	264964	19TROY2	120	268740	TROY	41.57	2
538	264966	19TROY4	120	268740	TROY	41.57	4
539	264592	19LNGLAKETP2	120	264922	19BLMFD4	120	1
540	264592	19LNGLAKETP2	120	265108	19LONGLAKE2	120	1
541	264677	19TROY1	120	264964	19TROY2	120	Z1
542	264817	19WHITR1	120	264970	19LINCN3	120	1
543	264677	19TROY1	120	264966	19TROY4	120	Z1



Cont. No.	From - ID	From - Name	From - Volts	To - ID	To - Name	To - Volts	CKT
544	264677	19TROY1	120	265028	19ARIEL	120	1
545	264582	19FMTEC1	120	264677	19TROY1	120	1
546	264966	19TROY4	120	264968	19APACE3	120	1
547	264922	19BLMFD4	120	264923	19BLMFD5	120	Z1
548	264922	19BLMFD4	120	268552	BLMFD5	41.57	4
549	264642	19KERNTP2	120	264922	19BLMFD4	120	1
550	264591	19LOGAN2	120	264852	19SLOAN	120	1
551	264748	19L-N-NW	120	265038	19CTL3	120	1
552	264582	19FMTEC1	120	264817	19WHITR1	120	1
553	264593	19LNGLK1	120	265028	19ARIEL	120	1
554	264967	19APACE2	120	264968	19APACE3	120	Z1
555	264529	19BLMFD1	120	264923	19BLMFD5	120	Z1
556	264920	19BLMFD2	120	264923	19BLMFD5	120	Z1
557	264642	19KERNTP2	120	264833	19GIDDINGTP1	120	1
558	264642	19KERNTP2	120	265105	19KERN2	120	1
559	265038	19CTL3	120	265039	19CTL11	120	1
560	264593	19LNGLK1	120	264946	19WHEL3	120	1
561	264517	19APACE1	120	264967	19APACE2	120	Z1
562	264529	19BLMFD1	120	264552	19LEBRT2	120	1
563	264529	19BLMFD1	120	268526	BLMFD	41.57	1
564	264920	19BLMFD2	120	265107	19TEMPEST2	120	1
565	264920	19BLMFD2	120	265231	19BARTLETT2	120	1
566	264920	19BLMFD2	120	268526	BLMFD	41.57	2
567	264754	19AULEBT	120	264921	19BLMFD3	120	1
568	264833	19GIDDINGTP1	120	264904	19CLRDT2	120	1
569	264833	19GIDDINGTP1	120	265106	19GIDDINGS1	120	1
570	265039	19CTL11	120	265040	19CTL12	120	1
571	264552	19LEBRT2	120	264641	19KERNTP1	120	1
572	264673	19TEMPEST1	120	265107	19TEMPEST2	120	Z1
573	264525	19SP1-L1	120	264754	19AULEBT	120	1
574	264904	19CLRDT2	120	265104	19SUNBIRD2	120	1
575	264775	19COLRD2	120	264904	19CLRDT2	120	1



C. Location of HVDC Yard and Transmission Lines

Figure 3: New HVDC Yard





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STATE OF MICHIGAN

BEFORE THE MICHIGAN PUBLIC SERVICE COMMISSION

In the matter of the Application of **DTE ELECTRIC COMPANY** for approval of Certificates of Necessity pursuant to MCL 460.6s, as amended, in connection with the addition of a natural gas combined cycle generating facility to its generation fleet and for related accounting and ratemaking authorizations

U-18419

ALJ Suzanne D. Sonneborn

PROOF OF SERVICE

On the date below, an electronic copy of **the Direct Testimony of Josh Berkow with Exhibits MEC-88 and MEC-89 on behalf of Michigan Environmental Council** was served on the following:

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The statements above are true to the best of my knowledge, information and belief.

OLSON, BZDOK & HOWARD, P.C.
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Date: January 12, 2018

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