Exhibit PET-JP-04

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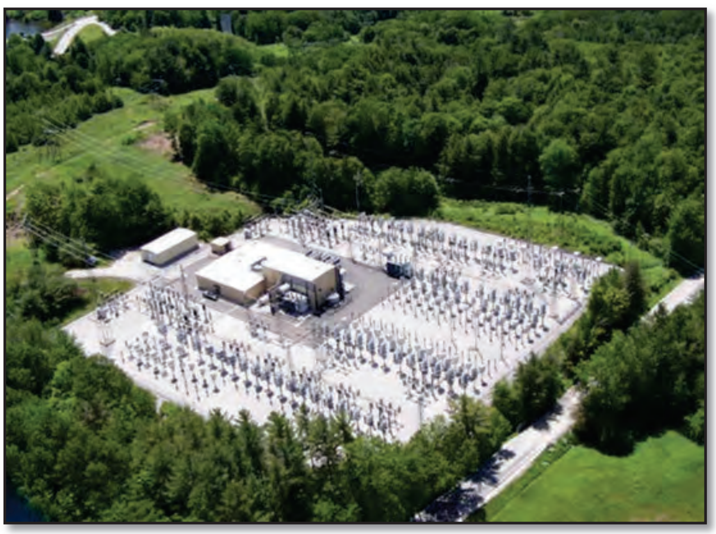
Highgate Converter
Updated performance review



Hantz A. Présumé
VELCO System Planning
Revision 3
October 28, 2015

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Summary

In 1985, Vermont Electric Power Company, Inc. (VELCO) received a DOE permit (PP-82) to operate a 200 MW back-to-back HVDC converter at its Highgate substation in the northwest corner of Vermont, near the Canadian/US border. The presidential permit was amended (PP-82-2) in 1994 to allow the converter to operate at 225 MW, subject to some operating conditions and limitations. The presidential permit was again amended (PP-82-3) in 2005 to allow imports of up to 250 MW via the transmission facilities that cross the US-Canadian border. However, the PP-82-3 permit required that VELCO, as the facility's transmission operator and on behalf of the joint owners, continue to adhere to the operating protocols outlined in the prior PP-82-2 permit because no new information had been submitted to support the conclusion that the existing protocols would no longer be required. This report describes the analysis conducted to support the recommendation to remove the existing operating conditions due to several system, market and regulatory changes that have occurred since 1994. These protocols are either not applicable or impossible to follow due to these changes. These protocols are addressed individually below.

<u>Presidential permit requirement #1:</u>

> **Revision of the pre-contingency dispatch of VELCO's switched capacitors as detailed in Table 1 of the DOE Reliability Determination dated November 26, 1993, to prevent post-contingency reactive deficiency and pre-contingency overvoltages;**

The voltage control range of the capacitor banks that existed back in 1992 was raised at that time in order to force the capacitor banks in service at a higher pre-contingency voltage, and address anticipated post-contingency low voltages. In this new study, several modeling changes were made in order to stress the system more severely than the 1992 study. This testing approach, described below, demonstrates that the system is no longer dependent on a specific capacitor bank dispatch.

- Summer peak load was tested instead of a winter peak. In recent years, the highest system peak has occurred in the summer, and summer loads are more severe in terms of low voltage concerns. The load level tested was approximately 150 MW higher than the prior analysis, and hydro generation was approximately 70 MW lower.

- The 100 MVAr fictitious synchronous condenser that was used at Highgate in the prior study to represent the automatic switching of capacitor banks was turned off entirely in this study. The analysis no longer takes advantage of any post-contingency switching of capacitor banks at Highgate, and the negative voltage squared effect could be observed when the voltage is reduced below 1.0 pu, compared to the output of the fictitious machine, which is unaffected by the reduced voltage.

- Transformer taps were not allowed to move, and capacitor banks were not allowed to switch post-contingency in order to avoid the post-contingency voltage support from these devices. The 115 kV capacitor banks noted in table 1 of the 1992 study were switched off and not allowed to switch on post-contingency. Specifically, the Georgia (Fairfax), Sand Bar, Middlebury, Rutland, and Williston capacitor banks were out of service. The low voltage capacitor banks, Ascutney, Barre, and Highgate were in service.

In addition, the system has been upgraded since the prior study. Approximately 460 MVAr of capacitor banks, not including capacitor banks installed on the low voltage system, have been installed in addition to the 210 MVAr modeled in the prior study. More significantly, several dynamic reactive devices have been installed, which removed the reliance on fast post-contingency switching of capacitor banks. In total, approximately 300 MVAr of dynamic reactive support were added to the transmission system in the last few years, not including synchronous condensers installed on the low voltage system. Finally, the transmission network has been strengthened over the years to improve reliability and ensure the system performs adequately based on the planning standards of the North American Reliability Corporation (NERC) and regional reliability standards. This stronger system also has the effect of reducing reliance on specific capacitor bank dispatch and post-contingency switching of capacitor banks.

The results of the summer peak analysis showed none of the low voltages identified in the 1992 study. Voltage performance was acceptable even with the capacitor banks in table 1 of the 1992 study modeled out of service. While the prior study utilized every capacitor bank to improve voltages, and was concerned about one 24.75 MVAr capacitor bank being out of service, the tested summer peak base case included approximately 175 MVAr of dynamic reactive margin, not counting the 425 MVAr of capacitor banks that were not switched in, but available. The current system is robust and flexible enough to withstand multi-element outages that were not required to be tested in the 1992 study.

Based on the above assessment, VELCO recommends:

The permit be amended to remove the requirement to follow the pre-contingency dispatch of VELCO's switched capacitors as detailed in Table 1 of the DOE Reliability Determination dated November 26, 1993, to prevent post-contingency reactive deficiency and pre-contingency overvoltages.

<u>Presidential permit requirement #2:</u>

> **Addition of a new relaying scheme whereby imports through the Highgate converter are reduced to 150 MW upon loss of the Sand Bar-Essex 115 kV line;**

The 1992 study proposed an automatic runback of the Highgate converter to 150 MW following the outage of the Sand Bar-Essex 115 kV K22 line. This runback scheme addressed a potential overload of the Georgia-IBM-Essex 115 kV K21 line, particularly during light load conditions and heavy generation in the northern region of the system. In this new study, the system was stressed in the same way as the prior study. This testing approach demonstrates that the system no longer requires automatic runback schemes. Further, regional market rules are such that the Highgate automatic runback schemes are unnecessary and, in fact, undesirable.

As indicated in the prior study, system overloads were more severe in the light load cases. The light load level was modeled at approximately 505 MW in the current study, representing approximately 45% of the summer peak load, consistent with the New England testing methodology. All cases used in this study originated from 2013 cases generated by ISO-NE. This light load level is approximately 70 MW higher than the previously tested load. Similar to the prior study, the PV20 Plattsburgh-Sand Bar tie flow was modeled at 150 MW, and hydro generation was modeled at 90 MW. In addition, approximately 55 MW of wind generation was modeled in the northern area near Highgate, which tends to increase flows on the lines south of Highgate. This wind generation did not exist twenty years ago and, consequently, was not modeled in the 1992 study. The hydro generation at Comerford and Moore was dispatched at approximately 355 MW compared to 120 MW in the prior study. This generation tends to increase flows on the limiting lines south of Highgate.

Since the prior study, market rules have been put in place to ensure that the system is operated securely and economically. When a part of the system is constrained, dispatch rules described in the tariff and operating procedures allow ISO-NE to determine which resources need to be reduced to prevent system concerns. These market rules supersede VELCO's operating procedures. Highgate is treated like any other resource, and will be reduced only if it is uneconomic relative to other resources inside the constrained area. Likewise, Highgate has no priority over any other resource in terms of which resource gets to run.

Study results showed that the Georgia-IBM line section could overload by 3% over its 248 MVA LTE rating. When power flows are greater than the LTE rating but less than the STE rating, operators have fifteen minutes to reduce the loading below the LTE rating. This 3% overload does not require a fast response. The operators would have sufficient time to reduce either Highgate imports or one of several other resources in the northern area by approximately 15 MW to mitigate this theoretical overload concern, which should not occur due to the ISO-NE dispatch rules. This standard operating procedure allows the operators to adjust and optimize the system's configuration based on specific set of circumstances.

Based on the above assessment, VELCO recommends:

The permit be amended to remove the requirement to add a new relaying scheme whereby imports through the Highgate converter are reduced to 150 MW upon loss of the Sand Bar-Essex 115 kV line.

<u>Presidential permit requirement #3:</u>

> **Establishment of an operating agreement between VELCO and the other members of the New England Power Pool or its successor to limit imports through the Highgate converter to 200 MW whenever electric power is being imported through the Comerford converter;**

The 1992 study identified potential overloads in New Hampshire when the Comerford HVDC converter was running, whether Highgate was dispatched at 225 MW or not. It was determined that a 25 MW increase in Highgate imports had negligible impact on the preexisting overloads. [redacted]

In this current study, the Comerford converter was not modeled because it has been retired. Therefore, the operating agreement discussed in the 1992 study no longer applies. Results of this study did not show any exposure to voltage collapse. Furthermore, if the Comerford converter were still operational, it would have been subject to the same market and operational rules described in the previous section. Therefore, VELCO recommends:

The permit be amended to remove the requirement to establish an operating agreement between VELCO and the other members of the New England Power Pool or its successor to limit imports through the Highgate converter to 200 MW whenever electric power is being imported through the Comerford converter

Presidential permit requirement #4:

> **Adherence to the operating procedures outlined in Figure 1 of the DOE Reliability Determination dated November 26, 1993, which limits imports through the Highgate converter for various system operating configurations.**

The operating procedure in the 1992 study is reflective of the fact that operators did not have the tools necessary to make dispatch decisions in real time. This concern no longer exists with today's local and regional contingency system analysis tools. In addition to the ability to determine import levels during the day-ahead resource commitment analysis based on expected system conditions, dispatch decisions can be made with the use of real-time contingency analyses performed every 5 minutes.

Results of the 1992 study showed that imports could be increased above 200 MW only under favorable system conditions at that time. In the prior study, three conditions were necessary to consider allowing higher imports: all critical lines and capacitors needed to be in service, both the Granite autotransformer (a parallel transformer was added) and the Coolidge autotransformer (four transformers were added) needed to be in service, and the Comerford HVDC converter was to be out of service (this converter no longer exists, so this condition is always met today).

The 1992 study noted that, depending on the PV-20 line flows, less than or greater than 100 MW towards Vermont, higher Highgate imports would be possible depending on the load level and whether the McNeil generator was on line or not. If the flow on the PV-20 line was less than 100 MW, higher imports were possible if the load level was less than 880 MW, or if the load level was greater than 880 MW but less than 1000 MW and McNeil was on line. If the flow on the PV-20 line was greater than 100 MW, higher imports were possible if the load level was less than 830 MW, or if the load level was greater than 830 MW but less than 880 MW and McNeil was on line.

Today, ISO-NE dispatch rules are utilized for all resources in New England. The procedure outlined in the permit is not allowed under the current market rules. The transmission network has evolved significantly since the 1992 study, and the steps outlined in the procedure are no longer necessary or valid. The most severe set of system conditions were tested in the current study as described in the following table.

System model	1992 study Peak base case	Current study Peak base case	Notes
Highgate reactive support	40 MVAr capacitor bank plus a 100 MVAr synchronous condenser	130 MVAr capacitor bank and no synchronous condenser.	More severe model due to absence of dynamic reactive support, 10 MVAr less than the full 140 MVAr capacitor bank, and subject to the voltage squared effect.
Capacitor banks	All capacitors in service	Several capacitor banks out of service and dynamic devices at near 0 MVAr level	Results in lower voltage support from the capacitor banks noted in the 1992 study, while showing the significant amount dynamic reactive support that exists today
PV-20 flow	Varies less than or greater than 100 MW	Tested at 0 MW and 150 MW	In the current system, higher PV20 flow is beneficial. 0 MW flow is more severe.
Load level	Varies between 830 MW and 1000 MW	Tested at 1135 MW	Higher load level is more severe
Hydro generation	90 MW	18 MW	Lower hydro generation is more severe
McNeil generator	54 MW	Off-line	McNeil being off line is more severe

The modeling assumptions in the current study demonstrate that the system can comfortably accommodate higher imports with none of the 1992 conditions respected. The results of this current study showed that voltage performance was acceptable with a large reactive margin and no exposure to voltage collapse with a transmission facility out of service.

Based on the above assessment, VELCO recommends:

The permit be amended to remove the requirement to adhere to the operating procedures outlined in Figure 1 of the DOE Reliability Determination dated November 26, 1993, which limits imports through the Highgate converter for various system operating configurations.

The operating requirements are clearly covered in the remainder of Article 3 ensuring the safe and reliable operation of the facility:

Article 3. The facilities described in Article 2 above shall be designed and operated in accordance with all applicable reliability criteria, standards, and guides of the North American Electric Reliability Council, Regional Councils, independent system operators, or Regional Transmission Organizations, as appropriate, and on such terms as expressed therein and as such criteria, standards, and guides may be amended from time to time.

The results of the current analysis show that system performance is acceptable with Highgate cross-border flows of 225 MW and 250 MW. As determined by ISO-NE, the study supports the current Hydro Québec TTC request of 225 MW, and would support a 250 MW TTC when requested and as currently authorized under Presidential Permit PP-82-3.

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Figure 1: Highgate Converter Layout

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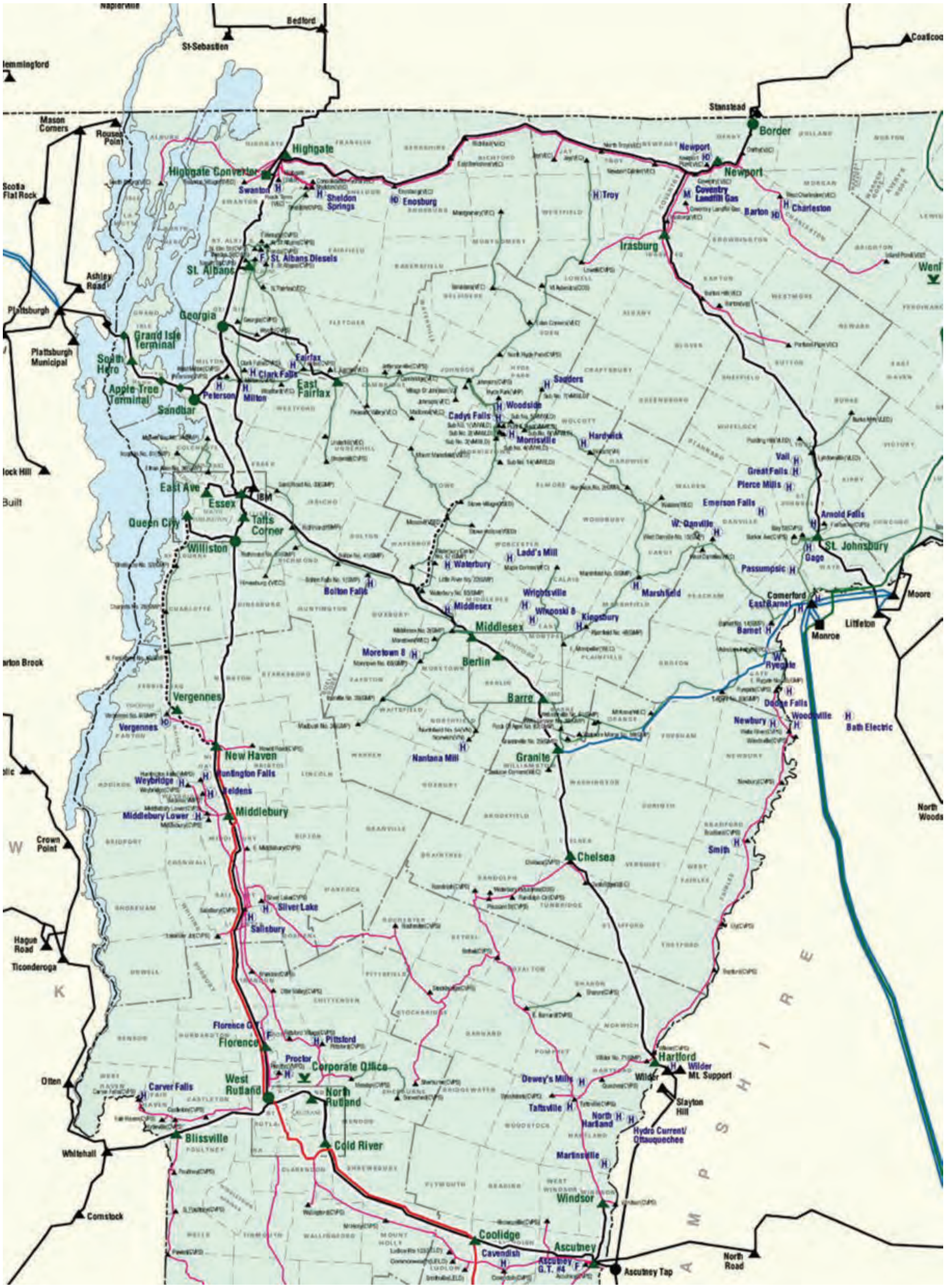

Figure 2: Map of Central and Northern Vermont

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Figure 3: Simplified one-line diagram of Central and Northern Vermont

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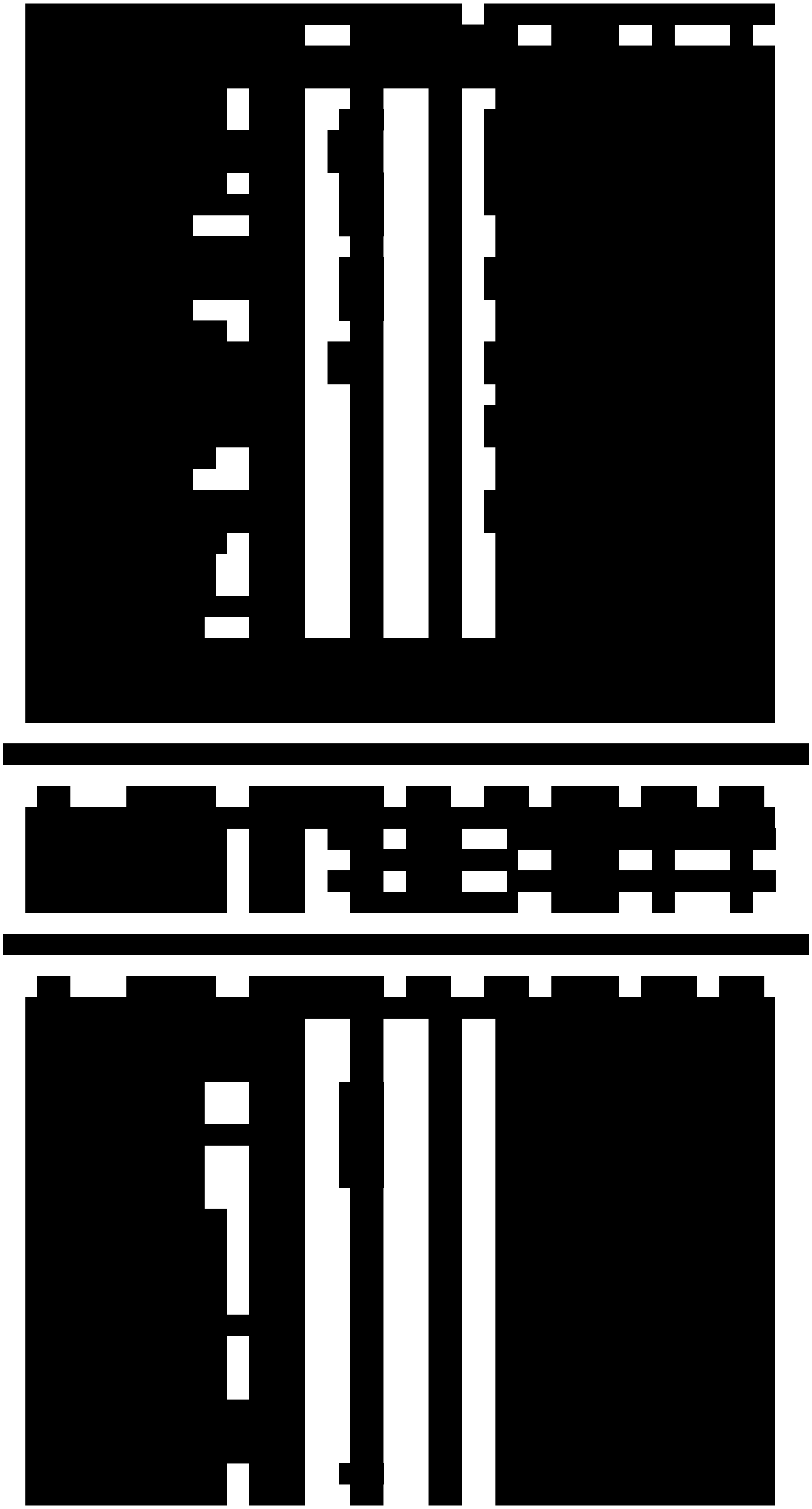

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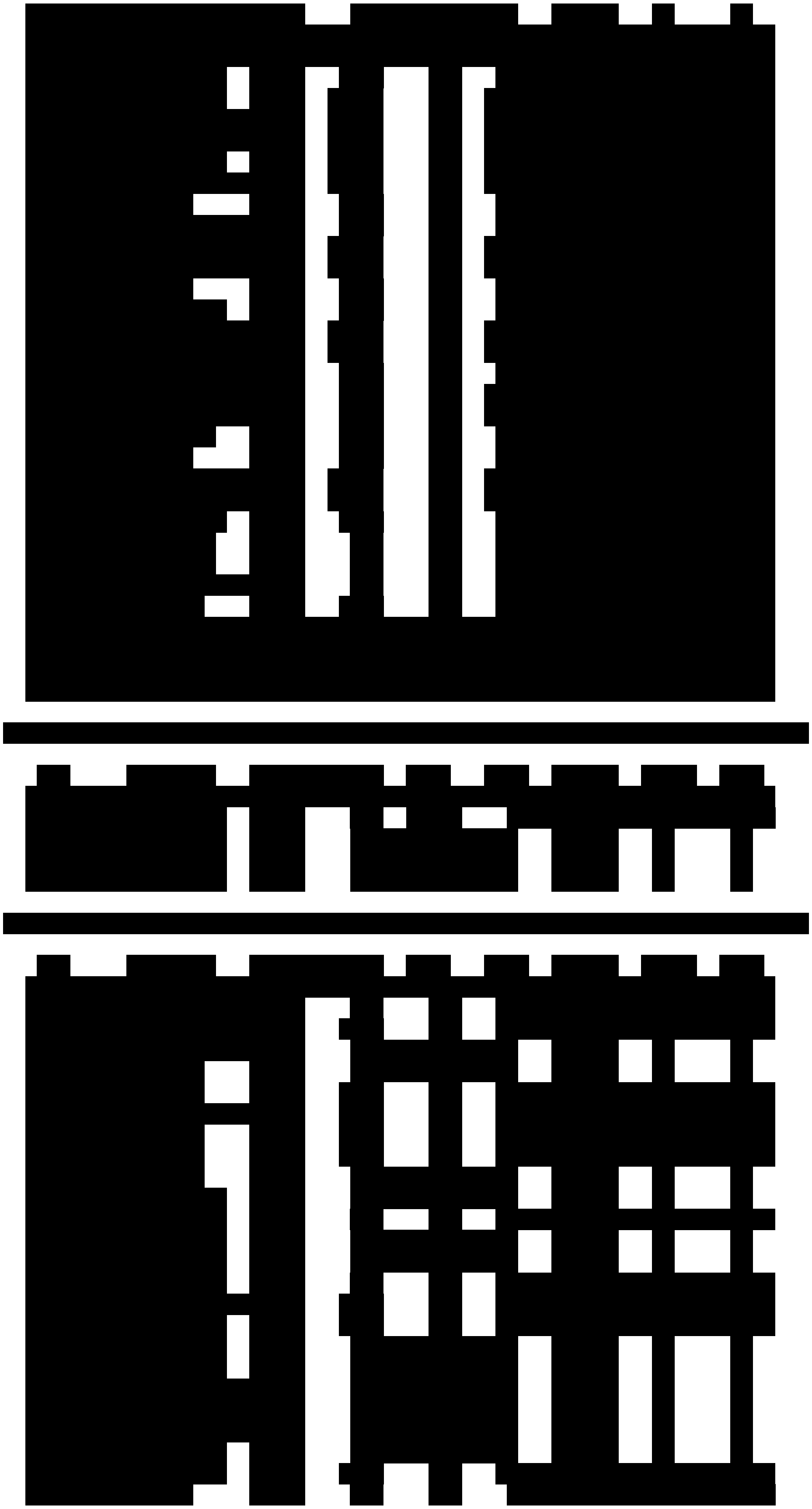

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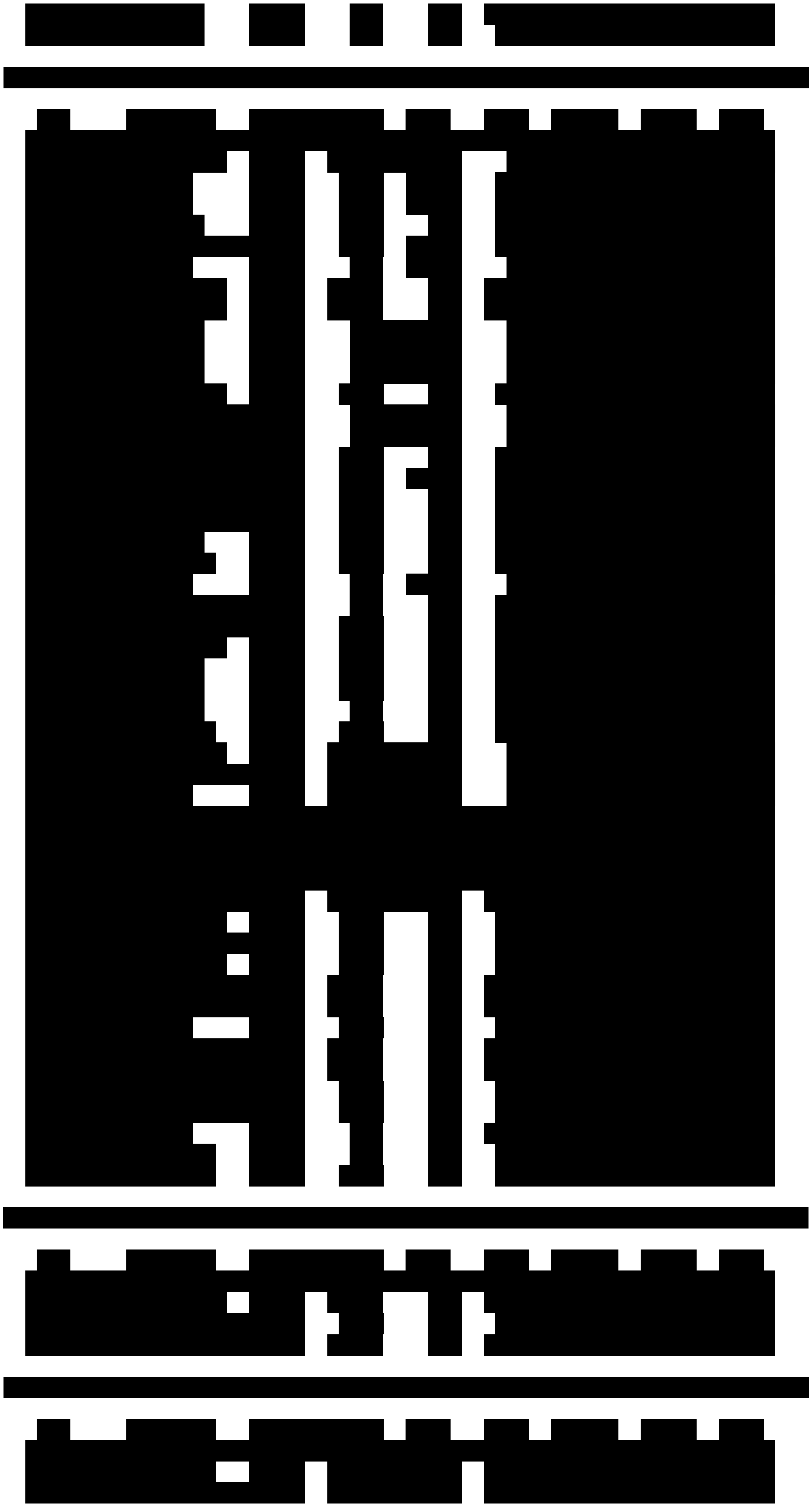

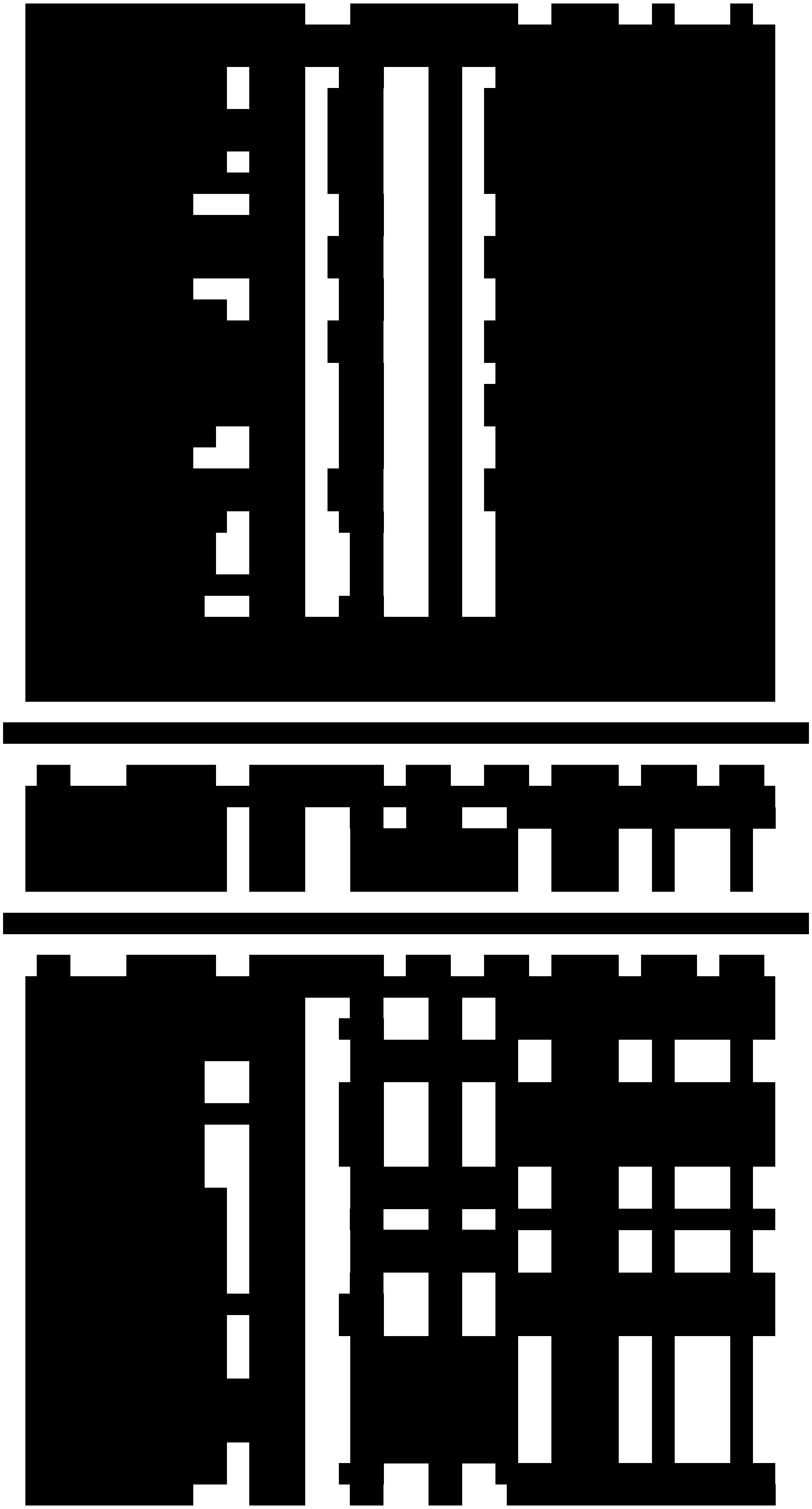

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