CIGRE – 299

MANITOBA HYDRO, ESTELLA SUBSTATION, MVROT PILOT PROJECT FOR THE ENERGY EFFICIENCY AND REDUCTION OF LOSSES IN ELECTRICAL POWER DISTRIBUTION GRIDS "THE MVROT PROJECT"

Authors:

A. Lemez, B.Sc. - Energo-Group d.o.o., Sarajevo, Bosnia and Herzegovina
D. Lemez, B.Sc. - Energo Group Canada Inc., Calgary, AB – Canada

Presenting:

Dragan Lemez

2020 CIGRE Canada Conference, Toronto ON, October 19-22

CIGRE – 299

MANITOBA HYDRO, ESTELLA SUBSTATION, MVROT PILOT PROJECT FOR THE ENERGY EFFICIENCY AND REDUCTION OF LOSSES IN ELECTRICAL POWER DISTRIBUTION GRIDS "THE MVROT PROJECT"

EGC Patents Implemented on the Project:

USPTO Patent # 10,205,318:

Method and System for reducing losses during electrical power distribution

Effective Feb. 12, 2019

Total claims 18

USPTO Patent # 10,650,954:

Losses Reduction for Electrical Power Distribution

Effective May 12, 2020

Total claims 28

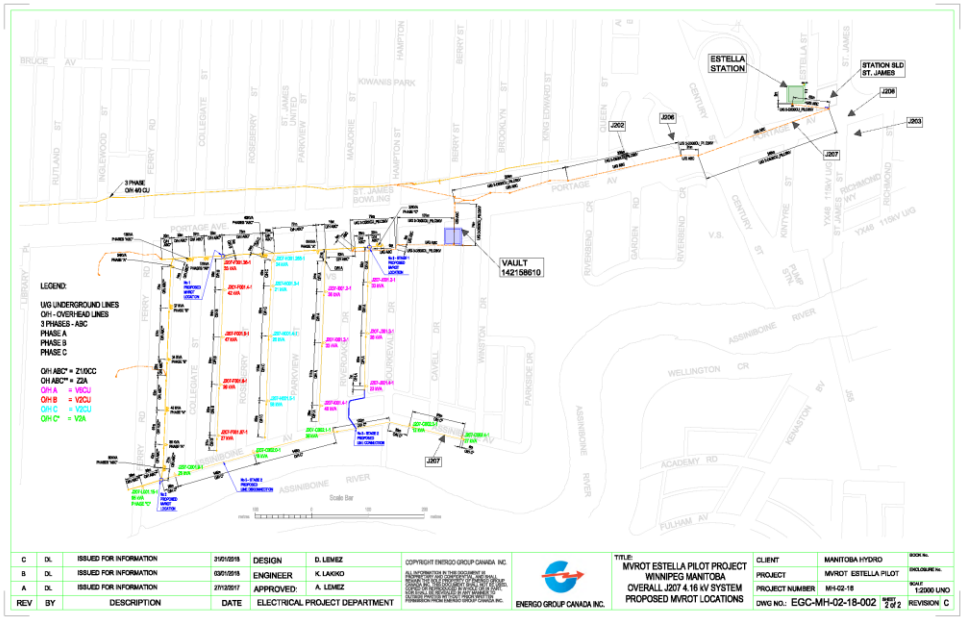
USPTO Patent # 10,763,029:

Losses Reduction for Electrical Power Distribution - MVROT

Effective September 01, 2020

Total claims 11

INTRODUCTION / PROJECT GOALS



Parties Introduction

- Manitoba Hydro (MH)
  - Estella Substation
  - Field crew
- Energo Group Canada (EGC)
  - MVROT Pilot Project
  - Method and System

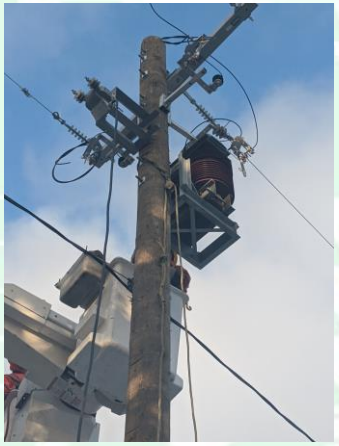
Project goals

- **Safety:** Elimination of currents in neutral line and circuit currents
- **Quality:** Voltage stability in long runs, balancing phase loads
- **Efficiencies:** Reduced voltage drops, power losses, more energy to deliver
- **Visibility:** Automatization and control, grid selectivity protection
- **Future expansion:** Capital investment for reconstruction reduced

FIELD PROGRAM

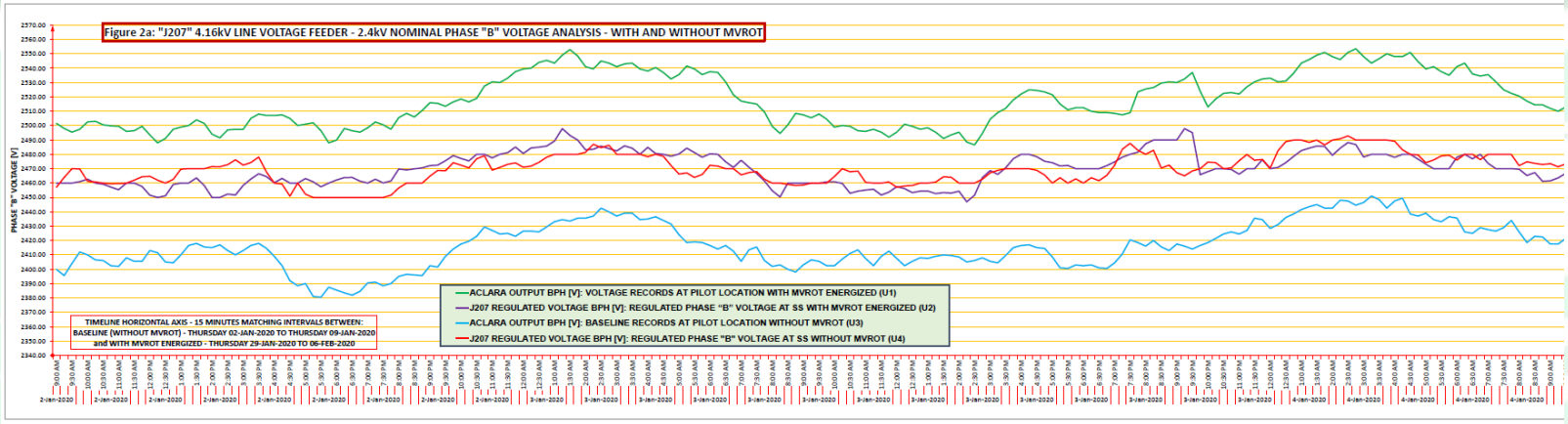
DATA RECORDED	EQUIPMENT USED	DATA COLLECTED
<u>At Substation J207 feeder</u> <u>(With and Without MVROT):</u> • Regulated Phase Voltages: APH, BPH, CPH, • Amperage: IA, IB, IC, IN <u>At MVROT location</u> <u>(Phase B branch - bypass):</u> • Phase output Voltage: BPH • Amperage: IA, IB, IN, Ia • Line Voltage: UAB	• Aclara Sensors at Substation For phase voltage and amperage • Aclara Sensors at MVROT location For phase voltage and amperage • Cooper sensors at MVROT location For amperage • HIOKI 3196 analyser at MVROT location • Rogowski CT at MVROT location • Voltage Instrument Transformer (ABB) at MVROT location • MVROT-250-4.16//2.4 (185kVA)	<u>Baseline Records (Without MVROT):</u> From Jan 02, 2020 to Jan 09, 2020 <u>Second Records with MVROT:</u> From Jan 28, 2020 to Feb 06, 2020 All records collected at 15min 24h/day Total nominal power at the pilot project location branch is 162kVA





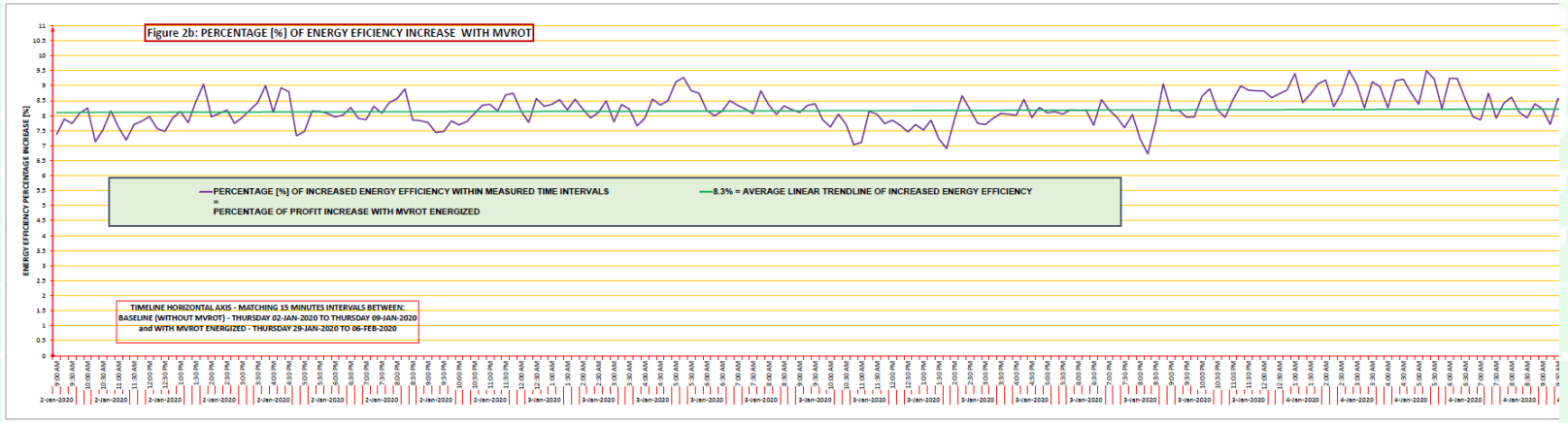
<u>Note: MVROT is NOT an autotransformer</u>

VOLTAGE & ENERGY EFFICIENCIES ANALYSIS



"**Figure 2a**" shows, Phase "B", phase voltage (2.4kV nominal) records.

https://www.egcanada.ca/PDF/Publishings%20Page/PilotProj/2a-GRAPHICAL%20REPRESENTATION%20OF%20MVROT_Voltage%20Efficiency%20Analyses_28-JAN%20to%2006-FEB%202020.pdf



"**Figure 2b**" shows, Phase "B", energy efficiency percentage increase with MVROT energized.

https://www.egcanada.ca/PDF/Publishings%20Page/PilotProj/2b-GRAPHICAL%20REPRESENTATION%20OF%20MVROT_Energy%20Efficiency%20Analyses_28-JAN%20to%2006-FEB%202020.pdf

ENERGY EFFICIENCIES ANALYSIS

With MVROT energized:	$W_1/W_2 = (U_1/U_2)^2$ $W_1 = (U_1/U_2)^2 * W_2$ $W_1 = k_1 * W_2$	• W_1=delivered energy to the end users. • W_2=energy that would be delivered to the end users if voltage level at MVROT location is equal to Substation (Ideal conditions). • k_1=Voltage ratio "$(U_1/U_2)^2$"; Records are showing improved voltage in feeder which resulted in "k_1" voltage ratio > 1. • Reduced power losses and requires less time required to deliver demanded power.
Without MVROT energized:	$W_3/W_4 = (U_3/U_4)^2$ $W_3 = (U_3/U_4)^2 * W_4$ $W_3 = k_2 * W_4$	• W_3 = delivered energy to the end users. • W_4 = energy that would be delivered to the end users if voltage level at MVROT location is equal to Substation (Ideal conditions). • k_2 = Voltage ratio "$(U_3/U_4)^2$"; The baseline records are showing voltage drops in feeder, resulting in "k_2" voltage ratio < 1. • Accrued power losses and requires more time to deliver demanded power.
Energy Efficiency	$E_f = (k_1\text{-}1) * 100 + (1\text{-}k_2) * 100$	• Ef = Energy Efficiency Percentage change; (total percentage of voltage change)

Table 2: Energy efficiency calculations

Recorded actual data:

- U_1 = BPH [V]: VOLTAGE RECORDS AT PILOT LOCATION WITH MVROT ENERGIZED
- U_2 = BPH [V]: REGULATED PHASE "B" VOLTAGE AT SS WITH MVROT ENERGIZED
- U_3 = BPH [V]: BASELINE VOLTAGE RECORDS AT PILOT LOCATION WITHOUT MVROT
- U_4 = BPH [V]: REGULATED PHASE "B" VOLTAGE AT SS WITHOUT MVROT

VOLTAGE & ENERGY EFFICIENCIES RESULTS

PHASE / DATA	BASELINE	WITH MVROT	IMPROVEMENTS*
Maximum Phase Voltage [V]	2451.5	2553.5	+102 [V] or (4.16%)
Minimum Phase Voltage [V]	2360.5	2481.0	+120.5 [V] or (5.10%)
Maximum Low Voltage [V]	122.58	127.68	+5.1 [V] or (4.16%)
Minimum Low Voltage [V]	118.03	124.05	+6.02 [V] or (5.10%)
Max voltage [V] drop [-] / improved [+]	-33.72	+146.50	-
Min voltage [V] drop [-] / improved [+]	-88.00	+53.50	-
Min / Max Increased voltage % -With MVROT		4.16% / 5.10%	
Min / Max / Avrg. efficiency increased -With MVROT		6.34% / 10.04% / 8.31%	

**Positive values are voltage improvements within allowable limits*

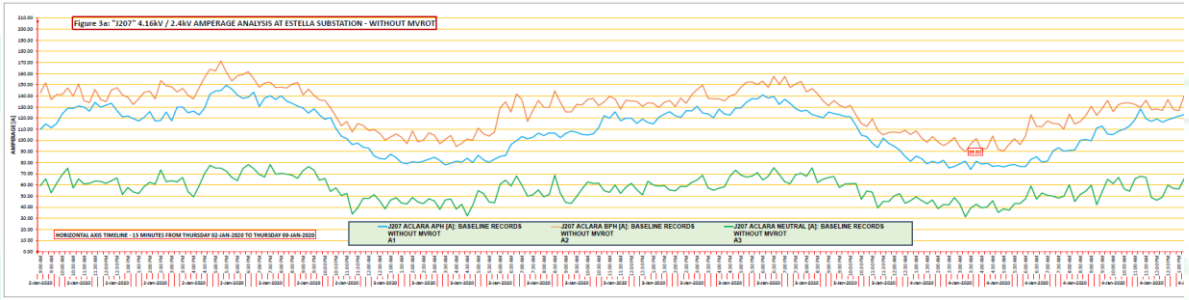
"**Table 1**" Significant records and results associated with Figure 2a and Figure 2b graphs.

INCREASED ENERGY EFFICIENCY [%] WITHIN MEASURED TIME INTERVALS

=

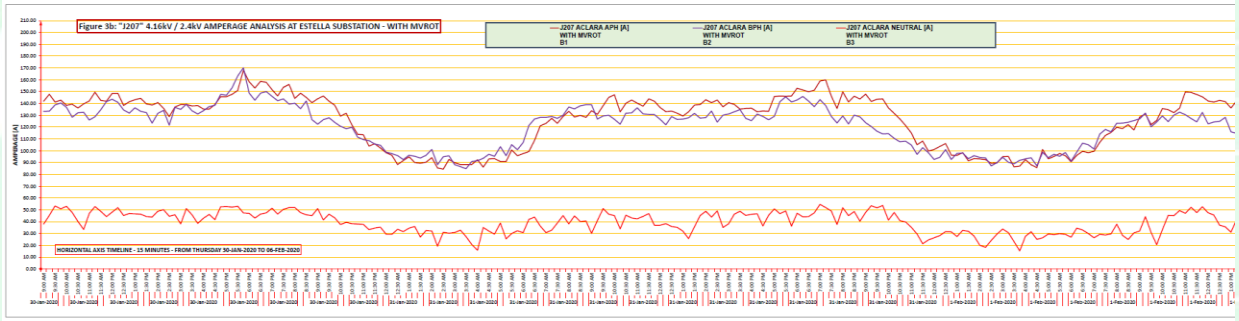
INCREASED PROFIT [%] WITH MVROT ENERGIZED

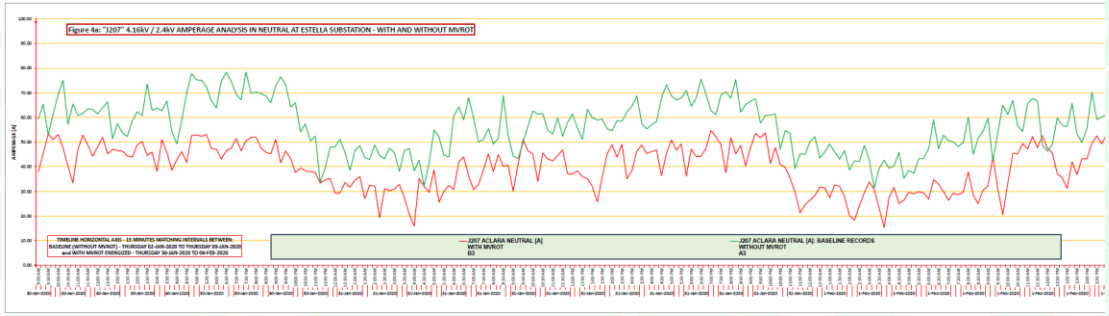
AMPERAGE ANALYSIS @ ESTELLA S/S



"Figure 3a"
Baseline amperage records in phase « A », « B » and neutral
https://www.egcanada.ca/PDF/Publishings%20Page/PilotProj/3a-Amperage%20at%20Estella%20Substation%20BASELINE%20-%20NO%20MVROT%20Analyses_02-JAN-2020%20to%2009-JAN-2020.pdf

"Figure 3b"
With MVROT amperage records in phase « A », « B » and neutral
https://www.egcanada.ca/PDF/Publishings%20Page/PilotProj/3b-Amperage%20at%20Estella%20Substation%20WITH%20MVROT%20Analyses_30-JAN-2020%20to%2006-FEB-2020.pdf





"Figure 4a"
differences between amperages within neutral conductor
https://www.egcanada.ca/PDF/Publishings%20Page/PilotProj/4a-Amperage%20in%20NEUTRAL%20at%20Estella%20Substation%20BASELINE%20and%20WITH%20MVROT%20Analyses_02-JAN-2020%20to%2006-FEB-2020.pdf

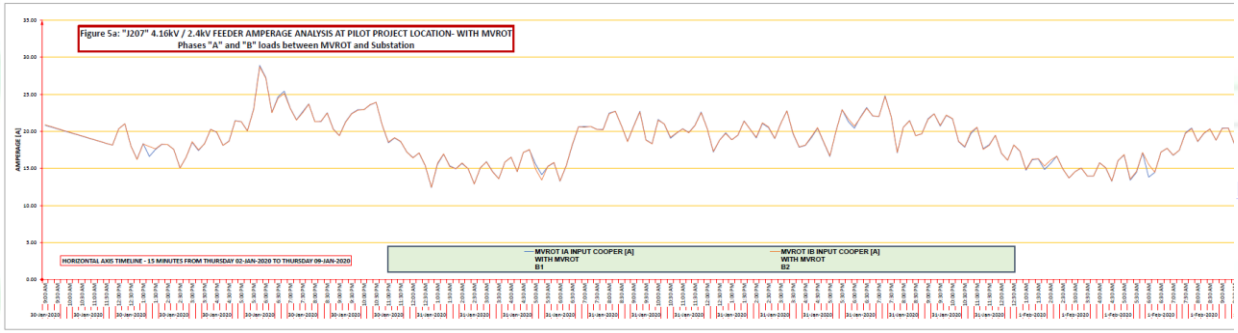
AMPERAGE ANALYSIS RESULTS @ S/S

PHASE / DATA	BASELINE	WITH MVROT	IMPROVEMENTS*
Maximum Amperage Phase A [A]	164.14	174.29	10.15 [A]
Minimum Amperage Phase A [A]	73.41	83.31	9.9 [A]
Maximum Amperage Phase B [A]	207.60	173.24	-34.36 [A]
Minimum Amperage Phase B [A]	89.80	80.02	-9.78 [A]
Maximum Amperage Neutral [A]	94.71	65.90	-28.81 [A]
Minimum Amperage Neutral [A]	30.16	11.74	-18.42 [A]
Min / Max reduction in Neutral [A]	-	-4.04 / 52.7	-
Neutral load [%] reduction trendline	-	29% and 39%	-
Overall percentage of energy efficiency	-	8.7%	-

**Positive values in IMPROVEMENTS column are amperage increase; negative values are amperage decrease achieved with MVROT energized. Negative values are representing phase/neutral line improvements.*

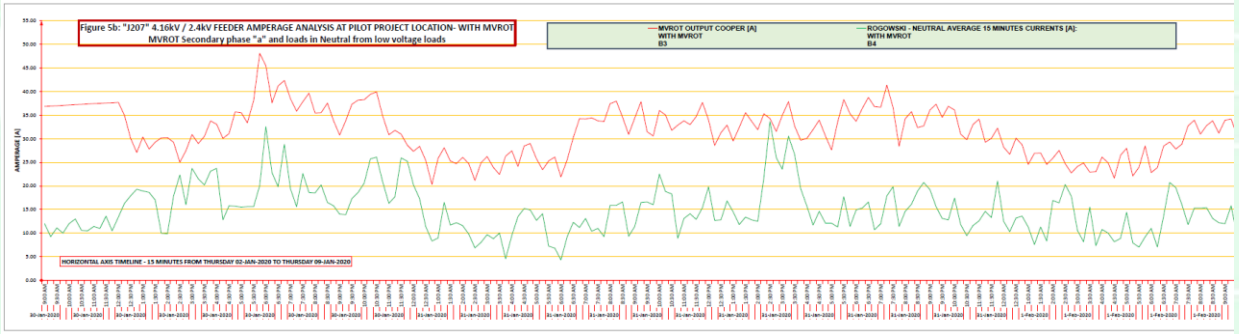
Table 3: Significant records associated with graphs shown in Figures 3a through Figure 4a

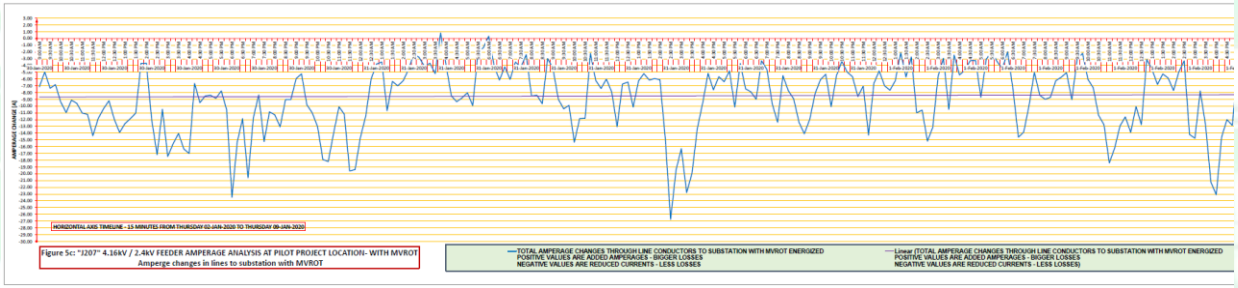
AMPERAGE ANALYSIS @ MVROT LOCATION



"Figure 5a"
load in phases "A" and "B" at primary side of MVROT
https://www.egcanada.ca/PDF/Publishings%20Page/PilotProj/5a%20-%20Amperage%20analyses%20at%20MVROT%20location%20-%20Phase%20A%20and%20phase%20B%20loads%20with%20MVROT%20energized_30-JAN%20to%2006-FEB%202020.pdf

"Figure 5b"
amperage in MVROT secondary phase "a"
https://www.egcanada.ca/PDF/Publishings%20Page/PilotProj/5b%20-%20Amperage%20analyses%20at%20MVROT%20location%20-%20MVROT%20Secondary%20Phase%20a%20and%20Neutral%20loads%20with%20MVROT%20energized_30-JAN%20to%2006-FEB%202020.pdf



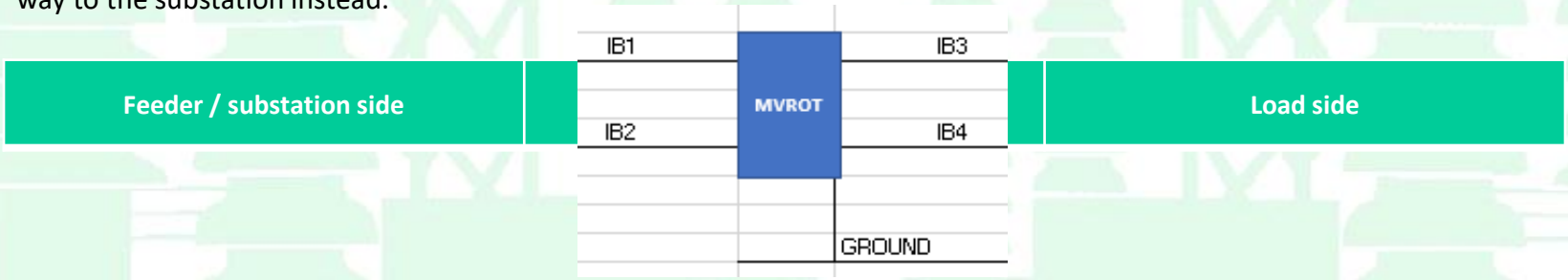


"Figure 5c"
differences between amperages within neutral conductor
https://www.egcanada.ca/PDF/Publishings%20Page/PilotProj/5c%20-%20Amperage%20analyses%20at%20MVROT%20location%20-%20Amperage%20changes%20in%20lines%20to%20substation%20with%20MVROT%20energized_30-JAN%20to%2006-FEB%202020.pdf

AMPERAGE ANALYSIS @ MVROT LOCATION

- I_{B1} = MVROT IA INPUT COOPER [A] WITH MVROT
- I_{B2} = MVROT IB INPUT COOPER [A] WITH MVROT
- I_{B3} = MVROT OUTPUT COOPER [A] WITH MVROT
- I_{B4} = ROGOWSKI - NEUTRAL AVERAGE 15 MINUTES CURRENTS [A] WITH MVROT

Without MVROT: Recorded amperages (I_{B3}, I_{B4}) are closing circuit all the way to the substation.
With MVROT energized: These amperages are transformed into I_{B1} and I_{B2} by MVROT, and I_{B1} and I_{B2} are closing circuit all the way to the substation instead.



Schematics of line amperages at MVROT location

- **I_A:** $I_{B1} - I_{B3}$ (reduction of I_{B3} amperages that would go all the way to the substation)
- **I_B:** $I_{B2} - I_{B4}$ (reduction of I_{B4} amperages that would go all the way to the substation)

Total amperage changed through these two conductors is an addition of these two: $I_A + I_B$

Losses in lines are: $P_v = r_v * I^2$

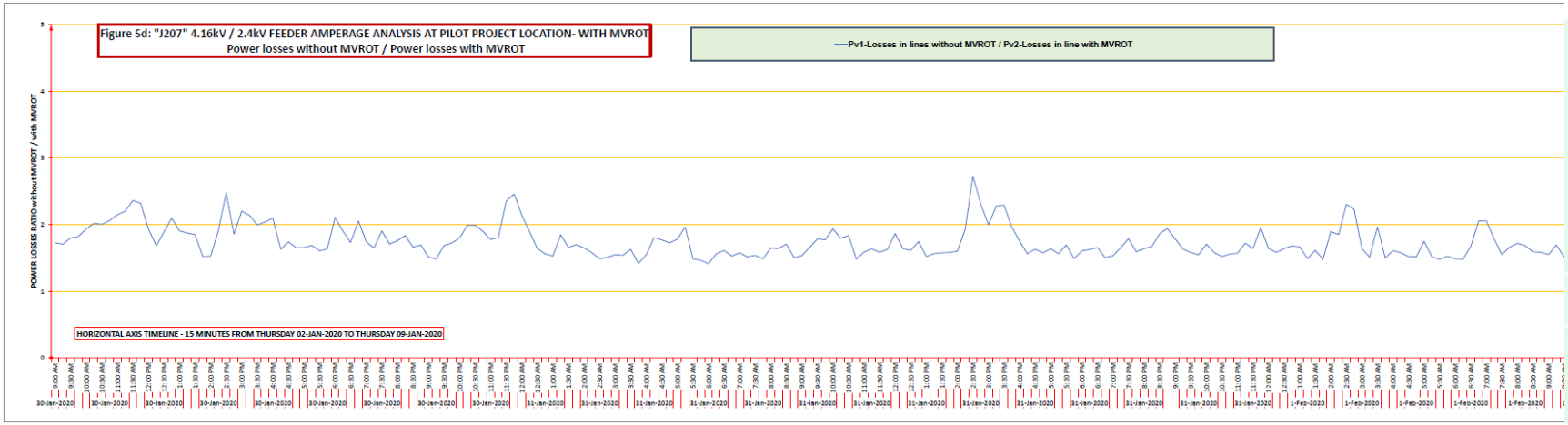
- Without MVROT: $I_1^2 = I_{B3}^2 + I_{B4}^2$; $P_{v1} = r_v * I_1^2$
- With MVROT: $I_2^2 = I_{B1}^2 + I_{B2}^2$; $P_{v2} = r_v * I_2^2$

Relationship between the losses in line without MVROT and with MVROT is: $P_{v1} = K * P_{v2}$

- P_{v1} - line losses without MVROT
- P_{v2} - line losses with MVROT

$K = P_{v1} / P_{v2} = (I_{B3}^2 + I_{B4}^2) / (I_{B1}^2 + I_{B2}^2) = I_1^2 / I_2^2$

POWER LOSSES REDUCED



"Figure 5d"

https://www.egcanada.ca/PDF/Publishings%20Page/PilotProj/5d%20-%20Amperage%20analyses%20at%20MVROT%20location%20-%20Power%20losses%20ratio%20in%20lines%20without%20MVROT%20_%20with%20MVROT%20energized_30-JAN%20to%2006-FEB%202020.pdf

With the loss's ratio > 1, the feeder has larger losses without MVROT than with MVROT.
For the whole monitoring time, these loss's ratios are always larger than 1.
Max: = 3.3098 and Min: = 1.3583.

Number of events in one week that total amperage changes are greater with MVROT installed in this feeder is **7, with maximum increased losses of 0.82 [A]**
Number of events in one week that total amperage changes are smaller with MVROT installed in this feeder: **661, with maximum reduced losses of -27.50 [A]**

SIGNIFICANT RESULTS AND ECONOMICS

Significant Results:

- On average increased feeder energy efficiency between 8.2% and 8.7%.
- Improved phase voltage levels (~ 4.45%) at load side of MVROT.
- Reduced overall amperage in system neutral line at substation between 29% and 39%. Maximum amperage in neutral line before MVROT was 94[A] and with MVROT 68[A].
- Load balanced between phase A and B as we did not utilize phase C at all with this Project.
- Reduction in surges from Max. 207.6 [A] before MVROT to Max. 173.24 [A] with MVROT.
- Maximum power losses reduction of 38.22% at one point in time.

Economic Benefits:

- Balancing entire three phase distribution system with many single-phase take-offs.
- Quality of power delivered
- Selectivity of distribution grid
- Increased grid protection and reduce number of outages
- Increased energy efficiency, more energy available for retail
- Extended distribution life and distribution coverage
- Increased safety by eliminating currents in neutral and circuit currents in the ground
- Instrumentation transformers are built in as integral part of MVROT
- Minimum to no Maintenance
- Small capital investments for reconstruction of the existing grids / building new ones

CONCLUSION

- MVROT technology demonstrated extremely successful records and results.
- These field data records and results are validation of the EGC's patented technology.
- "Baseline / MVROT energized" records show significant improvements in this feeder:

  - Improved Voltage,
  - Amperages in phase lines reduced,
  - Amperage in system neutral eliminated / reduced,
  - Feeder Energy efficiency increased,
  - Power and Energy Losses reduced,
  - Grid selectivity achieved,
  - Three phase load balanced

- This technology is technically and economically superior for dealing with:
  - poor quality power, unbalanced systems, and overloaded distribution systems.

- Applicable in any medium voltage grids. (up to 25kV).
- All these benefits above were addressed in published White Paper at 2018 CIGRÉ Canada Conference in Calgary, and with Pilot Project field results they are validated in the live grid.

- Full field results and report is located at our website:
  https://www.egcanada.ca/PilotProject.html

Q & A