EGC-2020-PPR-001

Energo Group Canada Inc.

Estella SubStation Pilot Project Report

Prepared by Energo Group Canada Inc.

Authors: Aleksandar Lemez and Dragan Lemez

Calgary, Alberta May 15th, 2020

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

1.1. PROJECT OVERVIEW

The Estella SubStation MVROT Pilot Project was initiated between Manitoba Hydro (“MH”) and Energo Group Canada Inc. (“EGC”) during the CIGRÉ Conference in Winnipeg 2017. This Pilot Project addressed balancing loads in Manitoba Hydro, Estella station in Winnipeg, within one of its medium voltage (4.16kV) distribution feeders, by installing one MVROT (“Medium Voltage Regulating and Optimizing Terminal”). With MVROT implementation, a simple and cost-effective technology to reduce losses and balance loads, we wanted to demonstrate, increased distribution energy efficiencies, provide improved power quality, improve voltage levels at the load side far away from substation, reduce loads in neutral line and add grid selectivity.

EGC’s patented Method and System paired with MVROT patented (CSA certified) technology was implemented in this Pilot Project to collect and record electrical data in selected feeder before and after the energization of the MVROT. Pilot Project objective was to compare all recorded data and results between, data before and after MVROT implementation as per EN 50160 standard, proving power quality improvements within the existing selected feeder.

1.2. PROJECT GOALS AND SUMMARY OF RESULTS

Based on EGC’s analysis at the time of proposal to implement MVROT within one of MH grid, Pilot Project expected to show the following benefits listed below. The Pilot Project has successfully achieved all of them. To reduce Pilot Project cost and save time, harmonics were not monitored during baseline readings and we were not able to compare them this time.

- Improved safety through elimination of neutral currents from branch with MVROT connection.
  - ✓ **Successfully demonstrated this benefit.**
    - Achieved significant reduction of currents in neutral and eliminated neutral currents from the branch going to substation. **Accomplished overall reduction between 29% and 39% (See Section 3.3.4.).**
- Improved voltage stability through balancing phase loads and reduction in surges.
  - ✓ **Successfully demonstrated this benefit.**
    - Achieved complete balance between phase A and B and with that reduced maximum loads at substation within each of balanced phases, **from maximum 207.6 [A] before MVROT to maximum 173.24 [A] with MVROT (See Section 3.3.4 and Table 4)**.
- Reduced losses due to a reduction of neutral line loads and grounding currents (circuit currents).
  - ✓ **Successfully demonstrated this benefit.**
    - Energy **efficiency improved between 8.2% and 8.7%** in average (trendline). Amperage reduced in neutral all the way to the substation and with that reduced and eliminated possibility for circuit currents. **(See Sections 3.3.1. and 3.3.2.)**
    - Initially calculated reduction of the losses (~22%) was done based on one-time maximum static loads and correcting third phase “C” with additional branch switches once MVROT is energized. MVROT Pilot Project data analyses showed **maximum power losses reduction of 38.22% at one point in time**. Comparison is done between records collected on Wednesday January 8th 4:45 PM and Wednesday February 5th 4:45 PM (with similar “static” load at that time) and without additional phase “C” branch corrections.
- Improved reliability by prevention of harmonic propagation to primary side of MVROT into the grid.
  - ✓ **Not monitored this time.**
    - This was not measured and recorded in baseline readings, so no comparisons and analyses are possible. Due to station configuration this option was not readily available at the time of Pilot Project execution.

- Added possibility for accurate measuring, compatible with SCADA systems and becoming SMART grid.
  - ✓ **Successfully demonstrated this benefit.**
    - MVROT has two PTs and one CT built in so any auxiliary connections are possible. They were tested in Manitoba High Voltage Testing Facility prior to installation on the pole.
- Added flexibility for future expansion and compatibility with future Smart Grid initiatives.
  - ✓ **Successfully demonstrated this benefit.**
    - Reduced line voltage drops within the feeder and with that corrected phase voltage. This way it is possible to extend branch further than before if required for future loads.

1.3. SUMMARY OF BENEFITS TO ANY UTILITY DISTRIBUTION COMPANY AND ITS CUSTOMERS

Based on these recorded dynamic data, and the above successful achievements, the Estella SubStation Pilot Project in Winnipeg demonstrated several key benefits to Utilities and its customers:

1) On average (trendline) is showing **increased feeder energy efficiency between 8.2% and 8.7%** with only one MVROT installed. (Refer to Section 4, point 5, to see this key economic benefit of MVROT technology.)

2) **Improved phase voltage levels (~ 4.45%)** at load side of MVROT providing better power quality and reduced overall voltage drop in the entire feeder. (Refer to Section 4 this key economic benefit of MVROT technology.)

3) Reduced overall amperage (load) in system neutral line at substation. Trendline is showing **amperage reduction between 29% and 39%.** (Refer to Section 4 this key economic benefit of MVROT technology.)

4) Load balanced within phase A and B as we did not use phase C at all with this Project. Just based on these two phases balanced, from only one branch, currents in neutral line at Substation are significantly reduced. Maximum amperage in neutral line **before MVROT was 94[A] and with MVROT 68[A].** (Refer to Section 4 Economic benefits).

These positive project results also confirm that implementing the MVROT, new innovative energy efficiency technology, into Utilities distribution grids will make them efficient and in the same time Utilities will become “Utility of the Future”. There are no other traditional methods or technologies that could totally balance loads in three phase distribution grids with single phase branches and achieve these results. Only implementing MVROTs will totally balance loads in them.

1.4. MVROT POSITIVE RESULTS AND PLANNING NEXT STEPS

A. With these positive Pilot Project results, EGC would like to offer our MVROT units, currently made for 4.16 kV distribution voltage level, to all Utility companies as economically superior (cost reduction) solution to improve efficiencies generating more revenue when implemented within Utility distribution grids.

B. Expanding our MVROT units into 13.8kV distribution voltage level, to cover greater distribution system range within Utilities. This provide even bigger benefits for Utilities to implement MVROT technology into rural areas beside cities.

C. EGC’s technical paper on these Pilot Project results are going to be presented at the upcoming CIGRÉ Canada Expo, October 2020 in Toronto.

Please see **technical analyses** and graphical representation of the above results within the **Section 3**, of this Pilot Project Report together with the **Section 4 Economic benefits** showing several areas of savings, cost reduction and **revenue generation (up 10% to 12% in this distribution feeder**) for MH with MVROT installed and energized. **Payback for the MVROT installation could be between 2 to 6 years depending on its utilization**.

2. ENERGO GROUP CANADA INC.

In 2014, **Energo-Group Canada Inc. (EGC)** was incorporated in Canada and together with **Energo-Group Sarajevo D.O.O. (EGSA)** formed a Canadian company focused on Electrical Energy Efficiency and Power Quality within low and medium voltage electrical systems.

EGSA was incorporated as a private company in 2002 in East Sarajevo, Bosnia & Hercegovina as a Consortium of three major well established companies from former Yugoslavia:

Picture 1 - Factory Production Area - Dryer

- Factory of Measuring transformers (**FMT**) Zajecar, Serbia, in operation since 1969
- IPSA East Sarajevo – Engineering and Project Management, in operation since 1959 (Engineers experience through Energoinvest Sarajevo)
- Unioninvest Sarajevo – Field Construction and Installation, in operation since 1949 (Extension of Energoinvest)

EGC being in association with **EGSA,** brings forward all of **EGSA's** products, manufacturing capability, project experience and references. **EGSA's** principal and owner is also one of the principals of **EGC**.

Collectively having 180 years of diverse experience in Engineering, Design and Manufacturing of various electrical products, **EGC** together with **EGSA** is a versatile and fast-growing global company. We also boast full technical support, business collaboration and a contract with the **University of East Sarajevo – Electrical and Mechanical Departments**.

Picture 2 – Factory Epoxy mixing area

Furthermore, Energo-Group Sarajevo D.O.O. is listed on the University website as their business collaborator - see link: http://www.etf.unssa.rs.ba/etf.php?task=view&fak_id=69

Picture 3 – Factory Assembly area

With this significant foundation of experience, our Research and Development team (**R&D**) has a huge advantage when it comes to anticipating today's and tomorrow's needs. We continuously bring new and improved, innovative, environmentally friendly, reliable and quality products to markets around the globe. This includes smart dry type regulators / terminals as well as improving on old technologies based on client needs. Check some of our unique products: **VTOP**, **VROT** and **MVROT**

EGC can manufacture and supply electrical equipment, from our own dry type transformers to our unique smart patented technology and terminals up to 110kV nominal voltage. Our **R&D** team has engineered, developed and successfully deployed VTOP, VROT and MVROT lines of unique, ***smart*** and ***patented*** products. All of these products were developed based on industry needs and input from various parts of the world and are ***Innovative, Novel and Industry Applicable***.

We are proud to employ a simple "wish to have" concept. This means that we can develop and manufacture anything that our clients may have always wanted to have but have been unable to get in the past due to large manufacturers not being interested in changing their production for just one new request. We can accommodate all requests into our regular engineering and manufacturing production cycles.


CERTIFICATE

The Certification Body
of TÜV SÜD Management Service GmbH
certifies that

Fabrika mernih transformatora Zaječar d.o.o.
Stražilovska 57
19000 Zaječar
Serbia

has established and applies
a Quality Management System for

Design, production and sale of
transformers, voltage transformers, insulators of
epoxy resins, Earthing resistors and reactor.

An audit was performed, Order No. 707015930.
Proof has been furnished that the requirements
according to

ISO 9001:2015

are fulfilled.
The certificate is valid from 2019-12-13 until 2022-12-12.
Certificate Registration No.: 12 100 46865 TMS.

Product Compliance Management
Munich, 2019-12-10

TÜV SÜD Management Service GmbH • Zertifizierungsstelle • Ridlerstrasse 57 • 80339 München • Germany
www.tuev-sued.de/certificate-validity-check

Picture – 4 Factory ISO 9001 Certificate

Our quality is second to none and is guaranteed as we impose mandatory testing in our factory on every single piece of equipment we manufacture, regardless of order size. Our reputation is built on providing the highest quality products which meet the highest safety standards.

Having offices in Toronto, Ontario and Calgary, Alberta as well as distribution centres in High River, Alberta and Burlington, Ontario; **EGC** is well positioned to tend to all industries in American markets. **EGC** personnel have significant experience in the Oil and Gas Energy (**O&G**) sector and are actively involved in many current **O&G** Projects not only in Alberta, but worldwide as well.

With **EGSA** being positioned in central Europe we can serve all markets around the world. **EGSA** products are already well known in Europe, Asia, Africa and Australia where our products have already been installed successfully.

Our manufacturing centre **FMT** is **ISO 9001, ISO 14001**, **OHSAS 18001** and **CSA** certified. Two of our patented products were successfully tested and CSA certified in Manitoba Hydro's High Voltage Facility in Winnipeg.

Growing our business around new technologies is our goal. To achieve this, we continue to focus our **R&D** activities on energy efficiency and power quality within the electrical field. With that goal in mind we have been able to develop and demonstrate a few new and innovative technologies for reducing energy losses in low and medium voltage distribution grids. Our Engineering team have been actively involved with major conferences around the globe and publishing white papers on new technologies.

2.1. EGC MVROT TECHNOLOGY INTRODUCTION

EGC has developed and patented an **innovative** method and system together with **the now patented product, the MVROT** terminal. The MVROT increases distribution **energy efficiency** by **balancing loads** between three phase feeders having single phase branches within the Medium Voltage distribution systems, reducing power losses, and improving overall power **quality.** Through the implementation of this simple and **cost-effective** technology, the MVROT is able to reduce power losses, improve voltage at the load end and eliminate / reduce harmonics. It also provides an **adaptive infrastructure** for distribution grid segregation, expansions providing **customer value**, reducing outages, and improving overall distribution system **safety and reliability**.

EGC has received two patents, one for the "**Method and System Solution for Reducing Losses in Electrical Power Distribution Systems**" and a second one for the Medium Voltage Regulator and Optimizing Terminal (MVROT) - **"Losses Reduction for Electrical Power Distribution"**.

MVROT was certified by the Canadian Standard Association (CSA) and was successfully re-tested at Manitoba Hydro's High Voltage Testing Facility, before implementation into the Estella Substation grid, ensuring that it functions and operates as designed. **EGC took these extra steps to ensure 100% safety and reliability when the unit is energized**.

MVROT technology was implemented in this Pilot Project to demonstrate its benefits not only to Manitoba Hydro but to all Utility distribution companies in North America. By executing this project with innovative technology, Manitoba Hydro proved to be an industry leader in searching, testing, and applying new and better ways of delivering quality power to their end users and customers.

EGC is proposing to all Utility companies to validate these results on their own, research and implement MVROTs into its own grids, and get technical and financial advantages at the same time. Please contact EGC for any additional information.

3. MVROT PILOT PROJECT - ESTELLA SUBSTATION, WINNIPEG, MANITOBA – ANALYSES

EGC received, from MH Winnipeg Planning, Distribution Asset Management Development Department, design information for their Estella substation 4.16 kV grid in Winnipeg, Manitoba. MH and EGC selected J207 - 4.16kV / 2.4kV feeder for the MVROT technology to be implemented. The installation site location was finalized based on grid layout, distances from the substation, maximum loads in the branch and nominal load (185kVA) for one MVROT.

From the Estella substation in J207 distribution feeder, there are 4.16kV, 3 phase U/G cables (3-D500CU_PILC5KV) running approximately 1,020m to Vault 142158610. At this location power was brought up to the overhead (O/H), 3 phase “ABC” lines. These 3 phase O/H lines, together with the neutral wire, from this location are running approximately 330m (Z1/0CC) and 470m (Z2A) conduits, totalling approximately 800m in distance to the location where the last single-phase branch take off is located. This branch is supplying power to the residential area users through 5 Utility Transformers (total 162kVA).

3.1. FIELD WORK PROGRAM

Prior to any site work and agreements to proceed with the field program, EGC and MH Engineers held several meetings in Winnipeg, MB along with the numerous telephone conferences, addressing all potential scenarios to eliminate and mitigate any risks this new equipment might introduce into the system. This was successfully concluded, with all identified risks being addressed and mitigated prior to the field work program initiated.

To implement MVROT installation, MH was required to install three new poles (one 50’ tall and two 45’ tall, one on each side of the new 50’ pole). This was done to evenly transition O/H lines in the vertical plane and to eliminate possible line tension as the existing poles are 40’ tall. To install MVROT on the pole: one 50’, Class 2 pole, was selected. This was to satisfy MH standards for the equipment spacing and supporting equipment weights, MVROT alone weighs some 870kg. Together with MVROT, one ABB line voltage instrument transformer was installed high up on the pole.

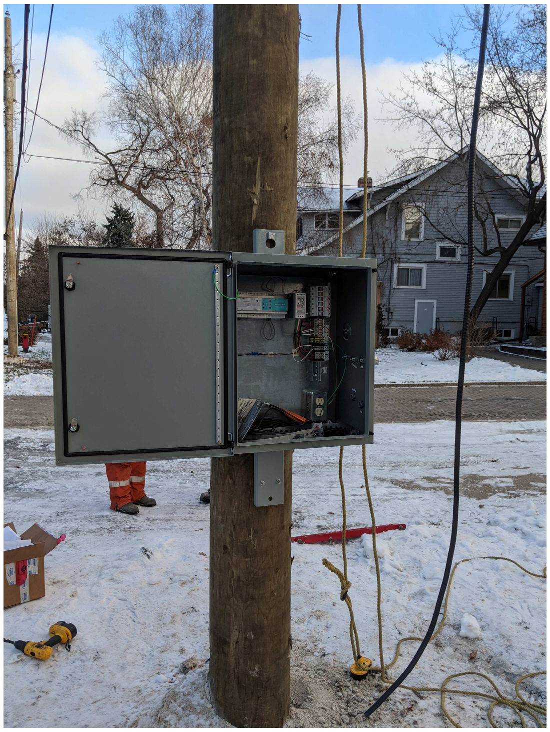
Picture-5 lifting MVROT on 50’ tall pole

The phase branch was connected to phase “B” from three phase feeder at this location, and second line, phase “A”, was brought up to the 50’ pole to be used when MVROT is energized. Aclara and Cooper sensors were mounted directly on the phases “A” and “B” (feeder side), and phase “B” (load side) close to the new 50’ pole, where MVROT was lifted and mounted together with ABB instrument transformer. Rogowski CT coil was installed around system neutral line on the new 50’ pole on the feeder side and its cables together with the ABB instrument voltage transformer cables were brought into the metering cabinet where the HIOKI analyser was located to record all data these two instrument transformers were reading (line voltage and currents in neutral line). All readings were synchronized to be recorded in 15minutes intervals for 24h a day for seven days prior to MVROT being energized and thereafter, the same recording procedure for another 7 days after MVROT is energized. Aclara and Cooper sensors were wirelessly connected to the MH distribution center where all recordings from Substation and Pilot Project site are recorded directly onto MH’s network server.

Pictures -6 and 7 capturing MVROT site installation

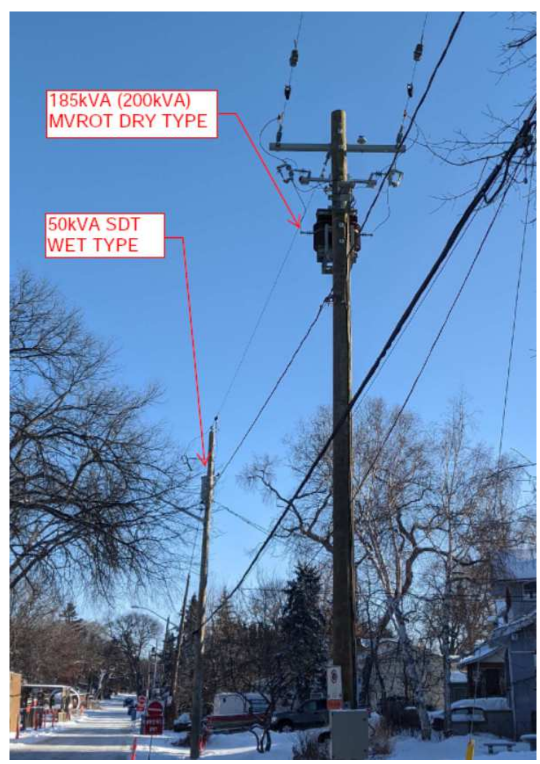
3.2. RECORDED DATA, EQUIPMENT AND DATES

DATA RECORDED	EQUIPMENT USED	DATA COLLECTED (15min 24h/day)
<u>At Substation J207 feeder (With and Without MVROT):</u> • Regulated Phase Voltages: APH, BPH, CPH, • Amperage: IA, IB, IC, IN **<u>At MVROT location (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 analyser at MVROT location • Rogowski CT at MVROT location • Voltage Instrument Transformer (ABB) at MVROT location • MVROT-250-4.16//2.4 (185kVA)	**<u>First baseline Records (Without MVROT):</u>** From Dec 04, 2019 to Dec 12, 2019 **<u>Second baseline Records (Without MVROT):</u>** From Jan 02, 2020 to Jan 09, 2020 **<u>First Records with MVROT:</u>** From Jan 09, 2020 to Jan 17, 2020 **<u>Second Records with MVROT:</u>** From Jan 28, 2020 to Feb 06, 2020



Pictures – 8 and 9 HIOKI metering cabinet on the same pole with MVROT

Total nominal loads in single phase "B" feeding Assiniboine Avenue residents is **162 kVA** (excluding 95kVA one on East side of the three-phase grid) spread over 590m and five (5) step down transformers 2.4kV//120V/240V: 50kVA, 25kVA, 37kVA, 25kVA and 25 kVA. By installing MVROT at this single-phase (Phase "B") branch take-off, MVROT <u>becomes the load source</u> for these five SDTs. MVROT nominal rated power is 185kVA.



Pictures-10 and 11 view showing 4 times larger power capacity of 185kVA MVROT versus Oil filled 50kVA SDT, physical sizes are almost the same

First round of baseline data recording by HIOKI Analyser and MH Server started:

- HIOKI Recording on Tuesday December 3rd at 11:30:26 AM and finished on Tuesday December 10th at 8:45:26 AM
- ACLARA Recordings by MH distribution center from their server on Wednesday December 4th at 11:30 AM and finished on Tuesday December 10th at 9:00 AM

Due to some technical difficulties and discrepancies with recorded data there was a need to repeat baseline recordings one more time. These discrepancies were resolved and addressed together with MH team. See important note and listed drawings below addressing amperage differences between phase and neutral at Pilot Project location prior to energization of MVROT.

See drawings: **EGC-MH-02-18-022-Rev A and EGC-MH-02-18-023-Rev A**

IMPORTANT NOTE:
Neutral line return from the five end users, getting power supply from the 50kVA step down transformer, is connected to the main system neutral upstream (feeder side) of the MVROT installation. There is a current in that system neutral generated from the low voltage (120V/240V) secondary side of this step-down transformer and it flows through Rogowski coil. That is the reason we still see in our recorded data some amperage in neutral at MVROT location. That low voltage circuit current is local between these five end users (houses) and 50kVA SDT and is not going to the substation.

3.3. RECORDED DATA ANALYSES - all completed using excel program

3.3.1. Voltage Analyses for the first round (Jan 2nd, 2020 till Jan 17th, 2020)

"**Figure 1a**" shows branch-off single phase "B" voltage (2.4kV nominal) records in graphical form connected to three phase J207 feeder. All loads, (5) step down transformers totaling 162kVA, along Assiniboine Avenue were connected to this phase "B". Baseline phase "B" voltage records at substation are shown with red line and at the MVROT location with cyan line. Once MVROT was energized, the voltage improved (green line from magenta line). **Note: MVROT is NOT autotransformer.**

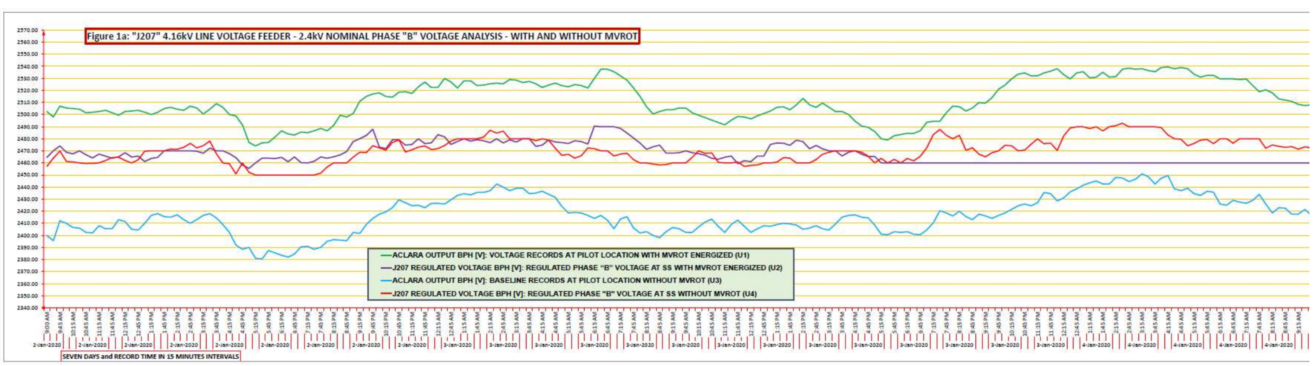


Figure 1a

(only one part shown here, see attachments to this report for full graph of one whole week)

"Figure 1b" shows the percentage of the overall energy efficiency increase over 15-minute intervals with the trend line being between 8.2% and 8.7% in phase "B". Percentages are calculated values derived from the actual voltage and load records. See "3.3.3 Calculation" section for the calculation formulas. These results show significant improvement of the feeder energy efficiency brought in by only one MVROT unit. There is significant potential to further increase overall grid efficiency, with a few additional, strategically located MVROT units within more than only one branch-off of the J207 feeder. Significant results are shown in **"Table 1"** below.

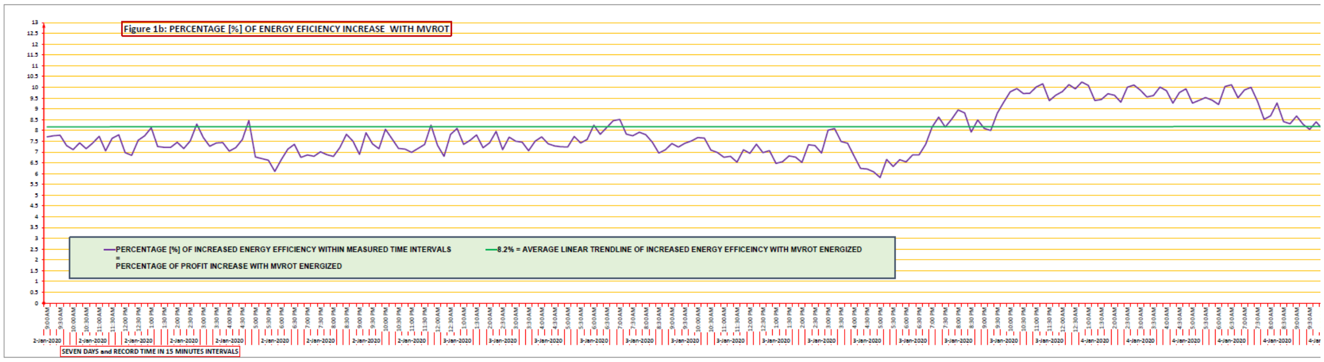


Figure 1b

(only one part shown here, see attachments to this report for full graph of one whole week)

Table 1: Significant records and results associated with graphs shown in Figure 1a and Figure 1b:

PHASE / DATA	BASELINE	WITH MVROT	IMPROVEMENTS*
Maximum Phase Voltage [V]	**2451.5**	**2558.5**	**+107 [V] or (4.36%)**
Minimum Phase Voltage [V]	**2360.5**	**2465.5**	**+105 [V] or (4.45%)**
Maximum Low Voltage [V]	**122.58**	**127.93**	**+5.36 [V] or (4.37%)**
Minimum Low Voltage [V]	**118.03**	**123.28**	**+5.25 [V] or (4.45%)**
Max voltage [V] drop [-] / improved [+]	**-33.72**	**+141.50**	**-**
Min voltage [V] drop [-] / improved [+]	**-88.00**	**+60.50**	**-**
Min / Max Improved voltage [%]	**-**	**4.36% / 4.45%**	**-**
Maximum efficiency increased	**-**	**12.02%**	**-**
Minimum efficiency increased	**-**	**5.43%**	**-**
Average efficiency increased	**-**	**8.2%**	**-**

*Positive values are voltage improvements

The comparison was done between data records saved within two weeks (in 15 minutes intervals):

1. Baseline without MVROT (timeline shown in Figures 1a and 1b) start: Thursday, Jan 2nd, 2020 at 9:00 AM ends Thursday Jan 9th at 8:45 AM
2. With MVROT energized start: Friday, Jan 10th, 2020 at 9:00 AM ends Friday, Jan 17th at 8:45 AM

Another view and analyses were done aligning the times and days to be coincident of the two weeks and review those results and graphs to see if they are any significant differences to the results above.

We compared the same data between baseline and MVROT starting with these dates:

3. Baseline without MVROT (timeline shown in Figures 1c and 1b) start Friday, Jan 3rd, 2020 at 9:00 AM ends Thursday Jan 9th at 9:00 AM
4. With MVROT energized start Friday, Jan 10th, 2020 at 9:00 AM ends Thursday, Jan 16th at 9:00 AM

"**Figure 1c**" shows, Phase "B", single phase voltage (2.4kV nominal) records in graphical form connected to three phase J207 feeder, with days in weeks aligned per time and dates indicated in points 3 and 4 above. There are no significant differences in comparison with the graph shown on "Figure 1a".

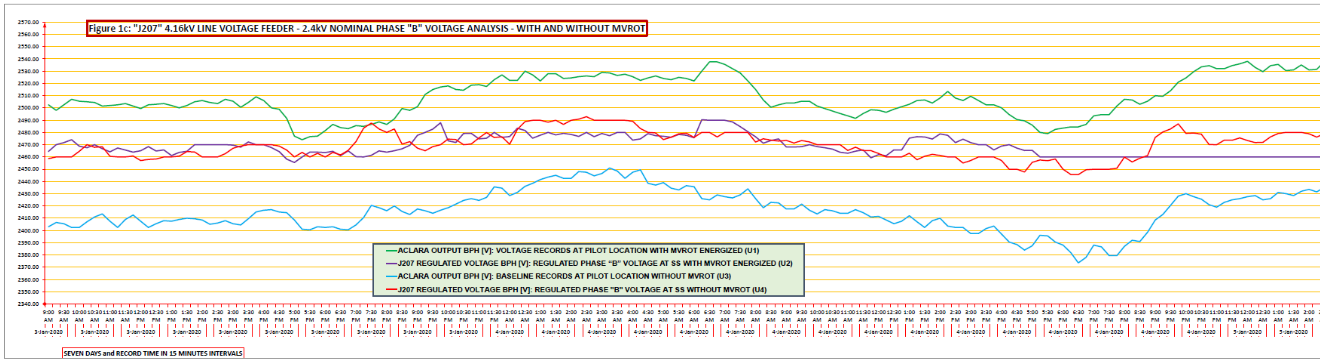


Figure 1c

(only one part shown here, see attachments to this report for full graph of one whole week)

"Figure 1d" shows the percentage of the overall energy efficiency increase over 15-minute intervals with the trend line being between 7.9 % and 8.9 % in phase "B", when days in weeks are aligned per time and dates indicated in points 3 and 4 above. There are slight differences in efficiency trendline, but overall, the results are similar. Average energy efficiency is increased to 8.41 %. Different significant results are shown in "**Table 2"** below and highlighted in **red** text.

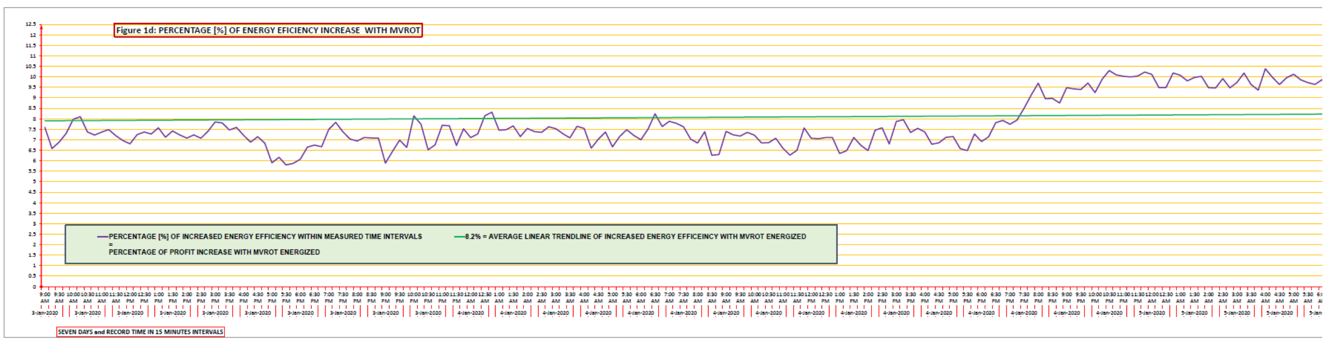


Figure 1d

(only one part shown here, see attachments to this report for full graph of one whole week)

Table 2: Significant records and results associated with graphs shown in Figure 1c and Figure 1d:

PHASE / DATA	BASELINE	WITH MVROT	IMPROVEMENTS*
Maximum Phase Voltage [V]	**2451.5**	**2558.5**	**+107 [V] or (4.36%)**
Maximum Phase Voltage [V]	**2360.5**	**2465.5**	**+105 [V] or (4.45%)**
Maximum Low Voltage [V]	**122.58**	**127.93**	**+5.36 [V] or (4.37%)**
Minimum Low Voltage [V]	**118.03**	**123.28**	**+5.25 [V] or (4.45%)**
Max voltage [V] drop [-] / improved [+]	**-33.72**	**+140.50**	**-**
Min voltage [V] drop [-] / improved [+]	**-88.00**	**+60.50**	**-**
Min / Max Increased voltage %	**-**	**4.36% / 4.45%**	**-**
Maximum efficiency increased	**-**	**11.79%**	**-**
Minimum efficiency increased	**-**	**5.78%**	**-**
Average efficiency increased	**-**	**8.41%**	**-**

*Positive values are voltage improvements

There were some technical difficulties with these records found upon analyses. Aclara at substation did not record properly from 11 Jan 2020 5:15 PM until 16 Jan 2020 8:45 PM and we identified slight problem with time stamp between Aclaras. To be sure we have accurate records, especially for the loads, within the same time (seconds) we repeated readings and recordings for the second time ensuring all equipment is time synchronized. Below are voltage analyses between baseline records and new round 2 data with MVROT energized.

3.3.2. Voltage Analyses for the second round (Jan 2nd, 2020 till Feb 06th, 2020)

- **Baseline:** Thursday, Jan 2nd, 2020 at 9:00 AM ends Thursday Jan 9th at 7:45 AM
- **MVROT Round 2 Records:** Thursday Jan 30th, 2020 at 9:00 AM ends Thursday Feb 6th, 2020 at 7:45 AM

"**Figure 2a**" shows, Phase "B", phase voltage (2.4kV nominal) records in graphical form connected to three phase J207 feeder. All recorded data are aligned with weekdays, dates and times as per bullets above. Baseline phase voltage records at substation are shown with the red line and at the MVROT location with the cyan line. Once MVROT was energized the voltage improved (green line from magenta line). **Note: MVROT is NOT autotransformer**

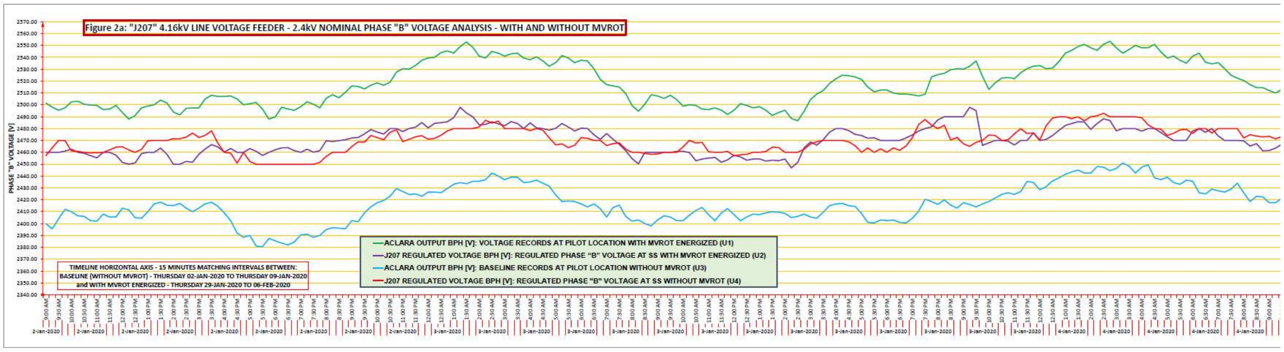


Figure 2a

(only one part shown here, see attachments to this report for full graph of one whole week)

"Figure 2b" shows the percentage of the overall energy efficiency increase over 15-minute intervals with the trend line between 8.2% and 8.5% in phase "B" when days in weeks are aligned per time and dates indicated in bullet points above. Average energy efficiency is increased to 8.31%. Significant results are shown in **"Table 3"** below.

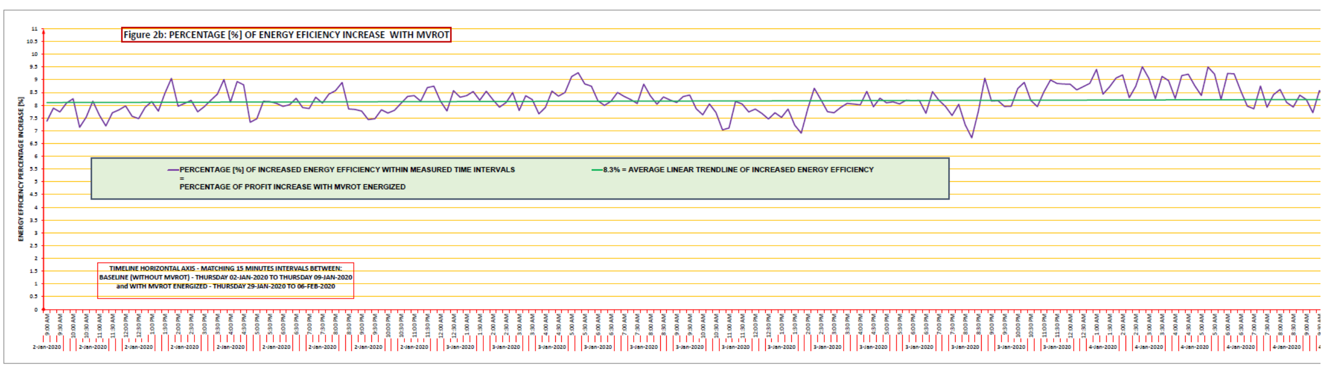


Figure 2b

(only one part shown here, see attachments to this report for full graph of one whole week)

Table 3: Significant records and results associated with graphs shown in Figure 2a and Figure 2b:

PHASE / DATA	BASELINE	WITH MVROT	IMPROVEMENTS*
Maximum Phase Voltage [V]	**2451.5**	**2553.5**	**+102 [V] or (4.16%)**
Maximum 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 %	**-**	**4.16% / 5.10%**	**-**
Maximum efficiency increased	**-**	**10.04%**	**-**
Minimum efficiency increased	**-**	**6.43%**	**-**
Average efficiency increased	**-**	**8.31%**	**-**

*Positive values are voltage improvements

Based on these significant records as shown in "**Table 3**", Minimum Low Voltage without MVROT is 118.03V. That is 1.65% lower voltage value than nominal 120V. At the same time Minimum Low Voltage with MVROT is 124.05 V. That is 3.38% higher voltage value than nominal 120V.

Based on analytical relationship for voltage drop, $\Delta U_{[V]} = r_{[ohm/km]} * L_{[km]} * I_{[A]}$ and if amperage (loads) are increased for about 5% (which is realistic expectation) voltage drop will increase by 5% and the voltage at the end user would be below standards if there is no MVROT in the system. In this situation to satisfy low voltage level standards, when loads are increased and no MVROT installed, to compensate voltage drops, Utility would need to reconstruct entire sections of the feeder lines by changing them for the larger cross section conductors (smaller resistivity $r_{[ohm/km]}$).

Adopting MVROT technology, proved through these recorded data, is giving us significant gain in stabilizing and improving voltage levels within standards for much wider spectrum of additional loads without need to change the existing conductors. There is significant technical and economical benefit to the Utilities.

3.3.3. Energy Efficiency Analyses and Calculations

Reducing voltage drops resulted in overall reduced time to deliver required energy (improved intermittence or latency) and thus increased energy efficiency of this feeder. Grid Energy efficiency is function of time $W_{[kWh]}=P_{[kW]}*t_{[h]}$ and with MVROT energized and online it reduces the time to deliver required power and opening the potential to deliver more available power from substation to the end users and new customers within the same time period (eliminates bottle neck in delivering energy).

Based on this above, feeder energy efficiency increases along phase "B", shown on Figure 1b, Figure 1d and Figure 2b is expressed through the comparison of delivered amount of energy to the end users at the pilot project location with and without MVROT, and the amount of energy that would be delivered if voltage level is equal as at Substation = ideal condition.

Calculation of these delivered energy amounts is based on actual voltage data records and energy formula $W_{[kWh]}=P_{[kW]}*t_{[h]}=(U^2/R) * t$; **R = constant, t = constant** is explained below:

Recorded data:

- U1 = ACLARA OUTPUT BPH [V]: VOLTAGE RECORDS AT PILOT LOCATION WITH MVROT ENERGIZED
- U2 = J207 REGULATED VOLTAGE BPH [V]: REGULATED PHASE "B" VOLTAGE AT SS WITH MVROT ENERGIZED
- U3 = ACLARA OUTPUT BPH [V]: BASELINE RECORDS AT PILOT LOCATION WITHOUT MVROT
- U4 = J207 REGULATED VOLTAGE BPH [V]: REGULATED PHASE "B" VOLTAGE AT SS WITHOUT MVROT

Energy:

$W_{[kWh]} = P_{[kW]} * t_{[h]} = ((U)^2 / R) * t$
U = voltage
R = constant; representing total number of the end users connected
t = constant; 15minute measuring intervals

With MVROT:

$W1/W2 = (U1/U2)^2$
$W1 = (U1/U2)^2 * W2$
$W1 = k1 * W2$

- W1 = delivered energy to the end users with MVROT energized
- W2 = energy that would be delivered to the end users if voltage level at MVROT location is equal as at Substation – With MVROT energized - Ideal conditions.
- k1 = Voltage ratio "$(U1/U2)^2$"with MVROT energized

Without MVROT:

$W3/W4 = (U3/U4)^2$
$W3 = (U3/U4)^2 * W4$

W3 = k2 * W4

- W3 = delivered energy to the end users without MVROT
- W4 = energy that would be delivered to the end users if voltage level at MVROT location is equal as at Substation – Without MVROT - Ideal conditions
- k2 = Voltage ratio "$(U3/U4)^2$"without MVROT

As power is in direct relation between amperage and voltage, any voltage change will change amperage to deliver the same power. Improvement in voltage will reduce amperage and will reduce voltage drops and power losses. By improving voltage, we are improving intermittence – time to deliver required power and with that improving feeder energy efficiency.

For illustration – ideal condition:

Assume: Energy losses at substation are = 0, ideal condition, so energy efficiency would be:
"energy at source" = "energy delivered".

If that is true throughout the grid, no voltage drops, energy losses would be "0" within the feeder.
That means: "energy at source" / "energy delivered" = 1 = no voltage drops no power/energy losses – ideal condition.

Without MVROT the baseline records are showing voltage drops in feeder, and that resulted in "k2" voltage ratio < 1.
(Accrued power losses and requires longer time to deliver demanded power)

With MVROT energized records are showing improved voltage in feeder and that resulted in "k1" voltage ratio > 1.
(Reduced power losses and requires less time to deliver demanded power)

Based on the above, and these pilot project recorded voltage data; total voltage changes compared for the same time frame in a weekday, is a sum of these two voltage ratios ("k1 and k2") converted into percentages. Absolute difference between them is total energy efficiency in this feeder (since it is in direct relationship with improved voltage and time) to deliver more energy within the same time frame.

Baseline Records:

Without MVROT, voltage drops in the feeder are reducing actual phase voltage at MVROT location from ones recorded at substation, and that ratio will always be less than 1.

That is voltage ratio $(U3/U4)^2$ = k2, (voltage at MVROT location / voltage at Substation) < 1.
So, energy delivered would be: "energy at source" * 1 - "energy at source" * k2 = "energy delivered" = 1-k2

Records with MVROT energized:

With MVROT efficiency implemented into the feeder, we have improved phase voltage at MVROT location in relation to ones recorded at substation, and that ratio is always greater than 1.

That is voltage ratio $(U1/U2)^2$ = k1, (voltage at MVROT location / voltage at Substation) > 1.
So, energy delivered would be: "energy at source" * k1 - "energy at source" * 1 = "energy delivered" = k1-1.

Based on the above we have calculation formula definition:
E_f = (k1-1) * 100 + (1-k2) * 100

- E_f = Energy Efficiency Percentage change (total percentage of voltage change)

Example (at one point in time as shown on Figure 2a and Figure 2b):

Without MVROT: Thursday, 09 Jan 2020 at 7:45 AM, U3 = 2381.00[V]; U4 = 2453.76[V]; k2= 0.94157

Energy delivered within above 15minutes interval without MVROT:

$W3 = (2.381/2.45376)^2 * W4 = k2 * W4 = 0.94157 * W4$
(indicating: if voltage at MVROT location is the same as in substation Utility could deliver ~6% more energy within this time)
$(P[kW] + 6 * P[kW]) / 100 * t[h] = P[kW] * (1/k2) * t[h]$

With MVROT: Thursday, 06 Feb 2020 at 7:45 AM, U1 = 2506.50[V]; U2 = 2474.48[V]; k1=1.02604

Energy delivered within above 15minutes interval with MVROT:
$W1 = (2.5065/2.47448)^2 * W2 = k1 * W2 = 1.02604 * W2$
(indicating: With MVROT Utility is delivering ~2.6% more energy within the same time)
$(P[kW] + 2.6 * P[kW]) / 100 * t[h] = P[kW] * (1/k2) * t[h]$

The end result based on the field records and above calculations, shows overall additional energy is possible to deliver by using MVROT by 8.45%:

$\mathbf{E_f}$ = (1.02604 - 1) * 100 + (1 - 0.94157) * 100 = 8.44704 [%]
(8.45% increased feeder energy efficiency)

PERCENTAGE [%] OF INCREASED ENERGY EFFICIENCY WITHIN MEASURED TIME INTERVALS
=
PERCENTAGE OF PROFIT INCREASE WITH MVROT ENERGIZED

3.3.4. Amperage Analyses (Jan 2nd, 2020 till Feb 06th, 2020) at Estella Substation location

For the load analyses we have compared data records completed as:

- **Baseline Records:** Thursday, Jan 2nd, 2020 at 9:00 AM ends Thursday Jan 9th at 7:45 AM
- **MVROT Round 2 Records:** Thursday Jan 30th, 2020 at 9:00 AM ends Thursday Feb 6th, 2020 at 7:45 AM

"Figure 3a" is showing baseline amperage (load) records at substation within phase "A" (cyan line)- maximum 164.14[A], phase "B" (orange line) – maximum 207.60[A] and neutral line (green line). The phase "A" and phase "B" are somewhat aligned but loads are visibly different. These unbalanced loads in combination with loads in phase "C", that was not address at all, produce some big amperages within neutral line (maximum 94.71[A]). These loads in neutral conductor are total waste, inefficient and their reduction or elimination will increase energy efficiencies within the entire grid.

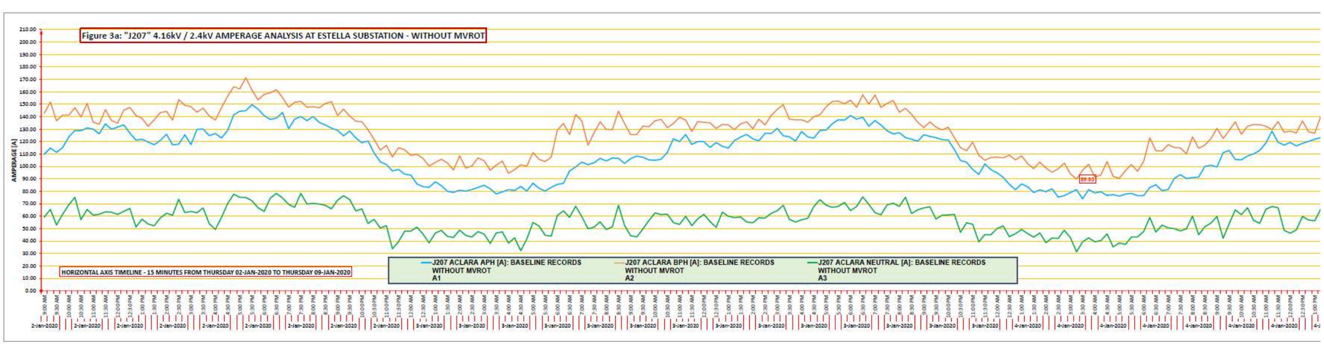


Figure 3a
(only one part shown here, see attachments to this report for full graph of one whole week)

"Figure 3b" is showing the same records with MVROT energized for the amperage (load) recorded at substation within phase "A" (dark red line) – maximum 174.29[A], phase "B" (blue line) – maximum 173.24[A] and neutral line (red line). The phase "A" and phase "B" are almost perfectly aligned, and their loads are in balance. These balanced loads, in combination with MVROT eliminating currents in neutral conduit at its location, reflected significant reductions in amperages (loads) within neutral line at substation (maximum 65.90[A]). Remining loads in neutral at substation are mainly product from the unbalanced phase "C" that we did not address with this Pilot Project.

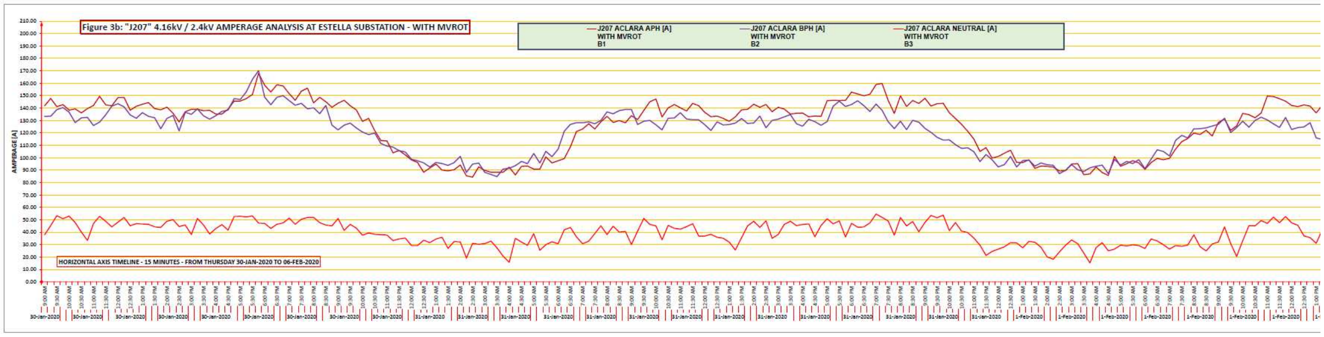


Figure 3b

(only one part shown here, see attachments to this report for full graph of one whole week)

"Figure 3c" is showing combination of these two graphs (Figure 3a and Figure 3b) for visual comparisons between two data records, without MVROT and with MVROT.

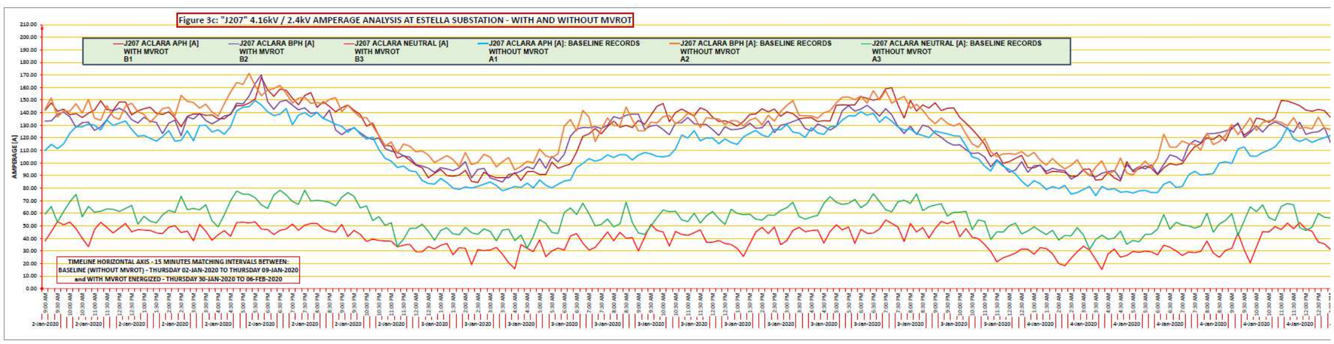


Figure 3c

(only one part shown here, see attachments to this report for full graph of one whole week)

"Figure 4a" is showing only differences between amperages (loads) within neutral conductor at substation. It is clearly visible significant constant reduction of the currents in neutral conductor.

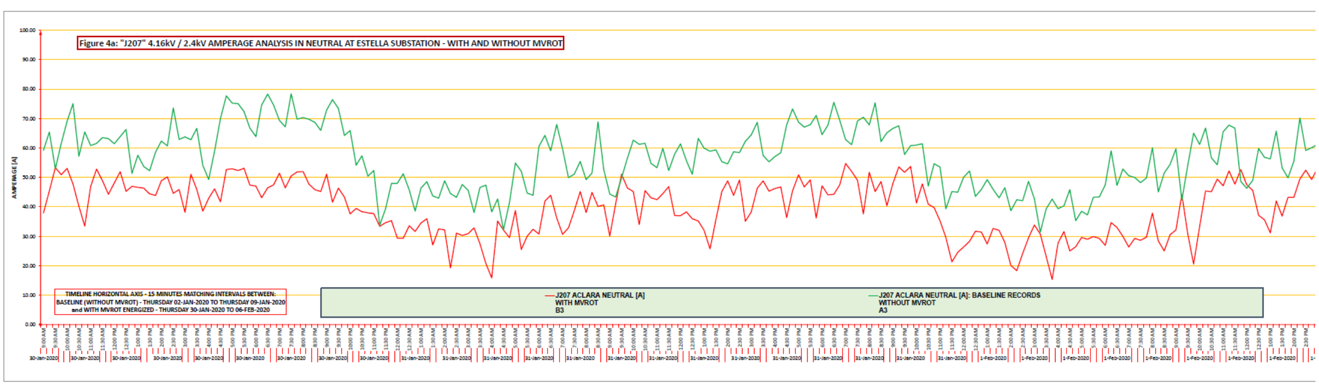


Figure 4a

(only one part shown here, see attachments to this report for full graph of one whole week)

"Figure 4b" is showing percentage differences (reduction) within neutral conductor at substation location between baseline amperages (loads) "A3" and amperages (loads) when MVROT is energized "B3". Trend line is showing reduction in loads between 29% and 39%.

Neutral amperage reduction percentage [%] = (A3-B3) / A3*100

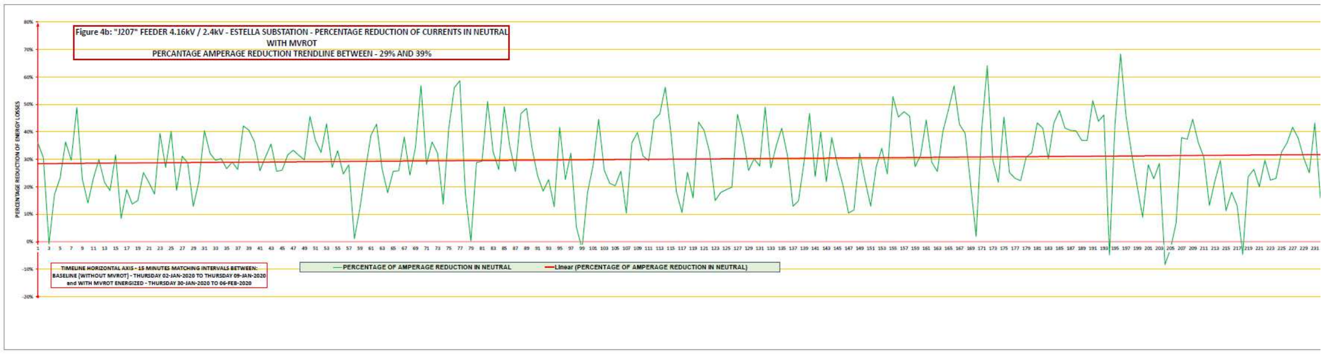


Figure 4b

(only one part shown here, see attachments to this report for full graph of one whole week)

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

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]**
Maximum reduction in Neutral [A]	**-**	**52.7**	**-**
Minimum reduction in Neutral [A]	**-**	**-4.04**	**-**
Neutral load percentage 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.*

3.3.5. Amperage Analyses (Jan 2nd, 2020 till Feb 06th, 2020) at MVROT Pilot Project location

For the load analyses the compared data records completed as:

- **Baseline Records:** Thursday, Jan 2nd, 2020 at 9:00 AM ends Thursday Jan 9th at 7:45 AM
- **MVROT Round 2 Records:** Thursday Jan 30th, 2020 at 9:00 AM ends Thursday Feb 6th, 2020 at 7:45 AM

"Figure 5a" is showing loads in phase A and B connected at primary side of MVROT completely balanced. Notice that both lines representing amperage in each phase are almost 100% identical. There are few minor differences that can be ignored as reading errors as they are less than 5[A]. Maximum / minimum errors are: 3.20[A] / - 1.90[A].

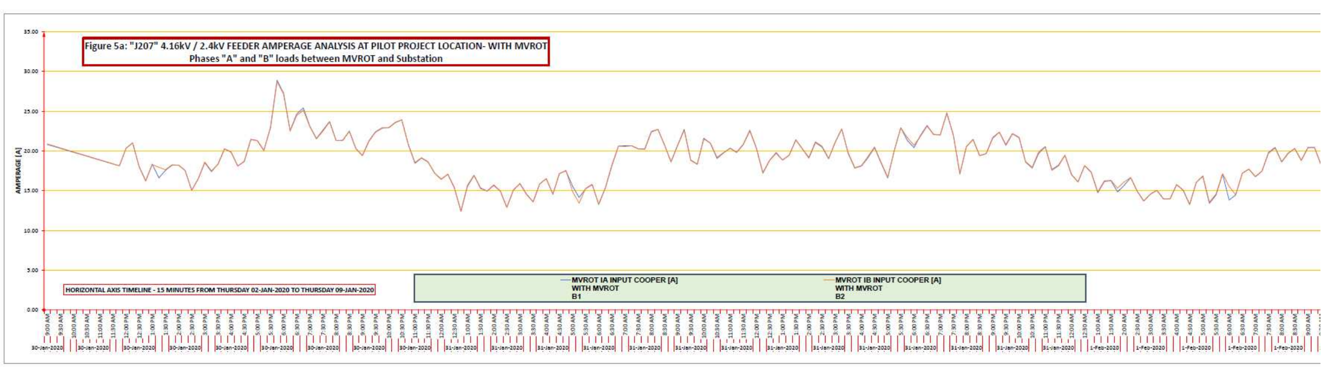


Figure 5a

(only one part shown here, see attachments to this report for full graph of one whole week)

"Figure 5b" is showing amperage in MVROT secondary phase "a" feeding five SDT and amperage in neutral line from low voltage loads whose current circuit is connected to this system neutral line. We have validated, checked and confirmed expected amperage within primary phase A and phase B based on the loads at secondary phase “a”. Multiplying the secondary amperages “B3” with constant transformation factor “0.6” resulted in getting amperages in phase “A” and phase “B” and they are matching to Cooper sensors recorded values. Maximum / minimum deviation between measured and calculated (expected primary amperage values) are negligible and they are: +3.36[A] / -4.43[A] which is <5[A].

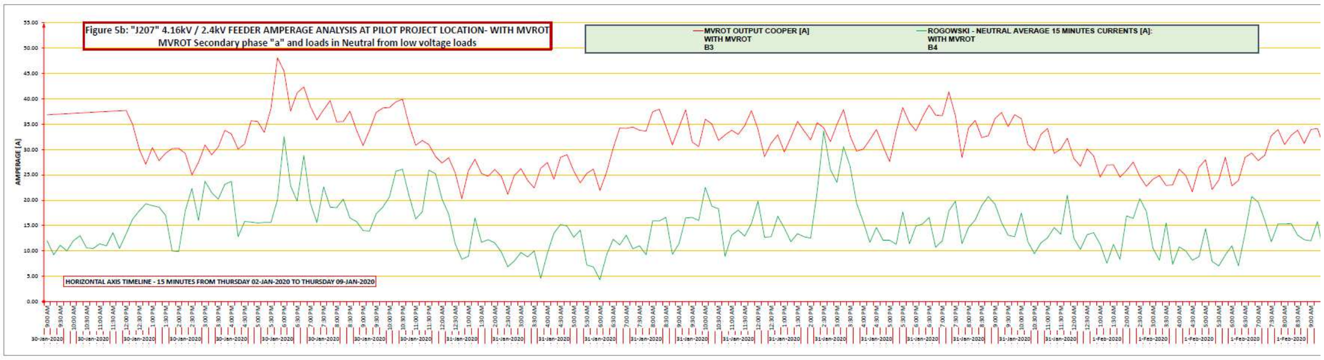


Figure 5b

(only one part shown here, see attachments to this report for full graph of one whole week)

To obtain power losses in the lines without and with MVROT energized, analyses were completed with the recorded amperages at MVROT location. Here is the summary and explanation of the analyses.

3.3.6. Amperage Data Collection and Power Losses Calculations:

- IB1 = MVROT IA INPUT COOPER [A] WITH MVROT
- IB2 = MVROT IB INPUT COOPER [A] WITH MVROT
- IB3 = MVROT OUTPUT COOPER [A] WITH MVROT
- IB4 = ROGOWSKI - NEUTRAL AVERAGE 15 MINUTES CURRENTS [A] WITH MVROT

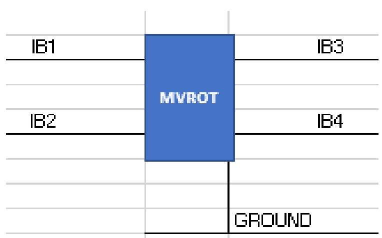
Without MVROT (bypassed):

- Amperages recorded as IB3 and IB4 are going all the way toward substation

With MVROT is energized:

- These amperages are transformed into IB1 and IB2 by MVROT and IB1 and IB2 are going all the way toward substation instead.

Feeder / substation side



Load side

Schematics of line amperages at MVROT location

Since these amperages are simultaneous, then we can compare amperages that would in any given time be circling all the way toward substation and see how much they are reduced by having MVROT installed and online. To determine this reduction, we had to compare compatible value differences between IB1 & IB3 and IB2 & IB4 amperages. Since these are single phase loads, we are looking at conductors through which power is distributed.

- **IA:** IB1 - IB3 (give us reduction of IB3 amperages that would go all the way to substation)
- **IB:** IB2 – IB4 (give us reduction of IB4 amperages that would go all the way to substation)

Total amperage changed through these two conductors is addition between these two:

- **IA + IB**

<u>**Losses in lines are:**</u> **$P_v = r_v * I^2$**

- Without MVROT: $I_1^2 = IB3^2 + IB4^2$; $P_{v1} = r_v * I_1^2$
- With MVROT: $I_2^2 = IB1^2 + IB2^2$; $P_{v2} = r_v * I_2^2$

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

$K = P_{v1} / P_{v2} = (IB3^2 + IB4^2) / (IB1^2 + IB2^2) = I_1^2 / I_2^2$

<u>For example:</u>

On January 30th, at 9:00AM records are showing:

IB1 = 20.80 [A] (MVROT IA INPUT COOPER [A] WITH MVROT)
IB2 = 20.88 [A] (MVROT IB INPUT COOPER [A] WITH MVROT)
IB3 = 36.82 [A] (MVROT OUTPUT COOPER [A] WITH MVROT)
IB4 = 12.00 [A] (ROGOWSKI - NEUTRAL AVERAGE 15 MINUTES CURRENTS [A] WITH MVROT)

Expected Primary amperages compared to recorded ones “IB1 and IB2” are based on recorded MVROT output amperages “IB3” and they are: IB1 = IB2 = IB3 * 0.6.

For this example, at above time:
36.82 [A] * 0.6 = 22.09 [A] ~ 20.80 [A] and 20.88 [A] with a **small acceptable deviation** of: **1.22[A] << 5.0[A].**

The end results for total amperage reduction in 15minutes when MVROT is energized:

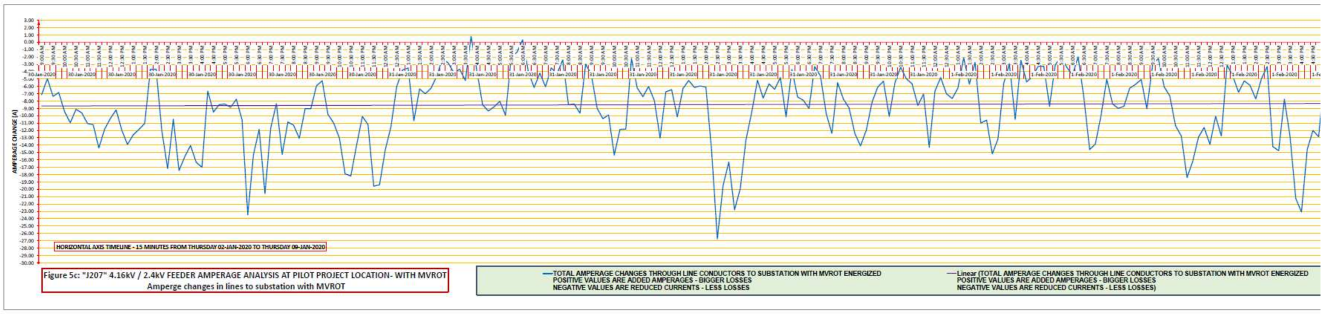
IA: IB1 - IB3 = 20.80 – 36.82 = -16.01 [A:]
IB: IB2 – IB4 = 20.88 – 12.00 = 8.88 [A]
IA + IB = -16.01 + 8.88 = -7.14 [A]

Negative resulted values indicate reduction of the amperage and less losses when MVROT is energized and positive values are indicating increasing amperages and losses when MVROT is present.
For example, based on currents combinations on January 31st, at 6:00 AM there were slight increase in losses:

IB1 = 13.27 [A]
IB2 = 13.30 [A]
IB3 = 21.91 [A]
IB4 = 4.33 [A]

IA: IB1 - IB3 = 13.27 – 21.91 = -8.64 [A:]
IB: IB2 – IB4 = 13.30 – 4.33 = 8.97 [A]
IA + IB = -8.64 + 897 = 0.33 [A]

“Figure 5c” is showing above calculated values of these amperage changes based on records within one week of data when MVROT was energized. Trendline is showing amperage reduction between -7.9 [A] and -8.9[A].



"Figure 5c

(only one part shown here, see attachments to this report for full graph of one whole week)

Based on these analyses as shown on **Figure 5c** it has identified numbers of two major events:

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

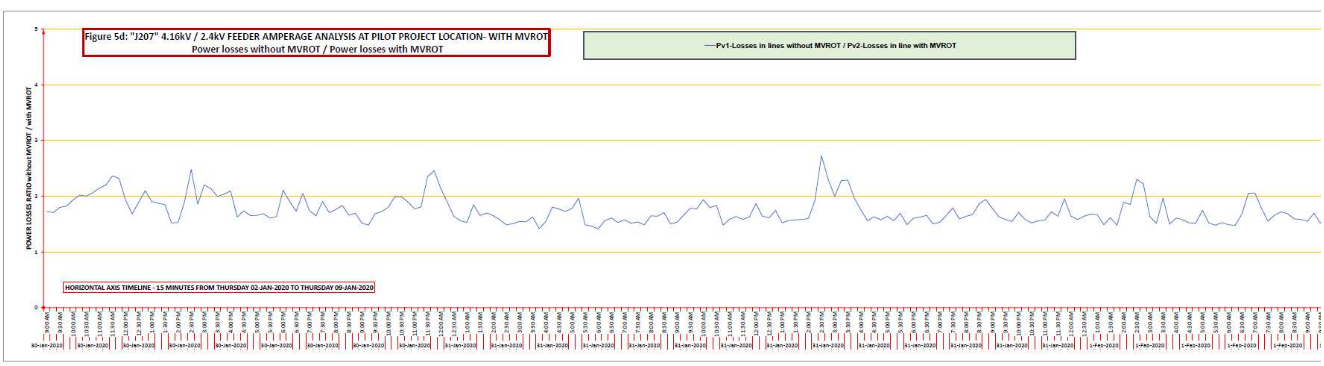
- Number of events in one week that total amperage changes are smaller with MVROT installed in this feeder is: **661 and with maximum reduced losses of -27.50 [A]**

Losses ratio in the lines on January 30th at 9:00 AM:

$K = P_{v1} / P_{v2} = (IB3^2 + IB4^2) / (IB1^2 + IB2^2) = I_1^2 / I_2^2$

$K = (36.82^2 + 12.00^2) / (20.80^2 + 20.88^2) = 1.7265$

"Figure 5d" is showing these calculated power losses ratios. With the loss's ratio > 1 feeder is having larger losses without MVROT than with MVROT. For the whole week, the measured data and per these saved records losses without MVROT are always larger than 1. Maximum is 3.3098 and minimum is 1.3583.



"Figure 5d

(only one part shown here, see attachments to this report for full graph of one whole week)

4. ECONOMIC BENEFITS

Above analyses are providing clear proof that EGC's patented MVROT technology is providing significant advantages to both, the Utilities and end users. In addition to having these technical benefits, as analysed in previous sections, this technology is economically viable solution as well. To address this question, there are several different economical values that MVROT provides into the system.

Depending on what Utilities are trying to resolve/overcome within their distribution grids each of listed solutions below can be converted into detailed economical assessments in comparisons with the existing traditional technologies and methods. One great advantage of the MVROT technology is in its overall economical value gained by adding together all these benefits listed below.

1. **Balancing entire three phase distribution system with many single-phase take-offs.**

   - There is no other technology that can achieve 100% balance in three phase feeders. Existing traditional methods are done by modeling simulations and computer analyses to find the best design to minimize these amperage unbalances but can not achieve the same as MVROT technology. Existing grids are constantly getting additional single-phase loads that will disrupt these designs and will end up with bigger unbalanced system over time. The MVROT will **always balance** these additional loads (single phase branches) into the existing feeders when they are connected into the existing three phase feeder trough MVROT.

   - Grids with large unbalanced loads are having significant issues with power and overall, the existing equipment are working in not ideal conditions and under constant stress. This reduces their life expectancy and would often need to be replaced or ongoing maintenance, putting under pressure the Utilities operating budget. For grids powered by diesel generators, the unbalanced systems are one of root causes for them to trip and entire grid would lose power.

     ✓ MVROT brings significant economical savings here as it is quick, inexpensive solution for the existing grids having this issue. No need to change out or maintain anything as they are maintenance free. Allowing all existing equipment to work in ideal conditions and their life expectancy is prolonged (estimated time extended by several years to a decade). Less maintenance, constant quality of power delivered, reduced possible outages.

     ✓ The magnitude of this economical benefit can be estimated in extremely wide dollar range, where big operation or capital budgets would be needed. Amounts of savings (with five to six digits $ values) are dependant to what exact issue utility experience with the unbalanced loads in their grid and traditional methods to correct them.

     ✓ One example for the dollar ratio savings, in the case of adding new single-phase branch into the existing feeder and resolving the unbalance load issue with MVROT versus attempting the same with traditional ways can be easily expressed.

     Traditionally, re-designing the entire feeder will need to be done. As a minimum switching other existing single-phase branches trying to balance loads as much as possible will need to be done. The total cost (design and field work) could be reduced by installing just one MVROT in the new branch connecting with the existing feeder and load balance would be established. No other work in the field will be needed. Dollar ratio savings magnitude for this solution "MVROT:Traditional" would be in the range of 1:5 to 1:10.

2. **Quality of power delivered**

   - To deliver power quality (voltage level to satisfy standards) to all end users regardless where they are connected to the grid utilities are sometime forced to investigate adding new substations, bringing higher voltage closer to the end users or rebuilding entire grids to the higher voltages.

- This is a huge investment and time consuming to execute this size project. Sometime that is not economically viable at all as it might be just small group of end users and the return on that investment will not be there.

- When loads in grids are increased, to compensate voltage drops and to satisfy low voltage level standards, Utility would need to reconstruct entire sections of the feeder lines by changing them for the larger cross section conductors. This is significant effort and cost to the operation budget.

  - ✓ MVROT resolve this issue easy and quick without big investment needed. As per the results and voltage analyses above it is obvious that voltage level to the end users, far away from the source (substation), are achieved and O/H even lines could be extended much further to add new users if needed.

  - ✓ Adopting MVROT technology, proved through these recorded data, is giving us significant gain in stabilizing and improving voltage levels within standards for much wider spectrum of additional loads without need to change the existing conductors.

  - ✓ These specific economical benefits can be estimated in wide dollar range as well and could be in seven $ digits, depends what exact capital cost for the new lines, new grids and new substations are.

3. Selectivity of distribution grid

- Selectivity of the existing grids are often done by adding extra cut-outs as protection within the grids to reduce number of users effected by the possible outage. For this existing method and system to work efficiently there are two conditions that must be satisfied:
  - First is protection sensitivity (cut-out fuses installed along the depth of the feeder must have lower reaction point than one in substation or previous one closer to the substation)
  - Second is that fault current in between substation and cut-out fuse is lower than fault current from cut-out fuse to the place where fault is.
  - **If only one of these two is present than it is considered that selectivity is partially satisfied** and will not work efficiently. This is the case by only adding cut-outs within feeder as fault current is always the same between fault location to the substation.

- Large number of consumers could be affected by possible outage and that would cause huge losses in revenue, possibly damage some equipment, crew will need to work extra to bring power back up etc.

  - ✓ Adding MVROT into the feeder we are fully satisfying both conditions.
    - MVROT has cut-out protection on primary and secondary sides.
    - MVROT input currents (between substation and MVROT – primary side) are always smaller and fault currents will be always smaller by a factor of 0.6 when compared with currents on secondary side of MVROT – toward fault location.
    - This way MVROT cut-out fuse on secondary side will always react first and will limit outage to the small area only.

  - ✓ Smaller consumer group would be affected by outage so minimum revenue would be lost and crew can fix the issue faster as it is localized. This can be estimated in the range of tens of thousand $ to hundreds of thousand $, depending how large consumer group is.

  - ✓ Although harmonics are not measured this time by isolating grid branches this way, this prevents any harmonics generated at secondary side of MVROT to pass back to the substation.

4. Increased grid protection and reduce number of outages

- Grids without layered protection could experience larger numbers of outages that again affect large number of customers. That could be costly if substation is tripping every time some fault happens in the feeder.

- ✓ MVROT brings extra protection that will react first and will reduce number of customers affected. With MVROT being dry type technology some of possible power outages that comes with wet (oil) based transformers are eliminated. This brings one more benefit as it is maintenance free and it is environmentally friendly.

- ✓ Estimated value that MVROT bring by resolving this issue would be in the range of tens of thousand $ to hundreds of thousand $, depends how long three phase feeder is and how many consumers could be affected.

5. Increased energy efficiency, more energy available for retail

- As per the above analyses of the actual dynamic data compared between one week of baseline readings and one week of records when MVROT was energized there are actual savings and revenue generated already at this location. In average we increased energy efficiency in phase "B" feeder line to **8.45% with MVROT** online.

- Based on calculated energy delivered (energy meter to record [kWh] was not part of this Pilot Project) within one week, without and with MVROT, we are getting significant increase for the MH revenue with the additional energy available for sale. Please note, we do not have load characteristics or "cos Φ" that can influence accuracy of these calculated energy delivered results. In our opinion, reasonable assumption would be that load characteristics are not significantly changing for the monitored residential area (no industrial loads are present) and based on this assumption and field records we can calculate delivered energy without and with MVROT.
  - Total energy delivered within one week without MVROT: 13899.32[kWh] (Jan 02nd till Jan 9th, 2020)
  - Total energy delivered within one week with MVROT: 15463.73 [kWh] (Jan 30th till Feb 06th, 2020)
  - (15463.73-13899.32) * $52_{[Weeks]}$ = **81,349.32 kWh/ Year**
  - This represent more energy delivered and sold in one year by using MVROT as is at this location.

- Even the location of the MVROT pilot project is not ideal for this benefit to be fully utilized and significant end results achieved, but still data are clearly demonstrating significant reduction of the energy losses and voltage improvement. There is a large, over a kilometer long, underground cable that has minimal losses due to its cross-sectional size and about 800m OH lines to the pilot project. This is a big factor in power losses as it is in direct relation to them. **Data info is based on a very small load sampling and underutilizing MVROT full capabilities!**

  - ✓ Recorded losses in this branch within a week without MVROT are: 1828.42 kWh
  - ✓ Recorded losses in this branch within a week with MVROT are: 1669.43 kWh
  - ✓ Average resistivity of U/G conduit and O/H lines over 1.82km are: 0.296 [ohm]
  - ✓ 52 weeks in a year
  - ✓ xxx$/kWh – price of electricity
  - ✓ Give us recovered savings of energy: (1828.42-1669.43) * 52 = 8,267.48 kWh/year
  - ✓ The financial gain is double as this recovered losses now can be sold to the consumers for additional gain: 8,267.48 kWh/year * 2 = **16,534.96 kWh / Year**

  - ✓ This economical benefit could be improved drastically if MVROT is installed within long feeder further away from the substation. Estimated gains could be in the range of $ 2,000/year to $ 20,000/year.
  - ✓ These savings and financial gains above are based on recorded small dynamic loads within that branch and underutilization of MVROT total power.

  - ✓ Based on increased energy efficiency, delivering energy is much faster to the end users as calculated above plus reducing losses we have **direct economic benefit** of 81,349.32 + 16,534.96 = **97,884.28 kWh**
  - ✓ **Approximate investment payback time for MVROT here would be between 2 and 6 years depending on $/kWh and if MVROT is fully utilized or not.**

  - ✓ MVROT installed here is already directly generating extra revenue to Utility by being online and energized (recovered energy losses and increased sales are estimated between 10% and 12%).

6. Extended distribution life and distribution coverage

- With constant and exponential growth of the power demands and increase of consumer area coverage, existing grids become overwhelmed and outdated faster than expected. The needs for the new upgraded grids are creating financial strain as they are extremely expensive.

  - ✓ MVROT installation will extend life of the grid and will expand existing substation coverage. Analyses above shows increased energy available for the new users and voltage levels increased. This results in possibility to extend grid into another area farther from substation and eliminate needs for the new substation.

  - ✓ This financial benefit (delayed investment for extra several years) can be estimated in the range of hundreds of thousands to a seven $ figures, depending how big consumer base is to be expanded into and needs for the new grid and substation.

  - ✓ MVROT installation at strategic places within the existing grids will significantly reduce voltage drops and feeder extension will be easy and fast to add. Time and cost will be minimal. Reconstruction of entire feeders will be lengthy and expensive process (requires new – higher voltage level feeder, exchanging all existing step-down transformers, lines, new substation etc.). Dollar ratio savings magnitude between these two are in the range of 1:10 to 1:20.

7. Increased Safety by eliminating currents in neutral and circuit currents in the ground

- Safety is not possible to monetize but it is one of the most important issue all Utilities must address. Depending what issue is in regard to safety the solution could be costly but must be done. One of the issues is current or loads in neutral.

- Currents in neutral line will cause increased voltage drop within neutral conductor that is in direct relation to its cross section and length. This voltage drop within neutral conductor will lower voltages within loaded phases to be below allowed ones, and within non-loaded phases their voltages to be above allowed ones and with that possible damages to the user equipment.

- At the same time these currents in neutral line caused by unbalanced loads and dependant on grounding resistivity could be transferred into the ground (circuit currents) creating unsafe situation to the animals and people within close proximity to the electrical grids.

- People and animals could be exposed to that and cause injuries or worst, fatalities, etc.

  - ✓ MVROT is eliminating currents in neutral from its location all the way to the substation. This will resolve this issue quickly and without big investment.

  - ✓ This safety issue is easily achievable with MVROT.

8. Instrumentation transformers are built in as integral part of MVROT

- Often, Utilities need to install a set of instrument transformers in the grid to collect specific electrical data at different locations along the feeders, and to control and regulate electrical parameters based on the information collected. This way Utilities have the ability to monitor and control grids and this is part of the SMART GRID program.

- These instrument transformer stations require additional equipment to be installed and maintained. Extra space on the poles is also required.

- SCADA system is used as one of the norms to collect the grid perimeters as well as data.

- ✓ Some integral parts of MVROT include built in instrument transformers, two voltage and one current transformer. This means that besides having a nominal 185kVA power transformer, MVROT can be used to connect any auxiliary equipment and do measurements, metering and controls that will eliminate the need for any stand-alone instrument transformer stations at that location.

- ✓ MVROT built in instrument transformers can add value to the SCADA system and can provide SCADA with the exact data in real time for the area MVROT is covering. It is an ideal hardware addition to SCADA systems.

- ✓ An MVROT which is installed within a grid can be easily connected to any auxiliary equipment and wireless data transfer protocols to fully automate and control distribution from control centers. This way these grids will become SMART GRIDS.

- ✓ Financial benefits of having the instrument transformers readily available are measured in tens of thousands to hundreds of thousand dollars in savings depending how big feeders and grids are.

9. Minimum to no Maintenance

- Oil type step down transformers (SDT) need frequent maintenance to ensure oil seals are not leaking and their performances varies with weather due to oil viscosity. Having cancerogenic components in the oil calls for special treatment and special personal protection equipment.

- Traditional dry type transformers are built as one piece and are entirely discarded if anything goes wrong with them.

  - ✓ MVROT, being dry type eliminates any needs for maintenance. Being completely encased in Epoxy resin there are not any environmental and cancerogenic materials present. No need for any special protective equipment when handling MVROTs.

  - ✓ Extremely fast and easy installation is another advantage MVROT has. No need for any big reconstruction of the grid and it works well within existing distribution systems.

  - ✓ The special construction of MVROT means it is easy to change epoxy casted windings from the magnetic core, providing another advantage over any traditional epoxy casted units. There are no other dry type transformers that can be salvaged if anything becomes defective. They are usually discarded.

  - ✓ Replacing casted windings will save time and money as only one component of MVROT needs to be purchased and changed before it becomes fully operational again. Additionally, delivery time is much shorter than ordering new units. Casted winding parts may be pre-ordered to be kept as spare parts.

  - ✓ Windings are the only part that may potentially be damaged in unfortunate events we can not predict. They are built robust, but physical damage due to mishandling or overloading could happen. That is why we construct MVROT in a way which allows us to salvage all other components which could last hundred of years.

  - ✓ Disposing damaged casted windings does not require any special treatment or handling. It can be disposed of at any regular landfill.

  - ✓ The economic benefits here can be measured in hundreds of thousand dollars.

5. CONCLUSION

The MVROT technology implemented within Pilot Project in Estella substation grid in Winnipeg Manitoba at the beginning of 2020 is demonstrating extremely successful records and results. The comparisons between the baseline records and records when MVROT was energized are showing significant improvements in this feeder from several points. Just to name several major ones:

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

Although this pilot project MVROT location was not ideal to accomplish and to demonstrate 100% efficiency and benefits of MVROT technology, these are still great results. MVROT was installed about 1.8 km from substation and just over kilometre of the power line is underground cable. MVROT best performance and benefits are achieved at further distances from the substation.

These live dynamic data records and results are confirmation of the EGC's patented technology beneficial use in live distribution grids and are proof that this technology is superior with dealing with poor quality power and overloaded distribution systems. MVROT technology is economically superior with fast implementation within the existing grids and its use is generating capital return as it significantly reduces energy losses, create grids that works in ideal conditions, so all existing equipment life span is prolonged, plus reducing / eliminating harmonics.

The trial installation of the MVROT has demonstrated the device is a least expensive solution to improving distribution line efficiencies, power quality and reliability. By adopting this approach utilities will increase the return on investment, reduce capital expenditures and improve power quality and reliability to its customers.

All these benefits were addressed in published EGC White Paper at 2018 CIGRÉ Canada Conference in Calgary and with Pilot Project field results they are validated in the live grid. Please refer to our paper published on our website and at CIGRÉ Canada website as well.

Published White Paper:

CIGRE - W2.07 – Abs 12. **2018 CIGRÉ Canada Conference**

Innovative and Effective Method and System for Voltage Improvement, Power Quality and Reduction of Losses in Electrical Power Distribution

A. Lemez, - Energo-Group d.o.o., Sarajevo, Bosnia and Herzegovina
K. Lakiko, D. Lemez, - Energo Group Canada Inc., Calgary, AB - Canada

6. ATTACHMENTS

A. Voltage and Efficiency analyses and graphs

A1. **Excel:** 1ab-GRAPHICAL REPRESENTATION OF MVROT Voltage and Energy Efficiency Analyses_02-JAN to 17-JAN 2020

- PDF: 1a-GRAPHICAL REPRESENTATION OF MVROT Voltage Analyses_02-JAN to 17-JAN 2020
- PDF: 1b-GRAPHICAL REPRESENTATION OF MVROT Energy Efficiency Analyses_02-JAN to 17-JAN 2020

A2. **Excel:** 1cd-GRAPHICAL REPRESENTATION OF MVROT Voltage and Energy Efficiency Analyses_03-JAN to 16-JAN 2020 - Week Dates aligned

-
- PDF: 1c-GRAPHICAL REPRESENTATION OF MVROT Voltage Analyses_03-JAN to 16-JAN 2020
- PDF: 1d-GRAPHICAL REPRESENTATION OF MVROT Energy Efficiency Analyses_03-JAN to 16-JAN 2020

A3. **Excel:** 2ab-GRAPHICAL REPRESENTATION OF MVROT Voltage and Energy Efficiency Analyses_28-JAN to 06-FEB 2020

- PDF: 2a-GRAPHICAL REPRESENTATION OF MVROT Voltage Efficiency Analyses_28-JAN to 06-FEB 2020
- PDF: 2b-GRAPHICAL REPRESENTATION OF MVROT Energy Efficiency Analyses_28-JAN to 06-FEB 2020

B. Amperage (loads) analyses and graphs

B1. **Excel:** 3-4 - GRAPHICAL REPRESENTATION OF MVROT Amperage Analyses_28-JAN to 06-FEB 2020

- PDF: 3a-Amperage at Estella Substation BASELINE - NO MVROT Analyses_02-JAN-2020 to 09-JAN-2020
- PDDF: 3b-Amperage at Estella Substation WITH MVROT Analyses_30-JAN-2020 to 06-FEB-2020
- PDF: 3c-Amperage at Estella Substation BASELINE and WITH MVROT Analyses_02-JAN-2020 to 06-FEB-2020
- PDF: 4a-Amperage in NEUTRAL at Estella Substation BASELINE and WITH MVROT Analyses_02-JAN-2020 to 06-FEB-2020
- PDF: 4b-Percentage of Amperage reduction in NEUTRAL at Estella Substation BASELINE and WITH MVROT Analyses_02-JAN-2020 to 06-FEB-2020

B2. **Excel:** 5 - GRAPHICAL REPRESENTATION OF MVROT-Load analyses at MVROT location_30-JAN to 06-FEB 2020

- PDF: 5a - Amperage analyses at MVROT location - Phase A and phase B loads with MVROT energized_30-JAN to 06-FEB 2020
- PDF: 5b - Amperage analyses at MVROT location - MVROT Secondary Phase a and Neutral loads with MVROT energized_30-JAN to 06-FEB 2020
- PDF: 5c - Amperage analyses at MVROT location - Amperage changes in lines to substation with MVROT energized_30-JAN to 06-FEB 2020
- PDF: 5d - Amperage analyses at MVROT location - Power losses ratio in lines without MVROT _ with MVROT energized_30-JAN to 06-FEB 2020

C1. Drawing: EGC-MH-02-18-022-Rev A
C2. Drawing: EGC-MH-02-18-023-Rev A