BC Hydro
Power smart

BCUC File: 54557

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January 30, 2018

Mr. Patrick Wruck
Commission Secretary and Manager
Regulatory Support
British Columbia Utilities Commission
Suite 410, 900 Howe Street
Vancouver, BC V6Z 2N3

Dear Mr. Wruck:

RE: British Columbia Utilities Commission (BCUC or Commission)
British Columbia Hydro and Power Authority (BC Hydro)
Meter / Meter Base Fire or High Temperature Safety Incident Semi-annual Compliance Report No. 3 – July 1, 2017 to December 31, 2017 (Report)

BC Hydro writes in compliance with Commission Order No. G-124-16 (the **Order**). The Order directs BC Hydro to provide semi-annual reporting for the next three years to the Commission 30 days after June 30 and December 31 on all incidents where a meter and/or meter base is reasonably assessed to be the likely or possible source of a high temperature or fire event that results in the meter and/or meter base replacement.

In June 2017, BC Hydro initiated an additional review process to examine meters returned from the field as a result of *operational work orders* such as meter replacements, new meter installations, service upgrades or changes, building demolitions, non-communicating meters, or non-urgent trouble calls. Meter shop personnel and meter engineers evaluate each returned meter documenting any observations of overheating and probable causes, and capturing photographs.

As a result, this third Semi-annual Compliance Report now provides a listing of all incidents with heat or arcing causing heat at the meter and/or meter base recorded in either the Distribution Trouble and Outage Report (**DTOR**) system or the Incident Management System (**IMS**), as well as any additional observations from the recently initiated meter shop review process, for the six month period ending December 31, 2017.

This review of returned meters from operational work orders has resulted in BC Hydro's identification of additional meters not considered in previous semi-annual reporting periods. Attachment C includes all meters returned from July 1, 2016 to December 31, 2016, and Attachment D includes all meters returned from January 1, 2017 to July 31, 2017 with signs of heat at the meter.

Semi-Annual Compliance Report No. 3

The DTOR system is used to record all BC Hydro trouble calls, the IMS is used to record all safety related incidents or near misses, and the new returned meter review process documents observations of meters returned during routine operational work orders.

There were a total of 10 incidents with heat or arcing causing heat at or around the meter and/or meter base between July 1, 2017 and December 31, 2017.

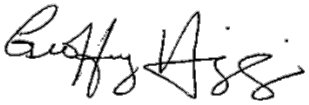
The table below categorizes these heat or arcing causing heat incidents based on BC Hydro's detailed review of the relevant records. Attachment A includes a listing of each incident with the corresponding meter serial number and summaries of Power Line Technician, Meter Technician, and/or Meter Shop comments. BC Hydro has completed its investigation of one of the incidents listed in Attachment A, and has included the report summarizing its conclusions and recommendations as Attachment B.

Category	Description	Number of Incidents
Abnormal Voltage	Customer voltage is outside limits (high or low) for the service class. Example is corrosion in the meter base causes high resistance, low voltage	5
Meter Base	Electrical incident caused by mechanical failure of one or more meter base components	5
Total		**10**

During this same period, BC Hydro attended 162 structure fires at the request of the local fire departments, to shut off power allowing first responders to safely deal with the situation. There were no meters retained by Fire Investigators.

For further information, please contact Geoff Higgins at 604-623-4121 or by email at bchydroregulatorygroup@bchydro.com.

Yours sincerely,



(for) Fred James
Chief Regulatory Officer

cu/af

Enclosure

No.	Meter Serial Number	Category	BC Hydro Observations / Comments
b1	[redacted]	Meter Base	Heat - Post Install - One terminal showed signs of discoloration and a heated backplate. Functioning meter. Disconnected for customer to make repairs to meter base before being re-energized.
2	[redacted]	Abnormal Voltage	Heat - Post Install - Three-phase service, delta connected customer-load meter failure. BC Hydro investigated and determined that the loss of a phase, the customer's dry (no coolant) transformer connected delta-style on the secondary, lightly loaded transformer, and the capacitance of the cable caused an overvoltage beyond the capability of the meter. Therefore ferroresonance is the most likely explanation to this incident. Investigation report is included as Attachment B.
3	[redacted]	Abnormal Voltage	Heat - Post Install - Three-phase service delta connected load meter failure. Further investigation is pending.
4	[redacted]	Meter Base	Arcing - Post Install - Meter base failed; burnt meter removed. Functioning meter.
5	[redacted]	Meter Base	Arcing - Post Install - Examination of customer's service revealed an issue with the meter base jaws causing arcing resulting in a burnt meter base, meter, and conductors. Customer was disconnected to allow them to make repairs to meter base before being re-energized.
6	[redacted]	Abnormal Voltage	Heat - Post Install - Three-phase service delta connected customer-load meter failure. BC Hydro conducted an onsite investigation with Technical Safety BC. The investigation concluded there were grounding issues on the customer side of the service in violation of CEC Code Part I. There was a line to ground fault on the customer's equipment which was also evident at the meter base that resulted in the meter failure.
7	[redacted]	Abnormal Voltage	Heat - Post Install - Three-phase service delta connected load meter failure. Further investigation is pending.
8	[redacted]	Abnormal Voltage	Heat - Post Install - Three-phase 240V delta service and connected load meter failure. Investigation indicated failure of customer equipment caused meter and meter base to fail.
9	[redacted]	Meter Base	Heat - Post Install - Burnt meter and meter base. Functioning meter. Crew was able to obtain reading from meter. Customer was disconnected to allow for repairs to meter base before being re-energized.
10	[redacted]	Meter Base	Heat - Post Install - Burnt meter base. Customer was disconnected to allow for repairs to meter base before being re-energized.

DISTRIBUTION
STANDARDS
BC Hydro

Power Quality Report

[redacted]

File #2017.10.0596

Completed By:		***Engineer of Record:***	
Name:	[redacted]		
Date:	2017-10-26		
Reviewed By:			
Name:	[redacted]	***Name:***	[redacted]
Date:	2017-10-30	***Date:***	2017-10-31

Report Disclaimer

This report was prepared by BC Hydro solely for the purposes described in this report, and is based on information available to BC Hydro as of the date of this report. Accordingly, this report is suitable only for such purposes, and is subject to any changes arising after the date of this report.

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Distribution Standards Power Quality Contacts

	[redacted]	[redacted]	[redacted]
Office:	[redacted]	[redacted]	[redacted]
Cell:	[redacted]	[redacted]	[redacted]
Email:	[redacted]	[redacted]	[redacted]

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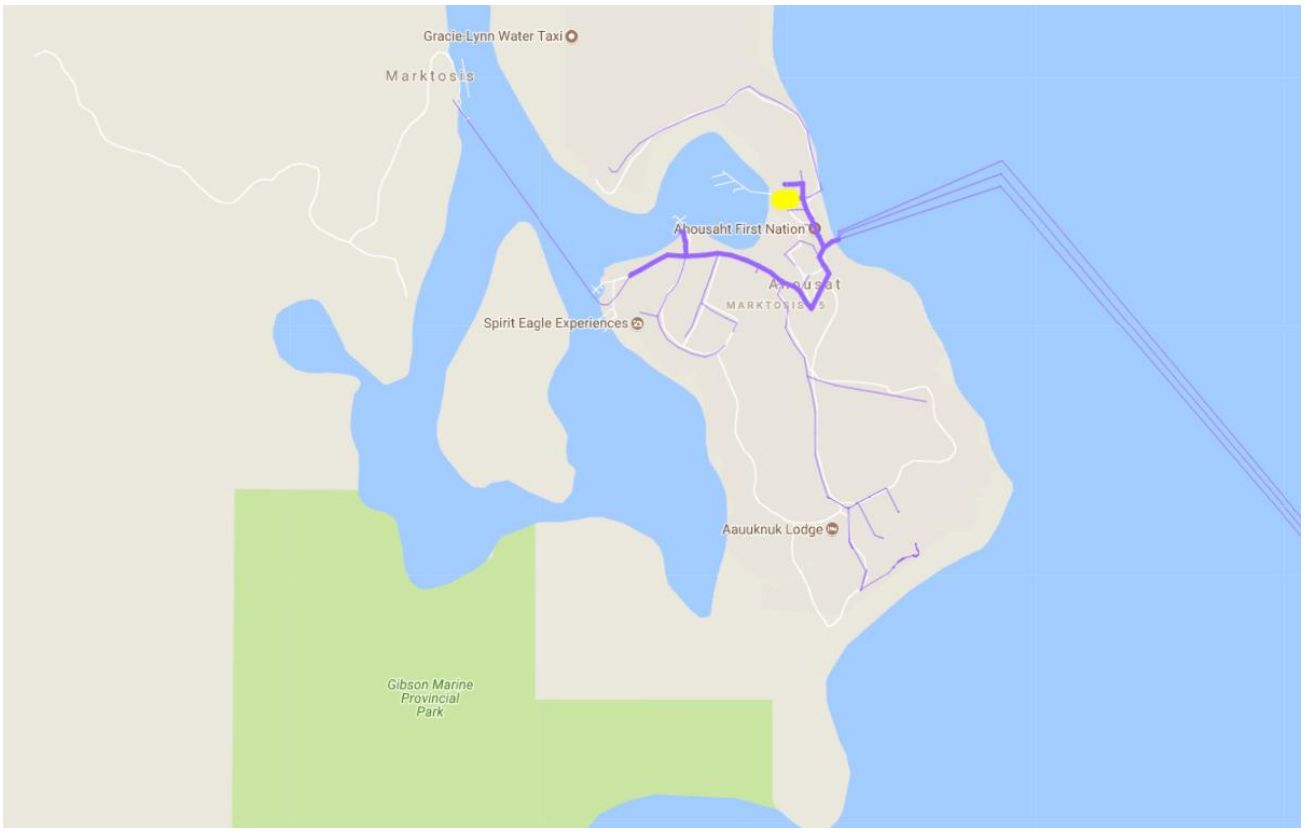
1 Site Information

Table 1 - Customer information

Name:	[redacted]	***Contact:***	[redacted]
Address:	[redacted]	***Phone:***	[redacted]
		Email:	[redacted]
Complaint From:	Line Crew	***BCH Circuit:***	[redacted]
Account Mgr:	N/A	***Meter ID:***	[redacted]



2 Background

On Saturday October 7, 2017 the line crew received a trouble call in Ahousat on circuit [redacted] The complaint was that the meter base [redacted] was arcing and sparking. The meter base is located outside on a private pole [redacted] Once on site, the crew discovered that the revenue meter had blown out of the meter base and landed approximately 4.5 metres away. The meter base sustained substantial damage, melting both the socket and the back of the meter as shown below.

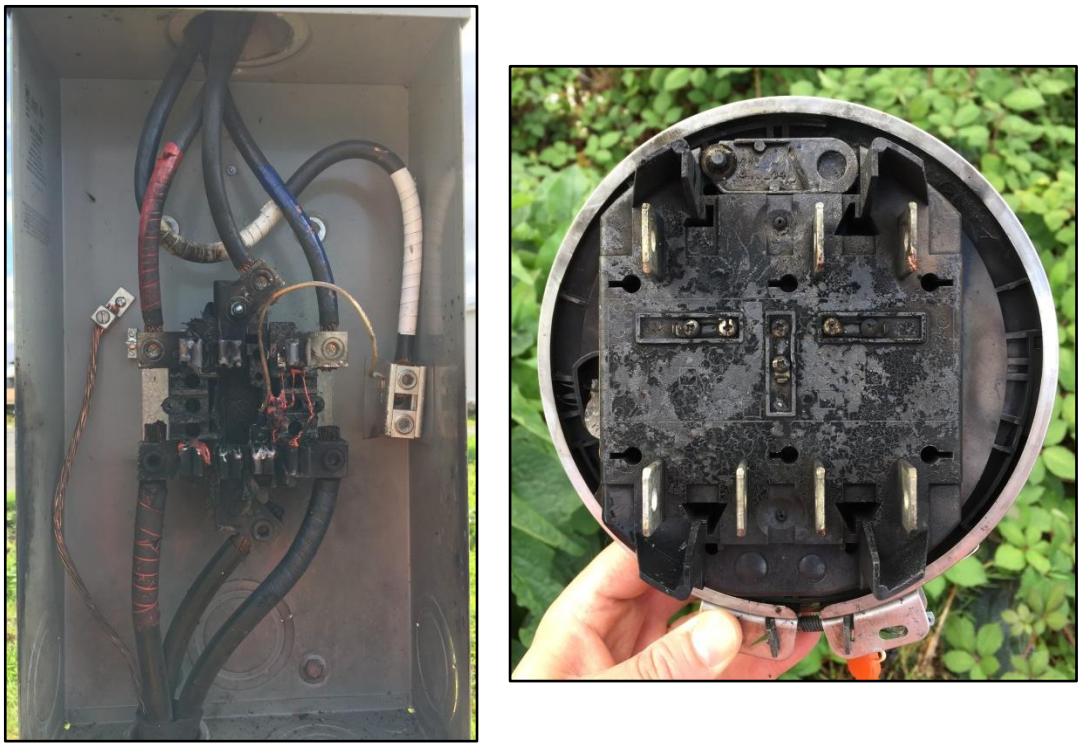


Figure 1 - Meter base and revenue meter damage

Further damage was observed at the conduit between the meter base and the weatherhead as the brackets and conduit appeared to be separated from the bottom half of the pole.

The crew also noticed that the B-phase transformer cutout was open. No birds or animals were found at the base of the pole.

A power quality investigation was initiated to determine the cause of the incident.

This report includes a summary of recorded data and network information retrieved during this investigation. It is intended to be a general overview of the relevant details with discussion about their implications, BC Hydro's conclusions, and recommendations for mitigation where applicable.

The raw data collected during this investigation, and/or other specific details relating to information discussed herein, may be available to the complainant upon request. Please contact PowerQuality@bchydro.com for more information; refer to the PQ reference number of this report when making any inquiries.

3 Investigation Timeline

Table 2 – Sequence of events

Date	*Event Description*
2017-10-07	Revenue meter blows out of meter base.
2017-10-07	Crew receives trouble call.
2017-10-10	Complaint received by Distribution Standards.
2017-10-18	Engineer, crew, and electrician attend site to investigate the incident.
2017-10-26	PQ report completed and investigation closed.

4 Discussion and Observations

The customer is served via dedicated 3x50 kVA transformer bank with approximately 13 metres of #1/0 Quadruplex to the meter base. The transformer configuration is grounded-wye – grounded-wye. The customer loading is minimal; with only a 1 kVA transformer serving approximately 10 LED dock lights, and three transformers (45 kVA, 45 kVA, and 30 kVA), serving receptacles for boat users. The duty on the receptacles is near zero as they are only used on an ad hoc basis.

The secondary network is shown in Figure 2 below.

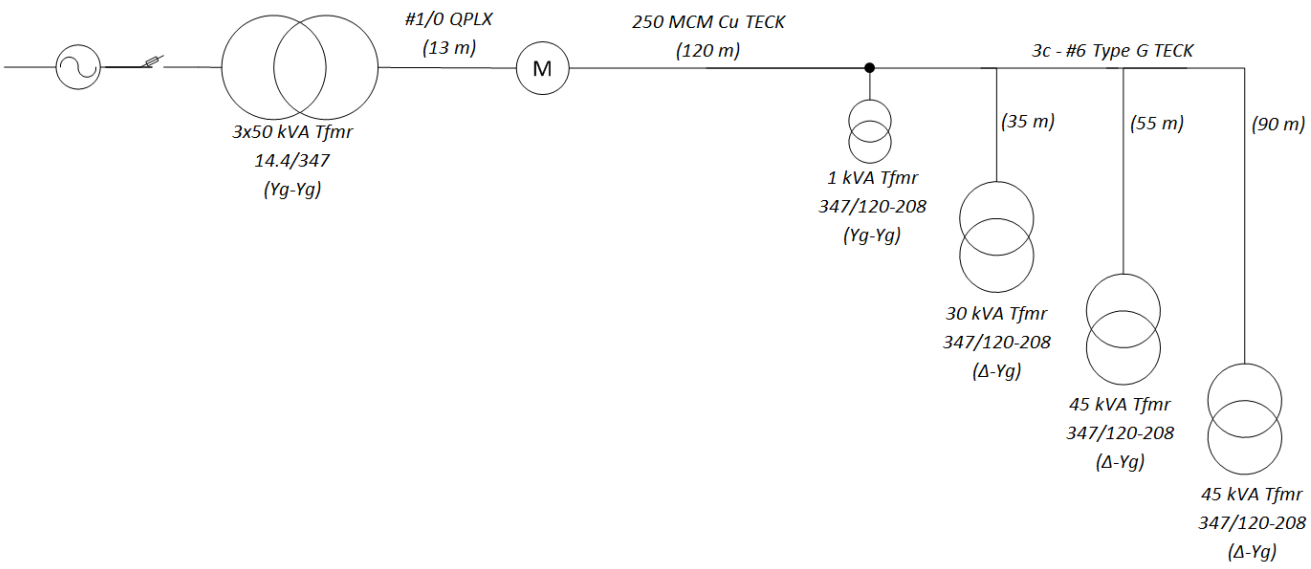


Figure 2 - Secondary network diagram

Since the transformers on the dock are connected delta-wye, only three conductor #6 TECK cable is used to supply them. A separate G-Type cable with a ground conductor runs in parallel out the dock fingers to provide a ground for the transformer secondary. This cable is grounded by three electrodes adjacent to the meter pole.

4.1 Ferroresonance Analysis

Ferroresonance is an electrical phenomenon that can cause critical equipment damage in extreme cases, or may not even be noticed in mild cases. The condition can occur in a circuit when there is capacitance (C) available to resonate with the transformer inductance (L).

Ferroresonance occurs when one or two phases of a lightly-loaded three-phase transformer are energized, either during switching or loss of phase(s). It will only occur in situations where the inductance of the transformer becomes in series with the capacitance of the de-energized phase(s).

There are several factors that determine whether or not ferroresonance can occur.

4.1.1 Transformer Configuration

The first factor is the configuration of the transformer. The table below shows that unless connected in a delta configuration, an overhead 3-phase transformer bank will not cause ferroresonance. The BC Hydro service to the [redacted] is therefore immune. However, the delta connected 3-phase transformers on the customer's secondary are susceptible due the direct electrical connection of the phases.

Table 3 - Transformer connection susceptibility to ferroresonance

Transformer Primary Connection	Overhead	Underground
Grounded Wye	Immune	Susceptible
Delta	Susceptible	Susceptible

Figure 3 shows the series resonant circuit of a delta connected primary transformer when one phase is open.

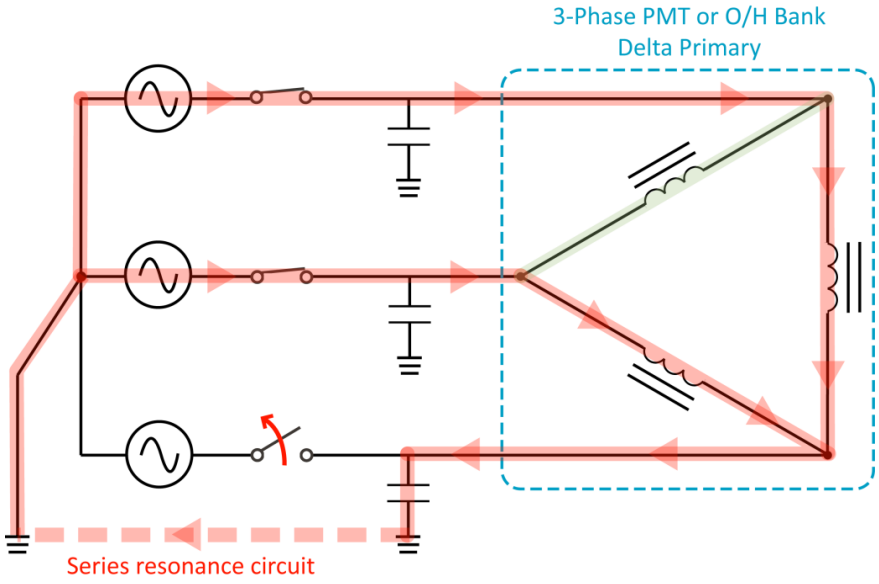


Figure 3 - Ferroresonant circuit in a delta connected primary transformer

4.1.2 Available Capacitance

Another factor that must be considered is the available capacitance in the circuit to resonate with the transformer. This is indicated in Figure 3 by the cable capacitance to ground and internal transformer capacitance that are in series with the transformer inductance. .

At the [redacted] there is between approximately 170 m and 225 m of cable between the BC Hydro service transformer and the customer's delta connected dock transformers. Note that for a smaller transformer such as the customer's dock transformers, it takes far less capacitance to cause resonance. This is due to the fact that the inductance in the transformer winding is much smaller in these transformers and when the transformer saturates (as in ferroresonance); the leakage inductance is even smaller than that.

4.1.3 Transformer Loading

Finally, the loading on the transformer is critical to ferroresonance. Loading greater than 5% of the transformer's nameplate capacity is generally enough to dampen the resonant response of ferroresonance. In this case, the transformers are unloaded almost all of the time and susceptible to ferroresonance

4.1.4 Ferroresonance Model

Ferroresonance can be modelled using EMTP when enough of the equipment information is known. The specific geometry and make of the service cables as well as the loss and saturation characteristics of the transformer are important to the model.

Unfortunately not enough information is available to accurately predict ferroresonance with an EMTP model in this case.

4.1.5 Proposed Sequence of Events

After investigating the scene, the electrical system, and factoring the anecdotal evidence, the suspected sequence of events is given below:

1. Animal contact at the BC Hydro transformer causes B-phase cutout to open. The contacted animal may have been carried away from the pole by other wildlife or by a stray dog in the village.
2. A series resonance is created with one of the customer transformers and the open circuited secondary cable.
3. One of the unloaded transformers saturates and begins to ferroresonate with the upstream cable capacitance.
4. The oscillations in the voltage magnitude cause vibrations in the conduit on the meter pole causing the conduit and brackets to separate from the pole.
5. The magnitude of the overvoltage associated with ferroresonance increases until the revenue meter flashes over and blows out of the meter base, open circuiting the system.

5 Conclusions and Recommendations

5.1 Conclusions

To summarize the criteria for ferroresonance and how they apply to th [redacted] the following conclusions can be made:

1. Was there a loss of phase?	**Yes** – B-phase found open when the crew attended site.
2. Is the 3-phase transformer a PMT or Vault or O/H delta or ungrounded-wye primary?	**Yes** – Customer transformers are delta primary.
3. Is the transformer lightly loaded?	**Yes** – The transformers are almost always unloaded.
4. Is there capacitance available to excite a resonant circuit?	**Yes** – There is 170 - 225 m of cable upstream of the customer's transformers.

Ferroresonance often causes symptoms of overheating on a transformer, or in this case the meter cabinet, which is consistent with what was found. The overvoltage associated with the resonance can also take several seconds to minutes to increase to magnitudes that cause damage. This would explain why the meter took so long to fault. Finally, none of the overcurrent protection on the customer's secondary operated during this event, nor is any damage evident to the breaker panels or transformers. Therefore, ferroresonance is the most likely explanation to this incident.

5.2 BC Hydro Recommendations

BC Hydro should work to assist the customer in mitigating the potential for ferroresonance to reoccur. Since the grounded wye-grounded wye service transformer is already immune to ferroresonance, it is the customer's responsibility to mitigate issues associated with their transformers. However BC Hydro can assist by installing more wildlife protection on the transformer pole. Several options for wildlife protection are given below:

1. Ensure that the bird guard on the HV bushing is installed under the top shed of the bushing.
2. Replace existing drop lead conductors with #2 bird wire (CAT ID 380-4850) as indicated:
    a. From the primary to the transformer cutout, and
    b. From the cutout to the transformer.
3. Ensure surge arrester caps are installed.
4. Inspect existing bird guards for damage (cracks, bent or missing teeth) or decay. Replace as required. Refer to ES43 W4-01.

The crew should install this additional protection at the direction of the regional distribution engineer.

The GIS shows that the next upstream feeder protection device from this customer is the recloser upstream of the submarine cables in Tofino. Therefore, losing one phase at the feeder level is not of concern since the recloser will operate on all phases if there is a permanent fault (gang operated). Therefore, for BC Hydro, only the service transformer protection is of concern in preventing ferroresonance.

IMPORTANT: The crew should be aware that the service is prone to ferroresonance if they ever need to switch at this transformer. The crew should ensure that either the service is loaded during switching, the customer's service is disconnected, or as a last resort, switching is completed in a timely manner.

5.3 Customer Recommendations

Since the issue is likely caused by customer equipment it is their responsibility to address concerns with their electrical system. It is recommended that the customer engage their electrical consultants to determine an appropriate course of action for mitigation of ferroresonance.

Currently any fault on the customer's network could theoretically cause the same issues. There are several mitigation techniques available to reduce or eliminate the risk of ferroresonance.

Eliminating ferroresonance:

1. Install permanent resistive load banks on each transformer secondary of 5% - 10% of the nameplate capacity.
2. Install loss-of-phase protection to ensure that if one phase of the service is lost, all three phases will trip.

Reducing the risk of ferroresonance:

1. Installing a ferroresonance dampening device on the transformer secondary could be considered.

If measures are not put in place it is possible that this type of incident and damage could reoccur in the future.

NOTE: BC Hydro power quality engineers are specialists in power system electrical engineering. As such, any recommendations presented for BC Hydro customers should be reviewed with a qualified engineering consultant and/or electrical contractor before implementation.

Meters Returned from Operational Work Orders for the period July 1, 2016 to December 31, 2016 (Not Previously Reported)

No.	Meter Serial Number	Category	BC Hydro Observations / Comments
1	[redacted]	Meter Base	Heat - Post Install - Demolition Order. Functioning meter. Discoloration on one terminal consistent with a loose meter base jaw issue.
2	[redacted]	Meter Base	Heat - At Install - Meter Removal and Replacement. Functioning meter. Discoloration on two terminals and minor areas on backplate consistent with a loose meter base jaw issue.
3	[redacted]	Meter Base	Heat - Post Install - Demolition Removal. Functioning meter. Discoloration on one terminal consistent with a loose meter base jaw issue.

Meters Returned from Operational Work Orders for the period
January 1, 2017 to June 30, 2017 (Not Previously Reported)

No.	Meter Serial Number	Category	BC Hydro Observations / Comments
1	[redacted]	Meter Base	Heat - At Install - New Install after removing temporary meter. Functioning meter. Discoloration on one terminal and black smoke trace on backplate of meter, consistent with a loose meter base jaw issue.
2	[redacted]	Meter Base	Heat - At Install - Meter Replacement. Non-functioning meter. Discoloration and burnt backplate on three of four terminals and internal burnt component consistent with a loose meter base jaw issue.
3	[redacted]	Meter Base	Heat - Post Install - Demolition Removal. Functioning meter. Discoloration on one terminal consistent with a loose meter base jaw issue.
4	[redacted]	Electrical Overload	Heat - Meter Replacement. Functioning meter. Discoloration on one terminal. Appears to be an current overload condition as meter captured a peak power usage of 50kW which is higher than the service is rated for.
5	[redacted]	Meter Base	Heat - At Install - Service Upgrade. Functioning meter. Discoloration on one terminal and backplate slight melting around the terminal consistent with a loose meter base jaw issue.
6	[redacted]	Meter Base	Heat - At Install - Meter Replacement. Functioning meter. Discoloration on two terminals and backplate slight melting consistent with a loose meter base jaw issue.
7	[redacted]	Meter Base	Heat - At Install - Meter Replacement. Non-functioning meter. Discoloration on one terminal consistent with a loose meter base jaw issue. Further investigation is pending.
8	[redacted]	Meter Base	Heat - Post Install - Demolition Removal. Functioning meter. Discoloration on one terminal consistent with a loose meter base jaw issue.
9	[redacted]	Meter Base	Heat - At Install - Demolition Removal. Non-functioning meter. Discoloration on one terminal consistent with a loose meter base jaw issue.
10	[redacted]	Meter Base	Heat - At Install - Maintenance Order. Functioning meter. Discoloration on one terminal and melted backplate consistent with a loose meter base jaw issue.
11	[redacted]	Meter Base	Heat - At Install - Service Upgrade. Functioning meter. Discoloration and on one terminal and melted backplate consistent with a loose meter base jaw issue.