
Consultancy Services for the Plant Audit in various Pump Stations and Reservoirs (OP18REFCS03)

Technical Report for Ayala South Vale (ASV) Pump Station
(Mechanical and WEM)

reference: OP18REFCS03-GHD-ASV-REP-G001B

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Contents

1	Introduction	1
1.1	General introduction	1
1.2	Objectives	2
1.3	Scope of Work	2
1.4	Limitations	2
1.5	Glossaries	2
2	Preliminary Assessment and Data Gathering	5
2.1	Maynilad's data	5
2.1.1	Intervention records	5
2.1.2	Interview data	6
2.1.3	Asset hierarchy	6
2.2	Preliminary assessment	7
2.3	Summary of the inspection test plan (ITP)	7
2.3.1	Mechanical Audit	8
2.3.2	Vibration and structural assessment	11
2.3.3	Workplace environment management	11
2.3.4	Fire protection and safety (FDAS) audit	12
2.4	Electrical Audit	13
2.5	Database	13
3	Methodology	15
3.1	The Integrated Asset Management Approach (IAM)	15
3.2	Deterioration process and rating index	15
3.3	Condition State (CS) definition	18
3.4	Technical efficiency	18
3.5	Reliability	19
3.5.1	Qualitative and Operational Analysis	19
3.5.2	Weibull model	20
3.5.3	Markov model	21
3.6	Intervention Strategy (IS)	22
3.7	Determination of optimal intervention strategy	22
3.7.1	Block Replacement Model	22
3.7.2	Time-dependent replacement model	24
4	Data and Analysis	27
4.1	Qualitative and Operational Analysis	27
4.1.1	Facts and Data	27
4.1.2	Way forward/Recommendations	28
4.2	Pump discharge and suction pipe - thickness	28
4.2.1	Data and measurement	28
4.2.2	Analysis	28
4.3	Visual Inspection on Pipe, valves, fittings, supports, expansions, and appurtenances	33
4.3.1	Highlights	33
4.4	Vibration and structural assessment	36

4.4.1	Measurement and spectrum reading	36
4.4.2	Data and analysis	38
4.4.3	Recommendations	38
4.5	Energy management audit	38
4.5.1	Production and power data	38
4.5.2	Measurement errors	39
4.5.3	Data compilation for analysis	39
4.5.4	Analysis	40
4.5.5	Recommendation	41
4.6	Workplace environment management	42
4.6.1	Temperature and relative humidity	42
4.6.2	Air quality	43
4.6.3	Illumination	44
4.6.4	Industrial ventilation	45
4.6.5	Housekeeping	46
4.6.6	Noise	48
4.7	Visual inspection on electrical assets	49
4.8	Short circuit calculations and evaluation	49
4.8.1	Short circuit calculation	49
4.8.2	Evaluation of protective devices and bus bars	51
4.9	Voltage drop calculation	54
4.10	Load flow study	54
4.10.1	Analysis based on design	55
4.10.2	Analysis based on measured data from the PQA	55
4.11	Protection coordination study	59
4.12	Harmonic study	62
4.12.1	As per design	62
4.12.2	Per actual	62
4.13	Power quality analysis	67
4.13.1	Objectives and expected outcomes	67
4.13.2	Basic	68
4.13.3	Results	68
4.13.4	Conclusion and Recommendations	71
4.14	Grounding system study	72
4.15	Electrical system design and analysis	73
4.15.1	Basics	73
4.15.2	Results	74
4.15.3	Recommendations	76
4.16	Fire protection and safety (FDAS) audit	76
4.16.1	Fire alarm and detection system	76
4.16.2	Lighting protection system	84
4.16.3	Ground-Fault circuit interrupter (GFCI) or electric leakage circuit breaker (ELCB) or Residual circuit devices (RCD)	86
4.16.4	Electrical safety and protective devices	86
5	Conceptual Design and Reliability Study	89
5.1	Basis of Design	89
5.1.1	Drawings	89
5.2	Bill of Materials	89
	Bibliography	91
	A Recommended Maintenance Program	93
	B Vibration Data	99
	C Load Flow Analysis	127

D Power Quality Study	135
E Drawings	179
F Bill of Quantity	191

Preliminary

Preliminary

Chapter 1

Introduction

1.1 General introduction

The station is located in Ayala Alabang, Muntinlupa (refer to Figure 1.1 - a and Figure 1.1 - b). The station services two areas namely, Southvale and Sonera. Two 10HP long coupled pumps (Figure 1.2 - a) deliver to Southvale and another two 15HP close coupled pumps (Figure 1.2 - b) deliver water for Sonera area. Built in 1985, this is one of the stations with the smallest average power consumption of only 7,841 kW per month.



a - [14°23'55.86.74" N, 121°0'5.98" E]

b - Pump House

Figure 1.1: ASV PSR



a - Southvale service pumps

b - Sonera service pumps

Figure 1.2: Pump gallery

This PS has been included by the Client in the first cluster of pump stations for systems audit, benchmark establishment and asset management.

The Client has therefore awarded GHD and its sub-consultants (RB Sanchez and APSI) to conduct a plant audit project with an expectation to establish rigorous asset management framework based on reliability study and to determine optimal intervention program for the next five (5) years.

1.2 Objectives

The objectives of this work are as follows

- To evaluate the current operating condition of PS as compared to the original design intent and to provide recommendations for improving the operational efficiency and lowering operating cost;
- To be able to determine an optimal intervention program for the PS in the next 5 years with reference to the recommendations from the assessment and audit based on life cycle cost; and equipment efficiency study whether the equipment is subjected to replacement or repair. These equipment are:
 - Pumps;
 - Motors;
 - Generators;
 - Electrical System and Protective Device;
 - Substation (Transformer, Switchgears);
 - MCC (VFDs, Soft starters, Circuit Breakers, and Protective Devices);
 - Motorize Valves.

1.3 Scope of Work

Scope of Work (SOW) has been defined in the Contract Agreement and be in compliance with the GHD technical and financial proposal and the agreements made during a number of project meetings (refer to minutes of meeting of the project).

1.4 Limitations

Results of the study with analysis, conclusion, and recommendations are only within the scope of work and agreements, and particularly under the following major constraints:

- Operational constraint: It was not possible to shutdown the entire PS for visual inspection of assets, particularly mechanical assets;
- Incomplete historical data: It was a matter of fact that Maynilad has not established an asset management system, thus data regarding historical intervention is limited and incomplete, leading to non-optimal reliability analysis;

1.5 Glossaries

Following glossaries are defined and used in the report:

Level of Services (LOS)

A Level of Services (LOS) is any value or expectation of asset managers and beneficiaries regarding the functionality and serviability of an asset or a system of assets.

Intervention

Intervention is a generic and global term used to refer to non-physical and physical activities on assets. It encompasses do-nothing, or do somethings like repair, maintenance, rehabilitation, renewal, investment, and inspection and testing.

Corrective Intervention (CI)

A Corrective Intervention (CI) is an intervention executed without proper and systematic plan. An CI is often incurred by failure/breakdown of assets. In most of cases, it incurs significant negative impacts (e.g. cost to repair, disruption of service, loss in revenue).

Preventive Intervention (PI)

A Preventive Intervention (PI) is an intervention executed with proper and systematic plan. Note that an PI is executed on asset that is still working but not provide adequate level of services.

Intervention Type

An Intervention Type (IT) is a specific and well-defined type of work/task that can be executed on/for an asset (e.g. replacement of a bearing for a pump).

Intervention Strategy (IS)

An Intervention Strategy (IS) is a set/collection of intervention types.

Intervention Program (IP)

An Intervention Program (IP) is a set/collection of intervention strategies for one asset or more than one assets of the same system.

Work Program (WP)

A Work Program (WP) is an execution program consisting of Intervention Program and management program (e.g. project management, procurement) that shall be implemented in order to realize/actualize the Intervention Program.

Preliminary

Chapter 2

Preliminary Assessment and Data Gathering

GHD conducted preliminary assessment on a set of data provided by Maynilad. The data set includes a number of records on daily production and power consumption and intervention reports issued after Maynilad experienced failure/breakdown of assets.

The assessment provided a base for GHD to generate the Inspection Testing Plan (ITP) [6] aiming to gather necessary data for conducting reliability study. The ITP has been reviewed by Maynilad, together with the Work Safety Permit (WSP), prior to execution of visual inspections and testings at the site.

2.1 Maynilad's data

Maynilad provided a set of data as shown in Table 2.1

Table 2.1: Data provided by Client.

No.	Data	Remarks
1	As-built drawings	no CAD drawings, only PDF
2	Monitoring dashboard	Year 2015 to 2017
3	CI records	None
4	Asset registry	Asset registry was incomplete as confirmed by the IAM team of Maynilad.

2.1.1 Intervention records

There are no CI reports for this station. Furthermore, the most important historical data concerning specific failure of components of pumps with elapsed time is missing. Thus, the provided information is not useful for detailed reliability study on frequent failure of assets at component level.

The problem with missing specific failure data was due to a matter of fact that Maynilad still has not come up with preventive maintenance program within the overall asset management framework. The IAM team has recently established with expectation to generate short-term, medium-term, and long-term preventive intervention program. In close discussion with Maynilad, GHD learns that Maynilad has a regular/frequent activities for check-up (e.g. monthly and quarterly), however, recorded data has not been digitalized and the data itself has not aligned well with the asset registry.

Table 2.2 presents highlights on intervention data on pumps.

Table 2.2: Highlight of intervention data on pumps.

Pump	Description of PI/CI	Date/Remarks
All Pumps	Inspection of pump drive coupling, mechanical seal, MCC components. Conducted pump and motor vibration test using vibration meter and monitored bearing condition using thermal scanner. Also check gen-set's engine oil, radiator's coolant, battery solutions and filters.	Regular monthly maintenance activity, may vary at times depending on availability of test equipment
Southvale P2	Replacement of torishima pump	6/15/2015
	Replacement of mechanical seal	7/9/2015
	Pull-out of defective pump unit	7/27/2015
Southvale P1	Replacement of mechanical seal	7/9/2015
Sonera P1	Replacement of Element Coupling (Lovejoy 110)	N/A
N/A	Installation of Pump 1 - pump and motor alignment	4/9/2016

2.1.2 Interview data

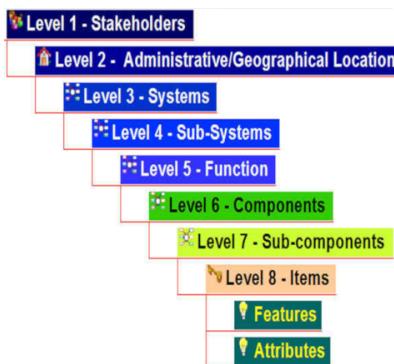
GHD conducted an interview session on 07/12/2018. Results of the interview are summarized in the minutes [4], with the following highlights.

- No further data is available aside from the provided set presented in earlier section;
- There is an existing regular check-up for assets but data is not digitalized and the information is only generic;
- Spare parts are not stocked for most of components, except for bearing. Regarding service delivery, the required discharge pressure remains the top priority in pump operation modulation and sequencing. Critical parts and components for VFD and bearing are usually stacked to have spared in case of emergency repair and replacements. The consumables on the other hand, are not stacked but ordered in advance for use in maintenance activities;
- No visual bank of assets;
- No standard testing regime that follows a regular scheme based on optimality;
- Pumps are operated based on pressure and not manual;
- No existing PI/CI procedure to be followed;
- No expansion plan is forecasted; physically impossible to add another pump in the existing pump room
- There is a problem with the inflow of incoming water, leading to lower level of reservoir chambers that has affected pump operations occasionally;
- no historical data on pump efficiency, which is a simple yet useful value in determining pump performance. The main impediment in the individual pump efficiency is the measurement of flow produced by each pump. The existing configuration of the pump-motor and piping system do not cater to conventional methods of flow determination;
- No intervention records for FDAS. It was revealed that different version on operation and functionality of the FDAS was reported by both guard and site operators.

2.1.3 Asset hierarchy

During the bidding phase, Maynilad did provide the first draft of the Asset Registry (AR) that describes a hierarchy of eight (8) levels. Figure 2.1 visualizes the hierarchy with brief description presented in Table 2.3.

GHD received the latest version of the AR with about 100 assets for this PS. The full list of assets is given in the excel file provided by Maynilad in 2018. GHD has developed a MS Access

**Figure 2.1:** Asset Hierarchy**Table 2.3:** Condition state definition - Multiple.

Asset hierarchy	Description
Level 1	Stakeholder level. For example, an pump station belongs to MWSI
Level 2	Geographical locations/ or administrative zone (e.g. a pump station belong to Quezon city or Makati)
Level 3	System (e.g. the entire pump stations and reservoir system)
Level 4	Sub-system (e.g. one specific pump station and reservoir such as the Lamesa PSR)
Level 5	Functional system (e.g. booster system or storage system)
Level 6	Component (e.g. Suction line, Reservoir line and Tank)
Level 7	Sub-component (e.g. Suction pipe and fittings, Concrete reservoir, pump)
Level 8	Items (e.g. valve, bearing, motor)

program to convert the data in the excel file to a relational database structure. Per agreement with Maynilad, GHD will only verify level 7 of the AR with the actual site condition for the study [5].

2.2 Preliminary assessment

Assessment on the latest provided intervention records reveals that the provided pertinent data is incomplete and cannot be used as representative data for a complete reliability study.

It is also confirmed from the provided data that the Client has done regularly check-up on GENSETs to ensure that it provides adequate level of services in case of emergency. To date, no failure records has been observed for the GENSET.

Further evaluations and tests have to be conducted to identify the areas for improvement of preventive measures in mitigating corrective measures and study the ways to strengthen preventive measures to improve operating conditions and life of pump components.

Improving the reliability of the pump stations for the next coming years require evaluation of the existing pump station conditions and maintenance practices, particularly assessment of the pump and its components. With that, areas for improvement of operation and maintenance be addressed through action items that come from the resulting recommendations.

In order to capture a relatively good picture on the reliability of the pump system and its associated assets, a number of tests shall be conducted.

2.3 Summary of the inspection test plan (ITP)

A complete write-up on testing shall be referred to the ITP [6], which has been submitted, reviewed, and approved by the Client. This section only provides highlights to help readers keeping abreast of the flow of the report.

2.3.1 Mechanical Audit

The Mechanical Tests to be conducted are enumerated and discussed hereunder including their background and applications, standards used if applicable, and the equipment to be used. During testing, the following are the assumptions and considerations:

- The operation of the pumps cannot be interrupted (at day time when demand is high).
- The valve settings then cannot be adjusted to produce different flow rates.

2.3.1.1 Structural Inspection for Pump Discharge and Suction Line

This activity measures the current thickness of the existing pipelines at the pump vicinity using ultrasonic thickness gauging. The flow regime especially around the elbow and possibly corrosion and scaling conditions are to be predicted from the measurements of this test.

Following procedures will be executed

Step 1: Locate and mark testing points

At a minimum of two (2) meters away from the pump intake/discharge flange, the test points shall be marked at 3, 6, 9 and 12 o'clock positions and at one (1) meter interval along the pipes, additional test sections with same set points shall be added as long as available beneath the immediate ground level.

Step 2: Prepare test point surfaces

- Wipe the surface free of dirt (no need to remove paint)
- Using a chalkstone (erasable), mark x on the test point

Step 3: Apply sufficient couplant on test point surface

- Use petroleum jelly/Vaseline as couplant

Step 4: Set transducer probe on test point

Step 5: Read and record value as indicated on module display

Step 6: Clean test point after reading

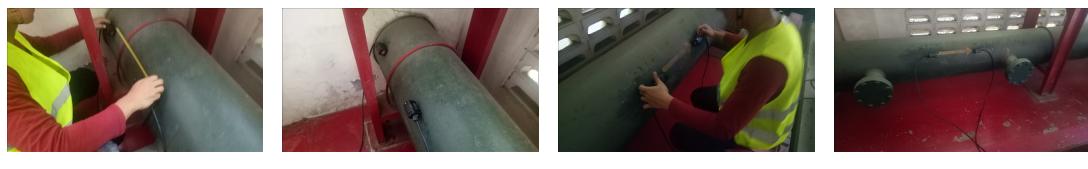
2.3.1.2 Unit Flow Measurement

The activity measures pump capacities. Pump efficiency is then calculated using the measured values.

Step 1: Locate Sensor Position Point Area and mark all points to be taken.

- Observe required offset distance from fittings/pump to consider the fully developed flow. At least 10 times the diameter distance away from the suction/discharge of the pump if applicable, otherwise consider at least 2D distance away from the fittings. This is to ensure the flow will be stable and fully developed for flow measurement accuracy
- Otherwise, test at near turbulent zones and consider normalizing the flow.

In particular, the headers can be chosen as set points for flow measurement. (Figures 2.2 - a to d).



a

b

c

d

Figure 2.2: UFM testing points

Step 2: Pipe Specification Input on the Flow Meter.

- Identify nominal pipe size with equivalent parameters such as schedule designation, equivalent thickness, OD, and etc.
- Input outside diameter.
- Input pipe thickness.
- Input pipe material (carbon steel).
- Input pipe medium (water).

Step 3: Prepare test point surfaces

- Clean the surface of pipe with a sandpaper and steel brush or any suitable abrasive materials, exposing the base metal.

Step 4: Install transducers at set points

- Apply enough couplant that it covers transducers sensors to ensure an acoustically conductive connection to the pipe. Also apply couplant on the test point surface
- Clamp the transducers at the side of pipe using metal chains, straps or mounting rails Observing proper spacing and alignment. Note flow direction and install transducers at either 0 or 45 degrees, whichever would give more stable reading
- Wait for the module to display "System Normal" before reading. Inspect set-up for any fault and properly reinstall if signal is poor/low (no reading)

Step 5: Data gathering

Read and record all necessary data measurement by the equipment, (i.e. flow, fluid velocity, sound velocity, Reynolds number, etc.)

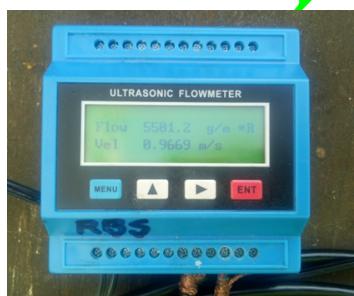


Figure 2.3: UFM Measurement Display

Step 6: Remove transducers and restore paints

Remove the transducers and restore the surface of pipe after measurement.

2.3.1.3 Suction and Discharge Pressure Measurement

The activity measures each pump suction and discharge pressure. The pump efficiency is then calculated using the measured values.

Step 1: Disassembly of existing Pressure Gauge

- Inspect for any leaks or unusual noise before proceeding: If anything is detected, report immediately to the operator;
- Close gate valve located before the pressure gauge and wait for the pressure reading to drop;
- Remove the pressure gauge: (1) Hold the adapter steady with one wrench and the grip the stationary socket of the pressure gauge with another; (2) Loosen the pressure gauge then remove it.

Step 2: Installing the Pressure Gauge

- Prepare the connections: (1) Clean the connections before installing; (2) Put Teflon tape on the pressure connection of the gauge;
- Install the pressure gauge: (1) Mount the pressure gauge on the adapter then hand tighten the arrangement; (2) Further tighten the assembly using a pair of wrenches: hold the adapter steady with one wrench and the grip the stationary socket of the pressure gauge with another; (3) Tighten the assembly;
- Inspect the assembly again.

Step 3: Reading the pressure

- Slowly open the gate valve: Observe any leaks or unusual noise;
- Measurement: (1) Wait until reading is stable; (2) Record the pressure as indicated.

Step 4: Restoring the earlier gauge

- Inspect for any leaks or unusual noise before proceeding: If anything is detected, report immediately to the operator;
- Close gate valve located before the pressure gauge and wait for the pressure reading to drop;
- Remove the pressure gauge: (1) Hold the adapter steady with one wrench and the grip the stationary socket of the pressure gauge with another; (2) Loosen the pressure gauge then remove it;
- Prepare the connections: (1) Clean the connections before installing; (2) Put Teflon tape on the pressure connection of the gauge;
- Install the pressure gauge;
- Mount the pressure gauge on the adapter then hand tighten the arrangement;
- Further tighten the assembly using a pair of wrenches: hold the adapter steady with one wrench and the grip the stationary socket of the pressure gauge with another;
- Tighten the assembly.

2.3.1.4 Parameters

Parameters was recorded using visual inspection form, interview questionnaire, and testing results. Main parameters are listed, but not limited to, in the Table 2.4. Raw data is enclosed in the Appendix.

Table 2.4: Main parameters to be collected.

Parameters	Symbol	Remarks
Pipe thickness Gauge	t	mm
Pump Capacity	Q	Gpm/cmh
Suction Pressure	Ps	mH2O
Discharge Pressure	Pd	mH2O
Vibration Data	-	-
Head	H	mH2O
Efficiency	e	%

2.3.2 Vibration and structural assessment

This activity measures the vibrations of the pump and motor at the drive and non-drive ends. The data will be used to address pump vibration problems such as cavitation, pump flow pulsation, bent pump shaft, pump impeller imbalance, shaft misalignment and bearing problems.

Following procedures will be executed

Step 1: Test location identification

Locate the testing points on drive and non-drive ends of pump and motor

Step 2: Set transducer probe on test point. Observe HIRAC for access to elevated positions

Step 3: Read and record value as indicated on module display (Figure 2.8 - d)



Figure 2.4: a



Figure 2.5: b



Figure 2.6: c



Figure 2.7: d

Figure 2.8: Vibration Analyzer Test

2.3.3 Workplace environment management

GHD/RBSanchez conducted measurements at designated locations (Figure 2.9) to record values of parameters presented in Table 2.5.

Table 2.5: WEM Parameters.

Parameters	Symbol	Units
Dry Bulb Temperature	tdb	oF/oC
Relative Humidity	RH	%
Sound Intensity	-	dB
PM 2.5 Count	PM2.5	$\mu\text{g}/\text{m}^3$
Visible useful light	-	Lux

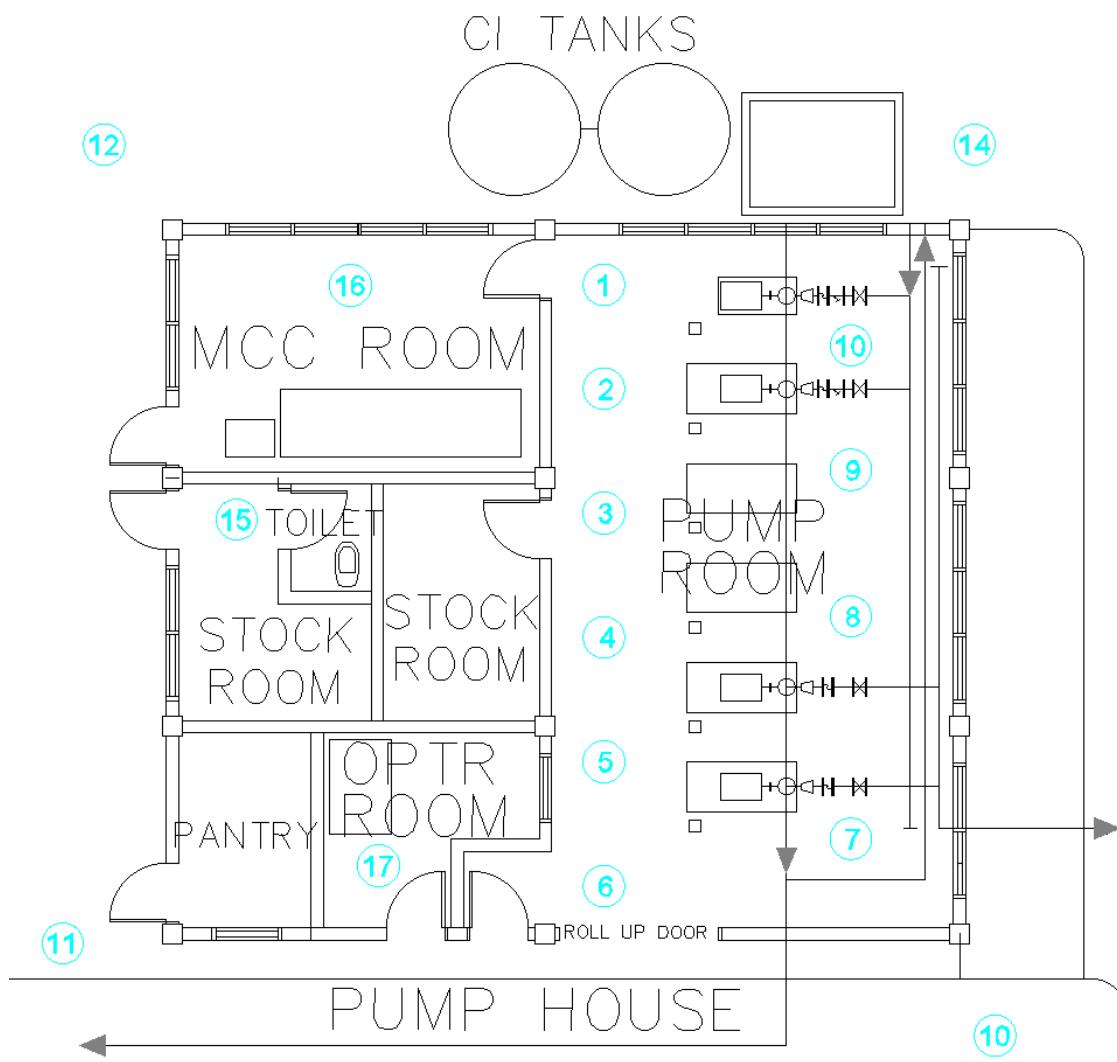


Figure 2.9: Testing locations

2.3.4 Fire protection and safety (FDAS) audit

Audit on FDAS has been conducted following sequences

Step 1: Assign (1) one person on the Fire Alarm Control Panel to operate / accept the fire alarm activation and another group/person to conduct spraying on the device, communicate using two way radio.

Step 2: Conduct spray of smoke detector tester (SOLO brand or any) directly on the smoke detector device for not more than 1 sec, repeat action until detector is activated. Note : If detector fails to respond after 3 tries, device will declared faulty (Figure ??-a).

Step 3: Hear and visually check strobe light and sounder every time you activated the smoke detectors.

Step 4: Remove device and clean, allow particles to disperse. Then return to socket (Figure ??-b).

Step 5: Check that strobe light is functioning/ blinking after returning. Note original status if no light is visible. Check that the control panel breaker feeding the device is reset

Step 6: Repeat steps 2, 3, and 4 on different locations until all the devices are tested.

Step 7: Conduct testing for manual call point /manual pull station by pressing the device, hear if the alarm bell / buzzer is activate after you trigger the device

Step 8: Check bells and buzzer audibility.

Step 9: Return Manual Call Point /Manual Pull Station on stand by position. Repeat it on all device.

Step 10: Make a record for the fault device.

Step 11: Record the status of FACP and reset the panel until the fault clear on trouble.

Step 12: Conduct closing of activities to all concerned .

2.4 Electrical Audit

The detail of the electrical audit testing procedure is presented in the Inspection Testing Plant (ITP) [6], which has been submitted to Maynilad along with the WSPs and were approved prior to the execution of tests.

2.5 Database

GHD developed an MS Access program that functions as a database used to record data collected from visual inspections and testings. The database has been developed using the concept of Relational Database Management System (RDMS), which is a must to record data systematically. The benefits of using the database are

- Eliminate redundancy and repetition of same data
- Eliminate incorrect data entry that is often found when working with excel files
- Provide linkages among asset hierarchy
- Provide ease for programming (e.g. reliability modeling and life cycle cost analysis)
- Support Maynilad AIM team to learn the benefits of using RDMS in developing an integrated Asset Management System for now and future
- Provide compatibility with any CMMS that is often using other RDMS such as Microsoft SQL Server, Oracle SQL server, or MySQL platform
- Provide ease for compilation of desire tables for further analysis using SQL (Structure Query Language)
- Provide ease for importing/exporting to different extension formats (e.g. flat, csv, xlsx)
- Provide a strong background for Maynilad team to migrate recording practices to Web-based that will be part of GHD's recommendation for future usage.

The MySQL database is then migrated into MySQL server, which is powerful database system that is used also to migrate, compile, and store all production and power consumption data into a single table. Main reasons behind the development of the MySQL server are for statistical computing with R and for faster compilation of queries.

GHD will provide these two sets of database as part of our deliverable and will provide training for Maynilad team to learn how to use the database in an efficient approach.

Preliminary

Chapter 3

Methodology

3.1 The Integrated Asset Management Approach (IAM)

We propose an Integrated Asset Management (IAM) approach with its framework shown in Figure 3.1 for executing this project. The IAM approach will eventually be beneficial to Clients as it will lay a foundation to build up a systematic asset management plan for the future.

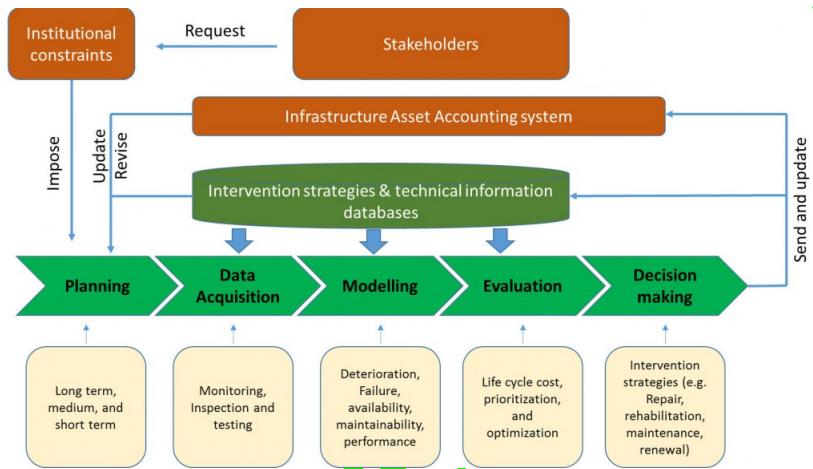


Figure 3.1: Integrated asset management approach (adopted from POM+ <http://www.pomplus.vn>)

As can be seen in Figure 3.1, we see the overall picture of works that should be executed in close connection to each other in order to make a full cycle of asset management effectively.

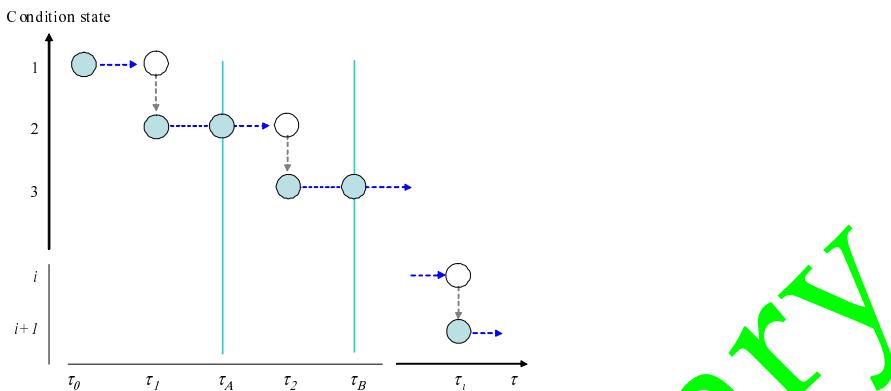
Works associated with auditing equipment and facilities of pump stations and reservoirs, coming up with a preventive maintenance program, tendering, and detailed design can be described explicitly using the framework in Figure 3.1. For example, various type of data concerning physical and operational condition and performance of equipment and facilities will be collected, filtered, and analyzed (Data Acquisition); the data will be further used for modeling purposes (e.g. prediction of failure rate, draw deterioration curve, reliability and efficiency); life cycle cost analysis will be then performed for each equipment and for its system. In this process, either prioritization or optimization technique can be used; finally a set of preventive maintenance intervention strategies will be generated for decision making purposes.

3.2 Deterioration process and rating index

In order to analyze and forecast the deterioration of assets, it is necessary to accumulate time series data on the CS of the assets. The historical deterioration process of an asset is described in Figure 3.2. This figure shows the deterioration progress of a component that has not been repaired. In reality, there exists uncertainty in the deterioration progress of the asset, and more-

over, the CS at each point in the time axis is restricted by the time, at which, visual inspection is carried out.

In this figure, τ represents real calendar time (the expression “time” will be used instead throughout this paper). The deterioration of the asset starts immediately after it begins to operate at time τ_0 . The CS of an asset is expressed by a rank J representing a state variable i ($i = 1, \dots, J$). For a component in the good or new situation, its condition state is given as $i = 1$, and increasing of CS i describes progressing deterioration. A value of $i = J$ indicates that an asset has reached its service limit. In Figure 3.2, for each discrete time τ_i ($i = 1, \dots, J - 1$) on the time-axis, the corresponding CS has increased from i to $i + 1$. Hereinafter τ_i is referred to the time a transition from a CS i to $i + 1$ occurs.



Note) In this example, the deterioration process of a infrastructure component if expressed in terms of calendar time $\tau_1, \tau_2, \dots, \tau_i$, and condition state of the section is increased in unitary units.

Figure 3.2: Transition Time of Condition State (adopted from [13]).

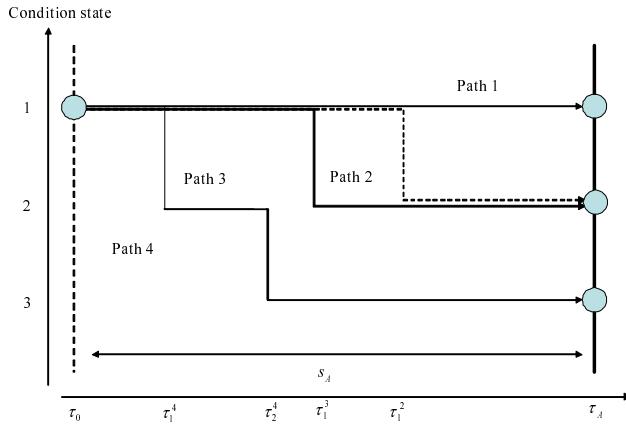
Information regarding the deterioration process of an asset can be acquired through periodical visual inspections. However, information on the CS based on continuous visual inspection is difficult to obtain. In this case, the initial inspections is carried out at times τ_A on the time-axis. It is supposed that at time τ_A the CS observed by inspection is i ($i = 1, \dots, J - 1$). The deterioration progress in future times is uncertain. Among the infinite set of possible scenarios describing the deterioration process only one path is finally realized.

Figure 3.3 shows four possible sample paths. Path 1 shows no transition in the CS 1 from initial time τ_0 to first inspection time τ_A . In paths 2 and 3, CS has advanced to one upper CS at the calendar times τ_1^2 and τ_1^3 respectively. The CS of these two paths observed at time τ_A become 2. In a periodical inspection scheme, the point times τ_1^2 and τ_1^3 in which the CS has changed from 1 to 2 are not determined. In addition, path 4 shows transitions in the CS at times τ_i^4 and τ_{i+1}^4 during the inspection interval. The CS observed at time τ_A becomes 3. That is, in spite of the transitions in the CS are observable at the time of periodical inspection, it is not possible to obtain information about the times in which those transitions occur.

Figure 3.4 further describes the deterioration process inferring the inspection approach and how the CS is assumed. In this figure, it is assumed that the CS at the calendar time τ_{i-1} has changed from $i - 1$ to i . The calendar time τ_{i-1} is assumed to be equivalent to $y_i = 0$. The time represented by the sample time-axis is referred from now on as a “time point”, and differs from “time” on the calendar time axis. The times τ_A and τ_B correspond to the time points y_A and y_B on the sample axis. It can be seen that $y_A = \tau_A - \tau_{i-1}$, $y_B = \tau_B - \tau_{i-1}$.

Information on the CS i at the beginning of the calendar time τ_{i-1} cannot be obtained in a periodical inspection scheme. Therefore, time points y_A and y_B on the sample time-axis cannot be correctly obtained either. For convenience of description, it is assumed that the information at the time a point is known in order to develop the model, despite this assumption is not necessarily essential. The following paragraph discusses that even without information at time points y_A and y_B an exponential hazard model can be estimated.

In the case the CS of an asset at time τ_i (time point y_C) is assumed to change from i to $i + 1$, the period length in which the CS has remained at i (referred as the life expectancy of a CS i) is represented by $\zeta_i = \tau_i - \tau_{i-1} = y_C$. The life expectancy of a CS i is assumed to be a stochastic

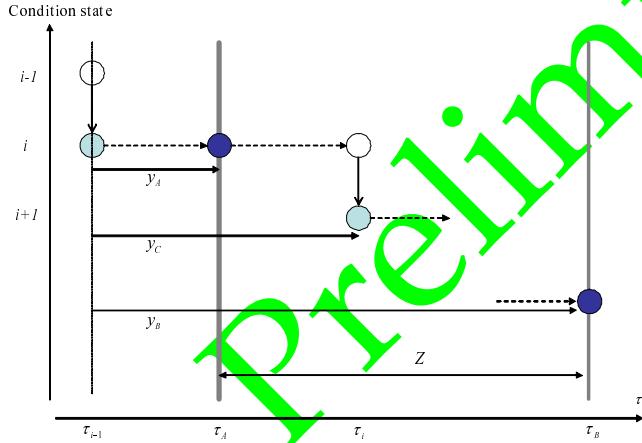


Note) In this example, the deterioration process of an asset is expressed in terms of four different sample paths. In paths 2 and 3 the CS has advanced to one upper CS at the calendar times τ_1^2 and τ_1^3 respectively. In path 4, the CS has increased one state at each time τ_1^4 and τ_2^4 . However, in the case of a periodical inspection carried out at times τ_A the CS at any point in time between inspections cannot be observed.

Figure 3.3: Transition Pattern of Condition State.

variable ζ_i with probability density function $f_i(\zeta_i)$ and distribution function $F_i(\zeta_i)$. Random variable ζ_i is defined in the domain $[0, \infty]$. The distribution function is defined as

$$F_i(y_i) = \int_0^{y_i} f_i(\zeta_i) d\zeta_i. \quad (3.1)$$



Note) In the case the condition state changes from $i - 1$ to i at the calendar time τ_{i-1} the inspections carried out at times τ_A and τ_B will also correspond to the points in time y_A and y_B when using τ_{i-1} as the time origin. The figure shows a sample deterioration path in which the condition state has advanced in one unit to y_C in the interval time $\tau_{i-1} - y_C$. However, observations at time τ_{i-1} are not possible in a periodical inspection scheme, so there is no way to obtain observation at y_A , y_B and y_C . Nevertheless, it is possible to use the information contained in $z = y_C - y_A \in [0, Z]$.

Figure 3.4: Model of Deterioration Process.

The distribution function $F_i(y_i)$ represents the cumulative probability of the transition in the CS from i to $i + 1$. CS i is assumed to be observed at initial time $y_i = 0$ (time τ_A). The time interval measured along the sample time-axis until the time point y_i is $\tau_{i-1} + y_i$. Therefore, using the cumulative probability $F_i(y_i)$, the probability $\tilde{F}_i(y_i)$ of a transition in the CS i during the time points interval $y_i = 0$ to $y_i \in [0, \infty]$ is defined by $\tilde{F}_i(y_i)$:

$$\text{Prob}\{\zeta_i \geq y_i\} = \tilde{F}_i(y_i) = 1 - F_i(y_i). \quad (3.2)$$

The conditional probability that the CS of an asset at time y_i advances from i to $i + 1$ during the

time interval $[y_i, y_i + \Delta y_i]$ is defined as

$$\lambda_i(y_i)\Delta y_i = \frac{f_i(y_i)\Delta y_i}{\bar{F}_i(y_i)}, \quad (3.3)$$

where the probability density $\lambda_i(y_i)$ is referred as the hazard function.

3.3 Condition State (CS) definition

Condition of an asset can be described either by a range of discrete condition state (CS) or by continuous values of one or more than one parameters such as cracking, thickness, and corrosion. In asset management practice, discrete range of CS is often for the following reasons:

- It can be converted/mapped from continuous value of monitoring data;
- It is convenient for non-technical persons and managers;
- It is suitable for determination of intervention strategy and thus for life cycle cost modeling.

Assets in pump stations are different in category and functionality, thus it is not easy to define a universal range of CSs. However, it is possible that a generic range of CSs can be used to map appropriately different type of assets. In this project, following definitions are used for multiple CSs (Table 3.1) and binary state (Table 3.2) systems.

Table 3.1: Condition state definition - Multiple.

CS i	Definition	Require Intervention	Remarks
1	New/likely new and provide adequate LOS	No	Good (None/Insignificant)
2	Install <=5 years, provide adequate LOS	No	Acceptable (Minor)
3	Moderate aging, not provide adequate LOS, observed moderate breakdown	Yes	Damaged (Significant)
4	Moderate aging, not provide adequate LOS, require frequent CI and PI	Yes	Poor (Extensive)
5	Aging and not provide adequate LOS	Yes	Safety is endangered

Table 3.2: Condition state definition - Binary.

CS i	Definition	Require Intervention	Remarks
0	Not provide adequate LOS	No	
1	Provide adequate LOS	Yes	

3.4 Technical efficiency

Technical efficiency is a coefficient measured as the ratio of actual parameter value and expected/design parameter value. In case of PSs, TE is often discussed around the value of pump efficiency (η), which is a factor that accounts for the kinetic energy lost during the operation [7]. The PE is a product of the followings:

- Hydraulic efficiency (primarily, disk friction against the liquid with impeller shrouds). This efficiency is contributed by the speed and impeller geometry. Shock losses during rapid changes in direction along the impeller and volute can also resulted in additional shock losses;
- Volumetric efficiency (recirculation losses at wear rings, interstage bushes and other);
- Mechanical efficiency (friction at seals or gland packing and bearings)

Hydraulic efficiency and volumetric efficiency are used at the design stage of PS when there is a need to determine suitable pump or group of pumps that satisfies the designed LOS. Whilst, mechanical efficiency is used to determine operational efficiency once pumps are in used.

The mechanical efficiency (η_m) is estimated based on the equation 3.4

$$\eta_p = \frac{P_W}{P_B} \quad (3.4)$$

Where P_W and P_B are water power and brake power, respectively.

Following equations are used to calculate the P_W and P_B :

$$P_{W(kW)} = \gamma \times H \times Q \quad (3.5)$$

$$P_{B(kW)} = P_E \times e_m \quad (3.6)$$

where

P_W	Water power (kW);
P_B	Brake power (kW);
P_E	Electric power (kW);
Q	Water flow rate (m^3/s);
H	Head produced by pump (m_{H_2O});
η_e	Motor efficiency (%);
γ	specific weight of fluid (water) (kN/m^3).

3.5 Reliability

3.5.1 Qualitative and Operational Analysis

3.5.1.1 Failure Mode and Effects Analysis (FMEA)

An FMEA is often the first step of a system reliability study. It involves reviewing as many components, assemblies, and subsystems as possible to identify failure modes, and their causes and effects. FMEA is an inductive reasoning (forward logic) single point of failure analysis and is a core task in reliability engineering, safety engineering and quality engineering.

A successful FMEA activity helps identify potential failure modes based on experience with similar products and processes—or based on common physics of failure logic. It is widely used in development and manufacturing industries in various phases of the product life cycle.

Functional analyses are needed as an input to determine correct failure modes, at all system levels. The FMEA is in principle a full inductive (forward logic) analysis, however the failure probability can only be estimated or reduced by understanding the failure mechanism. Hence, FMEA may include information on causes of failure (deductive analysis) to reduce the possibility of occurrence by eliminating identified (root) causes.

3.5.1.2 Reliability Centered Maintenance (RCM)

Reliability-centered maintenance (RCM) is a process to ensure that systems continue to do what their user require in their present operating context. It is generally used to achieve improvements in fields such as the establishment of safe minimum levels of maintenance. Successful implementation of RCM will lead to increase in cost effectiveness, reliability, machine uptime, and a greater understanding of the level of risk that the organization is managing. It is defined by the technical standard SAE JA1011, Evaluation Criteria for RCM Processes.

Reliability centered maintenance is an engineering framework that enables the definition of a complete maintenance regimen. It regards maintenance as the means to maintain the functions

a user may require of machinery in a defined operating context. As a discipline it enables machinery stakeholders to monitor, assess, predict and generally understand the working of their physical assets. This is embodied in the initial part of the RCM process which is to identify the operating context of the machinery, and write a Failure Mode Effects Analysis (FMEA). The second part of the analysis is to apply the "RCM logic", which helps determine the appropriate maintenance tasks for the identified failure modes in the FMEA. Once the logic is complete for all elements in the FMEA, the resulting list of maintenance is "packaged", so that the periodicities of the tasks are rationalised to be called up in work packages; it is important not to destroy the applicability of maintenance in this phase. Lastly, RCM is kept live throughout the "in-service" life of machinery, where the effectiveness of the maintenance is kept under constant review and adjusted in light of the experience gained.

RCM can be used to create a cost-effective maintenance strategy to address dominant causes of equipment failure. It is a systematic approach to defining a routine maintenance program composed of cost-effective tasks that preserve important functions.

3.5.2 Weibull model

In hazard analysis, the deterioration of element is subjected to follow a stochastic process [12]. For binary state system, two condition level 0, 1 are often used. When receiving a PI or CI, the CS from 1 must be changed into 0. In reliability study, this process is often regarded as renewal process. The renewal is carried out at alternative time t_k ($k = 0, 1, 2, \dots$). In this way, the next renewal time is denoted as $t = t_0 + \tau$, where τ indicating the elapsed time. The life span of an asset is expressed by a random variable ζ . The probability distribution and probability density function of the failure occurrence are $F(\zeta)$ and $f(\zeta)$ respectively. The domain of the random variable ζ is $[0, \infty]$. The living probability (hereafter named as survival probability) expressed by survival function $\tilde{F}(\tau)$ can be defined according to the value of failure probability $F(\tau)$ in the following equation:

$$\tilde{F}(\tau) = 1 - F(\tau). \quad (3.7)$$

The probability, at which the asset performs in good shape until time τ and break down for the first time during an interval of $\tau + \Delta\tau$ can be regarded as hazard rate and expressed in the following equation:

$$\lambda_i(\tau)\Delta\tau = \frac{f(\tau)\Delta\tau}{\tilde{F}(\tau)}, \quad (3.8)$$

where $\lambda(\tau)$ is the hazard function of the asset. In reality, the breakdown probability depends largely on the elapsed time of the asset since its beginning of operation. Thus, the hazard function should take into account the working duration of the asset (time-dependent). In another word, the memory of the system should be inherited. Weibull hazard function is satisfied in addressing the deterioration process [2, 11]:

$$\lambda(\tau) = \frac{1}{\eta} \beta \tau^{\beta-1}, \quad (3.9)$$

where η is the scale parameter expressing the arrival density of the asset, and β is the acceleration or shape parameter. The probability density function $f(\tau)$ and survival function $\tilde{F}(\tau)$ in the form of Weibull hazard function can be further expressed in equation (3.10) and (3.11):

$$f(\tau) = \frac{1}{\eta} \beta \tau^{\beta-1} \exp(-\alpha\tau)^\beta, \quad (3.10)$$

$$\tilde{F}(\tau) = \exp\left(-\frac{1}{\eta}\tau\right)^\beta. \quad (3.11)$$

Estimation for Weibull's parameter is often with Maximum Likelihood Estimation (MLE) approach on historical data. Thus, the model's parameter is sensitive to how data behaves. We recommend to use this model only when there is sufficient data to be used.

An example of source code for education purpose is given in Github site of Nam Le¹. The complete program is a copyright of Nam Le.

3.5.3 Markov model

The transition process among the condition states of an infrastructure component is uncertain. Therefore, future condition states cannot be forecasted deterministically. In this situation, Markov transition probability is employed to represent the uncertain transition pattern of the condition states during two time points. Markov transition probabilities can be defined for arbitrary time intervals.

For simplification, Markov transition probabilities can be defined and used to forecast the deterioration of a infrastructure component based on the information from periodical inspection scheme shown in Figure 3.4. The observed condition state of the component at time τ_A is expressed by using the state variable $h(\tau_A)$. If the condition state observed at time τ_A is i , then the state variable $h(\tau_A) = i$. A Markov transition probability, given a condition state $h(\tau_A) = i$ observed at time τ_A , defines the probability that the condition state at a future time (τ_B for example) will change to $h(\tau_B) = j$:

$$\text{Prob}[h(\tau_B) = j | h(\tau_A) = i] = \pi_{ij}. \quad (3.12)$$

The Markov transition probability matrix can be defined and rearranged by using the transition probabilities between each pair of condition states (i, j) as

$$\Pi = \begin{pmatrix} \pi_{11} & \cdots & \pi_{1J} \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \pi_{JJ} \end{pmatrix}. \quad (3.13)$$

The Markov transition probability (3.12) shows the transition probability between the condition states at two given times τ_A and τ_B , therefore, it is straightforward that the values of a transition probability will differ for different time intervals. Since deterioration continues as long as no repair is carried out $\pi_{ij} = 0$ ($i > j$). From the definition of transition probability $\sum_{j=1}^J \pi_{ij} = 1$. Following conditions must be satisfied:

$$\left. \begin{array}{l} \pi_{ij} \geq 0 \\ \pi_{ij} = 0 \text{ (when } i > j\text{)} \\ \sum_{j=1}^J \pi_{ij} = 1 \end{array} \right\}. \quad (3.14)$$

The worse level of deterioration is expressed by the condition state J , which remains as an absorbing state in the Markov chain as long as no repair is carried out. In this case $\pi_{JJ} = 1$.

Markov transition probabilities are defined independently from the deterioration history. As shown in Figure 3.4, the condition state at the inspection time τ_A is i , however, the time, at which, condition state changed from $i - 1$ to i is unobservable. In a Markov chain model, it is assumed that the transition probability between the inspection times τ_A and τ_B is only dependent on the condition state at time τ_A .

The Markov chain model is operative and widely applied in management of infrastructure system. Particularly, at management of network level, Markov chain model is used to define the average transition probability of the entire system, or a group of infrastructure components given two periodical inspection data.

Estimation for the Markov transition probability can be done by the MLE approach [12, 13] or Bayesian Estimation approach [8, 10] based on historical data. One advance of using the Markov model is that one time monitoring data can be used. A generic formula to estimate the transition probability is given in following Equations:

¹<https://github.com/namkyodai/Models>

$$\pi_{ii} = \exp(-\theta_i Z), \quad (3.15-a)$$

$$\pi_{ii+1} = \frac{\theta_i}{\theta_i - \theta_{i+1}} \{-\exp(-\theta_i Z) + \exp(-\theta_{i+1} Z)\}, \quad (3.15-b)$$

$$\pi_{ij} = \sum_{k=i}^j \prod_{m=i}^{k-1} \frac{\theta_m}{\theta_m - \theta_k} \prod_{m=k}^{j-1} \frac{\theta_m}{\theta_{m+1} - \theta_k} \exp(-\theta_k Z), \quad (3.15-c)$$

$$\pi_{iJ} = 1 - \sum_{j=i}^{J-1} \pi_{ij}, \quad (3.15-d)$$

$$(i = 1, \dots, J-1) \quad (j = i, \dots, J).$$

An example of source code for education purpose is given in Github site of Nam Le ². The complete program is a copyright of Nam Le.

3.6 Intervention Strategy (IS)

Intervention Strategy (IS) is at asset level (level 7). It is a collection of intervention type for component level (level 8). A collection of ISs will form an Intervention Program for (IP) the station. A collection of IPs will form a Work Program (WP) for network level intervention (e.g. a bid awarded for a designer/contractor can be a WP that consists of intervention program for one or more than one pump stations). Following generic IS is defined to guide the selection of IPs that will be details in the later part of the report.

Table 3.3: Generic intervention strategy (IS).

IS	Definition	Remarks
1	Do Nothing	
2	Minor repair	Require minimal effort and can be done only for certain asset type
3	Major repair	Require extensive efforts to return the asset to likely new condition
4	Replacement/Renewal	Replacing assets or components of asset with identical one or with new model

For each type of asset, IS will be selected based on reliability study and consideration of cost. Further more, Employers inputs and requirements are also taken into account.

3.7 Determination of optimal intervention strategy

Following subsections briefly describe the model that can be used to determine optimal intervention strategy.

3.7.1 Block Replacement Model

It is assumed that a PI is executed after a pre-defined time $n \cdot T$ ($n = 0, 1, 2, \dots, N$). Once the PI is executed, the functionality and serviceability of the asset could be the same or different from that of the asset before the intervention. In between the time Δt ($[0 \leq \Delta t \leq T]$), hazards could occur and cause the asset in worse CSs (hereafter denoted as i ($i = 1, \dots, I$)), in which the asset is no longer providing an adequate level of services (LOS). In both cases, when the PI or CI is executed, there are impacts incurred by stakeholders s (e.g. the owner, the users, the public).

Following notations are used to describe the formulation of the model.

²<https://github.com/namkyodai/Models>

$\theta(\Delta t t)$	Conditional failure rate i ($i = 1, \dots, I$) when the asset has been in service in an interval t after the PI
$\Psi(\cdot t)$	Any conditional function Ψ given that a PI is executed by a unit of age t , where t is a random variable
$F(t)$	Cumulative distribution function (cdf) of age t of a unit for a PI at execution time
$w_p^s(t)$	Impacts incurred by stakeholder s due to the execution of PI
$w_c^s(t)$	Impacts incurred by stakeholder s due to the execution of CI
$w_o^s(\Delta t t)$	Conditional impacts incurred by stakeholder s when the structure is remains in normal operation (<i>i.e.</i> providing an adequate LOS) during time interval Δt after a PI has been carried out and the asset has not entered failure state
ρ	discount factor
$p_l^k(t)$	probability of failure at time t of the affecting other assets k
$C_c^{s,k}$	Impacts incurred by stakeholder s due to the execution of an CI on other assets k
T	interval between the PIs
T^*	Optimal interval time between PIs, which is the variable of the model
$\Omega_p(T, t)$	minimum expected total discounted impact for an infinite time span when the asset has been in service during an interval t after the execution of the PI and the asset has not entered failure state
$\Omega_c(T, t)$	minimum expected total discounted impact for an infinite time span when a CI has been executed, of the asset that has been in service during a time interval t after the execution of the PI and the asset has entered failure state

In the model, it is assumed that at each damage level i , there exists a corresponding well defined CI. Within an increment of time Δt , after the asset has been under the PI after time t , the total expected impacts due to the execution of CIs are:

$$v_c(\Delta t|t) = \sum_{s=1}^S \left[w_c^s(\Delta t) + \sum_{k=1}^K p_l^k \cdot C_c^{s,k} \right] \cdot \theta(\Delta t|t). \quad (3.16)$$

The total impacts due to the execution of PIs and the total impacts incurred by stakeholders during the service time of the asset are defined in Eq. (3.17) and Eq. (3.18), respectively.

$$v_p(t) = \sum_{s=1}^S w_p^s(t). \quad (3.17)$$

$$v_o(t) = \sum_{s=1}^S w_o^s(t). \quad (3.18)$$

According to the principle of optimality, which is described in [1, p. 15], the minimum expected total discounted impact $\Omega_c(T, t)$ for infinite time is formulated in following equation.

$$\Omega_c(T, t) = \int_0^\infty [v_c(\Delta t|t) + \Omega_p(T, \Delta t|t)] dF(t). \quad (3.19)$$

The minimum expected total discounted impact $\Omega_p(T, \Delta t|t)$, which appears inside Eq. (3.16), is obtained as follows

$$\Omega_p(T, \Delta t) = \min \Gamma(\Delta t). \quad (3.20)$$

where $\Gamma(\Delta t)$ is defined as

$$\begin{aligned} \Gamma(\Delta t) = & \int_0^\infty \left[v_o \int_0^{dt} \exp(-\rho \tau) d\tau + \{1 - \theta(\Delta t|t) dt\} \cdot \Omega_p(T, \Delta t + dt|t) \exp(-\rho dt) \right. \\ & \left. + \theta(\Delta t|t) dt \cdot \Omega_c(T, \Delta t + dt|t) \exp(-\rho dt) \right] dF(t). \end{aligned} \quad (3.21)$$

According to [9], Eq. (3.21) is rewritten in following form

$$\begin{aligned} \Gamma(\Delta t) = & \Omega_p(T, \Delta t) + [\rho \Omega_p(T, \Delta t) + d\Omega_p(T, \Delta t)/dt] dt \\ & + \int_0^\infty [v_o + v_c(\Delta t|t)] dF(t) dt. \end{aligned} \quad (3.22)$$

Thus, from $\Omega_p(T, \Delta t) = \Gamma(\Delta t)$ (Eq. (3.20)), the following equation can be derived:

$$\Omega_p(T, \Delta t) = \exp(\rho \Delta t) \left[\Omega_p(T, 0) - \int_0^\infty \int_0^t \exp(-\rho \tau) \{v_o + v_c(\tau|t)\} d\tau dF(t) \right] dF(t). \quad (3.23)$$

where,

$$\begin{aligned} \Omega_p(T, 0) &= \{1 - \exp(-\rho T)\}^{-1} \int_0^\infty \left[\exp(-\rho T) \{v_p(T, t)\} \right. \\ &\quad \left. + \int_0^T \exp(-\rho \Delta t) \{v_o(\Delta t|t) + v_c(\Delta t|t)\} dt \right] dF(t). \end{aligned} \quad (3.24)$$

when T tends to infinity $T \rightarrow \infty$, Eq. (3.24) becomes

$$\Omega_p(\infty, 0) = \int_0^\infty \int_0^\infty \exp(-\rho t) [v_o + v_c(\Delta t|t)] dt dF(t). \quad (3.25)$$

Eqs. (3.24) and (3.25) are the explicit forms of the expected total discounted impact in infinite time horizon. This is the classical optimization problem. By differentiating the expected total discounted impact $\Omega_p(T, 0)$ and $\Omega_p(\infty, 0)$ and setting it equal to zero, the optimal time T^* can be obtained. The optimal time T^* for PI is the solution of the following system of equations:

$$\begin{cases} T^* = \arg \min_{T^* \in [0, T]} \Theta_p(T, 0) \\ T^* = \arg \min_{T^* \in [0, \infty]} \Theta_p(\infty, 0) \end{cases} \quad (3.26)$$

in which the differentiates of $\Theta_p(T, 0)$ and $\Theta_p(\infty, 0)$ are respectively:

$$\begin{aligned} \Theta_p(T, 0) &= \frac{\delta(\Omega_p(T, 0))}{\delta T} \\ &= [1 - \exp(-\rho T)] \int_0^\infty \left[-\rho v_p(T, t) \right. \\ &\quad \left. + d(v_p(T, t))/dT + v_o(T, t) + v_p(T, t) \right] dF(t) \\ &\quad - \rho \int_0^\infty \left[\exp(-\rho T) \{v_p(T, t)\} \right. \\ &\quad \left. + \int_0^T \exp(-\rho \Delta t) \{v_o(\Delta t|t) + v_c(\Delta t|t)\} dt \right] dF(t). \end{aligned} \quad (3.27)$$

and

$$\begin{aligned} \Theta_p(\infty, 0) &= \frac{\delta(\Omega_p(\infty, 0))}{\delta T} \\ &= \int_0^\infty \left[-\rho \left\{ v_p(\infty|t) + \int_0^\infty \exp(-\rho t) \{v_o(\Delta t|t) + v_p(\Delta t|t)\} \right\} \right. \\ &\quad \left. + \lim_{T \rightarrow \infty} d(v_p(T, t))/dT + v_o(\infty|t) + v_p(\infty|t) \right] dF(t) \end{aligned} \quad (3.28)$$

3.7.2 Time-dependent replacement model

Time-dependent replacement model (or Age replacement model) are the ones where the following conditions apply:

- the asset starts operating at $t = 0$, i.e. it is newly built or newly restored to a like new condition following an intervention;
- the probability of failure is described with $f(t)$ and $F(t)$, i.e. the lifetime density and the lifetime;
- if the asset fails on the interval $(0, T]$ a CI is executed;

- if the object does not fail on the interval $(0, T]$ the object is replaced at T , i.e. the PI replacement is executed, regardless if the object has failed and been restored in the time interval $(0, T]$;
- the execution of a PI restores the object to a like new condition;
- the execution of a CI restores the object to a like new condition.

3.7.2.1 Minimize impact

If an age replacement IS is followed the time to the first intervention, Z , is the minimum amount of the time to failure of the length of the renewal period:

$$Z = \min(\tau, T) \quad (3.29)$$

The expected, or mean, time to the first intervention is then determined by

$$E[Z] = \int_0^T (1 - F(x))dx \quad (3.30)$$

The mean impact in one renewal period then equals the probability of failure on T multiplied by the impacts associated with the CI plus the probability that no failure occurs on T multiplied by the impacts associated with the PI:

$$F(T) \times I^{CI} + (1 - F(T)) \times I^{PI} \quad (3.31)$$

The mean impacts per unit time, therefore, equal the mean cost in one renewal period divided by the length of the renewal period, i.e. the time to the first intervention.

$$\eta_{AC} = \frac{F(T) \times I^{CI} + (1 - F(T)) \times I^{PI}}{\int_0^T (1 - F(x))dx} \quad (3.32)$$

3.7.2.2 Maximize availability

If it is desired to determine the age replacement IS that maximizes availability the following is often assumed, additionally that:

- the PI replacement takes t^{PI} ,
- the PI takes t^{CI} ,

If the asset fails before T then the length of the renewal period will, therefore, be $X = t + t^{CI}$, which has the probability $f(t)dt$ of occurring, and if the object does not fail before T then the length of the renewal period will be $X = t + t^{PI}$, which has the probability $1 - F(T)$ of occurring.

In this case, the expected, or mean, renewal period length is:

$$E[X] = \int_0^T (1 - F(x))dx + t^{CI}F(T) + t^{PI}(1 - F(T)) \quad (3.33)$$

As the asset is operational on average $\int_0^T (1 - F(x))dx$ then the availability is given by:

$$\eta_{AA} = \frac{\int_0^T (1 - F(x))dx}{\int_0^T (1 - F(x))dx + t^{CI}F(T) + t^{PI}(1 - F(T))} \quad (3.34)$$

Preliminary

Chapter 4

Data and Analysis

4.1 Qualitative and Operational Analysis

4.1.1 Facts and Data

Summary of facts and data concerning operational and overall plan reliability is presented in this subsection.

4.1.1.1 Operation Scenario

- Pump station is already 17 years in operation
- 2 pumps (10hp) for Southvale but only 1 in operation at any one time. Pumps switch every 24 hours.
- 2 pumps (15hp) for Sonera but only 1 pump in operation at any one time.
 - P1 operates from 6PM to 6AM.
 - P2 operates from 6AM to 6PM.
 - P1 is used during low demand period because it cannot maintain pressure during high demand period.
- Maintain 50psi 24 hours for all distribution lines.

4.1.1.2 Spares Policy

- Since only 1 pump is used, the other acts as spare.

4.1.1.3 Emergency Situation (loss of electrical power from Meralco)

- Auto-start of pumps

4.1.1.4 Maintenance

- For operational problems, operator will call Control Center to report problem.
- Control Center to send contractor within 1 to 2 hours.
- Maintenance contractors conduct a weekly visit to do some maintenance activities.

4.1.1.5 Current (Reliability) Problems

- None.

4.1.2 Way forward/Recommendations

In order to ensure the PS to provide adequate level of services around the clock, it is important to establish a good operational scheme that allows optimization of use of pumps to reduce breakdown and to conserve energy. A summary of the observations and their corresponding recommendations to be considered are:

- There is enough flexibility in the system to allow for the smaller pumps to fail. The larger spare 15hp pump can supply the requirements. However, if P2 of the 15hp pumps fails, the system cannot maintain the 50psi requirements and there will be a loss of water to some customers. First, overhaul Sonera Service Pump1 to upgrade its performance equal to its pair Pump2. Then, consider an additional storage pump3 (15hp) to increase the reliability of the whole system (including the Sonera system).
- Consider a dedicated duty and a dedicated spare set-up for the pumps. If this is not acceptable, then consider doing a much longer switch of the storage pumps. Currently, it is being switched daily. This allows for almost an equal rate of deterioration between the two pumps and if one pump fails due to age-related component failure, the other one is close to a similar failure which may occur before the first pump is fully repaired. It is suggested that the switch happen once a month or even every 3 months.
- In place of the longer switching cycle (e.g. every 3 months), there should be a corresponding maintenance program for the standby pump for both booster and storage.
- Know what maintenance activities are done weekly and how the contractors/Maynilad use the information gathered to predict equipment failures.
- Develop a more structured discipline in applying routine maintenance work process to ensure that maintenance tasks are given the proper priority in terms of mitigation measures and avoid unplanned shutdown of critical pumps in operation.

Aside from the above recommendations, we also generate a list of recommendations based on the RCM methodology. This is presented at the end of the document (refer to Appendix A). The list shall be considered as a living program, which requires continuously improvement as part of the total quality management system (refer to Deming cycle presented in GHD's technical proposal).

4.2 Pump discharge and suction pipe - thickness

4.2.1 Data and measurement

Thickness data on discharge and suction pipes of pumps is presented in Table 4.1 and the positions and the distances for the Ultrasonic Thickness Gauging (UTG) are referred to Figure 4.1 and Figure 4.2.

4.2.2 Analysis

This section provides analysis/discussion on estimation of minimum allowable thickness of pipes and statistics around the measured data collected during inspection and testings.

Sonera BP1

- Suction Piping System-Suction side thickness is not critical when compared to the discharge side of the pump.
- Discharge Piping System- The discharge pipe side of the pump is not so critical, however, this sonera pump has lower thickness when compared to the other sonera pump by around 92 - 97 percent which might be associated to the health condition of the pump - which as per vibration analysis is not acceptable.

Table 4.1: Thickness data - Booster Pumps (mm).

Asset	Position	Distance					
		Suction	Discharge				
		1.0 m	0.7 m	1.2 m			
Sonera BP1	12	13.82	6.92	-	-	-	-
	3	14.25	6.71	-	-	-	-
	6	14.21	6.91	-	-	-	-
	9	-	6.67	-	-	-	-
Sonera BP2	12	13.02	7.19	6.12	-	-	-
	3	13.62	7.07	6.21	-	-	-
	6	14.22	7.12	6.14	-	-	-
	9	-	7.21	6.38	-	-	-
		-	A	B	C	D	E
Sonera Main Line	12	-	5.68	6.07	6.16	6.08	6.09
	3	-	5.71	6.16	6.14	5.78	6.18
	6	-	5.98	6.12	6.36	5.75	5.92
	9	-	5.44	6.13	6.08	5.62	6.03
Spare 1	12	13.31	-	-	-	-	-
	3	13.22	-	-	-	-	-
	6	14.38	-	-	-	-	-
	9	-	-	-	-	-	-
Spare 2	12	13.35	-	-	-	-	-
	3	12.82	-	-	-	-	-
	6	14.04	-	-	-	-	-
	9	-	-	-	-	-	-
		-	0.7 m	1.0 m	1.3 m	1.6 m	2.5 m
Southvale BP1	12	14.55	6.56	6.38	5.41	6.23	8.08
	3	13.43	6.73	6.39	5.36	6.22	8.32
	6	13.21	6.55	6.67	5.83	6.19	8.15
	9	-	6.83	6.31	5.93	6.19	-
Southvale BP2	12	14.83	6.88	6.25	5.32	6.27	8.11
	3	14.15	6.68	6.24	5.83	6.21	8.4
	6	13.21	6.54	6.32	5.88	6.5	8.02
	9	-	6.82	6.24	5.42	6.28	-

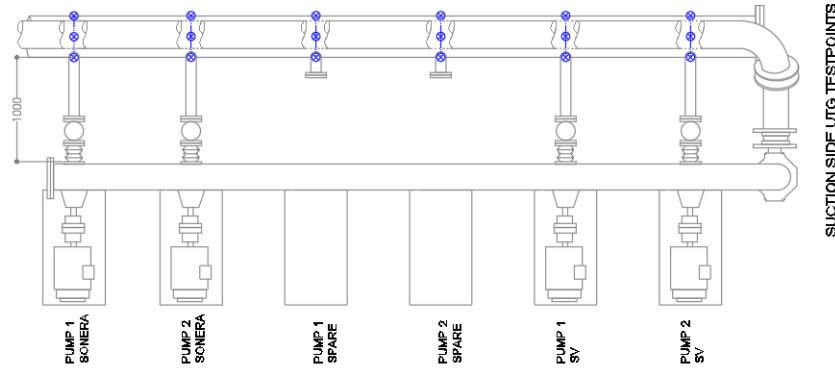


Figure 4.1: Positions and distances of UTG - Booster Pump Suction Side

Sonera BP2

- Suction Piping System- In comparison to the thickness at the discharge side, suction side is thinner by a great number, almost a factor of two thus this side is relatively not critical compared to the discharge side.

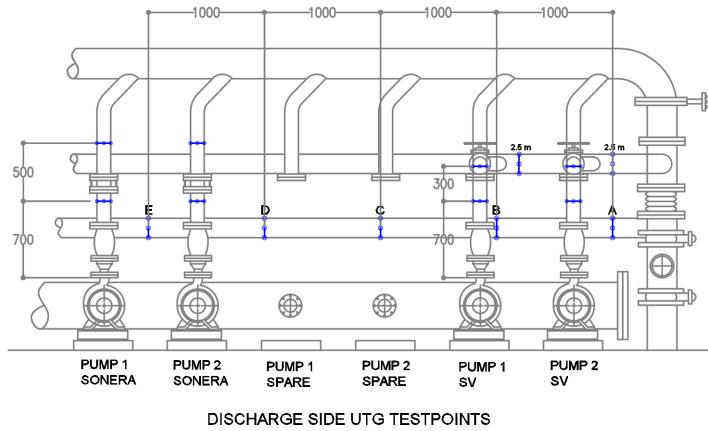


Figure 4.2: Positions and distances of UTG - Booster Pump Discharge Side

- Discharge Piping System- This pump is observed to have a thinner section at 1.2 m compared to that of in 0.7 m from the pump flange. It has a 2.14 mm per m of length of pipe but, the thickness of the 0.7 m of Sonera Pump 2 is thicker than of Pump 1, and thus might be projected that Pump 1 might have thinner 1.2 m section than of Pump 2. Such factor might be associated to its pump performance over time and possible system operations reconfiguration that need to be analyzed further to have a concrete comparison of Sonera BP1 and BP2.

Southvale BP1

- Suction Piping System- Suction side is not critical when compared to the discharge side of the pump. The distance between pumps is 1 meter. When the suction header is to be analysed, it can be observed that the flow of water from Sonera BP1 up to Southvale BP2 has a thinning pattern, that might corresponds to its flow pattern. It can be seen that the flow from the start of the header (referenced to Pump 1) flows in the top of the piping, continued and swirls slowly clockwise (referenced by facing the reservoir) to the 3 o'clock position for 2 meters and then flows at the bottom in a span of 2 meters again. This might means that the flow of water in the suction header does not flow erratically as the other pump suction sides.
- Discharge Piping System- The 1.3 m section of the discharge side is the thinnest part of the section with thickness of 5.36 mm to 5.93 mm, minimum and maximum , respectively. This is apparent to that section, which is the turning area of an elbow. This might means that it receives most of the shearing energy of the water flow due to the change in direction and momentum. It is also evident that the both 1.0 m and 1.6 m section of the discharge line has the next thinnest section, because these sections are the entering and exiting part of the bend.

Southvale BP2

- Suction Piping System- Thi side is not critical when compared to the discharge side of the pump, similar with the other pumps where the thickness is twice greater than of the discharge side.

- Discharge Piping System- The 1.3 m section of this pump is the thinnest section of the discharge side as it might receives the shearing effect of the change in direction of the water flowing in it. It is also evident that the pre- and pro-elbow sections have thickness difference when compared to the 0.7 m section of the pump. .

4.2.2.1 Assumptions

Following assumptions are used in calculating the required thickness of pipe

- Maximum Working Head – based on the design drawings and pump nameplate;
- Pipe Material – assume pipe material is ASTM A570 Grade 33 (market available material for spiral welded pipe);
- Design Guide – basis used for the simulated calculation is AWWA Manual M11 – Steel Pipe, A Guide for Design and Installation, 4th Edition. Statement for corrosion allowance is located at Chapter 4, which states "*At one time, it was a general practice to add a fixed, rule-of-thumb thickness to the pipe wall as a corrosion allowance. This was not an applicable solution in the water work field, where standard for coating and lining materials and procedures exists. The design shall be made for the required wall-thickness pipe as determined by the loads imposed, then linings, coatings, and cathodic protection selected to provide the necessary corrosion protection*";
- Thickness calculation will be based on the internal pressure. External pressure will not be considered because much of the discharge line is not buried.
- Surge Pressure was not considered since there are surge protection along the line.
- This document will only consider the calculation of the minimum thickness along the discharge line since this is the part of the system where maximum pressure is experienced.

4.2.2.2 Limitations

As confirmed by Maynilad, there is no available data regarding the design report. Design assumptions herein may be different from what was used by the designer/contractor of this station.

This document will not be able to provide the corrosion/degradation factor of the pipe since there is no available historical data on the thickness of the pipe.

4.2.2.3 Parameter values for thickness estimation

In order to estimate the minimum allowance thickness for pipes in straight line considering material handling (t_{mh}) and maximum internal pressure based on AWWA M11 (t_{sp}), following equations are used, respectively:

$$t_{mh} = \frac{\Phi}{\delta} \quad (4.1)$$

$$t_{sp} = \frac{\epsilon \times P_{max} \times \Phi}{2 \times S_e} \quad (4.2)$$

where P_{max} is maximum internal pressure

$$P_{max} = \frac{\rho_{H_2O} \times g \times H_{max}}{1000} \quad (4.3)$$

In order to estimate the minimum allowance thickness for pipes at elbows (Miter Bend), only maximum internal pressure is considered:

$$t_{mb} = \frac{P_{max} \times \Phi}{2 \times S_e} \times \left[1 + \frac{\Phi}{(3 \times R) - (1.5 \times \Phi_d)} \right] \times \epsilon \quad (4.4)$$

Paramater values used for computation are given in Table 4.2

Table 4.2: Parameter values for thickness estimation.

Parameters	Symbol	Unit	Pumps	Remarks
			Booster	
Discharge diameter	Φ_d	mm	150	
Max flow rate	Q_{max}	m^3/s	0.0094	nameplate data
Max pump head	H_{max}	m	46	nameplate data
Yield strength of material	S_y	MPa	227.5	ASTM A570 Grade 33, spiral welded pipe based on AWWA C200
Allowable stress	S_e	MPa	113.75	
Density of water	ρ_{H_2O}	kg/m^3	1000	
Gravity constant	g	m/s^2	9.81	
Safety factor	ϵ		1.5	
Bulk modulus of compressibility of liquid	k	Pa	2.1E+09	
Young's modulus of elasticity of pipe wall	E	Pa	2.1E+11	
Radius of Elbow	R	mm	225	
Empirical constant	δ		288	

4.2.2.4 Required thickness

Results of computation for minimum allowable thickness for booster pumps and storage pumps are given in Table 4.3.

Table 4.3: Minimum thickness allowance.

Pumps	Internal pressure (Mpa) P_{max}	Minimum allowable thickness (mm)		
		t_{mh}	t_{sp}	t_{mb}
Booster	0.451	0.521	0.595	0.793

4.2.2.5 Recommendations

Given the current thickness of pipe the lack of design information, it is advisable to

- Not perform any major intervention on the pipes;
- Keep regular testing on exact locations using the same type of UTG device. It is important for Maynilad to establish a testing regime for obtaining thickness at exact same location over time (e.g. every year). Information obtained from testing will be then used to compute deterioration rate based on thickness value;
- Establish an approach to inspect/test the thickness of underground pipe, which is considered to be more vulnerable to leakage and corrosion on external wall;

- The elbows in the suction and the discharge piping systems must be monitored regularly;
- It is recommended to have a profiling of the piping systems above and below the ground in order to have a baseline in the analysis of the Maynilad Piping System. In order to have a profiling of pipe thickness at differential time T, additional measurement at similar locations shall be conducted periodically, behavior can then be monitored;
- Perform coating regularly of the pipe to prevent possible corrosion/erosion and damage that cause by external factors and surrounding condition;

4.3 Visual Inspection on Pipe, valves, fittings, supports, expansions, and appurtenances

4.3.1 Highlights

Visual inspection data on pipes, valves, fittings, supports, expansions, and appurtenances is highlighted in Table 4.4.

Table 4.4: Highlights of visual inspection

No.	Items	Remarks
1	Existing suction pipe and fittings	Suction line too short and is jam packed with fittings. Does not promote good flow development. Intake water will be turbulent and is not desired
2	Discharge piping and fittings	Pressure gauge near pump discharge is preferred for measuring head of individual pump
2	Pump vibration isolation	Does not appropriately serve its function to isolate vibration from building and reduce noise
3	As built difference	Actual system contains many differences from provided copy of old as-built including valve positions and pipe design
4	Pump foundation block	Unitary block with multiple slots and may
5	Space	Modifications for improvement are possible because of available space inside pump room
6	Instrumentation and monitoring	Pump instrumentation do not include PLC and other important parameters typically displayed by PLC not monitored

Visual inspections are supported with the photos taken at particular locations/positions in question.

The pump station is situated in Ayala Southvale subdivision where the available space is quite ample relative to the other stations. As earlier mentioned, the station services two areas namely, Southvale and Sonera. Two 10HP long coupled pumps (Figure 1.1 - a) deliver to Southvale and another two 15HP close coupled pumps (Figure 1.1 - b) deliver water for Sonera area. In contrast to other pumping stations, the pumps and motors installed have relatively smaller capacity.

Machine support

The four booster pump units in this station are bolted onto spring-mounted base-plates (Figure 4.3) typical of small Goulds pumps installations. Designed to allow displacement under applied loads associated with thermal expansion of piping, such as those employed in small chilled water or hot water systems, said spring-mounted base-plates typically sit or slide on a smooth floor. However, the station designers choose to bolt the spring mounts onto concrete blocks, which defeats the purpose of the spring-mount design. (Refer to Goulds Pumps Installation, Operation and Maintenance Instructions.)

If possible, it is best to inquire the station designers to re-examine the assumptions or reasons behind this unusual mounting design.



a - Southvale service pump baseplate b - Sonera service pump baseplate c - Deflection Spring Mounting Assembly

Figure 4.3: Spring Mounted Baseplates

On another point of view, assemblies on the pump mounting such as spring isolators are for isolating or reducing the damaging structure vibration and annoying vibration induced noise produced by the mechanical equipment. This is designed for modern buildings with which vibration and noise can become the major source of occupant complaint. Also, installation of vibration isolators is for the purpose of protecting the building from micro-vibrations which could potentially lead to structural failures.

Special spring isolators are important and appropriate for industries that have sensitive process machining, where more damping is required and less motion can be tolerated due to certain special requirements, precision for example. Special cases such as wind loads will require isolators for pumps or fans of cooling towers and condensers. None of the conditions stated above do not fit the situation for the pump station. Vibration isolators are not necessary for the pump system. Furthermore, springs might have deteriorated with time and might need to be removed and the equipment foundation and mounting be refurbished.

Pipe design and flow profile Fittings neary the pump intake will cause flow disturbances and turbulence (Figure 4.4)

It is important to observe good flow development for water as it enters the pump. As is always noted, a developed water inflow helps in the reducing vibration, cavitation, noise and many other problems that will occur in long term operation of the pump. In this regard, it is best to reinstall the pump and lengthen the suction pipe and reposition them. Follow recommended straight pipe provisions, resize the existing pipe diameters and refurbish the machine mounting and foundation to improve pump performance. on the other end the foundation blocks instead. Since in actual, the jockey pumps are not really needed, the foundation block for pump 1 might as well be refurbished. Even then, these changes are only quick fixes and do not really involve massive overhaul or redesign of the whole system but will definitely help improve the operating conditions. These are made more expedient with the results of the vibration analyzer tests presented in Section 4.4.

Parameter monitoring opportunities. The longer suction run will also allow use of flow meters for individual pumps. Current spots for tapping flow meter probes are not very convenient for both device accuracy and technician access.

(Note that these recommendations are not oriented towards total plant redesign but only for addressing existing plant problems and providing possible solution as the consultant see fit. If total plant redesign is desired, it will have to be done in a separate contract and will likely disregard the most if not all of the current problems stated.)

Other pertinent observations include the following:

- The motors lack frame ground wires (Figure 4.5). The motor frames should



a -Southvale service pump suction



b - Sonera service pump suction

Figure 4.4: Suction side

be bonded to the station grounding bus. If there are any, the grounding design/policies for this station should be reviewed.

- Defective valves – valves have already locked up either due to age and/or corrosion (Figure 4.6).
- Valve not easily accessible - located above head level and require ladder to access (Figure 4.7)
- Clogged tapping point - during testing, clogged pressure tapping points and pressure gauges on the same line were found.
- Inconveniently placed gauges (Figure 4.8)
- Cluttered Electric wires (Figure 4.12)
- Minor Deteriorations (Figure 4.9)
- Exhaust fan not easily accessible for cleaning or repair (Figure 4.10)
- Inconvenient blank nameplate (Figure 4.11)

It is acknowledged that the station is already old and will suffer from issues typical to deterioration with time. However, it is necessary to do refurbishments to meet desired level of performance of the station.

As built discrepancy

Differences in as-builts are observed for the machine foundation. Initially, there was only one discharge header where all pumps would deliver water (Figure 4.13 - a). However, there are two headers, one to Southvale and the other to Sonera. Old as-built



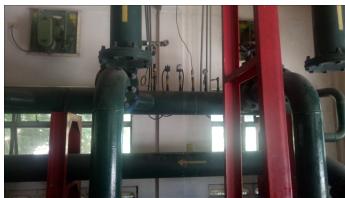
Figure 4.5: no frame ground wires



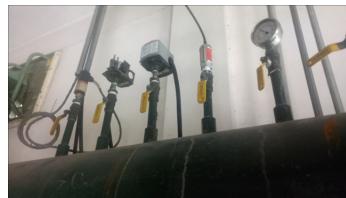
Figure 4.6: defective valve



Figure 4.7: over-head valve location



a



b

Figure 4.8: Different gauges tapped at header

show that there are 7 slots with 2 outer jockey pumps and the rest in between the main storage pumps (Figure 4.13 - b). However, there are only 5 slots for main storage pumps and 1 slot for the jockey pump. Installed on the jockey pump slot is Southvale service pump1. Pumps 2 to 4 are installed on the main storage pump slots. Corresponding piping adjustments then follows.

4.4 Vibration and structural assessment

4.4.1 Measurement and spectrum reading

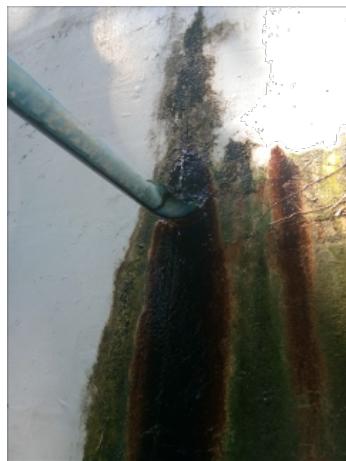
Rotating equipment generate vibration waveforms that are mathematical functions of machine dynamics, such as speed, alignment, and rotor balance, among others. Vibration analysis entails measurement and analysis of the amplitude of vibration at certain frequencies to gather useful information relating to the accuracy of shaft alignment and balance, the physical condition of bearings, and the possible effects of structural issues; in the case of Maynilad, the problem of impeller possible cavitation is an added and serious concern.

Three main parameters are measured to determine the severity or amplitude of vibration; namely: displacement, velocity and acceleration. Along with temperature, the vibration level is a primary indicator of the physical condition of a machine. As a generally rule, higher vibration levels indicate greater defects.

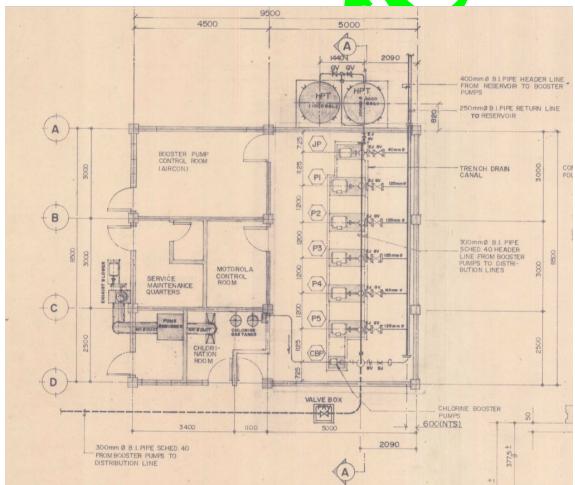
Rotating speeds below 600 rpm (10 Hz) generate minimal acceleration, moderate velocity, but relatively high displacement. Hence, shaft displacement is a critical parameter for slow speed rotors, such as steam turbines. Between 600 – 60000 rpm (10 - 1000 Hz) velocity and acceleration levels provide useful indications of the severity of defects. While velocity as a parameter may indicate the presence or relative magnitude



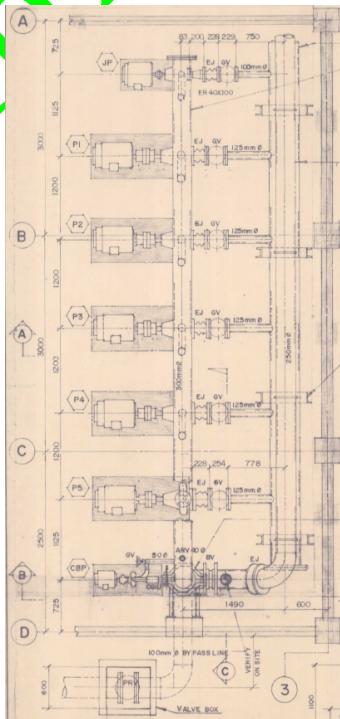
a



b

Figure 4.9: Other deterioration**Figure 4.10:** exhaust fan**Figure 4.11:** blank nameplate**Figure 4.12:** wire clutters

a - Pumps and pipings



b - Pump slots

Figure 4.13: Old as-built plan

of a problem, it makes no distinction as to the source or cause. This is where an FFT vibration analyzer comes in. A fast Fourier transform algorithm converts acceleration

waveforms into functions of frequency in a way suitable-trained humans can distinguish the component sources or causes of the vibration.

By means of a OneProd Falcon high-resolution FFT analyzer equipped with tri-axial accelerometer with a linear frequency range of 2Hz-30kHz, vibration spectral readings were taken from four bearing locations in each motor-pump unit. Analysis and results are summarized as follows:

4.4.2 Data and analysis

Raw data of vibration measurement is provided in separately digital format. The raw data of each pump is used to generate a set of graphs provided in Appendix B. Analytical results on vibration are also included.

A summary of grading for each pump is given in Table 4.5.

Table 4.5: Pump vibration condition state.

Assets	Operational issues detected	Condition	
		Motor	Pump
Pump 1	Health is not acceptable for a long time service. Rutting (Metal to metal) at Motor NDE (Rutting at 21 Hz peak)	3	
Pump 2	Health is not acceptable for a long time service. Motor NDE Bearing Inner Race Fault Motor NDE Bearing Inner Race Fault - Stage 2 out of 4 Motor NDE Bearing noise with Ringing rate at shaft rate	3	
Pump 3	Misalignment, Unbalance, Rotating Loosening Overall state NOT acceptable for both pump and motor Highest vibrations measured at Motor NDE Axial with Overall velocity of 14.4 and dominant peak at 1x,2x,3x caused by Misalignment and Unbalance Fault Severe Rotating Loosening at Pump	4	4
Pump 4	Rotating Loosening and Misalignment Highest vibration measured at Pump IB Bearing Vertical with Overall Velocity of 6.07mm/s, with Defect Factor of 5.18 due to 1x Rate Repetitive 1x Harmonics caused by Rotating Loosening High 2x peak caused by Misalignment Impact caused by Rotating Loosening at Pump Bearings, Rutting and Misalignment	4	4

Note that the unusual installation of the spring-mounted baseplates as mentioned earlier can lead to unusual operating behaviour and/or vibration characteristics.

It is noted that the CS 2, and 3 shown in Table 4.5 infers good and fair, respectively¹.

4.4.3 Recommendations

Recommendations are shown in Table 4.6

4.5 Energy management audit

4.5.1 Production and power data

Production data for this station has been recorded in excel files. Each file represents a month with 24 hours of daily records. Maynilad provided this set of data of 2018 per

¹The CS is slightly different from that defines in Table 3.1

Table 4.6: Corresponding recommendations from Vibration Analysis

Assets	Condition		Recommendations	IT
	Motor	Pump		
Pump 1	3		Check rubbing noise at Motor NDE	3
Pump 2	3		Continue monitor and trend Motor NDE Brg.	3
Pump 3	4	4	Schedule Reconditioning of Motor and Pump to include Shop Balancing of Motor Rotor, Pump impeller assembly balancing Resleeving or restoration of shaft and housing bearing clearances.	3
Pump 4	4	4	Schedule reconditioning of Pump Bearings. Check Pump bearings fit for shaft wear or Pump housing wear. Rectify those first prior bearing replacement. Realign shaft/coupling using precision laser alignment tool upon installation of pump onsite.	3

GHD' request. Initial verification on this set was conducted with following conclusions

- The structure of data is not homogeneous with numerical errors. This problem is due to the fact that excel file is not suitable for recording a large volume of data, particularly cells are not set up to reject string and value outside the lower and upper bounds. content.

In order to compile such a data set, it is not possible with manual inputting, instead, GHD has developed a hybrid program consisting of Visual Basic (VBA) Code and MySQL code for fast compilation. VBA code is used to add header, fill up missing information in excel file, and ignore rows and columns that should not exist with regard to database structure. MySQL codes are used to eliminate measurement errors and bring together all individual files to one file that allows statistical analysis with R.

4.5.2 Measurement errors

Following measurement errors are with the provided excel files

- String/text values are found numerous in columns that shall be only numerical values;
- Extreme values are found numerous;
- Negative values are found in many places that shall only be positive

4.5.3 Data compilation for analysis

Out of all recorded attributes, useful attributes that can be used for energy audit are total production per hour and total power consumption per hour. There is no record on production and power consumption for individual pump.

4.5.4 Analysis

As a matter of fact, power consumption of a PS is mostly contributed by the operation of pumps. Thus, the audit has been centralized on

- Analyzing given production and power consumption data to understand the trend and establish a benchmark ratio of production vs power for future audit and management;
- Evaluating other part of the audit such as pump efficiency and reliability in order to derive better intervention program that will eventually beneficial to the Client to maintain a benchmark level of power consumption against the production.

Figure 4.14 shows the statistical correlation between production and power. It can be seen from the correlation graph and correlation value that there is very weak correlation among these two values (coefficient is 0.118). A careful inspection on data reveals that data has been recorded inappropriately. It could be possible that the meters were not provide adequate level of services.

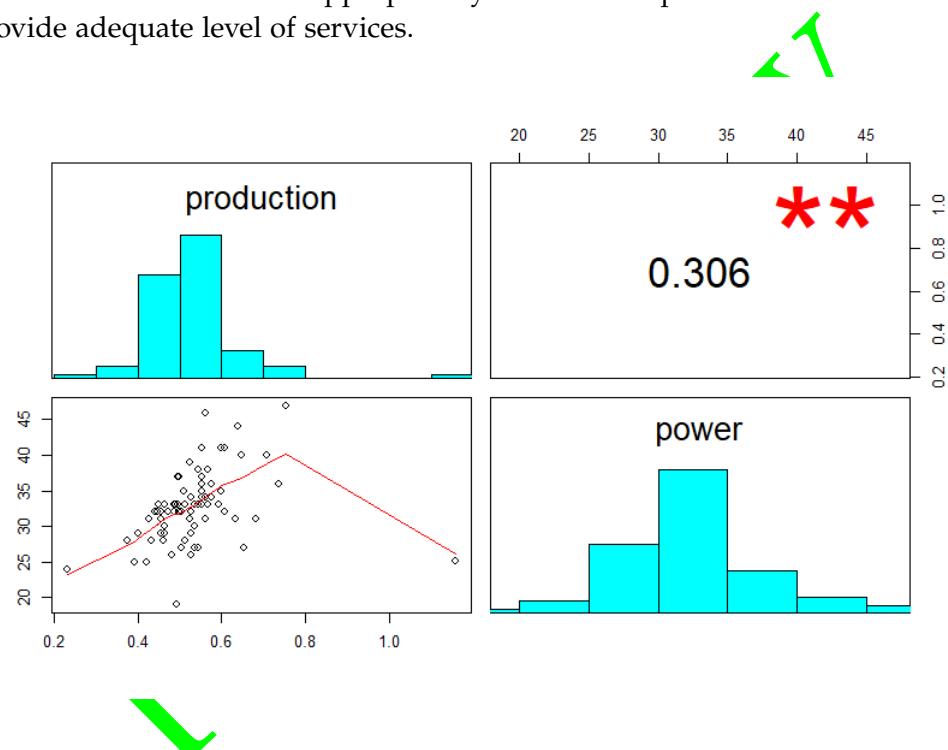


Figure 4.14: Correlation between production and power consumption

Figure 4.15 shows a trend in time series production, power, and its ration in 2018. Whilst, Figure 4.16 presents the distributions.

It can be seen from the time series and distribution graphs that the values of the three parameters are randomly distribute without clear trends. This explains the reason why the value of correlation is about 0.3. The shapes of distribution graphs have some distortion at their tails. In normal operation condition, it is expected that when there is high energy consumed, there will be higher production. However, in many cases, the production was lower than average but the energy was not proportional decreasing. This issue could be a result of low water level in the reservoir causing more power as the pumps were still in need of operations or even more. In order to minimize this impact, it is important to maintain the water level in the reservoir chambers from the source.

Interpretation from these graphs can be summarized as follows

Total Daily Production, Power Consumption, and Ratio (ASV)

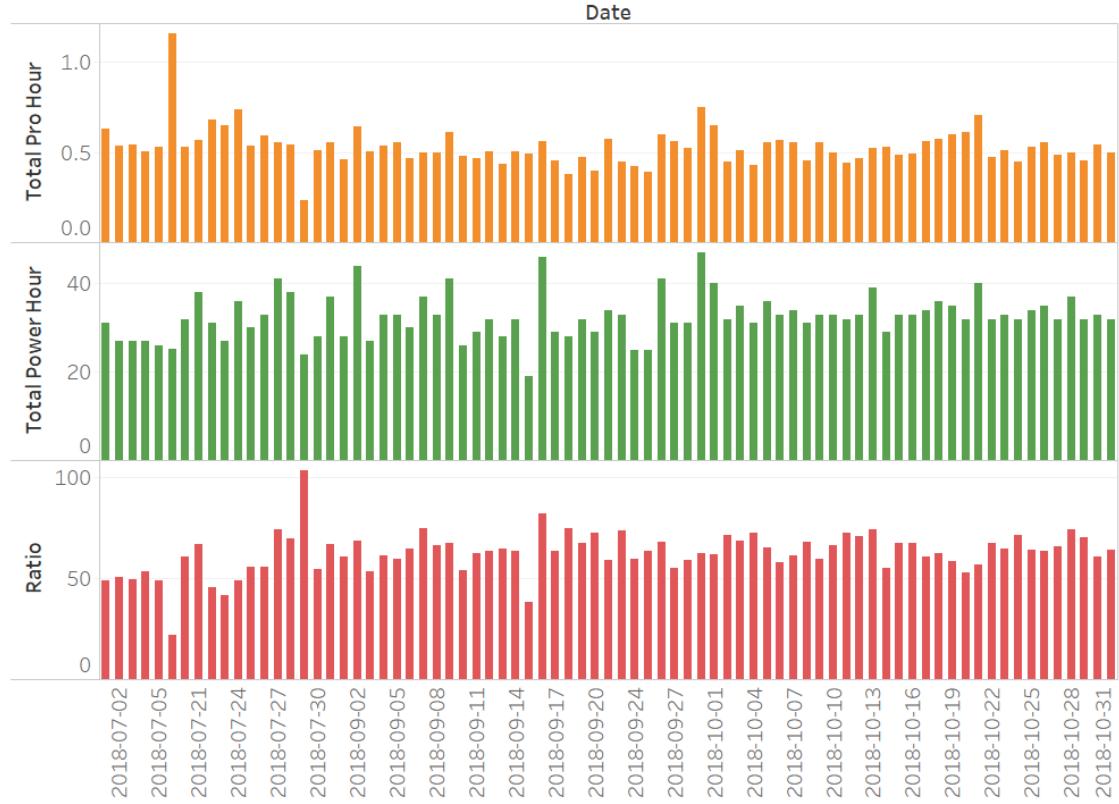


Figure 4.15: Time series analysis

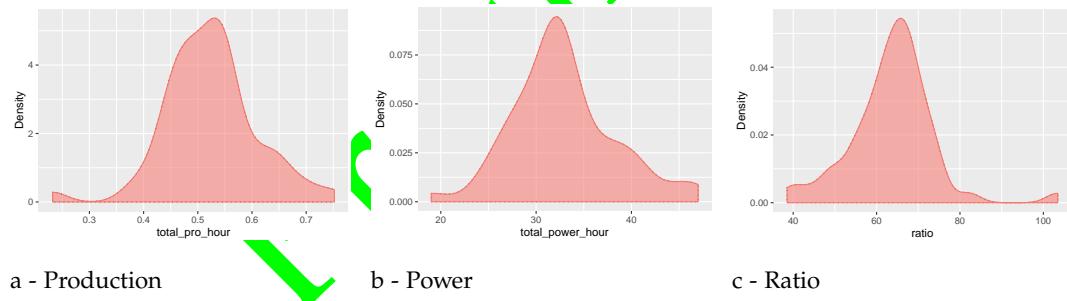


Figure 4.16: Density distribution

- There is almost low level of correlation between the production and power, which has been contributed by a certain abnormal trend in the graphs which might due to the failure of reading devices;
- Average daily production could be in between of 0.45 to 0.6 MLD;
- Average daily power consumption could be in the range from 30 to 35;
- Average ratio between power and production is between 60 to 70. It is believed that the benchmark ratio should be at least equal to the average or better. Optimistically, the benchmark ratio could be 70.

Table 4.7: Temperature and Relative Humidity

Point	Description of the Point Location	Temperature Reading (F)		Humidity Reading	
		Actual	Range	Actual	Range
1	A. Pump room point 1	83.5	72-80	63.4	45-60
2	Pump room point 2	83.3	72-80	62.9	45-60
3	Pump room point 3	83.8	72-80	63.6	45-60
4	Pump room point 4	84.0	72-80	61.7	45-60
5	Pump room point 5	84.2	72-80	62.5	45-60
6	Pump room point 6	84.4	72-80	61.9	45-60
7	Pump room point 7	84.4	72-80	61.5	45-60
8	Pump room point 8	84.7	72-80	61.1	45-60
9	Pump room point 9	84.6	72-80	62	45-60
10	Pump room point 10	85.6	72-80	60	45-60
	Average	84.3		62.1	
11	B. Pump house corner 1	92.3	72-80	52.2	45-60
12	Pump house corner 2	87.8	72-80	57.9	45-60
13	Pump house corner 3	89.78	72-80	53.9	45-60
14	Pump house corner 4	88.7	72-80	56.2	45-60
	Average	89.6		55.1	
15	C. Comfort Room	97.7	72-80	58.4	45-60
16	MCC room	87.8	72-80	57.3	45-60
17	Operator room	86.7	72-80	60.6	45-60

4.5.5 Recommendation

In order to operate the PS in a manner that is energy efficient, it is advisable to

- Establish an optimal operation scheme;
- Establish a benchmark energy efficiency ratio for continuous monitoring and reporting. This ratio shall become a Key Performance Indicator (KPI) used for managerial purpose. GHD suggests to first fix the issue of data recording and compilation for getting reliable set of data. This can be done from now to the end of 2019 for another round of energy audit.

4.6 Workplace environment management

4.6.1 Temperature and relative humidity

4.6.1.1 Data

Air temperatures and relative humidity measured are presented in Table 4.7. Data was measured at targeted points shown in Figure 2.9. Raw data is with the site inspection reports, which will be provided to the Client separately. Persuant to ASHRAE standard, the recommended ranges for temperature and humidity are [72 - 80 °F] and [45 - 60 %], respectively.

4.6.1.2 Data and Analysis

The pump station is situated near dense forestry and is connected to the subdivision roads via an access road. There are no significant sources of pollution and almost no passersby. As an old pump station building, there is no mechanical air conditioning.

The pump room relies on natural ventilation via the access door and room windows. The MCC room beside the pump room is also naturally ventilated and has windows installed. Air properties are similar for all the areas in the station. From the table, the temperatures inside the pump house at every measurement points are significant higher than the maximum value of the recommended range (80 F). The average value is around 87 F. High values of temperature compared to the range have also been observed for points outside the pump house. The same is observed for the values of RH.

Solar load on the operators room is high during the day until noon (Figure 4.19 - a) and is low for the afternoon. To avoid consistent exposure to heat, the operator can stay on the shaded areas for cooling where the guard's booth is also positioned. Thus, comfort is sought of by the operator by feel and by shading himself when especially when the sun is up.

In terms of operatorship, there is not much significance deviation of the readings from recommended range since the operator spends small amount of time intermittently to record information or to start or stop the pumps during his shift.

Nonetheless, temperature and humidity are correlated and as per ASHRAE standard 55 under summer comfort zone, the recommended combination of temperature and humidity shall be within the comfortable zone as shown in Figure 4.17.

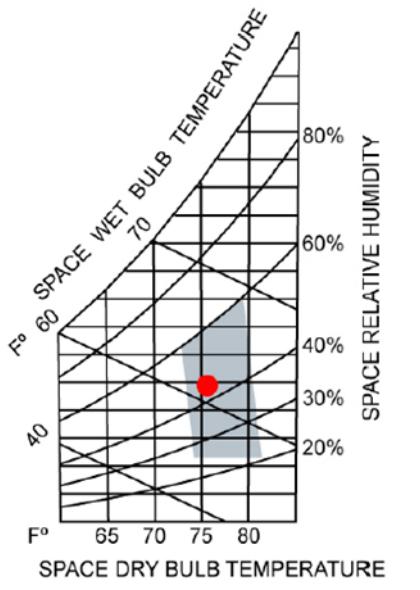


Figure 4.17: ASHRAE standard 55 : Summer Comfort Zone

4.6.1.3 Recommendations

In order to reduce the negative impacts from high temperature, particularly inside the pump house, the Client shall consider

- Establishing a good daily monitoring, exercise, and management considering ergonomic and health and occupational activities (e.g. appropriate time window for break in designated resting area);
- Transfer operators room or refurbish existing room to negate heat especially during day.

Table 4.8: Air Quality - PM2.5

Point	Description of the Point Location	PM2.5
A.		
1	Pump room point 1	6
2	Pump room point 2	6
3	Pump room point 3	6
4	Pump room point 4	7
5	Pump room point 5	6
6	Pump room point 6	6
7	Pump room point 7	6
8	Pump room point 8	6
9	Pump room point 9	6
10	Pump room point 10	6
	Average	6
B.		
11	Pump house corner 1	5
12	Pump house corner 2	4
13	Pump house corner 3	4
14	Pump house corner 4	4
	Average	4
C.		
15	Comfort Room	5
16	MCC room	5
17	Operator room	6

- Install AC equipment at least for the MCC room where cool air is desired to help MCC function efficiently and safely.

4.6.2 Air quality

4.6.2.1 Data and analysis

Air particulate matter concentrations are presented in Table 4.8. Data was measured at targeted points shown in 2.9. Raw data is with the site inspection reports, which will be provided to the Client separately. Pursuant to currently applied standard, excellent air quality range for PM2.5 is in [0-35].

The air quality for the pump station in terms of particulate matter is excellent. This is simply because there are no nearby significant sources of pollution such as emissions from vehicles for pump stations situated near heavy traffic roads.

4.6.2.2 Recommendations

Follow strictly safety and environmental regulation. For example, all employees and staff to wear appropriate dust-proofed masks when working with activities that potentially incurs dusts or other harmful particles.

4.6.3 Illumination

4.6.3.1 Data and analysis

Illumination within various areas of the pump station are presented in Table 4.9 with the LUX value. Data was measured at targeted points shown in Figure 2.9. Raw data is with the site inspection reports, which will be provided to the Client separately. Pursuant to RULE 1075.4 of DOLE-OSH standard [3], the recommended minimum for LUX is in 100.

Illumination levels measured are above recommended minimum. The pump station is mostly solar lit during the day thru door and windows (Figure 4.18). Lightings can

Table 4.9: Illumination

Point	Description of the Point Location	Sound
1	A. Pump room point 1	87.3
2	Pump room point 2	86.1
3	Pump room point 3	86.2
4	Pump room point 4	88.3
5	Pump room point 5	86.4
6	Pump room point 6	86.7
7	Pump room point 7	87.1
8	Pump room point 8	86
9	Pump room point 9	87.7
10	Pump room point 10	85.5
	Average	86.7
11	B. Pump house corner 1	69.5
12	Pump house corner 2	70.4
13	Pump house corner 3	66.3
14	Pump house corner 4	64.8
	Average	67.8
15	C. Comfort Room	67.4
16	MCC room	79.3
17	Operator room	65.4

provide necessary illumination if brighter working area is needed, especially during afternoon and evenings. Concern is raised for evening or graveyard shifts where the operator needs to inspect around the reservoir area. Ample lighting is desired to help operator safely roam and inspect the area.

4.6.3.2 Recommendations

- Install necessary lighting along path to reservoir and vicinity

4.6.4 Industrial ventilation

4.6.4.1 Data and analysis

The pump room relies on natural ventilation via the access door and room windows. The MCC room beside the pump room is also naturally ventilated and has windows installed. The open access doors and windows serve double purpose to both promote air change in the rooms and also provide natural lighting inside (Figure 4.18)

4.6.4.2 Recommendations

- No action needed.

4.6.5 Housekeeping

4.6.5.1 Documentation

Following problems are the facts:

- Current documentation practice is heavily dominated with paper based system, which follows the current practice in Maynilad. There is a large amount/collection of papers that recorded past activities but is of no use and beneficial if data cannot



Figure 4.18: Pump house openings

Table 4.10: Housekeeping.

Description	Status	CS	IT	Remarks
- Sufficient waste segregation assets	yes	1	1	
- waste segregation policy	yes	1	1	
- Signage	yes	1	1	
- Genset emission control	yes		1	

be transformed into digital format for time series analysis, which is an essential part of asset management practice;

- No proper filing/library system with standardized coding rule that will provide convenience for operators/users to timely find appropriate documents;
- Daily operation data is crucial information for future analysis but it is recorded in excel based file without relational tables, which makes it from hard to impossible for data compilation, filtering, and mining. Many past data has been recorded with outliers and incorrect data types.

4.6.5.2 Waste management and environmental control

There is no issue with regard to waste management and environmental control as confirmed by the checklist shown in Table 4.10

4.6.5.3 Office arrangement and ergonomic

Table 4.11 shows the data concerning parameters associated with office arrangement and ergonomic considerations.

4.6.5.4 Recommendations

Followings are recommendations

- Development of a web-based database management system, with appropriate set of relational data tables to record operational data, power consumption data, and intervention data;
- Development of documentation code and naming for appropriate filing and library/referencing;
- Refurbish operator's office (Figure 4.19 - b) and include necessary organizing items such as file cabinet

Table 4.11: Ergonomics.

Parameters	Sub-parameters	Status	Remarks
Posture	Head	1	Ceiling height is high enough to cause head injury while sitting or when standing.
	Neck	1	Neck posture is in good ergonomic condition. Consider having an interval for fit-break to avoid neck muscles stiffening.
	Back	1	Back posture while sitting is in good posture. Consider standing and doing fit-break exercises to relax spine.
	Hands/Wrist	0	Proper hand positioning in the keyboard is not observed. Wrist bending is seldom.
	Feet	1	Feet position is in good posture. Good clearance below worktables.
	Eyes	0	The computer monitor is on eyelevel in a certain operator only. Consider adjusting the monitor level comfortable to every operator. Look away into distance in order to rest the eyes for every 10 minutes or so.
Equipment / Tool	Computer display	0	Not adjusted and the operator get used to its current setting. Display brightness must be adjustable in the comfort of the operator-in-charge. Consider the use of anti-glare and blue light to reduce the possibility of eyestrain.
	Keyboard	1	Keyboard position causes poor hand posture that can lead to injury at long exposure.
	Mouse	1	Mouse usage is average due to monitoring. Prolong usage may cause reduced blood flow leading to muscular injury.
	Chair	0	Consider using ergonomic chair that is capable of back support, height, armrest adjustments.
	Table	0	Consider use of ergonomic tables to adjust the height of the table in desired position easily without exerting much effort to adjust manually.
	Files	1	Hard copy file system and location is well observed. Too high or too low file location may require a person to bend his body or force his hand to grip a file in an awkward posture. Frequent situation may lead to MSD.
Operations / Maintenance	Illumination	0	According to the maintenance team, the motion-activated light is not bright enough to complete their task efficiently at night. Moreover, the light has short on-off delay operation that means that the team must move more often to avoid the light to dim. Consider having a manual switch option to by-pass the motion sensors and le the light on while doing maintenance.
	Noise Exposure	1	Noise emitted by the machines in the pump station is high. Consider the use of proper ear protections to reduce the sound intensity. In offices, the sound intensity is acceptable.
	Temperature	1	Temperature in the pump station is not acceptable at long exposure. Consider cooling down the body temperature at the designated area (i.e. outside, office).
Facility / General Workplace	Layout	1	Layout of the pump station is well observed. Distance between pumps is acceptable for well maintenance movement.
	Height clearances	1	Height clearances from ceiling to head is high. Chance of getting head injury is very low.



a - High solar load during the day

b - Operator's desk

Figure 4.19: Operator's room

Table 4.12: Sound Levels.

Point	Description of the Point Location	Sound
A.		
1	Pump room point 1	104
2	Pump room point 2	104
3	Pump room point 3	74
4	Pump room point 4	115
5	Pump room point 5	91
6	Pump room point 6	172
7	Pump room point 7	93
8	Pump room point 8	184
9	Pump room point 9	622
10	Pump room point 10	666
	Average	222
B.		
11	Pump house corner 1	13980
12	Pump house corner 2	4880
13	Pump house corner 3	4470
14	Pump house corner 4	2190
	Average	6380
C.		
15	Comfort Room	57
16	MCC room	44
17	Operator room	731

4.6.6 Noise

4.6.6.1 Data and analysis

Sound level measurements are presented in Table 4.12. Data was measured at targeted points shown in Figure 2.9. Raw data is with the site inspection reports, which will be provided to the Client separately.

Regular operation was considered during the sound level measurement and so the reading closely represents the normal daily noise generated by the pump system inside the plant. The average sound level inside the Pump room is around 86 dBA which means the operator; maintenance team can inspect or repair inside the room for considerably long without hearing impairment.

Sound levels are recorded around the vicinity of the pump room have an average of dBA. This means that sound levels within these areas are considered safe even for prolonged stay. Safe lower values are also recorded for the operator room and mcc room.

4.6.6.2 Recommendations

- Continue to use protective hearing equipment when working inside the Pump House to further bring down sound level during repair or maintenance.

4.7 Visual inspection on electrical assets

Results of the visual inspection are reflected in the database that describes also the Asset Registry. Highlights of the outcome for this station are shown in Table 4.13 with visual images shown in Figure 4.20.

Table 4.13: Highlights of visual inspection - Electrical assets

Item	Description	Model	Brand	Status	Remarks
1	Main Switch/Switchboard	MDP 460V/MDP230V	Local Fabrication	1	Still being used
2	Distribution Transformer	75kVA, 460V	Wescor	1	Still being used
3	Maynilad Owned Load Break Switch (LBS)	n/a	N/a	0	Low voltage installation
4	Power Cables (secondary side of DT to the Elect. Loads)	THHN cables	Not visible	1	cable visually not maintained
5	Motor Control Center	230V and 460V MCC	Local Assembly	1	With defective components
6	Capacitor Bank	n/a	n/a	0	Not found
7	TVSS	n/a	N/a	0	Not found
8	Power Meter	Analog V and A	Not visible	1	Pointer still moving and has reading
9	Filters and Reactors	n/a	n/a	0	Not found
10	Instrument Transformers	Current and Voltage	n/a	1	wiring acceptable
11	Electrical Protective Relays	n/a	n/a	0	Not found
12	Motor and Switches	Nameplate blurred	nameplate blurred	1	Nameplate already blurred
13	Transfer Switch	Automatic	Synchrogen	1	Functioning as Manual Transfer
	Transfer Switch	Manual	n/a	1	Not functioning; not used
14	Uninterruptible Power System (UPS)	n/a	n/a	0	Not found
15	Distribution Panelboards and assoc. appurtenances	DP and LPB	locally fabricated	1	Breakers are obsolete
16	Ground-Fault Circuit Interrupter (GFCI) or ELCB or (RCD)	n/a	n/a	0	Not found
17	Lighting and Lighting Control System	1x40 lighting fixture	Not visble	1	w/ non-functioning fixtures
18	Emergency Generator	Standby Genset	Cumper	1	Rusted enclosure
19	Building Service and Distribution	utility owned	Not visble	1	Open delta connection

4.8 Short circuit calculations and evaluation

4.8.1 Short circuit calculation

Short circuit calculation (SCC) has been done using the software ETAP version 16.2 under following considerations:

- **Available MVA Short Circuit:** Utility supplying normal power to the PS via a 34.5 KV line is MERALCO. The maximum projected fault is to be requested by the owner from the utility. In the calculation, 500MVA available short circuit was used;



(a - Transfer switch)



(b - Distribution transformer)



(c- GENSET)



(d - MCC)



(e - MDP 230 V)



(f - MDP 460 V)



(g - Motor 1)



(h - Motor 2)



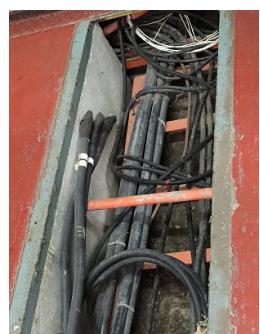
(i -MTS)



(j -Panel board 01)



(k -Transformer)



(l -Power cabling)



(m -Panel board 02)

Figure 4.20: Existing electrical assets

- **Transformer:** The SCC was based on a 65kVA transformer feeding the transfer switch going to the motors. Transformer impedance used in the calculation is per standard;
- **GENSET:**
 - Emergency power will be supplied by 1 Genset, rated at 165 kVA feeding downstream distribution power lines;
 - Subtransient value of the generator should be provided for a more accurate calculation.
- **Length of wires and cables:** Actual measured length of wires and cables.

Calculation has been done for Three Phase of short circuit current. Results of the calculations are summarized in Table 4.14. Figure 4.21 and Figure 4.22 represent the graphical representation of Nodes and Links as well as associated values.

Table 4.14: Short circuit calculation - results

Item	Description	SCC (kA)	Kaic & CB (kA)	remarks
1	From Utility to transformer	8.357	Utility owned trafo	Protection c/o Utility
2	Pole Mounted transformer to main disconnect switch	1.295	Rating of CB is 400A per nameplate	Cover of MDS stuck. Advised not to open due to arc flash
3	Main disconnect switch 400A to Automatic transfer switch panel	1.266	Rating not visible	n/a
4	Automatic transfer switch panel to MDP-P 460V	1.258	35	Existing acceptable
5	MDP-P 460V to Enclosed CB 200A	1.233	25	Existing acceptable
6	Enclosed CB 200A to dry type transformer 112.5 kVA	1.882	25	Upstream protection is ECB 200A
7	Dry type transformer 112.5 kVA to MDP-S 230V	1.781	42	Existing acceptable
8	MDP-S 230V to MCC 230V	1.781	65	Existing acceptable
9	MDP-P 460V to MCC 460V	1.254	65	Existing acceptable
10	MDP-P 460V to MCC 440V	1.248	35	Existing acceptable
11	MDP-P 460V to dry type transformer 75kVA	1.232	None	N/a
12	Dry type transformer 75 kVA to Enclosed CB 150A	1.862	22	Existing acceptable
13	Enclosed CB 150A to Lighting Panel	1.754	10	Existing acceptable

The values of SCC shown in the table indicates the followings:

- the values of the FAULT observed to be lower than the values of the protective devices. This infers that the existing protective devices are capable to protect the assets.

4.8.2 Evaluation of protective devices and bus bars

It can be interpreted from the results of the SCC that

- the protective devices and bus bars are still provided adequate level of services and performed per applied standards;
- there is no undersized electrical components.

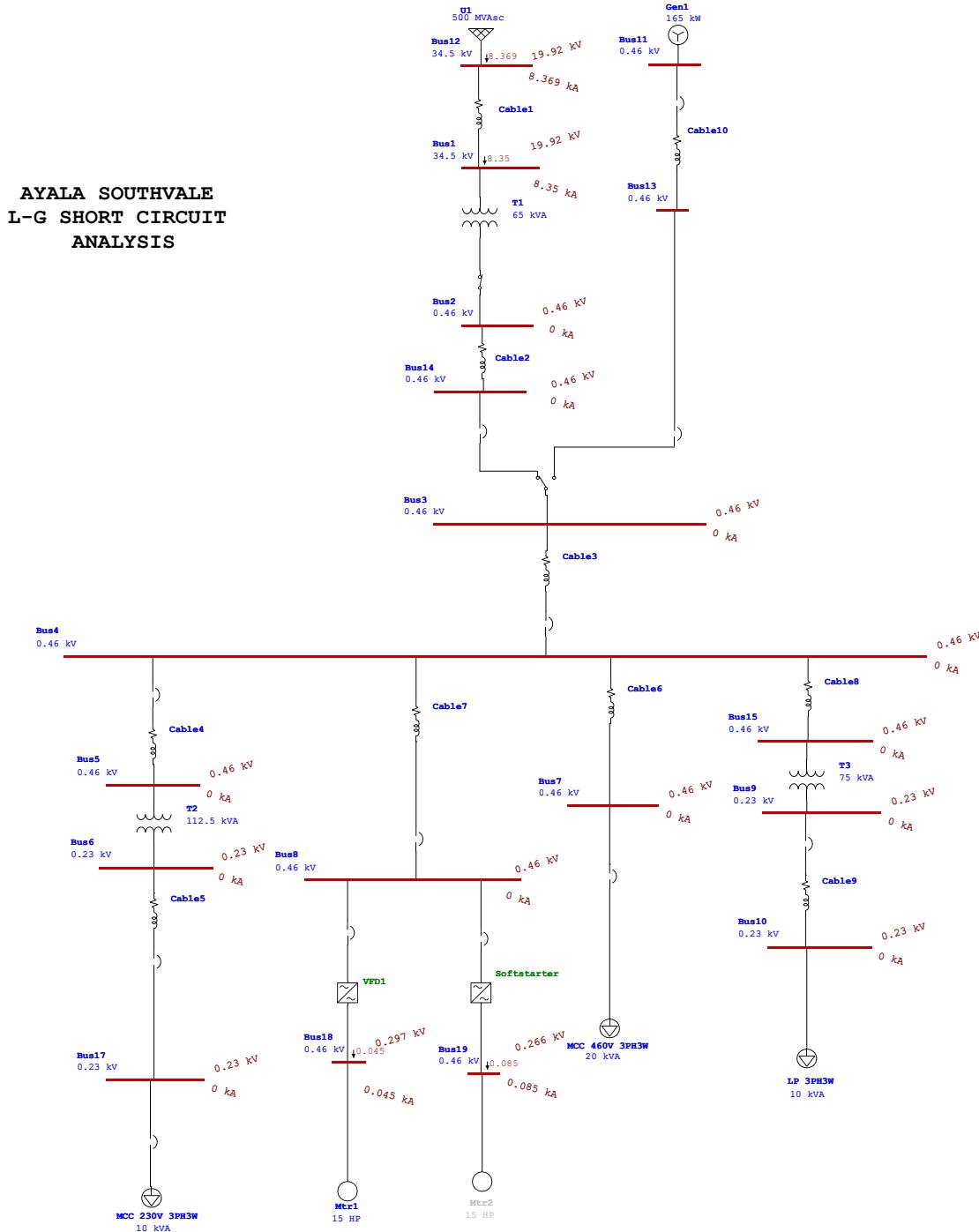


Figure 4.21: LGfault

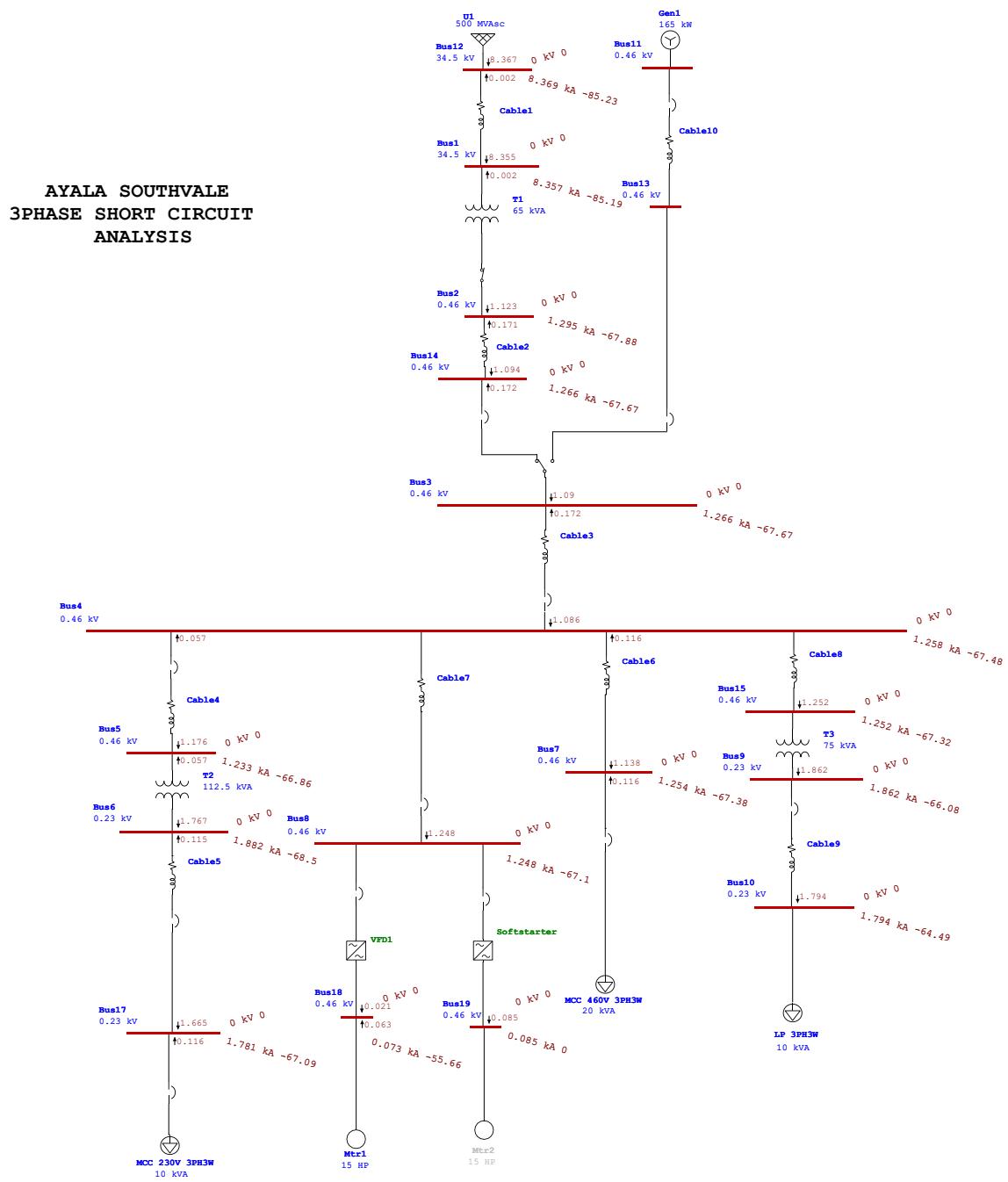


Figure 4.22: Three Phase SCC

4.9 Voltage drop calculation

Voltage drop calculation (VDC) has been conducted in compliance with the code (PEC 2017 ARTICLE 2.15.1.2(A)(1)(b)FPN NO.2) which states the following

- Conductors for feeders, as defined in Article 1.1, sized to prevent a voltage drop exceeding 3% at the farthest outlet of power, heating and lighting loads, or combinations of such loads, and where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5%, will provide reasonable efficiency.

Results of the VDC is presented in Table 4.15

Table 4.15: Voltage drop calculation - results

Item	From	To	Wire Size mm ²	I Ampe	L m	R Ω/305 m	X Ω/305 m	Vd	%Vd	Remarks
1	Pole Mounted Transformer 50kVA	Main Disconnect Switch	250.0	425	21	0.048	0.027	2.788	0.58	Within Limits
2	Main Disconnect Switch 400	ATS PANEL	250.0	425	35	0.048	0.027	4.647	0.97	Within Limits
3	ATS PANEL	MDP-P 460V	250.0	425	7.464	0.048	0.027	0.991	0.21	Within Limits
4	MDP-P 460V	MCC 1	250.0	425	3.56	0.048	0.027	0.273	0.06	Within Limits
5	MDP-P 460V	MCC 2	250.0	425	6	0.048	0.027	0.797	0.17	Within Limits
6	MDP-P 460V	ECB 200A	250.0	425	9	0.048	0.027	0.691	0.14	Within Limits
7	ECB 200A	DRY TYPE TRANSFORMER 112.5KVA	125.0	285.0	2	0.057	0.052	0.249	0.05	Within Limits
8	DRY TYPE TRANSFORMER 112.5KVA	MDP-S 230V	125.0	285	20.5	0.057	0.052	2.557	1.11	Within Limits
9	MDP-S 230V	MCC 230V	125.0	285	1	0.057	0.052	0.125	0.05	Within Limits
10	MDP-P 460V	DRY TYPE TRANSFORMER 75KVA	250.0	425	4.5	0.063	0.051	0.879	0.22	Within Limits
11	DRY TYPE TRANSFORMER 75KVA	LP PANEL	60.0	170	9	0.1	0.054	0.986	0.43	Within Limits

It can be interpreted from the values of the calculation that the VDC is within the limits defined in the applied standard.

4.10 Load flow study

The load flow study (analysis) has been conducted per applied standard. Following Terms are important in the study, thus being extracted from the Philippines Distribution Code for ease of readers.

- Active Power:** The time average of the instantaneous power over one period of the electrical wave, measured in watts (W) or multiples thereof. For AC circuit or Systems , it is the product of the root-mean –square (RMS) or Effective value of the voltage and the RMS value of the in-phase component of the current. In a three phase system, it is the sum of the Active Power of the individual phases;

Table 4.16: Alert setting

	% Alert Settings	
	Critical	Marginal
Loading		
Bus	100.0	95.0
Cable	100.0	95.0
Reactor	100.0	95.0
Line	100.0	95.0
Transformer	100.0	95.0
Panel	100.0	95.0
Protective Device	100.0	95.0
Generator	100.0	95.0
Inverter/Charger	100.0	95.0
Bus Voltage		
OverVoltage	105.0	102.0
UnderVoltage	95.0	98.0
Generator Excitation		
OverExcited (Q Max.)	100.0	95.0
UnderExcited (Q Min.)	100.0	

- **Apparent Power:** The product of the root-mean –square (RMS) or Effective value of the current and root –mean –square of the voltage. For AC circuit Systems, it is the square root of the sum of the squares of the Active Power and Reactive power, measured in volt-amperes (VA) or multiples thereof;
- **Reactive Power:** The component of the electrical power representing the alternating exchange of stored energy (inductive or capacitive) between sources and loads or between two systems, measured in VAR, or multiples thereof. For AC circuits or systems, it is the product of the RMS voltage and the RMS value of the quadrature component of alternating current. In a three phase system, it is the sum of the Reactive power of the individual phases;
- **Harmonics (THD):** Harmonics shall be defined as sinusoidal voltage and currents having frequencies that are integral multiples of the fundamental frequency.

4.10.1 Analysis based on design

The analysis has been conducted under the assumption of the Alerting Setting shown in Table 4.16. Results of the analysis are shown in the diagram (refer to Figure 4.23) with all details summarized in tabular forms (refer to the Appendix C)

As can be seen from the figure, parameter values are all acceptable. However, there is an indication in pink color for VFD1, inferring that this asset might have reached the marginal setting, but not critical. It is recommended that this asset shall be closely monitored. The conclusion on this asset will be validated together with the analysis on the Power Quality which is in subsection 4.13.

Summaries on the results are also shown in Table 4.17, Table 4.18, and Table 4.19.

It is concluded from this analysis that all parameter values are within the acceptable ranges.

4.10.2 Analysis based on measured data from the PQA

Analysis has been conducted for the overall system (referherein as MAIN), for Feeder to motor with VFD1 and softstarter, respectively. The detailed reports were obtained from the analytical software (refer to Appendix) with highlights presented in Figure 4.24, Figure 4.25, and Figure 4.26.

Following conclusions can be derived from the reports

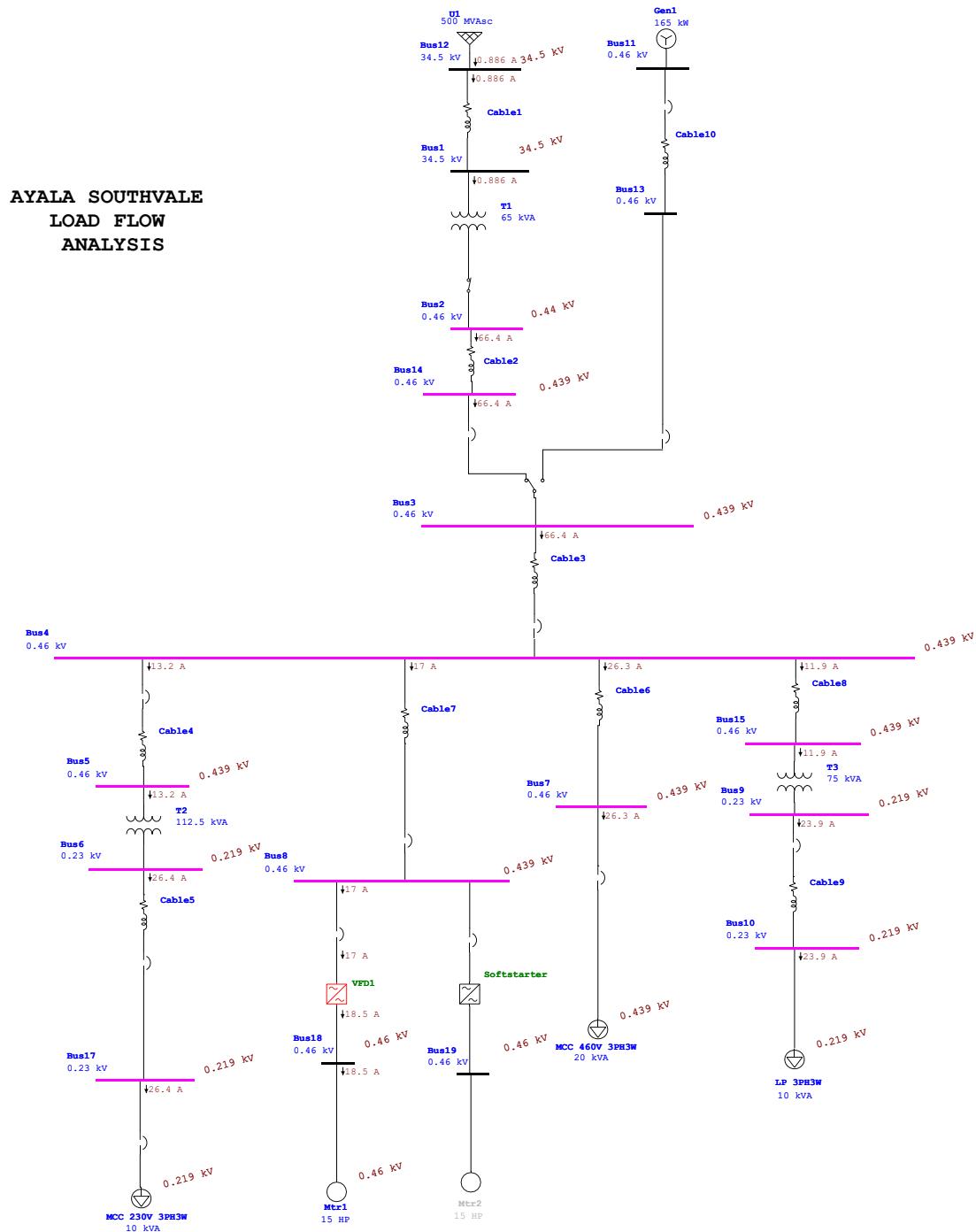


Figure 4.23: Load flow analysis

Table 4.17: Summary of total generation, loading, and demand

	MW	Mvar	MVA	% PF
Source (Swing Buses):	0.047	0.024	0.053	89.48 Lagging
Source (Non-Swing Buses):	0.000	0.000	0.000	
Total Demand:	0.047	0.024	0.053	89.48 Lagging
Total Motor Load:	0.038	0.023	0.045	85.85 Lagging
Total Static Load:	0.008	0.005	0.009	85.00 Lagging
Total Constant I Load:	0.000	0.000	0.000	
Total Generic Load:	0.000	0.000	0.000	
Apparent Losses:	0.001	-0.004		
System Mismatch:	0.000	0.000		

Number of Iterations: 2

Table 4.18: Bus loading

Bus	ID	KV	Rated Amps	Directly Connected Load				Total Bus Load					
				Constant kVA		Constant Z		Constant I		Generic			
				MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar		
Bus18		0.460								0.015	87.5	18.5	
Bus19		0.460											
Bus1		34.500								0.053	89.5	0.9	
Bus2		0.460								0.051	91.2	66.4	
Bus3		0.460								0.051	91.3	66.4	
Bus4		0.460								0.051	91.3	66.4	
Bus5		0.460								0.010	84.9	13.2	
Bus6		0.230								0.010	85.0	26.4	
Bus7		0.460		0.017	0.011					0.020	85.0	26.3	
Bus8		0.460			0.013					0.013	100.0	17.0	
Bus9		0.230								0.009	85.0	23.9	
Bus10		0.230				0.008	0.005			0.009	85.0	23.9	
Bus12		34.500								0.053	89.5	0.9	
Bus14		0.460								0.051	91.3	66.4	
Bus15		0.460								0.009	84.9	11.9	
Bus17		0.230			0.008	0.005				0.010	85.0	26.4	

* Indicates operating load of a bus exceeds the bus critical limit (100.0% of the Continuous Ampere rating).

Indicates operating load of a bus exceeds the bus marginal limit (95.0% of the Continuous Ampere rating).

Table 4.19: Branch loading

CKT / Branch		Cable & Reactor			Transformer				
ID	Type	Ampacity (Amp)	Loading Amp	%		Loading (input)		Loading (output)	
						MVA	%	MVA	%
Cable1	Cable	302.68	0.89	0.29					
Cable2	Cable	302.68	66.45	21.95					
Cable3	Cable	138.93	66.44	47.83					
Cable4	Cable	138.93	13.20	9.50					
Cable5	Cable	166.19	26.40	15.89					
Cable6	Cable	138.93	26.29	18.93					
Cable7	Cable	91.38	16.96	18.56					
Cable8	Cable	138.93	11.94	8.59					
Cable9	Cable	91.38	23.87	26.13					
T1	Transformer				0.065	0.053	81.4	0.051	77.9
T2	Transformer				0.113	0.010	8.9	0.010	8.9
T3	Transformer				0.075	0.009	12.1	0.009	12.1

* Indicates a branch with operating load exceeding the branch capability.

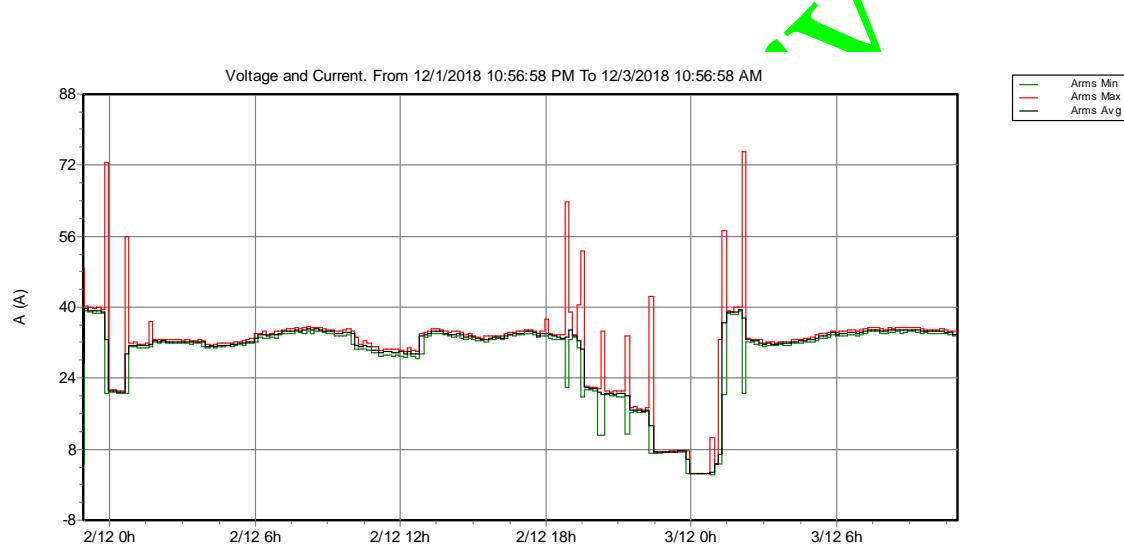


Figure 4.24: Main

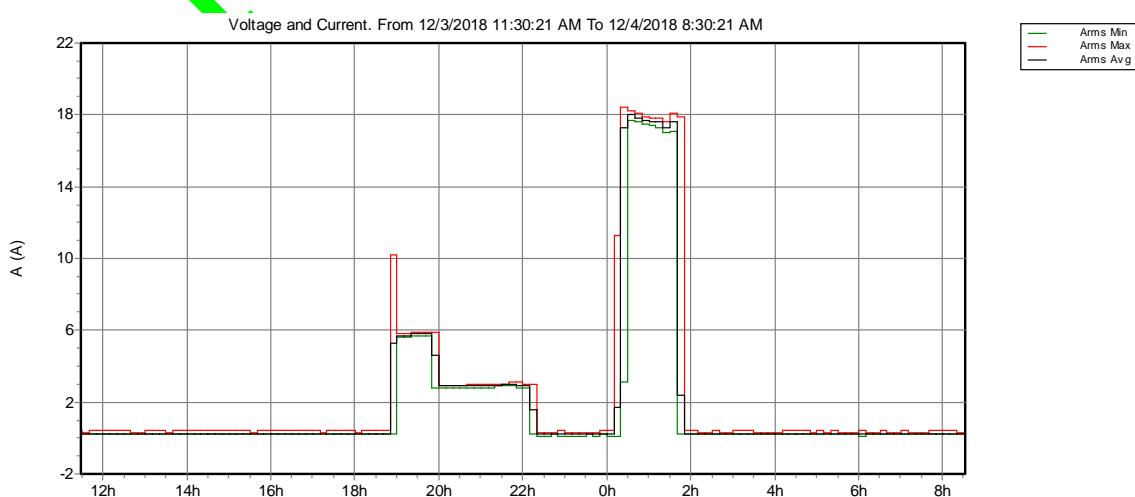


Figure 4.25: VFD-1

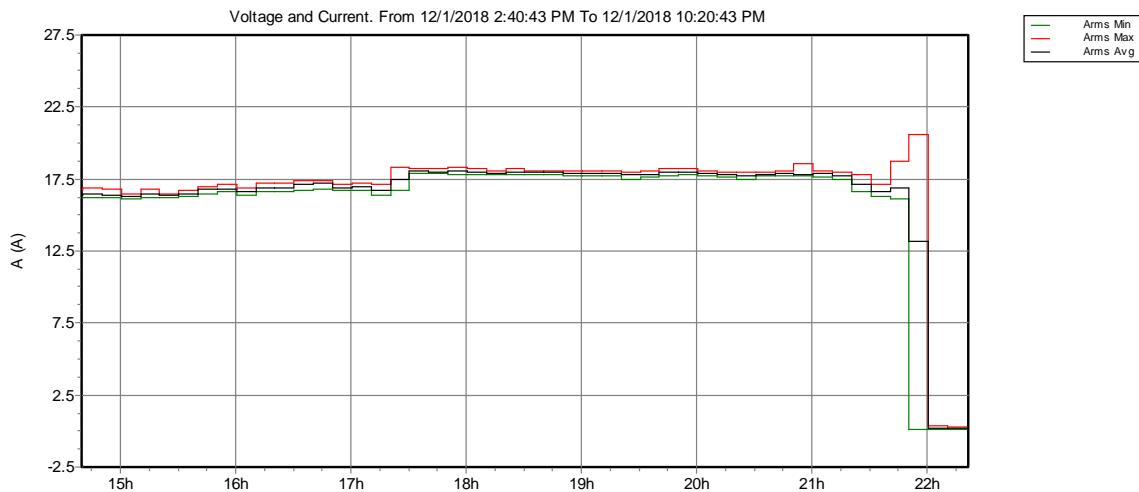


Figure 4.26: soft starter

- For the overall system, the maximum loading reached about about Phase A :75.1A, Phase B:67.7A, and Phase C: 68.6 (Figure 4.24), which is close to the theoretical values (66.4 A)obtained from ETAB software (Figure 4.23). This indicates that actual parameter values are within the acceptance range;
- For the VFD1, the maximum loading reached about Phase A:18.4A, Phase B: 9.9A, Phase C: 18.5 A (Figure 4.25), which is higher than the theoretical values (16.98 A)obtained from ETAB software (Figure 4.23). This indicates that actual parameter values are not within the acceptance range due to very low phase B value;
- For the softstarter, the maximum loading reached about Phase A: 20.6 A, Phase B: 18.5A, Phase C: (Figure 4.26), which is lower than the theoretical values (33.9 A) obtained from ETAB software (Figure 4.23). This indicates that actual parameter values are within the acceptance range.

From this analysis, it is recommended that continuous monitoring on VFD1 shall be implemented to ensure that the loading is not going to exceed the limit. Furthermore, continuity test on VFD shall be conducted to determine the probable issue in phase B.

4.11 Protection coordination study

In protection coordination study, the protective devices nearest to the FAULT shall trip first and the remaining of the protective devices shall not be affected. The results were obtained from the ETAB software and shown in Table 4.20, Table 4.21, and Table 4.22.

Table 4.20: Protective Device Settings - Low Voltage Circuit Breaker with Thermal-Magnetic Trip Device

LVCB ID	Manufacturer	Breaker		Thermal		Magnetic (Inst.)	
		Model	Size	Setting	Trip	Setting	Trip
						(Amps)	(Amps)
CB8	Schneider	EZC	63	100%	63	Fixed	
CB9	Schneider	EZC	63	100%	63	Fixed	
CB7	Schneider	EZC	250	90%	225	5X	1250
CB1	Siemens	JFC SENTRON	500	Fixed	500	5	4710
CB3	Siemens	JFC SENTRON	500	Fixed	500	3	3860

Further illustration of the coordination is shown in Figure 4.27.

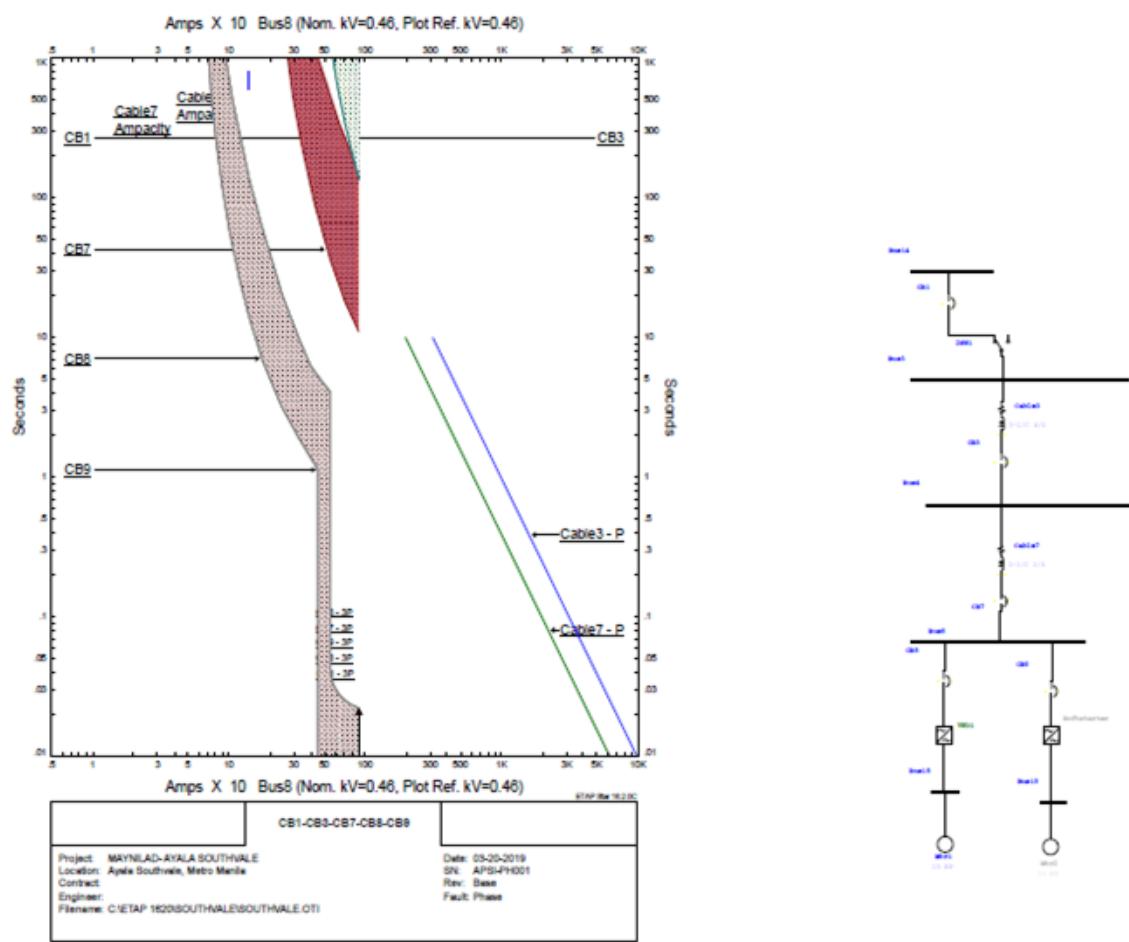


Figure 4.27: Coordination plot

Table 4.21: Cable-circuit breaker coordination

Items	Protective Device			Cable Protection				Max Fault 3Ph-Amps	Reference kV
	Location	ID	Type	Pickup Limit	Ampacity	Damage Curve	Condition		
Cable1	Load	CB1	TM-Thermal	Pass	Warning	Pass	Cable is underutilized due to Therm. Trip 500 A < 18161 A (242.1 A 34.5 kV) = Ampacity x 80%	1094	0.46
Cable1	Load	CB1	TM-Thermal	Pass	Warning	Pass	Therm. Trip 500 A is within 22701 A (302.7 A 34.5 kV) = Ampacity	1094	0.46
Cable1	Load	CB1	TM-Thermal	Pass	Warning	Pass	Therm. Trip 500 A is within max. limit of 22701 A (302.7 A 34.5 kV) = Ampacity x 100%	1094	0.46
Cable1	Load	CB1	TM-Thermal	Pass	Warning	Pass	Trip curve protects the damage curve	1094	0.46
Cable2	Load	CB1	TM-Thermal	Alert	Alert	Pass	Therm. Trip 500 A above max. limit of 302.7 A = Ampacity x 100%	1094	0.46
Cable2	Load	CB1	TM-Thermal	Alert	Alert	Pass	Therm. Trip 500 A is set above 302.7 A = Ampacity	1094	0.46
Cable2	Load	CB1	TM-Thermal	Alert	Alert	Pass	Trip curve protects the damage curve	1094	0.46
Cable3	Load	CB3	TM-Thermal	Alert	Alert	Pass	Therm. Trip 500 A above max. limit of 138.9 A = Ampacity x 100%	1086	0.46
Cable3	Load	CB3	TM-Thermal	Alert	Alert	Pass	Therm. Trip 500 A is set above 138.9 A = Ampacity	1086	0.46
Cable3	Load	CB3	TM-Thermal	Alert	Alert	Pass	Trip curve protects the damage curve	1086	0.46
Cable6	Load	CB12	TM-Thermal	Alert	Alert	Pass	Therm. Trip 400 A above max. limit of 138.9 A = Ampacity x 100%	1138	0.46
Cable6	Load	CB12	TM-Thermal	Alert	Alert	Pass	Therm. Trip 400 A is set above 138.9 A = Ampacity	1138	0.46
Cable6	Load	CB12	TM-Thermal	Alert	Alert	Pass	Trip curve protects the damage curve	1138	0.46
Cable7	Load	CB7	TM-Magnetic	-	-	Pass	Trip curve protects the damage curve	1248	0.46
Cable7	Load	CB7	TM-Thermal	Alert	Alert	Pass	Therm. Trip 225 A above max. limit of 91.4 A = Ampacity x 100%	1248	0.46
Cable7	Load	CB7	TM-Thermal	Alert	Alert	Pass	Therm. Trip 225 A is set above 91.4 A = Ampacity	1248	0.46
Cable7	Load	CB7	TM-Thermal	Alert	Alert	Pass	Trip curve protects the damage curve	1248	0.46
Cable8	Load	CB10	TM-Thermal	Pass	Warning	Pass	Cable is underutilized due to Therm. Trip 150 A < 222.3 A (111.1 A 0.46 kV) = Ampacity x 80%	1862	0.23
Cable8	Load	CB10	TM-Thermal	Pass	Warning	Pass	Therm. Trip 150 A is within 277.9 A (138.9 A 0.46 kV) = Ampacity	1862	0.23
Cable8	Load	CB10	TM-Thermal	Pass	Warning	Pass	Therm. Trip 150 A is within max. limit of 277.9 A (138.9 A 0.46 kV) = Ampacity x 100%	1862	0.23
Cable8	Load	CB10	TM-Thermal	Pass	Warning	Pass	Trip curve protects the damage curve	1862	0.23

Following remarks/recommendations can be interpreted from values shown in the tables and figure.

- Trip curve is covered by other protective functions or clipped by fault current.
- Some of the Circuit breaker trip devices are fixed and can not be adjusted. Hence coordination is deemed to be partial since some of the branch breaker TCC curves crossed the TCC curve of Main breaker on the instantaneous region.

Table 4.22: MCCB coordination

Zone		Stream		Max Fault		Ref. kV	Coord. status	Amp Range		Condition
ID	type	up PD	down PD	type	Amp			From	To	
Bus4	Bus	CB3	CB5	3Ph	1201	0.46	Pass	317.9	1201	Devices are coordinated between amp range of 317.9 A to 1201A 0.46 kV
	Bus	CB3	CB7	3Ph	1248	0.46	Pass	282.4	1248	Devices are coordinated between amp range of 282.4 A to 1248A 0.46 kV
	Bus	CB3	CB12	3Ph	1138	0.46	Alert	528.5	1138	Miscoordination, downstream trip curve is above and right of upstream
Bus8	Bus	CB7	CB9	3Ph	1248	0.46	Alert	1125	1125	Miscoordination, the time gap is smaller than 0.001 sec margin at I=1125 A, Plot Ref. kV=0.46
	Bus	CB7	CB8	3Ph	1248	0.46	Alert	1125	1125	Miscoordination, the time gap is smaller than 0.001 sec margin at I=1125 A, Plot Ref. kV=0.46

- L-G fault coordination is not possible. Trip unit of protective device has no ground fault protection provided due to the type of breaker supplied. However , this is allowed under the Philippine Electrical Code.
- For better coordination, main breaker should be of adjustable and electronic type.

4.12 Harmonic study

Harmonic study has been conducted under the following basics

- Harmonics shall be defined as sinusoidal voltage and currents having frequencies that are integral multiples of the fundamental frequency;
- The total harmonic distortion (THD) shall be defined as the ratio of the RMS value of the harmonic content to the RMS value of the fundamental quantity, expressed in percent;
- PHILIPPINE DISTRIBUTION CODE sets the THD of the voltage at any user system to not exceed 5% during normal operating conditions.

4.12.1 As per design

Results of the study as per design are shown in Figure 4.28 and Figure 4.29

It can be seen from the figures that there are a number of distortions, which are connected to bus 4. It is notable to observe that the percentage of the THD is 23.48%, which is very close to the margin of 5%.

4.12.2 Per actual

Results of the study based on the PQA are presented in Figures 4.30, 4.31, 4.32, 4.33, 4.34, and 4.35

Table 4.23 shows also the summary of the study, in which the min, average, and max values are presented along with the limit of 5%.

It can be interpreted from the table that values Main and VFD1 infer that there might be a concern, particularly for the harmonic orders of 3rd, 5th, and 7th being dominant registers. This might cause heating on the equipment.

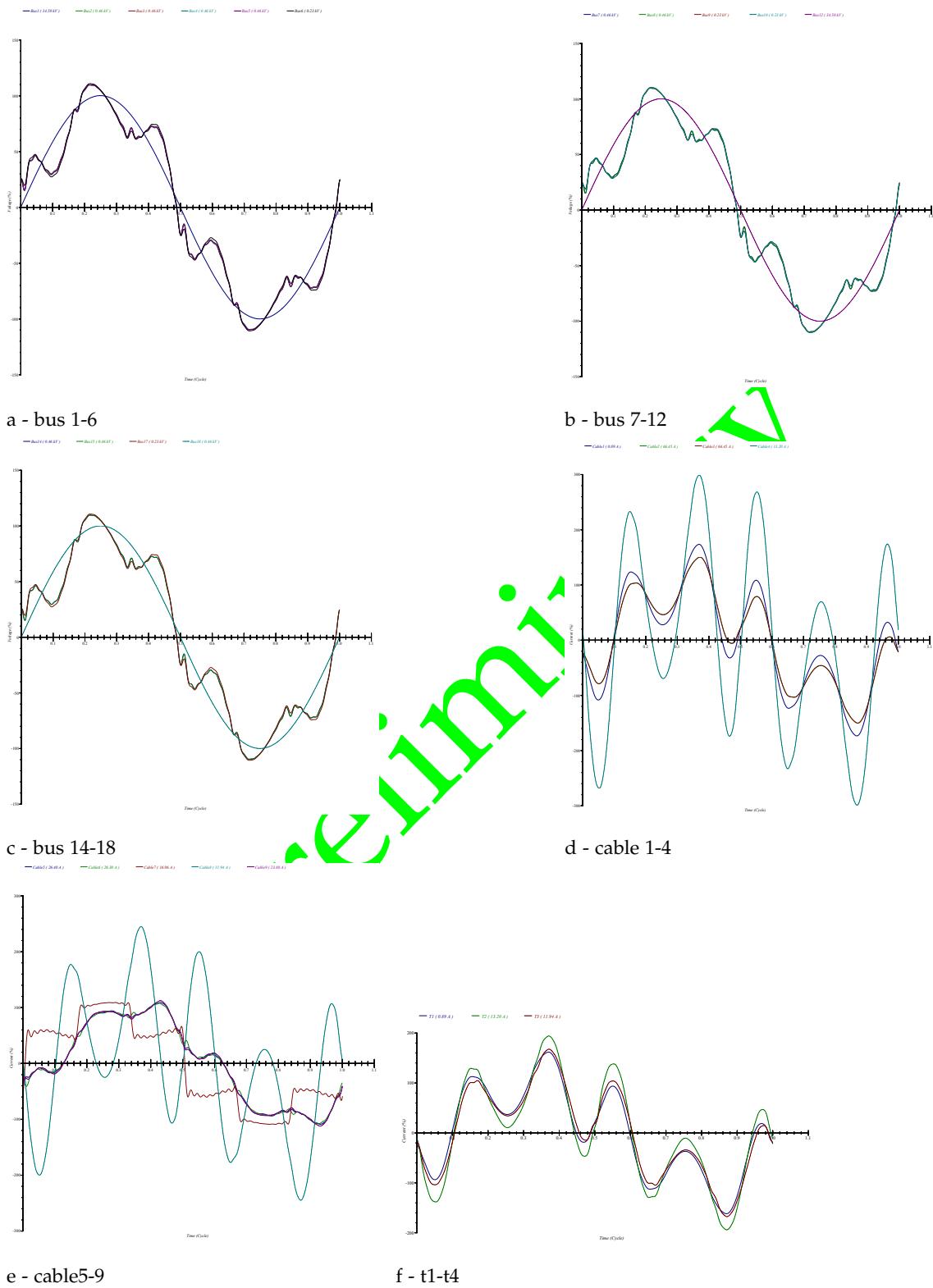


Figure 4.28: Harmonic wave form

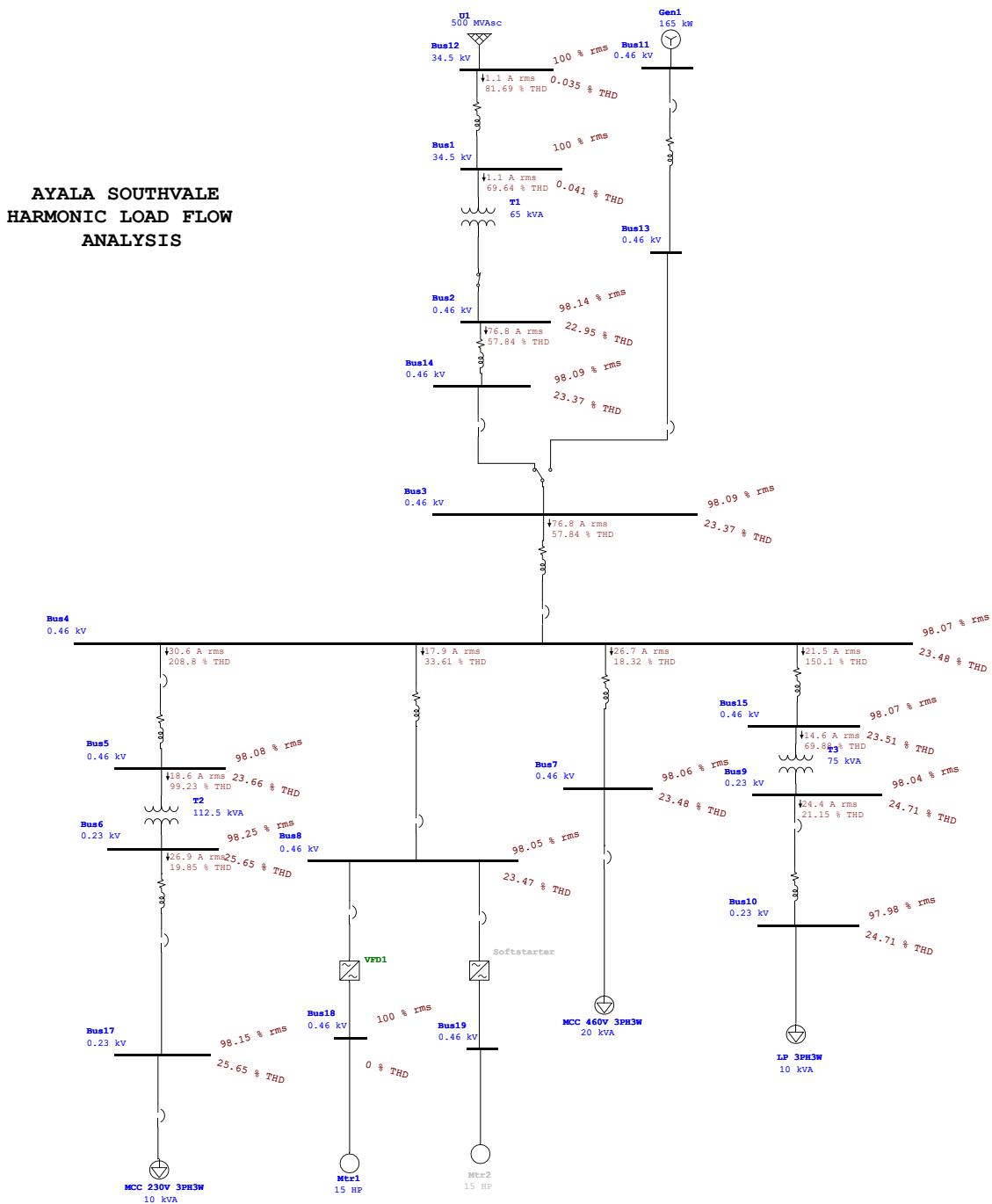


Figure 4.29: Load flow

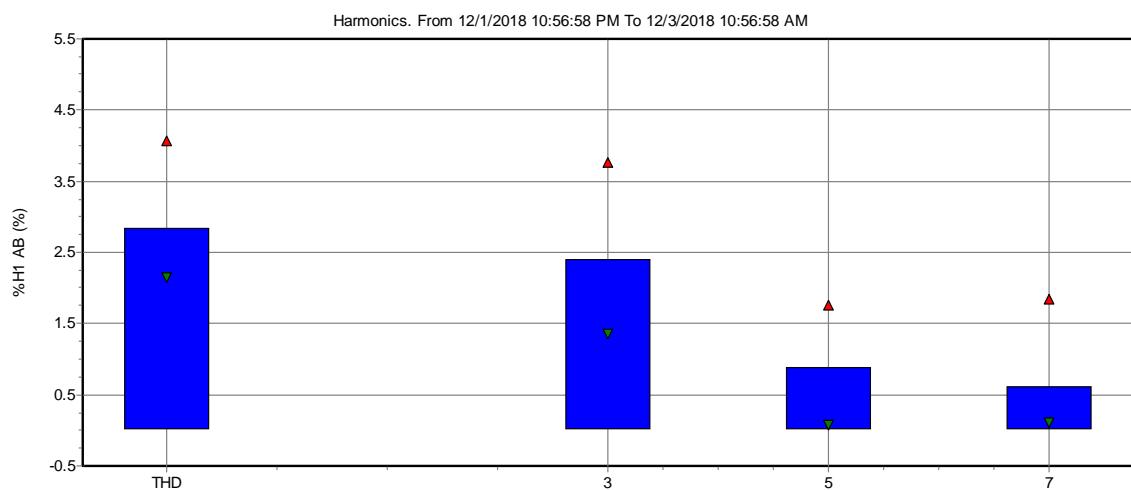


Figure 4.30: Voltage harmonic - AB

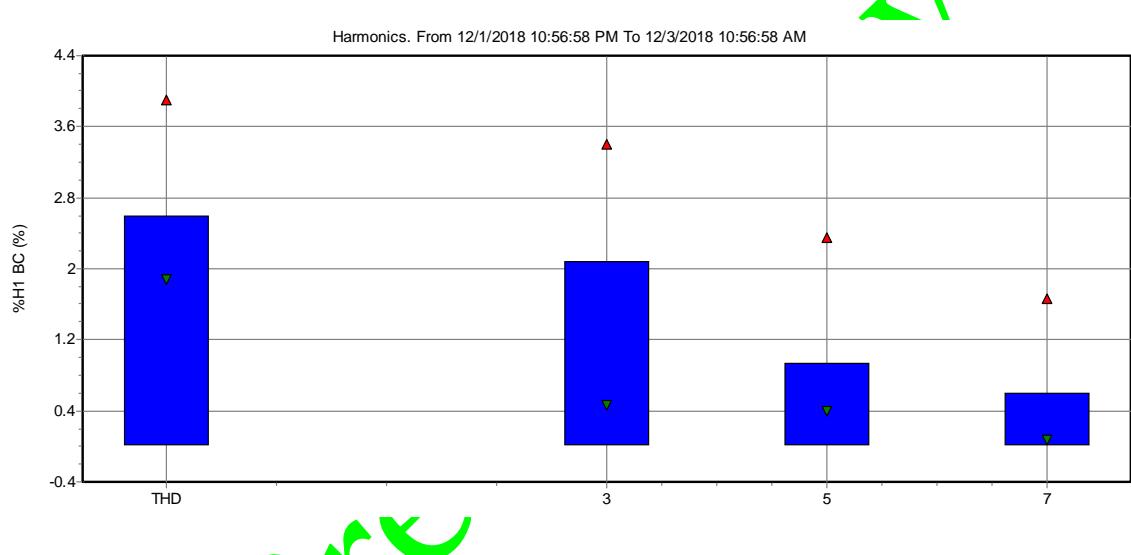


Figure 4.31: Voltage harmonic - BC

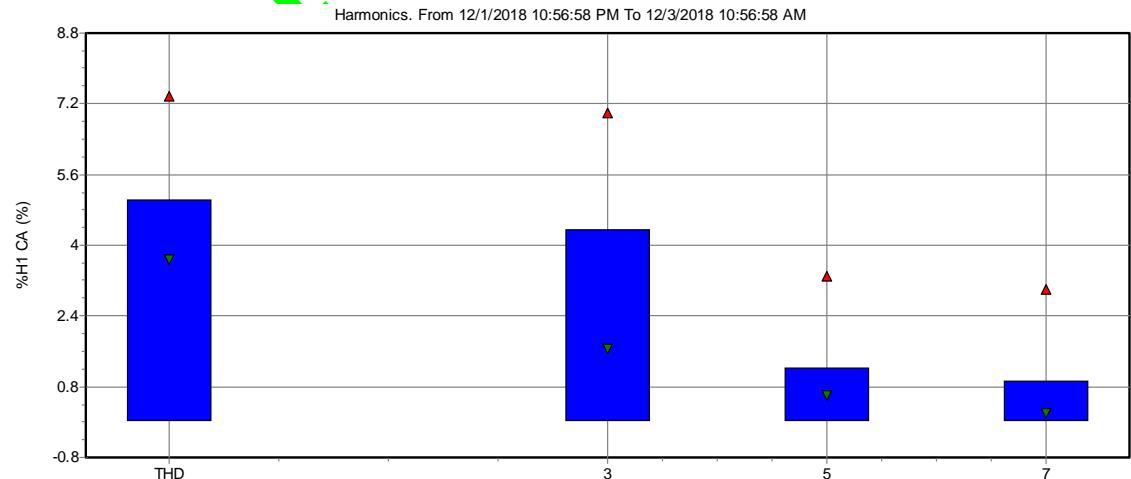


Figure 4.32: Voltage harmonic - CA

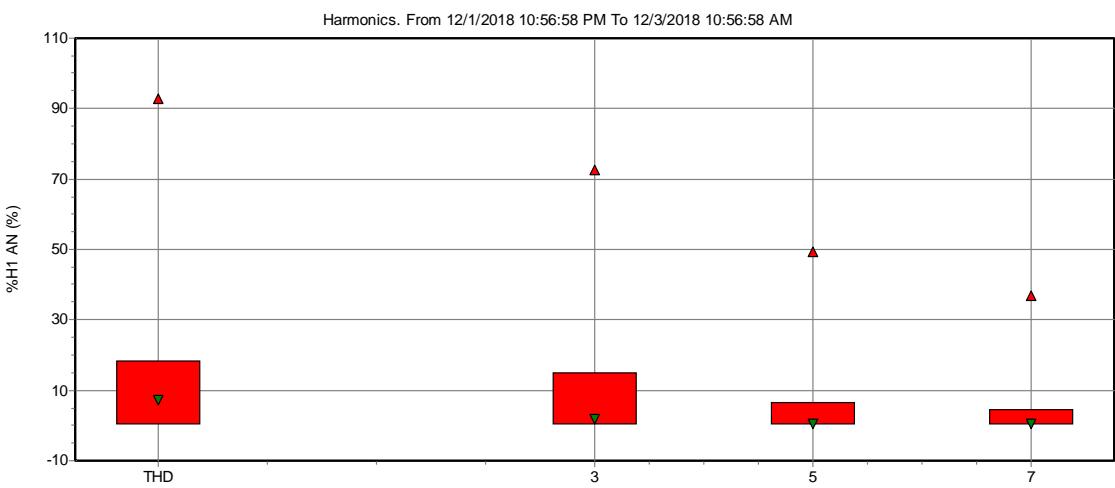


Figure 4.33: Current harmonic -AB

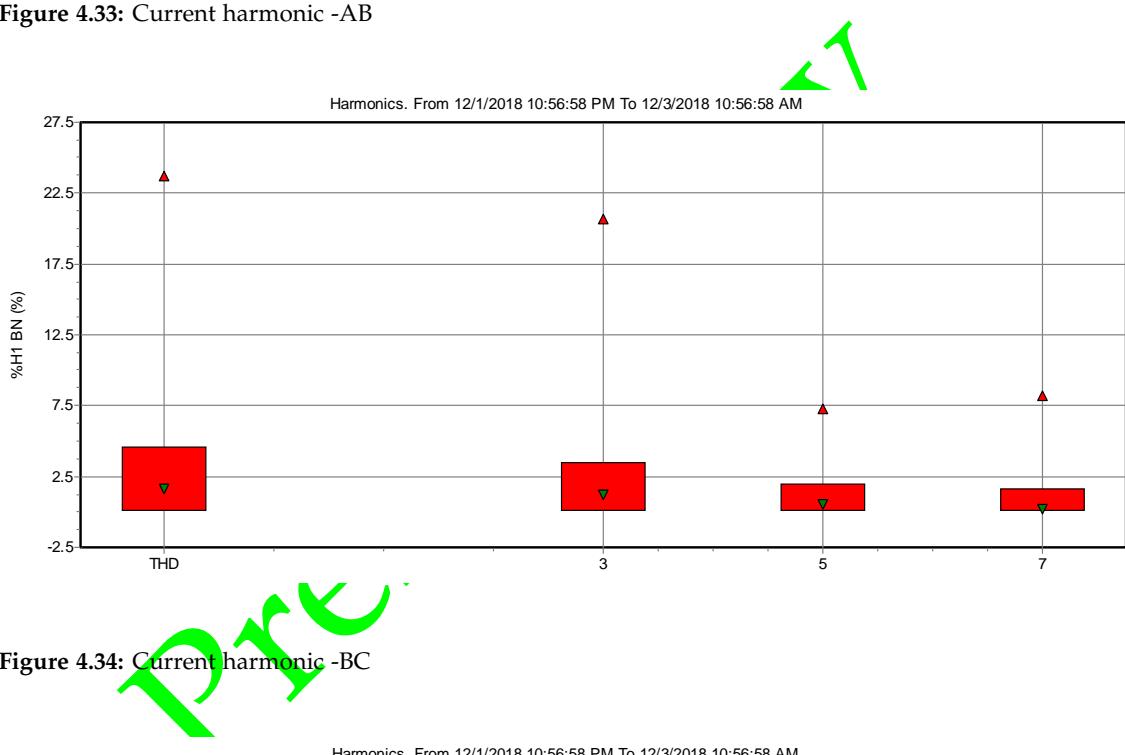


Figure 4.34: Current harmonic -BC

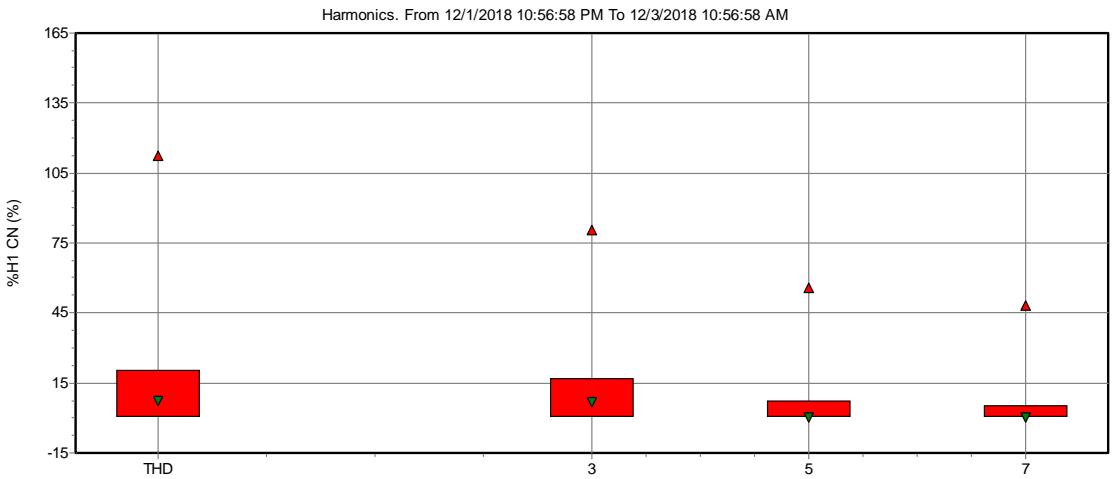


Figure 4.35: Current harmonic -CA

Table 4.23: Harmonic study

Total Harmonic Distortion (%)	Phase	Minimum	Average	Maximum	Limits (5%)	Remarks
Main 200A (Load side)	AB	3.89	3.93	4.94	5	Within Limits
	BC	3.58	3.6	4.68		
	CA	3.89	3.93	4.94		
VFD-1	AB	4.54	4.58	4.79	5	Within Limits
	BC	4.00	4.07	4.31		
	CA	4.54	4.58	4.79		
Softstarter	AB	2.86	4.01	4.38	5	Within Limits
	BC	2.68	3.62	3.86		
	CA	2.86	4.01	4.38		

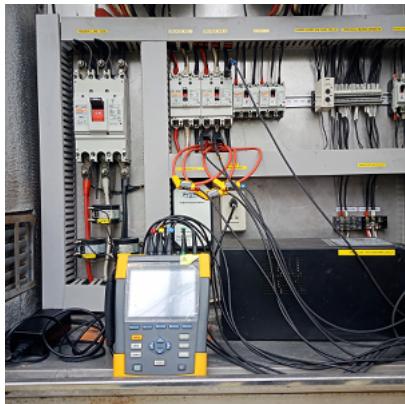


Figure 4.36: Power quality analyzer plugging during measurement

Recommendation shall be realized together with the recommendation from the study of Power Quality Analysis (refer to subsection 4.13)

4.13 Power quality analysis

The Power Quality Analysis (TQA) has been conducted on the Main system, VFD1, and VFD2 of this PS. The Power Quality Analyzer used is FLUKE 430-II. Figure 4.36 shows the analyzer during the course of measurement for the station.

4.13.1 Objectives and expected outcomes

The preliminary objectives and expected outcomes from this analysis are

- Record the voltage and current profile on the load side of Circuit Breaker with the recording interval set every five (10) minutes;
- Record power profile (KW, KVA, KVAR) on the load side of Circuit Breaker with the recording interval set every ten (10) minutes.
- Record Total Harmonic Distortion (THD);
- Record Values of Short Duration Voltage Variation that will exceed the limit set by Philippine Distribution code;
- Record values of Long Duration Voltage Variation that will exceed the limit set by the Philippine Distribution Code;
- Record values of Frequency Variation that will exceed the limit set by Philippine Distribution code;

- Record Transient voltage Surge defined by PDC and using Computer Business Equipment Manufacturer's Association(CBEMA) and Information Technology Industry Council (ITIC) Curve International Standard;
- Compute for Voltage Unbalance and compare it on the Voltage unbalance limit set by PDC;
- Recommendations.

4.13.2 Basic

The assessments made in this report are in accordance to IEEE Standard 1159-1995 “IEEE Recommended Practice for Monitoring Electric Power Quality”.

The Philippine Distribution Code was used as the local reference for power quality standards. According to the Philippine Distribution Code, a power quality problem exists when at least one of the categories in the tables of following sections is present during the normal operation of the electrical system

4.13.3 Results

Results are summarized in this section together with the enclosed tables and graphs in the Appendix D

Any values outside these limits are noted in the report. Values within the limits are considered to be within safe operating range.

4.13.3.1 RMS Voltage compliance

The steady-state rms voltage must remain within the range of 90.00% to 110.00%.

- Over Voltage – if the RMS value of the voltage is greater than or equal to 110% of the nominal value
- Under Voltage – if the RMS value of the voltage is less than or equal to 90% of the nominal voltage

Results are shown in Table 4.24.

Table 4.24: Power quality - RMS Voltage compliance

RMS VOLTAGE (460 VOLTS)	Phase	Minimum	Average	Maximum	Limits	Remarks
Main 250A (Load side)	AB	441.18	468.00	472.86	$\pm 10\%$ (414-506V)	Within Limits
	BC	438.68	464.40	469.70		
	CA	441.18	468.00	472.86		
VFD-1	AB	443.84	467.70	472.96	$\pm 10\%$ (414-506V)	Within Limits
	BC	441.76	463.50	468.26		
	CA	443.84	467.70	472.96		
Soft Starter	AB	441.71	458.50	463.26	$\pm 10\%$ (414-506V)	Within Limits
	BC	439.34	456.00	459.50		
	CA	441.71	458.50	463.26		

4.13.3.2 Voltage unbalance compliance

Voltage Unbalance shall be defined as the maximum deviation from the average of the three phase voltages divided by the average of the three phase voltages expressed in percent. The maximum voltage unbalance at the connection point of any user, excluding

the voltage unbalance passed on from the grid shall not exceed 2.5% during normal operating conditions.

Results are shown in Table 4.25.

Table 4.25: Power quality -Voltage unbalance

Voltage unbalance	Minimum	Average	Maximum	Limits (%)	Remarks
MAIN 200A (Load Side)	0.38	0.51	0.45	2.5	Within Limits
VFD-1	0.31	0.60	0.66	2.5	Within limits
Softstarter	0.36	0.36	0.54	2.5	Within Limits

4.13.3.3 Current unbalance compliance

Results are shown in Table 4.26 with note that the current unbalance should not exceed 10%.

Table 4.26: Power quality -Current unbalance

Current unbalance	Minimum	Average	Maximum	Limits (%)	Remarks
MAIN 200A (Load Side)	13.07	8.73	6.74	≤ 10%	Outside Limits
VFD-1	77.36	8.73	6.47	≤ 10%	Outside Limits
Softstarter	13.72	9.71	6.74	≤ 10%	Outside Limits

4.13.3.4 Harmonic - THD compliance

Results are shown in Table 4.27 with the following notes:

- Harmonics shall be defined as sinusoidal voltage and currents having frequencies that are integral multiples of the fundamental frequency;
- The total harmonic distortion (THD) shall be defined as the ratio of the RMS value of the harmonic content to the RMS value of the fundamental quantity, expressed in percent;
- PHILIPPINE DISTRIBUTION CODE sets the THD of the voltage at any user system to not exceed five percent (5%) during normal operating conditions.

Table 4.27: Power quality -Harmonic THD compliance

THD compliance	Phase	Minimum	Average	Maximum	Limits (%)	Remarks
Main	AB	3.89	3.93	4.94	≤ 5%	Within Limits
	BC	3.58	3.6	4.68		
	CA	3.89	3.93	4.94		
VFD-1	AB	4.54	4.58	4.79	≤ 5%	Within Limits
	BC	4.00	4.07	4.31		
	CA	4.54	4.58	4.79		
Softstarter	AB	2.86	4.01	4.38	≤ 5%	Within Limits
	BC	2.68	3.62	3.86		
	CA	2.86	4.01	4.38		

Note: Reading should be cause for alarm since the values are almost borderline. Kindly note that the dominant component are 3rd, 5th, and 7th order harmonics, respectively.

4.13.3.5 Harmonic - TDD compliance

Results are shown in Table 4.28 with the following notes:

- The Total Demand Distortion (TDD) shall be defined as the ratio of the RMS value of the harmonic content to the RMS value of the rated or maximum fundamental quantity, expressed in percent;
- PHILIPPINE DISTRIBUTION CODE sets the TDD of the current at any user of the system to not exceed five percent (5%) during normal operating conditions.

It is important to note that the values obtained for the THD (refer to previous sections) might declare the parameter values within the limits. However, the overall conclusion shall be derived together with the TDD compliance as the values of the TDD coming from the asset while the THD values coming normally from the sources.

Table 4.28: Power quality -Harmonic TDD compliance

TDD compliance	Phase	Minimum	Average	Maximum	Limits (%)	Remarks
Main	AB	18.23	15.66	62.39	$\leq 5\%$	Outside limits
	BC	1.09	1.15	22.33		
	CA	17.90	16.57	60.13		
VFD-1	AB	15.73	15.90	41.79	$\leq 5\%$	Outside limits
	BC	2.88	3.47	6.79		
	CA	16.58	16.89	25.48		
Soft starter	AB	9.25	13.67	44.67	$\leq 5\%$	Outside limits
	BC	1.84	2.46	83.07		
	CA	8.61	12.55	30.98		

In this situation, results of TDD are significant higher than the limit of 5%, indicating a certain degree of probability that there is an existing issue.

4.13.3.6 100% Power frequency (HZ) compliance

Results are shown in Table 4.29 with the following notes:

- A nominal fundamental frequency of 60HZ, PHILIPPINE DISTRIBUTION COCE set an acceptable limit of 59.7 HZ. for low frequency and 60.3 hz for high frequency.

Table 4.29: Power quality -Harmonic TDD compliance

Frequency	Minimum HZ	Average HZ	Maximum HZ	Limits HZ	Remarks
Main	59.476	60.14	60.423	59.7-60.3	Outside Limits
VFD-1	59.734	60.06	60.405	59.7-60.3	Outside Limits
Softstarter	59.721	60.06	60.328	59.7-60.3	Within Limits

4.13.3.7 Power factor

Results are shown in Table 4.30 with the following notes:

- The ideal situation is a cos phi or DPF equal or close to 1. Utilities may charge additional cost (penalty when var readings are high because they need to provide apparent power (VA, kVA) that does not include both var and W).

Table 4.30: Power quality -powerfactor

Power factor	Minimum	Average	Maximum	Limits	Remarks
Main	0.90	0.90	0.90	>0.85	Within Limits
VFD-1	0.53	0.53	0.58	>0.85	Outside limits
Softstarter	0.89	0.91	0.91	>0.85	Within Limits

4.13.3.8 Flicker

Results are shown in Table 4.31 with the following notes:

- A measuring period of 2 hours (Plt) is useful when there may be more than one interference source with irregular working cycles and for equipment such as welding machines. $Plt \leq 1.0$ is the limit used in standards like EN15160;
- The 10 min (Pst) uses a longer measuring period to eliminate the influence of random voltage variations.

Table 4.31: Power quality -powerfactor

Flicker	Parameter	Minimum	Average	Maximum	Limits	Remarks
Main	Plt	0.431	0.405	0.534	≤ 0.80	Within Limits
	Pst	0.879	0.787	1.071	≤ 1.0	Outside Limits
VFD-1	Plt	0.284	0.293	0.371	≤ 0.80	Within Limits
	Pst	0.568	0.587	0.760	≤ 1.0	Within Limits
Soft starter	Plt	0.134	0.145	0.159	≤ 0.80	Within Limits
	Pst	0.545	0.532	0.700	≤ 1.0	Within Limits

4.13.4 Conclusion and Recommendations

- In general the most efficient way to troubleshoot electrical systems, is to begin at the load and work towards the building's service entrance. Measurements are taken along the way to isolate faulty components or loads;
- Monitoring up to a period of one week is recommended to perform a quality check. That allows you to obtain a good impression of power quality;
- According to IEEE 519. "Most motor loads are relatively tolerant of harmonics". However, IEEE 519-1992 states further that, "Even in the case of the least susceptible equipment, harmonics can be harmful. Harmonics, can cause dielectric thermal or voltage stress, which causes premature aging of electrical insulation. A major effect of harmonic voltages and currents in rotating machinery (induction and synchronous) is increased heating due to iron and copper losses at the harmonic frequencies. The harmonic components thus affect the machine efficiency, and can also affect the torque developed";
- In the case of this station, the total demand distortion is outside the limits set in the Philippine Distribution Code. From the application perspective, we're most concerned with the maximum harmonic current levels, and the impact they have on the distribution system. This makes TDD a much more useful metric for power inverter distortion;
- the current unbalance occurred in the absence of voltage unbalance, hence it is recommended to look for the cause of current unbalance which could be faulty insulation or a phase shorted to ground. Correcting the current unbalance helps prevent



Figure 4.37: Visual inspection on electrical safety

overheating and deterioration of motor-winding insulation and other equipment. Thermal scanning of motor is recommended;

- The measured power factor is low for VFD-1. Consider addressing first the issues on harmonics before improving the power factor
- Crest Factor – A high crest factor value for current was recorded to signify a distorted current waveform. A CF of 1.8 or higher means high waveform distortion. This can be attributed on the current drawn by the variable frequency drive;

Main Phase	VOLTAGE		CURRENT	
	MIN	MAX	MIN	MAX
A	1.36	1.46	1.50	5.65
B	1.37	1.72	1.36	6.23
C	1.41	1.58	1.29	6.41

VFD-1 phase	VOLTAGE		CURRENT	
	MIN	MAX	MIN	MAX
A	1.36	1.42	1.32	10.37
B	1.37	1.58	1.04	9.13
C	1.41	1.49	1.24	9.89

Soft starter	VOLTAGE		CURRENT	
	MIN	MAX	MIN	MAX
A	1.36	1.42	1.27	5.27
B	1.37	1.42	1.18	28.75
C	1.43	1.50	1.25	4.70

- When second measurements will be taken and current harmonics is still high, consider an active filter to properly address the 3rd, 5th and 7th harmonics. An active filter (cancellation of all harmonics) can be considered altogether.

4.14 Grounding system study

The study has been conducted in accordance with the ITP. Figure 4.37 shows the grounding points and activities conducted during the test.

Results of the study are shown in Table 4.32 with the following note:

- The resistance between the main grounding electrode and ground should be no greater than five ohms for large commercial or industrial systems and 1.0 ohm or less for generating or transmission station grounds unless otherwise specified by the owner. (Reference ANSI/IEEE Standard 142)

Table 4.32: Ground system measurement results

Locations	Asset/Room	Resistance	Findings	Recommendations	Effects	Risks
ECB OUT-DOOR	TEST POINT 1 BARE COPPER WIRE	NO DATA	BCW WAS SUBMERGED IN WATER	REMOVE WATER AND ESTABLISH GROUNDING CONNECTION TO ATS	(1) Unwanted voltage maybe present on non-current carrying metal objects (2) Equipment might be damaged during a fault condition	(1) Incorrect Operation of overcurrent device with ground fault protection (2) Health and safety risks for facilities and personnel
ATS EQUIPMENT GROUND GENSET GROUND	TEST POINT 1 COPPER WIRE TEST POINT 2 GROUND ROD	0.62Ω 8.01Ω	Within the 5 ohms limit as per NFPA and IEE standards (1) Already exceeds the 5 ohms limits as per NFPA and IEE standards	None (1) Checking and retightening of loose grounding terminal connections (2) Replacement of improper lugs for grounding terminations	None (1) Overheating on conductors and possible nuisance tripping of ground fault protection or relays	None Damage to equipment or accessories
PANELBOARD TEST 460V	TEST POINT 1 BARE COPPER WIRE	NO DATA	CONNECTED TO BCW SUBMERGED IN WATER.	REMOVE WATER AND ESTABLISH GROUNDING CONNECTION TO ATS	(1) Unwanted voltage maybe present on non-current carrying metal objects (2) Equipment might be damaged during a fault condition	(1) Incorrect Operation of overcurrent device with ground fault protection (2) Health and safety risks for facilities and personnel
PANELBOARD TEST 400V	TEST POINT 1 BARE COPPER WIRE	NO DATA	CONNECTED TO BCW SUBMERGED IN WATER.	REMOVE WATER AND ESTABLISH GROUNDING CONNECTION TO ATS	(1) Unwanted voltage maybe present on non-current carrying metal objects (2) Equipment might be damaged during a fault condition	(1) Incorrect Operation of overcurrent device with ground fault protection (2) Health and safety risks for facilities and personnel
PANELBOARD TEST 230V	TEST POINT 1 BARE COPPER WIRE	NO DATA	CONNECTED TO BCW SUBMERGED IN WATER.	REMOVE WATER AND ESTABLISH GROUNDING CONNECTION TO ATS	(1) Unwanted voltage maybe present on non-current carrying metal objects (2) Equipment might be damaged during a fault condition	(1) Incorrect Operation of overcurrent device with ground fault protection (2) Health and safety risks for facilities and personnel

4.15 Electrical system design and analysis

4.15.1 Basics

In accordance with Article 1.3 Electrical Plans and specifications of the Philippine Electrical Code 2017 Edition, Electrical design analysis shall be included and submitted separately together with the electrical plans. These includes the followings:

1. Branch circuits, sub-feeders, feeders, busways, and service entrance;
2. Types, ratings, and trip settings of overload protective device;
3. Calculation of voltage drops;
4. Calculation of short circuit current for determining the interrupting capacity of overcurrent protective device for residential, commercial and industrial establishment;
5. Protection coordination of overcurrent protective devices;
6. ARC-flash Hazard Analysis to determine the required personal protective equipment (PPE).

ARC flash Hazard Analysis is required and is intended for concerned parties to be informed and made aware of the importance of personal protective equipment (PPE)

and its type for the flash hazard risk category determined by the analysis (refer to Table 4.33).

Table 4.33: ARC flash hazard risk categories and PPE ratings (Appendix H, PEC 2017)

Risk CAT.	Range of calculated incident energy [cal/cm ²]	Minimum Ppe Rating [Cal/Cm ²]	Clothing Required
0	0 < E ≤ 1.2	N/A	4.5-14.0 Oz/Yd ² Untreated Cotton
1	1.2 < E ≤ 4	4	Flame Retardant (Fr) Shirt And Pants
2	4 < E ≤ 8	8	Cotton Underclothing Plus Fr Shirt And Pants
3	8 < E ≤ 25	25	Cotton Underclothing Plus Fr Shirt, Pants, Overalls Or Equivalent
4	25 < E ≤ 40	40	Cotton Underclothing Plus Fr Shirt, Pants, Plus Double Layer Switching Coat And Pants Or Equivalent
5	40 < E ≤ 100	100	Cotton Underclothing Plus Fr Shirt, Pants, Plus Multi-Layer Switching Suit Or Equivalent

4.15.2 Results

Results are briefly presented in the following subsections. Details reports generated by the software are enclosed as part of the Appendix of this report (can also be an electronic files)

4.15.2.1 Branch circuits, sub-feeders, feeders and service entrance

Figure 4.38 shows the SLD with values associated with each nodes and links.

4.15.2.2 Types, ratings, and trip settings of overload protective device

Types, ratings, and trip settings of overload protective devices are shown in Table 4.34

Table 4.34: Protective Device Settings - Low Voltage Circuit Breaker with Thermal-Magnetic Trip Device

LVCB ID	Manufacturer	Breaker		Thermal		Magnetic (Inst.)	
		Model	Size	Setting	Trip (Amps)	Setting	Trip (Amps)
CB3	Siemens	Sentron JFC	500	Fixed	500	Fixed	xIn
CB12	Siemens	Sentron JFC	400	Fixed	400	Fixed	xIn
CB11	Siemens	CQD	100	Fixed	100	Fixed	xIn
CB6	GE	QB	225	Fixed	225	Fixed	xIn
CB10	GE	QJ	150	Fixed	32	Fixed	xIn
CB5	GE	EDNC	200	Fixed	200	Fixed	xIn
CB7	Schneider	NS	225	Fixed	225	Fixed	xIn

4.15.2.3 Calculation of voltage drops

Basic for analysis is per PEC 2017 ARTICLE 2.15.1.2(A)(1)(b)FPN NO.2, which states "Conductors for feeders, as defined in Article1.1, sized to prevent a voltage drop exceeding three (3) percent at the farthest outlet of power, heating and lighting loads, or combinations of such loads, and where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed five (5) percent , will provide reasonable efficiency.".

Results of voltage drop are summarized in Table 4.35

4.15.2.4 Calculation of short circuit current 3-PHASE

Table 4.36 show summaries of results on short circuit.

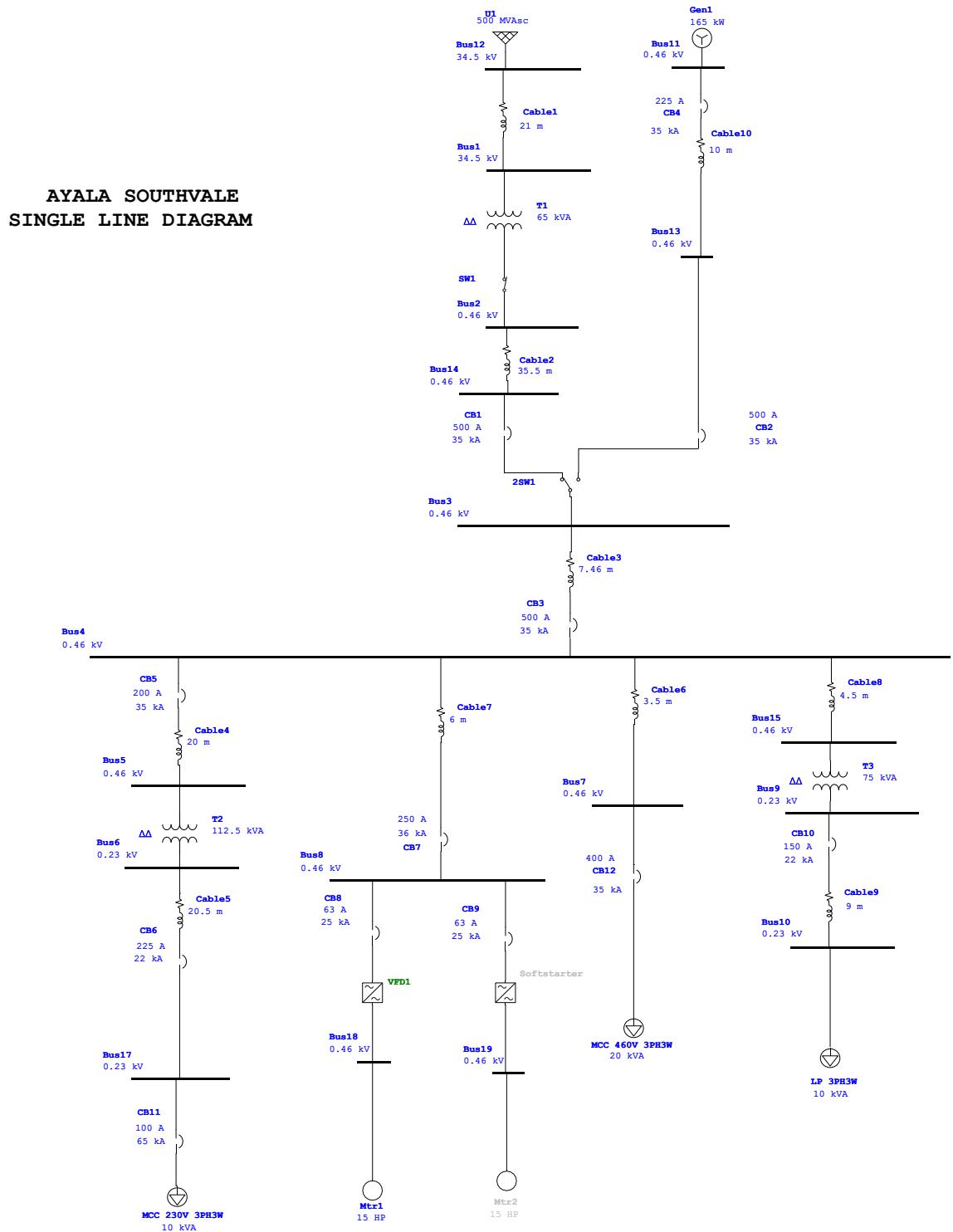


Figure 4.38: Single line diagram

Table 4.35: Voltage drop summary

Item	From	To	Wire Size, Mm^2	I	Length Meters	R $\Omega/305M$	X $\Omega/305M$	Vd	%Vd	Remarks
1	Pole Mounted Transformer 50kVA	Main Disconnect Switch	250	425	21	0.048	0.027	2.788	0.58	Within Limits
2	Main Disconnect Switch 400	ATS PANEL	250	425	35	0.048	0.027	4.647	0.97	Within Limits
3	ATS PANEL	MDP-P 460V	250	425	7.46	0.048	0.027	0.991	0.21	Within Limits
4	MDP-P 460V	MCC 1	250	425	3.56	0.048	0.027	0.273	0.06	Within Limits
5	MDP-P 460V	MCC 2	250	425	6	0.048	0.027	0.797	0.17	Within Limits
6	MDP-P 460V	ECB 200A	250	425	9	0.048	0.027	0.691	0.14	Within Limits
7	ECB 200A	DRY TYPE TRANSFORMER 112.5KVA	125	285.0	2	0.057	0.052	0.249	0.05	Within Limits
8	DRY TYPE TRANSFORMER 112.5KVA	MDP-S 230V	125	285	20.5	0.057	0.052	2.557	1.11	Within Limits
9	MDP-S 230V	MCC 230V	125	285	1	0.057	0.052	0.125	0.05	Within Limits
10	MDP-P 460V	DRY TYPE TRANSFORMER 75KVA	250	425	4.5	0.063	0.051	0.879	0.22	Within Limits
11	DRY TYPE TRANSFORMER 75KVA	LP PANEL	60	170	9	0.1	0.054	0.986	0.43	Within Limits

4.15.2.5 Protection coordination of overcurrent protective devices

Results of study on protection coordination are presented in subsection 4.11. With reference to the coordination plot shown in Figure 4.27, it is remarked that partial coordination only for the main and feeder breakers. TCC of feeders crosses the TCC of enclosed circuit breaker upstream of the feeders. Trip curve is covered by other protective functions or clipped by fault current.

4.15.2.6 Arc-flash Hazard Analysis

4.15.3 Recommendations

According to the results of the Arc Flash Analysis, Cotton underclothing plus FR shirt, pants, plus multi-layer switching suit or equivalent should be worn when opening the cover of the MCC. Arc flash Boundary (AFB) is about 8 feet (2.44 meters). Contributors to the arc flash are the motor loads and the VFD's.

An Arc flash label (refer to Figure 4.40) should be placed on the MCC as per requirement of the Philippine Electrical code.

4.16 Fire protection and safety (FDAS) audit

4.16.1 Fire alarm and detection system

4.16.1.1 Data and analysis

Summary of data and information from FDAS audit is presented in Table 4.38 with visual images on as-found devices and panels (Figure 4.41 and Figure 4.42, and Figure 4.43).

Table 4.36: Short circuit Summary

1/2 Cycle - 3-Phase, LG, LL, & LLG Fault Currents

Prefault Voltage = 100 % of the Bus Nominal Voltage

Bus ID	kV	3-Phase Fault			Line-to-Ground Fault			Line-to-Line Fault			*Line-to-Line-to-Ground		
		Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.	Real	Imag.	Mag.
Bus1	34.500	0.701	-8.328	8.357	0.704	-8.321	8.350	7.212	0.607	7.237	-7.566	3.550	8.358
Bus2	0.460	0.488	-1.199	1.295	0.000	0.000	0.000	1.039	0.422	1.121	1.039	0.422	1.121
Bus3	0.460	0.481	-1.171	1.266	0.000	0.000	0.000	1.014	0.417	1.096	1.014	0.417	1.096
Bus4	0.460	0.482	-1.162	1.258	0.000	0.000	0.000	1.006	0.417	1.089	1.006	0.417	1.089
Bus5	0.460	0.485	-1.134	1.235	0.000	0.000	0.000	0.982	0.420	1.068	0.982	0.420	1.068
Bus6	0.230	0.690	-1.751	1.882	0.000	0.000	0.000	1.517	0.597	1.630	1.517	0.597	1.630
Bus7	0.460	0.482	-1.158	1.254	0.000	0.000	0.000	1.003	0.418	1.086	1.003	0.418	1.086
Bus8	0.460	0.486	-1.149	1.248	0.000	0.000	0.000	0.995	0.421	1.081	0.995	0.421	1.081
Bus9	0.230	0.755	-1.702	1.862	0.000	0.000	0.000	1.474	0.654	1.612	1.474	0.654	1.612
Bus10	0.230	0.773	-1.619	1.794	0.000	0.000	0.000	1.402	0.669	1.554	1.402	0.669	1.554
Bus12	34.500	0.696	-8.340	8.369	0.695	-8.340	8.369	7.223	0.602	7.248	6.875	4.772	8.369
Bus14	0.460	0.481	-1.171	1.266	0.000	0.000	0.000	1.014	0.417	1.096	1.014	0.417	1.096
Bus15	0.460	0.483	-1.155	1.252	0.000	0.000	0.000	1.000	0.418	1.084	1.000	0.418	1.084
Bus17	0.230	0.693	-1.640	1.781	0.000	0.000	0.000	1.421	0.600	1.542	1.421	0.600	1.542
Bus18	0.460	0.041	-0.060	0.073	0.042	-0.015	0.045	0.052	0.035	0.063	-0.066	-0.034	0.074
Bus19	0.460	0.085	0.000	0.085	0.085	0.000	0.085	0.000	0.073	0.073	-0.042	0.073	0.085

All fault currents are symmetrical (1/2 Cycle network) values in rms kA.

*LLG fault current is the larger of the two faulted line currents.

Table 4.37: Incident Energy Summary

Faulted Bus ID	Nom. kV	Equipment Type	Gap (mm)	Fault Current			Trip Device			Arc Flash Boundary (ft)	Incident Energy (cal/cm²)	Working Distance (inches)	Energy Level
				Bolted Fault (kA) Bus	PD Bus	PD Arc Fault (kA)	Source Trip Device ID	Trip (cycle)	Open (cycle)				
# Bus1	34.500	Other		8.357						6.00	11.5	17.7	36
Bus2	0.460	Switchboard	32	1.295						6.00	0.7	0.3	Level A
Bus3	0.460	Other	13	1.266						480.00	8.0	34.3	18
Bus4	0.460	Switchgear	32	1.258						480.00	13.7	20.4	Level D
Bus5	0.460	Other	13	1.233	1.176	1.032	CB5		1.83	0.00	1.83	0.5	0.1
Bus6	0.230	Other	13	1.882						480.00	9.0	43.4	18
Bus7	0.460	Other	13	1.254						480.00	8.0	34.1	18
Bus8	0.460	Other	13	1.248						480.00	8.0	33.9	18
Bus9	0.230	Other	13	1.862						480.00	9.0	43.0	18
Bus10	0.230	Other	13	1.794	1.794	1.128	CB10		602.71	0.00	602.71	9.1	44.0
# Bus12	34.500	Other		8.369						6.00	11.5	17.7	36
Bus14	0.460	Cable Bus	13	1.266						6.00	0.9	0.4	Level A
Bus15	0.460	Other	13	1.252						480.00	8.0	34.0	18
Bus17	0.230	Other	13	1.781						480.00	8.8	41.5	18
# Bus18	0.460	Other		0.073						480.00	1.1	0.7	18

The theoretically derived Lee method was used to determine the incident energy and arc flash boundary for this location since the bolted fault current or nominal voltage are outside the empirical method range. ((Ib^m < 0.7 kA or I^b_m > 106 kA) and (0.208 ≤ Nominal kV ≤ 15 kV))

**AYALA SOUTHVALE
ARC FLASH HAZARD
ANALYSIS**

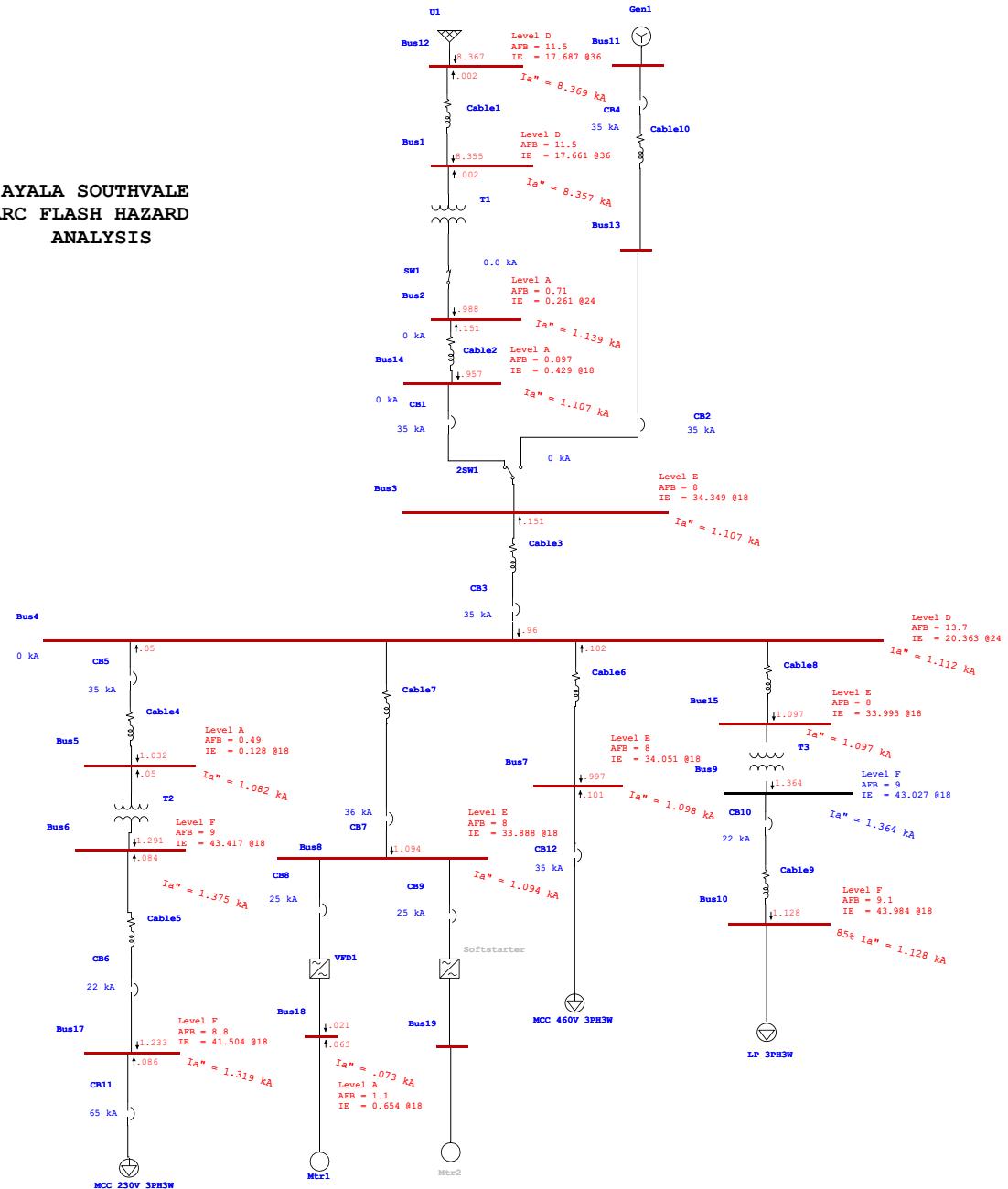


Figure 4.39: ARC flash analysis

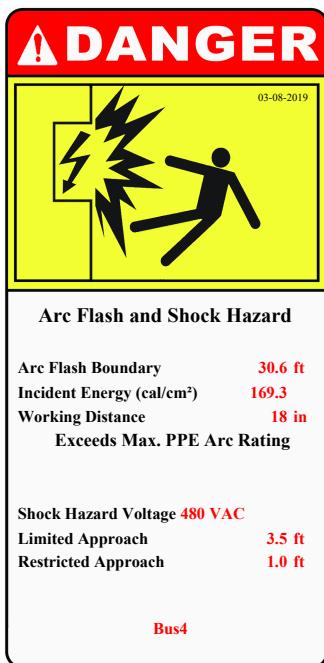


Figure 4.40: Arc flash label

Table 4.38: FDAS data highlights 01.

No.	Assets	Status	Remarks
A.	VISUAL CHECK OF FIRE ALARM CONTROL PANEL		
1	Panel Status, installed and location area	1	INSTALLED IN THE CONTROL ROOM
2	Power indicator lamp operational	0	NO POWER (NO LIGHT)
3	Devices properly indicated and marked	0	NO MARKINGS
4	Panel clear from trouble indicators	0	NO INDICATOR, NO POWER
5	Lamp test indicator operational	0	NO MARKINGS
6	Zones properly indicated and marked	0	NO MARKINGS
7	Check if it's connected to sprinkler system	0	NO SPRINKLER INSTALLED AT SITE
B.	CHECKING OF INSTALLED DEVICES		
1	Check floor plan lay-out and location of the device if accessible/easy to access	0	No As Built Plan
2	Heat detectors and / or smoke detectors indicator lamp functioning	1	LOCATION OKAY, ONE ROOM HAS NO SMOKE DETECTOR DEVICE FOR VERIFICATION ON TESTING
3	Heat detectors and / or smoke detectors indicator lamp functioning		
4	Pull station locations acceptable	1	ACCESSIBLE FOR VERIFICATION
5	Bells and buzzers operated correctly	0	NO BELL INSTALLED
6	Bells and buzzers audibility	0	NO STROBE LIGHTS
7	Strobe lights locations are acceptable	0	NO DEVICE
8	Strobe light operated correctly	0	NOT MARKED
9	Are Fire alarm zones (areas) clearly marked	0	FOR VERIFICATION
10	Is there a maintenance and service contract for the fire alarm system		
11	Does the Fire Alarm System smoke detector, heat detector, manual call point , horn and strobe light working and have a current inspection tag	0	NO INSPECTION TAG
12	Is the fire alarm system in full working order	0	NO INSPECTION TAG

On the inspection date, it was established that there is Fire Alarm Control Panel P-2 TYPE 1 ZONE , National brand and the devices are SMOKE DETECTOR "NATIONAL" brand.

It is a conventional fire alarm system which is an early warning system design that detects a fire, that tells the zone/ area of the fire but not the exact location of the fire. The existing design plan did not consider where a specific fire alarm can signal exactly



(a - Fire alarm control panel)



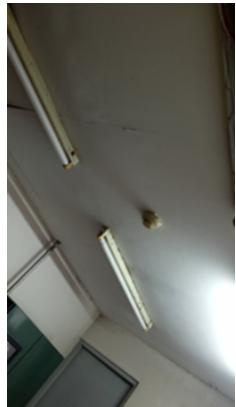
(b -Manual push button)



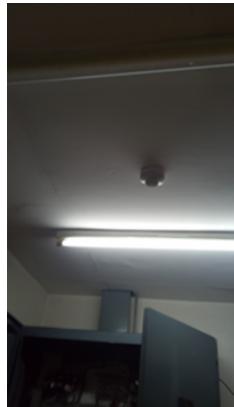
(c -Missing belt)



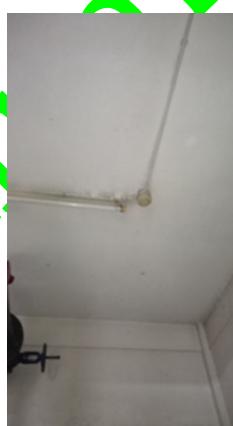
(d -SM01)



(e -SM02)



(f -SM03)

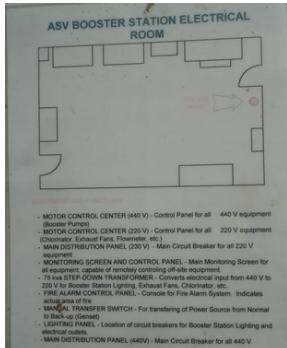


(h -SM05)



(i -SM06)

Figure 4.41: As-found devices and panels



(a - ASV booster)

(b -Fire extinguisher 01)

(c -Fire extinguisher 02)

Figure 4.42: Electrical safety

where the fire is occurring.

The existing Fire Detection and Alarm system consists of 7 pcs of smoke detector, 1 pc manual push button, and 1 pc bell.

On the testing date, the activity was witnessed by the operator on duty for this pump station.

Findings are shown in Table 4.39 and Figure 4.43

In brief, FDAS of the station is not provide adequate level of services mainly due to:

- Most of the smoke detector devices, manual call point, buzzer and the FACP were not functioning. These were established during the conducted testing of FDAS and devices;
- Manual push button was not functioning when the button was pushed;
- Bell was missing from its original location;
- FACP is with input voltage but was not functioning when tested.

Recommendations

- The smoke detectors are not stand alone type and is dependent on the Fire Alarm control panel for proper operation;
- The FACP, though still have input voltage has no output voltage and is recommended for replacement together with all the devices. All devices in the system should be compatible to be able to operate. Replacement of FACP alone does not guarantee that the existing smoke detectors will operate;
- After replacement of battery, push test/ "hush" button. This will decrease the sensitivity for approximately 8 minutes. During this time, the RED LED will flash every 10 seconds. This will indicate that the device is functioning;
- Owing to the years, the wires and other auxiliaries have deteriorated and must be replaced by a new FDAS system.



Smoke Detector #1



Dust SD#1



Testing of Smoke Detector



Testing At pump area SD#5,6,7



Smoke Detector#2



Dust SD#2



Smoke Detector#3



Dust SD#3



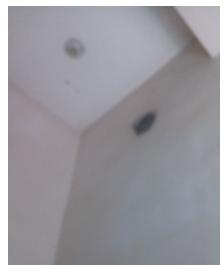
Smoke Detector#4



Opening SD#4



Manual Push Button



Missing Bell



Fire Alarm Control Panel



Animal droppings

Figure 4.43: Visual inspection on FDAS and safety devices

Table 4.39: FDAS findings

ITEM	DESCRIPTION	YES	NO	Findings During Testing	Test Results
1.	Smoke Detector #1		X	-With dust inside and outside -Spray Smoke Detector Maximum 3 times	-No response on smoke tester -Repeat spray again but no response in the device -Repeat clean -After 3x spray no response on smoke tester
Analysis: After spraying of smoke tester, removal of the device from base to Reset contact point and cleaning did not show any improvement on the device. Hence device is declared not functioning and there is communication failure between device and FACP panel.					
2.	Smoke Detector#2		X	Same as Smoke detector#1	Same as Smoke detector#1
Analysis: Same as Smoke detector#1					
3.	Smoke Detector #3			Same as Smoke detector#1	Same as Smoke detector#1
Analysis: Same as Smoke detector#1					
4.	Smoke Detector #4		X	With dust outside -Difficulty in removing smoke detector head. -Spray Smoke Detector Maximum 3 times	Same as Smoke detector#1
Analysis: Same as Smoke detector#1					
4.	Smoke Detector #5 At pump Area		X	-Elevation too high. Scaffolding or manual lift not possible to inspect inside of SD	--No response on smoke tester
5.	Smoke Detector #6 At pump Area		X	Same as Smoke detector#4	Same as Smoke detector#4
6.	Smoke Detector #7 At pump Area		X	Same as Smoke detector#4	Same as Smoke detector#4
7.	Manual Push Button		X	-Push the button 3x -No audible response	- Repeat pushing the button
Analysis : Manual push button should have an audible alarm response after pushing the button. Hence this device is declared not functioning					
6.	Missing Bell		X	- Bell is missing. Only wiring is visible	-No test to be performed
7.	FACP			- with accumulated dust and dirt -with insect and rat "droppings" -No light indicator -No response on sounder, system reset, fire report and battery test when toggle pressed -evidence of rusty enclosure	Measured supply voltage. Value 205 volts Measured output voltage. Value: 0 volts
Analysis : FACP is not functioning					

System Testing

FDAS shall be subjected to the following tests conforming to the Philippine Electronics Code of 2014 and Philippine Electrical Code of 2017

- ✓ Testing of insulation resistance and continuity of wires;
- ✓ Verification of installed devices;
- ✓ Operation and response of FDAS;
- ✓ Testing the operation of initiating devices;
- ✓ Measuring sound pressure level generated by notification devices;

Records

Every FDAS system shall keep the following documentations

- ✓ A complete set of operation and maintenance manuals of the manufacturer covering all equipment used in the system;
- ✓ A complete set of as-built drawings;
- ✓ A written sequence of operation;
- ✓ Record of completion and results of every inspection, testing and maintenance;
- ✓ Record of components within the database.

4.16.2 Lighting protection system

4.16.2.1 Data and analysis

No lightning protection was installed for this PS.

4.16.2.2 Recommendations

Refer to the conceptual design in Chapter 5

Short term Recommendations

Plan for the installation of a new lightning protection system

- ✓ the LPS conforms to the design and is based on the standard;
- ✓ all components of the LPS are in good condition and capable of performing their designed functions, and that there is no corrosion.

Long term Recommendations

Plan for the installation of a new lightning protection system

- ✓ According to the standard, an inspection should be undertaken during the construction of the structure, after the installation, after alterations or repairs, and when it is known that the structure has been struck by lightning;
- ✓ It is also recommended that inspections take place “periodically at such intervals as determined with regard to the nature of the structure to be protected”, taking into account the local environment, such as corrosive soils and corrosive atmospheric conditions and the type of protection measures employed;

- ✓ The inspection comprises checking the technical documentation, visual inspections and test measurements;
- ✓ Prepare an inspection guide to facilitate the inspection process containing sufficient information on the installation and its components, tests methods and previous inspection/test data;
- ✓ During the visual inspection, the following should be checked;
 - the deterioration and corrosion of air-termination elements, conductors and connections
 - the corrosion of earth electrodes
 - the earthing resistance value for the earth-termination system
 - the condition of connections, equipotential bonding and fixings.
- ✓ For those parts of an earthing system and bonding network not visible for inspection, tests of electrical continuity should be performed;
- ✓ An inspection report should be prepared detailing the status of the system, any deviations from the technical documentation and the results of any measurements undertaken. Any obvious faults should also be reported.

No lightning protection system is 100% effective. A system designed in compliance with the standard does not guarantee immunity from damage. Lightning protection is an issue of statistical probabilities and risk management. A system designed in compliance with the standard should statistically reduce the risk to below a pre-determined threshold. The IEC 62305-2 risk management process provides a framework for this analysis. An effective lightning protection system needs to control a variety of risks. While the current of the lightning flash creates a number of electrical hazards, thermal and mechanical hazards also need to be addressed.

Risk to persons (and animals) include:

- Direct flash;
- Step potential ;
- Touch potential ;
- Side flash ;
- Secondary effects
 - asphyxiation from smoke or injury due to fire
 - structural dangers such as falling masonry from point of strike
 - unsafe conditions such as water ingress from roof penetrations causing electrical or other hazards, failure or malfunction of processes, equipment and safety systems

Risk to structures & internal equipment include:

- Fire and/or explosion triggered by heat of lightning flash, its attachment point or electrical arcing of lightning current within structures ;

- Fire and/or explosion triggered by ohmic heating of conductors or arcing due to melted conductors;
- Punctures of structure roofing due to plasma heat at lightning point of strike ;
- Failure of internal electrical and electronic systems ;
- Mechanical damage including dislodged materials at point of strike.

4.16.3 Ground-Fault circuit interrupter (GFCI) or electric leakage circuit breaker (ELCB) or Residual circuit devices (RCD)

4.16.3.1 Data and analysis

No ground fault circuit interrupter (GFCI) or earth leakage Circuit breaker (ELCB) protection was installed in the panel for FDAS for this PS.

4.16.3.2 Recommendations

Refer to the conceptual design in Chapter 5

4.16.4 Electrical safety and protective devices

4.16.4.1 Data and analysis

Facts obtained from inspection are presented in Table 4.40 with indicative figures for each devices presented in Figure 4.43.

Table 4.40: Electrical Safety

ITEM	DESCRIPTION	STATUS	Findings During Inspection	Remarks
1	Materials near door	0	- Improper storage - Blocking of exit door - Risk to people	-Should be kept away from exit door in cases of emergency
2	Accumulated Materials	0	-Improper Storage - can cause spreading of fire	-Unsafe -Housekeeping necessary for fire not to accelerate
3	Broken Window Glass 1	0	- Glass not yet replaced	-Unsafe if unnoticed -May cause cut in hands if accidentally touched -Replace broken glass
4	Broken Window Glass 2	0	- Glass not yet replaced	--Unsafe if unnoticed -May cause cut in hands if accidentally touched -Replace broken glass
5	Lighting 1	0	- Fluorescent light not functioning when switched on - inadequate lighting	- Unsafe for person working around the workplace - Replace bulb or starter to function
6	Lighting 2	0	-Missing Fluorescent light installed in the lamp holder - inadequate lighting	- Unsafe -Workplace needs to be well lit - Replace bulb or starter to function
7	GENSET	0	-Genset enclosure already rusting -Moisture can get in -Grounding can be compromised	-Unsafe for person & equipment - Test grounding integrity to avoid electrocution - Replace enclosure for protection of Genset
8	Street lamp post	0	- Exposed wiring and rusted lamp post - Grounding can be compromised	- Unsafe in cases of accidental touching of metal -Electrocution when metal post is exposed to rain
9	Exposed Wiring going to genset	0	-Splices of wiring, unprotected	-Unsafe in cases of touching bare wires -Electrocution
10	Exposed wiring tied to tree	0	-Using of tree as support	Unsafe -Electrocution
11	Fire Extinguisher	0	- Misplaced fire extinguisher without inspection tag -	- Unsafe -Should be placed back to the proper FEX location
12	Exposed control wiring	0	- wires exposed - Risk to people	-Unsafe , can cause electrocution - Harness wiring
13	Lamp post	0	- Lamp post rusty and supported by wood - Lamp post is not balance and may fall	-Unsafe - Correct installation of lamp post and modify base
14	Fire Extinguisher	0	- Misplaced fire extinguisher - Without inspection tag	- Not effective if not working in cases of fire - Should be inspected yearly by Safety officers
15	Exit Door	0	-Door without exit signage - Exit signage should be provided	-Exit Doors should be properly labeled - Required per OHSAS
16	Fire Extinguisher	0	Missing fire extinguisher - Every confined space should have FEX	-FEX should be found in the designated location - Replace missing FEX



Materials near door



Accumulated Materials



Broken Glass 1



Broken Glass 2



Lighting 1
Not functioning



Lighting 2
Not functioning



Genset Enclosure Rust



Genset Rust



Street Lamp
Wiring Hazard



Wiring to Genset
Wiring Hazard



Wires tied to tree



Fire extinguisher misplaced



Exposed wiring to genset



Wood support for Lamp Post



FEX W/o tag



Exit Door w/o signage



Exit Door w/o signage



Missing fire extinguisher



Ceiling with termites



Open Ceiling above restroom



Umbrella inside Unused Enclosure



Tripping hazard



Tripping Hazard

Figure 4.44: Visual inspection on electrical safety

4.16.4.2 Recommendations

Based on the status of devices, recommendations are with intervention types shown in Table 4.40. Chapter 5 further illustrates the recommendation with the conceptual design.

Preliminary

Chapter 5

Conceptual Design and Reliability Study

5.1 Basis of Design

5.1.1 Drawings

A collection of as-built drawings and conceptual drawings are given in electronic files saved both in PDF and CAD formats.

5.2 Bill of Materials

Based on the recommendations and conceptual design, a high level Bill of Quantity (BOQ) can be generated . The BOQ table includes the condition states and intervention types respectively.

Preliminary

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Preliminary

Appendix A

Recommended Maintenance Program

Preliminary



Maintenance Program

Code	Name	Station ID	Asset Description	Component	Failure Mode	Criticality	Failure Pattern	Task	Frequency	Done by	Comments
For dedicated spare pumps & motors only	Pump	AYA	Horizontal pump between bearings	Bearings	bearing failure caused by false brinelling	High	Age-related	Rotate pump shaft 2-1/4 times	Every shift	Operator	Ensure that pump is isolated from power source
For dedicated spare pumps & motors only	Pump	AYA	Horizontal pump between bearings	Bearings	Brining failure caused by contaminated oil	High	Random	Inspect oil for water contamination Regrease as necessary	Weekly	Maintenance contractor	
For dedicated spare pumps & motors only	Motor	AYA	Horizontal pump between bearings	Starter; Auto start System	High	Random	Start pump and run for at least 2 hours. Check all functionalities.	Monthly	Operator	Do this during visit by maintenance contractor.	
WSO-AYAPR-0031	Discharge Valve SP4	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annual	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0009	Air Valve SP1	AYA	Air Valve	Actuator	Fail Open/Fail Close	Medium	Random	Overhaul pneumatic actuator & clean internals	Annual	Maintenance contractor	Assign task to OEM contractor.
WSO-AYAPR-0016	Air Valve SP2	AYA	Air Valve	Actuator	Fail Open/Fail Close	Medium	Random	Overhaul pneumatic actuator & clean internals	Annual	Maintenance contractor	Assign task to OEM contractor.
WSO-AYAPR-0023	Air Valve SP3	AYA	Air Valve	Actuator	Fail Open/Fail Close	Medium	Random	Overhaul pneumatic actuator & clean internals	Annual	Maintenance contractor	Assign task to OEM contractor.
WSO-AYAPR-0030	Air Valve SP4	AYA	Air Valve	Actuator	Fail Open/Fail Close	Medium	Random	Overhaul pneumatic actuator & clean internals	Annual	Maintenance contractor	Assign task to OEM contractor.
WSO-AYAPR-0008	Check Valve SP1	AYA	Check Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annual	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0015	Check Valve SP2	AYA	Check Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annual	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0022	Check Valve SP3	AYA	Check Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annual	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0029	Check Valve SP4	AYA	Check Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annual	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0034	Discharge Butterfly Valve 1	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annual	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0033	Discharge Pipe and Fittings	AYA	Piping	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annually	Maintenance contractor	Use proper bolt tightening methods (e.g. manual hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0044	Fuel Storage	AYA	Tank	Tank wall & bottom	Leaks due to corrosion	High	Age-related	Inspect tank for leaks	Daily	Operator	Anytime during day shift.
WSO-AYAPR-0044	Fuel Storage	AYA	Tank	Tank wall & bottom	Leaks due to corrosion	High	Age-related	Clean tank & inspect bottom plates for corrosion	Every 2 years	Maintenance contractor	Use qualified maintenance contractor.
WSO-AYAPR-0010	Motorized Discharge Valve SP1	AYA	Motor Valve	Motor winding	Motor burns due to failure of winding insulation	Low	Age-related	Inspect motor winding insulation	Annual	Maintenance contractor	Use qualified maintenance contractor.



Maintenance Program

WSO-AYAPR-0017	Motorized Discharge Valve SP2	AYA	Motor Valve	Motor winding	Motor burns due to failure of winding insulation	Low	Age-related	Inspect motor winding insulation	Annual	Maintenance contractor	Use qualified maintenance contractor.
WSO-AYAPR-0024	Motorized Discharge Valve SP3	AYA	Motor Valve	Motor winding	Motor burns due to failure of winding insulation	Low	Age-related	Inspect motor winding insulation	Annual	Maintenance contractor	Use qualified maintenance contractor.
WSO-AYAPR-0045	Overhead Travelling Crane	AYA	Lifting	Chain & gear mechanism	Failure of manual chain hoist due to wear & tear	High	Age-related	Inspect manual chain hoist for wear	Annual	Maintenance contractor	Use qualified maintenance contractor.
WSO-AYAPR-0045	Overhead Travelling Crane	AYA	Lifting	Motor drive	Failure of winding insulation	High	Random	Inspect motor winding insulation	Annual	Maintenance contractor	Use qualified maintenance contractor.
WSO-AYAPR-0005	Pipes and Fittings SP1	AYA	Piping	Flange	Leak due to loose bolts or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annual	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0012	Pipes and Fittings SP2	AYA	Piping	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annual	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0019	Pipes and Fittings SP3	AYA	Piping	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annual	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0026	Pipes and Fittings SP4	AYA	Piping	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annual	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0004	Reservoir Blow-off Butterfly Valve	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annual	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0003	Reservoir Inlet Butterfly Valve 1	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annual	Maintenance contractor	Use qualified maintenance contractor. Failure of this valve may cause problems during maintenance of pump/motor.
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Bearings	Loss of lubrication	High	Age-related	Scheduled greasing	Weekly	Maintenance contractor	Avoid over greasing. Use correct grease as stipulated by bearing manufacturer.
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Bearings	High vibration due to cavitation	High	Random	Monitor suction pressure go below xx head.	Every hour	Operator	Refer to pump specifications on minimum NPSH requirements. Follow company policy in dealing with cavitation issues (e.g. call MCC to increase suction pressure and/or shutdown pumps)
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Bearings	High vibration due to bearing failure (e.g. foreign materials in lubrication)	High	Random	Vibration monitoring	12-weekly (every 2 weeks)	Maintenance contractor	Use trained contractor for the appropriate vibration monitoring device. Report findings every month.
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Packing	Excessive leaks	Medium	Age-related	Tighten packing bolts	Monthly (every 2 weeks)	Maintenance contractor	Avoid overtightening of packing bolts.
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annual	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.



Maintenance Program

WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Vibration dampers	Leaks due to deteriorated materials caused by fatigue	Medium	Age-related	Replace vibration dampers based on recommended life	Every 10 years	Maintenance contractor	Refer to recommended life of dampers by manufacturer. Otherwise, purchase spare damper before its recommended life to ensure availability when needed.
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	System	General system leaks	Low	Random	Inspect system for leaks	Shift	Operator	Report excessive leaks for scheduled repairs.
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Impeller	Impeller wear	Low	Age-related	-Replace impeller -Inspect and measure clearances	-10 years -Annually	Maintenance contractor	Inspect during annual overhauls.
WSO-AYAPR-0007	Storage Pump 1	AYA	Storage pump	Suction strainer	Blowage	Medium	Age-related	Clean strainer	Annualy	Maintenance contractor	During annual overhauls.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Bearings	Loss of vibration	High	Age-related	Scheduled greasing	Weekly	Maintenance contractor	Avoid overgreasing. Use correct grease as stipulated by bearing manufacturer.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Bearings	High vibration due to cavitation	High	Random	Monitor suction pressure not to go below xx head.	Every hour	Operator	Refer to pump specifications on minimum NPSH requirements. Follow company policy in dealing with cavitation issues (e.g. call MCC to increase suction pressure and/or shutdown pumps)
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Bearings	High vibration due to bearing failure (e.g. foreign materials in lubrication)	High	Random	Vibration monitoring	2-weekly (every 2 weeks)	Maintenance contractor	Use trained contractor for the appropriate vibration monitoring device. Report findings every month.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Packing	Excessive leaks	Medium	Age-related	Tighten packing bolts	2-weekly (every 2 weeks)	Maintenance contractor	Avoid overtightening of packing bolts.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annualy	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Vibration dampers	Leaks due to deteriorated materials caused by fatigue	Medium	Age-related	Replace vibration dampers based on recommended life	Every 10 years	Maintenance contractor	Refer to recommended life of dampers by manufacturer. Otherwise, purchase spare damper before its recommended life to ensure availability when needed.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	System	General system leaks	Low	Random	Inspect system for leaks	Shift	Operator	Report excessive leaks for scheduled repairs.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Impeller	Impeller wear	Low	Age-related	-Replace impeller -Inspect and measure clearances	-10 yrs -Annually	Maintenance contractor	Inspect during annual overhauls.
WSO-AYAPR-0014	Storage Pump 2	AYA	Storage pump	Suction strainer	Blockage	Medium	Age-related	Clean strainer	Annualy	Maintenance contractor	During annual overhauls.
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Bearings	Loss of lubrication	High	Random	Scheduled greasing	Weekly	Maintenance contractor	Avoid overgreasing. Use correct grease as stipulated by bearing manufacturer.
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Bearings	High vibration due to cavitation	High	Random	Vibration monitoring	2-weekly (every 2 weeks)	Maintenance contractor	Refer to pump specifications on minimum NPSH requirements. Follow company policy in dealing with cavitation issues (e.g. call MCC to increase suction pressure and/or shutdown pumps)
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Bearings	High vibration due to bearing failure (e.g. foreign materials in lubrication)	High	Random	Vibration monitoring	2-weekly (every 2 weeks)	Maintenance contractor	Use trained contractor for the appropriate vibration monitoring device. Report findings every month.



Maintenance Program

WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Packing	Excessive leaks	Medium	Age-related	Tighten packing bolts	2-weekly (every 2 weeks)	Maintenance contractor	Avoid overtightening of packing bolts.
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annually	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Vibration dampers	Leaks due to deteriorated materials caused by fatigue	Medium	Age-related	Replace vibration dampers based on recommended life	Every 10 years	Maintenance contractor	Refer to recommended life of dampers by manufacturer. Otherwise, purchase spare damper before its recommended life to ensure availability when needed.
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	System	General system leaks	Low	Random	Inspect system for leaks	Shift	Operator	Report excessive leaks for scheduled repairs.
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Impeller	Wear	Low	Age-related	-Replace impeller -Inspect and measure clearances	-10 years -Annually	Maintenance contractor	Inspect during annual overhauls.
WSO-AYAPR-0021	Storage Pump 3	AYA	Storage pump	Suction strainer	Blockage	Medium	Age-related	Clean strainer	Annually	Maintenance contractor	During annual overhauls.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Bearings	Loss of lubrication	High	Age-related	Scheduled greasing	Weekly	Maintenance contractor	Avoid over greasing. Use correct grease as stipulated by bearing manufacturer.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Bearings	High vibration due to cavitation	High	Age-related	Monitor suction pressure not to go below XX head.	Every hour	Operator	Refer to pump specifications on minimum NPSH requirements. Follow company policy in dealing with cavitation issues (e.g. call MCC to increase suction pressure and/or shutdown pumps)
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Bearings	High vibration due to bearing failure (e.g. foreign materials in lubrication)	High	Random	2-weekly vibration monitoring	2-weekly (every 2 weeks)	Maintenance contractor	Use trained contractor for the appropriate vibration monitoring device. Report findings every month.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Packing	Excessive leaks	Medium	Age-related	Tighten packing bolt	2-weekly (every 2 weeks)	Maintenance contractor	Avoid overtightening of packing bolts.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annually	Maintenance contractor	Use proper bolt tightening methods (e.g. manual, hydraulic, pneumatic, tensioning, etc.) Apply required bolt torque values.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Vibration dampers	Leaks due to deteriorated materials caused by fatigue	Medium	Age-related	Replace vibration dampers based on recommended life	Every 2 years	Maintenance contractor	Refer to recommended life of dampers by manufacturer. Otherwise, purchase spare damper before its recommended life to ensure availability when needed.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	System	General system leaks	Low	Random	Inspect system for leaks	Shift	Operator	Report excessive leaks for scheduled repairs.
WSO-AYAPR-0028	Storage Pump 4	AYA	Storage pump	Impeller	Impeller wear	Low	Age-related	-Replace impeller -Inspect and measure clearances	-10 years -Annually	Maintenance contractor	Inspect during annual overhauls.
WSO-AYAPR-0011	Storage Pump Motor 1	AYA	Motor	Motor winding	Motor trip due to overloading	High	Random	Motor skin temperature measurement	Annually	Maintenance contractor	During annual overhauls.
WSO-AYAPR-0011	Storage Pump Motor 1	AYA	Motor	Motor winding	Motor burns due to failure of winding insulation	Low	Age-related	Inspect motor winding insulation	Every hour	Operator	Refer to motor specifications on maximum allowable surface temperature.
RECOMMENDATION											



Maintenance Program

Item ID	Equipment Type	Location	Model	Manufacturer	Fault Type	Metric	Test Frequency	Maintenance Contractor	Operator	Notes
WSO-AYAPR-0018	Storage Pump Motor 2	AYA	Motor	Motor winding	Motor trip due to overloading	High	Random	Motor (skin) temperature measurement	Every hour	Operator
WSO-AYAPR-0018	Storage Pump Motor 2	AYA	Motor	Motor winding	Motor burns due to failure of winding insulation	Low	Age-related	Inspect motor winding insulation	Annually	Maintenance contractor
WSO-AYAPR-0025	Storage Pump Motor 3	AYA	Motor	Motor winding	Motor trip due to overloading	High	Random	Motor (skin) temperature measurement	Every hour	Operator
WSO-AYAPR-0025	Storage Pump Motor 3	AYA	Motor	Motor winding	Motor burns due to failure of winding insulation	Low	Age-related	Inspect motor winding insulation	Annually	Maintenance contractor
WSO-AYAPR-0032	Storage Pump Motor 4	AYA	Motor	Motor winding	Motor trip due to overload	High	Random	Motor (skin) temperature measurement	Every hour	Operator
WSO-AYAPR-0032	Storage Pump Motor 4	AYA	Motor	Motor winding	Motor trips due to failure of winding insulation	Low	Age-related	Inspect motor winding insulation	Annually	Maintenance contractor
WSO-AYAPR-0006	Suction Butterfly Valve Sp1	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor
WSO-AYAPR-0013	Suction Butterfly Valve Sp2	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor
WSO-AYAPR-0020	Suction Butterfly Valve Sp3	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor
WSO-AYAPR-0027	Suction Butterfly Valve Sp4	AYA	Valve	Valve disc & seat	Valve passing (leaks)	Medium	Age-related	Test valve integrity	Annually	Maintenance contractor
WSO-AYAPR-0001	Suction Pipes and Fittings	AYA	Piping	Flange	Leaks due to loose bolts and/or gasket failure	Medium	Age-related	Re-tighten bolts using specified torque values	Annually	Maintenance contractor

Appendix B

Vibration Data

Preliminary



DOCUMENT TITLE

SOUTHVALE MOTOR & PUMP UNITS
VA STATUS REPORT
AS OF 15 FEB 2019

COMMENT

SOUTHVALE PUMP STATION

VISA

Written by	Approved by	State	Date
ENGR.JAY DIMALIBOT	ENGR. PETER VASQUEZ	PHI	25/03/2019 08:52:27

Preliminary



Table of contents

Synthesis Report	3
Expertise Report	4
Analysis Report	12

Preliminary



Synthesis Report

Filter: Equipment name (+) \ Tree order (+)

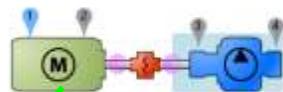
Location	Equipment	Diagnosis		Recommendations	
		Previous Date	Current Date		
SOUTHVALE PUMP\	BOOSTER PUMP UNIT 1		FAIR	Check rubbing noise at Motor NDE	
			15/02/2019 15:08:12		
		Oper.	Oper. DfCnd		
SOUTHVALE PUMP\	BOOSTER PUMP UNIT 2		FAIR	Continue monitor and trend Motor NDE Brg	
			15/02/2019 14:59:51		
		Oper.	Oper. DfCnd		
SOUTHVALE PUMP\	BOOSTER PUMP UNIT 3	Motor NDE Bearing Inner Race Fault		Schedule Reconditioning of Motor & Pump	
			CRITICAL		
			15/02/2019 15:15:27		
SOUTHVALE PUMP\	BOOSTER PUMP UNIT 4	Oper.	Oper. DfCnd	Schedule Reconditioning of Pump	
		Misalignment, Unbalance, Rotating Looseness			
			CRITICAL		
			15/02/2019 15:18:55		
		Oper.	Oper. DfCnd		
		Rotating Looseness and Misalignment			

Preliminary

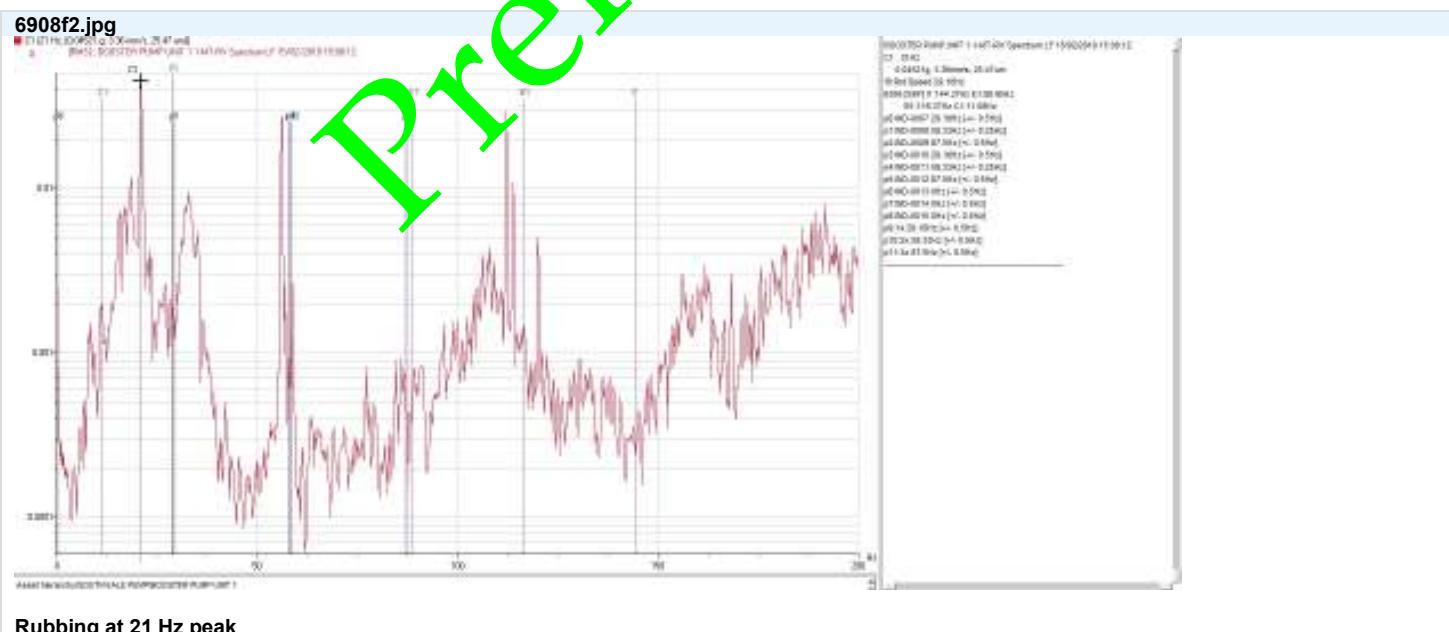
Expertise Report

Filter: Equipment name (+) \ Tree order (+)

Location	SOUTHVALE PUMP\
Designation	SOUTHVALE PUMP STATION
Equipment	BOOSTER PUMP UNIT 1
Designation	
Abbreviation	BP#1
Serial No	
Model	
Periodicity (d)	Normal 60 Alarm 15



Date	FAIR	Speed	56.1 Hz / 3368 rpm
15/02/2019 15:08:12	<i>Health is not acceptable for a long time service.</i>	Author	u1
Condition	DfCnd	System	- Serial Sensor Connector
Diagnosis & Recommendation			
Diagnosis			
<i>Rubbing (Metal to metal) at Motor NDE</i> Fair state for the component 'Electric motor'.			
Rumbling or Metal to metal contact at below 1x peak Cr. at 21 Hz			
Recommendations			
<i>Check rubbing noise at Motor NDE</i> <i>Check rubbing noise at Motor NDE</i>			



Rubbing at 21 Hz peak



Location	SOUTHVALE PUMP\		Fixed speed			
Designation	SOUTHVALE PUMP STATION					
Equipment	BOOSTER PUMP UNIT 2					
Designation						
Abbreviation	BP#2					
Serial No						
Model						
Periodicity (d)	Normal 60	Alarm 15				
Previous Advice	Condition	Rotation Speed				
Date 15/02/2019 14:59:51	FAIR	Health is not acceptable for a long time service.		Speed 50 Hz / 1750 rpm Author u1 System Serial FALCON - 11407 Sensor connector		
Condition DfCnd						
Diagnosis & Recommendation	Parameters sheet					
Diagnosis						
Motor NDE Bearing Inner Race Fault						
Fair state for component 'Electric motor'.						
Motor NDE Bearing Inner Race Fault - Stage 2 out of 4						
Recommendations						
Continue monitor and trend Motor NDE Brdg						
Continue monitor and trend Motor NDE Brdg.						

IP1.jpg

Preliminary



corrosion

390896.jpg



Motor NDE Bearing noise with Ringing rate at shaft rate

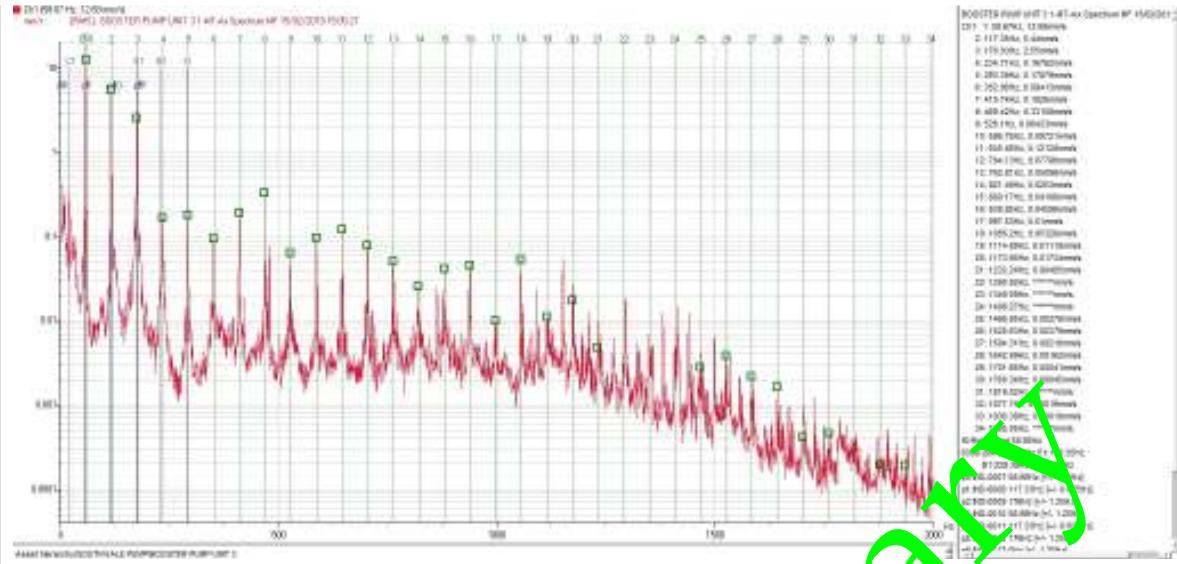
Location	SOUTHVALE PUMP\		Fixed speed	
Designation	SOUTHVALE PUMP STATION			
Equipment	BOOSTER PUMP UNIT 3			
Designation				
Abbreviation	BP#3			
Serial No				
Model				
Periodicity (d)	Normal	60	Alarm	15
Previous Advice	Condition	Rotation Speed		
Date 15/02/2019 15:05:27	CRITICAL <i>Measurement observed shows that vibration levels could generate damages!</i>	Speed 58.7 Hz / 3520 rpm Author u1 System - Serial FALCON - 11407 Sensor Connector		
Condition DfCnd				
Diagnosis & Recommendation	Parameters sheet			
Diagnosis <i>Misalignment, Unbalance, Rotating Loosen</i> Overall state NOT acceptable for the component 'Electric motor'. Highest vibrations measured at Motor NDE Axial with Overall velocity of 14.4 and dominantly peak at 1x,2x,3x caused by Misalignment & Unbalance Fault				
Overall state NOT acceptable for the component 'Pump'. Rotating Looseness				
Recommendations				
Schedule Reconditioning of Motor & Pump Schedule Reconditioning of Motor & Pump to include Shop Balancing of Motor Motor, Pump impeller assy balancing, Resleeving or restoration of shaft and housing bearing clearances.				

1308a6.jpg



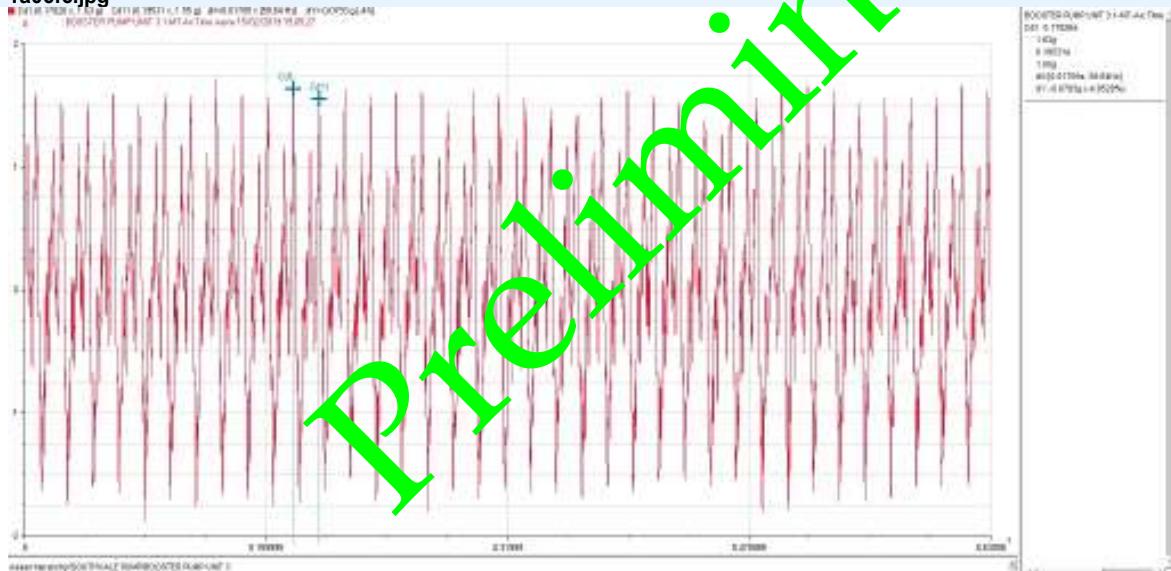
Severe Rotating Looseness at Pump

5e06cc.jpg



Misalignment and Unbalance at 1x,2x,3x peaks

1a06f6.jpg



Misalignment fault pattern in Time Signal



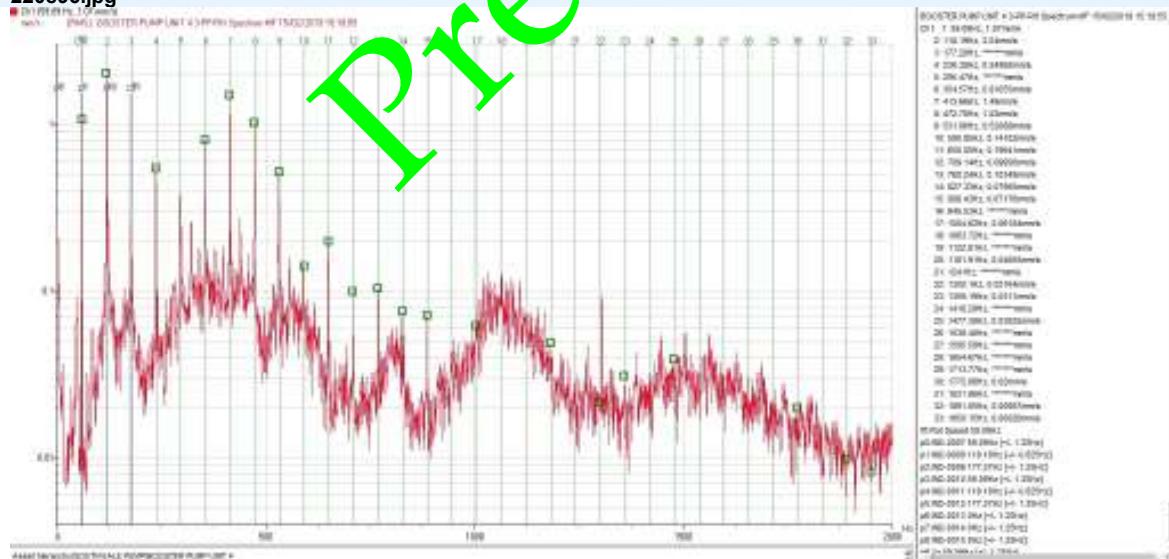
Location	SOUTHVALE PUMP\		Fixed speed			
Designation	SOUTHVALE PUMP STATION					
Equipment	BOOSTER PUMP UNIT 4					
Designation						
Abbreviation	BP#4					
Serial No						
Model						
Periodicity (d)	Normal 60	Alarm 15				
Previous Advice	Condition	Rotation Speed				
Date 15/02/2019 15:18:55	CRITICAL	<i>Measurement observed shows that vibration levels could generate damages!</i>	Speed 2 Hz / 3545 rpm Author u1 System Serial FALCON - 11407 Sensor connector			
Condition DfCnd						
Diagnosis & Recommendation	Parameters sheet					
Diagnosis						
<i>Rotating Looseness and Misalignment</i> Overall state still acceptable for the component 'Electric motor'. Overall state NOT acceptable for the component 'Pump'. Highest vibration measured at Pump IB Bearing Vertical with Overall Velocity of 6.07mm/s, with Defect Factor of 5.18 due to 1x Rate Repetitive Impact caused by Rotating Looseness at Pump Bearings, Rubbing and Misalignment						
Recommendations						
<i>Schedule Reconditioning of Pump</i> Schedule reconditioning of Pump Bearings. Check Pump bearings fit for shaft wear or Pump housing wear. Rectify those first prior bearing replacement. Realign shaft/coupling using precision laser alignment tool upon installation of pump onsite.						

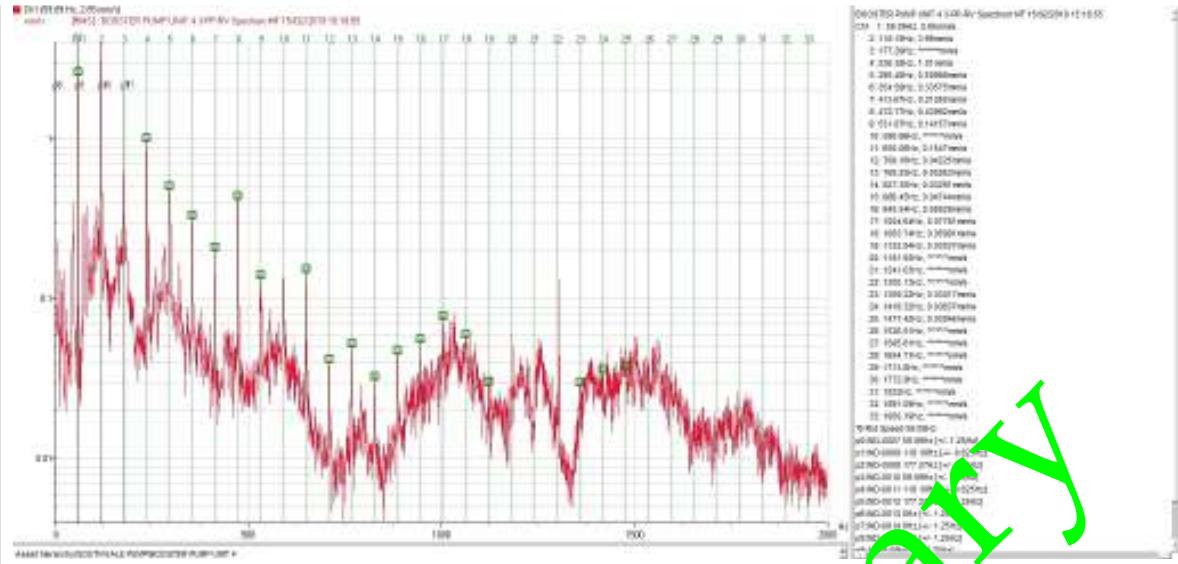
IP2.jpg



corrosion

220896.jpg





High 2x peak caused by Misalignment

alignment

Preliminary



Analysis Report

Filter: Equipment name (+) \ Tree order (+)

Alarm type: Danger \ Alarm \ Pre-Alarm \ Error \ Ok \ Undefined \ Inhibited

SOUTHVALE PUMP

BOOSTER PUMP UNIT 1

Selected Date

15/02/2019 15:08:12

Speed

56.1 Hz / 3368 rpm

Author

u1

Connector

System - Serial No

FALCON - 11407

Sensor

		H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overl:Rotation speed	Rot Spd	Hard	15/02/2019 15:08:12	3368	rpm		3368		DfCnd	High	0	0	0	2	3.5	6	0
1-MT-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	DfCnd	High	0	0	0	4	6	9	0
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12	3.32	mm/s		3.32		DfCnd	High	0	0	0	0	1.5	3	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12	0.504	g		0.504		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12	2.54	DEF		2.54		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12	0.374	mm/s		0.374		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12	1.10	mm/s		1.10		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12	0.0239	mm/s		0.0239		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12	0.103	g		0.103		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12	0.471	g		0.471		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12	0.164	g		0.164		DfCnd	High	0	0	0	0	2	4	0
1-MT-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12	4.00	mm/s		4.00		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12	0.408	g		0.408		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12	2.55	DEF		2.55		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12	1.84	mm/s		1.84		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12	0.916	mm/s		0.916		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12	0.0288	mm/s		0.0288		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12	0.117	g		0.117		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12	0.282	g		0.282		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12	0.255	g		0.255		DfCnd	High	0	0	0	0	2	4	0
1-MT-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12	5.45	mm/s		5.45		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12	0.454	g		0.454		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12	2.55	DEF		2.55		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12	0.760	mm/s		0.760		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12	0.408	mm/s		0.408		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12	0.0284	mm/s		0.0284		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12	0.0867	g		0.0867		DfCnd	High	0	0	0	0	.15	.3	0



SOUTHVALE PUMP

BOOSTER PUMP UNIT 1

		Selected Date	15/02/2019 15:08:12		Speed		56.1 Hz / 3368 rpm									
		Author	u1		Connector											
		System - Serial No	FALCON - 11407		Sensor											
En-MF	En-MF	Soft	15/02/2019 15:08:12	0.417g		0.417	DfCnd	High	0	0	0	0	.5	1	0	
En-HF	En-HF	Soft	15/02/2019 15:08:12	0.158g		0.158	DfCnd	High	0	0	0	0	2	4	0	
2-MT-Ax Overall Vib Vel	9 IND-0001	H/S Hard	Last Date 15/02/2019 15:08:12	Value 2.82mm/s	Unit mm/s	T-1 Ref. 2.82	Avg	Oper. AlmTyp Dg- AL- pA- pA+ AL+ DG+	Dg- AL- pA- pA+ AL+ DG+	Err	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12	0.229g		0.229	DfCnd	None								
Defect factor	IND-0003	Hard	15/02/2019 15:08:12	2.47DEF		2.47	DfCnd	High	0	0	0	4	6	9	0	
1x	1x	Soft	15/02/2019 15:08:12	0.538mm/s		0.538	DfCnd	High	0	0	0	0	3	6	0	
2x	2x	Soft	15/02/2019 15:08:12	1.17mm/s		1.17	DfCnd	High	0	0	0	0	1.5	3	0	
3x	3x	Soft	15/02/2019 15:08:12	0.0655mm/s		0.0655	DfCnd	High	0	0	0	0	1	2	0	
En-LF	En-LF	Soft	15/02/2019 15:08:12	0.153g		0.153	DfCnd	High	0	0	0	0	.15	.3	0	
En-MF	En-MF	Soft	15/02/2019 15:08:12	0.156g		0.156	DfCnd	High	0	0	0	0	.5	1	0	
En-HF	En-HF	Soft	15/02/2019 15:08:12	0.0627g		0.0627	DfCnd	High	0	0	0	0	2	4	0	
2-MT-RH Overall Vib Vel	9 IND-0001	H/S Hard	Last Date 15/02/2019 15:08:12	Value 1.69mm/s	Unit mm/s	T-1 Ref. 1.69	Avg	Oper. AlmTyp Dg- AL- pA- pA+ AL+ DG+	Dg- AL- pA- pA+ AL+ DG+	Err	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12	0.37g		0.324	DfCnd	None								
Defect factor	IND-0003	Hard	15/02/2019 15:08:12	2.52DEF		2.52	DfCnd	High	0	0	0	4	6	9	0	
1x	1x	Soft	15/02/2019 15:08:12	0.98mm/s		0.988	DfCnd	High	0	0	0	0	3	6	0	
2x	2x	Soft	15/02/2019 15:08:12	0.448mm/s		0.448	DfCnd	High	0	0	0	0	1.5	3	0	
3x	3x	Soft	15/02/2019 15:08:12	0.0303mm/s		0.0303	DfCnd	High	0	0	0	0	1	2	0	
En-LF	En-LF	Soft	15/02/2019 15:08:12	0.0640g		0.0640	DfCnd	High	0	0	0	0	.15	.3	0	
En-MF	En-MF	Soft	15/02/2019 15:08:12	0.310g		0.310	DfCnd	High	0	0	0	0	.5	1	0	
En-HF	En-HF	Soft	15/02/2019 15:08:12	0.0604g		0.0604	DfCnd	High	0	0	0	0	2	4	0	
2-MT-RV Overall Vib Vel	9 IND-0001	H/S Hard	Last Date 15/02/2019 15:08:12	Value 2.14mm/s	Unit mm/s	T-1 Ref. 2.14	Avg	Oper. AlmTyp Dg- AL- pA- pA+ AL+ DG+	Dg- AL- pA- pA+ AL+ DG+	Err	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12	0.210g		0.210	DfCnd	None								
Defect factor	IND-0003	Hard	15/02/2019 15:08:12	2.38DEF		2.38	DfCnd	High	0	0	0	4	6	9	0	
1x	1x	Soft	15/02/2019 15:08:12	0.975mm/s		0.975	DfCnd	High	0	0	0	0	3	6	0	
2x	2x	Soft	15/02/2019 15:08:12	0.391mm/s		0.391	DfCnd	High	0	0	0	0	1.5	3	0	
3x	3x	Soft	15/02/2019 15:08:12	0.0391mm/s		0.0391	DfCnd	High	0	0	0	0	1	2	0	
En-LF	En-LF	Soft	15/02/2019 15:08:12	0.0584g		0.0584	DfCnd	High	0	0	0	0	.15	.3	0	
En-MF	En-MF	Soft	15/02/2019 15:08:12	0.195g		0.195	DfCnd	High	0	0	0	0	.5	1	0	
En-HF	En-HF	Soft	15/02/2019 15:08:12	0.0479g		0.0479	DfCnd	High	0	0	0	0	2	4	0	



SOUTHVALE PUMP

BOOSTER PUMP UNIT 1

		Selected Date		15/02/2019 15:08:12		Speed		56.1 Hz / 3368 rpm									
		Author		u1		Connector											
		System - Serial No		FALCON - 11407		Sensor											
3-PP-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12						DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	2	4	0
3-PP-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12						DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	2	4	0
3-PP-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12						DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:08:12						DfCnd	High	0	0	0	0	2	4	0
4-PP-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:08:12						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12						DfCnd	None							



SOUTHVALE PUMP

BOOSTER PUMP UNIT 1

		Selected Date	15/02/2019 15:08:12				Speed	56.1 Hz / 3368 rpm								
		Author	u1				Connector									
		System - Serial No	FALCON - 11407				Sensor									
Defect factor	IND-0003	Hard	15/02/2019 15:08:12				DfCnd	High	0	0	0	4	6	9	0	
1x	1x	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	3	6	0	
2x	2x	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	1.5	3	0	
3x	3x	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	1	2	0	
En-LF	En-LF	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	.15	.3	0	
En-MF	En-MF	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	.5	1	0	
En-HF	En-HF	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	2	4	0	
4-PP-RH Overall Vib Vel	9 IND-0001	H/S Hard	Last Date 15/02/2019 15:08:12	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+ Err
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12				DfCnd	High	0	0	0	2	3.5	6	0	
Defect factor	IND-0003	Hard	15/02/2019 15:08:12				DfCnd	High	0	0	0	4	6	9	0	
1x	1x	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	3	6	0	
2x	2x	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	1.5	3	0	
3x	3x	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	1	2	0	
En-LF	En-LF	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	.15	.3	0	
En-MF	En-MF	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	.5	1	0	
En-HF	En-HF	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	2	4	0	
4-PP-RV Overall Vib Vel	9 IND-0001	H/S Hard	Last Date 15/02/2019 15:08:12	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+ Err
Overall Acc	IND-0002	Hard	15/02/2019 15:08:12				DfCnd	High	0	0	0	2	3.5	6	0	
Defect factor	IND-0003	Hard	15/02/2019 15:08:12				DfCnd	High	0	0	0	4	6	9	0	
1x	1x	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	3	6	0	
2x	2x	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	1.5	3	0	
3x	3x	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	1	2	0	
En-LF	En-LF	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	.15	.3	0	
En-MF	En-MF	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	.5	1	0	
En-HF	En-HF	Soft	15/02/2019 15:08:12				DfCnd	High	0	0	0	0	2	4	0	

SOUTHVALE PUMP

BOOSTER PUMP UNIT 2

		Selected Date	15/02/2019 14:59:51				Speed	29.2 Hz / 1750 rpm							
		Author	u1				Connector								
		System - Serial No	FALCON - 11407				Sensor								



SOUTHVALE PUMP

BOOSTER PUMP UNIT 2

Selected Date

15/02/2019 14:59:51

Speed

29.2 Hz / 1750 rpm

Author

u1

Connector

System - Serial No

FALCON - 11407

Sensor

Operating param.		1	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Ovrl:Rotation speed	Rot Spd	Hard	15/02/2019 14:59:51		1750	rpm		1750										
1-MT-Ax	9	H/S	Last Date		Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51		3.33	mm/s		3.33		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51		0.680	g		0.680		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51		2.76	DEF		2.76		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51		0.0220	mm/s		0.0220		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51		0.265	mm/s		0.265		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51		0.0046	mm/s		0.0046		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51		0.0496	g		0.0496		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51		0.575	g		0.575		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51		0.353	g		0.353		DfCnd	High	0	0	0	0	2	4	0
1-MT-RH	9	H/S	Last Date		Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51		1.42	mm/s		1.42		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51		1.10			1.10		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51		3.03	DEF		3.03		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51		0.014	mm/s		0.0244		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51		0.242	mm/s		0.242		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51		0.0037	mm/s		0.0037		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51		0.0534	g		0.0534		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51		1.06	g		1.06		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51		0.230	g		0.230		DfCnd	High	0	0	0	0	2	4	0
1-MT-RV	9	H/S	Last Date		Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51		2.00	mm/s		2.00		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51		0.414			0.414		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51		2.91	DEF		2.91		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51		0.0717	mm/s		0.0717		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51		0.0850	mm/s		0.0850		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51							DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51		0.0449	g		0.0449		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51		0.159	g		0.159		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51		0.365	g		0.365		DfCnd	High	0	0	0	0	2	4	0
2-MT-Ax	9	H/S	Last Date		Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err



SOUTHVALE PUMP

BOOSTER PUMP UNIT 2

		Selected Date	15/02/2019 14:59:51		Speed		29.2 Hz / 1750 rpm										
		Author	u1		Connector												
		System - Serial No	FALCON - 11407		Sensor												
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51	2.05 mm/s	2.05		DfCnd	High	0	0	0	2	3.5	6	0		
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51	0.773g	0.773		DfCnd	None									
Defect factor	IND-0003	Hard	15/02/2019 14:59:51	3.05 DEF	3.05		DfCnd	High	0	0	0	4	6	9	0		
1x	1x	Soft	15/02/2019 14:59:51	0.0471 mm/s	0.0471		DfCnd	High	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 14:59:51	0.495 mm/s	0.495		DfCnd	High	0	0	0	0	1.5	3	0		
3x	3x	Soft	15/02/2019 14:59:51	0.0489 mm/s	0.0489		DfCnd	High	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 14:59:51	0.105g	0.105		DfCnd	High	0	0	0	0	.15	.3	0		
En-MF	En-MF	Soft	15/02/2019 14:59:51	0.296g	0.296		DfCnd	High	0	0	0	0	.5	1	0		
En-HF	En-HF	Soft	15/02/2019 14:59:51	0.691g	0.691		DfCnd	High	0	0	0	0	2	4	0		
2-MT-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+ Err	
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51	1.18 mm/s		1.18			DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51	0.918g		0.918			DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51	3.32 DEF		3.32			DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51	0.0218 mm/s		0.0218			DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51	0.243 mm/s		0.243			DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51	0.0170 mm/s		0.0260			DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51	0.0589g		0.0589			DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51	0.401g		0.401			DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51	0.806g		0.806			DfCnd	High	0	0	0	0	2	4	0
2-MT-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+ Err	
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51	1.40 mm/s		1.40			DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51	0.848g		0.848			DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 14:59:51	3.21 DEF		3.21			DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 14:59:51	0.0699 mm/s		0.0699			DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 14:59:51	0.466 mm/s		0.466			DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 14:59:51	0.0100 mm/s		0.0100			DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 14:59:51	0.0334g		0.0334			DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 14:59:51	0.346g		0.346			DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 14:59:51	0.770g		0.770			DfCnd	High	0	0	0	0	2	4	0
3-PP-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+ Err	
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51						DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51						DfCnd	None							



SOUTHVALE PUMP

BOOSTER PUMP UNIT 2

			Selected Date	15/02/2019 14:59:51		Speed		29.2 Hz / 1750 rpm								
			Author	u1		Connector										
			System - Serial No	FALCON - 11407		Sensor										
Defect factor	IND-0003	Hard	15/02/2019 14:59:51			DfCnd	High	0	0	0	4	6	9	0		
1x	1x	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	1.5	3	0		
3x	3x	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	.15	.3	0		
En-MF	En-MF	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	.5	1	0		
En-HF	En-HF	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	2	4	0		
3-PP-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+ Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	2	3.5	6	0	
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51			DfCnd	None									
Defect factor	IND-0003	Hard	15/02/2019 14:59:51			DfCnd	High	0	0	0	4	6	9	0		
1x	1x	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	1.5	3	0		
3x	3x	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	.15	.3	0		
En-MF	En-MF	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	.5	1	0		
En-HF	En-HF	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	2	4	0		
3-PP-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+ Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	2	3.5	6	0	
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51			DfCnd	None									
Defect factor	IND-0003	Hard	15/02/2019 14:59:51			DfCnd	High	0	0	0	4	6	9	0		
1x	1x	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	1.5	3	0		
3x	3x	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	.15	.3	0		
En-MF	En-MF	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	.5	1	0		
En-HF	En-HF	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	2	4	0		
4-PP-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+ Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	2	3.5	6	0	
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51			DfCnd	None									
Defect factor	IND-0003	Hard	15/02/2019 14:59:51			DfCnd	High	0	0	0	4	6	9	0		
1x	1x	Soft	15/02/2019 14:59:51			DfCnd	High	0	0	0	0	3	6	0		



SOUTHVALE PUMP

BOOSTER PUMP UNIT 2

		Selected Date	15/02/2019 14:59:51				Speed	29.2 Hz / 1750 rpm									
		Author	u1				Connector										
		System - Serial No	FALCON - 11407				Sensor										
2x	2x	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	1.5	3	0	
3x	3x	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	1	2	0	
En-LF	En-LF	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	.15	.3	0	
En-MF	En-MF	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	.5	1	0	
En-HF	En-HF	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	2	4	0	
4-PP-RH Overall Vib Vel	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
	IND-0001	Hard	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	2	3.5	6	0	
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51				DfCnd	None									
Defect factor	IND-0003	Hard	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	4	6	9	0	
1x	1x	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	3	6	0	
2x	2x	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	1.5	3	0	
3x	3x	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	1	2	0	
En-LF	En-LF	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	.15	.3	0	
En-MF	En-MF	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	.5	1	0	
En-HF	En-HF	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	2	4	0	
4-PP-RV Overall Vib Vel	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
	IND-0001	Hard	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	2	3.5	6	0	
Overall Acc	IND-0002	Hard	15/02/2019 14:59:51				DfCnd	None									
Defect factor	IND-0003	Hard	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	4	6	9	0	
1x	1x	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	3	6	0	
2x	2x	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	1.5	3	0	
3x	3x	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	1	2	0	
En-LF	En-LF	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	.15	.3	0	
En-MF	En-MF	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	.5	1	0	
En-HF	En-HF	Soft	15/02/2019 14:59:51				DfCnd	High	0	0	0	0	0	2	4	0	

Preliminary

SOUTHVALE PUMP

BOOSTER PUMP UNIT 3

		Selected Date	15/02/2019 15:05:27				Speed	58.7 Hz / 3520 rpm									
		Author	u1				Connector										
		System - Serial No	FALCON - 11407				Sensor										
Operating param.	1	H/S	Last Date	Value	Unit	T-1	Ref.	Avg									
Ovrl:Rotation speed	Rot Spd	Hard	15/02/2019 15:05:27	3520	rpm		3520										
1-MT-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	14.4	mm/s	14.4			DfCnd	High	0	0	0	2	3.5	6	0



SOUTHVALE PUMP\

BOOSTER PUMP UNIT 3

	Selected Date	15/02/2019 15:05:27		Speed	58.7 Hz / 3520 rpm												
	Author	u1		Connector													
	System - Serial No	FALCON - 11407		Sensor													
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.739g	0.739	DfCnd	None										
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.47DEF	2.47	DfCnd	High	0	0	0	4	6	9	0			
1x	1x	Soft	15/02/2019 15:05:27	12.2mm/s	12.2	DfCnd	High	0	0	0	0	3	6	0			
2x	2x	Soft	15/02/2019 15:05:27	4.93mm/s	4.93	DfCnd	High	0	0	0	0	1.5	3	0			
3x	3x	Soft	15/02/2019 15:05:27	2.62mm/s	2.62	DfCnd	High	0	0	0	0	1	2	0			
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.718g	0.718	DfCnd	High	0	0	0	0	.15	.3	0			
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.194g	0.194	DfCnd	High	0	0	0	0	.5	1	0			
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.0344g	0.0344	DfCnd	High	0	0	0	0	2	4	0			
1-MT-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	10.8mm/s		10.8			DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.535g		0.53			DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.40DEF		2.40			DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	10.2mm/s		10.2			DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	0.777mm/s		0.747			DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	0.305mm/s		0.305			DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.412g		0.412			DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.338g		0.338			DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.0361g		0.0361			DfCnd	High	0	0	0	0	2	4	0
1-MT-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	11.5mm/s		11.5			DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.474g		0.474			DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.39DEF		2.39			DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	10.8mm/s		10.8			DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	0.0774mm/s		0.0774			DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	0.557mm/s		0.557			DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.433g		0.433			DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.191g		0.191			DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.0470g		0.0470			DfCnd	High	0	0	0	0	2	4	0
2-MT-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	9.16mm/s		9.16			DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.791g		0.791			DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.53DEF		2.53			DfCnd	High	0	0	0	4	6	9	0



SOUTHVALE PUMP

BOOSTER PUMP UNIT 3

		Selected Date	15/02/2019 15:05:27		Speed		58.7 Hz / 3520 rpm										
		Author	u1		Connector												
		System - Serial No	FALCON - 11407		Sensor												
1x	1x	Soft	15/02/2019 15:05:27	5.92 mm/s	5.92	DfCnd	High	0	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 15:05:27	4.36 mm/s	4.36	DfCnd	High	0	0	0	0	0	1.5	3	0		
3x	3x	Soft	15/02/2019 15:05:27	1.41 mm/s	1.41	DfCnd	High	0	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.474 g	0.474	DfCnd	High	0	0	0	0	0	.15	.3	0		
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.629 g	0.629	DfCnd	High	0	0	0	0	0	.5	1	0		
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.0878 g	0.0878	DfCnd	High	0	0	0	0	0	2	4	0		
2-MT-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	10.9	mm/s		10.9		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.605	g		0.605		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.61	DEF		2.61		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	10.1	mm/s	●	10.1		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	1.05	mm/s	●	1.05		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	0.0924	mm/s	●	0.0924		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.474	g	●	0.412		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.431	g	●	0.431		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.102	g	●	0.102		DfCnd	High	0	0	0	0	2	4	0
2-MT-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	9.17	mm/s		9.17		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.631	g		0.631		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.56	DEF		2.56		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	6.22	mm/s	●	6.22		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	4.98	mm/s	●	4.98		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:05:27	0.903	mm/s	●	0.903		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.506	g	●	0.506		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.363	g	●	0.363		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.103	g	●	0.103		DfCnd	High	0	0	0	0	2	4	0
3-PP-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:05:27	6.68	mm/s		6.68		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.965	g		0.965		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.67	DEF		2.67		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	2.51	mm/s	●	2.51		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:05:27	1.73	mm/s	●	1.73		DfCnd	High	0	0	0	0	1.5	3	0



SOUTHVALE PUMP

BOOSTER PUMP UNIT 3

		Selected Date	15/02/2019 15:05:27				Speed	58.7 Hz / 3520 rpm										
		Author	u1				Connector											
		System - Serial No	FALCON - 11407				Sensor											
3x	3x	Soft	15/02/2019 15:05:27	1.97 mm/s	1.97		DfCnd	High	0	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.292 g	0.292		DfCnd	High	0	0	0	0	.15	.3	0			
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.899 g	0.899		DfCnd	High	0	0	0	0	.5	1	0			
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.191 g	0.191		DfCnd	High	0	0	0	0	0	2	4	0		
3-PP-RH Overall Vib Vel	9 IND-0001	H/S	Last Date Hard	15/02/2019 15:05:27	Value 7.29 mm/s	Unit mm/s	T-1 7.29	Ref. 7.29	Avg	Oper. DfCnd	AlmTyp High	DG- 0	AL- 0	pA- 0	pA+ 2	AL+ 3.5	DG+ 6	Err 0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	1.09 g			1.09			DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.81 DEF			2.81			DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	4.99 mm/s	4.99		DfCnd	High	0	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 15:05:27	1.90 mm/s	1.90		DfCnd	High	0	0	0	0	0	1.5	3	0		
3x	3x	Soft	15/02/2019 15:05:27	0.802 mm/s	0.802		DfCnd	High	0	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.275 g	0.275		DfCnd	High	0	0	0	0	.15	.3	0			
En-MF	En-MF	Soft	15/02/2019 15:05:27	1.02 g	1.02		DfCnd	High	0	0	0	0	.5	1	0			
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.211 g	0.211		DfCnd	High	0	0	0	0	0	2	4	0		
3-PP-RV Overall Vib Vel	9 IND-0001	H/S	Last Date Hard	15/02/2019 15:05:27	Value 12.1 mm/s	Unit mm/s	T-1 12.1	Ref. 12.1	Avg	Oper. DfCnd	AlmTyp High	DG- 0	AL- 0	pA- 0	pA+ 2	AL+ 3.5	DG+ 6	Err 0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.952 g			0.952			DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.64 DEF			2.64			DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	9.41 mm/s	9.41		DfCnd	High	0	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 15:05:27	4.64 mm/s	4.64		DfCnd	High	0	0	0	0	0	1.5	3	0		
3x	3x	Soft	15/02/2019 15:05:27	0.826 mm/s	0.826		DfCnd	High	0	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.544 g	0.544		DfCnd	High	0	0	0	0	.15	.3	0			
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.757 g	0.757		DfCnd	High	0	0	0	0	.5	1	0			
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.175 g	0.175		DfCnd	High	0	0	0	0	0	2	4	0		
4-PP-Ax Overall Vib Vel	9 IND-0001	H/S	Last Date Hard	15/02/2019 15:05:27	2.85 mm/s	Unit mm/s	2.85	Ref. 2.85	Avg	Oper. DfCnd	AlmTyp High	DG- 0	AL- 0	pA- 0	pA+ 2	AL+ 3.5	DG+ 6	Err 0
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.575 g			0.575			DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.58 DEF			2.58			DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:05:27	0.965 mm/s	0.965		DfCnd	High	0	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 15:05:27	1.50 mm/s	1.50		DfCnd	High	0	0	0	0	0	1.5	3	0		
3x	3x	Soft	15/02/2019 15:05:27	0.993 mm/s	0.993		DfCnd	High	0	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.170 g	0.170		DfCnd	High	0	0	0	0	.15	.3	0			



SOUTHVALE PUMP\

BOOSTER PUMP UNIT 3

			Selected Date	15/02/2019 15:05:27				Speed	58.7 Hz / 3520 rpm									
			Author	u1				Connector										
			System - Serial No	FALCON - 11407				Sensor										
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.527 g			0.527		DfCnd	High	0	0	0	0	.5	1	0	
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.142 g			0.142		DfCnd	High	0	0	0	0	2	4	0	
4-PP-RH Overall Vib Vel	9 IND-0001	H/S	Last Date Hard 15/02/2019 15:05:27	Value 5.20mm/s	Unit mm/s	T-1	Ref. 5.20	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err	
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	0.707 g			0.707		DfCnd	High	0	0	0	2	3.5	6	0	
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.73 DEF			2.73		DfCnd	High	0	0	0	4	6	9	0	
1x	1x	Soft	15/02/2019 15:05:27	4.13mm/s			4.13		DfCnd	High	0	0	0	0	3	6	0	
2x	2x	Soft	15/02/2019 15:05:27	0.481mm/s			0.481		DfCnd	High	0	0	0	0	1.5	3	0	
3x	3x	Soft	15/02/2019 15:05:27	0.876mm/s			0.876		DfCnd	High	0	0	0	0	1	2	0	
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.206 g			0.206		DfCnd	High	0	0	0	0	.15	.3	0	
En-MF	En-MF	Soft	15/02/2019 15:05:27	0.642 g			0.642		DfCnd	High	0	0	0	0	.5	1	0	
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.165 g			0.165		DfCnd	High	0	0	0	0	2	4	0	
4-PP-RV Overall Vib Vel	9 IND-0001	H/S	Last Date Hard 15/02/2019 15:05:27	Value 12.3 mm/s	Unit mm/s	T-1	Ref. 12.3	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err	
Overall Acc	IND-0002	Hard	15/02/2019 15:05:27	1.36			1.36		DfCnd	None								
Defect factor	IND-0003	Hard	15/02/2019 15:05:27	2.69 DEF			2.69		DfCnd	High	0	0	0	4	6	9	0	
1x	1x	Soft	15/02/2019 15:05:27	4.76mm/s			4.76		DfCnd	High	0	0	0	0	3	6	0	
2x	2x	Soft	15/02/2019 15:05:27	8.53mm/s			8.53		DfCnd	High	0	0	0	0	1.5	3	0	
3x	3x	Soft	15/02/2019 15:05:27	1.30mm/s			1.30		DfCnd	High	0	0	0	0	1	2	0	
En-LF	En-LF	Soft	15/02/2019 15:05:27	0.704 g			0.704		DfCnd	High	0	0	0	0	.15	.3	0	
En-MF	En-MF	Soft	15/02/2019 15:05:27	1.15 g			1.15		DfCnd	High	0	0	0	0	.5	1	0	
En-HF	En-HF	Soft	15/02/2019 15:05:27	0.147 g			0.147		DfCnd	High	0	0	0	0	2	4	0	

SOUTHVALE PUMP\

BOOSTER PUMP UNIT 4

			Selected Date	15/02/2019 15:18:55				Speed	59.1 Hz / 3545 rpm									
			Author	u1				Connector										
			System - Serial No	FALCON - 11407				Sensor										
Operating param.	1	H/S	Last Date	Value	Unit	T-1	Ref.	Avg										
Ovrl:Rotation speed	Rot Spd	Hard	15/02/2019 15:18:55	3545	rpm		3545											
1-MT-Ax	9 IND-0001	H/S	Last Date Hard 15/02/2019 15:18:55	Value 4.43	Unit mm/s	T-1	Ref. 4.43	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err	
Overall Vib Vel	IND-0002	Hard	15/02/2019 15:18:55	0.414 g			0.414		DfCnd	None								
Overall Acc	IND-0003	Hard	15/02/2019 15:18:55	2.71 DEF			2.71		DfCnd	High	0	0	0	4	6	9	0	
Defect factor																		



SOUTHVALE PUMP

BOOSTER PUMP UNIT 4

		Selected Date	15/02/2019 15:18:55		Speed		59.1 Hz / 3545 rpm									
		Author	u1		Connector											
		System - Serial No	FALCON - 11407		Sensor											
1x	1x	Soft	15/02/2019 15:18:55	3.75mm/s	3.75	DfCnd	High	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 15:18:55	1.09mm/s	1.09	DfCnd	High	0	0	0	0	1.5	3	0		
3x	3x	Soft	15/02/2019 15:18:55	0.748mm/s	0.748	DfCnd	High	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.196g	0.196	DfCnd	High	0	0	0	0	.15	.3	0		
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.355g	0.355	DfCnd	High	0	0	0	0	.5	1	0		
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.0867g	0.0867	DfCnd	High	0	0	0	0	2	4	0		
1-MT-RH Overall Vib Vel	9 IND-0001	H/S	Last Date Hard	Value 3.88mm/s	Unit	T-1	Ref. 3.88	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+ AL+ DG+ Err		
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.520g		0.520		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	2.35DEF		2.35		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	3.55mm/s	3.55	DfCnd	High	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 15:18:55	0.520mm/s	0.520	DfCnd	High	0	0	0	0	1.5	3	0		
3x	3x	Soft	15/02/2019 15:18:55	0.442mm/s	0.442	DfCnd	High	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.152g	0.152	DfCnd	High	0	0	0	0	.15	.3	0		
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.495g	0.495	DfCnd	High	0	0	0	0	.5	1	0		
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.0632g	0.0632	DfCnd	High	0	0	0	0	2	4	0		
1-MT-RV Overall Vib Vel	9 IND-0001	H/S	Last Date Hard	Value 9.90mm/s	Unit	T-1	Ref. 9.90	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+ AL+ DG+ Err		
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.522g		0.522		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	2.49DEF		2.49		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	9.42mm/s	9.42	DfCnd	High	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 15:18:55	1.95mm/s	1.95	DfCnd	High	0	0	0	0	1.5	3	0		
3x	3x	Soft	15/02/2019 15:18:55	0.724mm/s	0.724	DfCnd	High	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.400g	0.400	DfCnd	High	0	0	0	0	.15	.3	0		
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.328g	0.328	DfCnd	High	0	0	0	0	.5	1	0		
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.0813g	0.0813	DfCnd	High	0	0	0	0	2	4	0		
2-MT-Ax Overall Vib Vel	9 IND-0001	H/S	Last Date Hard	Value 5.27mm/s	Unit	T-1	Ref. 5.27	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+ AL+ DG+ Err		
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.454g		0.454		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	3.02DEF		3.02		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	4.07mm/s	4.07	DfCnd	High	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 15:18:55	1.93mm/s	1.93	DfCnd	High	0	0	0	0	1.5	3	0		



SOUTHVALE PUMP

BOOSTER PUMP UNIT 4

		Selected Date	15/02/2019 15:18:55		Speed		59.1 Hz / 3545 rpm								
		Author	u1		Connector										
		System - Serial No	FALCON - 11407		Sensor										
3x	3x	Soft	15/02/2019 15:18:55	0.308 mm/s	0.308	DfCnd	High	0	0	0	0	1	2	0	
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.251 g	0.251	DfCnd	High	0	0	0	0	.15	.3	0	
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.349 g	0.349	DfCnd	High	0	0	0	0	.5	1	0	
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.176 g	0.176	DfCnd	High	0	0	0	0	2	4	0	
2-MT-RH	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+ AL+ DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	4.42	mm/s		4.42		DfCnd	High	0	0	0	2	3.5 6 0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.540	g		0.540		DfCnd	None					
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	3.46	DEF		3.46		DfCnd	High	0	0	0	4	6 9 0
1x	1x	Soft	15/02/2019 15:18:55	3.66	mm/s		3.66		DfCnd	High	0	0	0	0	3 6 0
2x	2x	Soft	15/02/2019 15:18:55	1.15	mm/s		1.15		DfCnd	High	0	0	0	0	1.5 3 0
3x	3x	Soft	15/02/2019 15:18:55	0.346	mm/s		0.346		DfCnd	High	0	0	0	0	1 2 0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.183	g		0.183		DfCnd	High	0	0	0	0	.15 .3 0
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.484	g		0.484		DfCnd	High	0	0	0	0	.5 1 0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.195	g		0.195		DfCnd	High	0	0	0	0	2 4 0
2-MT-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+ AL+ DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	5.21	mm/s		5.21		DfCnd	High	0	0	0	2	3.5 6 0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.382	g		0.382		DfCnd	None					
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	3.15	DEF		3.15		DfCnd	High	0	0	0	4	6 9 0
1x	1x	Soft	15/02/2019 15:18:55	3.66	mm/s		3.66		DfCnd	High	0	0	0	0	3 6 0
2x	2x	Soft	15/02/2019 15:18:55	2.29	mm/s		2.29		DfCnd	High	0	0	0	0	1.5 3 0
3x	3x	Soft	15/02/2019 15:18:55	0.391	mm/s		0.391		DfCnd	High	0	0	0	0	1 2 0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.273	g		0.273		DfCnd	High	0	0	0	0	.15 .3 0
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.205	g		0.205		DfCnd	High	0	0	0	0	.5 1 0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.210	g		0.210		DfCnd	High	0	0	0	0	2 4 0
3-PP-Ax	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+ AL+ DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	3.53	mm/s		3.53		DfCnd	High	0	0	0	2	3.5 6 0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.982	g		0.982		DfCnd	None					
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	4.15	DEF		4.15		DfCnd	High	0	0	0	4	6 9 0
1x	1x	Soft	15/02/2019 15:18:55	1.83	mm/s		1.83		DfCnd	High	0	0	0	0	3 6 0
2x	2x	Soft	15/02/2019 15:18:55	0.840	mm/s		0.840		DfCnd	High	0	0	0	0	1.5 3 0
3x	3x	Soft	15/02/2019 15:18:55	0.405	mm/s		0.405		DfCnd	High	0	0	0	0	1 2 0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.174	g		0.174		DfCnd	High	0	0	0	0	.15 .3 0



SOUTHVALE PUMP

BOOSTER PUMP UNIT 4

		Selected Date	15/02/2019 15:18:55		Speed		59.1 Hz / 3545 rpm											
		Author	u1		Connector													
		System - Serial No	FALCON - 11407		Sensor													
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.744g		0.744	DfCnd	High	0	0	0	0	0	.5	1	0		
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.601g		0.601	DfCnd	High	0	0	0	0	0	2	4	0		
3-PP-RH Overall Vib Vel	9 IND-0001	H/S Hard	Last Date 15/02/2019 15:18:55	Value 4.20mm/s	Unit mm/s	T-1 4.20	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err	
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	1.47 g		1.47	DfCnd	None										
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	5.18DEF		5.18	DfCnd	High	0	0	0	0	4	6	9	0		
1x	1x	Soft	15/02/2019 15:18:55	1.11 mm/s		1.11	DfCnd	High	0	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 15:18:55	1.98 mm/s		1.98	DfCnd	High	0	0	0	0	0	1.5	3	0		
3x	3x	Soft	15/02/2019 15:18:55	0.240 mm/s		0.240	DfCnd	High	0	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.189g		0.189	DfCnd	High	0	0	0	0	0	.15	.3	0		
En-MF	En-MF	Soft	15/02/2019 15:18:55	1.29g		1.29	DfCnd	High	0	0	0	0	0	.5	1	0		
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.683g		0.683	DfCnd	High	0	0	0	0	0	2	4	0		
3-PP-RV Overall Vib Vel	9 IND-0001	H/S Hard	Last Date 15/02/2019 15:18:55	Value 6.07mm/s	Unit mm/s	T-1 6.07	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err	
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	1.09 g		1.09	DfCnd	None										
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	3.78DEF		3.78	DfCnd	High	0	0	0	0	4	6	9	0		
1x	1x	Soft	15/02/2019 15:18:55	2.7 mm/s		2.74	DfCnd	High	0	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 15:18:55	3.91 mm/s		3.91	DfCnd	High	0	0	0	0	0	1.5	3	0		
3x	3x	Soft	15/02/2019 15:18:55	0.464 mm/s		0.464	DfCnd	High	0	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.389g		0.389	DfCnd	High	0	0	0	0	0	.15	.3	0		
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.885g		0.885	DfCnd	High	0	0	0	0	0	.5	1	0		
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.490g		0.490	DfCnd	High	0	0	0	0	0	2	4	0		
4-PP-Ax Overall Vib Vel	9 IND-0001	H/S Hard	Last Date 15/02/2019 15:18:55	4.58mm/s	Unit mm/s	T-1 4.58	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err	
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.856 g		0.856	DfCnd	None										
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	3.44DEF		3.44	DfCnd	High	0	0	0	0	4	6	9	0		
1x	1x	Soft	15/02/2019 15:18:55	2.09 mm/s		2.09	DfCnd	High	0	0	0	0	0	3	6	0		
2x	2x	Soft	15/02/2019 15:18:55	1.52 mm/s		1.52	DfCnd	High	0	0	0	0	0	1.5	3	0		
3x	3x	Soft	15/02/2019 15:18:55	0.594 mm/s		0.594	DfCnd	High	0	0	0	0	0	1	2	0		
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.214g		0.214	DfCnd	High	0	0	0	0	0	.15	.3	0		
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.783g		0.783	DfCnd	High	0	0	0	0	0	.5	1	0		
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.222g		0.222	DfCnd	High	0	0	0	0	0	2	4	0		



SOUTHVALE PUMP

BOOSTER PUMP UNIT 4

Selected Date

15/02/2019 15:18:55

Speed

59.1 Hz / 3545 rpm

Author

u1

Connector

System - Serial No

FALCON - 11407

Sensor

	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	3.77	mm/s		3.77		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	1.10	g		1.10		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	3.28	DEF		3.28		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	1.03	mm/s		1.03		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:18:55	2.11	mm/s		2.11		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:18:55	0.183	mm/s		0.183		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.200	g		0.200		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:18:55	1.04	g		1.04		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.250	g		0.250		DfCnd	High	0	0	0	0	2	4	0
4-PP-RV	9	H/S	Last Date	Value	Unit	T-1	Ref.	Avg	Oper.	AlmTyp	DG-	AL-	pA-	pA+	AL+	DG+	Err
Overall Vib Vel	IND-0001	Hard	15/02/2019 15:18:55	4.81	mm/s		4.81		DfCnd	High	0	0	0	2	3.5	6	0
Overall Acc	IND-0002	Hard	15/02/2019 15:18:55	0.935	g		0.935		DfCnd	None							
Defect factor	IND-0003	Hard	15/02/2019 15:18:55	3.11	DEF		3.11		DfCnd	High	0	0	0	4	6	9	0
1x	1x	Soft	15/02/2019 15:18:55	1.72	mm/s		1.72		DfCnd	High	0	0	0	0	3	6	0
2x	2x	Soft	15/02/2019 15:18:55	2.61	mm/s		2.61		DfCnd	High	0	0	0	0	1.5	3	0
3x	3x	Soft	15/02/2019 15:18:55	0.41	mm/s		0.411		DfCnd	High	0	0	0	0	1	2	0
En-LF	En-LF	Soft	15/02/2019 15:18:55	0.265	g		0.265		DfCnd	High	0	0	0	0	.15	.3	0
En-MF	En-MF	Soft	15/02/2019 15:18:55	0.868	g		0.868		DfCnd	High	0	0	0	0	.5	1	0
En-HF	En-HF	Soft	15/02/2019 15:18:55	0.205	g		0.205		DfCnd	High	0	0	0	0	2	4	0

Appendix C

Load Flow Analysis

Preliminary

Project: MAYNILAD- AYALA SOUTHVALE
Location: Ayala Southvale, Metro Manila
Contract:
Engineer:
Filename: SOUTHVALE

ETAP
16.2.0C
Study Case: LF

Page: 1
Date: 03-15-2019
SN: APSI-PH001
Revision: Base
Config.: Normal

Bus Loading Summary Report

Bus	Directly Connected Load								Total Bus Load			
	Constant kVA		Constant Z		Constant I		Generic		MVA	% PF	Amp	Percent
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MVA			Loading
Bus18		0.460							0.015	87.5	18.5	
Bus19		0.460										
Bus1		34.500							0.053	89.5	0.9	
Bus2		0.460							0.051	91.2	66.4	
Bus3		0.460							0.051	91.3	66.4	
Bus4		0.460							0.051	91.3	66.4	
Bus5		0.460							0.010	84.9	13.2	
Bus6		0.230							0.010	85.0	26.4	
Bus7		0.460	0.017	0.011					0.020	85.0	26.3	
Bus8		0.460	0.013						0.013	100.0	17.0	
Bus9		0.230							0.009	85.0	23.9	
Bus10		0.230			0.008	0.015			0.009	85.0	23.9	
Bus12		34.500							0.053	89.5	0.9	
Bus14		0.460							0.051	91.3	66.4	
Bus15		0.460							0.009	84.9	11.9	
Bus17		0.230	0.008	0.005					0.010	85.0	26.4	

* Indicates operating load of a bus exceeds the bus critical limit (100.0% of the Continuous Ampere rating).

Indicates operating load of a bus exceeds the bus marginal limit (95.0% of the Continuous Ampere rating).

Preliminary

Project: MAYNILAD- AYALA SOUTHVALE
Location: Ayala Southvale, Metro Manila
Contract:
Engineer:
Filename: SOUTHVALE

ETAP
16.2.0C
Study Case: LF

Page: 2
Date: 03-15-2019
SN: APSI-PH001
Revision: Base
Config.: Normal

Branch Loading Summary Report

CKT / Branch		Cable & Reactor			Transformer			
ID	Type	Ampacity (Amp)	Loading Amp	%	Capability (MVA)	Loading (input) MVA	Loading (output) MVA	
Cable1	Cable	302.68	0.89	0.29				
Cable2	Cable	302.68	66.45	21.95				
Cable3	Cable	138.93	66.44	47.83				
Cable4	Cable	138.93	13.20	9.50				
Cable5	Cable	166.19	26.40	15.89				
Cable6	Cable	138.93	26.29	18.93				
Cable7	Cable	91.38	16.96	18.33				
Cable8	Cable	138.93	11.94	8.59				
Cable9	Cable	91.38	22.77	26.11				
T1	Transformer				0.065	0.053	81.4	
T2	Transformer				0.113	0.010	8.9	
T3	Transformer				0.075	0.009	12.1	
							0.010	
							8.9	
							0.009	
							12.1	

* Indicates a branch with operating load exceeding the branch capability.

Preliminary

Project: MAYNILAD- AYALA SOUTHVALE
Location: Ayala Southvale, Metro Manila
Contract:
Engineer:
Filename: SOUTHVALE

ETAP
16.2.0C
Study Case: LF

Page: 3
Date: 03-15-2019
SN: APSI-PH001
Revision: Base
Config.: Normal

Branch Losses Summary Report

Branch ID	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd in Vmag
	MW	Mvar	MW	Mvar	kW	kvar	From	To	
Cable1	-0.047	-0.024	0.047	0.024	0.0	0.0	100.0	100.0	0.00
T1	0.047	0.024	-0.046	-0.021	1.2	0.9	95.7	95.7	4.35
Cable2	0.046	0.021	-0.046	-0.021	0.0	0.1	95.7	95.5	0.13
Cable3	0.046	0.021	-0.046	-0.021	0.0	0.1	95.5	95.5	0.05
Cable4	0.009	0.005	-0.009	-0.005	0.0	0.0	95.5	95.4	0.03
Cable6	0.017	0.011	-0.017	-0.011	0.0	0.0	95.5	95.5	0.01
Cable7	0.013	0.000	-0.013	0.000	0.0	0.0	95.5	95.5	0.01
Cable8	0.008	0.005	-0.008	0.005	0.0	0.0	95.5	95.5	0.01
T2	0.009	0.005	-0.009	-0.005	0.0	0.0	95.4	95.2	0.28
Cable5	0.009	0.005	-0.008	-0.005	0.0	0.0	95.2	95.1	0.10
Cable9	0.008	0.005	-0.008	-0.005	0.0	0.0	95.2	95.1	0.06
T3	-0.008	-0.005	0.008	0.005	0.0	0.0	95.2	95.5	0.28
						1.3		3.1	

Preliminary

Project: MAYNILAD- AYALA SOUTHVALE **ETAP**
 Location: Ayala Southvale, Metro Manila 16.2.0C
 Contract:
 Engineer:
 Filename: SOUTHVALE Study Case: LF
Page: 4
Date: 03-15-2019
SN: APSI-PH001
Revision: Base
Config.: Normal

Alert Summary Report

<u>% Alert Settings</u>		
	<u>Critical</u>	<u>Marginal</u>
<u>Loading</u>		
Bus	100.0	95.0
Cable	100.0	95.0
Reactor	100.0	95.0
Line	100.0	92.0
Transformer	100.0	95.0
Panel	100.0	95.0
Protective Device	100.0	95.0
Generator	100.0	95.0
Inverter/Charger	100.0	95.0
<u>Bus Voltage</u>		
OverVoltage	105.0	102.0
UnderVoltage	95.0	98.0
<u>Generator Excitation</u>		
OverExcited (Q Max.)	100.0	95.0
UnderExcited (Q Min.)	100.0	

Critical Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
VFD1	VFD	Overload	14.039	Amp	16.963	120.8	3-Phase

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus10	Bus	Under Voltage	0.230	kV	0.219	95.1	3-Phase
Bus14	Bus	Under Voltage	0.460	kV	0.44	95.5	3-Phase
Bus15	Bus	Under Voltage	0.460	kV	0.44	95.5	3-Phase
Bus17	Bus	Under Voltage	0.230	kV	0.22	95.1	3-Phase
Bus2	Bus	Under Voltage	0.460	kV	0.44	95.7	3-Phase
Bus3	Bus	Under Voltage	0.460	kV	0.44	95.5	3-Phase
Bus4	Bus	Under Voltage	0.460	kV	0.44	95.5	3-Phase
Bus5	Bus	Under Voltage	0.460	kV	0.44	95.4	3-Phase
Bus6	Bus	Under Voltage	0.230	kV	0.22	95.2	3-Phase
Bus7	Bus	Under Voltage	0.460	kV	0.44	95.5	3-Phase
Bus8	Bus	Under Voltage	0.460	kV	0.44	95.5	3-Phase

Project: MAYNILAD- AYALA SOUTHVALE
Location: Ayala Southvale, Metro Manila
Contract:
Engineer:
Filename: SOUTHLAKE

ETAP

16.2.0C

Page: 5

Date: 03-15-2019

SN: APSI-PH001

Revision: Base

Config.: Normal

Marginal Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus9	Bus	Under Voltage	0.230	kV	0.219	95.2	3-Phase

Preliminary

Project: MAYNILAD- AYALA SOUTHVALE
Location: Ayala Southvale, Metro Manila
Contract:
Engineer:
Filename: SOUTHVALE

ETAP
16.2.0C
Study Case: LF

Page: 6
Date: 03-15-2019
SN: APSI-PH001
Revision: Base
Config.: Normal

SUMMARY OF TOTAL GENERATION, LOADING & DEMAND

	MW	Mvar	MVA	% PF
Source (Swing Buses):	0.047	0.024	0.053	89.48 Lagging
Source (Non-Swing Buses):	0.000	0.000	0.000	
Total Demand:	0.047	0.024	0.053	89.48 Lagging
Total Motor Load:	0.038	0.023	0.045	85.85 Lagging
Total Static Load:	0.008	0.005	0.009	85.00 Lagging
Total Constant I Load:	0.000	0.000	0.000	
Total Generic Load:	0.000	0.000	0.000	
Apparent Losses:	0.001	-0.004		
System Mismatch:	0.000	0.000		

Number of Iterations: 2

Preliminary

Preliminary

Appendix D

Power Quality Study

Preliminary



Instrument Information

Model Number	435-II
Serial Number	34843110
Firmware Revision	V05.04

Software Information

Power Log Version	5.4
FLUKE 430-II DLL Version	1.2.0.13

General Information

Recording location	MAIN ATS 200AMPS
Client	AYALA SOUTHVALE
Notes	

Preliminary

Measurement Summary

Measurement topology	3-element delta mode
Application mode	Logger
First recording	12/1/2018 10:56:58 PM 280msec
Last recording	12/3/2018 10:56:58 AM 280msec
Recording interval	0h 10m 0s 0msec
Nominal Voltage	460 V
Nominal Current	200 A
Nominal Frequency	60 Hz
File start time	12/1/2018 10:46:58 PM 280msec
File end time	12/3/2018 10:56:58 AM 280msec
Duration	1d 12h 10m 0s 0msec
Number of events	Normal: 4 Detailed: 0
Events downloaded	No
Number of screens	1
Screens downloaded	Yes
Power measurement method	Unified
Cable type	Copper
Harmonic scale	%H1
THD mode	THD 40
CosPhi / DPF mode	DPF

Scaling

Phase:	
Current Clamp type	i430Flex
Clamp range	N/A
Nominal range	200 A
Sensitivity	x10 AC only
Current ratio	1:1
Voltage ratio	1:1
Neutral:	
Current Clamp type	i430Flex
Clamp range	N/A
Nominal range	200 A
Sensitivity	x10 AC only
Current ratio	1:1
Voltage ratio	1:1

Recording Summary

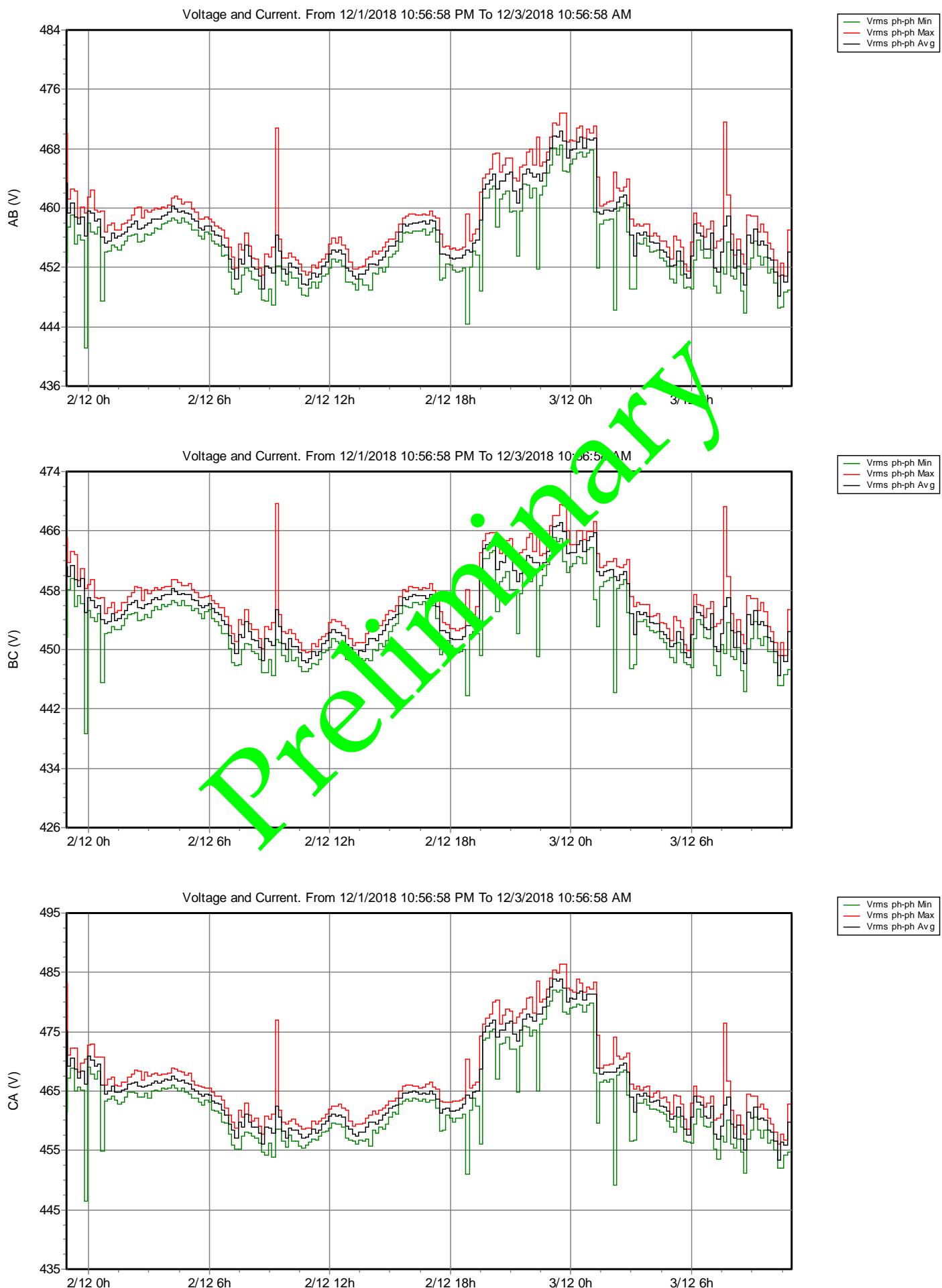
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Frequency recordings	217
Unbalance recordings	217
Harmonic recordings	217
Power harmonic recordings	217
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Power unbalance recordings	0
Energy recordings	217
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Flicker recordings	217
Mains signaling recordings	217

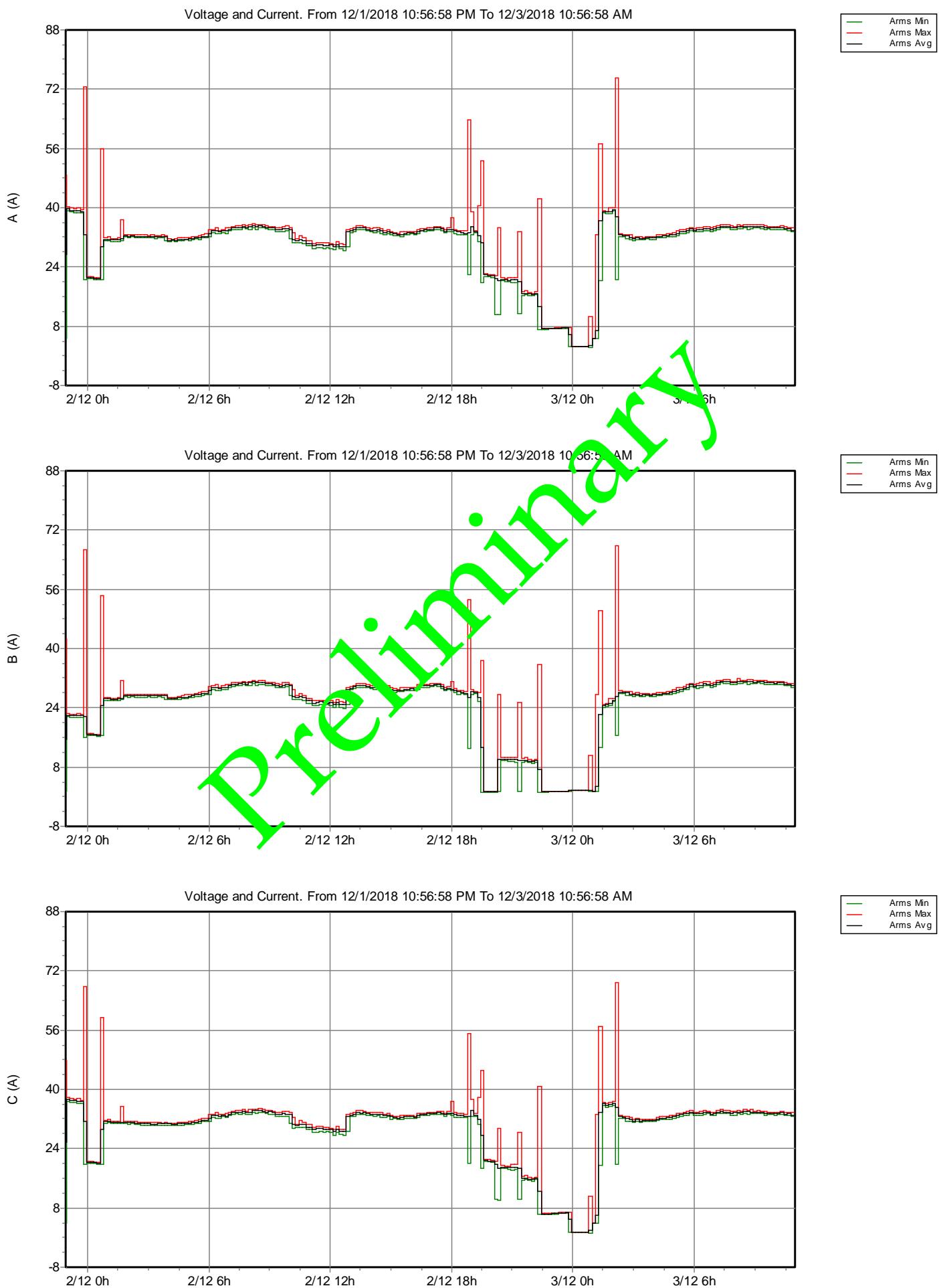
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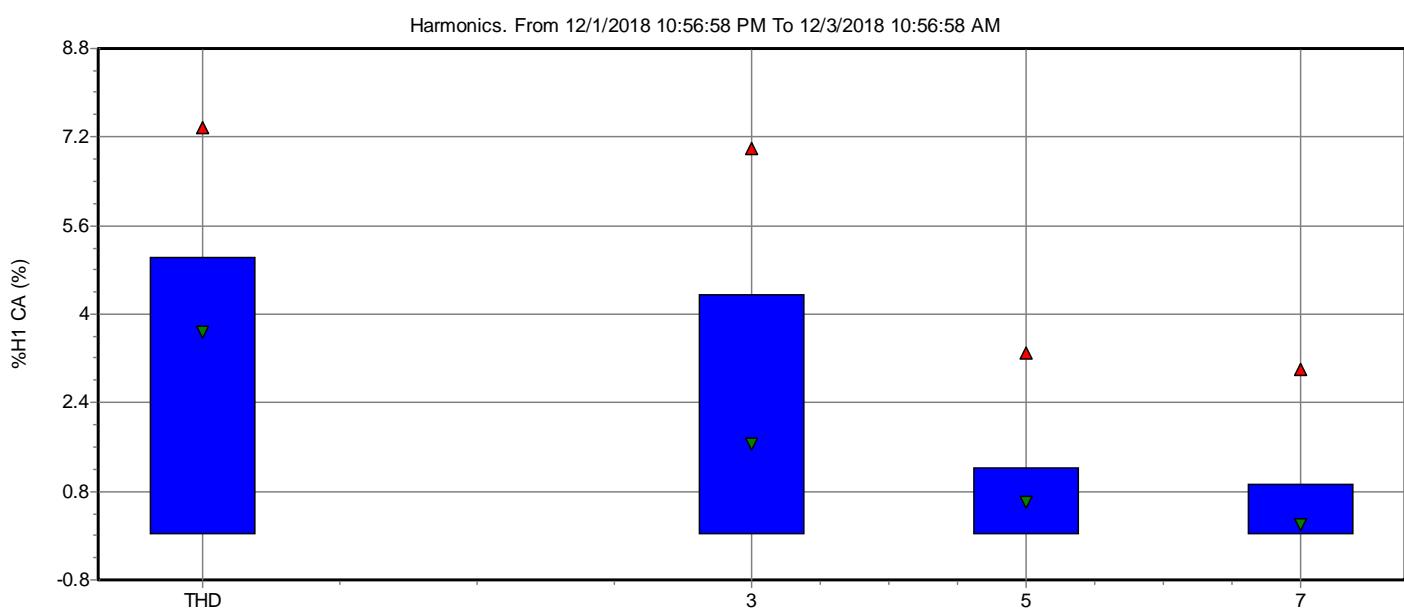
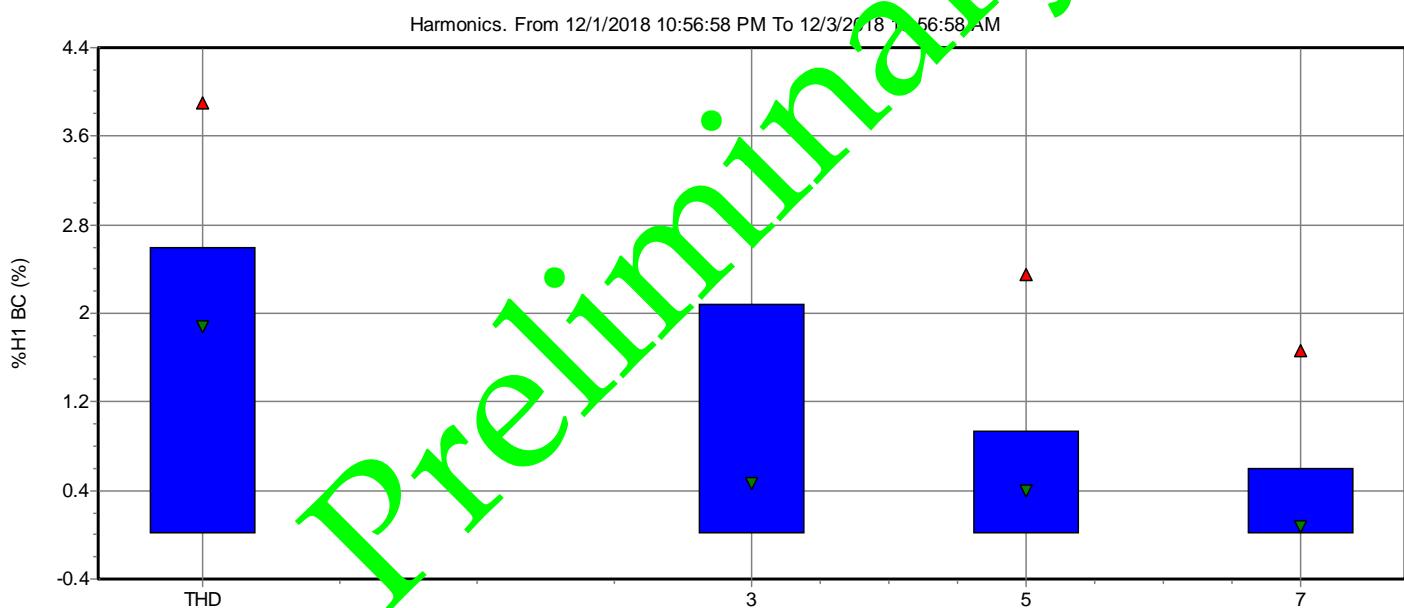
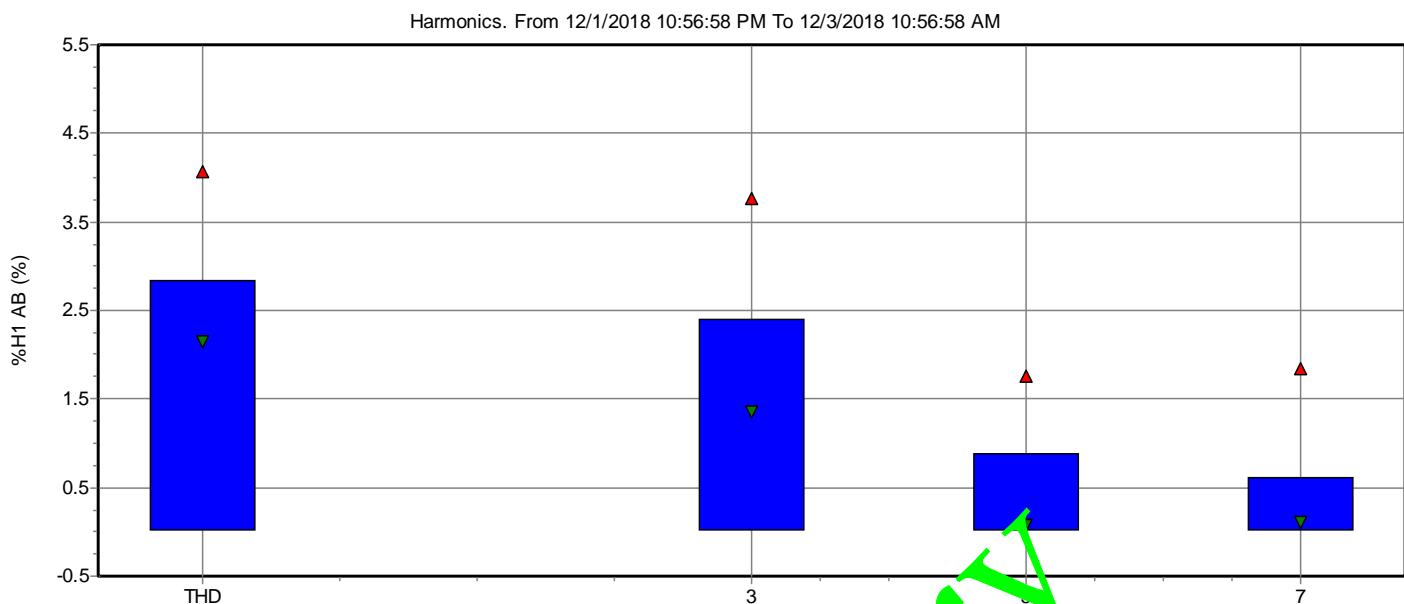
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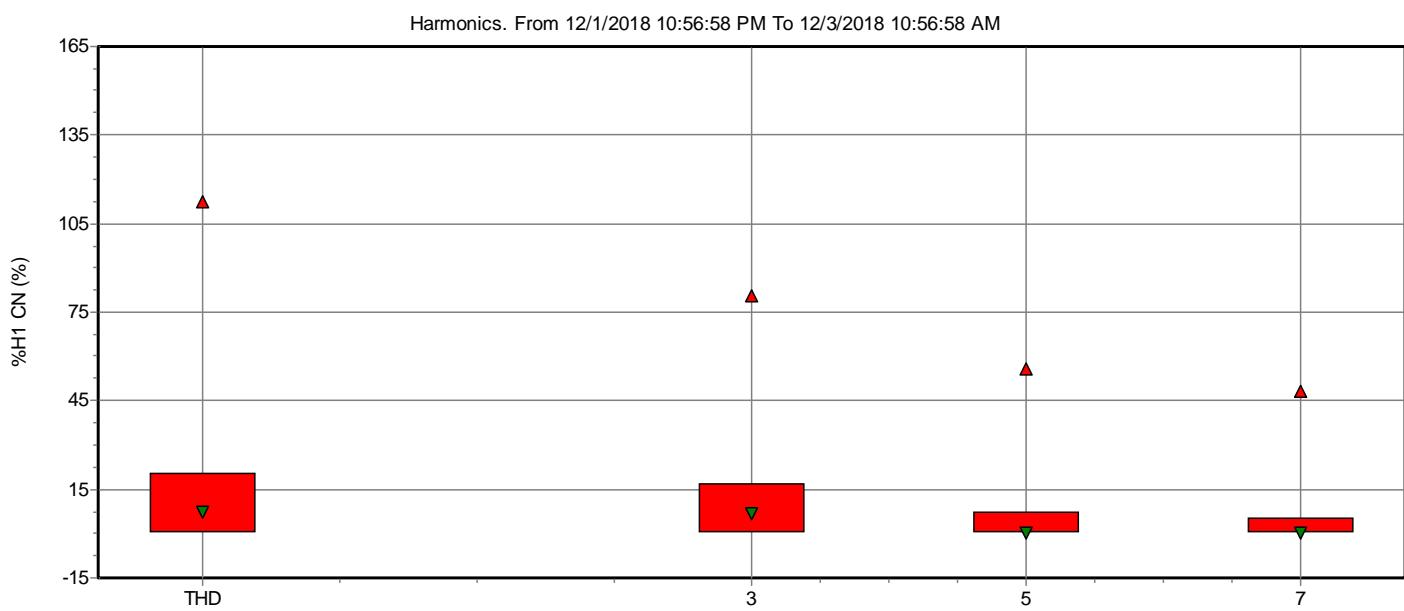
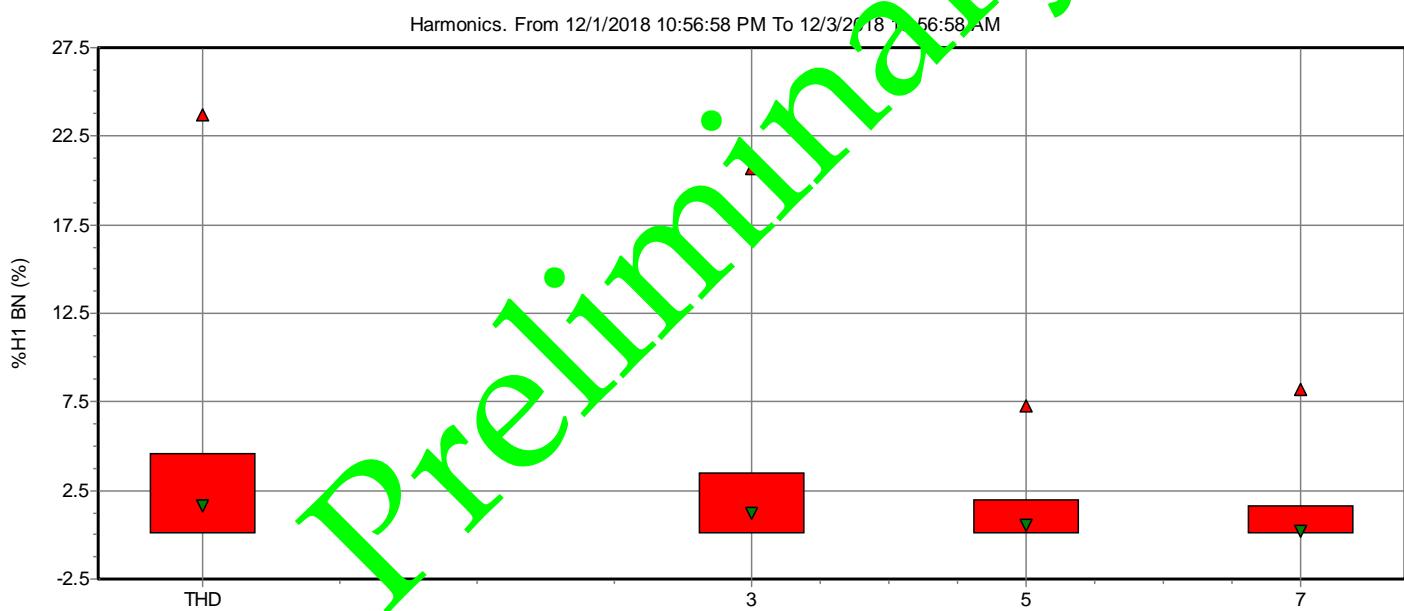
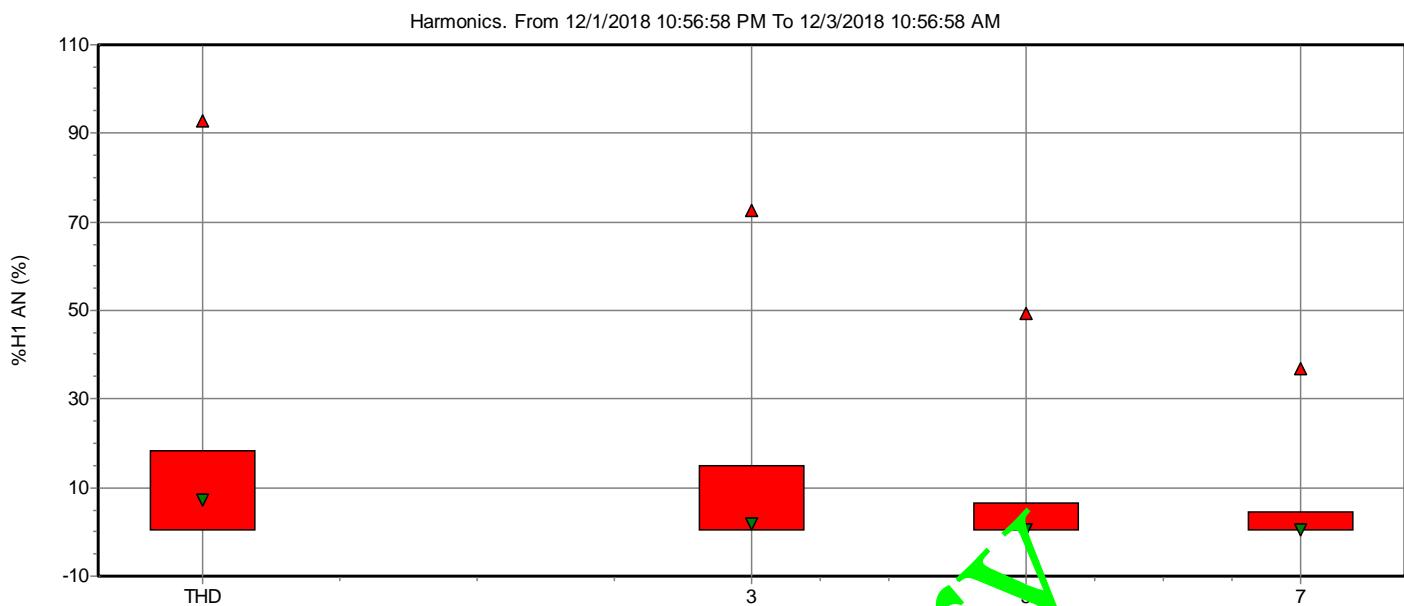
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Transients	0
Interruptions	0
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Rapid voltage changes	0
Screens	1
Waveforms	0
Intervals without measurements	0
Inrush current graphics	0
Wave events	0
RMS events	0

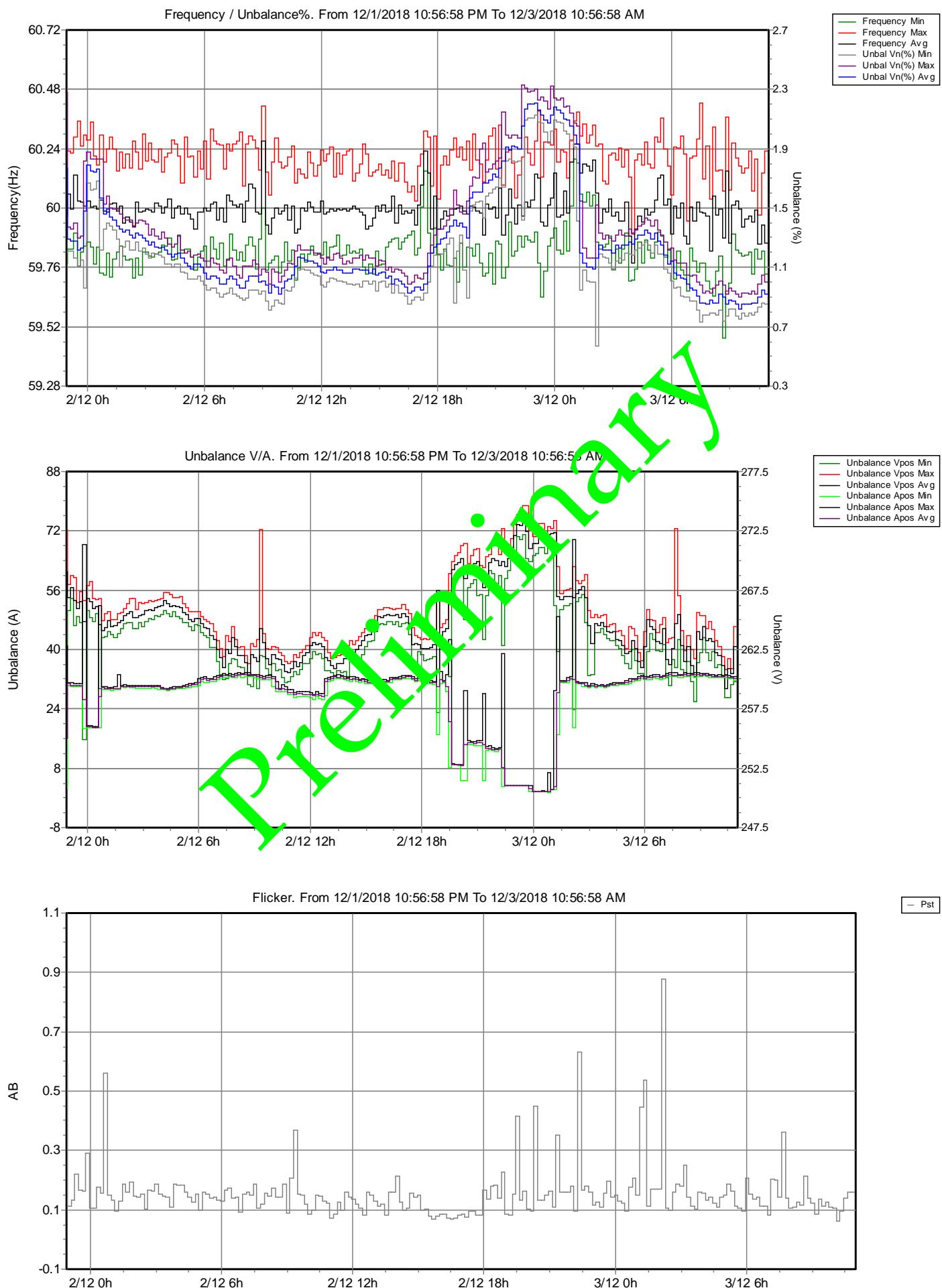
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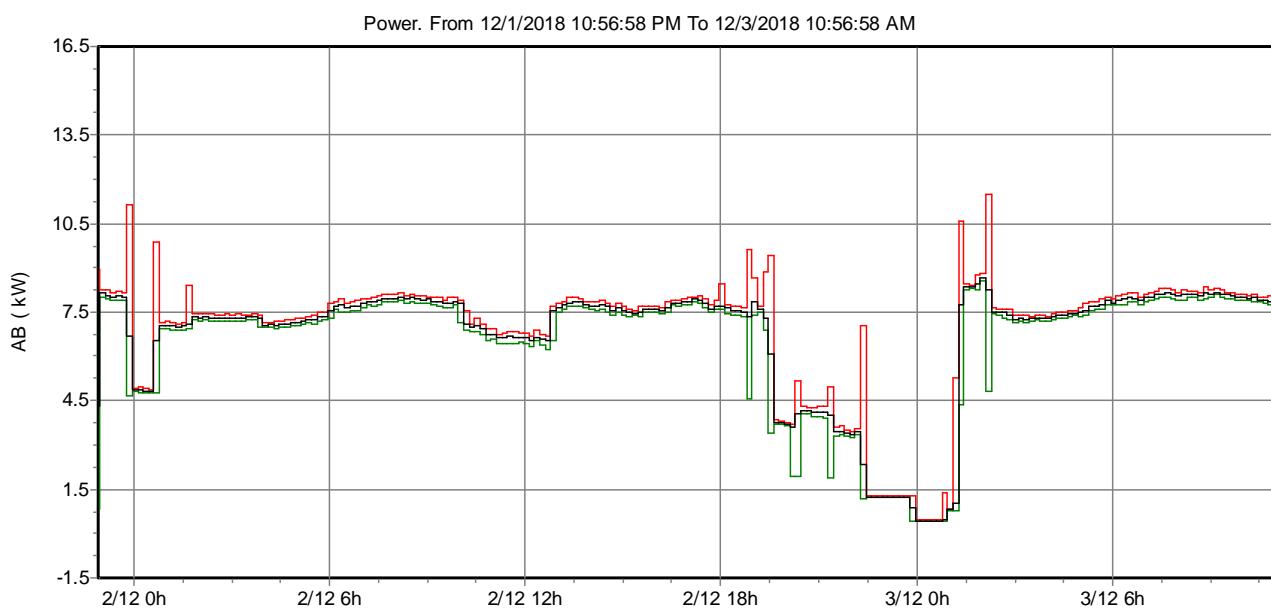
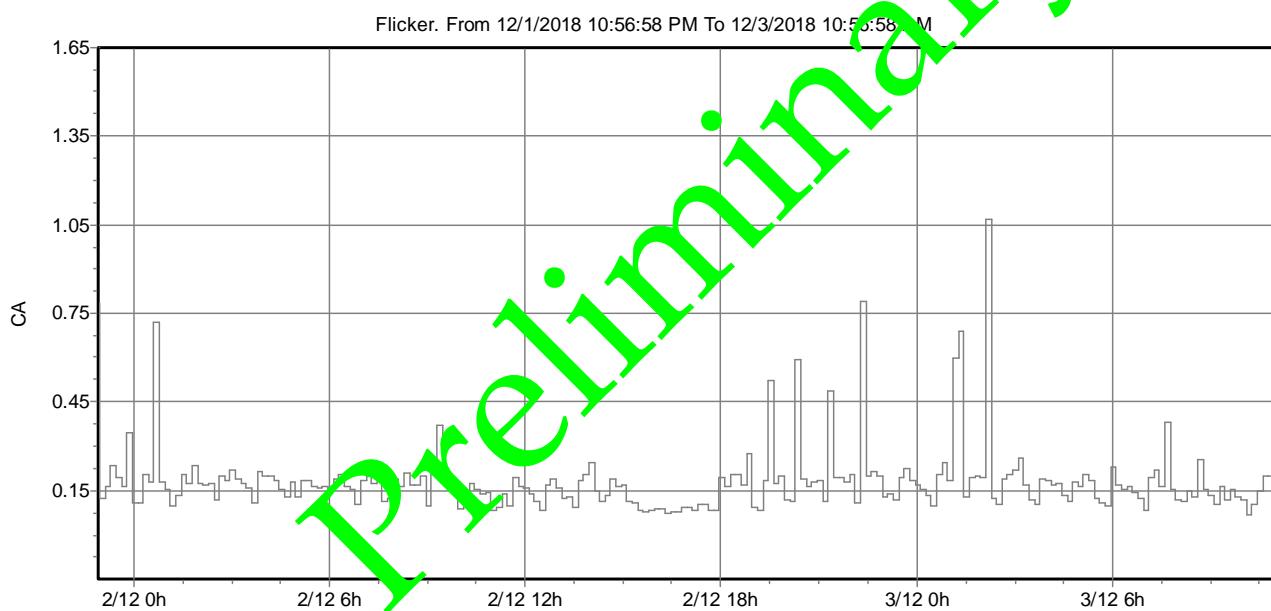
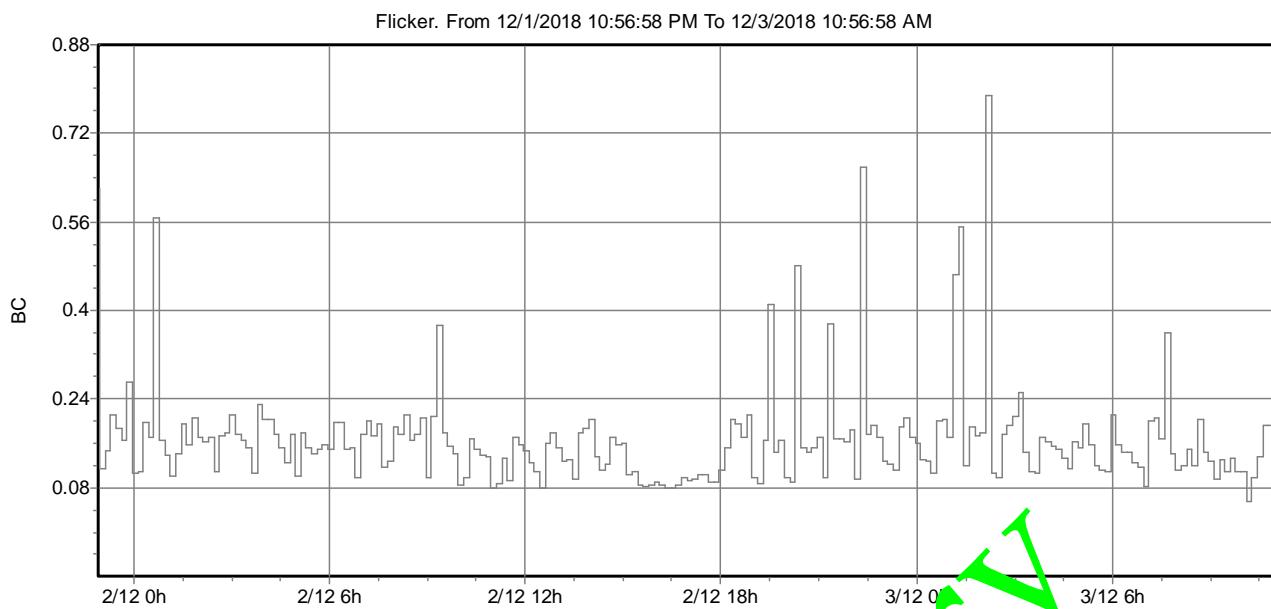


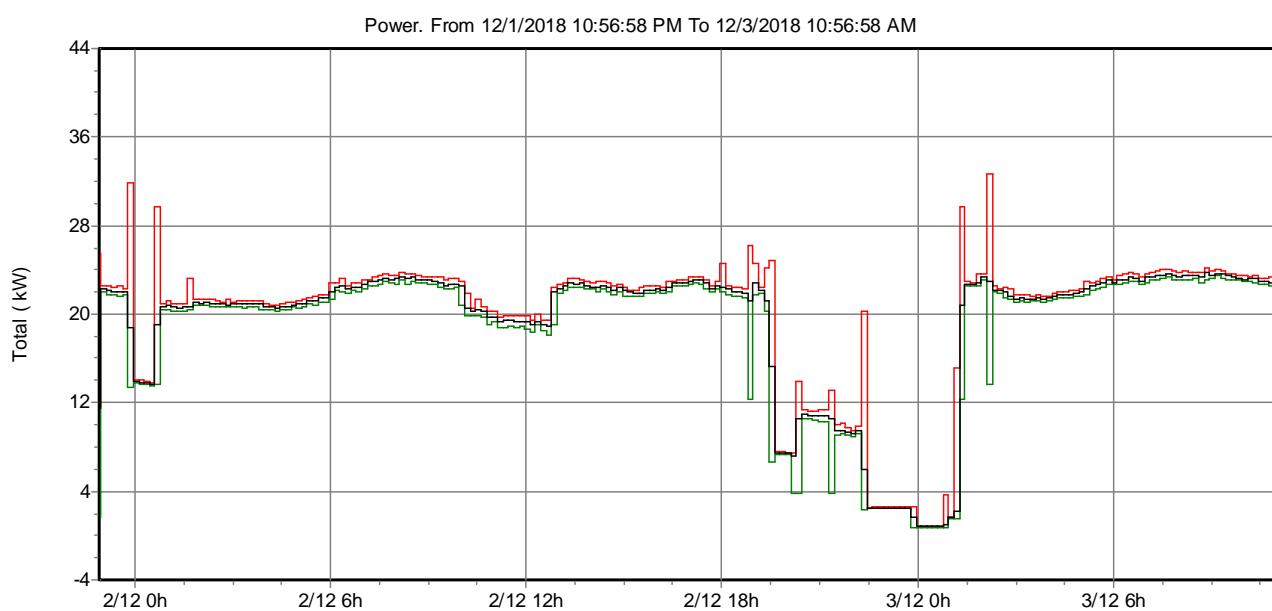
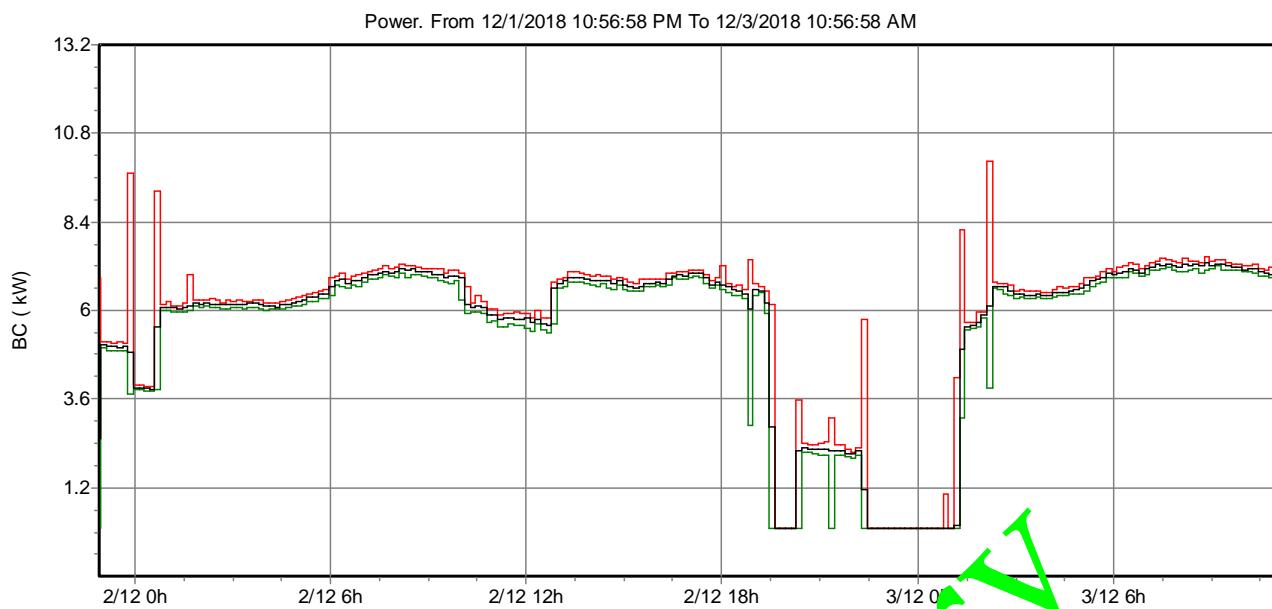




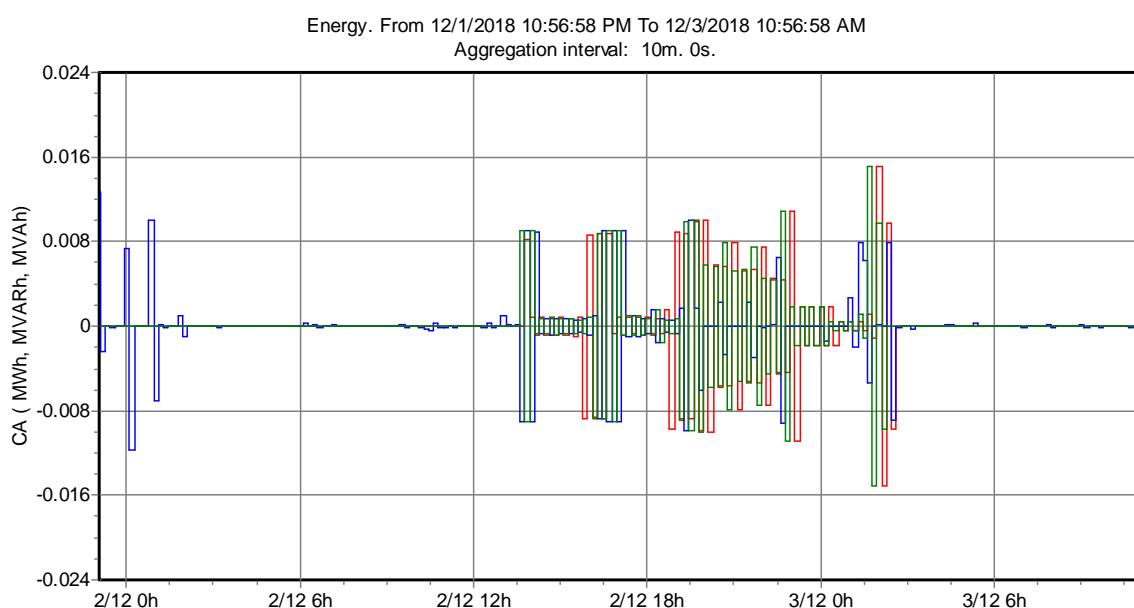
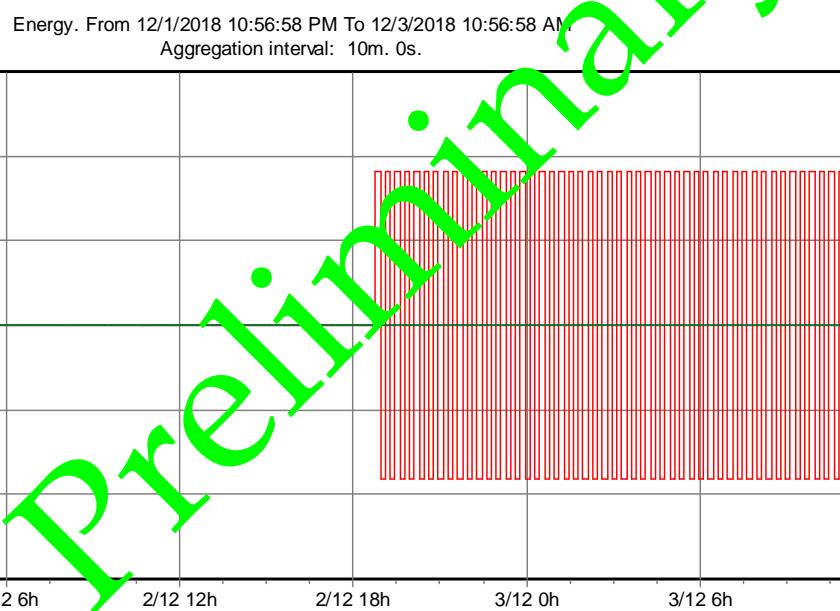
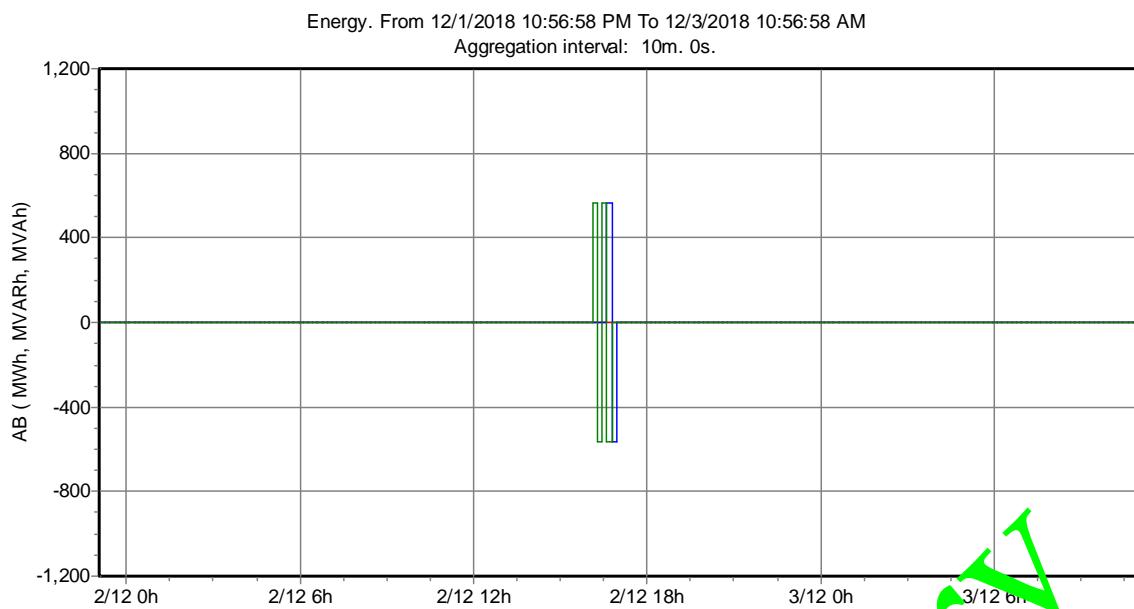


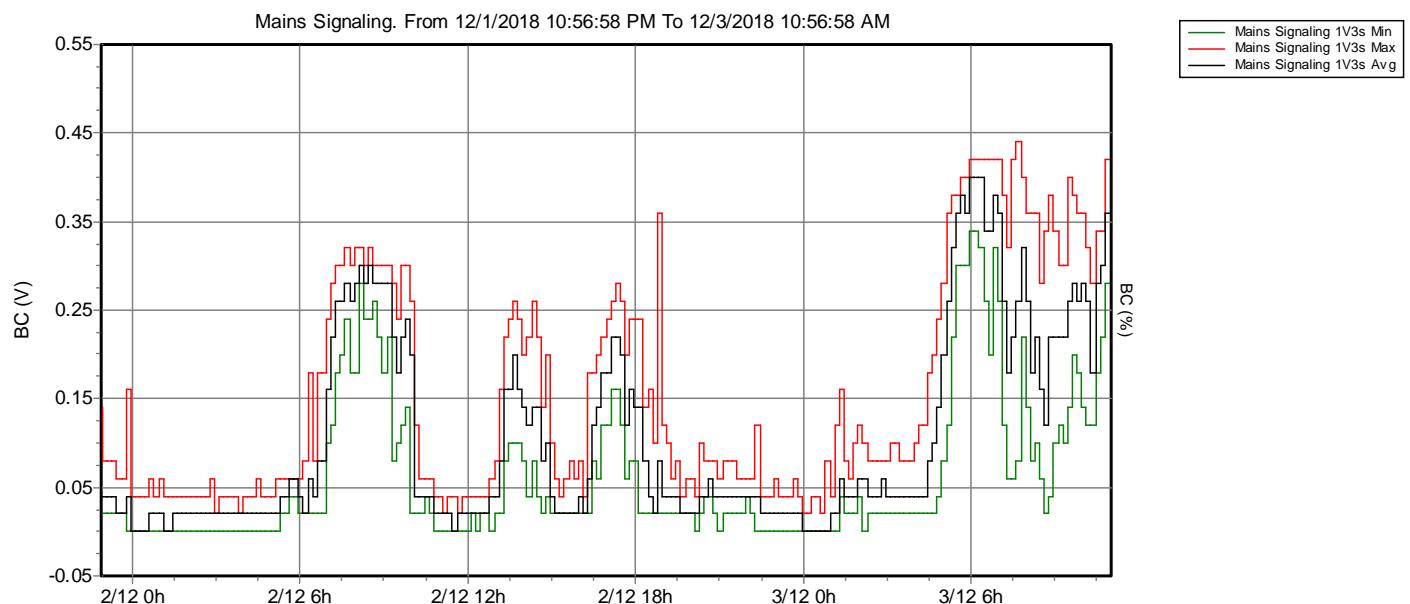
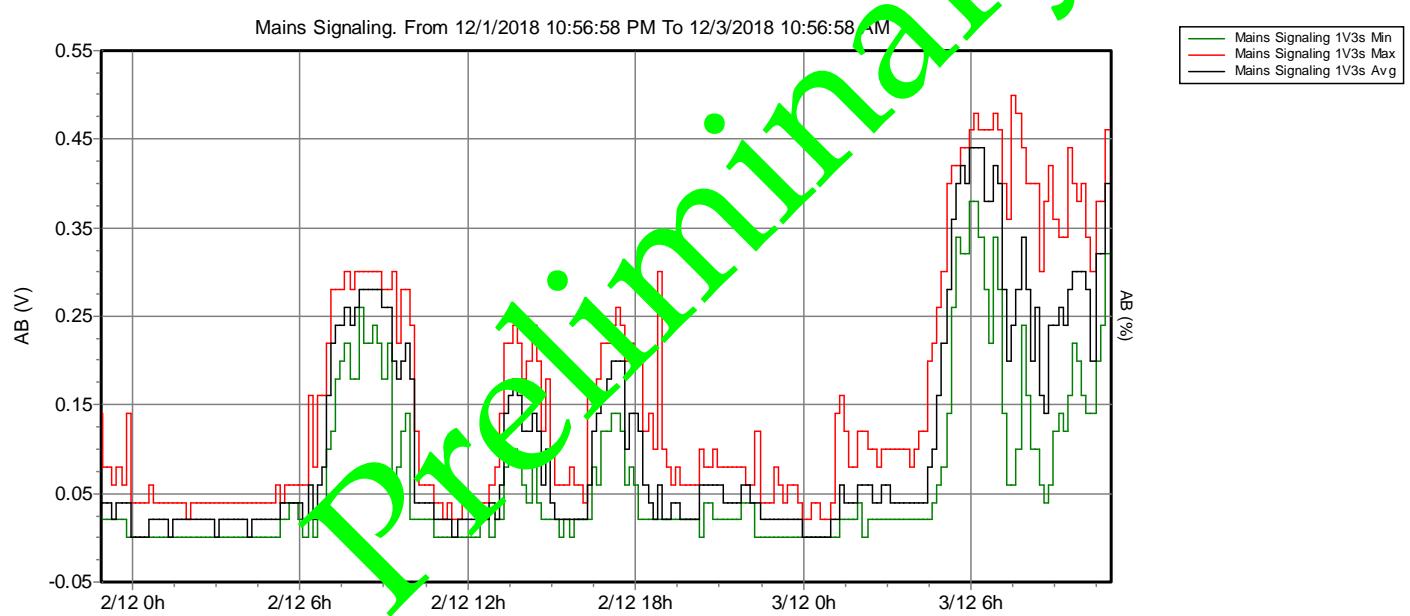
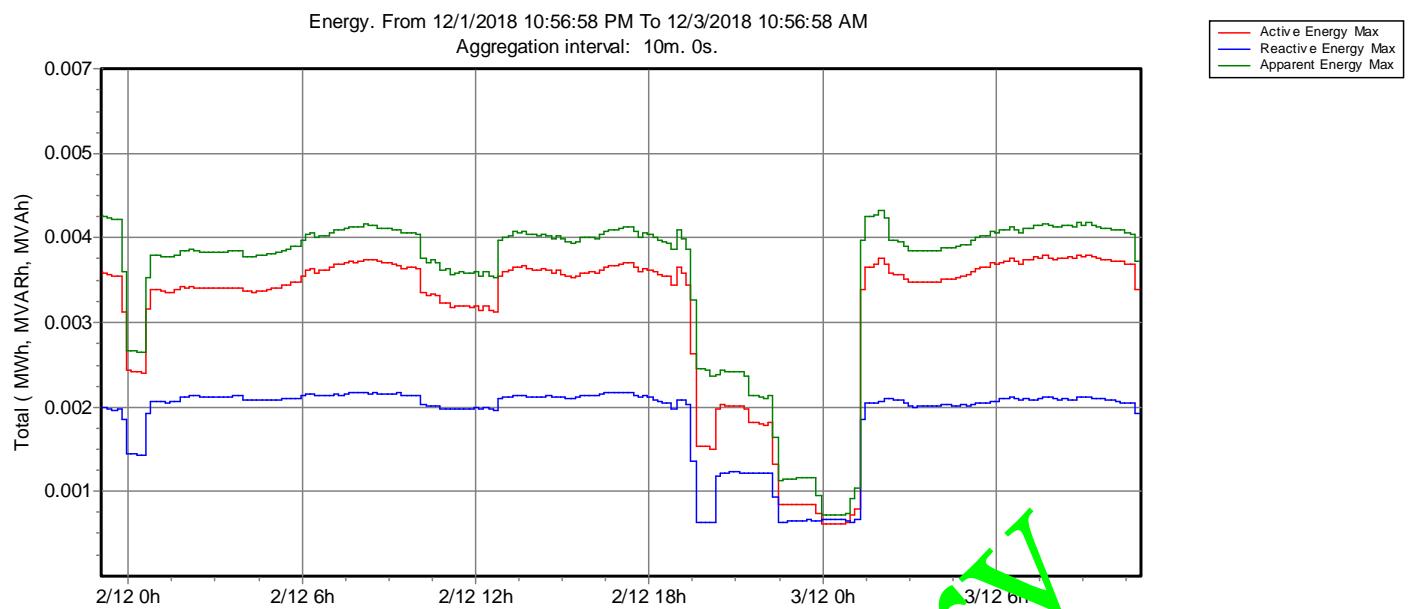


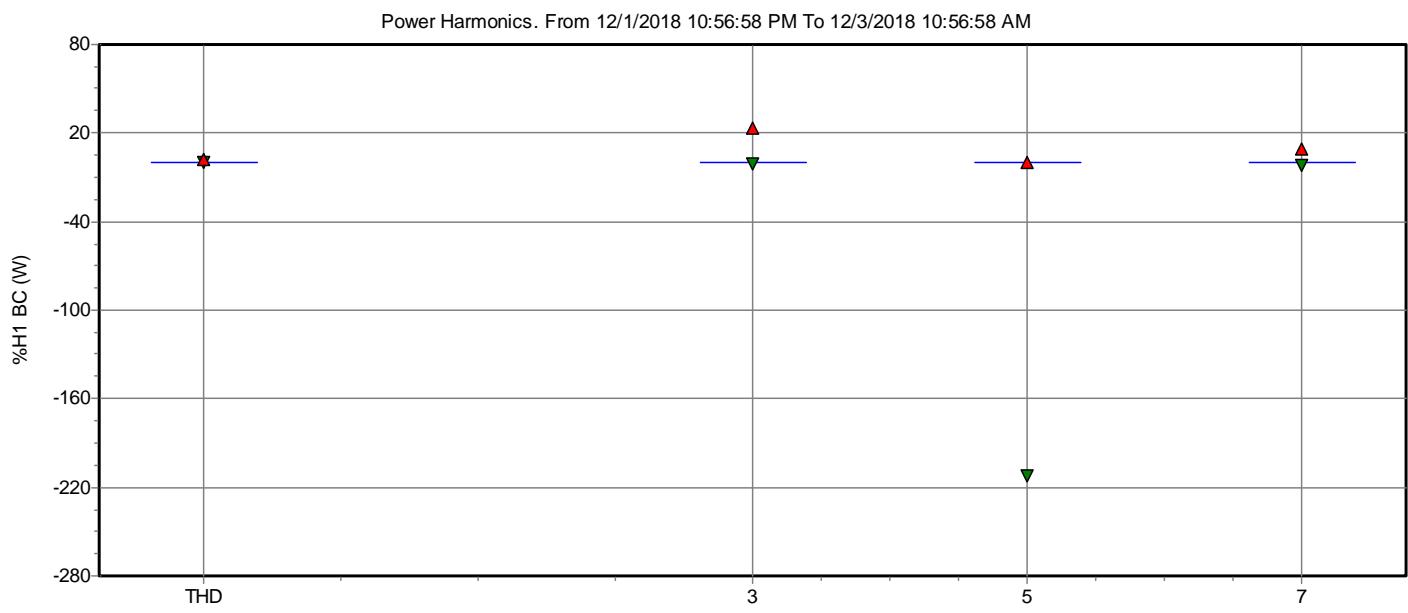
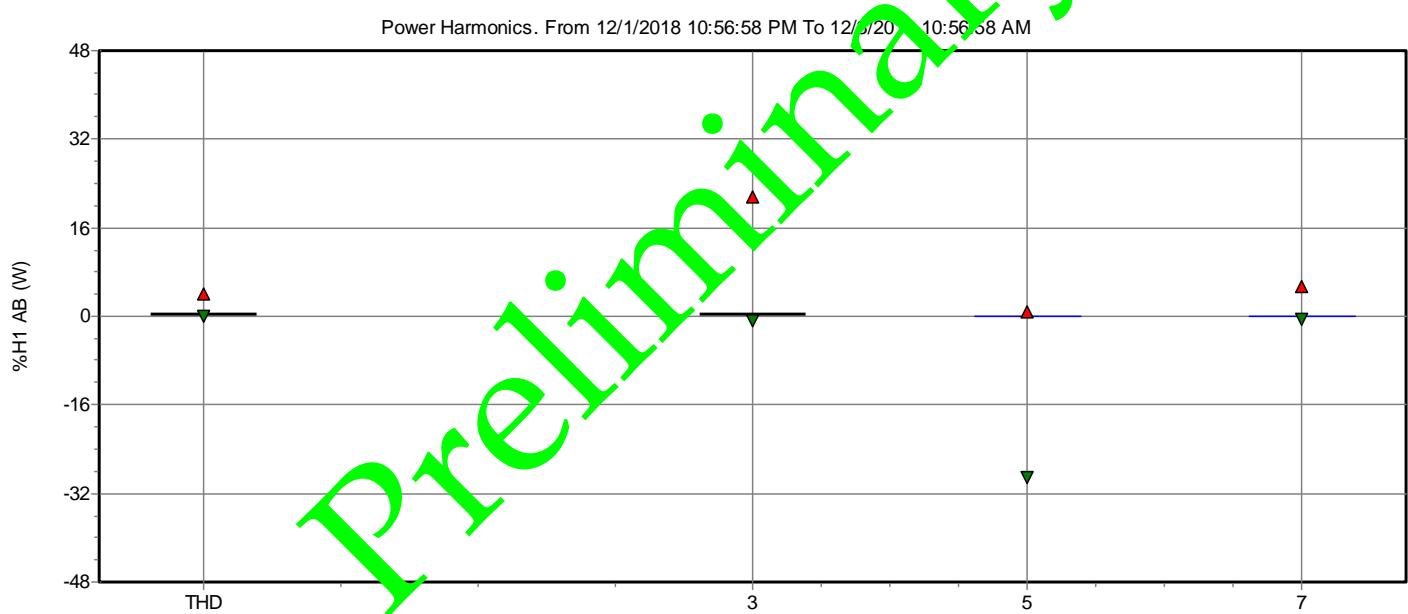
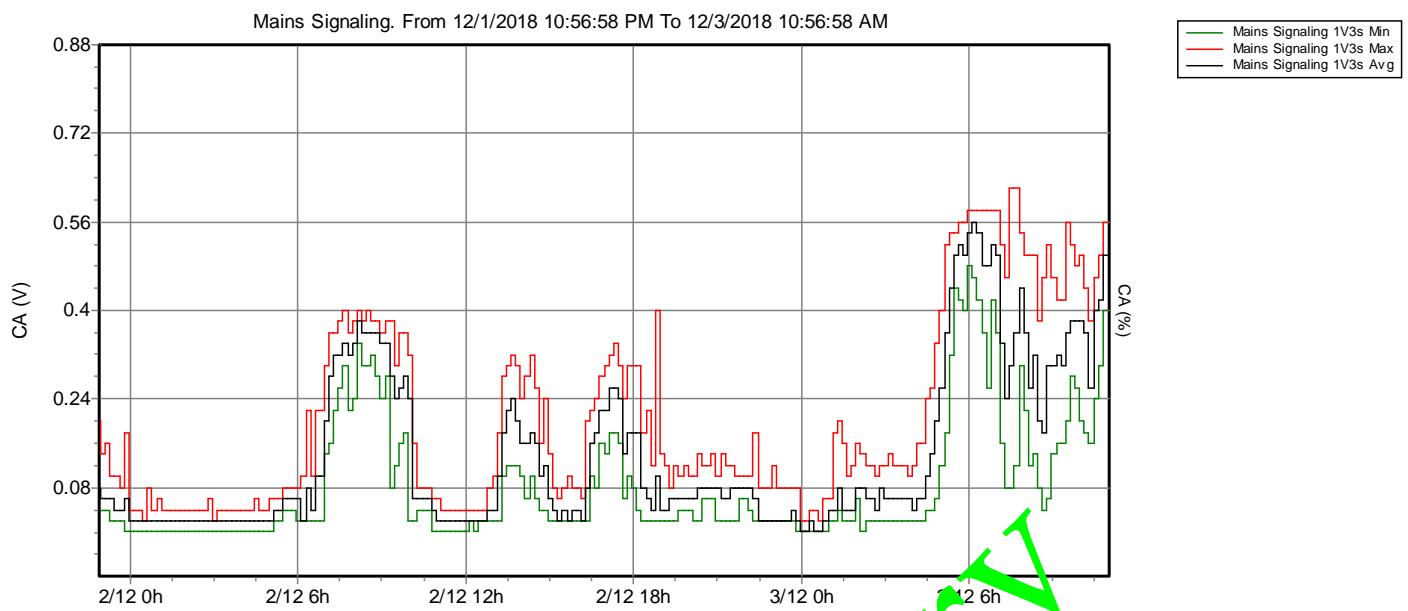


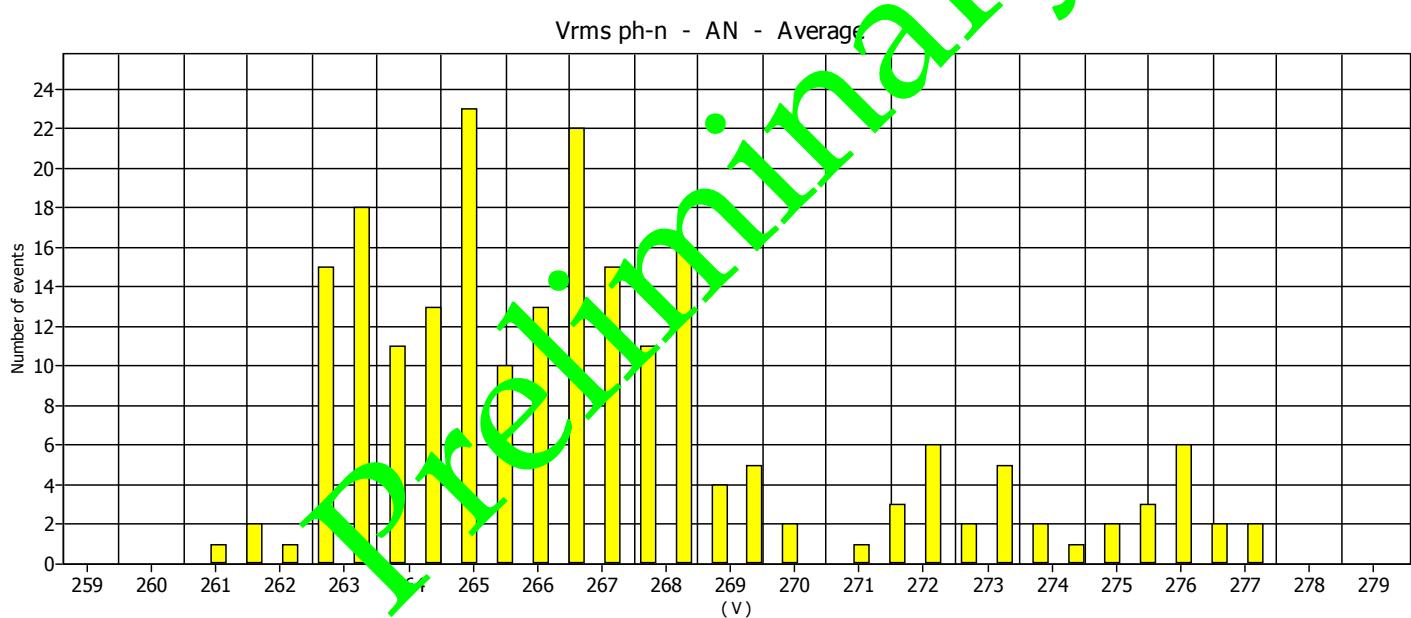
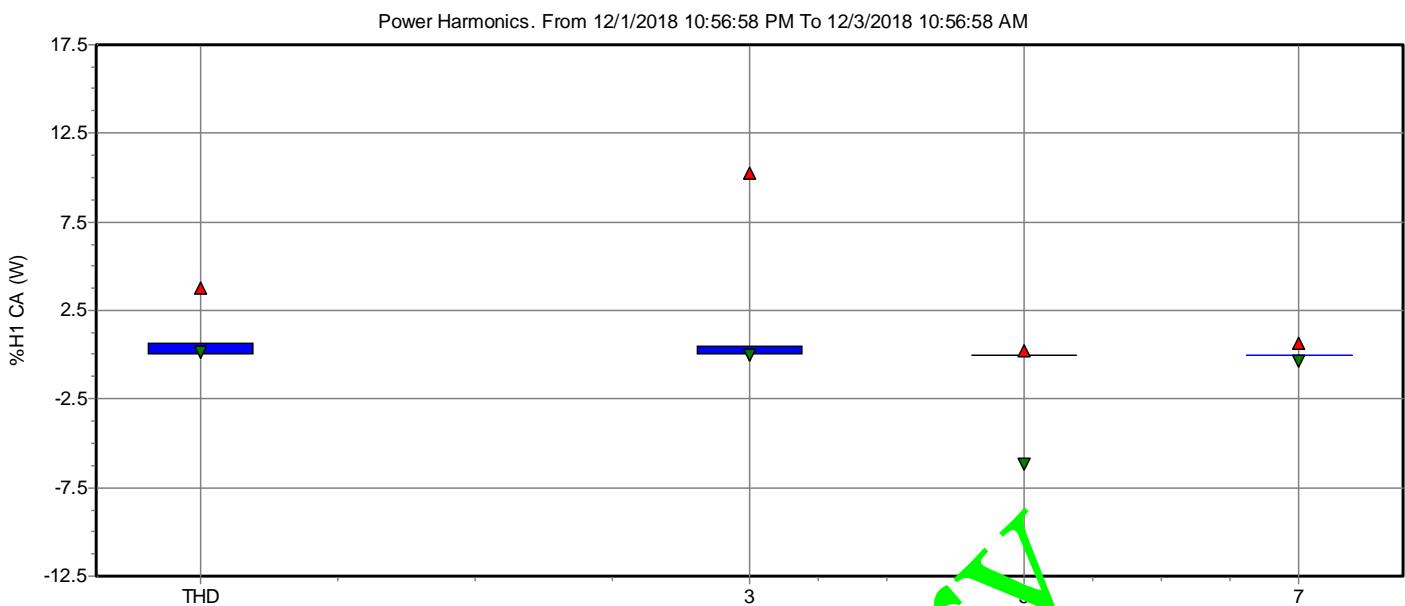


Preliminary











Instrument Information

Model Number	435-II
Serial Number	34843110
Firmware Revision	V05.04

Software Information

Power Log Version	5.4
FLUKE 430-II DLL Version	1.2.0.13

General Information

Recording location	VFD-1 (15 HP MOTOR)
Client	AYALA SOUTHVALE
Notes	

Preliminary



Measurement Summary

Measurement topology	3-element delta mode
Application mode	Logger
First recording	12/3/2018 11:30:21 AM 567msec
Last recording	12/4/2018 8:30:21 AM 567msec
Recording interval	0h 10m 0s 0msec
Nominal Voltage	460 V
Nominal Current	60 A
Nominal Frequency	60 Hz
File start time	12/3/2018 11:20:21 AM 567msec
File end time	12/4/2018 8:30:21 AM 567msec
Duration	0d 21h 10m 0s 0msec
Number of events	Normal: 3 Detailed: 0
Events downloaded	No
Number of screens	1
Screens downloaded	Yes
Power measurement method	Unified
Cable type	Copper
Harmonic scale	%H1
THD mode	THD 40
CosPhi / DPF mode	DPF

Scaling

Phase:	
Current Clamp type	i430Flex
Clamp range	N/A
Nominal range	60 A
Sensitivity	x10 AC only
Current ratio	1:1
Voltage ratio	1:1
Neutral:	
Current Clamp type	i430Flex
Clamp range	N/A
Nominal range	60 A
Sensitivity	x10 AC only
Current ratio	1:1
Voltage ratio	1:1

Recording Summary

RMS recordings	127
DC recordings	0
Frequency recordings	127
Unbalance recordings	127
Harmonic recordings	127
Power harmonic recordings	127
Power recordings	127
Power unbalance recordings	0
Energy recordings	127
Energy losses recordings	0
Flicker recordings	127
Mains signaling recordings	127

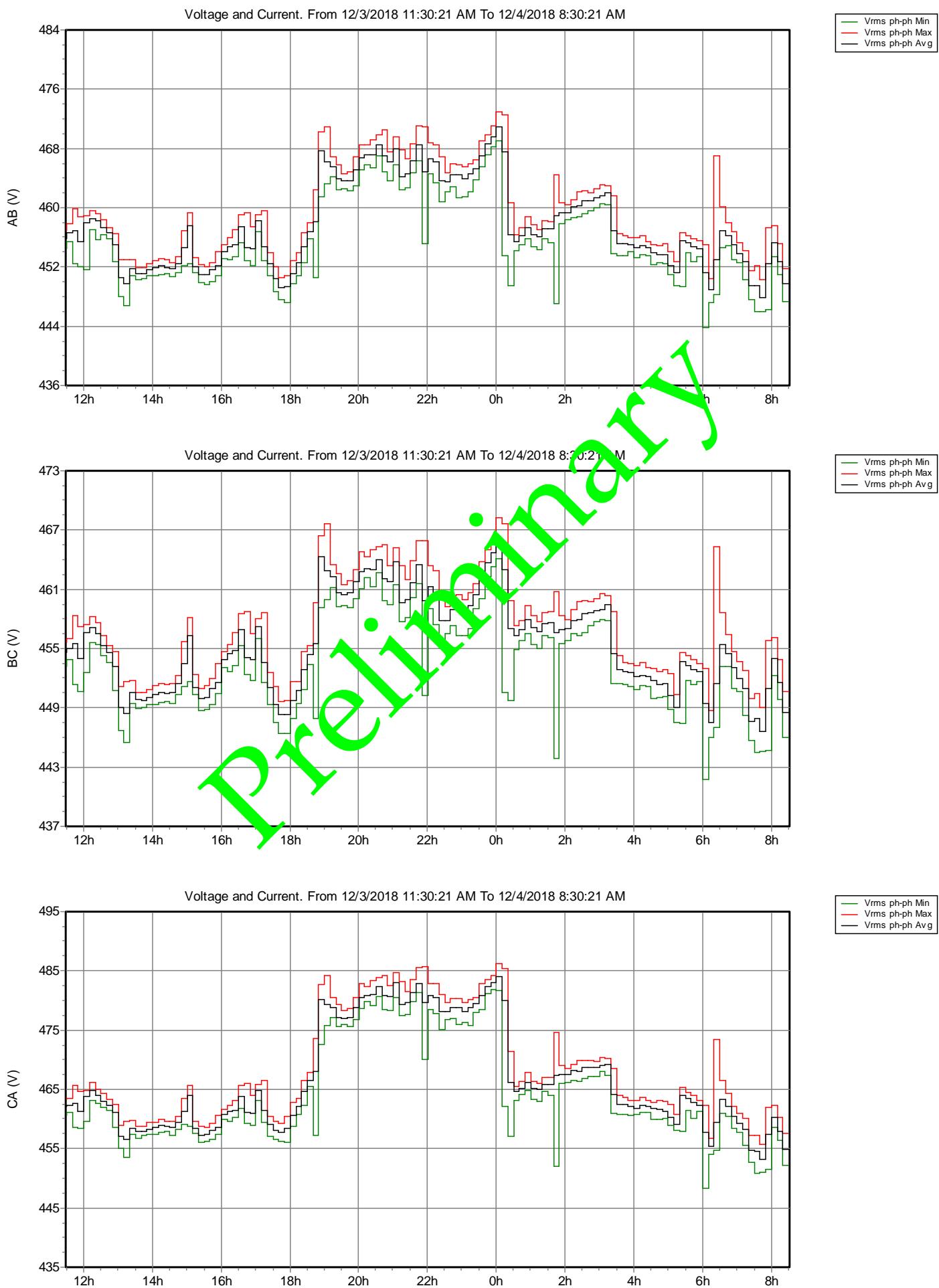
Preliminary

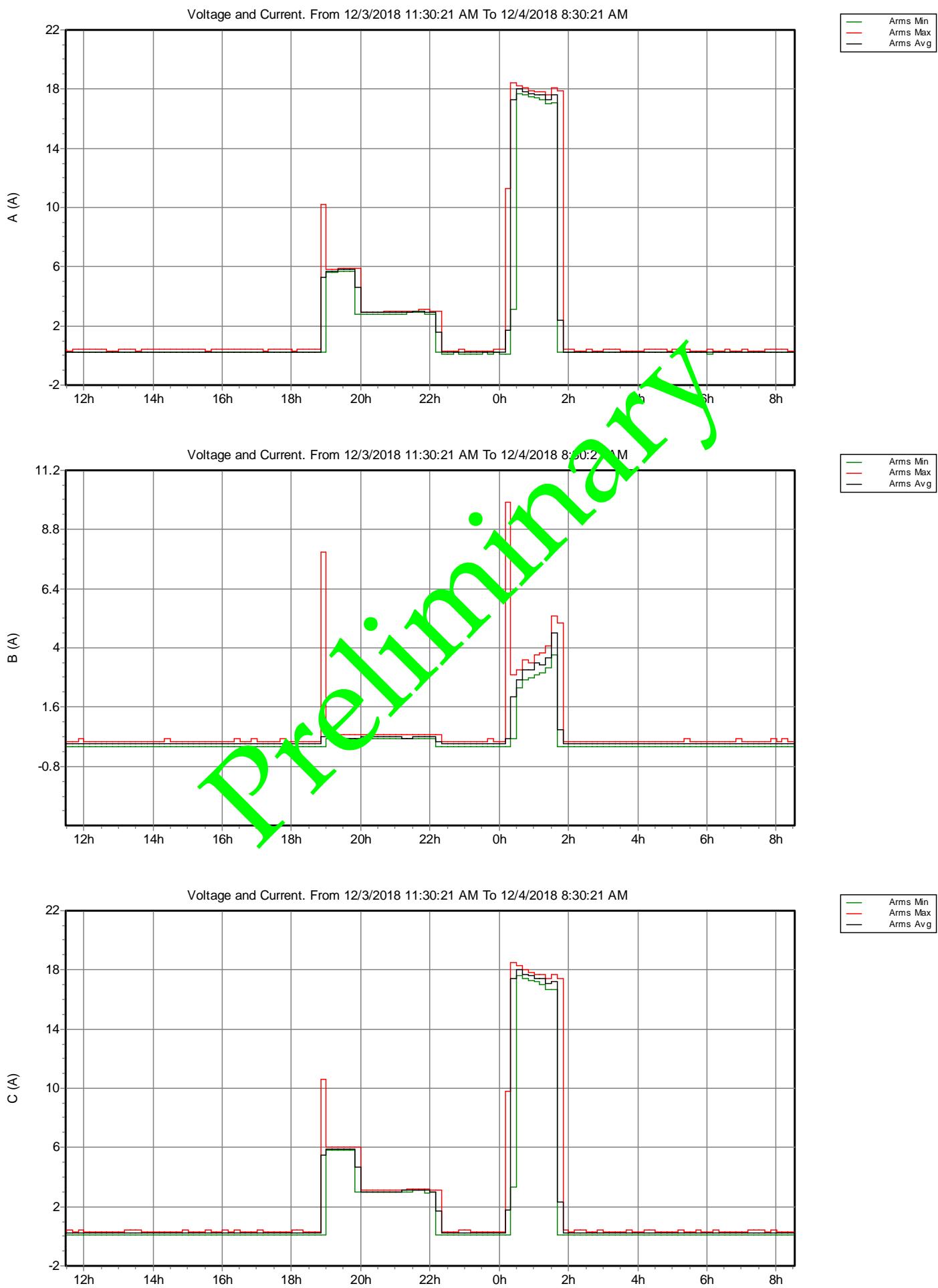


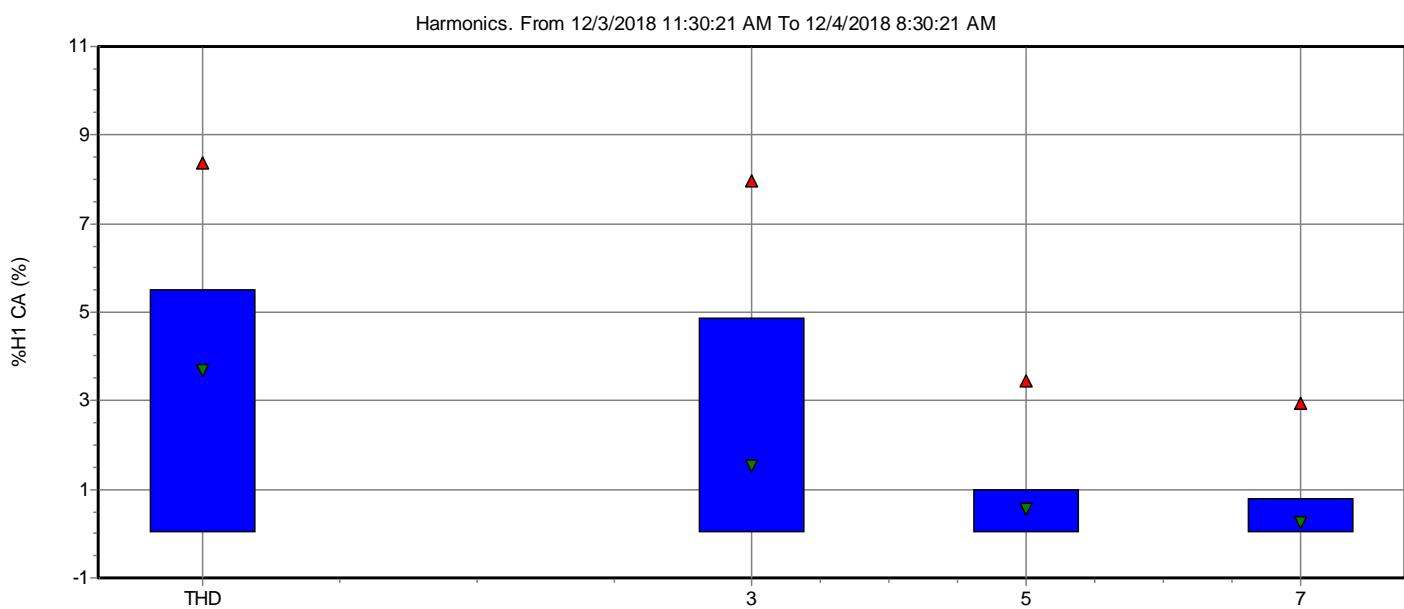
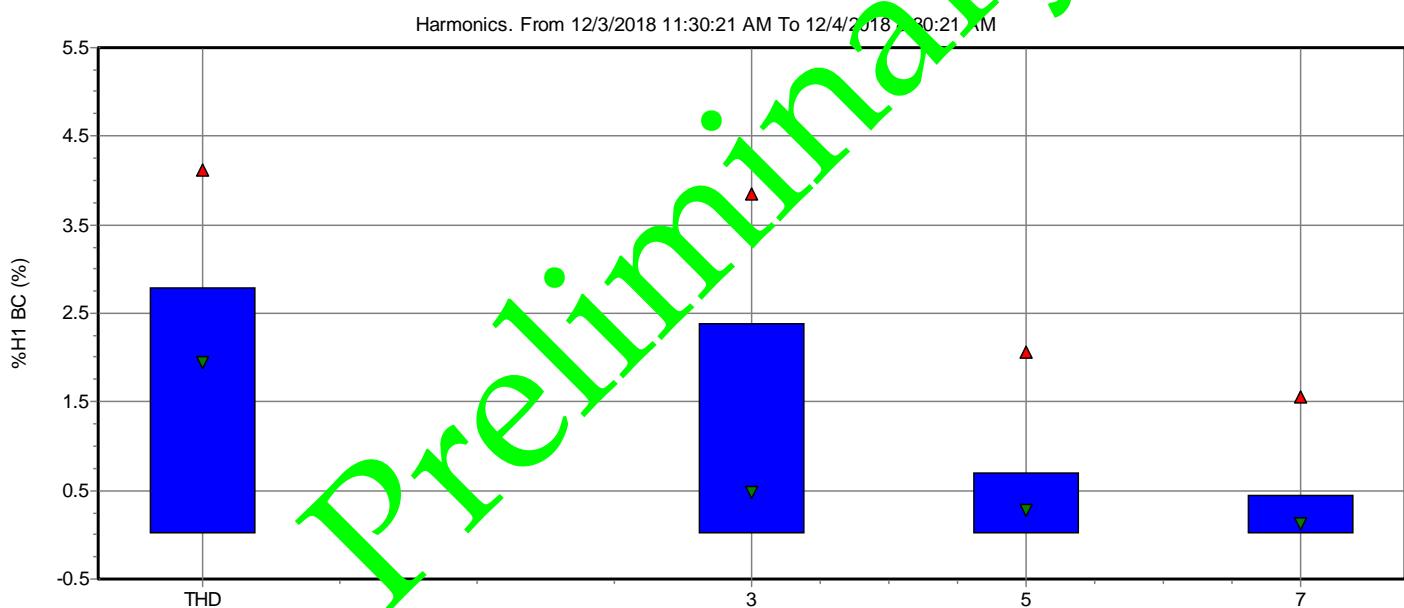
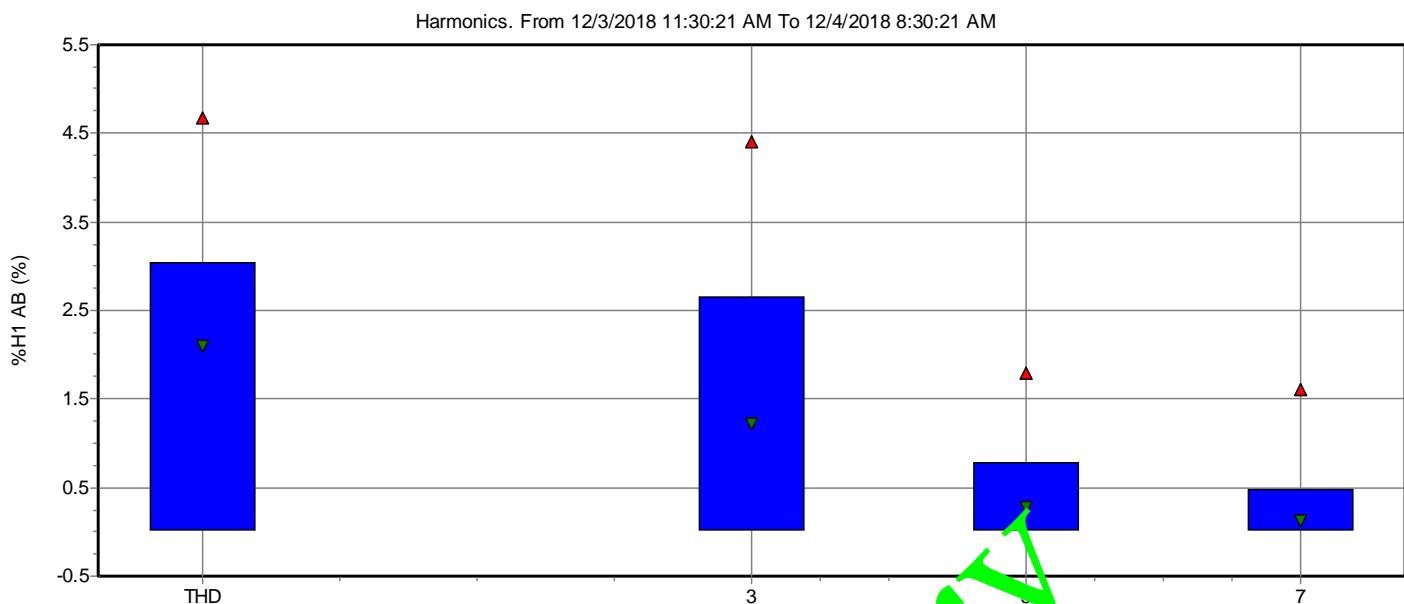
Events Summary

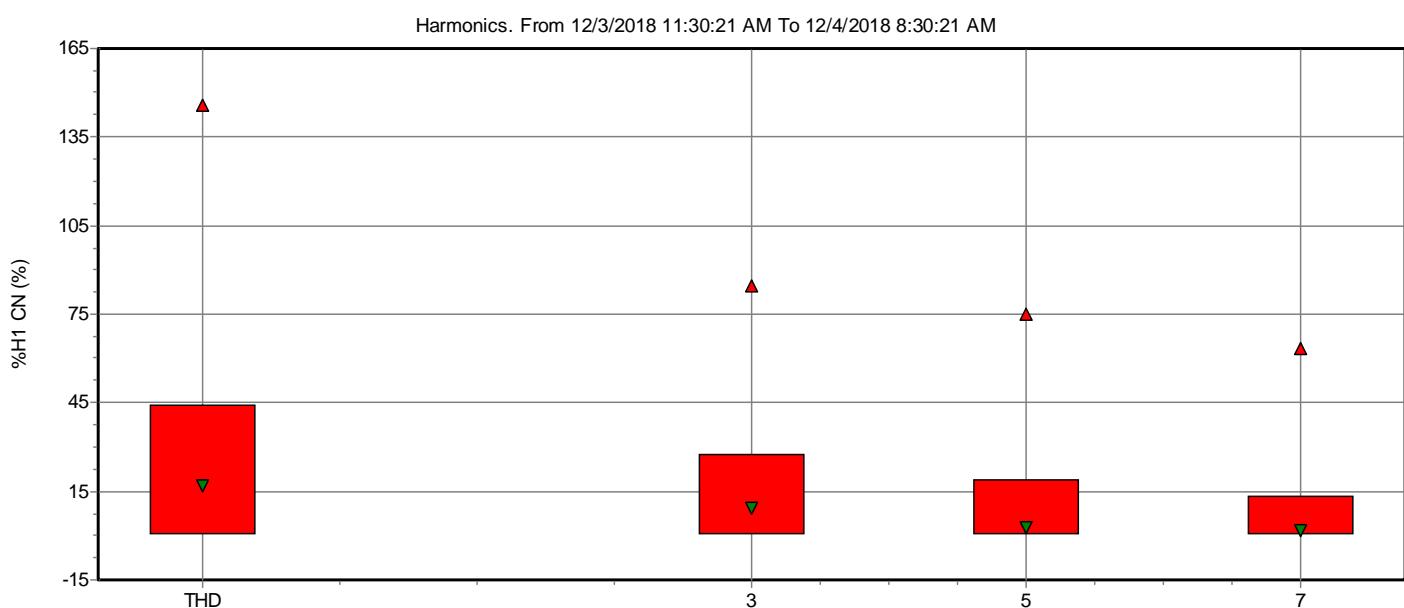
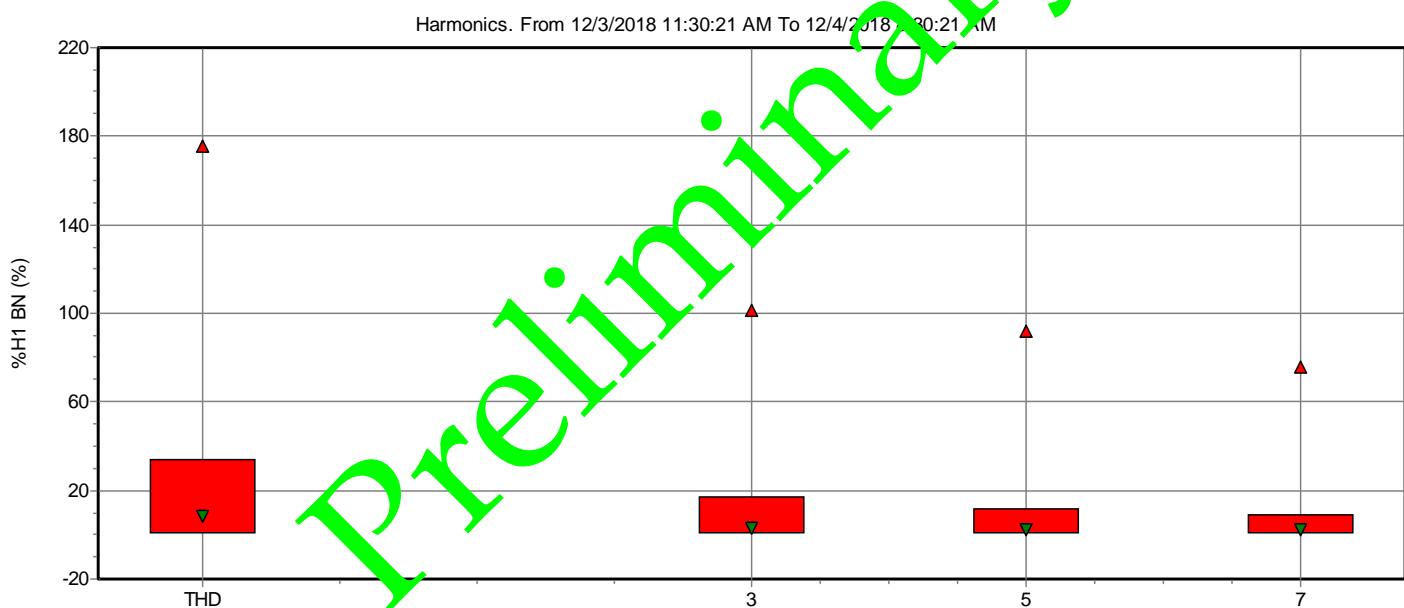
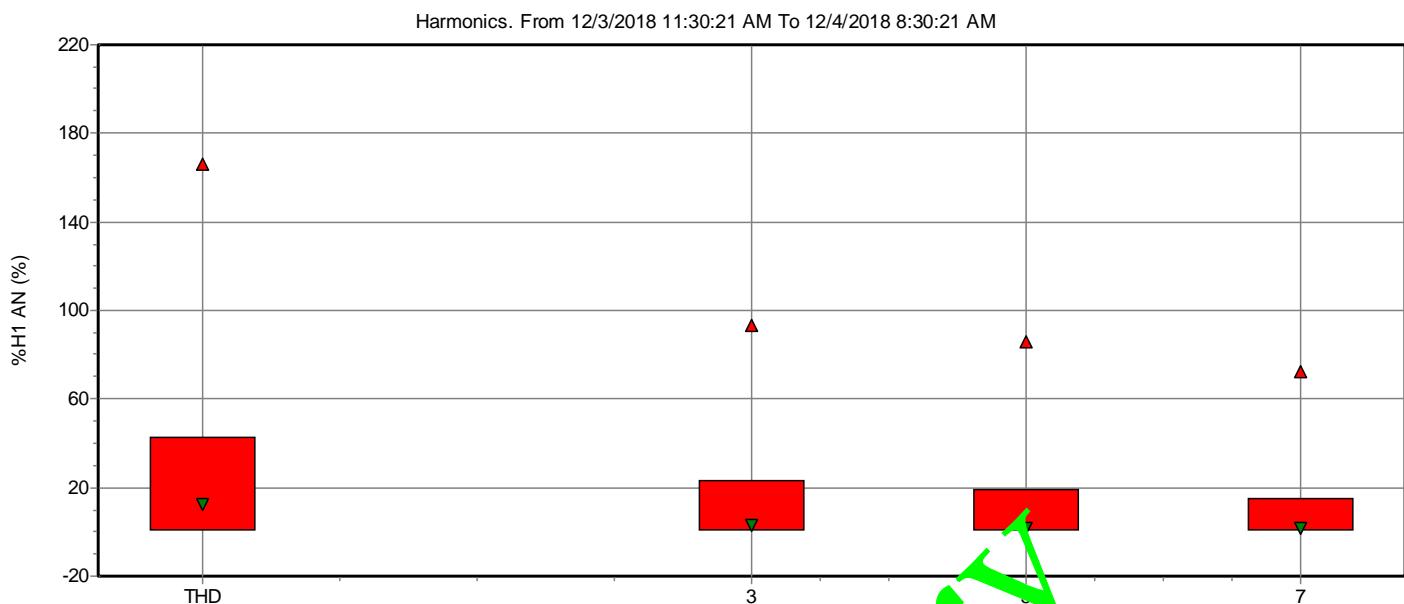
Dips	0
Swells	0
Transients	0
Interruptions	0
Voltage profiles	0
Rapid voltage changes	0
Screens	1
Waveforms	0
Intervals without measurements	0
Inrush current graphics	0
Wave events	0
RMS events	0

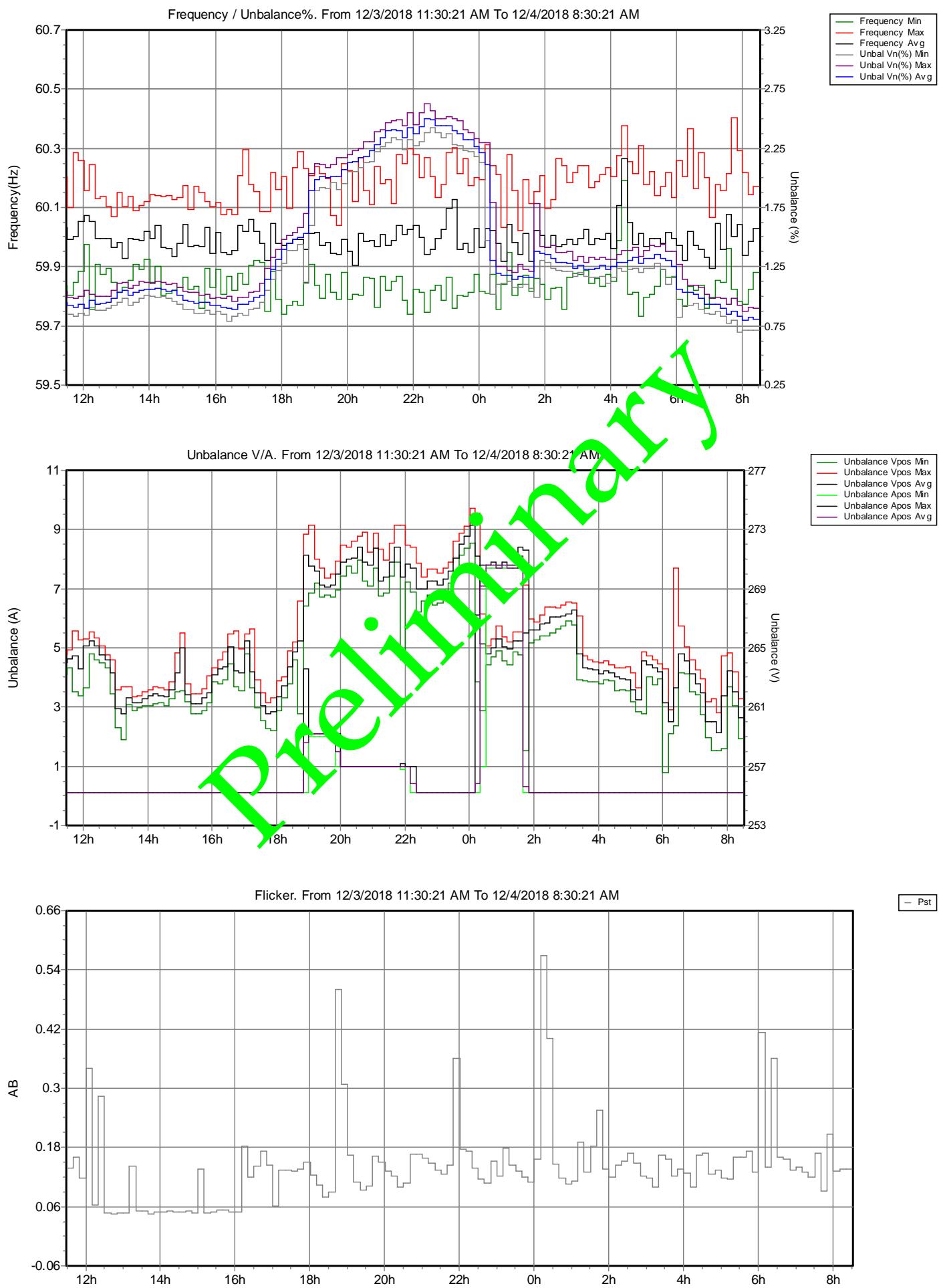
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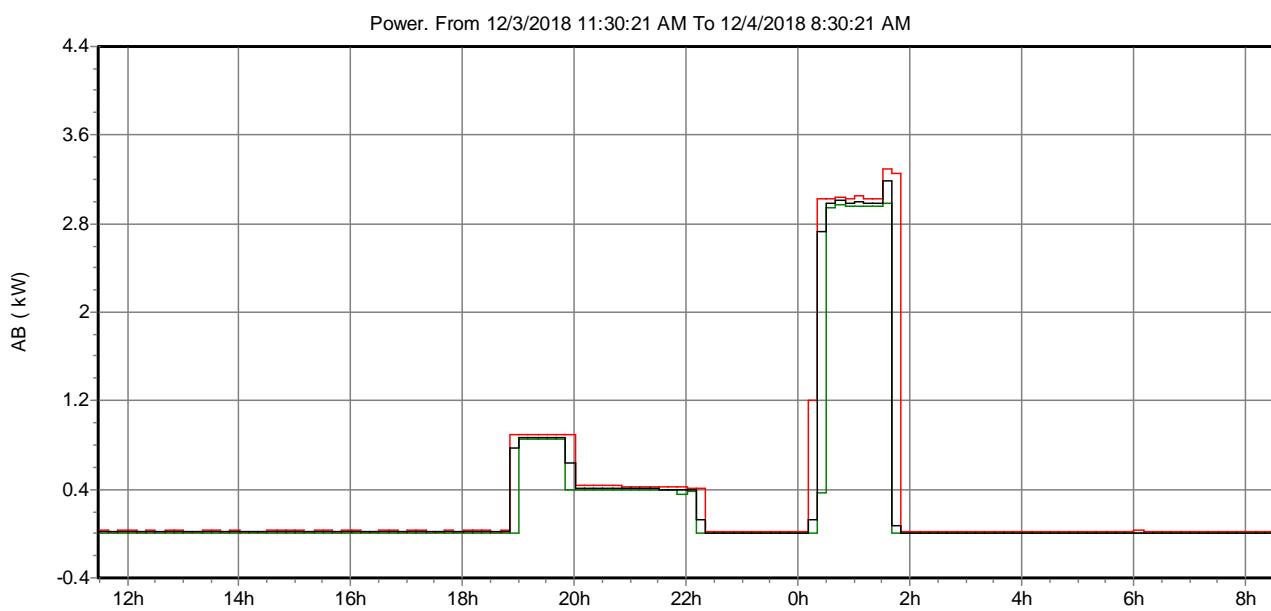
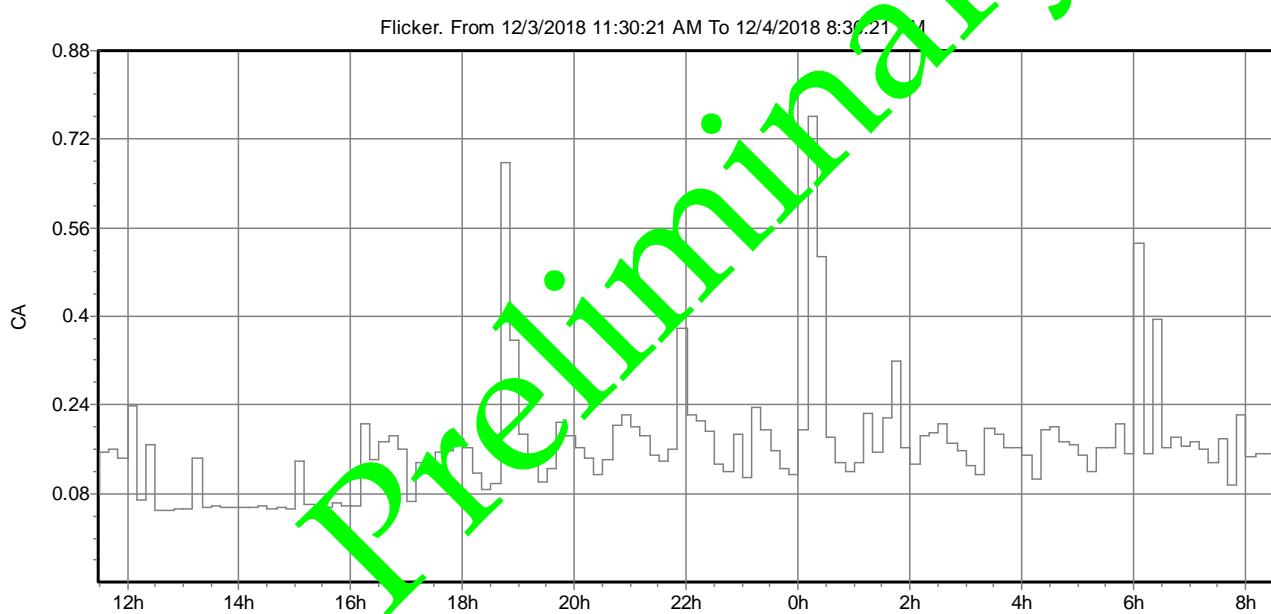
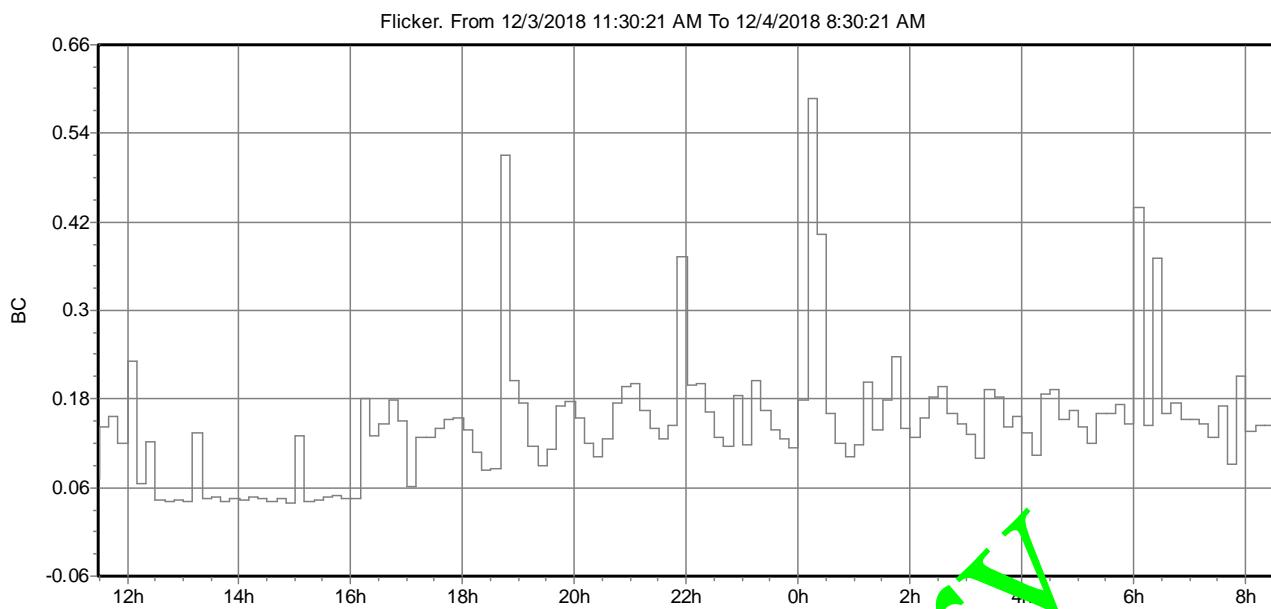


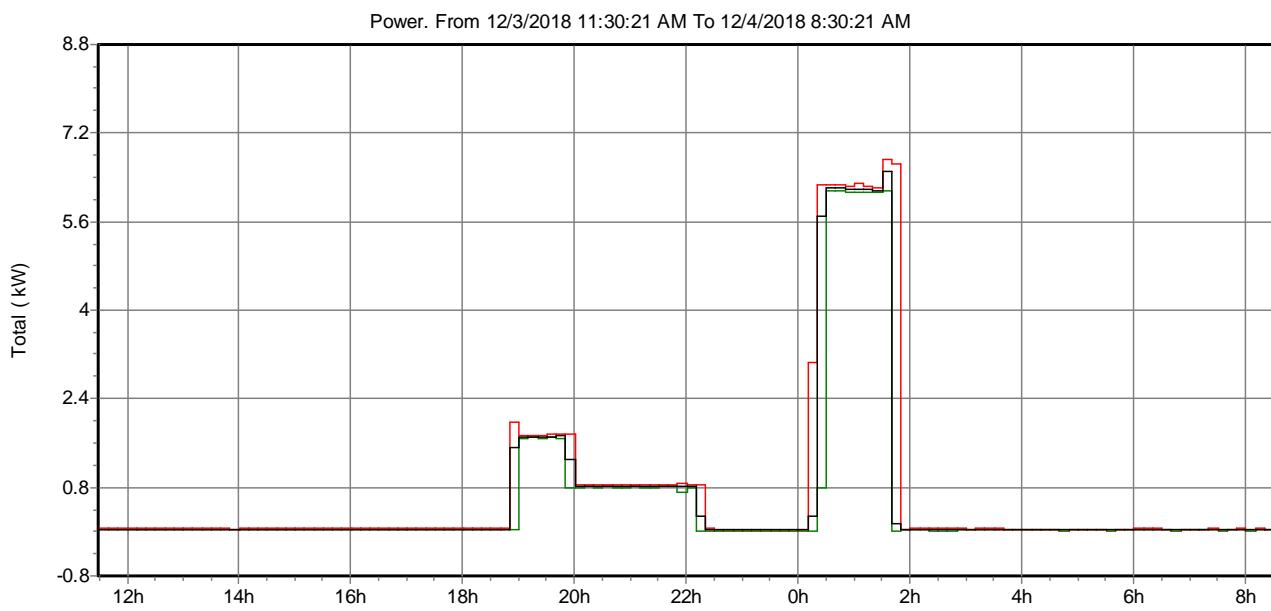
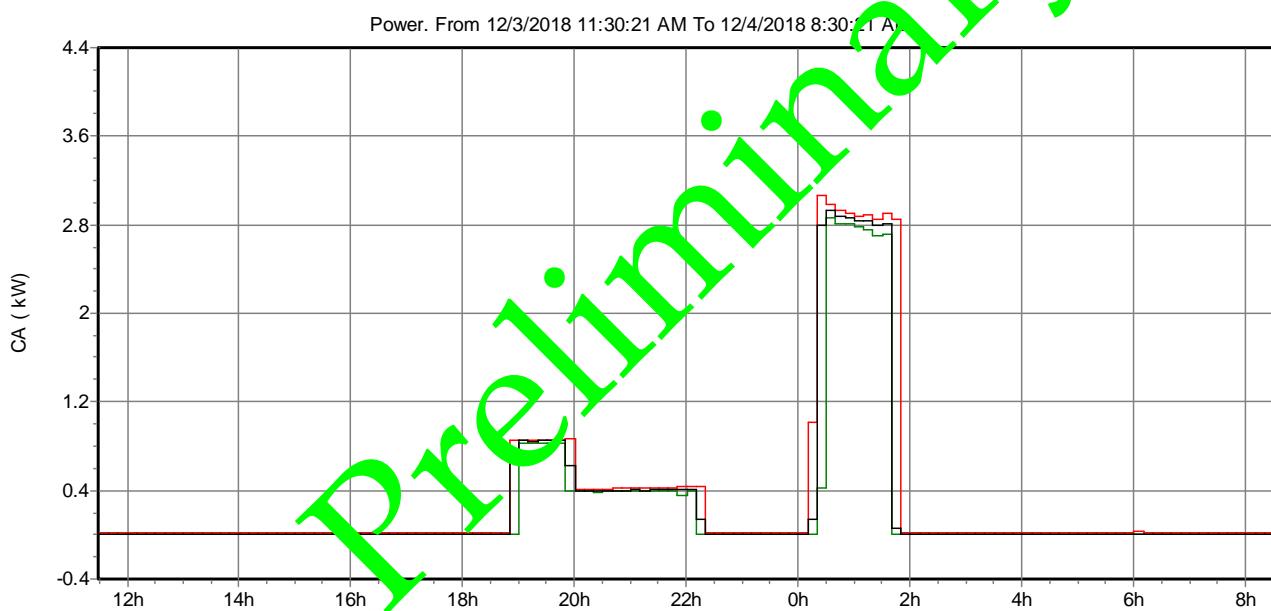
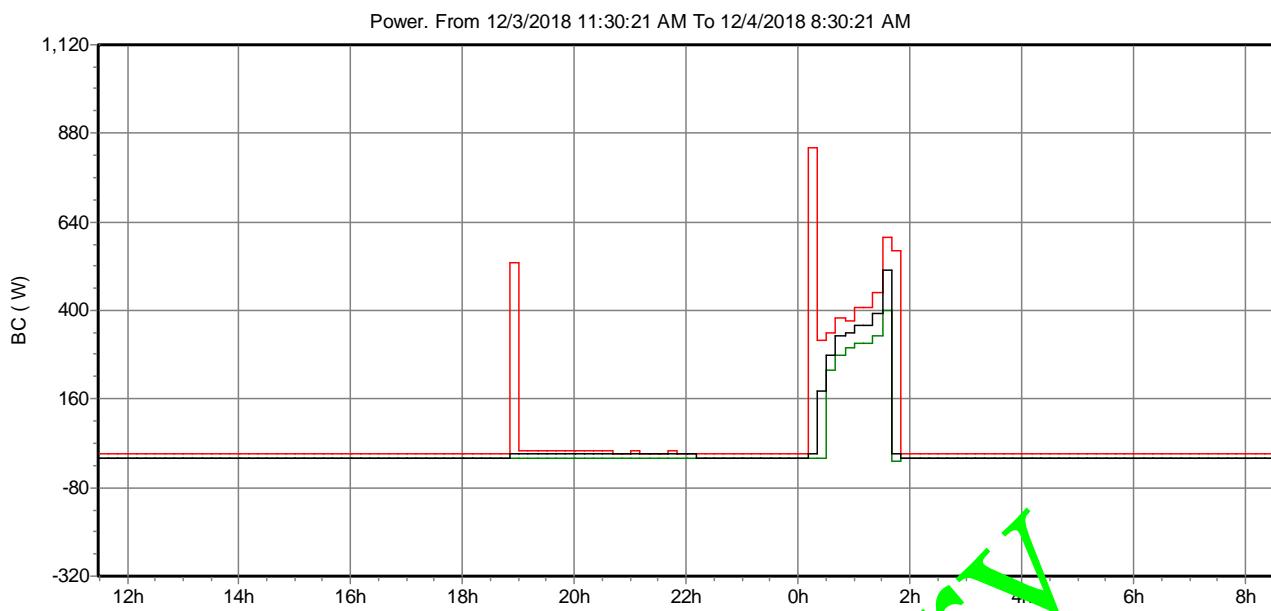


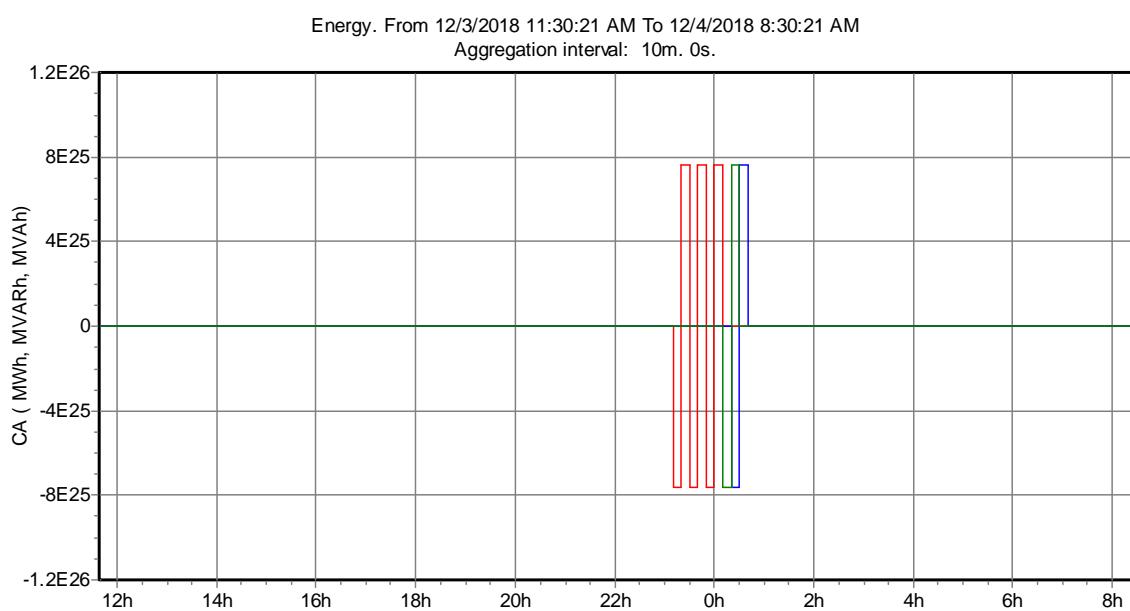
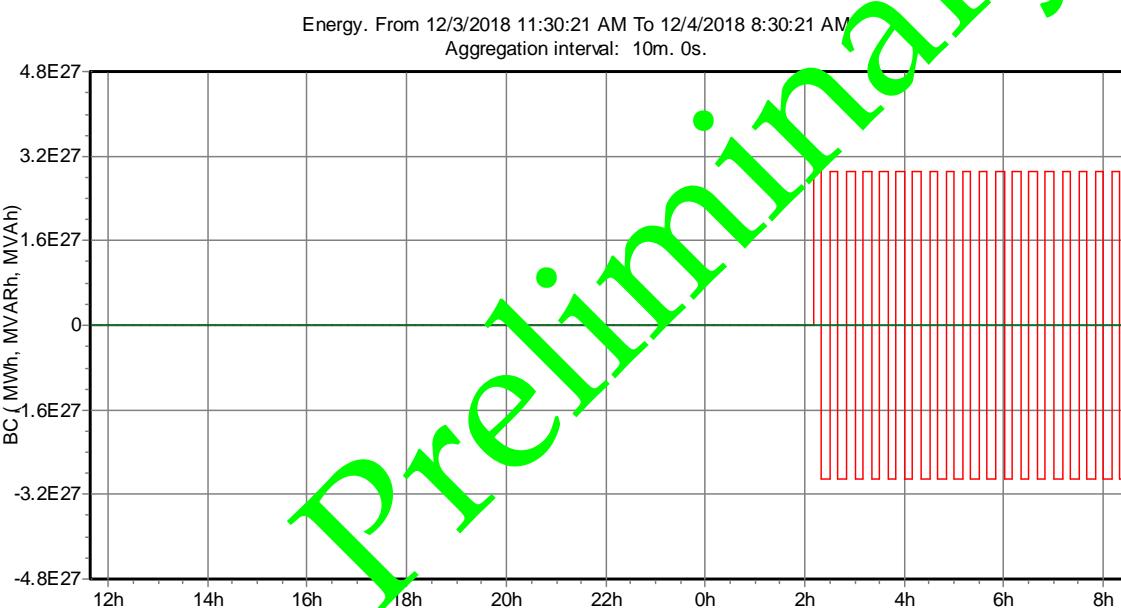
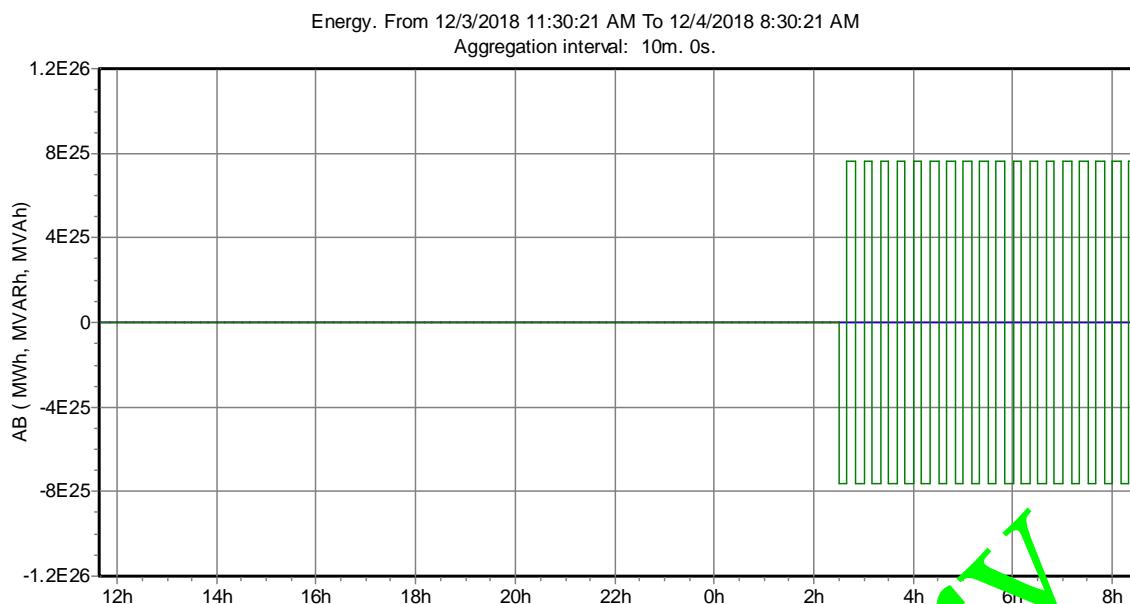


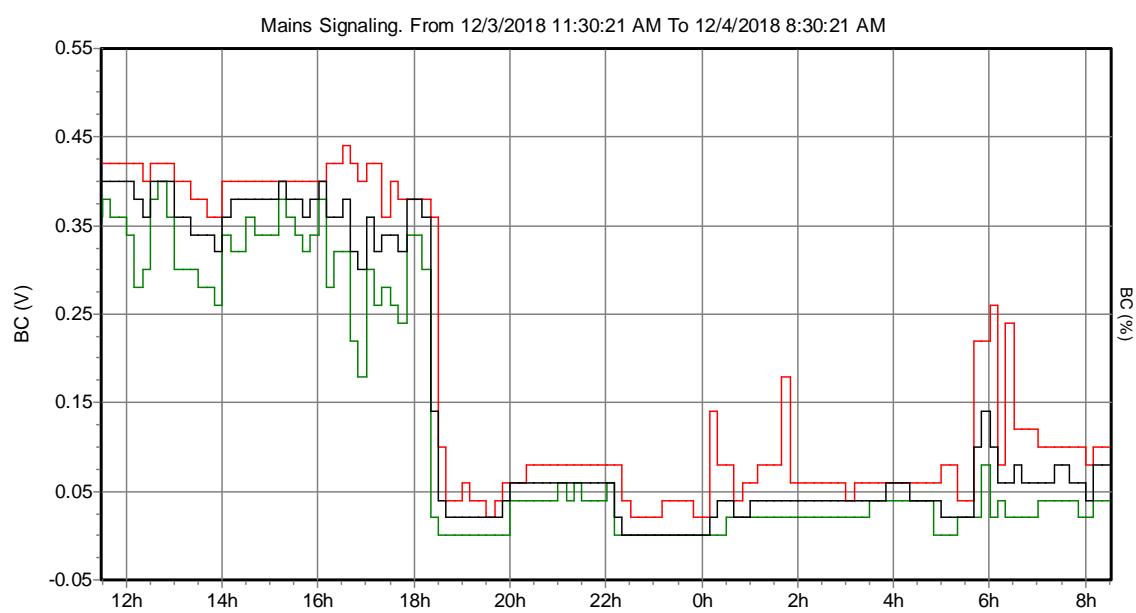
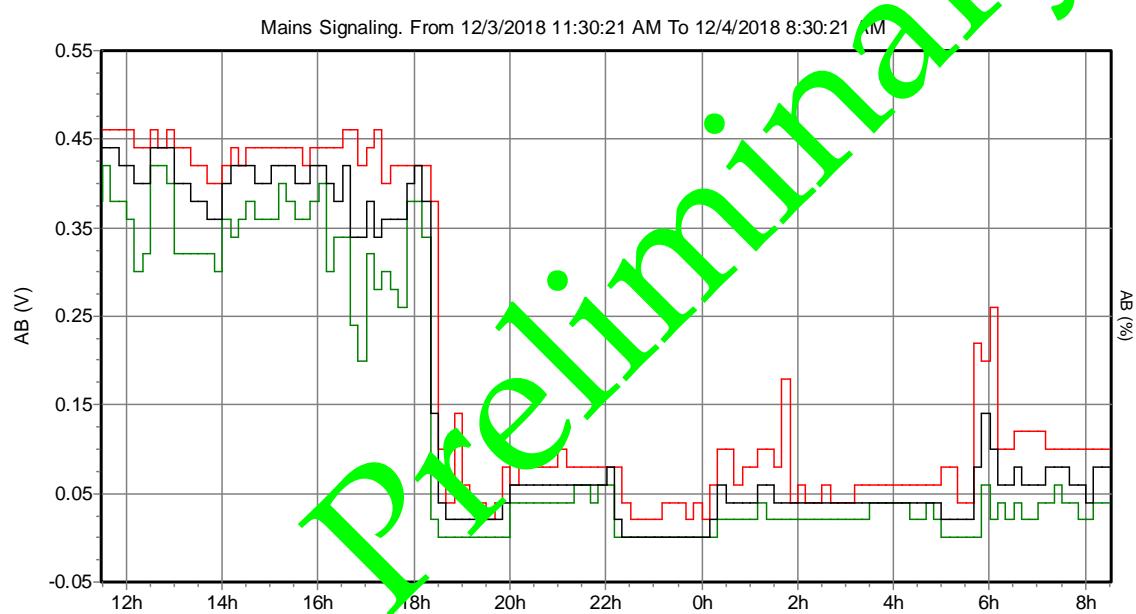
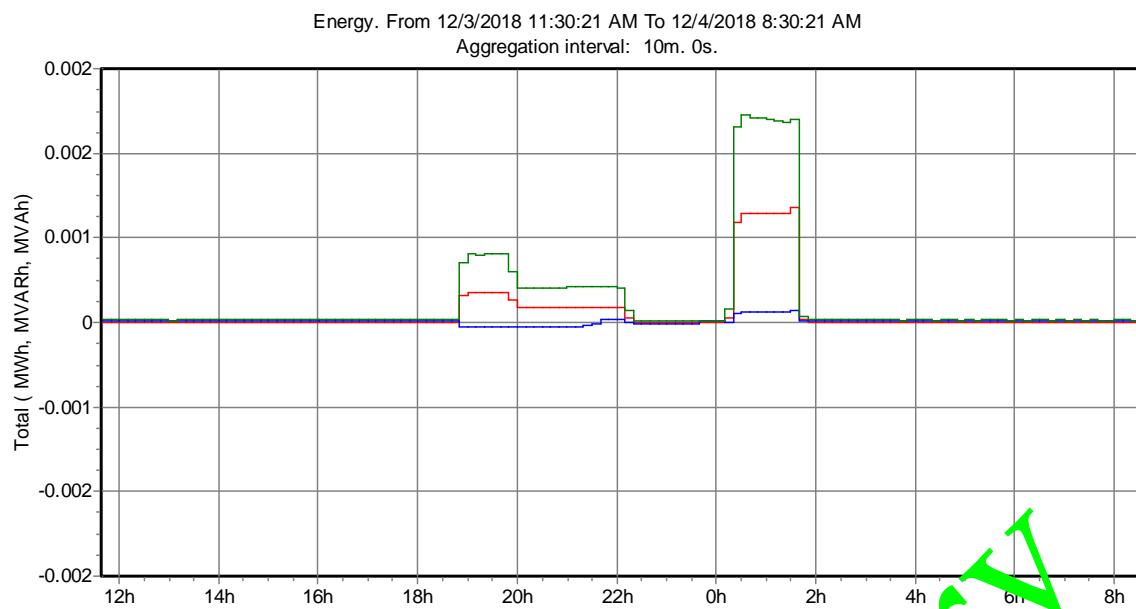


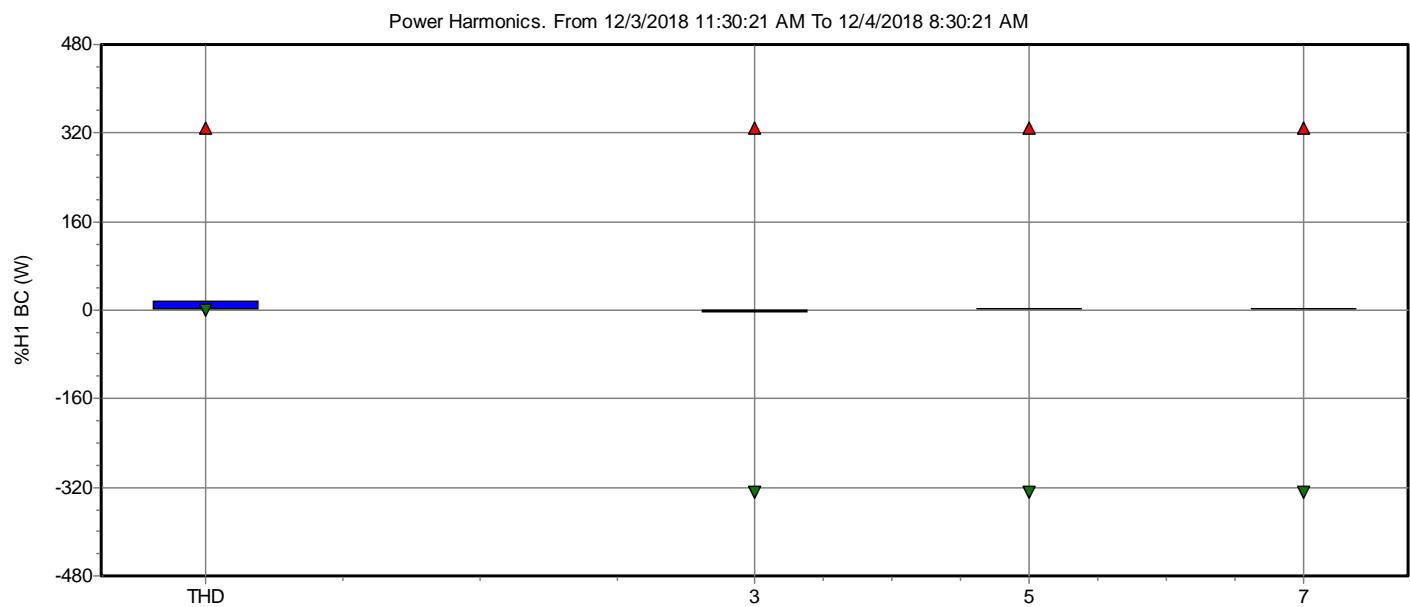
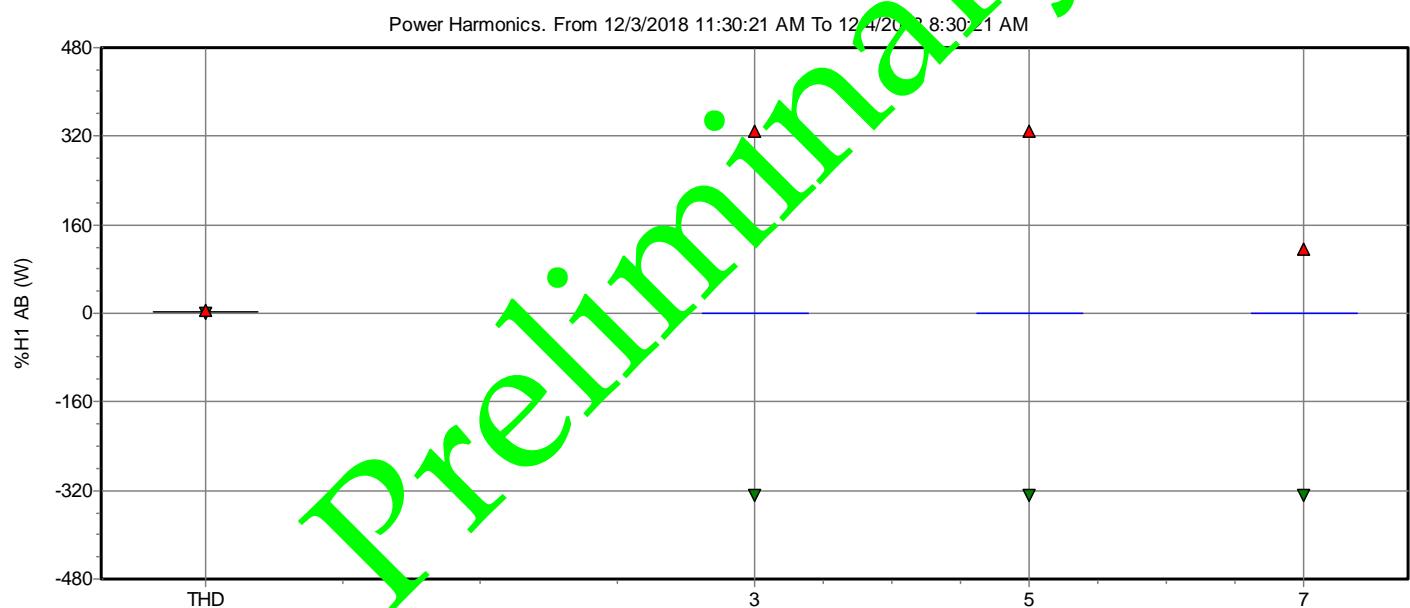
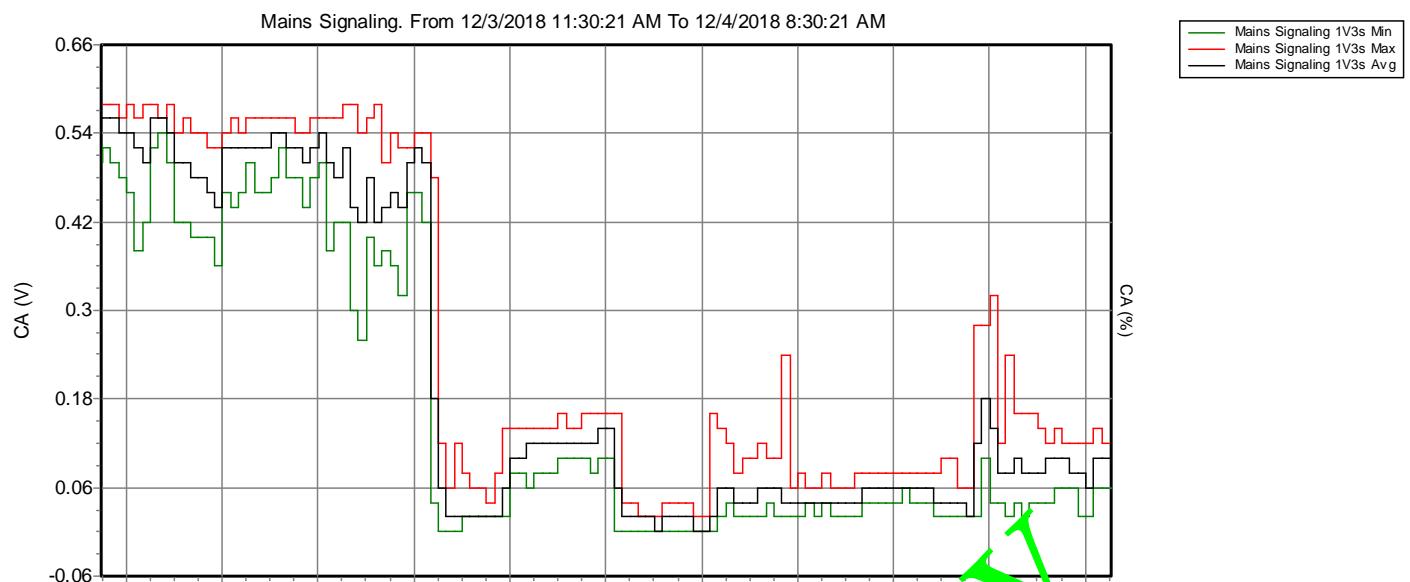


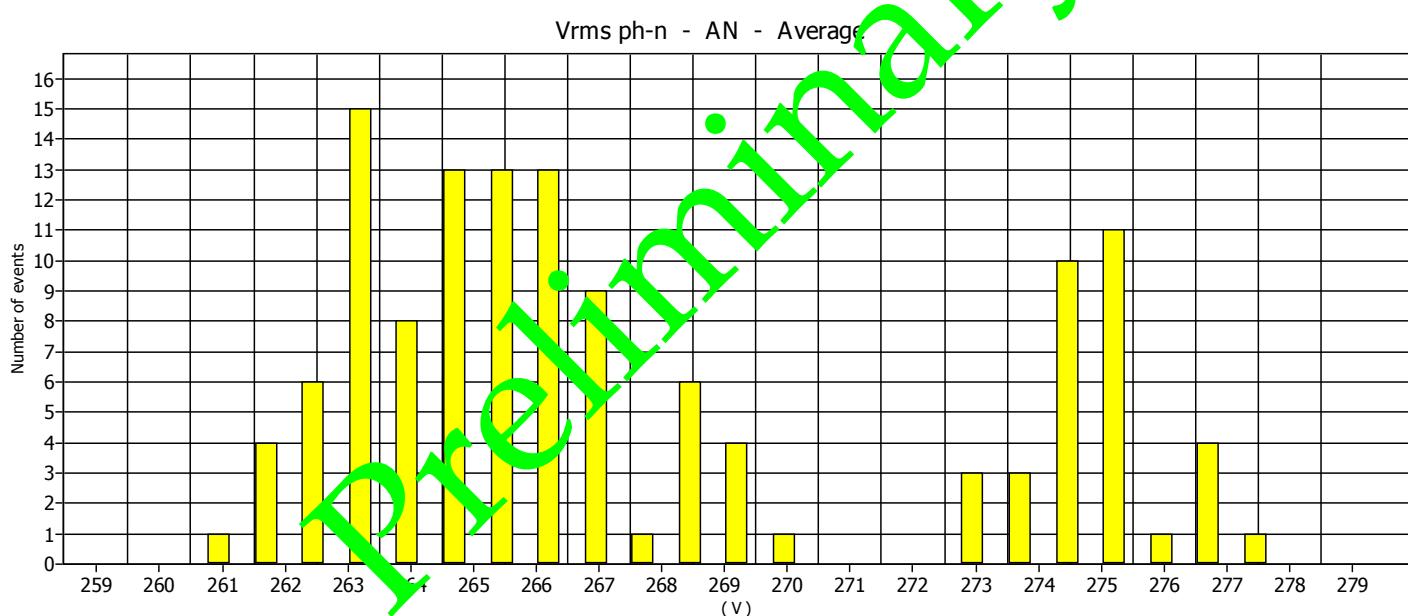
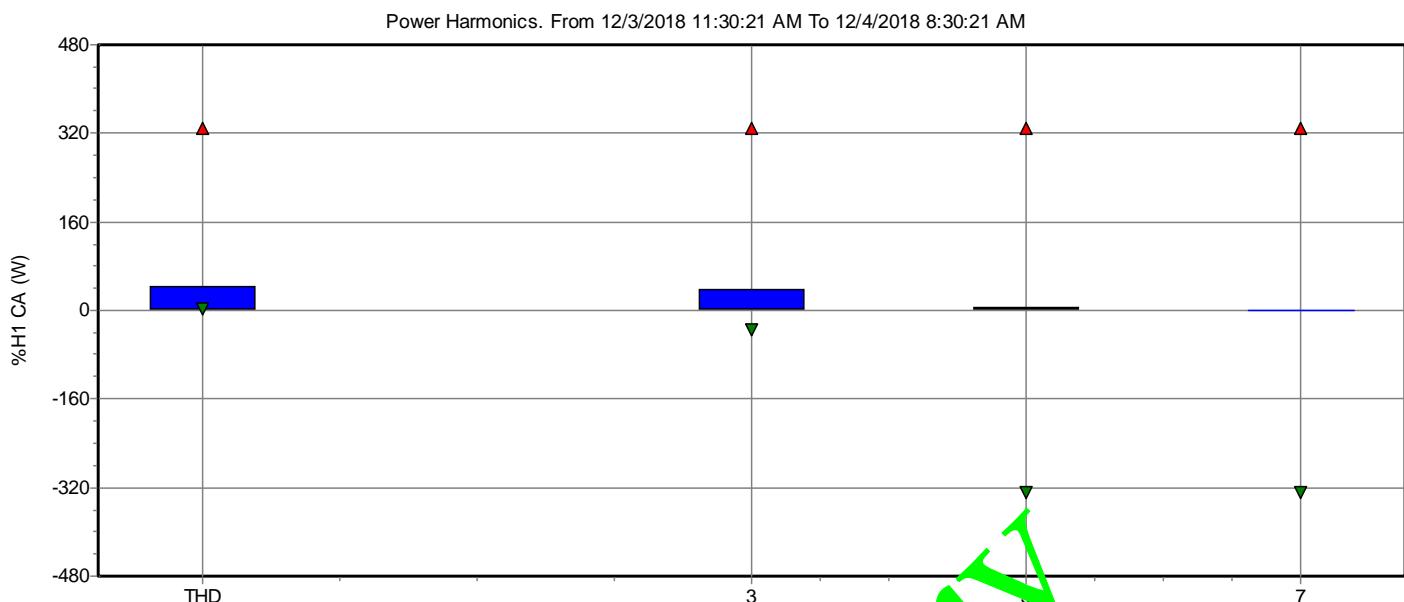














Instrument Information

Model Number	435-II
Serial Number	34843110
Firmware Revision	V05.04

Software Information

Power Log Version	5.4
FLUKE 430-II DLL Version	1.2.0.13

General Information

Recording location	FEEDER SOFTSTARTER-2, 45 KW (15HP MOTOR)
Client	AYALA SOUTHVALE
Notes	

Preliminary

Measurement Summary

Measurement topology	3-element delta mode
Application mode	Logger
First recording	12/1/2018 2:40:43 PM 236msec
Last recording	12/1/2018 10:20:43 PM 236msec
Recording interval	0h 10m 0s 0msec
Nominal Voltage	460 V
Nominal Current	60 A
Nominal Frequency	60 Hz
File start time	12/1/2018 2:30:43 PM 236msec
File end time	12/1/2018 10:20:43 PM 236msec
Duration	0d 7h 50m 0s 0msec
Number of events	Normal: 0 Detailed: 0
Events downloaded	No
Number of screens	1
Screens downloaded	Yes
Power measurement method	Unified
Cable type	Copper
Harmonic scale	%H1
THD mode	THD 40
CosPhi / DPF mode	DPF

Scaling

Phase:	
Current Clamp type	i430Flex
Clamp range	N/A
Nominal range	60 A
Sensitivity	x10 AC only
Current ratio	1:1
Voltage ratio	1:1
Neutral:	
Current Clamp type	i430Flex
Clamp range	N/A
Nominal range	60 A
Sensitivity	x10 AC only
Current ratio	1:1
Voltage ratio	1:1

Recording Summary

RMS recordings	47
DC recordings	0
Frequency recordings	47
Unbalance recordings	47
Harmonic recordings	47
Power harmonic recordings	47
Power recordings	47
Power unbalance recordings	0
Energy recordings	47
Energy losses recordings	0
Flicker recordings	47
Mains signaling recordings	47

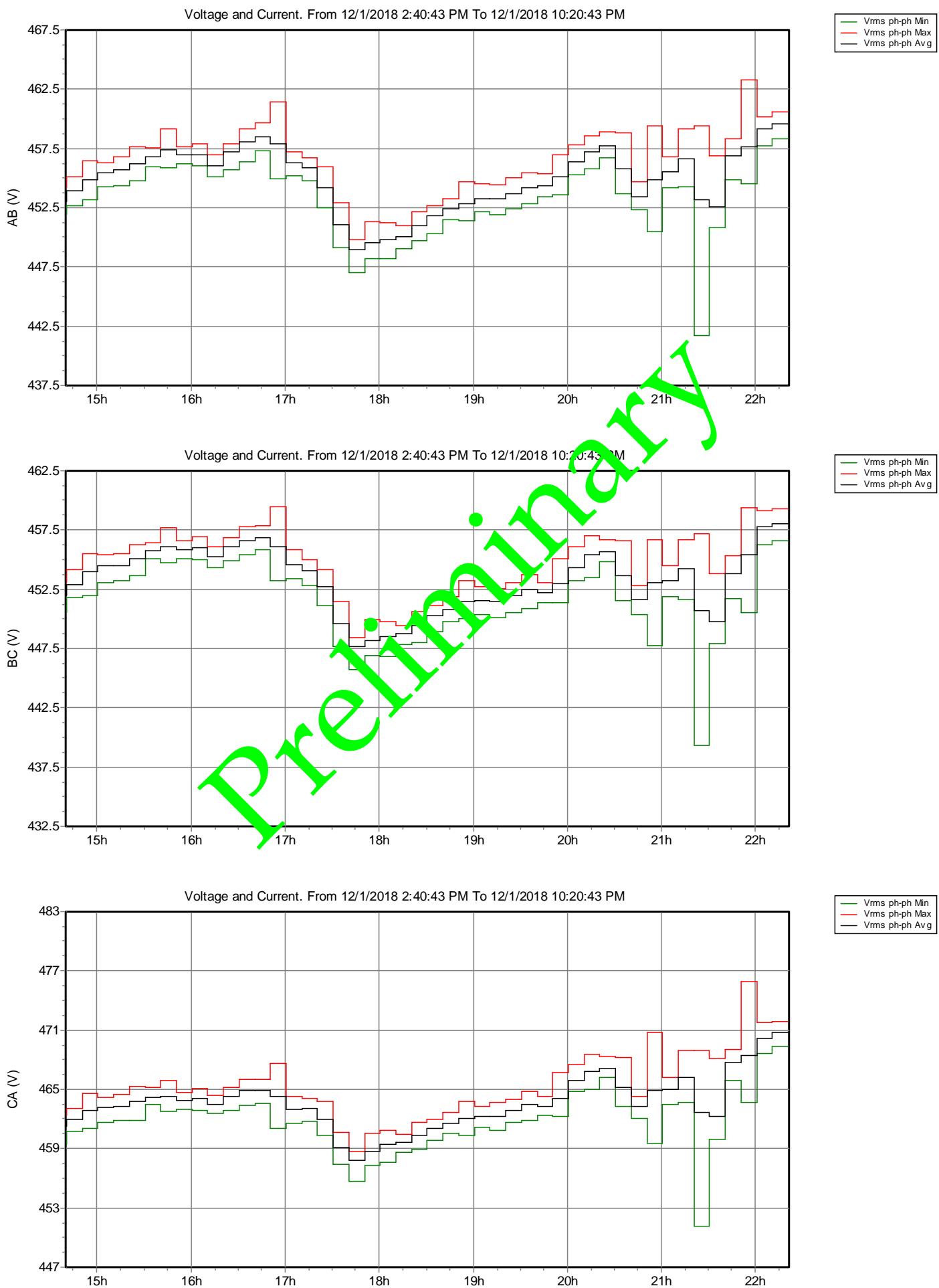
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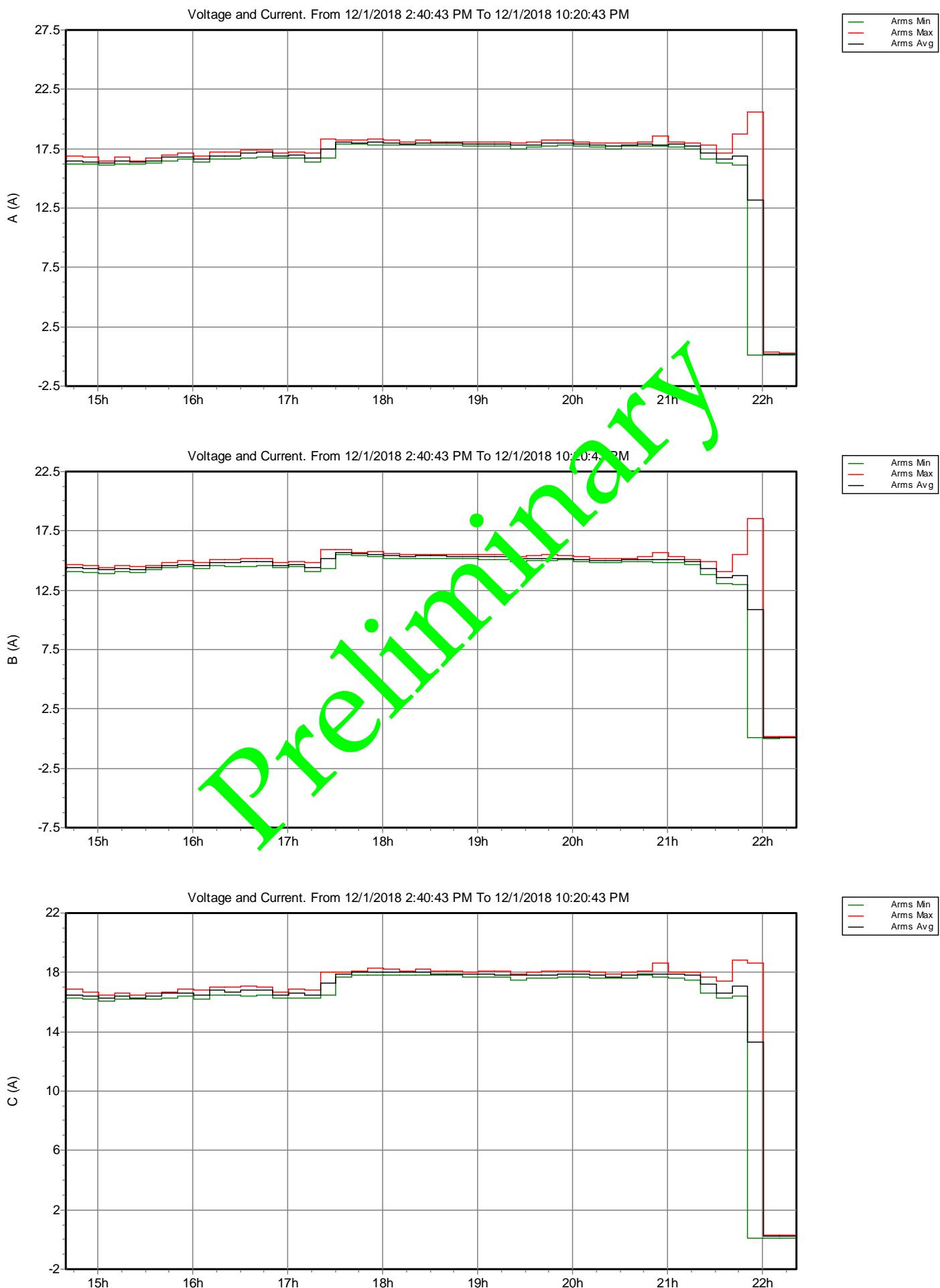


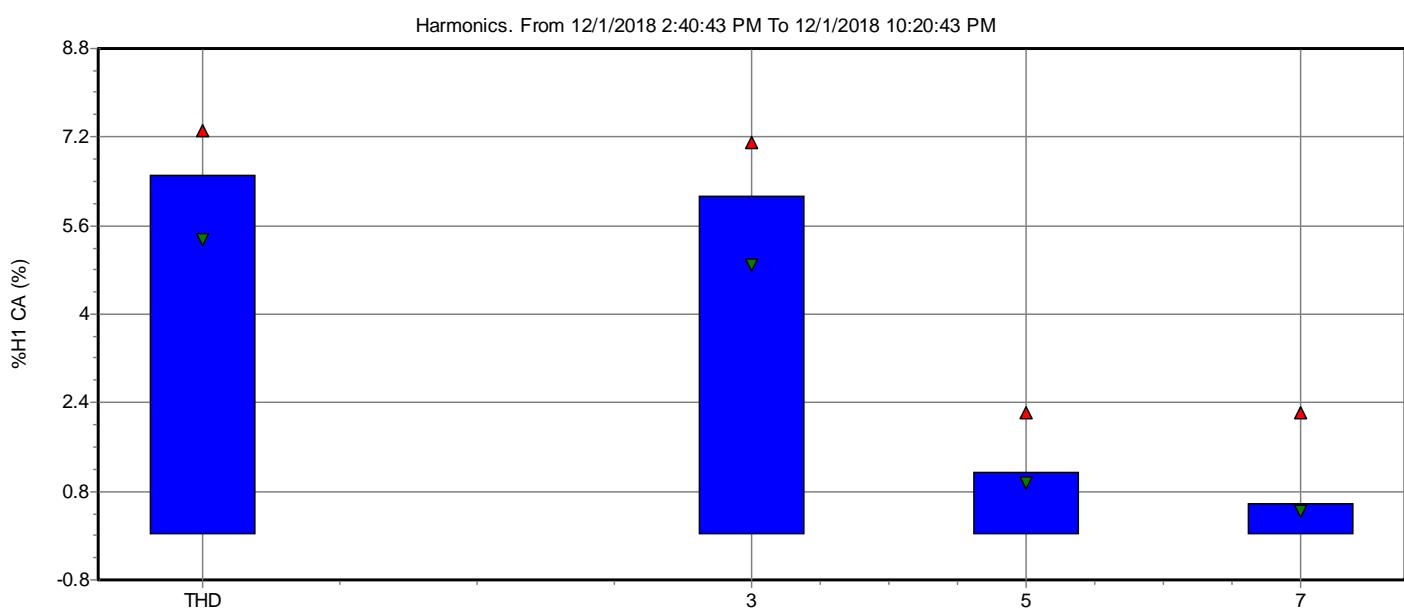
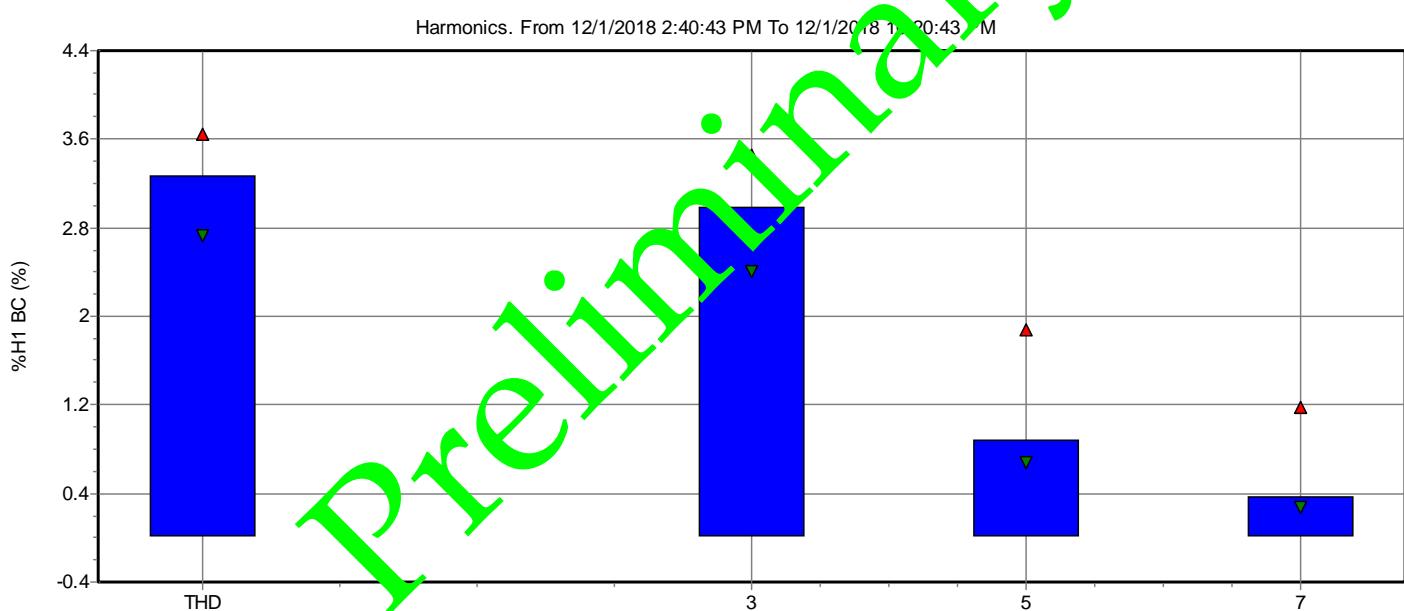
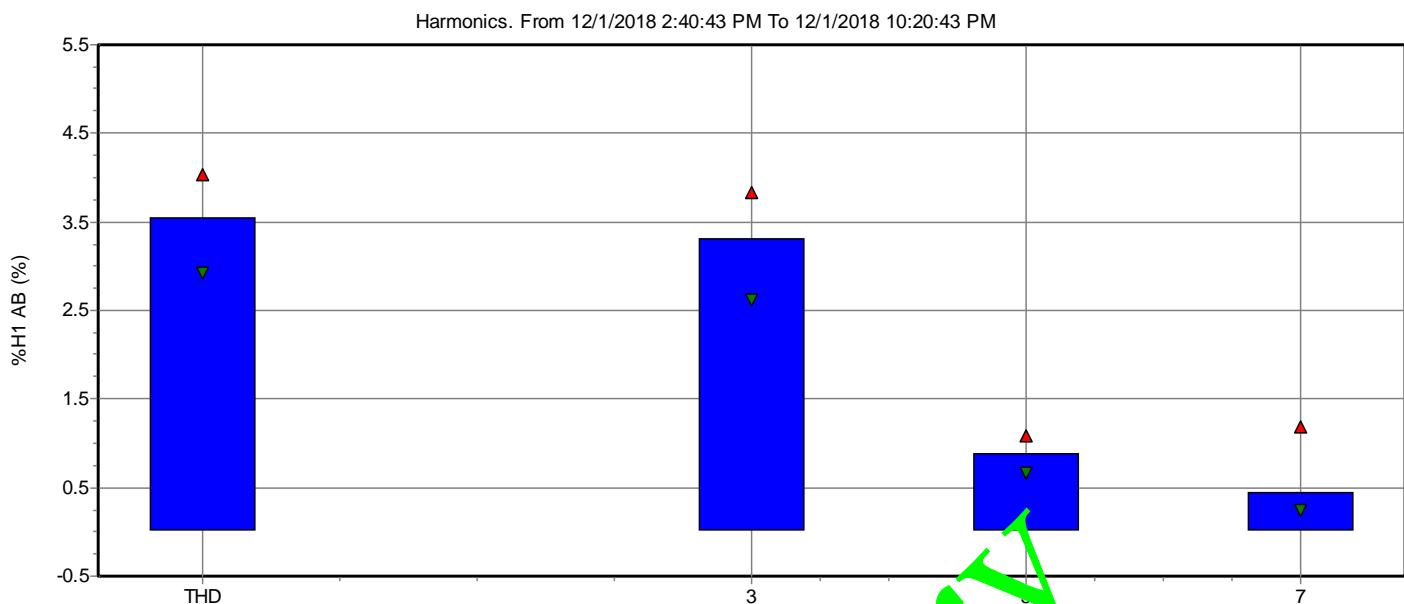
Events Summary

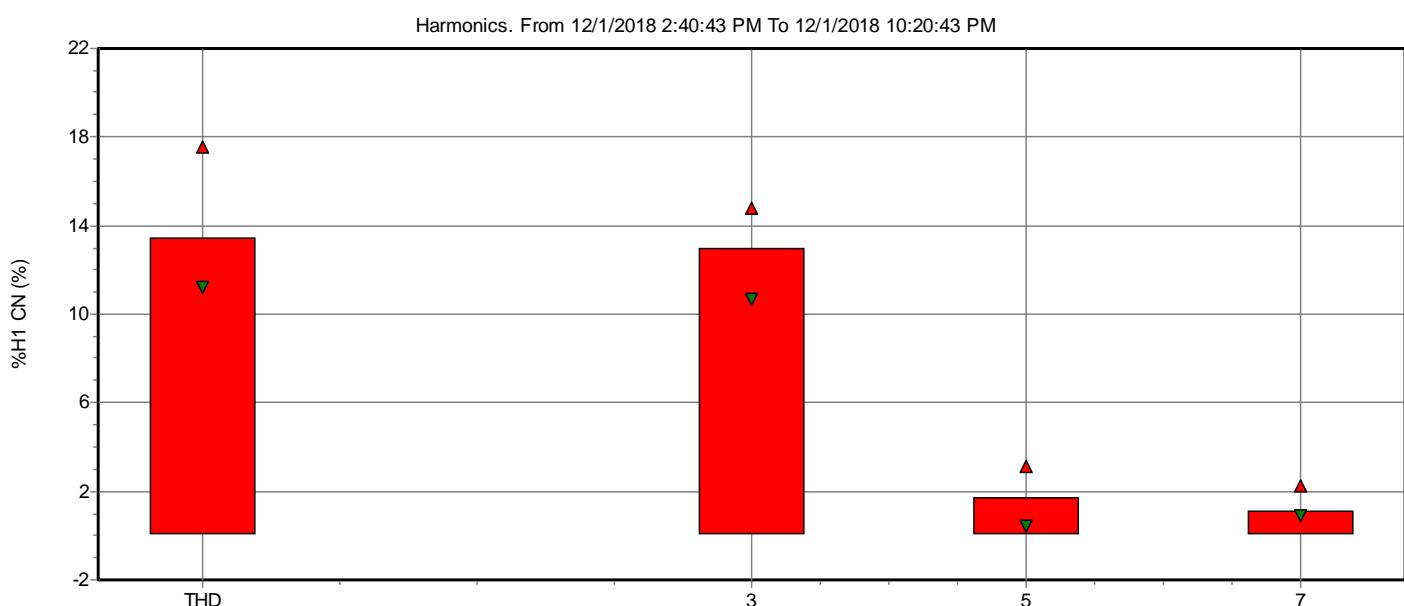
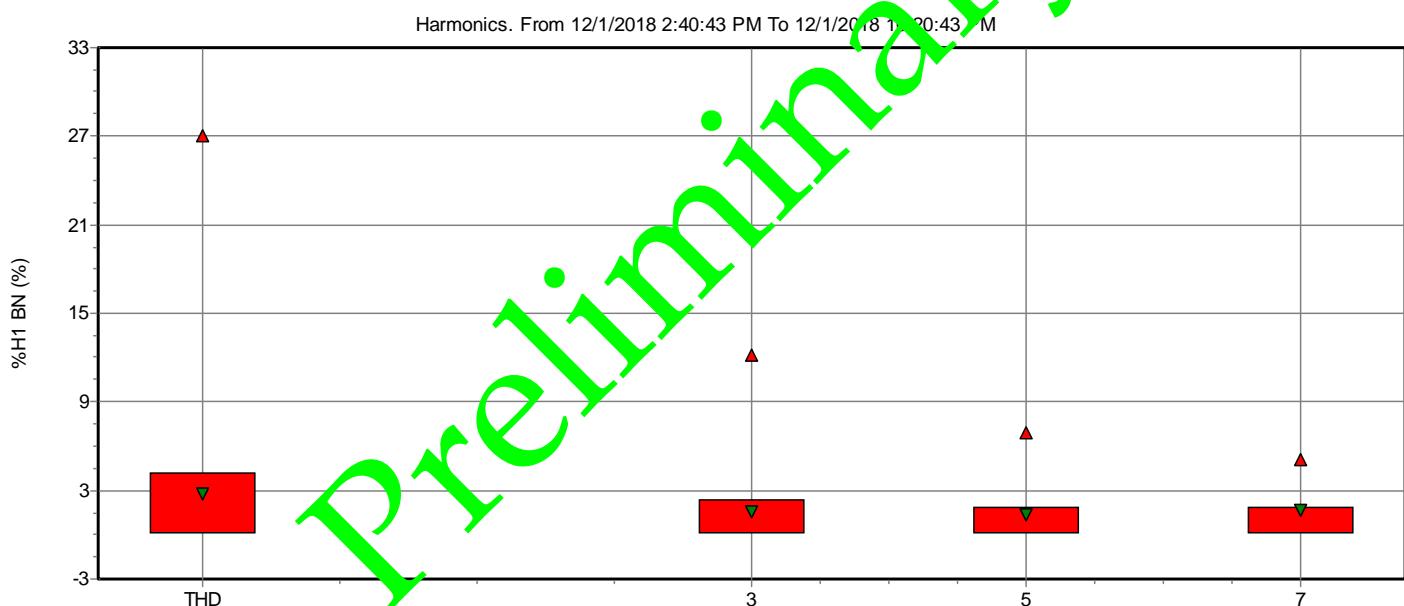
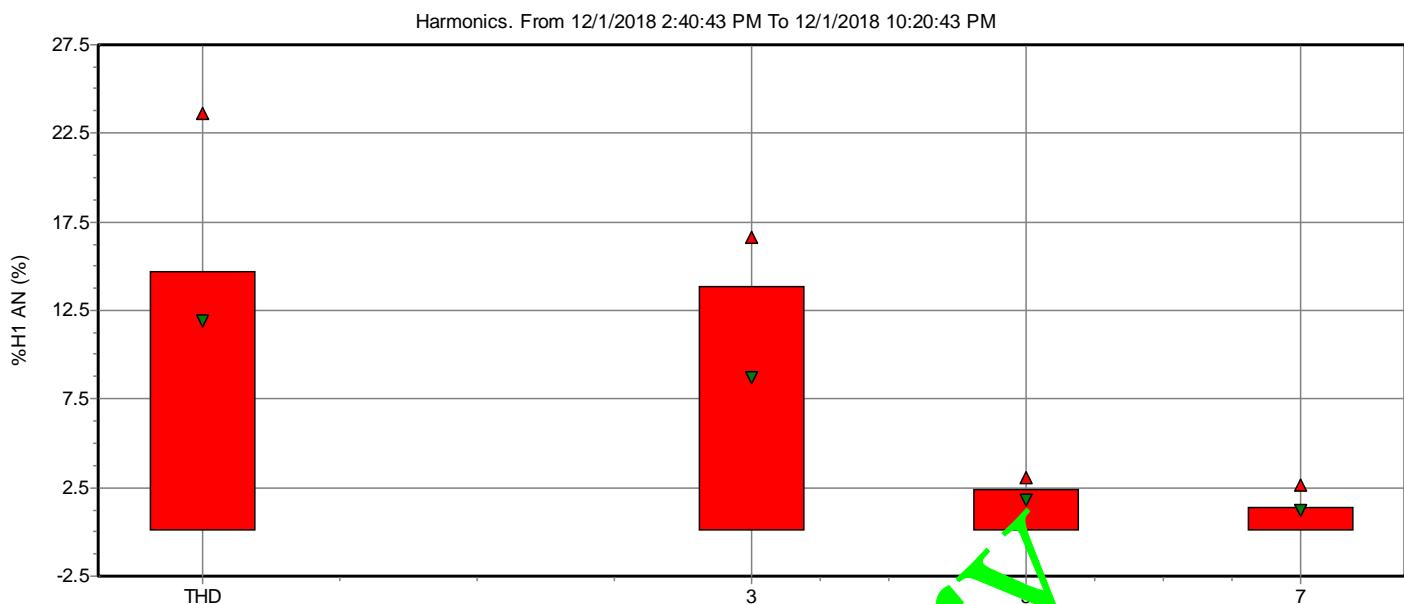
Dips	0
Swells	0
Transients	0
Interruptions	0
Voltage profiles	0
Rapid voltage changes	0
Screens	1
Waveforms	0
Intervals without measurements	0
Inrush current graphics	0
Wave events	0
RMS events	0

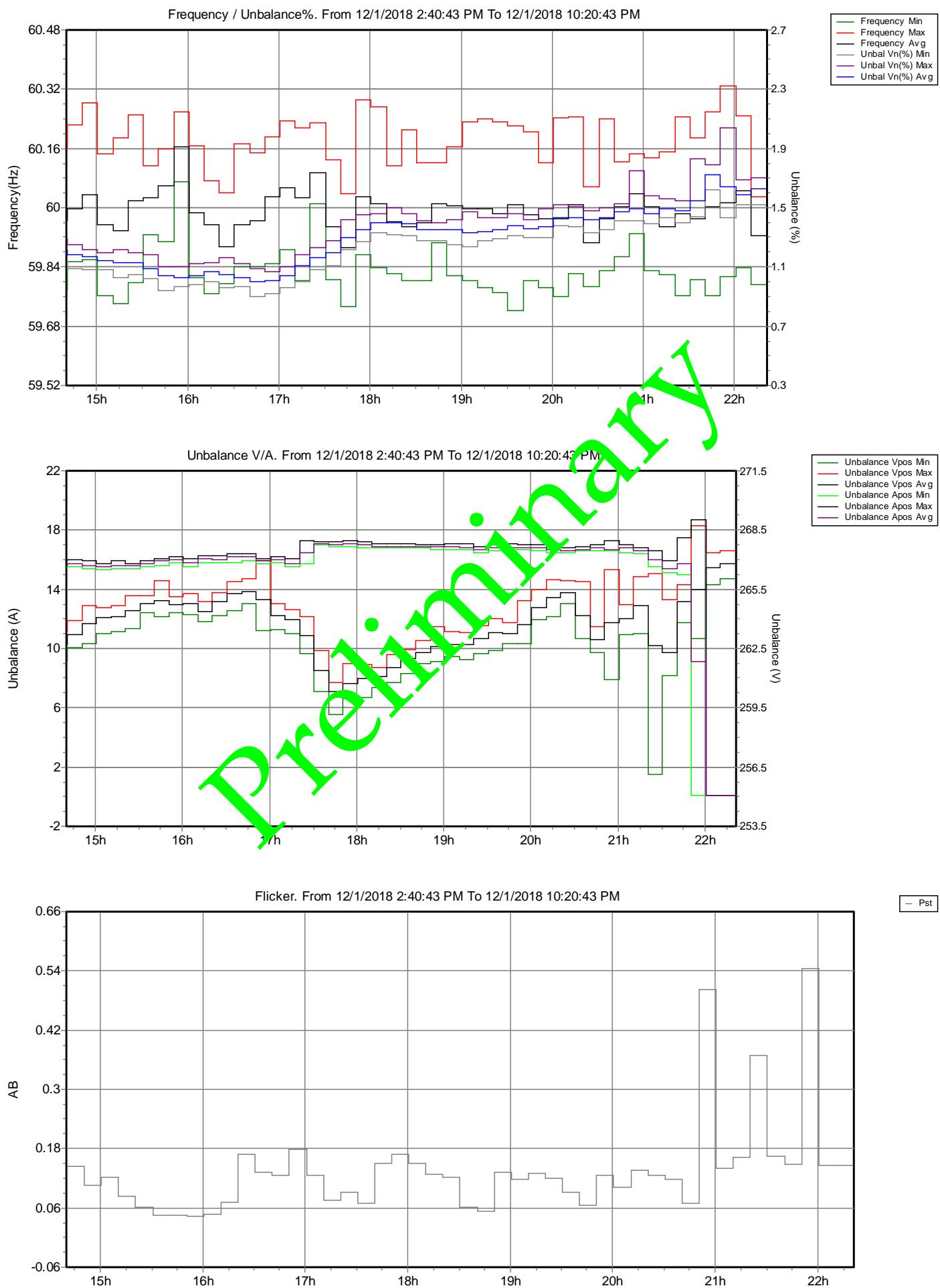
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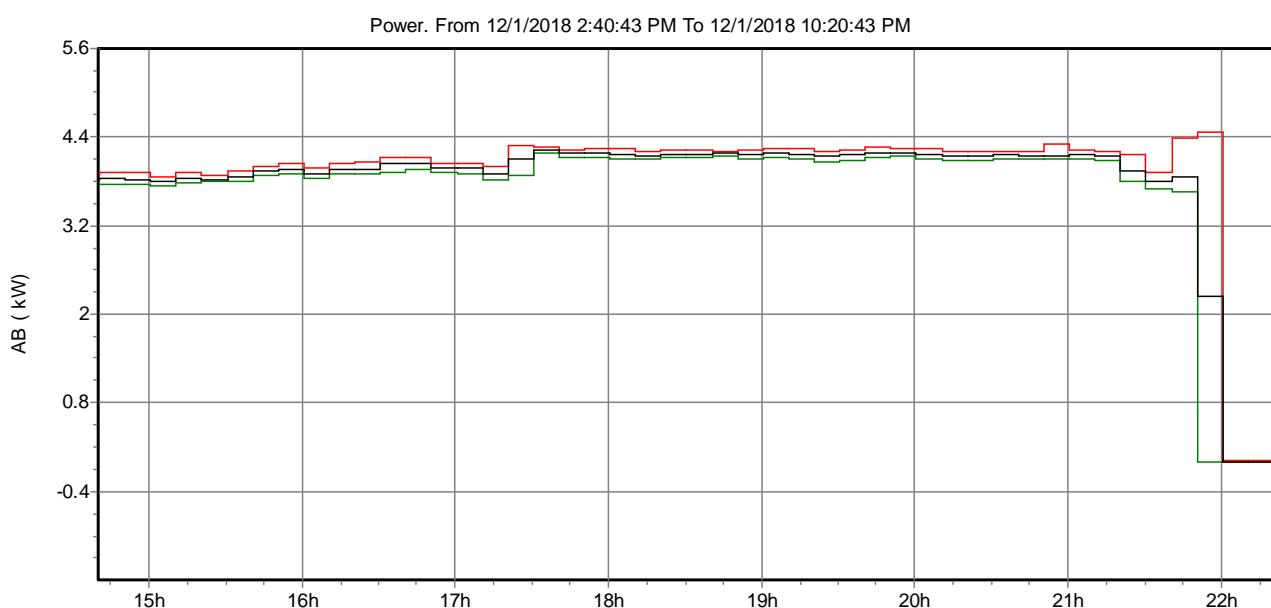
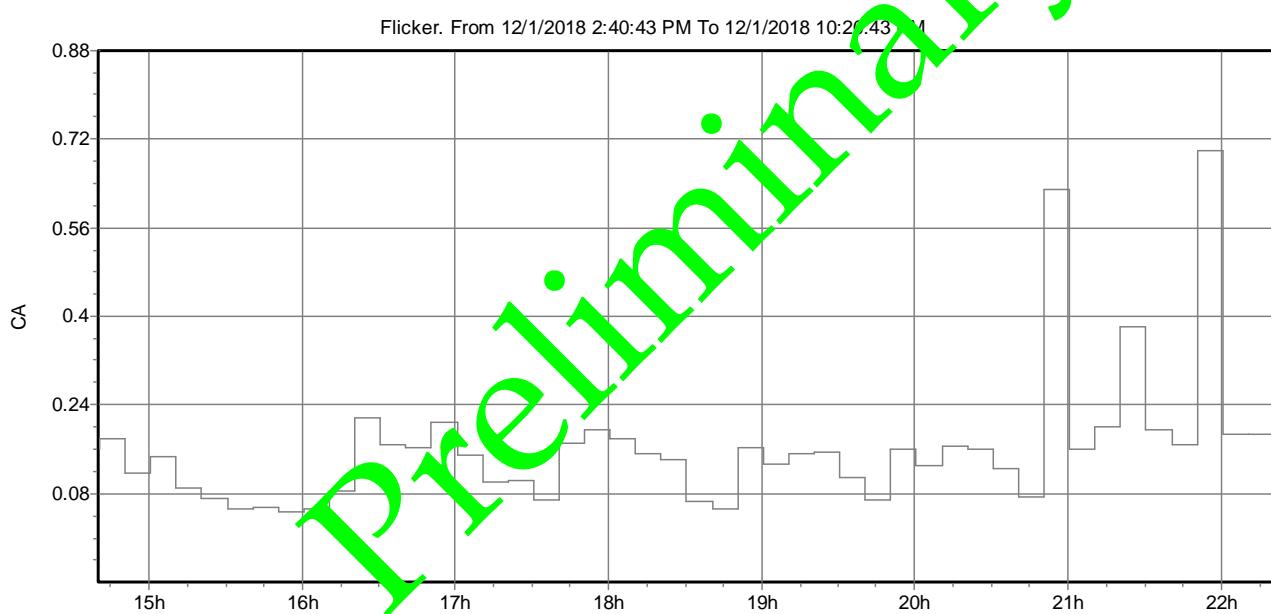
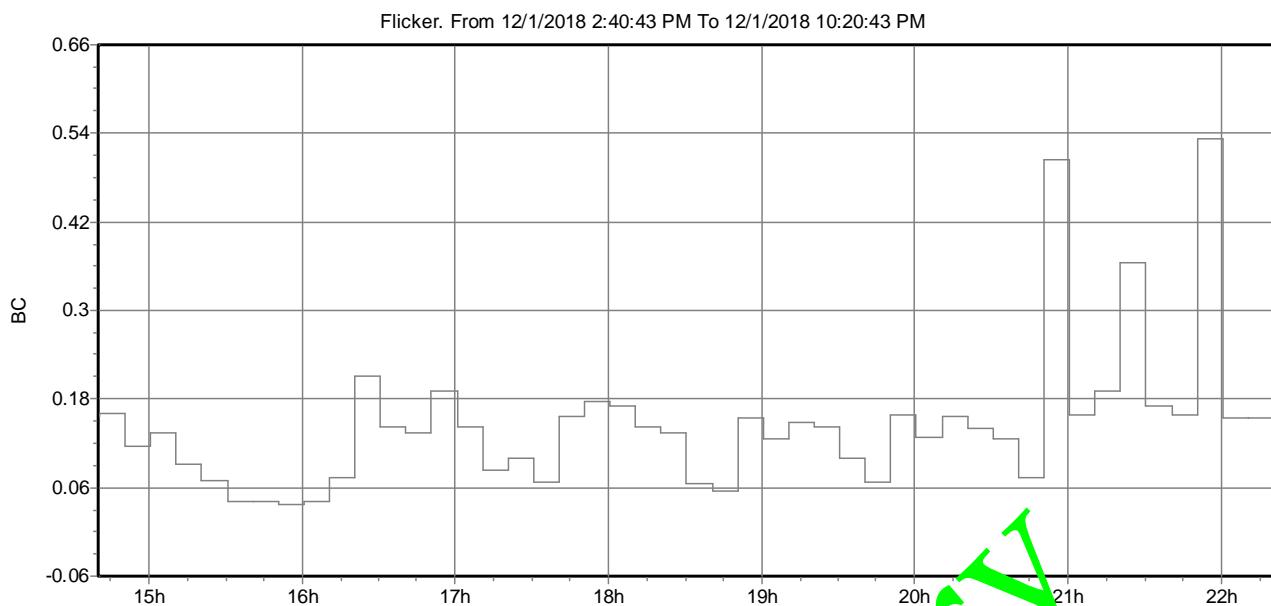




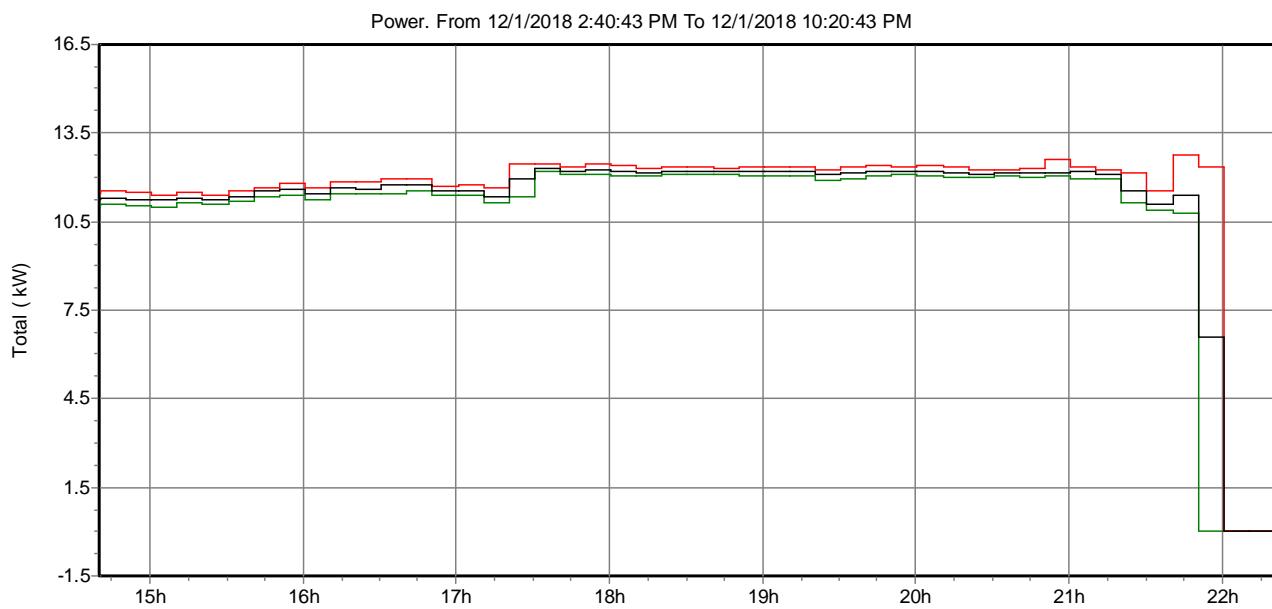
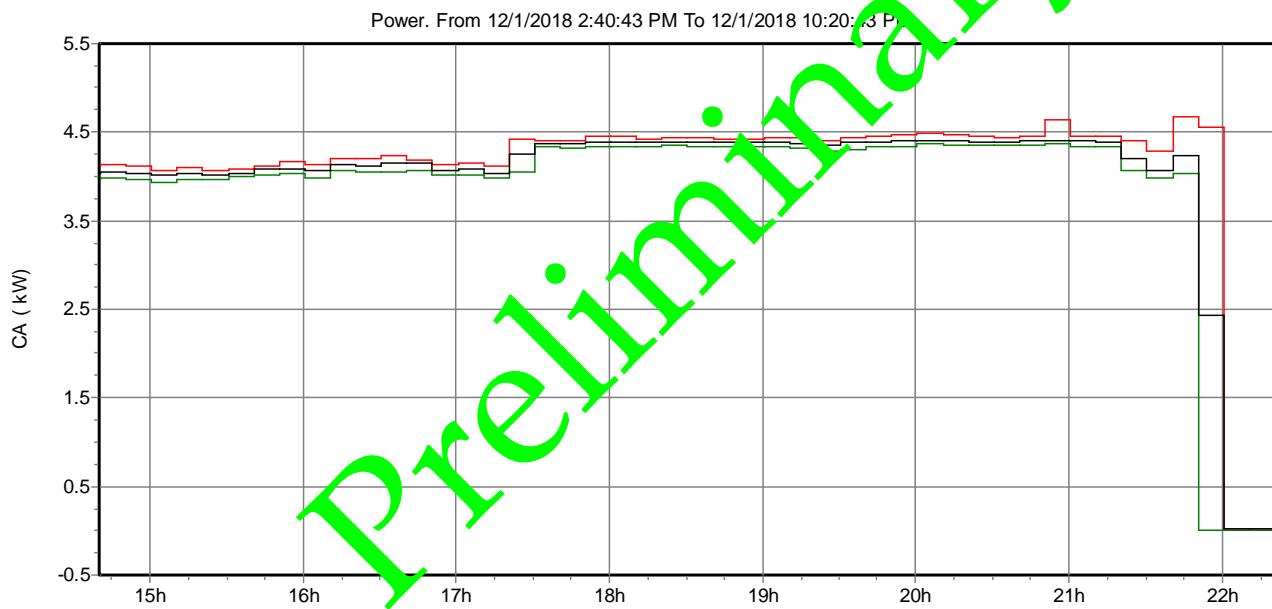
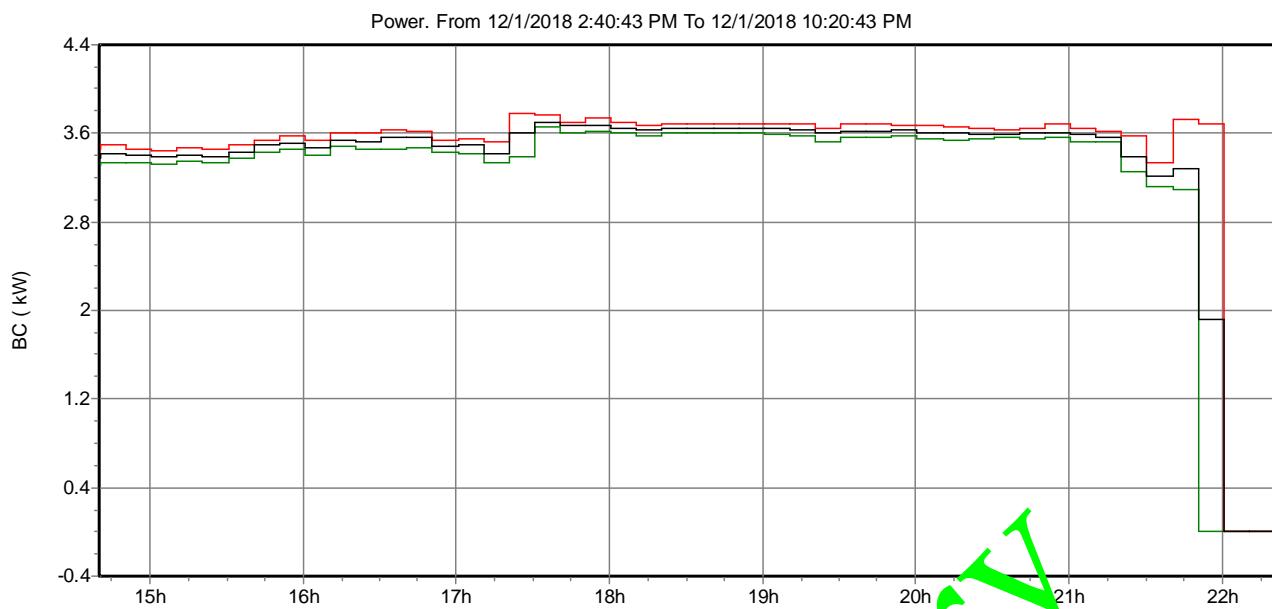


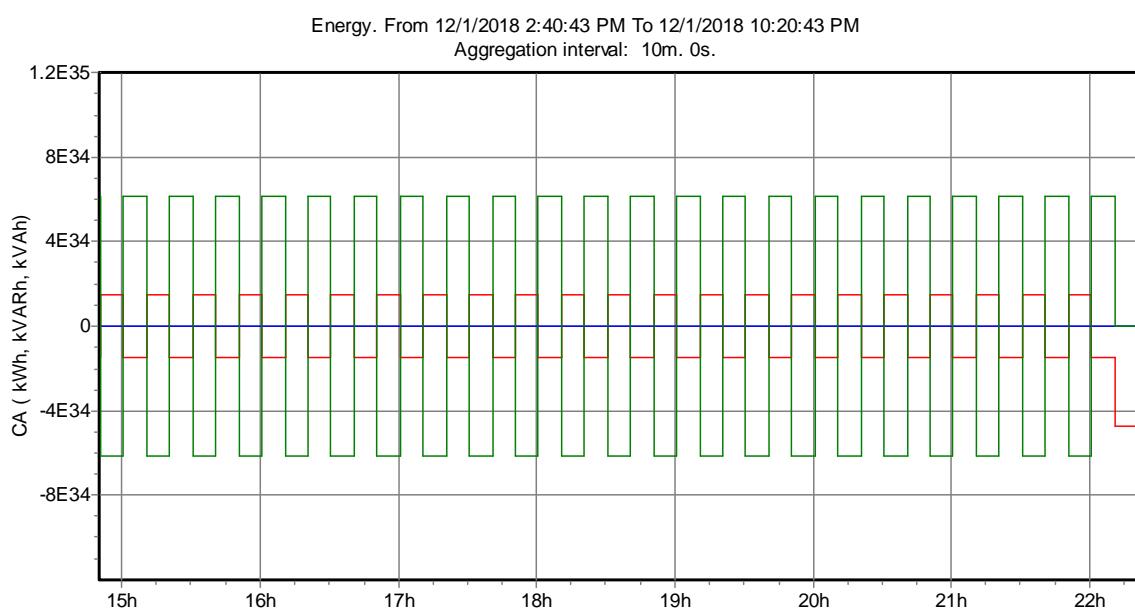
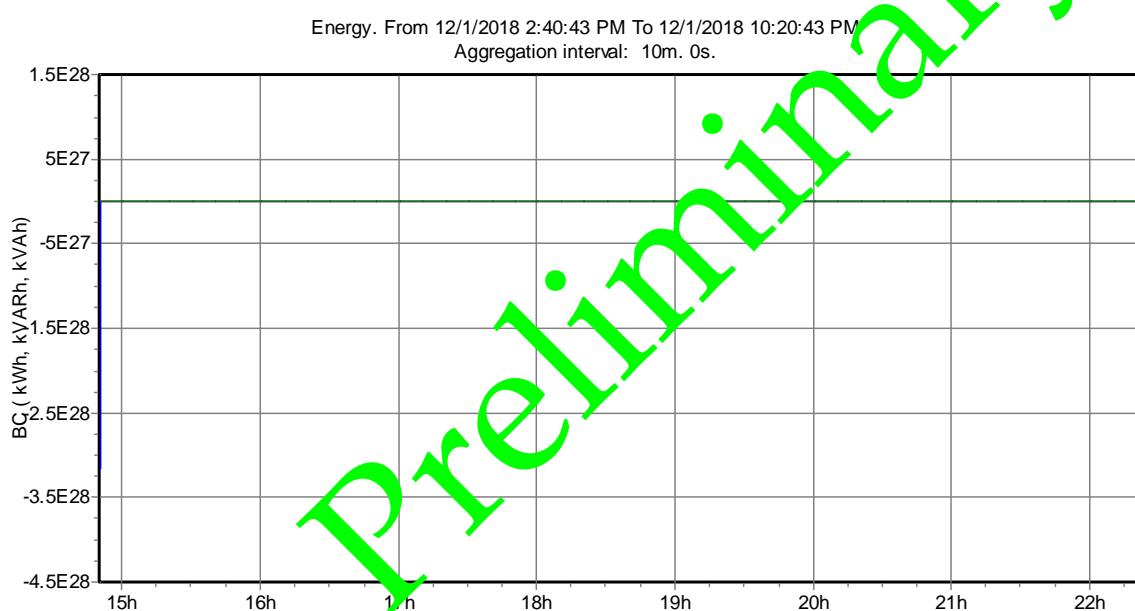
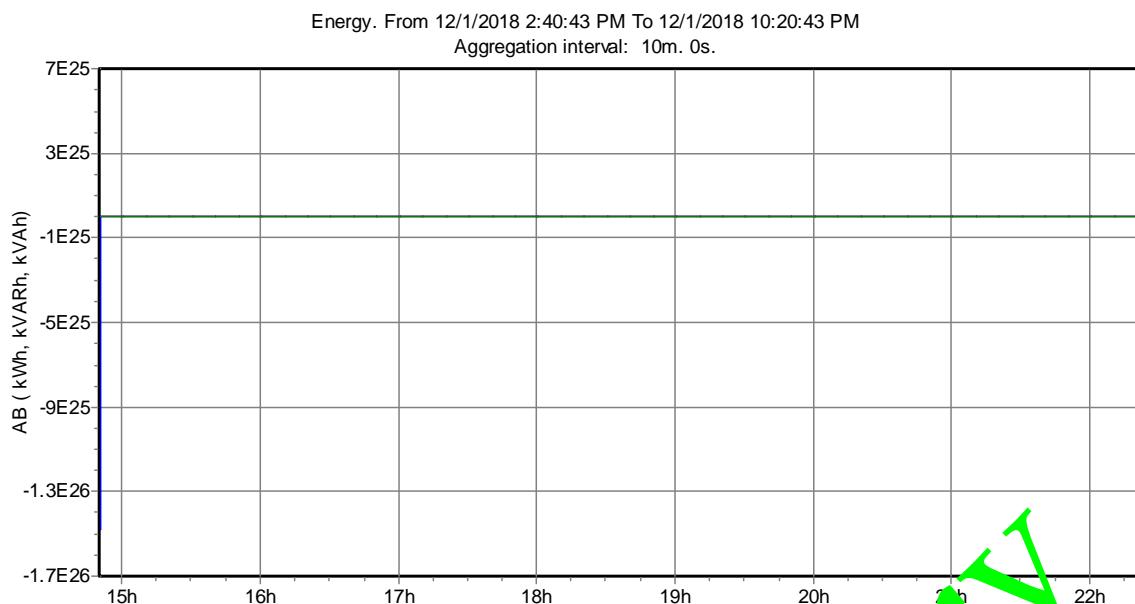


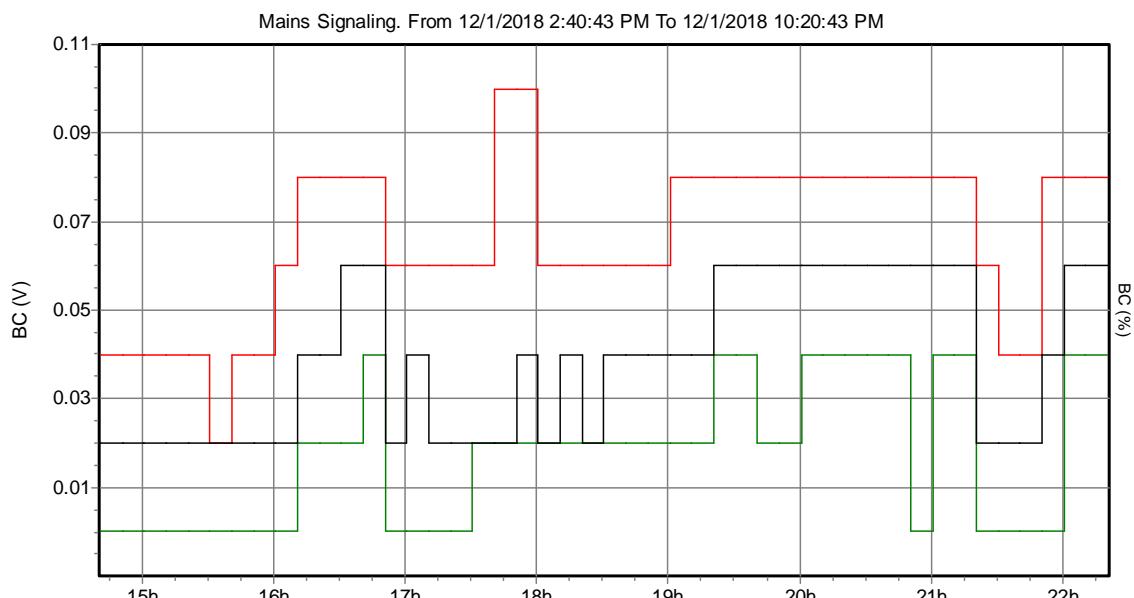
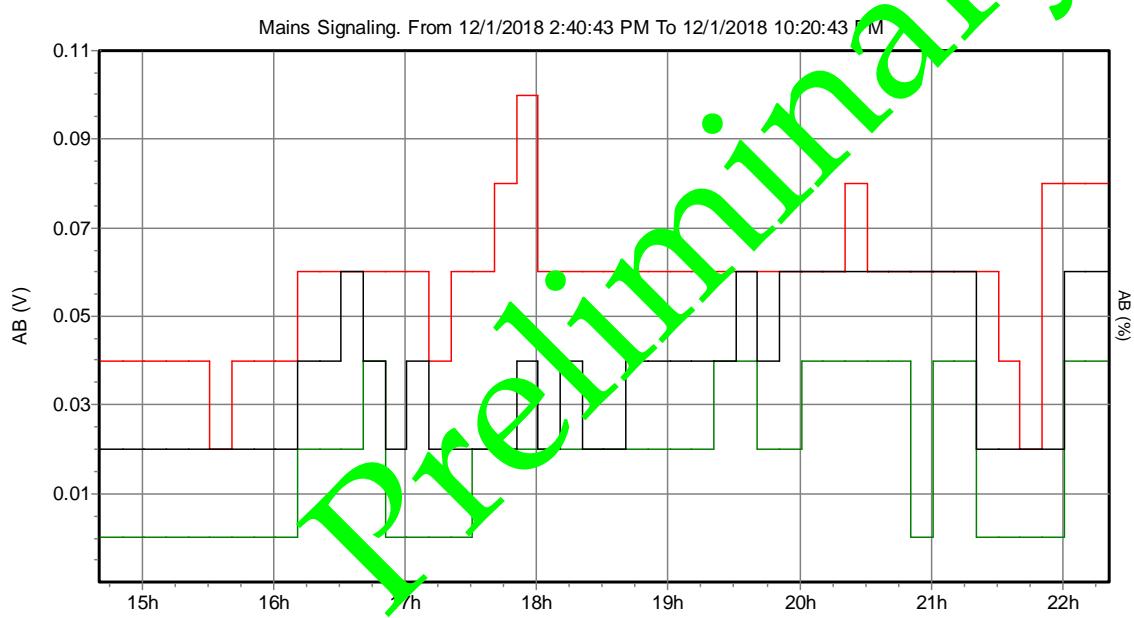
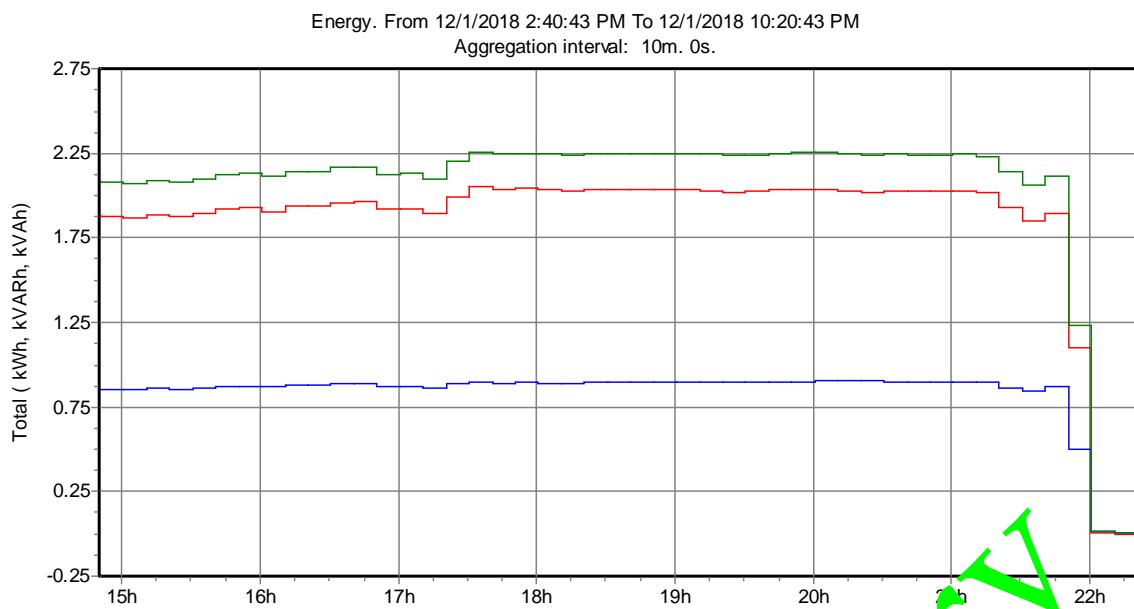


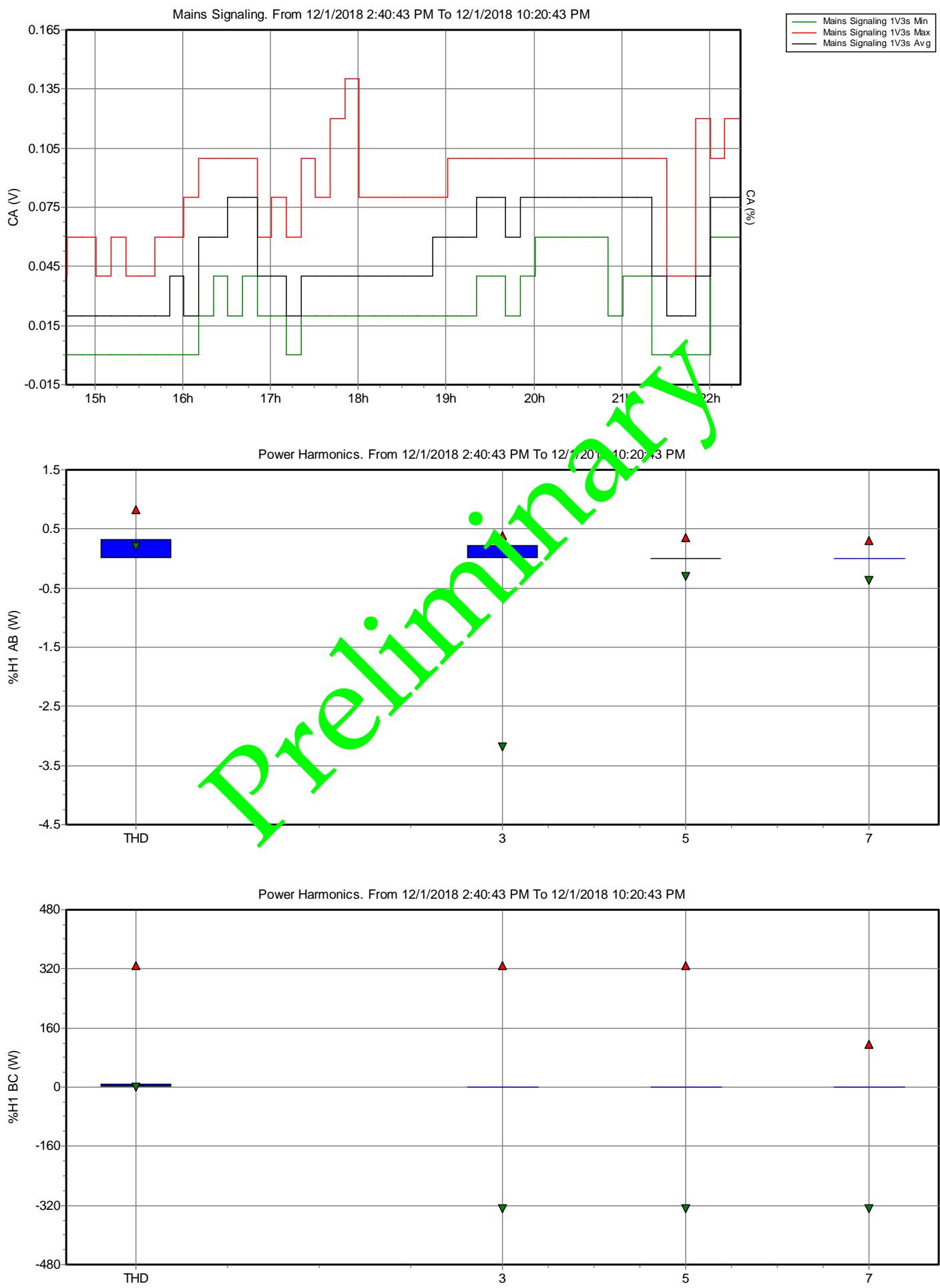


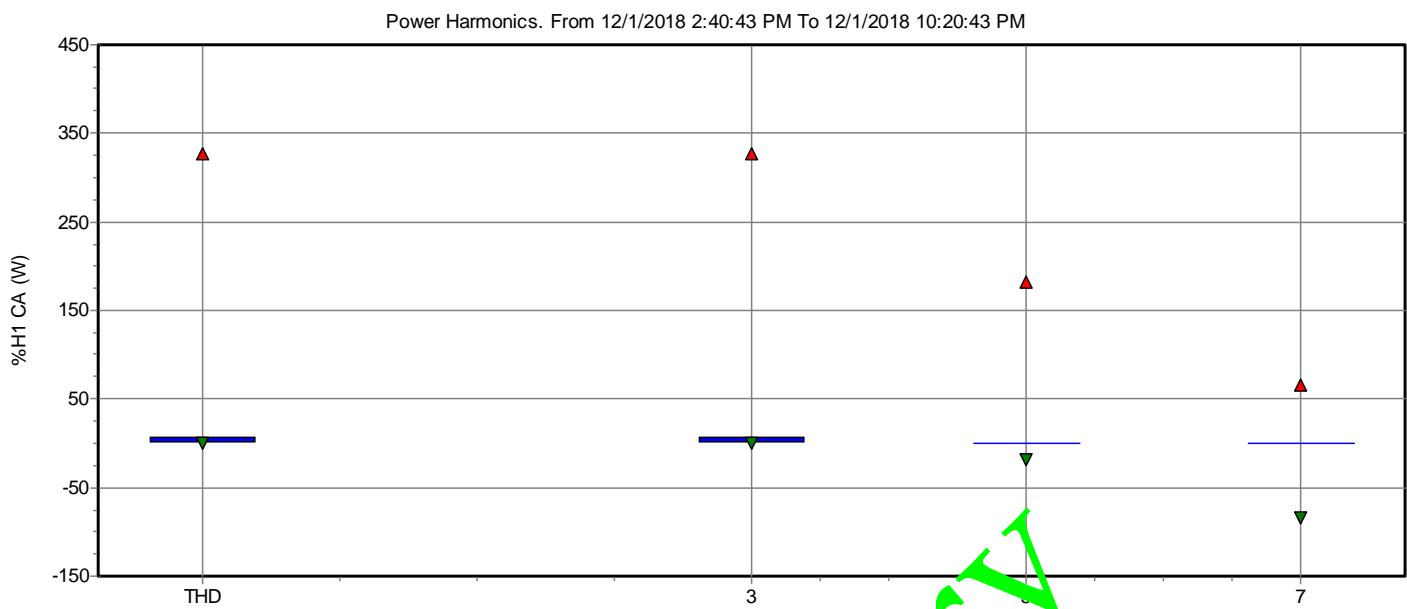
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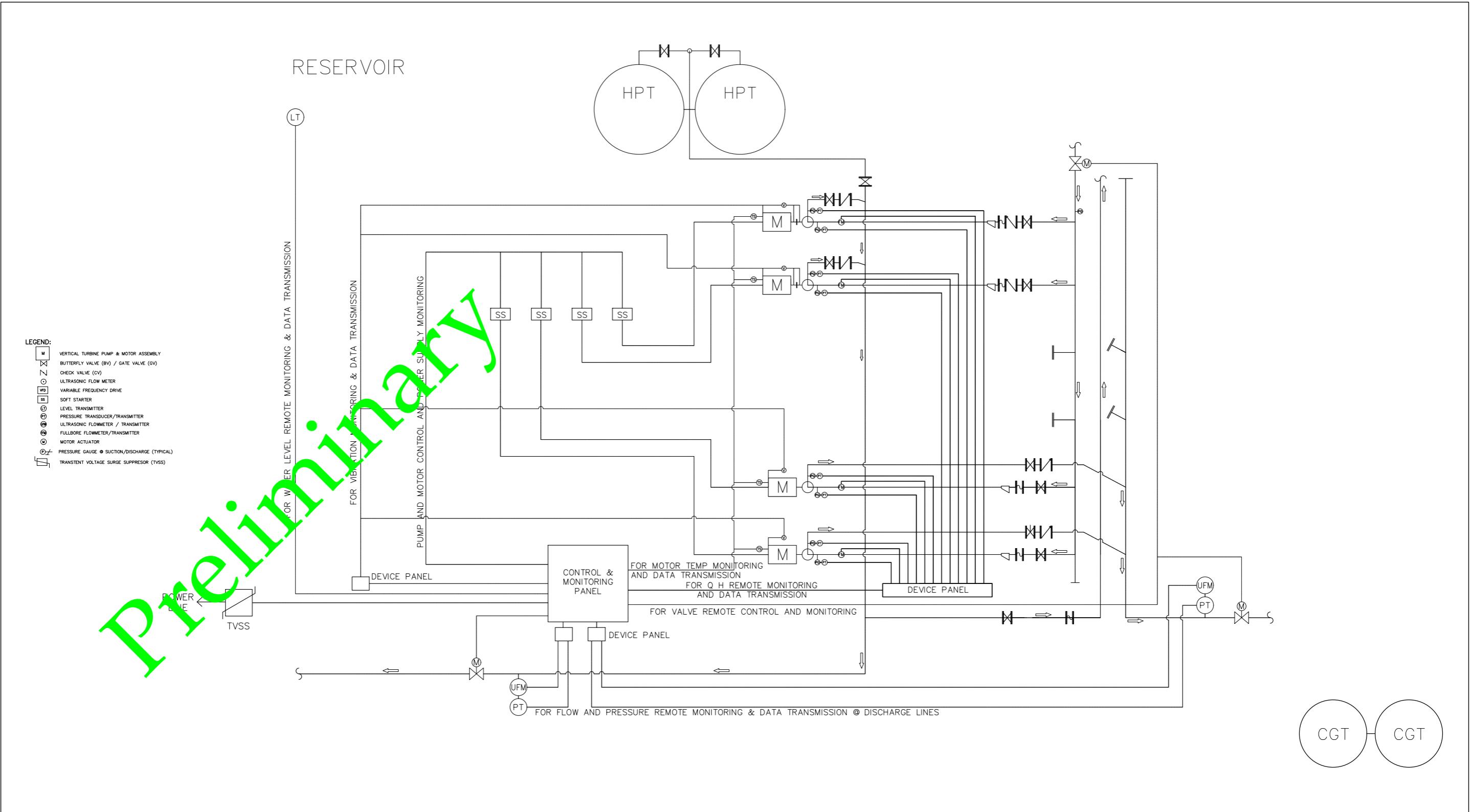


Preliminary

Appendix E

Drawings

Preliminary



Maynilad				Maynilad			
CONFORME:				CONFORME:			
HEAD, Division (End User)		HEAD, Department (End User)					
DRAWN	SURVEYED	DESIGNED	CHECKED				
DRAW	SURVEYED	DESIGNED	CHECKED				
REVISION							
REV	DATE	BY	APPROVED BY				

A **INSTRUMENTATION AND MONITORING DIAGRAM**

NTS

ME
SCALE



11/F Alphaland Southgate Tower 2258 Chino Roces Ave corner
EDSA Makati City 1232 Philippines
T 63 2 479 5600 F 63 2 479 5601
E mnmail@ghd.com W www.ghd.com



RBSANchez PME CONSULTANTS & ASSOCIATES, INC.
Makati Corporate Office: 28th Floor Cityland Pasong Tamo Tower U2807, 2210
Chino Roces Avenue, Makati City, Philippines
Telefax No. 776-5879 Cell No. +639 273 006 000
Website: www.rbs-engineers.com

CONTRACT DRAWING

PROJECT TITLE: CONSULTANCY SERVICES FOR THE PLANT AUDIT IN VARIOUS
PUMP STATIONS AND RESERVOIRS

LOCATION: AYALA SOUTHVALE PUMP STATION AND RESERVOIR

SHEET CONTENT: INSTRUMENTATION AND MONITORING DIAGRAM

SCALE: NTS CONTRACT NO. OP18REFCS03-AYA-MECH-001 SHEET NO. 1 OF 1 REV. A

Approved :

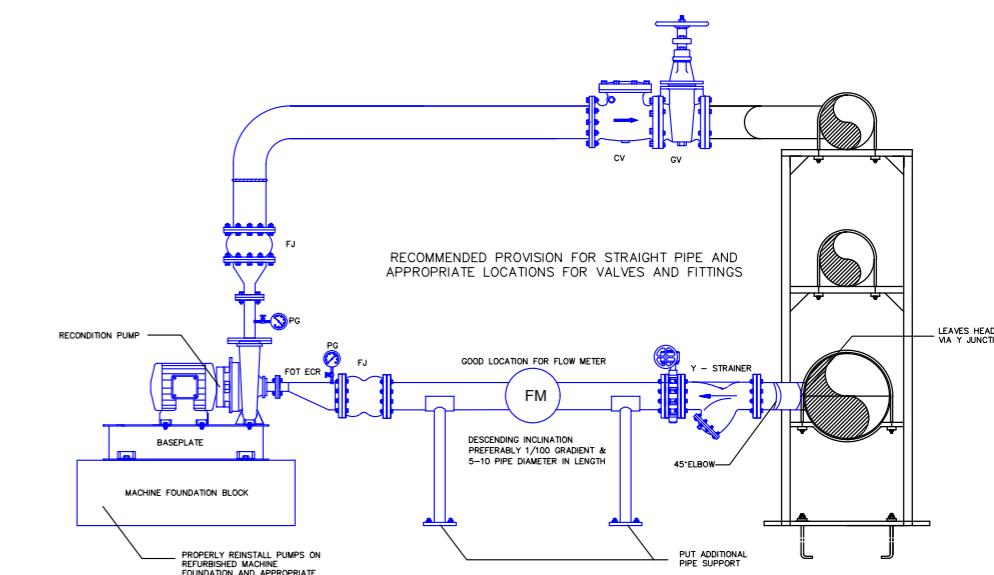
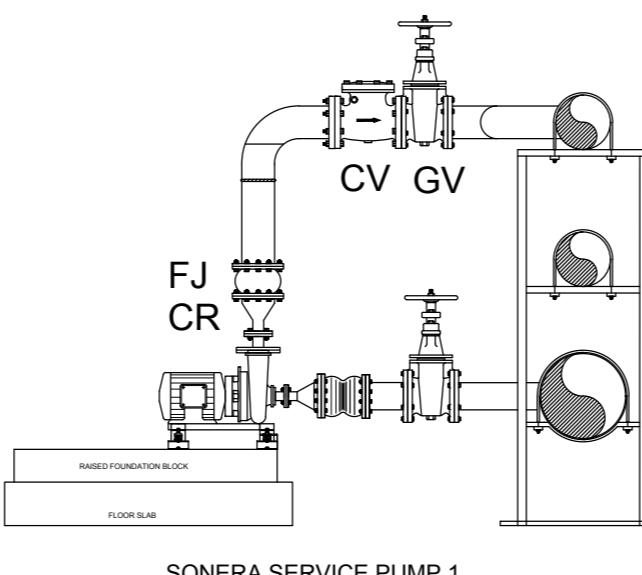
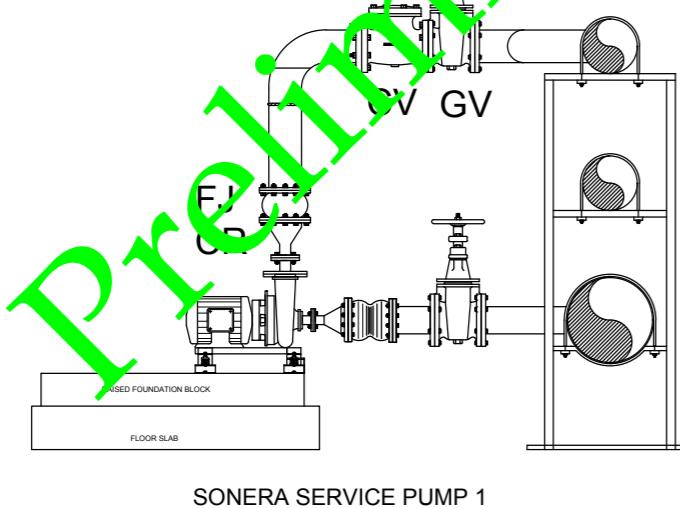
NAM LE
Project Manager

RBS
DESIGN UNIT

ROSENDO B. SANCHEZ, PME
HEAD, Engineering

CONCEPTUAL DESIGN NOTES:

1. RECONDITION PUMPS AS PER RECOMMENDATIONS OF AUDIT REPORT.
2. PIPING AND FITTINGS
 - 2.1. PROVISION FOR STRAIGHT PIPE TO IMPROVE FLOW DEVELOPMENT AND USE OF FLOW METER; FOLLOWS CORRESPONDING PIPE SUPPORTS
 - 2.2. CONSISTENT PIPING AND VALVE LOCATION
 - 2.3. CONCENTRIC REDUCER TO ECCENTRIC FOT REDUCER.
 - 2.4. REMOVE REDUNDANCY BETWEEN STC AND FJ
 - 2.5. CONSTRUCT IDENTICAL PIPING
3. PUMP MOUNTING AND FOUNDATION REHAB
 - 3.1. RAISED FOUNDATION BLOCK AND BASE PLATE FOR MACHINE MOUNTING
4. CONDITION MONITORING DEVICES (SCHEMATIC)
 - 4.1. FLOW METERS
 - 4.2. PRESSURE GAUGES/TRANSDUCER
 - 4.3. VIBRATION METERS
 - 4.4. POWER SUPPLY MONITORING (SS)
 - 4.5. MOTOR TEMP SENSOR/TRANSDUCER
 - 4.6. TOTAL SYSTEM INTEGRATION
5. INSTALLATION OF ADDITIONAL PUMP (15HP)
6. REMOVE OBSTRUCTIONS AROUND GENSET, TREES, DUMPS, ETC) OTHERWISE RELOCATE GENSET TO MORE OPEN AREA



Maynilad				Maynilad			
CONFORME:				CONFORME:			
HEAD, Division (End User)		HEAD, Department (End User)					
DRAWN	SURVEYED	DESIGNED	CHECKED				
DRAW	SURVEYED	DESIGNED	CHECKED				
REVISION							
REV	DATE	BY	APPROVED BY				

A
ME
SCALE

APPROPRIATE LOCATIONS FOR VALVES AND FITTINGS

NTS

Checked & Certified :

ROSENDO B. SANCHEZ, PME
PROFESSIONAL MECHANICAL ENGINEER

DRAWN : _____ SURVEYED : _____ DESIGNED : _____ CHECKED : _____

DRAW : _____ SURVEYED : _____ DESIGNED : _____ CHECKED : _____

PROFESSION : PME PTR : 7341148

REGISTRATION NO. : 3999 DATE ISSUED : 01-07-2019

TIN : 205-811-966 PLACE ISSUED : MAKATI CITY

GHD

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Approved :

NAM LE
Project Manager

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RBS DESIGN UNIT

ROSENDO B. SANCHEZ, PME
HEAD, Engineering

CONTRACT DRAWING

PROJECT TITLE: CONSULTANCY SERVICES FOR THE PLANT AUDIT IN VARIOUS PUMP STATIONS AND RESERVOIRS

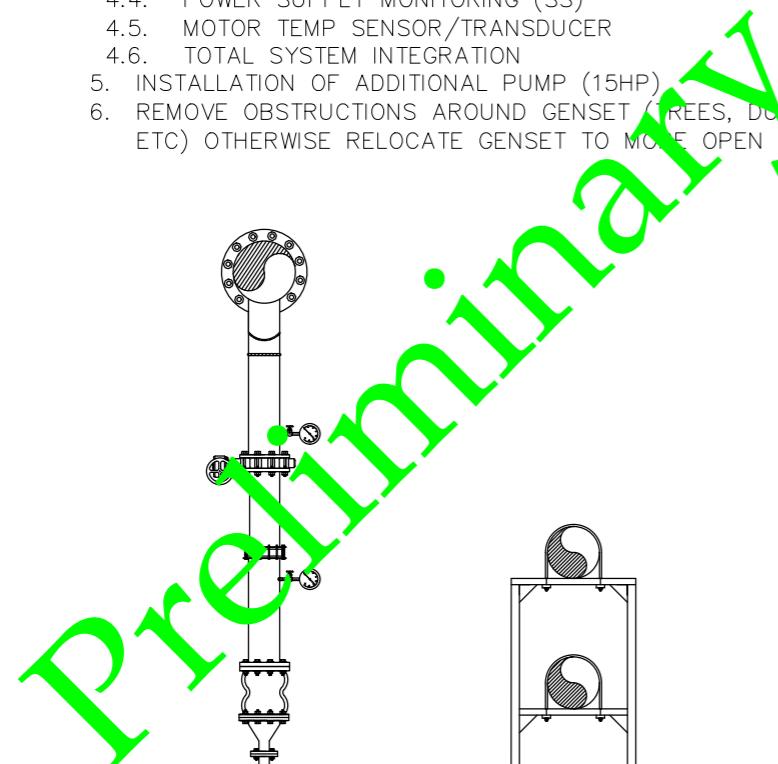
LOCATION: AYALA SOUTHVALE PUMP STATION AND RESERVOIR

SHEET CONTENT: PIPING SYSTEM MODIFICATION FOR SONERA LINES

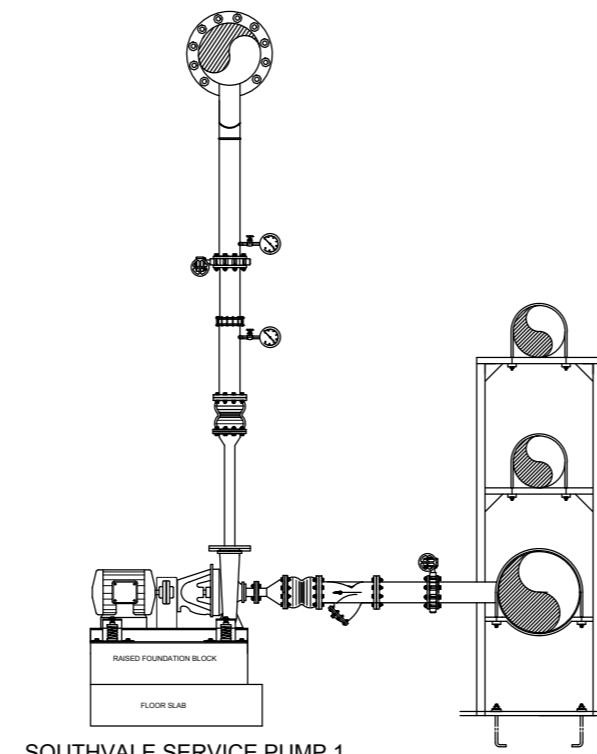
SCALE: NTS CONTRACT NO. OP18REFCS03-AYA-MECH-002 SHEET NO. 1 OF 1 REV. A

CONCEPTUAL DESIGN NOTES:

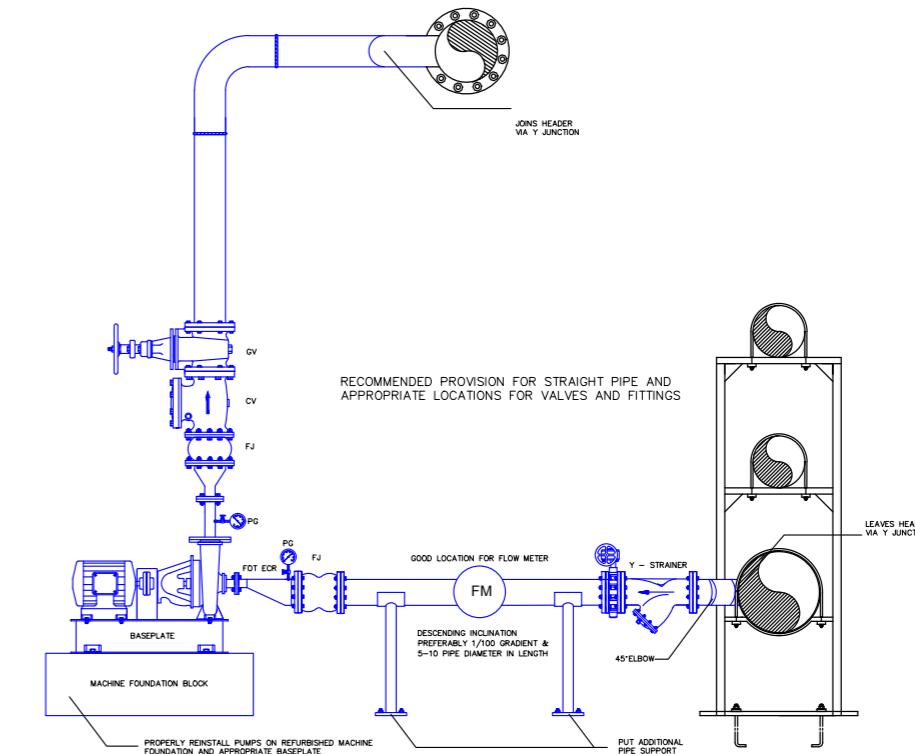
1. RECONDITION PUMPS AS PER RECOMMENDATIONS OF AUDIT REPORT.
2. PIPING AND FITTINGS
 - 2.1. PROVISION FOR STRAIGHT PIPE TO IMPROVE FLOW DEVELOPMENT AND USE OF FLOW METER; FOLLOWS CORRESPONDING PIPE SUPPORTS
 - 2.2. CONSISTENT PIPING AND VALVE LOCATION
 - 2.3. CONCENTRIC REDUCER TO ECCENTRIC FOT REDUCER.
 - 2.4. REMOVE REDUNDANCY BETWEEN STC AND FJ
 - 2.5. CONSTRUCT IDENTICAL PIPING
3. PUMP MOUNTING AND FOUNDATION REHAB
 - 3.1. RAISED FOUNDATION BLOCK AND BASE PLATE FOR MACHINE MOUNTING
4. CONDITION MONITORING DEVICES (SCHEMATIC)
 - 4.1. FLOW METERS
 - 4.2. PRESSURE GAUGES/TRANSDUCER
 - 4.3. VIBRATION METERS
 - 4.4. POWER SUPPLY MONITORING (SS)
 - 4.5. MOTOR TEMP SENSOR/TRANSDUCER
 - 4.6. TOTAL SYSTEM INTEGRATION
5. INSTALLATION OF ADDITIONAL PUMP (15HP)
6. REMOVE OBSTRUCTIONS AROUND GENSET (TREES, DUMPS, ETC) OTHERWISE RELOCATE GENSET TO MORE OPEN AREA



SOUTHVALE SERVICE PUMP 2



SOUTHVALE SERVICE PUMP 1



Maynilad	Maynilad	A <small>ME</small> <small>SCALE</small>				APPROPRIATE LOCATIONS FOR VALVES AND FITTINGS		NTS			
CONFORME:		CONFORME:									
HEAD, Division (End User)		HEAD, Department (End User)									
DRAWN	SURVEYED	DESIGNED	CHECKED								
DRAW	SURVEYED	DESIGNED	CHECKED								
REVISION											
REV	DATE	BY	APPROVED BY								

Checked & Certified :

ROSENDO B. SANCHEZ, PME
PROFESSIONAL MECHANICAL ENGINEER

GHD

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Website: www.rbs-engineers.com

Approved :

PROFESSION : PME	PTR : 7341148
REGISTRATION NO. : 3999	DATE ISSUED : 01-07-2019
TIN : 205-811-966	PLACE ISSUED : MAKATI CITY

RBS DESIGN UNIT	ROSENDO B. SANCHEZ, PME
Project Manager	HEAD, Engineering

CONTRACT DRAWING

PROJECT TITLE: CONSULTANCY SERVICES FOR THE PLANT AUDIT IN VARIOUS PUMP STATIONS AND RESERVOIRS

LOCATION: AYALA SOUTHVALE PUMP STATION AND RESERVOIR

SHEET CONTENT: PIPE SYSTEM MODIFICATION FOR SOUTHVALE LINES

SCALE: NTS

CONTRACT NO.: OP18REFCS03-AYA-MECH-003

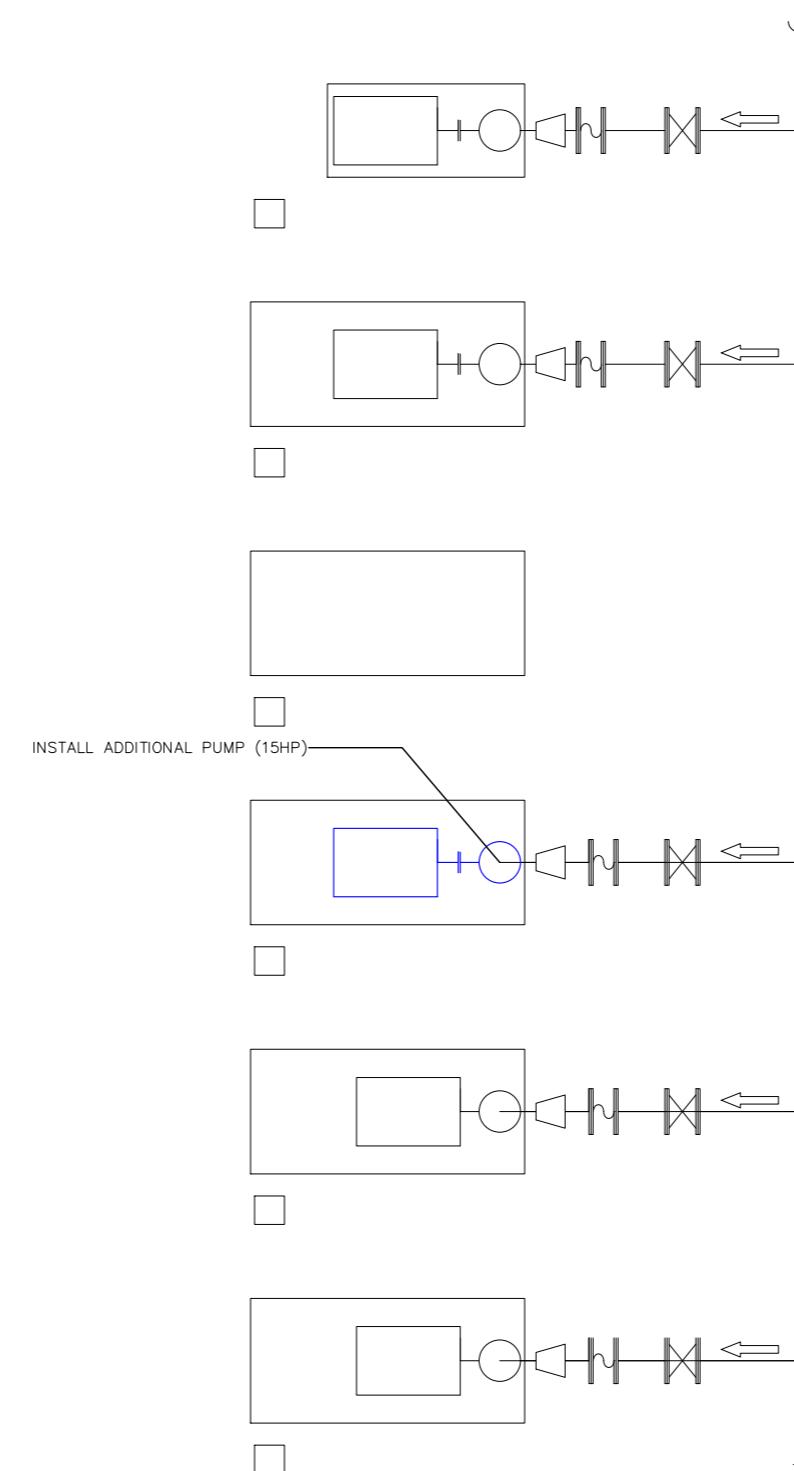
SHEET NO.: 1 OF 1

REV. A

CONCEPTUAL DESIGN NOTES:

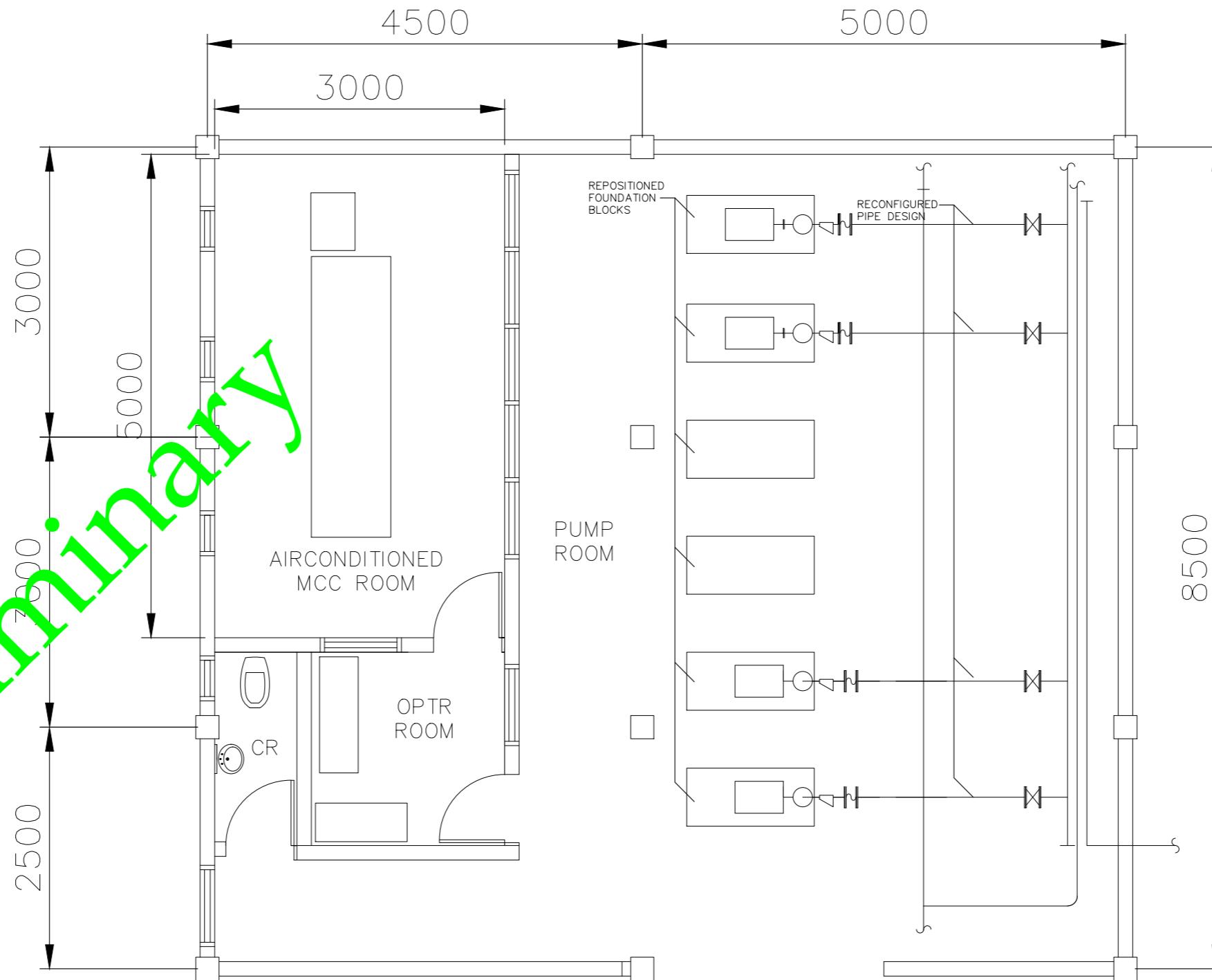
1. RECONDITION PUMPS AS PER RECOMMENDATIONS OF AUDIT REPORT.
2. PIPING AND FITTINGS
 - 2.1. PROVISION FOR STRAIGHT PIPE TO IMPROVE FLOW DEVELOPMENT AND USE OF FLOW METER; FOLLOWS CORRESPONDING PIPE SUPPORTS
 - 2.2. CONSISTENT PIPING AND VALVE LOCATION
 - 2.3. CONCENTRIC REDUCER TO ECCENTRIC FOT REDUCER.
 - 2.4. REMOVE REDUNDANCY BETWEEN STC AND FJ
 - 2.5. CONSTRUCT IDENTICAL PIPING
3. PUMP MOUNTING AND FOUNDATION REHAB
 - 3.1. RAISED FOUNDATION BLOCK AND BASE PLATE FOR MACHINE MOUNTING
4. CONDITION MONITORING DEVICES (SCHEMATIC)
 - 4.1. FLOW METERS
 - 4.2. PRESSURE GAUGES/TRANSDUCER
 - 4.3. VIBRATION METERS
 - 4.4. POWER SUPPLY MONITORING (SS)
 - 4.5. MOTOR TEMP SENSOR/TRANSDUCER
 - 4.6. TOTAL SYSTEM INTEGRATION
5. INSTALLATION OF ADDITIONAL PUMP (15HP)
6. REMOVE OBSTRUCTIONS AROUND GENSET (TREES, DUMPS, ETC) OTHERWISE RELOCATE GENSET TO MORE OPEN AREA

Preliminary



Maynilad				Maynilad				A <small>ME</small> <small>SCALE</small>				INSTALLATION LOCATION OF SPARE PUMP				NTS							
CONFORME:				CONFORME:																			
HEAD, Division (End User)				HEAD, Department (End User)																			
DRAWN		SURVEYED		DESIGNED		CHECKED																	
DRAW		SURVEYED		DESIGNED		CHECKED																	
REVISION <small>REV DATE BY APPROVED BY</small>														CONTRACT DRAWING <small>PROJECT TITLE: CONSULTANCY SERVICES FOR THE PLANT AUDIT IN VARIOUS PUMP STATIONS AND RESERVOIRS</small>									
														<small>LOCATION: AYALA SOUTHVALE PUMP STATION AND RESERVOIR</small>									
														<small>SHEET CONTENT: INSTALL SPARE PUMP FOR SONERA</small>									
														<small>SCALE: NTS CONTRACT NO. OP18REFCS03-AYA-MECH-004 SHEET NO. 1 OF 1 REV. A</small>									

Preliminary



CONFORME:

HEAD, Division (End User)



CONFORME:

HEAD, Department (End User)

REVISION

REV

DATE

BY

APPROVED BY

A
ME
SCALE

PROPOSED LAYOUT FOR PUMP HOUSE

NTS

Checked & Certified :
ROSENDO B. SANCHEZ, PME
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CONTRACT DRAWING

PROJECT TITLE: CONSULTANCY SERVICES FOR THE PLANT AUDIT IN VARIOUS
PUMP STATIONS AND RESERVOIRS

LOCATION: AYALA SOUTHVALE PUMP STATION AND RESERVOIR

SHEET CONTENT: PROPOSED PUMP STATION LAYOUT

SCALE: NTS CONTRACT NO. OP18REFCS03-AYA-MECH-005 SHEET NO. 1 OF 1 REV. A

Approved :

NAM LE
Project Manager



RBS
DESIGN UNIT

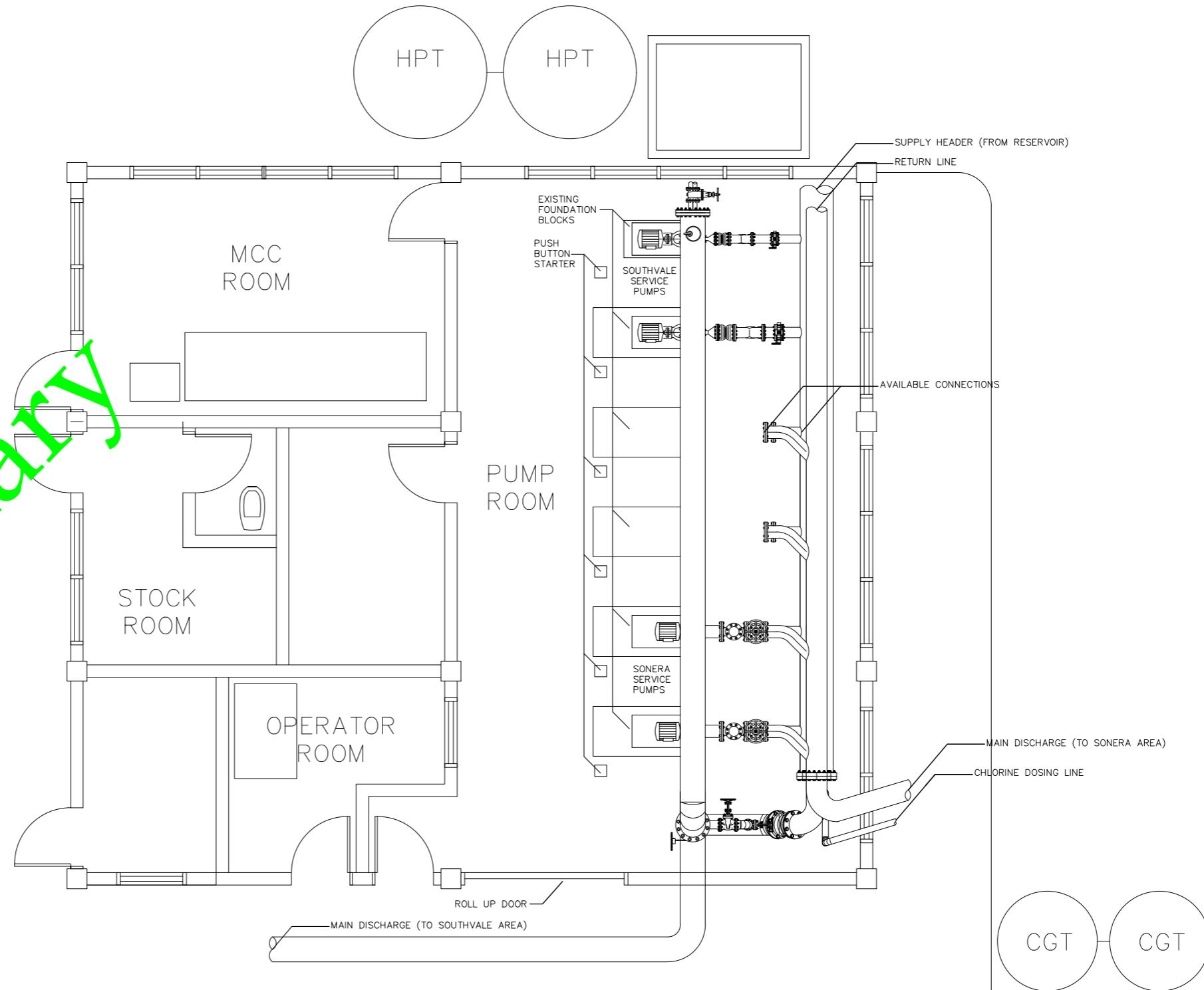
RBS
DESIGN SECTION

ROSENDO B. SANCHEZ, PME
HEAD, Engineering

Preliminary

AS-FOUND NOTES:

1. PIPING AND FITTINGS
 - 1.1. THERE ARE CURRENTLY TWO SEPARATE DISCHARGE LINES: TO SOUTHLAVER AND TO SONERA; CORRESPONDING PIPING FOLLOWS
 - 1.2. LINE FROM RESERVOIR TO PUMP HOUSE NOT SHOWN
 - 1.3. SOME PIPING FOUND IN FRONT OF PUMP HOUSE NOT SHOWN IN OLD AS BUILT
2. INSTALLATION
 - 2.1. NO CBP INSTALLED INSIDE PUMP HOUSE; NO CORRESPONDING PIPING, FITTINGS AND FOUNDATION BLOCK
 - 2.2. SOUTHLAVER BOOSTER PUMP 1 IS INSTALLED IN PLACE OF JOCKEY PUMP
 - 2.2. SOUTHLAVER SERVICE PUMPS (10HP) ARE INDIRECT DRIVEN WHILE SONERA SERVICE PUMPS (15HP) ARE DIRECT DRIVEN
3. PIPE SUPPORT
 - 3.1. STEEL SADDLE SUPPORT USED INSTEAD OF PIPE HANGER
 - 3.2. SPACING OF SUPPORT OUTLINE FOLLOWED
4. PUMP HOUSE
 - 4.1. ROLL UP DOOR PROVIDED
 - 4.2. NO CI TANKS AND DUCTING AS CHLORINATION ROOM WAS CONVERTED INTO OPERATOR'S ROOM
 - 4.3. CHLORINE GAS TANKS LOCATED OUTSIDE BESIDE PUMP HOUSE



Maynilad				Maynilad			
CONFORME:				CONFORME:			
HEAD, Division (End User)		HEAD, Department (End User)					
DRAWN	SURVEYED	DESIGNED	CHECKED				
DRAW	SURVEYED	DESIGNED	CHECKED				
REVISION							
REV	DATE	BY	APPROVED BY				

A
ME
SCALE
NTS
AS-BUILT

Checked & Certified :
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Approved :

NAM LE
Project Manager



RBS DESIGN UNIT
RBS DESIGN SECTION

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HEAD, Engineering

CONTRACT DRAWING

PROJECT TITLE: CONSULTANCY SERVICES FOR THE PLANT AUDIT IN VARIOUS PUMP STATIONS AND RESERVOIRS

LOCATION: AYALA SOUTHLAVER PUMP STATION AND RESERVOIR

SHEET CONTENT: AS-BUILT

SCALE: NTS CONTRACT NO. OP18REFCS03-AYA-MECH-006 SHEET NO. 1 OF 1 REV. A

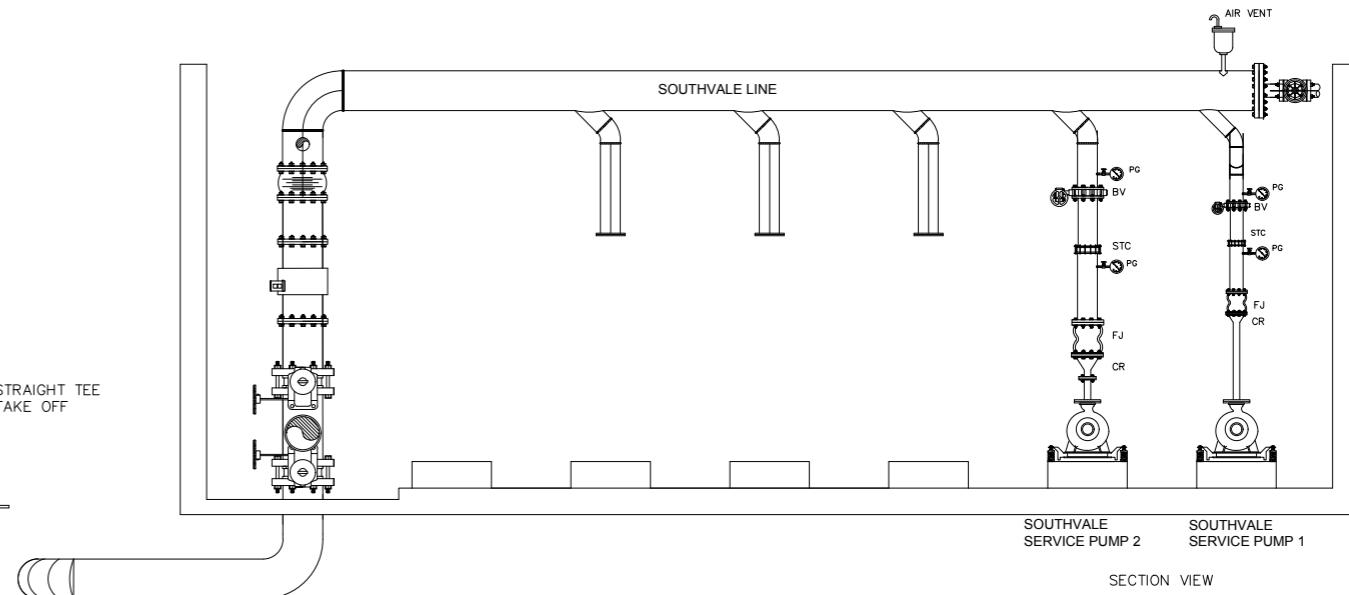
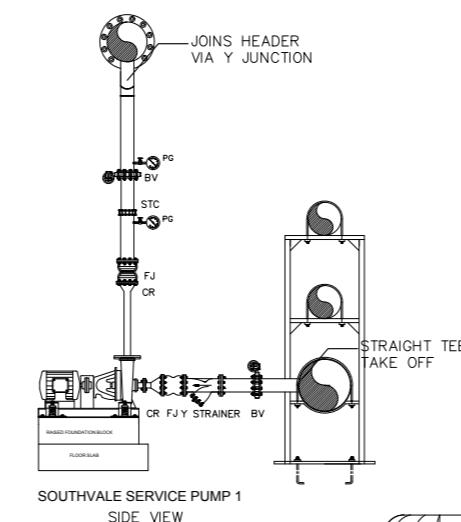
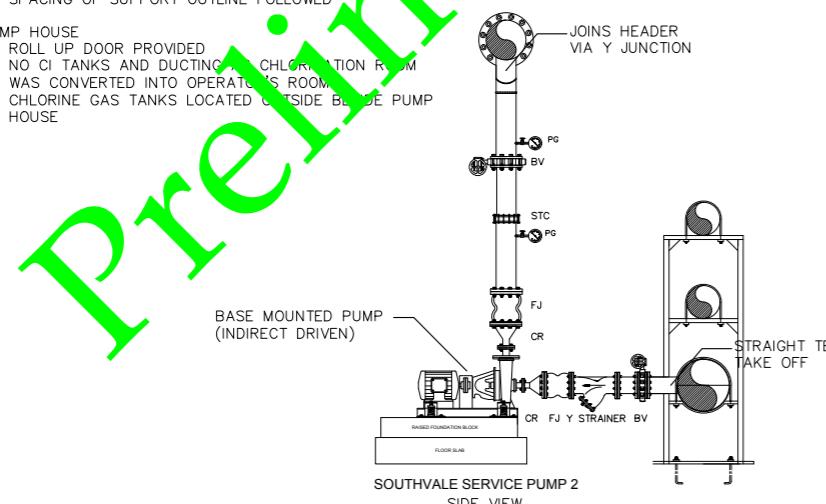
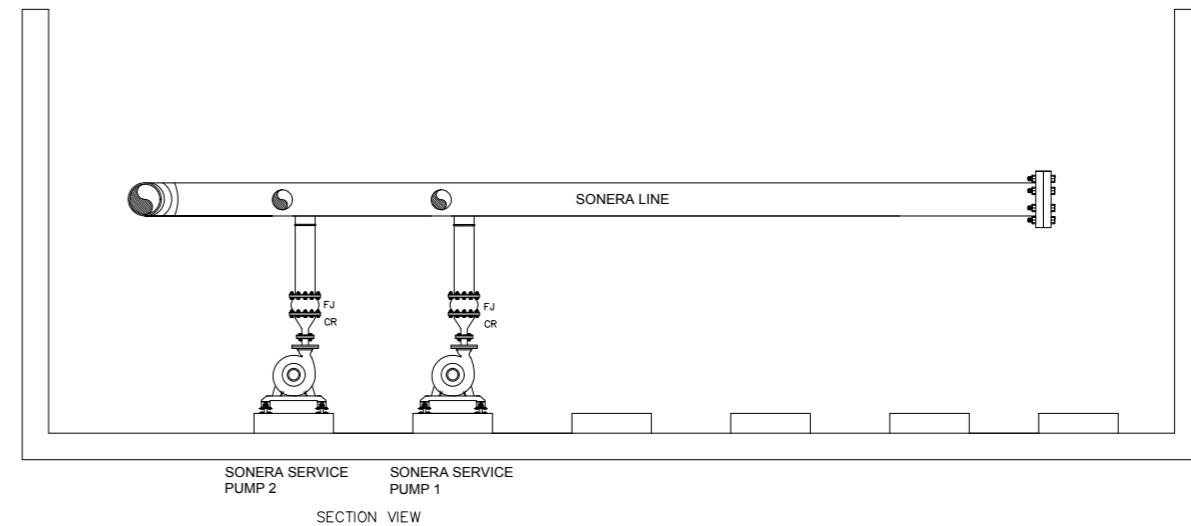
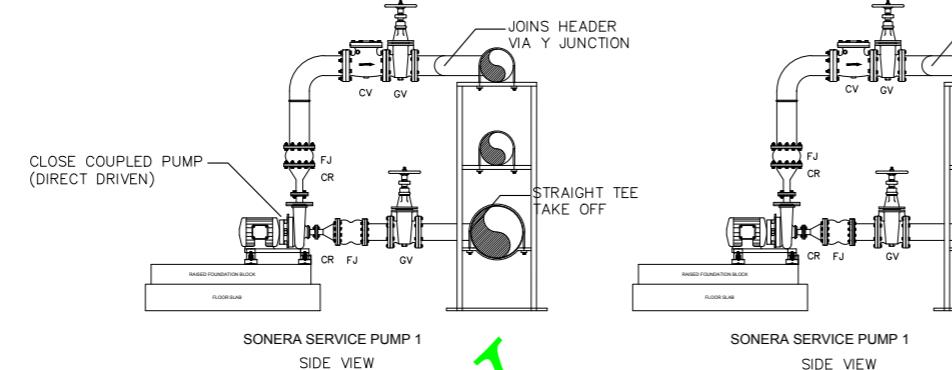
AS-FOUND NOTES:

1. PIPING AND FITTINGS
 - 1.1. THERE ARE CURRENTLY TWO SEPARATE DISCHARGE LINES: TO SOUTHLALE AND TO SONERA; CORRESPONDING PIPING FOLLOWS.
 - 1.2. LINE FROM RESERVOIR TO PUMP HOUSE NOT SHOWN
 - 1.3. SOME PIPING FOUND IN FRONT OF PUMP HOUSE NOT SHOWN IN OLD AS BUILT

2. INSTALLATION
 - 2.1. NO CBP INSTALLED INSIDE PUMP HOUSE; NO CORRESPONDING PIPING, FITTINGS AND FOUNDATION BLOCK
 - 2.2. SOUTHLALE BOOSTER PUMP 1 IS INSTALLED IN PLACE OF JOCKEY PUMP
 - 2.3. SOUTHLALE SERVICE PUMPS (10HP) ARE INDIRECT DRIVEN WHILE SONERA SERVICE PUMPS (15HP) ARE DIRECT DRIVEN

3. PIPE SUPPORT
 - 3.1. STEEL SADDLE SUPPORT USED INSTEAD OF PIPE HANGER
 - 3.2. SPACING OF SUPPORT OUTLINE FOLLOWED

4. PUMP HOUSE
 - 4.1. ROLL UP DOOR PROVIDED
 - 4.2. NO CI TANKS AND DUCTING; CHLORINATION ROOM WAS CONVERTED INTO OPERATOR'S ROOM
 - 4.3. CHLORINE GAS TANKS LOCATED OUTSIDE BEHIND PUMP HOUSE



Maynilad		Maynilad	
CONFORME:		CONFORME:	
HEAD, Division (End User)		HEAD, Department (End User)	
DRAWN	SURVEYED	DESIGNED	CHECKED
DRAW	SURVEYED	DESIGNED	CHECKED
REVISION			
REV	DATE	BY	APPROVED BY

A AS-FOUND
ME SCALE NTS

Checked & Certified :
ROSENDO B. SANCHEZ, PME
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Approved :
NAM LE
Project Manager

RBS DESIGN UNIT
ROSENDO B. SANCHEZ, PME
HEAD, Engineering
RBS DESIGN SECTION

CONTRACT DRAWING

PROJECT TITLE: CONSULTANCY SERVICES FOR THE PLANT AUDIT IN VARIOUS
PUMP STATIONS AND RESERVOIRS

LOCATION: AYALA SOUTHLALE PUMP STATION AND RESERVOIR

SHEET CONTENT: AS-FOUND

SCALE: NTS CONTRACT NO. OP18REFCS03-AYA-MECH-007 SHEET NO. 1 OF 1 REV. A

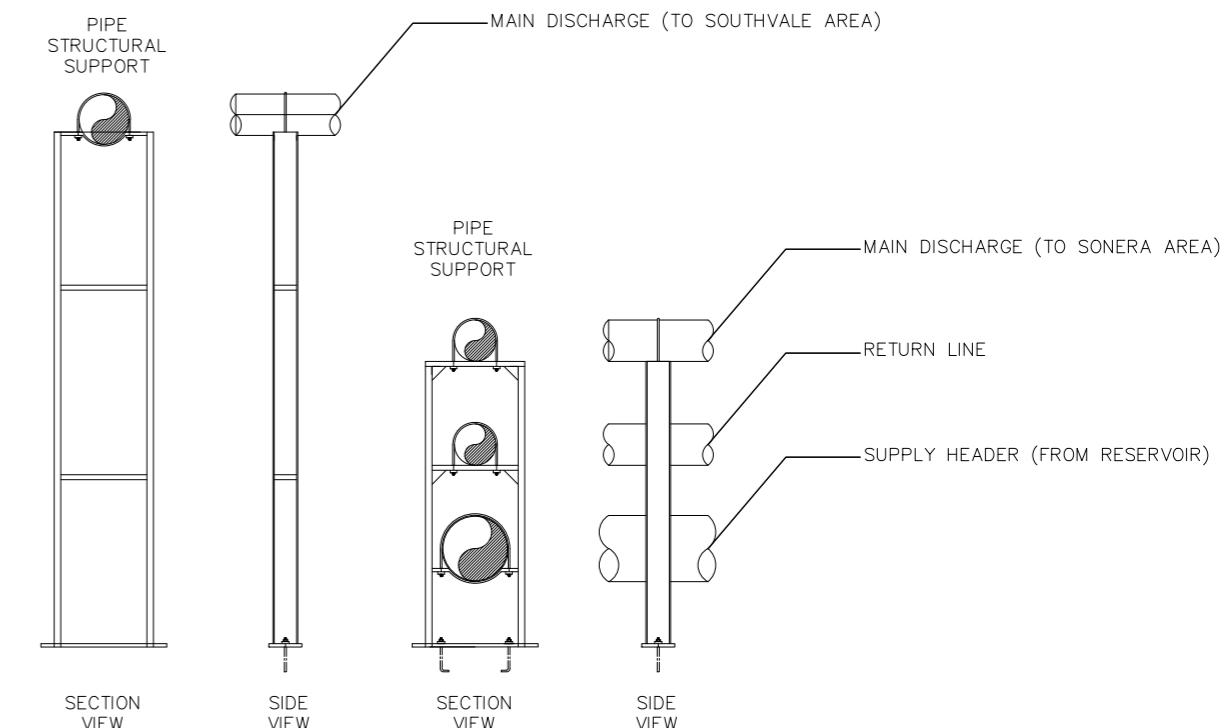
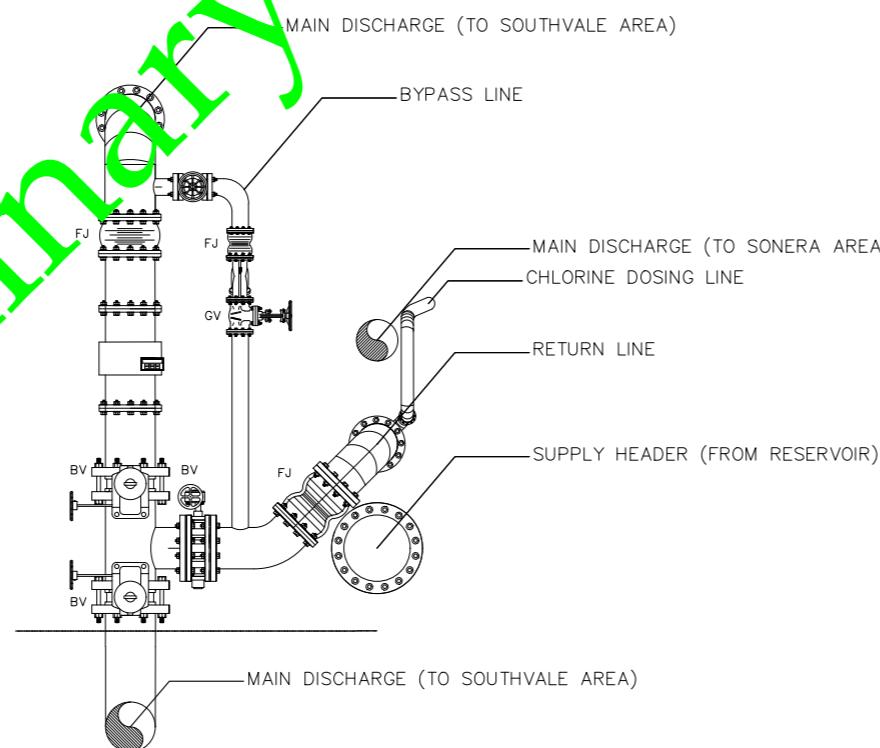
AS-FOUND NOTES:

1. PIPING AND FITTINGS
 - 1.1. THERE ARE CURRENTLY TWO SEPARATE DISCHARGE LINES: TO SOUTHLAKE AND TO SONERA; CORRESPONDING PIPING FOLLOWS
 - 1.2. LINE FROM RESERVOIR TO PUMP HOUSE NOT SHOWN
 - 1.3. SOME PIPING FOUND IN FRONT OF PUMP HOUSE NOT SHOWN IN OLD AS BUILT

2. INSTALLATION
 - 2.1. NO CBP INSTALLED INSIDE PUMP HOUSE; NO CORRESPONDING PIPING, FITTINGS AND FOUNDATION BLOCK
 - 2.2. SOUTHLAKE BOOSTER PUMP 1 IS INSTALLED IN PLACE OF JOCKEY PUMP
 - 2.3. SOUTHLAKE SERVICE PUMPS (10HP) ARE INDIRECT DRIVEN WHILE SONERA SERVICE PUMPS (15HP) ARE DIRECT DRIVEN

3. PIPE SUPPORT
 - 3.1. STEEL SADDLE SUPPORT USED INSTEAD OF PIPE HANGER
 - 3.2. SPACING OF SUPPORT OUTLINE FOLLOWED
4. PUMP HOUSE
 - 4.1. ROLL UP DOOR PROVIDED
 - 4.2. NO CI TANKS AND DUCTING AS CHLORINATION ROOM WAS CONVERTED INTO OPERATOR'S ROOM
 - 4.3. CHLORINE GAS TANKS LOCATED OUTSIDE BEHIND PUMP HOUSE

Preliminary



Maynilad				Maynilad			
CONFORME:				CONFORME:			
HEAD, Division (End User)		HEAD, Department (End User)					
DRAWN	SURVEYED	DESIGNED	CHECKED				
DRAW	SURVEYED	DESIGNED	CHECKED				
REVISION							
REV	DATE	BY	APPROVED BY				

A
ME SCALE
AS FOUND DETAILS OF PIPE SUPPORT

NTS

Checked & Certified :
ROSENDO B. SANCHEZ, PME
PROFESSIONAL MECHANICAL ENGINEER



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Approved :

NAM LE
Project Manager



ROSENDO B. SANCHEZ, PME
HEAD, Engineering



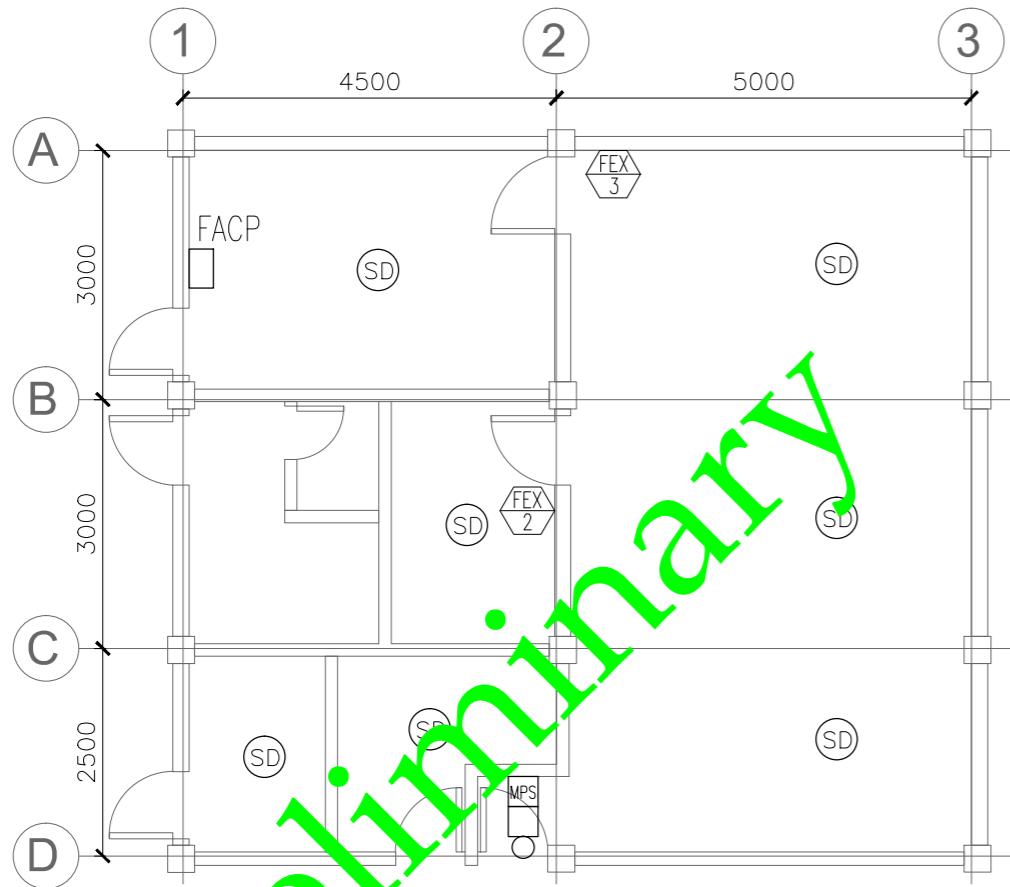
CONTRACT DRAWING

PROJECT TITLE: CONSULTANCY SERVICES FOR THE PLANT AUDIT IN VARIOUS
PUMP STATIONS AND RESERVOIRS

LOCATION: AYALA SOUTHLAKE PUMP STATION AND RESERVOIR

SHEET CONTENT: AS FOUND DETAILS OF PIPE SUPPORT

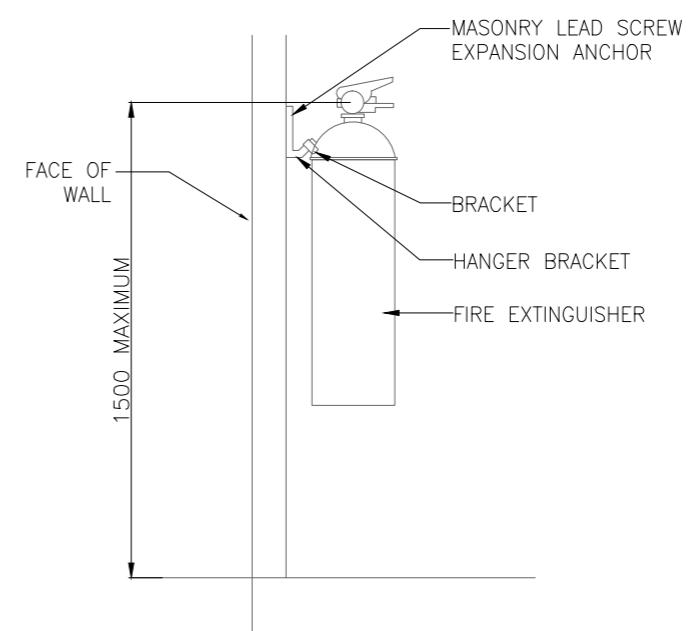
SCALE: NTS CONTRACT NO. OP18REFCS03-AYA-MECH-008 SHEET NO. 1 OF 1 REV. A



Preliminary

FDAS AND FEX LOCATION PLAN

EE-01



LEGEND:

SYMBOL	QTY	DESCRIPTION
(FEX 2)	1 UNITS	MULTI-PURPOSE DRY CHEMICAL W/ 2A MIN. RATING (RED)
(FEX 3)	1 UNITS	CLEAN EXTINGUISHER AGENT (GREEN)
(SD)	7 UNITS	SMOKE DETECTOR
()	1 UNITS	ALARM BELL 6" DIAMETER
(MPS)	1 UNITS	MANUAL PULL STATION
FACP	1 UNIT	FIRE ALARM CONTROL SYSTEM

FIRE EXTINGUISHER INSTALLATION PLAN

2
EE-01

CONFORME:	CONFORME:		
HEAD, Division (End User)	HEAD, Department (End User)		
DRAWN	SURVEYED	DESIGNED	CHECKED
REVISION			
REV	DATE	BY	APPROVED BY

Checked & Certified :
ENGR. MARITES R. PANGILINAN
 Professional Electrical Engineer



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**ALTERNATIVE POWER
SOLUTIONS, INC.**
 142 LIBRAZA AVELINO STREET PANDACAN MANILA
 TEL 02 403281 TEL 02 403281

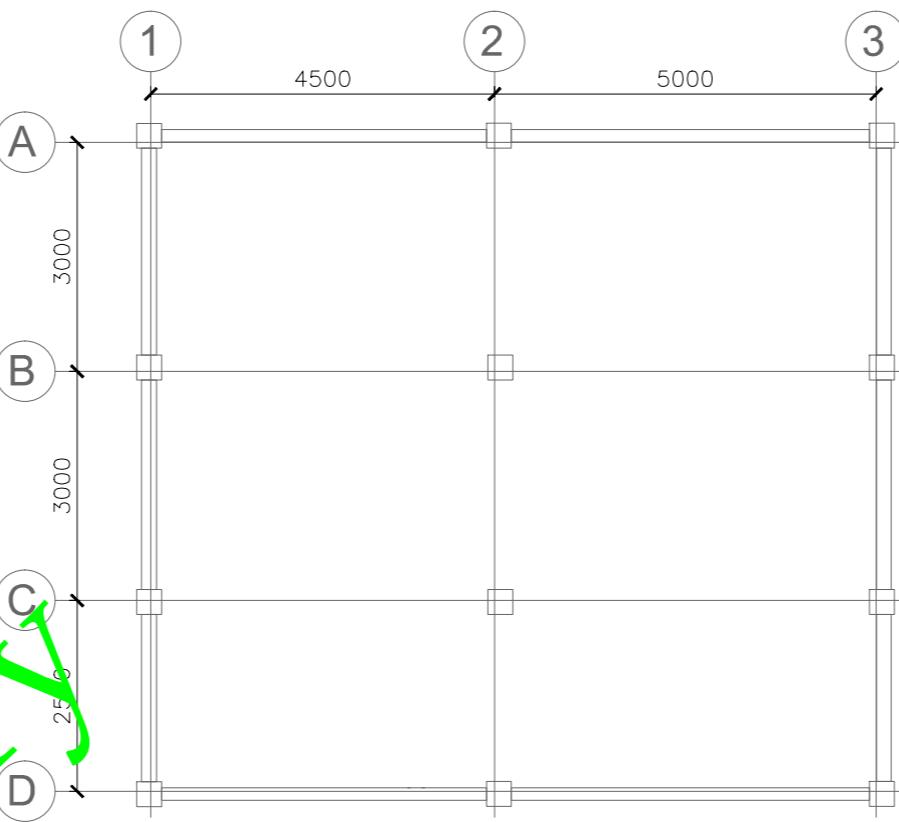
AS-BUILT DRAWING

PROJECT TITLE:	CONSULTANCY SERVICES FOR THE ENGINEERING, PROCUREMENT AND CONSTRUCTION MANAGEMENT FOR THE LA MESA TREATMENT PLANT 2 PROCESS IMPROVEMENT WORKS		
LOCATION:	MAYNILAD – AYALA SOUTHVALE		
SHEET CONTENT:	FDAS AND FEX LOCATION PLAN FIRE EXTINGUISHER INSTALLATION PLAN		
SCALE:	CONTRACT NO. OP18REFCS03-ASV-EE01-FDAS	SHEET NO. 01 OF 01	REV. 00

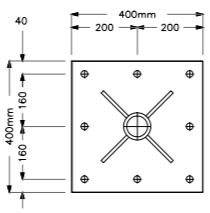
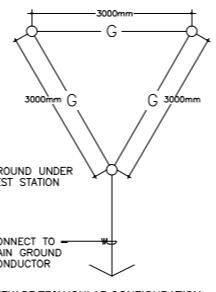
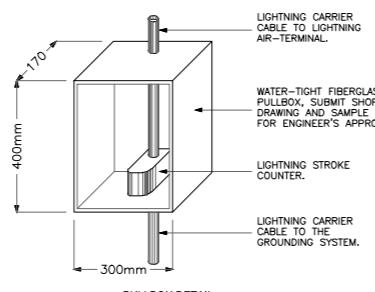
Approved :
 Project Manager

DESIGN UNIT
ENGR. MARITES R. PANGILINAN
 VP-OPERATIONS
 DESIGN SECTION

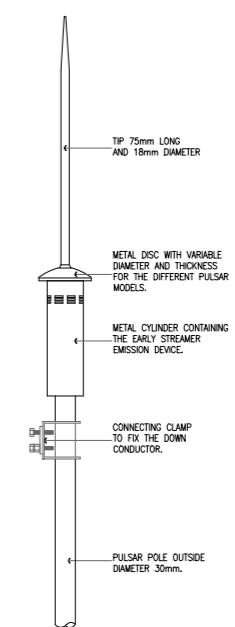
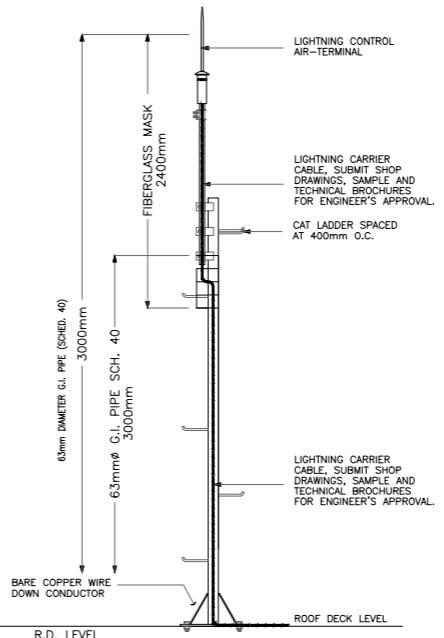
Preliminary



1 ROOF DECK PLAN
EE-02



STEEL BASE DETAIL

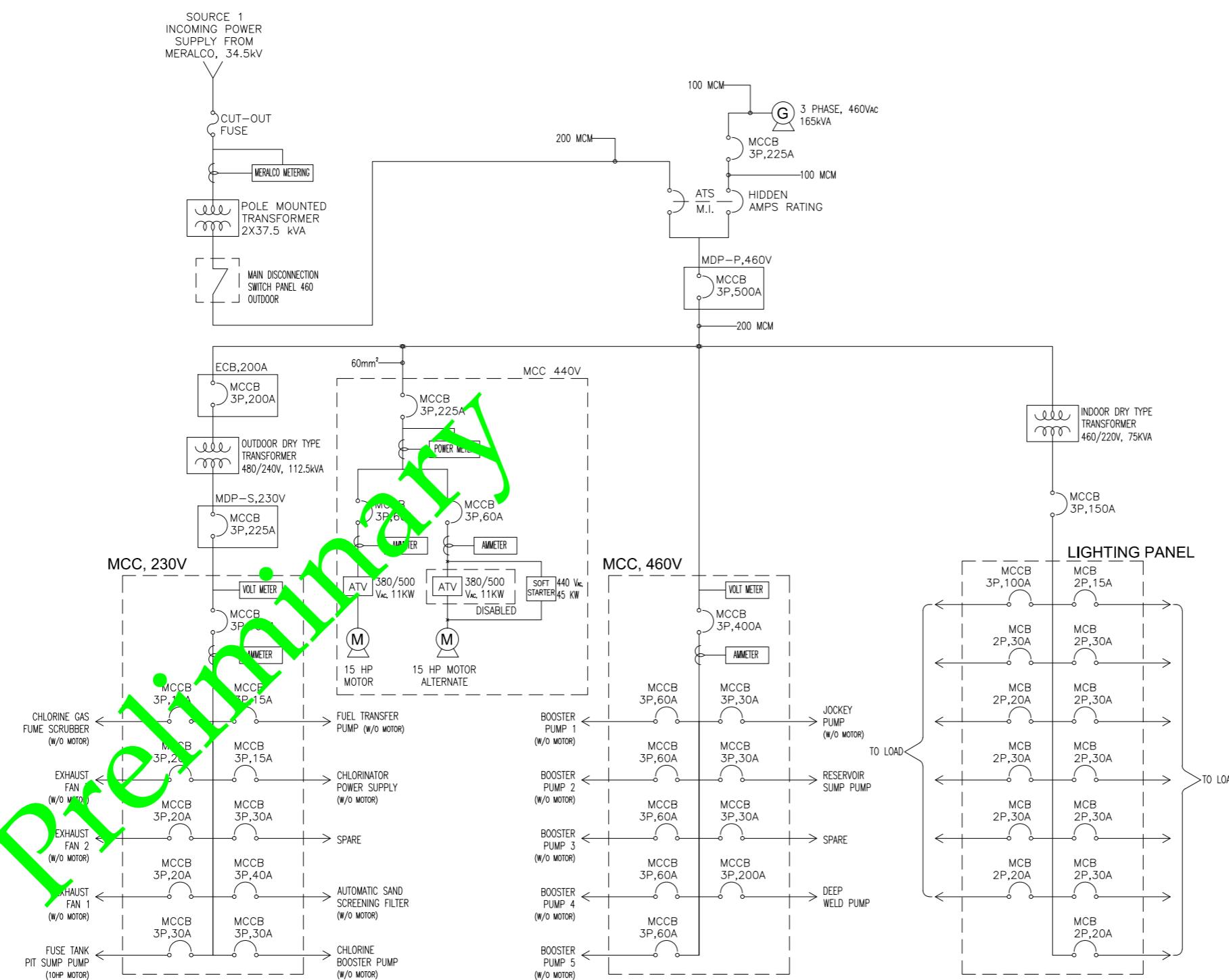


CONFORME:	CONFORME:
HEAD, Division (End User)	HEAD, Department (End User)

2
EE-02

PROPOSED LIGHTNING PROTECTION SYSTEM

DRAWN SURVEYED DESIGNED CHECKED				Checked & Certified :		CONCEPTUAL DRAWING	
				ENGR. MARITES R. PANGILINAN Professional Electrical Engineer		11/F Alphaland Southgate Tower 2258 Chino Roces Ave corner EDSA Makati City 1232 Philippines T 63 2 479 5600 F 63 2 479 5601 E mnmail@ghd.com W www.ghd.com	
REVISION							
REV	DATE	BY	APPROVED BY	PROFESSION : PTR :	Approved :	DESIGN UNIT	LOCATION: MAYNILAD – AYALA SOUTHVALE
				REGISTRATION NO. : DATE ISSUED :			SHEET CONTENT: ROOF DECK PLAN PROPOSED LIGHTNING PROTECTION SYSTEM
				TIN : PLACE ISSUED :	Project Manager	ENGR. MARITES R. PANGILINAN VP-OPERATIONS	SCALE: CONTRACT NO. OP18REFCS03-ASV-EE02-LA SHEET NO. 01 OF 01 REV. 00



LEGEND:

- (G) - GENERATOR SET
- (M) - MOTOR
- (PM) - POWER METER
- (MCC) - MOTOR CONTROL CENTER
- (ATS) - AUTOMATIC TRANSFER SWITCH
- (VFD) - VARIABLE FREQUENCY DRIVE

1
SCHEMATIC DIAGRAM

Maynilad	Maynilad		
CONFORME:	CONFORME:		
HEAD, Division (End User)	HEAD, Department (End User)		
DRAWN	SURVEYED	DESIGNED	CHECKED
REVISION			
REV	DATE	BY	APPROVED BY

1
EE-03

Checked & Certified :
ENGR. MARITES R. PANGILINAN
Professional Electrical Engineer



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ALTERNATIVE POWER
SOLUTIONS, INC.
1421 LIBRAZA AVENUE STREET PANDACAN MANILA
TEL 02 403201 TEL 02 403201

AS-BUILT DRAWING

PROJECT TITLE:	CONSULTANCY SERVICES FOR THE ENGINEERING, PROCUREMENT AND CONSTRUCTION MANAGEMENT FOR THE LA MESA TREATMENT PLANT 2 PROCESS IMPROVEMENT WORKS		
LOCATION:	MAYNILAD – AYALA SOUTHVALE		
SHEET CONTENT:	SCHEMATIC DIAGRAM		
SCALE:	CONTRACT NO. OP18REFCS03-ASV-EE03-SD	SHEET NO. 01 OF 01	REV. 00

Appendix F

Bill of Quantity

Preliminary

Bill of Quantity

No.	Description	Items	CAT	CS	IT	Unit Cost	Quan.	Unit	Total	Remarks
A	FDAS									
1	Fire alarm control Panel						1	set	-	
2	Smoke Detectors		F	5	4	2,160.00	7	units	15,120.00	
3	Heat Detectors		F	5	4	1,620.00		units	-	
4	Manual Pull Station		F	5	4	1,890.00	3	units	5,670.00	
5	Horn Strobe Annunciator		F	5	4	2,700.00	1	units	2,700.00	
6	Twisted Pair wire 2.5mm ²		F	5	4	108.00	60	lm	6,480.00	
7	20mmØ IMC pipe		F	5	4	540.00	15	lm	8,100.00	
8	Locknut and Bushing		F	5	4	10,000.00	1	lot	10,000.00	
9	15mmØ FMC Conduit		F	5	4	10,000.00	1	lot	10,000.00	
10	FMC Connectors		F	5	4	1,890.00	1	pcs	1,890.00	
11	Junction Box		F	5	4	2,160.00	1	pcs	2,160.00	
12	Hangers and Supports		F	5	4	2,000.00	1	lot	2,000.00	
13	Testing and Commissioning		F	5	4	10,000.00	1	lot	10,000.00	
B	Mechanical									
1	Installations for Instrumentation/Controls	SCADA integration (Total and individual kW, V, A, PF, eff, data logger and organizer)	M	-	6	-		1 lot	10,000,000.00	Refer to conceptual design
2		PLC integration	M	-	6					
3		Flow meter at mains	M	-	6					
4		Flow meter at branches (per pump)	M	-	6					
5		Pressure gauge and transmitter mains	M	-	6					
6		Pressure gauge and transmitter branch	M	-	6					
7		Vibration monitoring probes	M	-	6					
8		Motor Wind temperature sensor	M	-	6					
9		Thermodynamic efficiency device	M	-	6					
10		Motorization of Discharge isolation valve	M	-	6					
11		MOV position sensor and actuator	M	-	6					
12		Reservoir water level meter	M	-	6					
13		Chlorine tank level meter	M	-	6					
14		Chlorine dosage monitoring device	M	-	6					
15		VFD upgrade	M	-	6					
16	Pump performance	Pump Reconditioning	M	-	1		1	lot	2,000,000.00	See vibration analysis recommendations. Immediate attention required
17		Automatic pump lubrication system upgrade	M	-	6	80,000.00	8	point	640,000.00	
18		Replace existing motor with new high efficiency motors	E	-	3				200,000.00	
19	Building layout reconfiguration	Pump house layout reconfiguration	M	-	4				2,500,000.00	Improve space utilization
20		Control center and operator room refurbishing	M	-	4				1,000,000.00	Ergonomically sound Pump Station for Operator's Welfare
21	Pipe and fitting reconfiguration and refurbishing	Adjustment of pump positions	M	-	4	-		1 lot	3,000,000.00	Refer to conceptual design
22		Provision of straight pipe at suction side of pumps and use of eccentric FCW reducer	M	-	4					
23		Relocation of valves: BV at suction and discharge side only	M	-	4					
24		Removal of redundancy between FJ and STC (remove STC return in FJ)	M	-	4					
25		Modification of suction take off line int Y-connection (preferably at 45deg)	M	-	4					
26		Replacement of defective dial pressure gauges	M	-	4					
27		Replacement of defective valves	M	-	4					
28		Refurbishment of corroded areas and cleaning of clogged orifices	M	-	4					
29		Installation of pressure gauges at desirable points near pump	M	-	4					Refer to conceptual design
30	Rehabilitation of machine foundation	Single main slab with each baseplate mounted spaced accordingly	M	-	4	-		1 lot	1,000,000.00	Refer to conceptual design
31		Replace existing mounting with appropriate pump baseplate	M	-	4					Refer to conceptual design. Follow proper installation (sequence, alignment, etc.)
32	Condition monitoring	Regular vibration analysis		-	7	10,000.00	4	pump	500,000.00	Cost considered is for long term monitoring at regular interval
33	Reliability	Installation of additional pump (with corresponding pipes, fittings, labor and monitoring devices)	M	-	6	-	1	lot	1,000,000.00	
34	Reservoir leakage	Additional recommendation on the reservoir (analysis and investigation regarding the structural integrity and cause of leakage, provide recommendations to the problem)	M	-	1	-	1	lot	500,000.00	For analysis and investigation, rehabilitation cost not yet included
d	Lighting	Installation of lights for pump vicinity and reservoir	M	-	6	-	1	lot	100,000.00	

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date

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