RESIDUAL LIFE ANALYSIS FOR TRANSFORMER

BY

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Laxmi Associates

Transformer Remaining Life Assessment Report			
Project	**: RLA of Transformer**	**Client**	**: Reliance Industries Ltd**
Rating	**: 53 MVA, 220/34.5 kV**	**Sr. No.**	**: B-29391**
Location	**: DTA CPP PLANT**	**Date**	**: 24-12-2018**

Report Title : Residual Life Assessment for Transformer

Client : Reliance Industries Ltd., Jamnagar

Test witnessed by : Mr. Vinod Dhokia

Report version : Final

Reliance – Jamnagar

Field Test Conducted by

Mr. Dharmendra Chaudhary
Testing & Commissioning Engg.

Remaining Life Assessed by

Dr. Aradhana Ray,
Engineering Consultant

Report Reviewed By

Dr. Aradhana Ray,
Engineering Consultant

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Summary:

This residual life analysis of Transformer is divided into four following stages

1. Engineering Analysis
2. Field/Lab tests
3. External inspections
4. Life and risk of failure assessment

Stage	Activity Description	Purpose
1	**Engineering Analysis**	**Reviewing historical condition**
	Winding Insulation loss of life calculation	Estimate the loss of life of the paper insulation based on operating conditions
2 a	**Field Electrical Test**	**Reconfirm / verify the electrical characteristics**
	Overall winding Insulation tests (IR &Tan delta)	Measure deterioration of overall insulation (winding to ground and inter winding)
	Bushing Tests	Measure condition of bushing insulation
	No Excitation current tests	Measure condition of inter turn insulation, core and LTC system
	Turns Ratio test	Identify the defect in inter winding insulation and LTC
	Winding Resistance test	Evaluate the continuity condition of the winding conductor
	Short circuit impedance & Leakage reactance test	Evaluate the winding deformation
	Sweep Frequency Response Analysis	Evaluate the winding deformation , mechanical and electrical condition of winding and core
2 b	**Lab Tests**	**Reconfirm / verify the physical and chemical characteristics**
	Dissolved Gas Analysis	Evaluate possible fault conditions
	Full Oil quality screen test	Physical and chemical condition of oil
	Evaluation of Cellulosic material by Furan test	Estimate the paper aging
3	**Visual Inspection**	**Verify the condition of visible components and construction**
	External inspection	Identify broken or deteriorated exterior components
4	**Life and Risk of Failure assessment**	**Evaluate the overall condition in key areas based on data from stages 1, 2 and 3**

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This report mentioned about the complete condition assessment of transformer as mentioned below.

Findings:

✓ Visual Inspection	- Found normal
✓ Magnetizing Current Test	- Found normal
✓ Tan delta and Capacitance test	- **Found normal**
✓ Winding Resistance test	- Found normal
✓ Turns Ratio test	- Found normal
✓ Sweep Frequency Response Analysis	- Found normal
✓ Dielectric aging assessment (Frequency Domain Spectroscopy)	**- Found normal**
✓ Short circuit impedance test	-Found normal
✓ Moisture assessment	**- Moderate Wet**
✓ Magnetic Balance test	-Found normal
✓ DGA Analysis	-Found normal
✓ Furan Analysis	-Found normal
✓ Oil Routine test	-Found normal

Condition assessment :

Mechanical condition of Core and winding assembly: Normal aging profile

Dielectric condition of Overall insulation: Normal aging profile

Thermal condition of oil and winding assembly: Normal aging profile

The overall assessment of transformer health is as summarized below:

- The Tan delta values in GST & UST mode for HV and LV windings are **Marginally high** for this type of rating and age of Transformer**.**
- Average moisture content absorbed by cellulose insulation indicate **moderate wet** insulation, for this type of age, rating and application of Transformer. Note that moisture reduces the breakdown strength of paper and has direct impact on life of transformer.
- The IR & PI values are within acceptable limits and it indicates the normal aging of oil-paper insulation.
- The variation in measured voltage ratio is found to be within 0.5% , when compared to designed rated value indicated on nameplate and hence the results are found OK as per IEEE Standard 62: 1995 and is thus acceptable.

- Capacitance and SFRA test indicate no abnormality in mechanical condition of Core & winding assembly inside the transformer.
- Magnetizing current data is also indicating that electrical condition of Transformer is okay.
- Winding resistance measurements indicate normal data when compared on three phase basis. The unbalance in winding resistances for HV & LV winding is not exceeding the permissible limit of 5 % as specified by IEEE Standard 62: 1995 and is thus acceptable.
- All the oil routine test results are within the limits as prescribed in the IEEE Std C57.106-2002, and it indicate normal aging of oil.
- The total combustible gas limits are within the permissible range as specified under "Condition 1" of Total Dissolved Key Gas Concentration analysis specified by IEEE C57-104-2008.
- The Furan content is NIL.
- The tan delta values as measured in UST mode are mainly concerned with the Insulation of the HV Core insulation of Bushing (C1). The tan delta values of C1 as measured for U, V & W phase HV & LV Bushings are normal (less than 0.5 %) and it indicate normal aging of insulation.
- Variation of Tan delta with change in frequency indicate normal aging profile of U, V, W-phase and Neutral Bushings.
- The short circuit current and Impedance is comparable among three phases & the results are found acceptable as per IEEE Standard 62: 1995.

Recommendation:

Based on above observed results and information available, following points shall be noted:

- Oil quality is good .
- All Electrical tests indicate that transformer is working satisfactorily.
- Oil Sample for DGA test should be taken on Yearly basis, to monitor if any further rise in gas content is there.

- Moisture content of Insulation should be monitored after three years to see any further gradual rise of moisture content is there in Insulation.

- Tan delta and Capacitance Monitoring of HV Bushing is required on Annual basis, as the Bushing reliability has to be insured for future operation.

Overall performance of this **21 year old transformer is satisfactory for normal operation in the system.**

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1.0 Introduction:

The **RIL-Jamnagar** planned to do life assessment of Power transformer. The background for this plan is, the transformer in plant has been in service since **21 years and Life assessment of Power Transformer was necessary.**

To carry out this task, planned shutdown schedules were made for Transformer. Our testing team carried out all field testing both online and offline. Based on field test reports, historical information, temperature and loading profile the remaining life of this transformer is evaluated.

This document describes the detailed assessment and various tests done in the **53 MVA Power Transformers.**

2.0 Scope of work:

To carry out remaining life assessment in Transformers by conducting a detail study about the present condition. These analyses have to be made by conducting an evaluation based on the various tests carried out and historical information like temperature and loading profile.

3.0 Reference:

The residual life analysis on power transformer evaluated in reference with the following standards and publications.

IEEE.62.1995. IEEE Guide for diagnostic field testing of electric power apparatus Part-1: Oil filled Power transformers, Regulators and Reactors.

IEEE Std C57.12.90-1999.IEEE Standard test code for liquid immersed distribution power and regulating transformer

IEEE Std C57-104-1991.IEEEGuide for the detection and determination of generated gas in oil-immersed transformers and their relation to the serviceability of the equipment.

IEEE Std C57-106-2002.IEEE Guide for acceptance and maintenance of insulating oil in equipment

IEEE Std C57.91-1995.IEEE Guide for loading mineral oil immersed transformers

IEC 60450-1974 Measurement of the average viscometric degree of polymerization of new and aged cellulosic electrically insulating materials

4.0 Instruments used:

Sl. No.	Instrument	Make	Instrument Sr. No.	Date of Calibration	Calibration due on
1	Resistance Meter	OMICRON	SE639Y	06-08-2018	05-08-2019
2	Tan delta	OMICRON	SE639Y	06-08-2018	05-08-2019
3	Ratio Meter	OMICRON	SE639Y	06-08-2018	05-08-2019
4	Digital Megger	KYORITSU	3616028	09-01-2018	08-01-2019
5	Sweep Frequency Response Analyzer	MEGGER	1400754	22-06-2018	21-06-2019
6	IDAX – DIRANA	MEGGER	1800711	25-04-2018	24-04-2019
7	Oil testing for Furan at GEL	GEL	-	-	-

5.0 Name Plate Details:

Company	RIL	**Serial Number**	B-29391
Location	Jamnagar	**Special ID (Tag No.)**	ET-RU772-06
Manufacturer	GEC Alstom	**Vector Group**	YNyn0
Yr. Manufactured	1997	**Phases**	3
kV	220/34.5	**MVA**	53

6.0. Test Data:

6.1. Off-line test data

6.1.1. Visual Inspection

Sl. No	Description	Observation
1	Check the equipment is cleaned and insulators are free from dust/dirt etc	OK
2	Check any Oil Leakage	OK
3	Check that Earthing has been properly done and connected to the Earthing grid for the following.	OK
	a. Main Tank	OK
	b. Marshalling box	OK
4	Check the HV/LV Neutral is grounding properly, connected to two earth pits.	OK
5	Check Silica gel in the Main breather is active	Blue
6	Oil is filled in the oil cup of breather up to the level marked	OK
7	Check there is no oil leakage in Radiator side	OK
8	Check any Leakage found in Main Tank	OK
9	Check any Signs of Overheating	OK
10	Check the Oil Level in conservator	OK
11	Check the Gaskets or Seals, Leaks etc.	OK
12	Check the marshalling box wiring and condition	OK

6.1.2 Capacitance and Tan delta test

Tangent Delta and Capacitance Measurement of Transformer Winding:

In a two-winding transformer there are main three insulation zones: HV-TANK (CH) , HV-LV (CHL) , and LV-CORE (CL).

CH (HV to earth) :

The typical components of the space HV-TANK are the oil, oil-pressboard space, coil support insulation (situated between the bottom or top turn and the ground), high-voltage bushings and shunting insulation of leads, LTC, etc.

The main part of this insulation space is the oil. This insulation zone presents a good opportunity to identify the condition of the oil. The relatively small capacitance of the coil support insulation, bushings and shunting insulation components allows us to detect only severe defects in these components. Thus, the main goal of the measurements in the zone HV-TANK is to determine the condition of the oil and to detect severe defects in the other components.

CHL (HV to LV):

The inter winding space includes component: oil-pressboard space . The composition of the space allows us to detect and identify the condition of the pressboard barriers as well as of the oil. This is the only space where one can practically estimate water content in the pressboard.

CL (LV to earth):

The typical components of the LV-CORE space are: oil-pressboard space, coil support insulation, shunting insulation of the leads, LTC, LV bushings, etc. This space is the least useful in evaluating the condition of the solid insulation. The main goal of the measurements in the space LV-CORE is the detection of severe surface contamination or significant local moisture concentration in the insulation components, etc.

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Test Data Analysis:

I. Tangent Delta and Capacitance Measurement of Transformer Winding:

OTI: 40°C

WINDING COMBINATION	VOLTAGE (kV)	TEST MODE	CAPACITANCE (nF)	TAN DELTA (%)
HV/LV	2	UST	6.03192	0.7263
	5		6.03162	0.7265
	10		6.03156	0.7315
HV/ground with LV Guard	2	GST-g	4.90630	0.4149
	5		4.90613	0.4159
	10		4.90596	0.4182
HV/LV+Ground	2	GST	10.9381	0.5856
	5		10.9375	0.5876
	10		10.9375	0.5904
LV/HV	2	UST	6.0323	0.7242
	5		6.0319	0.7268
	10		6.0317	0.7303
LV/ground with HV Guard	2	GST-g	12.1693	0.7839
	5		12.1693	0.7959
	10		12.1711	0.8182
LV/HV Ground	2	GST	18.2020	0.7672
	5		18.2025	0.7753
	10		18.2046	0.7908

REMARKS:

- ✓ The tan delta values measured in UST mode are mainly concerned with the Insulation of the HV winding and LV winding. These values are **Marginally high** for HV voltage rating Transformer.
- ✓ The tan delta values in GST mode takes all currents that flow to ground into consideration and the dielectric losses are high compared to UST mode. These values are **Marginally high** for HV voltage rating Transformer.

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II. Tangent Delta and Capacitance Measurement of Transformer Bushing:

Bushing	Applied Voltage (kV)	Capacitance (pF)	Tan Delta (%)
Phase: 1U Make: GE Sr.No: 37997006674	2	414.439	0.2105
	5	414.348	0.2112
	10	414.337	0.2105
	1	1105.39	0.2462
Phase: 1V Make: GE Sr.No: 37997010498	2	408.249	0.2314
	5	408.235	0.2329
	10	408.266	0.2325
	1	1121.12	0.2464
Phase: 1W Make: GE Sr.No: 37997006672	2	409.744	0.2103
	5	409.754	0.2113
	10	409.750	0.2112
	1	1068.30	0.1859
Phase: 1N Make: BHEL Sr.No: 9749714	2	277.653	0.4024
	5	277.652	0.4069
	10	277.654	0.3978
	1	272.548	0.5207

III. Variable Frequency Tangent Delta Measurement of Bushings:

Applied Voltage (kV)	Frequency (Hz)	37997006674 1U-Phase		37997010498 1V-Phase		37997006672 1W-Phase		9749714 1N – Neutral	
		Capacitance (pF)	Tan Delta (%)	Capacitance (pF)	Tan Delta (%)	Capacitance (pF)	Tan Delta (%)	Capacitance (pF)	Tan Delta (%)
3.6	17	414.927	0.1998	408.758	0.2637	410.337	0.2016	278.307	0.3325
	34	414.536	0.2062	408.386	0.2402	409.974	0.2077	277.908	0.3764
	68	414.163	0.2141	407.921	0.2296	409.571	0.2142	277.448	0.4228
	85	414.014	0.2168	407.828	0.2291	409.461	0.2166	277.291	0.4591
	102	413.948	0.2188	407.729	0.2284	409.347	0.2187	277.156	0.4756
	119	413.862	0.2206	407.866	0.2282	409.266	0.2203	277.038	0.4882
	136	413.790	0.2226	407.791	0.2285	409.192	0.2216	276.931	0.5003
	187	413.607	0.2260	407.616	0.2292	409.008	0.2250	276.669	0.5138
	255	413.417	0.2311	407.436	0.2319	408.831	0.2295	276.394	0.5409
	323	413.295	0.2353	407.299	0.2348	408.694	0.2334	276.173	0.5624
	391	413.180	0.2417	407.181	0.2399	408.585	0.2392	275.987	0.5783

6.1.3 Turns Ratio test:

HV/LV

Tap No.	MEASURED RATIO			CALCULATED RATIO	%DEVIATION		
	1U – 1N/ 2U -2N	1V – 1N/ 2V – 2N	1W – 1N/ 2W – 2N		U	V	W
1	7.3336	7.3338	7.3333	7.3333	0.00	-0.01	0.00
2	7.2489	7.2486	7.2489	7.2536	0.06	0.07	0.06
3	7.1731	7.1732	7.1727	7.1739	0.01	0.01	0.02
4	7.0890	7.0888	7.0888	7.0942	0.07	0.08	0.08
5	7.0129	7.0123	7.0124	7.0145	0.02	0.03	0.03
6	6.9279	6.9279	6.9275	6.9348	0.10	0.10	0.11
7	6.8524	6.8522	6.8524	6.8551	0.04	0.04	0.04
8	6.7675	6.7672	6.7668	6.7754	0.12	0.12	0.13
9	6.6916	6.6922	6.6920	6.6957	0.06	0.05	0.06
10	6.6069	6.6068	6.6068	6.6159	0.14	0.14	0.14
11	6.5313	6.5308	6.5311	6.5362	0.07	0.08	0.08
12	6.4460	6.4463	6.4464	6.4565	0.16	0.16	0.16
13	6.3711	6.3706	6.3708	6.3768	0.09	0.10	0.09
14	6.2855	6.2851	6.2852	6.2971	0.18	0.19	0.19
15	6.2102	6.2101	6.2103	6.2174	0.12	0.12	0.11
16	6.1258	6.1257	6.1255	6.1377	0.19	0.20	0.20
17	6.0502	6.0497	6.0499	6.0580	0.13	0.14	0.13
18	5.9647	5.9650	5.9646	5.9783	0.23	0.22	0.23
19	5.8895	5.8896	5.8896	5.8986	0.15	0.15	0.15
20	5.8046	5.8043	5.8047	5.8188	0.24	0.25	0.24
21	5.7287	5.7291	5.7289	5.7391	0.18	0.17	0.18

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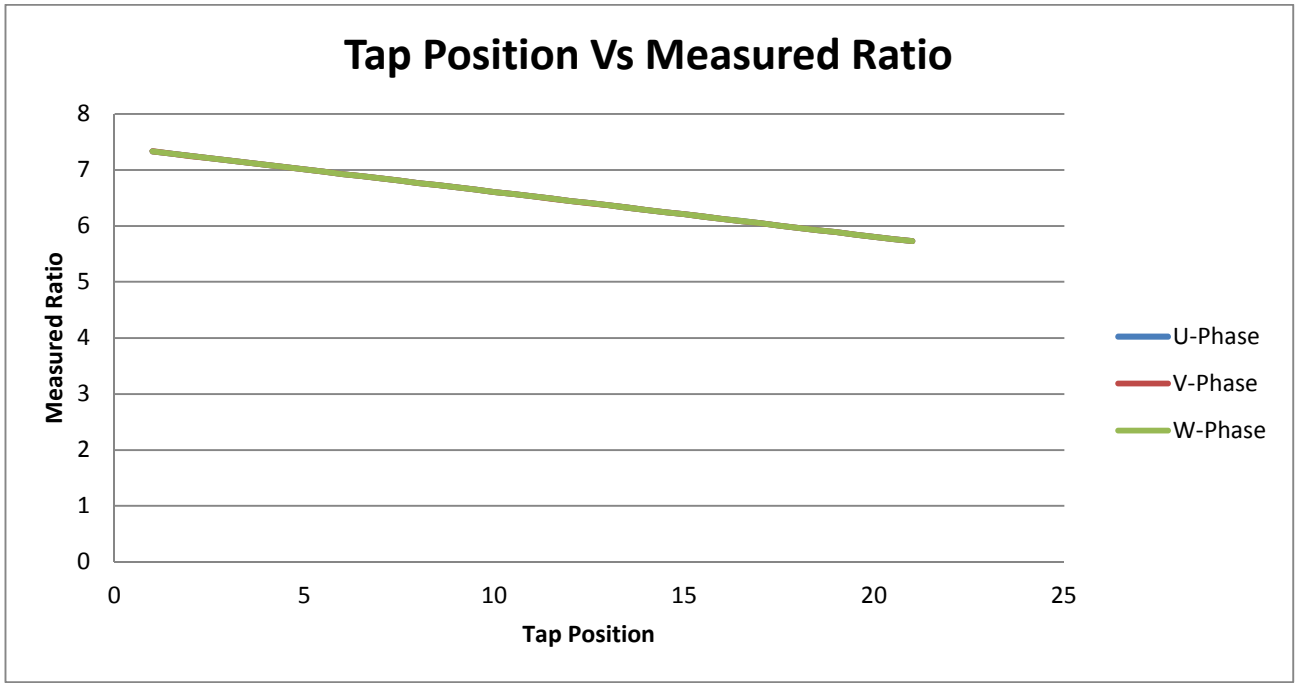
PLOT: Tap Position Vs Measured Ratio



REMARKS:

The variation in measured voltage ratio is found to be within 0.5% , when compared to designed rated value indicated on nameplate and hence the results are found OK as per IEEE Standard 62: 1995 and is thus acceptable.

6.1.4 No Load excitation current test:

Applied 1 Phase on HV Side and Current measured in HV. (LV Side kept Open)

TAP POS.	Voltage Applied HV Side (Volts)			Measured Current (mA)		
	1U – 1N	1V – 1N	1W – 1N	1U	1V	1W
13	230	230	230	1.1189	0.8250	1.0261
	440	440	440	1.6310	1.1500	1.5104
	2000	2000	2000	4.4120	2.9470	4.1110
	5000	5000	5000	8.5779	5.6390	8.0750
	10000	10000	10000	14.497	9.4886	13.753

Applied voltage on LV Side and Current measured in LV. (HV Side kept Open)

TAP POS.	Voltage Applied LV Side (Volts)			Measured Current (mA)		
	2U – 2N	2V – 2N	2W– 2N	2U	2V	2W
13	230	230	230	21.215	14.543	20.127
	440	440	440	34.345	22.900	32.530

6.1.5 Winding Resistance test:

Note: OTI Temp: 38°C

HV Side Winding Resistance:

Tap No.	1U – 1N (Ω)	1U – 1N (Ω)	1V – 1N (Ω)	1V – 1N (Ω)	1W – 1N (Ω)	1W – 1N (Ω)
	R@38°C	R@75°C	R@38°C	R@75°C	R@38°C	R@75°C
1	1.2577	1.4282	1.2596	1.4303	1.2639	1.4352
2	1.2357	1.4032	1.2382	1.4060	1.2416	1.4099
3	1.2157	1.3805	1.2131	1.3775	1.2219	1.3875
4	1.1940	1.3558	1.1968	1.3590	1.2001	1.3628
5	1.1743	1.3335	1.1768	1.3363	1.1803	1.3403
6	1.1526	1.3088	1.1554	1.3120	1.1585	1.3155
7	1.1329	1.2864	1.1353	1.2892	1.1387	1.2930
8	1.1109	1.2615	1.1158	1.2670	1.1170	1.2684
9	1.0908	1.2386	1.0937	1.2419	1.0970	1.2457
10	1.0689	1.2138	1.0722	1.2175	1.0752	1.2209
11	1.0483	1.1904	1.0509	1.1933	1.0531	1.1958
12	1.0716	1.2168	1.0749	1.2206	1.0776	1.2236
13	1.0910	1.2389	1.0938	1.2420	1.0971	1.2458
14	1.1134	1.2643	1.1163	1.2676	1.1198	1.2716
15	1.1327	1.2862	1.1353	1.2892	1.1389	1.2933
16	1.1552	1.3118	1.1578	1.3147	1.1616	1.3190
17	1.1745	1.3337	1.1768	1.3363	1.1807	1.3407
18	1.1969	1.3591	1.1994	1.3620	1.2032	1.3663
19	1.2162	1.3810	1.2181	1.3832	1.2222	1.3878
20	1.2387	1.4066	1.2408	1.4090	1.2446	1.4133
21	1.2547	1.4248	1.2597	1.4304	1.2637	1.4350

LV Side Winding Resistance:

Tap No.	2U – 2N Res (mΩ)	2U – 2N Res (mΩ)	2V – 2N Res (mΩ)	2V – 2N Res (mΩ)	2W – 2N Res (mΩ)	2W – 2N Res (mΩ)
-	R@38°C	R@75°C	R@38°C	R@75°C	R@38°C	R@75°C
	21.15	24.02	21.06	23.91	21.03	23.90

Formula for Calculating Resistance@ 75 C = ((235+75)/(235+Measured Temp)) x Resistance @ Measured Temp.

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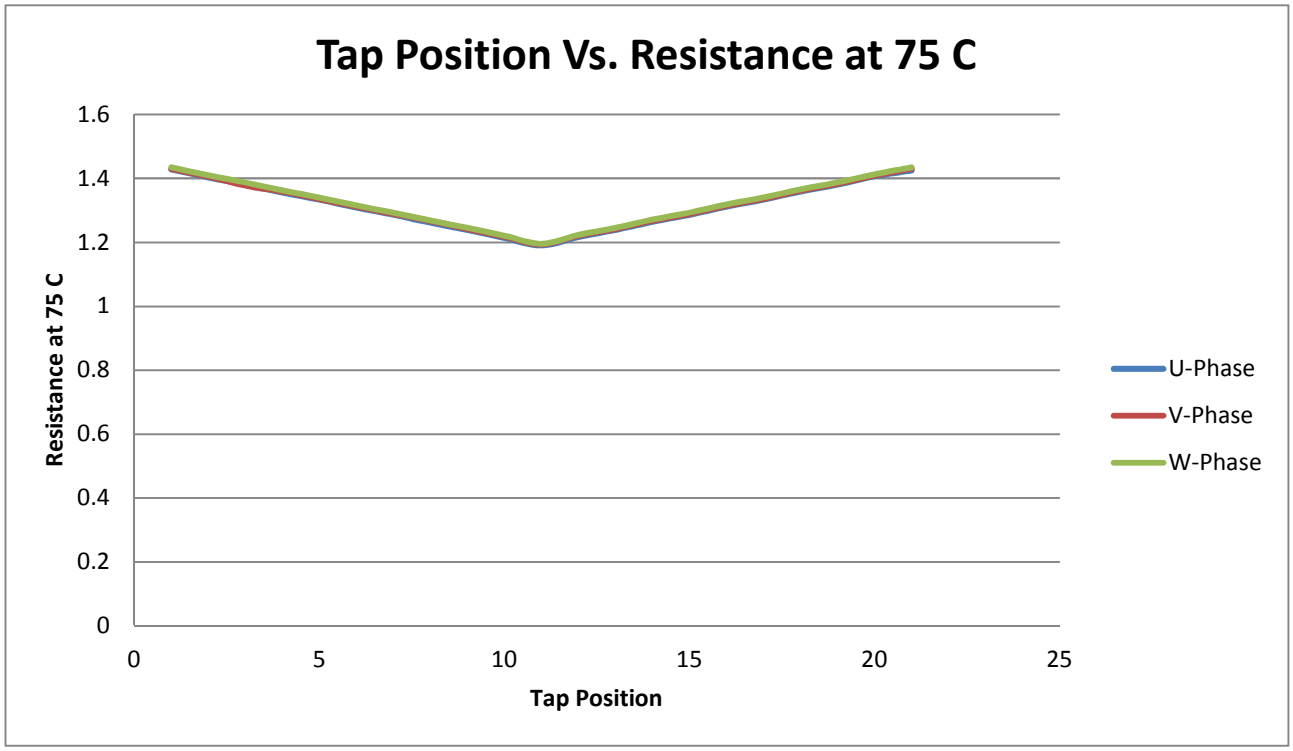
PLOT: Tap Position Vs Resistance at 75°C



REMARKS: The unbalance in winding resistances for HV & LV winding is within the permissible limit of 5 % as specified by IEEE Standard 62: 1995 and is thus acceptable

6.1.6 Insulation Resistance test:

When we carry out the Insulation resistance test the reading of IR is time dependent as the total current flowing in the circuit varies and is equal to the sum of the three components mentioned below.

1. Capacitive Charging current: is the initial surge of current that occurs when we apply DC voltage to a conductor insulation . Capacitive current starts high and then drops very fast and lasts only for a few seconds as the dc voltage is applied .

2. Polarization Absorption current: Starts high and then drops. Absorption current is caused by the polarization of molecules within dielectric material. In low-capacitance equipment, the current is high for the first few seconds and decreases slowly to nearly zero. Normally in one minute reading of IR the absorption current will be dominant for all insulation Bad or good. In case of wet and contaminated insulation, there will be no decrease in the absorption current for a long time and in 10 minute reading also these component are dominant and PI value will be lower.

3. Conductive Leakage current: also called "conduction current," is the steady flow of current through and on the insulation. No insulation is perfect; even new insulation will have some leakage current, albeit small. This leakage current will increase as the insulation ages. It also will worsen when the insulation is wet or contaminated.

The total current flowing in the circuit is equal to the sum of the components, when a DC voltage is applied. It starts at a relatively high value and then drops, settling at a value just slightly above the leakage current. In bad or deteriorated insulation, the total current will drop slowly, or may even increase.

Note: I) **PI** - Polarization Index = $\frac{\text{IR Value at 600 seconds}}{\text{IR Value at 60 seconds}}$

IR – It indicates status of insulation, however it fails to detect contamination and voids. Its absolute value is less important than continuous steep fall.

PI – It indicates dryness of insulation. Minimum value of Oil –Paper insulation should be 1.5.

OTI=38˚C
Applied 5kV

Test Connection	15 Sec.GΩ	1 Min. GΩ	10 Min.GΩ	PI (600s/60s)
HV/E	0.366	0.583	1.08	1.85
LV/E	0.296	0.670	1.45	2.16
HV/LV	0.450	0.627	1.94	3.09

- **Formula for Calculating PI (Polarization Index) = IR@ 600 Sec / IR@60 Sec**

REMARKS:

1. The IR & PI values are within acceptable limits and it indicates that the moisture content of oil-paper insulation is low.
2. There is no significant aging byproducts exists and aging profile is normal.

6.1.7 Magnetic Balance test:

1-phase supply Apply

TAP-13

Voltage Applied on HV Side

1U – 1N (Volt)	1V – 1N (Volt)	1W – 1N (Volt)
230	206.5	22.65
110.9	**230.1**	120.3
21.9	207.6	**230.1**

Voltage Applied on LV Side

2U – 2N (Volt)	2V – 2N (Volt)	2W – 2N (Volt)
230	188.4	42.95
112.3	**230.1**	117.6
39.38	192.0	**230.0**

6.1.8 Short Circuit Test:

3-Phase supply applied at HV Side, and Measured current at HV & LV Side. While LV Side kept shorted.

Tap No.	Applied Voltage (Volts)			Measured Current (Amp)			Isc(A)
	1U-1V	1V-1W	1U-1W	1U	1V	1W	
13	415.2	415.4	414.3	1.46	1.46	1.44	9.53

6.1.9 Sweep Frequency Response Analysis test:

Brief Description of SFRA:

The SFRA test involves measuring the frequency responses of each individual winding. The frequency response is measured by injecting a sine wave signal with respect to earth at one end of winding to be tested and measuring the signal amplitudes there and at other end of the winding as shown in Figure 2 . The attenuation (in dB) of the transmitted signal relative to reference signal at the input terminal is measured over a frequency range from 10 Hz to 2 MHz.

Measurement of Open circuit SFRA plot of winding:

Sr. No.	Test winding	SFRA connections
1	HV winding Open circuit SFRA plot **HV terminals- HV** **HV terminals- N**	Signal injected in "HV" bushing terminal with respect to earth and measured at "N" bushing terminal with respect to earth.
2	LV winding Open circuit SFRA plot **LV terminal - LV** **Neutral Terminal –N**	Signal injected in "LV" bushing Terminal with respect to earth and measured at "N" bushing terminal with respect to earth.

- All other bushings were floating and not connected to ground during the individual measurement. Measurements were carried out for tap no. 1.

Measurement of Short circuit SFRA plot of winding:

Sr. No.	Test winding	SFRA connections
1	HV winding Short circuit SFRA plot	Signal injected in "HV" and "N" bushing terminal with respect to earth and measured at phase bushing terminal with respect to earth. Terminal of LV winding was shorted for the test.

- All other bushings were floating and not connected to ground during the individual measurement.
- Measurement was carried out at tap no 1.

Figure 2: Circuit description of SFRA

PURPOSE:

- Assess Mechanical Condition of Transformers (Mechanical distortions)
- Detect Core and Winding Movement due to large electromagnetic forces from fault currents
- Winding Shrinkage causing release of clamping pressure
- Transformer Relocations or Shipping damages

The SFRA test is not required under normal operating conditions, but is recommended to be repeated over different time periods, if the transformer is subject to sudden load fluctuations or surges from external system or any short circuit faults.

REMARKS:

- **The SFRA plots are enclosed inAnnexure-1 of this report.**
- These plots are taken as initial signatures and may be compared with any SFRA measurements taken in future.
- For HV winding the SFRA Open and Short circuit plots are identical when compared on three phase basis, which indicates that there is no significant winding movement in this transformer as shown in Annexure 1.
- For LV winding also, the SFRA Open circuit plots are identical when compared on three phase basis, which indicates that there is no significant winding movement in the transformer as shown in Annexure 1.

6.1.10 Frequency Domain Spectroscopy (FDS) Analysis test:

Moisture Analysis of Transformer Insulation:

The dryness of the oil-paper insulation systems in power transformers is a key factor in both their short and long term reliability since moisture has deleterious effects on dielectric integrity and insulation ageing rates.

The dielectric frequency response analysis method, which is based on wide range measurements in time and frequency domains, is a useful tool to evaluate the moisture condition of the electrical insulation systems.

In the Dielectric method using the Frequency Domain Spectroscopy (FDS), the dissipation factor of the insulation system under test is measured by frequency sweep. The onsite measurement is considerably accelerated by a combination of time and frequency domain measurements. The frequency range from 1 kHz down to 0.1 Hz is measured in frequency domain, whereas the range from 0.1 Hz down to 0.1 mHz is measured in time domain.

A dielectric response measurement is a three terminal measurement that includes the output voltage, the sensed current and a guard as shown in Figure 2. The moisture analysis is obtained for the solid insulation between HV and LV winding separately as indicated in Table below.

Insulation	Moisture Content of inter winding insulation	Remark
HV-LV	2.3%	Moderately Wet

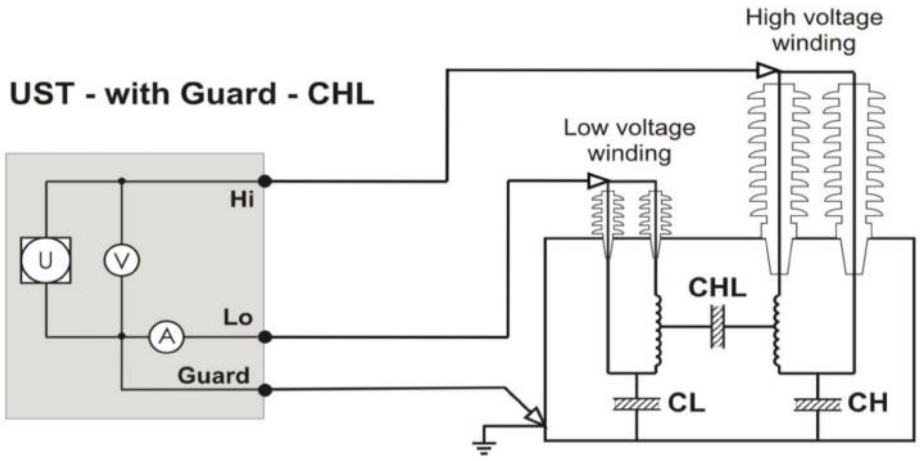


Figure 2: Schematic for UST connection of dielectric response measuring system to a transformer for CHL configuration

Transformer Remaining Life Assessment Report			
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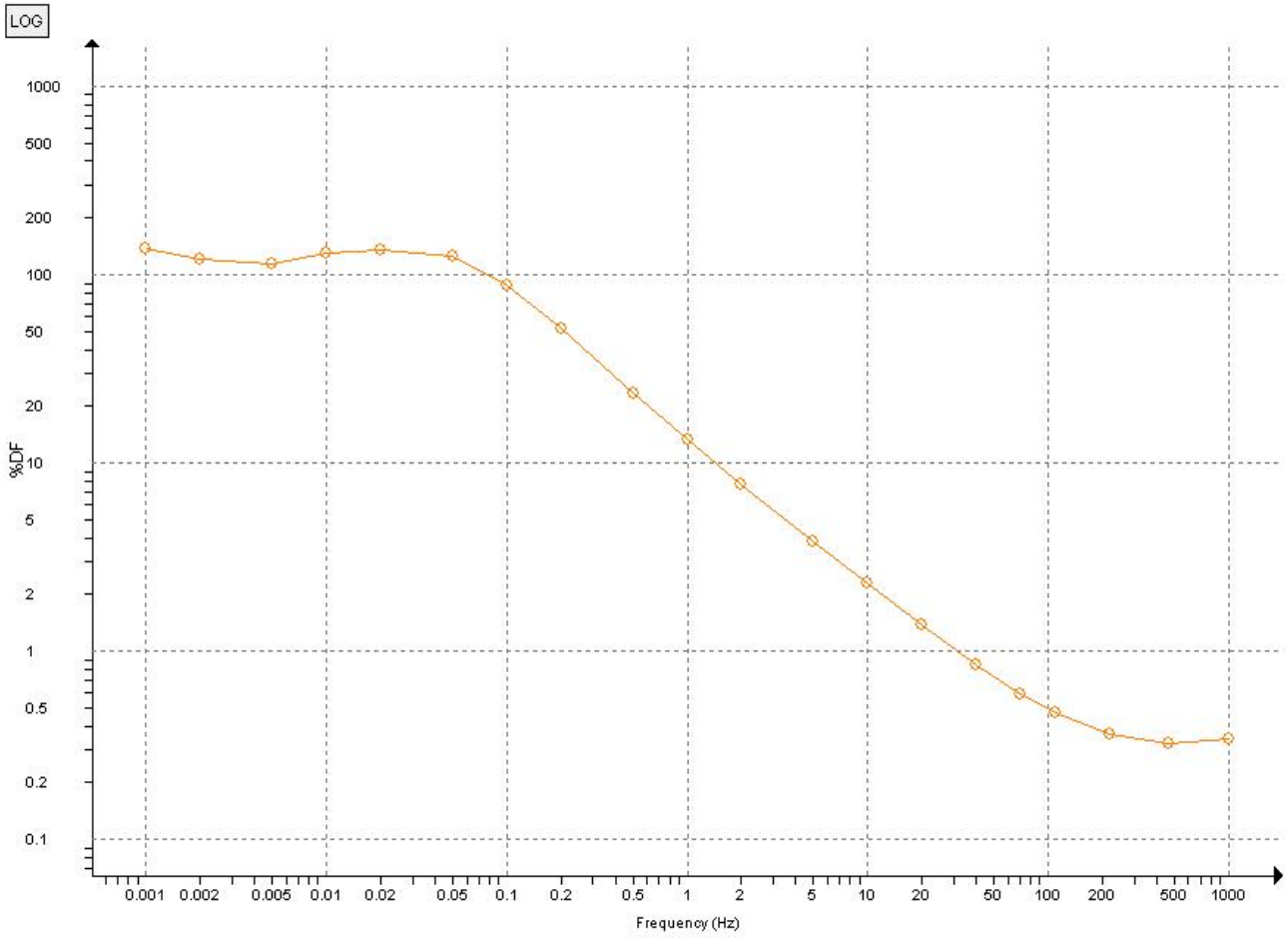
Moisture Assessment curve for CHL insulation measured by FDS+PDC combined method

Plot:



Remarks:

Moisture measurement by FDS+PDC method (DIRANA Test) indicates a Moderately Wet insulation (as per International Standards for in-service Auto Transformers). Note that moisture reduces the breakdown strength of paper and has direct impact on life of transformer.

6.2 On Line Test data:

6.2.1. Oil Analysis:

Sl No	Test Description	Test Method	Unit	Result	Requirement as per Specification
1	Breakdown Voltage	**IEC 60422**	KV	69	**30 KV Min**
2	Flash point	**IEC 60296**	-	161	**135°C Min**
3	Water Content	**IEC 60422**	ppm	3	**25 Max.**
4	Inter Facial Tension	**IEC 60422**	mN/m at 27◦c	37	**22 Min.**
5	Total Acid Number	**IEC 60422**	mgKOH/g	0.04	**0.3 Max.**
6	Sludge	**IEC 60422**	%Wt	N/D	**<0.02%**
7	Specific Resistivity at 90°C	**IEC 60666**	Ohm.cm	7 X 10^{12}	0.2 x 10^{12} Min
8	Dissipation Factor @90°C	**IEC 60422**	-	0.02	**0.5 Max.**
9	**Furan Analysis**	**IEC-61198: BS148**			
	5-hydroxy-methyl-2-furfuraldehyde		Ppm	NIL	
	2-furfural		Ppm	NIL	
	2-Acetyl furan		Ppm	NIL	
	5-methyl-2-furaldehyde		Ppm	NIL	
	2-furfuryl alcohol		Ppm	NIL	
	Total Furan		Ppm	NIL	5 ppm Max
10	**Dissolved Gas Analysis**	**IEEE-C57.104-2008**			
	Hydrogen H2		Ppm	9	100
	Methane CH4		Ppm	BDL	120
	Ethane C2H6		Ppm	BDL	65
	Ethylene C2H4		Ppm	BDL	50
	Acetelyne C2H2		Ppm	BDL	1
	Carbon Monoxide CO		Ppm	262	350
	Carbon Di Oxide CO2		Ppm	2255	2500
	Oxygen O2		Ppm	2181	-
	Nitrogen N2		Ppm	16621	-
	Propane+Propylene (C3H6+C3H8)		Ppm	BDL	-

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REMARKS: OIL ROUTINE TEST DATA

- All the results are within the limits as prescribed in the IEEE Std C57.106-2002.

REMARKS: DGA DATA

- The total combustible gas limits are within the permissible range as specified under "Condition 1" of Total Dissolved Key Gas Concentration analysis specified by IEEE C57-104-2008.

REMARKS: FURAN TEST DATA

- Furan content is NIL.

7.0 Historical Information:

The below Historical Information are all Gathered from Client.

Sr. No	Historical Information	Information gathered
1	All previous Oil routine tests, DGA, Furan data	No
2	List of maintenance history like bushing, OLTC & LA failure, repair, relocation.	No
3	Loading profile of transformer	<70 %
4	Oil processing, degassing, replacement history	No
5	Any major fault in the system, transformer has withstood	No
6	Copy of nameplate detail	Yes
7	All previous condition assessment data like Capacitance, PF, Leakage reactance, Resistance, Ratio, SFRA, No load excitation current test	No
8	Test data of sister units in the system if available	Yes
9	Any major internal failure and factory repair	No
10	Average Ambient	33 C
11	Outdoor Application	YES
12	Pollution level	Industrial
13	Bushings	OK
14	Tap Changer	OK
15	Surge Arresters	OK
16	Main Tank	
	➢ Bulged	NO
	➢ Cracked	NO
	➢ Leaks	NO
	➢ Signs of Overheating	NO
	➢ Oil Level in conservator	OK
	➢ Gas pressure on sealed Transformer	NO
	➢ Control Cabinet Problem	NO

8.0 Condition Assessment & Residual life assessment:

Mechanical condition of Core and winding assembly: Normal aging Profile

Dielectric condition of Overall insulation: Normal aging Profile

Thermal condition of oil and winding assembly: Normal aging Profile

There are three category of conditions :

- Good
- Normal- Within acceptable limit
- Abnormal

Assessment Criteria	Type of Diagnostic Test	Mechanical Condition	Dielectric Condition	Thermal Condition
Off- line diagnostic test	SFRA	Normal	Normal	
	Capacitance Test	Normal	Normal	
	No load excitation Test	Normal	Normal	
	Tan Delta test		Normal	Normal
	Insulation Resistance Measurement		Normal	Normal
	Winding resistance test		Normal	Normal
	Turns Ratio Test	Normal	Normal	
	Magnetic Balance test		Normal	Normal
	Short circuit test		Normal	Normal
	FDS Testing of Winding		Normal	Normal
On- line diagnostic test				
	Oil Routine Test		Normal	Normal
	DGA test		Normal	Normal
	Furan analysis		Normal	Normal
Visual Inspections	Main Tank	Normal	Not applicable	Not applicable
	Bushing	Normal	Not applicable	Not applicable
Overall Assessment		Normal	Normal	Normal

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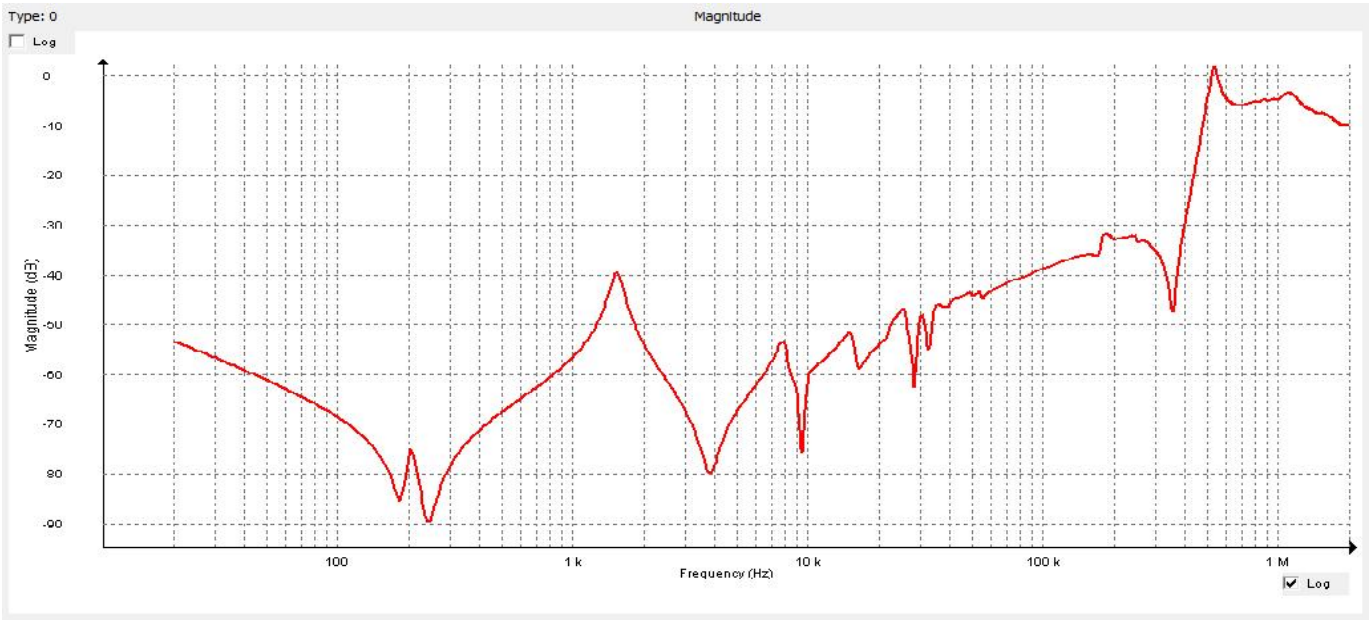
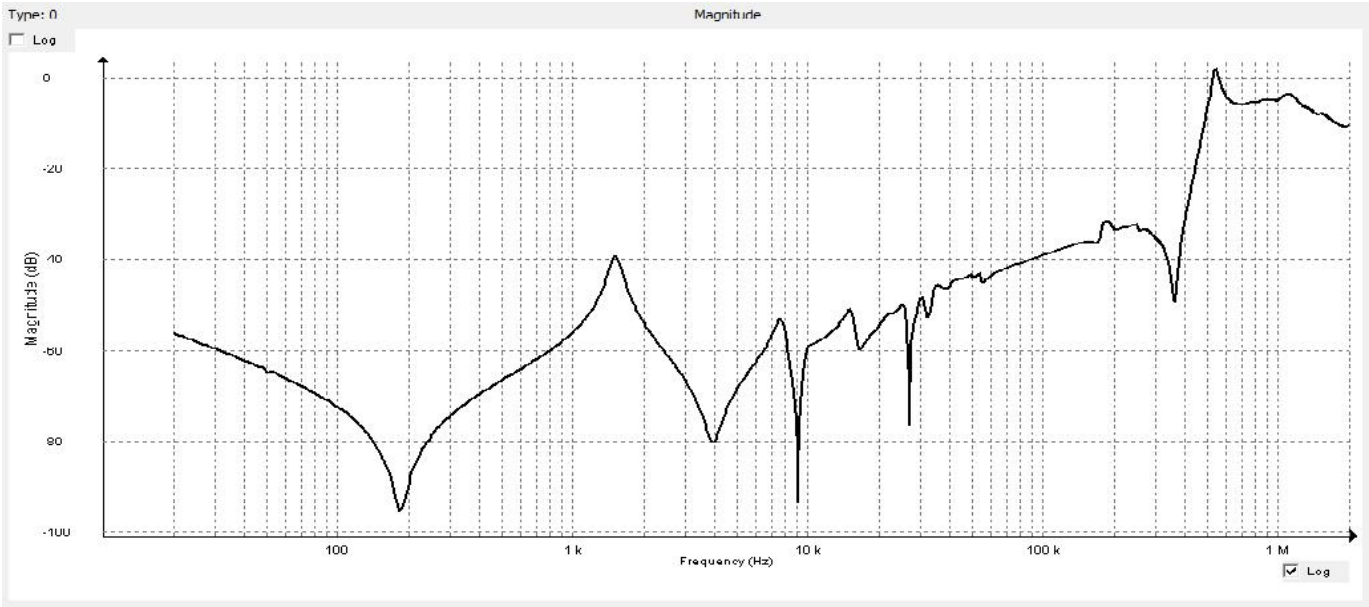
ANNEXURE - 1
Sweep Frequency Report Analysis Report

1U-1N ALL OPEN TAP 1



1V-1N ALL OPEN TAP 1



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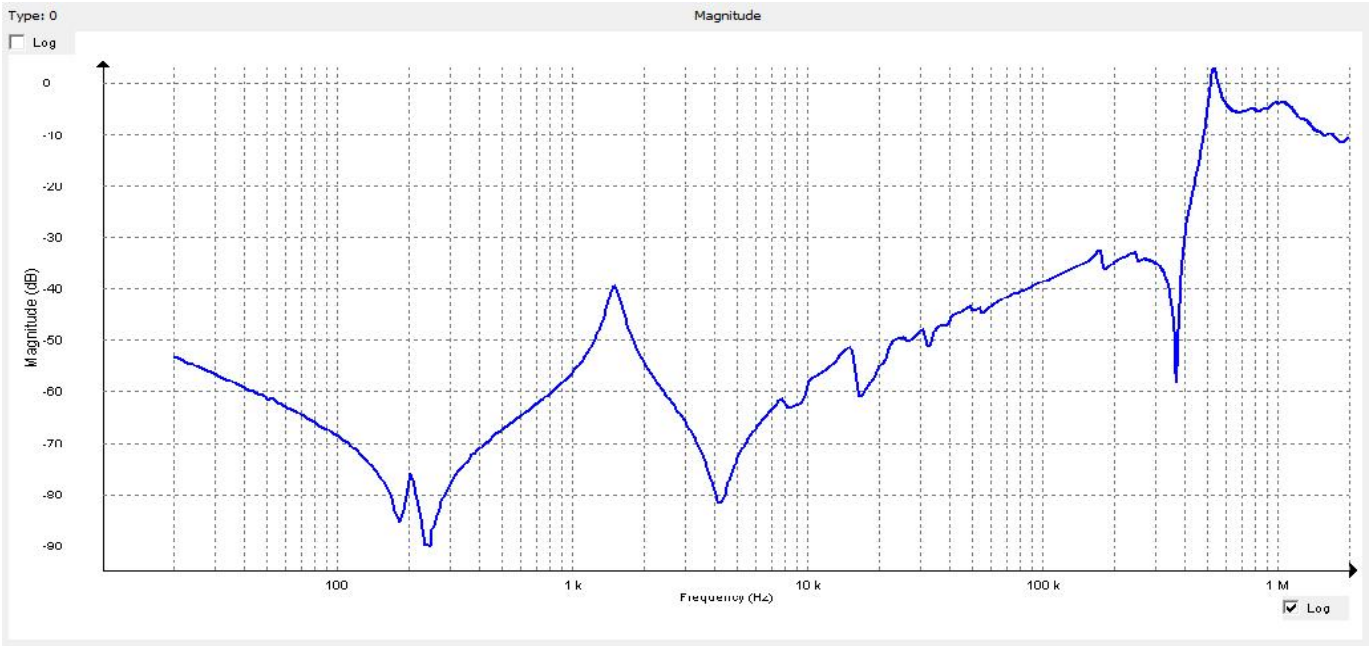
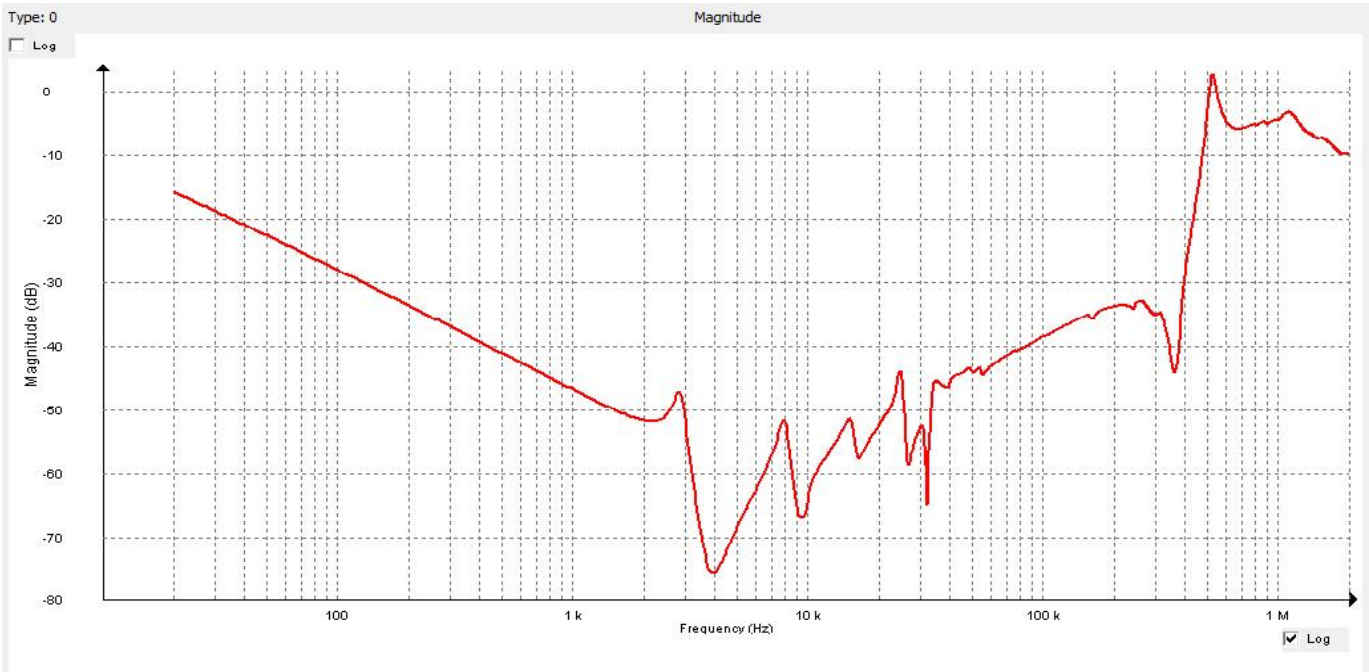
1W-1N ALL OPEN TAP 1



1U-1N LV SHORT TAP 1



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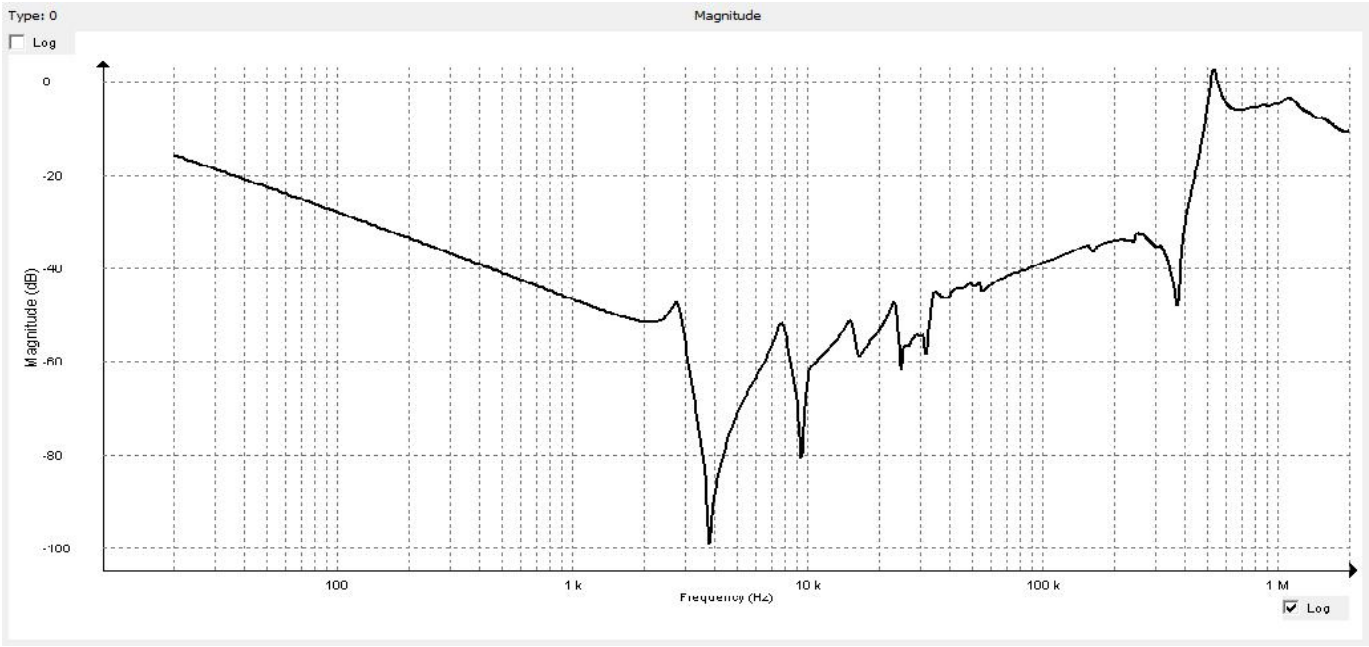
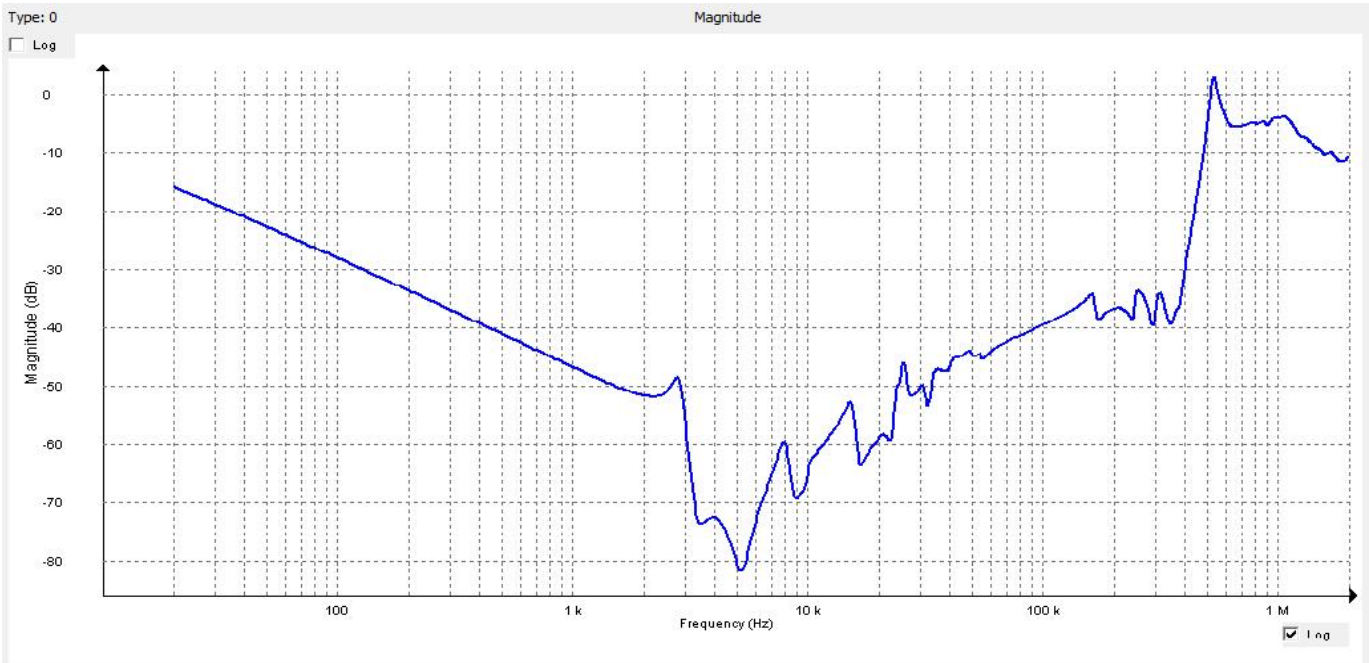
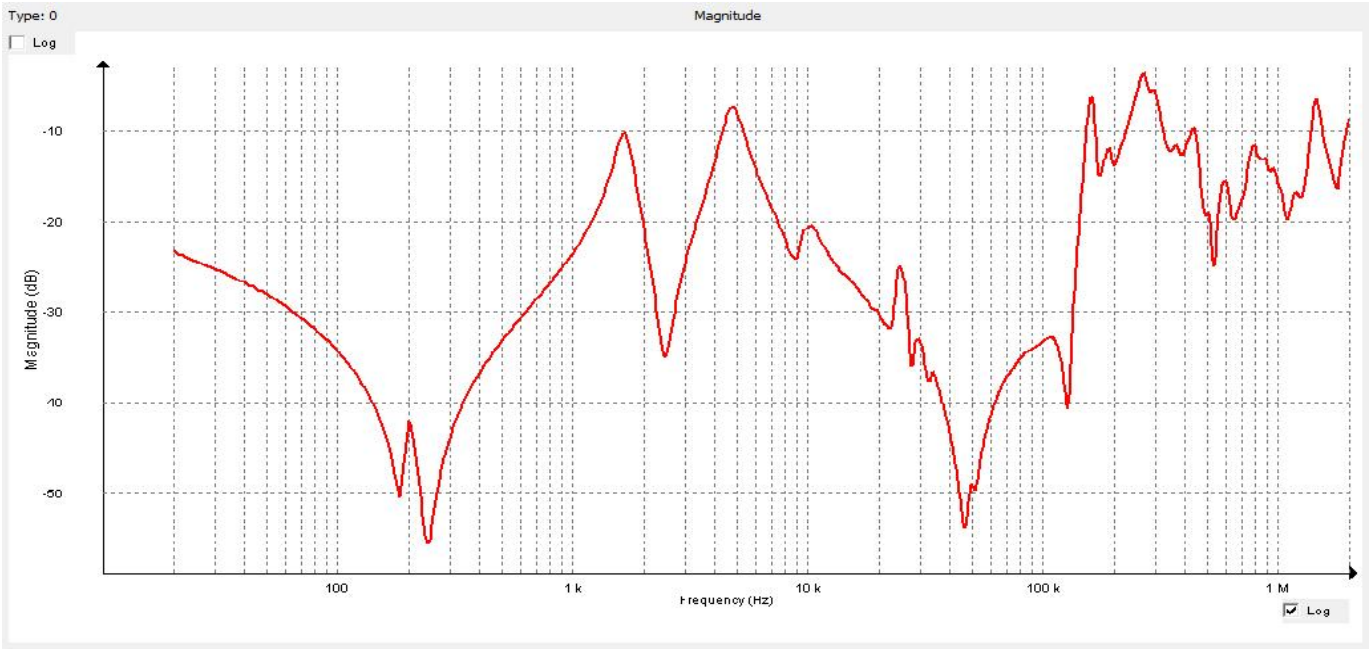
1V-1N LV SHORT TAP 1



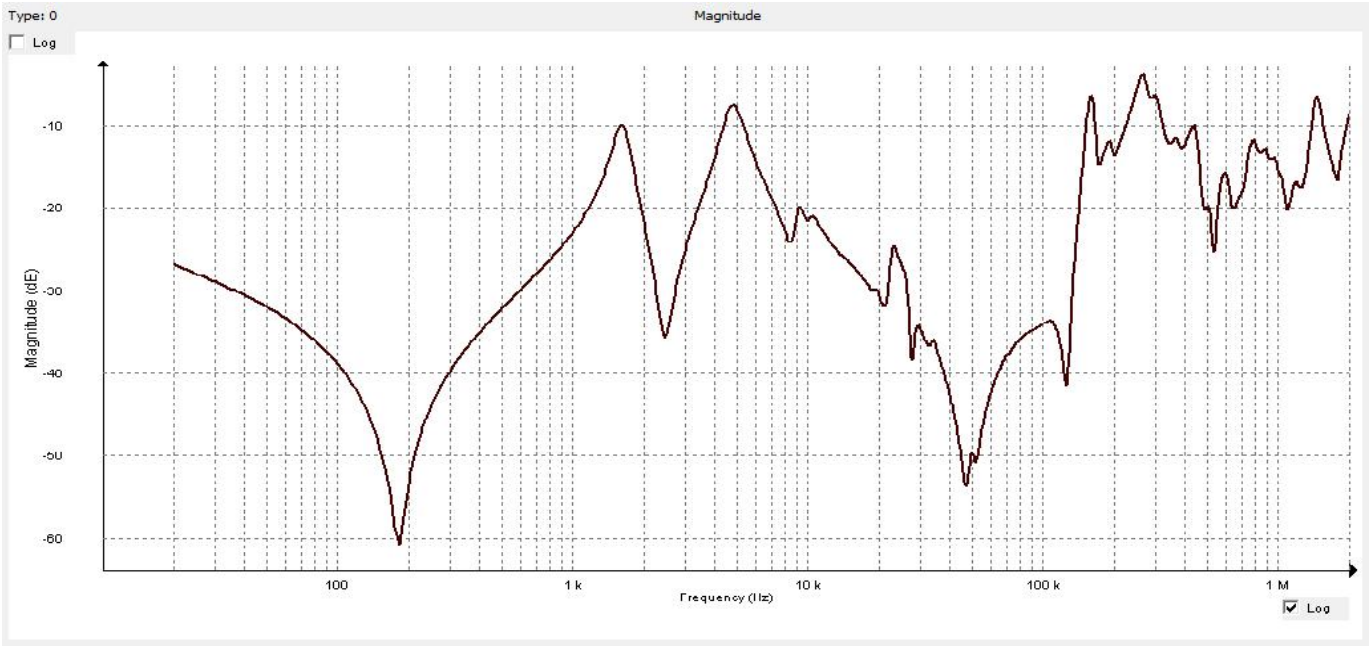
1W-1N LV SHORT TAP 1



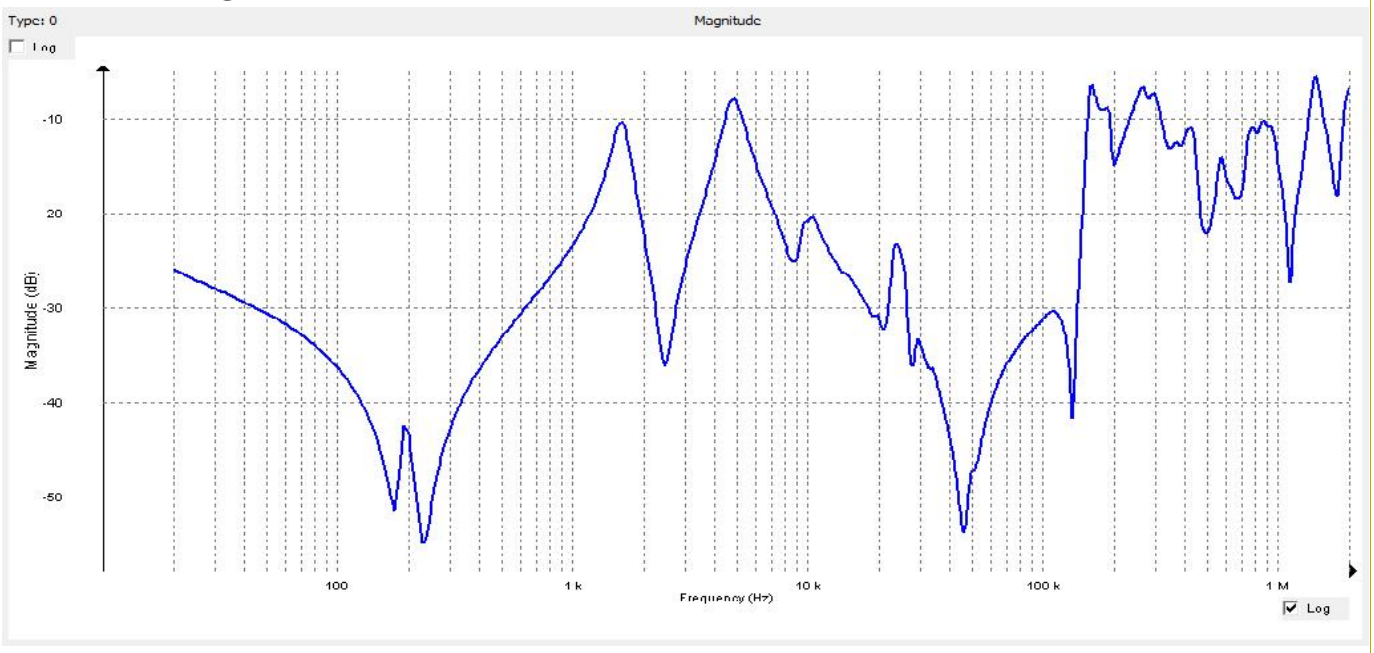
2U-2N ALL OPEN



2V-2N ALL OPEN

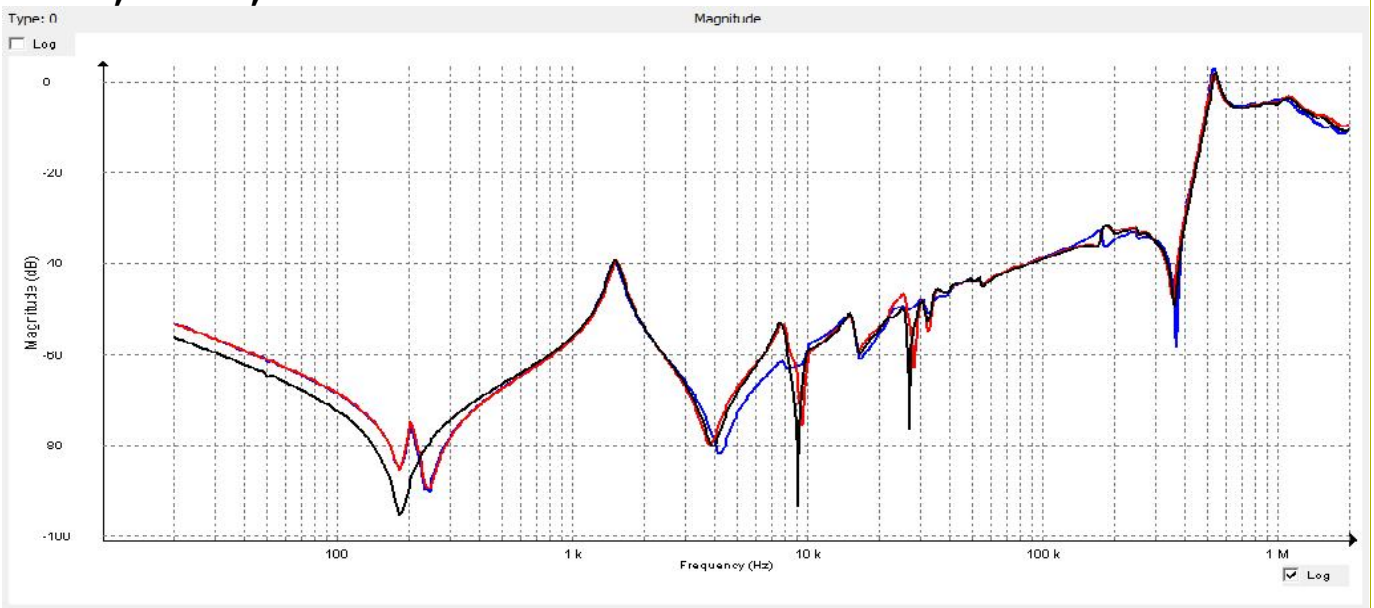


2W-2N ALL OPEN



THREE PHASE COMPARISON

1U-1N, 1V-1N, 1W-1N ALL OPEN TAP 1



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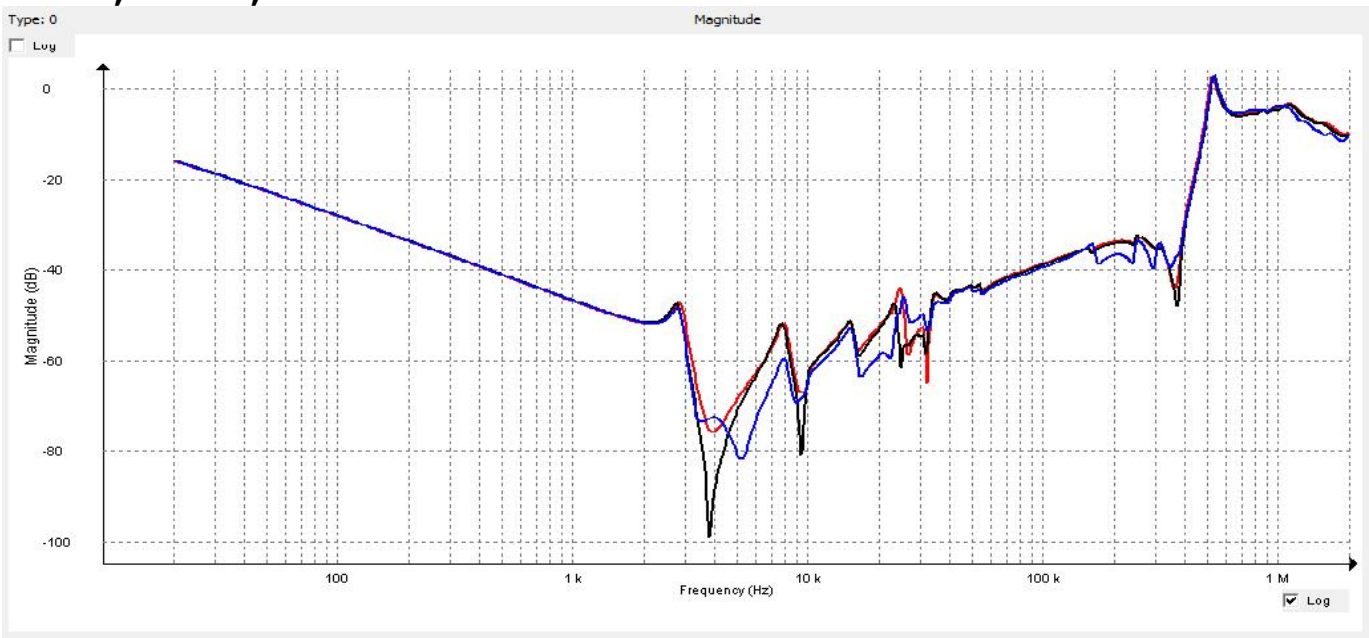
1U-1N, 1V-1N, 1W-1N LV SHORT TAP 1



2U-2N, 2V-2N, 2W-2N