Web Applications for Transmission System Asset Health Monitoring

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SUMMARY

POWERGRID is India's largest electric power transmission utility and wheels around 50% of country's power on its transmission network. As on April 2019, POWERGRID owns 242 EHV Substations having 153128 circuit kilometres of transmission lines and 365467 MVA of transformation capacity.

National Transmission Asset Management Centre (NTAMC) is POWERGRID's flagship project which is equipped with SCADA system communicating over MPLS cloud. At present as many as 583 transformers, 330 bus reactors and 573 line reactor devices are being remotely operated and monitored from NTAMC round the clock.

Along with SCADA system NTAMC is equipped with data historian subsystem which stores history of data pertaining to Power System parameters such as voltage, active/reactive power, dissolved gases, switching devices status & events etc.

Web based analytics applications have been developed with in-house expertise to analyse large volume of data in order to identify abnormalities in the transmission assets. Case studies of analysis and visualization of Over voltage, Transformer N-1 contingency loading and predictive maintenance based upon Dissolved gas analysis using this application have been presented here.

KEYWORDS

Dissolved Gas Analysis, Duval Triangle, Condition Based Asset Maintenance

Case Study-1: Over Voltage Profile

Prolonged Overvoltage conditions cause stress on asset and reduce it's life. This application presents visualization of overvoltage stress on substation assets by calculating percentage of the time overvoltage persists on a substation. The results of this analysis are being used in planning of reactive compensation.

Per Unit (PU) value of Substation Voltages have been categorized into four zones such that PU <0.95 lies in Zone1, 0.95< PU<1 in Zone2, 1< PU<1.05 in Zone3 and PU>1.05 in Zone4 respectively. Figure1 shows Voltage Profile history dashboard past 6 months (1st November 2018-1st May 2019) depicting percentage of time the voltage lies in Zone4 verses 10 minutes Average Voltage Peak for substations having PU >1.05 for more than 50% of time.
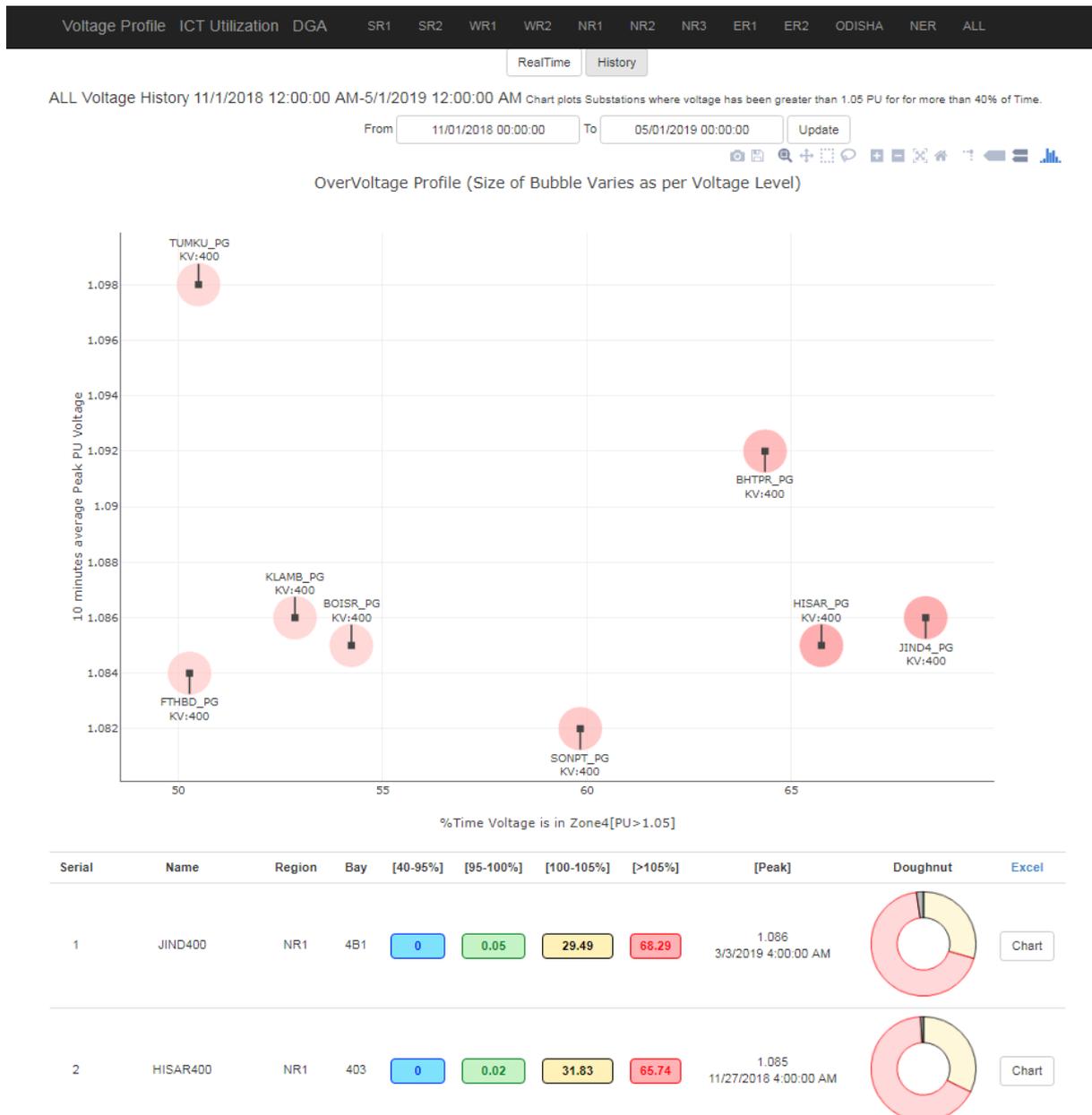
Figure-1 Substation Voltage Dashboard for past 6 months (1st November 2018-1st May 2019)

Figure 1 shows that for Jind400(JIND4_PG), Hisar400 (HISAR_PG), Bhatpara400 (BHTPR_PG) substations, voltages lie in Zone4(>1.05PU) for more than 60% of time in past 6 months, and for Tumkur400 (TUMKU_PG), 10 minutes average Peak has been observed above 1.098PU. These results state that the reactive compensation at these locations needs to be reviewed in order to maintain the voltage within permissible limits.

Case Study-2: N-1 Contingency Violation for Transformers:

This application helps to determine the sufficiency of redundancy to withstand transformer failure at a substation. Figure 2a shows history dashboard for N-1 Contingency Analysis of Transformer Units where Peak Utilization is plotted against percentage time Transformer Units at a substation violates N-1 contingency criteria. Figure 2b represents transformer loading profile of Gajuwaka substation for past 6 months (1st November 2018-1st May 2019).
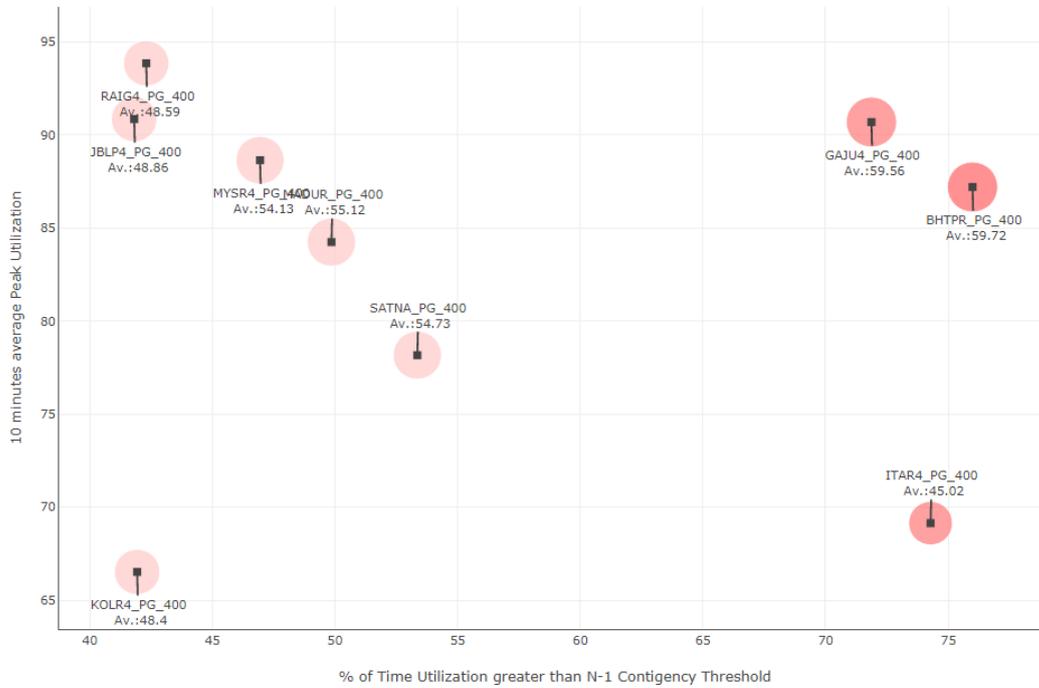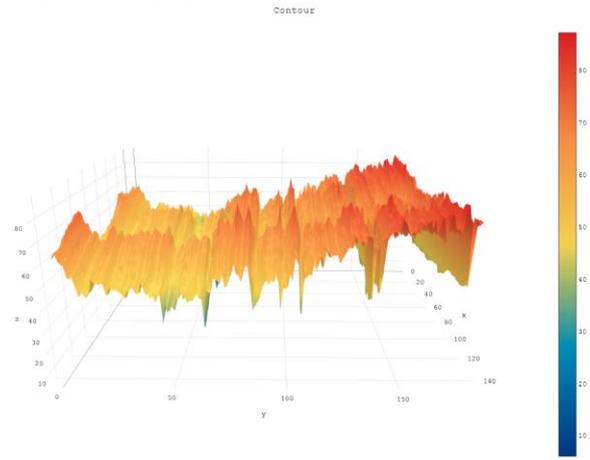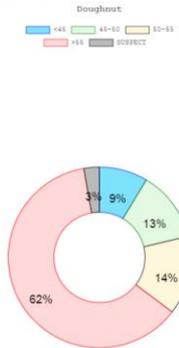
Figure2a: Transformer Utilization Dashboard, Figure 2b: Transformer Utilization for Gajuwaka Substation for Past 6 months (1st November 2018-1st May 2019)

As shown in Figure 2a, Transformers located at Gajuwaka (GAJU_PG_400), Bhatpara (BHTPR_PG_400) and Itarsi (ITAR4_PG_400) have 2 units each and have violated N-1 contingency threshold for more than 70% of time. Bhatpara and Gajuwaka have 10 minutes

average peak utilization of greater than 85% of their transformation capacity in past 6 months. These results state that transformer capacity at these locations needs to be augmented.

Case Study3: Predictive Maintenance using online Dissolved Gas Analysis Dashboard:

Dissolved gas analysis of transformer/reactor gives an indicator of incipient fault in the equipment. Dissolved Gas Analysis application analyses dissolved gases as per C57.139-2015 IEEE standard. When dashboard is accessed by operator, DGA analysis based on Duval triangle and IEEE limit violations are checked on dissolved gases real time values, and current limit/duval condition violations are alarmed (Figure 3a).

Two case studies of predictive maintenance based upon DGA have been presented here. In the first one rate of rise of C_2H_2 and other gases has stabilized over time and is not increasing rapidly while in the second one rate of rise for H_2 & C_2H_2 had been increasing beyond limits. Details of subsequent maintenance activity to find out root cause and rectify the problem have been described in this section.


Serial	Substation	Devtyp	Device	Bay	DGH2 95-100	MOIS 12-15	DGCO 320-350	C2H2 0-1	CO2 2200-2500	C2H4 45-50	C2H6 60-65	CH4 110-120	DGN2 -	O2 -	OTI 80-85	WTI 90-95	Excel	
1	BETUL400	RE	F_09_LR2	409	6	10	1531	4	6010	2	1	0			68.63	76	Chart	Rate of Rise
2	BALLABGARH400	XFMR_P	FEB_ICT1_P	404	0	2.49	0	3.75	814.3	26.14	0	700.77		0	64.99	86.54	Chart	Rate of Rise
3	MANDOLA400	XFMR_P	FEB_ICT1_P	415	76.38	5.04	586.95	1.88	3165.43	60.09	17.3	33.64	0	0	62.63	61.68	Chart	Rate of Rise
4	SILCHAR400	RE	F_22_BR3	422	36.34	10.24	200.36	4.32	731.45	34.18	0	17.33			47.27	69.66	Chart	Rate of Rise

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Figure3a: DGA Duval violations present in the system on 8th May 2019 10:23 AM

Case Study 3a: Mandola Transformer 1:

At Mandola substation violation in CO, C_2H_2, CO_2 & C_2H_4 have been observed (Figure 3a). Duval triangle[1] plot of weekly history values of past 6 months for Mandola Transformer Unit-1 is shown in Figure 3b. White Dots in the duval triangle plot lie in T3 zone which signifies high intensity thermal type of fault. C_2H_2 is primary gas in high intensity thermal faults [2]. as Figure 3c and 3d represent chart of C_2H_2 and its rate of rise over past 6 months.
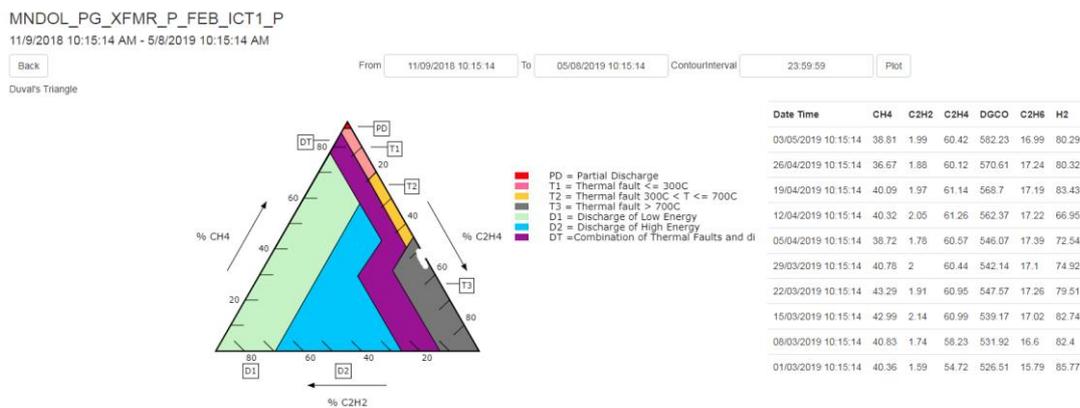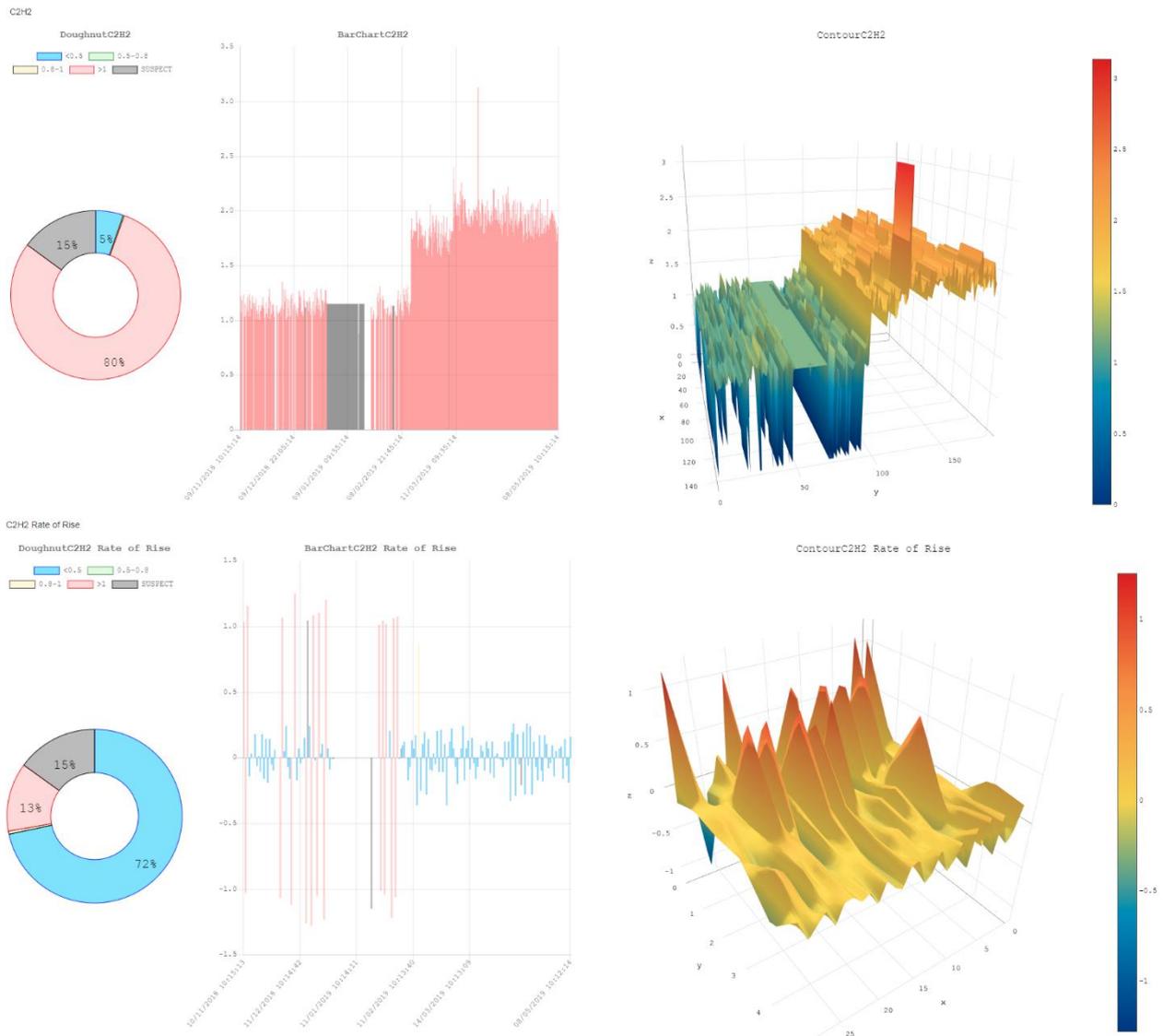
Figure3b,3c,3d: Duval Triangle Plot (Weekly duval violations indicated with white dots lying in T3 Zone), Chart and Rate of rise trend for Mandola Transformer-1 for past 6 months

In the above analysis it has been observed that C2H2 started increasing from February 2019 (Figure 3b) and has become stable in the month of May 2019 however C2H4 is still increasing. As rise in C2H2 has become stable over time (Figure 3c) no further actions such as oil resampling have been taken however this unit is under constant supervision.

Case Study 3b: Tuticorin Bus Reactor 1:

In Tuticorin Bus Reactor rapid increase in Hydrogen and acetylene was observed. In this case only 3 dissolved gases namely are reporting as 3-gas sensor is installed at site, hence online duval triangle analysis is not possible. Hence by monitoring limits and rate of rise violations it was apparent that Hydrogen and acetylene had violated limits beyond IEEE standard as their trends had been increasing continuously (Figure 3e,3f,3g,3h). H2 and C2H2 are referred to as arcing gases. Hydrogen is primary gas generated during low intensity discharges while C2H2 is primarily generated during high intensity arcing faults in 700-1800 ℃ temperature range [2]. Hence several inspections had been carried out to investigate the possible reasons for arcing.

During first two internal inspections on 8th August 2018 and 5th November 2018 all HV bushing corona shield were found loose. HV bushings were replaced after second inspection but still DGA trend was increasing rapidly. Shutdown of the reactor device was availed on 23rd February 2019 and oil draining of reactor had been done. At this time arcing in corona shields of R & Y phase HV RIP Bushings had been found. After opening of the main tank cover of reactor black powder type dust particles were observed in core shield of Y-Phase, top yoke of Y and R phase. After opening of top yoke of the reactor and removing the belly washers it was found that the aluminium cups of both R and Y phase surrounding the belly washers were touching with the tie rods causing hotspot due to vibration. After cleaning of tie rods and balance areas, the top yoke had been reinstalled. The reactor was again charged 24th April 2019 after taking dissolved gases samples which were found within limits.
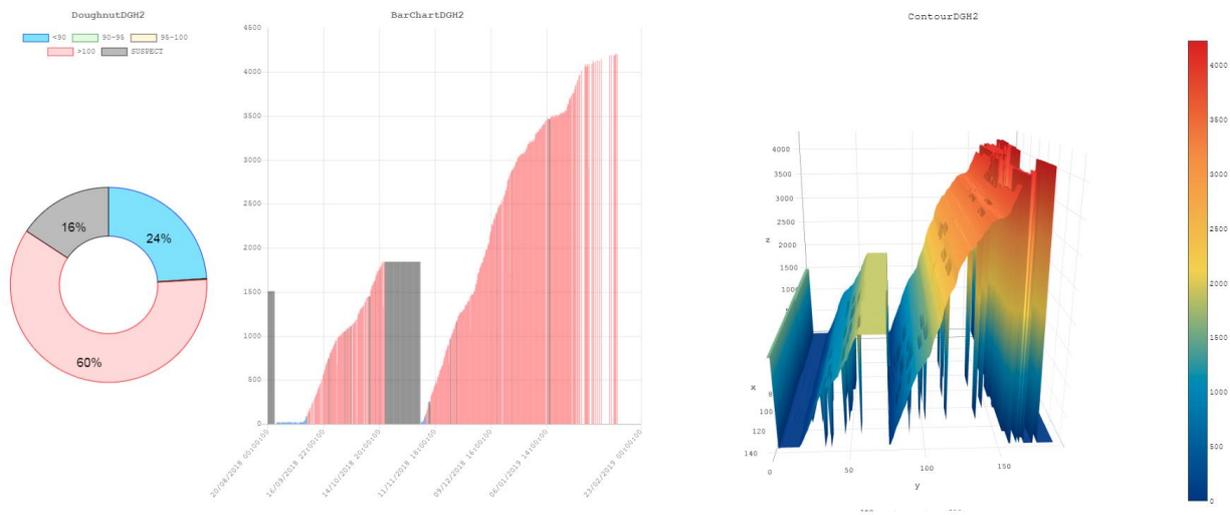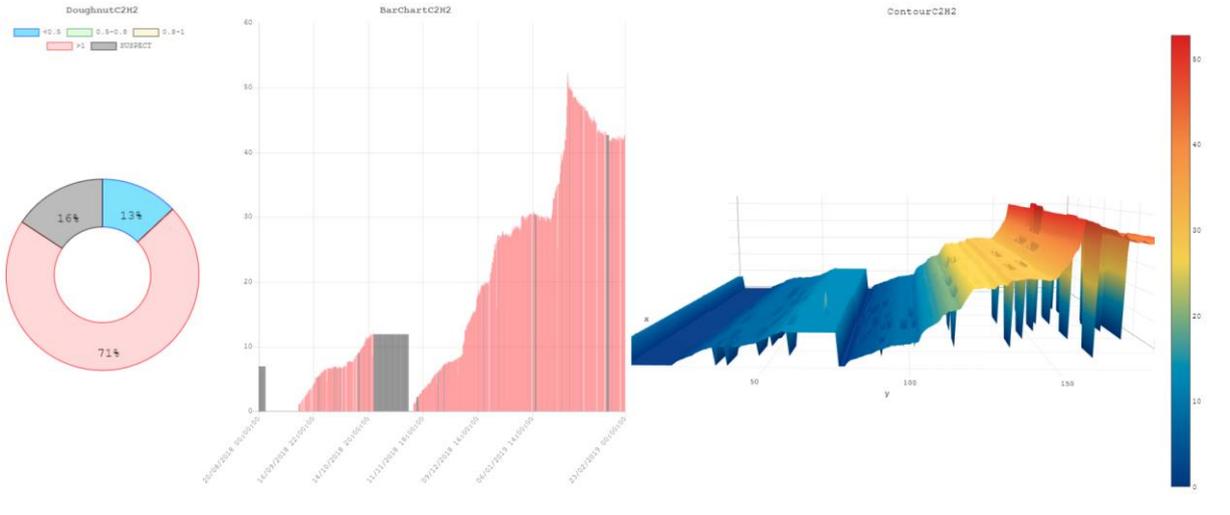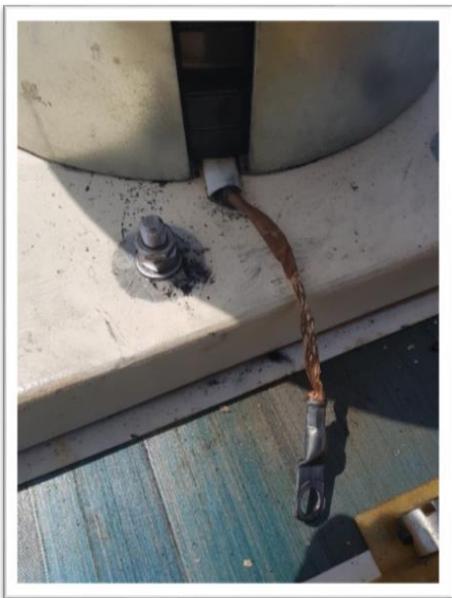
Figure3e,3f: Rising Trend of DGH2 & C2H2,Figure 3g,3h: Rate of Rise of DGH2 & C2H2
(Both trend and rate of rise depict rapid increase in gases for Tuticorin Bus Reactor 1)
Figure 3i: Core Shield of Y Phase, Figure 3j:Y Phase aluminium cup showing black powder
generated because of arcing

CONCLUSION

The above-mentioned history based applications analyse huge repository of data to identify assets needing attention over large geographical spread. Dissolved Gas Analysis application plays a key role for predictive maintenance of assets while Voltage Profile and Transformer Utilization applications have proved to be handy in obtaining regulatory approvals for commissioning of new assets wherever required.

FUTURE SCOPE

C57.91-2011 standard provides a method for calculation of loss of insulation life of power transformer based upon history values of ambient temperature and load profile of transformer[3]. Dashboard based upon residual insulation life of transformer will further aid predictive maintenance of transformers. Integration of residual life of transformer dashboard is under progress.

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[3] C57.91-2011 IEEE Guide for mineral oil immersed transformers and step voltage regulators.