ELECTRICAL DISCHARGES ON THE CONDENSABLE HYDROCARBONS UNDER THE INFLUENCE OF DC VOLTAGE: AN EXPERIMENTAL APPROACH

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ABSTRACT

Electrical discharge induced by multiple species of condensable hydrocarbons is not deeply researched. The present study reports on characterization of electrical discharges that arise due to condensable hydrocarbons under the influence of DC voltage.

1. INTRODUCTION

Condensable hydrocarbons are undesirable substance that has to be removed from the 'producer gas' well before their energetic utilization [1]. Currently practiced method in eliminating multiple species of condensable hydrocarbons is achieved through an electrostatic precipitator unit [2]. The multiple species of condensable hydrocarbons are electrically separated and collected in the cleaning chamber. During this process, electrical discharges inevitably arise between the discharge and collecting electrodes and on the contaminated surface of the ceramic support insulator. The electrical discharges that arise between discharge and collecting electrode are necessary while the same on the contaminated surface of the ceramic insulator remains critical.

Present investigations on condensable hydrocarbons focus on dielectric condition assessment and ageing of ceramic insulator [3-4]. In addition to this, performance of electrostatic precipitator unit and its cleaning efficiency are studied [2]. On contrary, the characteristics of electrical discharges due to condensable hydrocarbons are not deeply researched. It is experimentally proven that the condensable hydrocarbons induce severe electrical discharges, irrespective of the material onto which they are deposited [3-4]. Recent attempt to understand the characteristics of electrical discharges due to condensable hydrocarbons involve conventional and non-conventional Partial Discharge (PD) measurements [3-5]. Nevertheless, most of these investigations are conducted at AC voltage which is more dynamic. In this context, an effort to characterize the nature of electrical discharges due to condensable hydrocarbons under the influence of DC voltage is attempted.

2. PROCEDURE

The objective of the present study is resolved on a sample extracted from a ceramic insulator contaminated with condensable hydrocarbons. It is usual practice to measure and analyze the electrical discharges through PD measurements. Naturally, conventional PD test method is employed for measuring and analyzing electrical discharges. The adopted PD test circuit is in conformal with IEC standard (IEC 60270). The only difference is the applied Test Voltage (TV) which is DC in the present context. The chosen insulator sample is energized with HV DC test voltage and the respective PD level (QIEC) is recorded. Being a DC TV, the existing AC based

Phase Resolved PD (PRPD) pattern is modified into an approach termed as the “Quasi Phase Resolved PD (QPRPD)” pattern.

QPRPD pattern: The current trend during DC based PD analysis involves counting the number of PD events that arise due to DC voltage. Such an approach remains reasonable since there is no dynamic variation in the test voltage, henceforth, in the respective PD signal. So, there is no possibility to perform a pattern analysis similar to that of the AC investigations. However, the adopted HV setup employs a half-wave uncontrolled bridge rectifier for converting AC into DC. Although the test voltage applied to the sample is DC, the actual input to the rectifier unit is an AC signal. So, there is a possibility to correlate and/or synchronize the PD signals to the AC input of the rectifier unit. By this way, the dynamic variations of the PD pulses are still (indirectly) correlated to the AC input of the rectifier unit. At the same time, it is not appropriate to term the corresponding pattern analysis as Phase Resolved PD (PRPD). Hence, the phase resolving of PD signals, in the present context, is technically termed as “Quasi Phase Resolved PD (QPRPD)” pattern.

3PARD diagram: The 3 Phase amplitude Relation Diagram (3PARD) is mainly used to identify and discriminate the occurrence of multiple PD events in the same HV apparatus. Due to their complex propagation and coupling characteristics, every possible PD source has a unique PD-triple magnitude relation and consequent characteristic signature. In order to visualize the amplitude ratio of PD triple pulses, the so called 3PARD diagram is developed and constantly employed along with PRPD pattern.

3. SETUP

Fig. 1(a) shows the setup involved in the present study. The adopted PD test circuit comprises of a half-wave uncontrolled HV arrangement (upto 135 kV DC), a coupling capacitor and a digital PD detector (MPD 600). The PD signals are decoupled through a Medium frequency Current Transformer (MCT 100). The decoupled PD signals are measured and recorded in the PD detector. Following this, the respective QPRPD pattern and 3PARD diagram are analyzed. Fig. 1(b) shows the pictorial description of test sample adopted in the present study. The surface of the chosen sample is contaminated with multiple species of condensable hydrocarbons. There were locations on the surface of the contaminated sample indicating occurrence of localized electrical discharges (tracking) that has partially bridged the area. Since measurements on this area might not reveal the actual electrical behaviour of contaminations, these locations are carefully avoided. Once this is ensured, the characteristics of electrical discharges due to the contaminations on the surface of the broken insulator sample is measured and analyzed.

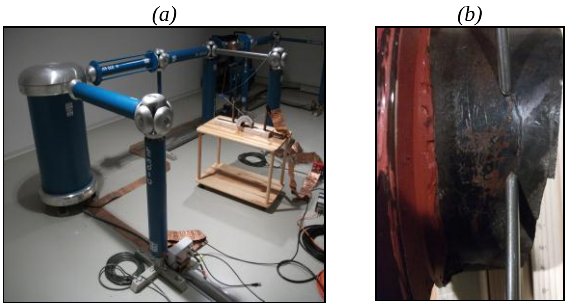

Fig. 1 *Pictorial description of test setup and sample adopted in the present study: (a) Measurements of electrical discharges (b)Test sample (broken insulator) contaminated with multiple species of condensable hydrocarbons*

4. EXPERIMENTS

Prior to measurements, it is important to calibrate the test circuit to ensure PD detection sensitivity and measurement accuracy. Hence, the PD test circuit adopted in the present study is calibrated to a known calibration signal. Fig. 2 and 3 shows the QPRPD pattern and 3PARD diagram of calibration.

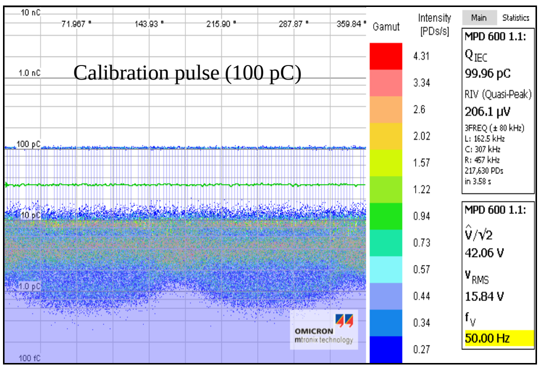

Fig. 2 *QPRPD pattern pertaining to calibration signal injected into the test sample adopted in the present study*

The adequacy of such calibration procedure remains well accepted since the respective calibration pulse closely resembles a PD signal. The calibration pulse (of 100 pC) is injected over the surface of the test sample and the respective charge measured by the PD detector is calibrated to the magnitude of injected pulse. Once calibrated, the baseline data is recorded and its respective QPRPD pattern (Fig. 2) and 3PARD diagram (Fig. 3) is analysed to ensure that there is no interference coupled to the PD measurement circuit respectively. On brevity grounds, detailed information regarding calibration and baseline data are not reported.

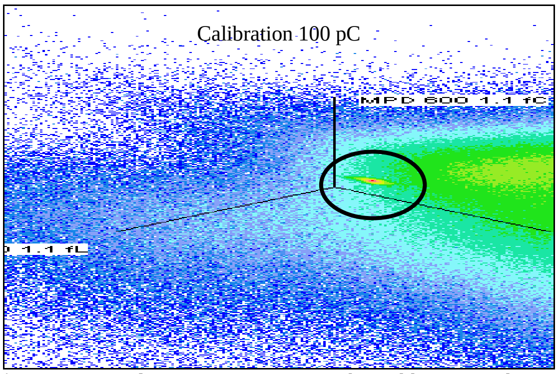

Fig. 3 *3PARD diagram pertaining to the calibration pulse and baseline data respectively (A zoomed version)*

Positive DC voltage: Fig. 4 and 5 shows the QPRPD pattern pertaining to electrical discharges arising on the surface of the chosen sample under the influence of positive DC voltage. It becomes clear from Fig. 4 that the PD pulses are stable, phase correlated and emerges at the positive cycle of AC voltage input to the rectifier unit. Such electrical discharges arise only after the test voltage reaches + 8.1 kV.

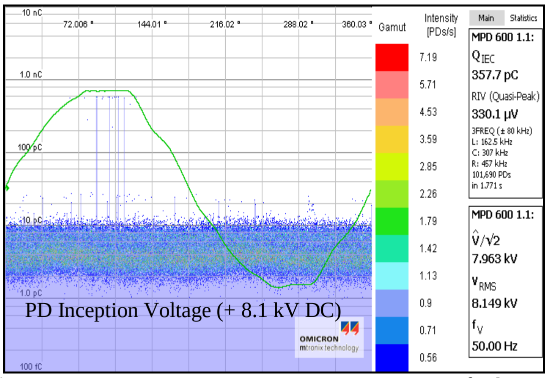

Fig. 4 *QPRPD pattern pertaining to inception of electrical discharges due to condensable hydrocarbons during positive DC voltage*

The PD magnitude increases drastically with test voltage. It becomes clear from Fig. 5 that more stronger and stable pulses evolve with increase in test voltage. These pulses occupy the complete first quadrant with more dominancy in the rising part of test voltage. Fig. 6 shows the charge-time (q-t) characteristics of the electrical discharges that arise due to the positive DC voltage on condensable hydrocarbons. It could be observed from Fig. 6 that the electrical discharges arise intermittently throughout the measuring time.

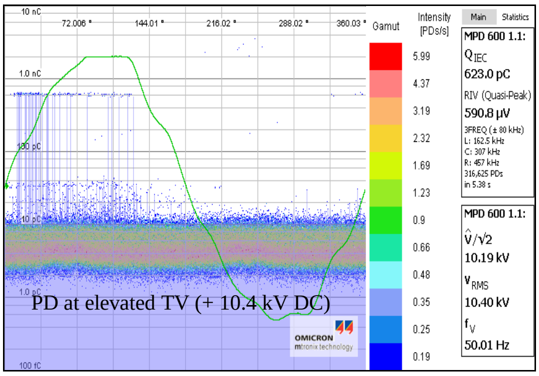

Fig. 5 *QPRPD pattern pertaining to electrical discharges due to condensable hydrocarbons during increased test voltage*

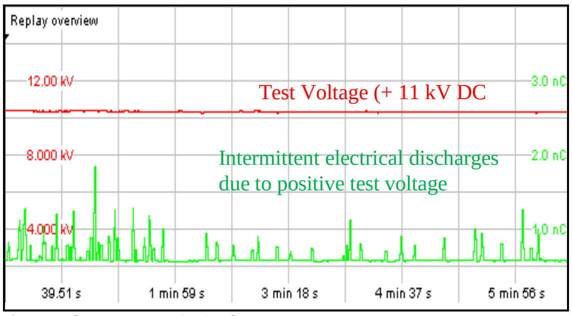

Fig. 6 *Charge-time (q-t) characteristics pertaining to intermittent electrical discharges that arises on the condensable hydrocarbons during positive DC voltage*

Negative DC voltage: Fig. 7 and 8 shows the QPRPD pattern pertaining to the electrical discharges induced on the condensable hydrocarbons during negative DC voltage. It becomes clear from Fig. 7 that the PD pulses appear at the negative half cycle indicating the dependency of the polarity of test voltage. Also, the magnitude of inception voltage of PD pulses is quite less compared to the positive DC voltage. The PD activity increases drastically along with the test voltage.

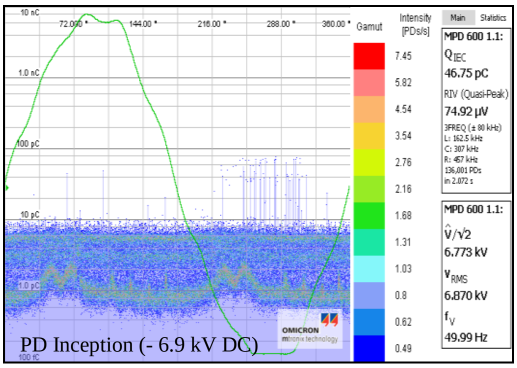

Fig. 7 *QPRPD pattern pertaining to measured PD signal pertaining to elevated electrical discharges arising over the contaminated surface of the test sample during positive DC voltage*

Fig. 8 shows the QPRPD pattern pertaining to elevated negative DC voltage conditions. It appears from Fig. 8 that stronger PD pulses emerges under elevated DC voltage condition. This indicates that the negative DC voltage might induce more stress conditions on the condensable hydrocarbons. Also, as opposed to positive DC voltage conditions (Fig. 6), the pertinent electrical discharges are continuous and not intermittent. Fig. 9 shows the charge-time (q-t) characteristics of electrical discharge arising on condensable hydrocarbons during negative DC voltage.

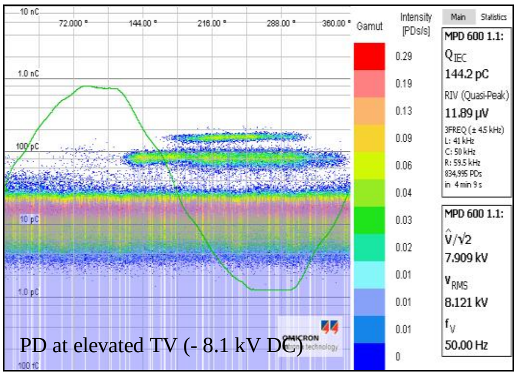

Fig. 8 *QPRPD pattern pertaining to measured PD signal pertaining to elevated electrical discharges arising over the contaminated surface of the test sample during negative DC voltage*

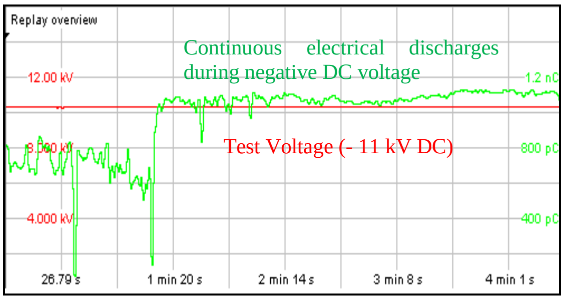

Fig. 9 *Charge-time (q-t) characteristics pertaining to intermittent electrical discharges that arises on the condensable hydrocarbons during negative DC voltage*

(a) *(b)*

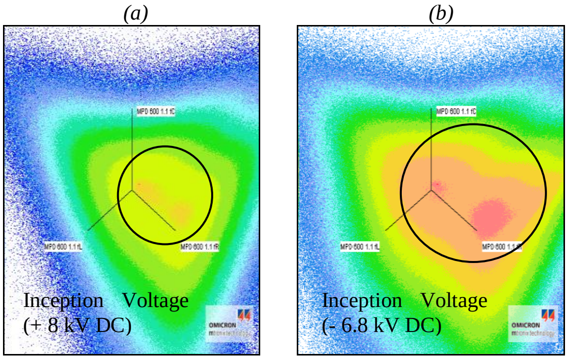

Fig. 10 *3PARD diagram pertaining to Fig. 4 and Fig.5 respectively (a) Positive DC elevated voltage (b) Negative DC elevated voltage*

Fig. 10 shows the 3PARD diagram of Fig. 5 and 8 respectively. It could be observed from Fig. 10 that irrespective of the polarity of test voltage, the location of PD pulses remain the same in the 3PARD diagram. At the same time, the intensity of PD activity remains higher at negative DC voltage. Also there exists a possibility of two PD sites on the test sample. This observation is in consonance with Fig. 8 respectively.

5. INFERENCE

It appears from the present study that the electrical discharges due to condensable hydrocarbons could be analysed through modern PD methods. Occurrence of PD pulses depends on the polarity and magnitude of the test voltage. Comparatively, the negative DC voltage induces more severe stress conditions on condensable hydrocarbons. Pertinent q-t characteristics indicate that the electrical discharge due to positive voltage is intermittent while the same during negative voltage emerged as continuous.

6. CONCLUSION

Thus it emerges from the present study that there is more interesting information within the electrical discharges. More investigations become necessary to gain deeper insight into the electrical discharges initiated by the condensable hydrocarbons. This forms the future scope of this research work.

REFERENCES

[1] Y. Neubauer, "Strategies for tar reduction in biofuels and synthesis-gases from biomass gasification", Journal of Sustainable Energy and Environment, Special Issue, pp. 67-71, 2011

[2] Philipp Schroeder, et all., "Performance characteristics and dielectric condition of a wet electrostatic precipitator application for tar removal," 21st BioMass Conference, Copenhagen, Denmark, pp. 789-794, 2013

[3] Philipp Schroeder, et all., "Investigations on ageing phenomena of a tar contaminated porcelain insulator," 19th International Conference on Gas Discharge and Their Applications, GD-2012, pp.778 - 781, Sept. 2012

[4] Saravanakumar Arumugam, et all., "Diagnosis of operating conditions of high voltage insulators in electrostatic precipitators," VDE 2012, Germany, 2012

[5] Saravanakumar Arumugam, et all., "An experimental study on electrostatic precipitator with tar contaminated HV insulator through UHF based PD tests," ISH 2013, Seoul, Korea, pp.1234 - 1239, Jan. 1937., 2013