Correlation between corona current and radio interference due to high voltage insulator string

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Abstract **-- The Radio Interference (RI) from electric power transmission line hardware, if not controlled, poses serious electromagnetic interference to system in the vicinity. The present work mainly concerns with the RI from the insulator string along with the associated line hardware. The laboratory testing for the RI levels are carried out through the measurement of the conducted radio interference levels. However such measurements do not really locate the coronating point, as well as, the mode of corona. At the same time experience shows that it is rather difficult to locate the coronating points by mere inspection. After a thorough look into the intricacies of the problem, it is ascertained that the measurement of associated ground end currents could give a better picture of the prevailing corona modes and their intensities. A study on the same is attempted in the present work. Various intricacies of the problem, features of ground end current pulses and its correlation with RI are dealt with. Owing to the complexity of such experimental investigations, the study made is not fully complete nevertheless it seems to be first of its kind.**

***Index Terms*--Radio interference, corona, high voltage transmission, insulators, conductor hardware, corona current.**

I. Introduction

A. Sources of corona on line conductors and hardware

The local electric breakdown of air or the corona is quite common on the high voltage power transmission line hardware. The operating stress is ideally lower than the corona inception levels, however, due to some manufacturing defects, damages caused during the transportation and installation, deposition of contaminants like dust particles or water droplets etc. the local field can get significantly intensified. As a result, the corona can occur on line conductors, nuts and bolts of the hardware, arcing horns, guard rings, suspension clamps, etc. Also, since the conductors and tie-wires with the tops of the insulator; and the pins with the entire surface of the thread in the pin holes, do not make perfect electrical contacts, corona may occur in the intervening air gaps.

B, The generation mechanism of Radio noise

Radio noise in High Voltage transmission line is associated with the pulsating modes of corona discharges developing at the line conductor and hardware, sparking resulting from poor electrical contact and scintillations on the contaminated insulator surfaces. The current pulse associated with individual corona discharges typically possess a rise time measurable in 10s of ns, which is followed by a slow tail measured in 100s of ns. A several discharges are produced in every half cycle of the power frequency voltage and there could be several sites producing corona and the noise generated has considerably wide frequency spectrum. The RI level is high in the broadcast frequency range (0.5-1.6MHz) and then decreases gradually at higher frequencies [1]. Detailed studies of corona current characteristics have shown that positive corona is the main source of radio noise from transmission line [1].

C. *Consequence of radio noise:* The Radio Interference (RI) from electric power transmission line hardware, if not controlled, poses serious electromagnetic interference to system in the vicinity [2,3]. Also, in future, if the transmission lines are to be employed for general communications, it becomes imperative to limit the corona generated electromagnetic noise [4-6].

With regard to the transmission lines, the sources of RI are both line conductors and the line hardware including the insulator strings [8]. The present work mainly concerns with the insulator string along with the associated line hardware. The existing standards have two tests pertaining to RI and corona. First one involves measurement of conducted RI through suitable circuit configuration and a radio noise meter. The second one involves identification of onset a visual corona, which is relatively subjective.

D. Associated standard: Hence, governing standards have prefixed upper limits for radio interference levels from different components of high voltage transmission lines [2]. For convenience, the laboratory testing for the RI levels are carried out through the measurement of the conducted radio interference levels [2,7,12].

E. Problem identification

The RI measurement does not really locate the coronating point, as well as, the modes of corona. At the same time experience shows that it is rather difficult to locate the coronating points by mere inspection. The associated geometry involves both highly localized field intensification points, as well as, relatively extended moderate field intensification points. This in turn leads to both point corona and a diffuse corona to start with, which later transform into corona streamers at high field points. In other words, different modes of corona like burst, glow and streamer all will be onset as the test voltage is increased. After a thorough look into the intricacies of the problem, it is ascertained that the measurement of associated ground end currents along with the resulting conducted noise could give a better picture of the prevailing corona modes and their intensities. This forms the basic objective of the present work. It is worth mentioning here that the literature addressing the above stated problem is hard to find and hence the present work can be considered as one of the first attempts in this area.

II. PRESENT WORK

In the intended experimental approach, on the application of voltage to the insulator string both resulting radio noise and ground end currents are to be measured. With regard to the ground end current it can be conveniently measured indirectly by measuring the voltages.

A. Details of experimental investigations

Experimental arrangement commonly used test circuits for measuring radio interference are those recommended by IEC and NEMA. For the present work the IEC circuit shown in Figure 1 is employed. The main components of the circuit are high voltage source (50 Hz, 150 kV, 300 kVA transformer with primary voltage of 230/440 V and with a rated continuous current of 2A), low pass filter which can be tuned to the required frequency, high voltage bus end terminations, coupling capacitor (0.00161 μF realised by two units of 0.00322 μF of GE make connected in series), measuring impedance (R1=265Ω , R2=50Ω and L=2.2 mH) and radio noise meter type SMV 11, VEB Messelektronik Berlin make is used for the measurements. The input voltage to the transformer is 400 V two phase ac. The testing arrangement is so designed to be simpler for operation and all the necessary precautions have been incorporated for proper safety and protection with essential tripping arrangements. The test object consisted of 9-disc insulators(132kV system) and the test voltage was 85kV.

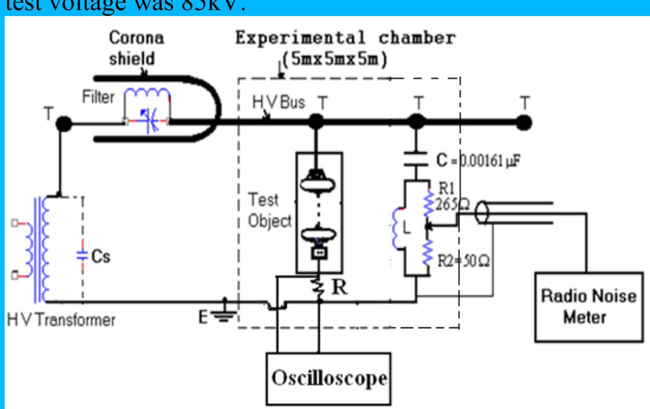

Fig. 1. RIV Measuring circuit as per IEC [2] augmented with ground end current measurement

The details of the parameters measured are as follows:

B. Radio Interference Measurements

The International Standard [2] specifies the procedure for a radio interference (RI) test carried out in a laboratory on clean and dry insulators at a frequency of 0,5 MHz or 1 MHz or, alternatively, at other frequencies between 0.5 MHz and 2 MHz. The frequencies of 0.5 or 1 Mhz are preferred because, usually the level of radio noise at this part of the spectrum and also because 1 MHz lies between the low and medium frequency radio broadcast bands.

As per the standard [2], the measuring apparatus, as per the specification of CISPR 16-1, has been currently used for the RI characteristics of insulators.

The voltage is gradually applied in steps, to reach a value of 90 kV (15% above phase voltage), held for at least five minutes, to allow RIV phenomenon to stabilize. Then, voltage is reduced slowly in steps. The radio noise generated by the insulator string is observed. Three such cycles are repeated, and RIV in dB (above 1 mV) at different voltages is recorded for four insulator strings. The experiments were repeated at least five times to check for repeatability.

C. Current Measurements

The corona current in principle is measurable at two ends of the string i.e. from high voltage end and from ground end. Of course, for very accurate measurements, optical link between measuring system and the oscilloscope would be essential. At present, due to the non-availability of such a system at our laboratory, conventional method is only employed. The current is indirectly sensed by measuring the voltage across a 50 Ω resistor connected at the ground end. It applies to both the ground end lead of insulator string, as well as, the input to RIV meter as indicated in the figure. However, for safety purpose, in the ground end lead of insulator string a high resistance 5 kΩ is also inserted. However, before proceeding further on measurement, the following needs to be discussed.

The corona current pulses are known to have short front durations measured in 10s of ns. As a consequence, their propagation characteristics would be more like waves on antenna rather than classical circuit domain pulses and further, their propagation is not governed by the applied voltages. A very similar situation prevails with the measurement of partial discharge pulses in high voltage power apparatus and cables. Therefore, the quantity measured at any given point on the circuit need not be and will not be the actual corona current pulse generated at the source. Nevertheless, owing to the linearity of the system for such pulses, measured current should be directly related to the corona pulse at the generation point.

Amongst the two possible current measurement points, the investigation is started with measuring the current at the input to RIV meter. The reasons for the same are as follows. Firstly, the reference value as per prevailing standards, the RIV measurement as per the prescribed circuit is the testing method and therefore, the current coupled through the RIV coupling capacitor governs the test result. Therefore, it would be prudent first to consider this current and study whether intended identification of coronating source could be carried out. Secondly, as mentioned before, the corona pulse will propagate on ground lead in an antenna mode and hence several reflections and attenuation can be expected in the path of the ground lead which has several bends and runs along supporting steel frame. It will therefore be quite involved to correlate the signal strength at the RIV input. Considering these, first the input to the RIV meter itself is considered for its characteristics.

III. EXPERIMENTAL RESULTS

A. Some observations on the waveshape of measured current

Sample voltage waveforms at the RIV input is presented in figure 2. To verify whether a small surface abrasion such as bird droppings or collection of conducting dust can significantly alter the noise levels, a contour of GI wire is placed firmly on the surface (using tape) around the cap region (with a physical contact to the cap). The results with and without this GI wire loop is categorized by with defect in the figures. Due to the strong influence of local radio broadcasting stations and other communication towers, there was a consistent background noise measuring peak-to-peak amplitude of less than 10 – 20 millivolts. The same can be seen in figures 2 & 3. There are several types of waveforms that could be seen, however, two kinds of waveforms were very frequent. They have been shown in figure 2 as type 1 and 2. The type1 waveform has initial high frequency oscillations (caused by the corona pulse initiated travelling waves on the system), which is followed by the lower frequency oscillations. The excitation of the low frequency oscillations can be attributed to the 1 MHz tuned filter at the source end and the coupling capacitor of the RIV arm. The inductor at the low voltage arm of RIV part may not be participating much due to the existence of parallel relatively low strength resistive branch. The excitation of the low frequency oscillation is expected due to a surface discharge on the insulator (porcelain disc and supporting insulating surface of the source side tuned filter).

On the other hand, the type 2 waveform is attributed to the conductor to air type discharges, which on average is found to have lower magnitude and much shorter duration. Study is being continued to further ascertain the above identification of the source.

B. Correlation between the radio noise and averaged peak amplitude of corona generated current

It is evident from the earlier sections that the actual corona generated pulse will be extremely difficult to be measured on any high voltage test system for RIV level. As explained earlier, the corona pulse induces the waves in the system and due to linearity of the system, possesses a direct correlation with respect to the measurable current at the ground end. The ground end current waveforms at the RIV coupling capacitor (measured through the voltage across a 50 Ω resistor) and RIV levels are compared in table 1. It is worth noting here that the amplitude of the waveforms at any voltage level is not the fixed one. Measured peak to peak values vary from lower level to higher levels. However, for the tabulation, only the most frequently observed values are given along with some infrequent values at the higher end. There seems to be a good correlation between the most frequent values and the RIV levels.

IV. SUMMARY AND CONCLUSIONS

The practical RI measurement does not really locate the coronating point, as well as, the modes of corona on insulator string and associated hardware. This work proposed the measurement of ground end currents to possibly aid the identification of types of corona involved. The experimental investigation carried out indicated the difficulties arising out of noise due to radio and communication signals, distortion of the corona current pulse along the path to ground and existence of simultaneous sources of corona on the test specimen. Based on the distinct features of ground end currents, an attempt is made to at least identify two kinds of corona sources. Also, a correlation is shown to exist between the most frequent peak to peak values of ground end currents and the radio interference levels. Even though the present study made is not fully complete it is opined that it is first of its kind.

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Table 1. Comparison of measured RIV levels and peak to peak voltage (current X 50 Ω) levels

Voltage (kV)	RIV(dB)	Most frequently measured voltage levels (mV)p-p		Less frequently measured voltage levels (mV)p-p
		forward	backward	
40**	19-20	100		
50	26-27	132-140	94-122	
60	31-31.5	134-146	136-180	152
70	36-36.5	184-230	170-200	190-230
75/76	37-37.5	238	180-236	260 – 300
80	39-39.5	244	236-250	300+ - 400

** This correspond to ambient noise, which exhibits some fluctuations

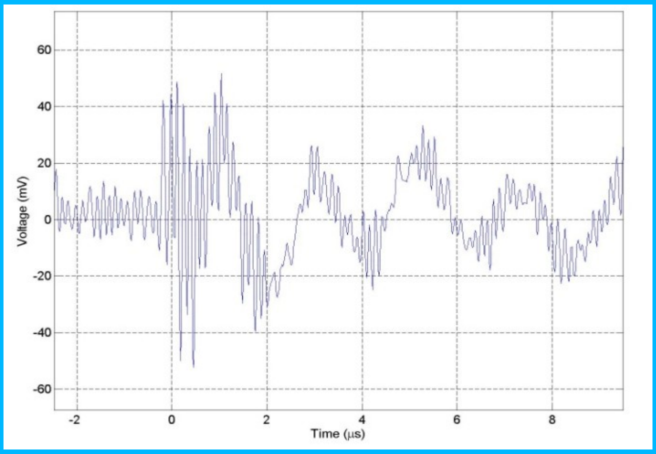

Fig.2(a) 80 kV type 1 with defect

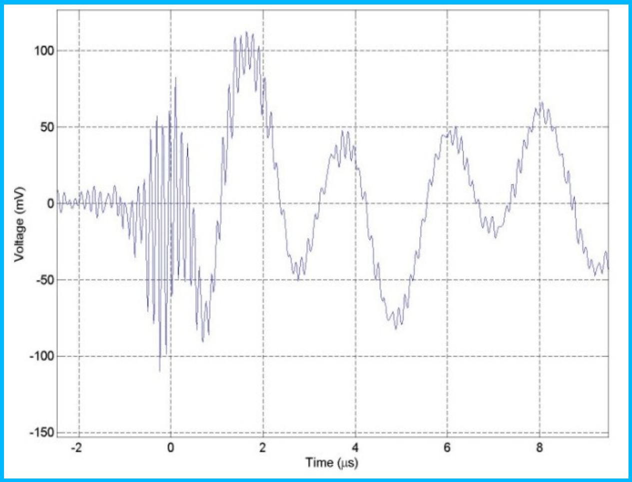

Fig.2(b) 85 kV type 1 with defect

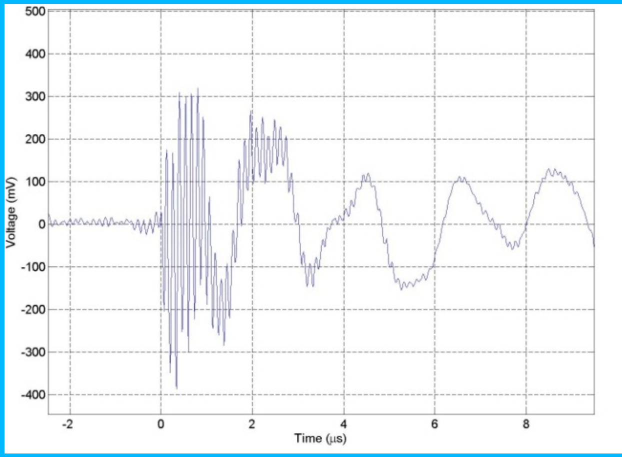

Fig. 2(c) 90 kV type 1 with defect

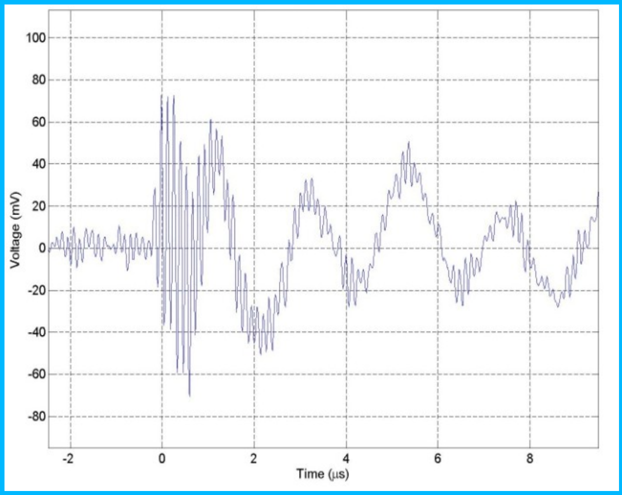

Fig. 2(d) 85 kV type 1

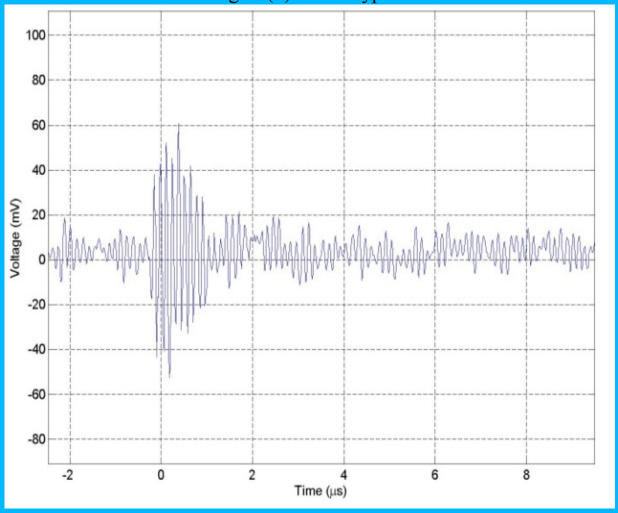

Fig.2(e) 85 kV type 2 with defect

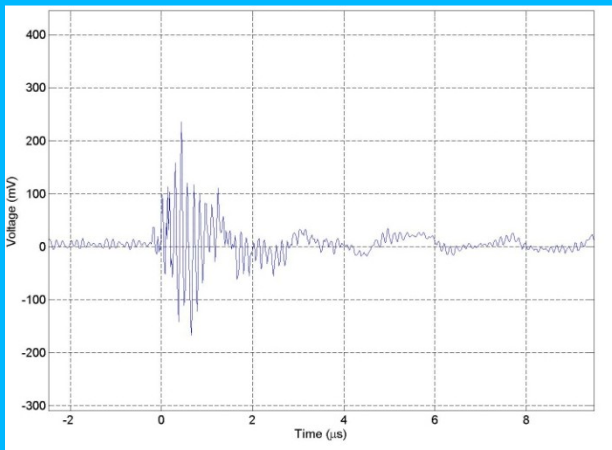

Fig.2(f) 90 kV type 2 with defect

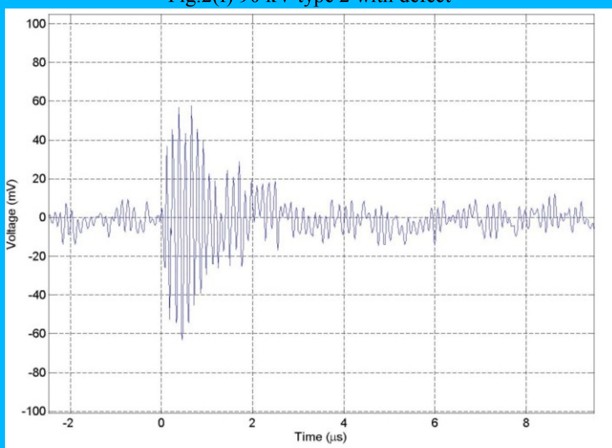

Fig.2(g) 85 kV type 2

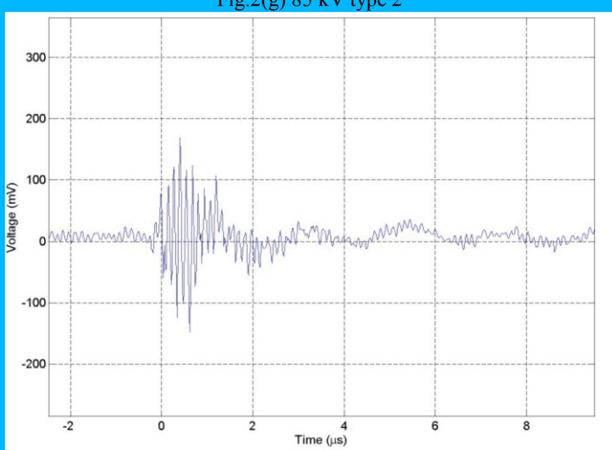

Fig.2(h) 90 kV type 2

Figure 2. Sample measured voltage (current X 50 Ω) waveforms at the input to the RIV meter

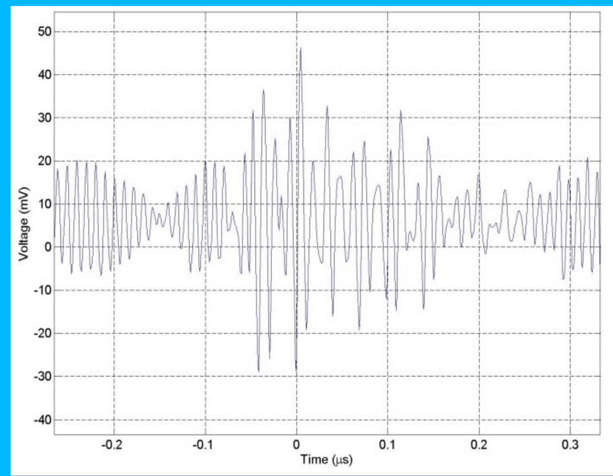

Fig.3(a) 85 kV with defect

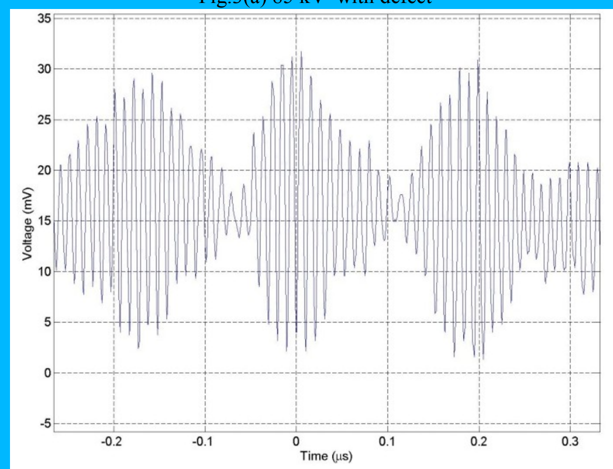

Fig.3(b) 90 kV with defect

Figure 3. Sample measured voltage(current X 50 Ω) waveforms at the ground end lead of insulator string