REMOTELY OPERATED HIGH VOLTAGE LABORATORY FOR PARTIAL DISCHARGE MEASUREMENT

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Abstract: Rapid growth of power in global perspective needs the development of high voltage laboratory for research, testing and evaluation of high Voltage (HV) power apparatus. To meet the challenges, many institutes are offering number of courses in the field of high voltage engineering in graduate and post graduate level, all over the world. In view of hands on practice of the subject, in the HV laboratory, the traditional high voltage Laboratories are serving an important role for providing the engineering education in the field of HV engineering. However, it is not sufficient to cater the world's growing need. As a result, the students are not getting the access of HV laboratory and the students are not acquainted with hands on experimentation of the offered courses leads the lack of interest as well as knowledge in the HV courses among the students. It also results the shortage of skilled personnel in the field of HV engineering. To overcome the above, an Information and Communication Technologies (ICT) enabled remotely operated HV laboratory (ICTRHVL) at National Institute of Technology (NIT), Durgapur, has been developed. It caters the need of students for hands on experiments for the HV courses with real equipped laboratory at anywhere and anytime. It is an economical means in view of quality education for Electrical and Electronic Engineering programs at undergraduate and post graduate level. The ICTRHVL is also equipped with the testing facilities for on-line testing of HV power apparatus and on-line test report facilities for industry as well as the utilities. This paper explains the mechanisms and approaches for hands-on experimentation in partial discharge (PD) measurement and testing by using ICT facilities. With the inclusion of ICT facilities, PDs can be measured, monitored and analyzed remotely from anywhere in the world by using the Local area network (LAN) as well as through the internet. ICT enabled high voltage laboratory not only supports all objectives of the traditional lab but also be student centered as well as economical and efficient sharing of resources.

1 INTRODUCTION

Throughout the history of engineering education, high quality laboratory experiences have enhanced the learning of model-based knowledge domain concepts and theories. The educators around the world have recognized the need to transform students from passive listeners to active learners and the paradigm has shifted from teacher-centered to learner-centered environment. It has enabled a variety of new concepts in education for enhancing the experience of learning and teaching [1-25]. In engineering education, high quality laboratory experiences and facilities are limited to few institutions which made them available through ICT to economically poor institutes in remote places with a minimal cost. ICT enabled laboratories, whether accessed locally or remotely, have the immense potential to provide greatly enhanced and more effective deep learning experiences. The traditional laboratories have some limitations in achieving their objectives efficiently and economically, associated with their costly infrastructure and maintain skill technicians as well as efficient faculty members. Efforts are being made around the world to overcome these limitations by using ICT. In this paper, development of an ICT enabled remote HV laboratory at NIT, Durgapur, is described with mechanisms and approaches for development of hands on experimentation in partial discharge test by using the ICTRHVL. It is an economical means in view of quality education for Electrical and Electronic Engineering programs at undergraduate and post graduate level. The ICTRHVL is also equipped with the testing facilities for industry as well as the utilities for on-line testing of HV power apparatus and on-line test report facilities. It culminates in the "access to all" opportunity to every incumbent to build the trust between industry, Government agencies and individuals which is a powerful tool for the development of underdeveloped and developing countries.

Fig. 1 Experimental setup for partial discharge test in IRCTHVL

2 DESCRIPTION OF ICT ENABLED REMOTELY OPERATED HIGH VOLTAGE LABORATORY FOR PARTIAL DISCHARGE MEASUREMENT

The remotely operated high voltage laboratory with ICT enabled technology assists the students as well as faculty members to perform HV experiments and tests online, in real-time on real equipment, from anywhere and anytime. It is a cost effective tool in the field of High Voltage Engineering as well as digital e-learning, as becomes to setup a HV laboratory involves huge costs. It is also not economical for each and every institution to set up a HV laboratory. The partial discharge measurement test in HV laboratory is essential to reinforce learning of theoretical concepts of partial discharge generation, testing & evaluation of the test results which enhances the theoretical concepts in multifold directions. As the development of the partial discharge test facilities in HV laboratory is expensive for the poorly funded educational institutions, virtual and remotely operated HV laboratory offers an alternative reliable solution for HV engineering education. The concept of HV virtual laboratory was first conceived at NIT, Durgapur in year 2003 [18-25]. It is a successful tool for HV engineering course which enables the students to do their simulation, testing and firsthand experience in HV engineering with the help of ICT. After the success of virtual HV laboratory, ICTRHVL was developed at NIT, Durgapur and commissioned in February 2009. ICTRHVL requires four major components such as traditional laboratory equipment, hardware for ICT enabled equipment, software with upgrading capability and skilled laboratory personnel.

The traditional partial discharge test system consists of High Voltage Transformer, voltage divider, coupling capacitor, test object and control of partial discharge test system and test setup is shown in Fig. 1(a). It consists of high voltage Generator, rated 300 kV, 150kVA, divider, rated 300 kV, coupling capacitor, rated 300 kV and the dielectric test cell with needle flat electrode configuration which is consider as a model transformer (i.e., test object). The control module of ICT enabled impulse system consists of MS Window based server, interface card, automation module, digital storage oscilloscope (DSO, Agilent), internet camera which is shown in Fig. 1(b).

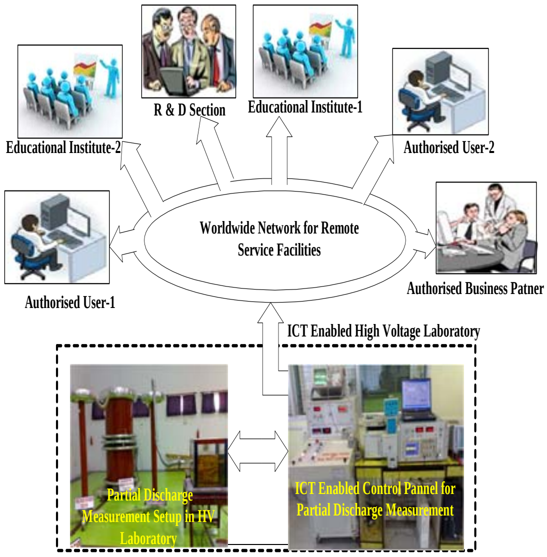

Fig. 2 Typical modules to conduct the partial discharge test in IRCTHVL

ICT enabled high voltage laboratory can enhance laboratory experience by three generic methods such as ICT Aided Experiments in Real Labs, Experiments by Simulation Programs and Experimentation in Remote Laboratories. The ICT enabled HV laboratory will be networked for digital e-learning towards fulfilling the dream of the nation as a smart Information Communication Technology (ICT) user.

2.1 Remote desktop for ICTRHVL

The ICTRHVL is equipped with state of the art hardware and software for remote operation of the experiments. It is performed by observing the real data and status of the test set up from a distance location through internet. To operate the ICTRHVL at NIT Durgapur from remote places, the host server is installed at HV laboratory with remote access software, called ‘Simple Desktop’ which is shown in Fig. 3. The ‘Simple desktop’ is user friendly where the remote user can connect the host server from the remote places by putting the user name, password and IP address of the host server with proper authentication. Once the ICTRHVL is successfully accessed by the remote users, the control and commands of the laboratory are with the remote users along with the host. The laboratory can be accessed by one remote user at a time as the time slot for remote users are monitored by host server. Thus, a number of universities can form a group of user to access the ICTRHVL. This ‘Simple Desktop’ is capable to detect any unauthenticated access of the server and it can terminate easily. ‘Simple Desktop’ is also able to communicate with users sitting at remote place for clear its doubts, status of the experiment from remote end. The typical module for conduct the partial discharge test in ICTRHVL is shown in Fig. 2.

2.2 Remote Operation of ICTRHVL for Partial Discharge Test

In order to start the ICTRHVL for high voltage partial discharge test some of the following steps are to be carefully followed

Step 1: Send the message or communicate to the ICTRHVL at NIT, Durgapur to switch on the camera, server, control of AC voltage and all safety interlocking switches to be made ON after checking all the connection of the high voltage power apparatus and safety requirements.

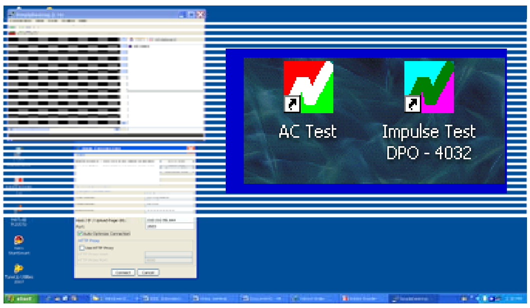

Fig. 3 Screen shot of log-on to ICTRHVL

Step 2: Log on to the program ‘Simple Desktop’ module with proper authentication and IP addresses at remote place.

Step 3: After Logging on, click on the icon of “AC Test” from the desktop shown in the inset of

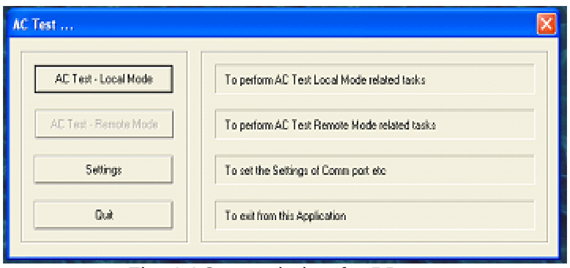

Fig. 4 AC test window for PD test

Fig. 3. This will open the “AC Test” window of ICTRHVL as shown in Fig. 4.

Step 4: Click on “AC Test-local mode” in the AC test window. This will open “AC test input details” window.

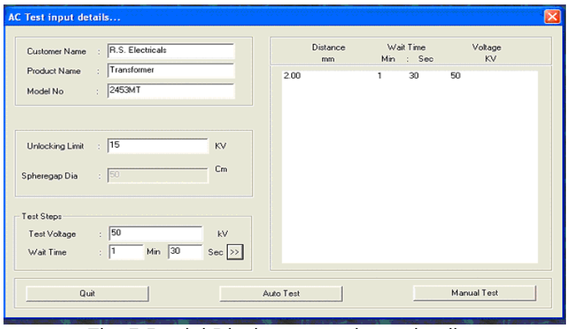

Fig. 5 Partial Discharge test input details

Step 5: Fill up all the input details mention in the “AC Test Input detail” window which is shown in Fig. 5 and click on the “Auto Test button” from the same window. This will open a new window (AC Test Process-AUTO) where the entire control button (Emergency Off, Reset, Siren, sensor indicator etc.) including all the meter reading of the control panel together display into this window which is shown in Fig. 6. Finally the data are stored in the hard disk

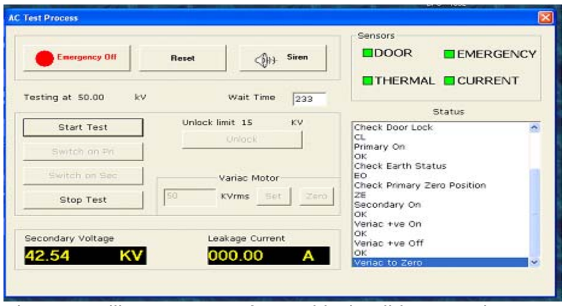

Fig. 6 Oscilloscope waveform with detail input and output parameter

of the computer.

3 TESTING FACILITIES AT ICTRHVL

The laboratory course is entitled for the engineering students of forth year final semester as well as Master degree program are generally taken for purpose of the fulfilment of the laboratory experiment. The goal of this course is to give a thorough understanding of the knowledge based theories and the practical experience to the students setting in different universities at different remote places through ICT facilities. The number of the experiment such as air breakdown test, breakdown of gases, HV Impulse testing, HV Dry / Wet power frequency testing, Capacitance and Tan delta measurement, partial discharge measurement, Insulation resistance, RIV, Corona measurement, HV Calibration, CT/PT Calibration etc. related to the HV engineering can be performed with the help of ICT enabled laboratory. For an example the partial discharge detection in high voltage equipment i.e., a model transformer has been used as case study.

3.1 Experimental Setup and procedure for Partial Discharge Measurement

A high voltage source of 0-300kV, along with other computerized control circuit and measuring equipments are used to simulate the PDs in the model transformer in the above voltage range. A photograph of the schematic experimental setup is shown in Fig. 1(a). In order to get the wide range of PD in the dielectric test cell the needle-plate electrode are separated horizontally by 40 mm distance. A computer measurement system usually consists of a digital computer, digital storage oscilloscope, data acquisition (DAQ) hardware device, and a software package to support obtaining, displaying and analyzing data from the DAQ device and has been used as a valuable tool for modern engineering education [5-15]. The results are obtained by capturing the screen or by saving the data files for future analysis. The acquired data are analyzed by using a Laptop

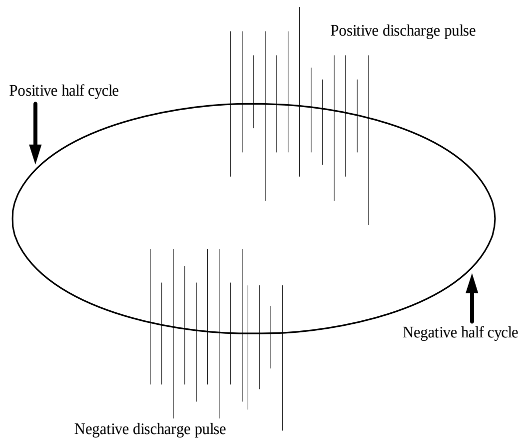

Fig. 7 Typical partial discharge pattern representation on elliptical time base.

computer with 'PDGold' environment. As per the IEC-60270 standard the 'PDGold' software facilitates to represents the PD magnitude in three different unit such as milli-volt (mV), decibel (dB) and Pico-coulomb (pC). With the help of the facilities the PD characteristics are observed in model transformer. The typical elliptical representation of the PD is shown in Fig. 7. The partial discharge pattern representation on elliptic time base can be observed by using this digital technique with a proper selection of option available on main PDGold window shown in Fig. 9.

3.2 Results and Discussion

For measurement of PDs in the model transformer, the HV unit (0-300kV) along with the measurement devices are standardized as per IS 2071 and IEC60270. To generate the PDs between the needle-flat electrodes inside the model transformer kept horizontally at a distance of 40 mm a sinusoidal voltage of 10-40 kV range, 50 Hz is applied. It is observed that the PD magnitude is increases with increase of applied voltage between the electrodes. The inception voltage of the PD is found for this case is 24 kV. The typical PD pattern observed under the sinusoidal applied voltage of 28 kV between the electrode which is shown in Fig. 8. In order to continuous monitoring of the PD level inside the model transformer DAQ and PD Gold software package is used which is shown in Fig. 9. It is found from the several studies that the magnitude of discharge pulse (q), the number of the discharge pulse (n) and the phase angle (φ) at which the discharge occurs are the three basic and major parameters used for PD pattern recognition. The computer aided processing technique has facilitated the automation of the recognition task. As a result, the PD pulses are grouped by their phase angle with respect to the 50 Hz sine wave. In case of

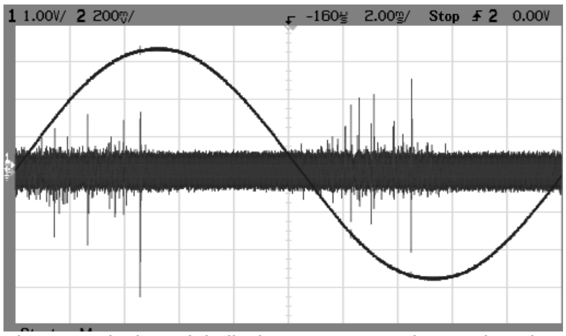

Fig. 8 Typical partial discharge pattern observed under sinusoidal applied voltage of 28 kV between the need-flat electrode.

observation takes place for several voltage cycles, the statistical distribution of individual PD events can be determined in each window. A two dimensional PD distribution φ-q represents the PD magnitude apparent charge (q) as a function of the phase angle (φ), on the other hand three dimensional φ-q-n represents the relationship between the PD magnitude 'q' and the pulse count 'n' as a function of Phase angle φ. This two and three dimensional representation of partial

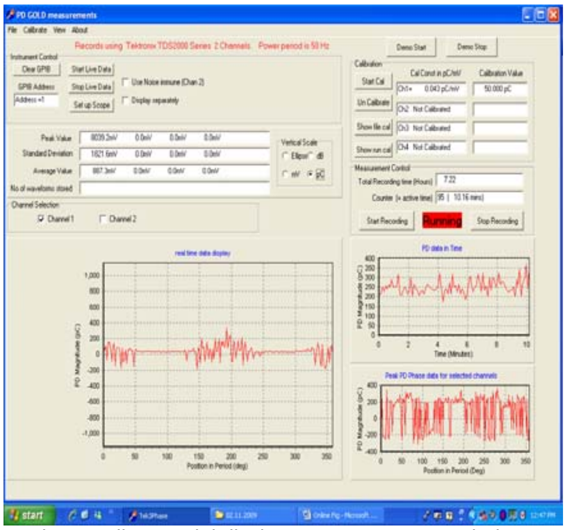

Fig. 9 Online Partial discharge measurement window

discharge phenomena eventually call the phase resolved partial discharge (PRPD) pattern. Fig 10 shows the analysis of the PD pattern in different dimensions like *φ-q, q-n,* liner mono-polar, liner-bipolar and polar representation for each cycle after collecting the raw data for 14 minutes. The continuous monitoring of such model transformer can be done for 7 hours and 22 minutes and same operation can be done from the remote end with the help of ICT facilities. Fig. 10(a) shows the PD activity inside the model transformer for a time duration of 14 minutes. It is found that PDs are random in nature and the peak values of the PDs are changes with the recorded duration of the time. It is also observed that the several cycle of the applied voltage is introduced throughout the total recorded time period. Therefore, during the analysis of the collected PD data throughout the total recorded time period each and every cycle of the applied voltage can be individually represented for recognition of the PD patterns. Here the PDs are analyzed for a single cycle (i.e., 20ms) between the time spaces of 9 to 10 minutes of the total recoded time of 14 minutes. Figure 10(b) shows the variation of magnitude of PDs (*q*) in pico coulomb with phase angle (*φ*) during the recorded period of one cycle of applied voltage between the need-flat electrodes. Figure 10 (b) shows the PDs are appearing mostly on the positive and negative

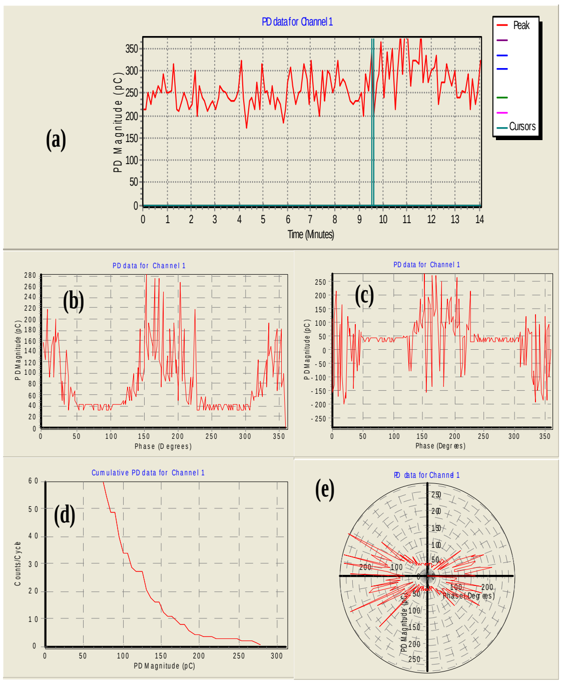

Fig. 10. Analysis of the recorded PDs through PRPD technique. (a) Variation of magnitude of PDs (*q*) with time. (b) Linear mono-polar representation of the magnitude of PDs (*q*) and the phase angle (*φ*) of applied voltage. (c) Linear bi-polar representation of *q* and *φ*. (d) Number of PDs (*n*) per cycle with *q*. (e) Polar representation of PDs recorded for a cycle (20ms duration).

half cycle of the applied voltage. It is also observed that the magnitude of the partial discharge varies from 40 pC to 280 pC. Figure 10(c) shows the linear bi-polar representation of the same recorded PDs which gives the complete idea about the nature of PDs i.e., rise time and the fall time of the each pulse. Figure 10(d) shows the variation of magnitude of PDs (*q*) with the number of pulses (*n*) in each power cycle. It is observed that the number of PDs per cycle is decreasing with the increase of it's magnitude. Figure 10(e) shows the distribution of PDs with the phase angle in polar scale. The most of the PDs occurred in the first (0-40°), second and third (140°-230°) quadrant and (320°-360°) of positive and negative half cycle of the applied voltage, respectively, which indicates that the PDs present in the model transformer is 'electrical tree type partial discharge' [14]. Further the report for PD measurement is generated with the base of the collected data for future analysis.

4 CONCLUSIONS

Rapid development of modern electrical power system has made it necessary to go for higher and higher system voltages to transfer the power efficiently and sustain the modern civilization. Therefore, it is necessary that students should be acquainted with the knowledge of high voltage testing. Because of high cost for setting up high voltage laboratory, ICTRHVL is an effective educational tool for all the institutes that offer Electrical and Electronic Engineering programs at either undergraduate or post graduate level. With the help of information and communication technology, ICTRHVL makes distance disappear and provide an opportunity to share the scarce teaching resources in terms of personnel and facilities. ICTRHVL can enhance laboratory experience by three generic methods such as ICT aided experiments in real laboratories, experiments by simulation programs and experimentation in remote laboratories. The ICT enabled high voltage laboratory is also equipped with the testing facilities for the industries as well as the utilities around the world where they can utilize the laboratory for on line testing and report generation of PD tests of high voltage power apparatus. The presented method has several advantages including that it is effective for on-line monitoring of PDs. Therefore, with the inclusion of ICT facilities, PDs can be measured, monitored and analyzed from anywhere in the world by using the Local area network (LAN) as well as through the internet. The ICTRHVL will be networked for digital e-learning towards fulfilling the dream of the nation as a smart Information Communication Technology user. An ICT enabled high voltage laboratory not only supports all objectives of the traditional lab but also be student centered as well as economical and efficient sharing of resources.

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