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A remotely operated high voltage laboratory for impulse voltage testing

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ABSTRACT: This paper reports on the development of an ICT-enabled remotely operated high voltage laboratory at the National Institute of Technology, Durgapur, India, for online control of generation, measurement and analysis of steady state and transient high voltage phenomena. In the field of education, the laboratory is a potential tool for all institutions that offer electrical power engineering programs at undergraduate and postgraduate levels. The students can access and familiarise themselves with operations of the laboratory for conducting experiments and for testing high voltage power apparatus by using a local area network (LAN) as well as through the Internet. The laboratory can also be used for commercial high voltage tests for industries and utilities. This paper explains the approaches developed at the laboratory for experimentation in remote impulse voltage testing and online report generation.

INTRODUCTION

The availability of information and communication technologies (ICT), web and agent technologies in cost effective infrastructure have led to the rapid expansion of applications of ICT in the field of maintenance, testing and online monitoring of electrical systems. The education world has also been changed by the pace of ICT advancement. Educators around the world have recognised the need to transform students from passive listeners to active learners and the paradigm has shifted from teacher-centred to learner-centred environments. It has enabled a variety of new concepts in education for enhancing the experience of learning and teaching [1-7]. ICT-enabled laboratories, whether accessed locally or remotely, have immense potential to provide greatly enhanced and more effective learning experiences, with access to unique and/or expensive equipment. Traditional laboratories have some limitations in achieving their objectives efficiently and economically, which is associated with their costly infrastructure and need for skilled technicians and academic staff members. In this paper, the development of an ICT-enabled remote high voltage laboratory at the National Institute of Technology, Durgapur, is described with mechanisms and approaches to hands-on experimentation in impulse voltage test by using the laboratory. It presents an economical means for providing quality education in electrical engineering programs at undergraduate and postgraduate level. The laboratory also provides the testing facilities for industry for online testing of high voltage power apparatus and online test reporting. It gives an opportunity to build the collaboration between industry, government agencies and individuals, which is a powerful tool for progress in underdeveloped and developing countries.

DESCRIPTION OF THE REMOTE HIGH VOLTAGE LABORATORY FOR IMPULSE VOLTAGE TESTING

The laboratory assists both students and staff to perform high voltage experiments and tests online, in real-time on real equipment, from their own location. It is a cost effective tool in the field of high voltage engineering as well as in digital e-learning as setting up a fully equipped high voltage laboratory involves huge costs. Therefore, it is not economical for each and every institution to create a high voltage physical laboratory.

The impulse voltage test in high voltage laboratory is very important for reinforcing the learning of theoretical concepts of impulse voltage generation, testing and evaluation of results and it enhances theoretical concepts in several areas. The development of impulse voltage test facilities in a high voltage laboratory is expensive; virtual and remotely operated high voltage laboratory offer an alternative reliable solution for high voltage engineering education. The concept of a high voltage virtual laboratory was first conceived at the National Institute of Technology, Durgapur in 2003 and then developed further [8-11] to enable the students to do their simulation, testing and skill development in high voltage engineering with the help of ICT. After the success of the virtual high voltage laboratory, the laboratory was developed at the National Institute of Technology, Durgapur and commissioned in February 2009. A remotely operated high voltage laboratory requires four major components i.e. traditional laboratory equipment, hardware for ICT enabled equipment, software with upgrading capability and some skilled laboratory personnel.

The typical traditional impulse test setup is shown in Figure 1. It consists of a 800 kV, 40 kJ Marx generator, a 100 kV rated rectifier, a 800 kV rated divider and the test sample e.g. 33 kV insulator. The control module of an ICT-enabled impulse system consists of an MS Window based server, interface card, automation module, an Agilent digital storage oscilloscope, an Internet camera and software for a Graphical User Interface (GUI) which is shown in Figure 2. A schematic diagram of a typical multistage impulse voltage generator based on the Marx circuit is shown in Figure 3.

Figure 1: Hardware of the impulse voltage test setup.

Figure 2: Control module and GUI of the impulse test setup.

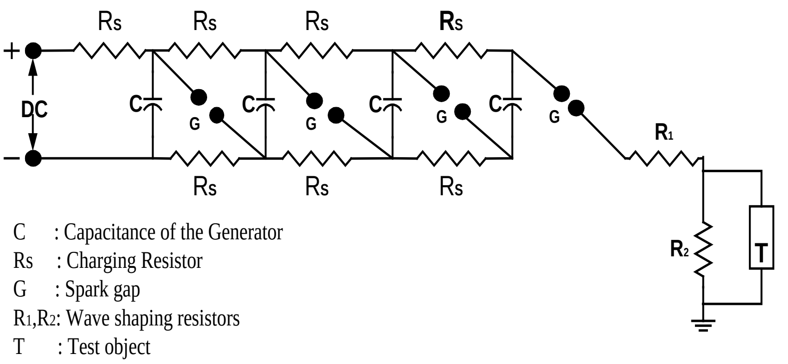

Figure 3: Marx generator for impulse voltage generation.

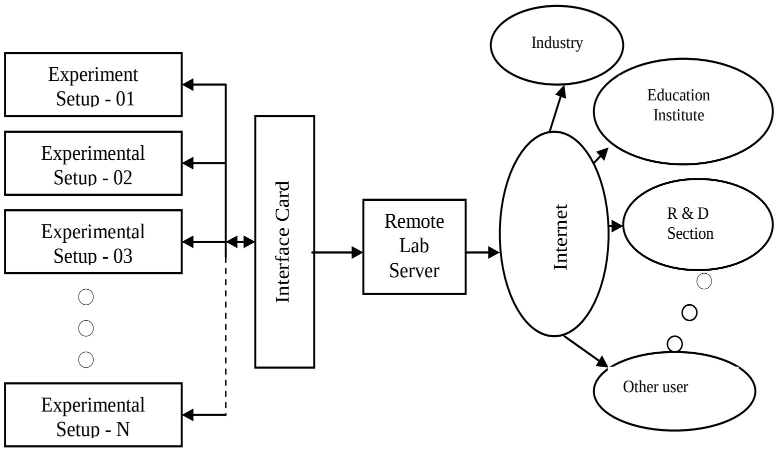

Figure 4: Functional block diagram of ICTRHVL.

The computer-based measurement system consists of a digital computer, a digital storage oscilloscope, a data acquisition (DAQ) hardware device, and a software package to support obtaining, displaying and analysing data from the DAQ device. The laboratory is equipped with real devices and instruments and experiments can be performed by controlling the instruments and observing the real data from a distant location through the network. The functional block diagram of the laboratory is shown in Figure 4. The laboratory at the National Institute of Technology, Durgapur has the facilities for AC power frequency test, partial discharge test and impulse voltage test as shown in Figure 5, with the flow chart of the impulse test illustrated in Figure 6.

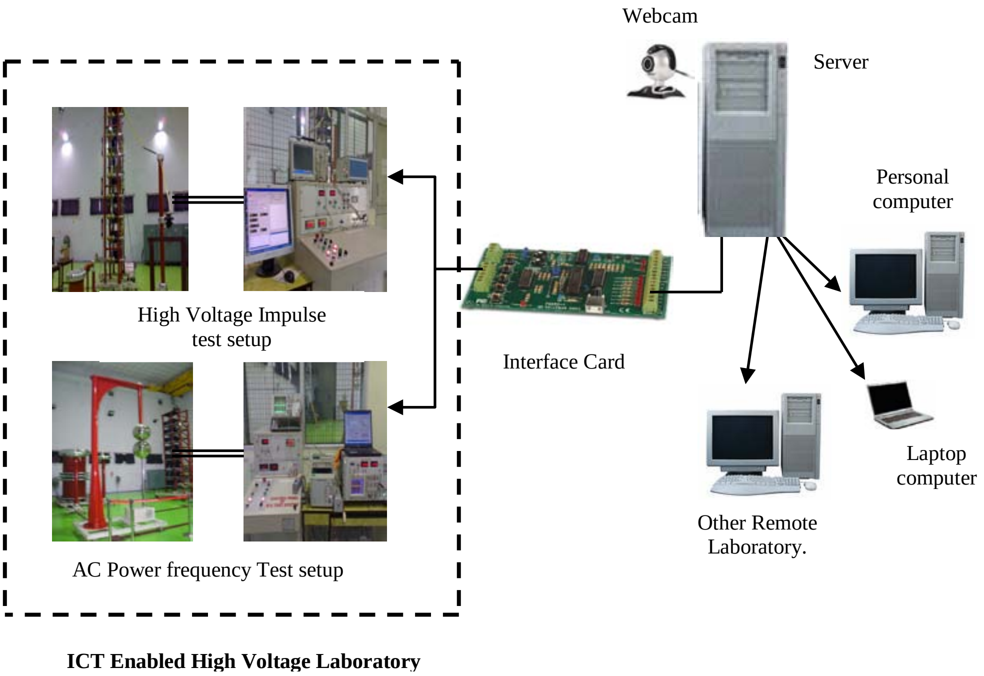

Figure 5: Modules of ICTRHVL.

RESULTS AND DISCUSSION

In a case study, a 33 kV rated post insulator was connected to the impulse voltage test in a Marx generator rated at 800 kV, 40 kJ, having eight stages with the manual and automation module. To check the stability of the laboratory, charging voltages of 21.87 kV to 68.94 KV per stage of a four-stage Marx generator were applied and impulse voltages of 82.3 kV to 273.4 kV were observed by using the laboratory. The efficiency of the impulse generator was above 93%. The front time and the tail time were also within the limits of the standard impulse voltage of 1.2/50 μs which is shown in Table 1. The tolerance limit for the front time and the tail time of the standard impulse test were ±30% and ± 20% respectively. The wave shape of the lightning impulse voltage of the laboratory was acquired through the automation module and the ICT-enabled client server management system. The wave shape and test results were stored automatically on the hard disk for further analysis. In the second test, the same 33 kV rated post insulator was connected to the impulse voltage test to a Marx generator rated 400 kV, 40 kJ, having four stages with the manual and automation module and the impulse voltage test was conducted. A positive impulse voltage of 160 kV was applied to the insulator at the 40 kV per stage, so that the voltage applied was the positive peak voltage of 160kV in the fourth stage with a 400 kV, 40 kJ Marx generator, in line with the basic insulation level of 33 kV insulator material.

From the test results it was observed that the sample withstands the positive test voltage of 152 kV of 1 µs as front time and 49.13 µs as tail time as shown in Table 1. Similarly, another fourteen shots were also applied to the insulator as per the specification and it withstood it satisfactorily.

Table 1: Impulse voltage stability.

Sl. No.	DC Charging Voltage /Stage (kV)	Total Impulse Voltage (kV)	Front Time (µs)	Tail Time (µs)	Efficiency (%)
1	21.87	82.03	1.44	45.3	93.8
2	25.19	93.74	1.34	46.3	93
3	35.54	136.71	1.12	48.8	96.2
4	41.2	162.1	1.14	47.5	98.4
5	45.11	177.72	1.21	47.5	98.5
6	48.83	191.39	1.11	48.4	98
7	59.18	236.31	1.24	48.8	99.8
8	68.94	273.42	1.17	51.1	99.2

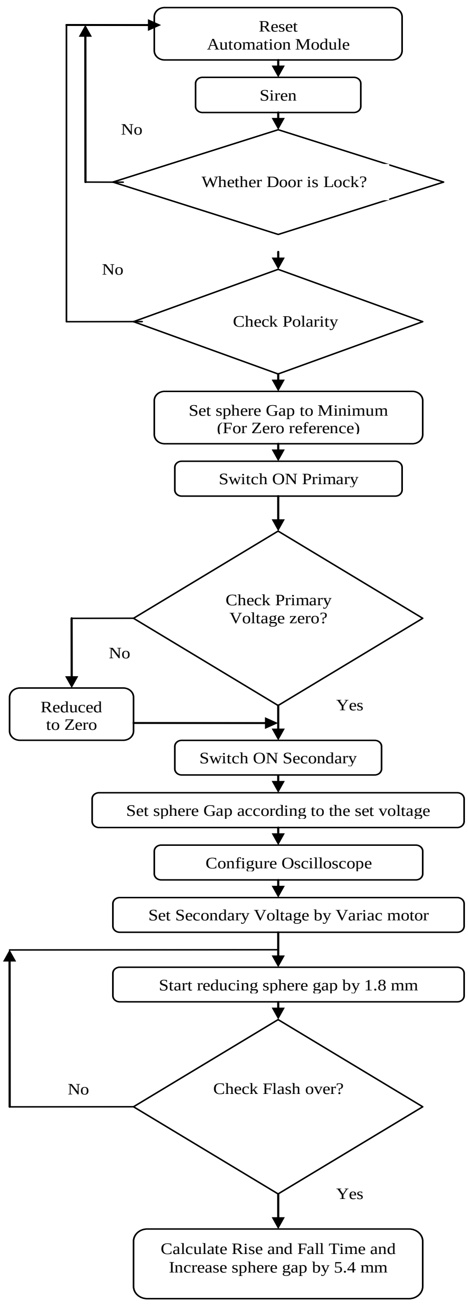

Figure 6: Operation flowchart of ICT-enabled impulse test.

CONCLUSIONS

In electrical power engineering education, it is advisable for students to be acquainted in laboratory courses with practical high voltage engineering knowledge. Because of high cost for setting up a high voltage laboratory, the laboratory is a potential cost effective educational tool for all the institutions that offer such programs at undergraduate or postgraduate levels. The laboratory provides an opportunity to share the teaching resources in terms of personnel and facilities. It has the opportunity to support all the learning objectives of the traditional high voltage laboratory in a remote setup. To the authors' knowledge, the laboratory is the first remote educational high voltage laboratory in the world. It is foreseen that it will be part of an e-learning network nationally and internationally, similar to that being developed in LabShare – a project that has been funded by the Australian Government's Department of Education, Employment and Workplace Relations, through the Diversity and Structural Adjustment Fund [12].

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