

# RI-KFUPM High Voltage Laboratory

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**Abstract:** The aim for establishing the High Voltage Laboratory was to support the study about high voltage insulator performance in the Kingdom. Later to that, the HV lab capabilities were expanded to cope with increasing needs for research and testing about high voltage equipment and to support the teaching and training of students in the electrical engineering department. The HV Lab is equipped with high voltage AC, DC and impulse sources. Additional measuring and sample preparation equipment are also available to support the lab work. At the same time, the HV Lab is assisted by the Research Institute diversified facilities. This paper will present the current facilities and services of the HV Laboratory, in addition to future planes to enhance the Lab. It was clear that the services of the HV Lab, especially to make type, acceptance and special testing for locally manufactured electrical equipment, are highly needed. The Lab is looking for broadening its capabilities and services to address the local utilities and industry testing needs.

## 1 INTRODUCTION

The aims of the High Voltage Laboratory are to perform research and development, technical training and to perform tests for verifying the performance of different high voltage equipment [1,2]. The Research Institute and Electrical Engineering Department of the King Fahd University of Petroleum and Minerals (KFUPM) joined their efforts to establish the nucleus of high voltage laboratory (HV Lab) at the University in 1984.

The major drive to establish the HV lab was to support the project of the national study about high voltage insulator performance in the Kingdom [3,4,5], which extended for a period of eight years. Accordingly, the HV Lab is built in accordance with the international IEC-507 standards, which defines the specifications for the high voltage testing facilities and presents requirements and conditions to test the high voltage contaminated insulators. In order to diversify the services of the HV Lab and to enhance its capabilities to respond to different testing requirements from electric equipment manufacturers and electric utilities, the lab acquired additional important testing facilities. Also, the HV Lab is getting involved in the research related to high voltage engineering and supports the teaching of electrical high voltage courses in the electrical

engineering department and the training for students.

## 2 HV LAB FACILITIES

The Lab is located at the Research Institute and occupies a floor area of about 200 m<sup>2</sup> and is 10.5 m high. It is accessible by trailer and truck through a large gate and is equipped with a 10-ton crane to facilitate loading and unloading of heavy equipment. The purpose of the lab is to carry out type, research, special and routine test of electrical equipment up to 250 kV phase to ground voltage. The HV Lab undertakes the tests according to IEC, ANSI or client's specification. The tests, which can be done at the Lab, are:

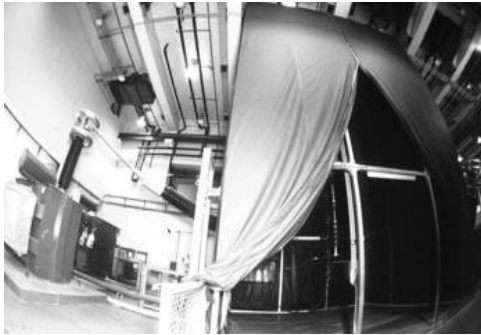
- AC voltage, 60 Hz up to 500 kV<sub>rms</sub> (phase to phase).
- AC pollution test up to 420 kV<sub>rms</sub> (phase to phase).
- Lightning impulse up to 140 kV.
- Switching Impulse up to 140 kV.
- Partial discharge test.

The following high voltage facilities available at the Lab are utilized to make the required tests:

### 2.1 High Voltage Insulator Testing Setup

The high voltage insulator testing system consists of the following main parts:

- ◆ **The high voltage supply:** The high voltage source has to have special features to be suitable for testing contaminated insulators [6,7,8], specially regarding the source short circuit current and X/R ratio. The voltage source is a single phase, 250 kV, 500 kVA regulated transformer. At the 100% output voltage level, the X/R parameter and short-circuit current are 1.44 and 38.7 Ampere, respectively. The input voltage to the HV Lab is 13.8 kV provided through a switchgear system to isolate the HV Lab activities from the utility network.



**Fig. 1:** High voltage insulator testing setup.

- ◆ **Fog chamber:** Where is the insulator samples are tested. This chamber is measuring 6 m X 6 m X 9 m high. It's equipped for performing the two standard tests of clean fog and salt fog tests. The chamber is plastic tent supported by steel frame with an internal aluminum structure for reinforcement. The chamber is equipped with two spray nozzle frames. Each frame has ten nozzles to cover the full length of the test string and each nozzle has individual flow control.
- ◆ **Wetting and polluting facilities:** The HV Lab is equipped with the facilities to perform the salt fog and clean fog tests. For pollution tests by salt fog, The salt-water solution is supplied to the nozzles by one common pipe on each rack from a top tank. The compressed air is provided from a compressor with a capacity of 1000 l/min. For the clean fog test, the system utilizes five steam generators each producing 24 kg/hour.
- ◆ **Measuring and recording system:** The automatic data acquisition system is used to measure and record the I-highest current surges and voltage levels. Additional equipment such as X-Y recorders, digital and analog multimeters, strip-chart recorders, storage oscilloscope and high-speed camera are available.

## 2.2 High Voltage Series Resonance test set

This high voltage source is 600kVA, 300 kV single



phase. It's a dielectric test set suitable for conducting alternating current tests on various capacitive test objects. This voltage source is also capable of providing the ac excitation for partial discharge tests.

**Fig. 2:** High voltage series resonance test set.

## 2.3 Partial Discharge Measurement Setup

This system measure the partial discharges levels in high voltage insulated objects, and localizes those weak points in the cables in accordance with the relevant standards [9].

## 2.4 High Voltage Measuring Facilities

Although, all the high voltage sources available at the lab have their own voltage measuring systems, another reference and calibration high voltage measuring facilities were available, such as:

- **Electrostatic voltmeter:** This meter is suitable for measurement of AC and DC voltages up to 100 kV.
- **High Voltage Divider:** This capacitive and resistive divider is suitable for AC and DC voltage measurement up to 300 kV.

## 2.5 Oil Quality Testing Facilities

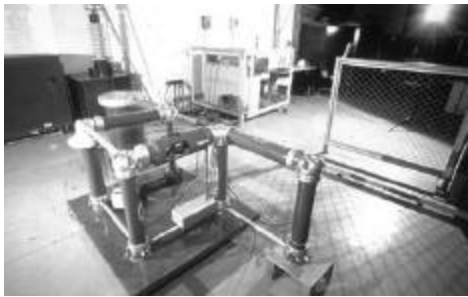
Testing the insulating oil quality is very crucial to monitor the performance of the high voltage electrical equipment as transformer, circuit breakers and capacitors. Following are the available tools at the Lab:

- **Dielectric strength measuring system:** This meter is suitable for measurement of dielectric strength of the electrical insulating oil.

- **Oil water content measuring system:** This instrument is used to calculate the water contents in the insulating oil.

### 2.6 High Voltage Construction Kit

This high voltage source is capable of producing high voltage AC 100 kV,  $\pm$  DC 140 kV and 140 kV Impulse voltage. It consists of different connectable components, which are easily arranged to produce the desired voltage type.



**Fig. 3:** High voltage construction kit.

### 2.7 Digital High Voltage Oscilloscope

This is a digital impulse measurement system used in testing high voltage equipment. It's a dual channel, 12 bit digital recorder.

### 2.8 Interference and Field Strength Meter

This metering system is a general-purpose receiver that measures electrical field strength and voltage signal waves and interference waves. It consists of two measuring receivers in addition to the suitable antennas.

### 2.9 High Speed Camera Setup

This camera is suitable for recording high-speed activities, which proves to be very useful in the basic research regarding the flashover mechanism.

### 2.10 Research Institute Analysis and Testing Facilities

The HV Lab is an integral part of the Research Institute and the University in general. The RI is having many testing and analytical facilities that can support the HV Lab to meet the requirements of the different research and testing services. The RI is equipped with the latest chemical, material characterization, mechanical and standardizing facilities that can support the HV Lab.

## 3 HIGH VOLTAGE LAB ACTIVITIES

The HV Lab performed many studies and provided testing services for different local and international clients. Also, the lab participated and supported the teaching and training of the electrical engineering students in their related courses or senior projects. Some of these main projects and activities are:

### 3.1 Research and Testing

The HV Lab since it's inception performed different studies and testing services. Following is a list of the main studies and testing services provided by the Lab to different clients:

- 3.1.1 *High Voltage Insulator Performance in the Kingdom of Saudi Arabia.* (January 1982 - November 1990). Sponsored by the Saudi General Electricity Corporation, Riyadh, Saudi Arabia.
- 3.1.2 *Laboratory Investigation of Naturally Contaminated Insulators of 132 kV Transmission System of Dubai Electricity Company.* (September 1986-March 1987). Sponsored by CERAVÉR, France. March 1987.
- 3.1.3 *Assessment of 13.8 kV Line Post Insulator for Use in Heavily Contaminated Environment of Saudi Arabia.* (October 1986-April 1987). Sponsored by Al-Gihaz Establishment, Riyadh Saudi Arabia. April 1987.
- 3.1.4 *Pollution Performance of Aerodynamic Disc and Longrod Insulator Strings Designed For 132 kV Transmission Systems in Yanbu, Saudi Arabia.* Sponsored by National Power Construction Company Ltd. Riyadh. February 1988.
- 3.1.5 *Exposure Test at Wadi Dawasir: Pollution Assessment and Electrical Performance of Naturally Contaminated Insulators.* Sponsored by National Power Construction Company Ltd. Riyadh Saudi Arabia. July 1988.
- 3.1.6 *Pollution Performance of Longrod Suspension Insulator Strings Designed for 132 kV Transmission System in Tabouk-Albir, Saudi Arabia.* Sponsored by Al-Kadi Establishments for Trading and Contracting. Riyadh, Saudi Arabia. December 1988.
- 3.1.7 *Electrical Performance of Naturally Contaminated Insulator Of The 275 kV Kuwaiti Transmission System.* Sponsored by Zedan Consulting Firm. Khobar, Saudi Arabia. April 1991.
- 3.1.8 *Electrical Performance of Solvent-Washed Porcelain Insulator Under Dry and Wet Conditions.* Sponsored by Zedan Consulting Firm. Khobar, Saudi Arabia. April 1991.
- 3.1.9 *Measurements of ESDD on Insulator Strings.* Sponsored by SCECO East, Dammam, Saudi Arabia.

- 3.1.10 *Effect of AME-1080 Rust Remover on the Performance of Porcelain Insulators.* Sponsored by SCECO East, Dammam, Saudi Arabia. March 1993.
- 3.1.11 *HV impulse withstands test of a Raychem insulated busbar coupling.* Sponsored by Saudi Lucy Co. Ltd., Saudi Arabia, Al-Khobar, March 1996.
- 3.1.12 *Current loading performance of the MCCB with respect to temperature Rise.* Sponsored by Al Abdulkarim Trading (AKTE), Jeddah, Saudi Arabia, October 1997.
- 3.1.13 *Current loading performance of the MCCB with respect to temperature Rise.* Sponsored by Al Fanar Co., Dammam Branch, Saudi Arabia, September 1998.
- 3.1.14 *Testing of Sediver Toughened Glass Suspension Insulator.* Sponsored by Al-Najem Saudi International Co. Ltd., Dammam, Saudi Arabia, March 1999.
- 3.1.15 *Study of Water Trees in Underground High Voltage Cables using Nuclear Microscopy.* Sponsored by KACST, Riyadh, Saudi Arabia, On going study.

### 3.2 Teaching and Training

The HV Lab extended its services to the EE Department to teach and train their students. Different groups of students took their summer training, senior and capstone projects, HV lab course and power engineering course-related presentations. Following is a list of the senior and capstone projects done in the Lab:

- 3.2.1 *“High Voltage Engineering”.* Laboratory course EE 464, second semester, 1999-2000.
- 3.2.2 *Design of Measuring Device for Corona on Monopolar Conductors”.* March 18, 1997 to June 30, 1997.
- 3.2.3 *Determination of DC/AC Burning Voltage on Contaminated Surfaces”.* March 18, 1997 to June 30, 1997.
- 3.2.4 *Design & Construction of HV Sphere Gap Device”.* March 18, 1997 to June 30, 1997.
- 3.2.5 *Measurement of Corona Power Loss under Rainy Conditions”.* March 7, 1998 to June 3, 1998.
- 3.2.6 *Measurement of Corona Wind.* May 4, 1998 to June 3, 1998.
- 3.2.7 *HVDC Transmission Line.* April 5, to May 19, 1999.

## 4 CURRENT AND FUTURE PLANES FOR THE HIGH VOLTAGE LAB

The HV Lab is currently involved in new projects and testing services. Different requests for carrying specialized studies and testing are continuously received from local and international clients. The lab is looking forward to expand its capabilities and to strengthen its ties with the domestic market. As the local manufacturers are increasing their role in the local economy and trying to provide the market with the required electrical equipment, (i.e: transformer, switchgear and electrical machines, it's becoming imperative to keep the level of internationally accepted quality control. Accordingly, the HV Lab is working to contribute towards improvement of quality control and, therefore, to assist the national industry in research and development and perform special quality control tests for verifying the performance of such equipment.

In this regard. The HV Lab is looking forward to cooperate with the local industry and the electric utilities to define clearly the most immediate needs and testing inquires, and to establish systematic programs, which can help the HV Lab to strengthen its capabilities.

## 5 CONCLUSION

The KFUPM-High Voltage Laboratory is equipped with several modern facilities, which are essential for assessment quality monitoring of different electric equipment. Also, the Lab is trying to acquire other new facilities to upgrade its current capabilities. The Lab is supported by the Research Institute and University capabilities to handle different specialized studies. The HV Lab is extending its services to national manufacturers and electric power utilities, besides research and development work in this important area.

## ACKNOWLEDGEMENT

The authors would like to acknowledge the support of the Center for Engineering Research at the Research Institute-KFUPM.

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