Current Status of High Voltage Engineering in Indonesia

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This paper reports current status of research activities in the field of high voltage engineering and its application in Indonesia. In general, the activities were driven by the application of high voltage (HV) and extra high voltage (EHV) transmission systems in the country. The operation and maintenance of HV and EHV equipments are greatly affected by the tropical climate of the country. This attracts researchers to investigate the effects of tropical climate on HV and EHV equipments. Other researches concentrated on the investigation of physics of tropical lightning and lightning protection. In this paper, applications and problems of high voltage engineering, research activities in universities, as well as in research institutes and utilities are briefly introduced.

Keywords: Indonesia, tropical environment, lightning, insulator

1. Introduction

Voltage levels of 500 kV, 275 kV, 150 kV and 70 kV are used in transmission systems of public utility in Indonesia, while 20 kV and 220/380 V are used in distribution systems. The 500 kV EHV transmission system is the back bone of the Java power system, which at present consists of 20 EHV substations and over 3600 circuit-km of EHV lines. The 275 kV networks are being used in Sumatra. It has been planned that 275 kV grid will be expanded in Sumatra, while 500 kV grid will also be introduced in the island. About 600 km circuit of 275 kV is also under construction in Sulawesi. The 150 kV and 70 kV transmission systems are used as the main supply to distribution networks, which now comprises of over 19,000 circuit-km of lines. This 150 kV voltage level is also used for submarine interconnection between Java and Bali Island, as well as between Java and Madura⁽¹⁾.

Main problems of high voltage systems, as well as those of telecommunication systems, are associated with the environment, i.e., tropical maritime continent that produce lots of rain and lightning. Many researches have been carried out to get high quality and reliable electric power system.

2. Environmental Condition

2.1 Tropical Climate Indonesia is a tropical country which is situated around the equator. The sun is overhead throughout the year. The tropical characteristics of the country can be described as follows⁽²⁾.

2.2 Temperature Temperature in the most part of Indonesia exhibits a diurnal variation and has an almost constant range along the year. The maximum temperature varies between 30 and 34°C at sea level and 27 and 31°C at an altitude of 500 m. The typical minimum temperature is between 20 and 25°C at sea level, and between 17 and 22°C at 500 m. This temperature characteristic should be taken

into consideration in the design, operation and maintenance of electrical and electronic equipments.

2.3 Rainfall and Humidity The rainfall in Indonesia depends on the season. There are 2 seasons, rainy season and dry season. During rainy season, the rainfall is usually high. During dry season the rainfall is low, but several places like Bogor have their “wet” local weather even in the dry season. Papua has the highest rainfall with mean annual rainfall of up to 3185 mm. Java and Madura as the most populous area have mean annual rainfall of 2571 mm. Due to high rainfall, the relative humidity (RH) in most Indonesian parts is relatively very high. During night and early morning, the humidity can reach as high as 95%. The RH decreases and reaches the minimum value at noon, and then rises to reach maximum at midnight.

2.4 Corrosion and Fungus The high values of rainfall and humidity easily cause corrosion and trigger the growing of fungus on the surface of outdoor materials, such as insulators. The environment is also a heaven of many termites and rats which is hazardous to electrical apparatuses.

2.5 Wind and Strom The surface winds, in general, are relatively calm. The typical average of wind speeds are 2–3 m/s in coastal areas to 1 m/s in land regions. During infrequent tropical storms, however, wind speed can be as high as 22 m/s.

2.6 Solar Radiation Since the sunshine is bright throughout the year, the solar radiation is high in Indonesia. The typical value of the solar radiation is 1.250 W/m². This high solar radiation contributes to the warm air radiation. This also contributes to the acceleration of aging of electrical apparatuses, especially outdoor high voltage equipments.

2.7 Lightning In general, Indonesia has a high frequency of lightning incidents. According to the data from the Directorate of Meteorology and Geophysics⁽²⁾, there are some areas that have thunderstorm days of more than 200, while the ground flash density in certain areas can be as high as 24 flashes/km sq. per year⁽³⁾. Lightning activity in the

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Fig. 1. Distribution of lightning current amplitudes in Indonesia⁽⁴⁾

region exhibits a diurnal variation, where most of lightning flashes occur in the afternoon⁽⁴⁾. Oceanic lightning activity, on the other hand, reaches its peak in early morning with much less density but higher average amplitudes. Figure 1 shows the distribution of current amplitudes in Indonesia by using data from lightning location systems⁽⁴⁾. Thin line in the figure was obtained by magnetic link measurement on top of EHV transmission lines.

3. Applications and Problems of High Voltage Engineering

Ratio of electrification in Indonesia as per 2006 is 54%, with the total number of customers of 36 millions and about 1.5 million new customers growth. To cope with such a high demand, the government has decided to speed up the development of new power plants totaling 10,000 MW by the year of 2010. The total investment is expected reach 40 billion USD up to the year of 2015. For the year 2007 alone, the allocated investment for transmission and distribution is 1.1 million USD.

Most recent and near future projects in transmission and distribution include: 50 km HVDC submarine cable to tie Java and Sumatra grid; 500 km 275-kV transmission line in Sulawesi; 1,000 km 150-kV transmission lines in Java and Sumatra; 80 km AC submarine cable to electrify small islands north of Jakarta. The existing submarine power distribution cable now operating in the Java sea is estimated 600 km with voltages extends from 5 kV to 35 kV.

Experiences of PLN and other power grid operators show that most of overhead power transmission disturbances are associated with lightning strokes that initiate flashover on the insulator surfaces⁽⁵⁾⁽⁶⁾. Almost all of 20-kV overhead distribution lines operated by PLN are not equipped with ground wire and have very long arrester interval. This is worsened by additional pollution on the insulator surfaces. Some examples of such incidents are: HV circuit breakers blow up, explosion of lightning arresters, flashover across insulators, and malfunction of transformers/reactors. Submarine and underground cables, on the other hand, experience problems mostly due to internal failure, especially in jointings.

Telecommunication sector grows rapidly in Indonesia. The

number of customers of 40 millions in 2006 is expected to grow to 100 millions in 2010. Thousands of new BTS's are now being erected annually to cope with the growth of customers. However, the development of telecommunication sector is hindered by the problem of lightning. The insurance claims paid by a major insurer to PT Telkom (the market leader in telecommunication) was estimated about 10 million USD for damages associated with lightning in 2006, which is more than 85% of the total insurance claims.

Many problems and mishaps in oil and gas industries are also associated with lightning. On one recorded incident, for example, a lightning induced over voltage had caused a black out and total damage of 2-MW gas turbine of an oil contractor at Malacca strait.

Based on observations and inspections conducted by the authors, most of the problems associated with lightning are worsened by lack of knowledge on physics of lightning and misunderstanding on the principle of lightning protection.

4. Research Activities

Research activities in high voltage engineering are mainly driven by the needs of reliable power delivery to customers, as well as by the demand of public safety and quality of services of communication systems. Some of the activities are reviewed here:

4.1 Lightning Researches on lightning focus on two main areas. One area is physics of tropical lightning. Observation of lightning current is conducted on top of Mount Tangkuban Perahu, 20 km north of Bandung. Major findings of the experiment include facts that none of currently available lightning arresters in the market can withstand lightning current in the experiment ground, probably due to the extremely high energy of the lightning current. Other research on physics of lightning covers spatial and temporal distribution of lightning activity in the tropics. The other area of research on lightning is protection of lightning and over voltages. In this area, researches include topics on lightning performance of distribution lines, distribution of lightning on structures, impulse response of grounding, distribution of lightning current on buried conductors, detection and warning of very close lightning strikes, and development of lightning simulators⁽³⁾⁻⁽¹²⁾.

4.2 Application of New Polymeric Materials Application of polymeric insulation in Indonesia is relatively new. Its application is mostly limited to indoor installation, such as MV instrument transformers and support insulators. However, at present, polymeric cables are widely used. Polymeric outdoor insulators are also introduced in the power systems. Investigation on the performance of epoxy resin and SIR has been done by taking into account the tropical climate factors⁽¹³⁾⁻⁽¹⁶⁾. The water absorption characteristics, dielectric constant and losses patterns of the materials have been investigated⁽¹⁷⁾⁽¹⁸⁾. The loss and recovery of hydrophobicity, thermal stability and long term properties of polymeric insulating materials have been investigated⁽¹⁹⁾⁻⁽²²⁾. Investigation on partial discharge and electrical treeing in polymeric materials has also been reported⁽²³⁾⁻⁽²⁵⁾.

4.3 Environmentally Friendly Insulations Due to environmental consideration, research has been made to find environmentally friendly insulating materials. Investigation

on the applicability of new liquid insulating materials has been reported⁽²⁶⁾⁽²⁷⁾.

4.4 Ceramics Insulator and Pollution As a tropical and archipelago country, Indonesia is blessed with long coastal lines, yet with high salt pollution. In addition there are many industrial areas with high level of pollution. This may cause the failure of apparatuses^{(28)–(31)}. Many efforts have been carried out to improve the performance of outdoor insulators, such as life-line washing and silicone compound coating⁽³²⁾. The effectiveness of the methods has been reported⁽³³⁾⁽³⁴⁾.

4.5 Diagnosis of Equipments It is important to know the condition of apparatuses in power systems. Diagnosis of equipments is necessary to determine their status. Diagnosis of insulators using leakage current waveforms has been introduced⁽³⁵⁾⁽³⁶⁾.

4.6 Effects of Power Frequency EMF on Biological Systems Since the introduction of the 500 kV transmission system in Indonesia, there have been some concerns on the effects of the electric as well as magnetic field on the biological systems including human being. In order to clarify the effects of the fields, there have been some research groups investigating the level of the fields underneath and nearby the EHV lines, and re-examining its conformity with the existing international standards, such as IRPA and WHO. The effects of electric and magnetic fields on biological systems have also been reported^{(37)–(39)}.

4.7 Future Research by Power Utility As the main player in power utility in the country, PLN has established a research centre recently. It has a number of testing facilities, including a HV laboratory. PLN in collaboration with researchers from Bandung Institute of Technology is embarking onto research activities on new methods of insulation diagnosis, such as frequency dielectric spectroscopy, as well as research on application of polymeric insulation on UV and corona affected applications.

5. Conclusions

Research on HV engineering in Indonesia has been mainly related with the tropical environment of the country. There have been rather low activities on collaborative research between electric power utility and universities. This may be caused by the fact that majority of HV equipments are linked with overseas companies in which their R&D is carried out abroad. It is expected that this situation would improve in the future as the power utility is now prepared for having closer collaboration with universities.

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