Diagnosis of Water Tree Deterioration for Service Aged XLPE Cables
− Study on Detection Technique of Very Small Signals for On-line Monitoring −

Background

Due to a request about urban landscape and site land restrictions, under ground electric power cables are growing. Among them, XLPE cable, whose insulating material is cross linked polyethylene, is dominant because of its convenience for installation and maintenance. Some XLPE cables installed at early period have aged more than 30 years, which is generally supposed as lifetime. On the other hand, due to recent calls for cost reduction and equipment investment suppression in the electric utility, more effective utilization of electric power apparatus is intended. There is a strong need to utilize XLPE cables until there lifetime limit by using a suitable diagnose technique, too. In order to realize this, deterioration diagnose technique, which has enough reliability and is applicable to on-line monitoring, is necessary.

Objectives

Water tree growing is said to be a main cause of deterioration in XLPE cables of 60kV class or less. A detection technique for very small signals in order to monitor growth of water tree on-line is proposed and model experiments are conducted in order to confirm the principle.

Principal Results

1. Proposal of on-line monitoring system

It is well known that *[1]third-harmonic currents are generated due to water tree deterioration, therefore a *[2]diagnostic method to monitor the signal should be available. By considering safe detection of the third harmonics and convenience of installing, the detection system with the optical fiber current sensor, shown in Fig.1, has been proposed. For this purpose, the current sensor is required to distinguish the very small third-harmonics from relatively big load current. Concretely speaking, the sensor must have a wide dynamic range of 5 or 6 figures; however, it is very difficult to achieve such specification using conventional current sensors. By utilizing the optical fiber current sensor and a compensation method for load current signals, the method for increasing the equivalent dynamic range of the sensor has been proposed.

2. Confirmation of the compensation method by model experiments

In order to confirm the compensation method, some experiments with model signals have been made. Model signals, which include 50 Hz signals and 150 Hz signals, were generated by a function generator and an amplifier. Results are shown in Fig.2. According to Fig.2, the assumed minimum deterioration signal is 1/100000 of the assumed load current, which means the equivalent dynamic range of 5 figures is achieved by this compensation method. The applied image of this system is shown in Fig.3.

Future Developments

The dynamic range of 5 figures, which is conceivable to be the minimum requirement in actual site, has been achieved. As next step, an actual cable sample will be measured. Moreover, increasing of the dynamic range and auto following system to change of load currents will be investigated for practical use.

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Reference

T. Takahashi, et al., 2005, “Study on on-line monitoring system of very small deterioration signal caused by water tree in XLPE cables - Verification of compensation method for load current using model signals -”, Technical Report H04016 (in Japanese)

＊1：If there is water tree, there generate so-called loss currents, which include third-harmonics of commercial frequency.
＊2：For example, Y. Yagi, et al., “Study on Diagnostic Method for XLPE Cable by Harmonics in Loss Current”, Trans. of IEEJ, Vol. 119B, No. 4, pp.438-444 (1999) (in Japanese)

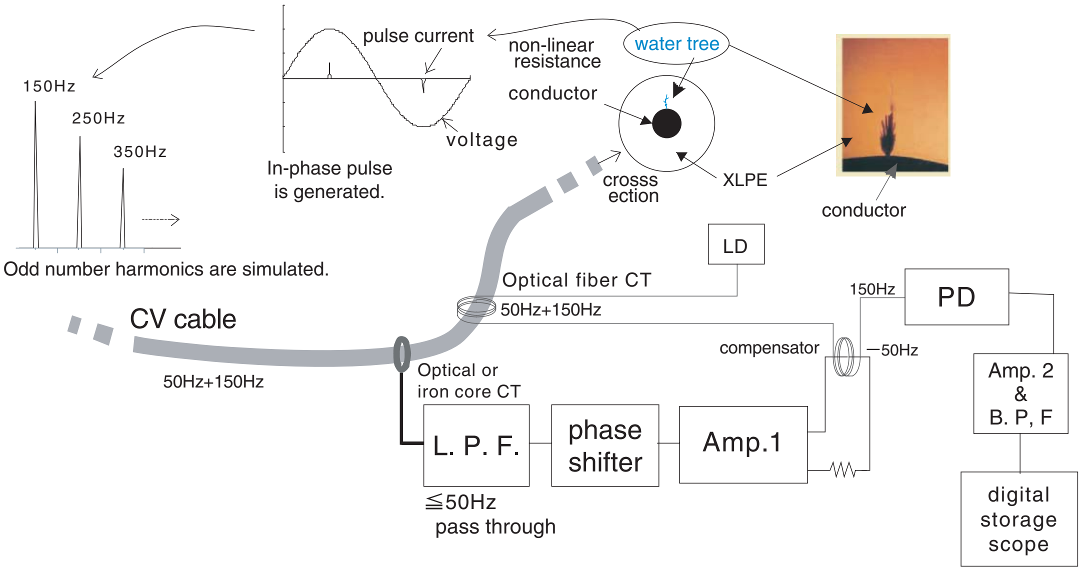

Fig.1 Concept of deterioration signal (third-harmonics) on-line sensing system

Water tree, which is a cause for concern in insulating material (polyethylene) of service aged XLPE cables, works as non-linear resistance; therefore in deteriorated cables, together with load currents, there generate harmonics of odd number orders (third-harmonics is the largest) , which is in-phase with operating voltage. In order to distinguish the signals from load currents, the detection system by using the optical fiber current sensor has been proposed. Main idea is adoption of the compensator, which compensates relatively large (generally 5 or 6 figures lager than deterioration signals) load currents. With this method detection of the very small signals comes to be realized. By measuring the third-harmonics at every cable joint and comparing, the deteriorated section can be determined.

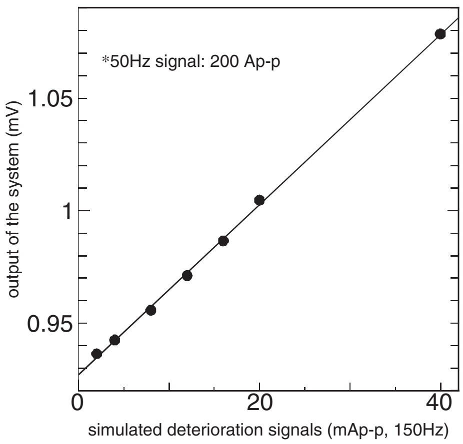

Fig.2 Relation between 150 Hz conductor currents and outputs of the sensor system

The 50 Hz current has been set to 200 Ap-p (substantial value) and the 150 Hz signals have been set from 2 mAp-p to 40 mAp-p. Final outputs from the system are DC voltages from the lock-in amplifier in this experiment. In order to secure enough integral time in the lock-in amplifier, it took from 15 to 30 minutes for every measurement point (for reducing noise). In the case the 150 signal is set to 2 mAp-p, the assumed deterioration signal is 1/100000 of the assumed load current, which means the equivalent dynamic range of 5 figures is achieved by this compensation method.

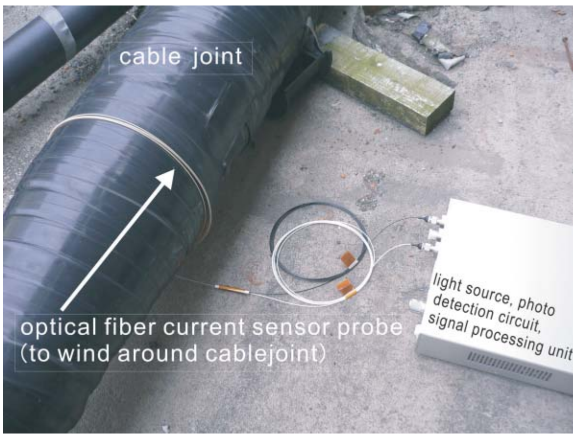

Fig.3 Applying image of the detection system to cable joint

Installing to cables, such as to cable joint, is only winding of the optical fiber, therefore the applying image is like as this picture.