Chapter 6

Conclusions and Future Research

The theoretical acoustic wave propagation equation was derived. A time-harmonic solution including dispersion relation is assumed and solved. Simulation on the theoretical solution in water and oil medium is presented and compared. It is found that the attenuation of wave peak amplitude is a function of both location and source frequency. At a fixed location from the source, as the wave frequency goes higher, more attenuation is found. On the other hand, for a fixed source oscillation frequency, the wave peak amplitude attenuates as the observing point moves further from the source. In addition, the peak amplitude attenuation is more drastic in oil than in water due to the larger coefficient of viscosity,; in other words, the oil is much more viscous than water. Simulation results and Experiment measurements in water are consistent with the theoretical results, which the wave peak amplitudes do not show much attenuation across locations in 200 mm range.

This thesis also documented the measured acoustic data and signal processing results from the Northfleet West SGT3A 500MVA, 400kV/275kV transformer. The measurements were taken using fiber optic sensors and piezoelectric transducers (PZT) from a top drain valve and two bottom drain valves. In some cases, magnitude trigger was used to capture the possible PD generated spikes from the fiber sensors.

The measured fiber sensor data contains noises mostly from the fiber light source, some are from EMI and vibrations. Wavelet-based denoising techniques were used to extract possible PD generated acoustic signals. The level of wavelet transform is different for fiber and PZT data to better differentiate the possible PD signals from noises. The threshold limit was determined based on the maximum Gaussian noise removal for each decomposition level. Different 'mother wavelet' affect the correlation between the measured signal and denoised signal. It is found that Daubechies 8 wavelet is best suit for fiber optic sensor signals and Daubechies 2 wavelet is best suit for PZT signals. The denoising technique removes much of the noise from the measured signals and only the most dominant spikes were left.

The signals captured with the fiber sensors fall in the frequency range of 70 kHz-250 kHz. All of the PD-like signals were captured from sensors in the 3'' drain valve at the bottom of the transformer on the 400 kV side. The top drain valve fiber sensors (FT1, FT2, FT3) can still see 100Hz core vibration signal even though the lower cut-off frequency of the filter is around 18 kHz. There is hardly any PD like signal captured from the group of fiber sensors install on the top 2" drain valve of the transformer though this group actually has sensors with higher sensitivity. The reason could be that the PD source was far away or there may be something that blocked the sensors near the top drain valve.

The phase of occurrence of the PD like signals (spikes) with respect to a sinusoidal reference of the transformer voltage were statistically summarized. If a certain acoustic wave propagation time delay and single PD source condition were assumed, all the recorded signal fall exactly in the first and third quadrant (0-90° and 180°-270°) of the sinusoidal reference (Fig 57). Since this is a 3-phase transformer, a different, but fixed time delay is associated with each of the 3 phases. Our calculations show that if PD occurs in Phase A, the PD source is about 4.2 meters away from the bottom fiber sensors (FB1 and FB2) installed on the 400kV side. If PD was to occur in phase B, it should be at a location about 9.2 meters away from the same group of sensors. If it was from phase C, the PD would have to be located almost next to this group of sensors.

PZT sensors were also installed to compare with the fiber signals. The tank surface wall mount PZT sensors also show obvious pickup of 100 Hz core vibrations. No other obvious signal was observed from the wall mount PZT sensors except in the case of PZTBS when it was place on the wall surface next to the 3'' valve wall where the fiber sensors were able to pick up some possible PD generated spikes. The statistical properties of the PZTBI measured data indicate the randomness of the occurrence of the PD like signals.

The PZT sensor placed inside the 2'' drain valve at the bottom was able to record some information very different from the wall mount PZT sensors. However, due to limited fiber/PZT sensor location combinations, the correlation between the two groups can not be easily established at this time.

For PZT measurement data inside the bottom valve (PZTBI), the frequency spectrum can be obtained by performing discrete Fourier Transform (DFT) on the major burst group. The frequency content is mostly concentrated in the range of 80 kHz to 300 kHz with distinct spikes around 100kHz and 250kHz. The dominant energy range in frequency spectrum is consistent between the PZT data and the estimation from fiber optic sensor data. As for possible magnetization interference noises (Barkhansen noise (BN) and Magnetomechanical Acoustic Emission (MAE)) below 100kHz; from our analysis, it is not shown that these two magnetization noises are coupled into our measurement.

An interesting phenomenon was observed during the test. The valve shut seems to have very small effect on the fiber sensor pick up. The signal level dropped about 10-15% after the valve was closed. In the PZT sensor inside the 2’’ valve, there seems to be no obvious trend between valve open and close conditions.

Suggested future research:

- More sophisticated simulation model, such as having a solid plate in the fluid, can be set up to model the acoustic wave propagation encountering with some solid obstacle.

- More on-site PD measurement results that could establish deeper understanding of PD signal characteristics.

- Automatic mother wavelet, level of decomposition, and threshold limit selection are the key to help denoise any on-site or laboratory measurement. Development of such algorithm that allows automatic signal processing