A New Method to Improve the Sensitivity of Leak Detection in Self-Contained Fluid-filled Cables

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A method of real-time detection of leaks for self-contained fluid-filled cables without taking them out of service has been assessed and a novel machine learning technique, i.e. support vector regression (SVR) analysis has been investigated to improve the detection sensitivity of the self-contained fluid-filled (FF) cable leaks.

The condition of a 400 kV underground FF cable route within the National Grid transmission network has been monitored by Drallim pressure, temperature and load current measurement system. These three measured variables are used as parameters to describe the condition of the cable system. In the regression analysis the temperature and load current of the cable circuit are used as independent variables and the pressure within cables is the dependent variable to be predicted. As a supervised learning algorithm, the SVR requires data with known attributes as training samples in the learning process and can be used to identify unknown data or predict future trends.

The load current is an independent variable to the fluid-filled system itself. The temperature, namely the tank temperature is determined by both the load current and the weather condition i.e. ambient temperature. The pressure is directly relevant to the temperature and therefore also correlated to the load current. The Gaussian-RBF kernel: $K(x_i, x_j) = exp\left(-\gamma \|x_i - x_j\|^2\right)$ has been used in this investigation as it has a good performance in general application. The SVR algorithm was trained using 4 days data, as shown in Figure 1, and the optimized SVR is used to predict the pressure using the given load current and temperature information.

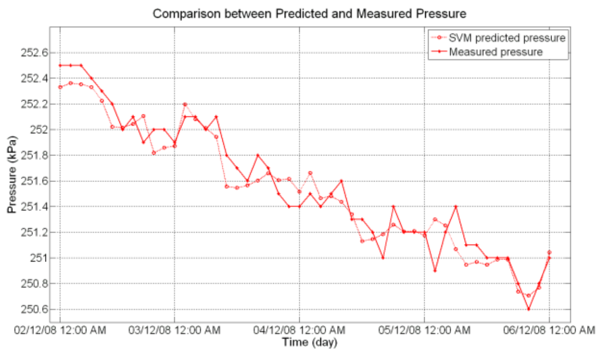

Figure 1: Predicted pressure on training data and measured pressure for cable 1_1_R_A_NC.

When compared the predicted pressure and the measured pressure in 6 cables for 3 days, the average error rate ($Ave\left(\frac{|P_p - P_m|}{P_m} \times 100\%\right)$, p_p-predicted pressure, p_m-measured pressure) is between 0.11% and 0.19% and the maximum error rate ($Max\left(\frac{|P_p - P_m|}{P_m} \times 100\%\right)$) is between 0.24% and 0.43%.

A comparison between the existing system alarm strategy and the alarm sensitivity achieved using the SVR method has also been assessed using equation $\frac{|P_p - P_m|}{P_m - P_{fa}} \times 100\%$, where p_{fa} is the falling alarm pressure. The adjusted average error rate is between 0.7% and 1.09% and the maximum error rate is between 1.62% and 2.38%. The results represent that the new machine learning based technique has a 50 times better sensitivity than the existing alarm system.

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