On-line Power Factor Measurement on a 6MVA Cast Resin Transformer

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INTRODUCTION

The ship has seven 11kV 6MVA cast resin transformers driving the thruster motors. Previous off-line inter-winding power factor measurements had found faulty coils (PF increased from about 0.2% to over 2%). PD/RFI monitoring had been problematic. The client wanted to monitor the transformers in service at sea.


Instead of bushings, the monitoring on this transformer is of the insulation between the high voltage winding and the normally-grounded electrostatic shield. This shield is designed to prevent high frequency noise, generated by the rectifier/motor control system, feeding back into the primary winding and from there into the ship's network.

In order to make connection to the shields on each phase, the copper foils normally bolted to the frame were removed and isolated using custom-made brackets with terminal strips and insulating stand-offs. See photos below.

INSTALLATION
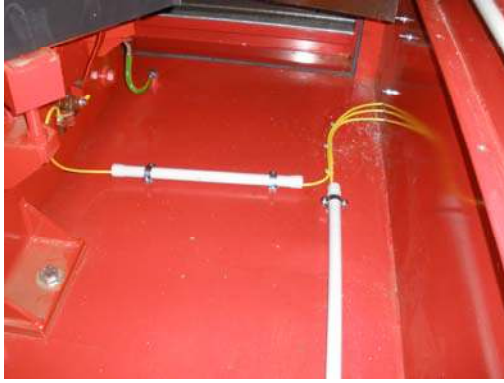
Engineers ran cable via conduits installed in the base of the transformer housing from the terminal strips to the CT sensor enclosure mounted on the outside. See photos above.

Allseas engineers then mounted the IDD and ran cable from the sensors to the shorting block. See photos below.

IDD is Serial No. 121001334 running Firmware v2.5 Build 402.


The addition of an extra ground wire and some tidying of the cables remained to be done in the photo right.

COMMISSIONING

The IDD was powered up and connected to a laptop. System, location, identification and, as far as possible, nameplate information was entered and saved.

Following brief discussions it was decided to modify the Expert System trigger levels for Capacitance but, despite the novel application, to leave the Power Factor levels unchanged. New levels are shown in Figure 1 below.
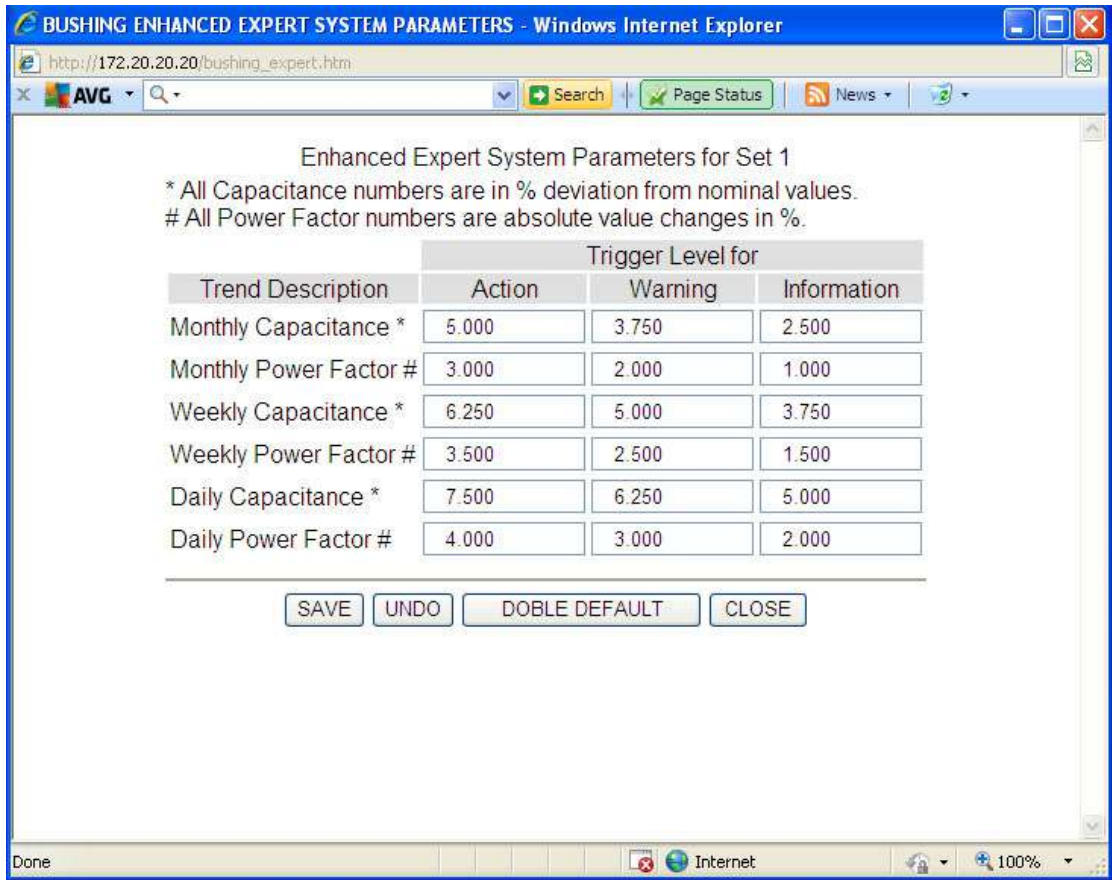
Figure 1

TESTING

The transformer was energised with the rectifier/motor control deactivated. Based on measurements performed on sister transformer TM8, the measured currents were a little higher than expected at an average of 2.57mA per phase.

The Recordings file was downloaded and viewed with an Excel Template. Plot of waveforms is shown as Recording 1 in Figure 3 below.

The motor control was then activated and the measurement repeated. Plot of waveforms is shown as Recording 2 in Figure 4 below. Note amplitude scale is 4-times that of Recording 1. Despite the high frequency noise the calculated currents and phase angles were very similar to those obtained from Recording 1. Two more recordings were made with similar results. The Calculated Features summary is shown in Figure 2 below.

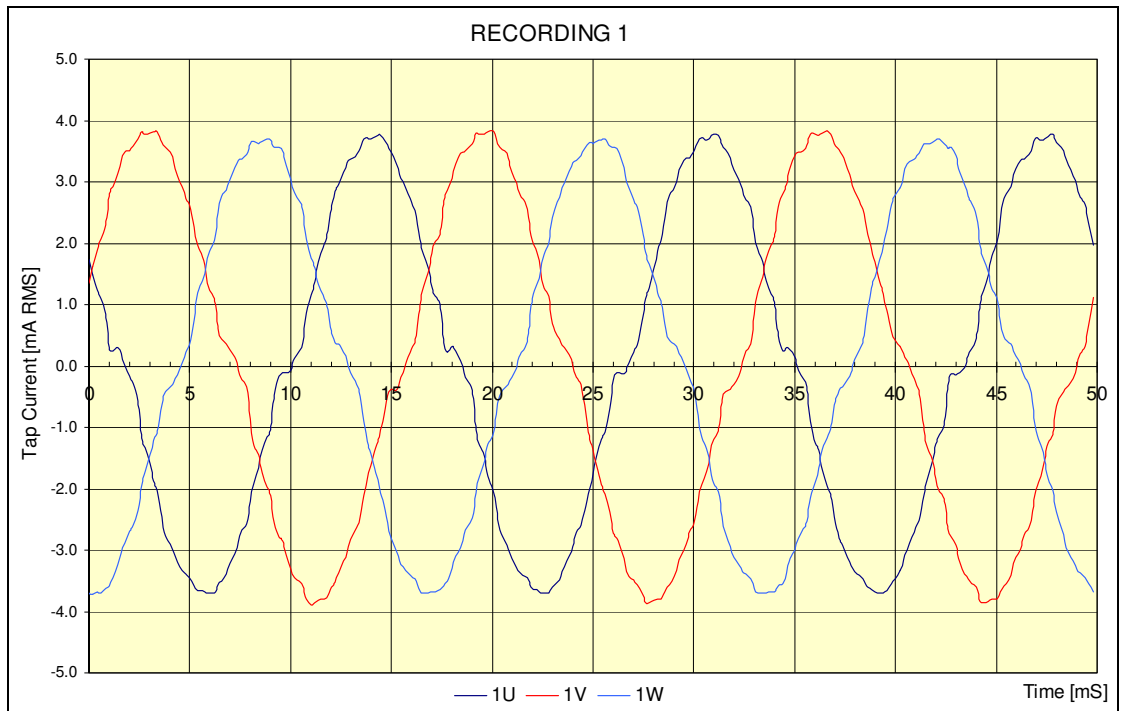| CALCULATED FEATURES								
			1U		1V		1W	
REC	DATE/TIME	Tap1 mA	Tap1 Angle	Tap2 mA	Tap2 Angle	Tap3 mA	Tap3 Angle
4	04/02/2011 19:00	2.519	120.109	2.569	0	2.512	239.878
3	04/02/2011 18:00	2.551	120.209	2.597	0	2.542	240.064
2	04/02/2011 17:00	2.555	120.352	2.613	0	2.556	240.354
1	04/02/2011 16:00	2.559	120.104	2.582	0	2.558	239.627

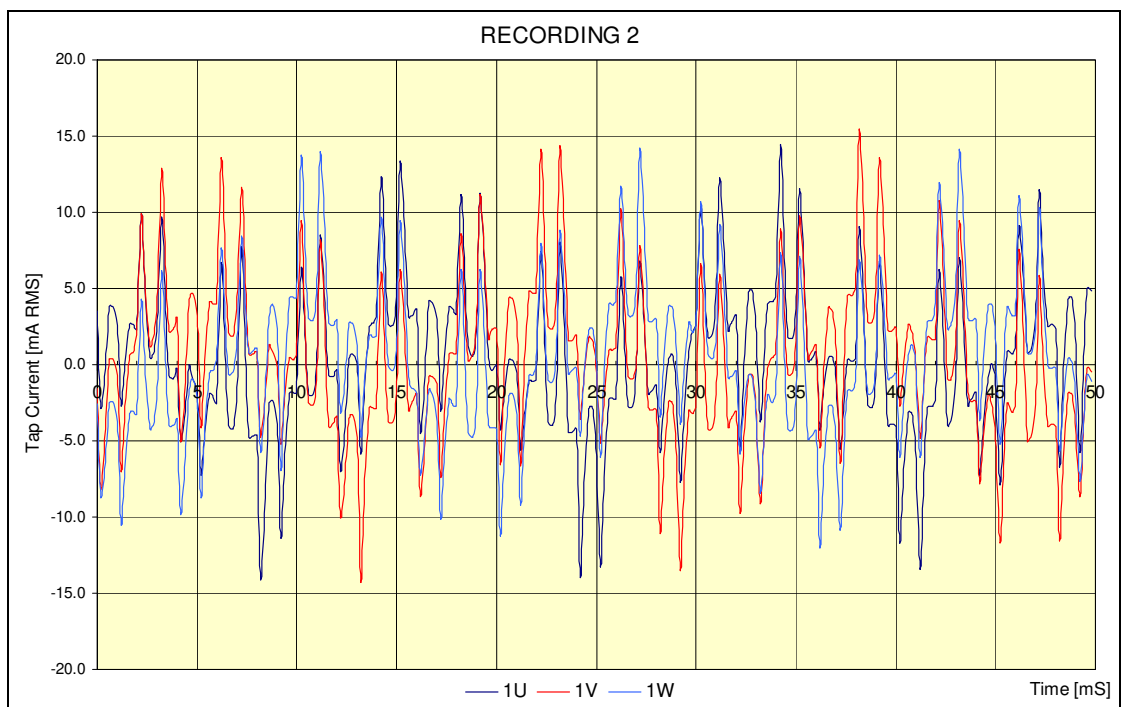**Figure 2**

Figure 3

Figure 4

With commissioning completed the system was powered down pending return to service of the ship.

WORKSHOP TRIALS   A program was made available to convert the .CSV Recordings file into the COMTRADE format. With the Doble TransWin program and an F6150 relay test set the Recording 2 current waveforms shown above were "looped" and applied to a demo IDD with the same modified Expert System parameters. In combination with a special routine for the IDD which speeds up the measurement cycle by 180 times (IDD makes a measurement every 20 seconds instead of every hour), the response of the Features Calculation was investigated with data equivalent to a month of continuous operation. Initial results were very encouraging with both capacitance

and Power Factor corresponding very closely with expected values and no spurious Alerts.

"FIELD" DATA

Following a period of in-service operation the Waveform and Features files were retrieved from the IDD on 2nd August 2011. An example of the current waveforms with the thruster motor running is shown in Figure 5 below.
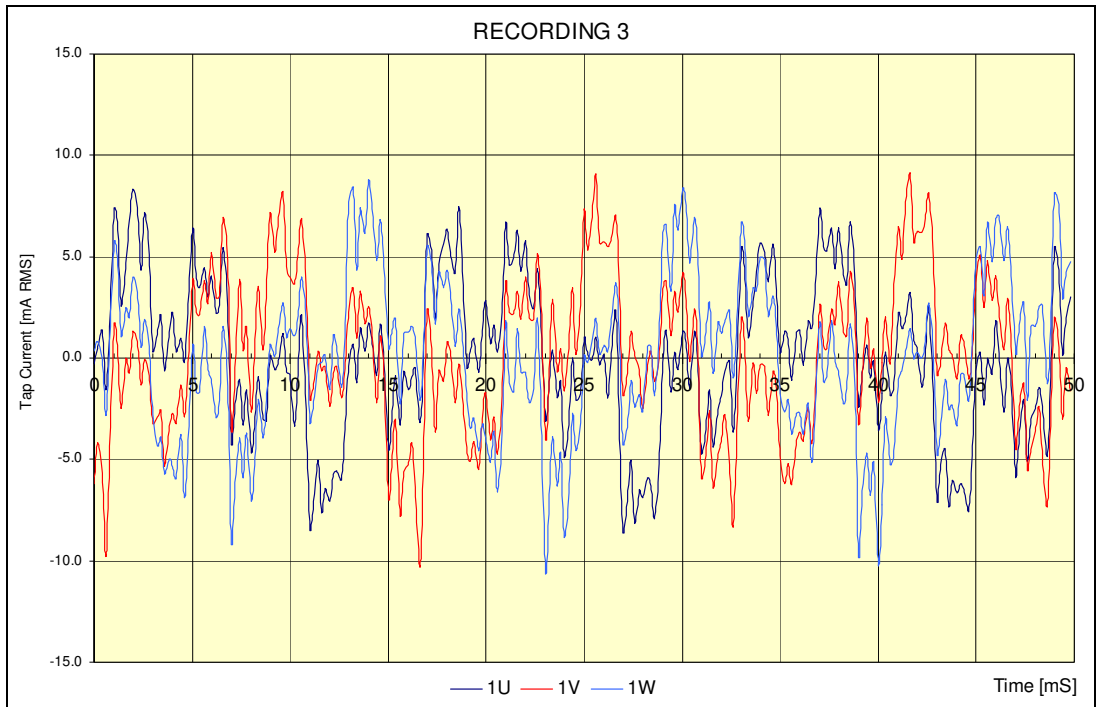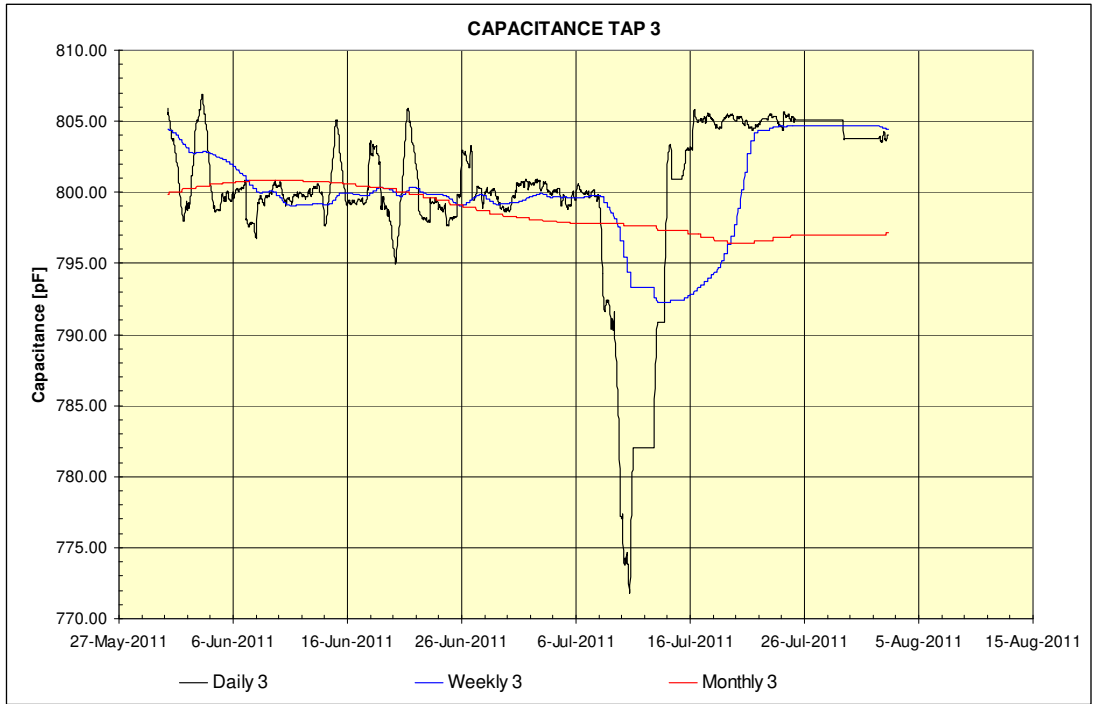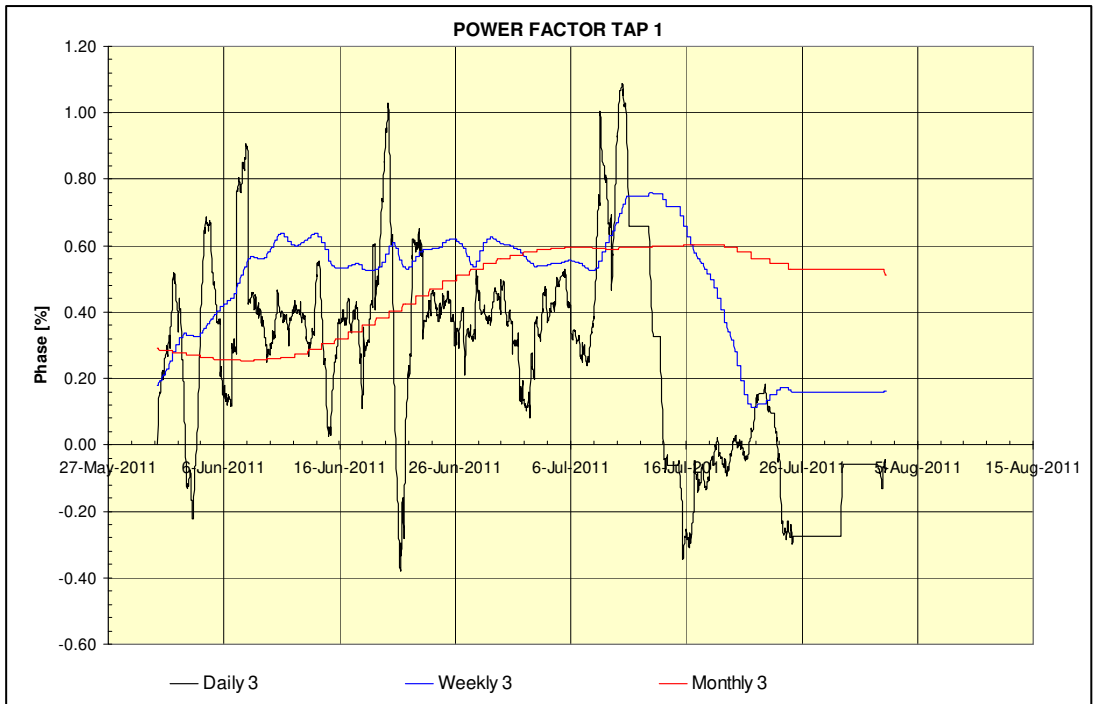

Figure 5

The Daily, Weekly and Monthly rolling averages for both Capacitance and Power Factor were then plotted from the Features data. Tap 1 (Phase U) and Tap 3 (Phase W) are shown in Figures 6 to 9 below [Tap 2 (Phase V) is the Reference channel and therefore not plotted].
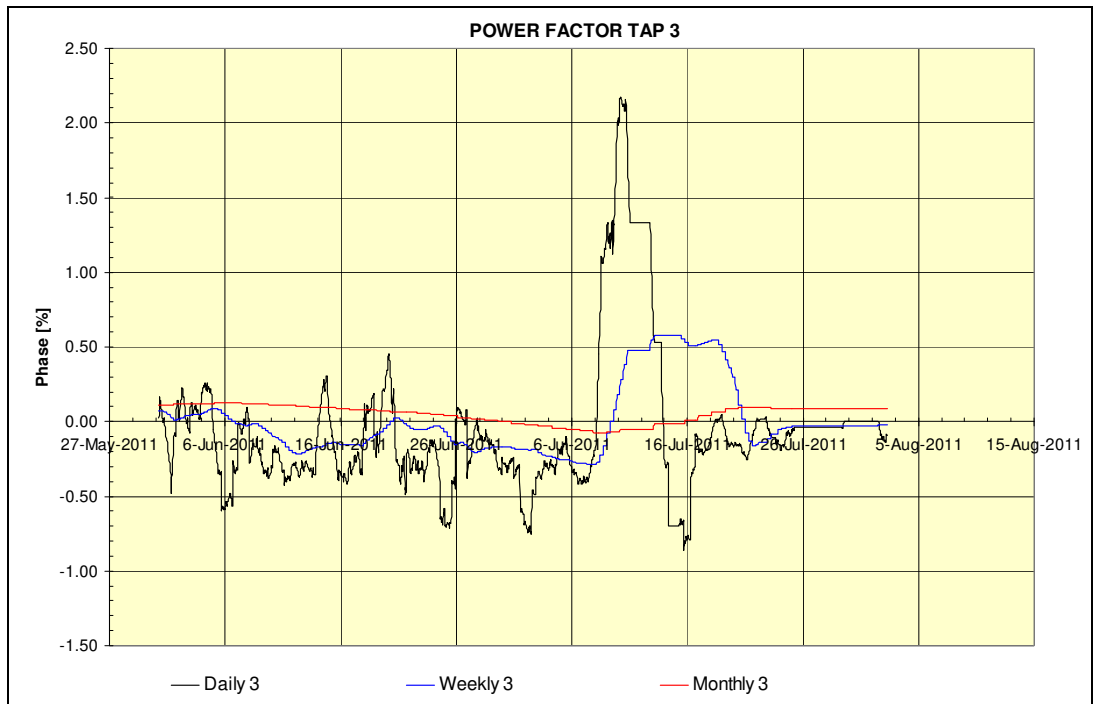

Figure 6

5
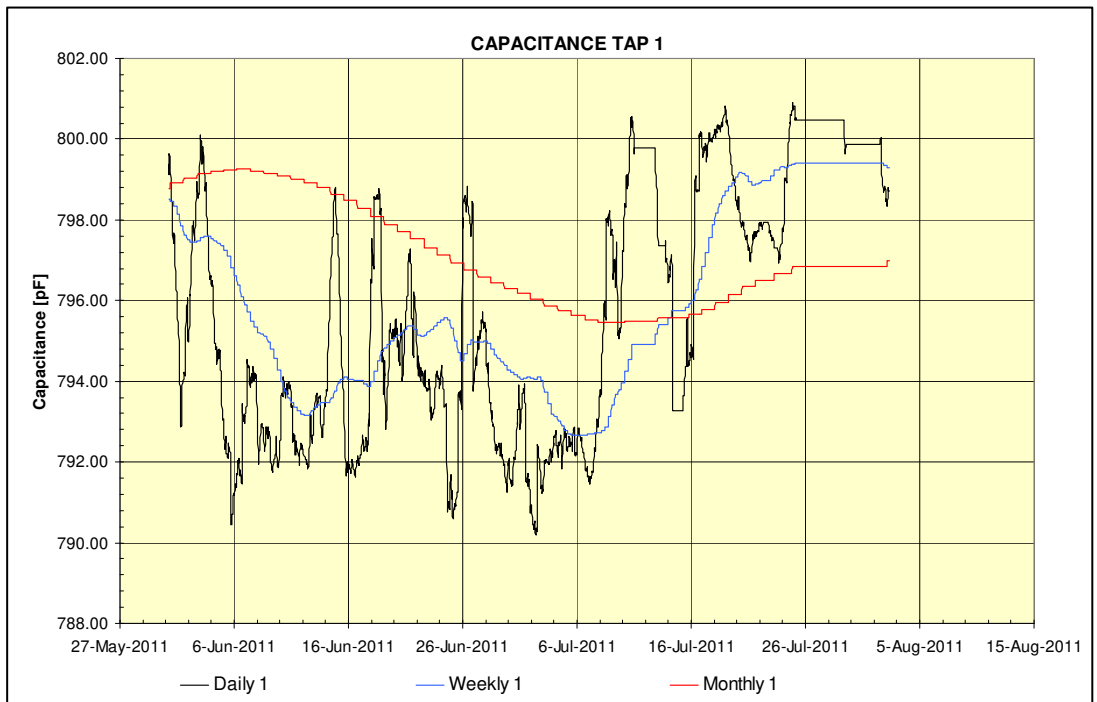
Figure 7

Figure 8

(Due to an error in the Features Template the labels read "Daily 3" etc. instead of "Daily 1" etc.)

Figure 9

CONCLUSIONS

Despite the heavily distorted waveforms and novel application the IDD seems to be performing well. No spurious or erroneous Alerts have been generated.

The system could be applied to any transformer with an electrostatic shield grounded by a removable connection.

THANKS

The authors would like to express their thanks for assistance with this project.