Heriot-Watt University - EPS

Impedance measurements of wire cable tray and (Mk II) couplings for Aitken Electrics Ltd

Author: Mark Leonard BSc.
Heriot Watt University
Dept. of Electrical and Electronic Engineering
Riccarton
Edinburgh
EH14 4AS
Email: m.leonard@hw.ac.uk
Tel: 0131 451 8243

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1. Introduction

Aitken Electrics Ltd approached Heriot Watt University through Interface initially in September 2010 to evaluate the electrical continuity of a new cable tray coupler they had developed. The report for these measurements was issued in October 2010. Aitken Electrics Ltd has since then modified the coupling design and so in May 2012 asked Heriot Watt to repeat the tests with the new coupling design. The wire tray used for these tests is slightly smaller (0.6mx0.22m) of a welded steel wire frame construction of galvanised steel wire (4.0mm Ø) and the mechanical coupler is fabricated (guillotined and bent to shape) from galvanised steel sheet 1.1mm thick. Two sections of cable basket were supplied and sufficient couplers to perform multiple tests. As previously the objective of the tests was to establish that sufficient electrical conductivity resulted between two trays when joined by a pair couplers i.e. through the couplers and also to measure the cable basket conductivity. The trays were coupled together as shown in Figure 1 and the tests conducted to comply with the requirements of BS EN 61537:2001.

2. Experimental setup

The current supplied to the coupled wire basket (CWB) was provided from a transformer which was supplied from a Variac, which in turn was supplied from a second Variac supplied at 240V 50Hz AC. It was found that just using one Variac did not provide sufficient resolution of the setting of supplied current, so an additional Variac was added. The Variac (1) supplied from 240V was set to an output of 10% (~24V) and this was supplied to the second Variac (2), which was used to control the supplied current. This provided good control of the current through the CWP. It was observed that the current became more stable once the system had been passing current for about 20 minutes so all tests were conducted with after a 30 minute warm up period. The open circuit voltage for the circuit when set for ~25A was ~1.6V, which is well below the 12V maximum required for EN 61537:2001.

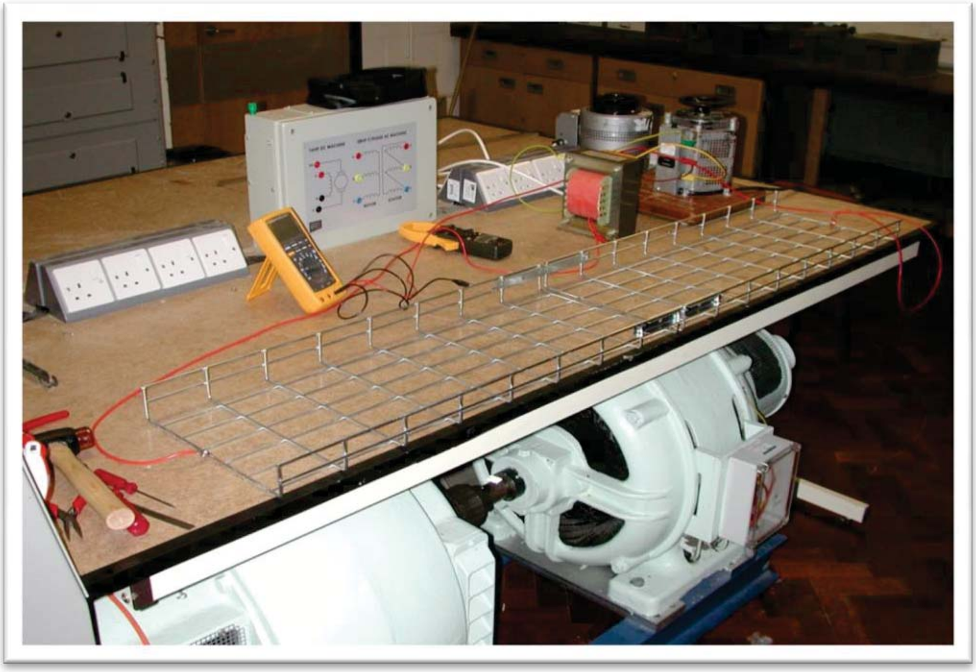

Figure 1: Two lengths of cable basket coupled together and connected into the circuit for impedance measurement.

The two electrical power connections were made to each end of CWB by means of a pair of in-house fabricated copper straps 10mm wide, made-up by bending a strip of drilled copper around the ends of the CWB to accommodate an M4 hexagonal socket cap screw and nut to provide a tight, low impedance connection (see Fig2). These were soldered to a pair of 1M insulated copper wires rated at 41A, which were connected directly across the secondary winding of the transformer. Current measurement through the CWP was made from a current clamp meter, applied to one of the supply wires from the transformer.

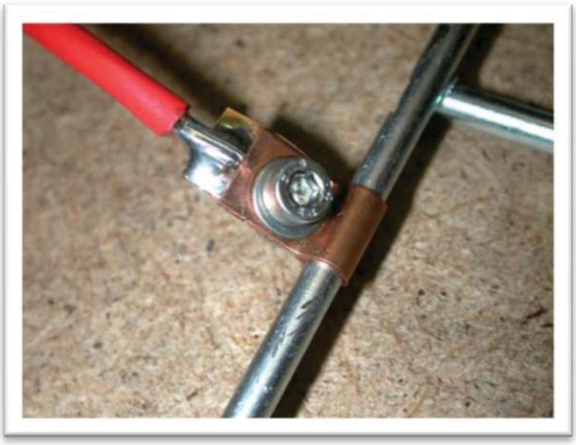

Fig 2: Electrical connection to wire basket

Fig 3: Coupled wire baskets.

3.1 Procedure for measuring coupling impedance

For each separate test a new pair of tray couplings was fitted to the CWB. Once the trays were coupled the current was switched on and the voltage probes attached 50mm either side of the coupling at position 1-1(as specified in EN 61537.2007 – see Fig 3). A reading of the current flow and voltage drop across the coupling was taken. The voltage probes were then moved to the next rung down and the measurements repeated – see Fig.4; horizontal red dots pairs indicate test point locations. The voltage drop across these points was fairly consistent. This was repeated for all 8 rungs so that 8 measurements for each coupling test were taken. The current was then switched off and the coupling was removed. A total of 10 separate couplings were measured giving a total of 80 voltage drop readings.

3.2 Procedure for measuring wire basket impedance

The wire clamps were attached to each end of a single uncoupled wire basket and connected to the transformer secondary coil as above. The supply was then set to ~25A and the voltage probes connected along the side of the basket 0.5m apart – see Fig.5. A reading of current and voltage drop across the 0.5m length was then taken. The voltage probe pair placement was then move one rung along (therefore maintaining the 0.5m separation) and the measurement repeated. This gave 2 measurements per side. The opposite side was then measured giving another 2 measurements. Four trays were available for measurement and each tray was measured a total of 4 times.

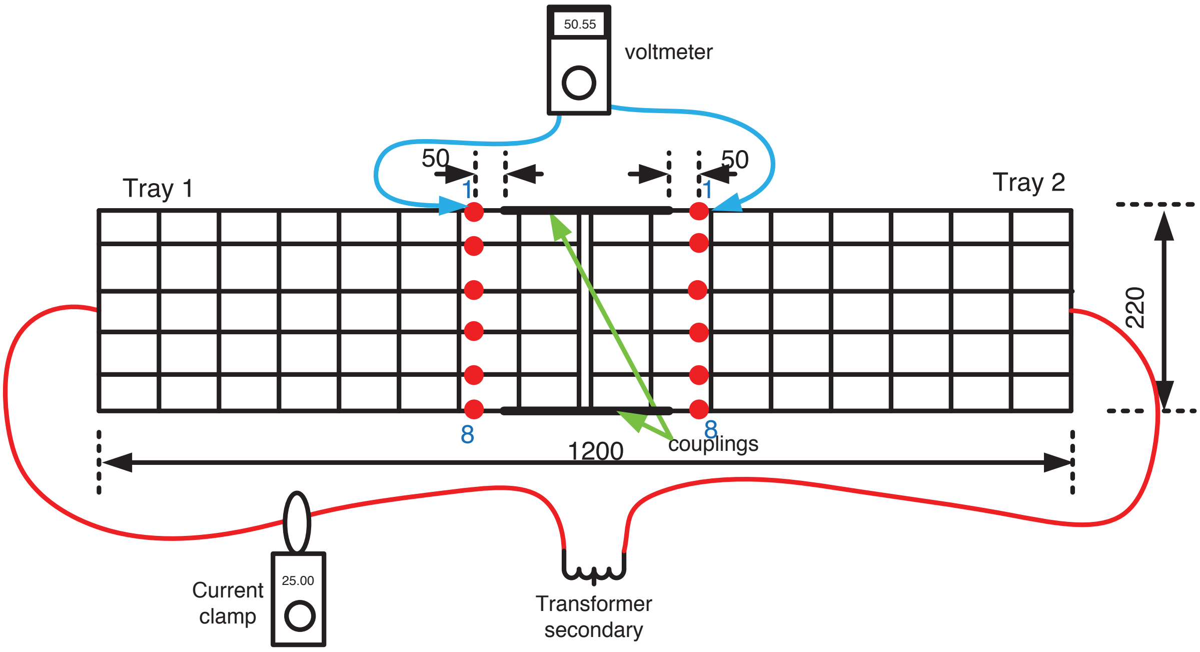

Fig.4 Schematic diagram of coupling impedance set-up

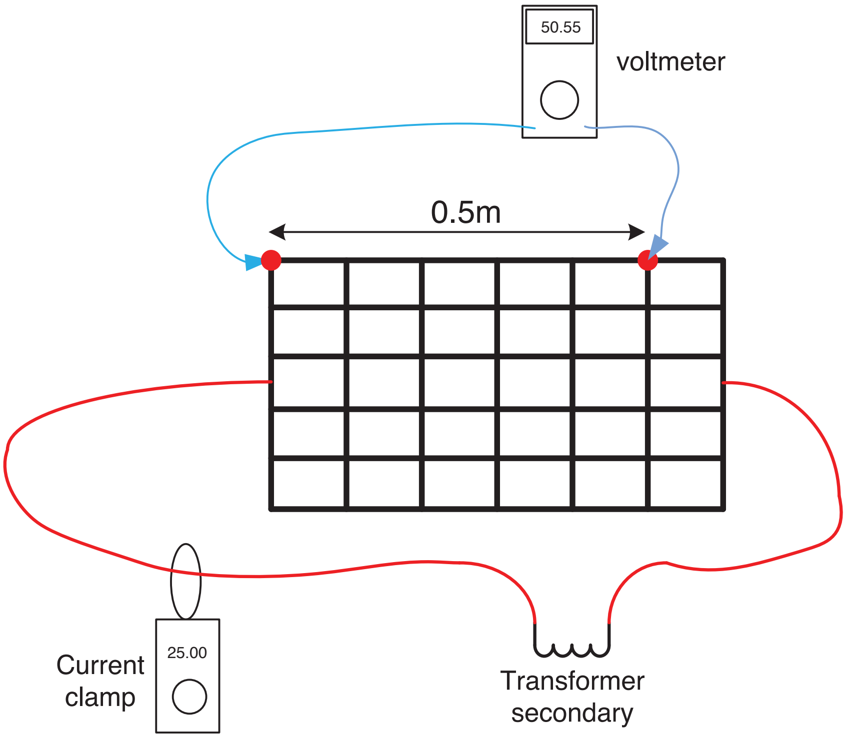

Fig.5 Schematic diagram of wire tray impedance measurement set-up.

4. Results

4.1 Tray Coupler impedance

The current clamp readings were all corrected according to the calibration (see appendix C) and the voltage readings used as recorded (see appendix B). Ohms law was then used to calculate the impedance across each pair of measurement points. Table 1 shows the results of the coupling impedance measurements; 8 separate measurements conducted on 10 separate CWB tests with positions indicated as 1-8 (see Fig. 4). The average and standard deviation for each of the 8 tests is also recorded.

Test # position	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	1.02	1.63	1.50	2.16	2.59	2.08	3.18	3.51	2.23	4.46
2	1.07	1.71	1.46	2.65	2.77	2.08	3.71	4.31	2.15	5.19
3	1.18	1.71	1.71	2.98	3.11	2.19	3.04	3.18	2.03	4.87
4	1.22	1.67	1.63	2.69	2.98	3.01	3.04	3.10	2.07	2.39
5	1.26	1.67	1.75	2.73	2.53	2.65	2.75	3.06	1.99	2.47
6	1.18	1.67	1.50	2.79	2.41	3.28	2.07	2.42	1.59	1.78
7	1.18	1.39	1.42	2.50	2.25	2.69	1.75	2.06	1.88	2.11
8	1.10	1.43	1.30	2.29	2.38	2.70	1.91	2.44	1.72	1.94
average	**1.15**	**1.61**	**1.53**	**2.60**	**2.63**	**2.58**	**2.68**	**3.01**	**1.96**	**3.15**
std deviation	0.08	0.13	0.15	0.27	0.30	0.44	0.70	0.71	0.22	1.43

Table 1: Coupling impedance results. All result values in mΩ.

4.2 Wire Tray impedance

The voltage and current readings were treated as above and impedance calculated in the same manner. Table 2 shows the impedance results for the 16 measurements made on each of the four trays 0.5 meters apart with the factor of multiplying 2 to give the $m\Omega m^{-1}$ value.

TEST/position	1	2
tray 1 top	1.80	1.72
tray 1 bottom	1.72	1.72
tray 2 top	1.88	1.88
tray 2 bottom	1.73	1.80
tray 3 top	1.70	1.64
tray 3 bottom	1.71	1.56
tray 4 top	1.57	1.50
tray 4 bottom	1.57	1.58

Table 2: Tray impedance values for two trays supplied. All result values in $m\Omega m^{-1}$

5. Conclusions

The results for the tray coupling impedance tests range from 1.02 to 5.19 mΩ, with an average for the 80 measurements of 2.29 mΩ. The maximum permitted value given to comply with EN 61537(clause 11.1) is 50 mΩ. This is clearly well below the allowable maximum impedance.

The average value for resistivity of the four wire trays was 1.69 mΩm^{-1}. The value required to comply with EN 61537 is 5 mΩm^{-1} and therefore the 4 wire trays supplied satisfy the requirements specified.

References:

[1] **BS EN61537:2001**, "Cable tray systems and cable ladder systems for cable management" BSI

[2] Report prepared for Aitken Electrics Ltd Impedance measurements of wire cable tray and (Mk II) couplings for Aitken Electrics Ltd

Appendix A: Equipment used for impedance measurements.

Current clamp: **Heme LH240**

Multimeter (voltage): **Fluke 187 true RMS multimeter**

Variac (1): **Zeneth 2.2KVA type Y16HMTF**

Variac (2): **Claud Lyons Ltd**

Transformer: **Axiel Akerman 976VA (240-48,24V) (24V tap used)**

Fixed resistor: **Arcol HS 300 (1Ω, 300W)**

Current and Voltage calibrator: **TIME Electronics 5021 multifunction AC/DC calibrator. Last calibrated 7/5/2010. Next calibration due 6/5/2011**

Appendix B: Calibration of Fluke 187 meter.

The checking of the Fluke 187 meter was relatively straightforward with the TIME Electronics 5021 calibrator. A voltage output can be specified which is connected directly to the Fluke meter and over a range of applied voltages the readings taken. The table below is a summary of the check over the range of 10mV – 1V on the AC milivolt setting.

TIME calibrator output (V)	FLUKE 187 reading (mV)
0.01	10.088
0.02	20.111
0.03	30.032
0.04	40.066
0.05	50.122
0.06	60.05
0.07	70.09
0.08	80.14
0.09	90.19
0.10	100.12
0.20	200.22
0.30	300.47
0.40	400.57
0.50	500.69
0.60	601.1
0.70	700.6
0.70	800.2
0.90	899.8
1.00	999.4

Table 3: Results of Fluke 187 multi-meter calibration (AC mV setting)

Appendix C: Calibration of Hume LH240 current clamp meter.

The calibration of the Hume clamp meter was not straightforward as the TIME Calibrator has a maximum current output of 10A. It was decided to use this to accurately establish the value of a fixed resistor and then use this in the circuit in place of the CWP to check against the current clamp meter. A 300W 1Ω resistor was used up to 4.5A (maximum the TIME calibrator will deliver into 1Ω). The clamp meter was put into the circuit and the voltage across the resistor was recorded. A linear regression was then carried out on the results which established the resistor value as 1.0037Ω. This was then inserted into the power supply circuit in place of the CWP, with the current clamp meter and volt meter across the resistor. A series of measurements were then taken increasing the current from 1 to 25A; clamp reading and voltage across resistor taken at each point. A linear regression was then carried out on the data to give a correction factor to apply to the current probe values. This was: probe reading x 0.9715 +0.0858. This was then applied to all current readings taken. The table below shows the Clamp reading, voltage across the 1Ω resistor, calculated current through 1Ω resistor, the error of the clamp meter, the adjusted clamp reading with the above factor applied and the revised error produced by this correction.

I clamp (A)	V across 1Ω (V)	I through 1Ω (A)	I clamp error (A)	corrected I clamp reading (A)	corrected clamp error (A)
1.14	1.18	1.18	-0.04	1.19	0.02
2.05	2.07	2.06	-0.01	2.08	0.01
3.04	3.04	3.03	0.01	3.04	0.01
4.13	4.11	4.09	0.04	4.10	0.00
5.15	5.09	5.07	0.08	5.09	0.02
6.12	6.05	6.03	0.09	6.03	0.00
6.98	6.89	6.86	0.12	6.87	0.00
8.1	7.99	7.96	0.14	7.95	-0.01
9.16	9.02	8.99	0.17	8.98	0.00
10.01	9.85	9.81	0.20	9.81	0.00
11.05	10.87	10.83	0.22	10.82	-0.01
12	11.8	11.76	0.24	11.74	-0.01
13.03	12.81	12.76	0.27	12.74	-0.02
14.01	13.76	13.71	0.30	13.70	-0.01
15.05	14.78	14.73	0.32	14.71	-0.02
16.01	15.71	15.65	0.36	15.64	-0.01
17.05	16.74	16.68	0.37	16.65	-0.03
18.01	17.66	17.59	0.42	17.58	-0.01
18.98	18.61	18.54	0.44	18.52	-0.02
20.08	19.67	19.60	0.48	19.59	0.00
21.16	20.72	20.64	0.52	20.64	0.00
22.12	21.64	21.56	0.56	21.58	0.02
23.18	22.67	22.59	0.59	22.61	0.02
24.14	23.63	23.54	0.60	23.54	-0.01
25.14	24.57	24.48	0.66	24.51	0.03
25.98	25.39	25.30	0.68	25.33	0.03

Table 4: Results of Hume current clamp calibration.

Head Office
5 Mathieson Road
Rutherglen, Glasgow,
G73 1DA.
T 141 647 3111
F 0141 613 1338
E sales@aitkenscotland.co.uk

Leeds Branch
Unit 2A Silver Royd Hill,
Silver Royd Business Park,
Silver Royd Hill, LS12 4QQ.
T 0113 255 1111
F 0113 255 1101
E leeds@aitkenscablemanagement.co.uk

Manchester Branch
Unit N9 Central Park Trading Estate,
Mosley Road, Trafford Park,
M17 1PG.
T 0161 872 6214
F 0161 872 7411
E manchester@aitkenscablemanagement.co.uk

www.aitkenscablemanagement.co.uk