PLASMA CONDUCTORS AND WINDINGS

A novel type of high voltage transformer has been constructed, achieving a voltage step-up using only a short length of magnet wire and no magnetic core. This is just one example of the exciting applications which may follow investigation into EW-initiated plasma conductors.

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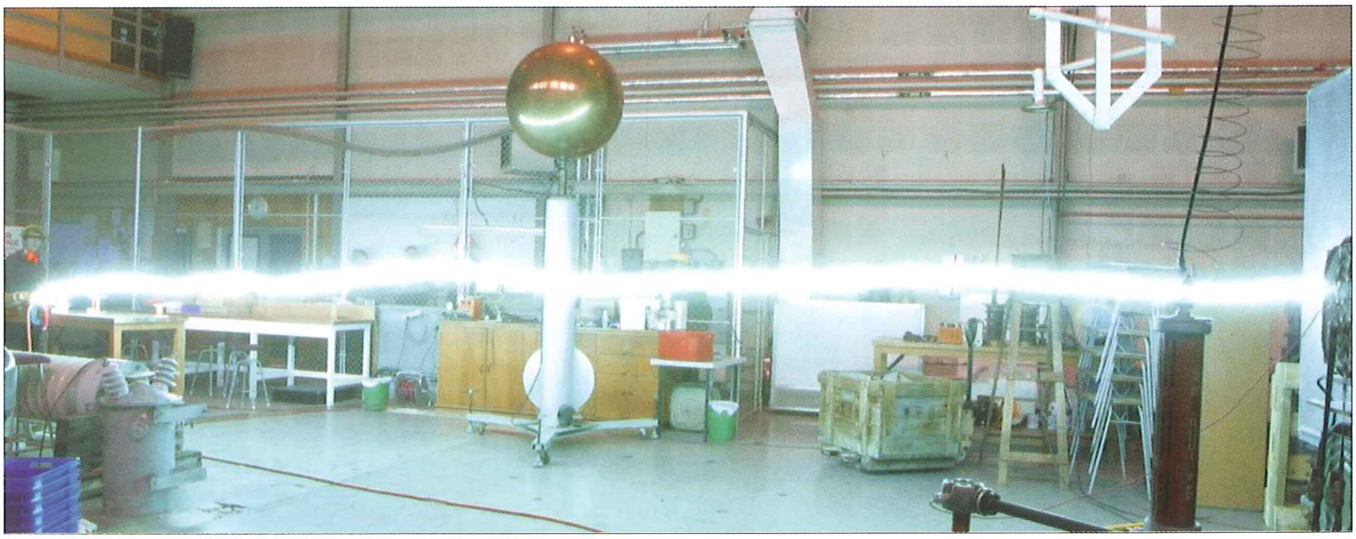

Figure 1 *A 10m plasma conductor in the University of Canterbury High Voltage Laboratory. 40kVdc, 0.3mm wire diameter, 31.6μF capacitance*

The University of Canterbury has had an interest in creating long distance plasma conductors in atmospheric air, starting five years ago. An experimental setup was constructed, using a bank of capacitors as an impulse source, and used for extensive experimentation creating plasma conductors up to 20 metres long. Attempts were also made to create a 70 metre plasma conductor; to date only a partial plasma conductor has been achieved over this length.

EXPLODING WIRES

The plasma conductors can be created by an exploding wire (EW). The term "exploding wire" defines the process in which a thin metallic wire, when subjected to a large current, undergoes one of several modes of explosion. These can include state changes (i.e. to liquid or gaseous phases), formation of plasma and fragmentation in the solid or liquid state. The current is supplied as an impulse of tens of kiloamps from a charged capacitor. Serious research into the exploding wire (EW) phenomenon began in the 1950s, with applications focused on shockwave theory, creation of nano-particles and even fusion. All documented exploding wires to date, however, are relatively short – usually much less than one metre in length.

EW experiments at the University of Canterbury can typically be categorised into three physical outcomes (Figure 2), one of which is a plasma conductor. The outcome depends on the initial conditions of the experiment – wire length, wire diameter and capacitor voltage. Enamelled copper wires have been used for all experiments. One aspect of work undertaken at the University of Canterbury is to determine what initial conditions will create a plasma conductor of a desired length. The aim is a mathematical model which can predict the operation of longer plasma conductors – in excess of 100m.

It is interesting to note that relationships between initial conditions and the outcomes in this model are not always intuitive. One example of this is that increasing the voltage does not guarantee plasma formation as one might expect; in fact it will reliably inhibit plasma formation at a certain level. A family of voltage traces (Figure 3) – identical wires exploded with varying voltage – demonstrates a defined region where a full plasma path is formed. The voltage traces which are seen to fall sharply to near-zero after a period of time indicate the formation of a highly conductive plasma path, which discharges the remaining capacitor energy.

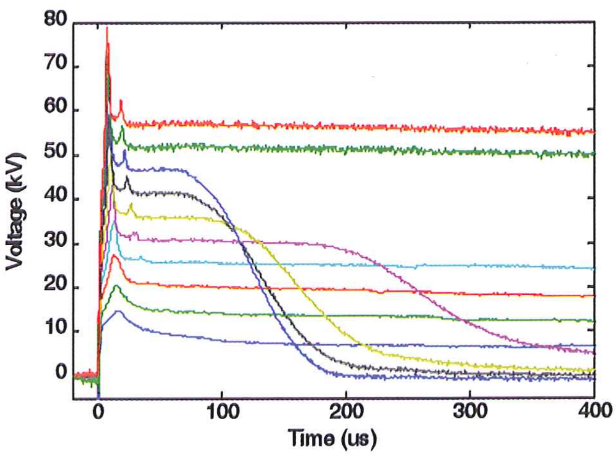

Figure 3 *5m experiments, 15 to 60kVdc in 5kV steps, 0.27mm wire diameter, 21.374uF capacitance*

PLASMA WINDINGS FOR ELECTRICAL MACHINES

In the summer of 2007/08, it was realised that EW-initiated plasma conductors could be formed into coils. Powerful magnetic fields were observed through various experiments, created by the violent impulse currents. The plasma coil idea was extended to plasma transformers by adding a concentric secondary copper (non-exploding) winding in an air-cored configuration. The rapidly building and collapsing magnetic fields of the plasma winding,

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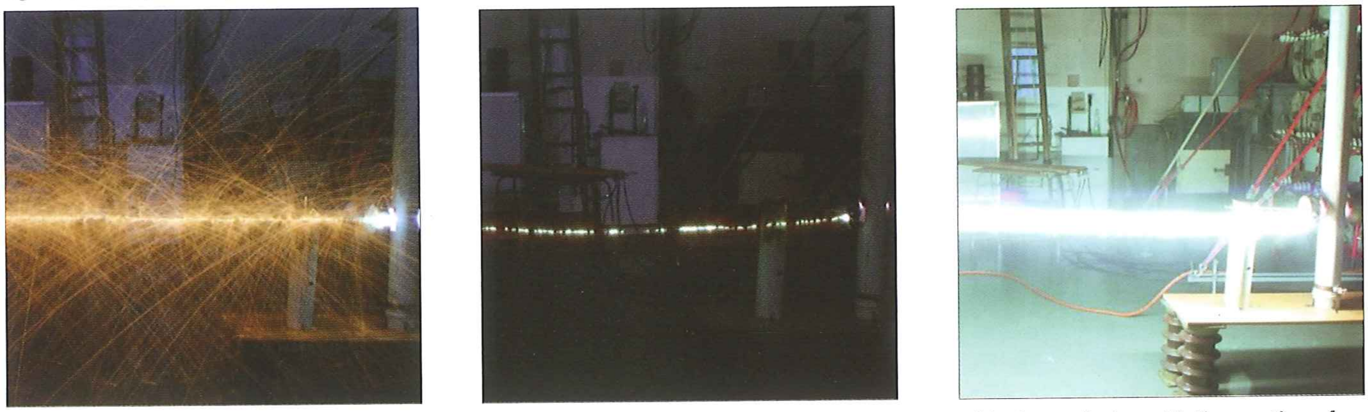
Figure 2 *3m experiments, 15 – 30 kVdc, wire diameter 0.3 mm, capacitance 21.374μF*



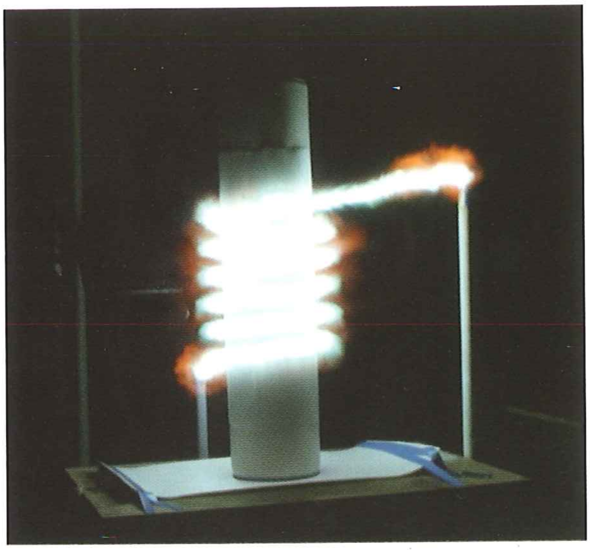
(a) Wire explosion without plasma formation

(b) Wire explosion with partial plasma formation

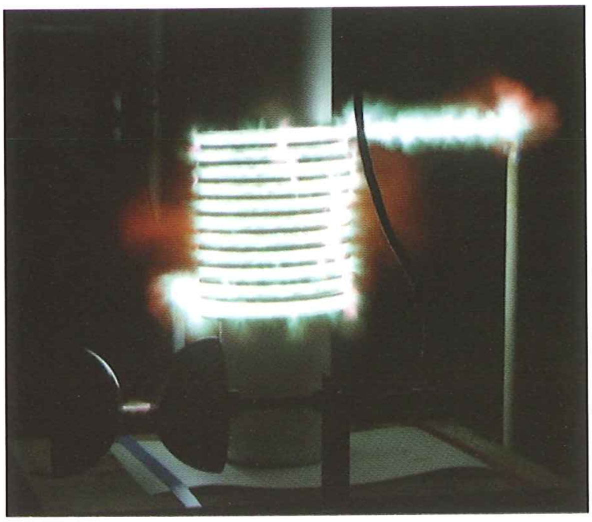
(c) Wire explosion with the creation of a plasma conductor

when coupled to a secondary with more turns, induced high voltages without the need for a very large number of copper turns or a magnetic core. No magnetically coupled devices that use a plasma winding had been noted in the literature to date. This device represents new possibilities for electrical machines and as such was submitted to TechCon® Asia-Pacific 2009 for presentation.

Figure 4 *Plasma windings and transformers*



(a) 5-turn experiment at 35kVdc. The plasma-primary has a 50mm winding pitch.



(b) 10-turn experiment at 40kVdc. A PVC baffle was used for inter-turn plasma confinement.

Several prototype plasma-winding transformers (fig. 4) were built by Campbell Hammond while studying at the University of Canterbury in 2008. The insulation coordination required to keep the plasma winding stable and produce high voltage in the secondary coil resulted from numerous experiments and prototype re-builds. The final insulation system is dry-type and makes use of Nomex-Mylar-Nomex (NMN 5-10-5), Dow Corning 838 and PVC.

In the lower left-hand corner of Figure 4(b), a sphere gap can be seen to flash-over. This gap is set to breakdown at 75kVpeak and is connected to the secondary (copper) winding of the transformer. The authors of this paper are excited by the fact that greater than 75kV can be induced within only 25 metres of 0.335mm magnet wire, in a single layer h.v. winding of 50 turns. We find a dry-type and air-cored plasma winding transformer that produces 1.5kV per turn, and induces 3kV/m in a copper conductor – a most interesting achievement.

FUTURE WORK

The University of Canterbury is interested in extending the capabilities of the prototype shown in Figure 4(b); the target is e.h.v – up to hundreds of kilovolts. The output voltage from the plasma transformer can be maximised once the mechanism producing time-varying primary current is better understood. This requires further study of straight exploding wire. Also, the secondary winding pitch of 5mm could be reduced down to a little as 1 mm, producing an estimated 375kV – and this is before multiple layer copper windings are considered.

Extensions of the prototype single-shot plasma transformer are pulsing and steady-state versions. The pulsing version will attempt to re-use the plasma conductor several times with a quick succession of current impulses. A steady-state version could allow an a.c. current to be passed through the plasma coil (once established by EW), generating a continuous a.c. output from the transformer.

The University of Canterbury is also investigating the possibility of creating plasma shorted rings by induction. Electrically isolated plasma conductors can be used to investigate plasma in partial vacuums, under pressure or within other than air gas filled sealed chambers.

CONCLUSIONS

A novel type of high voltage transformer has been constructed, achieving a voltage step-up using only a short length of magnet wire and no magnetic core. This is just one example of the exciting applications which may follow investigation into EW-initiated plasma conductors. Focus has turned to better understanding the mechanisms behind EW, so that longer and more controllable plasma conductors may be created and used.