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Short communication

Continuously balanced pulse-DC ioniser to minimise the offset voltage

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ABSTRACT

In our previous work, the AC type of ionisers was employed to demonstrate a prospective theory obtained by numerical simulations in which continuously emitting quasi-neutralised positive and negative ions from corona ionisers can transport ions effectively to a charged object and yield zero offset voltage. In this paper, we show that this can also be applied to pulse-DC ionisers, resulting in significant improvements in the offset voltage as well as charge-decay times. In addition, we present an implementation method with an electronic circuit design to create such an ion emission from a pulse-DC ioniser.

1. Introduction

Reliable production of sensitive electronic components requires balanced ionisers where the offset voltage (steady-state potential induced by ionisers to an object to be neutralised) is minimised.

2-D electrohydrodynamic simulations [1] of ions emitted from DC, AC, and pulse-DC corona ionisers with air blowing during the neutralisation of a charged conductive plate have disclosed how the offset voltage is produced and can be eliminated. Although the cause and solution are discussed in Ref. [1], briefly, any electric fields produced by ionisers that exist at the steady state cause a certain offset voltage; therefore, eliminating the electric fields can make the offset voltage zero. This is because the drifts of positive and negative ions in an electric field are imbalanced due to the difference in their mobility, and this imbalance anywhere influences the balance of the currents of positive and negative ions to the object [1]; in addition, at the surface of the object, the influence of the electric fields is superimposed on the surface electric field created by the free charges themselves on the surface of the object (the superposition principle). The latter corresponds to electrostatic induction for conductive objects or polarisation for insulating ones, while the polarisation induced slightly affects the offset voltage. The electric fields causing the offset voltage are those produced by the space charges of imbalanced ions and those leaking from high-voltage parts of ionisers, e.g., corona needles. Therefore, the elimination of these electric fields can lead to zero offset voltage.

For elimination of the electric fields leaking from high-voltage parts, shielding by the grounding of the bodies and the outlet grids of ionisers is necessary. When the objects to be neutralised are conductive or partially conductive, this also works as a function for the prevention of the electrostatic induction that causes the offset voltage.

The results of the simulations showed that, at the steady state, the electric fields by the ion space charges significantly causing the offset voltage are produced only near the grounded ioniser outlet due to an imbalanced ion emission from the ioniser because the positive and negative ion density distributions in another region become approximately the same. They have also revealed that the ion space charges can be eliminated only when quasi-neutralised (balanced) ions are continuously emitted from an ioniser; as a result, a quasi-neutralised ion distribution is created in the entire region at the steady state, leading to zero offset voltage. This is equivalent to a quasi-neutralised ion space surrounded with grounded walls yielding the zero potential and zero electric field distributions, which situation corresponds to the solution of Poisson's equation with zero charge density and outer boundaries of zero potential; thus, the continuous emission of quasi-neutralised ions can eliminate the offset voltage.

In addition, the space-charge electric field created by the imbalanced ions near the grounded ioniser outlet forces the ions having the same polarity as the space charge to go back to the outlet; therefore, the ion transport towards the object is disturbed

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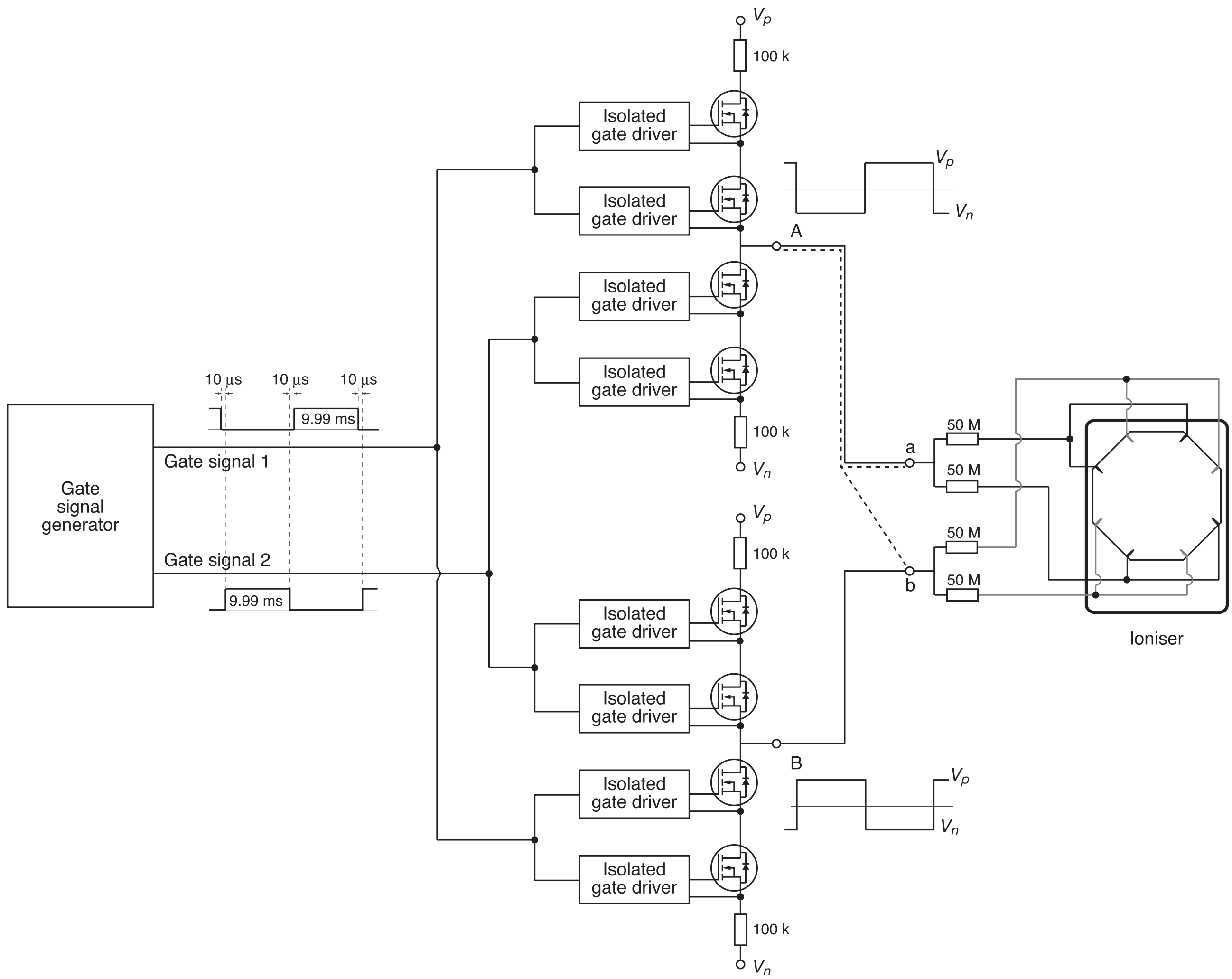

Fig. 1. Reversing and non-reversing square-wave voltage generator and ioniser used for this demonstration. Connections A–a and A–b for an ordinary pulse-DC ioniser and connections A–a and B–b for an improved (continuously balanced) pulse-DC ioniser were used.

by the electric field, resulting in slower charge-decay times.

The simulations have also revealed that for ordinary balanced AC and pulse-DC ionisers, alternately emitted positive or negative ions produce an alternate positive or negative ion space charge in front of the ioniser outlet that produces the alternate electric fields there, resulting in an imbalance of positive and negative ion currents; then an unwanted offset voltage involving AC oscillation arises. However, a simulation [1] using a continuously balanced AC ioniser with air blowing, in which at any given time, quasi-neutralised ions are emitted, has demonstrated complete elimination of the offset voltage, including its AC component, because such emitted ions can essentially remove the electric field by the alternate ion space charge that causes the offset voltage. Furthermore, we experimentally demonstrated this theoretical prospect for the improvement of AC ionisers, in which a much smaller offset voltage and faster charge-decay times were obtained [2].

In this paper, this theory will be experimentally applied for the modification of pulse-DC ionisers.

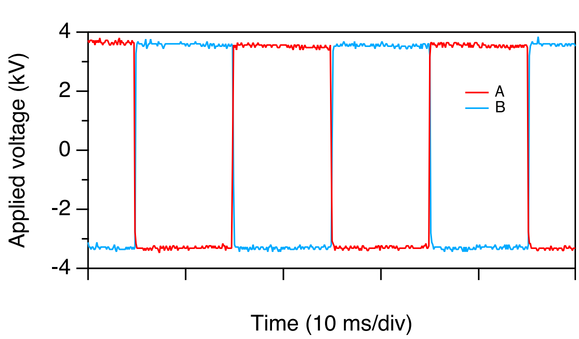

Fig. 2. Voltages of outputs A and B of the FET push–pull circuits which are applied to corresponding needles.

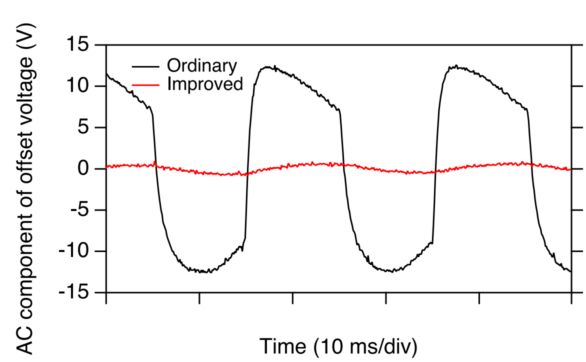

Fig. 3. AC components of the offset voltages.