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Investigation of wires layout in exploding wire array

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Abstract. Results of experimental investigation of wires layout in exploding wire array are presented. Straight and zigzag layouts are considered. Zigzag layout can be used to minimize the wire array length. Zigzag layout requires additional insulation to prevent array breakdown – pressurized SF_6 was used. Requirements for SF_6 pressure and distance between wires for zigzag layout were obtained. Influence of wire damage caused by extra tension applied to wires during installation on exploding wire array operation is considered.
Keywords: exploding wire array, opening switches, inductive energy storage.

1. Introduction

Exploding wires serving as opening switch are widely used for generation of high-voltage pulse and for switching energy stored in inductive storage to a load. Two factors should be taken into account when designing an exploding wire array (EWA). First, the specific high-voltage pulse amplitude and duration are necessary for specific load. Second, dynamics of wires explosion depends on coating of wire and impurities in metal. So parameters of EWA such as wires material and environment, length, diameter and number of wires should be taken into account and experimentally tested. Geometry of exploding wire array (EWA) could also significantly influence on the output parameters of the opening switch [1, 2].

Compacting EWA could be useful for parameters of pulse forming network and minimization of inductance of the load connection to EWA. Compact EWA design implies use of non-strait wires, for example, zigzag layout [3]. High-voltage breakdown should be thoroughly considered for a compact EWA design: insulating gas should be considered as an option. According to multiple studies SF_6 looks to be the best choice for EWA.

Minimal pressure of SF_6 and minimal distance between wires for compact EWA are considered in the paper. Experiments demonstrate possibility to keep the amplitude of the EWA-produced high-voltage pulse with twice as short length of array with zigzag layout immersed in pressurized SF_6. Array damage caused by extra tension applied to wires during installation in array supporting frame is considered.

2. Experimental setup

2.1. Circuit layout

Fig.1 shows a block diagram of the experimental setup for EWA test. Primary energy is stored in capacitor bank C. Inductance L1 is used as inductive storage. Controlled spark gap SG1 serves as closing switch. Uncontrollable spark gap SG2 picks voltage pulse over the load (high-power microwave source with impedance ~37 Ω.

2.2. EWA

Test of EWA with straight wires layout was used for reference. The supporting frame enables operate with straight wires of 750 mm length in air without extra pressure at full EWA length 750 mm. Frame for zigzag layout has length 300 mm for wires of 750 mm length. Seven supports are used for zigzag layout. The frame for zigzag layout is placed in a sealed casing suitable for filling with pressurized gas. Copper wire with diameter 100 μm is used. The number of wires in EWA used for reference tests is 28, but in some experiments the number of wires was varied according to specific purpose of test. Up to 40 wires can be installed in the frame if required. Photo of EWA with zigzag layout is shown in Fig.2.

2.3. Measurements and data comparison

Comparison of EWA operation for different wire layouts was done by comparison the amplitude and duration of the produced current pulse at the load. Current was measured by Rogowski coil. Circuit diagram of experimental setup is shown in Fig.1 with values for the components.

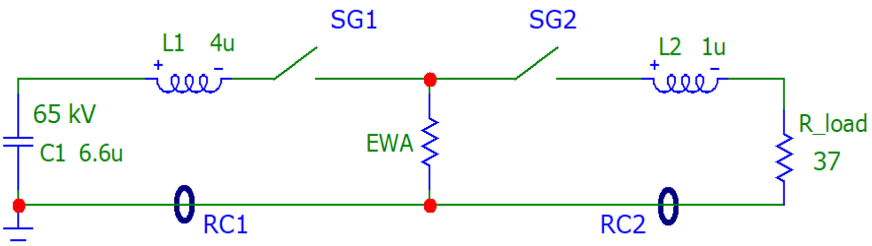

Fig.1. Circuit diagram of experimental setup. (C is the capacitor bank, L1 and L2 are the inductances, SG1 and SG2 are the switches (spark gaps), RC1 and RC2 are the Rogowski coils.).

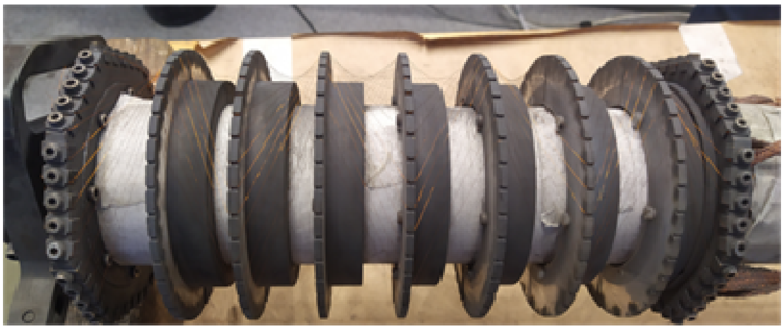

Fig.2. Exploding wire array with zigzag layout (No. of wires is 28).

3. Results

3.1. SF_6 pressure

SF_6 was used to prevent electrical breakdown in EWA with zigzag layout. Measured current pulse in the load for different values of SF6 pressure is shown in Fig.3. It is seen that for regular operation of considered EWA, the pressure of SF6 should be higher than 2 atm. The surface breakdown in EWA revealed itself at 2 atm pressure as decrease of amplitude of current transfered to the load.

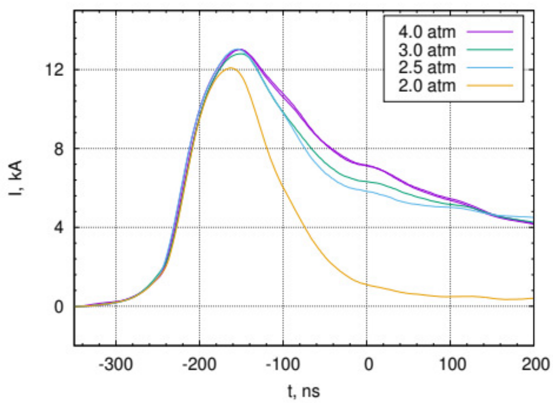

Fig.3. Current in the load for different values of SF6 pressure in EWA with zigzag layout (No. of wires is 28).

3.2. Comparison of EWA with straight wires and zigzag layout.

Tests of EWA with 28 wires in straight and zigzag layouts were carried out in same conditions using the circuit shown in Fig.1; gas type and pressure were varied. The distance between wires was about 11 mm in straight layout. The minimal distance between wires for zigzag layout was 5 mm. The amplitude of load current and pulse duration for different EWA are shown in the Table 1.

Table 1. Comparison of EWAs with different wires layout (No. of wires is 28)

Wires layout	Medium	Pressure, atm	Current pulse amplitude at the load (±5%), kA	FWHM of current pulse at the load (±10%), ns
Straight	Air	1	14.5	150
Zigzag	SF6	4	13	260

We can see from the Table 1 that the amplitude of load current drops by 10% for zigzag layout. It is not critical for load operation. The possible reason of such drop is smaller distance between wires in zigzag layout as compared to straight wires. Pulse duration for zigzag layout increases up to 70% due to pressurized SF_6.

To study influence of distance between wires on EWA operation, the minimal distance between wires was increased to 10 mm for zigzag layout. 20 wires were installed in straight and zigzag layouts. The distance 11 mm between the straight wires remained the same as in previous test. Parameters and current amplitudes are shown for both layouts in Table 2.

Table 2. Comparison of EWAs with different wire layouts (No. of wires is 20)

Wires layout	Medium	Pressure, atm	Current pulse amplitude at the load (±5%), kA	FWHM of current pulse at the load (±10%), ns
Straight	Air	1	13	190
Zigzag	SF_6	4	12.8	200

From Table 2 it follows that the amplitude and duration of current pulse in the load are almost the same for two wire layouts. So, the distance between wires is recommended to exceed 5 mm (value approaching 10 mm is better).

3.2. Procedure of wires installation.

We observed the variation of current amplitudes while working with EWA with zigzag layout. A possible reason of this is wire damage due to extra tension applied to wires during installation. Additional experiments were carried out to check the influence of extra tension on EWA with zigzag layout. Experiments were done with use of the set-up shown in Fig.1 with changed parameters: voltage at capacitors bank C1 was 57 kV, load impedance was ~33 Ohm, the number of wires was 22. Results of this test are shown in Table 3. According to results in Table 3, extra tension applied to wires during installation could cause reducing of current amplitude by 15%.

Table 3. Comparison of EWAs with different tension applied to wires during installation (No. of wires is 22)

	Current pulse amplitude at the load (±5%), kA	FWHM of current pulse at the load (±10%), ns
No or weak tension	10	230
Extra tension	8.5	320

4. Conclusion

Compact EWA design implies use of non-strait wires, for example, zigzag layout. High-voltage breakdown should be thoroughly considered for a compact EWA design: insulating gas should be considered as an option. According to multiple studies SF_6 looks to be the best choice for EWA.

Minimal SF_6 pressure is shown to be higher than 2 atm to prevent EWA breakdown in the proposed EWA design enabling to reduce the EWA length twice as many by zigzag layout in pressurized SF_6. Use of pressurized SF6 also increase the pulse duration in the load by 70% as compared to the pulse produced with straight wires exploded in air. Wires damage is shown to be of high importance during installation. Any extra tension, applied to wires, can reduce the amplitude of high-voltage pulse by 15%.

5. References

[1] Mesyats G.A., *Pulsed power*. (Boston: Springer, 2005).

[2] Borisevich A.E., Cherkas S.L., *Tech. Phys.*, **57**(10), 1380, 2012; doi: 10.1134/S1063784212100027

[3] McCauley D., Belt D., Mankowski J., Dickens J., Neuber A., and Kristiansen M., *Proc. of 16th IEEE International Pulsed Power Conference*, 1018, 2007; doi: 10.1109/PPPS.2007.4652362