# Facilities Ensuring Substation Direct Current Auxiliary Power System Survivability under Electromagnetic Pulse (HEMP) Part 2 Mobile Substations

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***Abstract:*** **The article explains the concept of mobile substation direct current auxiliary power system (DCAPS) design, ensuring resistance to high altitude electromagnetic pulse (HEMP), with due account for the features of the mobile substation. The measures improving mobile substation survivability under such impact are presented. The article is the sequel to an earlier article [1] related to the measures aimed to improve the survivability of stationary substations.**

***Keywords:*** **Power Substation, Electromagnetic Pulse, HEMP, Direct Current Auxiliary Power System.**

## I. INTRODUCTION

This article is the sequel to an earlier article related to the measures aimed to ensure the survivability of stationary substations [1]. However, the mobile substations (MS) are also widely used world-wide, see Fig. 1. MS direct current auxiliary power system (DCAPS) differs from the stationary substation DCAPS, and such differences must be considered during development of survivability measures.

**Fig. 1. Several types of mobile substations**

One of the differences is a very limited space the DCAPS of MS occupies. This particularly explains the application of nominal DC control voltage of 60V instead of 250V, as well as the usage of a 60V auxiliary power supply, consisting of in-series 12V compact sealed batteries for MS DCAPS in-feeding. However, five in-series 12V batteries require a floating charging voltage of approximately 67V, as against 60V. On the other hand, some types of electronic equipment (such as communication and data transfer systems) used in MS are designed to operate under nominal voltage of 48V, with the possibility to increase it up to 60V maximum, therefore the battery charger (BC) must provide two output voltages: 67V for battery charging and 60V to supply power to electronic equipment installed in MS. Such BCs built on an adjustable thyristor-based diode bridge were manufactured and previously used in MS. They were complex, expensive and large [2]. Later, switched mode power supplies with high-frequency link allowed the development t of very small BCs and improve the MS DCAPS survivability.

## II. NEW CONCEPT OF MS DCAPS

One option of protected MS DCAPS design is shown in Fig. 2.

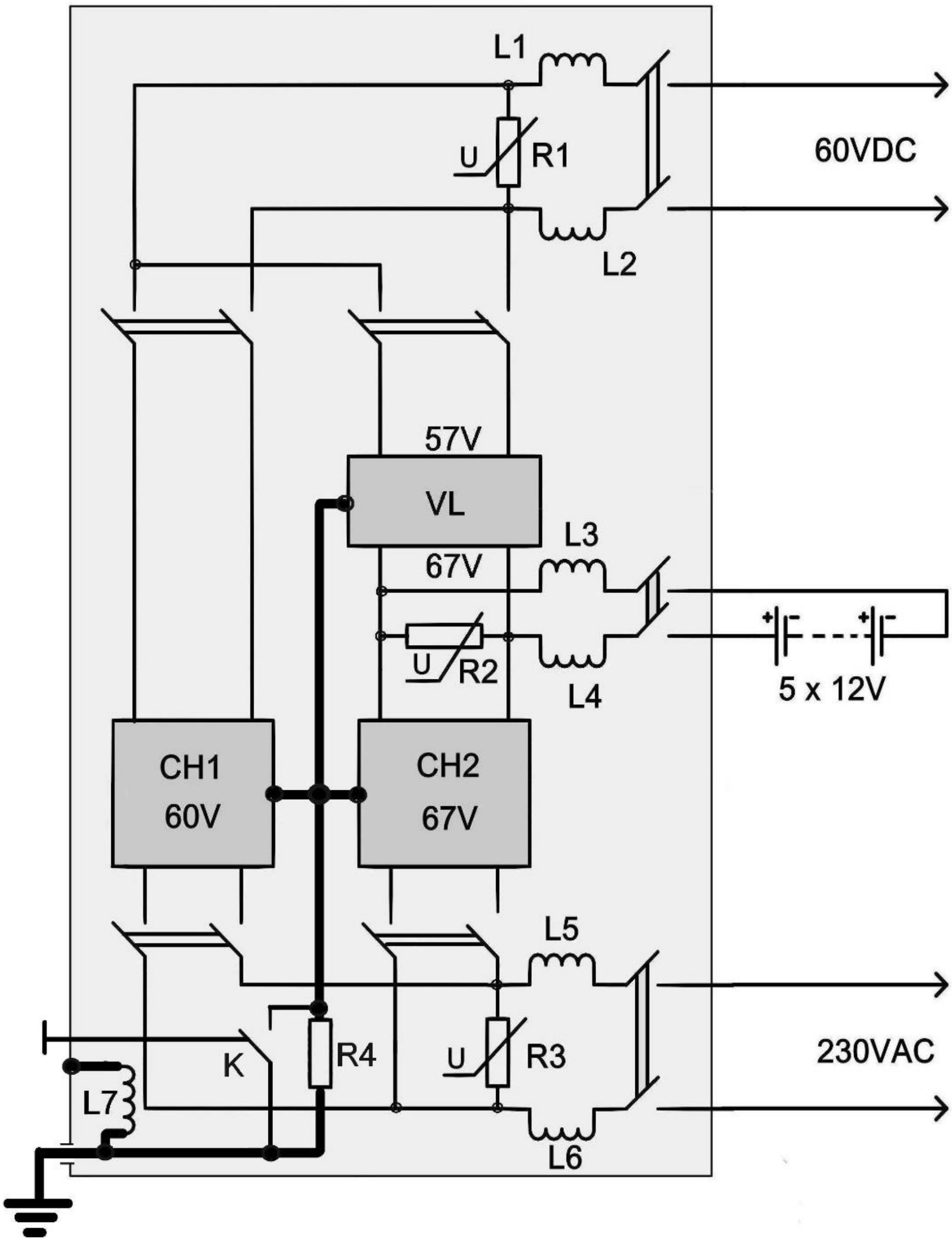


**Fig. 2. One option of MS DCAPS design. CH1 and CH2 – battery chargers; VL – voltage limiter; R1 – R3 – high-power block varistor; L1 – high-frequency chokes; L7, K, R4 – elements of cabinet and electronic module enclosure grounding, so called "floating ground", detailed in [3].**

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**Fig. 3. Compact BCs with intermediate high frequency link. Variable output voltage: 60V or 67V, output current up to 30A.**

As we see from the above arrangement, DCAPS consists of two BCs (the first outputs 67V and the second outputs 60V) and a voltage limiter (VL) ensuring 67V voltage decrease to the safe level of 60V, Fig. 3.

A VL can be simple in design and built on a base of a high-power Darlington transistor, see Fig. 4.

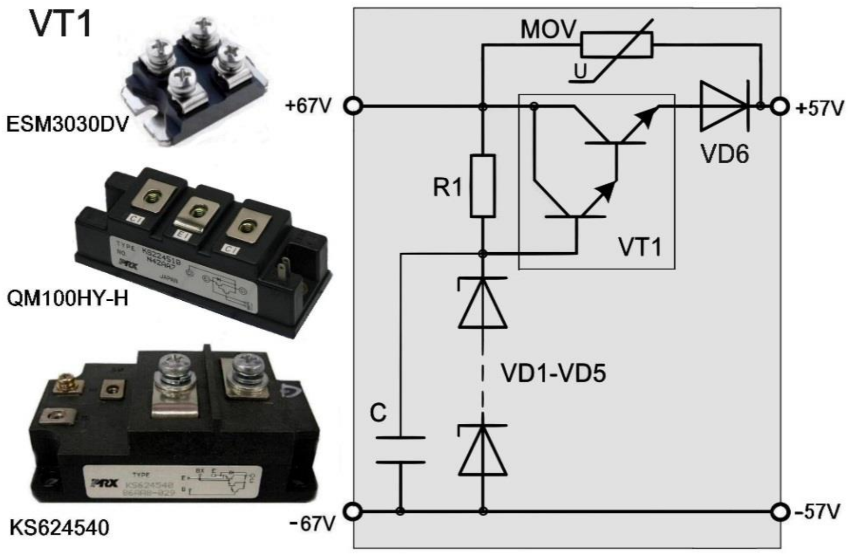


**Fig. 4. A voltage limiter (VL) built on a high-power Darlington transistor (VT1) and appearance of transistors with the different power rating**

Such transistors with a maximum current up to 100A and a voltage of 300V–600V are mounted in different enclosures designed for different dissipated energy. For example, a transistor type ESM3030DV dissipates up to 225W, a transistor type QM100HY-H dissipates 620W, and a transistor type KS624540 dissipates 1500W. When selecting a transistor, the voltage redundancy must be ensured to improve the resistance to surge overvoltage and to ensure the coordination with metal oxide varistor (MOV) parameters.

Selected output voltage of a VL is a little lower than 60V (57 – 58 V for example) in order to keep it in a closed mode (deenergized) by reverse voltage 60V of BC CH1, and exclude it from the DCAPS operation when connected in parallel with CH1 of 60V output voltage. The VL comes into operation only upon the AC control power failure and supplies the power to consumers from the battery bank. Given that in the absence of the floating charge 67V from CH2, the battery bank voltage decreases immediately, the requirements of the VL dissipated energy are not that high, and even the small transistor in ISOTOP-type enclosure (e.g. type ESM3030DV, see Fig. 4) installed on a radiator can safely cope with this task.

Alternatively, DCAPS can be built on the set consisting of a battery charger 230/67V, a DC/DC converter 67/60V and battery bank connected between them, see Fig. 5.

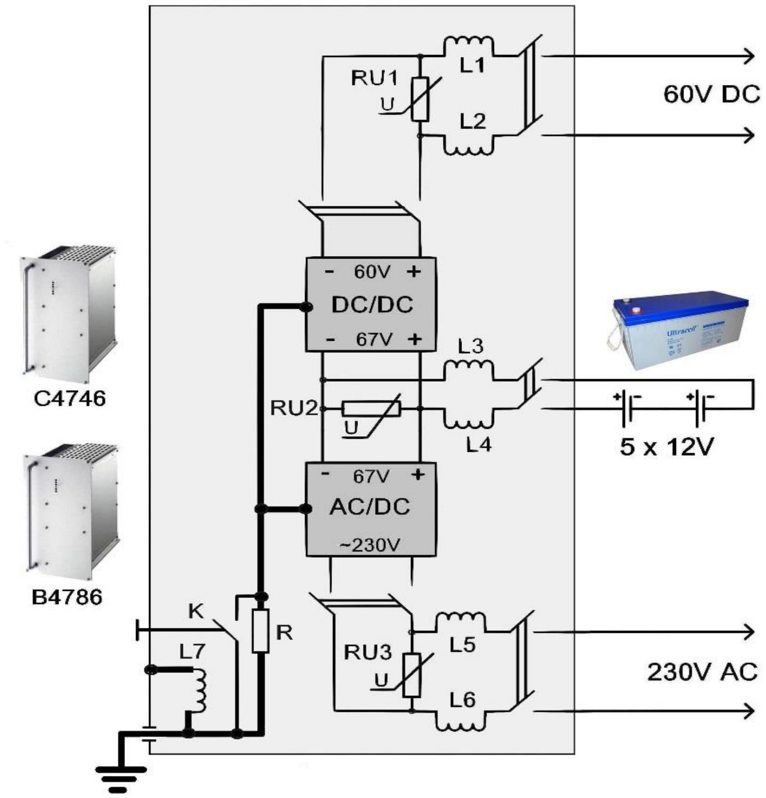


**Fig. 5. The design of MS DCAPS based on BC 230/67V (AC/DC) and converter 67/60V (DC/DC). L1–L6 – chokes; RU1-RU3 – varistors; L7, К, R4 – elements of cabinet and electronic module enclosure grounding, so called "floating ground", detailed in [3]**

Very different kinds of battery chargers and DC/DC converters for power 1.5 kW are available on the market. From very cheap construction ($160) with fan cooling, produced by Chinese companies (a), to more expensive ($700), but also with fan cooling and rectangular characteristics of current limiting (b), and up to very expensive ($5000), with natural convection cooling, and a wide range of operating temperatures more suitable for battery charger output current characteristics, etc., Fig. 6.

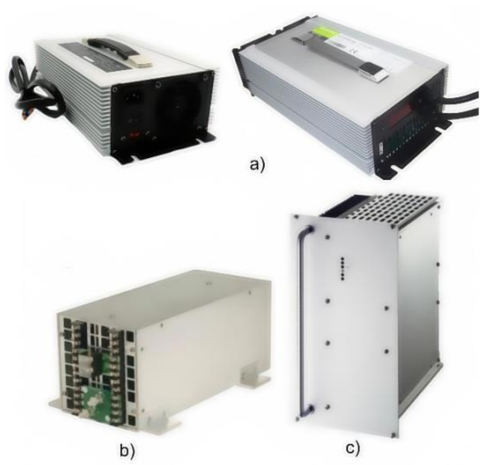


**Fig. 6. Three kinds of battery chargers and DC/DC converters: a) – very cheap (Guangzhou DongLong Electronics Co., China, Hangzhou Reacher Technology Co., China), b) - inexpensive (Absopulse Electronics Ltd., Canada); c) – very expensive (BC type B4786 and converter type C4746, produced by Powerbox Pty Ltd., Australia).**

For a correct choice of BC type, its' current limiting characteristic (current regulation mode), must be considered. Fig.7. For using the BC in the floating mode (voltage stabilization mode) only, any type of characteristics may be used. But for initial charging of a discharged accumulator battery, with very low internal impedance, "C" type characteristics that determine voltage and current for each point would be much more suitable. Concerning “B” or “D” type characteristics, the output voltage of BC may quickly drop towards zero at current reach to limit setting point (with these characteristics, the voltage level for this point is not determined at all and may reach zero). From this state the BC may turn to “Hiccup Mode” (interrupted charging). Therefore, the possibility for the BC of a specific type to work with a fully discharged battery must be examined before continuing.

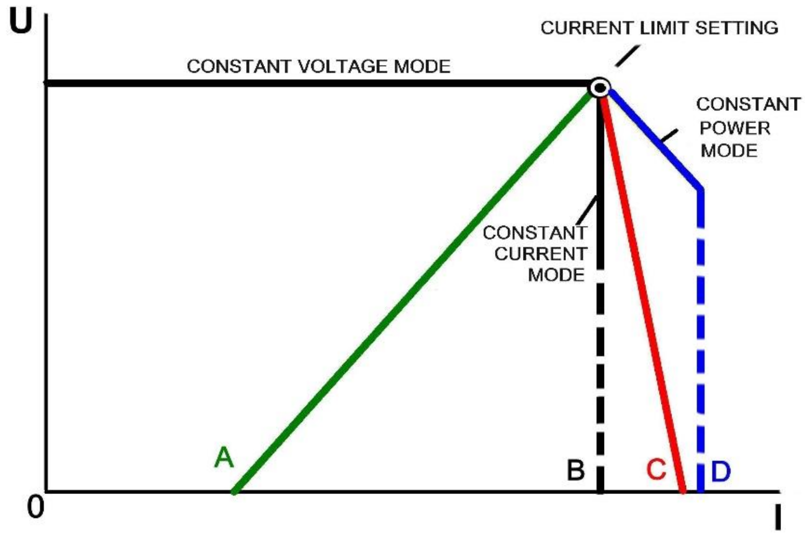


**Fig. 7. Most widely used kinds of current regulation modes (current limiting characteristics) for switching mode based power supply, chargers and converters. A – Fold-Back; B – Constant Current Mode; C – Fold-Forward; D – Constant Power**

## III. CONCEPT FOR MS DCAPS PROTECTION AGAINST HEMP

Within the described options, the protection of MS DCAPS electronic equipment against HEMP is ensured as follows:

- Special design of equipment cabinet is selected (or modified) according to the consideration mentioned in [4, 5];

- Special protection elements (chokes and varistors) are installed inside the cabinet, see Fig. 8:

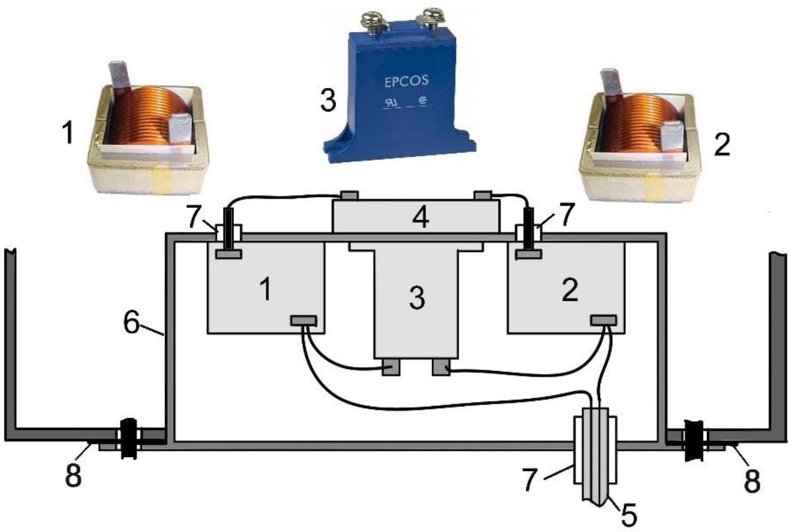


**Fig. 8. Cabinet inlet box with DCAPS electronic apparatus. 1 and 2 – special high-current high-frequency chokes with helical coils manufactured by CWS; 3 – block varistors; 4 – terminal strip installed inside the cabinet; 5 – input or output cabinet cable; 6 – metal section for protecting elements; 7 – wall tube insulators; 8 – spacer made of conductive rubber.**

- internal MS cables are routed in the flexible metal hoses, see Fig. 9.

**Fig. 9. Flexible metal hoses of different diameters designed for routing internal MS cables.**

- special electromagnetic filters (honeycomb ventilation panels) are installed in control cabinets with electronic equipment instead of regular vent screens, see Fig. 10:

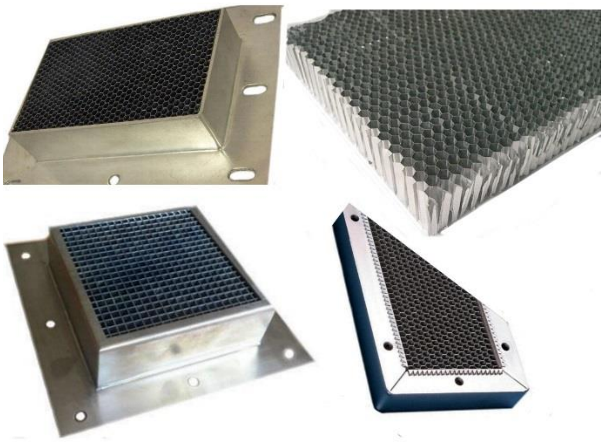

**Fig. 10. Honeycomb vent panels based on so called "below-cutoff waveguides" applied instead of regular vent screens in control cabinets**

- disconnected grounding of "special floating ground" type [3]:

- Spare replacement modules [6], in this case, spare BC and converter (or two BCs and a VL ) are stored in the t MS in the tightly closed aluminum container.

## IV. CONCLUSION

The above simple and affordable technical measures can be successfully used for building of small-size, effective and HEMP-protected direct current auxiliary power systems, suitable for mobile substations of different types and power.

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