ELECTRIC POWER SUPPLY

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Enhancing Reliability of Electric Power Supply of Unattended Stations in Transmission Systems*

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Extended communications lines generally include remotely supplied unattended booster stations (UBS), located along a route at distances of 5-10 km. A break in the remote electric power supply (REPS) at any point along the route disrupts operation of the entire transmission system; this may lead to serious consequences and is frequently intolerable. In this connection, it is advisable to provide the UBS electric power supply system with special means for forming loops (DFL), which represent two-position unistable relays.

Let us consider the operation of an electric power supply system with DFL units (Fig. 1). Under idle conditions, all the switching DFL contacts are closed. When the electric power supply is switched on, the working value of current is established only in the first UBS-1 from the supply source. This current then branches into two parts, one of which (I_2) is fed to UBS-2, and the other (I_1) flows through a ballast resistance RI. Beyond UBS-2, current I_2 again branches into components I_3 and I_4, etc. The ballast resistance decreases with distance from the supply source and it is chosen according to the relation

$$R_{b\,i} = R_{\Sigma} - R_{1\,i}, \quad (1)$$

where R_Σ is total line resistance; R_{1i} is resistance of the line section up to the point where the i-th ballast resistance is installed. As the DFL operating current decreases, requirements are lowered for the exact satisfaction of Eq. (1). Moreover, the following relation is established between the currents in the line:

$$I_2 = I - I_1;\ I_4 = I - I_1 - I_3;\ I_6 = I - I_1 - I_3 - I_5.$$

Current I_2 only is sufficient for operating a DFL. When the contact in DFL opens, the relations between currents change:

$$I_1 = 0;\ I_2 = I;\ I_4 = I - I_3;\ I_6 = I - I_3 - I_5.$$

In this case, current I_4 also becomes sufficient to fire a DFL. When the contact opens in DFL-2, current in the DFL-3 circuit similarly increases, etc. There thus occurs successive connection of DFL units and successive entering of all system sections into a nominal regime. When the power supply circuit is disrupted, for example at point 3 (Fig. 1), all DFL return to the initial state and all UBS, except the first, lose their electric power supply. In this case, the process described above – of successive operation of DFL units – begins, and it ends when the failure point is reached. As a result of this, only the section of the system that lies beyond the failure point remains without power supply, i.e., failed section is cut-off from the system, having been replaced in terms of power supply circuit by a loop (ballast resistance) of the triggered DFL.

A number of specific requirements are imposed on the loop formation devices. For example, in the example considered above, there is the need to switch voltages greater than 1 kV at a current of 0.1 A; sufficient isolation of the control circuit from the output circuit, capable of sustaining volage of not less than 3 kV; small size for placing in UBS containers. The devices should also have a special volt-ampere characteristic that ensures their switching at small currents (10-20 mA) with a subsequent 5-10 fold rise in the working current. Moreover,

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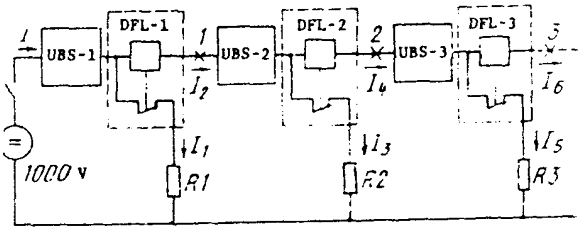

Fig. 1

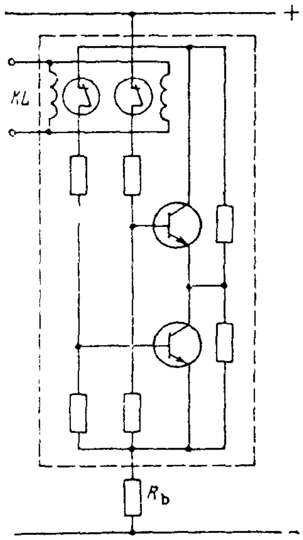

Fig. 2

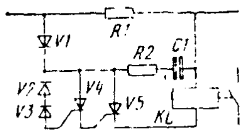

Fig. 3

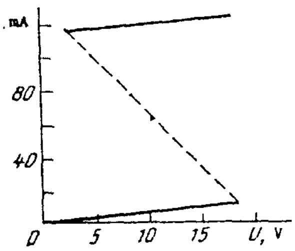

Fig. 5

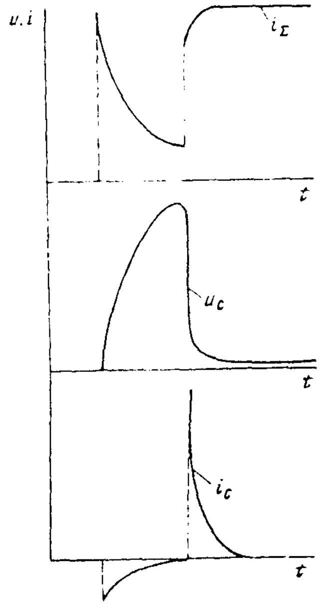

Fig. 4

the unit should indefinitely long maintain the effect of this current (until a break occurs on a line or during planned disconnection) and have a very small internal resistance (in order not to exert substantial effect on the general level of the UBS power supply voltage when there are many such devices connected in series).

Devices that are capable of functioning as DFL units are nonexistent among a long list of currently mass produced relay devices. A possibility of implementing the described system of the UBS power supply has arisen in connection with development in recent years of electromagnetic devices of a new type, the so-called "hercotrons" [1, 2], which are hercon relays with high-voltage insulation between the input (control winding) and output (hercon). One of the variants of such devices are high-voltage low-current switches based on hercons (for example, type MKA-52141 mass-produced vacuum hercons that switch voltages up to 5 kV). However, high-voltage hercons have a highly limited value of allowable switched power: up to 50 W at voltages up to 1 kV, and up to 10 W at voltages above 1 kV, which is unsatisfactory for using them in DFL units.

These hercons at the same time permit switching of large currents (up to 3-4 A) within the indicated power values. Consequently, considerable increase in the switched current at high voltage is possible by connecting the hercons in series, substantially simplifying construction since it is simpler to balance voltage distribution in series-connected elements than to balance current distribution for parallel elements.

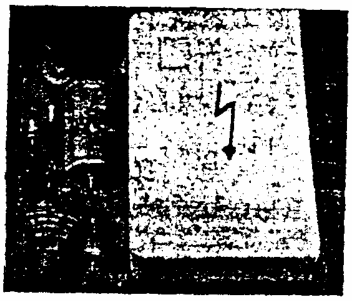

Fig. 6

A device that satisfies the DFL requirements and switches the 0.1 A current at a voltage of 1 kV has been constructed on the basis of two series-connected type MKA-52141 hercons, each of which was furnished with a separate excitation coil. Both coils are connected to each other in a common control winding. To avoid breaking a closed hercon two type DZhB.04.2.0325 permanent magnets were used, placed with their magnetization axes perpendicular to the excitation coil field vector. The voltage divider consisted of two type KEV-0.5 100-Mohm resistors connected in parallel with the hercons. To compensate the scatter of the hercon and magnet parameters, magnetic shunts were placed directly on the magnets in the form of steel plates that could be moved freely for adjustment. The entire structure is mounted on a frame 90 × × 55 × 28 mm and filled with epoxy compound. Internal connections are made with high-voltage wire.

Since the remote power supply voltage in modern communications systems may reach 2 kV at currents from 400 to 500 mA, further increase in commutator power is necessary; this allows the device to be used for any type of remotely supplied UBS. The unavailability of hercons of required power made in the USSR has led to the construction of a hybrid transistor-hercon switch whose circuit is shown in Fig. 2. In this unit, hercons switch only small transistor base currents and operate under alleviated conditions, and two series-connected type 2T713A transistors easily tolerate the working and also test voltages.

Using individual hercons for each transistor allowed us to decouple their base circuits reliably and to eliminate dependence of one transistor state on the other. In this case, the small natural firing asynchronism (tens of microseconds in the case of a control system for the excitation winding described below) has no effect on device efficiency, since type 2T713A transistors permit application of pulsed voltage between the emitter and collector up to 2500 V, which allows a certain nonconcurrency of their triggering (blocking).

Development of a switch that satisfies the operating conditions in a DFL constitutes a solution of one of the problems. The second problem is that of giving the switch a special volt-ampere characteristic (VAC). This problem was sovled by means of an electronic VAC converter (Fig. 3).

The device works as follows. When voltage is applied to the line, a small current begins to flow in it, which produces a noticeable voltage drop in the high-resistance shunt *R1*. Capaictor *C1* begins to be charged under the effect of this voltage by a current that flows through diode *V1* and resistor *R2*. At this time, thyristors *V4* and *V5* are blocked and the winding *KL* is practically de-energized. After capacitor *C1* is charged to the breakdown voltage of the stabilitrons *V2* and *V3*, their equivalent resistance is reduced, which leads to triggering of the thyristors, first *V4* and then *V5*. In this case, capacitor *C1* discharges through thyristor *V5* and resistor *R2* to the winding *KL*, generating a current pulse that is sufficient to fire the relay (Fig. 4).

When the relay contacts are made, a low-resistance winding KL' becomes connected in parallel to the high-resistance shunt *R1*, which leads to a sharp reduction in the equivalent resistance of the device and a voltage drop across it (although it remains sufficient to maintain the relay). The presence of a low-power thyristor *V4* that has a rather large resistance of the control junction compared to the resistance of the control junction of thyristor *V5*, enables one to reduce substantially the leakage current of *C1* during its charging and to increase the efficiency of its utilization.

The use of stabilitrons jointly with a transistor as a threshold triggering element ensures stable and low firing threshold, in contrast with dynistors. Diode *V1* prevents discharge of the condenser through the shunt *R1*.

An essential difference between known relay-type devices and the switching device described above, having a converter, consists in the specific dependence of firing current on voltage (Fig. 5) and the nature of variation of the equivalent resistance, which, until firing, remains high and the current is very small; after firing, it drops sharply and the current rises.

The DFL units developed (Fig. 6) are assembled on small boards that are directly built into equipment; they are reliable to operate and satisfy all requirements imposed on them.

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