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The autonomous sources of energy supply for the liquidation of technogenic accidents

***Abstract**. We have formed an approach to the creation of autonomous sources of energy supply to improve the reliability of power supply systems. We have proposed the solutions to energy supply systems enabling the decrease of influence of the unfavorable coincidence of climatic conditions or anthropogenic circumstances. The proposed solutions improve the conventional energy supply systems of the critical purpose objects. We have presented the principles of forming the local autonomous sources of energy supply, created in non-steady situations and completed with regular electric equipment that is in constant production operation at local enterprises or establishments. We have determined the limits for the stable operation of local autonomous sources of energy supply at the connection of typical consumers of electric power.*

***Streszczenie.** Zaproponowaliśmy podejście do tworzenia autonomicznych źródeł zaopatrzenia w energię w celu poprawy niezawodności systemów zasilania. Zaproponowaliśmy rozwiązania systemów zasilania w energię, które pozwalają na zmniejszenie wpływu niekorzystnej zbieżności warunków klimatycznych lub warunków antropogenicznych. Proponowane rozwiązania poprawiają konwencjonalne systemy zasilania energią obiektów o znaczeniu krytycznym. Zaprezentowaliśmy zasady tworzenia lokalnych autonomicznych źródeł zaopatrzenia w energię, stworzonych w niestabilnych sytuacjach i zbudowanych z klasycznego wyposażenia elektrycznego, które jest w ciągłej produkcji w lokalnych przedsiębiorstwach lub zakładach. Ustaliliśmy limity dla stabilnego funkcjonowania lokalnych autonomicznych źródeł zaopatrzenia w energię przy podłączeniu typowych odbiorców energii elektrycznej. (**Autonomiczne źródła zasilania w energię przy likwidacji wypadków technogennych**)*

Keywords: autonomous sources of energy supply, induction generator**,** dynamic loads.
Słowa kluczowe: autonomiczne źródła zaopatrzenia w energię, generator indukcyjny, obciążenia dynamiczne.

Introduction

The problems of the improvement of the reliability of energy supply systems as a complex branched network of the generation, conversion, transmission of energy to consumers have become especially topical due to the realization of the fact that not only enterprises but also the social sphere of the society are vulnerable when the energy supply is disrupted even for a short time. The underestimation of this circumstance has already resulted in a number of big emergency situations of different nature [1, 2].

Unfavorable coincidence of climatic conditions or anthropogenic circumstances may result in creation of emergency situations caused by system disruption of energy supply to the critical-purpose objects. First of all, it is about emergency medical care facilities, heating networks and water supply and sewage systems as long absence of energy supply to them may cause serious and even tragic consequences. According to [3] (Fig.1), the number of catastrophic events in the world, of both technogenic and natural character, constantly grows.

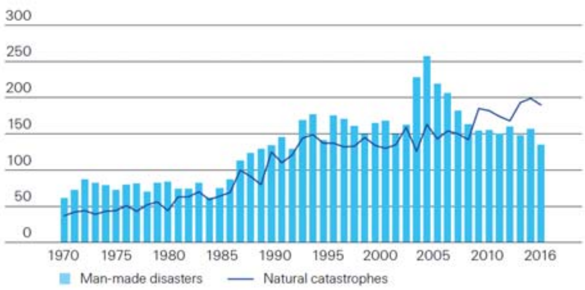


Fig. 1. Number of catastrophic events

The liquidation of the consequences of accidents in energy supply systems requires great human and material resources. A guaranteed trouble-free energy supply can be practically inaccessible for most enterprises due to considerable capital expenditure at technical realization of particular solutions.

A sufficiently simple solution to the problem is possible with the use of local autonomous sources of energy supply (ASE). However, technical problems have not been solved yet – the principal circuit designs, the organizational and technical measures providing ASE introduction during the minimal time.

So, it is topical to create ASE based on the electric equipment and power plants of another functional purpose, to synthesize the system of their control providing energy generation for industrial and communal consumers during the elimination of anthropogenic accidents.

Theoretical research

A. The theory concerning local ASE creation.

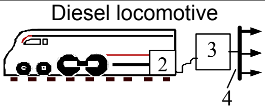
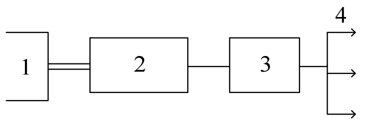
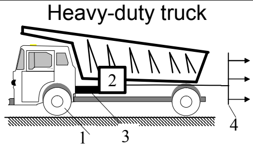
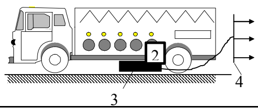
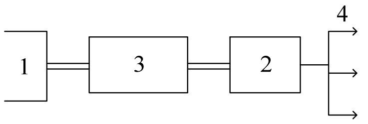
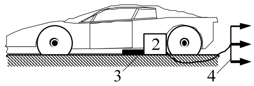
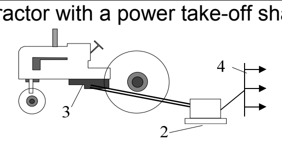
When relevant subdivisions and services plan their actions in the case of a large-scale energy supply disruption, a great number of such objects present certain economic obstacles to the realization of the standard solutions as to the acquisition of backup energy supply units and keeping them on balance [4]. That is why the solution to this problem consists in the development and introduction of a program on the formation of local ASE created in the emergency situations and completed by the standard electric equipment of local enterprises or establishments.

Local ASE is formed by the personnel of corresponding enterprises during the period that precedes the emergency, during its development or after the termination of its active phase. A local ASE is completed by the available and normally functioning components of technological, electrotechnical and transport equipment. The regulation of the personnel's actions as to the creation of a local ASE provides its putting into operation within several hours.

Local ASE is formed by the personnel of corresponding enterprises during the period that precedes the emergency, during its development or after the termination of its active phase. A local ASE is completed by the available and normally functioning components of technological, electrotechnical and transport equipment. So, local ASE is formed temporarily and is not on the balance of the enterprise as a stationary or mobile electric station. The funds required for the creation of a local source of energy supply just include the cost of its formation and the cost of its subsequent de-completion.

In a general case a complete set of local ASE equipment is to include: 1) a power unit, 2) an energy-generating unit, 3) a communication and control module.

Table 1. The technological scheme of local ASE creation

Initial vehicle type	Type of coordination system	Output power, kW
Diesel locomotive 	 1 – vehicle: a diesel locomotive or a heavy-duty truck; 2 – electrical generator; 3 – frequency converter; 4 – electrical grid	300…2200
Heavy-duty truck 		350…1200
Truck 	 1 – vehicle: a truck, a car, a tractor; 2 – electrical generator; 3 – mechanical connection of the vehicle shaft with an electrical generator; 4 – electrical grid	70…200
Car 		30…60
Tractor with a power take-off shaft 		30…120

As a power unit, we recommend to use any internal combustion engine (diesel, carburettor, injector one), installed on vehicles as a driving force (Table 1). The latter condition provides the self-propelled motion of the energy-power unit and the other components to the place of formation and use of the local ASE.

Self-propelled vehicles with electromechanical transmission are equipped with a generator used by its direct purpose, so, there is no necessity for an additional electricity-generating unit.

Automobiles with mechanical transmission require an additional electricity-generating unit wherein the power is taken off depending on the design special features – either from the engine shaft or from the secondary shaft of the transmission box or from the axle of the driving wheel (Fig. 2).

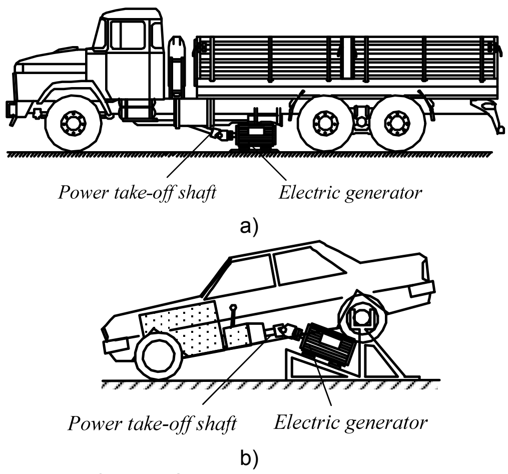


Fig. 2. Example of local ASE based on a truck (a) and a car (b)

A usual electric motor (direct current, induction, synchronous) of corresponding power and voltage is used as an electricity-generating unit. For the period of the emergency it is dismantled from objects non-critical production equipment.

The communication and control module provides: the interaction of the power unit with the elements of the electricity supply system; the conversion of the generated electric energy and synchronization of the frequency and amplitude of the output voltage according to the consumer's needs; the safe service of the local ASE.

B. Modeling results

Transient processes in the ASE were analyzed by means of computer modeling in MATLAB application package [5].

An internal combustion engine (ICE), used in Viper Defint 125 scooters was modeled as an energy-power unit. Its parameters are: the engine type – a four-stroke engine with one cylinder; volume – 124.9 m^3; $P_{dizel.max} = 5.6$ kW; $n_{max} = 7500$ rev/min; transmission – a wedge-belt variator.

Short circuit induction motors (IM) with the following parameters: $P_n = 1.2$ kW; $n_n = 2740$ rev/min; $I_s = 2.93$ A; $R_s = 9.37$ Ohm; $R_r = 5.13$ Ohm; $L_s = L_r^{/} = 22$ mG; $L_\mu = 66$ mG were used as a self-excited induction generators (SEIG). The capacity of excitation capacitors for each SEIG phase was $C = 30$ μF.

The communication and control module is presented by two regulators – a speed controller (SC) of ICE, created by the Polzunov-Watt principle, and a capacitive excitation controller (CEC) of SEIG. Additional capacities of excitation are input/output by signal $\Delta U_{st} = U_z - U_{IG}$ (U_z, U_{IG} – the assigned and real values of SEIG voltage) of the generator voltage disagreement.

Fig. 3 shows the dynamic characteristics of local ASE at connecting electric power typical consumers – direct current (DCM) induction motors (IM) and lighting devices (L). The results were obtained at ASE mathematical model described in [5]. At time moment $t_{on} = 7$ s the mode of connecting typical electric energy consumers to SEIG terminals was simulated and time moment $t_{off} = 12$ s the consumers were disconnected. The following designations are adopted in the figure: ICE power P_{dizel}, ICE rotation frequency ω_d , ICE torque M_{kr} and ICE resistance moment M_{res} creating SEIG together with the connected consumers of electric energy.

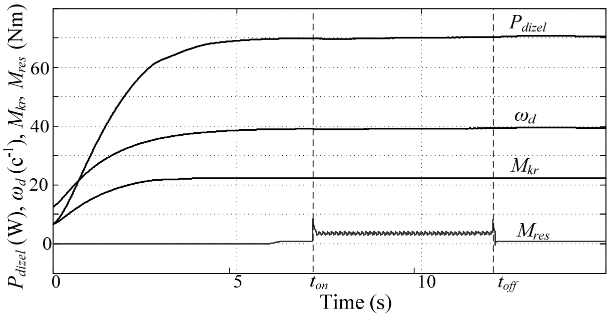


Fig. 3. ASE dynamic characteristics

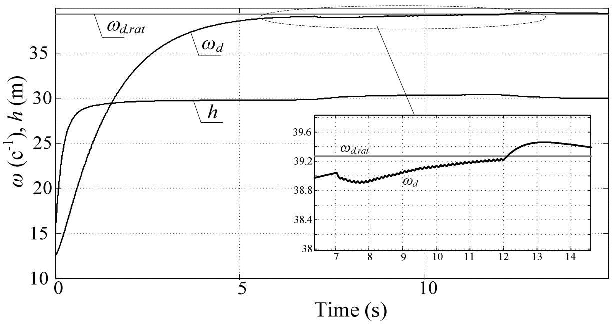


Fig. 4. The stabilization of ICE rotation frequency

The characteristics in Fig. 3 are presented in the scale: $P_{dizel} = 1/60$; $\omega_d = 1/4$; $M_{kr} = 1/2$; $M_{res} = 1/1$. The characteristics presented in Fig.4 demonstrate ICE SC operation, where $\omega_{d.rat}$, ω_d – the assigned and the real ICE rotation frequencies, h – the motion of the fuel rack. The characteristics in Fig 4 are presented in the scale: $\omega_{d.rat} = 1/4$; $\omega_d = 1/4$; $h = 1500/1$.

The analysis of the obtained characteristics reveals that ICE SP completely compensates for the action of the destabilizing factor – resistance moment M_{res} .

Fig. 5 shows the graphs of SEIG instantaneous values of voltages and currents at the supply of L-consumers with static active ($R_d = 30$ Ohm) and active-inductive ($R_d = 30$ Ohm; $L_d = 15$ mG) load characters.

Electric machines exert increased destabilizing influence upon ASE as they are characterized by presence of starting currents and variation of power coefficient according to the load. This is why the limits of SEIG steady operation, when direct current consumers are supplied, are determined under the condition of various-power IM and DCM cascade connection [5].

When SEIG overload capacity was determined, as in the previous research, IM or DCM direct connection was used without SOFT-start system.

It has been determined that the start is possible when a certain relation between generator power P_{IG} and motive load power is observed:

(1) $$P_{IM} / P_{IG} = 0.2 \div 0.3$$

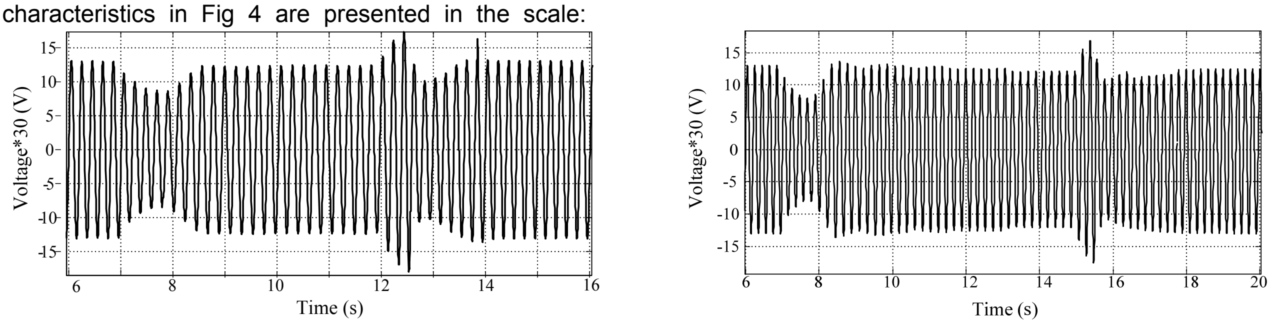
(2) $$P_{DCM} / P_{IG} = 0.35 \div 0.4$$

where P_{IM} , P_{DCM} – power consumers of the type IM and DCM.

If static-load consumers (lighting units, ovens, etc.) are connected, this relation increases to [5]:

(3) $P_c / P_{IG} \le 0.5 \div 0.6$

where P_c – power of static-load consumers.



a)

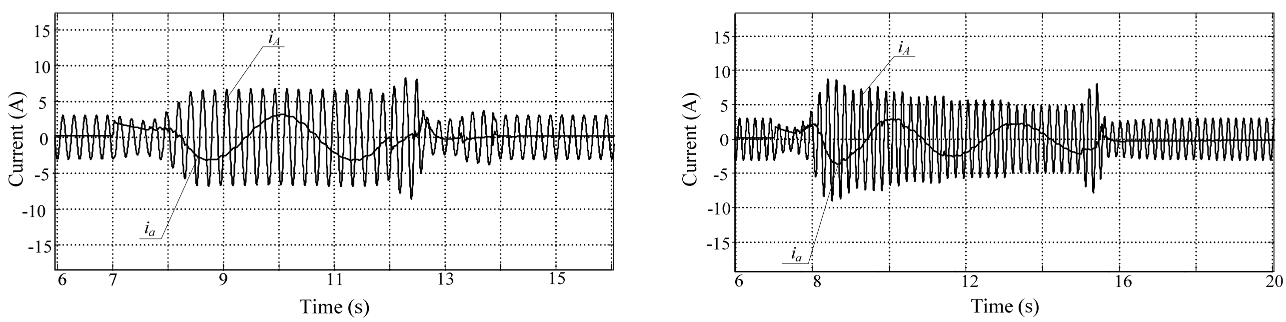
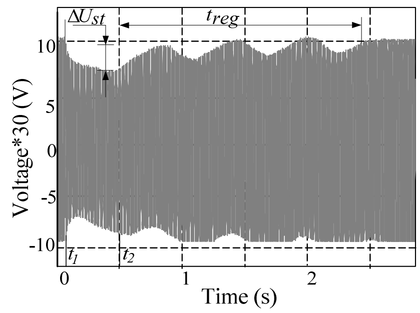


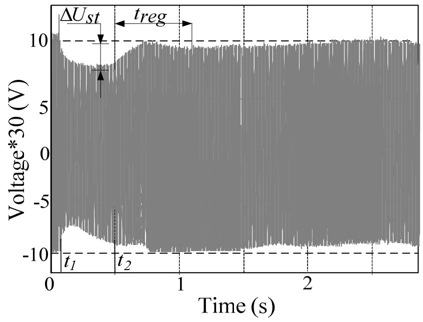
Fig. 5. The instantaneous values of SEIG stator and rotor voltage and current at the connection/disconnection of L-consumers with active (a) and active-inductive (b) load characters

Experimental research

Fig. 6 demonstrates the experimental research at time moment t_1 of the connection of L-consumers (lighting devices of the power of $P_L = 150$ W) and SEIG voltage stabilization (from time moment t_2) by two methods by means of ICE SC (Fig. 6, a) and SEIG CEC (Fig. 6, b). The parameters and characteristics of ICE and SEIG are identical to those used in modeling.



a)



b)

Fig. 6. Voltage at SEIG terminals at the connection of L-consumers of the power of $P_L = 0.12P_{IG}$

The analysis of the obtained dependences revealed that SEIG voltage stabilization with the use of CEC is most acceptable as to the operation speed (Fig. 6, b). In this case the time of regulation is t_{reg}=0.6 s. However, at this variant of SEIG voltage stabilization additional capacitors batteries are required. So, for this case of connection of L-consumers of the power of $P_L = 0.12P_{IG}$, the capacity of the additional battery is by 1.4 times higher than the initial capacity of excitation of SEIG. At SEIG voltage stabilization by means of the use of ICE SC (Fig. 6, a) the regulation time is practically three time as big as for SEIG CEC and makes t_{reg}=1,9 s. In this case there is no need in the use of additional electrotechnical equipment

However, to provide high-quality indices and wide range of the regulation of ASE output voltage it is necessary to regulate the parameters of both the energy-power and the energy-generating units included into ASE.

Conclusions

We have proposed and practically confirmed the approach to the creation of ASE for the period of non-steady situations of a technogenic or anthropogenic character occurring due to the system or incidental violation of the energy supply of dwelling buildings, hospitals or other objects of critical purpose. By the methods of mathematical modeling and industrial experimental research we have proved the possibility of the formation of local ASE based on the vehicle energy-power unit mechanically connected with an electric motor operating in the mode of energy generation.

We have determined the limits of the steady operation of typical consumers of electric energy during the connection to local ASE, which makes it possible, at their formation, to choose the required electrotechnical and electromechanical components according to the load.

The use of the proposed ASE allows obtaining the social and economic effects. The social effect is determined by the elimination of the consequences of non-steady situations in minimal time especially when human life is in danger. The economic component of the effect relates to the exclusion of the expenditure on the stationary reserve source of energy supply, amortization and storage of the equipment However, its quantitative indices essentially depend on the engineering solution of the created local ASE and its power.

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