Energy-efficient hybrid system start diesel

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Abstract. The paper considers the energy-efficient hybrid system start the diesel. Presentation of the main advantages of the proposed system in comparison with the standard system. The modeling system start shunting locomotive diesel, which provides a two-step start by using supercapacitors blocks composed of standard system. A mathematical model, simulation model simulation shows the curves of the current change over time.

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Introduction

In few last years, one of the important requirements of the market is reducing of the fuel consumption of the internal combustion engine. The diesel engines of diesel locomotives are not exception. Calculations show that the economy of diesel fuel in the warmer months, in case of reduction of locomotive idling with the subsequent launch is guaranteed, is about 1,000 liters per month with one of the vehicle [1]. For these purposes, the most promising avenue is the use of supercapacitors block in the system start the diesel engine locomotive [2, 3].

In [4] proposed an advanced start system, which provides a two-stage launch diesel locomotive through the use of blocks of supercapacitors. Supercapacitor battery is used to produce maximum torque at the initial period of cranking the engine crankshaft, which significantly reduces the current load on a full battery at the time of the initial launch of the diesel engine.

Using the power of supercapacitors in the proposed system can achieve the following results [5, 6, 7]:

- Reducing the impact of power on the battery charge starting characteristics;
- Increasing the life of the system;
- Providing guaranteed start diesel, including operation during the cold season;
- Increase engine life, due to the possibility of frequent stopping the engine, followed by a guaranteed start.
- Reduction of the nominal capacity of the battery is 1.5-2 times;
- Reduction of fuel consumption.

The proposed two-stage system start-up is an easy to implement. Payback period of the system is less than 1 year. It should be noted supercapacitor unit is a compact device that does not require special maintenance for the product, which gives the ability to place it in remote places compartments locomotive.

The main part

As the object of investigation, the shunting locomotive series TEM-2: four-stroke generator PDG-1M (64N31, 8/33) with direct fuel injection, turbo-inflating pressurized air cooling, the number of cylinders - 6; M14B2 type of engine oil; kinetic viscosity at 40 ºC - 144 cSt; traction generator DC series PG300B [8].

Traction DC generators are designed to start producing diesel and EMF applied for traction locomotive. The rotor of the generator is connected to the crankshaft for a diesel engine by bolting.

A simplified circuit diagram is shown on Fig.1. The principle of operation of the circuit is as follows. With closure of the main switch AB start starter (SG) is carried out by precharged unit supercapacitors battery (BC). In this mode, the peak inrush current falls on the block supercapacitors. As the discharge of the capacitor reduces the voltage across its terminals. If voltage transition at the contacts of the capacitor voltage relay operation occurs (VR), which connect contacts batteries (B). When the voltage U_{set} on the contacts BC the voltage relay operation occurs (CM), which connects the accumulator battery (AcB).

Due to the fact that the voltage of the super-capacitor is less than the battery voltage the diode (VD) will be locked and the current will flow from the starter battery, while the current drawn from the battery, will be significantly less due to the fact that already rotating starter armature will produce anti-EMF proportional to its rotational speed. Supply starter from battery operating until completion of the start-up.

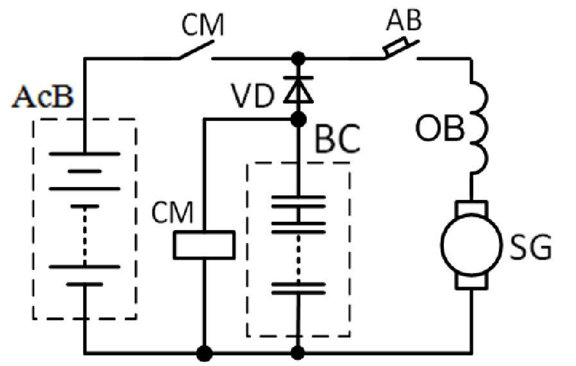

Figure 1. Simplified start circuit of the starter of the locomotive TEM-2 electro-engine

A correct analysis of the transition processes at startup diesel engine locomotive, and in particular the magnitude of inrush currents and voltage drop can be made on the basis of modern simulation systems. The system of equations can be represented as follows [9]:

$$\begin{cases} U_s = i_s \cdot R_\Sigma + L_\Sigma \cdot \frac{di_s}{dt} + e(\omega); \\ e(\omega) = K_e \cdot \omega; \\ M_i - M_в = J \cdot \frac{d\omega}{dt}; \\ M_i = K_м \cdot i_s; \\ U_\Sigma = i_s \cdot R_{BC} + \frac{1}{C}\int i\,dt; \\ U_\Sigma = i_s \cdot R_B + U_B. \end{cases} \quad (1)$$

where U_s - voltage on the starter contacts;

i_s- current of the anchor;

R_Σ - total resistivity of the armature circuit;

L_Σ - total inductivity of the starter;

$e(\omega)$ - EMF starter;

K_e-back-EMF;

$K_м$ - constant of the electric machine;

R_{BC} - resistivity of the capacitor;

R_B - resistivity of the battery.

Running a diesel engine provides traction generator. During start-up traction generator operates on a series-wound motor.

Rotation of the crankshaft starter leads to energy losses for overcoming of the friction forces in kinematics pairs, for filling cylinders and removing of the working charge or combustion elements, for compensation of the difference between contraction and expansion. There is neediness to overcome the resistance torque of the scrolling crankshaft (M_R) for well starting. This torque can be defined as sum of three components:

$$M_R = M_f + M_{r.c.} + M_j. \quad (2)$$

where M_f - torque of resistance arising from friction forces crank mechanism;

$M_{r.c.}$ - torque required to overcome the resistivity of the compression;

M_j - resistance torque required for overcoming of the kinetic energy of all moving parts of the engine during acceleration.

Due to the fact that the consumption of energy to overcome the resistance torque of the diesel engine cranking depend on a number of factors: friction surface area, the viscosity of the engine oil, the engine speed, the loss and heat the working fluid during of the compression and expansion, which are difficult to calculate. Calculation of the torque of resistance scrolling has been performed by the formula:

- for the six-cylinder diesel engines [10]:

$$M_R = 8{,}523 \cdot V_h \left(0{,}1 + 0{,}033 \cdot \frac{n}{100}\right) \cdot \nu^{0{,}41}. \quad (3)$$

where V_h - total working volume of the engine cylinders;

n - scrolling frequency of the crankshaft;

ν - kinematics viscosity of the engine oil.

A simulation model of a two-step diesel shunting locomotive TEM-2 system in Matlab Simulink, was developed and presented on Fig.2. Modeling of the proposed system for the values of the power supplies $U_B = U_{BC} = 57V$, $C_{BC} = 62.5$ F was performed.

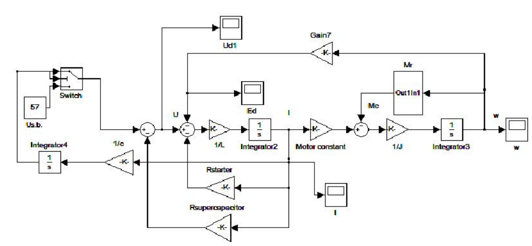

Figure 2. A simulation model of a two-steps start process of the diesel shunting locomotive TEM-2

Figure 3 shows the curve of the variation of the current with time t, which is running with start of the diesel engine. The simulation results are in good agreement with the experimental data.

Conclusion

The results of this research can be used for further development and manufacturing of the microprocessor control combined start systems of diesel locomotives engines.

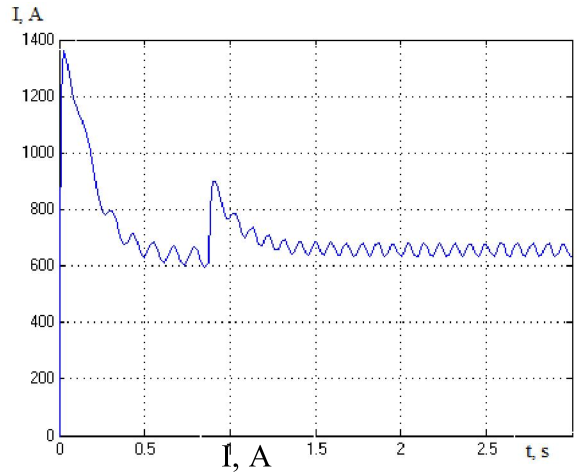

Figure 3. Variation of current with time

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