ANALYSIS OF SELF-STARTING OF OWN NEEDS OF HEAT POWER PLANTS

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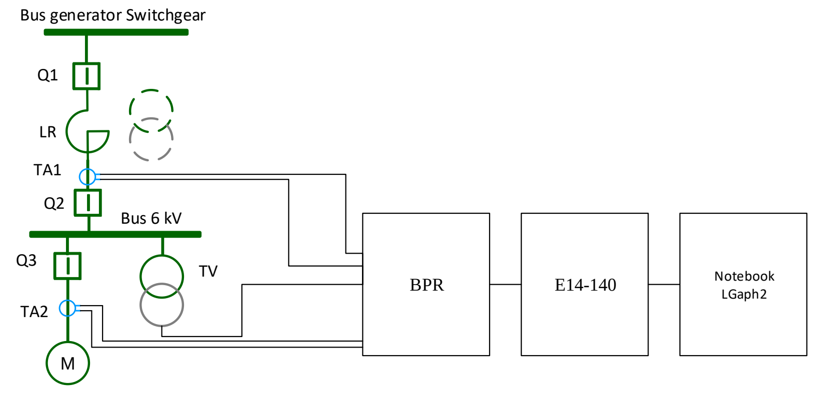
This article presents the results of the analysis of self-start of asynchronous engines of the existing power plant, it`s based on the research conducted at the Department of Power Plants and Electric Power Systems of Siberian Federal University.

Keywords— self-starting, own needs of the power plant, stability of electrical engine

I. INTRODUCTION

When starting an AC motor, the starting current can exceed the rated current by 5-8 times. The start-up process causes severe loads on the electric motor [1] – [5]. A large starting current also causes a voltage drop in the mains, which, in turn, impedes the operation of other objects, impairs the insulation of the motor, shortens its service life, etc.



LR - current-limiting reactor; TA1 - current transformer; TA2 - current transformer in an electric motor circuit; TV - voltage transformer; BPR - transducer block; E14-140 - ADC board.

Fig. 1. Connection diagram of the self-start control device.

All of the above, there is a need to verify the success of self-starting electrical engines of the own needs of thermal power plants, a result of short power interruptions [6] – [8]. A reliable and complete answer to the question whether the self-starting of electrical engines is successful or unsuccessful after a break in the supply of their own needs can only be obtained after preliminary calculations and additional experimental tests. Characteristics of large-capacity motors in their self-starting and self-starting in-group are examined. Comparisons of theoretical calculation, with measurements, taken from the current installation show the correct modeling results.

In general, the self-starting of electrical engines is a complex electromechanical process. The nature of the electromechanical transient process depends on the duration of the power interruption, engine load, engine parameters and network parameters. Each engine participating in the self-starting can go into the generator mode and develop the emf in the stator winding, which further complicates the analysis of the self-starting process.

The process of self-start can be divided into two stages:

- The first stage lasts from the moment of the disappearance of the power supply till the moment of the restoration of voltage on the power supply buses of the engines. At this stage, there is a decrease in the frequency of rotation of the electric motors [7].
- The second stage includes the acceleration of electric motors up to the nominal speed. The duration of this stage is from the moment of restoration of power supply of electrical engines, till the moment when the rotational speed comes back to the operating mode [8].

The analysis of the engine self-starting process should be accompanied by experimental confirmation of the calculations, according to [10].

II. MEASUREMENTS

Experimental verification of the conditions for the self-starting of the electrical engine of their own needs should be carried out with monitoring the current consumption of electrical engine and the voltage on the busbar section [12], [13].

Also, the method of calculating the power interruption and self-starting of electrical engine of own needs of power plants with simplified methods stipulates the need to control the operating conditions of the mechanisms of their own needs. In the case af absence of an emergency event recorders at the plant, a small number of monitored parameters and a small amount of testing, a portable, autonomous device for monitoring the parameters of self-starting can be used.

In Figure 1, the converter unit contains a 50 A shunt to extend the range of the E842/1 0–5A converter with an extended frequency range, E843EC 125 V. Structurally, the external ADC module is located in the converter unit.

III. ELECTRICAL ENGINE SELF-START ANALYSIS

A. *Analysis of the steady-state*

To calculate the steady-state mode, we need to know the voltage on the section to which the motor is connected. To determine the voltage and current in the normal mode, panel devices and a control device were used.

Voltage an the section with the correction “Fig. 2 ”: 6017 V for instruments is equal 6200 V.

On panel devices, the current of the A-113-4 electrical engine of the mains pump is 29 A. According to the oscillogram, taking into account the correction of the ADC value, the current of the normal mode of the electric motor is *"Fig. 3"*: 30,24 A.

The calculation of the steady state of electrical engine of their own needs of power plants before the interruption of the power and after self-starting allows to determine: current, active and reactive power flowing through the external network (cable line, current-limiting reactor, transformer); current, active and reactive power consumed by each ED; rotational speed (or slip) of each ED.

Depending on the purpose of the calculations, the requirements for their accuracy, it is possible to adopt various assumptions while can significantly reduce the amount of calculations.

If it is necessary to know only the value of the ED rotation speed and the voltage value on the SN buses is unknown, it is recommended to take the voltage value equal to 0.9 nominal (the lower limit of the permissible PTE [11]) and determine the value of the ED rotation speed in the steady state mode using the formula.

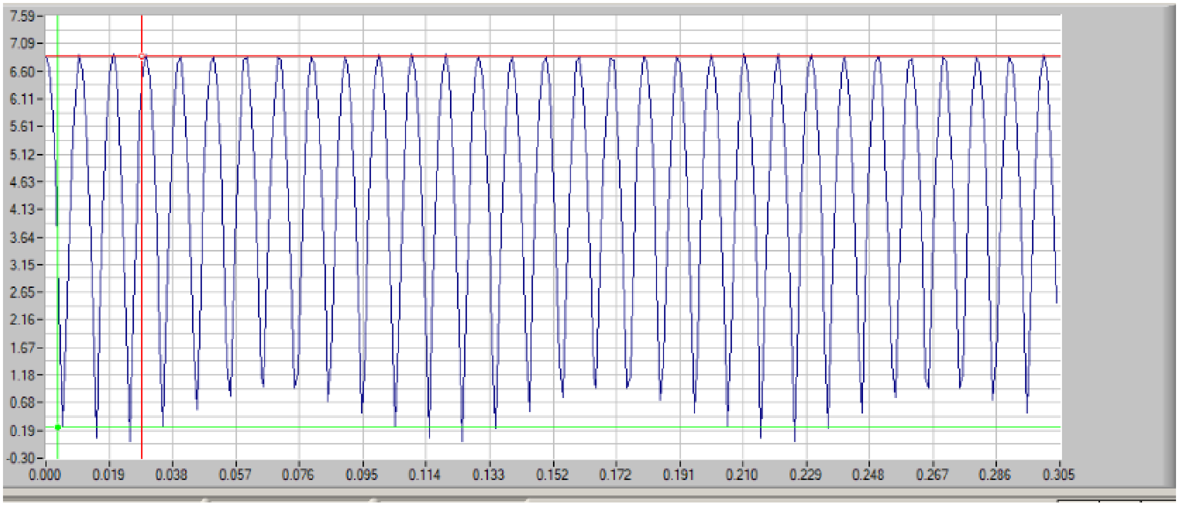


Fig. 2. Normal mode, the voltage on the section with the included electric motor.

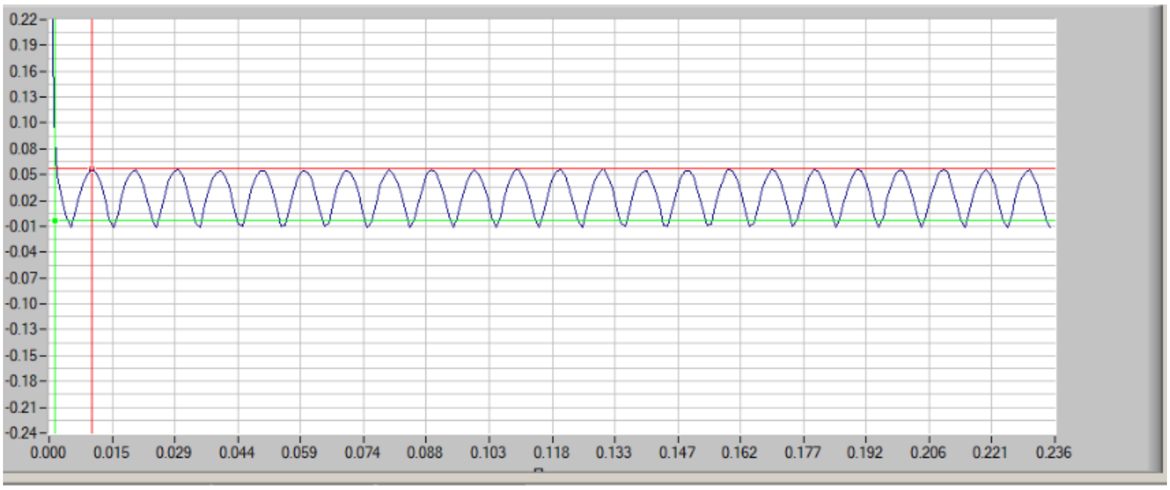


Fig. 3. Normal mode, motor current

$$n_{\text{уст}j} = 1 + \sqrt{\left(\frac{M_{maxj} K_u^2 s_{\text{кр}j}}{K_{\text{з}j}}\right)^2 - s_{\text{кр}j}^2} - \frac{M_{maxj} K_u^2 s_{\text{кр}j}}{K_{\text{з}j}} = \\ = 1 + \sqrt{\left(\frac{2{,}5 \cdot 1{,}03^2 \cdot 0{,}064}{0{,}96}\right)^2 - 0{,}064^2} - \frac{2{,}5 \cdot 1{,}03^2 \cdot 0{,}064}{0{,}96} = 0.988$$

The critical and nominal slip of the electric motor, in relative units, are determined by the following formulas:

$$s_{\text{кр}j} = s_{\text{ном}} \left(\text{M}_{maxj} + \sqrt{\text{M}_{maxj}^2 - 1}\right) = 0{,}0133 \cdot \left(2{,}5 + \sqrt{2{,}5^2 - 1}\right) = 0{,}064$$

$$s_{\text{ном}j} = 1 - \frac{n_{\text{ном}j}}{n_{\text{синх}j}} = 1 - \frac{p_j n_{\text{ном}j}}{3000} = 1{,}33$$

The relative value of the voltage on the buses of their own needs of power plants, relative units, is calculated by the formula:

$$K_u = \frac{U}{U_{\text{ном}}} = \frac{6200}{6000} = 1{,}03$$

With a known value of the voltage on the buses of their own needs of power plants, if this necessary, the following values can be calculated: currents, active and reactive power, power factor of each ED, total active and reactive power per section.

Consumed active power of the engine

$$P_{\text{д}j} = K_{\text{з}j} P_{\text{ном}j} K_u^2 \frac{10^2}{\eta} = 0{,}96 \cdot 250 \cdot 1{,}03^2 \cdot \frac{10^2}{92} = 278{,}551 \text{ кВт}$$

Reactive power of magnetization of the engine section

$$Q_{\mu j} = \sqrt{3} U_{\text{ном}} I_{\text{ном}j} \left(\sqrt{1 - \cos^2 \varphi_{\text{ном}}} - \frac{\cos \varphi_{\text{ном}} \, s_{\text{ном}j}}{s_{\text{кр}j}}\right) K_U^2 \times 10^3 = \\ = \sqrt{3} \cdot 6000 \cdot 29{,}41 \left(\sqrt{1 - 0{,}889^2} - \frac{0{,}889 \cdot 0{,}0133}{0.064}\right) \cdot 1{,}03^2 = \\ = 88{,}895 \text{ кВар}$$

Reactive power dissipation of the engine section

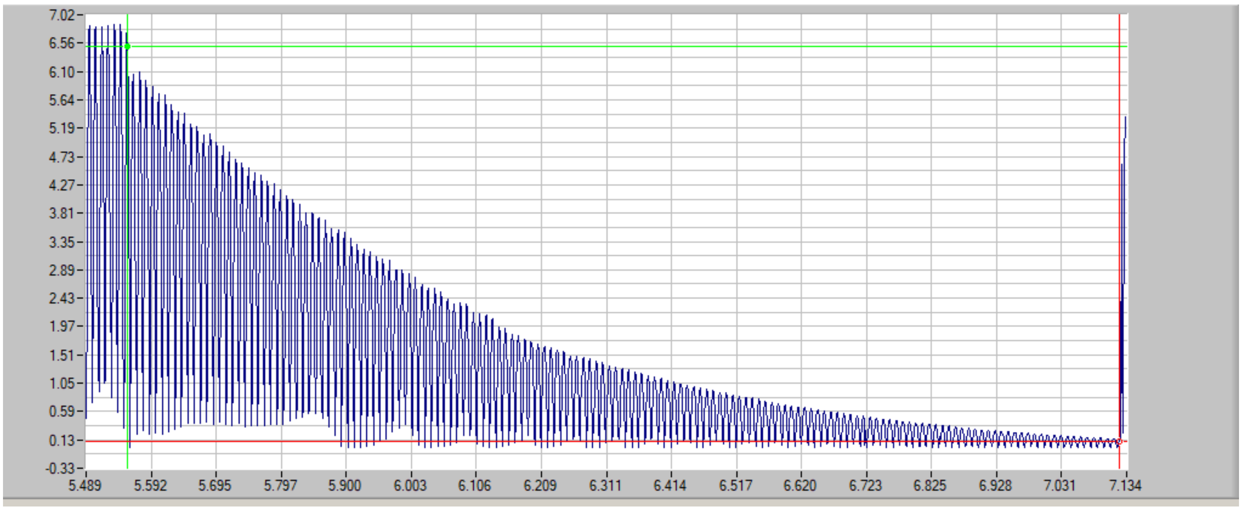


Fig. 4. Section voltage when power is off.

$$Q_{\text{р}j} = \sqrt{3}U_{\text{ном}}I_{\text{ном}j}\cos\varphi_{\text{ном}j}\frac{K_{\text{з}j}^2}{K_U^2}\frac{s_{\text{ном}j}}{s_{\text{кр}j}}10^{-3} = P_{\text{д}j}\frac{K_{\text{з}j}^2}{K_U^2}\frac{s_{\text{ном}j}}{s_{\text{кр}j}}10^{-3} =$$

$$= \sqrt{3}\cdot 6000\cdot 29{,}41\cdot 0{,}889\cdot\frac{0{,}7^2}{1{,}03^2}\cdot\frac{0{,}0133}{0{,}064} = 50{,}178\ \text{кВар}$$

Total reactive engine power per section

$$Q_{\text{д}j} = Q_{\mu j} + Q_{\text{р}j} = 88{,}57 + 26{,}37 = 139{,}073\ \text{кВар}$$

Full engine power per section

$$S_{\text{д}j} = \sqrt{P_{\text{д}j}^2 + Q_{\text{д}j}^2} = \sqrt{201{,}8^2 + 114{,}94^2} = 311{,}339\ \text{кВА}$$

Engine power factor per section

$$\cos\varphi_{\text{д}j} = \frac{P_{\text{д}j}}{S_{\text{д}j}} = \frac{201{,}8}{232{,}238} = 0{,}895$$

Stator current

$$I_{\text{д}j} = \frac{S_{\text{д}j}\cdot 10^3}{\sqrt{3}U} = \frac{232{,}238\cdot 10^3}{\sqrt{3}\cdot 6200} = 28{,}992\ \text{А}$$

IV. ANALYSIS OF SELF-STARTING ELECTRICAL ENGINES FOR OWN NEEDS

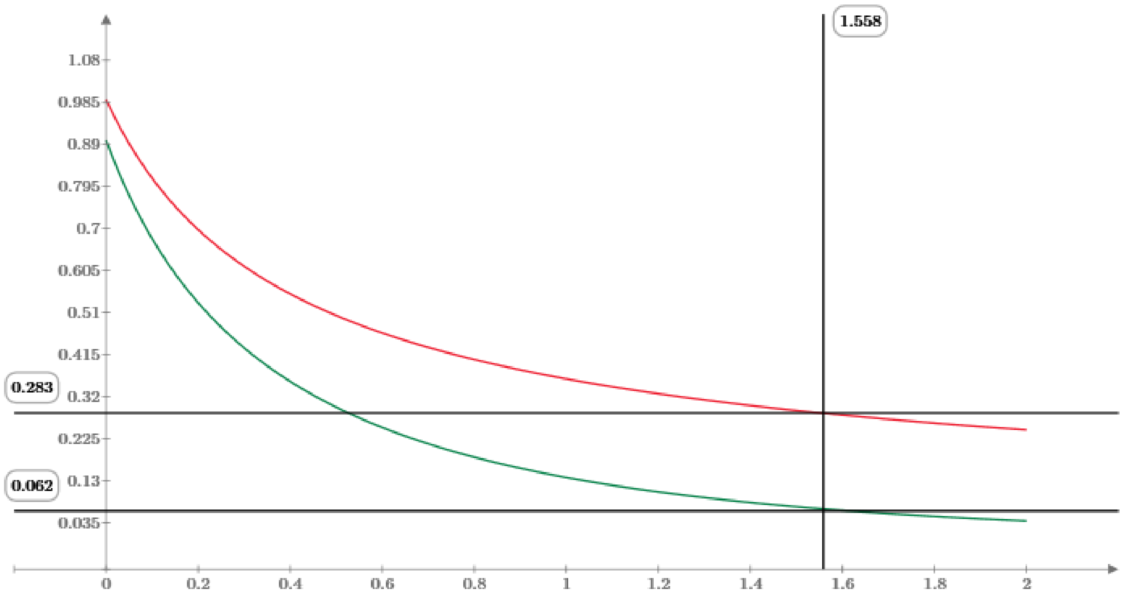


Fig. 5. Graph of speed and voltage versus time

The analysis of self-starting electrical engines for own needs can be divided into two stages: this is the calculation of the engine stoppage and the calculation of the electrical engine self-start. The calculation of the stoppage of the electrical engine is made to determine the initial conditions for the self-starting of the electrical engines. The calculation of the self-starting of electrical engines consists of determining the success or non-success of the self-starting.

A. *The analys of engine stoppage*

The duration of the power interruption by oscillograms was 1.565 sec. *“Fig. 4”*.

The voltage on the busses at the end of the run out will be 310,8 V.

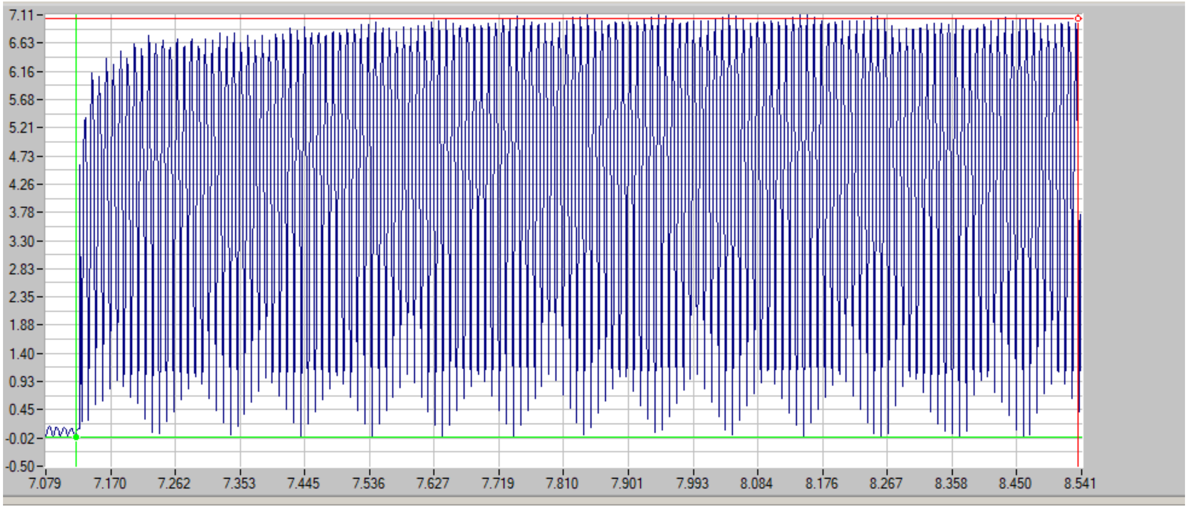


Fig. 6. Осцилограмма напряжения секции IV при самозапуске.

The calculation of the power interruption mode of a group of electrical engine when the operating power supply circuit breaker is disconnected by an analytical method is performed in the following sequence.

1. For electrical engines, the electromechanical time constant is determined.
2. Nominal power factor.
3. Rated apparent power.

$$S_{\text{н}} = \sqrt{3} I_{\text{ном}} U_{\text{ном}} = 305{,}668 \text{ кВА}.$$

4. Nominal slip.
5. Electromagnetic decay time constant for residual voltage

$$T_{\text{э}} = \frac{2M_{max}}{314 \cdot \left(M_{max}\sqrt{1 - cos\varphi_{\text{ном}}^2} - cos\varphi_{\text{ном}}\right) \cdot s_{\text{ном}}}.$$

Equivalent electromagnetic decay time of residual voltage

$$T_{\Sigma} = \frac{S_{\text{н}} T_{\text{э}}}{S_{\text{н}}}.$$

The equivalent speed and the time of group run

$$n_{\text{гр}} = 1 - \frac{\sum_{j=1}^{N} T_{Jj} P_{\text{ном}j} \left(1 - n_{ij}\right)}{\sum_{j=1}^{N} T_{Jj} P_{\text{ном}j}}.$$

The estimated value of the voltage on the buses during the time of power failure

$$E_{|0|} = \sqrt{(U_{\text{ш}} cos\varphi_c)^2 + \frac{\left(U_{\text{ш}}\sqrt{1 - cos\varphi_c{}^2} - I_c x_{\Sigma}\right)^2}{U_{\text{ном}}}} = 5444 \text{ В}.$$

Calculate the value of the residual voltage in the buses at the moment of the power appearance

$$U_{\text{гр}} = E_{|0|} n_{\text{гр}} e^{-\left(\frac{t_{\text{гр}i}}{T_{\Sigma}}\right)} = 396{,}7 \text{ В}.$$

B. *The calculation of self-starting electric motors*

Equivalent self-resistance is determined by the expression

$$x_{\text{сам}} = x_{\text{вн}} + x_{\text{экв}} = 20{,}664.$$

The residual voltage on the buses of their own needs, which are powered by electrical engines

$$U_{\text{ост}} = U_{\text{ш}} \frac{x_{\text{экв}}}{x_{\text{сам}}} = 6093 \text{ В}.$$

The voltage «fig. 6.» at the time of power recovery during self-starting, taking into account the correction of the values of the ADC 4373 V. The steady-state value is 6173.5 V.

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