SECTION 6. ELECTRIC POWER ENGINEERING, ELECTRIC ENGINEERING AND ELECTROMECHANICS

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STRUCTURAL-FUNCTIONAL MODEL OF A PROACTIVE CONTROL SYSTEM FOR A SHIP SYNCHRONOUS GENERATOR

СТРУКТУРНО-ФУНКЦІОНАЛЬНА МОДЕЛЬ СИСТЕМИ УПЕРЕДЖУЮЧОГО КЕРУВАННЯ СУДНОВИМ СИНХРОННИМ ГЕНЕРАТОРОМ

Ushkarenko O. O.
Doctor of Engineering Sciences, Professor,
Professor at the Department of Programmable Electronics, Electrotechnics and Telecommunications,
Admiral Makarov National University of Shipbuilding
Mykolaiv, Ukraine

Ушкаренко О. О.
доктор технічних наук, професор,
професор кафедри програмованої електроніки, електротехніки і телекомунікацій
Національний університет кораблебудування імені адмірала Макарова
м. Миколаїв, Україна

Direct starting of induction motors in ship electric power systems can have several negative consequences for both the motors [1, p. 1674; 2, p. 63] and other consumers. This direct starting process notably causes significant voltage dips in the ship's network [3, p. 262]. If the magnitude and duration of these voltage dips exceed the thresholds set by protection systems, it can trigger these systems and lead to the power plant [4, p. 968] shutting down, as the situation might be mistakenly identified as a short circuit.

A detailed analysis of the direct starting process of induction motors, based on simulations, was conducted in [5, p. 144]. However, the results from [5, p. 147] focus on the starting of unloaded induction motors and do not address the impact on the electric power source. In ship electric power systems with limited generated power, direct starting of the motor causes substantial voltage dips, adversely affecting other consumers connected to the network. On ships and drilling platforms, induction motors are often used in pumps, and their power frequently matches that of the generators. To reduce voltage dips during the direct starting of induction motors, special soft starter systems are employed.

To reduce the magnitude of voltage dips, a method of proactive changing the excitation voltage of ship synchronous generator ${}^{\pm}U_{\varphi 1\text{-}3}(\omega t)_{ex}$ and output energy argument of voltage ${}^{\pm}U_{\varphi 1\text{-}3}\sin(\omega t)_{out}$ of ship synchronous generator when connecting an induction drive $f_2(\text{Drive}^{\text{Power}}{}_{\omega}{}^{\pm\Delta\omega})$ to it is proposed.

The functional structure of the main drive $f_1(\text{Drive}^{\text{Power}}{}_{\omega}{}^{\pm\Delta\omega})$ corresponds to the mathematical model shown in Fig. 1.

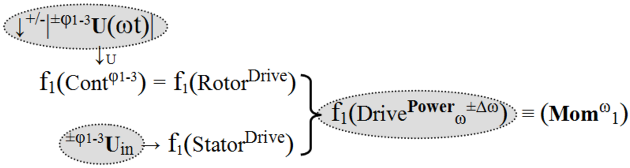

Fig. 1

On the contact system structure $f_1(\text{Cont}^{\varphi 1\text{-}3})$ of the rotor $f_1(\text{Rotor}^{\text{Drive}})$ positive and conditionally negative energy arguments of voltage $\downarrow^{+/-}|^{\pm\varphi 1\text{-}3}U(\omega t)|$ are supplied. On the functional structure of the stator $f_1(\text{Stator}^{\text{Drive}})$ the energy arguments of voltages ${}^{\pm\varphi 1\text{-}3}U_{in}$ of three phases $({}^{\pm}\varphi_{1\text{-}3})$ are supplied, as a result of which the drive activates the torque energy argument $(\text{Mom}^{\omega}{}_1)$, which, in accordance with the mathematical model shown in Fig. 2 is fed to the rotor $f_1(\text{Rotor}^{\text{Gener}})$ of the generator $f_1(\text{Gener}^{U})$ to activate the output energy voltage argument ${}^{\pm}U_{\varphi 1\text{-}3}\sin(\omega t)_{out}$ and excitation voltage ${}^{\pm}U_{\varphi 1\text{-}3}(\omega t)_{ex}$.

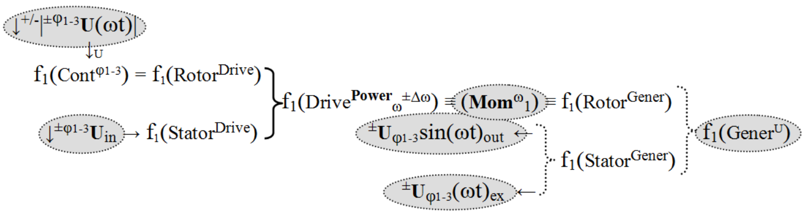

Fig. 2

It is shown in [6] that the current load of the electric power plant may be represented as one equivalent active-inductive load. In the considered model such load is represented as functional structure $f_n(L_L, R_L)$.

Using the functional structure $f_1(\text{Core}^{\text{MC}})$ of the microcontroller core, at the output port $f_1(\text{Port}^{\uparrow})$ and at the output port $f_3(\text{Port}^{\uparrow})$ there are energy arguments for the voltage ${}^{\pm\varphi 1\text{-}3}U_{in}$ of three phases $({}^{\pm}\varphi_{1\text{-}3})$ to change the speed $f_1(\text{Drive}^{\text{Power}}{}_{\omega}{}^{\pm\Delta\omega})$, and at the output port $f_2(\text{Port}^{\uparrow})$ the start signal $\downarrow({}^{1}\text{Start})$, is activated, which is supplied to the first inputs of the functional structure of the «Three phase breaker» $f_1[\&_3]$-I for connecting energy voltage arguments ${}^{\pm}U_{\varphi 1\text{-}3}\sin(\omega t)_{out}$ of the generator $f_1(\text{Gener}^{U})$ to external load $f_n(L_L, R_L)$. In this case, the structure of information arguments of voltages $[U_j]_T$ is supplied to the input port $f_2(^{\downarrow}Port)$ of the functional structure $f_1(Core^{MC})$ of the microcontroller core, which corresponds to the required period «T^{ω}» of the drive rotor revolutions $f_1(Drive^{Power}_{\omega}{}^{\pm\Delta\omega})$, and to the input port $f_1(^{\downarrow}Port)$ of the functional structure $f_1(Core^{MC})$ of the microcontroller core is represented by an information pulse sequence of voltage $[U_{out}{}^{\pm T(t)}{}_{\omega}{}^{1}]$, which corresponds to the current value «T(t)» of the rotation period of the drive rotor $f_1(Drive^{Power}_{\omega}{}^{\pm\Delta\omega})$.

The axis of the functional structure of the rotor is fixed with the axis of the laser disk $f_2(^{Laser}Disk^{\omega}{}_{Inform}{}^{T})$ with semiconductor structures of the optical radiation source $f_2(n\text{-}p^{\uparrow}{}_{h\nu})$ and the optical radiation receiver $f_2(^{\downarrow}{}_{h\nu}n\text{-}p)$ to activate information arguments $[U_{out}{}^{T(t)}{}_{\omega}{}^{2}]\uparrow$, which using the functional structure $f_1(Core^{MC})$ of the microcontroller core in accordance with the mathematical model in Fig. 3 are supplied to the input port $f_3(^{\downarrow}Port)$to adjust the voltage control arguments $^{\pm\varphi 1\text{-}3}U_{ctrl}\uparrow$.

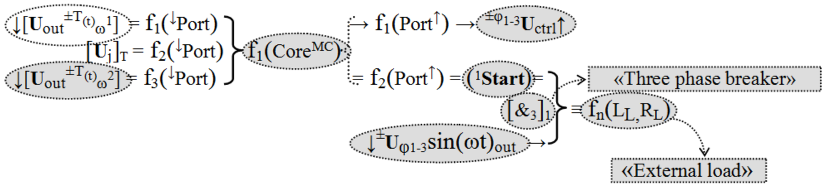

Fig. 3

In this case, the functional connections of the drive $f_1(Drive^{Power}_{\omega}{}^{\pm\Delta\omega})$, asynchronous drive $f_2(Drive^{Power}_{\omega}{}^{\pm\Delta\omega})$ and the functional structure of the generator $f_1(Gener^{U})$ are performed in accordance with the mathematical model presented in Fig. 4.

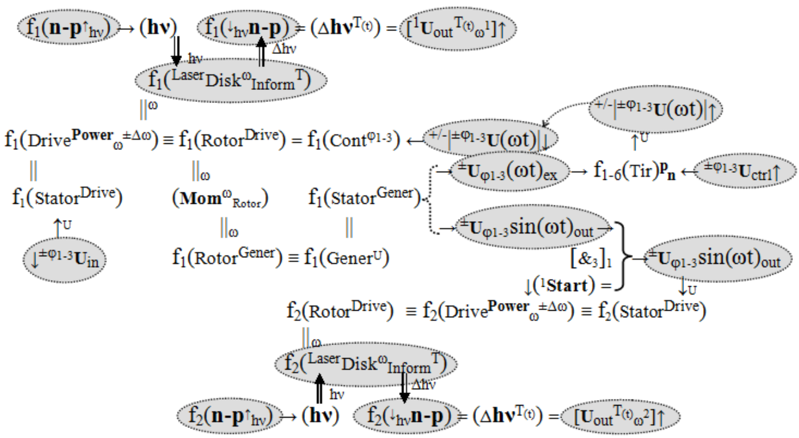

Fig. 4

It should be noted that the system also uses the functional structure of the disk of rotation $f_1(Disk^{\omega})$ with information about the rotation period «T^{ω}» of the drive rotor $f_1(Drive^{Power}{}_{\omega}{}^{\pm\Delta\omega})$ and semiconductor structures of the optical radiation source $f_1(n\text{-}p^{\uparrow}{}_{hv})$ and the optical radiation receiver $f_1({}^{\downarrow}{}_{hv}n\text{-}p)$. In this case, the rotation disk f1(Diskω) of the drive $f_1(Drive^{Power}{}_{\omega}{}^{\pm\Delta\omega})$ is made in the form of a functional structure of a laser disk $f_1({}^{Laser}Disk^{\omega}{}_{Inform}{}^{T})$ with written optical information «Inform» about the rotation period «T^{ω}», and is fixed on the functional structure of the rotor $f_1({}^{Fe}Rotor^{Drive})$ of drive $f_1(Drive^{Power}{}_{\omega}{}^{\pm\Delta\omega})$. In this model, the input arguments are formed in accordance with the analytical expression in Fig. 5.

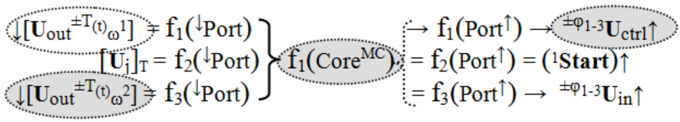

Fig. 5

As was shown, in addition to the examined methods for reducing voltage dips caused by induction motors start and localizing their sources, other control techniques can be utilized. Using the proposed method of proactive changing the excitation voltage ${}^{\pm}U_{\varphi 1\text{-}3}(\omega t)_{ex}$ and output energy argument of voltage ${}^{\pm}U_{\varphi 1\text{-}3}\sin(\omega t)_{out}$ of a ship synchronous generator $f_1(Gener^{U})$ when connecting an asynchronous drive $f_2(Drive^{Power}{}_{\omega}{}^{\pm\Delta\omega})$ to it potentially reduces voltage dips.

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