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THE MODEL OF HVDC BASED ELECTRIC POWER SUPPLY SYSTEM FOR THE OFFSHORE DRILLING PLATFORM

The paper concerns HVDC light subsea transmission system which could be used for electric power supply of the stationary marine oil-gas platforms placed in Black sea waters.

1 INTRODUCTION

The question of own oil-gas sector (OGS) development is actual in Ukraine today, because in comparison with other fuel and energy resources, which consumption and mining levels are commensurable, the factor mining/consumption for hydrocarbons – oil and natural gas, respectively amounts 0,75 and 0,35 relative units (r.u.), that specifies deficiency of their internal production [2]. Taking into account, that the deposits of hydrocarbons in north-eastern part of Ukraine are exhausted on 70 – 80%, and opening of new is unprofitable, the main loading concerning oil and gas mining should be transferred on the marine sources. At the same time, insufficient scientific and material support of the marine part of Ukrainian oil-gas sector is a ponderable factor, which limits depth of drilling works and constrains volumes of hydrocarbons extraction in Black Sea on the level equal to 1,2 billion m^3 each year – 3% from the explored reserves [2].

Marine drilling platforms (MDP) are the most effective industrial instruments of modern OGS for drilling woks realization on the continental shelf and beyond its bounds. Semiconductor electric drives of technological complexes and gas compressor stations with extended powers rising to the hundreds kW – dozen MW are the main electric consumers of MDP. The continuous character of technological processes demands from the MDP electric power systems (EPS) providing power supply of electrical consumers during the 6 – 8 thousands hour's per year considering operation life of MDP – 25…30 years. Hence, the questions of reliable and high-quality electric power supply, which determines all operation conditions and total effectiveness of MDP, remaining enough actual today. The predecessors of HVDC light – thyristor HVDC's are widely used today for industrial electric systems communication [1].

Today's HVDC light intended for transmission electric power levels equal to hundreds kW at dc voltages ±150 kV or ±300 kV [4]. Such HVDC have numerous advantages in comparison with traditional thyristor HVDC's, for example, independent (distributed) management of active and reactive power (AP and RP) [3,4].

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The object of present paper is a development of mathematical model for HVDC light transmission which is necessary for electromagnetic processes investigation in the complex “Coast EPS – HVDC light with subsea cable line – MDP EPS”.

In the general case HVDC light consists of two converter stations (CS) based on IGBT bridge converters with PWM control and dc cable line (Fig.1). Each converter can work in the mode of active rectifier (AR) or voltage source converter (VSC). For example, in the case of power supply from the coast C1 works in the mode of AR and C2 works in the VSC mode.

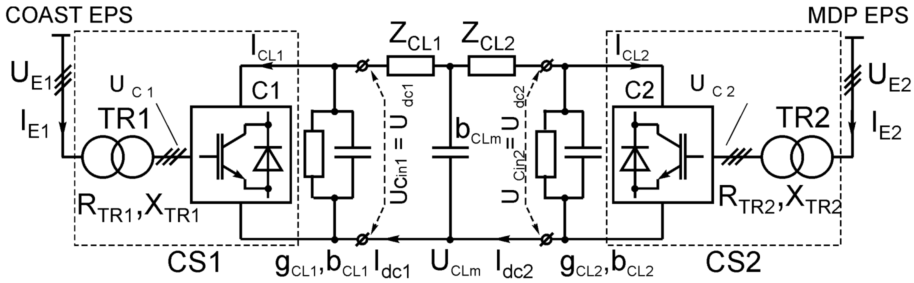

Fig.1. Equivalent circuit of HVDC light which conceder parasitic parameters of electrical equipment

In the Fig.1 were accepted next symbols: U_{E1}, U_{E2}, I_{E1}, I_{E2} – voltages and currents of the coast and MDP EPS’s; R_{TR1}, X_{TR2} – active and reactive resistances of transformers TR1, TR2; $U_{Cin1} = U_{dc1}$, $U_{Cin2} = U_{dc2}$, U_{C1}, U_{C2} – accordingly input and output voltages of converters C1, C2; Z_{CL1}, Z_{CL2} – impedances of dc cable sections; $g_{\tilde{N}L1}, g_{\tilde{N}L2}, b_{\tilde{N}L1}, b_{\tilde{N}L2}$ – active and reactive conductivity of dc cable sections; I_{CL1}, I_{CL2} – currents in dc cable sections.

The simultaneous adjustment of amplitudes and phases of CS output voltages in Fig.1 provides operative management of AP and RP in connected EPS’s in four quadrants of complex plane. Furthermore, when one CS supports specified voltage level in dc cable line, another CS maintains specified active power in the EPS’s.

During the dc cable line idling CS can be used separately as independent STATCOMS for the connected EPS’s.

The control of AP exchange between the dc link and ac side in the system (Fig.1) is realized by the way of δ_n changing with the purpose to balance dc link voltage.

The directions of RP transmission in the system (Fig.1) are determined by the ratio of fundamental harmonics U_{En} and U_{Cn} under relatively small values of δ_n.

Hence, when $U_{Cn} > U_{\hat{A}n}$ and $U_{Cn} < U_{\hat{A}n}$, converters are accordingly generating and consuming reactive power.

Approximating switching functions by their fundamental harmonics (neglecting high order harmonics) for the twelve-pulse three-level converter, we get

(1) $$\begin{cases} u_{C\ A\ n}^{max} = 4U_{dc}\cos(\beta)\sin(\omega_0 t + \theta + \alpha)/\pi \\ u_{C\ B\ n}^{max} = 4U_{dc}\cos(\beta)\sin(\omega_0 t + \theta + \alpha - 120^\circ)/\pi \\ u_{C\ C\ n}^{max} = 4U_{dc}\cos(\beta)\sin(\omega_0 t + \theta + \alpha - 240^\circ)/\pi \end{cases}$$

Bus voltage of EPS's can be expressed as

(2) $$\begin{cases} u_{ÀÂn} = \sqrt{2/3}U_{ÀÂn}\sin(\omega_0 t + \theta) \\ u_{ÂÂn} = \sqrt{2/3}U_{ÂÂn}\sin(\omega_0 t + \theta - 120^\circ) \\ u_{ÂÑn} = \sqrt{2/3}U_{ÂÑn}\sin(\omega_0 t + \theta - 240^\circ) \end{cases}$$

For the dc link of the HVDC light we can get

(3) $$dU_{dc1}/dt = -(g\omega/b_{CL})U_{dc1} - I_{dc1}(\omega_b/b_{CL}) - - I_{CL}(\omega_b/b_{CL})$$

(4) $$dU_{dc2}/dt = -(g\omega/b_{CL})U_{dc2} - I_{dc2}(\omega_b/b_{CL}) - - I_{CL2}(\omega_b/b_{CL})$$

(5) $$dU_{dcm}/dt = I_{CL1}(\omega_b/bcm) - I_{CL2}(\omega_b/b_{CLm})$$

(6) $$I_{CL1} = -\begin{bmatrix} k_{m1}\sin(\theta_1 + \alpha_1)I_{d1} + \\ + k_{m1}\sin(\theta_1 + \alpha_1)I_{q1} \end{bmatrix}$$

(7) $$I_{CL2} = -\begin{bmatrix} k_{m2}\sin(\theta_2 + \alpha_2)I_{d2} + \\ + k_{m2}\sin(\theta_2 + \alpha_2)I_{q2} \end{bmatrix}$$

where I_{d1}, I_{q1}, I_{d2}, I_{q2} – d-q components and converters transformer currents $I_{ÒR1}$, $I_{ÒR2}$; I_{CL1}, I_{CL2} – dc currents in the left and right section of cable line. Functional diagram of the control block for the HVDC converter is shown in the Fig.2.

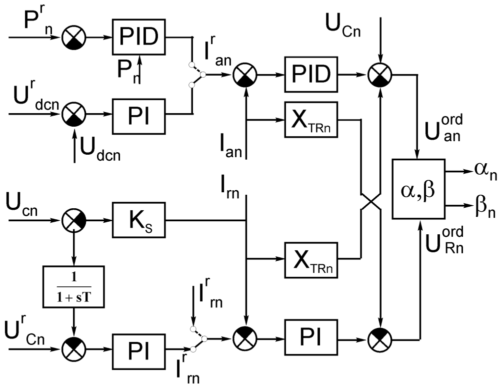

Fig.2. IGBT bridge converter control system

Reference reactive current of the n^th converter I_{rn}^{r} is supported on the permanent level or adjusted with the aim to provide the necessary value of U_{Cn}^{m}. Reference active

current I^r_{an} is coming from dc voltage or power regulator.
For the diagram (Fig.4) we can get

$$I^r_{an} = I^r_{dn}\sin\theta_n + I^r_{qn}\cos\theta_n \qquad (8)$$

$$I^r_{rn} = -I^r_{dn}\cos\theta_n + I^r_{qn}\sin\theta_n$$

2 CONCLUSIONS

The mathematical model of HVDC light was achieved in the paper. The model is necessary for the further investigation of the electromagnetic processes in the complex "Coast EPS – HVDC light – MDP EPS". The equivalent circuit of HVDC light had been developed in the paper concerning parasitic parameters of the electrical equipment. Equivalent circuit allowed to achieve mathematical equations for the AP and RP in the EPS's connected by HVDC, and also voltages and currents in DC(AC) side of HVDC. The scheme of control system for the HVDC converter stations with relevant mathematical equations have been proposed. The materials of the paper could be used for HVDC modeling at the different stages of MDP EPS's technical designing.

3 REFERENCES

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MODEL HVDC NA BAZIE UKŁADU ZASILANIA ENERGIĄ ELEKTRYCZNĄ DLA PRZYBRZEŻNYCH PLATFORM WIERTNICZYCH

Referat dotyczy systemów HVDC do zasilania morskich aparatów podwodnych, które mogą być wykorzystane jako źródła energii elektrycznej na platformach wiertniczych na morzu Czarnym.