ESTIIMATION OF INFLUENCE OF GENERATOR'S RELATIVE MOTION ON SYNCHRONOUS DYNAMIC STABILITY IN THE MULTIMACHINE ELECTRICAL POWER SYSTEM (EPS)

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ABSTRACT

The degree of generators relative motion influence on the calculation value of limit time of short circuit switching off in order to keep synchronous dynamic stability in multimachine electrical power system (EPS) has been estimated. Calculations have been carried out on the base of various programs for calculations of the synchronous dynamic stability. It was shown that the most correct calculation might be achieved at the expense of substitution of the nearest to the short circuit point power station with two equivalent generators at least.

Keywords: generators, synchronous, dynamic, calculations.

I. INTRODUCTION

The studies of various factors influences on the accuracy of electromechanical transient process calculations basically focused on the small power systems such as elementary systems consisting of generators - trunks of infinite power or two machines. Complex researches considering the preservation of synchronous dynamic stability in the real complex EPS – AzerEnergy allows to draw concrete practical conclusions for the further operative calculations as well as to estimate the real physical processes occuring in EPS in terms of quality and quantity.

The purpose of that investigation is to determine the generators relative motion influence on the limit time of short circuit switching off to preserve the synchronous dynamical stability in multimachine EPS.

Authors put a task to determine the changes of value of the limit time of switching-off short circuit switching off at the various account of relative motion of generators of the power stations electrically placed near the point of short circuit.

Calculations of dynamic stability and a choice of EPS mathematical model have been carried out on the base of below mentioned basic assumptions:

1. Transformation EMF and sliding EMF in the Park-Gorev equations were not taken into account.
2. Active resistances in the circuits of rotor and stator were not taken into account.
3. Actions of system of regulation of excitation were taken into account in a simply way.
4. Influence of saturation of magnetic circuits of synchronous machines were not taken into account.
5. Transient electromagnetic processes in circuits of rotors of asynchronous machines as well as the saturation of their magnetic circuits were not taken into account.

II. THE INITIAL DATA AND EQUIVALENT CIRCUIT

The initial data includes two groups of parameters:
1. The data required for mode calculation before emergency.
2. The data for dynamic stability calculation.

The first group consists of various information files including the graphs and parameters of a network, voltages values and node loads. The second group includes the common data for calculation of dynamic stability, parameters of an automatic regulator of excitation, an automatic regulator of rotation speed of synchronous machines with variable E.M.F., the data of generators dampfer factors, the data of dynamic and static characteristics of loads and the data of all generators according to the initial data. The initial data given concern to a mode which is accepted as the basic.

The equivalent circuit of system consists of 30 nodes, 40 branches and 9 transformers. There are 10 generators (11, 14, 19, 24, 39, 40, 52, 64, 75, 78), 6 synchronous compensators and 22 loads in the circuit. Loads values were taken on the base of winter maximum data.

III. THE DATA OF CHANGES IN THE CIRCUIT

As a trial failure two phase short circuit to the ground near the 220 kV trunks of substation (node 38) has been accepted.

At moment t_1 in one of two parallel lines of electrical transmission (LET)-220 кV (branch 38-39) near the trunks of substation (node 38) two phase short circuit to the ground was occured. At the moment t_2=var damaged LET and short circuit have been disconnected. Two - three cycles (approximately 4 seconds) of changes of generators EMF angles concerning to basic EMF (node 75) in the point of an adjunction of a power system with the United Power System (UPS) have been calculated. Taking into account the changes of relatives angles it is possible to determine the preservation of synchronous dynamic stability of the electrical power system. The same calculations allows to determine $t_2 = t_{off.\lim}$ value when stability is still kept with sufficient accuracy for operational calculations (down to 0.1 sec.).

According to the task statement at the moment $t_1 = 0.04$ sec. real and imaginary components of conductivities of the shunt in the node 38 Δy_1^1 and Δy_1^{11} are added with the values y_0^1 and y_0^{11} in order to get conformity with the value of two phase short circuit to the ground shunt conductivity in the node 38. As it is accepted that y_0^1 and y_0^{11} then $\Delta y_1^1 = y^{(1,1)1}$ and $\Delta y_1^{11} = y^{(1,1)1,1}$.

At the moment t_2=var parameters (r, x, x_c) of branches 38-39 are replaced to correspond one circuit switching-off. Besides, values $\Delta y_2^1 = -\Delta y_1^1$ and $\Delta y_2^{11} = -\Delta y_1^{11}$ should be added to the shunt conductivity in node 38 to restore former value of the shunt in this node that corresponds to disappearance of short circuit.

The value of short circuit shunt has been determined by means of the program of calculation of short circuit currents and the subroutine of shunts calculation. The results are in good compliance with the values of the shunts calculated by means of static model of the power system.

IV. RESULTS OF SWITCHING OFF LIMIT TIME ($t_{OFF.LIM}$) CALCULATION

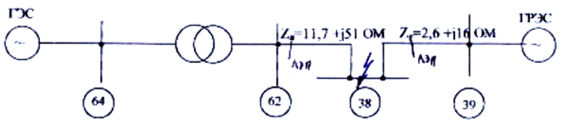
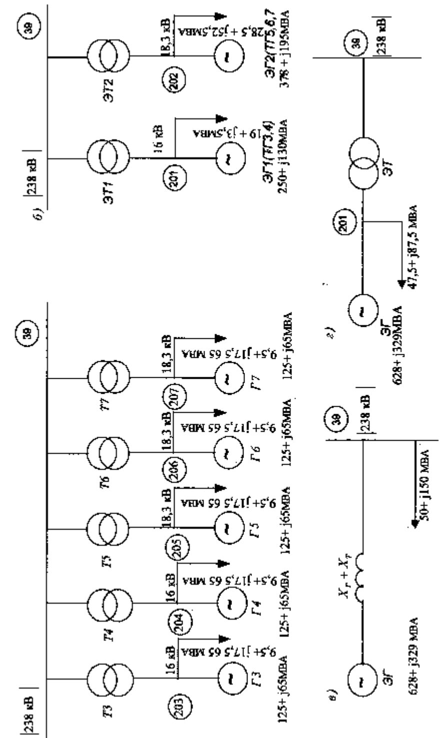


Fig. 1. Trial part of EPS

As it is known during the calculations of dynamic stability of EPS power stations are replaced by equivalent generators. Thus relative motion of generators rotors in substituted power stations is not taken into account. It has been put the task to estimate change of limit time of the short circuit switching-off in node 38 for various representation of the electrically nearest to the place of short circuit power station connected to node 39 (the part of a state district power station working on the trunks 220 kV). Further using the term "State District Power Station"(SDPS) we mean just this part of EPS.

Some calculations show that the state district power station (G 39) keeps stability, but hydroelectric power station (HPS) (G 64) placed at a long distance from the point of short circuit is out of synchronism. Therefore, the influence of various representation of a SDPS on the value of switching off limit time has been investigated. SDPS (G 39) and HPS (G 64) were replaced by one equivalent generator, two equivalent generators and all generators consequently. Trial circuit of a SDPS is shown on Fig. 2 and HPS – on Fig. 3.



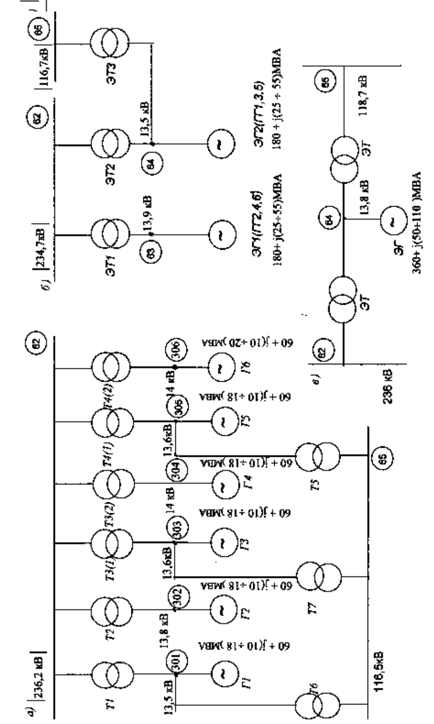


Fig.2. SDPS (G-39).

Fig.3. HPS (G-64).

Calculation results for various account of relative motion of generators on a SDPS and HPS are represented in Table 1 and on Fig. 4,5,6.

Table 1.

HPS represented by / SDPS represented by		One EG (Fig.3.a)	Two EG (Fig.3.b)	All HG (Fig.3.c)
One EG (Fig.2.a)	Var.	0	A1	A2
	$t_{off.lim}$	1.4	1.4	1.3
	For $t_{off} \succ t_{off.lim}$ Stability breakdown	HPS	HPS-EG2	HPS-HG2 and HG3 and 4
Two EG (Fig.2.b)	Var.	A3	A4	A5
	$t_{off.lim}$	1.2	1.2	1.1
	For $t_{off} \succ t_{off.lim}$ Stability breakdown	All PS	All PS except G78	HPS-HG4
All HG (Fig.2.c)	Var.	A6	A7	A8
	$t_{off.lim}$	1.2	1.2	1.1
	For $t_{off} \succ t_{off.lim}$ Stability breakdown	All PS	All PS except G 78	HPS-HG4
EG-Transformer	Var.	A9		
	$t_{off.lim}$	1.4		
	For $t_{off} \succ t_{off.lim}$ Stability breakdown	HPS		

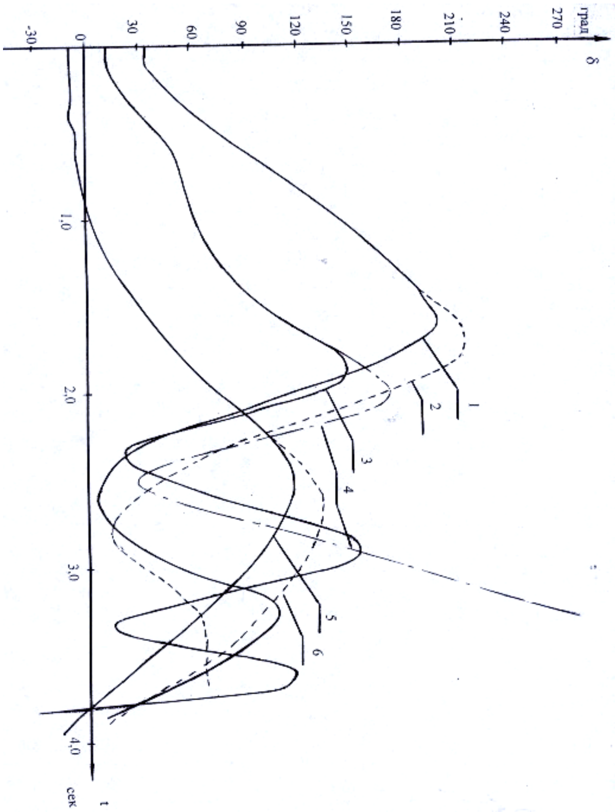


Fig.4.a.Angles of E.M.F. of G39, G64 and G75 relatively to synchronous axis (In 75 node point).Variant 0. $\delta = f(t)$

1- δ_{39} for $t_{off} = 1.4\sec$. 2- δ_{39} for $t_{off} = 1.5\sec$.

3 - δ_{64} for $t_{off} = 1.4\sec$. 4- δ_{64} for $t_{off} = 1.5\sec$.

5 - δ_{75} for $t_{off} = 1.4\sec$. 6 - δ_{75} for $t_{off} = 1.5\sec$.

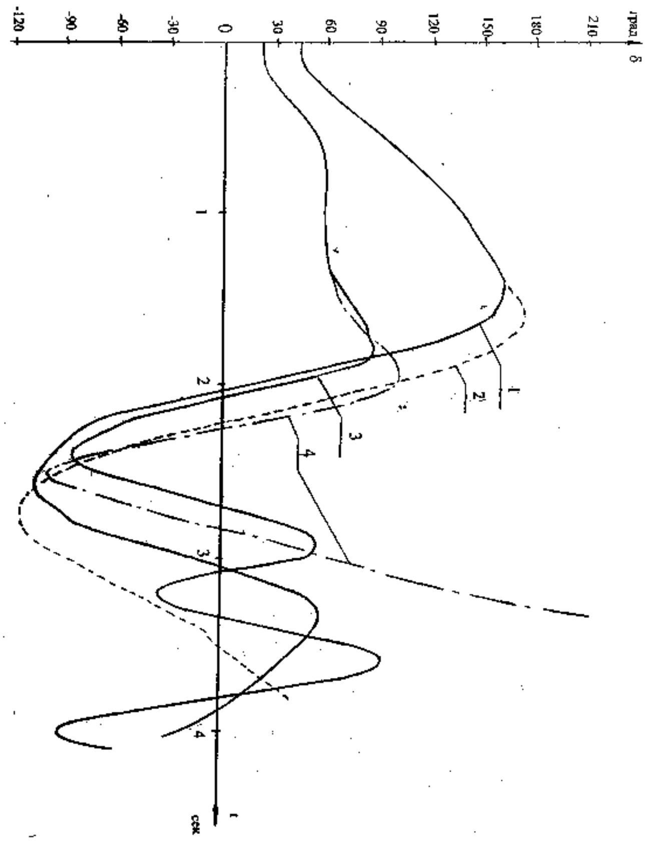


Fig.4.b. Angles of E.M.F. of G39 and G64 relatively to G 75.Variant 0. $\delta = f(t)$

1- δ_{39-75} for $t_{off} = 1.4\sec$.

2- δ_{39-75} for $t_{off} = 1.5\sec$.

3 - δ_{64-75} for $t_{off} = 1.4\sec$.

4- δ_{64-75} for $t_{off} = 1.5\sec$.

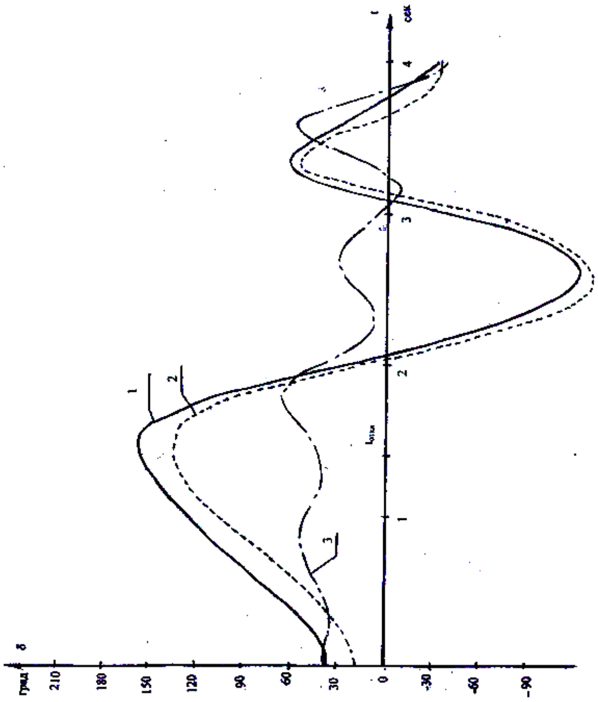


Fig. 4.c. Angles of E.M.F. of G14, G24 and G78 relatively to G75 (for $t_{off} = t_{off.\lim} = 1.4$ sec).

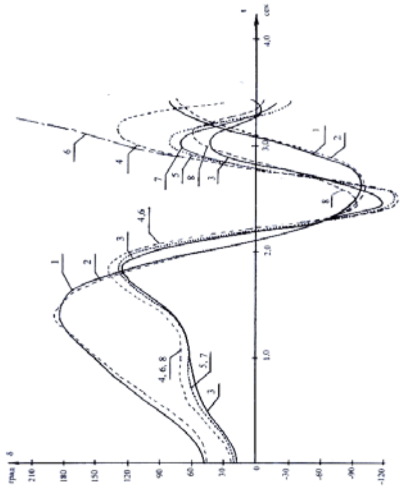
1- δ_{14-75} for $t_{off} = 1.4\,\text{sec}.$

2- δ_{24-75} for $t_{off} = 1.4\,\text{sec}.$

3- δ_{78-75} for $t_{off} = 1.4\,\text{sec}.$

Fig.5. Angles of E.M.F. of generators for t_{off} = 1.2 sec. Variant A8.

1- $\delta_{203-75}(\delta_{204-75})$ 2- $\delta_{205-75}(\delta_{206-75})$



3- δ_{301-75} 4- δ_{302-75}

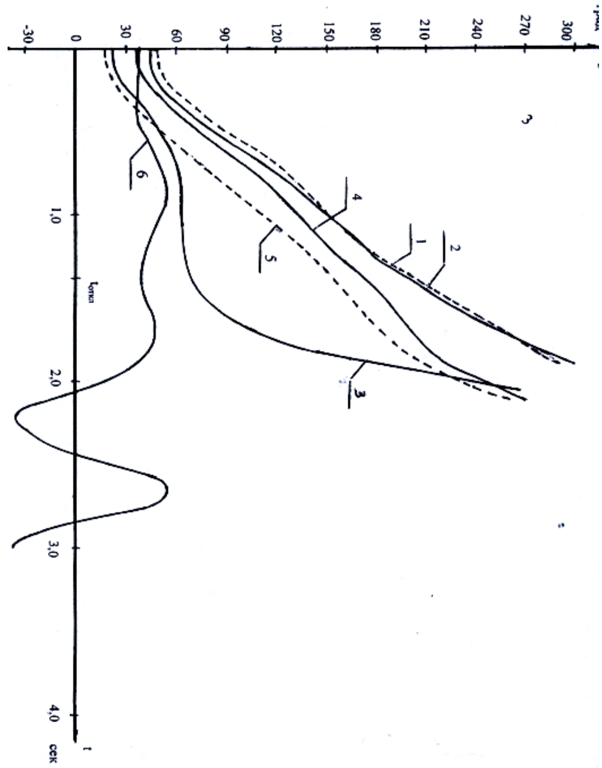
5- δ_{303-75} 6- δ_{304-75}

7- δ_{305-75} 8- δ_{306-75}

Fig.6. Angles of E.M.F. of generators for t_{off} = 1.4 sec. Variant A3.

1- δ_{201-75} 2- δ_{202-75}

3- δ_{64-75} 4- δ_{14-75}



5- δ_{24-75} 6- δ_{78-75}

The change of conditional - absolute (concerning a synchronous axis) angles of EMF of power stations G 39, G 64 and G 75 for basic variant N 0 for $t_{off} = t_{off.\lim} = 1.4$ sec. and $t_{off} = 1.5$ sec. is shown on Fig. 4.a.

Fig. 4.b illustrates the change of relative (concerning to EMF angle of G75) angles of EMF of power stations G 39 and Г 64 for the same cases. On Fig 4.c illustrates the change of relative angles of EMF of power stations G 14, G 24 and G 78 electrically placed at a long distance from the point of short circuit for a variant N 0 for $t_{off} = 1.4$ sec. Fluctuations of rotors of generators G 14 and G 24 as well as the generators G11, G19, G40 and G52 are in the same phase with the fluctuations of a rotor of generator G 39. It is connected with a close relative positions of the above mentioned power stations (for instance, G 39 and G 40 are in the same power station) and big number of communications between them. Fig. 5 illustrates the change of relative angles of EMF of generators of SDPS and HPS for variant A8 for t_{off} = 1.2 sec.

On Fig. 6 the changes of relative angles of EMF of two equivalent generators of SDPS (G 201, G 202), equivalent generators of HPS (G64) and power stations G14, Г24, Г78 for variant A3 for $t_{off} = 1.4$ sec. are shown.

The influence of substitution of group of generators by one equivalent generator on the calculation results of stability depends on closeness of parameters values of replaced generators and similarity of the circuit of their connection to a network.

On SDPS two groups of the same type generators can be distinguished. One group includes generators 3 and 4 (On Fig. 2. G 203 and G 204 accordingly). The second group consists of generators 5, 6 and 7 (G 205, G 206, G 207 accordingly). The difference in parameters of the generators from different groups, is insignificant, and the circuit of connection of all generators is identical.

There are five identical generators 1-5 (G 301, G 302, G 303, G 304 and G 305 on Fig. 3.a) and one of different type on HPS. It is accepted that generators 1, 3 and 5 work on trunks 110 кv and 220 кV and generators 2, 4 and 6 work only on trunks 220 kV. Thus, two groups of generators are conditionally formed. Thus it is necessary to take into account, that actually "transformers" T3 (1) and T3 (2), T4 (1) and T4 (2) are the split windings of a low voltage of real transformers T-3 and T-4.

So, it is possible to assume that the divergence of angles of EMF of generators of SDPS among them are insignificant, not so big inside the groups (it is especial for G 301, G 303 and G 305) for generators of HPS and more essential between groups. The results of calculation submitted on Fig.5 confirm this assumption.

The most full account of relative motion of generators of SDPS and HPS is carried out in variant A8 where the SDPS and HPS are represented by all generators. Not taking into account the relative motion of generators (the variant N 0) increases the limit time of short circuit switching off on 0.3 sec., that makes 27.2 % from real value from variant A8. Replacement of SDPS by two equivalent generators (Variant A3) essentially changes the view of electromechanical transient process (Fig. 6) in comparison with a variant N 0. In this case the value of $t_{off.\lim}$ is more than in variant A8 on 0.1 sec., i.e. on 9.1 % (Determination of $t_{off.\lim}$ was made with accuracy to 0.1 sec.).

These results are in good accordance with the generally accepted conclusion about sufficiency for the account of relative motion inside group of the same generators by their replacement with two equivalent generators. The further specification by representation of SDPS by all generators does not change the results (Var. A3 and A6, A4 and A7, A5 and A8). Replacement of HPS with two equivalent generators practically does not change the result (Var. 0 and A1, A3 and A4, A6 and A7). Representation of HPS by all generators essentially changes a view of electromechanical transient process and reduces the value of short circuit switching off time on 0.1 sec. (Var. A1 and A2, A4 and A5, A7 and A8). It is interesting to mention that in some cases (Var. 0, A1, A2, A5, A8) for $t_{off} \succ t_{off.\lim}$ SDPS located close to a place of short circuit keeps stability in relation to other generators but the HPS placed at a long distance from the point of short circuit loses stability not in the first, but in the second cycle of fluctuations (Fig. 4.b). It is possible to explain by influence of ARE of proportional action, low dampfer fluctuations of relative angles of generators on communication 39-38-62 and rather small dampfer asynchronous moments in hydrogenerators.

In [2] mentioned that for equivalency circuit design is necessary to avoid loads transfers from trunks of a generator voltage to the trunks of higher voltage of substation as such transfer renders significant influence on results of calculations of dynamic stability. To check that calculation for replacement of SDPS by the equivalent block "Generator – Transformer" has been done (Fig. 2.d).(Var. A9). Calculation has shown that the value $t_{off.\lim}$ in comparison with variant N 0 did not change.

V.CONCLUSIONS

1. The account of mutual motion of generators on the nearest to a place of short circuit power stations reduces the value of limit time on 0.3 sec or on 27.2 %.
2. For the same type of generators equally connected to a network replacement of power station by two equivalent generators gives the same value of $t_{off.\lim}$ as representation by all generators.

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