O. S. Yandulskyi, Dc. Sc. (Eng.), Prof.; O. V. Timokhin; A. O. Timokhina

CERTAIN ASPECTS OF AUTOMATIC FREQUENCY SHEDDING OPERATION

The paper considers the problem of efficiency increase of automatic frequency shedding system operation (AFS) as a result of introduction of additional functional algorithms, based on the analysis of voltage phase angles, obtained from the system of transient modes monitoring (STMM).

Key words: *automatic frequency shedding, electric power system, systems of transient modes monitoring, deficient energy system.*

Introduction

Deficit energy system is the system, where power consumption is greater than generating power, that is why, maintaining of the balance between consumption and generation is very urgent problem. The example of such system is energy system of the Crimea, if it is disconnected from unified energy system (UES) of Ukraine. As it is known, to prevent the violation of the balance between generation and consumption the facilities of emergency control automatics are provided. These facilities comprise systems of automatic frequency shedding (AFS), which play especially important role in deficit power systems. It is known that AFS systems operate in conditions of frequency decrease to minimum operating value of AFS and after their operation there appears the necessity to restore frequency in ES [1 – 3] that is why, the aim of the given research is the increase of AFS performance that will reduce negative impact of power imbalance on ES operation.

Development of the method of AFS performance improvement

The research has been carried out on 14-node test circuit IEEE shown in Fig. 1, in the software package Digsilent Power Factory.

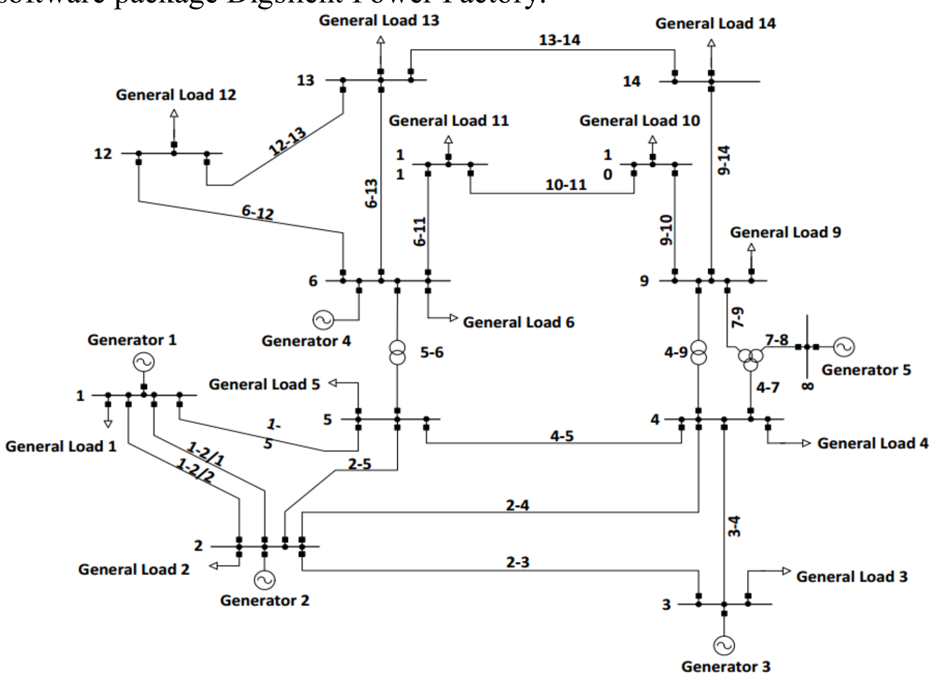


Fig. 1. Diagram of investigated electric grid

Studies were carried out for different variants of emergency situations, given in Table 1. The duration of the short-circuit (SC) for the grids of voltage rating of 110, 220 kV is 140 ms, consisting of a maximum response time of relay protection (RP) and the response time of the switch.

Table 1

Variants of emergency situations scenarios

Circuit element	Failure
Transmission Line 2-4	Single phase short – circuit of phase A with further disconnection of SC in 140 мs
	Two-phase short- circuit of phases AB with further disconnection of SC in 140 ms
Transmission Line 2-3	Three- phase short-circuit with further disconnection of SC in 140 ms
	Line disconnection
Transmission Line 4-5	Two-phase short-circuit of phases AB with further disconnection of SC in 140 ms
Transformer 4-9	Transformer disconnection
Load 1	Load Disconnection
	Load-surge
Generator Г1	Disconnection of the generator
Generator Г2	Disconnection of the generator

Research carried out (Fig. 2, 3) showed dependence between generation of disturbing impact in ES and the speed of voltage angle change in ES nodes. In case of disconnection/ load surge or generator disconnection, the frequency changes monotonically. Frequency change during 1 s is 0.012% and angle change – 20%, i. e., frequency change is slower. Thus, usage of voltage angle change for evaluation of energy system modes enables to respond faster to the failure in the grid, especially in the first 2 s after its initiation, this is the base for development of fast acting system of ECA.

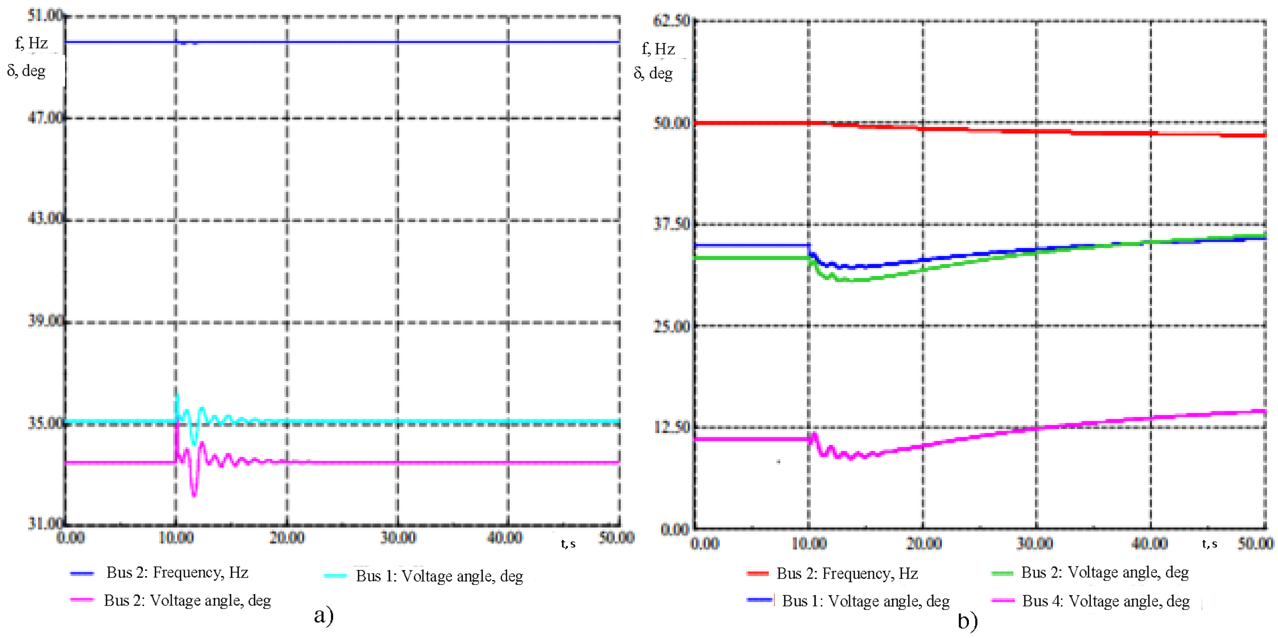


Fig. 2. Dependence of frequency and voltage angle change time at different emergency situations: a) two-phase short-circuit (phases a, b) at transmission line 2 - 4, b) load surge at General Load1

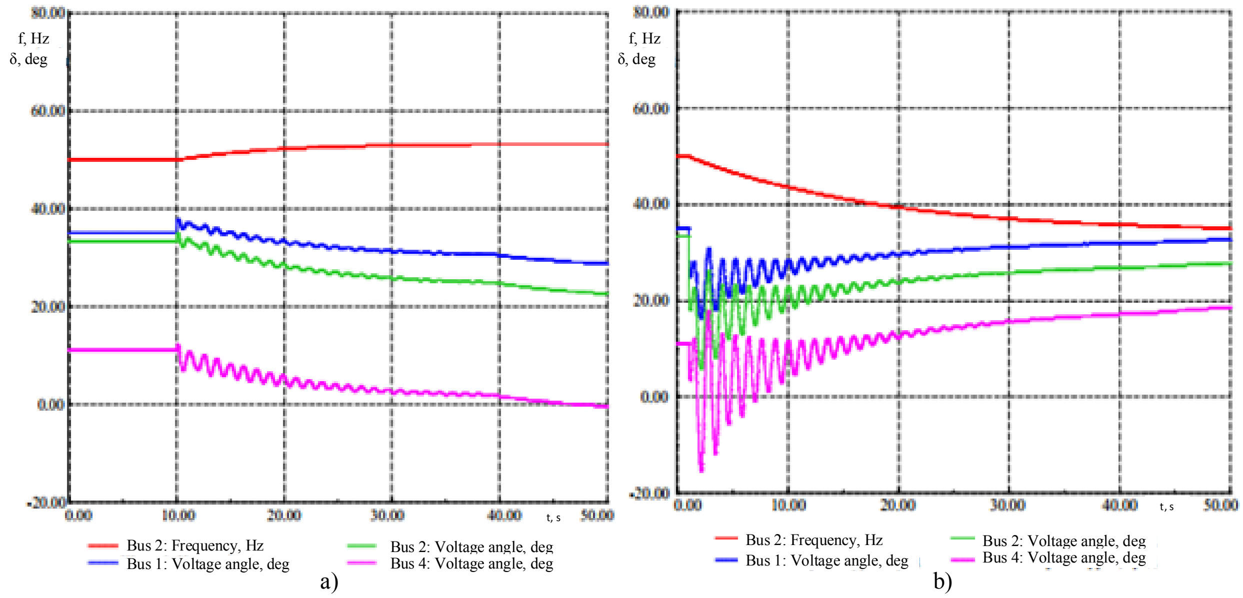


Fig. 3. Dependence of frequency and voltage angle on the time at various emergency situations:
a) load disconnection at General Load, b) disconnection of G2 generator

As the index of voltage angle change the speed of angle change was chosen. The results of the research are shown in Fig. 4. As it is seen from the dependences obtained, in case of failure, angle change speed reaches its maximum in modulus. In case of SC two peaks appear: one – at the moment of initiation, the second – at the moment of SC disconnection by relay protection devices.

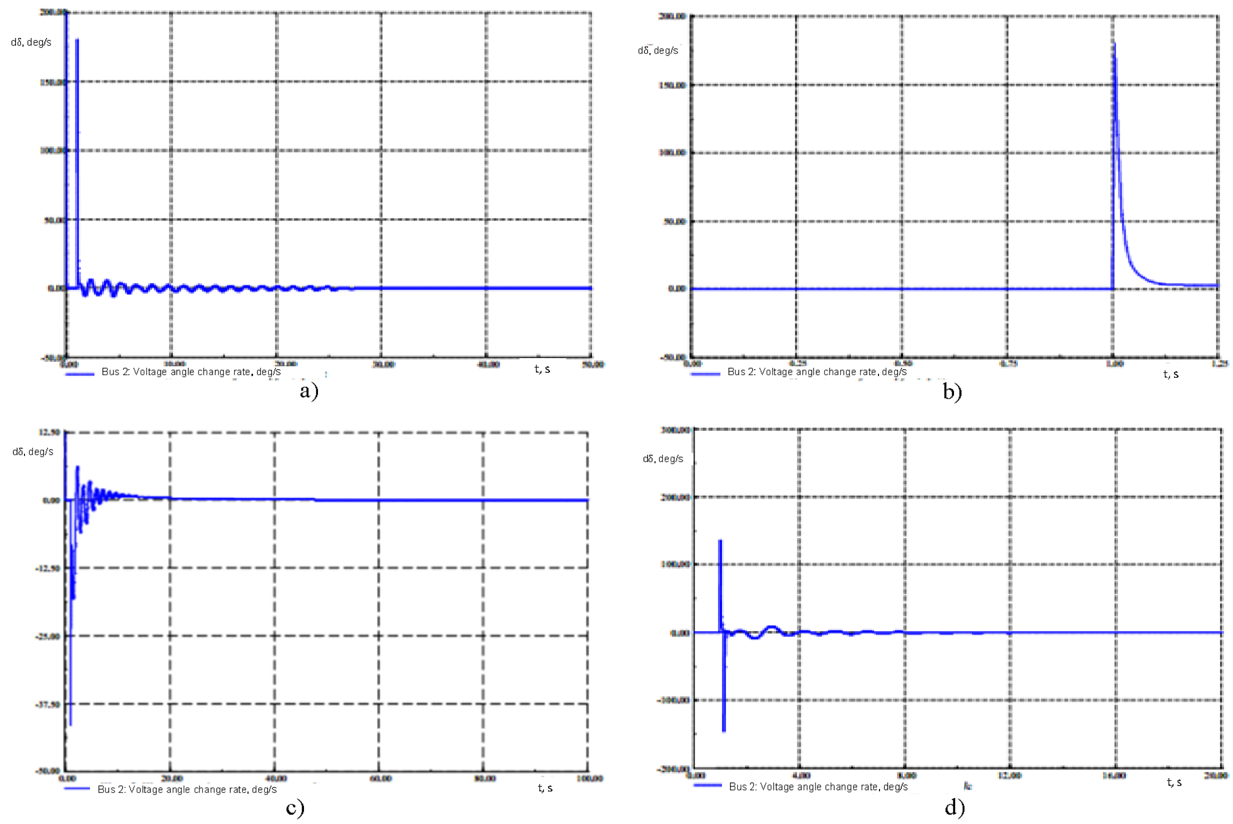
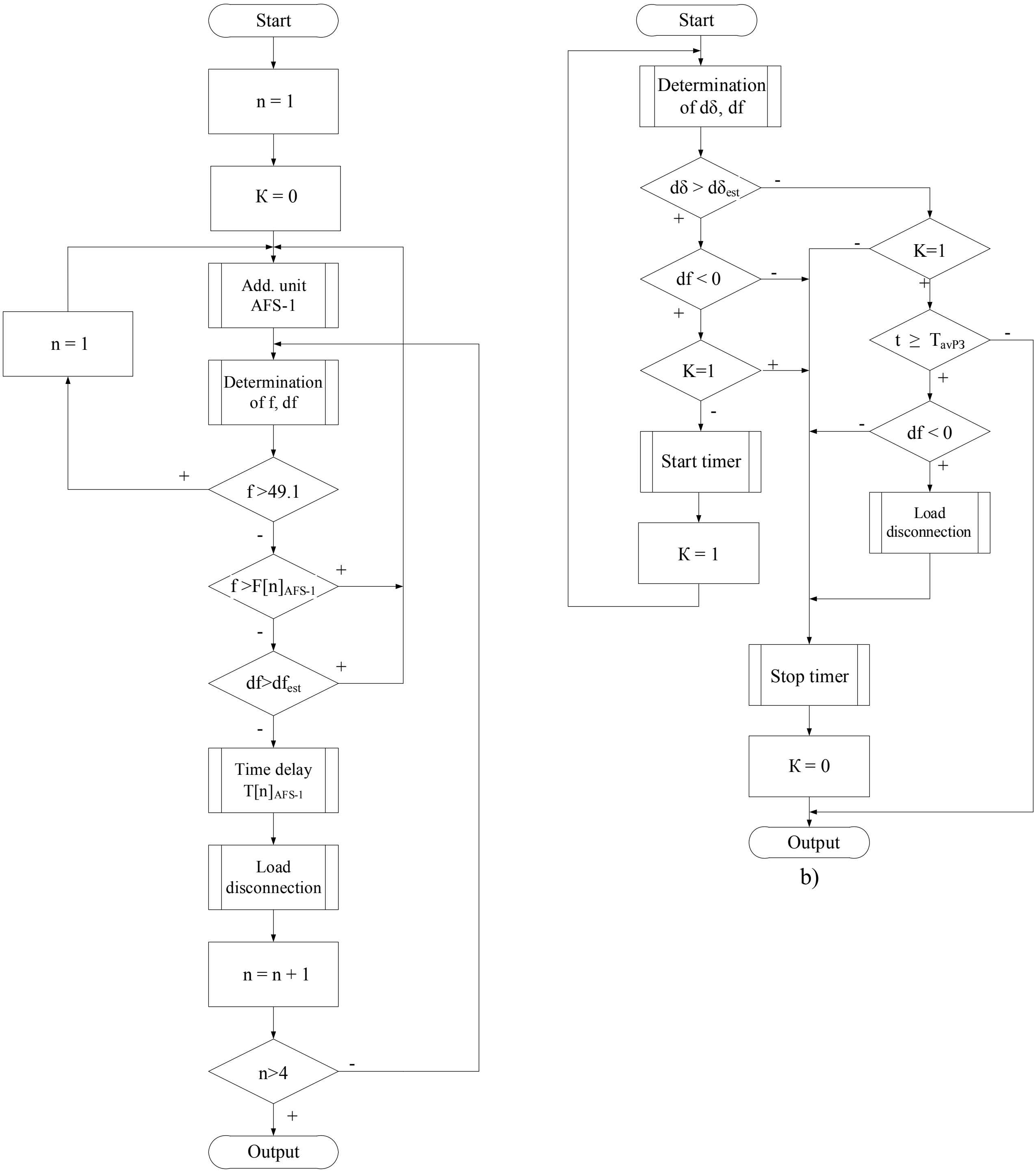


Fig. 4. Dependences of voltage angle change speed on time:
a) transmission line-2-3 disconnection at the moment of time t=1 s, b)increased part of the dependence of voltage angle change speed on the time of transmission line 2-3 disconnection at the moment t=1 s, c) load surge on the bus 3 at the moment *t*=1 s, d) two-phase short-circuit at transmission line 2-4 at the moment *t*= 1 s

The obtained dependences were used for the development of improved AFS-1 operation algorithm. The given algorithm is shown in Fig. 5. The improved AFS-1 contains additional unit, that responds to voltage angle change speed [4].



a)

Fig. 5. Block-diagram of the algorithm:
a) ACR-1 using the dependence of voltage angle change on time, b) additional unit of ACR-1 using the dependence of voltage angle change on time

On the base of improved AFS-1 operation algorithm the model of the unit was developed, the model responds to the speed of voltage angle change (Fig. 6). As the model of existing AFS the model of four-stage AFS from the library of Power Factory was used. On the investigated 14 node test circuit IEEE, additional 10 kV buses were placed for further installation of AFS devices.

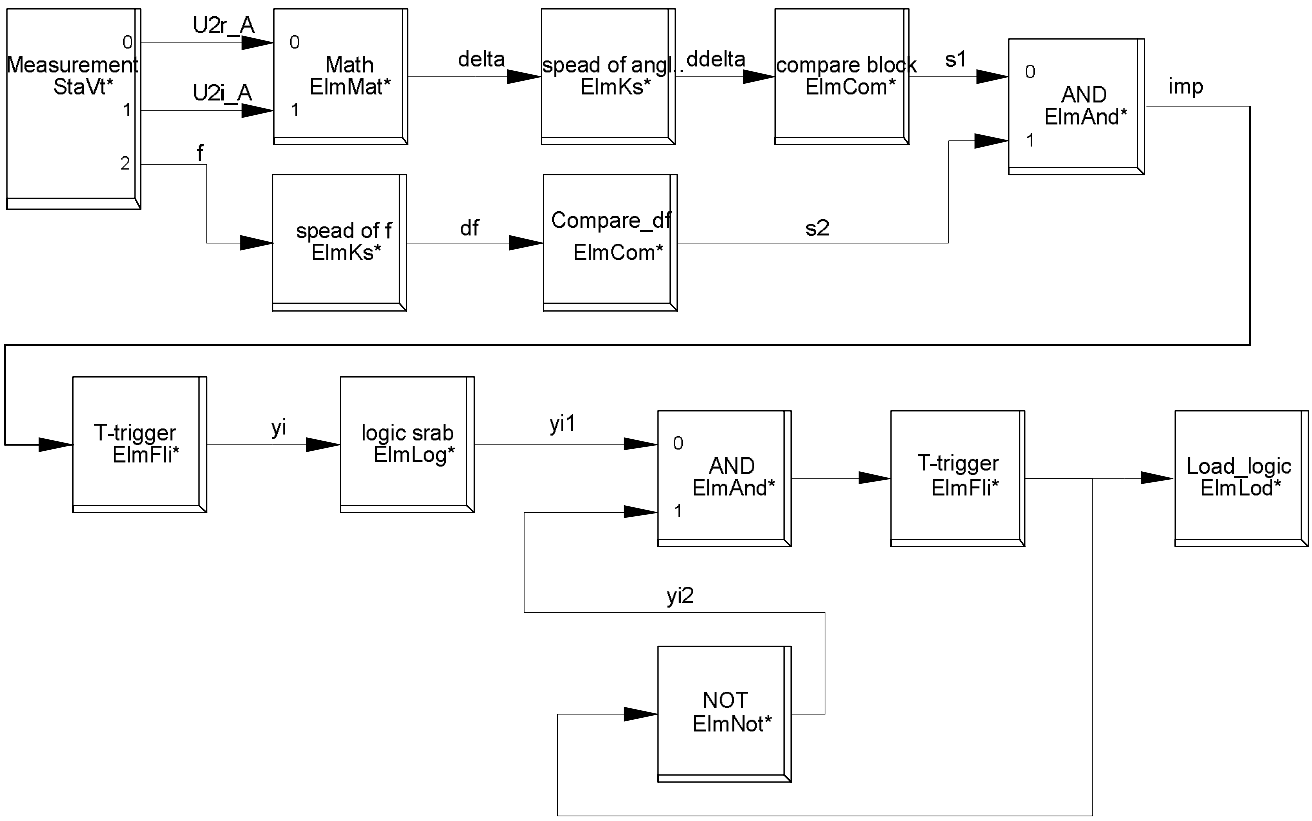


Fig. 6. Model of the unit, that responds to the speed of voltage angle change

The following units are used in the model:

1. Measurement – unit, representing VT, at the output of which values of phase A voltage (active and reactive components) and frequency values are obtained.

2. Math – computational unit. The unit calculates the value of voltage angle.

3. Speed of angle – unit for calculation of voltage angle change speed.

4. Compare block – comparison unit. If the speed of angle change is greater than the setting, then logic one is formed at the output.

5. Speed of f – unit of frequency change speed calculation.

6. Compare_df – comparison unit. If the sign of frequency change speed is negative, then at the output logic one is formed, in case of positive sign of frequency change speed logic zero is formed.

7. AND unit provides coperation of AFS-1 additional unit only in cases, that lead to frequency decrease.

8. T-trigger unit consists of master/slave T-trigger. This unit provides the registration of the appeared signal of load surge.

9. Logic srab – operation logic. This unit performs the registration of failure character verification: in case of SC logic zero will be at the output of this unit, and in case of load surge – logic one.

10. The following three units *NOT, AND, T-trigger are* used for the registration of load surge signal.

11. Load_logic – unit for switch disconnection. When logic unit arrives at the input of the given unit, then the load disconnection on the bus takes place.

The results of simulation of the improved AFS-1 operation (Table. 2, Fig. 7) showed that AFS on the base of the developed method is fast acting because it reveals failure in first milliseconds after its origination and launching the additional AFS-1 unit, as a result the speed decreases or frequency decrease stops.

The results obtained may serve as the base for further studies of AFS-1 and development of [5, 6]: adaptive system, that calculates the value of power imbalance; technique of settings selection; technique of determination of load disconnection places; investigation of energy grid operation in case of complex failures and interaction of the improved AFS-1 with the operation of other automatic devices of ES.

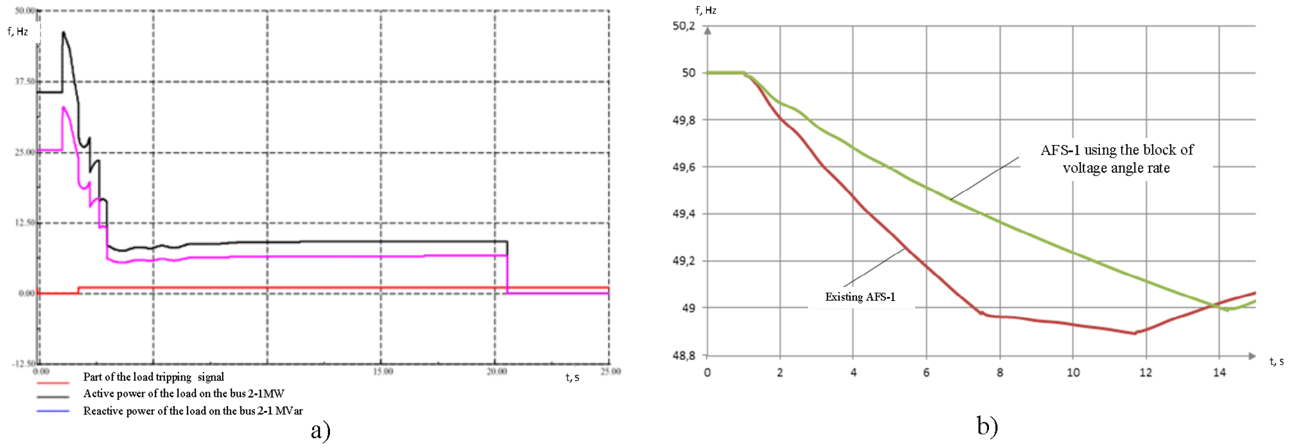


Fig. 7. a) Disconnection of the part of the load and further operation of AFS-1 when G2 is disconnected, b) Operation of the existing system AFS-1 and AFS-1, using the unit of voltage angle speed change in case of load surge on the bus 3 by the value (70.65+j5.7) MVA

Table 2

Table of frequency change

Type of failure	$f_{t=100\ s}$, Hz without AFS	$f_{t=100\ s}$, Hz with AFS	$f_{t=100\ s}$, Hz Improved AFS	Value of load surge		Time of setting response AFS, s	
				P, MW	*Q*, MVAr	Existing AFS	Improved AFS
Load surge on bus 3	46.566	49.919	49.832	42.3	2.85	11.62	0.1611
Load surge on bus 1	46.506	49.941	49.910	50	15	12.85	0.1546
Load surge on bus 3	43.446	49.934	49.734	70.65	5.7	7	0.1561
G2 generator disconnection	9.507	49.538	50	–	–	1	0.704
2-phase short-circuit on TL 2-4	f_{min}=49.828	f_{min}=49.828	f_{min}=49.828	–	–	–	–

Conclusions

1. Results of simulation showed that AFS on the base of the developed method is fast acting because of revealing the failure in the first milliseconds after its origination and launching of additional AFS-1 unit, as a result the speed decreases or frequency decrease stops.
2. The obtained results are the base for further studies of AFS-1 and development of:
- adaptive system, that calculates the value of power imbalance;
- techniques of actuation setpoints selection
- techniques of load disconnection places determination
- investigation of energy system operation in complex failures and interaction of the improved AFS-1 with the operation of other automatic devices of ES.

REFERENCES

1. Совалов С. А. Противоаварийное управление в энергосистемах / С. А. Совалов, В. А. Семенов. – М. : Энергоиздат, 1988. – 416 с.
2. Рабинович Р. С. Автоматическаячастотнаяразгрузкаэнергосистем / Рабинович Р. С. – [2-е изд.]. – М. :

Энергоатомиздат, 1989. – 352 с.
3. Голота А. Д. Автоматика в електроенергетичних системах / Голота А. Д. – К. : Вища школа, 2006. – 365 с.
4. Mohd Zin A. A. Static and Dinamic Under-freequency Load Shedding: A Comparison / A. A. Mohd Zin, H. Mohd Hafiz, W. K. Wong // International Conference on Power System Technology, POWERCON, Singapore. – 21 – 24 November 2004. – P. 941 – 945.
5. Bai D. Under frequency load shedding scheme based on information sharing Technology / D. Bai, J. He, X. Yang, B. Kirby, D. Writer, L. Liu // CIRED: 22nd International Conference on Electricity Distribution, Stockholm. – 10 – 13 June 2013. – P. 1 – 4.
6. Bevrani H. Power system load shedding: Key issues and new perspectives / H. Bevrani, A. G. Tikdari, T. Hiyama // World Academy of Science, Engineering and Technology. – 2010. – № 65. – P. 177 – 182.

Yandulskyi Olexander – Dc. Sc. (Eng.), Professor, Dean of the Department of Electric Power Engineering and Automation, e-mail: yandu_kpi@ukr.net, tel.:(044) 236-41-11.

Timokhin Olexander – Senior Lecture with the Department of Energy Systems Automation, e-mail: tymokhin@ukr.net.

Timokhina Anastasija – Post-Graduate, Assistant with the Department of Energy Systems Automation, e-mail: a.planida@ukr.net, tel.: (044) 406-86-14.

National Technical University of Ukraine «Kyiv Polytechnical Institute».