ANALELE UNIVERSITĂȚII

"EFTIMIE MURGU" REŞIȚA

ANUL XVIII, NR. 2, 2011, ISSN 1453 - 7397

Florenţiu Deliu, Gheorghe Samoilescu, Beazit Ali

The Dynamics of Naval Power System with Integrator Proportional and Derivative Integrator Proportional Regulators

The essay analyses the dynamics activity of the naval power system regulators using the integrator proportional and derivative integrator proportional regulators, system that provides the necessary energy for ship consumers so that the voltage and the frequency is always within nominal values.

Keywords: *naval power system, regulators, generator*

1. Introduction

The central problems of essay advert to regulator's tuning because the analyzed system is nonlinear and it cannot apply unknown criteria. It is analyzing the PI and PID type regulator's tuning and it finds that the known oscillations which appear on proportional integrator and derivative integrator proportional regulators can get out from operation the naval power system.

2. The dynamics of naval power system with pi type regulators

From regulator's equation [1,2]:

$$\Delta R = K_1 \Delta\omega + K_2 \int \Delta\omega dt \qquad (1)$$

By derivation, it results:

$$-\frac{dR}{dt} = -K_1 \frac{d\omega}{dt} + K_2(252 - \omega) \quad (2)$$

For constant $K_{1,}$ it is choosing the previous value from regulator -P- :

K_1=0.3797 so results:

$$-\frac{dR}{dt} = -0.3797 \frac{d\omega}{dt} + K_2(252 - \omega) \quad (3)$$

Regulator's tuning

The choice of constants K_1, K_2 of PI regulator is a complicated problem in nonlinear systems, where the methods of linear systems can't be applied. For K_1, it can choose the value of P regulator.

For constant K_2, it can choose different values.

Choosing K_2=11, are presented the result of simulations:

Introducing K_2=11 in expression (3), it results:

$$\frac{dR}{dt} = 0.3797 \frac{d\omega}{dt} - 11(252 - \omega) \quad (4)$$

$$\begin{cases} 0 = (R + 1.6)I_d + 0.07 \frac{dI_d}{dt} - \omega 0.08 I_q \\ 0 = (R + 1.6)I_q + \omega(0.07 I_d + 1.6) + 0.08 \frac{dI_q}{dt} \\ 5 \frac{d\omega}{dt} = -0.01 I_q I_d + 1.6 I_q - 0.056\omega + 28.686 \\ I_d(0) = -4.5227 \\ I_q(0) = -8.518 \\ \omega(0) = 262 \\ R(0) = 37.876 \end{cases} \quad (5)$$

The differential equations system (5) and expression (4) determine the time evolution of admeasurements U, ω, M_{GSMP}, M_{MD},I for a regulator type PI [6,7]:

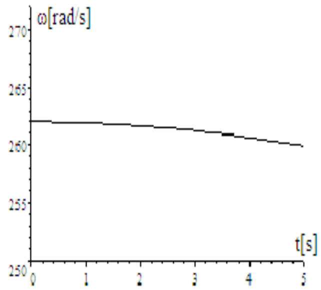

Figure 1. Time variation of ω

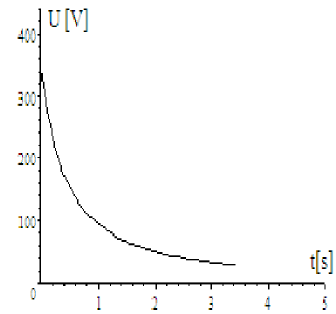

Figure 2. Time variation of U

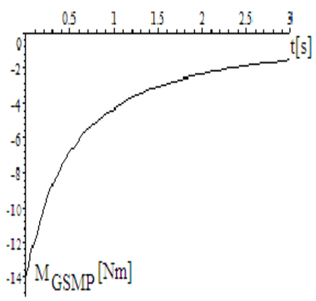

Figure 3. Time variation of couple GSMP

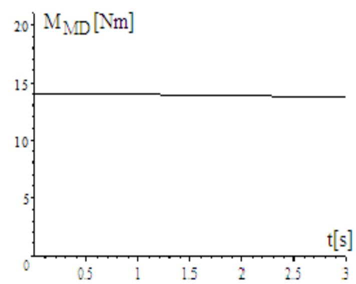

Figure 4. Time variation of couple MD

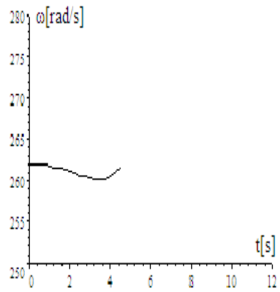

Figure 5. Time variation of ω - detail

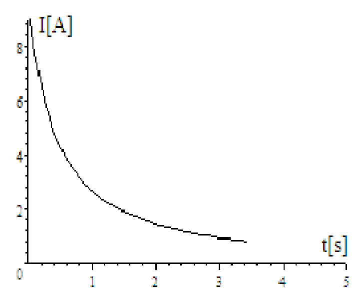

Figure 6. Time variation of current

From time evolution of main admeasurements: couple, stator tension, radian frequency ω, especially the time evolution of R designate the system is unstable, the ballast resistance declines to zero after 36[s] and probably will become negative if the estimate of time evolution will be continued. Like in other situations, the mathematical difficulties don't admit estimates for a long time, for concluding on the system's stability on different values of K_2 integration constant.

By above simulations, it observes the time variation of angular velocity ω, for t=0, ω(0)=262[rad/s] and which should be ω(∞)=252[rad/s]. In estimated time, under 32 seconds, ω does not become stabile at value ω(∞)=252[rad/s], thats why, in all the cases, those systems become unstable, although in all the cases it goes through system value. Because of that regulators type PI are not suitable for such application.

3. The dynamics of naval electroenergetics system with regulators type pid

The equation of the regulator being:

$$\Delta R = K_1 \Delta\omega + K_2 \int \Delta\omega dt + K_3 \frac{d\Delta\omega}{dt} \tag{6}$$

the derivation is:

$$-\frac{dR}{dt} = -K_1 \frac{d\omega}{dt} + K_2(252-\omega) - K_3 \frac{d^2\omega}{dt^2} \tag{7}$$

For K_1 constant the previous value from P type regulator is taken :

$K_1=0.3797$

resulting:

$$-\frac{dR}{dt} = -0.3797 \frac{d\omega}{dt} + K_2(252-\omega) - K_3 \frac{d^2\omega}{dt^2} \tag{8}$$

Note $b = \frac{d\omega}{dt}$ it results:

$$-\frac{dR}{dt} = -0.3797 \frac{d\omega}{dt} + K_2(252-\omega) - K_3 \frac{db}{dt} \tag{9}$$

Problem 1: with $b = \frac{d\omega}{dt}$, the differential equation of motion

$$J \frac{d\omega}{dt} = -0.01 I_q I_d + 1.6 I_q - 0.056\omega + 28.686 \tag{10}$$

becomes an algebraic equation:

$$Jb = -0.01 I_q I_d + 1.6 I_q - 0.056\omega + 28.686$$

and therefore the system 5 is not solvable, using numerical methods. in order to solve the problem, $b = \frac{d\omega}{dt}$ is calculated from the motion equation 10, knowing that J=5[kgm^2] it results:

$$b = \frac{d\omega}{dt} = \frac{-0.01 I_q I_d + 1.6 I_q - 0.056\omega + 28.686}{5}$$

Differentiating the above expression, it results:

$$\frac{db}{dt} = \left(-0.002 I_d \frac{dI_q}{dt} - 0.002 \frac{dI_d}{dt} I_q + 0.32 \frac{dI_q}{dt} - 0.0112 \frac{d\omega}{dt} \right) \qquad (11)$$

Introducing the expression 11 in regulator's equation, it results:

$$-\frac{dR}{dt} = -0.3797 \frac{d\omega}{dt} + K_2(252 - \omega) - K_3 \frac{db}{dt} = -0.3797 \frac{d\omega}{dt} + K_2(252 - \omega) - \\ - K_3 \left(-0.002 I_d \frac{dI_q}{dt} - 0.002 \frac{dI_d}{dt} I_q + 0.32 \frac{dI_q}{dt} - 0.0112 \frac{d\omega}{dt} \right) \qquad (12)$$

or:

$$\frac{dR}{dt} = 0.3797 \frac{d\omega}{dt} - K_2(252 - \omega) + K_3 \frac{db}{dt} = 0.3797 \frac{d\omega}{dt} - K_2(252 - \omega) + \\ + K_3 \left(-0.002 I_d \frac{dI_q}{dt} - 0.002 \frac{dI_d}{dt} I_q + 0.32 \frac{dI_q}{dt} - 0.0112 \frac{d\omega}{dt} \right) \qquad (13)$$

Implementation of PID regulator in the model

1) Knowing: K_2=-0.27, K_3=5 and the expression 13, the complete differential system with PID type regulator is:

obtained:
$$\begin{cases} 0 = (R + 1.6)I_d + 0.07\dfrac{dI_d}{dt} - \omega 0.08 I_q \\ 0 = (R + 1.6)I_q + \omega(0.07I_d + 1.6) + 0.08\dfrac{dI_q}{dt} \\ 5\dfrac{d\omega}{dt} = -0.01I_qI_d + 1.6I_q - 0.056\omega + 28.686 \\ \dfrac{dR}{dt} = 0.3797\dfrac{d\omega}{dt} + 0.27(252 - \omega) + \\ \quad + 5\left(-0.002I_d\dfrac{dI_q}{dt} - 0.002\dfrac{dI_d}{dt}I_q + 0.32\dfrac{dI_q}{dt} - 0.0112\dfrac{d\omega}{dt}\right) \\ I_d(0) = -4.5227 \\ I_q(0) = -8.518 \\ \omega(0) = 262 \\ R(0) = 37.876 \end{cases} \tag{14}$$

which can track time evolution of principal values: U, ω, M_{GSMP}, R.

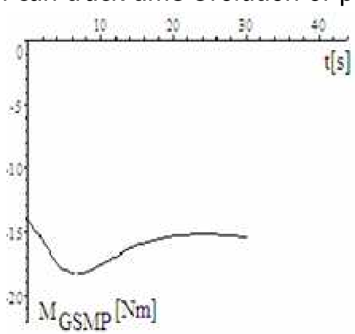

Figure 7. Time variation of GSMP torque

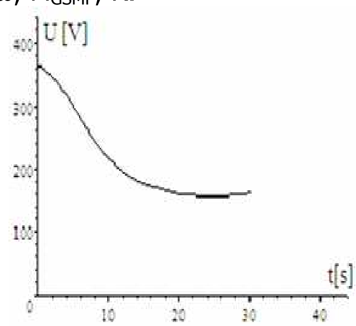

Figure 8. Time variation of voltage

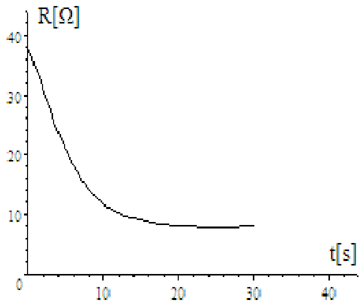

Figure 9. Time variation of R

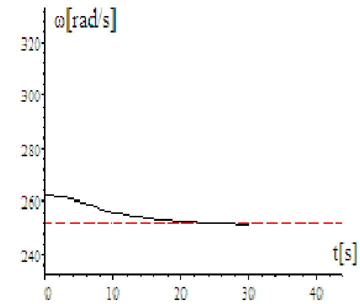

Figure 10. Time variation of ω

2) For K_2=-0.27, K_3=9, expression 13 is:

$$\frac{dR}{dt} = 0.3797\frac{d\omega}{dt} + 0.27(252-\omega) + 9\left(-0.002I_d\frac{dI_q}{dt} - 0.002\frac{dI_d}{dt}I_q + 0.32\frac{dI_q}{dt} - 0.0112\frac{d\omega}{dt}\right),$$

obtaining time evolution for the next main values:

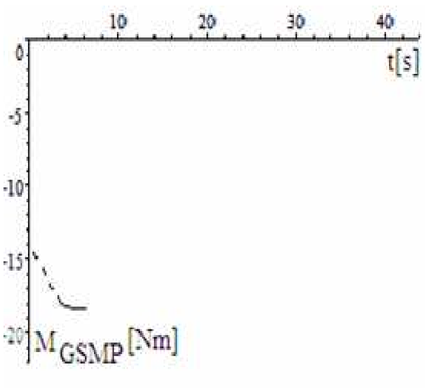

Figure 11. Time variation of GSMP torque

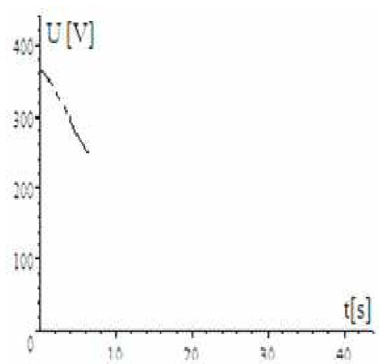

Figure 12. Time variation of voltage

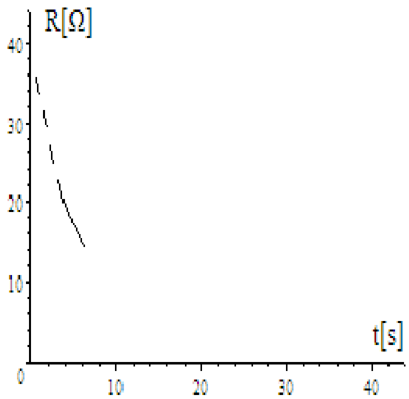

Figure 13. Time variation of R

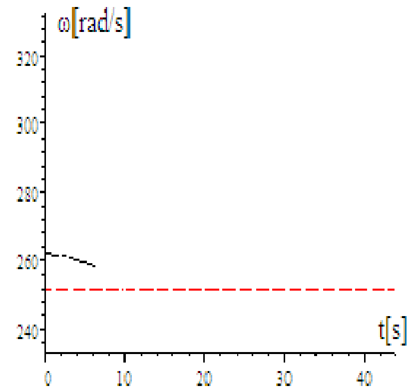

Figure 14. Time variation of ω

3) For K_2=-0.27, K_3=4.5, expression 13 is:

$$\frac{dR}{dt}=0.3797\frac{d\omega}{dt}+0.27(252-\omega)+4.5\left(-0.002I_d\frac{dI_q}{dt}-0.002\frac{dI_d}{dt}I_q+0.32\frac{dI_q}{dt}-0.0112\frac{d\omega}{dt}\right),$$

obtaining time evolution for the next main values:

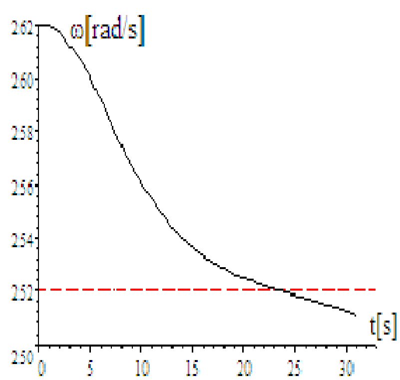

Figure 15. Time variation of ω

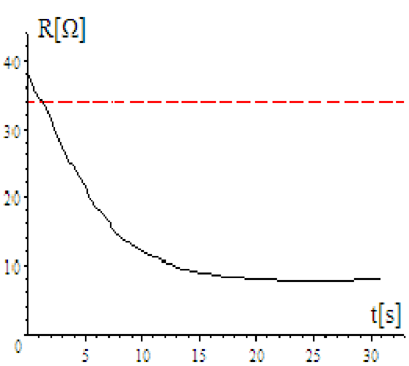

Figure 16. Time variation of R

4) For K_2=-0.27, K_3=9.5, expresion 13 is:

$$\frac{dR}{dt} = 0.3797\frac{d\omega}{dt} + 0.27(252-\omega) + 9.5\left(-0.002I_d\frac{dI_q}{dt} - 0.002\frac{dI_d}{dt}I_q + 0.32\frac{dI_q}{dt} - 0.0112\frac{d\omega}{dt}\right),$$

obtaining time evolution for the next main values:

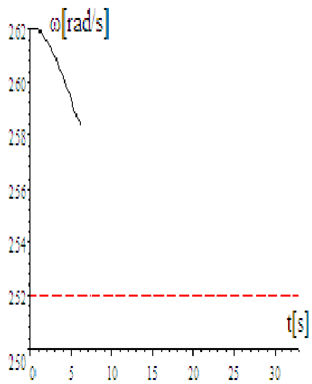

Figure 17. Time variation of ω

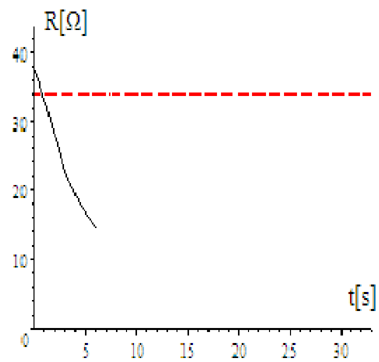

Figure 18. Time variation of R

4. Conclusion

As well as PI type regulator and PID type regulator for the four cases the system is unstable, as we can see from time variation of ω and R. Final values of ω(∞)=252[rad/s] and R(∞)=34[Ω] are obtained, but in all four cases the continuous dropping of those values, with time estimates, can not emphasize the stability of the naval power system because the limits of WorkPlace software, observation of the system can be possible only under 10 seconds, insufficient time in order to get to a stationary regime. This is due to the high values of moment of inertia J=5[kgm^2].

In conclusion, the issues of PID type regulators remains open, especially that the achievement of system management by angular speed ω estimation is probably an inefficient method.

References

[1] Ackermann, Solder L., *An overview of wind energy-status 2002*, Renew. Sustain. Energy Rev., vol. 6, no., pp. 67-128, 2002.

[2] Andreescu G.D., *Observers for speed, acceleration and load torque in motion control of electrical drives*, Proc. Automatic Control and Testing Conference A' 96 THETA 10, Cluj-Napoca, vol.1, pp. 307-312, May 1996.

[3] Babescu M., *Synchronous Electrical Machines - Modeling-Identification-Simulation*, ISBN 973-625-021-0, POLITEHNICA Timişoara, 2003.

[4] Boldea I., *Unified treatment of core losses and saturation in the othogonal axis model of electric machines*, IEEE Proceedings, Vol. 134, Pt.B., No.6, 1987.

[5] Deliu F., *Transitory phenomenons into naval electrical equipment hybrid powered*, Ph.D. Thesis, POLITEHNICA Timişoara, 2011.

Addresses:

- PhD.eng. Florenţiu DELIU, Naval Academy "Mircea cel Bătrân", Constanta, Romania, Fulgerului, nr. 1, deliuflorentiu@yahoo.com
- PhD. eng. Gheorghe SAMOILESCU, Naval Academy "Mircea cel Bătrân", Constanta, Romania, Fulgerului, nr. 1, samoilescugheorghe@yahoo.com
- PhD. eng. Beazit ALI, , Naval Academy "Mircea cel Bătrân", Constanta, Romania, Fulgerului, nr. 1, abeazit@yahoo.com