SYSTEM DYNAMICS SIMULATION MODEL OF THE MARINE STEAM TURBINE-DRIVE GENERATING SET

Marko Tomašević, Pančo Ristov, Ante Munitić
University of Split
Marittime Faculty
CROATIA

Abstract

One of the most suitable and effective way of dynamics modelling of the complex nonlinear natural, technical and organization systems is The System Dynamics Computer Simulation Modelling Methodology. The System Dynamics school of modelling does have its own set of strict rules for what constitutes proper professional procedure or methodology. Following a number of computer-laboratory researches, the system dynamics simulation models were manufactured out from 1991 to 2007, as under-graduate theses at the Maritime Faculty University of Split and the Polytechnic of Dubrovnik (former Maritime Faculty in Dubrovnik). The aims of this paper are:

1. to show the efficiency of this modelling approach,
2. to give marine students the better "point of view" or tool for the non-linear dynamics models simulation, as it would improve marine education processes, and
3. to show one example for supporting new education quality, exactly as it is in case of THE MARINE STEAM TURBINE-DRIVE GENERATING SET.

Key-Words: System Dynamics Simulation Modelling, nonlinear system, marine steam turbine, UNIREG-PID, Marine Synchronous Generating Set.

1. ABOUT SYSTEM DYNAMICS

Definition of the System Dynamics is: "System Dynamics deals with the time-dependent behaviors of managed system with the aim of describing the system and understanding, throughout qualitative (mental, verbal, structural) and quantitative (mathematical and computer simulation) models, how information feed-back governs its behavior, and designing robust information feed-back structures and control policies through simulation and optimization!"

The system dynamics mental-verbal, structural, mathematical and computer simulation models are continuous simulation models, because they are presented by the set of non-linear differential equations (level equations) and discrete simulation models as well, because they are presented by the set of linear difference equations and it solved in the discrete time period DT, which whose value is determined in total accordance with "Sampling Theorem" (Shannon and Koteljnikov and Nyquist).

2. SYSTEM DYNAMICS MODELS OF THE MARINE STEAM TURBINE-DRIVE GENERATING SET

2.1.System Dynamics Simulation Models of theMarine Steam Turbine and UNIREG-PID regulator

2.1.1.Mathematical model of the Marine Steam Turbine and UNIREG-PID regulator

The steam turbine working process is the conversion of water steam energy to mechanical energy converted to trust on the mechanical units. Therefore, turbine is subjected to various loads transmitted from the units. The steam turbine working system can be derived into two parts: regulating valve and nozzle ring steam space that can accumulate steam energy and rotational part that accumulate kinetic energy. The mathematical model or level equations could be represented as follows:

$$\frac{d\varphi}{dt}=\frac{1}{T_1}\left(K_1\psi_1+K_2\psi_2-\varphi-K_3\alpha\right) \tag{1}$$

$$\frac{d\psi_1}{dt}=\frac{1}{T_2}\left(K_0\psi_0-\psi_1+K_4\mu\right) \tag{2}$$

The first differential equation for the first part is defined according to Siromjatnikov (1983):

T_1 ....Time constant of rotating parts;

$\varphi =$ FI ....Relative increment of turbine shaft angular velocity;

$\psi_2 =$ PSI2 ......Relative pressure increment in main condenser;

$\alpha =$ ALPHA ... Relative turbine load change;

K_1, K_2, K_3...... Gain coefficients.

The second differential equation is defined:

T_2 ....Time constant of the steam space;

$\psi_1 =$ PSI1.......Relative value of the steam pressure increment in the steam space;

$\psi_0 =$ PSI0 ......Relative value of the steam pressure increment before regulating valve;

$\mu =$ MI ....Relative value of regulating valve opening change;

K_0, K_4 .... Gain coefficients.

The PID regulator incorporates in itself proportional (M1), integral (M2) and derivation (M3) regulators. The input function in the regulator is the discrepancy:

Mathematical model of the UNIREG-PID regulator is:

$$UNIREG = PREG + IREG + DREG \qquad (3)$$

$$PREG = KPP * X \qquad (3.1.)$$

$$IREG = KPI * \int X * dt \qquad (3.2.)$$

$$DREG = KPD * (dX/dt) \qquad (3..3.)$$

where there are:

UNIREG= Output of the Universal-PID regulator,
PREG= Proportional regulator,
IREG= Integral regulator,
DREG= Derivative regulator,
X= Input Function in the PID regulator,
KPP= Amplification Factor of the Proportional regulator,
KPI= Amplification Factor of the Integral regulator and
KPD= Amplification Factor of the Derivative regulator.

In this case, X= input function in the first UNIREG-PID regulator is DISC= discrepancy between FIN= nominal (goal) relative increment of turbine shaft angular velocity and φ= FI= relative changing of angular velocity, or exactly:

$$DISC = FIN - FI \qquad (4)$$

The PID regulator incorporates in itself proportional (M1), integral (M2) and derivation (M3) regulators. The input function in the regulator is the discrepancy-DISC (1).

2.1.2. Structural and Mental-Verbal Models of the Marine Steam Turbine and UNIREG-PID regulator

Fig.1. determinates the Structural Model of Steam Turbine and PID Regulator. It is determined in the accordance with System Dynamics Methodology. Mathematical model (equations 1.,, 2., 3., 4.) could be very suit for determining the mental-verbal qualitative model of the steam turbine and PID regulator.

Three self-regulating (-) dominated Feed Back Loops (FBL1, FBL2 and FBL3) are determined in the structural model (Fig. 1.) with a lot of Cause-Consequences Links (CCL).

Mental-Verbal Simulation Model of the FBL1 is : Link 1. - “If the variable dFI/dt (first derivation of FI – relative increment of turbine shaft angular velocity, or speed of FI), grow up, and the variable FI grow up also, then CCL (Cause-Consequences) Link1. has “positive” (+) dynamics character! Link 2.: “If the variable FI grow up and the variable dFI/dt will be drop, then Link 2. will have “minus” (-) dynamics character”! The FBL1 has “minus” (-) global dynamical character, because : sum of negative (-) sign in the FBL1. is odd-number. We could present them on this “short” symbolic mental-verbal qualitative system dynamics modeling version:

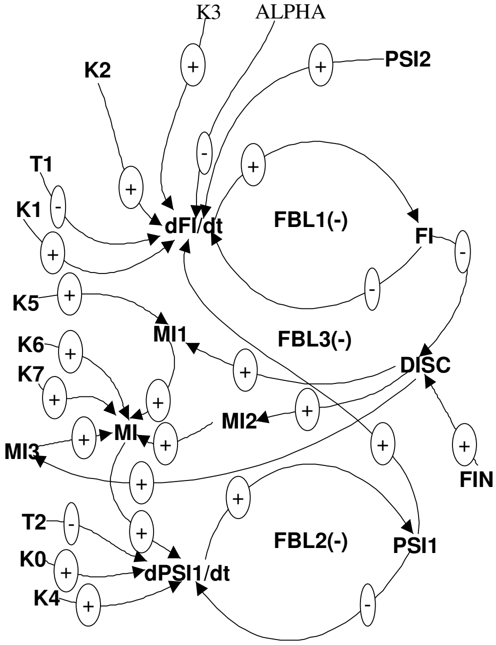

Fig. 1. System Dynamics Structural Model of the Marine Steam Turbine and UNIREG-PID regulator

FBL1(-): dFI/dt(+)=>FI(-)=>dFI/dt
FBL2(-): dPSI1/dt(+)=>PSI1(-)=dPSI1/dt
FBL3(-): FI(-)=> DISC(+)=> MI(+)=> dPSI1/dt(+) => PSI1(+) => dFI/dt(+)=>FI

2.1.3. System Dynamics Flow Diagram and Computer Simulation Models of Steam Turbine and UNIREG-PID regulator

In accordance with the System Dynamics (Forrester 1968) quantitative (mathematical) and qualitative (structural) models and POWERSIM-simulation symbols and its program package, it would be possible to work out the System Dynamics Structural Flow Diagram (Fig. 2.) and Computer Simulation Models of Steam Turbine and UNIREG-PID regulator.

System Dynamics Simulation Computer Model of the Steam Turbine in the PowerSim program package:

init FI = 0
flow FI = +dt*dFIdt
init PSI1 = 0

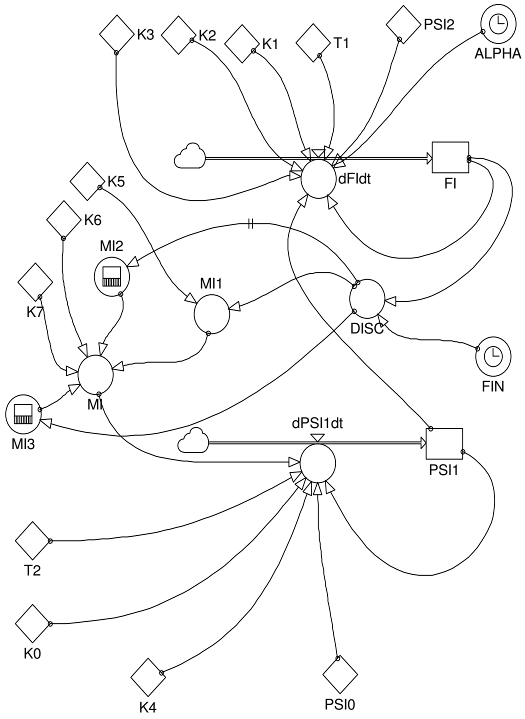

Fig. 2. System Dynamics Structural Flow Diagram of the Steam Turbine and PID Regulator in the PowerSim Symbols

flow PSI1 = +dt*dPSI1dt
aux dFIdt(1/T1)*(K1*PSI1+K2*PSI2-FI-K3* ALPHA)
aux dPSI1dt = (1/T2)*(K0*PSI0-SI1+K4*MI)
aux ALPHA = STEP(.05,60)+STEP(.45,100) + TEP (.5,140)
aux DISC = FIN-FI
aux FIN = .05+STEP(.45,20)+STEP(.5,40)
aux MI = MI1+K6*MI2+K7*MI3
aux MI1 = K5*DISC
aux MI2 = INTEGRATE(DISC)
aux MI3 = DERIVN(DISC,1)
const K0 = 1
const K1 = 1
const K2 = 1
const K3 = 1
const K4 = 1
const K5 = 13
const K6 = .3
const K7 = 10
const PSI0 = 0
const PSI2 = 0
const T1 = 20
const T2 = 1

About simulation scenario:

The mixed scenario has been implemented in the computer simulation models of the steam turbine and PID regulator:

- steam turbine with PID regulator starts in TIME = 0 and FIN = .05; TIME = 20 and FIN = .05+.45 = ..5; and TIME = 40 and FIN = .05+.45+.5 = 1.0 (100%).
- relative turbine load change ALPHA starts in TIME = 60 and ALPHA = .05; TIME = 100 and ALPHA = .05+.45 = .50; and TIME = 140 and ALPHA = .05+.45+.50= 1.0 (100%)

As the response dynamics behavior to this mixed scenario, after the modeler had finished process of “heuristics optimization” (K5=13, K6=.3 and K7=10) are next set of time curves (Fig. 3.).

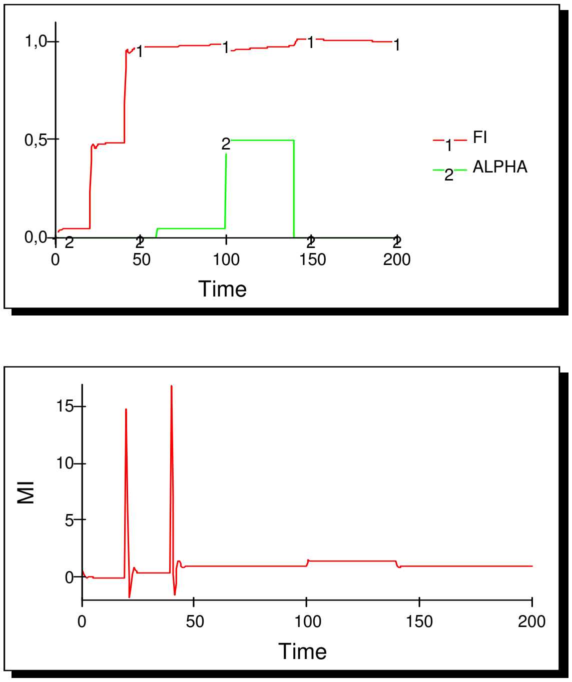

Fig.3. Graphics Results of Simulation and Heuristics Optimization

2.2. System Dynamics Simulation Models of the Marine Synchronous Generating Set and UNIREG-PID regulator

2.2.1. Mathematical model of the Marine Synchronous Generating Set and UNIREG-PID regulator

$$\frac{d\psi_d}{dt} = -\frac{r_S}{x_S}\psi_d + \psi_q\omega + \frac{r_S}{x_S}\psi_{ad} + u_d \qquad (5)$$

$$\frac{d\psi_q}{dt} = -\psi_d \omega - \frac{r_S}{x_S}\psi_q + \frac{r_S}{x_S}\psi_{aq} + u_q \tag{6}$$

$$\frac{d\psi_f}{dt} = -\frac{r_f}{x_f}\psi_f + \frac{r_f}{x_f}\psi_{ad} + u_f \tag{7}$$

$$\frac{d\psi_{1d}}{dt} = -\frac{r_{1d}}{x_{1d}}\psi_{1d} + \frac{r_{1d}}{x_{1d}}\psi_{ad} \tag{8}$$

$$\frac{d\psi_{1q}}{dt} = -\frac{r_{1q}}{x_{1q}}\psi_{1q} + \frac{r_{1q}}{x_{1q}}\psi_{aq} \tag{9}$$

$$\Psi_{ad} = X_1\left(\frac{1}{x_S}\Psi_d + \frac{1}{x_f}\Psi_f + \frac{1}{x_{1d}}\Psi_{1d}\right) \tag{10}$$

$$\Psi_{aq} = X_2\left(\frac{1}{x_s}\Psi_q + \frac{1}{x_{1q}}\Psi_{1q}\right) \tag{11}$$

$$u_d = r_L i_d + x_L\frac{di_d}{dt} - x_L i_q \omega \tag{12}$$

$$u_q = r_L i_q + x_L\frac{di_q}{dt} - x_L i_d \omega \tag{13}$$

$$u = \sqrt{u_d^2 + u_q^2} \tag{14}$$

$$\mathrm{M}_e = \frac{1}{x_s}\left(\psi_d \psi_{\alpha q} - \psi_q \psi_{\alpha d}\right) \tag{15}$$

$$X_1 = \frac{1}{\frac{1}{x_{ad}} + \frac{1}{x_s} + \frac{1}{x_f} + \frac{1}{x_{1d}}} \tag{16}$$

$$X_2 = \frac{1}{\frac{1}{x_{aq}} + \frac{1}{x_s} + \frac{1}{x_{1q}}} \tag{17}$$

$$i_d = -\frac{1}{x_s}\left(\Psi_d - \Psi_{ad}\right) \tag{18}$$

$$i_q = -\frac{1}{x_s}\left(\Psi_q - \Psi_{aq}\right) \tag{19}$$

$$i = \sqrt{i_d^2 + i_q^2} \tag{20}$$

$$i_f = \frac{1}{x_f}\left(\Psi_f - \Psi_{ad}\right) \tag{21}$$

Where there are:

ψ_d=PSID= stator flux linkage in the d-axis, r_S= stator resistance, x_S= stator reactance, ψs_q= PSIQ= stator flux linkage in the q-axis, ω= OME= diesel-engine angular velocity (angular frequency), Ψ_{ad}= PSAD= stator mutual flux linkage in the d-axis, u_d= stator voltage in the d-axis, Ψ_{aq}= PSAQ= stator mutual flux linkage in the q-axis, u_q= stator voltage in the q-axis, u= summary stator voltage, ψ_f= PSIF= rotor exciting flux linkage, r_f = rotor exiting resistance, u_f = rotor exciting voltage, Ψ_{1d}= PS1D= damping coil flux linkage in the d-axis, r_{1d}= damping coil resistance in the d-axis, x_{1d}= damping coil reactance in the d-axis, Ψ_{1q}= PS1Q= damping coil flux linkage in the q-axis, r_{1q}= damping coil resistance in the q-axis, x_{1q}= damping coil reactance in the q-axis, r_L= load resistance, x_L= load reactance, M_e= MEL= generator electromagnetic moment, i_d= stator current in the d-axis, i_q= stator current in the q-axis, i_f= rotor exciting current and i = summary stator current.

2.2.2. System Dynamics Structural Model of the Marine Synchronous Generating Set and UNIREG-PID regulator

In the analogues way ("If it is .....then will be.....”-logical methodology), it would be possible to work out the mental-verbal submodel of Synchronous Generating Set (Figure 4. and equations from 5. to 21.):

4.*FBL4.(-):* DPSIDDT(+)=>PSID(-)=>DPSIDDT;
5.*FBL5.(-):* DPSIQDT(+)=>PSIQ(-)=>DPSIQDT;
6.*FBL6.(-):* DPSIFDT(+)=>PSIF(-)=>DPSIFDT;
7.*FBL7.(-):* DPS1DDT(+)=>PS1D(-)=>DPS1DDT;
8.*FBL8.(-):* DPS1QDT(+)=>PS1Q(-)=>DPS1QDT;
9.*FBL9.(-):* U(-)=>DISK2(+)=>UF(+)=>DPSIFDT (+)> PSIF(+) => PSAD(+)=>ID(+)=>UQ (+)=>U;
10.*FBL10.(-):* U(-)=>DISK2(+)=>UF(+)=>DPSIFDT
11.*FBL11.(-):* MEL(+)=>ALFAD(-)=>D2FIDT2 (+) = DFIDT (+) =>FI(+)=>OME(+)=> DPSIDDT(+)=>PSID(+)=>MEL;
12.*FBL12.(-):* MEL(+)=>ALFAD(-)=>D2FIDT2(+) => DFIDT(+) => FI(+)=>OME(-)=>DPSIQDT(+)=>PSIQ(-) =>MEL;
13.*FBL13.(-):*MEL(+)=>ALFAD(+)=>DALFADT(-)=> D2FIDT2 (+) =>DFIDT(+)=>FI(+)=>OME(-)=> DPSIQDT(+) =>PSIQ(-)=>MEL;
14.*FBL14.(-):* IQ(+)=>UQ(+)=>DPSIQDT(+)=>PSIQ(-) => IQ;
15.*FBL15.(-):* IQ(-)=>UD(+)=>DPSIDDT(+)=>PSID(-) =>DPSIQDT(+)=>PSIQ(-)=>IQ;
16.*FBL16.(-):* ID(+)=>UD(+)=>DPSIDDT(+)=>PSID(-)=>ID;
17.*FBL17.(-):* ID(+)=>UQ(+)=>DPSIQDT(+)=> PSIQ(+) => DPSIDDT(+)=>PSID(-)=>ID;
18.*FBL18.(+):* PSAQ(+)=>DPS1Q(+)=>PS1Q(+)=>PSAQ;
19.*FBL19.(+):* PSAD(+)=>DPS1D(+)=>PS1D(+)=>PSAD;
20.-"If CFU= *nominal (goal's) relative changing of angular velocity* φ grow up then the variable DISK2= *discrepancy between CFU and FI= relative changing of*

angular velocity φ will be grow up, also" and this cause-consequences flows has "positive"(+) dynamics character.
21.-The UF= *rotor exciting voltage* has installed logical protected automation switch, which it has the next mathematical and logical system dynamics model in the DYNAMO-language package:

```
A  UF.K=CLIP(UNIREG(DISK2.K,KPP1,KPI1,KPD1),0,
DELAY1(RL.K,.4),1E-18)                              (22)
```

Where there are: UF= *rotor exciting voltage;* DELAY1= DYNAMO's sign for the MACRO function of the material flow exponential delay of the first order; RL= load resistance; .4= delay time of the DELAY1; 1e-18= computer's zero:

The system dynamics mental-verbal model is:
23.-"If the RL is >= 1e-18 then UF= UNIREG (DISK2.K, KPP, KPI,KPD)", and
24.-"If sthe RL is < 1e-18 (short circuit) then UF=0" (take off the rotor exciting voltage).

2.2.3. System Dynamics Flow Diagram and the Computer Simulation Models of Synchronous Generator Set with UNIREG-PID regulator

System Dynamics Computer Model of the Synchronous Generator Set with UNIREG-PID regulator in the PowerSim Symbols (Fig. 4).

```
****************************************************
•   "SYSTEM DYNAMICS SIMULATIN MODELLING
    AND  OPTIMIZATION OF THE MARINE STEAM
*    TURBO-GENERATING SET"
*  *********************************************
•   IT IS INSTALED AUTOMATIC'S PROTECTION OF
    THE  FUEL INPUT AND OF THE  SELF-EXCITED
    SYSTEM
****************************************************
*
MACRO SLOPE(X,DT)
A SLOPE.K=(X.K-SMOOTH(X.K,DT))/DT
MEND
*
MACRO UNIREG(X,KPP,KPI,KPD)        MACRO
FUNCTION *      OF THE UNI-REG PID-a
INTRN IBD,PREG,IREG,DREG
A PREG.K=KPP*X.K
L  IBD.K=IBD.J+DT*X.J
N IBD=X
A IREG.K=KPI*IBD.K
A DREG.K=KPD*SLOPE(X.K,DT)
A UNIREG.K=PREG.K+IREG.K+DREG.K
MEND
****************************************************
*
•   1. SIMULATION MODEL OF THE  MARINE STEAM
*      TURBINE
•   1.1. SIMULATION SUBMODEL  OF THE ROTOR`S
*      DYNAMICS EQAUATION (1):
**************************************************
R DFIT.KL=(1/T1)*(K1*PSI1.K+K2*PSI2.K-FIT.K-K3* ^
ALPHA.K)          RATE OF RELATIVE INCREMENT OF
*    TURBINE SHAFT ANGULAR VELOCITY
L FIT.K=FIT.J+DT*DFIT.JK        RELATIVE INCREMENT
*OF   TURBINE  SHAFT ANGULAR  VELOCITY
N FIT=0      INITIAL LEVEL OF FIT
C T1=20     TIME CONSTANT OF  TURBINES
* ROTATING PARTS
C K1=1                      GAIN COEFFICIENT
C K2=1                      GAIN COEFFICIENT
C K3=1                      GAIN COEFFICIENT
A PSI2.K=0                   RELATIVE PREASSURE
*                         INCREMENT IN MAINE CONDENSER
A ALPHA.K=MEL.K               RELATIVE TURBINE LOAD
*   CHANGE
SAVE DFIT,FIT,ALPHA
****************************************************
** 1.2. SIMULATION SUBMODEL OF THE VAPOR`S
*        VOLUME DYNAMICS EQUATION (2):
**************************************************
R DPSI1.KL=(1/T2)*(K0*PSI0.K-PSI1.K+K4*MI.K)     RATE
*OF RELATIVE VALUE OF STEAM  PRESSURE OF THE
*        VAPOR`S SPACE
L PSI1.K=PSI1.J+DT*DPSI1.JK       LEVEL OF PRESSURE
*OF   THE VAPOR`S SPACE
N PSI1=0          INITIAL  PSI1
C T2=1            TIME CONSTANT OF THE STEAM SPACE
C K0=1             GAIN COEFFICIENT
C K4=1              GAIN COEFFICIENT
A DISKT.K=FINT.K-FIT.K      DISCREPANCE BETWEEN
*FINT AND  FIT (4)
A FINT.K=.05+STEP(.45,20)+STEP(.5,40)    NOMINAL FIT
A MI.K=UNIREG(DISKT.K,K5,K6,K7)           RELATIVE
*      CHANGE OF POSITION OF THE
*     MANOEUVRING VALVE  (3)
C K5=13          P-GAIN COEFFICIENT
C K6=.3            I-GAIN COEFFICIENT
C K7=10            D-GAIN COEFFICIENT
A PSI0.K=0       RELATIVE VALUE OF THE STEAM
*  PRESSURE INCREMENT BEFOR   REGUALTING
*VALVE
SAVE DPSI1,PSI1,DISKT,FINT,MI,PSI0
****************************************************
* INSTALLING THE UNIREG-PID REGULATOR:
****************************************************
A  IDFIT.K=CLIP(UNIREG(DISKT.K,KPP,KPI,KPD),
  0,TIME.K,50)                                       (3)
C KPP=1
C KPI=0
C KPD=0
SAVE DISKT,PIDFIT
****************************************************
* 2. LEVEL EQUATIONS OF THE SYNCRONOUS
GENERATOR              (5,......24)
**************************************************
*  2.1.  THE FIRST EQUATION OF THE SYNCHRONOUS
GENERATOR:
***************************************************
R DPSIDDT.KL=((-RS*PSID.K)/XS)+PSIQ.K*OME.K+
((RS*PSAD.K)/XS)+UD.K
L PSID.K=PSID.J+DT*DPSIDDT.JK
N PSID=0
C RS=1
```

SAVE DPSIDDT,PSID,OME
****

* 2.2. THE SECOND EQUATION OF THE SYNHRONOUS GENERATOR:

****

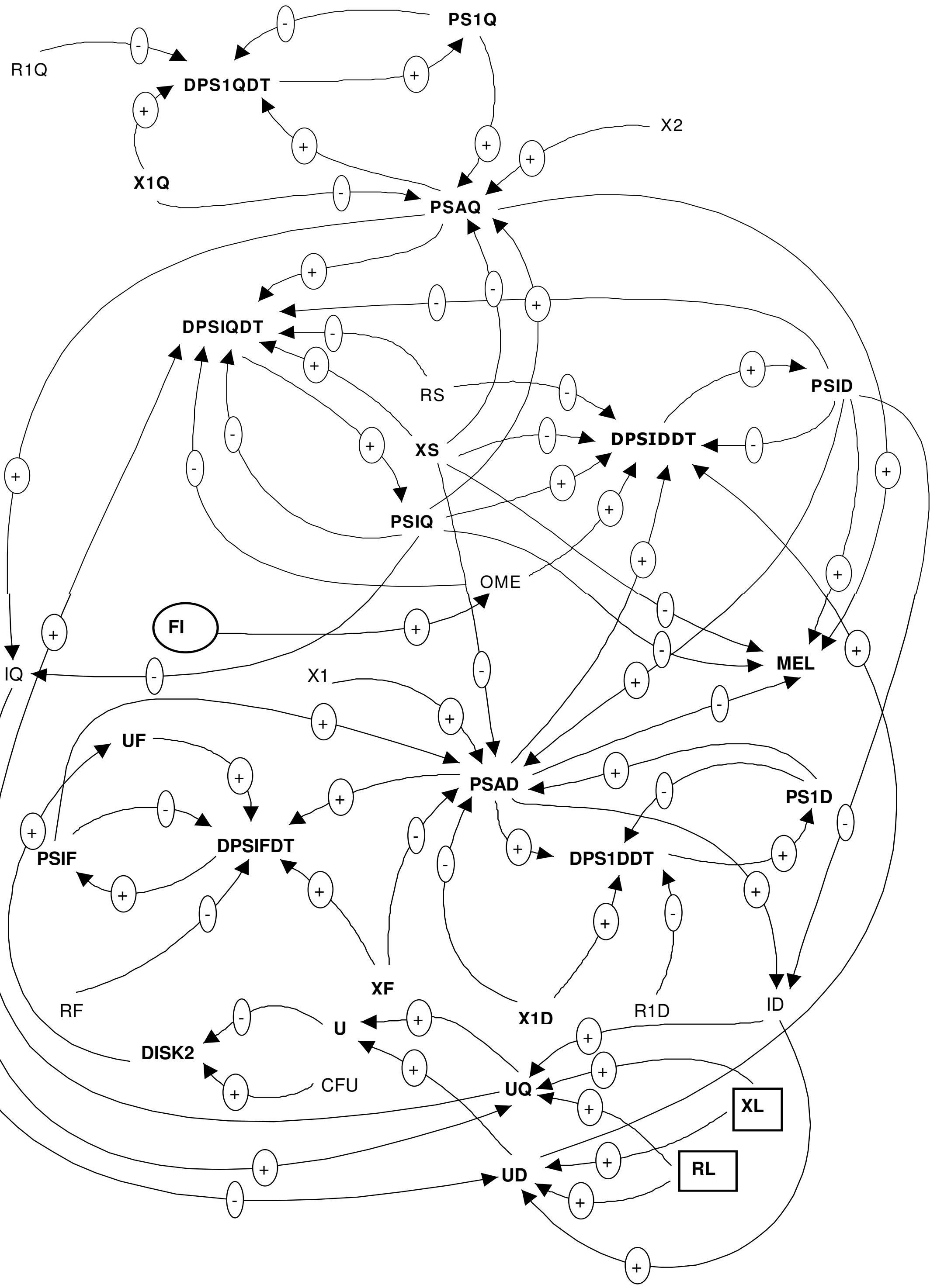

Fig. 4. System Dynamics Structural Flow Diagram of the Synchronous Generating Set with UNIREG-PID regulator

R DPSIQDT.KL=-PSID.K*OME.K-((RS*PSIQ.K)/XS)+((RS*PSAQ.K)/XS)+UQ.K

L PSIQ.K=PSIQ.J+DT*DPSIQDT.JK
N PSIQ=0

```
SAVE DPSIQDT,PSIQ
******************************************************************
* THE THIRD EQUATION OF THE SYNHRONOUS
GENERATOR:
************************************************************
R DPSIFDT.KL=((-
RF*PSIF.K)/XF)+((RF*PSAD.K)/XF)+UF.K
L PSIF.K=PSIF.J+DT*DPSIFDT.JK
N PSIF=0
C RF=1
SAVE DPSIFDT,PSIF
******************************************************************
* THE FOURTH EQUATION OF THE SYNHRONOUS
GENERATOR:
*****************************************************************
R
DPS1DDT.KL=((R1D*PS1D.K)/X1D)+((R1D*PSAD.K)/X1D)
L PS1D.K=PS1D.J+DT*DPS1DDT.JK
N PS1D=0
C R1D=1
SAVE DPS1DDT,PS1D
******************************************************************
* THE FIFTH EQUATION OF THE SYNHRONOUS
GENERATOR:
*****************************************************************
R DPS1QDT.KL=((-R1Q*PS1Q.K)/X1Q)+((R1Q*
PSAQ.K)/X1Q)
L PS1Q.K=PS1Q.J+DT*DPS1QDT.JK
N PS1Q=0
C R1Q=1
SAVE DPS1QDT,PS1Q
******************************************************************
* THE FIRST AUXILIARY EQUATION:
A PSAD.K=X1*((PSID.K/XS)+(PSIF.K/XF)+(PS1D.K/X1D))
C XAD=1
C XS=1
SAVE PSAD,PSAQ
******************************************************************
* THE SECOND AUXILIARY EQUATION:
A PSAQ.K=X2*((PSIQ.K/XS)+(PS1Q.K/X1Q))
C XAQ=1
C XF=1
C X1D=1
C X1Q=1
******************************************************************
* 3. SUBMODEL OF AUTOMATICAL REGULATION  OF
THE VOLTAGE BY UNIREG-PID-A
*****************************************************************
A UF.K=UNIREG(DISK2.K,KPP1,KPI1,KPD1)
A DISK2.K=CLIP(CUF-U.K,0,TIME.K,100)
C CUF=1
C KPP1=1
C KPI1=0
C KPD1=0
K X1=1/((1/XAD)+(1/XS)+(1/XF)+(1/X1D))
K X2=1/((1/XAQ)+(1/XS)+(1/X1Q))
SAVE UF,X1,X2,DISK2
******************************************************************
THE VOLTAGE  ON STATOR
*****************************************************************
A UD.K=RL.K*ID.K+XL.K*SLOPE(ID.K,DT)-
XL.K*IQ.K*OME.K
A UQ.K=RL.K*IQ.K+XL.K*SLOPE(IQ.K,DT)+
XL.K*ID.K*OME.K
A RL.K=4+STEP(-3,150)+STEP(-1,180)
A XL.K=1+STEP(-1,180)
A U.K=SQRT(UD.K*UD.K+UQ.K*UQ.K)
SAVE U,UD,UQ,RL,XL
******************************************************************
* AUXILIARY EQUATIONS:
*****************************************************************
A ID.K=CLIP(-(PSID.K-PSAD.K)/XS,0,TIME.K,100)
A IQ.K=CLIP(-(PSIQ.K-PSAQ.K)/XS,0,TIME.K,100)
A I.K=SQRT(ID.K*ID.K+IQ.K*IQ.K)
A I1D.K=CLIP((1/X1D)*(PS1D.K-PSAD.K),0,TIME.K,100)
A I1Q.K=CLIP((1/X1Q)*(PS1Q.K-PSAQ.K),0,TIME.K,100)
A IF.K=CLIP((PSIF.K-PSAD.K)/XF,0,TIME.K,100)
************************************************************** **
4. AUXILIARY EQUATIONS:
****************************************************************
A MEL.K=(1/XS)*(PSID.K*PSAQ.K-PSIQ.K*PSAD.K)
A OME.K=FIT.K
SAVE ID,IQ,IF,I,MEL
SPEC DT=.1,LENGTH=250,SAVPER=.5
******************************************************************
```

2.2.4. About simulating scenario

The mixed scenario has been built in this computer simulation model of TDSGS-Turbine Drive Simulation Synchronous Generating Set:

1.-Steam turbine starts in the TIME= 0 (s) and FINT-pre-heating (first degree of the nominal angular velocity) =.05;
2.-Steam turbine starts in the TIME= 20 (s) and FINT-pre-heating (second degree of the nominal angular velocity)=+.45;
3.-Steam turbine starts in the TIME= 40 (s) and FINT-pre-heating (third degree of the nominal angular velocity)=+.50 (FINT=.05+.40+.50=1.0);
4.-synchro generator starts with its self exiting process in the TIME= 20 (s)*;* 3.-load impedance or resistance RL and reactance XL starts in the TIME= 0 (s). The RL=150 and XL=0 and this means that TDSGS is in the “idle-running”.
5. In the TIME= 40 (s), the RL= 1 and XL= 1 (nominal load); and 4.-stator short-circuits starts in the TIME = 70 (s) and RL= 0 and XL=0 and this means that DDSGS is in the “short cuircuit”.
Authors had been installed two automatic short-circuit protection switch also. One of them has taken out the uf = rotor exciting voltage time reaction delay is .4 (s), and other of them have taken out the MI = relative value of regulating valve opening change reaction is 2 (s).

2.2.5.. Simulation results

As the response dynamics behavior to this mixed scenario, after the modeller has finished process of "heuristic optimization" by parameters of two UNIREG-PID regulators ("retry and error" computer manual method). Everybody who knows about thermodynamics and electrodynamics machine sets and DYNAMO software package could see the recognizes dynamically transient well known behaviors of the DDGSS.

3. CONCLUSION

Quality and economical steam turbine functioning depend on many parameters such as steam pressure before and after the regulating valve, condenser pressure, etc. Since successful turbine functioning depends on a large sequence of various parameters, this problem should be solved systematically. By use of the system dynamics in this paper, the complexity of steam turbine dynamics system behavior has been partially presented. The system dynamics mathematical model, dynamics continued computer simulation model and structural dynamic model of the steam turbine and automatic PID-regulator are presented. Therefore interaction links between each parameter and variables can be analyzed. A simulation model is used to enable optimization of all parameters of the steam turbine system and transient and steady state simulation according to the stated scenario. The most difficult operation conditions can be investigated, even those which in reality are not physically possible.

Instead of conclusion, it should be useful to quote a well-known Chinese proverb:

"When I hear, I forget. When I see, I remember. When I do, I understand.".

But it is useful also to re-modulate it in the marine system engineering-way:

"WHEN I HEAR A MENTAL-VERBAL MODEL OF A DYNAMIC PROCESS, I FORGET".
"WHEN I SEE A STRUCTURAL MODEL AND REALITY OF A DYNAMIC PROCESS, I REMEMBER".
"WHEN I DO A MATHEMATICAL OR COMPUTER SIMULATION MODEL OF A DYNAMIC PROCESS, I UNDERSTAND".
"WHEN I DO A SYSTEM DYNAMICS MODEL OF A. DYNAMICS PROCESS, I LEARN".
"WHEN I DO SIMULATION OR TRAINING BY SYSTEM DYNAMICS MODEL OF A DYNAMIC PROCESS, I WILL DO REFRESHMENT WITH THE MY ACQUIRED THEORETICAL AND PRACTICAL KNOWLEDGE OF A DYNAMIC PROCESS."

In the application area of System Dynamics Simulation Modelling Approach of the complex marine dynamic processes that the authors together with there's graduated students carried out at the Maritime Faculty University of Split Croatia seven years ago, the following facts have been found out also:

l. System Dynamics Modelling Approach is very suitable as software educate tools for the marine students and engineers.

2. System Dynamics Computer Simulation Models of marine systems or processes are very effective and successful for simulation and training courses in the marine educate processes.

3. The authors suggest the use of this modeling approach in designing, for the engineering educational processes as well, which will allow an active and creative participation of students. This method is, therefore, expected to be applied in organizing the educational process.

5. REFERENCES

[1] Milic L. and Milic I. 1995**, Osnove Automatizacije**,Sveuciliste u Splitu, Pomorski fakultet u Dubrovniku, Dubrovnik, (in Croatian)
[2] Munitić, A. 1989. **Komjutorska simulacija uz pomoć sistemske dinamike**, Brodosplit, Split, (in Croatian).
[3] Munitić, A.; Milić, L. and Milković, M. 1997. "**System Dynamics Computer Simulation Model of the Marine Diesel-Drive Generating Set Automatic Control System**", *Proceedings of the 15th IMACS World Congress on Scientific Computation, Modelling and Applied Mathematics, vol. 5*, Wissenschaft & Technik Verlag, Berlin.
[4]Forrester, J. W. 1968. **Principle of Systems***,* MIT Press, Cambridge, Massachusetts Institute of Technology and London, England.
[5]Siromjatnikov, V. F. 1983. **Osnovi avtomatiki i kompleksnaja avtomatizacija sudovih paroenerge-tičeskih ustanovok**, Transport, Moskva, (in Russian).