ANALYSED TRANSIENTS DURING ISLANDING OPERATION OF ONE HPP ON ITS AUXILLIARIES

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Lucrarea îşi propune studiul comportării în regim dinamic a unui hidrogenerator HG dintr-o centrală hidroelectrică CHE şi a unui motor electric ME din rețeaua de servicii proprii aferentă, în cazul trecerii bruşte de la funcționarea normală, de racord în cadrul sistemului electroenergetic zonal, la funcționarea insulară, pe o rețea izolată de sistem.

Sunt investigate cu ajutorul programului de simulare Simulink, principalele regimuri tranzitorii parcurse de HG–ME; pentru aceasta, se consideră o situație reprezentativă, respectiv o zonă din Sistemul Energetic Național SEN, formată dintr-o hidrocentrală (2 x 10MW) controlată de regulatoarele automate, un consumator local (2 MW) şi un motor electric asincron (7,5kW), conform schemei electrice monofilare tipice, aferentă unei centrale hidroelectrice de mică putere CHEMP.

The present work is aiming to study the significant dynamic behavior of one hydro power generator HG from one hydro electric power plant HPP, together with one electric motor ME from its internal network of auxiliaries, in the event of a sudden load rejection that follows one normal running regime into the powerful electric grid, to the islanding operation.

There are investigated through the Simulink program, the main transients undergone by the assembly HG-ME. In this respect, it is focused one representative situation in which one HPP (rated 2 x 10MW) affected by its automatic regulators is connected – then separated from one regional part from our National Power Grid SEN, together with one local consumer (rated 2 MW) and one electric asynchronous motor (rated 7.5 kW), according to one typical lay-out electric diagram for the medium hydro power plants MHPP.

Keywords: hydro power plant HPP, hydro generator HG, automatic regulators – speed governor, voltage regulator, electric asynchronous motor ME, electric power grid, islanding operation, Simulink , simulations

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1. Introduction

The work is aiming to study the significant dynamic behavior of one hydro power generator HG from one hydro electric power plant HPP, together with one electric motor ME from its internal network of auxiliaries, in the event of a sudden load rejection that follows one normal running regime into the powerful electric grid, to the islanding operation [8].

The analysed regional part from the National Power Grid is made up from one hydroelectric power plant HPP connected to the power grid through one overhead power transmission line, rated 110kV. From the substation of 110kV is supplied one group of consumers, having an average instant active power of 2 MW. The total amount of the HPP auxiliaries being approximately 307.5kW is represented by one important motor-pump of 7.5kW, while the rest of consumers are gathered into one single amount.

The electric motor M in the Fig. 1, of 7.5kW, is now under study. It is a motor of asynchronous type with short circuited rotor, driving one pumping unit for cooling water. The related technological installation of cooling water is surveyed by its automation system [3].

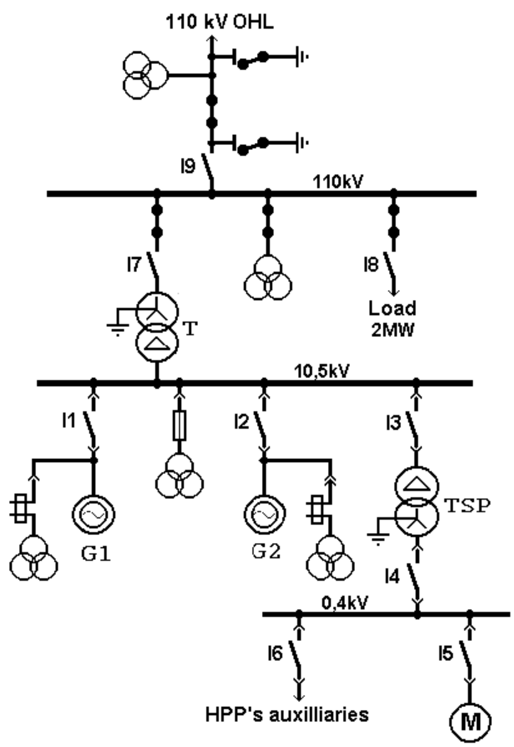


Fig. 1. The analysed network, portion from the system

The hydrogenerators HG have the following rated parameters, so:

- synchronous machines, with rotor salient poles
- stator winding is star connection, with isolated neutral point
- rated aparent power: 10MVA;
- rated line voltage: 10,5kV;
- synchronous longitudinal reactance: Xd = 1.096 [pu];
- transient longitudinal reactance: $X'd$ = 0.25 [pu];
- subtransient longitudinal reactance: $X''d$ = 0.241 [pu];
- synchronous transversal reactance: Xq = 0.638 [pu];
- subtransient transversal reactance: $X''q$ = 0.22 [pu];
- reactance of losses: X_l = 0.2 [pu];
- time constant, *d* axe, in short circuit;
- time constant, *q* axe, open circuit;
- transient longitudinal time constant: 4.2 s.;
- subtransient longitudinal time constant: 0.05 s.;
- -subtransient transversal time constant: 0.05 s.;
- stator winding resistance Rs = 0.0043 [pu];
- inertia coefficient $H(s)$ = 3.5 (the rapport between accumulated rotor energy to rated power, at rated speed);
- damping factor = 0[pu] (the rapport between the torque and speed deviation);
- number of poles pairs = 8;
- initial conditions:
- *dw* = 0[%];
    - *th* = - 95.9387(grades);
    - *ia* = 0.59387[kA];
    - *ib* = 0.59387[kA];
    - *ic* = 0.59387[kA];
    - phase angle, phase A = - 6.04235 [degrees];
    - phase angle, phase B = - 126.042 [degrees];
    - phase angle, phase C = 113.985 [degrees];
    - excitation voltage Vf = 0.9[pu]

The step-up power transformer, from 10.5 kV to 110 kV, has the following operational rated parameters:

- three phase transformer, double windings;
- aparent rated power: 25 MVA;
- rated frequency: 50 Hz;
- connection scheme on the primary winding: triangle;
- parameters for the primary winding:
    - line voltage: $V1$ = 10.5kV
    - resistance: $R1$ = 0.027 [pu]
    - reactance: $X1$ = 0.06 [pu]
- connection scheme, secondary winding: star, having the neutral point directly earthed;
- parameters for the secondary winding:
    - line voltage: $V2$ = 110kV
    - resistance: $R2$ = 0.027 [pu]
    - reactance: $X2$ = 0.06 [pu]
- magnetic resistance: Rm = 200 [pu]
- magnetic reluctance: Lm = 300 [pu]

The step-down transformer supplying the auxiliaries, from 10.5 kV to 0.4 kV, has the following rated operational parameters:

- three phase transformer, double windings;
- aparent rated power: 400kVA;
- rated frequency: 50Hz;
- connection scheme on the primary winding: triangle;
- parameters for the primary winding:
  - line voltage: $V1$ = 10.5kV
  - resistance: $R1$ = 0,027 [pu]
  - reactance: $x1$ = 0,06 [pu]
- connection scheme, secondary winding: star, having the neutral point directly earthed
- parameters for the secondary winding:
  - line voltage: $V2$ = 400 V
  - resistance: $R2$ = 0.027 [pu]
  - reactance: $x2$ = 0.06 [pu]
- magnetic resistance: Rm = 200 [pu]
- magnetic reluctance: Lm = 300 [pu]

The National Power System SEN is represented through one generator, which, at the considered level, has the following parameters:

- line voltage: 110kV;
- phase angle difference for the phase A: 0^{o};
- rated frequency = 50 Hz;
- connection: Y, with the neutral point, directly earthed;
- short circuit power = 10,000 MVA;
- rapport X/R = 10

The local consumer is equivalent for one group of consumers supplied at the voltage level of 110 kV. The consumer is three phased, star connected with the neutral point directly earthed. Every phase consists of one group RLC in parallel. The parameters regarding the consumer are the followings:

- rated line voltage: 110kV
- rated frequency: 50 Hz
- rated instant, three phased active power: P = 2 MW
- three phased reactive inductive power: Qi = 0.3 MVAr

The standard induction electric motor M, asynchronous type, belongs to the HPP's internal network supplying the auxiliaries, and it is driving one pumping unit for cooling water. The modeling was done into *d, q coordinates*, rotor–referenced. Both stator and rotor windings are in the star connection, having the neutral point N - isolated.

The calculus data regarding the induction motor M, are the followings:

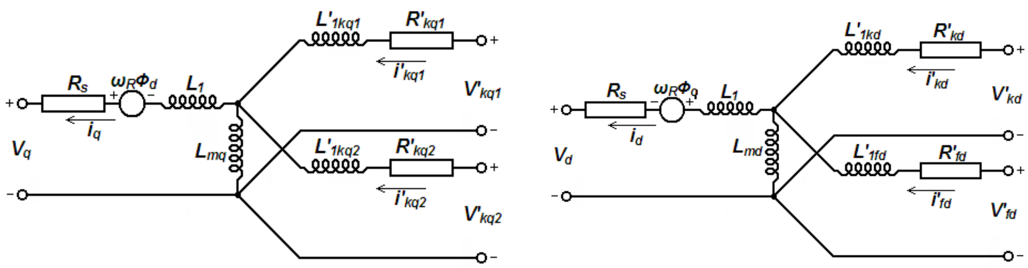
- the rotor's type of winding: in short circuit (squirrel cage, type);
- rated active power: 7.5kW;
- rated line voltage: 0.4kV;
- rated frequency: 50Hz;
- stator winding resistance: Rs = 0.0201 [pu];
- stator leakage inductance: Lls = 0.0349 [pu];
- rotor's leakage winding resistance: $R'r$ = 0.0377 [pu];
- rotor's leakage winding inductance: $L'lr$ = 0.0349 [pu];

- mutual inductance: Lm = 1.2082 [pu];
- inertia constant: H = 3.7;
- friction factor: F = 0 [N x m x s];
- number of poles pairs: p = 2.

2. The Simulink, program implementation

In the simulation program of *Simulink*, every circuit element is simulated through its specific electric equivalent [1,2,4].

The synchronous machine is simulated as a block which could action as a generator or as a motor, depending on the signum of the mechanical power, respectively positive for the generator, and negative for the motor. The machine's electrical part is represented following one six order space model. This model is taking into account, the dynamic behavior of the stator, excitation field and the rotor's damper windings [6].



Axis q Axis d

Fig. 2a and 2b. The equivalent circuits belonging to the machine HG

The equivalent circuit model is represented into the figs. 2a and 2b, in coordinates d and q, in respect with the rotor. All the rotor's parameters and electric dimensions are seen via the machine's stator. These are considered as primary variables.

The following herewith presented notations, are:

- d, q: measures done along d and respectively q axes;
- R, s: rotor and stator measures;
- l, m: leakage and individual proper inductances;
- f, k: measures related to the excitation field and dampers.

The synchronous machine's mathematic model was implemented with the aid of the following standard set of equations:

$$V_d = R_s i_d + \frac{d}{dt}\varphi_d - \omega_R \varphi_q \qquad \varphi_d = L_d i_d + L_{md}\left(i'_{fd} + i'_{kd}\right)$$

$$V_q = R_s i_q + \frac{d}{dt}\varphi_q + \omega_R \varphi_d \qquad \varphi_q = L_q i_q + L_{mq} i'_{kq}$$

$$V'_{fd} = R'_{fd}\, i'_{fd} + \frac{d}{dt}\varphi'_{fd} \qquad \varphi'_{fd} = L'_{fd} i'_{fd} + L_{md}\left(i_d + i'_{kd}\right)$$

$$V'_{kd} = R'_{kd}\, i'_{kd} + \frac{d}{dt}\varphi'_{kd} \qquad \varphi'_{kd} = L'_{kd}\, i'_{kd} + L_{md}\left(i_d + i'_{fd}\right)$$

$$V'_{kq1} = R'_{kq1}\, i'_{kq1} + \frac{d}{dt}\varphi'_{kq1} \qquad \varphi'_{kq1} = L'_{kq1} i'_{kq1} + L_{mq} i_q$$

$$V'_{kq2} = R'_{kq2}\, i'_{kq2} + \frac{d}{dt}\varphi'_{kq2} \qquad \varphi'_{kq2} = L'_{kq2}\, i'_{kq2} + L_{mq} i_q$$

where:

V_d, V_q – stator voltages on the *d* and *q* axis;
V'_{fd}, V'_{kd} – field and damper rotor voltages on the *d* axis;
V'_{kq1}, V'_{kq2} – damper rotor voltages on the *q* axis;
i_d, i_q – stator currents on the *d* and *q* axis;
i'_{fd}, i'_{kd} – field and damper currents on the *d* axis;
i'_{kq1}, i'_{kq2} – damper currents on the *q* axis;
φ_d, φ_q – total stator fluxes on the *d* and *q* axis;
φ'_{fd}, φ'_{kd} – total field and damper rotor fluxes on the *d* axis;
φ'_{kq1}, φ'_{kq2} - total damper rotor fluxes on the *q* axis
R_s - stator's winding resistance;
R'_{fd}, R'_{kd} – field and damper resistance on the *d* axis;
R'_{kq1}, R'_{kq2} – damper resistances on the *q* axis;
L_d, L_q – stator inductances on the *d* and *q* axis;
L'_{fd}, L'_{kd} – rotor field and damper inductances on the *d* axis;
L'_{kq1}, L'_{kq2} – rotor damper inductances on the *q* axis;
L_{md}, L_{mq} – mutual inductances on the *d* and *q* axis;
ω_R – electrical angular velocity.

The automatic speed governor RAV was modeled, following the block representation given into the below fig. 3 [4].

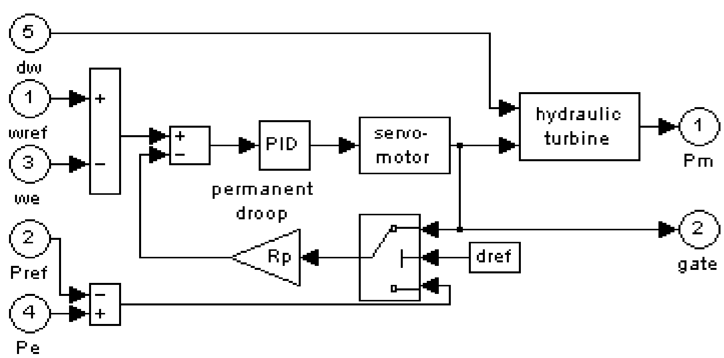


Fig. 3. The speed governor RAV – block diagram

In this figure are denoted with:

- w_{ref}, w_e – reference speed, measured speed (instant);
- P_{ref}, P_e – reference electric power, measured electric power (instant);
- gate – wicket gate (its opening);
- d_w – instant speed deviations, compared with the rated speed;
- P_m – mechanical power delivered by the turbine.

The static amplification introduced by the automatic regulator RAV is equal with the reversed permanent droop R_p from the feed-back loop. The regulator of PID type is characterized by the coefficients: *Kp* - for proportional, *Ki* - for integral and *Kd* - for derivative actions.

The servomotor is characterized by the amplification *Ka* and time constant *Ta*, [s].

There are set-up the lower / upper limits related with the speed operation at the wicket and also the limits regarding the opening / closing for this wicket gate AD.

The hydraulic turbine is characterized by the starting time (*Tw*), în seconds, and by the damping coefficient regarding the variation of the rotational speed (β).

It is realised the fact that the turbine's control can be done, following the "gate" (the opening at the wicket gate), following the electric power deviation or, following one fixed value of the speed.

The automatic voltage regulator AVR is modeled, conform the block scheme, the fig. 4 [3,4].

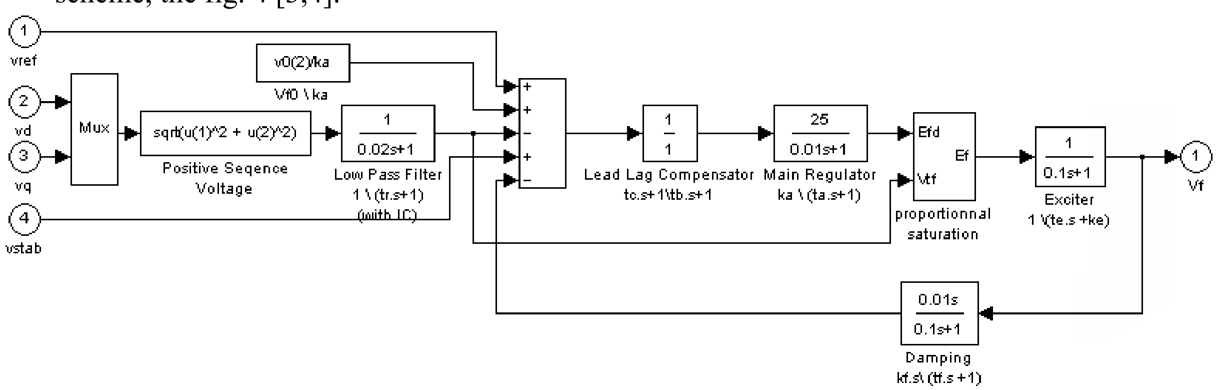


Fig. 4. The block scheme modeling one automatic voltage regulator AVR, in which:

- v_{ref}, v_{stab} – the reference voltage, stabilizing voltage signal;
- v_d, v_q – the measured voltage (components d and q);
- v_f- the voltage at the rotor's terminals, excitation winding

The filter's function, low-pass-limit, with the time constant *Tr*, is performed by the measuring voltage transformer.

The AVR is to control the excitation current of the HG with the amplifier called d.c. exciter, having as input, the magnitude data e_f (received from the regulator) and, as output, the voltage V_f. The exciter is modeled as an amplifier-integrator, having the following transfer function:

$$\frac{V_{fd}}{e_f} = \frac{1}{K_e + sT_e}$$

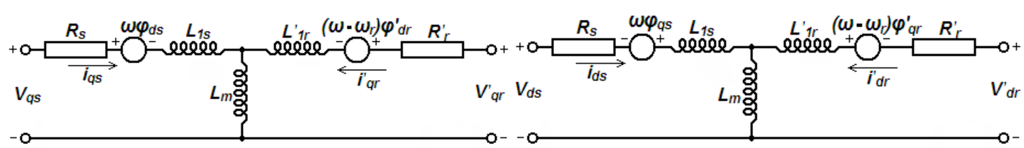
The reaction loop is one of derivative-type.

The asynchronous machine was simulated through one synthetic block which can act either as a generator, either as a motor, depending by the sign affecting the mechanical power: positive for the regime as motor, negative –as generator. The electrical part for M is represented through one space-model, fourth order; the mechanical part for M is also represented through one space-model, having second order.

All the variables and all the parameters – of electrical nature – are referring to the stator. All the data which are referring to the stator + rotor are done in respect with their components on reference axis, *d* and respectively *q*. The electric equivalent circuits corresponding on both reference axes are presented into the figs. 5a and 5b [5].

The used notations are, as follows:

- *d, q*: the sizes on both axis: *d* and respectively *q*;
- *R, s*: the dimensions regarding the rotor / stator;
- *l, m*: the leakage and individual inductances;



Figs. 5a and 5b. The common equivalent circuits for the induction motor

The math model of an asynchronous machine was implemented, aided by the following standard set of equations:

$$V_{qs} = R_s i_{qs} + \frac{d}{dt}\varphi_{qs} + \omega\varphi_{ds} \qquad \varphi_{qs} = L_s i_{qs} + L_m i'_{qr}$$

$$V_{ds} = R_s i_{ds} + \frac{d}{dt}\varphi_{ds} - \omega\varphi_{qs} \qquad \varphi_{ds} = L_s i_{ds} + L_m i'_{dr}$$

$$V'_{qr} = R'_r i'_{qr} + \frac{d}{dt}\varphi'_{qr} + (\omega - \omega_r)\varphi'_{dr} \qquad \varphi'_{qr} = L'_r i'_{qr} + L_m i_{qs}$$

$$V'_{dr} = R'_r i'_{dr} + \frac{d}{dt}\varphi'_{dr} - (\omega - \omega_r)\varphi'_{qr} \qquad \varphi'_{dr} = L'_r i'_{dr} + L_m i_{ds}$$

$$T_c = 1{,}5p(\varphi_{ds} i_{qs} - \varphi_{qs} i_{ds}) \qquad L_s = L_{ls} + L_m \qquad L'_r = L'_{lr} + L_m$$

The math model regarding the mechanical system was implemented, with the following equations [1,2]:

$$\frac{d}{dt}\omega_m = \frac{1}{2H}(T_e - F\omega_m - T_m) \qquad \frac{d}{dt}\theta_m = \omega_m$$

Were used the following standard notations, as indicated below:

- R_s, L_{ls} = resistance and leakage inductance, stator's winding;
- R'_s, L'_{ls} = idem, on the rotor's winding;
- L_m = magnetizing inductance;
- L_s , L'_r = total inductance for stator, respectively - rotor;
- V_{qs}, i_{qs} = the stator voltage respectively current, on the *q axis*;
- V'_{qr}, i'_{qr} = idem, for the rotor, *q axis*;
- V_{ds}, i_{ds} = idem, for the stator, onto the *d axis*;
- V'_{dr}, i'_{dr} = idem, for the rotor, onto the *d axis*;
- φ_{qs}, φ_{ds} = the stator fluxes, onto the axis *q* and respectively *d*;
- φ'_{qr}, φ'_{dr} = idem, for the rotor's;
- ω_m = angular rotor's speed;
- θ_m = angular rotor's position;
- *p* = the number of poles pair;
- $\omega_r = p\omega_m$ = rotational speed for the electromagnetic field;
- $\theta_r = p\theta_m$ = angular rotor's position, regarding its electromagnetic field;
- T_e = the electromagnetic torque;
- T_m = the axle-mechanical torque;
- *J* = the combined inertia coefficient regarding the load and the rotor itself. It has the infinite value when the rotor is blocked [kg x m^2];
- *H* = the combined inertia constant regarding the load and the rotor itself; It has the infinite value when the rotor is blocked;
- *F* = the combined friction coefficient, regarding the friction with viscosity for the load and the rotor itself [N x m x s].

3. Obtained results

The above–mentioned data - were introduced into the specialized program of simulations, called *Simulink*. This mentioned program has processed the input data in line with the already presented equations. The results are graphically shown in line with the subsequent further comments .The simulating scheme to be implemented, is shown into the fig. 6.

The situation to be considered was that in which is into operation only one hydro generator, HG2 and, suddenly , at the momentum t_0 = 5s, the breaker I9

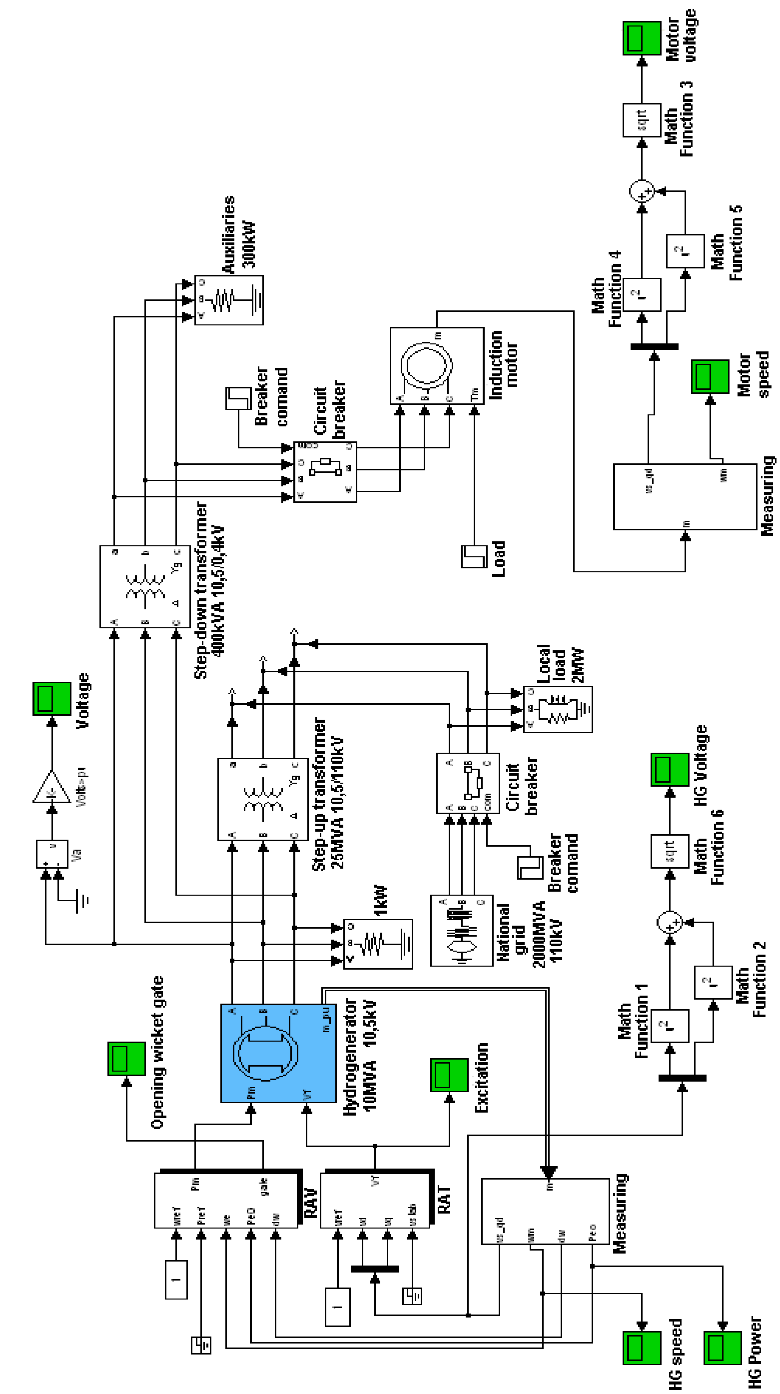


Fig. 6. The Simulink modeling scheme

opens and the HG2 is to operate at islanding conditions, having to supply its own auxiliaries as 0.4 kV consumers plus the consumers from the level of 110 kV. Automatic regulators of speed – RAV and voltage – AVR intervene and, after one period of transition, they have to assure the correct-stable operation at this islanding condition onto now isolated its own network.

We are interested to study the electro-mechanical parameters' evolution from the hydro power generator HG2 and also for the induction motor M, into two distinct transient operational regimes, respectively:

- after 5s from the emerging the start–up process at the motor M, took place the separation from the system, through the breaker I9, which is tripping;
- after 10s following the separation from the system through the opening of the breaker I9, is taken place the start-up process for the chosen motor M.

At the very moment when the breaker I9 opens, the HG2 was at stable running. Immediately, after the breaker I9 opens, it appears one transient regime, during both automatic regulators from the HG2 intervene, in order to bring the frequency and the voltage too, toward their prescribed rated values. Significantly, jumpings in frequency and voltage - which took place immediately after the separation from the system, have not performed excessive excursions, so none of the relay protections affected to the hydro generator is to give any trip – out.

However, when the protective relays would trip, if this intervention would occur, the hydro power generator HG would be automatically disconnected from the grid, having the immediate result of loosing all the consumers.

Within this occasion, the most probable working among the protections' list, are those protections to control the power unit against the over-speed and over-voltage at the generators' terminals. The over-speed protection was safe designed with three limits during the generator's over-speeded regime: 1,2; 1,35 and 1,45 n_n (where n_n denotes the rated value, as synchronous constant speed).

However, the over-voltage protection has only one single tripping limit, respectively at the value of 1,2 U_n (where U_n is the rated value for the HG voltage, measured at its terminals) [7].

Case study no.1

In the first studied case the separation from the system takes place when the induction motor M start-up is already finished. We are interested to study the generator's behavior during its separation from the system when begins to cope with islanding regime and also the behavior of the motor M - when one frequency and voltage variation occur at the supplying network within the very starting period.

The evolution of the main operational parameters is graphically done into the following figs. from below. On the abscise is marked the time in seconds, while on the ordinate are marked the measures of interest, in pu.

It is mentioned that the significant time values are the followings:

- *zero seconds* momentum, chosen when the motor is connected and begins the very start-up regime;

- *5 seconds* momentum, when the breaker I9 opens and the separation from the power system is to be initiated.

The whole transient regime takes no longer than 60 seconds.

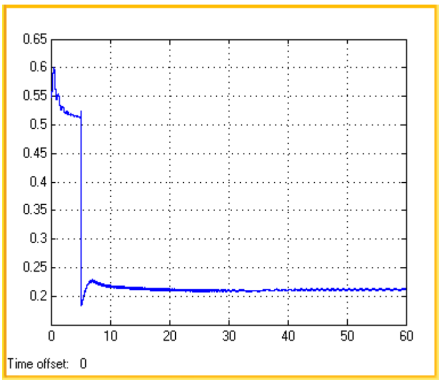


Fig. 7. HG - Power

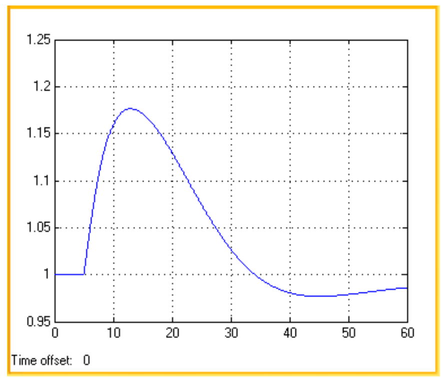


Fig. 8. HG - Speed

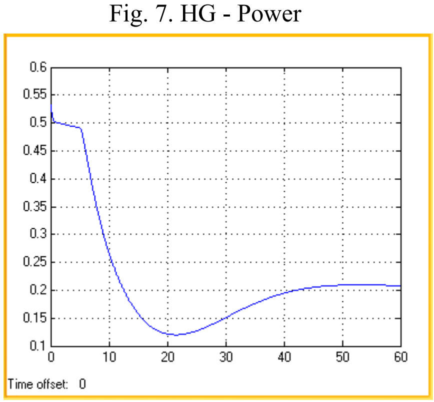


Fig. 9. Closing the wicket gate

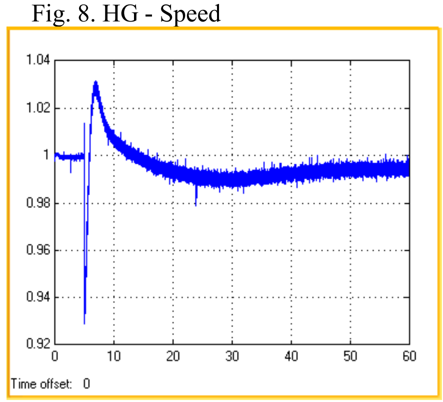


Fig. 10. HG - Voltage

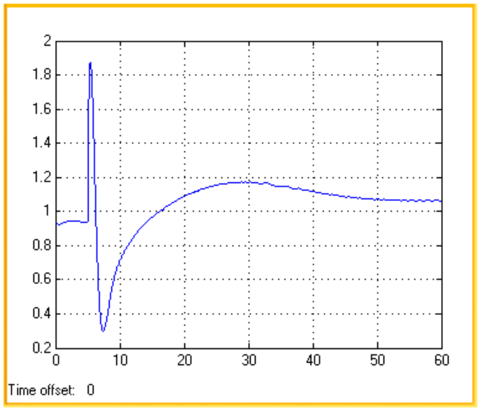


Fig. 11. HG Excitation

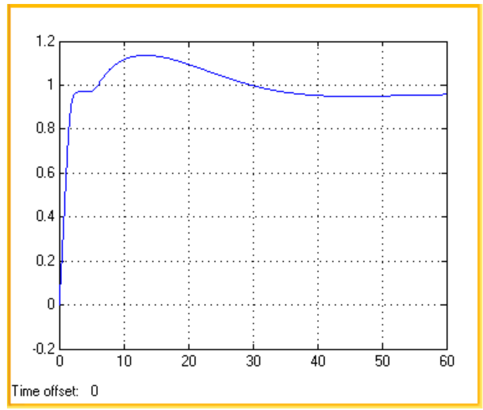


Fig.12. Motor M - Speed

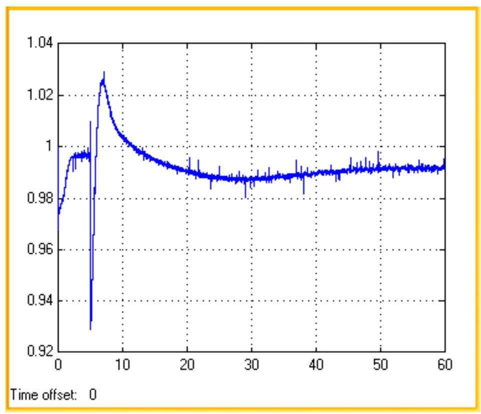


Fig. 13. Motor M - Voltage

When opens the breaker I9, which maintains the link with the system, the power injected is reduced from 6 MW (0,6 pu), at the value of 2,2 MW (0,22 pu), corresponding to the consumers of rated 2 MW from the 110 kV bus bar and also those from the HPP's auxiliaries. This situation is presented into the fig. 7. The significant down loading in the HG's injected power has as immediate effect one increase in its rotational speed (fig. 8). This is because the electromagnetic energy which initially was transferred to the power system, after tripping this system link, this energy will be converted into kinetic energy as far as the rotational parts. The automatic speed governor intervenes and commands one reduction into the turbine's water flow through the wicket gate which closes at some extent, corresponding to the new loading level. The action in closing at the wicket gate is done within one time constant delay, followed by some final rise, as it can be seen in the fig. 9.

The voltage at the hydro generator's terminals has, instantly, one drop, average 7% (fig. 10), because the reactive power flow is reconfigured, respectively HG has to cover the reactive power consumed by the transformers of 25 MVA and 400 kVA (TSP) and also the reactive power absorbed by the consumers of 2 MW, located at the 110 kV bus-bar. AVR is immediately in action, by rising the excitation current (fig. 11) at a stabilized value greater than that previously done, before the opening of the breaker I9. The voltage at the HG's terminals is stabilized at some fractions of percentage lower than the previous value, following one static philosophy of automatic control.

As far as the behavior of the electric motor M, this is studied in the graphics describing the time variations for speed (fig. 12) and supplying voltage at its terminals (fig. 13). One realizes that the motor start – up and, during of average 2 seconds, is at its rated speed, rated asynchronous slip. At the same time when the frequency rises into this island, takes place also some rise into the motor's speed within average 12%, above the synchronous speed. Through the time interval when the HG's speed is backed to the rated value, also the frequency in tis isolated island together with the motor's speed are to regain their rated value.

The voltage at M's terminals is registering one drop, average 3%, during the very start-up moment, because of the inrush current absorbed. Later, at the moments to come, the voltage at M's terminals has the same evolution as HG's – which is a normal situation, because of the existing link. One realizes the effect of voltage filtering, explained by the presence of the step down transformer TSP supplying the HPP's auxilliaries.

<u>Case study no. 2</u>

In this second approaching case of study, the separation from the main power grid, when one island grid was born, exactly when the induction motor M was at its severe transient regime of start-up. We are interested to study the both transient behaviors: 1- for HG which passes from the rigid connection with the power grid to one elastic connection into its own smaller isolated grid; 2- for M, when takes place variations into the supplying frequency and voltage, superimposed with the very moment of start-up period.

The evolution for the main operational parameters is graphically represented into the below figures, similar with the former case - study.

It is mentioned that the significant time moments are, as follows:

- momentum at *5 seconds*, which is the moment of breaking I9 and, the separation from the main power grid, is initiated;

- momentum at *15 seconds*, which is the moment when the motor is connected to the auxilliaries' supplying network and begins its start-up regime.

The duration for the whole transient regime is no longer than 60 seconds.

As far as the described phenomena, the hydrogenerator's behavior – these are similar with those described into the case 1.

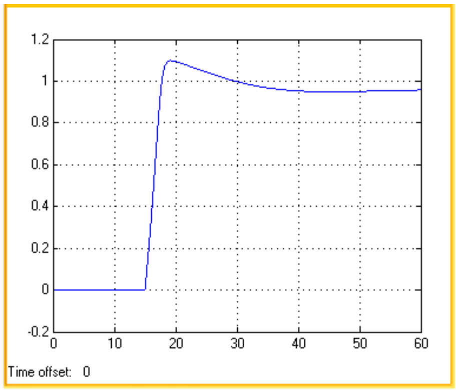


Fig. 14. Motor speed

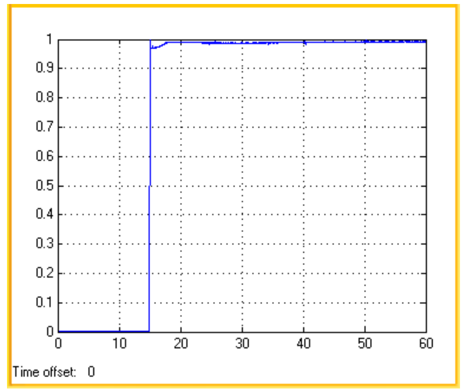


Fig. 15. Motor voltage

As far as the induction motor's M behavior, this is studied following the graphic representations regarding the time variations for the speed (fig. 14) and supplying voltage at the terminals (fig. 15). One realizes that the motor M start-up from zero and, during average 2 seconds attains one greater speed with 10 %, than the rated one.

This situation could be explained by the fact that the generator being at one transient regime of damping, its speed is greater than the initial rated value. Step by step, when the HG's speed is to turn at its rated synchronous value of rotational speed, also the island frequency goes back to the rated value. As a result, also the M's rotational speed is to come down at its rated asynchronous value, a little under the synchronous speed, according to its rated slip.

The voltage at the motor's terminal is to register one small drop of av. 3% during the star-up period, because of the current inrush absorbed, specific for this moment. Later, the motor's voltage will copy the same evolution as those seen at the generator's terminals, which is a normal behavior, by taking into account the elastic link between, HG – M

One realizes that the over rise at the generator's terminals does appear also at the motor's terminals but, at smaller scale in pu, corresponding to the very moment at which the motor M is to be connected at the supplying HPP's internal network for its auxiliaries.

4. Conclusions

1. The generator's behavior in both study-cases is practically, the same, taking into account the small rated power for motor compared with the huge from generator.

2. Starting / shut-down of the auxiliaries belonging to the HPP in question, are controlled by the specific equipment of automation; therefore the supplying power source has to be prepared at every moment to cope with the specific solicitations herewith implied into these commonly encountered operational regimes.

3. Has to be underlined the fact that the speed governor RAV is operating with sensible greater time constants, when is compared with the automatic voltage regulator AVR. This aspect could be easily understood, having in mind the following fact: while RAV is mainly mechanically operational and made-up, the AVR is quite entirely one electric/ electronic equipment, related to the electrical part of the hydro power generator itself.

R E F E R E N C E S

[1] "Hydraulic Turbine and Turbine Control Models for Dynamic Studies, IEEE Working Group on Prime Mover and Energy Supply Models for System Dynamic Performance Studies". IEEE Trans. on Power Systems, **Vol. 7**, No. 1, February, 1992, pp. 167-179

[2] "Recommended Practice for Excitation System Models for Power System Stability Studies" IEEE Standard 421.5-1992, August, 1992

[3] *B.D. Guzun, C. Mucichescu, A. Chiracu*, "Automatizări în hidroenergetică", Editura Tehnică, Publishing House, Bucharest, 1995, 272 p

[4] *** MATLAB^{TM}.Simulink

[5] *I.S. Gheorghiu, A.S. Fransua*, - "Tratat de maşini electrice, Vol 3-Maşina asincronă", "Editura Academiei" Publishing House, Bucharest, 1972

[6] *I.S. Gheorghiu, A.S. Fransua*, "Tratat de maşini electrice, **Vol 4**-Masina sincronă", "Editura Academiei" Publishing House, Bucharest, 1972

[7] *P.C. Krause*, - "Analysis of Electric Machinery". McGraw-Hill, 1986

[8] *B.D. Guzun, S.A. Gal., G. Darie, D. Olovinaru*, "CSRE – Centrale, Stații şi Rețele Electrice" (Electric Power Stations, Substations and Networks). "Editura Academiei" Publishing House, Bucharest, 2005, 450 p.