THE FUNCTION PSS ADDITIONAL SIGNAL INFLUENCE OF THE RAT STRUCTURE FOR A BETTER STATISTICAL AND TRANSITIONAL STABILITY CONCERNING UP-DATING THE IRON GATES HYDRO GENERATORS

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***Abstract* – We will present a study referring to the PSS additional function that influence the Rat structure for a better statistical and transitional stability concerning up-dating the iron gates hydro generators**

Keywords: *additional signal, statically stability, transitorily stability additional signals1.*

1. INTRODUCTION

The main lead for the additional signals is to act optimal in the regulation of the excitation system improving a better quality of the transitional process that can appear after a perturbation, meaning a strong and fast deaden of the oscillations and growing the stability limits.
In practice it is obvious the importance in the removable generators case, connected through electrical long lines, also a less contribution for the smaller active loads for the shortest line or for no load regime.
One of the main preoccupations is to eliminate the low power oscillations and frequency for the numerical regulations, using supplementary signals: frequency, angle speed, electrical power, accelerated power, derived voltage, variation for the excitation current speed. It is important to settle a correct channel parameter within the additional signals after the study, concerning the generator ensemble behavior, the size and the importance that he has in the system, the working system. We recommend that the study to be made for the exploitation conditions and to verify permanently if the changes made in the zonal configuration are bring new configurations in the transport and distribution system.
It is known that for huge perturbations in the electroenergetical system he has an unlined character, eliminating the uncalled effects it is possible also using an unlined action. So, using the adapted regulators with additional channels can bring a better working for the transitional process by a huge oscillations deadening, growing the statistical stability limit for a capacitate load system without bringing the instability in the voltage of the generator. Are used the lowest amplitude signals for the less perturbations, and using huge signals for the growing perturbations, and for some cases even for an unconnected signals supplementary actions for RAT. For cases like those, using the supplementary signals can lead to an easy worsen to the system transitional stability for the first oscillation, and respectively to un corresponding variations to the voltage. To avoid these situations, for these working systems it is unconnected and laminates the supplementary signals by the detection integrated logistics from the numerical and control structure of the RAT.
The oscillations occurred in the power system are classify by there frequency:
- inter –area oscillations specific features for some subsystems linked through decrease electrical tool line, with a frequency domain between 0,1÷0,8 Hz;
- local oscillations regarding to some generators electromagnetic oscillations though the connected systems, characterized with a frequency domain 0,8 ÷2 Hz;
- power station or proximity stations inter plant oscillations, with a frequency domain between 1,5÷2,3 Hz, that are working linked towards the same system.
Their appearance is provided by unsuitable adjustment for the roused system, the power flow between this generators and system.
Supplementary signals are used also to the oldest generators (endow with direct current rotation roused systems) with a speed answer, that are still useful for some systems. The efficiency adjustment is bigger for the modern and static systems, equipped with numerical regulators in which are combined the supplementary signals that are using those advantages in way to obtain the final scope: classify deaden oscillation, between a frequency gang keeping a settled terminal voltage with normal limits.

2. ADDITIONAL SIGNALS TYPE USED BY RAT

The most used supplementary signals for RAT structure are those that are using the angle speed, frequency, electrical power and the speeded once. In this paper is presented a classify of those structures using additional signals, the advantages and disadvantages for each supplementary channels. According with the supplementary signals presented above, with a less applicability are presented some channels using: terminal voltage derivation, variation speed for roused current, measures of the intern angle for generators and the mechanical power, superior derivations for frequency without having an important applicability.

In the past, because of the technical complexity for this supplementary signals, for the voltage regulators structure it was used only one additional channel. The most used were: angle speed, frequency and later on the electrical power.

For transitorily phenomena the changes of angle speed explains the fact that the first additional signal used to deaden the oscillations it was a signal equal to the angle speed deviation. The transfer function used must compensate the delay introduced by the system roused in way to obtain an opposite phase couple with the angle speed. The delay is compensate with some anaphase circuits, more difficult to realized in practice. In using this speed signal the big disadvantage is the high level to the noise present in the measure signal. For the transfer function is used electrical filters. The filter elements had the disadvantage that introduced dead times that must by compensate. In the deadened frequency domain, the channel amplification for the angular speed is equal to RAT growing and is different to the oscillation frequency and with a time constant of the roused infrastructure. The out going signal for the angle speed channel it is limited before the sum point of RAT , in way to prevent the unwanted values of the terminal voltage, mostly for some areas: insularization,

The frequency signal can eliminate the disadvantages produced by using the angle speed, the noise being reduced. This signal is more useful to amortize the oscillations between subsystems or between the power station groups, then to amortize the local oscillations between the system and generator. The explanation is the fact that the voltage to the terminal frequency generator is considerate an relative junction for the domain of local oscillations frequency. This signal is limited and is unconnected through the voltage distortions till 10% of the nominal value and through the growing up frequency. Frequency measure has still a high sensibility through the system noises produced by some consumers (arc furnace), fact that limits some time the use of this additional signal for RAT structure.

The established of the electrical power signal or the accelerator power has the advantage that the local amortization of the local oscillations and between the power systems, having an reduced influence in the inter-area oscillations amortization with a low frequency. The measurement power of the voltage value and stator current eliminate the disadvantage produced by noise ant the tonsorial influence oscillation for the angle speed signal, and also the measurement of the frequency sensibility determined by RAT, for some big variations of the power gradient because of an unsuitable working for the turbine adjustment. Also, to the throwing load, for the insular regime or the reduced flow it is recommended to unconnected this supplementary channel because of the unlikely effects that can occur in the generator voltage stability.

The modern regulators use a combination between this supplementary signals. The practice results had been obtained using two channels with supplementary sizes: the angle speed ant the electrical power, the models use to modulate the rotor movement equation to calculate the accelerate power without a measurement for the turbine mechanical power.

During the long time using of the hydro generators in Romania, that represents more than 1/3 from the national installed power, it is on work to realize a program for the hydro power groups. Such a program is to be finish to the HHP/ Iron Gates 1, that has as an major objective the growing up the producing capacity from 175Mw/group to 194Mw/group, a larger domain for reactive power 70 MVAr to 94 MVAr, changing the excitation system ant the turbine voltage regulation with modern and numerical equipment's, that allow a better performance of the voltage and speed regulation system for a better and safely function for all the oscillations regimes.

The tests results had demonstrate an accurate adopted solution, the algorithms used and a better function of generator (his stability) for some different regimes.

3. THE FUNCTION IMPLEMENTATION STRUCTURE PSS TO THE MODERNIZED HYDRO AGGREGATE FROM IRON GATES

In the numerical RAT structure it is implemented a PSS function allow with the IEEE 421.5-1992 Standard. PSS function contains 2 channels: an deadened oscillations through the angle variation speed. The outgoing signal for U function it is used to the beginning of the system regulator and to the regulator wanted point.

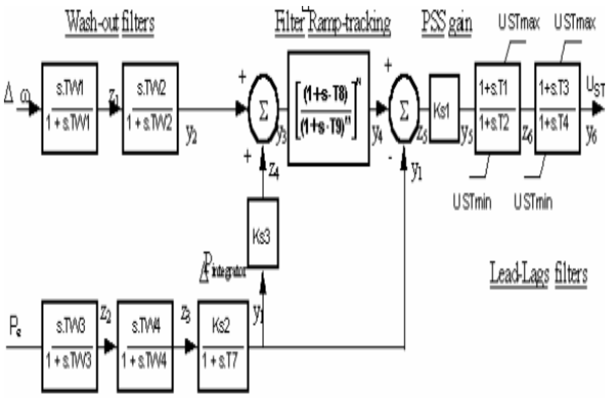

Figure 1. Computer representation of PSS type 2A, according IEEE Std. 421.5.1992

For oscillate regimes in isolated systems (insular regime), the PSS function in inactivated by a binary signal given from RAV automated installation. The insolated grid detection is realized by RAV if the frequency variation is out of the domain 49-51 Hz, the moment that RAV switches from power regulator to frequency regulator in way to keep the safety and stability of the whole system.

The mathematical equations for PSS 2A function from figure 1, that are describing the regime transitorily function in the linear model are:

$$z`_1 = T_{w1}^{-1} z_1 + \Delta\omega` \quad (1)$$

were $\Delta\omega` = v`_1$

$$y`_2 = T_{w2}^{-1} y_2 + z`_1 \quad (2)$$

$$y`_3 = y_2 + k_{s3} y_1 \quad (3)$$

$$z`_2 = T_{w3}^{-1} z_2 + P`_e \quad (4)$$

were $P`_e = v`_2$

$$z`_3 = T_{w4}^{-1} z_3 + z`_2 \quad (5)$$

$$y`_1 = T_7^{-1} (k_{s2} z_3 - y_1) \quad (6)$$

$$y_5 = k_{s1} (y_4 - y_1)$$

were $z_5 = y_4 - y_1$ (7)

$$z`_6 = T_2^{-1} ( y_5 - z_6 + T_1 y`_5) \quad (8)$$

$$y`_6 = T_4^{-1} ( z_6 - y_6 + T_3 z`_6) \quad (9)$$

The mathematical function for torsion filter are based on the standard filter configuration "Ramp Track", with M=5, N=1. From here the transfer function for the filter is given within the equation:

$$y_4(s) = \frac{1 + sT_8}{(1 + sT_9)^5} \; y_3(s) \quad (10)$$

The transfer function for the amortization filter of the torsion oscillations has the 5 the ordain in way to reduce the calculations:

$$y_4(s) = \frac{1+sT_8}{1+sT_9} \cdot y_{31}(s) \cdot \frac{1}{1+sT_9} \cdot y_{32}(s) \cdot \frac{1}{1+sT_9} \cdot y_{33}(s) \cdot \frac{1}{1+sT_9} \cdot y_{34}(s) \frac{1}{1+sT_9} \cdot y_3(s) \quad (11)$$

Resolving the equation above we obtain the mathematical expression for the torsion filter, using the intermediary variable:

$$y`_4 = T_9^{-1} ( y_{31} - y_4 + T_8 y`_{31}) \quad (12)$$

$$y`_{31} = T_9^{-1} (y_{32} - y_{31}) \quad (13)$$

$$y`_{32} = T_9^{-1} (y_{33} - y_{32}) \quad (14)$$

$$y`_{33} = T_9^{-1} (y_{34} - y_{33}) \quad (15)$$

$$y`_{34} = T_9^{-1} (y_3 - y_{34}) \quad (16)$$

The stationary regime values are given by the next relations:

$$\Delta\omega_0 = \omega_{co} - \omega_0 \quad (17)$$

$$y_{10} = k_{s2} z_{30} = k_{s2} P_{e0} \quad (18)$$

$$y_{40} = 0 \quad (19)$$

$$P_e = P_{e0} \quad (20)$$

$$y_{30} = y_{20} + k_{s3} y_{10} = 0 \quad (21)$$

$$y_{50} = k_{s1} y_{10} = y_{60} \quad (22)$$

The constant values (in seconds and relative unit) for the mathematical model are:

P-lolim = 0,1 (23)

U_{ST}-uplim = 1,1 (24)

U_{ST}-uplim = 0,9 (25)

Tw1 = Tw2 = Tw3 = 2 (26)

Tw4 = 0 (27)

T7 = 2 (28)

T8 = 0,2 (29)

T_9 = 0,1 (30)

Tl1 = 0,12 (31)

Tl2 = Tl4 = 0,04 (32)

Tl3 = 0,36 (33)

Ks1= 10 (34)

Ks2= 0,33 (35)

Ks3= 1 (36)

The PSS function is used to assure a high statically stability to obtain a deadened of the grid power oscillations by modulating the generator excitation response. PSS function effects in the static regime it is represented in the figure2, the power oscillations are almost eliminated.

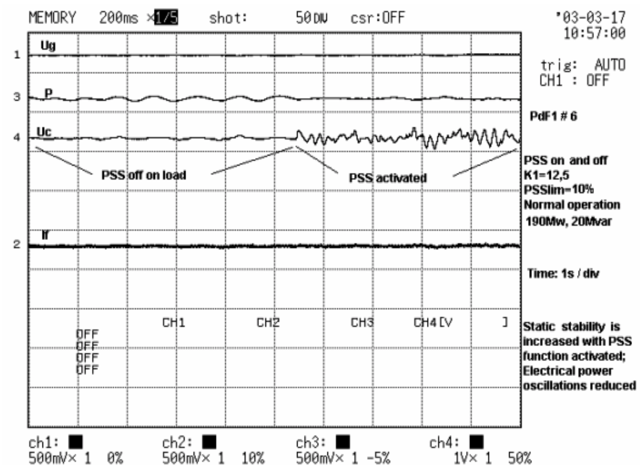

Figure 2. PSS statically stability influence in stationary regime

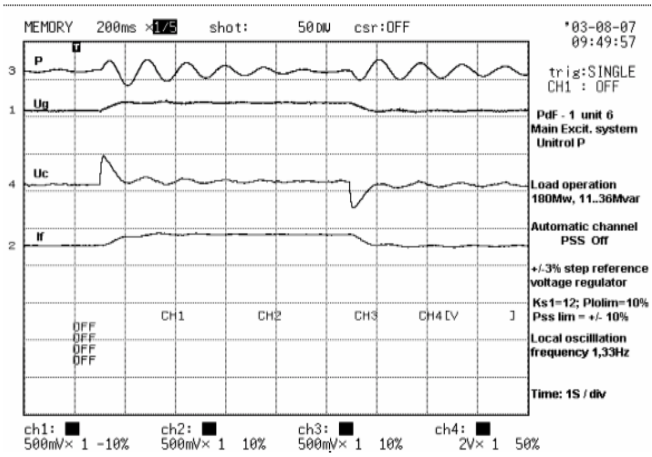

Figure 3. Load work in the transitorily regime with the PSS function

The recordings present a final result of the testate procedure from how we can observe the significant reduced number and electrical power oscillations deadened using RAT with an active PSS function. The test was made simulating some positive and negative oscillations referring to RAT and recording those transitorily response to the roused system load function.

A analyzed method of the low oscillations is the frequency response.

In the 5 figure it is represented the Bode frequency characteristically response diagram (amplitude and phase) to the open and close loop for the optimized roused system from Iron Gates.

The modernized roused system from Iron Gates 1 is characterized by some parameters values, performance index in the transitorily regime.

Vo parameter represents the gain for continuous current of the roused system.

Ts- the establish settling time to the terminal voltage after a oscillation around the final established value.

The index parameter: phase margin, amplitude and deadened shows the corresponding adjustment for the settled RAT parameter, fact confirmed by the practical results obtained in the recordings.

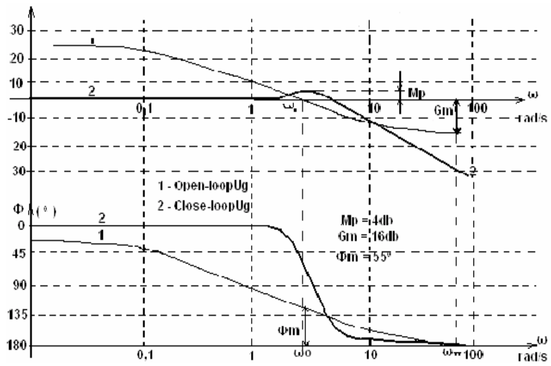

Figure 4. No loaded operation frequency characteristic

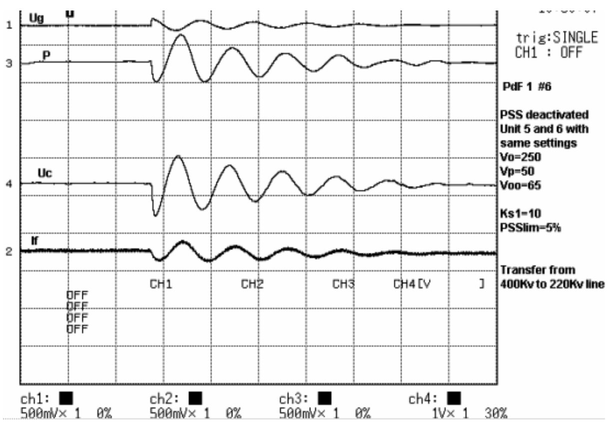

Figure 5. Load operation –Frequency responses graphic

We can see that the established reserve much better then for PSS activate case, effectuated to a nominal load with a low reactance (over-loaded power grid, established).

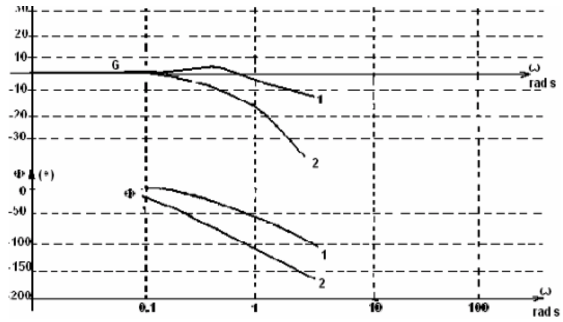

Figure 6. Load operation – Frequency responses characteristic; 1 – compensates plant phase; 2 – uncompensated plant phase

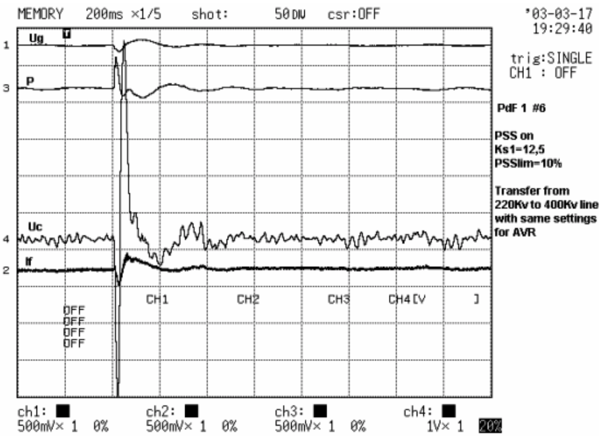

Figure 7. – The transfer couple from 220 kV in function with the activated PSS

Those diagrams represents the final results to the frequency response for low oscillations signals, in way to established the statically stability generator system – the analyzed routed system.

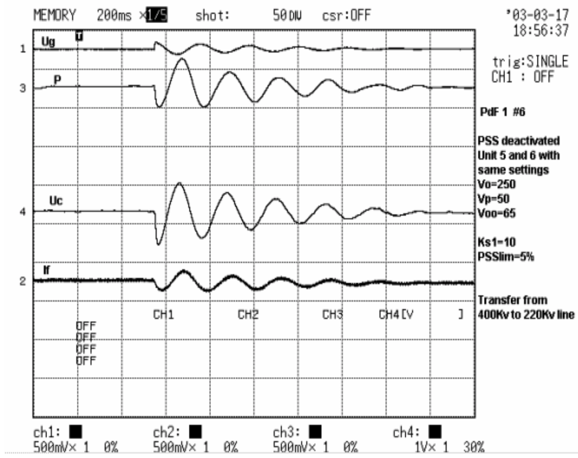

Figure 8. The transfer couple from 220 kV in function with the inactivated PSS.

The stability analyze take into account the connected generator to the extern network, in our case the extern reactance measured value 1,176 pu X_e is reduced and confer a growing stability of the reactive power for our system.
The values are presented in the figure 3 and 4, and also the excitation response of the frequency system for small perturbation are showing an ensuring and establish behavior for the normal functional regime, the regulator parameters being very well optimized. The average perturbations for our energetically group are those perturbations that can appear in to the system for some distance to the place that it is found our group and can be caused by: connections/unconnected of the biggest consumers, to the unconnected lines, to the unleashed for the high power of the energetic groups. The voltage regulator for our group keeps a established function of the generator in the functioned regime for those small and average tips out of order . An example in that way is offered by the connected test / unconnected transfer couple for the 20 kV/ 400 kV auto transformer in the Iron Gates 1.
Those tests have been effectuated allow with the behavior verification for the PSS included RAT to the transitorily regime, for an
184 Mw active power, means a 95 % for the active nominal power. According with the RAT response we can observe an positive influence (the reduced amplitude and number for the electrical power perturbations) in the case that PSS is activated (figure 7) to the transfer level 220 kV to the 400 kV system, through the situation in witch the PSS function in inactivated (figure 8). A better functional stability is offered with the RAT supplementary signals, the static voltage oscillations are quickly amortized. In the 7 figure we can observe a worsen behavior of the stability through the growing up amortized oscillations (almost 5) and the time for the 5 second in way to establish the defect previous value of the voltage, compare to the figure 12 where the PSS and RAT intervention it was a 2 second oscillation.
Established the RAT behavior for the insularizated transitorily regime had been considerate one of the practical for the modern excitation systems for an formatted island for some generator group, a transport line 400 kV (150km) and an 130 Mw consumer including some electrolyze electrical furnace for the Slatina works.
The static voltage deviation to the generator terminal had been 0,3 kV, that mean 2 % for the nominal value witch are 15, 75 kV. It is an negligible value according the fact that the excitation systems standards include a 10% maximal deviation by the transitorily regime, keeping a functional stability of the generator. This maximal deviation take place to the unloaded probe with about 53 % and loading the load with about 64% in the Slatina junction consumer, the registered probe is represented in the figure 9.

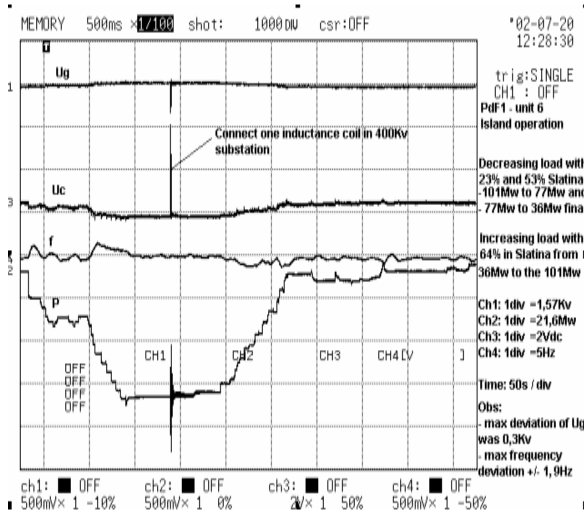

Figure 9. Transitory response to –23%, -53% unload, 64% loaded in Slatina

Analyzed the command voltage wave Uc from the outgoing RAT we can see that the PSS function had been blocked in all the probes by a extern binary signal for the isolated plant detection. (given by RAV to the $\Delta f > 1$ Hz detection), in way to prevent a uncoresponding function to some growing up frequency oscillations determinate by the load variations from the transitorily regime from island.
Concluded, the modernized excitation system had a better regulation, having a calibrated dynamical behavior during the tests, keeping a functional safety of the hydro generator .
The test results had demonstrated the accurately of the adopted solutions, of the used algorithms and also a better function of the generator (his stability) for some functional regimes.

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