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Excitation System Type ST1 for a Synchronous Machine

[1]Yoram Astudillo-Baza , [2]Saraín Montero-Corzo, [3]Nayeli Ramón-Lara
[1,2,3,]*Instituto Politécnico Nacional. ESIME Zacatenco*

ABSTRACT

This paper presents the behavior of a synchronous machine with a excitation system type ST1 during load variations and short circuit. A test system of machine bus-infinite is used, where the synchronous machine is connected to an infinite bus through external impedance.

Keywords - *Electric Power System, Regulator of Voltage, Short Circuit, Synchronous Machine, Excitation System Type ST1***.**

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I. Introduction

An electric power system works efficiently, if the system contains several machines working in parallel.The connection of synchronous machines in parallelrequiredthat the generators have concordance of phases, the same frequencyand the same terminal voltage. To comply with these requirementsequipment is requiredthat regulates the speed, the powerand terminal voltage.

It is well known, that the control system generator excitation it means an effective and lost cost to improve the stability of the power system. Recent advances in control theory and digital technologysuggestan extension of the results obtained through analog controlto derive potential improvements with the use of digital control[1].

An excitation control system is a feedback control system which includes the synchronous machine and excitation system and an excitation system is defined as the source of the field current for exciting a synchronous machine [2]. Since 1981 the IEEE published a way to identify excitation systems, and based on these documents, the following types of excitation systems mentioned.

The excitation system type ST, it is a static excitation system and can be classified according to the following types: ST1, ST2 and ST3 in these systems the excitation power is suppliedthrough transformers and rectifiers.These systems use transformers to bring the voltage to an appropriate level andcontrolled or uncontrolled rectifiers, provide direct current required for the generator field [3].

II. Excitation System Type ST1

The excitation system type ST1 also called controlled rectifier exciter with potential source [3], intended to represent all systems in which the excitation power is supplied through a transformer or a generator terminalsand regulated by a controlled rectifier.The maximum excitation voltage available for such systems is directly related to the terminal voltage of the generator.

In this type of system,the exciter time constant is very small and requires no stabilizer excitation system. Moreover, we are to reduce the transients gain. The model presented in this paper is versatile enough to represent the transient gain reduction, implemented either direct linkthroughT_B and T_C (where $K_F$takes the value of zero). It is needed for this case a suitable choice of the ranges of feedback parameters K_F and T_F.The gain of the voltage regulator and any inherent time constant of the excitation system are represented byK_A and T_A.

In many cases the internal limiter that this is discarded after the summation point. The field voltage limits are a function of the terminal voltage, except when the exciter is fed from an auxiliary bus and current field of the generator.

This type of excitation systems employ a bridge fully controlled, the model also applies to semi controlled systems, in such cases the negative limit is set to zero.

Examples of the excitation system type ST1 [2]:

1. Canadian General Electric Silcomatic Exciters.
2. WestinghouseCanadaSolidState Thyristor Exciter.
3. Westinghouse Type PS Static Excitation Systems with type WTA.

The excitation system used is a rotary type; this system is represented by the following differential equation:

$$TxpV_f = u - V_f \qquad (1)$$

The voltage regulation system used in this article, it is the regulator type ST1 proposed by the Committee on modern excitation systems. Considering that the time constants of the potential transformersto condition the terminal voltage signal at appropriate levels they are of the order of0.0001seconds, in this article are depreciated.

In this type of system, the voltage limit is proportional to the voltage generated, for this reason it is not considered the effect of saturation of the exciter.

To obtain the equations of state of excitation - regulation system, one starts the block diagram of theFig. 1which represents this regulator.

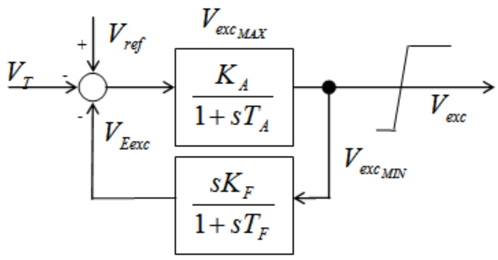

Fig. 1 Block diagram of the regulator type ST1.

Therefore, the equations are:

$$T_A pV_f = K_A (V_{ref} - V_T - V_{Eexc}) - V_f \qquad (2)$$

$$T_f pV_{Eexc} = K_f pV_f - V_{Eexc} \qquad (3)$$

In all cases:

$$p = \frac{d}{dt}$$

The way to tune the regulator is to apply a small signal when the generator is in open circuit [4]. The unitis carried the nominal voltage and in the reference voltage applies a small step, for this case have been found in publications that the step size is the 1 to 5% [5].

III. Mathemathical Model

The mathematical model that represents the synchronous machine is as follows [1]:

$$p\delta_r = \omega_0 s \qquad (4)$$

$$Mps = -K_d s + Tm - Te \qquad (5)$$

$$T'_{d0} pe'_q = V_f - (X_d - X'_d) i_d - e'_q \qquad (6)$$

$$T''_{d0} pe''_q = e'_q - (X'_d - X''_d) i_d - e''_q \qquad (7)$$

$$T''_{q0} pe''_d = (X_q - X''_q) i_q - e''_d \qquad (8)$$

Where

$$e''_d = V_d + r_a i_d - X''_q i_q \qquad (9)$$

$$e''_q = V_q + r_a i_q + X''_d i_d \qquad (10)$$

$$Te = e''_d i_d + e''_q i_q - (X''_d - X''_q) i_d i_q \qquad (11)$$

Without loss of generality, the transmission line is described by an equivalent impedance of Thevenin. Therefore, the terminal voltage and its components in direct axis and quadrature axis they are the following [1]:

$$V_d = V_\infty Sen\ \delta_r + r_e i_d - X_e i_q \quad (12)$$

$$V_q = V_\infty Cos\ \delta_r + r_e i_q + X_e i_d \quad (13)$$

$$V_T^2 = V_d^2 + V_q^2 \quad (14)$$

The speed governor it is the type mechanicalhydraulic, the model is idealized, because it is not considering the limiter valve positionand neither the transfer function describing the speed relay, it is solely depicted by block (b) of the Fig. 2.

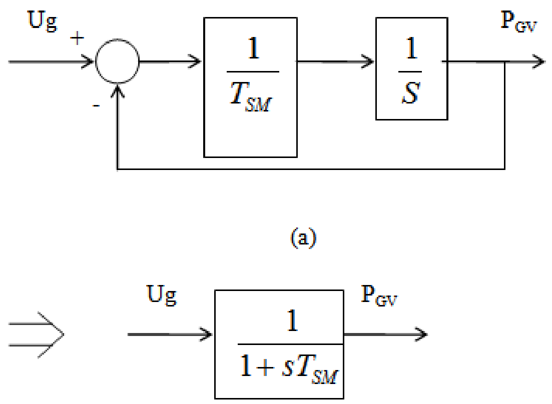

Fig. 2 Block diagram of the hydraulic mechanical speed governor.

In the case of the turbine, simple thermal modified reheating turbine is used. Is used only the turbine governor model with the basic elements necessary, for perform the functions of increase and decrease active powerby manipulating the entrance to the governor$U_g$without making control over the primary loop. Therefore, a more detailed discussion of the system is not required. So, the set of differential equations describing this system are as follows [1]:

$$T_{SM}\ pP_{GV} = U_g - P_{GV} \quad (15)$$

$$T_{CH}\ pP_{HP} = P_{GV} - P_{HP} \quad (16)$$

$$T_{RH}\ pTm = F_{HP}\ pP_{HP} + P_{HP} - Tm \quad (17)$$

IV. Simulation

For purposes of the simulation, we have the following considerations:

The transients in the circuit of the stator and the effect of damping windingsare omitted.A mathematical model of 5th order is used for the representation of the synchronous machine.When the excitation system ST1 is used, the system has to be tuned to compare your answer.

For the voltage regulatorinto the system machine infinite buswe have the following considerations:
The time constants T_B y T_C they are very small and are omitted and to the corresponding block it is considered the unit [3].The limiter that this after the summation point is omitted [2].The limiter of voltage it has the following values6.0 per unit until 6.0 for unit.

For the model of the transmission line, this simply is described for an impedance equivalent [1].

Table 1. Data of the Low System Prove

Variable	Value	Variable	Value
ω_0	377	X_e	1.1
M	5.5294	r_e	0.12
K_d	3.0	T_{SM}	0.1
T'_{do}	5.66	T_{CH}	0.15

T''_{do}	0.041	T_{RH}	5.0
T''_{qo}	0.065	F_{HP}	0.33
X_d	1.904	K_A	400
X'_d	0.312	T_A	0.02
X''_d	0.266	K_F	0.008
X_q	1.881	T_F	1.0

For the governor and turbine system, a steam turbine of simple overheating is using and employs an electrohydraulic governor [1].Besides that, the governor is controlled by the entryu_g.
To represent increases or decreases of loadis simulated that the mechanical torque moves the control of the governor; this varies the steam turbine and therefore increases or decreases the speed.
The data for voltage regulator ST1, of the transmission line, the speed governor, the thermal turbineand the synchronous machine (generator of 645 MVA) they are shown in the Table 1 [1], all data are expressed in for unit.

V. Test And Results

Is applied to the system machine bus infinite with regulator type ST1 the test of short-circuit. The initial point of operationthat is used in this test is of a terminal voltage$V_t=1\angle 7^o$ in forunit for the following 2 cases of failure.

Case 1. Fault to the one seconds with tree cycles of duration.The time when the short circuit occurs is in one seconds and is carried the bus voltage to 0.1 for unit.

The results for this case are shown in the following figures. The angle of load of the rotor Fig. 3, the active power Fig. 4, the reactive power Fig. 5, and the voltage in terminals Fig. 6.

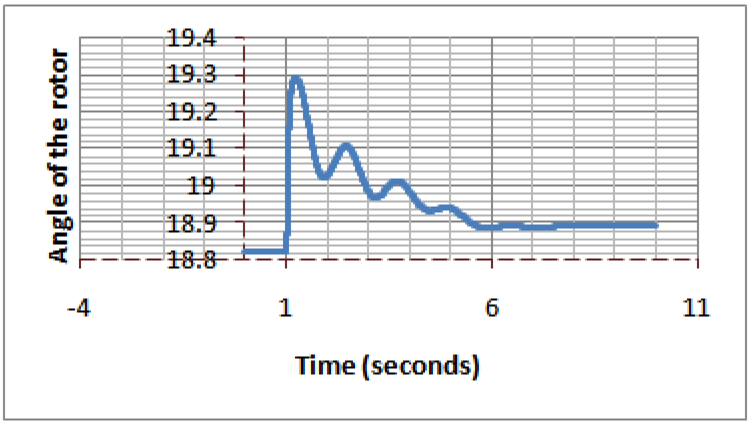

Fig. 3 Response of the rotor angle.

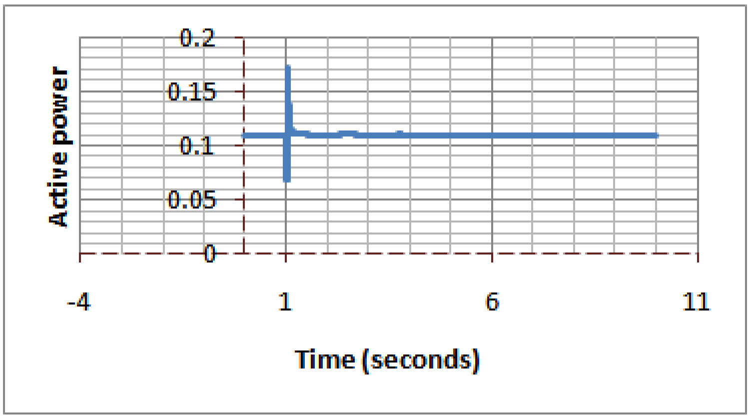

Fig. 4 Response of the active power.

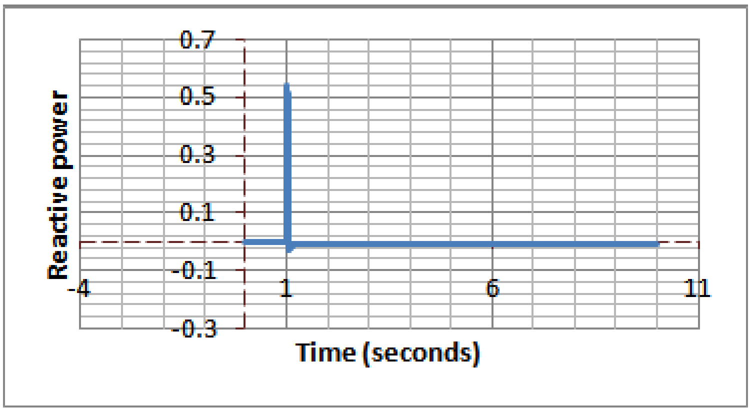

Fig. 5 Response of the reactive power.

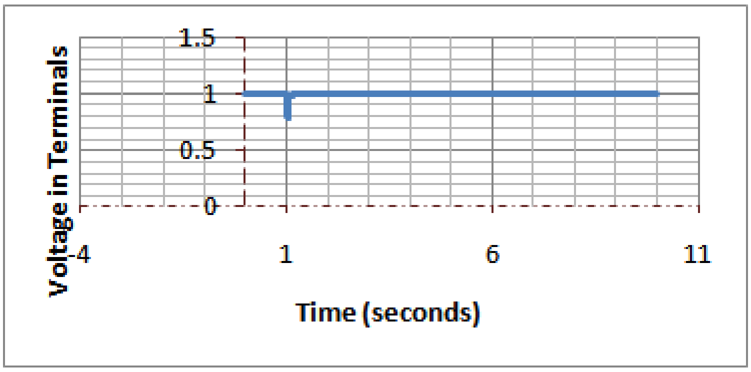

Fig. 6 Response of the voltage in terminals.

The voltage in terminals in this test in the moment of the fails suddenly lowtheir value, after that the fault is released, the control through the field voltage makes that the voltage in terminals returns to the reference value.

Case 2. Fault to the one seconds with six cycles of duration.The results for this case are shown in the figures 7, 8, 9 and 10.

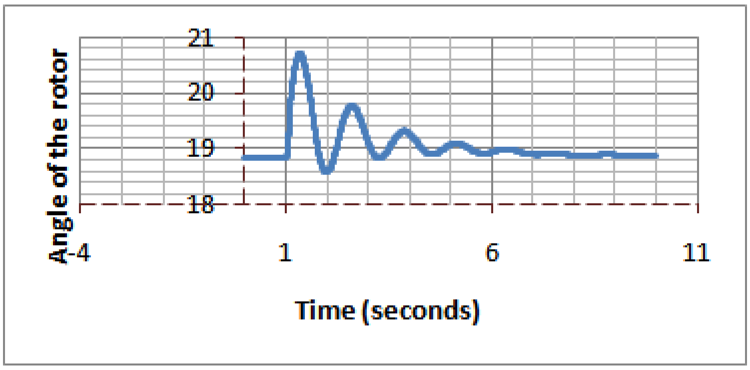

Fig. 7 Response of the rotor angle.

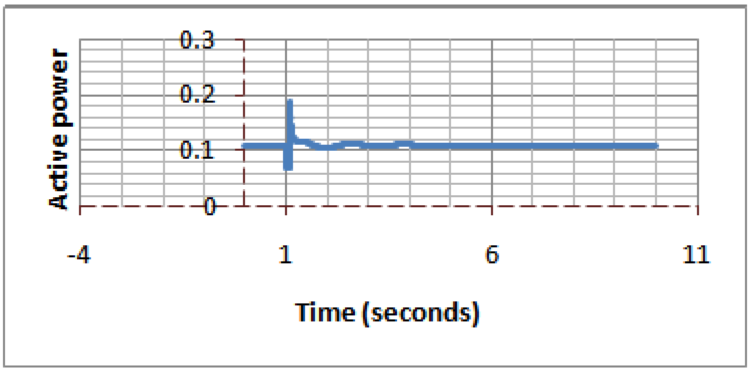

Fig. 8 Response of the active power.

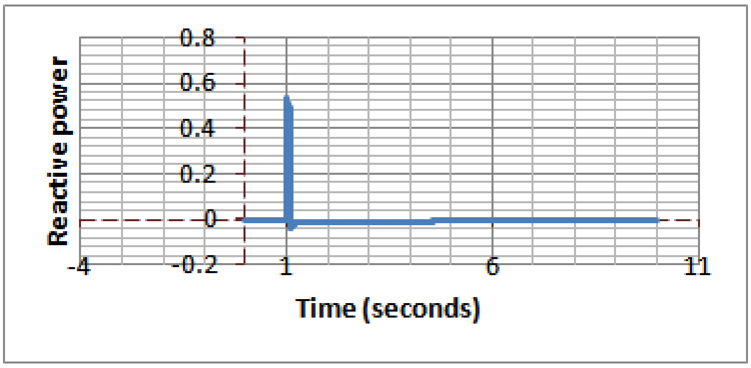

Fig. 9 Response of the reactive power.

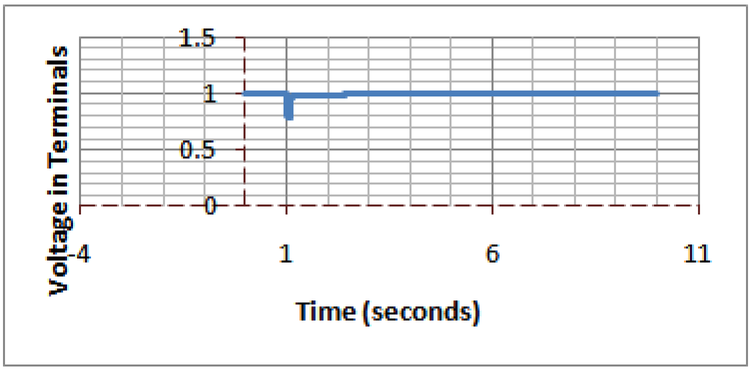

Fig. 10 Response of the voltage in terminals.

VI. Conclusions

In the test system, was proposedan excitation system type ST1 connected to an infinite busthrough a transmission line, which has the function of regulate voltageof the synchronous machinecausing thevoltage in terminalsto the reference voltage.

The excitation system tested presented a good performance under fault conditions but as shown in the figures, the system takes to return to the reference value.

With the help of modern digital control technology can be obtained a better potential stability of a power system even under load increments produced in the transmission line.

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Authors

YoramAstudilloBaza. M.Sc.in Electrical Engineering from SEPI-ESIME-IPN, Mexico in 2005. Nowadays is a Professor in mathematics from the Electrical Engineering Department in ESIME- Zacatenco. The interest areas are Analysis and Control of Electrical Power Systems, Electrical Machines, Intelligent Control, Renewable and no-Renewable energy sources.

Saraín Montero Corzo. M.Sc. in Electrical Engineering from SEPI-ESIME-IPN, México in 2006. ElectricalEngineergraduatedfrom Instituto Tecnológico de Tuxtla Gutiérrez, México in 1998. Nowadays is an associated professor at ESIME-Zacatenco. The interest areas for him are Electrical System analysis for Power and Distribution, Power Electronics and Energy Quality.

Nayeli Ramón Lara. Is an associated professor at the ESIME-IPN. M.Sc. in Electrical Engineering at SEPI-ESIME-IPN in 2006. Electronics and Communications engineer graduated from InstitutoTecnológico y de EstudiosSuperiores de Monterrey in 2002. The interest areas for her are, Electrical Machines Control, Power Electronics and Education.