MODELLING TECHNIQUES AND TUNING IN EXCITATION SYSTEMS FOR DYNAMIC REPRESENTATION

J SALINAS. and JESÚS R PACHECO P
Department Industrial Technology.
Universidad Simón Bolívar – Sede del Litoral.
Baruta, Estado Miranda, Postal Code: 1080-A, Post Office Box: 89000.
VENEZUELA

Abstract: - The performance of the excitation system can have a great influence on the stability of a power system. However, it depends mainly on parameter setting of the excitation system. Proper parameter setting of the excitation system can improve the stability and increase the damping of the power system. On the contrary, improper parameter setting of the excitation system can deteriorate the operation of the power system. In many countries, there are clear criteria for the dynamic performance (including large signal performance and small signal performance) of the excitation systems. In simulating a power system, there exist several problems about the parameter setting of the excitation systems: In stages of planning and designing of a power system, models and parameters of the excitation systems for the new generators may not be known, therefore, it is necessary to determine the models and the parameters of the excitation systems**.** The present paper is the result of a critical analysis, which will guide us to a good dynamic representation of the excitation systems in generating units, necessary for a realistic simulation of transients phenomena of electromecanics nature that define the power system stability. Verify the precision of the models used, beginning with a program of field tests of the excitation systems, in order to adjust them to reality.

Key – Words:- Simulation and test, excitation systems, dynamic representation realistic.

1 Introduction

The dynamic simulation studies in Interconnected System began many years ago using representative parameters for excitation systems supplied by manufacturers and experienced annalists. A good representation of excitation systems in generating units is indispensable if is wished a realistic simulation of the transients phenomena of electromecanics nature that define the power stability system. As a logic step for the evaluation of the digital simulation studies of the system, it was considered necessary verify the precision of the models employed. This evaluation began with a field test program of the most representative excitation systems, with the goal of adjusting the models to reality. The main thrust of the dynamic tests performed centers around small signal step responses and frequency responses of the excitation system. From these tests it is possible to model the linear characteristics of the system which make up the bulk of the computer model. Gains and time constants of the exciter and regulator can be obtained readily from offline response data. While running a unit offline at rated speed and voltage, a small step input is placed into the reference of the voltage regulator. The response of the generator terminal voltage is recorded. In this test program the excitation systems was externally disturbed, and the excitation voltage time response and the terminal voltage time response in generating units were oscillographly registered. Subsequently, the digital test was simulated changing the system parameters, until a correspondence in accord with the field test simulation was found. Before the process of comparing the estimated model to the test data can begin, it is first necessary to have a good model of the generator and the rotating exciter (if present). This means good test data for both machines, including reactances, time constants, and saturation characteristics must be available.

Once the data for the model have been completely assembled, it is then possible to begin simulations of the tests performed on the actual equipment, namely the offline step and frequency response tests.

Comparison of step response qualities such as rise time, overshoot, and settling time, as well as the frequency response plots, defines the level of agreement between the model and reality. If the responses do not agree well, the model parameters must be adjusted. Control theory techniques such as root locus are invaluable to understanding which parameters need adjustment. In this paper only show comparisons of step time responses between test data and simulation for the cases considered to be good matches.

2 Models used in the dynamic simulation of excitation systems.

Many models had been developed for the excitation systems, that simulate faithfully the differents excitation systems of the Interconnected System. In this work, will be only considerated the fallowing normalized models.

2.1 IEEE 1. Excitation systems of continue action in time.

In the blocks diagram show en the fig 1, corresponding to this kind of excitation, the first transfer function use a time constant TR, which represents the associated delay to the voltage transductor. This constant is small, almost zero (0) in many systems. Next, there exist first adder, which compare the reference voltage with the transductor output voltage and determines the voltage error applied to the regulator amplifier. Immediately, it is found a second adder that combines the voltage error with the damping signal of the excitation system. Finally, the regulator transfer function can be seen.

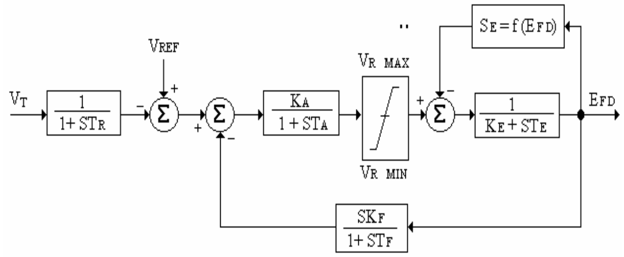

Fig 1. Excitation system of continuous action in time. Type IEEE 1.

The regulator output is compared in another adder with the exciter unit saturation function SE = f (EFD), noting that the excitation voltage EFD is multiply by a non lineal function. The result of this comparison is applied to the exciter transfer function, where the blocks diagram of the system has a feedback loop that goes from the exciter unit output (EFD) to the second adder, and allows damping the excitation system behavior.

2.2. IEEE 1S. Excitation system with controlled rectifier.

This kind of excitation system, show in the fig 2, is the most used at the present time, and represents the static systems that contain controlled rectifier (SCR). The response of this kind of system is fast, but with a maximum voltage proportional to the generator unit terminal voltage. EFD MAX = KP * VT

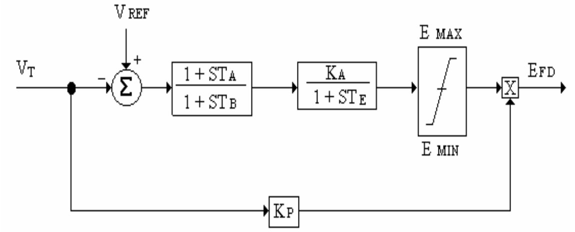

Fig 2. Excitation system with controlled rectifier. Type IEEE 1S.

2.3 IEEE 2. System with rotary exciting unit and rectifier.

In is this system, the damping loop is obtained from the regulating unit output, and the transfer function includes another time constant. The others features are similar to the ones found in IEEE 1.

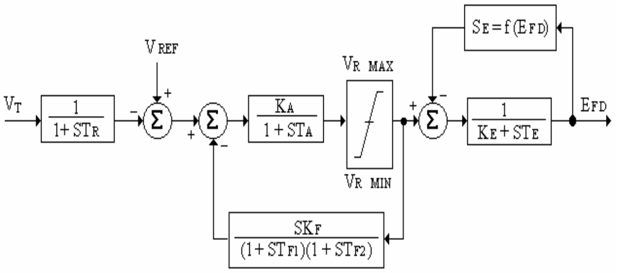

Fig 3. System with rotary exciting unit and rectifier. Type IEEE 2 .

2.4 IEEE 3. Static excitation system with current and voltage feeding.

This system represents some of the static systems employed in gas turbines. In the fig 4 is show. The excitation system is feed with current and voltage in the generating unit terminals. The adder located next to the first limiter, combines the regulating unit output with the representative signal of the self-excitation from the generator unit terminals.

KP is the proportionality coefficient between the component of the excitation voltage derived from the voltage transformer and the generating unit terminals voltage. KI is the proportionality coefficient between the component of the excitation current derived from the saturable transformer and the generating unit armature current. The multiply MULT considers the excitation voltage variations with the IFD changes. The limiter VB MAX limits the excitation system output to zero (0) if A > 1, that is to say, when the field current is greater than the maximum excitation current. The transfer function 1 / (KE + STE) represents the exciter unit and the transfer function SKF / (1 + STF) allow to damp the dynamic behavior of the excitation system.

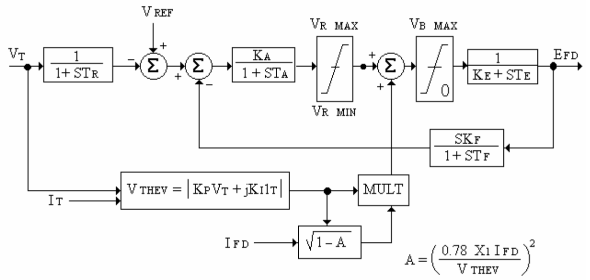

Fig 4. Static excitation system with current and voltage feeding. Type IEEE 3.

2.5 IEEE 4. Excitation system of discontinuous time action.

This representation, see fig 5, is particularly used for those systems preceding the development of the continuous time action systems. These systems response to two different velocities, depending of the voltage error magnitude. This excitation system actuate depending of the error type and the excitation source (regulating unit), and will act as the diagram shows. For big errors, the contact KV, whose function is to insert or to remove resistances, will actuate in such a way that a strong signal to the exciting unit will be applied. For small errors, a rheostat operated by an engine, is adjusted, and then, it will increase the voltage gradually (VRH). The definition of these parameters follows; KV = Contact which inserts fast action resistances (up or down), VRH = Voltage of the field rheostat. It is limited between VRH MAX and VRH MIN, TRH = Time delay of the field rheostat.

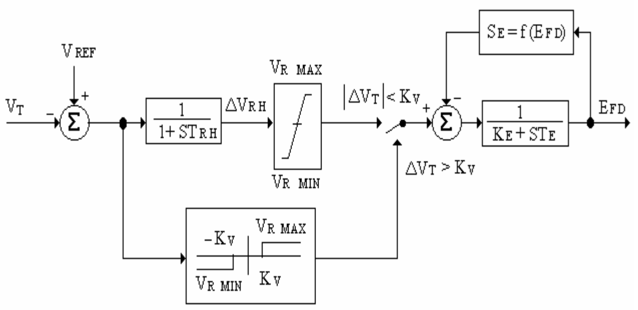

Fig 5. Excitation system of discontinuous time action. Type IEEE 4.

3. Field test to determine the response in time of an excitation system.

The principle used to create the excitation systems test is to apply a step disturbance to the generating unit, registering the voltage variations. There are many way to perform this test. Following, it will be shown some of them :

3.1 Method of the variable autotransformer directly feeder from the generating unit terminals.

This test method, show fig 6, uses a variable autotransformer connected to the secondary of the potential transformer, which is located at the generating unit output, and takes a sample of the voltage in the generating unit terminals. The steps for its realization are the following:

a) When the regulating unit voltage is found in automatic position, one proceed to adjust the variable autotransformer voltage to make it equal to the secondary of the potential transformer unit, with the purpose that the unit do not register any disturbance in its input signal when the contactor changes to the autotransformer position,

b) From this moment, the regulating unit input signal is directly controlled by the variable autotransformer; therefore, it will be possible to perform a voltage variation in this input signal, so as “to trick” the voltage regulating unit.

c) By pressing again the contactor to its initial position, the voltage regulating unit will captivate the existent difference voltage, which will be equal to the voltage difference in the secondary of the potential transformer and the voltage at which was adjusted the autotransformer. In this moment, it is registered in an oscillograph the variation in time of the field voltage (EFD) and the unit terminal voltage (VT).

3.2 Test method arranging the variable autotransformer feeder of an external voltage source.

This method uses the same principle that above, but in this case, the variable autotransformer is feeder from an external voltage source, and its output is connected to the secondary of the potential transformer in the regulating unit input. See fig 7. With this method it is normally found closed contacts in the secondary of the potential transformer and normally opened contacts at the autotransformer output. This contacts are activated by means of a contactor. Activating the contactor and changing the autotransformer voltage output, so as to obtain a voltage equal to the generating unit terminals, one pass to control directly the regulating unit input with the autotransformer cursor. Next, the regulating unit input voltage may be varied and the contactor pressed again, until the value at which it has been adjusted is found. At this moment, the variables (VT) and (EFD) are registered.

3.3 Test method using a variable resistance connected in series with the secondary of the potential transformer.

This method use a variable resistance connected in series with the secondary of the potential transformer and it is coupled to this one by means of a contact, just as it the show the fig 8. Like the preceding cases, it is wished to change the input voltage to the regulating unit by means of the resistance, and later by means of the contact "to trick" the regulating unit so to adjust the voltage value to the initial value.

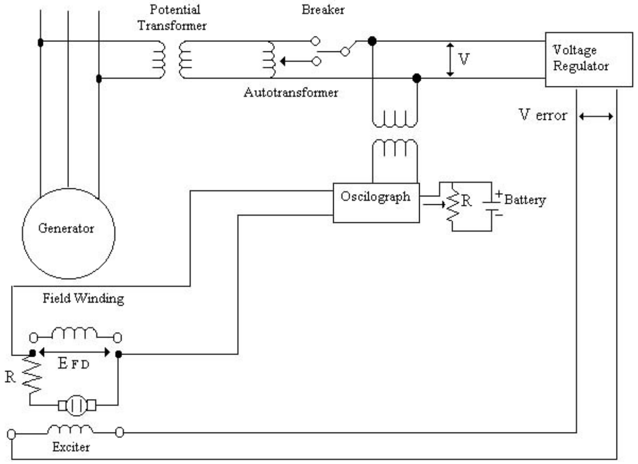

Fig 6. Method of the variable autotransformer directly feeder from the generating unit terminals.

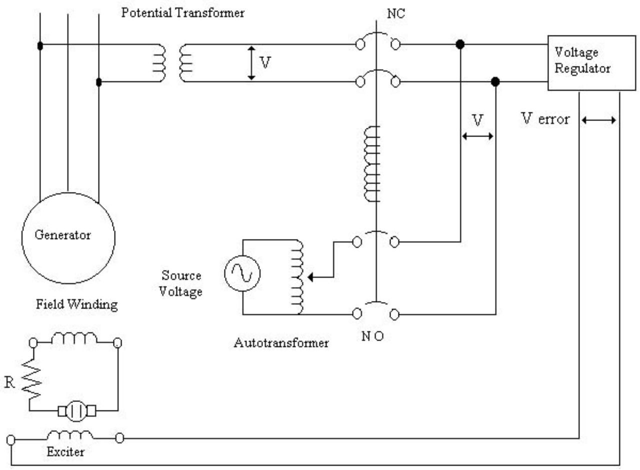

Fig 7. Test method arranging the variable autotransformer feeder from an external voltage source.

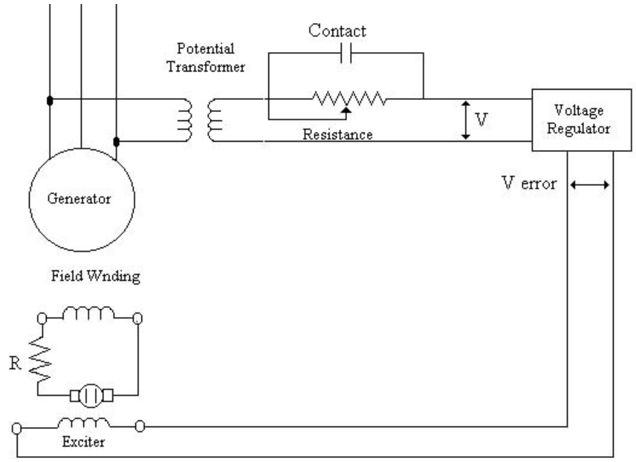

Fig 8. Test method using a variable resistance connected in series with the secondary of the potential transformer.

4. Results obtained from the field test.

The results obtained from the field tests realized in many regulating units, showed a great responses diversity, opposite to what it was waited. A considerable amount of units showed deterioration, that ranged from lack of regulation in the excitation system, until very slow responses, in the order of 20 to 30 seconds, which shows deterioration and/or misadjusting of the equipment. As a consequence of these tests, the necessary correctives measuring are been taking to repair these abnormalities, noting that the transitory response of a power system are adversely affected by an incorrect response of the excitation systems of the generating units.

The rest of the units gave satisfactory results, due that the response times of the excitation systems were found inside of a waited range in each one of them.

Examples of digital simulation and the corresponding oscillographics record, are shown in the figures 9 up to 14.

5. Typical constant of the excitation systems.

Between the excitation systems that exist today in the market, there is a great variety of models. In spite of their differences, the philosophy used in each one of them, allows to group them, and as a consequence, to normalize them inside some limits of gain and time constants, which later will be employed in digital simulation. This typical constants have grand utility as initial values, and making them variate until the representative constants to each type of excitation system are finally obtained that it is wanted to be modeled in agreement to the field tests.

It can be asked: Why is it not measured or directly determined all of these constants in each one of the excitation systems ?. These measurements can be performed with some simplicity only in those systems which present voltage regulating units based on thyristors, due that the regulating unit is exclusively formed by solid state components. This is what is presently made, and based on these measurement, small adjustments during the digital simulation are made:

a) Step type single-phase disturbance in the feedback signal of that automatic regulating units of potenciometric type, or with magnetic amplifiers, which accept only single-phase input signal.

b) Step type three-phase disturbance in the feedback signal of the automatic regulating units of potenciometric type, or with magnetic amplifiers, feeder with a three-phase signal.

c) Step disturbance in the reference signal of the solid state excitation systems.

d) Step disturbance by current in potenciometric excitation systems, or that employ magnetic amplifiers.

A voltage transductor that allows to transform electronically the alternating signal coming from the generating unit potential transformer in an easy registered continuous signal.

A variable three-phase autotransformer to insert a three-phase or single-phase disturbance to the feeding voltage of the automatic voltage regulating unit.

A measurement transformer used to isolate the potential transformer circuit of the generating unit to the electronic measurement circuit.

A feeding transformer, power source and contacts.

6. Test to achieve.

6.1 Off-Line Step Response of Automatic Voltage Regulator System test with manual regulation.

For the elaboration of this test it must be injected a voltage step in the reference signal of the regulating voltage unit, so as to obtain appreciable variations in the generating unit output voltage. The regulating unit must to be in manual position. To this test must to register the next variations:

a) The step voltage.
b) The generating unit excitation current.
c) The generating unit excitation voltage.
d) The generating unit terminals voltage.
e) The exciting unit excitation current.

6.2 Off-Line Step Response of Automatic Voltage Regulator System test with automatic regulation.

The elaboration of this test is similar as above and the same variables must be registered, but now the automatic voltage regulating unit must be in automatic position.

6.3 Gain determination of the voltage regulating unit.

By increasing the reference voltage, the respective increment in the excitation voltage of the generating unit is measured with the voltage regulating unit in manual position. It can be obtained by applying an step in the reference signal, as to variation in 30 % the reactive power applied to the system.

7. Determination of the voltage regulating unit parameters.

From the test 6.1 it is determined the exciter unit time constant of the excitation winding of vacuum generating unit. These values are obtained from the excitation current graphics of the exciter unit and the generating unit excitation current, respectively.

From the test 6.2 it is determined the response of the vacuum voltage regulating unit. From the test 6.3 it is determined the compensation of the automatic voltage regulating unit.

8. Conclusion.

The two waited objectives from the field tests performed to the excitation systems, were obtained, noting that they served to detect different defects in some excitation systems, which were corrected during the test or after it. In fact, the high time responses founded in any excitation systems, as well as the complet deficiency of action for operating in manual form, cuase a negative influence to the voltage regulation of the Interconnected System, particularly in post-deficiency dynamic conditions.

Given that in the Interconnected System, the dynamic behaviour is governed by instability voltage conditions, it can be appreciated the importance of an optimal and adequate response of the excitation systems.

The second objective, as important as the preceding, consist in obtaining a best knowledge of the different excitation systems installed in the generating units, from the modelation viewpoint, as well as from the equipment physical knowledge. It has been traduced in that the digital representation of them, and by consequence the dynamic response of the Interconnected System approach to reality. As a consequence of the above, it is considered and it is recommended that is it essential to perform periodically dynamic tests to the excitation systems, to verify if they are properly adjusted and if its operation is satisfactory.

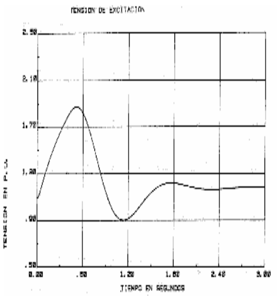

Fig 9. Simulation of excitation systems.

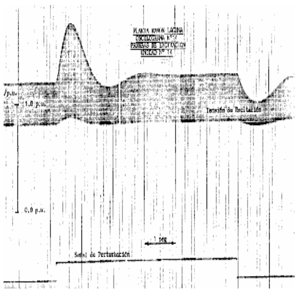

Fig 10. Test of Excitation System.

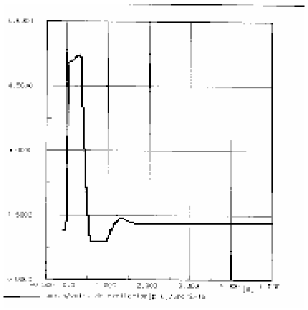

Fig 11. Simulation of excitation systems.

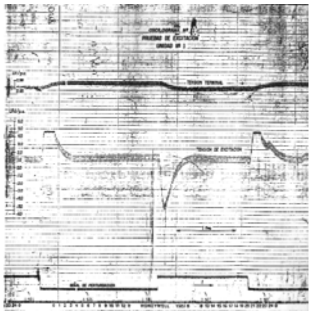

Fig 12. Test of Excitation System.

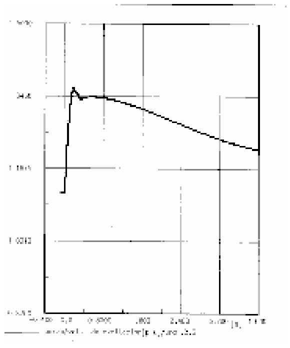

Fig 13. Simulation of excitation systems.

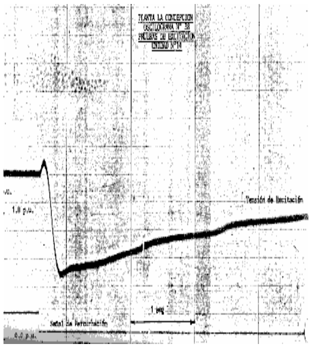

Fig 14. Test of Excitation System.

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