MATLAB MODELING AND SIMULATION OF HIGH ORDER SYNCHRONOUSE MACHINE MODEL [+]

تمثيل ومحاكاة الماكنه المتزامنة ذات الدرجة العالية باستخدام برنامج الماتلاب

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Abstract :

The enhancement and development in machine modeling is done by extraction of machine parameter ,generally, the advancement in computational tools and good understanding of machine characteristics ides to determine the best machine parameter which its near to practical case .

The stability in voltage transient of electrical power system is relatively a new problem , since the voltage stability phenomena can be divided in to long-term voltage stability and transient voltage stability . The complete, modified and simplified model of synchronous machine is presented in this paper, also for simplicity the separation between Automatic Gain Control (AGC) and Automatic Voltage Controller (AVC) of synchronous machine is done .The separated models can be used for studying the transient stability response of any synchronous generator .

The neural controller is used in this paper to obtain the best response for the system and obtain a good response rejection for the disturbance .

The proposed and the simulation method has been implemented using MATLAB software.

المستخلص :

التحسين والتطور في إيجاد موديل للماكنه يتم من خلال استخلاص متغيرات الماكنه وعلى العموم في السنوات الاخيره وخلال التطور الحاصل في الأدوات الحسابية ساعد في فهم وإيجاد المتغيرات الضرورية للماكنه وبالتالي اقتربنا من الحالات العملية للماكنه .

أن الاستقراريه بالجهد العابر في أنظمة الطاقة الكهربائية تعتبر من المشاكل ألحديثه نسبيا .وبشكل عام ظواهر استقرار الجهد يمكن ان تقسم الى استقرار الجهد العابر واستقرار الجهد الطويل المدى . في هذا البحث تم تكوين النموذج الكامل والمعدل للمولد المتزامن وتم تبسيط الموديل بالفصل بين (AVR &AGC) للمولد اللذان يسيطران على التردد والجهد وذلك بسبب علاقة الازدواج الضعيفة بينهم وقد اثبت هذا البحث بأنه يمكن الفصل بين (AVR &AGC) وبالتالي يمكن دراسة كل منهما على حده وبدون التأثير على النتيجة النهائية وبالتالي ببساطه يمكن دراسة رد الاستقرار العابر بالشبكة الكهربائية .

استخدم المسيطر العصبي في هذا البحث لاعطاء افضل استجابه للنظام والحصول على اشاره جيده في رفض الاشاره الخارجيه على النظام والطريقه المقترحه تم محاكاتها ب برنامج MATLAB

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Introduction to Artificial Neural Network (ANNs)

Neural networks are composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the network function is determined largely by the connections between elements. You can train a neural network to perform a particular function by adjusting the values of the connections (weights) between elements. Commonly neural networks are adjusted, or trained, so that a particular input leads to a specific target output. Such a situation is shown below. There, the network is adjusted, based on a comparison of the output and the target, until the network output matches the target. Typically many such input/target pairs are needed to train a network.[1]

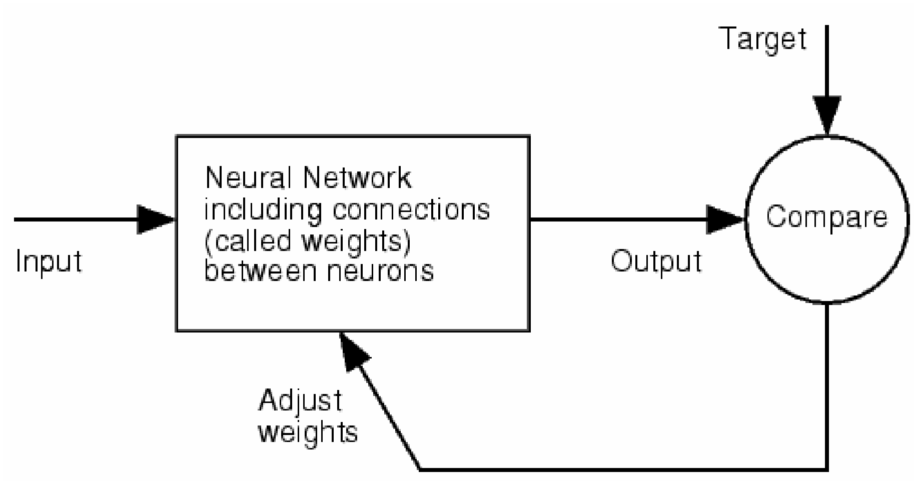


Figure (1): Basic configuration of

Neural networks have been trained to perform complex functions in various fields, including pattern recognition, identification, classification, speech, vision, and control systems.
Generally Three ways to represent ANN with Matlab:
- Using (**nftool**) function :graphical user interface
- Using (**nntool**) function : graphical user interface
- Using command-line program

1:Simple Neuron [1]
A neuron with a single scalar input and no bias appears on the left below.

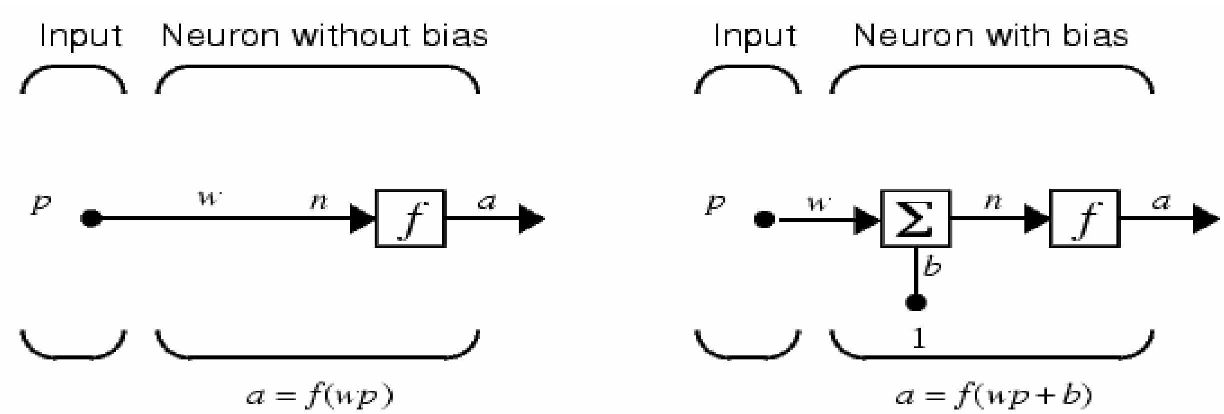


Figure (2): Basic neuron configuration

The scalar input p is transmitted through a connection that multiplies its strength by the scalar weight w to form the product wp, again a scalar. Here the weighted input wp is the only argument of the transfer function f, which produces the scalar output a. The neuron on the right has a scalar bias, b. You can view the bias as simply being added to the product wp as shown by the summing junction or as shifting the function f to the left by an amount b. The bias is much like a weight, except that it has a constant input of 1.

2: Transfer Function [1]

The transfer function net input n, again a scalar, is the sum of the weighted input wp and the bias b. This sum is the argument of the transfer function f.

Many transfer functions are included in Matlab program . Three of the most commonly used functions are shown below.

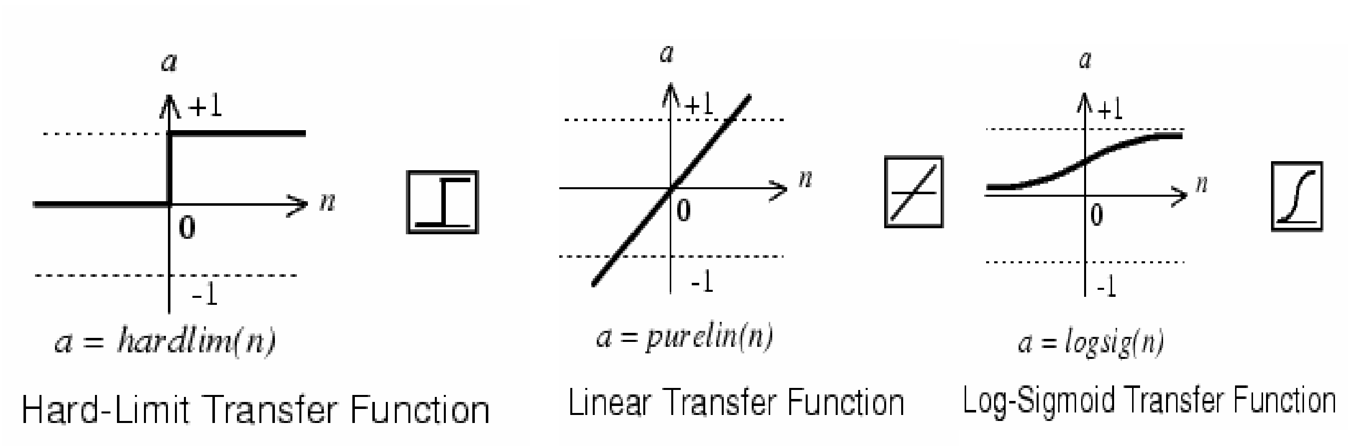


Figure (3): Different Transfer Function [1]

__Introduction To Synchronous Machine:__

To implement the simulation model, of synchronous machine a schematic diagram of important component is shown in figure (4) [2].

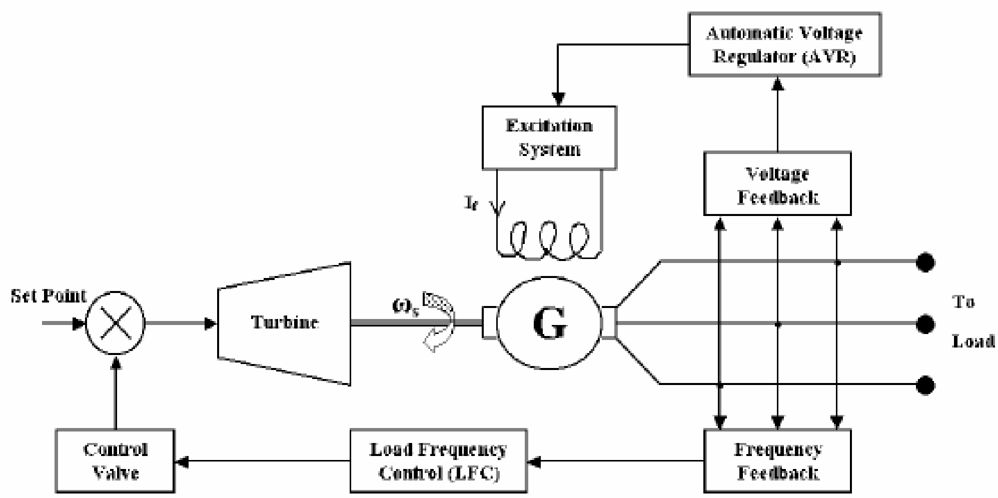


Figure 4: Schematic diagram of governor and AVR of the Synchronous Machine [2]

Each block in figure (4) will be explained and discussed bellow:

1: Automatic Voltage Regulator (AVR) [2]

A simple Automatic Voltage Regulator (AVR) is presented with a first order model of synchronous generator as shown in Figure (5):

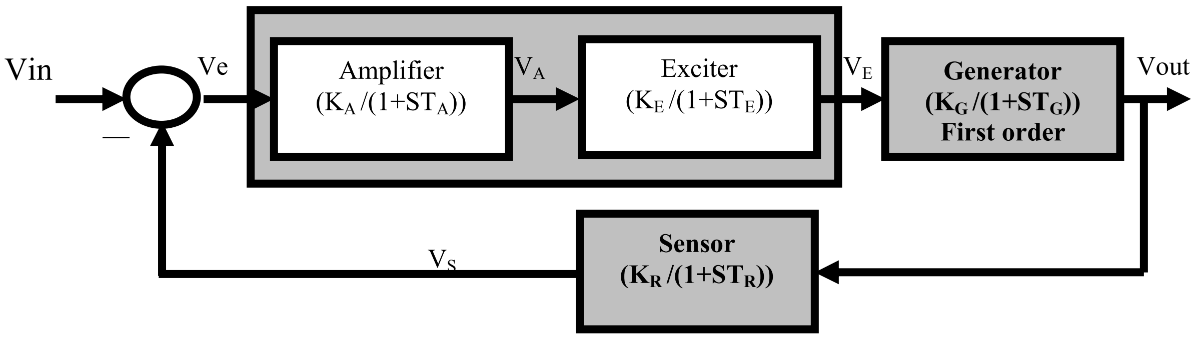


Figure (5):Automatic Voltage Regulator –AVR

Since:

$V_{in}(s)$ = Reference input voltage $V_e(s)$ = Error voltage signal

$V_A(s)$ = Amplifier Voltage $V_E(s)$ = Exciter Voltage

Vout(s) = Output Voltage Vs(s) = sensor voltage

K_A =Amplifier gain constant K_E=Exciter gain constant

K_G= Generator gain constant , K_R =Sensor gain constant

Note: All values of required constant are in per unit.

2:Governor block

The governor block works as a comparator to determine the difference between the reference power (ΔP_{ref}) and the power $(1/R)\Delta\omega$ .The governor output ΔP_g is:

$\Delta P_g(s) = \Delta P_{ref}(s) - (1/R)\Delta\omega(s)$ --- (1)

where R represents the speed regulation [4]. Speed governor output (ΔP_g)will be converted to steam valve position (ΔP_V) through the hydraulic amplifier. Assuming a linearized model with a single time constant T_g [3]:

$\Delta P_V(s) = (1 / (1 + sT_g))\ \Delta P_g(s)$ ----- (2)

3:Turbine block [4,5,6]

A turbine is a rotary engine that extracts energy from a fluid or steam or gas or another material. The simplest turbines have one moving part, a rotor assembly, which is a shaft with blades attached. Moving fluid acts on the blades, or the blades react to the flow, so that they rotate and impart energy to the rotor. Early turbine examples are windmills and water wheels. Gas, steam, and water turbines have a casing around the blades that contains and controls the working fluid.

The turbines are the source of the mechanical power in any synchronous machine, The simplest form of model for steam turbine can be expanded by using a single time constant T_T. The model for turbine associates the changes in mechanical power (ΔP_m) with the changes in steam valve position (ΔP_V). The general transfer function is [4]:

$G_T(s) = \Delta P_m(s) / \Delta P_V(s) = 1 /(1 + sT_T)$ ----- (3)

$G_T(s)$: Turbine transfer function

ΔP_m :Change of mechanical power

ΔP_V :Change in steam valve position

4:Automatic generation Control (AGC) block

Automatic Generation Control (AGC) is one of the most important issues in electric power system design and operation. The objective of the AGC in an interconnected power system is to maintain the frequency of each area and to keep tie-line power close to the scheduled values by adjusting the MW outputs the AGC generators so as to accommodate fluctuating load demands. The automatic generation controller design with better performance has received considerable attention during the past years and many control strategies have been developed **[2,5]**

Simulation Result :

In this section the complete system model has been examined by applying step input voltage response to check the effect on terminal voltage transient response also the separated voltage control has been tested.

Voltage disturbance has been applied to ensure the accuracy of the separation process .

1- **Complete System Simulation Model**

Figure (5) represent the simulation model for the fourth order synchronous generator drawing by Matlab- Simulink , all data for this model are listed here since the following data illustrated the optimum time constant extracted from the result of Walton[3,6,7]

The table bellow shows the time constant values for the model

All values in the tables shown below are taken from previous studies in [6,7].

Table (1) Optimum time constant [3,6,7]

ROTOR CIRCUIT	POLES TIME CONSTANT	ZEROS TIME CONSTANT
F	3.9517	0.9087
J	0.1481	0.1257
K	0.00838	0.00688
L	0.000937	0.000775

The F,J,K and L refer to the rotor branches parameters

Some data are required before represent this model such as turbine gains , governing gains constant ,and excitation control system parameters .The values chosen form previous work in this field .

Table(2):Turbine and Governing system values (all values in per unit) [3,6,7]

	KD	R	H	Tg	TT	
0	0.8	0.05	10	0.2	0.5	0.2

Table(3):Excitation control system values (all values in per unit) [3,6,7]

Vref	KE	KG	KR	K1	K2	K3	K4	K5	TE	TR	VL
1	200	1	1	0.2	1.5	1.4	0.1	0.5	0.005	0.05	0.05

The Simulink Simulation Model for fourth order generator without any controller has been demonstrated in Figure (6) and each Scop response are plotted in Figure(7)

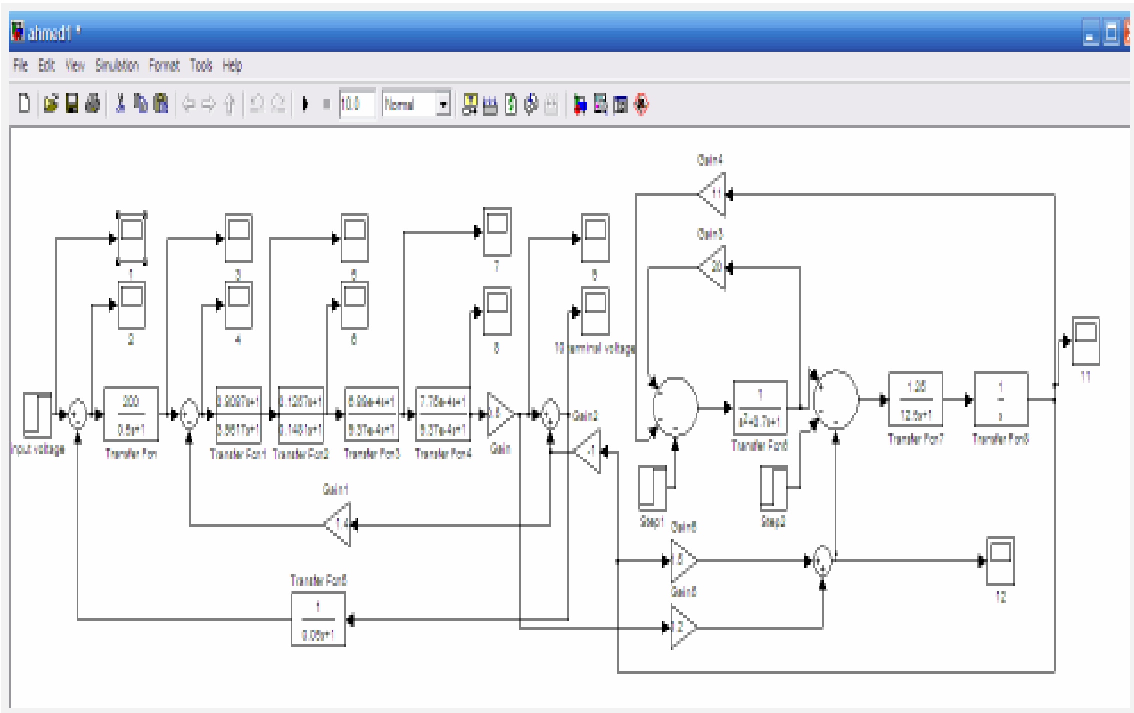


Figure (6): Simulink Simulation Model for fourth order generator without controller

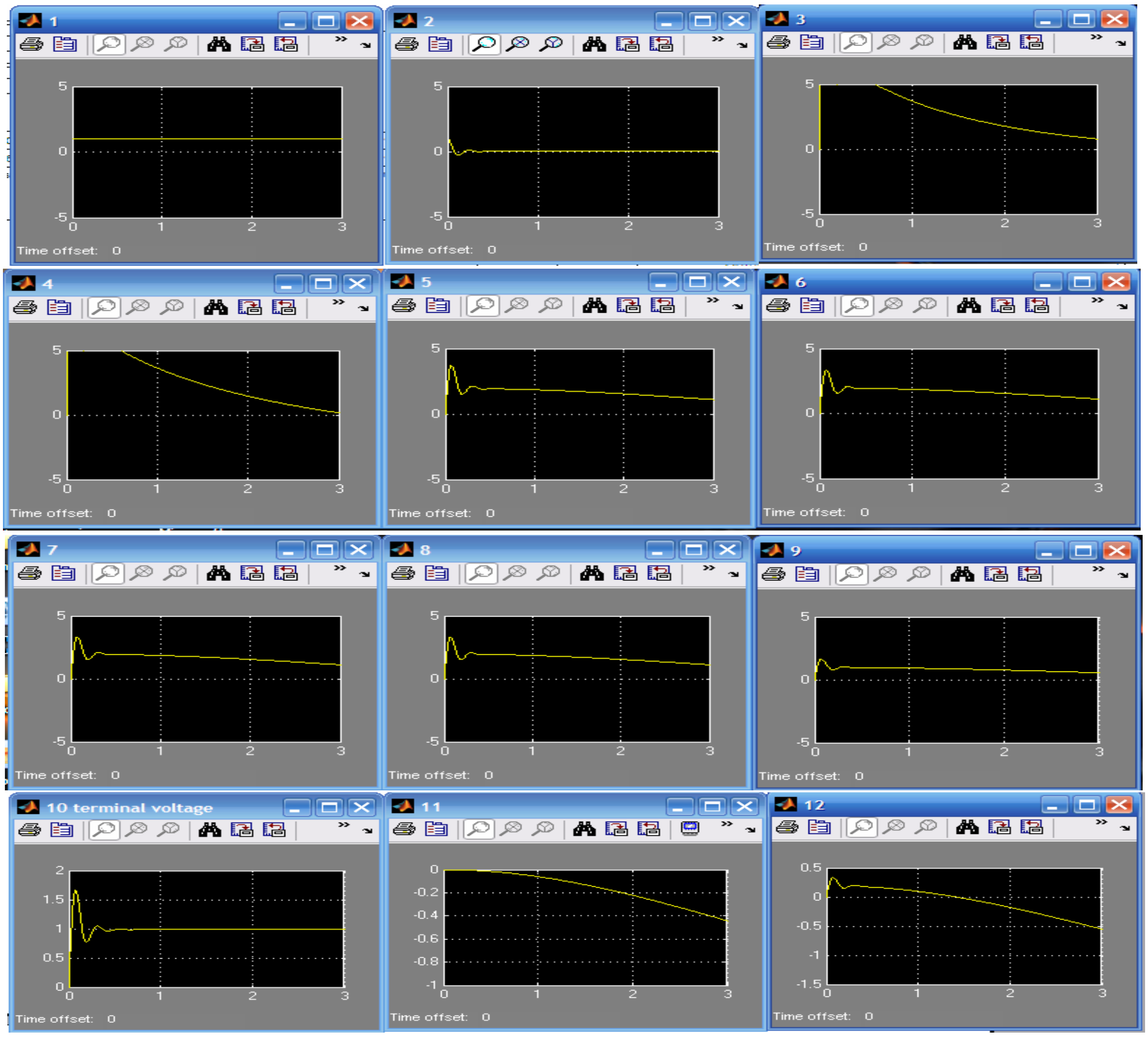


Figure (7): Scope Response for Figure (6)

Since figure (7) show the scope response for each branch in figure (6),the scope(1) represent the unite step input ,scope (2) represent the first error signal , scope (3) represent the amplifier response , scope (4) represent the error signal , scope (5) represent the first order generator response , scope (6) represent the 2nd order generator response , scope (7) represent the 3rd order response , scope (8) represent the 4th order response , scope (9) represent the 4th order response multiplied by gain (0.5), scope (10) represent the terminal response voltage , scope (11) represent the AGC response , scope (12) represent the error signal in AGC part.

2 – AVR Control System Simulation model

To demonstrate the controller effect on terminal voltage enhancement ,the model tested with and without controller .

2.1: Model Without Controller

The separation process between (LFC &AVR) can be done since the simulation results illustrate and prove that (when using the same data that applied for synchronous generator control system before and after separation the obtained result are very nearly in the transient response shape) .This mean that, each of the two control system can be processed separately .Figure (8) shows the AVR of fourth order simulation model after separation from general system model, also the disturbance input is applied on the same model to prove the separation accuracy process before and after separation.

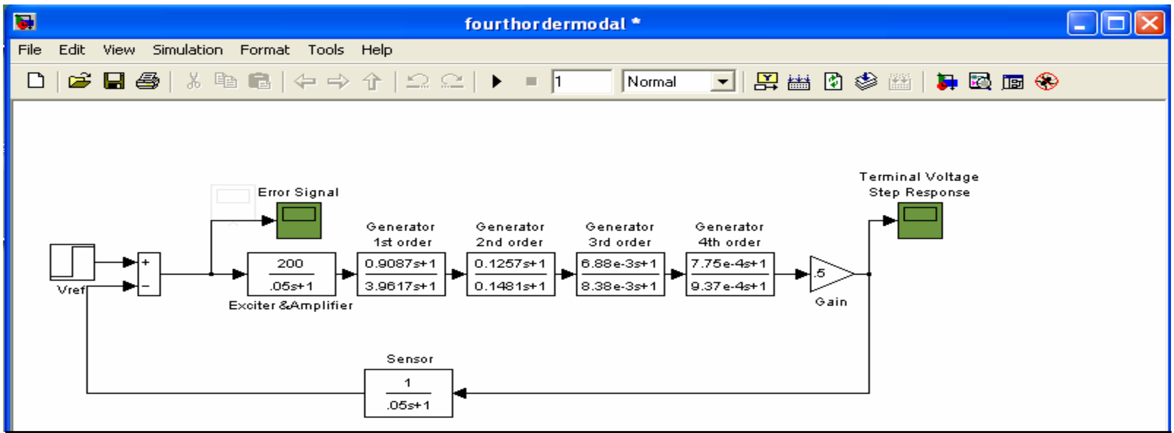


Figure (8)Automatic voltage regulator of Fourth order Model simulation without controller

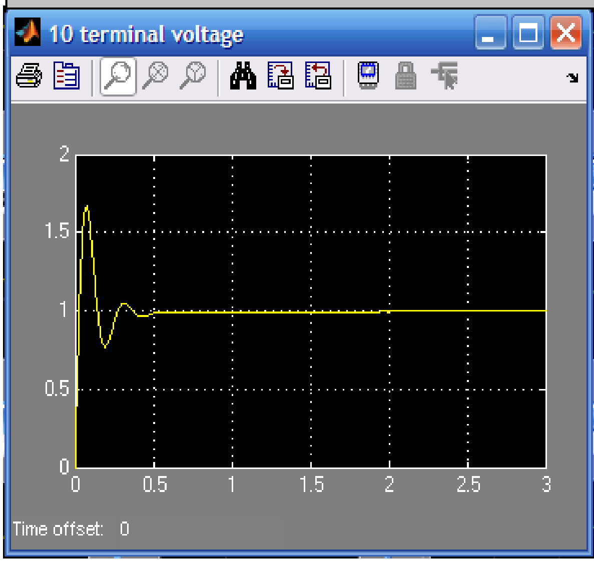


Fig.(9): terminal voltage response before Separation

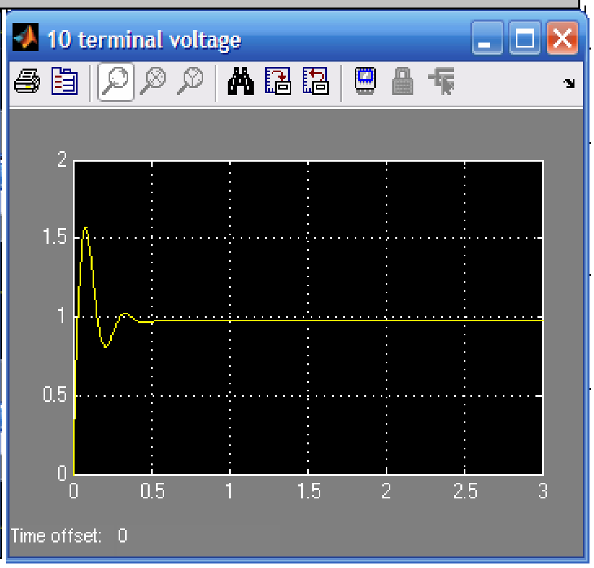


Fig.(10): terminal voltage response after separation

From Figure (9) & Figure(10) the very small effect will appear when the separation process is done ,this important point is Invested in studding the system since the each part (AVR and AGC)is taken separately therefore the simple model after separation will be analyzed without effect on all model .Table (4) show the small change in time response parameter

Table (4) : Time Response Parameters

Terminal voltage response	Overshoot	Rise time	Error steady state
Before separation	1.73	0.110	0.201
After separation	1.65	0.099	0.182

Figure (11) and figure(12) shows the disturbance effect on output responses for 4^{th} order model

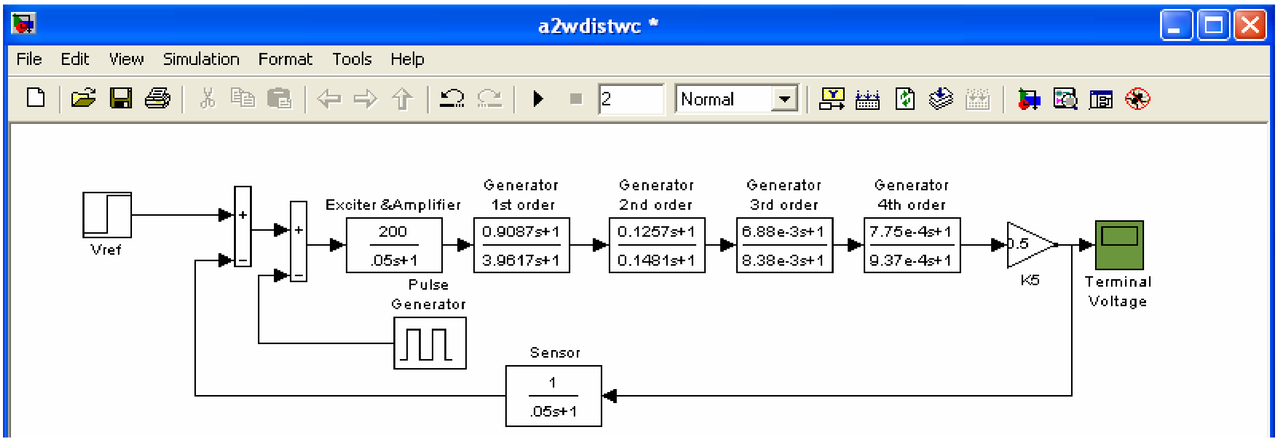
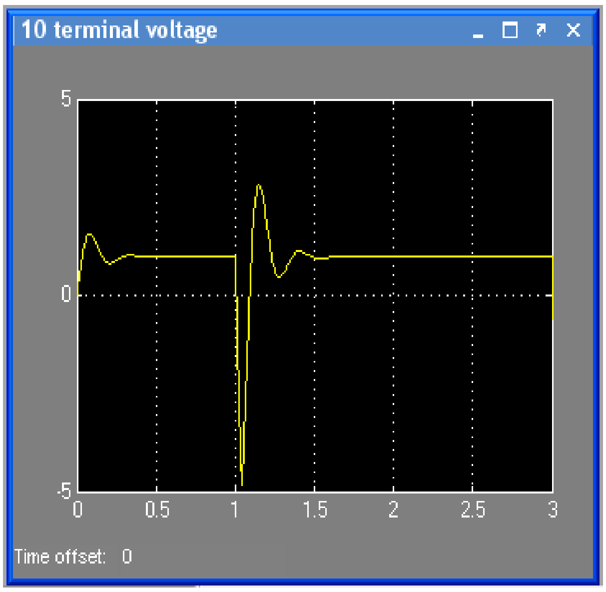


Figure (11): Automatic Voltage Regulator of Fourth Order Model with disturbance input



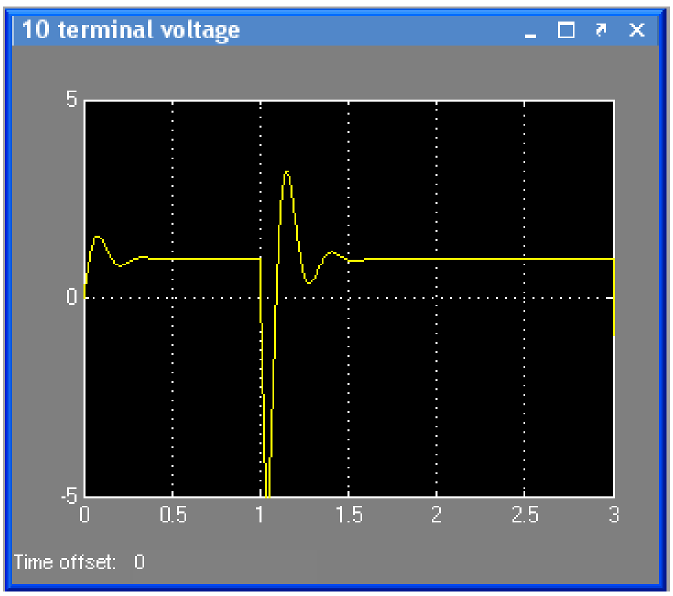


Fig.(12): terminal voltage response with disturbance after separation

Fig.(13): terminal voltage response with disturbance befor separation

2.2 Model With Neural Controller

From the previous section the disturbance input effect on the output signal clearly ,therefore the Neural controller is used here to reject this disturbance and enhance the output signal when step input is applied , the block diagram for the neural controller with important synchronies machine parameters is shown in figure (14) and the output responses are shown in figure (15) and figure (16).

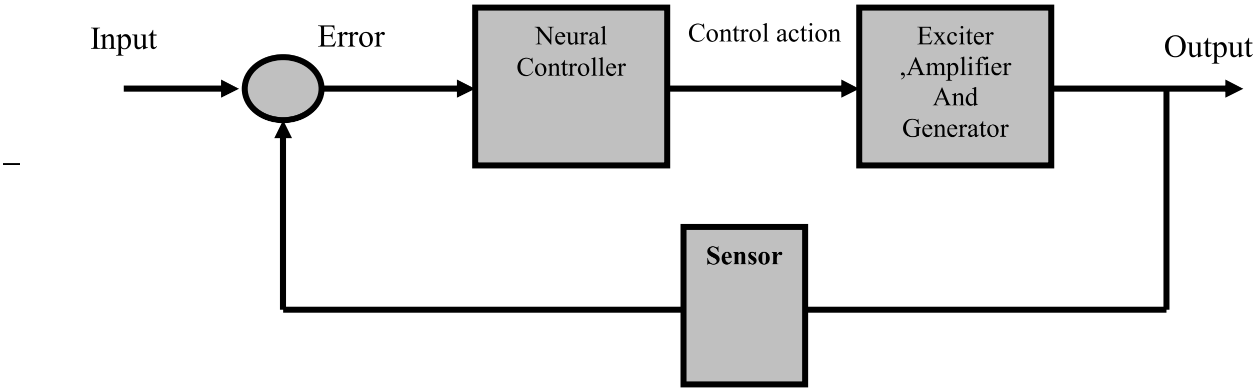
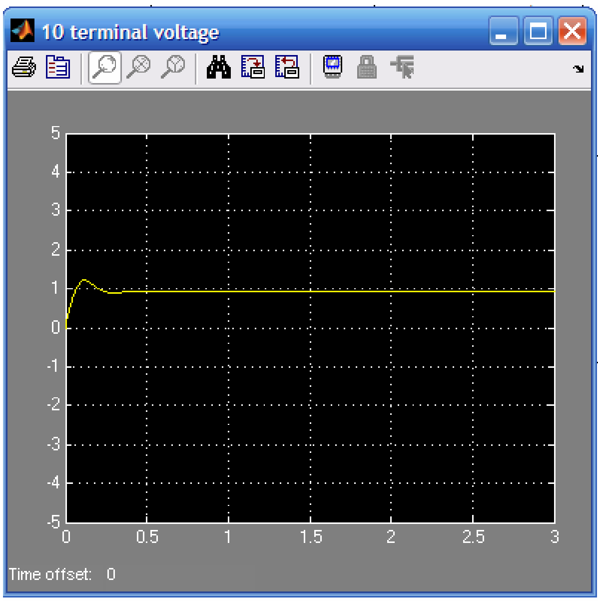


Figure (14):block diagram for the neural controller with important synchronies machine parameters

The Exciter , Amplifier and Generator blocks explained in the previous sections.



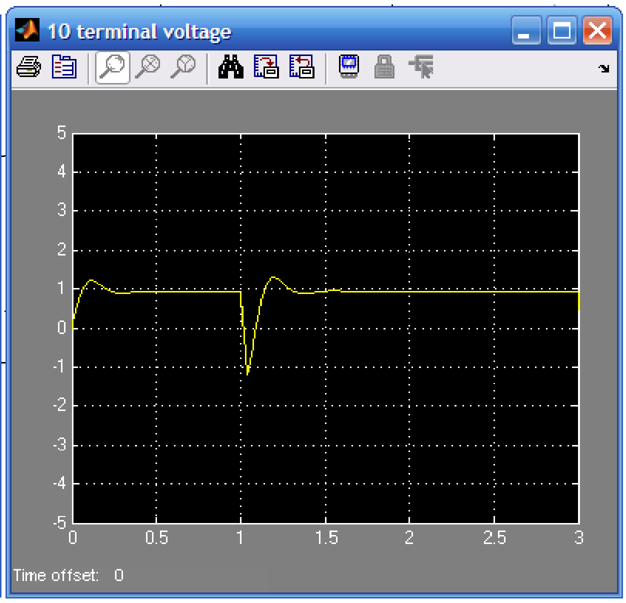


Fig.(15): terminal voltage response with Neural controller

Fig.(16): terminal voltage response Neural Controller with disturbance

Conclusion :

From the previous results, some important points about the model and its responses can be concluded as follows :

- Really can be separate between voltage and frequency controls in synchronous generator model due to the very weak coupled process between them.
- From separation method can be study the model in details and enhance the output response by adding a controller
- The accuracy of the separation process is provided and done by examine the two control system before and after separation when large disturbance occurs at the terminals of synchronous generator .
- Very good response for the synchronous machine obtained when the Neural Controller is integrated with a complete system.
- High rejection for any disturbance with Neural Controller .

References:

[1] Matlab help tool books(ver 7.4.0.287(R2007a)), January ,2007

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[5] Anderson P.M. and Fouad A.A, *Power System Control and Stability*, IEEE press, USA, NY, Revised printing, 1994.

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