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INTELLIGENT SYSTEM IDENTIFICATION FOR WIDE AREA MONITOR IN POWER SYSTEM

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ABSTRACT

In modern Electric Power System the complexity has raised which leads to the complete disaster of the network. Due to this the need for monitoring the Power Network has become an essential feature. Monitoring a Power Network depicts a clear picture of the Voltage, Current, Power angle etc and thereby a corrective action can be taken in advance before the occurrence of any catastrophe of the Power network. The Wide Area Monitoring, Protection and Control (WAMPAC) plays a vital role to maintain the network in equilibrium. The main objective of this paper is to develop an equivalent model of a part of the power system based on PMU measurement. It is the system identification and is an integral part of wide area monitoring and control. The Kundur's two area four machine power system is used to describe the process. Matlab system identification tool box is used. The non-linear estimation technique based on Hammerstein - Weiner model is utilized.

Keywords: intelligent system, PMU, WAMPAC, hammerstein, weiner model.

1. INTRODUCTION

The need for energy increases rapidly as there is an increase in the power infrastructure from domestic side till the Industrial sector. Due to the increase of Energy demand, the Distributed Generation have widen its strength which led to the complexity in the Power Networks. The steady state of the Power Network have also lost its quality and ultimately the Network fails completely known as Black out or Catastrophic failure. The main parameters in any Power Network are the Voltage, Current and Power Angle [3, 5, 6]. There is a need for complete monitoring of such parameters and necessary action need to be taken immediately in case of any deviation in those parameters.

A new technology to reduce the catastrophic failure is Wide Area Monitoring Protection and Control (WAMPAC). The Power Network will be monitored, Controlled and protected under all conditions. World wide there has been many blackout occurred in the past decade and the list of blackout occurred [1] is mentioned in Table-1.

Table-1. List of blackout world wide.

S. No.	Place	Year and date	No. of people affected in million
1	Turkey	31 March 2015	70
2	Pakistan	26 January 2015	140
3	Bangladesh	1 November 2014	150
4	India	30 July 2012-31 July 2012	620
5	Brazil, Paraguay	10-11 Nov 2009	87
6	Indonesia	18 Aug 2005	100
7	Italy, Switzerland, Austria, Slovenia, Croatia	28 Sep 2003	55
8	United States, Canada	14-15 Aug 2003	55
9	India	2 January 2001	230
10	Brazil	11 March, 1999	97

These blackout experiences led the technology to develop an automatic, self-healing and adaptive control system to prevent the catastrophic failure known as WAMPAC [2, 7, 9]. At present a standalone infrastructure

-SCADA is been utilized. The advanced WAMS utilize a device known as Phasor Measurement Unit (PMU). This PMU measures the Voltage and Current Phasors, Frequency etc. of the buses at different locations in a time synchronized manner. It makes uses of GPS for time synchronization. The data provided by PMU is similar to the SCADA but the number of samples obtained within the specified time is more.

Generally the PMUs synchronization is precise with µs accuracy. Also the measurements are reported nearly 60 times per second, [4, 11, 12] so that it is suited to track the grid dynamics. The present SCADA measures the data every second to minutes which lacks in predicting the performance of the grid.

The modern PMU using GPS was built in Virginia Tech in early 1980 and the commercial PMU was developed in1991 by Macrodyne along with Virginia Tech collaboration [2]. Now many manufacturers offers PMUs as there is a need for more PMUs to be installed world wide in all the Power Network. An AC waveform can be mathematically represented by

$x(t) = X_m \cos(\omega t + \varphi)$
where X_m = Magnitute of the sinusoidal waveform
$\omega = 2 * л * f$
f = instantaneous frequency
φ = Angular starting point of the waveform.

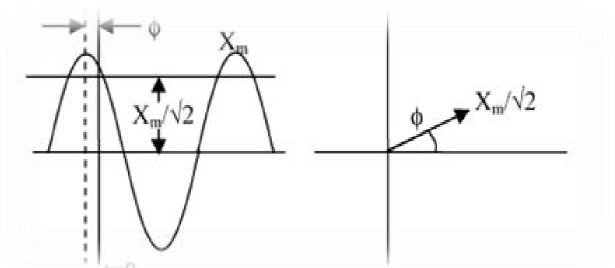

Figure-1. Representation of Phasor.

The modern PMUs utilize the GPS satellite receivers and the accuracy is more [3]. The block diagram of Phasor measurement unit is shown in Figure-2.

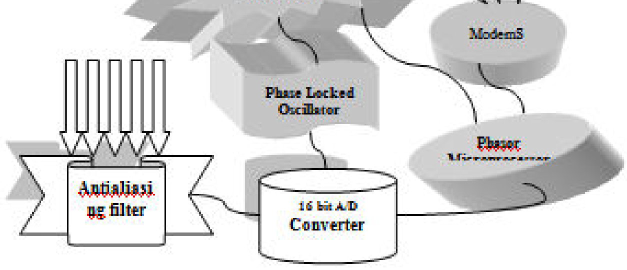

Figure-2. Block diagram of PMU.

The structure of the paper is the following. Section II describes the modeling of the power system network, Section III illustrates the structure and characteristics of the power system where the test have been done, Section IV concludes the paper.

2. MODELLING OF THE POWER SYSTEM NETWORK

In this paper an equivalent model of a part of the power system based on PMU measurement is developed. It is described as system identification and is an integral part of wide area monitoring and control. Kundur's two area four machine power system is used as shown in Figure-4. A pseudo random binary signal (PRBS) disturbance is applied at the PSS input of generator 1 as shown in Figure-6 and the speed deviation signal is captured. From the PRBS input and speed deviation output, the generator model is identified using Matlab System Identification toolbox.

Here non-linear estimation technique is utilized which is based on Hammerstein-Wiener model.

A. System identification

A methodology for building mathematical models of dynamic systems from the input and output measurement. The process of system identification areas follows:

- The input and output is measured in time or frequency domain.
- Model structure is selected.
- An estimated method is applied to estimate value for the adjustable parameters in the model structure.
- The estimated model is evaluated and whether the model is adequate for the application need is checked.

B. Pseudo random binary signal

PRBS is a random sequence of binary numbers. The value of an element of the sequence is independent of the values of any other elements. PRBS patterns are been used in high speed device testing. To generate PRBS patterns generation the following points need to be considered

- Generation of PRBS data stream
- Order of the waveform index.

The Binary sequence is a sequence $a_0, \ldots\ldots a_{N-1}$ of N bits. In a Pseudo random binary sequence (PRBS),

$$C(x) = \sum_{j=0}^{N-1} a_j \; a_j + v \tag{1}$$

The implementation of PRBS generator is based on the linear feedback shift register.

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C. Hammerstein Weiner model

The Hammerstein - Weiner model decomposes the input-output relationship into more interconnected elements if the output of a system depends nonlinearly on its inputs. The fig represents the block of Hammerstein-Weiner model.

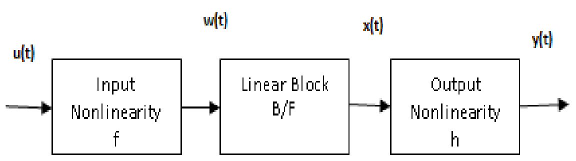

Figure-3. Block of Hammerstein -Weiner model.

where w(t)= f(u(t)) - nonlinear function transforming input data u(t).

x(t) = (B/F)w(t)- linear transfer function.

The Hammerstein-Weiner model computes in three stages

a) Computes w (t) = f (u (t)) from the input data.
b) Computes the output of the linear block using w (t) and initial conditions: x(t) = (B/F)w(t).
c) Computes the model output by transforming the output of the linear block x (t) using the nonlinear function h: y(t) = h(x(t)).

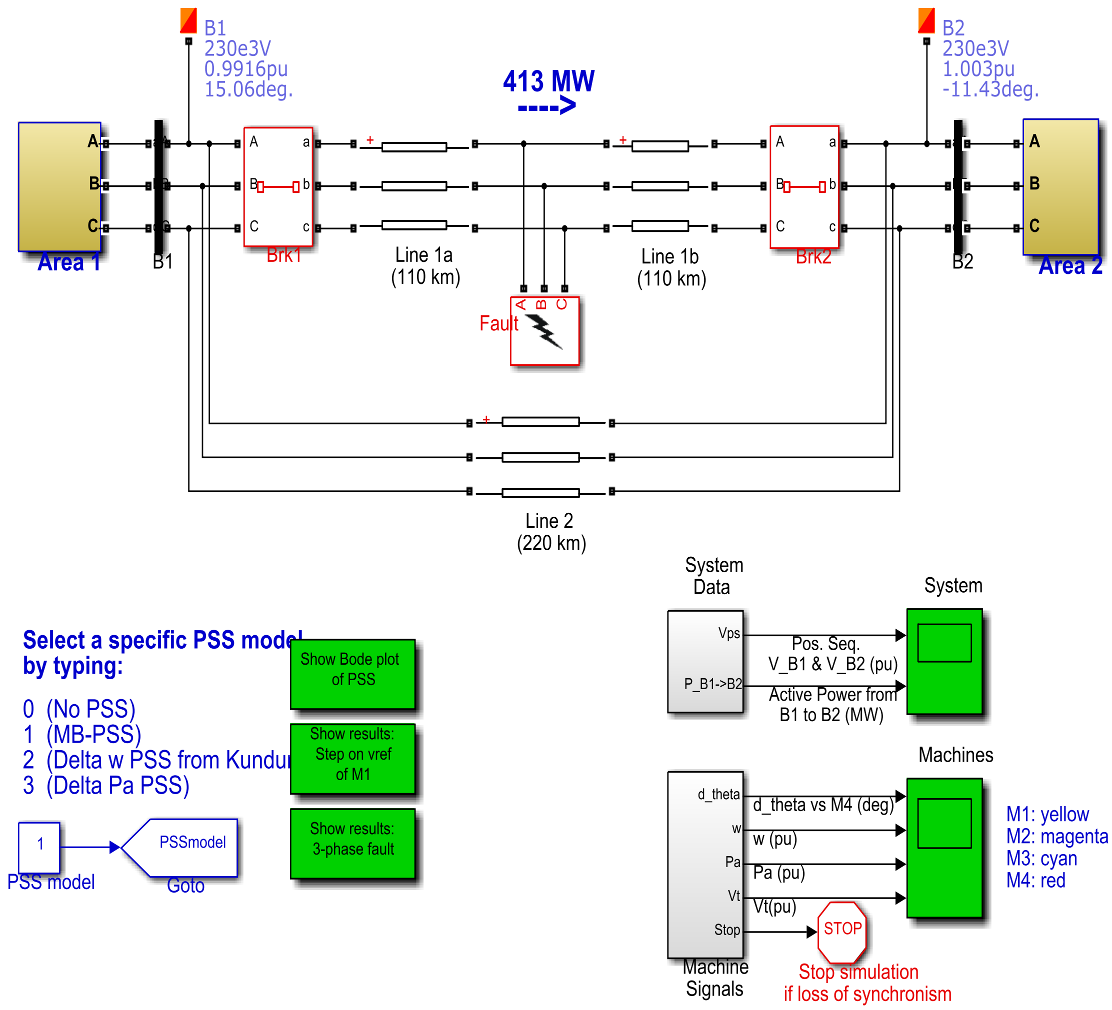

Figure-4. Test system - Kundur's two area four machine system.

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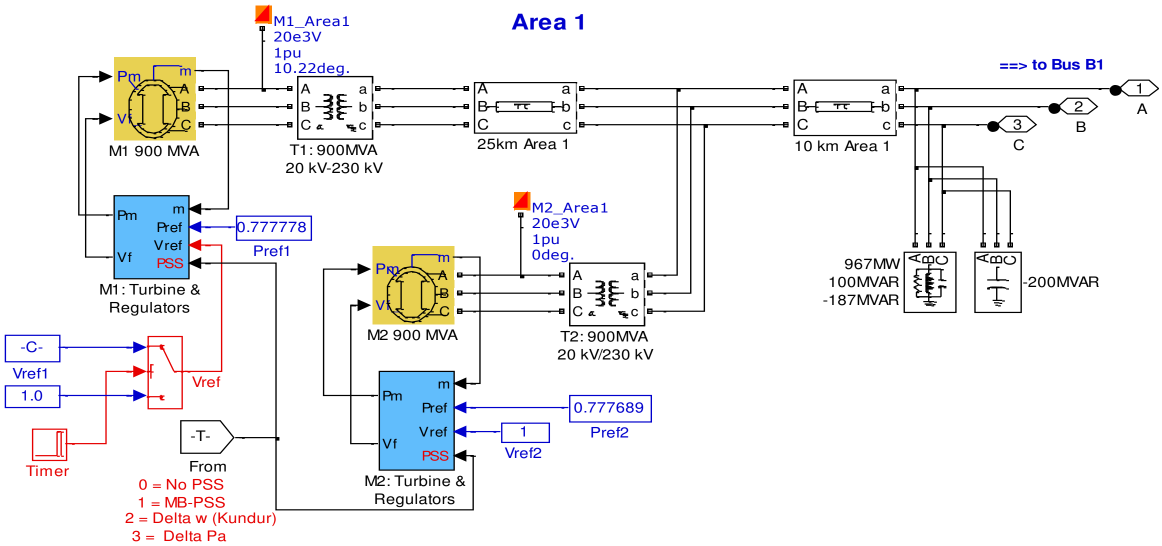

Figure-5. Area 1 of Kundur's TAFM system.

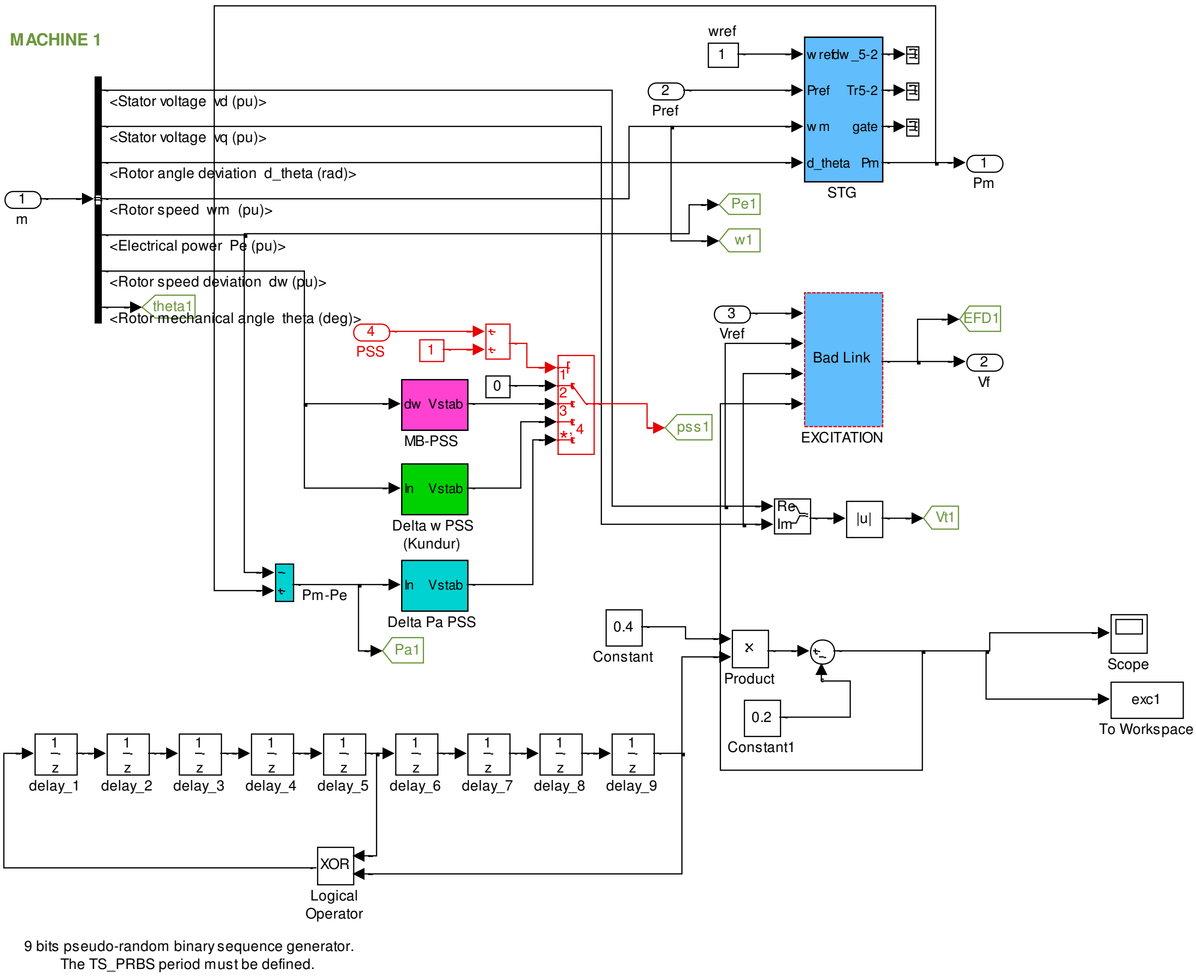

Figure-6. PRBS disturbance added to machine 1 PSS input.

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3. STRUCTURE AND CHARACTERISTICS OF THE POWER SYSTEM

In this section the structure of the power system utilized is described.

A. Kundur's two area four machine systems

The test system consist of two symmetrical areas which linked by 230kV lines of 220 km length. The low frequency electromechanical oscillations in large interconnected power systems are studied. The nature of the Kundur's TAFM is very close to the behavior of the typical power system. Both the areas are equipped with two identical round rotor generators rated 20kV/900MVA. In this the load is represented as constant impedance.

B. Results and discussions

To execute the simulation to obtain the output the following steps are followed:

- The Matlab system Identification toolbox window has to be opened first as shown in Figure-7
- The input and the output data are loaded. The input data is exciter 1 and the output data is speed pu 1.
- A nonlinear estimate is used as shown in Figure-8
- The linear block of the nonlinear estimate is shown in Figure-9
- The output voltage and the power of the buses are illustrated in Figure-10 and Figure-11, respectively.
- The final estimated and the actual output are shown in Figure-12

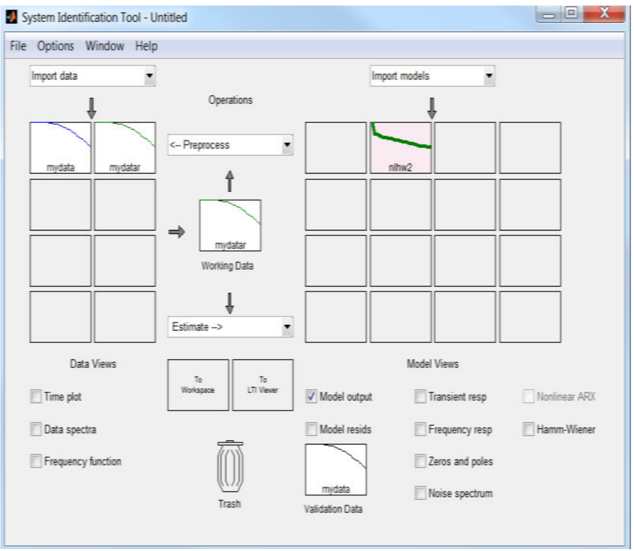

Figure-7. Matlab system identification toolbox window.

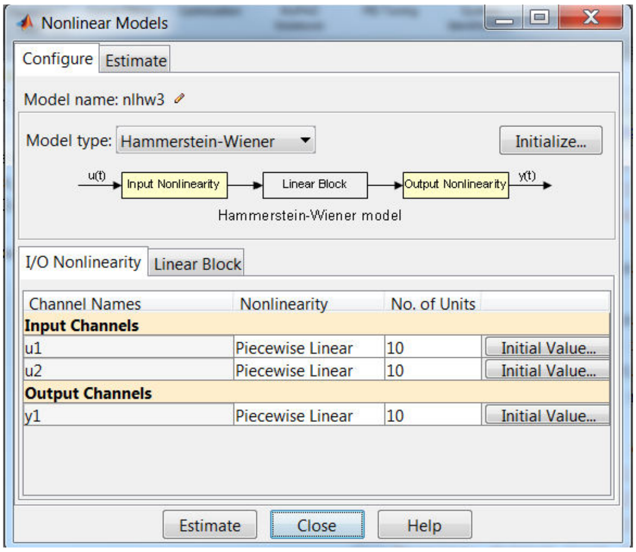

Figure-8. Non-linear estimation (I/O nonlinearity).

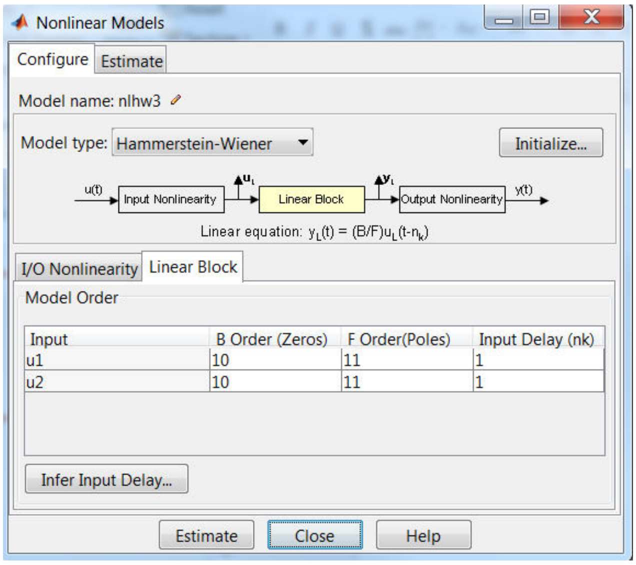

Figure-9. Linear block of the non-linear estimate.

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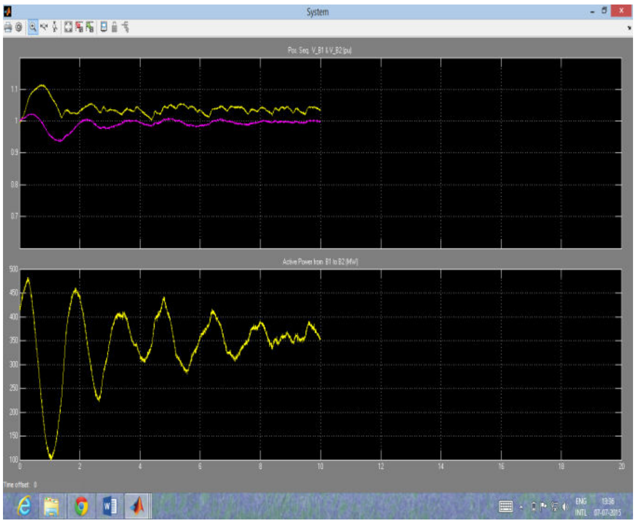

Figure-10. Positive sequence of voltage and active power.

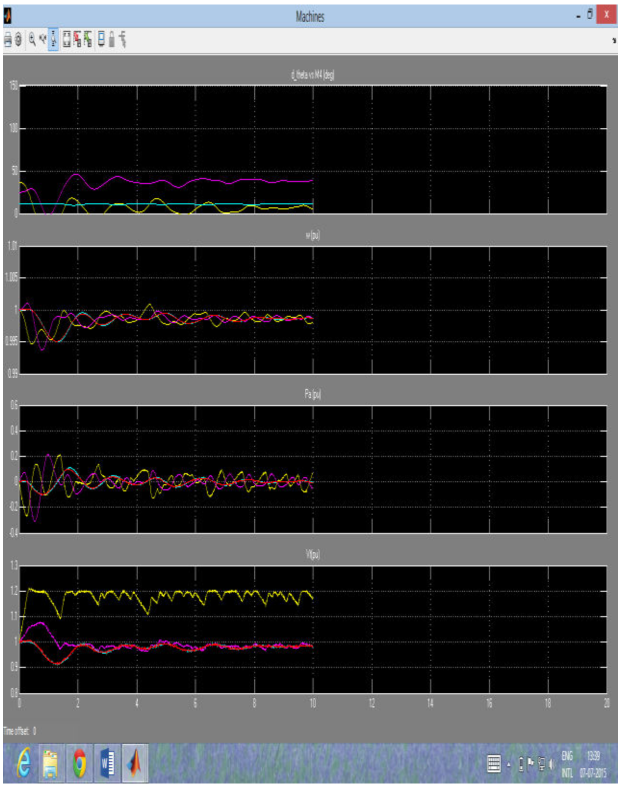

Figure-11. Voltage and Power of buses 1-4.

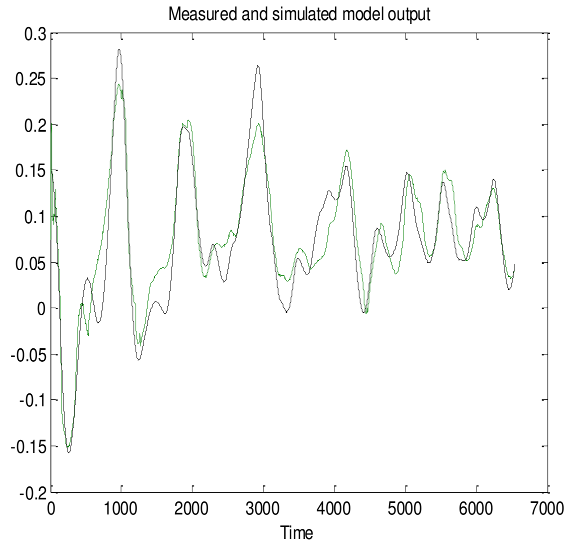

Figure-12. Output of the estimated and measured output.

4. CONCLUSIONS

The modeling and simulation of Kundur's TAFM system depicting the original power system is completed. The test results shows that the complete monitoring of the power networks can avoid major catastrophic failure there by maintaining the stability and reliability of the system. The actual and the estimated speed deviation is compared. Also it reveals that the same kind and improved performance can be obtained by implementing the PMUs in majority of the buses. The various outputs are illustrated in the figures.

However there is still scope of improvement in the monitoring by the incorporating the neural network and thereby the disturbances can be predicted systematically.

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