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Load Frequency Control in Power System Operation after Deregulation

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Abstract
This paper deals with load frequency control of interconnected power system before and after the deregulation. In this particular work two area concepts is considered. The primary purpose of the LFC (loud frequency control) is to balance the total system generation against system load and losses so that the desired frequency. Any mismatch between generation and demand causes the system frequency to deviate from schedule value. Thus frequency deviation may lead to system collapse. Further, in a restructured power system, the engineering aspects of planning and operation have to be reformulated although essential ideas remain the same.
Keywords: *Automatic Generation Control, load frequency Control, Disco Participation Factor.*

1. Introduction

Frequency deviation is a direct result of the imbalance between the electrical load and the active power supplied by the connected generators. A permanent off-normal frequency deviation directly affects power system operation, security, reliability, and efficiency by damaging equipment, degrading load performance, overloading transmission lines, and triggering the protection devices. The primary control performs a local automatic control that delivers reserve power in opposition to any frequency change. The supplementary loop gives feedback via the frequency deviation and adds it to the primary control loop through a dynamic controller. The resulting signal is used to regulate the system frequency. The objective of this paper is the modification of the traditional two area system to take into account the effect of Bilateral Contracts. The concept of DISCO participation matrix is used that helps the visualization and implementation of contracts.

2. Basic Generator Control Loops

In an interconnected power system, Load Frequency control (LFC) and Automatic Voltage Regulator (AVR) equipment are installed for each generator. The schematic diagram of the LFC loop and AVR loop is as shown in figure below. The controllers take care of small changes in load demand to maintain the frequency deviation within the specified limits. The small changes in real power are mainly dependent on the changes in rotor angle δ and thus, the frequency. The reactive power is mainly dependent on the voltage magnitude (i.e. on the generator excitation). The excitation system time constant is much smaller than the prime mover time constant and its transient decay much faster and does not affect the LFC dynamic. Thus the coupling between the LFC loop and the AVR loop is negligible and the load frequency and excitation voltage control are analyzed independently.

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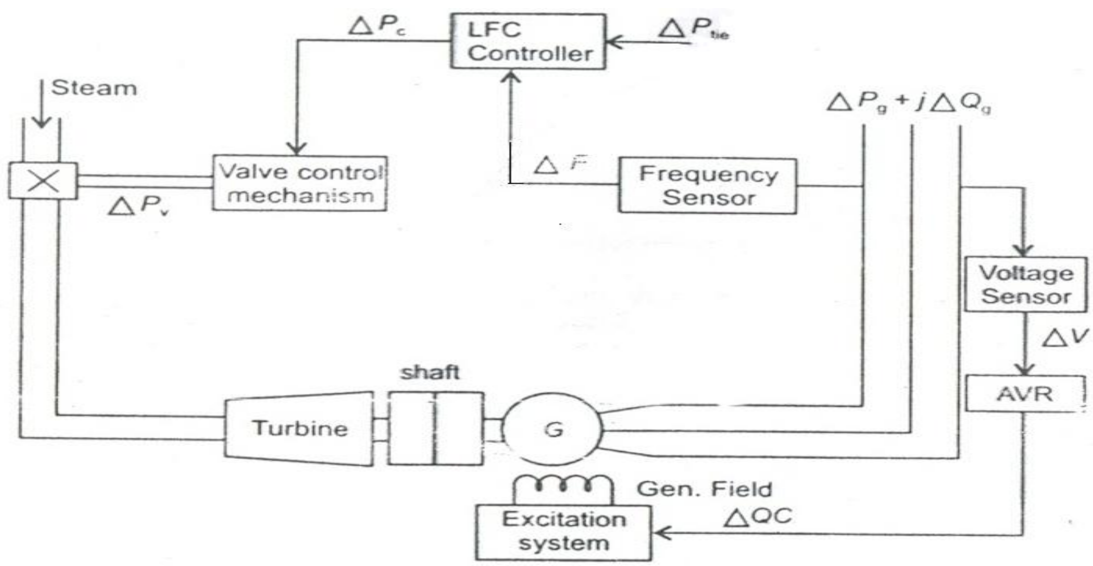

Figure 1: Basics Generator Control Loops

3. Load Frequency Control (in a Restructured Power System)

In a restructured power system, the engineering aspects of planning and operation have to be reformulated although essential ideas remain the same. Some countries like United Kingdom and Norway are along the path of restructuring than others and it is becoming clear that there will be many variations in the restructured scenario for electric power systems around the world. The electric power business at present is largely in the hands of vertically integrated utilities (VIUs) which own generation-transmission-distribution systems that supply power to the customer at regulated rates.

4. Disco Participation Matrix (DPM)

In the restructured environment, GENCOs sell power to various DISCOs at competitive prices. Thus, DISCOs have the liberty to choose the GENCOs for contracts. They may or may not have contracts with the GENCOs in their own area. This makes various combinations of GENCO-DISCO contracts possible in practice. I will describe here DISCO Participation matrix (DPM) to make the visualization of contracts easier. DPM is a matrix with the number of rows equal to the number of GENCOs and number of columns equal to number of DISCOs in the system. For the purpose of explanation, consider a two-area system in which each area has two GENCOs and two DISCOs in it. Let GENCO 1, GENCO 2, DISCO 1 and DISCO 2 are in area-1, and GENCO 3, GENCO 4, DISCO 3 and DISCO 4 are in area-2 as shown in figure.

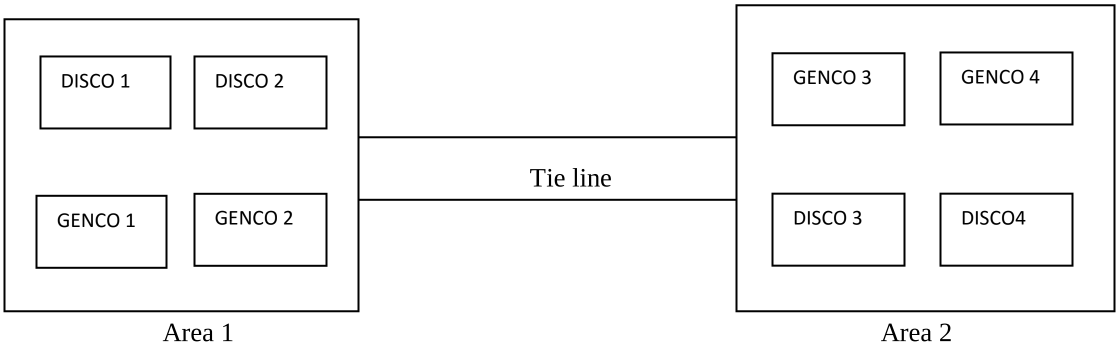

Figure 2: GENCO and DISCO

The DPM of above figure can be given as:

DPM =

	DISCO1	DISCO2	DISCO3	DISCO4
GENCO1	cpf_{11}	cpf_{12}	cpf_{13}	cpf_{14}
GENCO2	cpf_{21}	cpf_{22}	Cpf_{23}	cpf_{24}
GENCO3	cpf_{31}	cpf_{32}	cpf_{33}	cpf_{34}
GENCO4	cpf_{41}	cpf_{42}	cpf_{43}	cpf_{44}

Figure 3: DPM

5. Simulation and Result

The testing forms and the completed testing forms are included in this following assumption are made and are shown in table:

Table 1: Testing Forms

Quantity	Area-1	Area-2
Governor Speed Regulation	$R_1 = 0.051$	$R_2 = 0.065$
Frequency Bias Factors	$D_1 = 0.62$	D2= 0.91
Inertia Constant	$H_1 = 5$	$H_2 = 5$
Base Power	1000MVA	1000MVA
Governor Time Constant	T_{g1}= 0.2 sec	T_{g2}= 0.3 sec

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Turbine Time Constant	T_{T1}= 0.5 sec	T_{T2}= 0.6 sec
Constant	K= ½*π=0.159	K= ½*π=0.159
Nominal Frequency	F1 = 50 Hz	F2 = 50 Hz
Load Change	ΔPL1 = 200 MW	ΔPL2 = 200 MW
Load Disturbance in per unit	(ΔPL1)pu = 0.2	(ΔPL2)pu = 0.2

5.1 Open Loop LFC System for single Area System

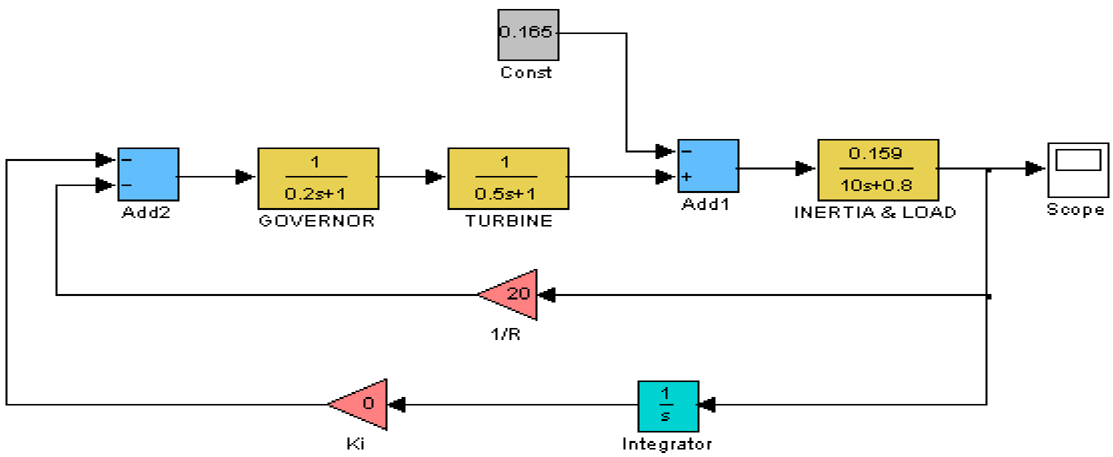
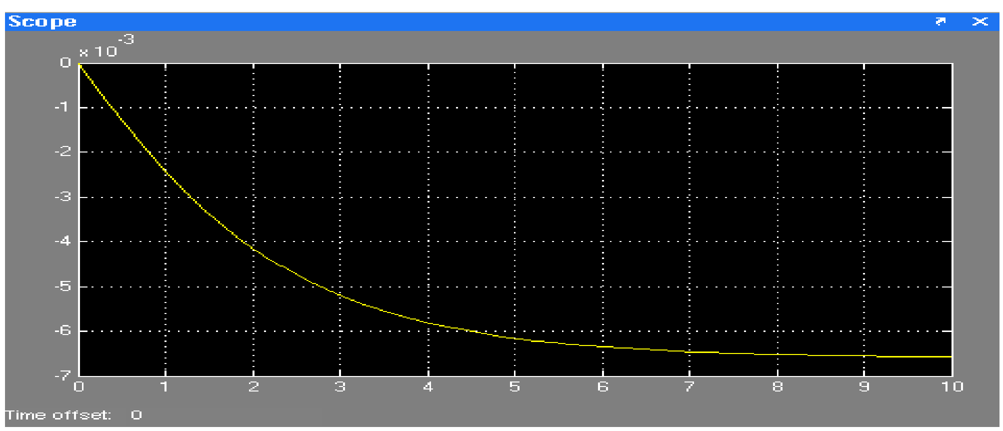


Figure 4: Open loop LFC System for Single Area



Time (seconds)
Figure 5: Frequency Response for open loop single area

The plot between frequency and time is shown in figure. It is found from graph that with open loop if demand changes to 0.165 pu, a steady state error exists in frequency of 0.007 unit. This frequency error must be removed.

5.2 Closed Loop LFC System for single Area System

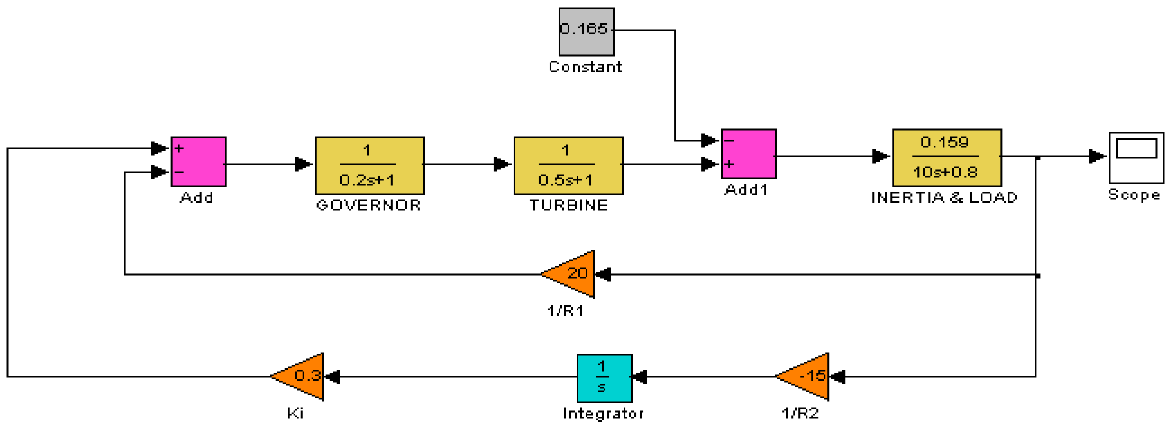
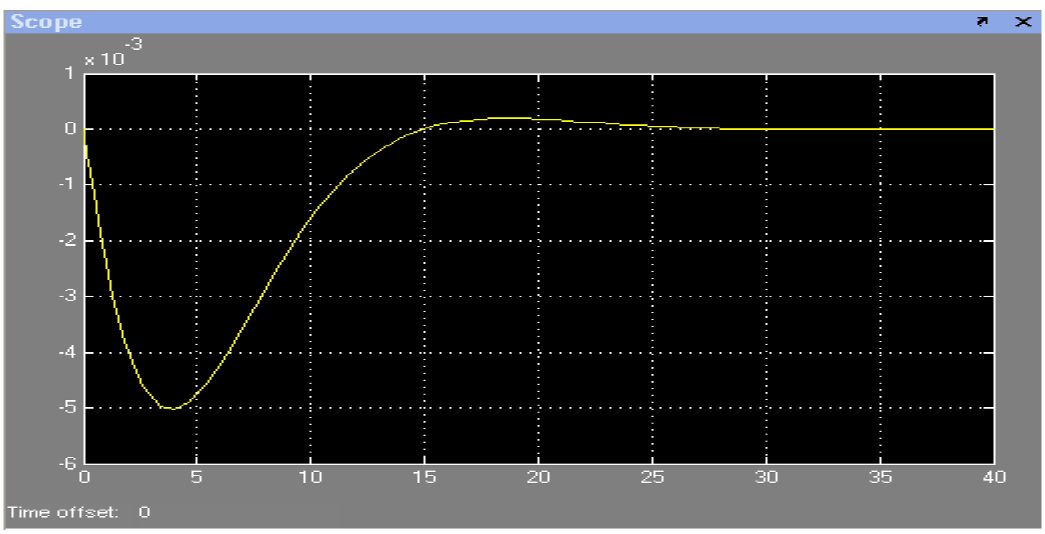


Figure 6: Closed loop LFC system for single area

The frequency response is as shown:



Time (seconds)

Figure 7: Response for close loop LFC system

It is concluded that the system now modifies to a proportional plus integral controller, which, as is well known from control theory, gives zero steady state error, i.e. Δf (steady state) = 0.

5.3 LFC System in Restructured Environment

Case – 2

Consider a case where the GENCOs in each area participate equally in AGC, i.e. ACE participation factors are apf1 =0.5, apf2=1-apf1=0.5; apf3=0.5, apf4=1-apf3=0.5. In this case, load is demanded only by DISCO1 and DISCO2. Note that as DISCO3 and DISCO4 do not demand from any GENCOs, corresponding participation factors (columns 3 and 4) are zero. DISCO1 and DISCO2 demand identically from their local GENCOs viz. GENCO1 and GENCO2.

The DPM of below figure can be given as:

DPM =

	DISCO1	DISCO2	DISCO3	DISCO4
GENCO1	0.5	0.5	0	0
GENCO2	0.5	0.5	0	0
GENCO3	0	0	0	0
GENCO4	0	0	0	0

Figure 8: DPM for GENCOs

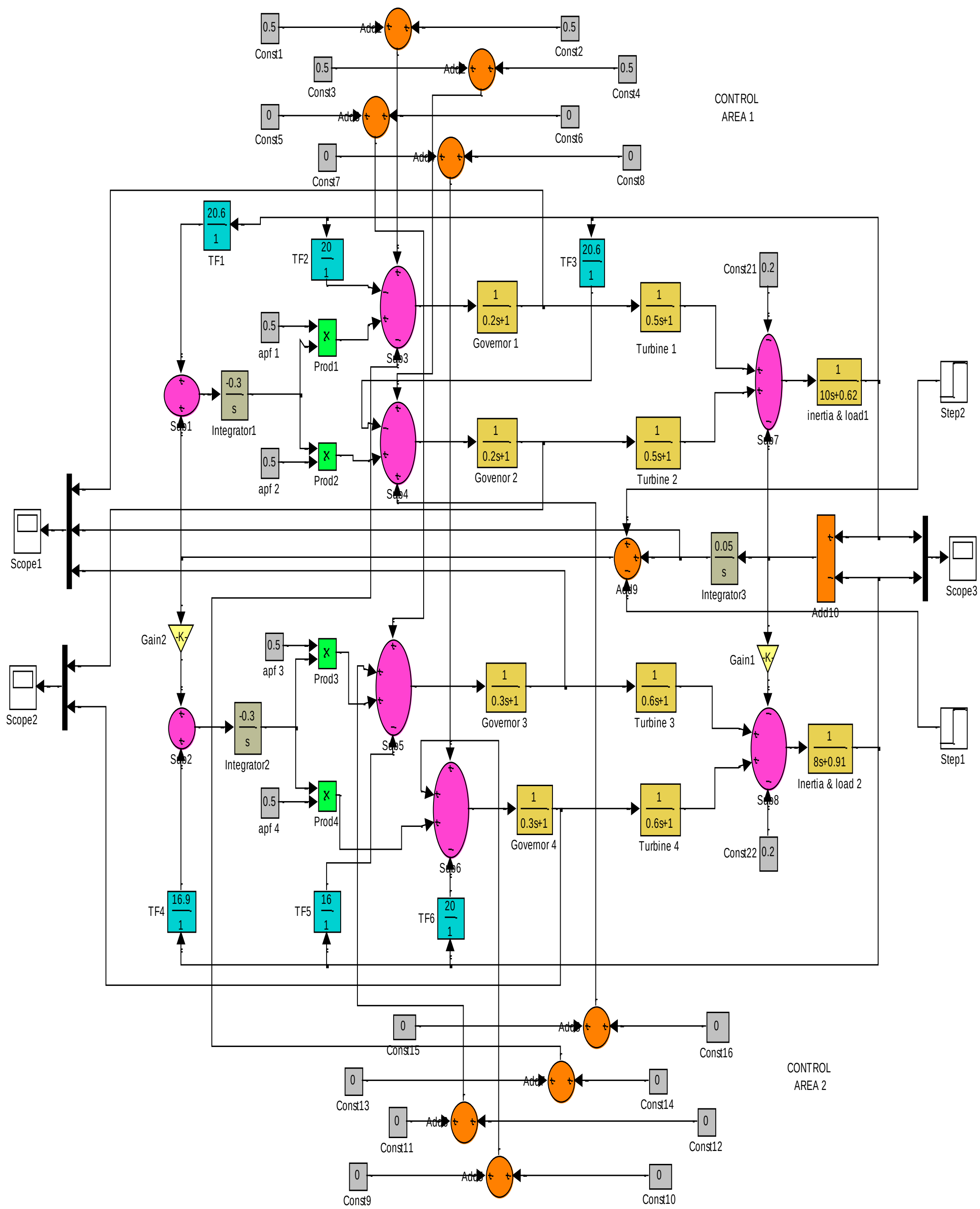
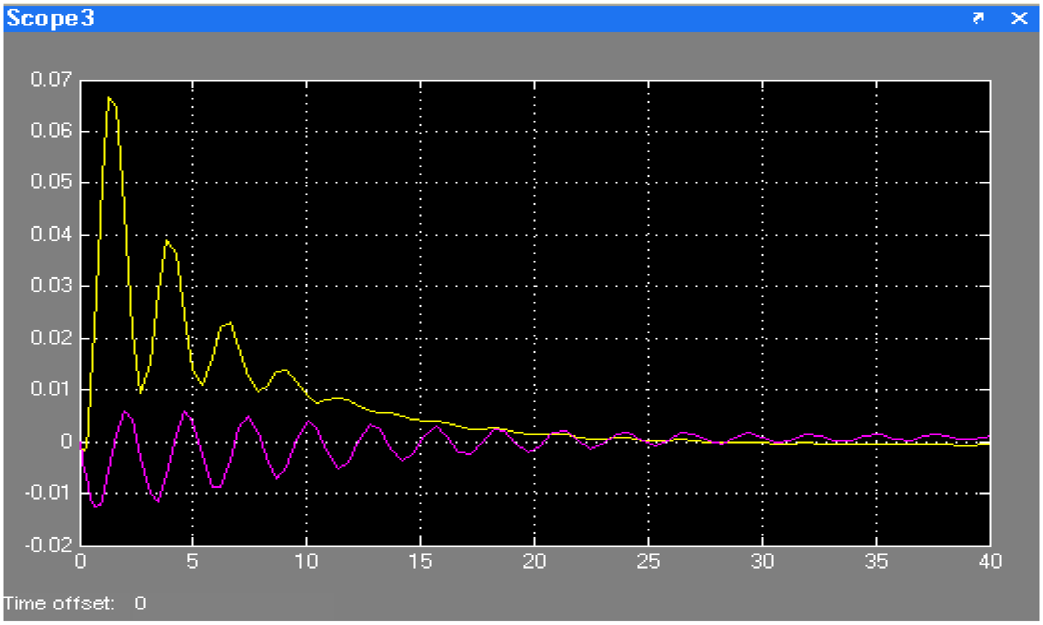


Figure 9: AGC model for complete two area system in restructured environment

The frequency response of the system is as shown below:-



Time (seconds)

Figure 10: Frequency Response for complete two area LFC system in restructured environment

The frequency deviation in each area goes to zero in the steady state. As only the DISCOs in area I, *viz.* DISCO1 and DISCO2, have nonzero load demands, the transient dip in frequency of area I is larger than that of area II.

CASE - 2

Consider a case where all the DISCOs contract with the GENCOs for power as per the following

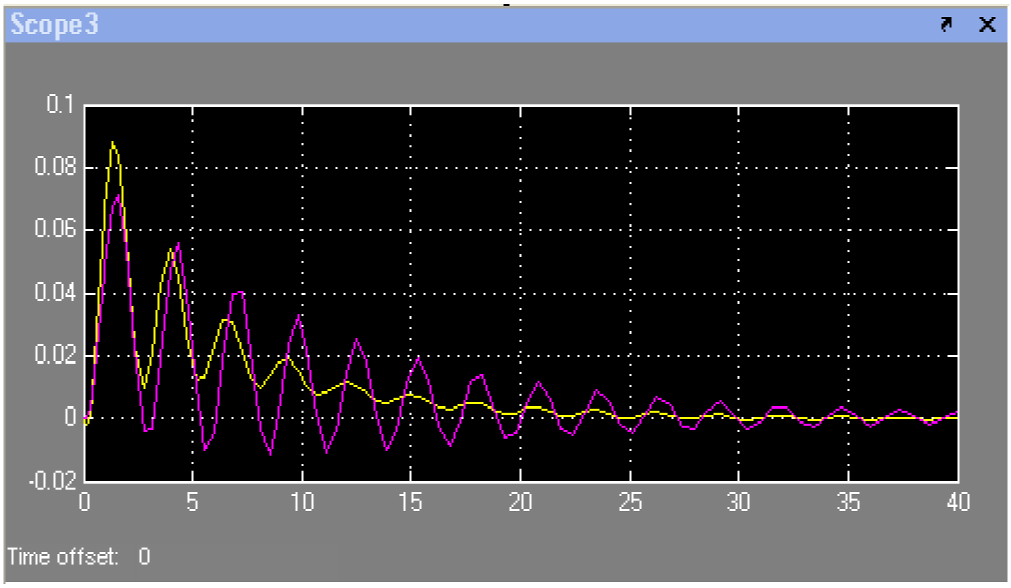
DPM =

	DISCO1	DISCO2	DISCO3	DISCO4
GENCO1	0.3	0.25	0	0
GENCO2	0	0.25	1	0.7
GENCO3	0.2	0.25	0	0
GENCO4	0.5	0.25	0	0.3

Figure 11: DPM for Case 2

Assume that the total load of each DISCO is perturbed by 0.1 pu and each GENCO participates in AGC as defined by following apfs: apf1=0.5, apf2=1-apf1=0.5; apf3=0.5, apf4=1-apf3=0.5.

Frequency Response for complete two area system in restructured environment:



Time (seconds)

Figure 12: Frequency Response for complete two area system in restructured environment

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