

Nonlinear Estimation of External Power System Dynamic Equivalent Parameters

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Received: 14 February 2012 Accepted: 2 March 2012 Published: 15 March 2012

Abstract

Based on the concept of the external power system dynamic equivalent for the study system, this paper proposes a novel evolutionary method for the identification of the equivalent parameters, comparing the answers of the complete network and its equivalent following the small disturbances which emerged in the study system. The proposed method is demonstrated and compared with the original system using the 10 machines 39 buses New England test system. The comparison shows that the proposed approach can preserve all dynamic properties of the original network.

Index terms— Dynamic equivalents, Dynamic modeling, Genetic algorithm, Nonlinear identification, Multimachine system, Parameter identification, Power system, Structure

Introduction Electric power systems have long been perceived and exploited like national entities or regional areas. The interconnections between such zones being mainly used with the aim of help in case of failure in a nearby zone. In the new context of the electricity sector, this situation has changed since the interconnections are increasingly used in order to maximize the exchange of electricity through power exchanges recently introduced. This leads the transmission system operators (TSOs) to operate their systems increasingly close to their limits. In an individual way, each TSO is obliged to re-examine its way of doing the usual studies on its own network. In particular, a more refined modeling of the influence of neighboring systems on its own should be considered. Moreover, the process of extension of the synchronous area which continues today, led to a significant increase in the size of dynamical systems to study. Besides the difficulty posed by the size, new structural phenomena occur from this extension as the electromechanical oscillations of low frequency observed between generators remote network.

Many dynamic equivalence techniques have been developed over the years [1]- [9]. More research focused on coherency equivalents and modal equivalents nowadays, however, they need detailed data of the external system which may be difficult to get in the power market environment. Some estimation methods are based on available information from the boundaries nodes and do not require any knowledge detail of the external network. The classical estimation methods are mainly based on the linearization of the system around an operating point with theoretical constraints validity [10] - [12]. Consequently, they are limited by their validity in nonlinear practical applications, offline and online applications. This paper proposes a new evolutionary approach for estimating parameters to determine a dynamic equivalent model of an external power system from synchronized measurements of disturbance occurred in internal system, which obtained by PMUs (Phasor Measurement Units). This approach was applied to 10 machines 39 buses New England test system [13]. Comparing the properties of the equivalent system with ones of the original system, the result shows that the reduced system can represent dynamic behaviors of the original system well, for any kind of disturbance.

41 **1 II.**

42 **2 Dynamic Equivalentts**

43 The equivalent is represented by a model with unknown parameters. In operation, the power system is often
 44 perturbed by small random disturbances. The estimation of unknown parameters of the equivalent model is
 45 operated by comparing the measurements obtained from the real network, and the same measurements made on
 46 the equivalent network by minimizing some objective function.

47 **3 a) Dynamic equivalent model**

48 The basic requirement of the dynamic equivalentts is that the response of the equivalent system can fit the
 49 original system dynamically and approximately when faults happen in the internal system. In our equivalent
 50 system, equivalent generator represents dynamic effect of the external system on the internal system located at
 51 the boundary bus (Fig. 1). When there are multiple boundary buses connecting the external system with the
 52 internal system, multiple generators are adopted to represent dynamic influence of the external system on the
 53 internal system, with an equivalent generator located at each boundary bus [14]. Parameters to be estimated
 54 are: $\delta, \dot{\delta}, \ddot{\delta}, \tau, \tau', \tau''$, voltage regulator gain K and its time constant T . The parameters
 55 identification for nonlinear systems includes deterministic and evolutionary methods. Evolutionary methods offer
 56 greater ease of adjustment problems and other advantages over deterministic methods because they:

57 -Require only the calculation of the objective function, without this last being forced to be continuous or
 58 differentiable.

59 -Easily adaptable to multi-objective problems optimization, and complex systems with very important
 60 unknown number of parameter.

61 -Have great theoretical probability to find the global optimum.

62 -Offer great simplicity of implementation.

63 An evolutionary approach based on genetic algorithms is presented in this document, to identify the dynamic
 64 equivalent model parameters, by minimizing the range of speed variation, electrical power variation and terminal
 65 voltage variation produced in all generators of the internal system between the original and the equivalent system.

66 **4 i. Error function**

67 The original system equations are generally written: (5) Where: A = State matrix ($4m \times 4m$). B = Control
 68 matrix ($4m \times 2m$). C = Output matrix ($2m \times 4m$).

69 $\dot{\delta}$ Absolute angle rotor variation (rad. elec/sec).

70 $\ddot{\delta}$ Angular velocity rotor variation (pu).

71 δ Internal voltage variation (pu).

72 $\dot{\delta}$ Internal excitation voltage variation (pu).

73 Mechanical torque variation (pu).

74 Order excitation systems variation (pu).

75 Active power variation (pu).

76 Change in terminal voltage generators (pu).

77 The equations describing the dynamic equivalent system are expressed similar to those of the original system
 78 (??), but with a simplified structure and less parameters. (6) are all functions of δ , the equivalent system
 79 parameter vector to be identified. Therefore, an error function may be defined by: (7) Where $\hat{\delta}$ represents
 80 the responses of the original system, which are directly measurable.

81 And $\hat{\delta}$ (??), must be calculated by simulating the equivalent system with the same disturbance.

82 **5 ii. Objective function**

83 The idea is to minimize the error function (7) between the measure and the model output for all machines
 84 belonging to the internal network. The mathematical model of the optimization problem is a multi-objective
 85 function and can be formulated as follows: (8) Where:

86 By weighting the measurements by a weighting factor w , our objective function becomes: (9) Where:
 87 N = number of machines belonging to the study system (internal system).

88 iii. Encoding and initial population

89 The encoding of individuals is an important parameter in population research methods. These are represented
 90 as a strings (chromosomes) containing characters or genes of a predetermined alphabet. There are different ways
 91 to code a solution. In our study, the individual is represented by eight parts of chromosome corresponding to the
 92 eight parameters to be estimated, each gene (parameter) is represented by its physical value, which means that,
 93 the real coding is adopted (fig. 2).

94 The GAs requires an initial population to start search process. Applied methods generate randomly a set of
 95 solutions belonging to the following area: (10) Where:

96 The individuals' number in the initial population is chosen such that: To form a group of (Local parents), in
 97 which each parent "i" satisfied the fitness function minimum: (13) Where:

98 -A number of individual « N » ;

99 To form a group of (Global parents), in which each parent "k" satisfied the fitness function minimum: (14)
100 Where:

101 The local parents group includes the favorable solutions for each type of measure that corresponds to each
102 machine belonging to the internal system. However the global parents group includes the favorable solutions for
103 each type of measure that corresponds to all the machines belonging to the internal system. The population
104 called, "Parents population" is made up of the two groups (Global parents & Local parents).

105 6 b. Multi-parent recombination

106 Recombination is used mainly in evolutionary strategies. Contrary to k points crossover operators, which
107 exchange information between two parents, the recombination creates the descendants, by weighting many parents
108 components'. We define three weighting operators: Where:

109 $h \in [1,8]$ Integer belonging to [1,8], which represents crossed chromosome order.

110 l, g : Two individuals of local parents group.

111 We generate h individuals for construct the new population (generation) from the two groups' "local
112 parents" and "global parents", with the following steps: -we choose a random pair of individuals from the local
113 parents group.

114 -a crossed chromosome is chosen randomly « chr ».

115 -a random real number, "h", is generated between 0 and 1, to select the weighting operator (Fig. 4). (15)

116 -we move to the next individual "i +1" when the number of weighting point "k" of the individual "i" is
117 complete.

118 3. Accordance with the procedure for selection of parents, the best individuals evaluated by the fitness function
119 (12) between parents population and this new population, construct the new parents population and clear the
120 old parents population for the next generation (elitist strategy).

121 III.

122 7 Algorithm

123 The complete algorithm of the proposed method is given below:

124 Step1 : Introduction of static and dynamic data of the complete system.

125 Step2 : Power flow calculation, linearization, disturbance choice and network dynamic simulation.

126 Step3 : Border node choice and equivalent system linear model construction from results of the power flow.

127 Step4 : Generating the initial population according to the procedure specified in subsection (III.B.3).

128 Step5 : Run equivalent system dynamic simulation and evaluate all individuals by fitness function (12).

129 Step6 : Construct the population of parents following the procedure described in paragraph (III.B.5.a), with
130 equations (13,14).

131 Step7 : While the number of generation has not reached the maximum number δ :

132 Step7.1 : Generate the new population using described procedure in paragraph (III.B.5.b).

133 Step7.2 : Run equivalent system dynamic simulation and evaluate all individuals by fitness function (12).

134 8 Application

135 To validate the proposed approach, developed algorithm was used to build the dynamic equivalent of transmission
136 network IEEE New-England 39 bus [13]. It represents a simplified New England transmission network
137 (northeastern United States) that is part of real U.S. network. This network consists of 10 generators (PGtotal=
138 6.19 GW, QGtotal= 1.28 GVar) and 39 bus with 19 load bus. The original system structure is as Fig. 5. new
139 population (Fig. 3). In Fig. 5, the shaded part is the internal system and the rest is the external system to be
140 reduced. There are a boundary bus 16 and two tie lines 16-15 and 16-17 between the internal and the external
141 systems. Fig. 6 is the sketch of the equivalent system. II. These parameters were obtained after several tests
142 with an appropriate adjustment.

143 9 ? > 0

144 10 Table II : Control Parameter Values

145 To allow a better parameters estimation, different disturbances were applied in different parts of the internal
146 system. Each proposed disturbance has a period of 10s. An event is generated each time to the first second of the
147 simulation. The algorithm verifies the equivalents behavior in period of 10s, by comparing its response with the
148 response of the original system. If the equivalent response exceeds some level relatively to the original systems
149 response in a new disturbance, the equivalent generator parameters are recalculated and updated. Each solution
150 obtained by applying the previous disturbances must be part of the initial population of the next estimation
151 procedure. The estimated parameters of the equivalent generator are presented in Table III.

152 11 b) Validation

153 A small perturbation represented by disconnecting the line 3-18 is applied to bus18 of the equivalent system and
154 the original system respectively at time, $t=2s$ and lasted for about 12 cycles. Time domain dynamic simulations

155 were performed both on the two systems. In order to verify the performance of the proposed dynamic equivalent
156 approach in the case of the large disturbances, three-phase fault was applied to bus 30 of the equivalent system
157 and the original system respectively at time $t=2s$, and the fault lasted for about 3 cycles. Time domain dynamic
158 simulations were carried out on the original system and the equivalent system, and dynamic responses are shown
159 in fig. 10 The simulation results of equivalent system with estimated parameters are encouraging and show the
160 effectiveness of the developed algorithm and the ability of the estimated equivalent to reproduce the influence of
161 the external system on internal system for small and severe disturbances.

162 V.

163 12 Conclusion

164 In this study, we proposed a nonlinear estimation method for parameters, based on an evolutionary algorithm. In
165 order to obtain the external system dynamic equivalent, several dynamic simulation disturbances were applied to
166 increase the accuracy of the model estimated by the developed algorithm. The proposed approach does not require
167 data of external system. This approach requires only configuration information, settings and operating status of
168 the internal system. Dynamic simulation was performed on both the original system and the equivalent system
169 under different operating conditions, and the results show that the obtained equivalent system can represent the
170 main dynamic characteristics of the original system well. Thus, the approach proposed is proved to be feasible
171 and has potential for tackling the complex practical application in power system.

172 13 Global Journal of Researches in Engineering



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Figure 1: Fig. 1 .

173 1 2 3 4

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²F © 2012 Global Journals Inc. (US) 2012 July

³© 2012 Global Journals Inc. (US) 2012 July

⁴F © 2012 Global Journals Inc. (US) 2012 July Fig. 8 : Angle of the machine 10

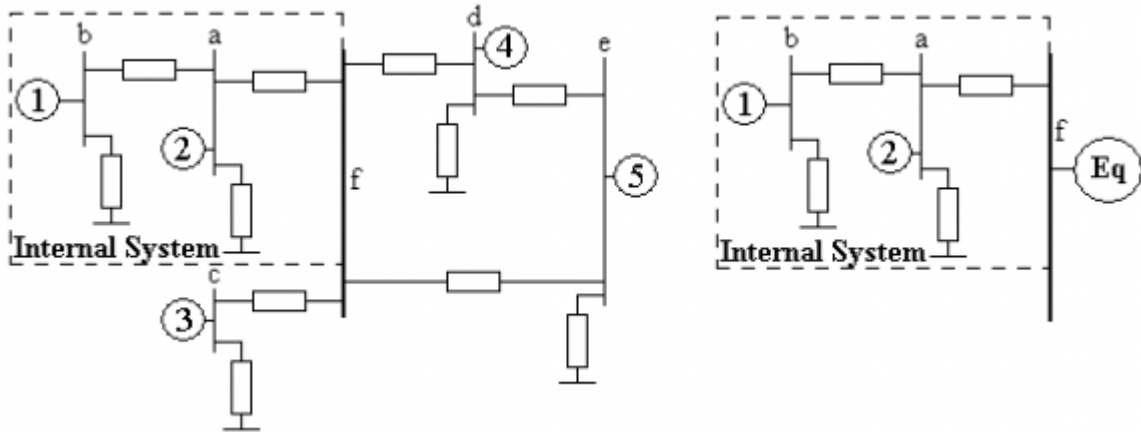
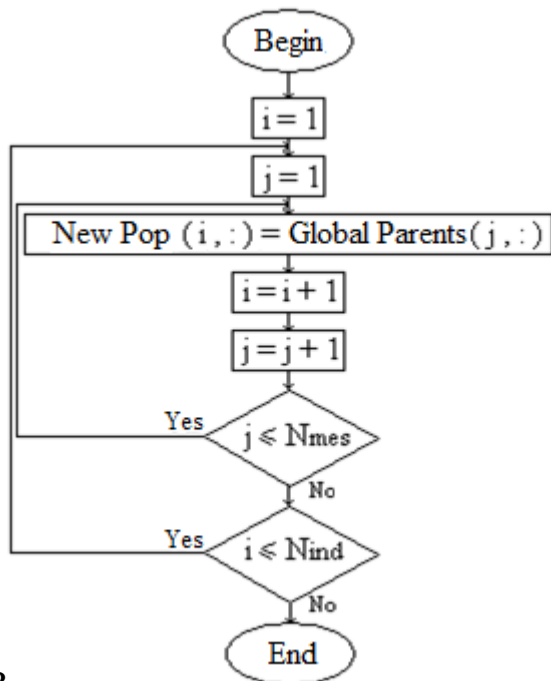


Figure 2: Nonlinear

Initial Population								
0.0200	0.2300	0.4000	0.013	1.000	0.1020	23.78	0.0500	1
0.1201	0.0340	0.2020	0.323	2.030	0.0030	10.79	0.0410	2
.
.
.
0.1500	0.0441	0.1460	0.020	0.031	0.0280	104.7	0.1001	Nind
Xd	Xq	Xd	H	D	Tdo	Ka	Ta	

Figure 3:



2

Figure 4: Fig. 2 :

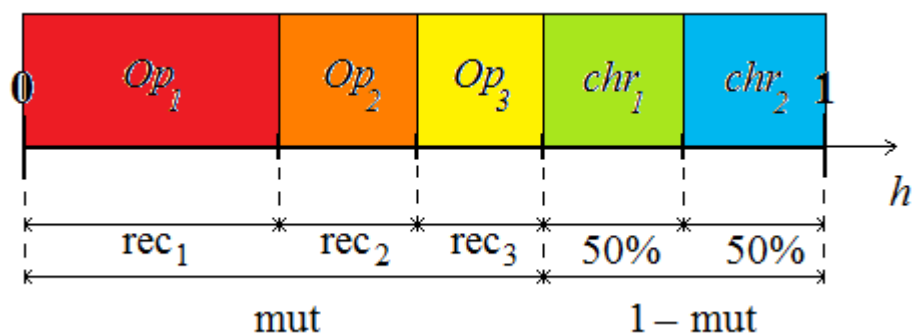


Figure 5:

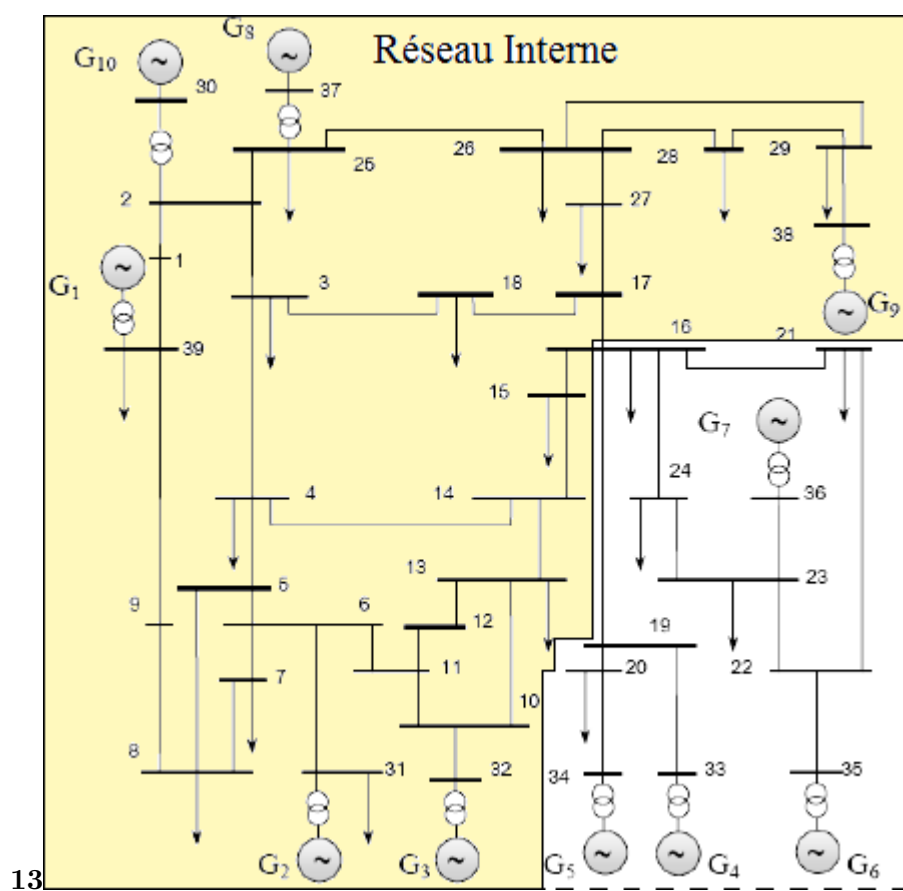


Figure 6: 1 .Fig. 3 :

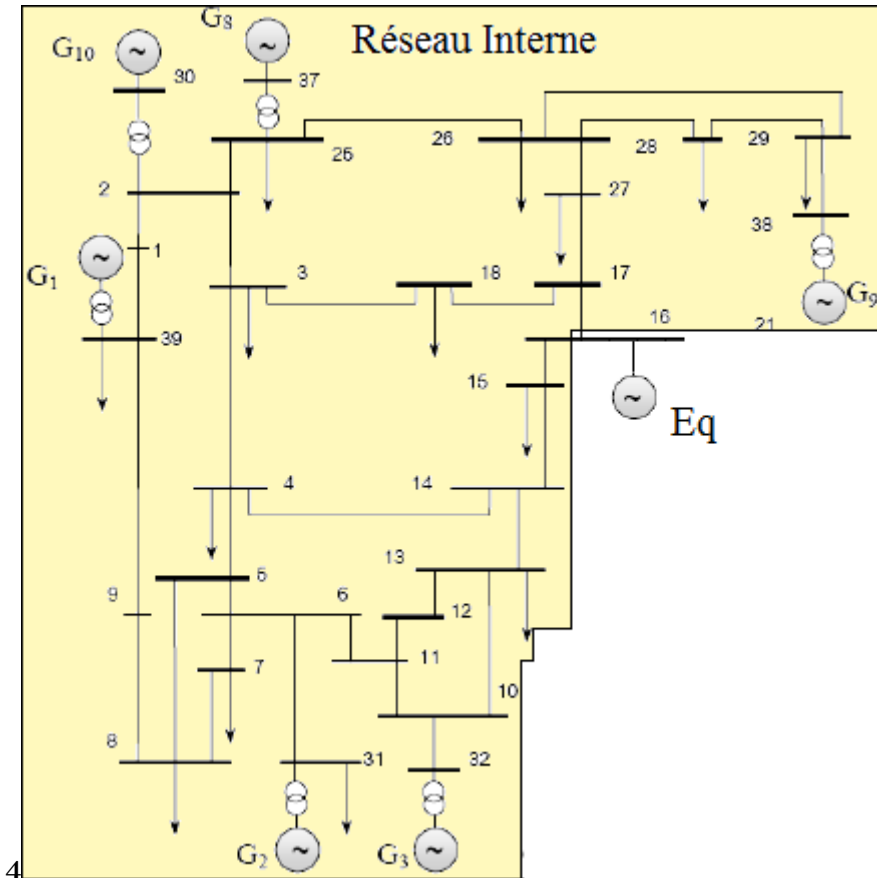
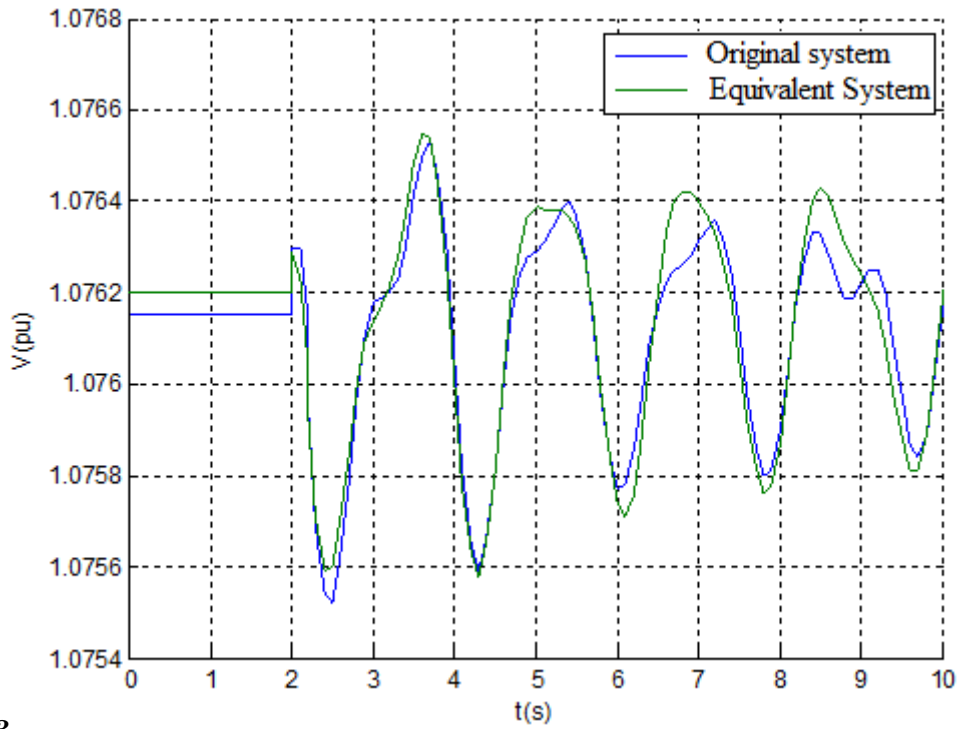
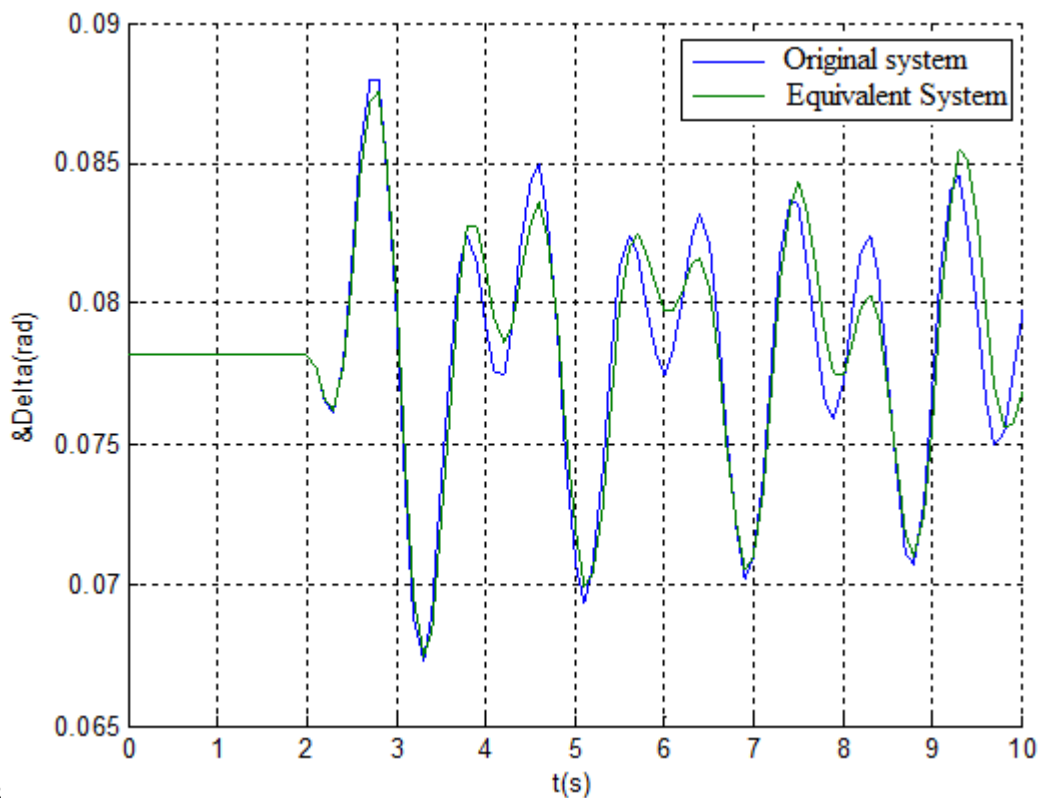


Figure 7: Fig. 4 :



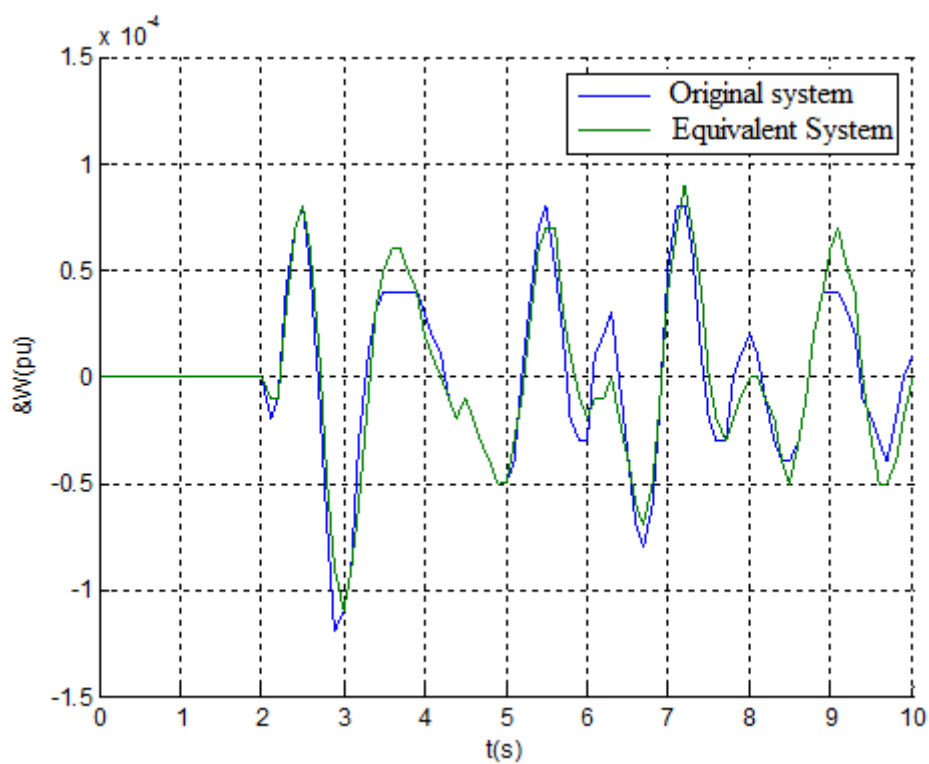
3

Figure 8: Step7. 3 :



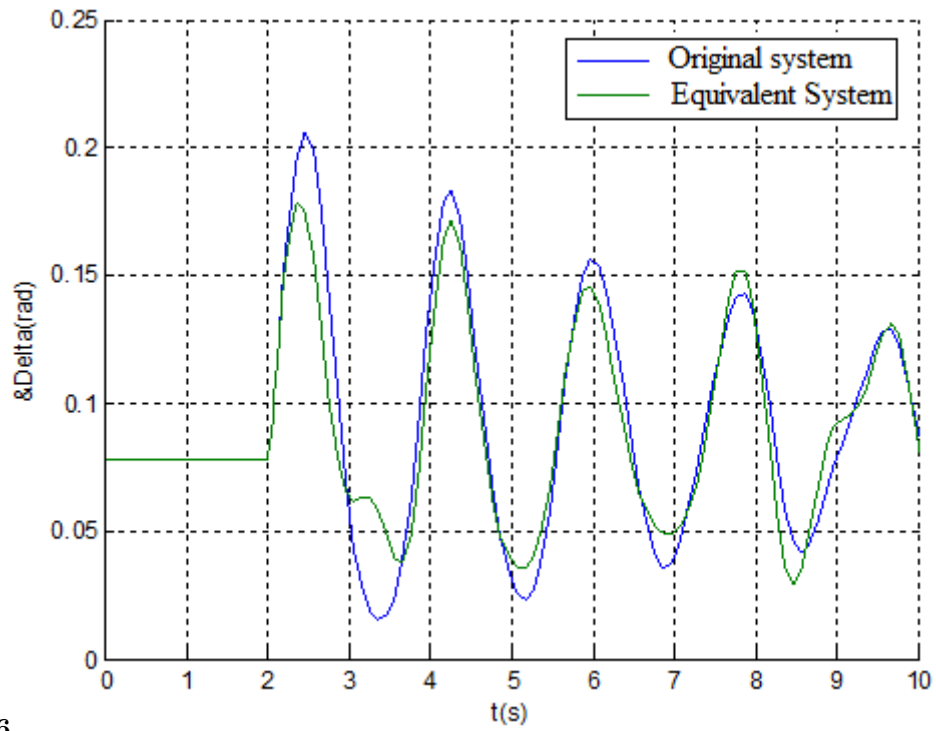
23

Figure 9: Nonlinear 2 ?? 3



5

Figure 10: Fig. 5 :



6

Figure 11: Fig. 6 :

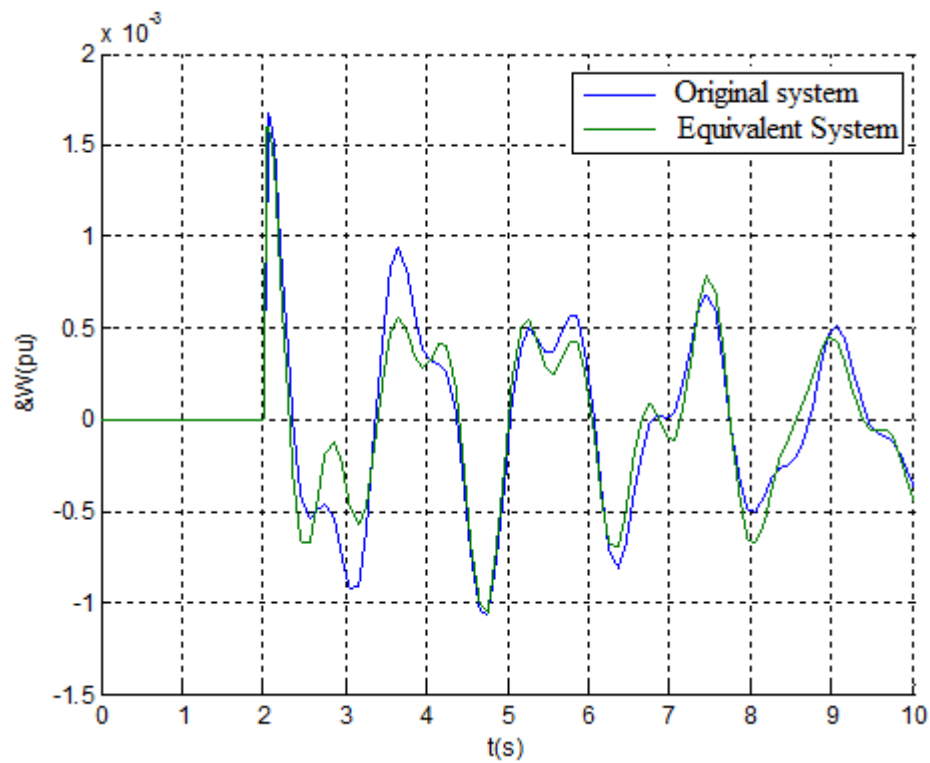


Figure 12:

Figure 13: Table . I

I

Figure 14: Table I :

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