Model order reduction using logarithmic assembly technique
and second Cauer form for power system models

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Abstract. Power system is broad, wide and complex area to do research therefore, for reducing
complexity; there is an enormous possibility of simplification of large system in the field of
science and technology. Hence, this paper presents a new vital advance methodology a mixed-
demand reduction that uses logarithmic assembly technique and the second Cauer form to
minimize the order of multivariate feed systems on a large scale power system. Model order
reduction technique helps to reduce the large scale power system into an approximate small scale
model without changing the inherent property of the actual system. A multi-boundary model of
the low-order model is achieved by utilizing new methodology for the aggregation of the pound
called the logarithmic mass of the poles, while the numeral coefficients are obtained in the
second form of Cauer. The usefulness of the anticipated technique has been tested on two-area
power system models.

Keywords: Model order reduction, logarithmic assembly technique, Cauer Second Form; immovability; Power System Models

1. INTRODUCTION

There is a quick advancement in engineering and technology that leads to tremendous study in ample
systems modeling and controller design. The arithmetical modeling of the comprehensive systems are
very frequently techniques and consequences the complex models. These complex models are required
to be reduced or simplified so that a more reliable and efficient controller could be designed for getting
desired objectives. A number of techniques for order reduction [1-6] have been suggested in the last few
decades for reducing the order of single as well as multivariable systems in frequency and time domain,
however, some reduction methods showed deficiency in reducing the order of all kind of systems and
also few methods [7-8] are lacking to keep hold of immovability of actual system in the decreased order
models. Therefore, by combining two reduction methods, numerous mixed order reduction techniques or methodologies [9-13] have been developed and discussed in the last few decades.

In the given article, a creative approach for order diminution of Multi-Input and Multi-Output models of power system is suggested such that it can be useful for reduced order controller design. The anticipated techniques are an incorporation of logarithmic assembly and Cauer second form [14]. The Clustering method originally suggested by Pal [15] and then it was modified by Vishwakarma [16] as modified pole clustering. Further modified pole clustering [16] is improved by Singh [17] which gives more dominant pole cluster centre than [15] and [16]. The modified pole clustering [16] has an interactive seven step computer oriented algorithm.

In the present work, a single step algorithm based dominant pole cluster centre is applied instead of Inverse Distance Measure (IDM) criterion with seven step algorithms.

2. DESCRIPTION OF THE METHOD

The problem statements for multivariable systems are as following:

\[ G_p(s) = \frac{1}{D(s)} \begin{bmatrix} A_1(s) & A_2(s) & \cdots & A_p(s) \\ A_1(s) & A_2(s) & \cdots & A_p(s) \\ \vdots & \vdots & \ddots & \vdots \\ A_1(s) & A_2(s) & \cdots & A_p(s) \end{bmatrix} \]  

\[ R_q(s) = \frac{1}{D(s)} \begin{bmatrix} B_1(s) & B_2(s) & \cdots & B_q(s) \\ B_1(s) & B_2(s) & \cdots & B_q(s) \\ \vdots & \vdots & \ddots & \vdots \\ B_1(s) & B_2(s) & \cdots & B_q(s) \end{bmatrix} \]  

Where, \( D(s) = A_{11} + A_{12}s + A_{13}s^2 + \ldots + A_{1n+1}s^n \)

\( p \): total input variables (in number)

\( q \): total output variables (in number).

The transfer function of diminished model with same quantity of inputs and outputs of but order ‘k’ can be given as:

\[ G_p(s) = \frac{1}{D(s)} \begin{bmatrix} A^k_1(s) & A^k_2(s) & \cdots & A^k_p(s) \\ A^k_1(s) & A^k_2(s) & \cdots & A^k_p(s) \\ \vdots & \vdots & \ddots & \vdots \\ A^k_1(s) & A^k_2(s) & \cdots & A^k_p(s) \end{bmatrix} \]  

\[ R_q(s) = \frac{1}{D(s)} \begin{bmatrix} B^k_1(s) & B^k_2(s) & \cdots & B^k_q(s) \\ B^k_1(s) & B^k_2(s) & \cdots & B^k_q(s) \\ \vdots & \vdots & \ddots & \vdots \\ B^k_1(s) & B^k_2(s) & \cdots & B^k_q(s) \end{bmatrix} \]  

Where, \( D(s) = B_{11} + B_{12}s + B_{13}s^2 + \ldots + B_{1k+1}s^k \)

The intention of this approach is to grasp the compressed request models as (2) from the actual model (1), such that it holds the significant attributes of main high order system.

The anticipated diminution method has the following two steps to obtain the abridged denominator polynomial and numerator coefficients as follows:

**Step-1:** Using logarithmic assembly technique, first determine the polynomial equation of denominator of reduced model with order ‘k’.

The important points to decide the pole clusters for finding pole cluster centre are as following:

- For real and complex poles, there must be separate pole cluster.
- The poles which are at the left side of the s-plane must not carry the poles that of the right side of the s-plane and vice versa.
- The poles that are on the imaginary (Y) axis should be in a shortened model.
- The diminished order model must have the origin poles.

Consider the real poles of \( i^{th} \) – cluster are ‘\( r \)’ i.e. \( \sigma_1, \sigma_2, \ldots, \sigma_r \), where \( |\sigma_1| < |\sigma_2| < |\sigma_3| < \ldots < |\sigma_r| \). The calculation of logarithmic pole cluster center is given as
\[
\sigma_{kj} = - \left[ \sigma_1 + \left[ \log_{10} \left( 1 + \frac{\sigma_1 + \sigma_2 + \cdots + \sigma_r}{k \times r} \right) + (r \times n) \right] \right]
\]

(3)

The above formula (3) is used to calculate the real and imaginary part both of complex poles individually. Now, the \( j^{th} \)-logarithmic pole cluster center can be written as:

\[
\Phi_{kj} = A_{kj} \pm jB_{kj}
\]

Where \( \Phi_{kj} = A_{kj} + jB_{kj} \) and \( \Phi_{kj} = A_{kj} - jB_{kj} \)

To synthesize the minimized denominator polynomial \( D_k(s) \), consider the given conditions:

**Case-I:** For real pole cluster centres, the reduced denominator \( k^{th} \) - order polynomial can be calculated as:

\[
D_k(s) = (s - \sigma_{k1})(s - \sigma_{k2}) \cdots (s - \sigma_{kk})
\]

(4)

**Case-II:** For complex conjugate pole cluster centres, the \( k^{th} \) – order polynomial for denominator can be obtained as

\[
D_k(s) = (s - \hat{\Phi}_{11})(s - \hat{\Phi}_{12}) \cdots (s - \hat{\Phi}_{kk})(s - \hat{\Phi}_{kk})
\]

(5)

**Case-III:** For some real and some complex conjugate pole cluster centres: as \((k - 2)\) cluster centres are real and a pair of cluster centres is complex conjugate, denominator of \( k^{th} \) order can be determined as

\[
D_k(s) = (s - \sigma_{k1})(s - \sigma_{k2}) \cdots (s - \sigma_{k(k-2)})(s - \hat{\Phi}_{kk})(s - \hat{\Phi}_{kk})
\]

(6)

**Step-2:** Using Cauer second form [14], determine the coefficients of the minimized numerator \( N_k(s) \).

First use Routh Array to determine the coefficients of Cauer second form \( H_p(s) \) \((p = 1,2,3,\ldots,k)\) as

\[
H_1 = \begin{pmatrix}
A_{11} & A_{12} & A_{13} & \cdots & A_{1,n-1} \\
A_{21} & A_{22} & A_{23} & \cdots & A_{2,n}
\end{pmatrix}
\]

\[
H_2 = \begin{pmatrix}
A_{21} & A_{22} & \cdots & A_{2,n} \\
A_{31} & A_{32} & \cdots & \cdots
\end{pmatrix}
\]

\[
H_i = \begin{pmatrix}
A_{i1} & A_{i2} & \cdots & \cdots \\
A_{i1} & A_{i2} & \cdots & \cdots
\end{pmatrix}
\]

In the above mentioned array, the initial two rows are the coefficients of denominator and numerator of the actual system \([G_s(s)]\) and the remaining rows are calculated by the recursive formula called as Routh’s algorithm.

\[
A_{ij} = A_{i-2,j+1} - H_{i-2,j} \quad \text{where} \quad i = 3,4,\ldots; j = 1,2,\ldots
\]

(8)

\[
H_i = \frac{A_{i1}}{H_{i-1,1}} \quad \text{where} \quad i = 1,2,\ldots,k
\]

(9)

To compare the coefficients of \( B_{i,j} \) \((j = 1,2,\ldots,k + 1)\) of (2) and Cauer quotients \( H_p(s) \) \((p = 1,2,\ldots,k)\) of (7) to calculate the coefficients of numerator of the diminished order model \([R_i(s)]\), the inverse Routh array can be developed as follows:

\[
B_{i+1,j} = \frac{B_{i,j}}{H_i} \quad \text{where} \quad (i = 1,2,\ldots,k)
\]

(10)

\[
B_{i+2,j} = \frac{(B_{i,j+1} - B_{i,j})}{H_i} \quad \text{where} \quad i = 1,2,\ldots,(k - j) \quad \text{&} \quad j = 1,2,\ldots,(k - 1)
\]

(11)
Now use (7) - (11), to calculate reduced polynomial of the numerator \( N_k(s) \)
\[
N_k(s) = B_{21} + B_{22}s + B_{23}s^2 + \ldots + B_{2k}s^{k-1}
\]  

(12)

3. PROBLEM STATEMENT

Two two-area power system models have been considered here and reduced to low order models utilizing the proposed technique to show its effectiveness. The integral Square Error (ISE) is determined between the transient parts of actual system and the shortened model in order to show the viability of the reduced models. The equation of ISE is as follows

\[
ISE = \frac{1}{0}^{\infty} [y(t) - y_k(t)]^2 dt;
\]  

(13)

Where, \( y(t) \): Original system’s unit step response
\( y_k(t) \): Unit step response of diminished system model
\( y(\sigma) \): Original system’s steady state value.

If ISE has small value, it indicates that the response of actual system and reduced order model highly matches.

Problem 1 A model of power system with optimal controller is considered as [18].

\[
A = \begin{bmatrix}
-0.05 & 6 & 0 & 0 & 0 & 0 & -6 & 0 & 0 \\
0 & -3.3 & 3.3 & 0 & 0 & 0 & 0 & 0 & 0 \\
-5.2083 & 0 & -12.5 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.05 & 6 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -3.3 & 3.3 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -5.2083 & 0 & -12.5 & 0 & 0 \\
0.5250 & 0 & 0 & -0.5250 & 0 & 0 & 0 & 0 & 0 \\
0.4250 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0.4250 & 0 & 0 & 0 & 0 & -1 \\
\end{bmatrix},
\]

\[
B = \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 12.5 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\end{bmatrix},
\]

\[
C = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
\end{bmatrix},
\]

\[
D = \begin{bmatrix}
0 & 0 & 0 \\
0 & 0 & 0 \\
0 & 0 & 0 \\
0 & 0 & 0 \\
0 & 0 & 0 \\
0 & 0 & 0 \\
\end{bmatrix},
\]

Hence, determine the transfer function matrix from the state model as

\[
G(s) = C[\lambda I - A]^T B + D
\]

\[
G(s) = \frac{1}{D(s)} A_{21}(s) A_{22}(s) A_{23}(s) + A_{24}(s)
\]

Where,

\[
D(s) = s^2 + 31.77s^3 + 343.5s^4 + 1761s^5 + 7292s^6 + 18100s^7 + 33030s + 27890
\]

\[
A_{21}(s) = 787.5s^2 + 12470s + 32810
\]

\[
A_{22}(s) = 250s^4 + 3971s^3 + 11400s^2 + 39030s + 32810
\]

\[
A_{23}(s) = 250s^4 + 3971s^3 + 11400s^2 + 39030s + 32810
\]

\[
A_{24}(s) = 787.5s^2 + 12470s + 32810
\]

\[
A_{41}(s) = -31.2s^3 - 2085s^2 - 5573s - 13940
\]
\[ A_{42}(s) = 31.2s^3 + 2085s^2 + 5573s + 13940 \]

The suggested approach is applied to calculate third order reduced model and finally \([R_j(s)]\) is obtained as

\[
[R_j(s)] = \frac{1}{D_j(s)} \begin{bmatrix} B_{2j}(s) & B_{22}(s) \\
B_{3j}(s) & B_{32}(s) \\
B_{4j}(s) & B_{42}(s) \end{bmatrix}
\]

Where,

\[
D_j(s) = s^3 + 2.6618s^2 + 8.361s + 10.8527 \\
B_{2j}(s) = -0.5978s^2 - 0.4299s + 12.76 \\
B_{22}(s) = -0.747s^2 + 9.904s + 12.76 \\
B_{3j}(s) = -0.747s^2 + 9.904s + 12.76 \\
B_{32}(s) = -0.5978s^2 - 0.4299s + 12.76 \\
B_{4j}(s) = -0.3774s^2 + 0.058s - 5.426 \\
B_{42}(s) = 0.3774s^2 - 0.058s + 5.426
\]

The comparison of the step responses of reduced model \([R_j(s)]\) and actual model \([G(s)]\) is represented in Figure 1.

The responses of actual system and reduced model are highly matched.

**Problem 2:** Consider two area model of power system with optimal controller and AC-DC parallel line given below[18].

**Figure 1:** Step response comparison for problem 1

| RM | \(R_{21}(s)\) | \(R_{22}(s)\) | \(R_{31}(s)\) | \(R_{32}(s)\) | \(R_{41}(s)\) | \(R_{42}(s)\) |
|----|---------------|---------------|---------------|---------------|---------------|---------------|
| ISE| 0.0547        | 0.5005        | 0.5005        | 0.0547        | 0.0188        | 0.0188        |

Here, reduced models (RM) are elaborated as

\[
R_{ij}(s) = \frac{B_{ij}(s)}{D_j(s)} \quad R_{22}(s) = \frac{B_{22}(s)}{D_j(s)} \\
R_{32}(s) = R_{32}(s) = \frac{B_{32}(s)}{D_j(s)} \\
R_{42}(s) = \frac{B_{42}(s)}{D_j(s)}
\]

**Problem 2:** Consider two area model of power system with optimal controller and AC-DC parallel line given below[18].
\[
\begin{bmatrix}
-0.05 & 6 & 0 & 0 & 0 & 0 & -6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -6 & 0 \\
0 & -3.33 & 3.33 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-5.2083 & 0 & -12.5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -0.05 & 6 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & -3.33 & 3.33 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & -5.2083 & 0 & -12.5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.525 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.425 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0.525 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
-5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
\]

\[
A=
\begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
9.375 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
9.375 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 3.125 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
\]

\[
B = \begin{bmatrix}
0 \\
0 \\
0 \\
6.25 \\
0 \\
0 \\
0 \\
0 \\
3.125 \\
0 \\
0 \\
6.25 \\
0 \\
0 \\
0 \\
0 \\
0 \\
0
\end{bmatrix}
\]

\[
C = \begin{bmatrix}
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
\]

\[
D = \begin{bmatrix}
0 \\
0 \\
0 \\
0
\end{bmatrix}
\]

Sol: The transfer function matrix can be attained from the state model as \[ G(s) = C[sI - A]^{-1}B + D \]

The suggested approach is applied to calculate third order reduced model and finally \[ R_3(s) \] is obtained as

\[
\begin{bmatrix}
R_3(s) \end{bmatrix} = \frac{1}{D_3(s)} \begin{bmatrix}
B_{21}(s) & B_{22}(s) \\
B_{31}(s) & B_{32}(s) \\
B_{41}(s) & B_{42}(s)
\end{bmatrix}
\]

Where,

\[
D_3(s) = s^3 + 3.0875 s^2 + 41.5065 s + 20.6505
\]

\[
B_{21}(s) = -3.021 s^2 + 20.24 s + 5.6115
\]

\[
B_{22}(s) = -0.058 s^2 + 0.3876 s + 5.6115
\]

\[
B_{31}(s) = -0.058 s^2 + 0.3876 s + 5.6115
\]
The comparison of the step responses of reduced model \([R(s)]\) and actual model \([G(s)]\) is represented in Figure 2. The responses of actual system and reduced model are highly matched.

![Step response comparison for problem 2](image)

**Figure 2** Step response comparison for problem 2

|   | **RM** | **R_{21}(s)** | **R_{22}(s)** | **R_{31}(s)** | **R_{32}(s)** | **R_{41}(s)** | **R_{42}(s)** |
|---|---|---|---|---|---|---|---|
| **ISE** | 0.0211 | 0.0005 | 0.0005 | 0.0211 | 0.0017 | 0.0017 |

4. **COMPARISON OF METHODS**

The suggested technique has the combination of pole for the reduced dynamic structures through ability of the use of logarithmic pole clustering technique and Cauer second form which has been recycled to calculate the coefficient of the numerator of decreased order system. In the aforementioned approach, the most predominant real pole has to maintain to avoid from the tendency of non-minimum phase which can also minimize the designing complexity of given network.

However, the method is computationally all-around, as the Cauer second form is utilized, so it exclusively requires straight mathematical conditions such as solution of linear algebraic equations to flip up at diminished order models. Moreover, the projected strategy recommends the approach for low order stable system, under the condition with stable high-order actual system. Subsequently, for actual stable system, the poles obtained by logarithmic pole clustering technique consistently provide a stable diminished request model as shown in Figure 1 & 2.

In addition, the most significant features of the proposed strategy are as per the following:

1. The suggested technique overcomes the drawback of continued fraction expansion based techniques [10, 13], which utilizes the stability equation method to analyze the stability of the actual system in preserve connection with the continued fraction expansion methodologies.
2. There is no need of the steady-state value which should be co-ordinated in the suggested approach as on account of Mannerfelt et al. [17], in which the differentiation method is utilized to analyze the minimized polynomials using reciprocal transformation.
3. The technique can be smoothly utilized for the models having real or complex poles and there is no need for error minimization [1, 4] for evaluating the unit step or impulse responses of both (actual and diminished) systems.

4. The method has been used through configuration of the Routh stability array as in [9, 10 and 13] to compute the coefficients of numerator; Hence, it may match with time moments of original system.

5. The performance Indices i.e. ISE is mentioned in the table 1 and 2 shows the minimization of errors.

5. CONCLUSIONS
A mixed reduction technique reliant on the logarithmic pole clustering technique and Cauer second form has been recommended in this work. The reduced denominator polynomial is calculated by utilizing logarithmic pole clustering technique while the numerator coefficients are determined by Cauer second form. The results have been checked and verified as the proposed technique applied on the two major problems considered over here, which have real and complex poles. For both examples, the step responses of actual and minimized models are highly matched, therefore, it is endurable. This strategy is basic, proficient and sets aside significantly less computational effort for ascertaining the reduced low order models. The developed methodology may also be utilized to develop the effective reduced controller for large-scale power systems i.e. two-area or multi-area models of power systems.

REFERENCES
[1] A.K. Mittal, R. Prasad, S.P. Sharma, Reduction of linear dynamic systems using an error minimization technique, J. Inst. Eng. India, IE (I) J. EL 84, March-2004, pp. 201–206.
[2] S.K. Nagar, S.K. Singh, An algorithmic approach for system decomposition and balanced realized model reduction, J. Franklin Inst. 341, 2004, pp. 615–630.
[3] J.C. Geromel, R.G. Egas, F.R.R. Kawaoka, H1 model reduction with application to flexible systems, IEEE Trans. Automat. Control. 50 (3), 2005, pp. 402–406.
[4] S. Mukherjee, Satakshi, R.C. Mittal, Model order reduction using response matching technique, J. Franklin Inst. 342, 2005, pp. 503–519.
[5] Tether A.J., Construction of minimal linear stable variable models from finite input output data, IEEE Trans. Automatic Control, Vol. AC-15, 1970, pp. 427-436.
[6] Wang J., Liu W., Zhang Q. and Xin Xin, H∞ Suboptimal model reduction for singular systems”, Int. Journal of control, Vol. 77, No.11, 2004, pp. 992-1000.
[7] Sinha, N.K. and Pille, W., A new method for order reduction of dynamic systems, International Journal of Control, Vol.14, No.1, 1971, pp.111-118.
[8] Sinha, N.K. and Berzani, G. T., Optimum approximation of high-order systems by low order models, International Journal of Control, Vol.14, No.5, 1971, pp.951-959.
[9] Y. Shamash, Model reduction using the Routh stability criterion and the Padé approximation technique, Int. J. Control 21 (3), 1975, pp. 475–484.
[10] J. Pal, Stable reduced order Pade approximants using the Routh Hurwitz array, Electron. Lett. 15 (8), April 1979, pp. 225–226.
[11] T.C. Chen, C.Y. Chang, K.W. Han, Model reduction using the stability equation method and the continued fraction method, Int. J. Control 32 (1), 1980, pp. 81–94.
[12] C.B. Vishwakarma & R. Prasad, MIMO system reduction using modified pole clustering and Genetic algorithm, Modelling and Simulation in Engineering, Hindawi Pub. Corp., USA, Volume 2009, 2009, pp.1-6.
[13] R. Prasad, Pade type model order reduction for multivariable systems using Routh approximation, Comput. Electr. Eng. 26, 2000, pp. 445–459.
[14] Parmar G., Prasad R. and Mukherjee S., A mixed method for large-scale systems modeling using eigen spectrum analysis and Cauer second form, IETE Journal of Research, Vol. 53, No.2, March-April 2007, pp. 93-102.
[15] J. Pal, A.K. Sinha and N.K. Sinha, Reduced-order modeling using pole clustering and time-moments matching, Journal of The Institution of Engineers (India), Pt EL, 76, 1995, pp. 1-6.
[16] C.B. Vishwakarma, Order reduction using Modified pole clustering and pade approximants,
[17] Jay Singh, C.B. Vishwakarma, Kalyan Chatterjee, Biased Reduction Method by combining Improved modified pole Clustering and Improved Pade Approximations, Applied mathematical modelling-Elsevier, 2016, (40), pp. 1418-1426.

[18] S.K. Sinha, R Prasad and R. N. Patel, Design of optimal and integral controllers for AGC of two area interconnected power system, XXXII National Systems Conference, NSC 2008, December 17-19, 2008.