Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 23s (2025)
https://www.jneonatalsurg.com

OPEN ACCESS

Application of Network Reduction Technique in Power System

Dr. S.Hemalatha[1], K.Akash[2], J.Kamlesh[3], M.Abirami[4], S.Pavithra[5], Joshna Sainan[6]

[1]Dept of EEE, St. Joseph's Institute of Technology.
Email ID: latharaju73@gmail.com
[2]Dept of EEE, St. Joseph's Institute of Technology.
Email ID: akashkannan2603@gmail.com
[3]Dept of EEE, St. Joseph's Institute of Technology.
Email ID: kamleshjg2004@gmail.com
[4]Dept of EEE, Velammal Engineering College.
Email ID: abiramimanikandan45@gmail.com
[5]Dept of EEE, Velammal Engineering College.
Email ID: pavithrasaravanakumar05@gmail.com
[6]Dept of EEE, Velammal Engineering College.
Email ID: joshnasainan@gmail.com

Cite this paper as: Dr. S.Hemalatha, K.Akash, J.Kamlesh, M.Abirami, S.Pavithra, Joshna Sainan, (2025) Application of Network Reduction Technique in Power System. *Journal of Neonatal Surgery*, 14 (23s), 178-183.

ABSTRACT

Modern electric power system is characterized by the growing size and complexity of the enormous number of generating units, loads and transmission lines that are included in the system. Studies of power system characteristics usually involve the solution of large numbers of equations, both algebraic and differential. This paper focuses on applying Kron's reduction technique in the power system to reduce the original complex power network model into a smaller network. A Java program is written for Kron's reduction technique for the ease of calculation of reduced network data. The data obtained from the Kron's reduction technique is employed in the reduced network by using ETAP software. The results obtained are validated by conducting load flow analysis. IEEE 5 and IEEE 30 bus system are taken to demonstrate the effectiveness of the proposed method.

Keywords: *Kron's Reduction, Power System*

1. INTRODUCTION

Modern power systems have become too highly interconnected to maintain acceptable levels of reliability and quality of the supply. These networks are now being operated under heavily loaded conditions in order to meet the ever-growing demand for electricity, with the limited generation, transmission, and distribution resources, and to maximize the economy. During the past few decades, the overall characteristics of the power system generation and loads have changed significantly due to increasing penetration of renewable energy sources, large-scale use of power-electronic converter interfaced sources and loads, and competitive electricity markets. Special attention, therefore, has to be given on the modelling of the power system for various types of analyses. Network reduction techniques are one of the useful means of analysing large, interconnected power systems. The most desirable property of the reduced network is that it should represent the original network as accurately as possible. The reasons for using the reduced model can be many, some of which are as follows: (i) It is required to monitor the system by using only a limited number of measurements from measuring instruments, such as phasor measurement units(PMUs); (ii) an interconnected power system typically consists of a number of areas owned by various utilities, each which are usually reluctant to share complete system information with others; (iii) practical limitations on the computational resources; and (iv) As the electrical distance from the point of interest increases, the requirement for detailed modelling of the remote location also reduces. Network reduction is usually performed by computing impedances and by eliminating unnecessary elements[5]-[10].This results in formation highly dense matrix which may not increase the efficiency significantly. In[10] a scheme is proposed to construct the reduced power system model approximating the Power Transfer Distribution Factors (PTDFs) and Injection Shift Factor of the original system using DC power flow model. In [11], a method is proposed to group the buses based on the congestion profile in the original network and to assign the flow limits of a reduced network. In[12], some of the commonly used reduction techniques such as Ward reduction, Kron reduction, Dimo's method, and Zhukov's method were discussed and concluded that the above methods are less complex than the methods used for aggregation. In [13],a network reduction technique using PDTF matrix is proposed for the power system planning. In this paper, One of the static reduction technique, Krons reduction technique is used and a program is written for Kron's reduction technique in a Java-programming language. The bus admittance data obtained is applied on the reduced network and load flow analysis is done using the ETAP software. The results are validated by comparing with the load flow results obtained from the original network.

2. NETWORK REDUCTION TECHNIQUES AND ITS NECESSITY:

Network reduction is a process which reduces the size of a network model by replacing sets of buses and the network elements (lines, transformers etc) that connect them with a smaller but exact, numerically equivalent network. For a properly chosen set of buses, this equivalent network will have fewer buses and branches than the original, yet provide the correct response to faults or load flow calculations in the reduced portion. In recent years, extensive studies have been directed towards simplifying the representation of the power system for specific applications. Many equivalent techniques have been developed, both steady state and dynamic. In general the network reduction techniques are classified into static and dynamic according to the representation of the model [1]-[2].

A. Static Reduction

The reduced model represents a snapshot of the system and is suitable of static analysis only. These kinds of models are appropriate for power flow calculations, for operational and planning analysis.

B. Dynamic Reduction

The reduced model is used for (a) large scale power system offline transient stability analysis with large disturbance, b) large scale power system off -line dynamic stability analysis with small disturbance, (c) large scale power system on-line security assessment.

3. EXISTING NETWORK REDUCTION TECHNIQUES

In recent years, extensive studies have been directed towards simplifying the representation of the power system for specific applications. Many equivalent techniques have been developed, both steady state and dynamic. The most popular network reduction techniques are Ward reduction, Kron's reduction, Dimo's reduction and Zhukov's reduction technique.In Ward reduction technique the generators are broken up into fractions and smeared everywhere to the boundary buses. This scheme no longer works when the objective is to develop a backbone model for a large power system for system planning purpose, since almost all the retained buses become the boundary buses. In Zhukov's network reduction techniques gives better results for the smaller systems with greater accuracy but is not found useful for the larger systems. This is due to the large X/R ratio of the lines in the equivalent system. Dimo's technique gives better result than the Zhukov's method for both smaller and larger networks. However it is helpful only with the small changes in loads and the reduced system does not follow the original system for the large changes in the loads. To overcome this disadvantages, Kron's reduction technique using java programming is proposed in this paper.

4. NODE ELIMINATION BY KRON'S REDUCTION:

The size of Y_{bus} admittanace matrix is very large. Computational time being a major problem, we needed to come up with an algorithm to reduce the size of such matrices. For this purpose Kron's reduction technique is being implemented in this paper. Gaussian elimination avoids the need of matrix inversion while solving the nodal equation of large power systems. It also leads to reduced order network equivalents. This is used to analyze power system with special focus on voltages at some selected buses.

For this purpose, selective numbering of system buses is required. Current injection is always zero at the buses which have no external loads or generators connected with them. Consider an equation of the form

Ax=b……………… (1)

where A is an (n X n) real or complex valued

matrix, x and b are vectors in either Rn or Cn .Assume that the b vector has a zero element in the nth row such that is given as

$$\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n-1,1} & a_{n-1,2} & \cdots & a_{n-1,n} \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_{n-1} \\ x_n \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_{n-1} \\ 0 \end{bmatrix} \quad (2)$$

Here the k[th] row and k[th] column are eliminated to obtain a reduced (n -1) number of equations of the form

$$\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1,n-1} \\ a_{21} & a_{22} & \cdots & a_{2,n-1} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n-1,1} & a_{n-1,2} & \cdots & a_{n-1,n-1} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_{n-1} \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_{n-1} \end{bmatrix} \quad (3)$$

The elimination is performed using the following elementary operations

$$a_{ij}^{new} = a_{ij} - \frac{a_{in}a_{nj}}{a_{nn}} \ldots\ldots\ldots\ldots \quad (4)$$

5. PROPOSED METHODOLOGY:

In this paper, the IEEE5 and IEEE30 bus systems are taken and are reduced to 3 and 24 buses respectively using Kron's reduction technique which is written using JAVA Programming language. The bus admittances obtained from the Kron's reduction technique is applied in the reduced network by using ETAP software. The load flow analysis is conducted by using Newton raphson method on the original network and the reduced network, the results are promising.

6. SYSTEM STUDIED:

In order to verify the proposed techniques, IEEE5 bus and IEEE30 are taken. The single line diagram of IEEE5, and IEEE30are shown in the figures1and 2 respectively.

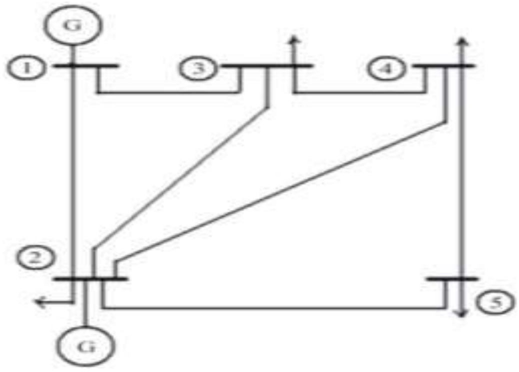

Fig.1 Single line diagram of IEEE 5 Bus system.

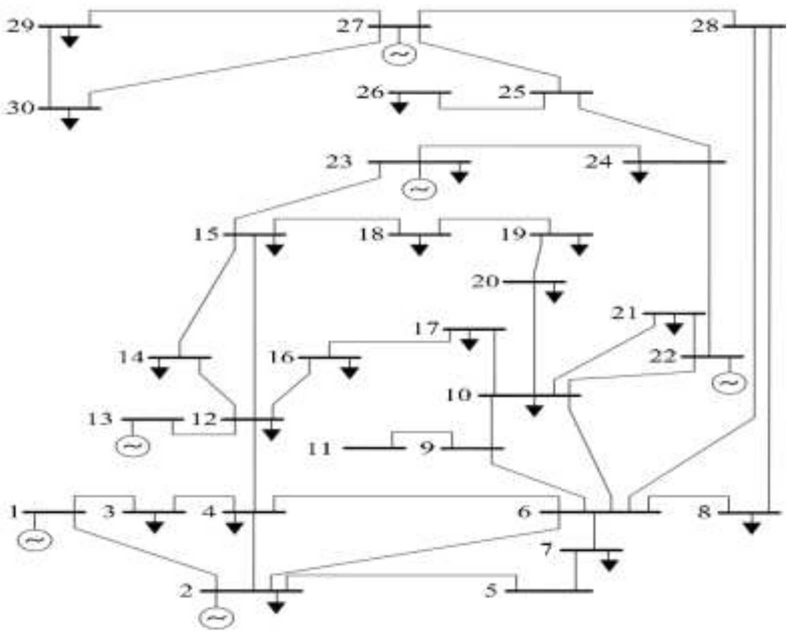

Fig.2 Single line diagram of IEEE30Bus system.

7. RESULTS AND DISCUSSIONS

CASE1: IEEE 5 BUS SYSTEM

The IEEE 5 bus system consists of seven lines, two generators and the admittance matrix of IEEE 5 bus system computed is given in table 1 and the simulation diagram is shown in fig 3.

Resultant Admittance Matrix

06.270-18.808j	**-05.020-15.058j**	**-1.250+03.750j**	**00.000+00.000j**	**00.000+00.00j**
-5.020+15.058j	**10.102-31.364j**	**-0.908+13.784j**	**-1.664+04.993j**	**-02.510-07.529j**
-1.256+03.750j	**-0.908+03.784j**	**12.040-37.180j**	**-9.882+29.646j**	**00.000+00.000j**
00.000-00.000j	**-1.664+04.9931j**	**-9.882+29.646j**	**12.796-39.383j**	**01.250+13.750j**
00.000-00.000j	**-02.510-57.529j**	**00.000-00.000j**	**01.250-03.750j**	**03.760-11.279j**

Table 1Admittance matrix of IEEE 5 bus system

After applying the Kron's reduction technique the reduced admittance matrix for the 4 bus system is given in table 2

Resultant matrix after bus 5 is reduced

06.270-18.808j	**-05.022-15.058j**	**-01.250-08.75j**	**10.255-20.00j**
-15.00-15.056j	**08.427-26.339j**	**-00905-03.784j**	**-02.495-07.496j**
-0.250-03.750j	**-00.408-03.784j**	**12.040-37.130j**	**-19.882-29.646j**
0.0-400.000j	**-02.489-07.4961j**	**-28.862-29.646j**	**12.382-37.142j**

Table2 Admittance matrix of reduced IEEE5 bus system

The final reduced admittance matrix for 3 bus system is given in table 3 and the simulation diagram is shown in fig 4.

Resultant Matrix after bus 4 is reduced

06.270-18.808j	**-05.020+15.058j**	**-01.250+03.750j**
-05.020+15.058j	**07.923-24.826j**	**-02.902+09.767j**
-01.250+03.7501j	**-02.902+09.767j**	**04.152-13.517j**

Table3 Admittance matrix of reduced IEEE 5 bus system

The following table 4 shows the comparison of admittance values obtained from the program and manual calculations. It is found that the bus admittance values obtained from the program are satisfied and same as the values obtained from the manual calculation method.

TABLE 4.COMPARISON OFPROGRAM AND MANUAL RESULTS OF KRON'S REDUCTION

Element	Theoretical Result		Program Result	
	R	X	R	X
Y11	0.160	0.053	0.159	0.0532
Y12	0.200	0.067	0.199	0.066
Y13	0.800	0.267	0.800	0.267
Y21	0.200	0.067	0.199	0.066
Y22	0.127	0.040	0.126	0.041
Y23	0.345	0.102	0.345	0.102
Y31	0.800	0.267	0.800	0.267
Y32	0.345	0.102	0.345	0.102
Y33	0.241	0.0739	0.241	0.074

The bus admittance values obtained are applied on the reduced 3 bus system and load flow analysis is carried using the ETAP Software. The results obtained from the ETAP Software for the reduced network are shown below in the following figures.

8. CASE2: IEEE 30 BUS SYSTEM

The IEEE 30 Bus system consists of 6 generators, 40 lines. Here the IEEE 30 Bus system is reduced to 24 bus system. It is seen that bus No's 26, 27, 28, 29, 30 are to be reduced to the single bus. The zone of reduction is shown in the figure.5. The Kron's reduction technique is applied for those buses to obtain bus admittances for the reduced network. The reduced admittance matrix of IEEE 30 Bus system by Kron's reduction technique is shown below in the figure.6. The load flow report and the losses report for the reduced 24 system is obtained by conducting the load flow analysis. The results obtained shows that the reduced bus system matches with the original network and the losses are within the specified limit. The Figure 7 and 8 shows the voltage profile and losses of the reduced system.

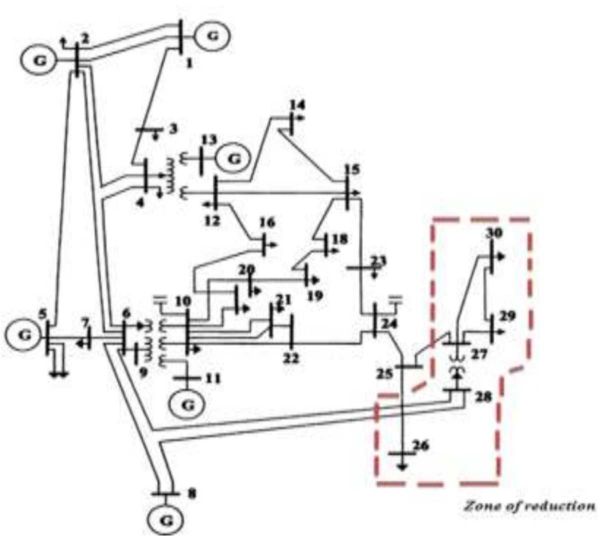

Fig.3 Reduced model of IEEE 30 Bus System

9. CONCLUSION

In the proposed paper, the optimal path of power transfer from generating station to consumers could be identified with ease using Kron's network reduction technique. To implement the concept, IEEE 5 bus test case system and IEEE 30 bus test system were considered and were reduced using the Kron's network reduction technique using Java programming. The system stability was verified by conducting load flow analysis of the original and the reduced networks. The results obtained were validated and was found efficient. The aim of network reduction is serving for different kinds of tests on the power system or for future planning. For the quality and security of the network reduction, a meticulous technique is necessary. The systemized network reduction procedures in this paper will be a useful tool for the study of large networks of the power system.

REFERENCES

[1] Jan Machowski, JanuszBialek, and Jim Bumby. Power System Dynamics: Stability And Control. John Wiley & Sons, 2011.

[2] J. F. Dopazo, G. Irisarri and A. M. Sasson, "Real-time External System Equivalent for On-line Contigency Analysis", IEEE Trans. on Power Apparatus and Systems, vol. PAS-98, no. 6, Nov./Dec. 1979.

[3] John J. Grainger, and William D. Stevenson. Power System Analysis. New York: McGraw-Hill, 1994.

[4] Buygi M. O., H. M. Shanechi, G. Balzer, and M. Shahideh-pour, Transmission Planning Approaches in RestructuredPower Systems, IEEE Powertech, June 2006.

[5] J. B. Ward, "Equivalent circuits for power flow studies," AIEE Trans.Power Appl. Syst., vol. 68, pp. 373–382, 1949.

[6] S. Deckmann, A. Pizzolante, A. Monticelli, B. Stott, and O. Alsac, "Numerical testing of power system load flow equivalents," IEEE Trans.Power App. Syst., vol. PAS-99, no. 6, pp. 2292–2300, Nov./Dec. 1980.

[7] S. Deckmann, A. Pizzolante, A. Monticelli, B. Stott, and O. Alsac, "Studies on power system load flow equivalencing," IEEE Trans.Power App. Syst., vol. PAS-99, no. 6, pp. 2301–2310, Nov./Dec. 1980.

[8] M. K. Enns and J. J. Quada, "Sparsity-enhanced network reduction for fault studies," IEEE Trans. Power Syst., vol. 6, no. 2, pp. 613–621, May 1991.

[9] W. F. Tinney and J. M. Bright, "Adaptive reductions for power flow equivalents," IEEE Trans. Power Syst., vol. 6, no. 2, pp. 613–621, May 1991.

[10] X. Cheng and T. J. Overbye, "PTDF-based power system equivalents," IEEE Trans. Power Syst., vol. 20, no. 4, pp. 1868–1876, Nov. 2005.

[11] HyungSeon Oh," Aggregation of Buses for a Network Reduction," IEEE Trans. Power Syst., vol. 27, no. 2,pp. 705 – 712, May 2012.

[12] SyedMohammadAshraf ; BhavnaRathore ; S. Chakrabarti, "Performance analysis of static network reduction methods commonly used in power systems", IEEE Trans.Power systems Conference,2014 Eighteenth National.

[13] HyungSeon Oh, " A new network reduction methodology for power system Planning studies", IEEE Trans. Power Syst., vol.25.,no.2 pp.677-684, May 2010.