



## Simulation and Modeling of Detailed Load flow Analysis for the 400kVA and 132kVA Iraqi Grid

Dr. Ahmed Abdul Sahib Hashim

Computer Science Department

College of Science for Women, Baghdad University, Baghdad, Iraq

dreng.ahmed@yahoo.com

### ABSTRACT:

A load flow program is developed using MATLAB and based on the Newton–Raphson method, which shows very fast and efficient rate of convergence as well as computationally the proposed method is very efficient and it requires less computer memory through the use of sparsing method and other methods in programming to accelerate the run speed to be near the real time. The designed program computes the voltage magnitudes and phase angles at each bus of the network under steady–state operating conditions. It also computes the power flow and power losses for all equipment, including transformers and transmission lines taking into consideration the effects of off–nominal, tap and phase shift transformers, generators, shunt capacitors, shunt inductors, line reactors and bus reactors. Thus, overloaded transformers and transmission lines are identified, and remedial measure can be designed and implemented. It also provides the ability of tie lines, area splitting, and contingency analysis.

Any generator station(s) or busbar(s) that exceeds the specified operation limits will be automatically checked and flagged and then the program will automatically suggest the best solution to the problem. It also automatically checks whether the system is sub divided into sub areas or not. If yes, it will find the solution for each area separately. A complete report about the results and the state of the system (the violated generators, busbars, and transmission lines, the required modifications to overcome the violations, the names of the areas splitted,...) will be displayed in working window as well as generating a text file containing all details .

It is important to mention that this program is used by the national control center of the Ministry of Electricity and its efficiency was tested through applying the data of the two major Iraqi networks (400kV and 132kV), the program shows very accurate results and provides efficient notes about the status of the networks.

**KEYWORDS:** Load flow, tie lines, contingency analysis, Newton –Raphson method, MATLAB

### نمذجة ومحاكاة مفصلة لتحليل سريان الاحمال للشبكة العراقية 400kVA و 132kVA

د. أحمد عبدالصاحب هاشم

قسم علوم الحاسوب

كلية العلوم للبنات، جامعة بغداد، بغداد، العراق

#### المستخلص

تم بناء برنامج سريان الاحمال بأستعمال برنامج ماتلاب، وبالاعتماد على طريقة نيوتن رافسن (NR) لإيجاد الحل، والذي أظهر معدل سريع وفعال للتقارب وكذلك حسابيا فإن الطريقة المقترحة فعالة جدا وتتطلب ذاكرة حاسوب اقل من خلال استعمال التقانات الخاصة بالمصفوفات التي تحتوي عدد كبير من الاصفار بالاضافه الى طرق اخرى في البرمجه لتسريع وقت التنفيذ لتقارب مع الوقت الحقيقي.

برنامج تدفق القدرة المصمم يقوم بحساب مقادير الجهد والطور في كل ناقل في الشبكة تحت ظروف تشغيل ثابتة. كما يقوم أيضا بحساب تدفق القدرة وخسائر القدرة في جميع المعدات، متضمناً المحولات وخطوط النقل آخذاً بنظر الاعتبار تأثير أنواع مختلفة من المحولات (off-nominal, tap, and phase-shift transformers)، المولدات، المتسعات، الملفات، رادات الخطوط وراتات النواقل. لهذا، فإن للبرنامج القدرة على تحديد المحولات وخطوط النقل التي تتجاوز حدود الحمل المحدد لها، مع إعطاء إجراءات علاجية ووقائية. إن البرنامج يتيح العمل والربط والتحليل للمناطق المنفصلة وتحليل حالات الطوارئ.

يقوم البرنامج بصورة أوتوماتيكية بالفحص والإعلام عن أي محطة توليد أو ناقلات كابلات تجتاز حدود التشغيل المحدده لها ومن ثم يقوم البرنامج باقتراح أفضل الحلول البديلة للمشكلة. كما يقوم البرنامج أوتوماتيكا بفحص في ما إذا كانت المنظومة الكهربائية مؤلفة من منطقة واحدة أو مقسمة إلى عدة مناطق. فإذا كانت مؤلفة من عدة مناطق يقوم بتحليل كل منطقة على حدة. البرنامج يقوم بعرض تقرير (بالإضافة إلى توليد ملف) كامل عن النتائج وحالة النظام (أي تجاوزات للشروط المحدده للمولدات والناقلات وخطوط النقل والتغييرات المطلوبة لتلافي هذه التجاوزات بالإضافة إلى إعطاء تسميات للمناطق المفصلة...)

أخيراً، من المهم أن نذكر أن البرنامج استعمل في مركز السيطره الوطني التابع لوزارة الكهرباء وإن كفاءة البرنامج تم اختبارها من خلال تطبيقها على منظومة اختبار قياسي وبعدها على أكبر شبكتين في العراق (400 كيلو فولت و 132 كيلو فولت). حيث أن البرنامج أعطى نتائج دقيقة وأعطى ملاحظات كفاءه عن حالة الشبكتين.

كلمات البحث: سريان الحمل، ربط التاي لاين، تحليل الطوارئ، نيوتن رافسون، ماتلاب

## 1. INTRODUCTION

Power flow analysis is the solution for the static operating condition of a power system [T. Gonen]. It is the most frequently performed of routine power network calculations in digital computers. Power flow analysis is used in power system planning, operational planning, and operations/control. It is also employed in multiple assessments, stability analysis, and system optimization [H. E. Brown].

The well-established power flow methods (Newton-Raphson N-R, Gauss-Seidel, and Fast-Decoupled) are all based on classical methodologies of applied mathematics. Classical computer programs for solving the power flow based on these methods have been in practical use for a relatively long number of years. All of these programs met with strict limitations to power network size and calculation speed [J. Mahseredjian]. With the development of object-oriented programming and operations methodology new boundaries are being set for power flow calculations [Bhabani Sankar Hota, Göran Andersson]. This paper presents fundamental concepts of applying object-oriented programming algebra to power system modeling of a package for the purposes of power flow, contingency, and tie line calculations.

This package is designed to perform a steady state analysis of a power transmission or distribution

network. The algorithm consists of an efficient and robust method based on the recursive solution of a full N-R AC Load flow. Because of the size and complexity of the problem much effort has been devoted to the improvement of convergence, reliability, accuracy, reduction of computation time and computer storage requirements.

This paper describes the implementation of N – R method to solve the load flow, contingency and tie lines problems using MATLAB software package all of them in one detailed program. It is subdivided into three parts; the first part presents the method used and the implementation of the algorithm. The second parts deals with the program structure and facilities. Finally the third part takes a case study to check the efficiency of the program with a given results and conclusions.

## 2. SOLUTION OF THE LOAD FLOW PROBLEM USING NEWTON-RAPHSON METHOD

The load flow problem can be solved by the Newton – Raphson (N-R) method using a set of nonlinear equations to express the specified real and reactive power in terms of bus voltages. The power at bus p is [T. Gonen , YongLi Zhu]:

$$P_p - jQ_p = E_p \times I_p \quad (1)$$

$$= E_p \times \sum_{q=1}^n Y_{pq} E_q \quad (2)$$

Where

$$E_p = e_p + jf_p, Y_{pq} = G_{pq} + jB_{pq}$$

Hence

$$P_p - jQ_p = (e_p - jf_p) \sum_{q=1}^n (G_{pq} + jB_{pq})(e_q + jf_q) \quad (3)$$

Separating the real and imaginary parts:

$$P_p = \sum_{q=1}^n \{e_p(e_q G_{pq} - f_q B_{pq}) + f_p(f_q G_{pq} + e_q B_{pq})\} \quad (4)$$

$$Q_p = \sum_{q=1}^n \{f_p(e_q G_{pq} - f_q B_{pq}) - e_p(f_q G_{pq} + e_q B_{pq})\} \quad (5)$$

The N-R method requires that a set of linear equations be formed expressing the relationship between the changes in real and reactive powers and the components of bus voltages.

Note that  $P_i$  and  $Q_i$  are functions of  $e_i, e_j, f_i$ , and  $f_j$ . For each PQ load bus,  $P_i$  and  $Q_i$  can be calculated from eq. (3), for some estimated values of  $e$  and  $f$ . After each iteration, the calculated values of  $P_p$  and  $Q_p$  are compared against the known (or specified) values of  $P_s$  and  $Q_s$ . also, for each PV generator bus, the magnitude of the bus voltage can be calculated from the estimated values of  $e$  and  $f$  as

$$|V_p|^2 = e_p^2 + f_p^2 \quad (6)$$

Then the calculated voltage magnitude is compared with its specified value. Therefore, the corrected values for the  $k^{th}$  iteration can be expressed as

$$\Delta P_p^{(k)} = P_s - P_p^{(k)} \quad (7)$$

$$\Delta Q_p^{(k)} = Q_s - Q_p^{(k)} \quad (8)$$

$$\Delta |V_p|^2 = |V_s|^2 - |V_p|^2 \quad (9)$$

The resultant values of  $\Delta P_p^{(k)}$ ,  $\Delta Q_p^{(k)}$ , and  $\Delta |V_p|^2$  can be used to determine the changes in the real and imaginary components of the bus voltages. Since the changes in  $P, Q$ , and  $V^2$  are related to the changes in  $e$  and  $f$ , it is possible to express them in a general form as:

$$\begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \Delta Q_2^{(k)} \\ \vdots \\ \Delta Q_{m-1}^{(k)} \\ \Delta |V_m|^2 \\ \Delta |V_n^{(k)}|^2 \end{bmatrix} = \begin{bmatrix} \frac{\partial P_2}{\partial e_2} & \dots & \frac{\partial P_2}{\partial e_n} & \frac{\partial P_2}{\partial f_2} & \dots & \frac{\partial P_2}{\partial f_n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{\partial P_n}{\partial e_2} & \dots & \frac{\partial P_n}{\partial e_n} & \frac{\partial P_n}{\partial f_2} & \dots & \frac{\partial P_n}{\partial f_n} \\ \frac{\partial Q_2}{\partial e_2} & \dots & \frac{\partial Q_2}{\partial e_n} & \frac{\partial Q_2}{\partial f_2} & \dots & \frac{\partial Q_2}{\partial f_n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \frac{\partial Q_{m-1}}{\partial e_2} & \dots & \frac{\partial Q_{m-1}}{\partial e_n} & \frac{\partial Q_{m-1}}{\partial f_2} & \dots & \frac{\partial Q_{m-1}}{\partial f_n} \\ \frac{\partial |V_m|^2}{\partial e_2} & \dots & \frac{\partial |V_m|^2}{\partial e_n} & \frac{\partial |V_m|^2}{\partial f_2} & \dots & \frac{\partial |V_m|^2}{\partial f_n} \\ \frac{\partial |V_n|^2}{\partial e_2} & \dots & \frac{\partial |V_n|^2}{\partial e_n} & \frac{\partial |V_n|^2}{\partial f_2} & \dots & \frac{\partial |V_n|^2}{\partial f_n} \end{bmatrix} \times \begin{bmatrix} \Delta e_2^{(k)} \\ \vdots \\ \Delta e_n^{(k)} \\ \Delta f_2^{(k)} \\ \vdots \\ \Delta f_n^{(k)} \end{bmatrix} \quad (10)$$

Where the coefficient matrix is the jacobian and the 1<sup>st</sup> bus is the slack bus.

Equations for determining the elements of the jacobian can be derived from the bus power equations. The real and reactive power from eq.(4) and eq. (5) is:

$$Q_p = f_p(e_p G_{pp} - f_p B_{pp}) + e_p(f_p G_{pp} + e_p B_{pp}) + \sum_{q=1}^n \{f_p(e_q G_{pq} - f_q B_{pq}) - e_p(f_q G_{pq} + e_q B_{pq})\} \quad (11)$$

$q \neq p, p=1,2,\dots,n-1$

$$P_p = e_p(e_p G_{pp} - f_p B_{pp}) + f_p(f_p G_{pp} + e_p B_{pp}) + \sum_{q=1}^n \{e_p(e_q G_{pq} - f_q B_{pq}) + f_p(f_q G_{pq} + e_q B_{pq})\} \quad (12)$$

$q \neq p, p=1,2,\dots,n-1$

Differentiating the off-diagonal elements of eq. (11), and eq. (12) then:

$$\begin{aligned} \frac{\partial P_p}{\partial e_q} &= e_p G_{pq} + f_p B_{pq} & q \neq p \\ \frac{\partial P_p}{\partial f_q} &= -e_p B_{pq} + f_p G_{pq} & q \neq p \\ \frac{\partial Q_p}{\partial e_q} &= -e_p B_{pq} + f_p G_{pq} & q \neq p \\ \frac{\partial Q_p}{\partial f_q} &= -e_p G_{pq} - f_p B_{pq} & q \neq p \end{aligned} \quad (13)$$

Differentiation the diagonal elements of eq. (11), and eq. (12) then:

$$\begin{aligned} \frac{\partial P_p}{\partial e_p} &= 2e_p G_{pp} - f_p B_{pp} + f_p B_{pp} + \sum_{\substack{q=1 \\ q \neq p}}^n (e_q G_{pq} - f_q B_{pq}) \\ \frac{\partial P_p}{\partial e_p} &= -e_p B_{pp} + 2f_p G_{pp} + e_p B_{pp} + \sum_{\substack{q=1 \\ q \neq p}}^n (f_p G_{pq} + e_p B_{pq}) \\ \frac{\partial Q_p}{\partial e_p} &= f_p G_{pp} - f_p G_{pp} - 2e_p B_{pp} - \sum_{\substack{q=1 \\ q \neq p}}^n (f_p G_{pq} + e_q B_{pq}) \\ \frac{\partial Q_p}{\partial f_p} &= e_p G_{pp} - 2f_p B_{pp} - e_p G_{pp} + \sum_{\substack{q=1 \\ q \neq p}}^n (e_p G_{pq} - f_q B_{pq}) \end{aligned} \quad (14)$$

The equation for the current at bus p is:

$$I_p = c_p + jd_p = (G_{pp} + jB_{pp})(e_p + jf_p) + \sum_{\substack{q=1 \\ q \neq p}}^n (G_{pq} + jB_{pq})(e_q + jf_q) \quad (15)$$

Hence

$$c_p = e_p G_{pp} - f_p B_{pp} + \sum_{\substack{q=1 \\ q \neq p}}^n (e_q G_{pq} - f_q B_{pq}) \quad (16)$$

$$d_p = f_p G_{pp} + e_p B_{pp} + \sum_{\substack{q=1 \\ q \neq p}}^n (f_q G_{pq} + e_q B_{pq}) \quad (17)$$

Substituting eq.(16) and eq.(17) in eq.(11) and eq.(12), then:

$$\begin{aligned} P_p &= e_p c_p + f_p d_p \\ Q_p &= f_p c_p - e_p d_p \end{aligned} \quad (18)$$

and eq. (14) will be:

$$\begin{aligned} \frac{\partial P_p}{\partial e_p} &= e_p G_{pp} + f_p B_{pp} + c_p \\ \frac{\partial P_p}{\partial f_p} &= -e_p B_{pp} + f_p G_{pp} + d_p \\ \frac{\partial Q_p}{\partial e_p} &= -e_p B_{pp} + f_p G_{pp} - d_p \\ \frac{\partial Q_p}{\partial f_p} &= -e_p G_{pp} - f_p B_{pp} + c_p \end{aligned} \quad (19)$$

Given an initial set of bus voltages, the real and reactive powers are calculated from eq. (18). The change in power is the difference between the specified and calculated values:

$$\begin{aligned} \Delta P_p^k &= P_s - P_p^k & p = 1, 2, \dots, n-1 \\ \Delta Q_p^k &= Q_s - Q_p^k & p = 1, 2, \dots, n-1 \end{aligned} \quad (20)$$

The estimated bus voltages and calculated powers are used to compute bus currents in order to evaluate the elements of the jacobian. The linear set of eq.(10) can be solved for  $\Delta f_p$  and  $\Delta e_p$ ,  $p=1, 2, \dots, n-1$ , by a direct or iterative methods. Then, the new estimates for bus voltages are:

$$e_p^{k+1} = e_p^k + \Delta e_p^k \quad (21a)$$

$$f_p^{k+1} = f_p^k + \Delta f_p^k \quad (21b)$$

The process is repeated until  $\Delta P_p^k$ ,  $\Delta Q_p^k$ , and  $\Delta |V_p|^2$  for all buses are within a specified limit.

### 3. PROBLEM FORMULATION

The Newton-Raphson method is a very powerful load flow solution technique that incorporates first-derivative information when computing voltage updates. Normally, only 3 to 5 iterations are required to solve the load flow problem, regardless of system size (It is generally quadratic in convergence) [Mbuli].

Typically the power flow is formulated to minimize the production cost and satisfy some constraints, including entire power flow equations, generation limits, voltage ranges and line transfer capability... etc.

The general steps for problem formulation are goes in the following sequence [M. delimar, Ian A. Hiskens]

1. Inputting the data
2. Converting the transformers (phase-shift transformers and tap transformers) to their  $\pi$  - equivalent.
3. Performing contingency analysis (removing transmission lies, busbars, and/or generators) if it is required.
4. Y-matrix formulation (admittance) for the area and for each area in case of area splitting.
5. Starting the iterative solving algorithm program (Newton Raphson method).
6. If the parameters converged within the specified tolerance then stop the iteration and print the results else continue with the iterative method of step 4.



7. Flagging the generators, that violated their reactive generation limit and then finding the correct operating voltage of the generators that maintain the reactive generation of the generators within the limit. This is can be done by converting the violated P-V busbars to P-Q busbars and the reactive power demand at these busbars are set equal to negative of the violated limit. The program (step 5) is run again to solve for the voltage magnitude at these busbars.
8. Flagging the busbars which violated their voltage magnitude limit then finding the required per unit MVAR that have to be connected at the violated busbars to bring the voltages back within the limits. Converting the violated P-Q busbars to P-V busbars, setting the violated busbars to the violated voltage limit, does this and the power generation at these busbars is set equal to zero. The program (step 5 for Newton Raphson method) is run again to solve for the generation reactive powers at these busbars.
9. Modifying the system (setting the new values of voltages for the violated P-V busbars and adding the MVAR to the violated P-Q busbars) the program will run again (step5) and finds the final results
10. Repeat step 4 for the next area in case of area splitting.
11. End

The program was written in a structured format. It asks the user to supply the name of the text file that contains the input data. The expected output will be two text files provide a record of all the results one for the flow results while the other for the bus results a third text file may be generated if we have tie lines. The sequence of steps for the load flow solution is shown in flowchart (see figure 1)

#### 4. PACKAGE STRUCTURE

The package has the following options:

##### I- Load Flow Analysis

This function starts the execution of the program without the facilities of contingency and tie line but with the optional system correction facility.

##### II- Contingency Analysis

This function starts the execution of the program without the facility of tie line but with the contingency and the optional system correction facilities. In this case the outage of branches, buses

(with all connected lines), and the outage of generation stations are permissible for the user through the execution of the program. For the purpose of planning, control, fault estimation...etc

##### III- Tie Line Analysis

This function starts the execution of the program without the facility of contingency but with the tie line and the optional system correction facilities. Large-scale power systems usually consist of several, or perhaps many, individual electric utility companies. In these cases, each area may have a desired net input or output power to satisfy sales and purchase agreements. The area interchange feature in a load flow program sums the tie line lows into each area for a net area power input. If these nets are not the desired values, to within a few megawatts, then an area-control generator within the area is adjusted by the error amount. The sum of all input powers for all areas must, of course, be zero [De Oliveira].

#### 5. PACKAGE FACILITIES

Some of the important facilities of the package are

##### a) Input Data File

Is a text file, which contains detailed information about the network to be solved (buses, branches, capacitors, reactors, tap changers (for all types of transformers), cables).

##### b) Voltage and VAR Compensation

This paper looks at the problem of placing Static VAR Compensators (SVC) to provide maximum transfer capability for all possible generation mixes. The margin to low voltage limit is one of the quantities used to determine power system transfer capability. A fast method for finding the location of SVC systems that will have the greatest impact on the low voltage margin is used.

The program asks the user whether he wants the program automatically diagnose the network violations after convergence to the solution within the specified tolerance or not, if yes, it will check and flag any violation in busbars voltages (in case of load busbars) and generators reactive power (in case of generator busbars), after that it will automatically fix them and gives the best solution to the problem then repeat solving of the network with the suggested modification without clearing the previous (actual) results.

**c) Splitting (Self Insertion)**

This software is designed to automatically identify the electrical island and nodal connectivity of a network. It checks the network whether it is subdivided into areas or not and tell the user if yes with the display of the names of each area busbars, then tell the program to run each area alone with the monitoring of each area selected slack busbare.

**d) Multi Area**

The software takes into consideration the case of tie lines and the problem of power transfer between countries.

**e) Output Reports**

The output results consists of two reports (three in case of tie line) one for bus results showing generated and/or consumed power at each busbare, also shows the removed buses or transmission lines in case of contingency analysis and the results of each area in case of area splitting all of these information are shown before and after modification (compensation) in case of voltage or Q violation. The second report for the flow results showing the power flow and losses in the transmission lines, also shows and flag the overloaded transmission lines (lines that exceed the rated MVA of the line), all of these information are shown before and after modification (compensation) in case of voltage or Q violation. The third report is automatically generated in case of multi area (tie line), which contains information about the required modification on the areas regulating generators in order to give the specified power transfer.

**f) User Error Detection**

When the user inputs any invalid, or out of range data the program flags these errors for example, in contingency analysis, when the user try to remove a branch and he enters the sending and receiving buses of not found branch, the program will flag this entrance error, also when the user try to remove a generation station, or part of the generation, the program display an error message when the entered busbare identifier is not generator busbare or when the required amount of generation is out of the generation capability, and so on.

**g) Visual Display**

The package provide a visual link with the user, for example, figure 2 shows the main menu of choices which appear for the user when he starts the execution of the program, clicking any one of these three choices will make the package execute the

corresponding program, when the user clicks "CONTINGENCY" bottom, another menu will appear (figure 3) asking him to choose which type of contingency he wants to done, if he clicks "REMOVING BUSBARS" for example, a third menu will appear (figure 4) asking him to enter the number of busbars he wants to remove, and so on.

**6. CASE STUDY**

To demonstrate the application of power for analyzing the performance of a power system, a 15-bus test system is considered [M. Kezunovic]. The one-line diagram of the test system is shown in figure 5. The system power base used is 100 MVA, and the voltage bases are selected to match the nominal voltages in various parts of the system. The input data file are provided in figure 6 in which transformer data of fixed-tap, which is set at 100%, and the percent resistances and reactances given are based on the device ratings, the system load data, and the system generator data are shown also. The generators at buses 1 and 4 represent in-feeds from the neighboring power system that is charged with the bulk-power generation and transmission in the region. The South generator is connected to bus 1, which is chosen as slack bus.

The transmission line parameters are calculated and converted to per unit based on the chosen bases. The transformer impedances are also automatically converted to per unit based on system bases. The load data and generator data are, likewise, automatically converted to system bases. The system input bus data are given in which a "flat voltage" start is assumed; that is, the voltage phase angle at each bus is set equal to zero, while the voltage magnitude at each load bus is set equal to 1.0 per unit. The voltage at each generator bus is held at the specified value provided the generator reactive power stays within specified minimum and maximum limits.

The test system was analyzed using the software package. A converged solution was reached in 3 iterations. The bus data from the converged solution are shown in figure 7. Figure 8 shows another results when bus 12 is removed through the application of contingency analysis program.

**7. RESULTS**

The program flagged the West generator as having violated its reactive generation limit. As can be seen from figure 6, the reactive power generated by the West generator is 1.18 per unit, exceeding its upper limit of 0.9 per unit. This means that the specified voltage at bus 13 is too high, and the

generator cannot maintain it at this level. To find the correct operating voltage of the generator, the P-V bus 13 is automatically (if we choose the correction facility of the package) converted to a P-Q bus and the reactive power demand at this bus is set equal to the negative of the violated limit  $Q_G^{\max}$ , or  $-0.90$  per unit. The program was run again to solve for the voltage magnitude at this bus. It was found to be 1.00 per unit.

The program also automatically checks all bus voltages and flags those that are less than 0.95 per unit or higher than 1.05 per unit. The voltages at load buses 14 and 15 are 0.935 and 0.922 per unit, respectively, which are both less than the minimum allowable level of 0.95 per unit. These P-Q buses are converted to P-V buses, with their power generations set equal to zero. The voltage magnitudes are set equal to the violated limit  $V_{\min}$ , or 0.95 per unit. The program is run again to find the generator reactive powers at buses 14 and 15. These are equal to the per-unit MVAR of the capacitors that have to be connected at the two buses to bring the voltages back within limits. These are 0.116 per unit and 0.139 per unit for buses 14 and 15, respectively.

Finally, with the generator voltage at bus 13 set to 1.00 per unit and capacitors of 0.116 and 0.139 per unit MVAR connected to buses 14 and 15, respectively, the program was run again. The final bus results are presented in figure 7 also. It may be noted that all previous constraint violations have been resolved. Another set of results (not shown in this paper) is available considering the power flow and losses through the transmission lines before and after correction of the system.

Figure 8 shows the results when we remove bus 12 from the network (see figure 5). The results show that due to the removal of this bus (with all its connections): bus 13 is disconnected from the circuit and hence removed from the analysis of the system (because it has no effect on the system) also the results show that the system is divided into two areas, the first one with first 11 buses and the second with two buses (14, 15). Here, the contingency analysis is performed without the facility of correction. Also there is another set of results (not shown in this paper) that show the power flow and losses through the transmission lines also shows the removed busbars.

## 8. CONCLUSION

In this paper effective power system operation requires power system engineers and operators to analyze vast amounts of information. In systems containing thousands of buses, a key challenge is to present this data in a form such that the user can assess the state of the system in an intuitive and quick manner. This is particularly true when trying to analyze relationships between actual network power flows, the scheduled power flows, and the capacity of the transmission system. With restructuring and the move towards having a single entity, such as an independent system operator or pool, operate a much larger system; this need has become more acute. This paper presents power system visualization technique to help in this task.

One contribution of the paper is introducing an efficient power flow model; obviously much computing time is saved. By observation, the time of computing the whole program running time. The efficiency is shown by comparison with a MATLAB based programming. The developed program based on Newton method is promising to be used to solve the load flow problem of large size practical power system because of its high efficiency in modeling power system and computing the Jacobian of power flows.

## REFERENCES

Bhabani Sankar Hota and Amit Kumar Mallick, "load flow study in power system", Thesis, National Institute of Technology, Rourkela, India, April 2011

De Oliveira, ...*etal*, "Distribution power flow method based on a real quasi-symmetric matrix", Journal: Electric Power Systems Research, Volume: 95, 2013, P 148-159 provider: Elsevier

Göran Andersson, "Modelling and Analysis of Electric Power Systems", lecture 227-0526-00, ITET ETH Zürich, EEH - Power Systems Laboratory, ETH Zürich, September 2008

H. E. Brown, "Solution of Large Networks by Matrix Methods", 2nd edition, JOHN WILEY & SONS, INC, 1985.

Ian A. Hiskens, "Power Flow Analysis", Department of Electrical and Computer Engineering, University of Wisconsin – Madison, November 6, 2003

J. Mahseredjian, F. Alvarado, G.Rogers, and W. Long, "MATLAB's Power for Power Systems", IEEE Computer Applications in Power, Vol. 14, No. 1, Jan.2001, P13 – 19.

Mbuli, N., Pretorius, ...*etal*, " Network studies for the interconnection of a concentrating solar power plant in a weak distribution network in the Uington area", Journal: IEEE Africon vol. 11, 2011, P 1- 6

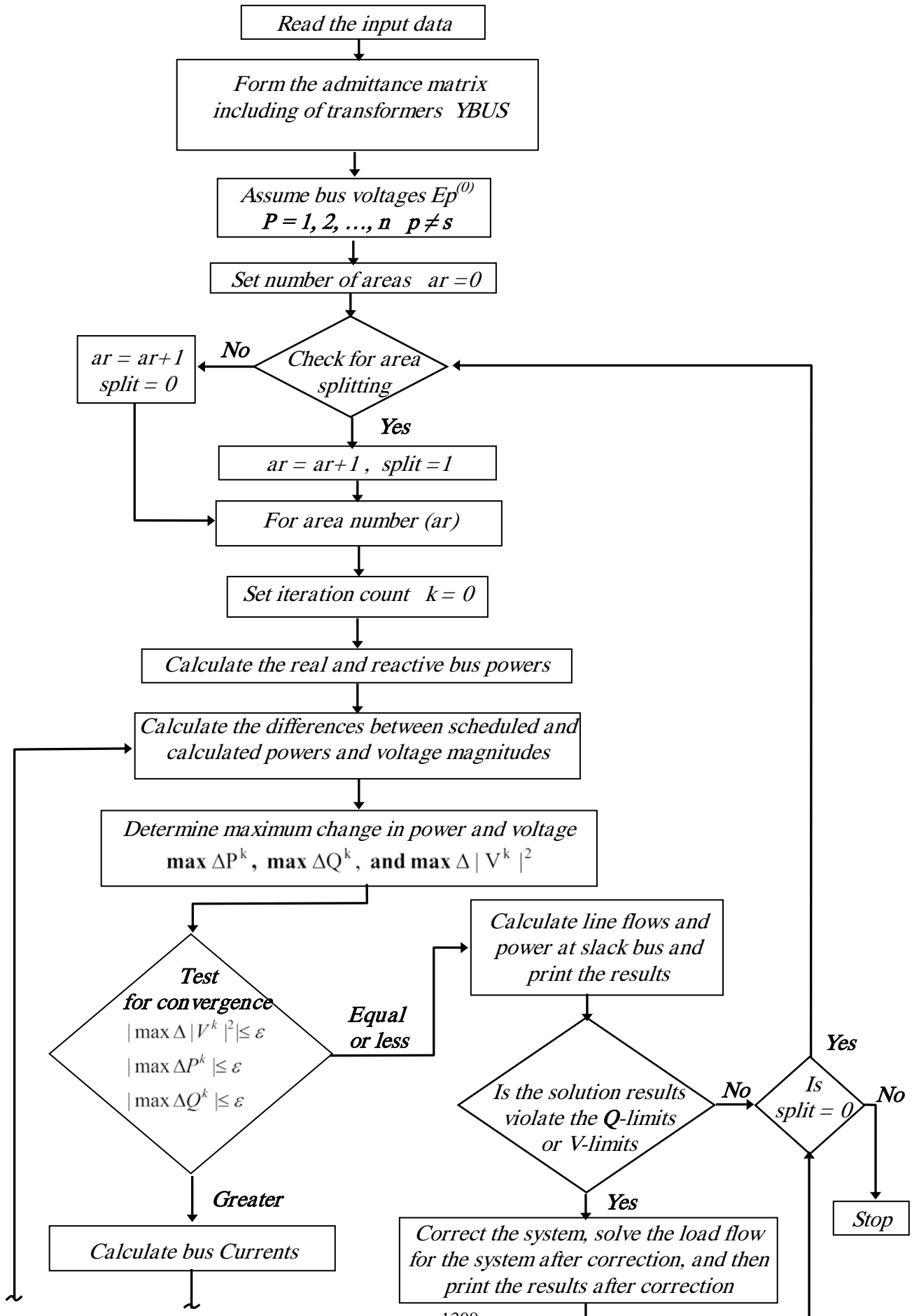
M. delimar, Z. Hebel, and I. Pavic, "Power System Modelling for Object – Oriented Power flow", International Journal for ENGINEERING MODELLING, Vol. 11, No. 1 – 2, 1998.

T. Gonen, "Modern Power System Analysis", JOHN WILEY & SONS, INC, 1988

YongLi Zhu and JianGuo Yao, " An Improved Newton Load Flow for Distributed Generation Based on Different Control Strategies", Journal: IEEE, Asia-Pacific Power and Energy Engineering Conference, 2011, P 1-5

M. Kezunovic, "Advanced Power Engineering Education Using Digital Simulation," CIGRE Workshop, 1998 CIGRE General Session, Paris, France, September 1998.





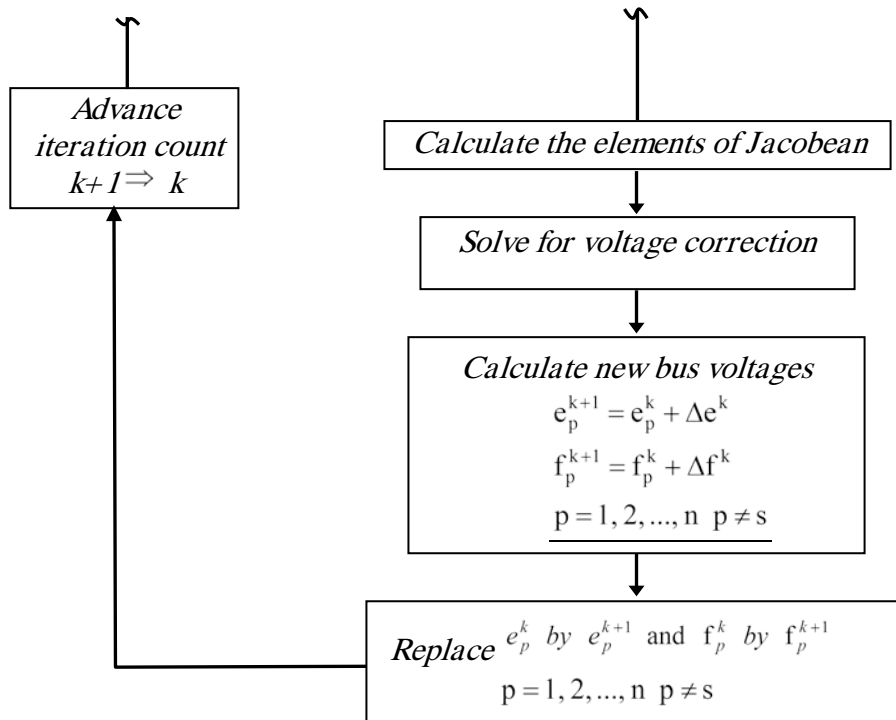


Figure 1 Flow chart of Newton – Raphson method

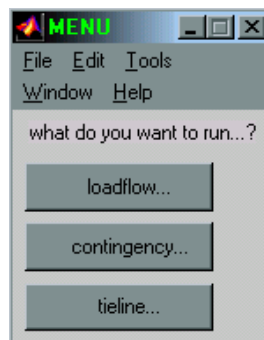


Figure 2 Software Main Menu of Choices

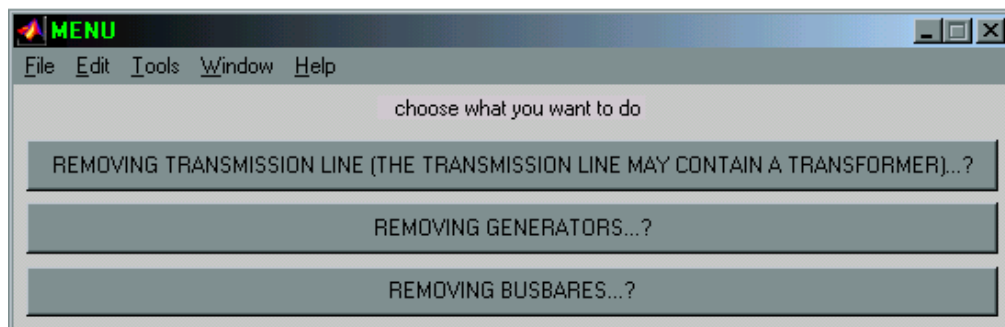


Figure 3 Contingency Main Menu

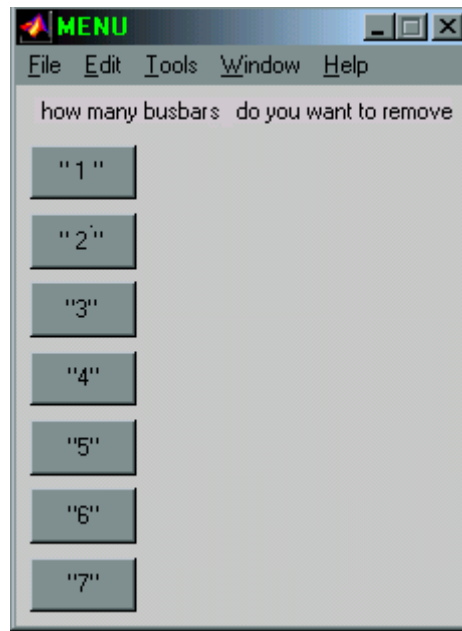


Figure 4 Contingency Analysis – Removing Busbars Main Menu

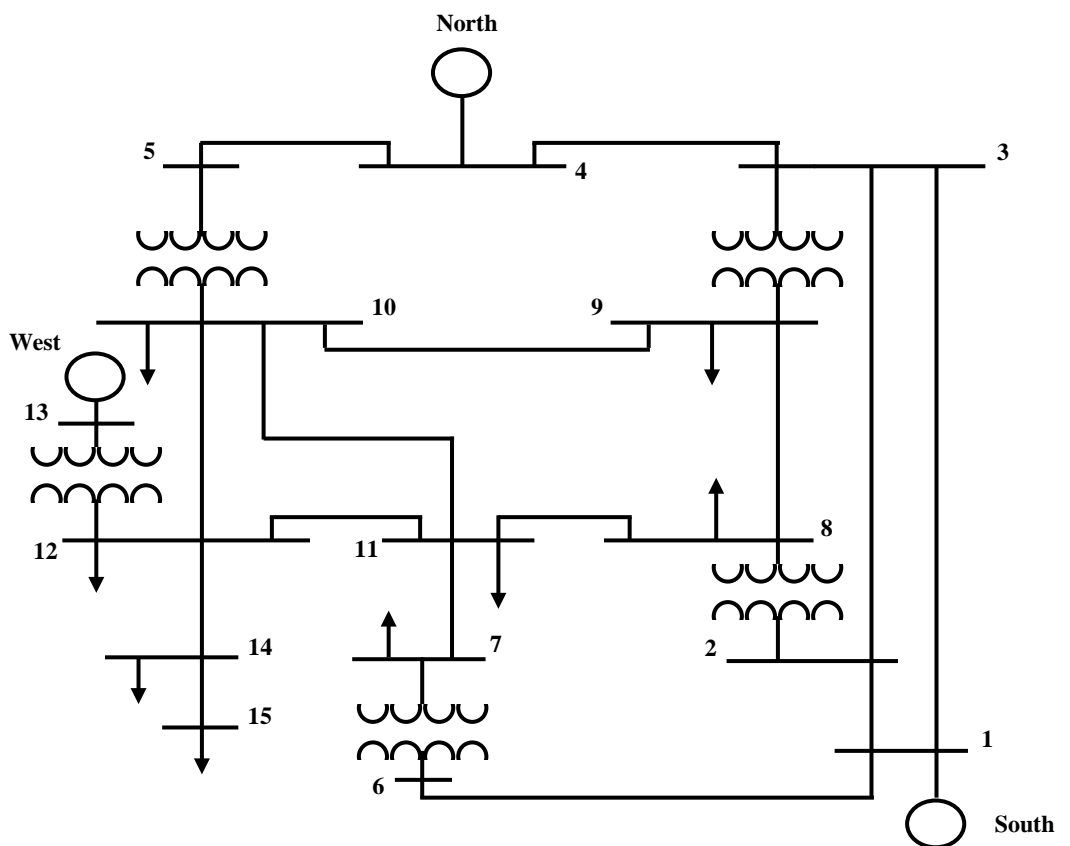


Figure 5 The One-Line Diagram of the Test System

MISMATCH VALUE 1e-5

NUMBER OF NODES 15

MVA BASE 100

BRANCH DATA

SEND.	NAME	REC.	NAME	RL(P.U)	XL(P.U)	GL	B(P.U)	REAC.(P.U.)	REF. TO	LIMIT
1	MICE	2	BASD	0.01	0.0528	0	0.1119	0	0	3
1	MICE	3	SENO	0.0233	0.1232	0	0.2611	0	0	3
1	MICE	6	LASS	0.0083	0.044	0	0.0933	0	0	3
2	BASD	3	RICE	0.0133	0.0704	0	0.1492	0	0	3
3	RICE	4	DIES	0.01	0.0528	0	0.1119	0	0	3
4	DIES	5	YORK	0.0066	0.0352	0	0.0746	0	0	3
7	TYRO	11	BRAZ	0.0277	0.1518	0	0.0271	0	0	3
8	YORB	9	SIDE	0.0332	0.1822	0	0.0325	0	0	3
8	YORB	11	NERO	0.0222	0.1214	0	0.0217	0	0	3
9	SIDE	10	DLHI	0.0277	0.1518	0	0.0217	0	0	3
10	DLHI	11	BRAZ	0.0277	0.1518	0	0.0217	0	0	3
10	DLHI	12	FORT	0.0222	0.1214	0	0.0217	0	0	3
11	BRAZ	12	FORT	0.0166	0.0911	0	0.0163	0	0	3
12	FORT	14	RICH	0.0222	0.1214	0	0.0217	0	0	3
14	RICH	15	HERO	0.0166	0.0911	0	0.0163	0	0	3
0	0	0	0	0	0	0	0	0	0	0

TAB-TRANSFORMER DATA

SEND.	NAME	REC.	NAME	RL(P.U)	XL(P.U)	TAP POSN
2	BASD	8	YORB	.0025	.03	0
3	RICE	9	SIDE	.0025	.03	0
5	YORK	10	DLHI	.0025	.03	0
6	LASS	7	TYRO	.002	.05	0
12	FORT	13	TETO	.0033	.0333	0
0	0	0	0	0	0	0

PHASE-SHIFT-TRANSFORMER DATA

SEND.	NAME	REC.	NAME	RL(P.U)	XL(P.U)	REAL-TAB POSN	IMAG-TAB POSN
0	0	0	0	0	0	0	0

SLACK NODE NUMBER

1

TIE LINES IDENTIFIERS

THE NO.OF AREAS IS 1

NOW YOU WILL ENTER THE TIE LINES CONNECTIONS AREAS

SEND. AREA	REC. AREA	SEN. BUS	REC. BUS	TIE LINE R(P.U)	TIE LINE X(P.U)	B (P.U)
0	0	0	0	0	0	0

AREA NO.	AREA DATA FILES	SPEC. POWER	REG.GEN.NO	NO. OF TIE LINES	TIE LINES AREA	BUSBARES
0	0	0	0	0	0	0

SPECIFIED NODE VALUES

-FOR THE NONINTERESTING VARIABLE PUT ZERO (0)

-IF THE NODE IS A LOAD FILL PS AND QS

-IF THE NODE IS GENERATOR FILL PS, VS, QMIN, QMAX

-IF THE NODE IS A SLACK FILL VS

-IF THE NODE IS A GENERATOR AND LOAD FILL PS, VS, QMIN AND QMAX FOR

THE GENERATOR AND QS AND PL FOR THE LOAD

BUS No.	NAME	BUS_REC	PL	QL	VS(MAG.)	VS(DEG)	QMIN	QMAX	PG	VMIN	VMAX	VOLTRAT
1	MICE	0	0	0	1.025	0	0	0	0	.95	1.05	230
2	BASD	0	0	0	1.00	0	0	0	0	.95	1.05	230
3	RICE	0	0	0	1.0	0	0	0	0	.95	1.05	230
4	DIES	0	0	0	1.025	0	-50	110	170	.95	1.05	230
5	YORK	0	0	0	1.0	0	0	0	0	.95	1.05	230
6	LASS	0	0	0	1.0	0	0	0	0	.95	1.05	230
7	TYRO	0	-25	-10	1.0	0	0	0	0	.95	1.05	115
8	YORB	0	-40	-20	1.0	0	0	0	0	.95	1.05	115
9	SIDE	0	-18	-10	1.0	0	0	0	0	.95	1.05	115
10	DLHI	0	-130	-40	1.0	0	0	0	0	.95	1.05	115
11	BRAZ	0	-160	-50	1.0	0	0	0	0	.95	1.05	115
12	FORT	0	-100	-30	1.0	0	0	0	0	.95	1.05	115
13	TETO	0	0	0	1.035	0	0	90	120	.95	1.05	13.8
14	RICH	0	-50	-20	1.0	0	0	0	0	.95	1.05	115
15	HERO	0	-24	-10	1.0	0	0	0	0	.95	1.05	115

SLACK NODE VOLTAGE

Figure 6 The Input Data File



LOAD FLOW BUS RESULTS						
Name	V	angle(deg)	PG(MW)	QG(MVAR)	PL(MW)	QL(MVAR)
MICE	235.75	0	269.79	7.981762	0	0
BASD	232.0589	-3.45218	0	0	0	0
RICE	233.9404	-3.68012	0	0	0	0
DIES	235.75	-3.32457	170	45.29895	0	0
YORK	230.3821	-6.22112	0	0	0	0
LASS	231.9283	-2.22981	0	0	0	0
TYRO	114.553	-4.91011	0	0	-25	-10
YORB	114.7307	-5.37925	0	0	-40	-20
SIDE	116.0614	-4.84473	0	0	-18	-10
DLHI	113.5732	-8.83897	0	0	-130	-40
BRAZ	111.2444	-11.05	0	0	-160	-50
FORT	114.2713	-12.0872	0	0	-100	-30
TETO	14.283	-10.0784	120	118.4851	0	0
RICH	107.55	-17.2546	0	0	-50	-20
HERO	105.9646	-18.6057	0	0	-24	-10
TOTAL		559.79	171.7658	-547	-190	
THE TOTAL AMOUNT OF SERIES LOSSES ARE			12.79-84.1853i			
THE TOTAL AMOUNT OF SHUNT LOSSES ARE			0+102.4194i			
AFTER CORRECTION						
Name	V	angle(deg)	PG(MW)	QG(MVAR)	PL(MW)	QL(MVAR)
MICE	235.75	0	269.3793	16.9437	0	0
BASD	231.6016	-3.43308	0	0	0	0
RICE	233.6063	-3.66511	0	0	0	0
DIES	235.75	-3.32051	170	58.0137	0	0
YORK	229.5934	-6.18764	0	0	0	0
LASS	231.542	-2.21096	0	0	0	0
TYRO	114.1388	-4.89541	0	0	-25	-10
YORB	114.3458	-5.36219	0	0	-40	-20
SIDE	115.7861	-4.82979	0	0	-18	-10
DLHI	112.8418	-8.81411	0	0	-130	-40
BRAZ	110.1602	-11.0374	0	0	-160	-50
FORT	112.1323	-11.9881	0	0	-100	-30
TETO	13.81438	-9.77439	120	68.3924	0	0
RICH	109.25	-17.5274	0	0	-50	-20
HERO	109.25	-18.965	0	0	-24	-10
TOTAL		559.3793	143.3498	-547	-190	
THE TOTAL AMOUNT OF SERIES LOSSES ARE			12.3793-81.0811i			
THE TOTAL AMOUNT OF SHUNT LOSSES ARE			0+102.0755i			
The added MVAR should be						
0.117063 at bus 14						
0.139495 at bus 15						

Figure 7 The Resulting Bus Data from the Converged Solution

DUE TO THE REMOVING OF THE SELECTED BUSBARS  
ANOTHER BUSBAR(S) IS (ARE) DISCONNECTED HENCE REMOVED THESE ARE  
'HERO'

THE SYSTEM IS SUBDIVIDED INTO AREAS

THIS AREA CONSISTS OF  
MICE  
BASD  
RICE  
DIES  
YORK  
LASS  
TYRO  
YORB  
SIDE  
DLHI  
BRAZ

LOAD FLOW BUS RESULTS

Name	V	angle(deg)	PG(MW)	QG(MVAR)	PL(MW)	QL(MVAR)
MICE	235.75	0	210.4013	28.3677	0	0
BASD	231.4482	-2.6089	0	0	0	0
RICE	233.6047	-2.3528	0	0	0	0
DIES	235.75	-1.3833	170.0001	55.6411	0	0
YORK	229.7209	-3.8337	0	0	0	0
LASS	231.3491	-1.8783	0	0	0	0
TYRO	113.7655	-4.2004	0	0	-25	-10
YORB	114.0739	-4.284	0	0	-40	-20
SIDE	115.7493	-3.3494	0	0	-18	-10
DLHI	112.8215	-6.0956	0	0	-130	-40
BRAZ	108.9442	-9.147	0	0	-160	-50
TOTAL		380.4014	84.0088	-373	-130	

THE TOTAL AMOUNT OF SERIES LOSSES ARE 6.34032-34.1718i  
THE TOTAL AMOUNT OF SHUNT LOSSES ARE 0+94.8781i

THIS AREA HAS NO GENERATION STATIONS SO IT CAN NOT BE ANALYZED  
RICH  
HERO

**Figure 8 Resulting Bus Data when Bus 12 is Removed Through the Application of Contingency Analysis Program**