T.C.
BAHÇEŞEHİR ÜNİVERSİTESİ

VOLTAGE SECURITY ASSESSMENT USING P-V AND Q-V CURVES

Master's Thesis

by
BÜLENT AYDIN

İSTANBUL, 2008

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I certify that this thesis meets all the requirements as a thesis for the degree of Master of Science.

Dr. Bülent BİLİR
Program Coordinator

____

This is to certify that we have read this thesis and that we find it fully adequate in scope, quality, and content as a thesis for the degree of Master of Science.

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ABSTRACT

VOLTAGE SECURITY ASSESSMENT
USING P-V AND Q-V CURVES

Aydın, Bülent

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In recent years, voltage instability and voltage collapse have been observed in power systems of many countries. Such problems have occurred even more often in developed countries because of utility deregulation. Currently, voltage security is of major importance for successful operation of power systems. Assessment of voltage security is needed to utilize power transmission capacity efficiently and to operate the system uninterruptedly.

In our research work, we study voltage security of two different power systems; one is the 20-bus IEEE system and the other is the 225-bus system of Istanbul Region. We assess voltage security of these systems using P-V and Q-V curves. In other words, we compute margins of real power (P) and reactive power (Q). To achieve what we promise, we first obtain the power-flow solution for the given data by running the power-flow program that we have coded using MATLAB. The solution is taken as the base case. Second, we choose candidate buses at which we incrementally change real power for plotting P-V curves and reactive power for plotting Q-V curves. The candidate buses are of load buses so that P and Q margins are computed against increase in demand. Third, we run the power-flow program for incremental changes in real power at the candidate bus and incremental changes in reactive power at the candidate bus. Beyond a critical point, the power-flow program does not converge. The point at which power-flow convergence is no more available is the critical point. Up to the critical point, we obtain voltages at the candidate bus corresponding to changing real power at the same bus. In a similar manner, we get voltages corresponding to changing reactive power at the candidate bus. Fourth, we plot P-V curves and Q-V curves using voltages versus P and voltages versus Q, respectively, for candidate buses. Finally, the difference between the real power demanded at the candidate bus at the critical point and that at the base case gives us the P-margin computed for the candidate bus. Similarly, the difference between the reactive power demanded at the candidate bus at the critical point and that at the base case gives us the Q-margin computed for the candidate bus.

Our investigation of power-flow solutions, P-V curves, and Q-V curves of the 20-bus IEEE system and the 225-bus system of Istanbul Region shows that we obtain power-flow solution using Newton-Raphson method and compute margins of voltage security with predefined tolerance. Such computations provide us indispensable information for the secure and efficient operation of power systems.

Keywords: Voltage Security, Voltage Instability, Voltage Collapse, Power Flow, P-V Curve, Q-V Curve.

ÖZET

P-V ve Q-V EĞRİLERİ YARDIMIYLA
GERİLİM GÜVENLİĞİNİN SAPTANMASI

Aydın, Bülent

Elektrik - Elektronik Mühendisliği

Tez Danışmanı: Dr. Bülent Bilir

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Son yıllarda gerilim kararsızlığı ve gerilim çökmesi birçok ülkede gözlemlenmekte; benzer sorunlar, kısıtlayıcı şartların kaldırılmasından dolayı, gelişmiş ülkelerde daha sıklıkla oluşmaktadır. Günümüzde, güç sistemlerinin başarılı şekilde işletimi için gerilim güvenliği büyük önem arz etmektedir. Gerilim güvenliğinin saptanması, güç iletim kapasitesinin etkin şekilde kullanımı ve sistemin kesintisiz işletimi için gereklidir.

Araştırmamızda, iki farklı güç sisteminin gerilim güvenliği üzerine çalışma yapmaktayız. Sistemlerden birisi 20 baralı IEEE sistemi; diğeri ise 225 baralı İstanbul Bölgesi'nin sistemidir. Bu sistemlerin gerilim güvenliğini P-V ve Q-V eğrilerini kullanarak saptamaktayız. Başka şekilde söylemek gerekirse, uygulanabilir aktif güç ve reaktif güç sınırlarını hesaplamaktayız. İfade ettiklerimizi başarmak için, ilk olarak eldeki verileri kullanarak güç-akış çözümünü bulmaktayız. Çözümü bulmak için MATLAB ortamında yazdığımız güç-akış programını çalıştırmaktayız. Elde edilen çözüm temel durum olarak alınmaktadır. İkinci olarak, aday baraları seçiyoruz. P-V eğrileri ve Q-V eğrilerini çizmek için aday baralardaki aktif güç ve reaktif gücü artırarak değiştirmekteyiz. P ve Q sınırları talepteki artışa karşı hesaplansın diye aday baraları yük baralarından seçmekteyiz. Üçüncü olarak, güç-akış programını aday baradaki aktif güç artımsal değişimleri ve reaktif güç artımsal değişimleri için çalıştırmaktayız. Kritik bir nokta ötesinde güç-akış programı yakınsamaz. Güç akışı yakınsamasının artık mümkün olamayacağı nokta kritik noktadır. Kritik noktaya kadar, aday baradaki değişen aktif güçlere karşı düşen gerilim değerlerini elde etmekteyiz. Benzer şekilde, aday baradaki değişen reaktif güce karşı düşen gerilimleri hesaplamaktayız. Dördüncü olarak, P değerlerine karşı düşen gerilim değerlerini ve Q değerlerine karşı düşen gerilim değerlerini kullanarak, aday baralar için P-V ve Q-V eğrilerini çizmekteyiz. Son olarak, aday barada kritik noktada talep edilen aktif güç ile aynı barada temel durumdaki aktif güç arasındaki fark bize aday bara için hesaplanan P sınırını vermektedir. Benzer olarak, aday barada kritik noktada talep edilen reaktif güç ile temel durumdaki güç arasındaki fark, aday bara için hesaplanan Q sınırını vermektedir.

20 baralı IEEE sistemi ve 225 baralı İstanbul Bölgesi sisteminin güç-akış çözümleri, P-V eğrileri ve Q-V eğrileri üzerine yaptığımız incelemeler gösteriyor ki Newton-Raphson yötemini kullanarak güç-akış çözümünü, önceden belirlenen kesinlikte elde edilmekte ve gerilim güvenliği sınırlarını yine önceden belirlediğimiz aralıkta hesaplamaktayız. Bu tür hesaplamalar, güç sistemlerinin güvenli ve etkin işletimi için bize çok yararlı bilgiler sağlamaktadır.

Anahtar Kelimeler: Gerilim Güvenliği, Gerilim Kararsızlığı, Gerilim Çökmesi, Güç Akışı, P-V Eğrisi, Q-V Eğrisi.

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LIST OF ABBREVIATIONS

Active Power-Voltage	:	P-V
Institute of Electrical and Electronics Engineer	:	IEEE
Kirchhoff's Current Law	:	KCL
per unit	:	p.u.
Reactive Power-Voltage	:	Q-V
Türkiye Elektrik İşletmeleri Anonim Şirketi	:	TEİAŞ

LIST OF SYMBOLS

Admittance	:	Y
Current	:	I
Jacobian matrix	:	J
Reactive power	:	Q
Real power	:	P
Transformation ratio	:	$1:a$
Voltage magnitude	:	$\|V\|$
Voltage phase angle	:	δ

1. INTRODUCTION

1.1 BACKGROUND

Today's power transmission systems become heavily loaded and more stressed due to increased loads and large inter-utility power transfers. Under these circumstances, a number of voltage security problems have arisen within electric power systems [Taylor 1994], [Abed et. al. 1998]. Efficient system operation is becoming increasingly threatened because of problems of voltage instability and collapse [Overby et. al. 1994], [Bilir 2000]. The term voltage instability is used to describe situations in which a disturbance, an increase in load, or other system change causes bus voltages to vary significantly from their desired operating range in such a way that standard mechanisms of operator intervention or automatic system controls fail to stop this deviation. If bus voltages ultimately fall in a more rapid decline, leading to loss of portions of the network, the term voltage collapse is used. The voltage related threats to system security are expected to become more severe as demand for electric power rises, while economic and environmental concerns limit the construction of new transmission and generation facilities.

Voltage security means the ability of a system, not only to operate stably, but also to remain stable following contingencies or load increases [IEEE Spec. Pub. 1990]. It often means the existence of considerable margin from an operating point to the voltage instability point following contingencies. The margin could be the real power transfer on a specific line, loading within an area, or reactive power margin at some buses in a studied area. Industry experience has shown that voltage stability analysis is often suited to static analysis [Bose et. al. 2001], [IEEE Spec. Pub. 1990], [Abed et. al. 1998].

A slow-spreading, uncontrollable decline in voltage, known as voltage collapse, is a specific type of transmission system voltage instability. Voltage collapse results when generators reach their field current limits which cause a disabling of their excitation voltage control systems. Voltage collapse has recently caused major blackouts in a number of different countries around the world [Dobson et. al. 2002].

In order to reduce the possibility of voltage collapse in a power system, system planning is performed by many utility companies. First, a mathematical model of the basic elements of the power system, and their interconnection, is constructed. These basic elements include generating stations, transmission lines, and sources of reactive reserves. Next, various computational techniques for analyzing system stability are performed using a suitably programmed computer.

In mathematical terms, voltage collapse occurs when equilibrium equations associated with the mathematical model of the transmission system do not have unique local solutions. This results either when a local solution does not exist or when multiple solutions exist. The point at which the equilibrium equations no longer have a solution or a unique solution is often associated with some physical or control capability limit of the power system. Such a point is the critical point; its detection plays a major role in determining voltage security margins [Huang and Abur 2002].

Current methods for assessing proximity to classic voltage instability are based on some measure of how close a power-flow Jacobian is to a singularity condition, since a singular power-flow Jacobian implies that there is not a unique solution [Mohn and Zambroni de Souza 2006]. Two of these proximity measures are:

1) The real power flow-voltage level (P-V) curve margin

2) The reactive power flow-voltage level (Q-V) curve margin

Power flow based methods, P-V curves and Q-V curves are widely used. These two methods determine steady-state loadability limits which are related to voltage stability [Taylor 1994].

1.2 LITERATURE REVIEW

The fundamentals of modeling power systems, specifically concentrating on voltage and reactive power topics, are covered well in [Taylor 1994] and [Kundur 1994]. Issues on power system static security analysis are introduced in [Wood and Wollenberg 1996]. This gives the background on the significant roles played by security analysis in modern bulk power system operation and control. Voltage stability and reactive power compensation are discussed in [Miller 1982].

The problems of voltage stability and collapse have attracted numerous research efforts from power systems researchers [Dobson and Chiang 1989], [IEEE Spec. Pub. 1990], [Greene et. al. 1999], [Van Cutsem and Vournas 2008]. Many voltage stability margins and indices have been proposed and used throughout the world for voltage security analysis. One category of voltage stability indices is based on eigenvalue and singular value analysis of the system Jacobian matrix [Gao et. al. 1992], [Lof et. al. 1993], [Canizares et. al. 1996]. The idea is to detect the collapse point by monitoring the minimum eigenvalue or singular value of the system Jacobian, which becomes zero at the collapse point. With the analysis of the associated eigenvectors or singular vector, one can determine the critical buses in the system by the right vector, and the most sensitive direction for changes of power injections by the left vector. However, the behavior of these indices is highly nonlinear; that is, they are rather insensitive to system parameter variations. In addition, for large systems, this process is also computationally expensive.

The more prominently applied methods in voltage stability analysis are those that try to define an index using the system load margin. The two most widely used are the real power margin, P, associated with the P-V curve, and the reactive power margin, Q, associated with the Q-V curve. The P margin can be calculated using the point of collapse method [Canizares et. al. 1992] or the power-flow continuation method [Ajjarapu and Christy 1992]. In [Parker 1996], it is formulated as an optimization problem. For fast calculation of the P margin, curve fitting methods are proposed to calculate the limit of the nose curve [Ejebe et. al. 1996], [Chiang et. al. 1997]. Similarly, in [Greene et al. 1999], a sensitivity based linear/quadratic estimation method is proposed.

The P-V curve-based and Q-V curve-based margins are the two most widely-used static methods for voltage security assessment [Bose et. al. 2001]. For voltage security, Q-V curve interpretations of energy measures are provided by [Overby et. al. 1994]. The V-Q curve power-flow method is discussed in [Chowdhury and Taylor 2000]. Using P-V and Q-V curves, Jaganathan and Saha [Jaganathan and Saha 2004] conduct a voltage stability analysis to evaluate the impact of embedded generation on distribution systems with respect to the critical voltage variations and collapse margins. The paper [Mohn and Zambroni de Souza 2006] investigates the use of constraint reactive implicit coupling method to trace P-V and Q-V curves. A measurement-based Q-V curve method, which can measure on-line part of the Q-V curve in the vicinity of the operating point employing some adjustable parameters and special compensation method to implement the measurement procedure, is proposed in [Huang et. al. 2007].

1.3 STATEMENT OF THE PROBLEM AND METHODOLOGIES

Voltage security assessment is of major concern in electric utility companies. With technological change and utility deregulation, the electric industry moves toward an open-access market. This transition is expected to place further stress on the transmission network due to an increase in power transactions carried over the transmission grid. Such heavily-loaded systems lead to reduced operating margins. Under these circumstances, utilities and system operators need to know voltage security margins for secure operations and power transactions.

Knowing that voltage security plays a crucial role in operations of power systems, we conduct a research study to assess margins of voltage security of the two power systems; one of which is the 20-bus IEEE system and the other is the 225-bus system of Istanbul Region. For our research study, we need power-flow solutions of the given systems. The power flow is widely used in power system analysis. The solution of power flow predicts what the electrical state of the network will be when it is subject to a specified loading condition. The result of the power flow is the voltage magnitude and the angle at each bus of the system. Power-flow solutions are closely associated with voltage stability analysis. It is an essential tool for voltage stability evaluation. Much of the research on voltage stability deals with the power-flow computation methods. Regarding security margin calculations, we develop a power-flow program as the tool for our analysis. We write the codes for the program in MATLAB environment.

Developing the power-flow program is one of the major parts our research study. Let us describe the power-flow problem. Consider an electric power system with n buses (not counting the ground bus). These n buses are comprised of a single swing bus,

n_{pv} buses at which active power *P* and voltage magnitude $|V|$ are specified (these are PV buses), and n_{pq} buses at which active and reactive power (*P*, *Q*) are specified (these are PQ buses). The single swing bus is a generation bus which is usually centrally located in the system; the voltage magnitude and phase angle (δ) are specified at this bus. The PV buses are mostly generation buses at which the injected active power is specified and held fixed by turbine settings. A voltage regulator holds $|V|$ fixed at PV buses by automatically varying the generator field excitation. This variation causes the generated reactive power to vary in a way as to bring the terminal voltage magnitude to the specified value. The PQ buses are primarily load buses. Evidently,

$$n = n_{pv} + n_{pq} + 1.$$

At PV buses,

$$P_i = specified\ quantity$$

$$|V_i| = specified\ quantity, \quad i = n_{pv} \text{ buses.}$$

At PQ buses,

$$P_i = specified\ quantity$$

$$Q_i = specified\ quantity, \quad i = n_{pq} \text{ buses.}$$

At the swing bus,

$$|V_i| = specified\ quantity$$

$$\delta_i = specified\ quantity, \quad i = \text{swing bus.}$$

We need to calculate δ_i and Q_i at PV buses, $|V_i|$ and δ_i at PQ buses, and P_i and Q_i at the swing bus. In order to obtain these values via bus voltages and bus injection currents, we solve the system of ($2n_{pv} + 2n_{pq} + 2 = 2n$) power-flow equations

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\delta_i - \delta_j - \theta_{ij}) \tag{1.1}$$

$$Q_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\delta_i - \delta_j - \theta_{ij}) \tag{1.2}$$

using the node-voltage equation in the matrix form

$$I = YV,$$

where I is the bus injection-current vector, V is the bus voltage vector, and Y is the bus admittance matrix. As easily seen in equations (1.1) and (1.2), the power-flow problem is a nonlinear problem because of the sinusoidal terms and the product of voltage magnitudes. For such a system of equations, there are no closed-form solutions. However, we obtain numerical solutions using Newton-Raphson method. In our program, starting with initial guess with voltage magnitudes of 1.0 p.u and voltage angles of 0 degrees, we calculate the power-flow solution under the contraints of reactive power limits of generators with the tolerance of 0.01 p.u.. For the two sample power systems, the 20-bus IEEE system and the 225-bus system of Istanbul Region, we run our power-flow program and obtain the solutions successfully.

We assess the voltage security by computing security margins via P-V and Q-V curves. Our major tool is the power-flow program to generate P-V and Q-V curves. For the computation of security margins, we choose candidate buses from load buses to apply incremental changes in real power and reactive power. At each candidate bus, we start with the base case solution of the power flow. To draw the P-V curve for a candidate bus, we increase real power by 0.2 p.u. at each time and run the power-flow program successively until the power flow does not converge. In this way, we have successive values of the real power P and the corresponding voltage magnitudes at the candidate bus. Using these values, the P-V curve is drawn for the real power and the voltage magnitude at the candidate bus. To fine tune the computation of the margins, between the last step at which the power flow converges and the next step at which it does not converge, we change the value of increment to 0.1 p.u. and 0.05 p.u. It means that we approach the nose of the curve, where increase in real power results in non-convergence of the power-flow convergence, by the tolerance of 0.05 p.u.. The difference between the real power at the nose of the curve and that at the base case gives the P-margin of the system at the candidate bus. To draw the Q-V curve for a candidate bus, we apply the similar procedures as we perform to draw P-V curves.

2. POWER-FLOW ANALYSIS

2.1 INTRODUCTION

Power-flow analysis is a quite important concept for energy system planning, operating and controlling. In this part, we discuss steady-state analysis of an interconnected power system during normal operation. The system is assumed to be operating under balanced three-phase steady-state conditions and is represented by a single-phase network. The network contains hundreds of buses and branches with impedances specified in per unit on a common MVA base [Saadat 2004].

Network equations can be formulated in various forms. However, the node-voltage method is commonly used, since it is the most suitable form for many power system analyses. The formulation the network equations in the nodal admittance form results in complex linear simultaneous algebraic equations in terms of node currents. When node currents are specified the set of linear equations can be solved for the node voltages. However, in a power system, powers are known rather than currents. Therefore, the resulting equations in terms of power, known as the *power-flow equation*, become nonlinear and must be solved by iterative techniques. Power-flow studies are the backbone of power system analysis and design. They are necessary for planning, operation, economic scheduling, and exchange of power between utilities.

2.2 BUS-ADMITTANCE MATRIX

In order to obtain the node-voltage equations, consider the simple power system in shown in Figure 2.1 where impedances are expressed in per unit on a common MVA base and for the sake of simplicity, resistances are neglected. Since the nodal solution is based upon Kirchhoff's current law (KCL), impedances are converted to admittance [Saadat 2004]; that is,

$$y_{ij} = \frac{1}{z_{ij}} = \frac{1}{r_{ij} + jx_{ij}} \tag{2.1}$$

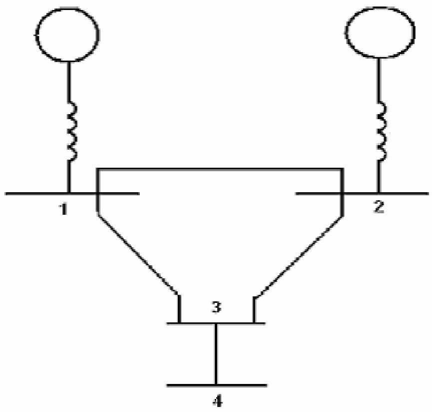

Figure 2.1: The impedance diagram of a simple system

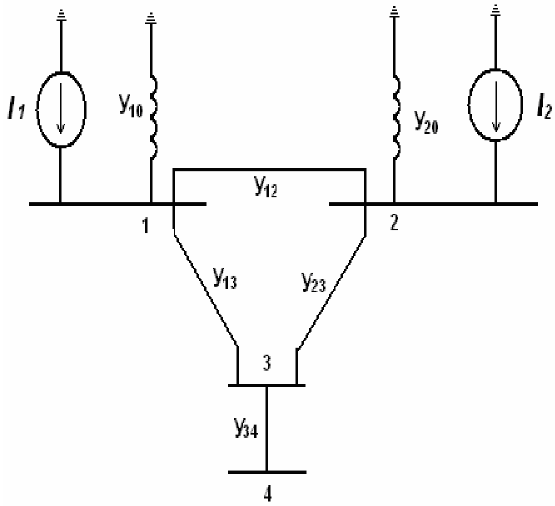

Figure 2.2: The admittance diagram of the system in Figure 2.1

The circuit has been redrawn in Figure 2.2 in terms of admittances and transformation to current sources. Applying KCL to the independent nodes 1 through 4 results in

$$
\begin{aligned}
I_1 &= y_{10}V_1 + y_{12}(V_1 - V_2) + y_{13}(V_1 - V_3) \\
I_2 &= y_{20}V_2 + y_{12}(V_2 - V_1) + y_{23}(V_2 - V_3) \\
0 &= y_{23}(V_3 - V_2) + y_{13}(V_3 - V_1) + y_{34}(V_3 - V_4) \\
0 &= y_{34}(V_4 - V_3)
\end{aligned}
\tag{2.2}
$$

Rearranging these equations yields

$$
\begin{aligned}
I_1 &= (y_{10} + y_{12} + y_{13})V_1 - y_{12}V_2 - y_{13}V_3 \\
I_2 &= -y_{12}V_1 + (y_{20} + y_{12} + y_{23})V_2 - y_{23}V_3 \\
0 &= -y_{13}V_1 - y_{23}V_2 + (y_{13} + y_{23} + y_{34})V_3 - y_{34}V_4 \\
0 &= y_{34}V_4 - y_{34}V_3
\end{aligned}
\tag{2.3}
$$

We introduce the following admittances

$$
\begin{aligned}
Y_{11} &= y_{10} + y_{12} + y_{13} \\
Y_{22} &= y_{20} + y_{12} + y_{23} \\
Y_{33} &= y_{13} + y_{23} + y_{34} \\
Y_{44} &= y_{34} \\
Y_{12} &= Y_{21} = -y_{12} \\
Y_{13} &= Y_{31} = -y_{13} \\
Y_{23} &= Y_{32} = -y_{23} \\
Y_{34} &= Y_{43} = -y_{34}
\end{aligned}
\tag{2.4}
$$

The node equation reduces to

$$
\begin{aligned}
I_1 &= Y_{11}V_1 + Y_{12}V_2 + Y_{13}V_3 + Y_{14}V_4 \\
I_2 &= Y_{21}V_1 + Y_{22}V_2 + Y_{23}V_3 + Y_{24}V \\
I_3 &= Y_{31}V_1 + Y_{32}V_2 + Y_{33}V_3 + Y_{34}V_4 \\
I_4 &= Y_{41}V_1 + Y_{42}V_2 + Y_{43}V_3 + Y_{44}V_4
\end{aligned}
\tag{2.5}
$$

In above network, there is no connection between bus 1 and 4. Thus, $Y_{14} = Y_{41} = 0$; similarly $Y_{24} = Y_{42} = 0$.

Extending the above relation to an *n* bus system, the node-voltage equation in matrix form is

$$\begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ I_i \\ \vdots \\ I_n \end{bmatrix} = \begin{bmatrix} Y_{11}Y_{12} \cdots Y_{1i} \cdots Y_{1n} \\ Y_{21}Y_{22} \cdots Y_{2i} \cdots Y_{2n} \\ \vdots \\ Y_{i1}Y_{i2} \cdots Y_{ii} \cdots Y_{in} \\ \vdots \\ Y_{n1}Y_{n2} \cdots Y_{ni} \cdots Y_{nn} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ \vdots \\ V_i \\ \vdots \\ V_n \end{bmatrix} \tag{2.6}$$

or

$$\mathbf{I}_{bus} = \mathbf{Y}_{bus}\mathbf{V}_{bus} \tag{2.7}$$

$\mathbf{I}_{bus}$ is the vector of the injected bus currents. The current is positive when flowing toward the bus and it is negative if flowing away from the bus. $\mathbf{V}_{bus}$ is the vector of bus voltages measured from the reference node. $\mathbf{Y}_{bus}$ is known as the *bus admittance matrix*. The diagonal element of each node is the sum of admittances connected to it. It is known as the *self-admittance*

$$Y_{ii} = \sum_{j=0}^{n} y_{ij} \qquad j \neq i\,. \tag{2.8}$$

The off-diagonal element is equal to the negative of the admittance between the nodes. It is known as the *mutual-admittance*

$$Y_{ij} = Y_{ji} = y_{ij}\,. \tag{2.9}$$

2.3 TAP CHANGING TRANSFORMERS

Transformers can be used to control the real and reactive power flows in a circuit. We now develop the bus admittance equations to include such transformers in a power flow studies. Figure 2.3 is detailed representation of the ideal transformer. The

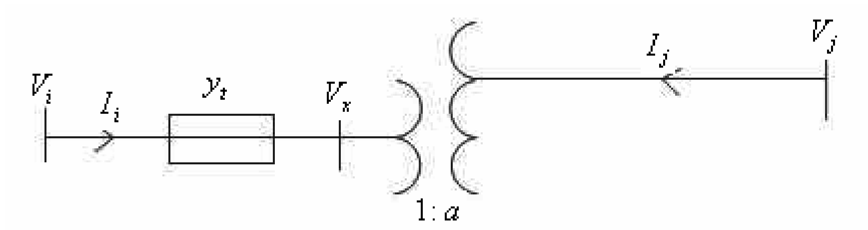

Figure 2.3: Transformer with tap setting ratio a:1

Admittance y_t in per unit is the corresponding of the per unit impedance of the transformer which has the transformation ratio 1:*a* as shown. In the case of phase shifting transformers, *a* is a complex number. Consider a fictitious bus *x* between the turn ratio and admittance of the transformer. Since the complex power on either side of the ideal transformer is the same, it follows that if the voltage goes through a positive phase angle shift, the current will go through a negative phase angle shift. For the assumed direction of currents, we have [Saadat 2004], [Grainger 1994]

$$V_x = \frac{1}{a} V_j \tag{2.10}$$

$$I_i = -a^* I_j \tag{2.11}$$

The current I_i can be expressed by

$$I_i = y_t (V_i - V_x) \tag{2.12}$$

Substituting for V_x, we have

$$I_i = y_t V_i - \frac{y_t}{a} V_j \tag{2.13}$$

From 2.11, we have

$$I_j = -\frac{1}{a^*} I_i \tag{2.14}$$

Substituting for I_i from 2.13, we have

$$I_j = -\frac{y_t}{a^*} V_i + \frac{y_t}{|a|^2} V_j \tag{2.15}$$

Writing (2.13) and (2.15) in the matrix form results in

$$\begin{bmatrix} I_i \\ I_j \end{bmatrix} = \begin{bmatrix} y_t & -\dfrac{y_t}{a} \\ -\dfrac{y_t}{a^*} & \dfrac{y_t}{|a|^2} \end{bmatrix} \begin{bmatrix} V_i \\ V_j \end{bmatrix} \qquad (2.16)$$

2.4 NEWTON-RAPHSON METHOD

The most widely-used method for solving simultaneous algebraic equations is the Newton-Raphson method. Newton-Raphson's method is a successive approximation procedure based on an initial estimate of the unknown and the use of Taylor's series expansion. Consider the solution of the one-dimension equation given by

$$f(x) = c \qquad (2.17)$$

If $x^{(0)}$ is an initial estimate of the solution, and $\Delta x^{(0)}$ is a small deviation from the correct solution, we must have

$$f\left(x^{(0)} + \Delta x^{(0)}\right) = c \qquad (2.18)$$

Expanding the left-hand side of the above equation in Taylor's series about $x^{(0)}$ yield

$$f\left(x^{(0)}\right) + \left(\frac{df}{dx}\right)^0 \Delta x^{(0)} + \frac{1}{2!}\left(\frac{d^2 f}{dx^2}\right)^0 \left(\Delta x^{(0)}\right)^2 + \cdots = c \qquad (2.19)$$

Assuming the error $\Delta x^{(0)}$ is very small, the higher-order terms can be neglected, which results in

$$\Delta c^{(0)} \cong \left(\frac{df}{dx}\right)^0 \Delta x^{(0)} , \qquad (2.20)$$

where

$$\Delta c^{(0)} = c - f\left(x^{(0)}\right). \quad (2.21)$$

Adding $\Delta x^{(0)}$ to the initial estimate will result in the second approximation

$$x^{(1)} = x^{(0)} + \frac{\Delta c^{(0)}}{(\frac{df}{dx})^{(0)}}. \quad (2.22)$$

Use of this procedure yields the Newton-Raphson algorithm

$$\Delta c^{(k)} = c - f\left(x^{(k)}\right) \quad (2.23)$$

$$x^{(k+1)} = x^{(k)} + \Delta x^{(k)} \quad (2.24)$$

$$\Delta x^{(k)} = \frac{\Delta c^{(k)}}{(\frac{df}{dx})^{(k)}}. \quad (2.25)$$

The last equation can be rearranged as

$$\Delta c^{(k)} = J^{(k)} \Delta x^{(k)}, \quad (2.26)$$

where

$$J^{(k)} = \left(\frac{df}{dx}\right)^{k} \quad (2.27)$$

Now expand these expressions according to n-dimensional Taylor's series

$$(f_1)^{(0)} + \left(\frac{\partial f_1}{\partial x_1}\right)^{(0)} \Delta x_1^{(0)} + \left(\frac{\partial f_1}{\partial x_2}\right)^{(0)} \Delta x_2^{(0)} + \cdots + \left(\frac{\partial f_1}{\partial x_n}\right)^{(0)} \Delta x_n^{(0)} = c_1$$

$$(f_2)^{(0)} + \left(\frac{\partial f_2}{\partial x_1}\right)^{(0)} \Delta x_1^{(0)} + \left(\frac{\partial f_2}{\partial x_2}\right)^{(0)} \Delta x_2^{(0)} + \cdots + \left(\frac{\partial f_2}{\partial x_n}\right)^{(0)} \Delta x_n^{(0)} = c_2$$

$$\vdots$$

$$(f_n)^{(0)} + \left(\frac{\partial f_n}{\partial x_1}\right)^{(0)} \Delta x_1^{(0)} + \left(\frac{\partial f_n}{\partial x_2}\right)^{(0)} \Delta x_2^{(0)} + \cdots + \left(\frac{\partial f_n}{\partial x_n}\right)^{(0)} \Delta x_n^{(0)} = c_n$$

or in the matrix form

$$\begin{bmatrix} c_1 - (f_1)^0 \\ c_2 - (f_2)^0 \\ \vdots \\ c_n - (f_n)^0 \end{bmatrix} = \begin{bmatrix} \left(\frac{\partial f_1}{\partial x_1}\right)^{(0)} \left(\frac{\partial f_1}{\partial x_2}\right)^{(0)} \cdots \left(\frac{\partial f_1}{\partial x_n}\right)^{(0)} \\ \left(\frac{\partial f_2}{\partial x_1}\right)^{(0)} \left(\frac{\partial f_2}{\partial x_2}\right)^{(0)} \cdots \left(\frac{\partial f_2}{\partial x_n}\right)^{(0)} \\ \vdots \\ \left(\frac{\partial f_n}{\partial x_1}\right)^{(0)} \left(\frac{\partial f_n}{\partial x_2}\right)^{(0)} \cdots \left(\frac{\partial f_n}{\partial x_n}\right)^{(0)} \end{bmatrix} \begin{bmatrix} \Delta x_1^{(0)} \\ \Delta x_2^{(0)} \\ \vdots \\ \Delta x_n^{(0)} \end{bmatrix}$$

In short form, it can be written as

$$\Delta C^{(k)} = J^{(k)} \Delta X^{(k)} \tag{2.28}$$

Consequently, the Newton-Raphson algorithm for n-dimensional case becomes

$$X^{(k+1)} = X^{(k)} + \Delta X^{(k)} \tag{2.29}$$

$J^{(k)}$ is called the Jacobian matrix. Newton's method, as applied to a set of nonlinear equations, reduces the problem to solving a set of linear equations in order to determine the values that improve the accuracy of the estimes.

2.5 POWER-FLOW SOLUTION

The problem consists of determining the magnitudes and phase angles of voltages at each bus and active and reactive power flow in each line. In solving a power-flow problem, the system is assumed to be operating under balanced condtions and a single-phase model is used. Four quantities are associated with each bus. There are voltage magnitude $|V|$, phase angle δ, real power P, and reactive power Q. The system buses are generally classified into three types. They are:

Swing bus: A bus, known as reference bus or slack bus, where the voltage magnitude and phase angle are specified. At this bus, the active power and the reactive power are unknown.

Load buses: At these buses are called P-Q buses. The active and reactive powers are specified; the voltage magnitude and voltage angle are unknown.

Generator buses: At these buses are called P-V or regulated buses. The real power and the voltage magnitude are specified; the voltage angle and the reactive power are unknown.

The power-flow problem is solving the resulting nonlinear system of algebraic equation suitable for the computer solution. In general, two methods are, used to solve these nonlinear equations; they are Gauss-Seidel and Newton- Raphson. However, in power industry, Newton-Raphson is preferred, because it is more efficient for large networks, quadratic convergence and equations are cast in natural power system form. In this respect, we have followed the preference in industry and have used Newton - Raphson method in our program.

In this part, the bus-admittance matrix is formulated, the Newton-Raphson method is explained, and it is employed in the solution of power-flow problems [Saadat 2004].

Consider a typical bus of a power system network as shown Figure 2.4 application of the KCL to this bus results in

$$\begin{aligned} I_i &= y_{i0}V_i + y_{i1}(V_i - V_1) + y_{i2}(V_i - V_2) + \cdots + y_{in}(V_i - V_n) \\ &= (y_{i0} + y_{i1} + \cdots + y_{in})V_i - y_{i1}V_1 - y_{i2}V_2 - \cdots - y_{in}V_n \end{aligned}$$

or

$$I_i = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij}V_j \qquad j \neq i \tag{2.30}$$

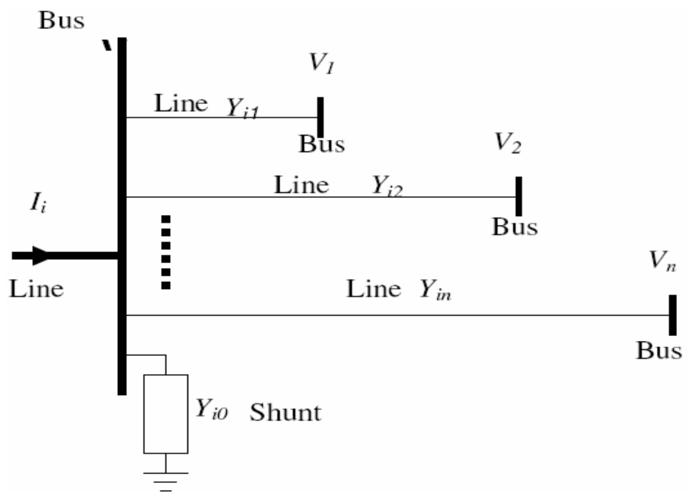

Figure 2.4: A typical bus of the power flow system

The real and reactive power at bus i is

$$P_i + jQ_i = V_i I_i^* \tag{2.31}$$

or

$$I_i = \frac{P_i - jQ_i}{V_i^*} \tag{2.32}$$

Substituting for I_i in (2.30)

$$\frac{P_i - jQ_i}{V_i^*} = V_i \sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij} V_j \qquad j \neq i \tag{2.33}$$

The above equation is the mathematical formulation of the power-flow problem results. This equation is a nonlinear equation, so it must be solved by iteration techniques.

2.6 POWER-FLOW SOLUTION BY NEWTON-RAPHSON

The Newton-Raphson method is found to be more efficient and practical for large power systems. In this method, the number of iterations required to obtain a solution is independent of the system size, but more functional evaluations are required at each iteration. For the typical bus of the power system shown in Figure 4, the equation of the current entering bus i can be rewritten in terms of the bus admittance matrix as

$$I_i = \sum_{j=1}^{n} Y_{ij} V_j \tag{2.34}$$

In the above equation *j* includes bus *i*. Expressing this equation in polar form,

$$I_i = \sum_{j=1}^{n} |Y_{ij}||V_j| \angle \theta_{ij} + \delta_j \tag{2.35}$$

The complex power at bus *i* is

$$P_i - jQ_i = V_i^* I_i \tag{2.36}$$

Then substituting from (2.35) for I_i in (2.36),

$$P_i - jQ_i = |V_i| \angle -\delta_i \sum_{j=1}^{n} |Y_{ij}||V_j| \angle \theta_{ij} + \delta_j \tag{2.37}$$

Separating the real and imaginary parts,

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\delta_i - \delta_j - \theta_{ij}) \tag{2.38}$$

$$Q_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\delta_i - \delta_j - \theta_{ij}) \tag{2.39}$$

The last equations constitute a set of nonlinear algebraic equations in terms of the independent variables, voltage magnitude in per unit and phase angle in radians. If the Newton-Rahpson method is applied these equations,

$$\begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ --- \\ \Delta Q_2^{(k)} \\ \vdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \begin{bmatrix} \frac{\partial P_2^{(k)}}{\partial \delta_2} & \cdots & \frac{\Delta \partial P_2^{(k)}}{\partial \delta_n} & | & \frac{\partial P_2^{(k)}}{\partial |V_2|} & \vdots & \frac{\partial P_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots & | & \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial P_n^{(k)}}{\partial \delta_n} & | & \frac{\partial P_n^{(k)}}{\partial |V_2|} & \vdots & \frac{\partial P_n^{(k)}}{\partial |V_n|} \\ -- & -- & -- & | & -- & -- & -- \\ \frac{\partial Q_2^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial Q_2^{(k)}}{\partial \delta_n} & | & \frac{\partial Q_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots & | & \vdots & \ddots & \vdots \\ \frac{\partial Q_n^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial Q_n^{(k)}}{\partial \delta_n} & | & \frac{\partial Q_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_n^{(k)}}{\partial |V_n|} \end{bmatrix} \begin{bmatrix} \Delta \delta_2^{(k)} \\ \vdots \\ \Delta \partial_n^{(k)} \\ --- \\ \Delta \left| V_2^{(k)} \right| \\ \vdots \\ \Delta \left| V_n^{(k)} \right| \end{bmatrix}$$

In short form, the above equation can be written as,

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 J_2 \\ J_3 J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix} \tag{2.40}$$

The Jacobian matrix gives the linearized relationship between small changes in voltage angle $\Delta \delta_i^k$ and the voltage magnitude $\Delta \left| V_i^k \right|$ with the small changes in real and reactive power ΔP_i^k and ΔQ_i^k. Elements of the Jacobian matrix are partial derivatives of the real and reactive power, evaluated at $\Delta \delta_i^k$ and $\Delta \left| V_i^k \right|$.

For voltage- controlled buses, the voltage magnitudes are known. Therefore, if m buses of the system are voltage-controlled, m equations involving ΔQ and ΔV and the corresponding columns of the Jacobian matrix are eliminated. Accordingly, there are $n-1$ real power constraints and $n-1-m$ reactive power constraints, and the Jacobian matrix is of order $(2n-1-m)\times(2n-1-m)$. J_1 is of the order $(n-1)\times(n-1)$, J_2 is of the order $(n-1)\times(n-1-m)$, J_3 is of the order $(n-1-m)\times(n-1)$, and J_4 is of the order $(n-1-m)\times(n-1-m)$.

The diagonal and off-diagonal elements of J_1 are

$$J_1(i,i) = \frac{\partial P_i}{\partial \delta_i} = -\sum_{j \neq i} |V_i||V_j||Y_{ij}| \sin\left(\delta_i - \delta_j - \theta_{ij}\right) \tag{2.41}$$

$$J_1(i,j) = \frac{\partial P_i}{\partial \delta_j} = |V_i||V_j||Y_{ij}| \sin\left(\delta_i - \delta_j - \theta_{ij}\right) \qquad j \neq i \tag{2.42}$$

The diagonal and off-diagonal elements of J_2 are

$$J_2(i,i) = \frac{\partial P_i}{\partial |V_i|} = 2|V_i||Y_{ii}|\cos(\theta_{ii}) + \sum_{j \neq i} |V_j||Y_{ij}| \cos\left(\delta_i - \delta_j - \theta_{ij}\right) \tag{2.43}$$

$$J_2(i,j) = \frac{\partial P_i}{\partial |V_j|} = |V_i||Y_{ij}| \cos\left(\delta_i - \delta_j - \theta_{ij}\right) \qquad j \neq i \tag{2.44}$$

The diagonal and off-diagonal elements of J_3 are

$$J_3(i,i) = \frac{\partial Q_i}{\partial \delta_i} = \sum_{j \neq i} |V_i||V_j||Y_{ij}| \cos\left(\delta_i - \delta_j - \theta_{ij}\right) \tag{2.45}$$

$$J_3(i,j) = \frac{\partial Q_i}{\partial \delta_j} = -|V_i||V_j||Y_{ij}| \cos\left(\delta_i - \delta_j - \theta_{ij}\right) \qquad j \neq i \tag{2.46}$$

The diagonal and off-diagonal elements of J_4 are

$$J_4(i,i) = \frac{\partial Q_i}{\partial |V_i|} = -2|V_i||Y_{ii}|\sin(-\theta_{ii}) + \sum_{j \neq i} |V_j||Y_{ij}| \sin\left(\delta_i - \delta_j - \theta_{ij}\right) \tag{2.47}$$

$$J_4(i,j) = \frac{\partial Q_i}{\partial |V_j|} = |V_i||Y_{ij}| \sin\left(\delta_i - \delta_j - \theta_{ij}\right) \qquad j \neq i \tag{2.48}$$

The terms $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$ are the difference between the scheduled and calculated values, known as the power residuals, given by

$$\Delta P_i^{(k)} = P_i^{(sch)} - P_i^{(k)} \tag{2.49}$$

$$\Delta Q_i^{(k)} = Q_i^{(sch)} - Q_i^{(k)} \tag{2.50}$$

The new estimates for bus voltages are

$$\delta_i^{(k+1)} = \delta_i^{(k)} + \Delta\delta_i^{(k)} \tag{2.51}$$

$$\left|V_i^{(k+1)}\right| = \left|V_i^{(k)}\right| + \Delta\left|V_i^{(k)}\right| \tag{2.52}$$

The procedure for power flow solution by the Newton-Raphson method is as follows:

1. Read system and load data.
2. Y_{bus} is constitute.
3. Initialize δ, V
4. Calculate ΔP and ΔQ.
5. Calculate Jacobian matrix (2.41 through 2.48).
6. Solve for the voltage angle and magnitude (2.51 and 2.52).
7. Update the voltage magnitude and angles.
8. Check the stopping conditions. If met then terminate, else go to step 3.

$$\begin{aligned} \left|\Delta P_i^{(k)}\right| &\leq \varepsilon \\ \left|\Delta Q_i^{(k)}\right| &\leq \varepsilon \end{aligned} \tag{2.53}$$

2.7 LINE FLOW AND LOSSES

After the iterative solution of bus voltage, the next step is the computation of line flows and line losses. Consider the line connecting the two buses i and j in Figure 2.5. The line current I_{ij}, measured at bus i and defined positive in the direction

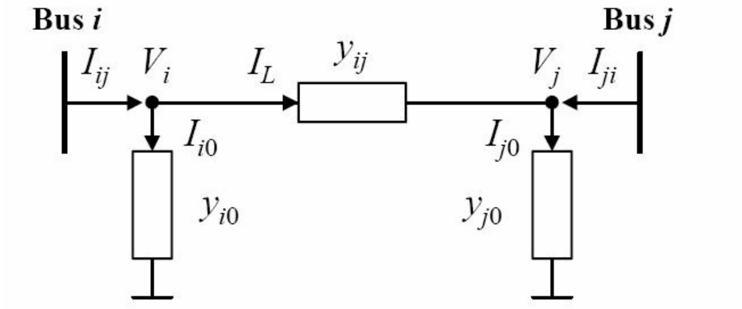

Figure 2.5: Transmission line model for calculating line flows

$i \rightarrow j$ is given by

$$I_{ij} = I_l + I_{i0} = y_{ij}(V_i - V_j) + y_{i0}V_i \tag{2.54}$$

The line current I_{ji} measured at bus j and defined positive in the direction $j \rightarrow i$ is given by

$$I_{ji} = -I_l + I_{j0} = y_{ij}(V_j - V_i) + y_{j0}V_j \tag{2.55}$$

The comlex powers S_{ij} from bus i and j and S_{ji} from bus j to i are

$$S_{ij} = V_i I^*_{ij} \tag{2.56}$$

$$S_{ji} = V_j I^*_{ji} \tag{2.57}$$

The power loss in line $i \rightarrow j$ is the algebraic sum of the power flows determined from (2.56 and 2.57)

$$SL_{ij} = S_{ij} + S_{ji} \tag{2.58}$$

2.8 POWER-FLOW PROGRAM

The power-flow computer program (called load flow) is the basic tool for invetigating these requirements. This program computes the voltage magnitude and voltage angle at each bus in a power system. Real power and reactive power flows for all equipment interconnecting the buses, as well as equipment losses, are also computed. Both existing power system and proposed changes including new generation and transmission to meet projected load growth are of interest [Glover and Sarma 1994] .

Conventional nodal or loop analysis is not suitable for power- flow studies because the input data for loads are normally given in terms of power. Generators are considered as power sources, not voltage or current sources. The power- flow problem is therefore formulated as a set of nonlinear algebraic equations suitable for computer solution [Glover and Sarma 1994].

In section 2.4 we review Newton- Rapson methods, including direct and iterative techniques for solving algebraic equations. Then in section 2.5 – 2.6 the power- flow problem is formulated, computer input data are specified, and solution method, Newton- Raphson, is presented. All power-flow equations and input/output data are given in per-unit.

We discuss the power-flow problem and its solutions by programs developed using MATLAB.

The power- flow computer main program is **pflow.** This program calls the other program**;** Newton- Raphson method is **newtraph,** bus admittance matrix is **network_f**.

pflow: This program produce the bus output result in a tabulated form. The bus output result includes the voltage magnitude and voltage angle, real and reactive power of generator and loads. It is designed to display the active and reactive power flow entering the line terminals and line losses as well as the net power at each bus. The total real and reactive power losses in the system. You can find the program **pflow** in APPENDIX A1. Its flowchart is shown in Figure 2.6.

network_f: This program requires the line and transformer parameters and transformer tap settings specified. It converts impedance to admittance and obtain the bus admittance matrix. You can find the program **network_f** in APPENDIX A2.

newtraph: This program obtain the power flow solution by Newton-Raphson method. This program computes the voltage magnitude and voltage angle at each bus in a power system. It is designed for the direct use of load and generation in MW and

Mvar, bus voltage in per unit, angle in degrees. Loads and generation are converted to per unit quantities on the MVA selected. You can find the program **newtraph** in APPENDIX A3. The flowchart for Newton-Raphson algorithm is shown in Figure 2.7.

plotcurv: This program is used for to find every bus's active and reactive powers seperately in a certain interval transfer ,voltage value against them and determine P-V and Q-V curves. You can find the programs, **plotcurv** in APPENDIX A4.

Flowchart for Power-Flow Program

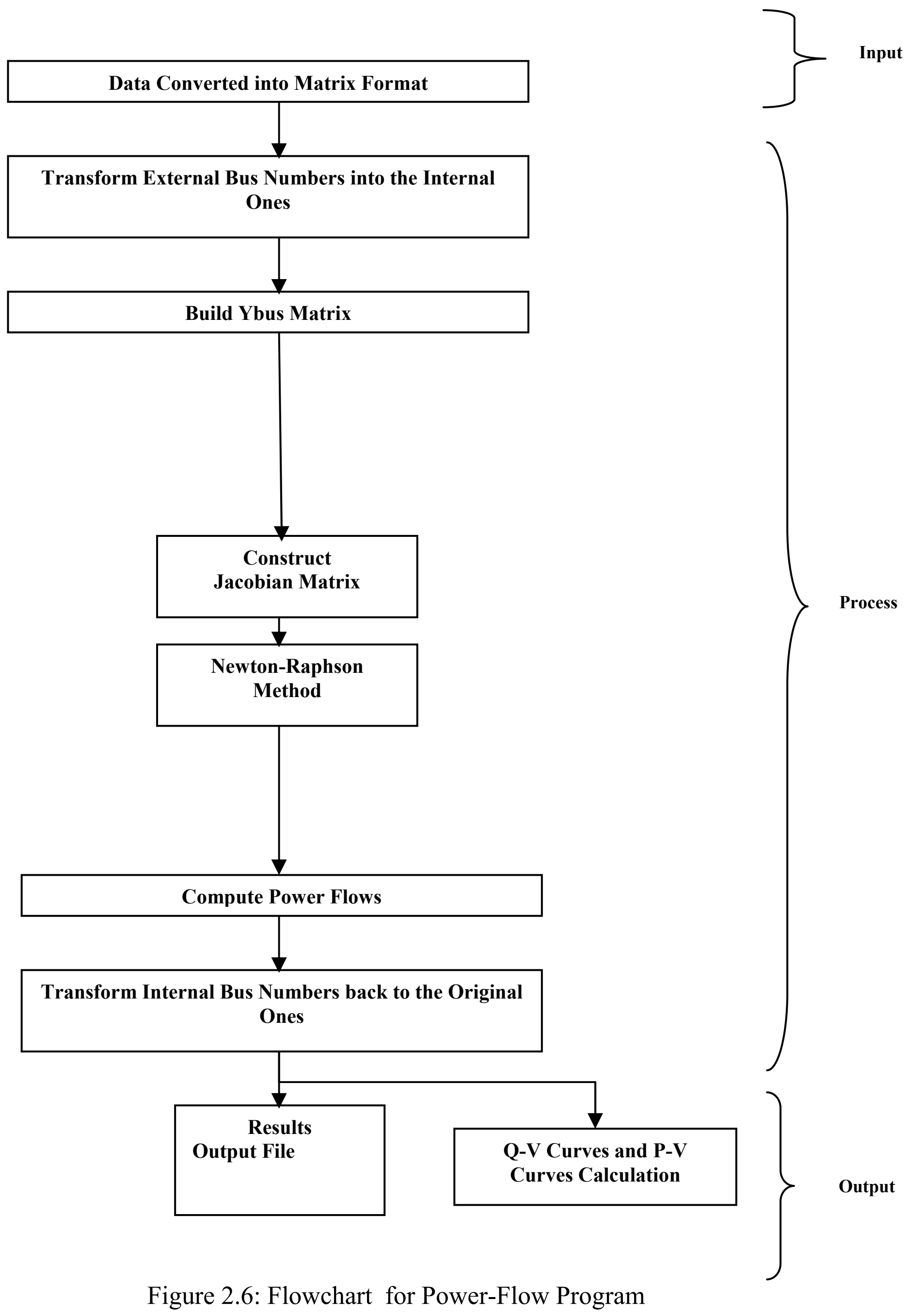

Figure 2.6: Flowchart for Power-Flow Program

Flowchart for Newton-Raphson Algorithm

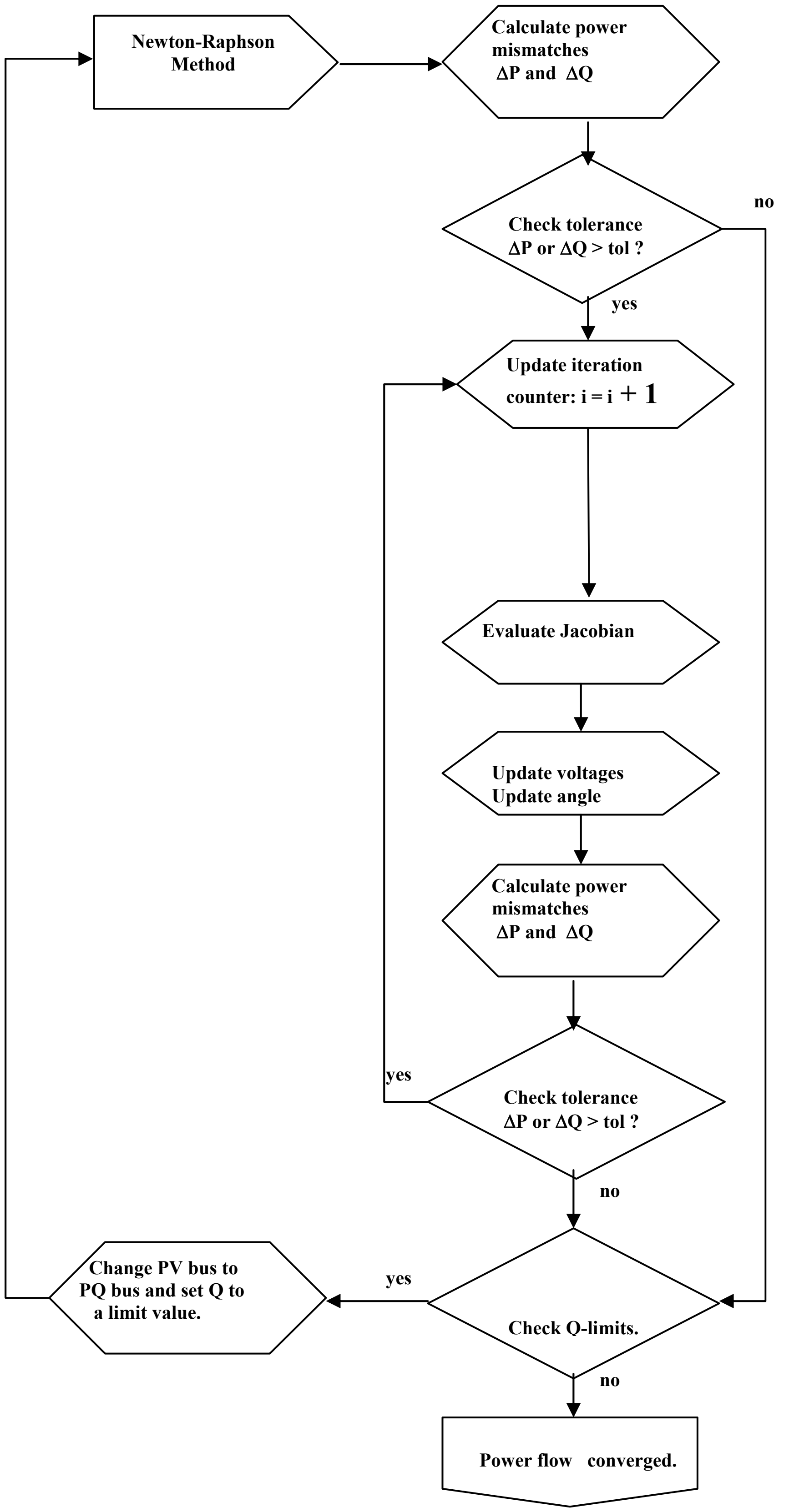

Figure 2.7: Flowchart for Newton-Raphson Algorithm

3. MARGIN CALCULATIONS USING P-V AND Q-V CURVES

3.1 INTRODUCTION

In assessing voltage security of power systems, we deal with P-V and Q-V curves. The methods of P-V and Q-V curves are widely accepted tools; they can provide real and reactive power margins, respectively. Variations in P and Q affect the voltages at the load buses. P-V and Q-V curves are generated by series of power-flow solutions.

In this chapter, we describe P-V and Q-V curves; explain how to compute security margins; and discuss research methodology that we follow for margin calculations. We also present our results with P-V and Q-V curves for various load buses of the 20-bus IEEE system and the 225-bus system of Istanbul Region.

3.2 P-MARGIN CALCULATION BY P-V CURVES

When considering voltage stability, the relationship between transmitted P and receiving end V is of interest. The process of voltage stability analysis involves the transfer of P from one region of a system to another, and monitoring the effects to the system voltages V. This type of analysis is commonly referred to as a P-V study [Kundur 1994].

The P-V curves, real power- voltage curve, are used to determine the MW distance from the operating point to the critical voltage. A typical P-V curve is shown in Figure 3.1. Consider a single, constant power load connected through a transmission line to an infinite-bus. Let us consider the solution to the power-flow equations, where P, the real power of the load, is taken as a parameter that is slowly varied, and V is the voltage of the load bus. The three regions shown in Figure 3.1 are related to the parameter P. In the first region, the power flow has two distinct solutions for each choice of P; one is the desired stable voltage and the other is the unstable voltage. As P is increased, the system enters the second region, where the two solutions intersect to form one solution for P, which is the maximum. If P is further increased, the power-flow equations fail to have a solution. This process can be viewed as a bifurcation of the power-flow problem. The method of maximum power transfer

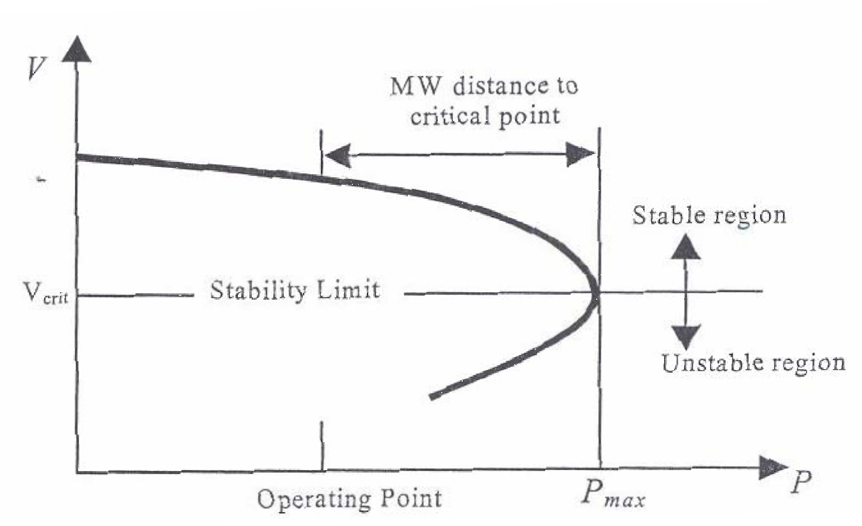

Figure 3.1: Real Power-Voltage (P-V) curve

determines critical limits on the load bus voltages, above which the system maintains steady-state operation.

The P-V curve is drawn for the load bus and the maximum transmissible power is calculated. Each value of the transmissible power corresponds to a value of the voltage at the bus until $V = V_{crit}$ after which further increase in power results in deterioration of bus voltage. The top portion of the curve is acceptable operation whereas the bottom half is considered to be the worsening operation. The risk of voltage collapse is much lower if the bus voltage is further away, by an upper value, from the critical voltage corresponding to P_{max}. Hence, the P-V curve can be used to determine the system's critical operating voltage and collapse margin [Kundur 1994].

3.2 Q-MARGIN CALCULATION BY Q-V CURVES

The Q-V curves, reactive power- voltage curve, are used to determine the Mvar distance from the operating point to the critical voltage. A typical Q-V curve is shown in Figure 3.2. It shows the sensitivity and variation of bus voltages with respect to reactive power injections or absorptions. Scheduling reactive loads rather than voltage produces Q-V curves. These curves are a more general method of assessing voltage stability. They are used by utilities as a workhorse for voltage stability analysis to determine the proximity to voltage collapse and to establish system design criteria based on Q and V margins determined from the curves. Operators may use the

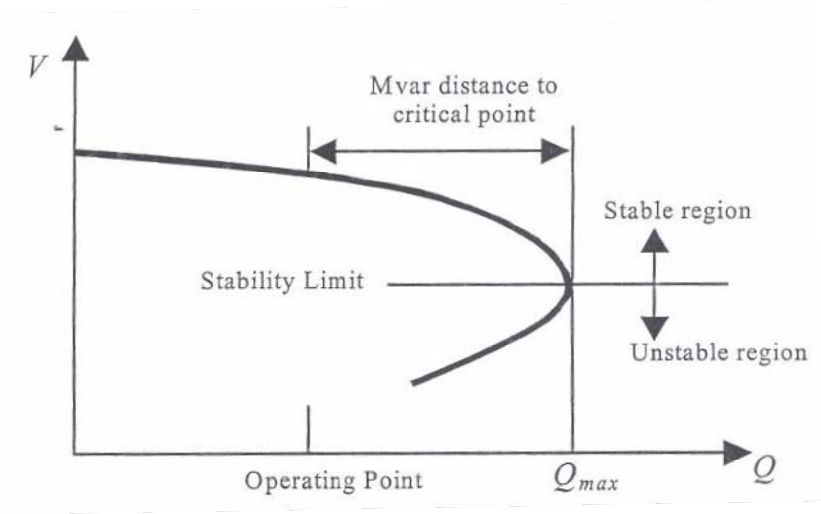

Figure 3.2: Reactive Power-Voltage (Q-V) Curve

curves to check whether the voltage stability of the system can be maintained or not take suitable control actions.

As a traditional solution in system planning and operation, the voltage level is used as an index of system voltage instability. If it exceeds the limit, reactive support is insatalled to improve voltage profiles.With such an action, voltage level can be maintained within acceptable limits under a wide range of MW loadings. In reality, voltage level may never decline below that limit as the system approaches its steady-state stability limits. Consequently, voltage levels should not be used as a voltage collapse warning index.

In Figure 3.2, the Q axis shows the reactive power that needs to be addedor removed from the bus to maintain a given voltage at a given load. The reactive power margin is the Mvar distance from the operating point to the bottom of the curve. The curve can be used as an index for voltage instability. Near the nose of a Q-V curve, sensitivities get very large and then reverse sign. Also, it can be seen that the curve shows two possible values of voltage for the same value of power. The power system operated at lower voltage value would require very high current to produce the power. That is why the bottom portion of the curve is classified as an unstable region; the system cannot be operated, in steady state, in this region. The top portion of the curve represents the stability region while the bottom portion from the stability limit indicates the unstable operating region. It is preferred to keep the operating point far from the stability limit.

3.3 RESEARCH METHODOLOGY OF MARGIN CALCULATION

In our research study, we generate P-V and Q-V curves by series of power-flow solutions. First of all, we run the power-flow program that we code in MATLAB environment using Newton-Raphson method to obtain the power-flow solution. Our program takes into account the reactive power limits of generators in the systems. As you may know, such constraints make power-flow difficult to convergence. However, the program reaches a solution successfully for each power system on which we study; one is the 20-bus IEEE system and the other is the 225-bus system of Istanbul Region. Note that the 225-bus system is a real power system of which data are provided us by TEİAŞ. The one-line diagram of this system is given in Figure 3.3.

The power-flow solution of the system is taken as a base case. After this point, we develop P-V and Q-V curves based on the methodology we describe below.

The methodology that we follow for development of a full P-V curve is as follows:

1. Choose a load bus at which the real power P is incrementally increased. This could be a load that is suspected or known to be susceptible to voltage collapse. We call the chosen bus the candidate bus.

2. The real power output of the generators should remain unchanged during the P-V analysis. The reactive power output of each generator should be allowed to adjust as the P-V analysis progresses. Voltage collapse occurs in the study region after the reactive power capability in the study region is depleted.

3. Increase the real power P by 0.2 p.u. at the candidate bus. Note that except this change, nothing else changes in the data. Run the power-flow program with this change. Obtain a new voltage value at the candidate bus against the increased P value.

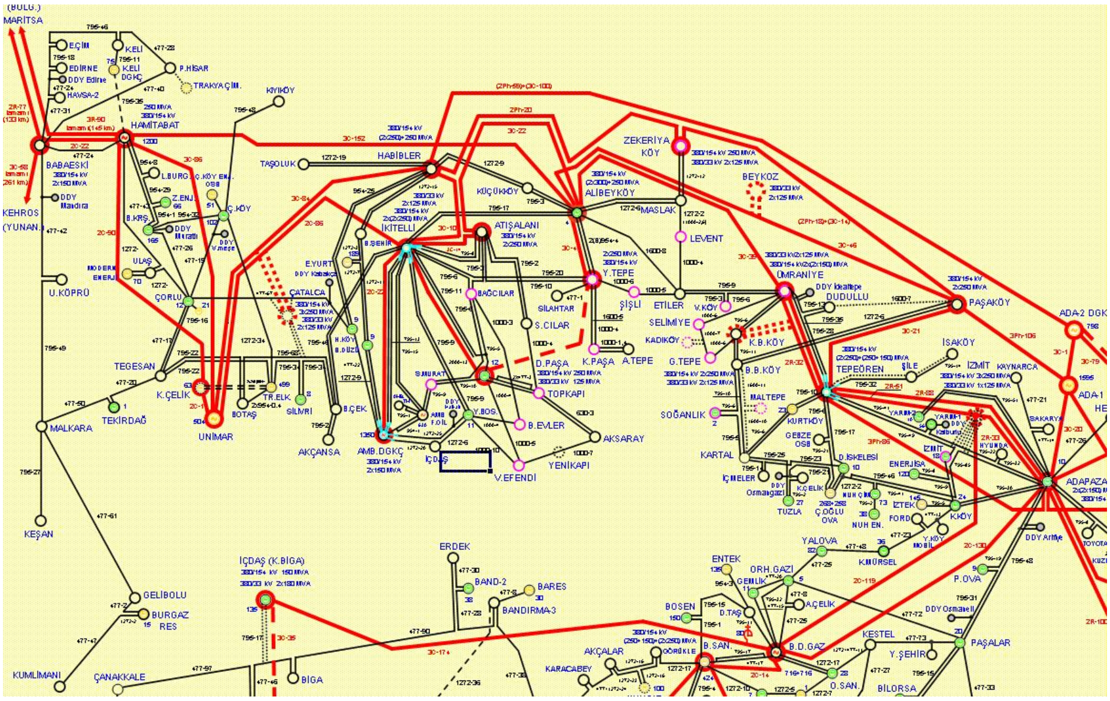

Figure 3.3: One-line diagram of the 225-bus system of Istanbul Region (Courtesy of TEİAŞ)

4. Iterate the processes at step 3 until the power flow does no more converge.

5. To reach the collapse point (the nose of the curve) closely, take the last case at which the power flow converges as the base case. Decrease the value of increment to 0.1 p.u. and execute steps 3 and 4.

6. Execute step 5, decreasing the value of increment to 0.05 p.u.

7. Run the program that plots the P-V curve using the calculated voltages corresponding to incrementally changed P values at the candidate bus.

8. Compute the P margin, substracting P value at the base case from maximum permissible real power P_{max}, which is at the collapse point.

Using the methodology for generating P-V curves which we discuss above, we generate P-V curves for load buses 5, 9, and 19 of the 20-bus IEEE system. They are given in Figures 3.4, 3.5, and 3.6. The approximate P margins for the given buses are easily obtained from the P-V curves in these figures.

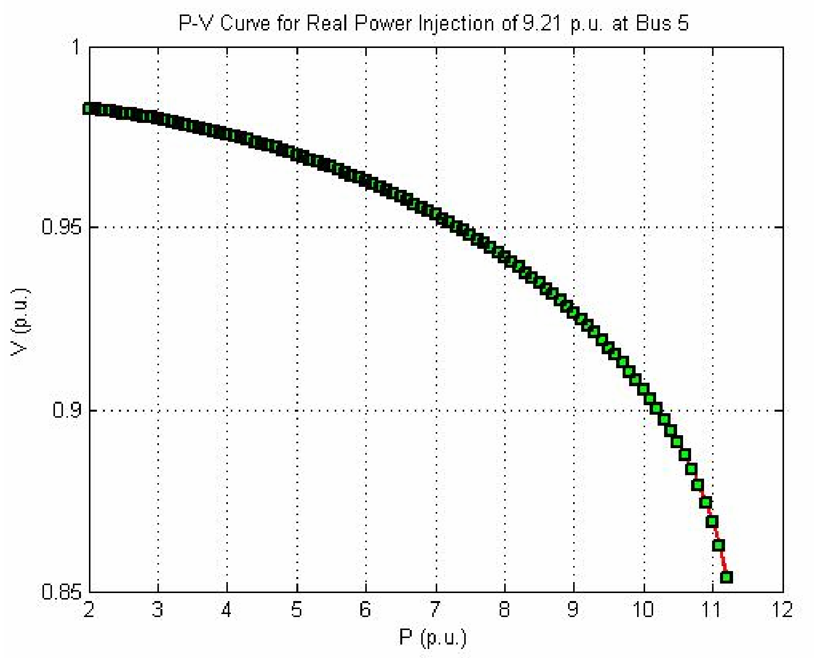

Figure 3.4: P-V Curve (5. Bus IEEE20)

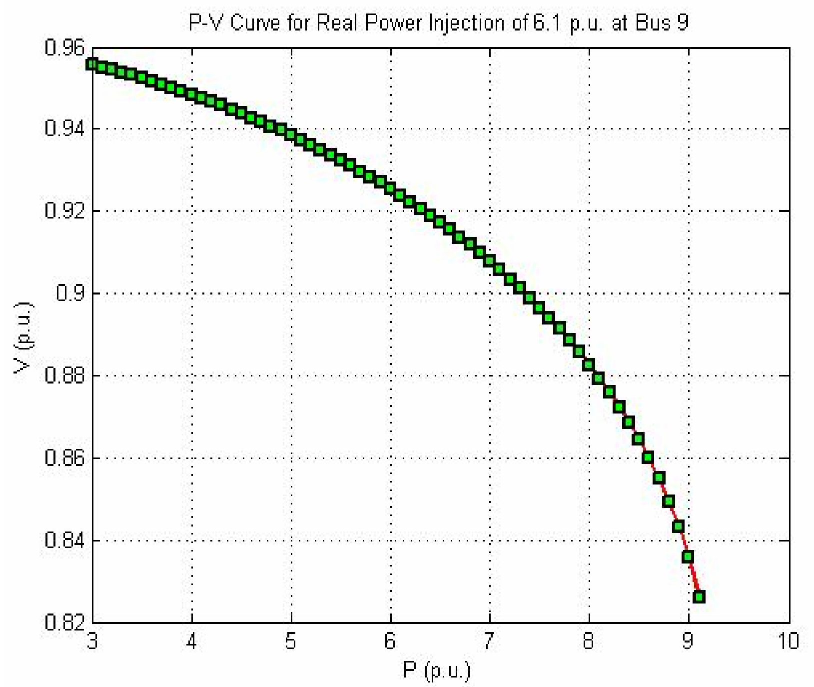

Figure 3.5: P-V Curve (9. Bus IEEE20)

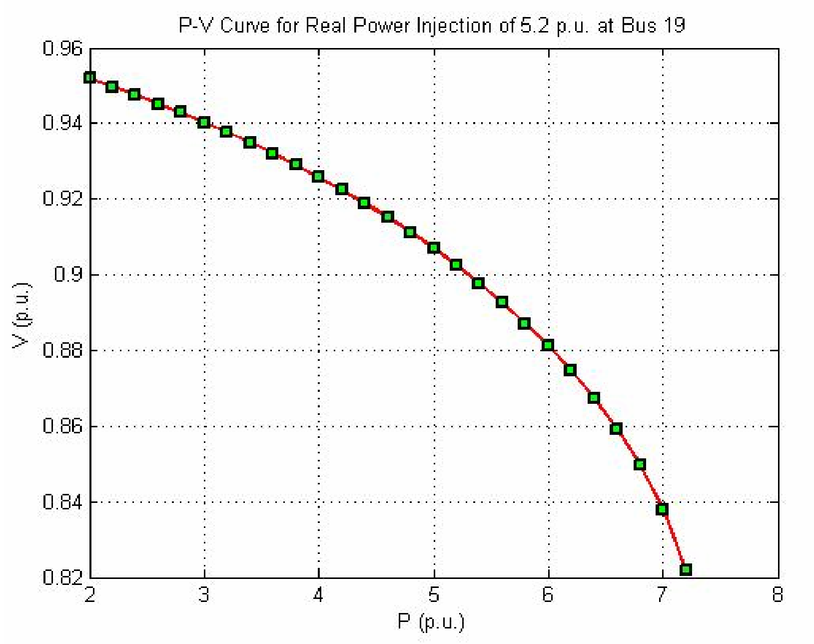

Figure 3.6: P-V Curve (19. Bus IEEE20)

The P-V curves for load buses 24, 81, and 116 of the 225-bus system of Istanbul Region are given in Figures 3.7, 3.8, and 3.9.

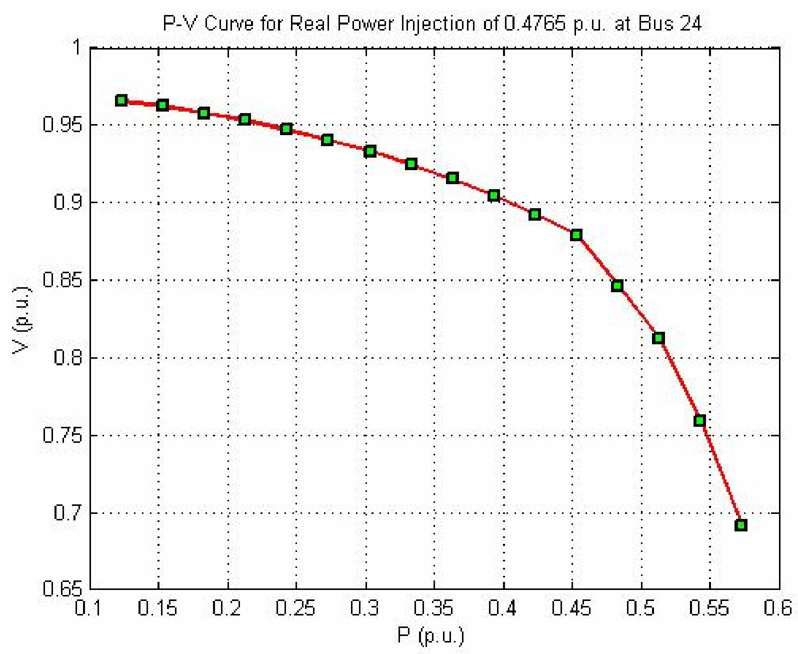

Figure 3.7: P-V Curve (24. Bus 1EDIRNE_A)

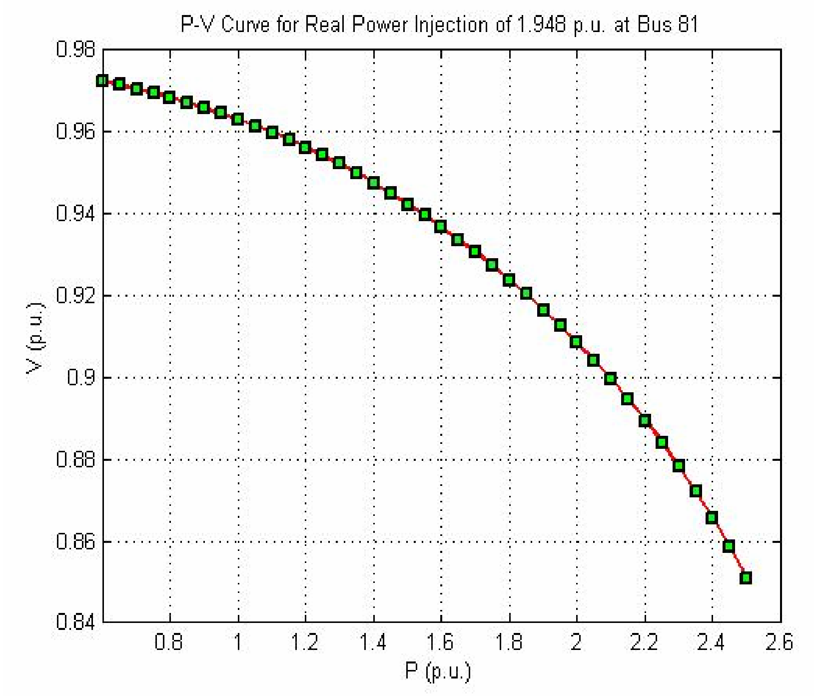

Figure 3.8: P-V Curve (81. Bus AMBARLI_A)

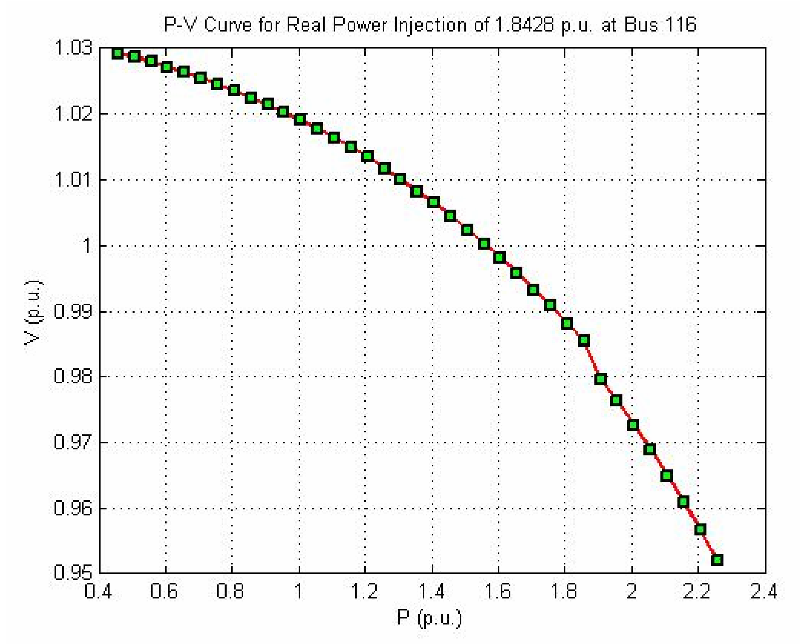

Figure 3.9: P-V Curve (116. Bus ETILER)

The methodology that we follow for development of a full Q-V curve is as follows:

1. Choose a load bus at which the reactive power Q is incrementally increased. This could be a critical bus for contingency. We call the chosen bus the candidate bus as in the methodology for P-V curves.

2. The reactive power output of each generator should be allowed to adjust as the Q-V analysis progresses. Voltage collapse occurs in the study region after the reactive power capability in the study region is depleted.

3. Increase the reactive power Q by 0.2 p.u. at the candidate bus. Note that except this change, nothing else changes in the data. Run the power-flow program with this change. Obtain a new voltage value at the candidate bus against the increased Q value.

4. Iterate the processes at step 3 until the power flow does no more converge.

5. To reach the collapse point (the nose of the curve) closely, take the last case at which the power flow converges as the base case. Decrease the value of increment to 0.1 p.u. and execute steps 3 and 4.

6. Execute step 5, decreasing the value of increment to 0.05 p.u.

7. Run the program that plots the Q-V curve using the calculated voltages corresponding to incrementally changed Q values at the candidate bus.

8. Compute the Q margin, substracting Q value at the base case from maximum reactive power Q_{max}, which is at the collapse point.

Using the methodology for generating Q-V curves which we discuss above, we generate Q-V curves for load buses 5, 9, and 19 of the 20-bus IEEE system. They are given in Figures 3.10, 3.11, and 3.12. The approximate Q margins for the given buses are easily obtained from the Q-V curves in these figures.

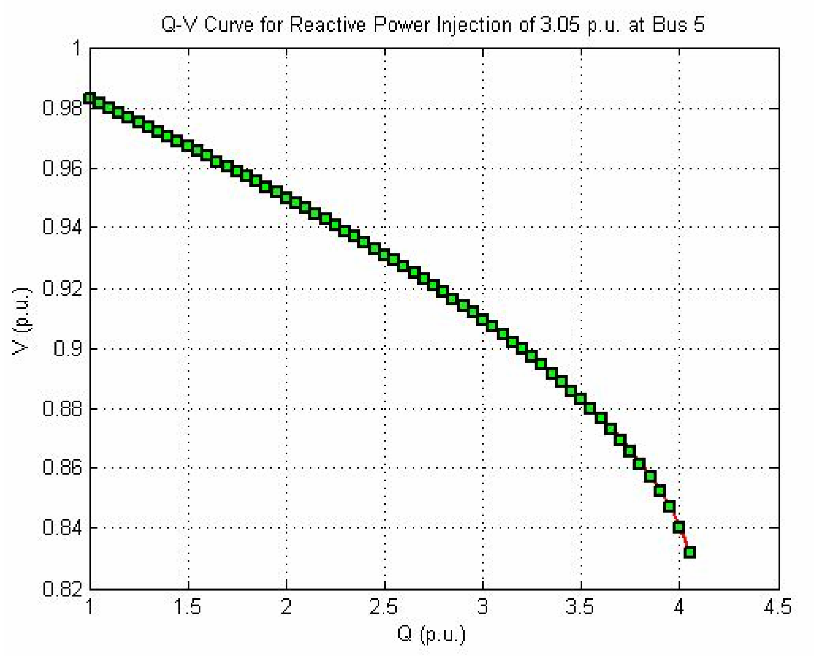

Figure 3.10: Q-V Curve (5. Bus IEEE20)

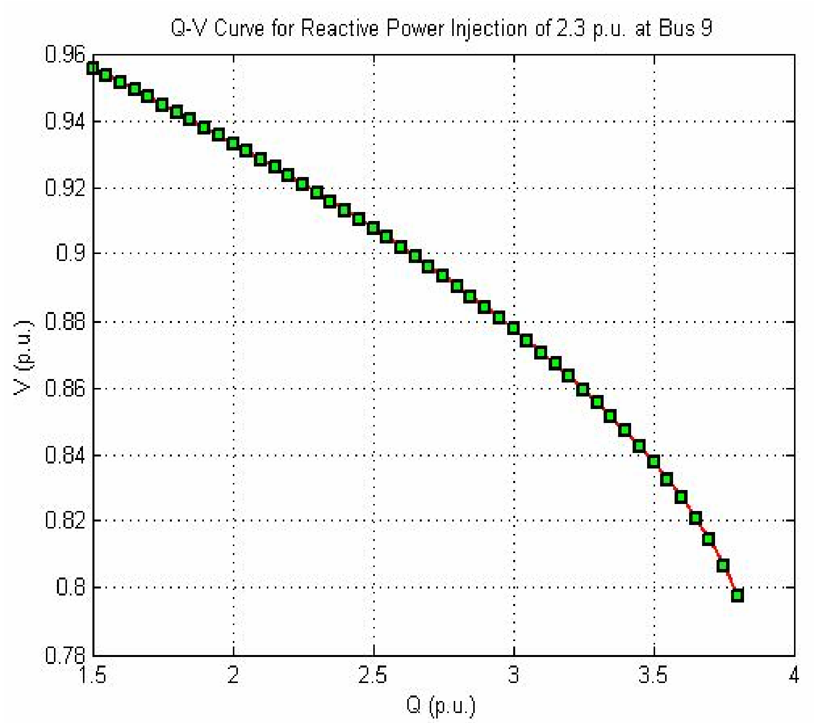

Figure 3.11: Q-V Curve (9. Bus IEEE20)

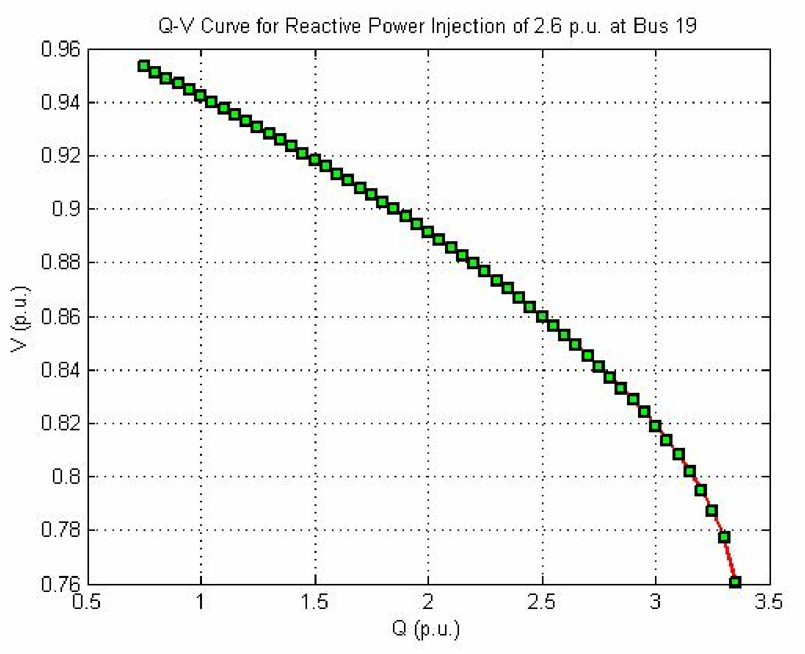

Figure 3.12: Q-V Curve (19. Bus IEEE20)

The Q-V curves for load buses 24, 81, and 116 of the 225-bus system of Istanbul Region are given in Figures 3.13, 3.14, and 3.15.

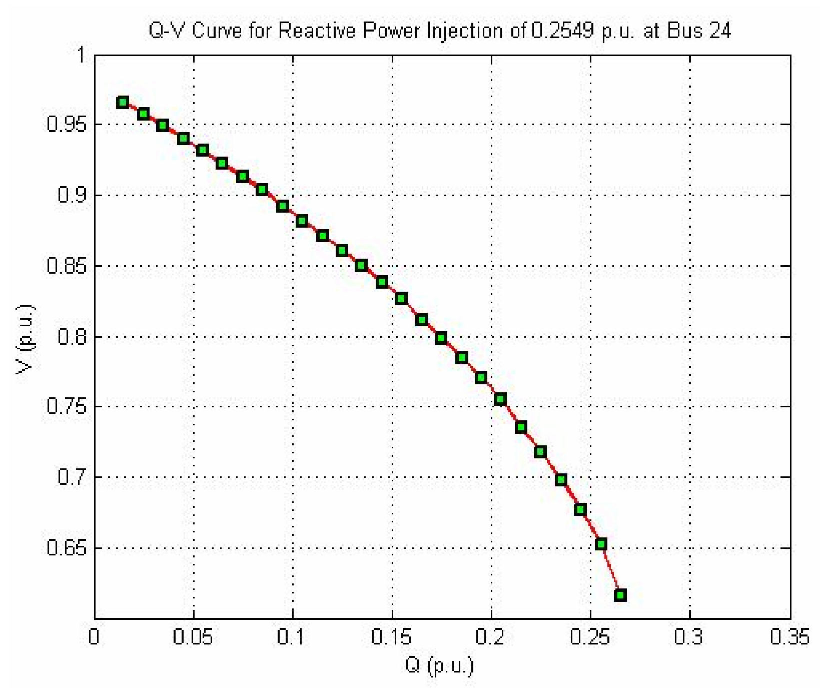

Figure 3.13: Q-V Curve (24. Bus 1EDIRNE_A)

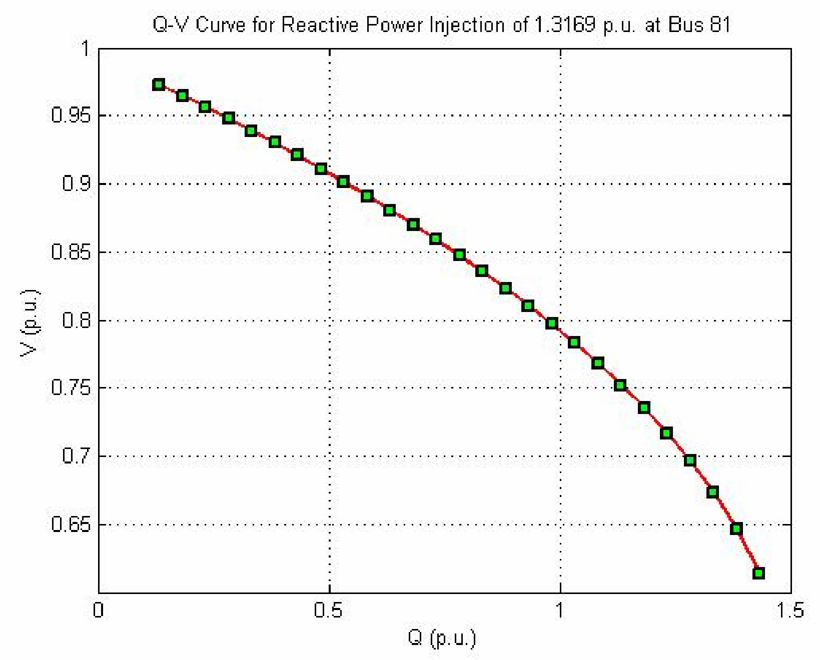

Figure 3.14: Q-V Curve (81. Bus AMBARLI_A)

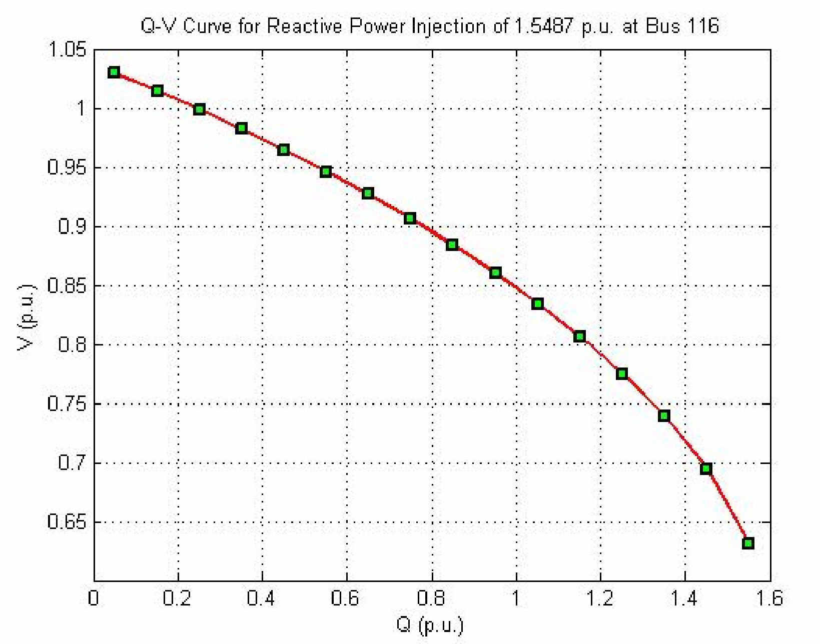

Figure 3.15: Q-V Curve (116. Bus ETILER)

4. CONCLUSIONS

4.1 CONTRIBUTIONS

This work enhances our understanding of power systems network and power-flow calculations. To analyze the power networks, we develop a sound power-flow program. It solves the power-flow problems of real power systems such as the power system of Istanbul Region whose data are provided by TEİAŞ. We confirm that the results of our program are very close to the solution obtained by TEİAŞ. This program is a major contribution to our further study regarding power systems.

We generate P-V and Q-V curves automatically by running the curve plotting program we develop. Using these curves, we compute voltage security margins, which are very useful for utility companies and secure operations of power systems.

4.2 FURTHER STUDY

The power-flow program can be elaborated, running the program for different power systems. Also, the program needs to speed up. P-V and Q-V curves can be analyzed mathematically in details.

APPENDIX

A. PROGRAMS

A 1. POWER-FLOW PROGRAM

```
function pflow(data_name,tol,a,b)
%PFLOW Obtains power-flow solutions.
%  Syntax: pflow(data_name,tol)

%  Author: Bulent Aydin
%  Copyright (c) 2008

global nb nbr

[baseMVA,bus,gen,branch] = feval(data_name);
[bus,gen,branch,ext]=intnum(bus,gen,branch); % Obtained from my advisor Dr.
Bulent Bilir
[Y]=network_f(branch,bus,baseMVA);
% If number of inputs is less than 1, take tolerance tol = 0.001.
% Otherwise, tol is given as an input.
if nargin < 2
   tol = 0.001;
end
[Vm,deltad,Pgt,Qgt,Plt,Qlt,iter,PSt,QSt,PSr,QSr,PSl,QSl,PStt,QStt,JC,z,tol]
= newtraph(bus,gen,Y,baseMVA,branch,tol);
[bus,gen,branch]=extnum(bus,gen,branch,ext); % Obtained from my advisor Dr.
Bulent Bilir
%nb = size(bus,1);
%nbr = size(branch,1);
ngn = size(gen,1);
bus(:,8)=Vm;
bus(:,9)=deltad;
bustype=bus(:,2);
fd= fopen('output.txt', 'wt');
fprintf(fd,
'\n=============================================================================')
;
fprintf(fd, '\n|                                Solution Summary
|');
fprintf(fd,
'\n=============================================================================')
;
fprintf(fd, '\n Base MVA: %4d          Tolerance: %4d',baseMVA,tol);
fprintf(fd, '\n');
fprintf(fd, '\n Power-flow solution converged in %2f seconds (in %1d
iterations).',z,iter);
fprintf(fd, '\n');
% Bus data starts here.
fprintf(fd,
'\n=============================================================================')
;
fprintf(fd, '\n|                                Bus Data
|');
fprintf(fd,
'\n=============================================================================')
;
fprintf(fd, '\n  Bus   Bus         Voltage           Generation
Load        ');
fprintf(fd, '\n  No    Code   Mag(pu)  Ang(deg)    P(MW)   Q(MVAR)     P(MW)
Q(MVAR) ');
fprintf(fd, '\n  ---   ----   -------  --------  --------  --------  -------
-  -------- ');
for i = 1:nb
    fprintf(fd, '\n%4d%6d%11.3f %8.2f', bus(i, [1,2, 8, 9]));
    fprintf(fd, ' %10.2f%10.2f', Pgt(i),Qgt(i));
    if bus(i, 3) | bus(i, 4)
```

```
        fprintf(fd, '%10.2f%10.2f', bus(i, [3, 4]));
    else
        fprintf(fd, '       -         -  ');
    end
end
fprintf(fd,     '\n                                  --------  --------  ---
-----  -------- ');
fprintf(fd,'      \n'); fprintf(fd,'                        Total:');
fprintf(fd,' %10.2f',sum( Pgt)); fprintf(fd,' %9.2f',sum( Qgt));
fprintf(fd,' %9.2f', Plt); fprintf(fd,' %9.2f', Qlt);
fprintf(fd, '\n');
fprintf(fd,
'\n=========================================================================')
;
fprintf(fd, '\n|                          Branch Data
|');
fprintf(fd,
'\n=========================================================================')
;
fprintf(fd, '\n  From  To   From Bus Injection   To Bus Injection
Loss       ');
fprintf(fd, '\n  Bus   Bus   P(MW)   Q(MVAR)      P(MW)    Q(MVAR)    P(MW)
Q(MVAR) ');
fprintf(fd, '\n  ---   ---  --------  --------  --------  --------   -------
-------- ');
for i=1:nbr
    fprintf(fd, '\n%4d%6d%', branch(i,[1,2]));
    fprintf(fd, '%10.2f%10.2f', PSr(i)*baseMVA,QSr(i)*baseMVA);
    fprintf(fd, '%10.2f%10.2f', PSl(i)*baseMVA,QSl(i)*baseMVA);
    fprintf(fd, '%10.2f%10.2f', PSt(i)*baseMVA,QSt(i)*baseMVA);
end
fprintf(fd,     '\n                                                    ---
----  --------');
fprintf(fd,'      \n');, fprintf(fd,'
Total:');
fprintf(fd,' %9.2f',sum( PStt)*baseMVA); fprintf(fd,' %9.2f',sum(
QStt)*baseMVA);
fclose(fd);

if nargin == 3
    len=length(Y);
    I=fopen('yb.txt','w');
    for i=1:len
        for k=1:len
            if Y(i,k) ~=0
                fprintf(I,'\n(%3d,%3d) %10.2f%10.2f j',i,k,
real(Y(i,k)),imag(Y(i,k)));
            end
        end
    end
    fclose(I);
end
if nargin == 4
    Jm=length(JC);
    I=fopen('Jac.txt','w');
    for i=1:Jm
        for k=1:Jm
            if JC(i,k) ~=0
                fprintf(I,'\n(%3d,%3d) %10.2f%10.2f ',i,k, JC(i,k));
            end
        end
    end
    fclose(I);
end
```

A 2. FUNCTION FOR BUS ADMITTANCE MATRIX

```
function[Y,fbus,tbus,R,X,b,Bs,fbuslen]=network_f(branch,bus,baseMV)

%  Author: Bulent Aydin
%  Copyright (c) 2008

j=sqrt(-1); i = sqrt(-1);
fbus=branch(:,1);
tbus=branch(:,2);
R=branch(:,3);
X=branch(:,4);
b=branch(:,5)/2;
Bs=bus(:,6)/baseMVA;
fbuslen=length(branch(:,1));
maxbus=max(max(fbus),max(tbus));
Z=R+j*X;
y=ones(fbuslen,1)./Z;
Y=zeros(maxbus,maxbus);
a=branch(:,9);
for  n=1:maxbus
    for k=1:fbuslen
        if fbus(k)==n
            if a(k)==0
                Y(n,n) = Y(n,n)+y(k)+j*b(k);
            else
                Y(n,n) = Y(n,n)+y(k)/(a(k)^2) + j*b(k);
            end
        elseif tbus(k)==n
            Y(n,n) = Y(n,n)+y(k)+j*b(k);
        end
    end
end
for n=1:maxbus
    Y(n,n) = Y(n,n)+j*Bs(n);
end
for i=1:fbuslen
    if a(i)==0
        Y(fbus(i),tbus(i))=Y(fbus(i),tbus(i))-y(i);
        Y(tbus(i),fbus(i))=Y(fbus(i),tbus(i));
    else
        Y(fbus(i),tbus(i))=Y(fbus(i),tbus(i))-y(i)/a(i);
        Y(tbus(i),fbus(i))=Y(fbus(i),tbus(i));
    end
end

   len=length(Y);
   I=fopen('yb.txt','w');
    for i=1:len
        for k=1:len
            if Y(i,k) ~=0
               fprintf(I,'\n(%3d,%3d) %10.2f%10.2f j',i,k,
real(Y(i,k)),imag(Y(i,k)));
            end
        end
    end
    fclose(I);
```

A 3. FUNCTION FOR NEWTON-RAPHSON METHOD

```
function[Vm,deltad,Pgt,Qgt,Plt,Qlt,iter,PSt,QSt,PSr,QSr,PSl,QSl,PStt,QStt,JC
,z,tol] = newtraph(bus,gen,Y,baseMVA,branch,tol);

% NEWTRAPH Calculates power flow using Newton-Raphson method.
%  Author: Bulent Aydin
%  Copyright (c) 2008

global nb nbr
tic;
nb = length(bus(:,1));
nbr = size(branch,1);
fbus = branch(:,1);
tbus = branch(:,2);
% Reading the system data and initial values from the file-------
bustype = bus(:,2);
V = bus(:,8);
delta = bus(:,9);
PL = bus(:,3)/baseMVA;
QL = bus(:,4)/baseMVA;
QBs = bus(:,6);
PG = zeros(nb,1);
Qmax = zeros(nb,1);
Qmin = zeros(nb,1);
gindx = find(bustype == 2);
ln = length(gindx);
for i = 1:ln
    ing(i) = find(gen(:,1) == gindx(i));
end
PG(gindx) = gen(ing,2)/baseMVA;
Qmax(gindx) = gen(ing,4)/baseMVA;
Qmin(gindx) = gen(ing,5)/baseMVA;

j=sqrt(-1);
for n=1:nb
    if V(n)<=0 V(n)=1.0; V(n)=1+j*0;
    else delta(n)=pi/180*delta(n);
        Vm(n)=abs(V(n)*(cos(delta(n))+j*sin(delta(n))));
    end
end
% Computing the magnitudes and angles of the Ybus matrix elements--
Ym=abs(Y);
Yang = angle(Y);
m=2*nb-2;
JC=zeros(m,m);
% Computing the elements of the jacobian matrix--
iter = 0;
nc=nb-1;
for i=1:nc
    DP(i)=100;
    DQ(i)=100;
end
% Checking the convergence--
while (any(abs(DP)> tol) | any(abs(DQ) > tol))
    iter=iter+1;
    for i=1:nb
        Vm2(i)=Vm(i);
    end
    for i=1:nc
        if  bustype(i) == 2
            Vm2(i)=abs(V(i));
        end

        PI=PG(i)-PL(i);
        DP(i)=0;
        DQ(i)=0;
```

```
        JC(i,i)=0;
        JC(i,i+nc)=0;
        JC(i+nc,i)=0;
        JC(i+nc,i+nc)=0;
        for j=1:nb
            DP(i)=DP(i)-Ym(i,j)*Vm(i)*Vm(j)*cos(delta(i)-delta(j)-
Yang(i,j));
            DQ(i)=DQ(i)-Ym(i,j)*Vm(i)*Vm(j)*sin(delta(i)-delta(j)-
Yang(i,j));
            if j==i
                continue
            else
                JC(i,i)=JC(i,i)+Vm(i)*Vm(j)*Ym(i,j)*sin(delta(i)-delta(j)-
Yang(i,j));
                JC(i,i+nc)=JC(i,i+nc)-Vm(j)*Ym(i,j)*cos(delta(i)-delta(j)-
Yang(i,j));
                JC(i+nc,i)=JC(i+nc,i)-Vm(i)*Vm(j)*Ym(i,j)*cos(delta(i)-
delta(j)-Yang(i,j));
                JC(i+nc,i+nc)=JC(i+nc,i+nc)-Vm(j)*Ym(i,j)*sin(delta(i)-
delta(j)-Yang(i,j));
            end
        end
        DP(i)=DP(i)+PI;
        if bustype(i)==2
            Q(i)=0;
            for j=1:nb
                Q(i)=Q(i)+Ym(i,j)*Vm2(i)*Vm2(j)*sin(delta(i)-delta(j)-
Yang(i,j));
            end
            Qmax1=Qmax(i)-QL(i);
            Qmin1=Qmin(i)-QL(i);
            if Q(i) > Qmax1
                DQ(i)=DQ(i)+Qmax1;
            elseif Q(i) < Qmin1
                DQ(i)=DQ(i)+Qmin1;
            else
                DQ(i)=0;
            end
        else
            DQ(i)=DQ(i)-QL(i);
        end

        JC(i,i+nc)=JC(i,i+nc)-2*Vm(i)*Ym(i,i)*cos(-Yang(i,i));
        JC(i+nc,i+nc)=JC(i+nc,i+nc)-2*Vm(i)*Ym(i,i)*sin(-Yang(i,i));
        for k=1:nc
            if k ==i
                continue
            else
                JC(i,k)=-Vm(i)*Vm(k)*Ym(i,k)*sin(delta(i)-delta(k)-
Yang(i,k));
                JC(i,k+nc)=-Vm(i)*Ym(i,k)*cos(delta(i)-delta(k)-Yang(i,k));
                JC(i+nc,k)=Vm(i)*Vm(k)*Ym(i,k)*cos(delta(i)-delta(k)-
Yang(i,k));
                JC(i+nc,k+nc)=-Vm(i)*Ym(i,k)*sin(delta(i)-delta(k)-
Yang(i,k));
            end
        end
    end
% Modifying the jacobian matrix for non- violating P-V buses
    for i=1:nb-1
        for j=1:nb-1
            if bustype(i)==2 & DQ(i)==0
                JC(i+nb-1,j)=0;
                JC(j,i+nb-1)=0;
            elseif i ~= j
                JC(i+nb-1,j+nb-1)=0;
                JC(j+nb-1,i+nb-1)=0;
            end
```

```
        end
    end
% Calculating bus voltage angles and magnitudes
    J=inv(JC);
    for i=1:nb-1
        for j=1:nb-1
            delta(i)=delta(i)-J(i,j)*DP(j)-J(i,j+nb-1)*DQ(j);
            Vm(i)=Vm(i)-J(i+nb-1,j)*DP(j)-J(i+nb-1,j+nb-1)*DQ(j);
        end
        if DQ(i) == 0
            Vm(i)=abs(V(i));
        end
    end
end
% Initialiazing the real and reactive power flow vectors
for j=1:nb
    for i=1:nb
        PS(i,j)=0;
        QS(i,j)=0;
    end
end
% Calculating the real and reactive bus power
for i=1:nb
    for j=1:nb
        PS(i,i)=PS(i,i)+Ym(i,j)*Vm(i)*Vm(j)*cos(delta(i)-delta(j)-
Yang(i,j));
        QS(i,i)=QS(i,i)+Ym(i,j)*Vm(i)*Vm(j)*sin(delta(i)-delta(j)-
Yang(i,j));
    end
end
% Calculating the real and reactive power flow
for j=1:nb
    for i=j+1:nb
        if Ym(i,j)~=0
            PS(i,j)=Ym(i,j)*Vm(i)*Vm(j)*cos(delta(i)-delta(j)-Yang(i,j))-
Ym(i,j)*Vm(i)^2*cos(Yang(i,j));
            PS(j,i)=Ym(j,i)*Vm(j)*Vm(i)*cos(delta(j)-delta(i)-Yang(j,i))-
Ym(j,i)*Vm(j)^2*cos(Yang(j,i));
            QS(i,j)=Ym(i,j)*Vm(i)*Vm(j)*sin(delta(i)-delta(j)-
Yang(i,j))+Ym(i,j)*Vm(i)^2*sin(Yang(i,j));
            QS(j,i)=Ym(j,i)*Vm(j)*Vm(i)*sin(delta(j)-delta(i)-
Yang(j,i))+Ym(j,i)*Vm(j)^2*sin(Yang(j,i));
        end
    end

end
for i=1:nb
    Ps(i,i)=0; Qs(i,i)=0;
    if  bustype(i) == 3
        Ps(i,i)= PS(i,i);
        Qs(i,i)= QS(i,i);
    else
        if bustype(i) == 2
            Qs(i,i)=QS(i,i);
            Ps(i,i)=PG(i);
        end
    end
end
for i=1:nbr
    PSr(i)=PS(fbus(i),tbus(i));
    QSr(i)=QS(fbus(i),tbus(i));
    PSl(i)=PS(tbus(i),fbus(i));
    QSl(i)=QS(tbus(i),fbus(i));
    PSt(i)=PS(fbus(i),tbus(i))+PS(tbus(i),fbus(i));
    QSt(i)=QS(fbus(i),tbus(i))+QS(tbus(i),fbus(i));
end
deltad=180/pi*delta;
bus(:,8)=Vm;  cd=bus(:,2);
```

```
Pgt= sum(Ps)*baseMVA;  Qgt = sum(Qs)*baseMVA;
Plt=sum(PL)*baseMVA;Qlt = sum(QL)*baseMVA;
PStt=sum(PSt);
QStt=sum(QSt);

toc;
z=toc;
```

A 4. PROGRAM FOR PLOTTING P-V AND Q-V CURVE

```
function  plotcurv(data_name,tol)

%  Author: Bulent Aydin
%  Copyright (c) 2008

if nargin < 2
    tol = 0.001;
end
[baseMVA,bus,gen,branch,Vm]=pcal(data_name,tol);
busno =input('Bus no = ');
per=input('Period = ');
limit=input('Limit = ');
m=input('For active power = 3 For reactive power = 4 = ');
x=bus(busno,m);
i=(limit-x)/per;
i=i+1;
V(1)=Vm(:,busno);
z=(limit-x)/baseMVA;
for s=2:i
    bus(busno,m)=bus(busno,m)+per;
    [bus,gen,branch,ext]=intnum(bus,gen,branch);
    [Y]=network_f(branch,bus,baseMVA);
    [Vm]=newtraph(bus,gen,Y,baseMVA,branch,tol);
    [bus,gen,branch]=extnum(bus,gen,branch,ext);
    V(s)=Vm(:,busno);
end
a = (x:per:(limit))/baseMVA;
t=1:i;
c = V(t);
plot(a,c,'-rs','LineWidth',2,...
    'MarkerEdgeColor','k',...
    'MarkerFaceColor','g',...
    'MarkerSize',5)
if m == 3
    title(['P-V Curve for Real Power Injection of ',num2str(z),' p.u. at Bus
',num2str(busno)])
else
    title(['Q-V Curve for Reactive Power Injection of ',num2str(z),' p.u. at
Bus ',num2str(busno)])
end
if m == 3
    xlabel('P (p.u.)')
else
    xlabel('Q (p.u.)')
end
ylabel('V (p.u.)')
grid on
```

A 5. FUNCTION FOR PLOTTING P-V AND Q-V CURVE

```
function [baseMVA,bus,gen,branch,Vm] = pcal(data_name,tol)
%PFLOW Obtains power-flow solutions.
%  Syntax: pflow(data_name,tol)

%  Author: Bulent Aydin
%  Copyright (c) 2008

global nb nbr

[baseMVA,bus,gen,branch] = feval(data_name);
[bus,gen,branch,ext]=intnum(bus,gen,branch); % Obtained from my advisor Dr.
Bulent Bilir
[Y]=network_f(branch,bus,baseMVA);
% If number of inputs is less than 1, take tolerance tol = 0.001.
% Otherwise, tol is given as an input.
if nargin < 2
   tol = 0.001;
end
Vm = newtraph(bus,gen,Y,baseMVA,branch,tol);
[bus,gen,branch]=extnum(bus,gen,branch,ext); % Obtained from my advisor Dr.
Bulent Bilir
```

B. DATA

B 1. DATA OF THE 20-BUS IEEE SYSTEM

```
function [baseMVA,bus,gen,branch]=ieee20

baseMVA = 100.0;

%bus type     Pd       Qd       Gs       Bs    area     Vm        Va     baseKV zone    Vmax      Vmin
bus = [
   1  2      0.00     0.00    0.000    0.000    1   1.02000    0.000   500.00  0     1.06000  0.94000
   2  2      0.00     0.00    0.000    0.000    1   1.02000    0.000   500.00  0     1.06000  0.94000
   3  1      0.00     0.00    0.000 -600.000    1   1.00000    0.000   230.00  0     1.06000  0.94000
   4  1      0.00     0.00    0.000    0.000    1   1.00000    0.000   230.00  0     1.06000  0.94000
   5  1    200.00   100.00    0.000    0.000    1   1.00000    0.000   230.00  0     1.06000  0.94000
   6  1   1000.00   800.00    0.000  200.000    1   1.00000    0.000    21.40  0     1.06000  0.94000
   7  2      0.00     0.00    0.000 -300.000    1   1.05000    0.000   230.00  0     1.06000  0.94000
   8  1      0.00     0.00    0.000    0.000    1   1.00000    0.000   230.00  0     1.06000  0.94000
   9  1    300.00   150.00    0.000   50.000    1   1.00000    0.000    69.00  0     1.06000  0.94000
  10  1      0.00     0.00    0.000    0.000    1   1.00000    0.000    69.00  0     1.06000  0.94000
  11  1   1200.00   700.00    0.000  300.000    1   1.00000    0.000    69.00  0     1.06000  0.94000
  12  2      0.00     0.00    0.000    0.000    1   0.98000    0.000    69.00  0     1.06000  0.94000
  13  1      0.00     0.00    0.000    0.000    1   1.00000    0.000    69.00  0     1.06000  0.94000
  14  1      0.00     0.00    0.000    0.000    1   1.00000    0.000   230.00  0     1.06000  0.94000
  15  1      0.00     0.00    0.000    0.000    1   1.00000    0.000   230.00  0     1.06000  0.94000
  16  1    100.00    50.00    0.000    0.000    1   1.00000    0.000   230.00  0     1.06000  0.94000
  17  1      0.00     0.00    0.000    0.000    1   1.00000    0.000   230.00  0     1.06000  0.94000
  18  1    200.00    75.00    0.000    0.000    1   1.00000    0.000   230.00  0     1.06000  0.94000
  19  2    200.00    75.00    0.000    0.000    1   1.02000    0.000   230.00  0     1.06000  0.94000
  20  3      0.00     0.00    0.000    0.000    1   1.05000    0.000   230.00  0     1.06000  0.94000
];

%bus     Pg        Qg      Qmax     Qmin     Vsp     baseMVA  status    Pmax      Pmin
gen = [
   1   750.00     0.00   600.00  -100.00  1.02000   100.00    1      1000.00     0.00
   2   750.00     0.00   600.00  -100.00  1.02000   100.00    1      1000.00     0.00
   7   600.00     0.00   400.00  -100.00  1.05000   100.00    1      1000.00     0.00
  12   800.00     0.00   600.00     0.00  0.98000   100.00    1      1000.00     0.00
  19   100.00     0.00    80.00     0.00  1.02000   100.00    1      1000.00     0.00
  20     0.00     0.00   600.00  -100.00  1.05000   100.00    1      1000.00     0.00
];

%fbus tbus     r        x        b      ratea     rateb     ratec   ratio     angle  status
branch = [
   3    1   0.00000  0.01000  0.00000  9900.00    0.00      0.00  0.00000    0.000    1
   3    2   0.00000  0.01000  0.00000  9900.00    0.00      0.00  0.00000    0.000    1
   3    4   0.00260  0.04600  3.50000  9900.00    0.00      0.00  0.00000    0.000    1
   3    4   0.00260  0.04600  3.50000  9900.00    0.00      0.00  0.00000    0.000    1
   3    7   0.00100  0.01500  1.20000  9900.00    0.00      0.00  0.00000    0.000    1
   4    5   0.00000  0.00500  0.00000  9900.00    0.00      0.00  1.01000    0.000    1
   4    8   0.00080  0.01000  0.95000  9900.00    0.00      0.00  0.00000    0.000    1
   4   15   0.00300  0.03000  2.50000  9900.00    0.00      0.00  0.00000    0.000    1
   5    6   0.00500  0.04500  0.10000  9900.00    0.00      0.00  0.00000    0.000    1
   5    6   0.00600  0.05400  0.15000  9900.00    0.00      0.00  0.00000    0.000    1
   5   17   0.00100  0.01200  0.03000  9900.00    0.00      0.00  0.00000    0.000    1
   6    9   0.00400  0.04000  0.10000  9900.00    0.00      0.00  0.00000    0.000    1
   6   11   0.00033  0.00333  0.09000  9900.00    0.00      0.00  0.00000    0.000    1
   6   19   0.00270  0.02200  0.30000  9900.00    0.00      0.00  0.00000    0.000    1
   7    8   0.00200  0.02500  2.00000  9900.00    0.00      0.00  0.00000    0.000    1
   7   10   0.00300  0.03000  2.50000  9900.00    0.00      0.00  0.00000    0.000    1
   8    9   0.00000  0.01000  0.00000  9900.00    0.00      0.00  1.01000    0.000    1
   9   11   0.00500  0.04500  0.08000  9900.00    0.00      0.00  0.00000    0.000    1
   9   11   0.00500  0.04500  0.08000  9900.00    0.00      0.00  0.00000    0.000    1
  10   11   0.00000  0.01000  0.00000  9900.00    0.00      0.00  1.01000    0.000    1
```

```
  11   12   0.00000  0.01000  0.00000  9900.00     0.00      0.00  1.02000    0.000     1
  20   13   0.00000  0.02500  0.00000  9900.00     0.00      0.00  0.00000    0.000     1
  20   14   0.00000  0.00800  0.00000  9900.00     0.00      0.00  0.00000    0.000     1
  13   15   0.00600  0.05400  0.09000  9900.00     0.00      0.00  0.00000    0.000     1
  14   16   0.00600  0.05400  0.09000  9900.00     0.00      0.00  0.00000    0.000     1
  14   16   0.00600  0.05400  0.09000  9900.00     0.00      0.00  0.00000    0.000     1
  15   16   0.00000  0.01000  0.00000  9900.00     0.00      0.00  0.00000    0.000     1
  16   17   0.00350  0.03000  0.07000  9900.00     0.00      0.00  0.00000    0.000     1
  16   18   0.00300  0.02500  0.06000  9900.00     0.00      0.00  0.00000    0.000     1
  16   19   0.00600  0.05000  0.12000  9900.00     0.00      0.00  0.00000    0.000     1
  18   19   0.00300  0.02500  0.06000  9900.00     0.00      0.00  0.00000    0.000     1
];
```

B 2. DATA OF THE 225-BUS ISTANBUL REGION SYSTEM

```
function [baseMVA,bus,gen,branch] = istanbul

baseMVA = 100.0;

%bus type    Pd       Qd       Gs       Bs    area    Vm        Va     baseKV zone   Vmax     Vmin
bus = [
   1  2     0.00     0.00    0.000    0.000   5   1.00000    2.460   400.00  1    1.06000  0.94000
   2  2     0.00     0.00    0.000    0.000   6   1.00000    0.750   400.00  1    1.06000  0.94000
   3  2     0.00     0.00    0.000    0.000   7   1.00000    7.840   400.00  1    1.06000  0.94000
   4  1     0.00     0.00    0.110   -0.280   1   0.99390    1.110   154.00  2    1.06000  0.94000
   5  1     0.00     0.00    0.130   -0.070   1   1.00190    2.540   400.00  1    1.06000  0.94000
   6  1     0.00     0.00    0.020   -0.040   1   1.00610    0.890   154.00  2    1.06000  0.94000
   7  1     0.00     0.00    0.000    0.000   1   1.00610    0.890    31.50  4    1.06000  0.94000
   8  1     0.00     0.00    0.080   -0.090   1   0.99640    1.140   154.00  2    1.06000  0.94000
   9  1    32.51     5.33    0.000    0.000   1   0.98210   -2.490    34.50  4    1.06000  0.94000
  10  1     0.00     0.00    0.000    0.000   1   0.99640    1.140     6.30  4    1.06000  0.94000
  11  1     0.00     0.00    0.000    0.000   1   0.99640    1.140     6.30  4    1.06000  0.94000
  12  1     0.00     0.00    0.090   -0.210   1   0.99180   -0.430   154.00  2    1.06000  0.94000
  13  1    32.50     5.07    0.000    0.000   1   0.98180   -3.310    31.50  4    1.06000  0.94000
  14  1    32.50     5.07    0.000    0.000   1   0.98180   -3.310    31.50  4    1.06000  0.94000
  15  1     0.00     0.00    0.090   -0.210   1   0.98440   -1.280   154.00  2    1.06000  0.94000
  16  1    57.00     9.48    0.000    0.000   1   0.96390   -6.460    31.50  4    1.06000  0.94000
  17  1    57.00     9.48    0.000    0.000   1   0.96390   -6.460    31.50  4    1.06000  0.94000
  18  1     0.00     0.00    0.160   -0.340   1   0.98770   -1.080   154.00  2    1.06000  0.94000
  19  1    38.26     5.33    0.000    0.000   1   0.96650   -6.570    31.50  4    1.06000  0.94000
  20  1    38.26     5.33    0.000    0.000   1   0.97660   -4.500    31.50  4    1.06000  0.94000
  21  1    38.26     5.33    0.000    0.000   1   0.97600   -4.470    31.50  4    1.06000  0.94000
  22  1     0.00     0.00    0.050   -0.140   1   0.98480   -1.200   154.00  2    1.06000  0.94000
  23  1    37.00     4.38    0.000    0.000   1   0.96640   -6.530    31.50  4    1.06000  0.94000
  24  1    12.35     1.51    0.000    0.000   1   0.96570   -7.050    15.80  4    1.06000  0.94000
  25  1     0.00     0.00    0.020   -0.040   1   0.98650   -0.910   154.00  2    1.06000  0.94000
  26  1    15.24     0.00    0.000    0.000   1   0.98330   -4.070    31.50  4    1.06000  0.94000
  27  1     0.00     0.00    0.190   -0.180   1   1.00310    2.780   400.00  1    1.06000  0.94000
  28  1     0.00     0.00    0.150   -0.240   1   1.00560    0.900   154.00  2    1.06000  0.94000
  29  1     0.00     0.00    0.020   -0.040   1   0.99270   -0.450   154.00  2    1.06000  0.94000
  30  1    12.19     2.37    0.000    0.000   1   0.98190   -2.950    31.50  4    1.06000  0.94000
  31  1     0.00     0.00    0.150   -0.240   1   1.00810    3.870   400.00  1    1.06000  0.94000
  32  1     0.00     0.00    0.000    0.000   1   1.00810    3.870    31.50  4    1.06000  0.94000
  33  1     0.00     0.00    0.000    0.000   1   1.00810    3.870    31.50  4    1.06000  0.94000
  34  1     0.00     0.00    0.040   -0.130   1   0.95180   -5.740   154.00  2    1.06000  0.94000
  35  1    42.67     5.92    0.000    0.000   1   0.92610  -12.370    31.50  4    1.06000  0.94000
  36  1     0.00     0.00    0.050   -0.160   1   0.99260    0.510   154.00  2    1.06000  0.94000
  37  1    10.50     1.92    0.000    0.000   1   0.98280   -1.840    31.50  4    1.06000  0.94000
  38  1    10.50     1.92    0.000    0.000   1   0.98280   -1.840    31.50  4    1.06000  0.94000
  39  1     0.00     0.00    0.040   -0.130   1   0.98540   -1.340   154.00  2    1.06000  0.94000
  40  1     1.02     0.00    0.000    0.000   1   0.98530   -1.490    33.60  4    1.06000  0.94000
  41  1     0.00     0.00    0.110   -0.160   1   1.00120    0.380   154.00  2    1.06000  0.94000
  42  1    39.63     5.92    0.000    0.000   1   0.99360   -1.790    31.50  4    1.06000  0.94000
  43  1     0.00     0.00    0.040   -0.130   1   0.96090   -4.620   154.00  2    1.06000  0.94000
  44  1    13.21     0.00    0.000    0.000   1   0.95920   -6.590    31.50  4    1.06000  0.94000
  45  1     0.00     0.00    0.110   -0.160   1   0.99210   -0.720   154.00  2    1.06000  0.94000
  46  1     0.00     0.00    0.000    0.000   1   0.99210   -0.720    31.50  4    1.06000  0.94000
  47  1     0.00     0.00    0.000    0.000   1   0.99210   -0.720    31.50  4    1.06000  0.94000
  48  1     0.00     0.00    0.030   -0.050   1   0.99640    0.360   154.00  2    1.06000  0.94000
  49  1     9.14     0.57    0.000    0.000   1   0.99280   -1.500    31.50  4    1.06000  0.94000
  50  1     9.14     0.57    0.000    0.000   1   0.98940   -3.290    31.50  4    1.06000  0.94000
  51  1     0.00     0.00    0.020   -0.020   1   0.99040   -0.390   154.00  2    1.06000  0.94000
  52  1     6.50     1.21    0.000    0.000   1   0.98020   -3.020    31.50  4    1.06000  0.94000
  53  1     6.50     1.21    0.000    0.000   1   0.98260   -2.190    31.50  4    1.06000  0.94000
  54  1     0.00     0.00    0.060   -0.170   1   0.98210   -1.560   154.00  2    1.06000  0.94000
  55  1     0.00     0.00    0.000    0.000   1   0.98210   -1.560    31.50  4    1.06000  0.94000
  56  1     0.00     0.00    0.000    0.000   1   0.98210   -1.560    31.50  4    1.06000  0.94000
  57  1     0.00     0.00    0.260   -0.190   1   0.99660    1.190   154.00  2    1.06000  0.94000
  58  1     0.00     0.00    0.050   -0.110   1   0.99210   -0.720   154.00  2    1.06000  0.94000
  59  1    15.11     1.18    0.000    0.000   1   0.98960   -2.050    33.60  4    1.06000  0.94000
```

60	1	0.00	0.00	0.310	-0.220	1	1.00810	3.890	400.00	1	1.06000	0.94000
61	1	0.00	0.00	0.050	-0.080	1	0.99750	0.010	154.00	2	1.06000	0.94000
62	1	21.34	4.74	0.000	0.000	1	0.98720	-2.150	31.50	4	1.06000	0.94000
63	1	0.00	0.00	0.140	-0.270	1	0.99220	-0.360	154.00	2	1.06000	0.94000
64	1	0.00	0.00	0.000	0.000	1	0.99220	-0.360	31.50	4	1.06000	0.94000
65	1	0.00	0.00	0.000	0.000	1	0.99220	-0.360	31.50	4	1.06000	0.94000
66	1	0.00	0.00	0.110	-0.160	2	0.95790	-3.520	154.00	2	1.06000	0.94000
67	1	0.00	0.00	0.050	-0.110	2	0.98500	-5.590	154.00	2	1.06000	0.94000
68	1	0.00	0.00	0.070	-0.100	2	0.98180	-5.130	154.00	2	1.06000	0.94000
69	1	62.00	15.34	0.000	0.000	2	0.95410	-11.270	34.50	4	1.06000	0.94000
70	1	62.00	15.34	0.000	0.000	2	0.94990	-10.790	34.50	4	1.06000	0.94000
71	1	0.00	0.00	0.380	-0.190	2	0.98000	-0.290	400.00	1	1.06000	0.94000
72	1	0.00	0.00	0.050	-0.110	2	1.00800	-2.600	154.00	2	1.06000	0.94000
73	1	0.00	0.00	0.050	-0.110	2	1.04460	-3.810	154.00	2	1.06000	0.94000
74	1	16.12	1.80	0.000	0.000	2	1.00460	-3.970	33.60	4	1.06000	0.94000
75	1	16.12	1.80	0.000	0.000	2	1.04130	-5.090	33.60	4	1.06000	0.94000
76	1	0.00	0.00	0.050	-0.110	2	1.04230	-4.310	154.00	2	1.06000	0.94000
77	1	69.09	15.99	0.000	0.000	2	1.01150	-9.960	34.50	4	1.06000	0.94000
78	1	0.00	0.00	0.140	-0.320	2	0.99920	-2.560	154.00	2	1.06000	0.94000
79	1	60.20	13.31	0.000	0.000	2	0.97250	-7.890	34.50	4	1.06000	0.94000
80	1	60.20	13.31	0.000	0.000	2	0.97250	-7.890	34.50	4	1.06000	0.94000
81	1	60.20	13.31	0.000	0.000	2	0.97250	-7.890	34.50	4	1.06000	0.94000
82	1	0.00	0.00	0.300	-0.190	2	0.97480	-0.790	400.00	1	1.06000	0.94000
83	1	0.00	0.00	0.250	-0.180	2	0.99770	-1.950	154.00	2	1.06000	0.94000
84	1	0.00	0.00	0.250	-0.180	2	1.00040	-2.300	154.00	2	1.06000	0.94000
85	1	0.00	0.00	0.080	-0.130	2	0.99990	-2.480	154.00	2	1.06000	0.94000
86	1	0.00	0.00	0.220	-0.110	2	0.97020	-1.140	400.00	1	1.06000	0.94000
87	1	0.00	0.00	0.050	-0.110	2	1.03520	-5.150	154.00	2	1.06000	0.94000
88	1	0.00	0.00	0.050	-0.110	2	1.00500	-3.960	154.00	2	1.06000	0.94000
89	1	26.00	4.93	0.000	0.000	2	0.99600	-6.200	33.60	4	1.06000	0.94000
90	1	26.00	4.93	0.000	0.000	2	1.02660	-7.260	31.50	4	1.06000	0.94000
91	1	0.00	0.00	0.090	-0.210	2	1.00070	-4.220	154.00	2	1.06000	0.94000
92	1	50.80	15.99	0.000	0.000	2	0.97140	-8.710	33.60	4	1.06000	0.94000
93	1	62.99	11.26	0.000	0.000	2	0.97680	-9.770	33.60	4	1.06000	0.94000
94	1	0.00	0.00	0.070	-0.100	2	0.98540	-4.370	154.00	2	1.06000	0.94000
95	1	0.00	0.00	0.050	-0.110	2	1.00020	-4.290	154.00	2	1.06000	0.94000
96	1	48.00	12.05	0.000	0.000	2	0.96160	-8.680	33.60	4	1.06000	0.94000
97	1	48.00	12.05	0.000	0.000	2	0.97760	-8.510	33.60	4	1.06000	0.94000
98	1	0.00	0.00	0.090	-0.210	2	1.00560	-1.210	154.00	2	1.06000	0.94000
99	1	22.38	3.53	0.000	0.000	2	0.99900	-3.130	33.60	4	1.06000	0.94000
100	1	22.38	3.53	0.000	0.000	2	0.99900	-3.130	33.60	4	1.06000	0.94000
101	1	0.00	0.00	0.140	-0.320	2	1.00050	-1.730	154.00	2	1.06000	0.94000
102	1	64.85	8.10	0.000	0.000	2	0.98130	-7.430	33.60	4	1.06000	0.94000
103	1	64.85	8.10	0.000	0.000	2	0.98130	-7.430	33.60	4	1.06000	0.94000
104	1	64.85	8.10	0.000	0.000	2	0.98130	-7.430	33.60	4	1.06000	0.94000
105	1	0.00	0.00	0.140	-0.320	2	0.95870	-3.430	154.00	2	1.06000	0.94000
106	1	26.75	5.13	0.000	0.000	2	0.94890	-5.960	34.50	4	1.06000	0.94000
107	1	26.75	5.13	0.000	0.000	2	0.94890	-5.960	33.60	4	1.06000	0.94000
108	1	26.75	5.13	0.000	0.000	2	0.94890	-5.960	33.60	4	1.06000	0.94000
109	1	0.00	0.00	0.090	-0.210	2	0.98620	-5.470	154.00	2	1.06000	0.94000
110	1	63.15	11.83	0.000	0.000	2	0.96080	-11.210	34.50	4	1.06000	0.94000
111	1	63.15	11.83	0.000	0.000	2	0.96080	-11.210	34.50	4	1.06000	0.94000
112	1	0.00	0.00	0.130	-0.330	2	1.00340	-1.030	154.00	2	1.06000	0.94000
113	1	0.00	0.00	0.160	-0.310	2	1.04020	-4.330	154.00	2	1.06000	0.94000
114	1	45.72	5.13	0.000	0.000	2	1.02860	-7.980	33.60	4	1.06000	0.94000
115	1	45.72	5.13	0.000	0.000	2	1.02930	-8.010	33.60	4	1.06000	0.94000
116	1	45.72	5.13	0.000	0.000	2	1.02930	-8.010	33.60	4	1.06000	0.94000
117	1	0.00	0.00	0.340	-0.170	2	0.99600	2.400	400.00	1	1.06000	0.94000
118	1	0.00	0.00	0.090	-0.210	2	1.01740	-0.770	154.00	2	1.06000	0.94000
119	1	33.47	8.29	0.000	0.000	2	1.00280	-3.590	33.60	4	1.06000	0.94000
120	1	32.39	7.70	0.000	0.000	2	1.00380	-3.500	33.60	4	1.06000	0.94000
121	1	0.00	0.00	0.140	-0.210	2	1.00940	-1.510	154.00	2	1.06000	0.94000
122	1	37.85	5.77	0.000	0.000	2	0.99740	-4.720	33.60	4	1.06000	0.94000
123	1	37.85	5.77	0.000	0.000	2	0.99740	-4.720	33.60	4	1.06000	0.94000
124	1	0.00	0.00	0.120	-0.160	2	0.98610	-4.250	154.00	2	1.06000	0.94000
125	1	59.37	4.44	0.000	0.000	2	0.97320	-9.590	34.50	4	1.06000	0.94000
126	1	59.37	4.44	0.000	0.000	2	0.98150	-6.620	34.50	4	1.06000	0.94000
127	1	0.00	0.00	0.490	-0.330	2	0.96850	-1.310	400.00	1	1.06000	0.94000

128	1	0.00	0.00	0.090	-0.210	2	0.99280	-3.200	154.00	2	1.06000	0.94000
129	1	0.00	0.00	0.150	-0.240	2	1.00420	-3.870	154.00	2	1.06000	0.94000
130	1	0.00	0.00	0.000	0.000	2	0.96850	-1.310	34.50	4	1.06000	0.94000
131	1	64.53	18.35	0.000	0.000	2	0.95680	-9.040	34.50	4	1.06000	0.94000
132	1	55.59	7.40	0.000	0.000	2	0.99390	-7.160	34.50	4	1.06000	0.94000
133	1	55.59	7.40	0.000	0.000	2	0.99390	-7.160	34.50	4	1.06000	0.94000
134	1	64.53	18.35	0.000	0.000	2	0.95680	-9.040	33.60	4	1.06000	0.94000
135	1	0.00	0.00	0.160	-0.240	2	1.04250	-4.290	154.00	2	1.06000	0.94000
136	1	39.41	10.15	0.000	0.000	2	1.02430	-7.430	33.60	4	1.06000	0.94000
137	1	39.41	10.15	0.000	0.000	2	1.02430	-7.430	33.60	4	1.06000	0.94000
138	1	0.00	0.00	0.000	0.000	2	1.04250	-4.290	11.10	4	1.06000	0.94000
139	1	0.00	0.00	0.180	-0.310	2	1.01430	-1.180	154.00	2	1.06000	0.94000
140	1	37.00	8.33	0.000	0.000	2	0.99870	-4.290	34.50	4	1.06000	0.94000
141	1	37.00	8.33	0.000	0.000	2	0.99920	-4.320	34.50	4	1.06000	0.94000
142	1	37.00	8.33	0.000	0.000	2	0.99870	-4.290	33.60	4	1.06000	0.94000
143	1	0.00	0.00	0.130	-0.340	2	1.03990	-4.160	154.00	2	1.06000	0.94000
144	1	27.70	3.75	0.000	0.000	2	1.02690	-7.700	33.60	4	1.06000	0.94000
145	1	27.70	3.75	0.000	0.000	2	1.03290	-6.380	33.60	4	1.06000	0.94000
146	1	27.70	3.75	0.000	0.000	2	1.03290	-6.380	33.60	4	1.06000	0.94000
147	1	0.00	0.00	0.090	-0.210	2	1.04010	-3.930	154.00	2	1.06000	0.94000
148	1	37.53	0.89	0.000	0.000	2	1.03640	-6.940	34.50	4	1.06000	0.94000
149	1	37.53	0.89	0.000	0.000	2	1.03640	-6.940	34.50	4	1.06000	0.94000
150	1	0.00	0.00	0.140	-0.320	2	1.02990	-5.670	154.00	2	1.06000	0.94000
151	1	66.04	14.81	0.000	0.000	2	1.00100	-11.190	35.00	4	1.06000	0.94000
152	1	66.04	14.81	0.000	0.000	2	1.00100	-11.190	35.00	4	1.06000	0.94000
153	1	66.04	14.81	0.000	0.000	2	1.00100	-11.190	33.60	4	1.06000	0.94000
154	1	0.00	0.00	0.050	-0.110	2	1.04290	-4.190	154.00	2	1.06000	0.94000
155	1	55.06	14.22	0.000	0.000	2	1.01710	-8.660	34.50	4	1.06000	0.94000
156	1	0.00	0.00	0.100	-0.190	2	0.97150	-1.800	154.00	2	1.06000	0.94000
157	1	23.40	4.67	0.000	0.000	2	0.95970	-4.540	33.60	4	1.06000	0.94000
158	1	23.40	4.67	0.000	0.000	2	0.96280	-3.950	33.60	4	1.06000	0.94000
159	1	0.00	0.00	0.090	-0.210	2	0.99280	-4.290	154.00	2	1.06000	0.94000
160	1	47.00	9.86	0.000	0.000	2	0.97350	-8.480	33.60	4	1.06000	0.94000
161	1	47.00	9.86	0.000	0.000	2	0.97350	-8.480	33.60	4	1.06000	0.94000
162	1	0.00	0.00	0.160	-0.340	2	1.04090	-4.360	154.00	2	1.06000	0.94000
163	1	36.00	7.12	0.000	0.000	2	1.02760	-7.230	34.50	4	1.06000	0.94000
164	1	36.00	7.12	0.000	0.000	2	1.02810	-7.260	33.60	4	1.06000	0.94000
165	1	36.00	7.12	0.000	0.000	2	1.01760	-9.000	11.10	4	1.06000	0.94000
166	1	0.00	0.00	0.090	-0.210	2	1.01520	-1.100	154.00	2	1.06000	0.94000
167	1	20.40	4.71	0.000	0.000	2	1.00720	-2.820	33.60	4	1.06000	0.94000
168	1	20.40	4.71	0.000	0.000	2	1.00720	-2.820	33.60	4	1.06000	0.94000
169	1	0.00	0.00	0.050	-0.110	2	1.02920	-5.770	154.00	2	1.06000	0.94000
170	1	57.00	15.88	0.000	0.000	2	1.00010	-10.530	34.50	4	1.06000	0.94000
171	1	0.00	0.00	0.050	-0.110	2	0.98530	-5.570	154.00	2	1.06000	0.94000
172	1	57.00	15.88	0.000	0.000	2	0.95440	-10.780	34.50	4	1.06000	0.94000
173	1	0.00	0.00	0.140	-0.210	2	0.98320	-4.910	154.00	2	1.06000	0.94000
174	1	0.00	0.00	0.070	-0.210	2	0.98560	-5.560	154.00	2	1.06000	0.94000
175	1	35.00	5.48	0.000	0.000	2	0.97170	-8.040	34.50	4	1.06000	0.94000
176	1	35.00	5.48	0.000	0.000	2	0.97170	-8.040	33.60	4	1.06000	0.94000
177	1	23.00	4.93	0.000	0.000	2	0.96520	-9.690	11.50	4	1.06000	0.94000
178	1	23.00	4.93	0.000	0.000	2	0.96520	-9.690	11.10	4	1.06000	0.94000
179	1	0.00	0.00	0.190	-0.420	2	0.98590	-4.310	154.00	2	1.06000	0.94000
180	1	51.00	3.29	0.000	0.000	2	0.97620	-8.880	34.50	4	1.06000	0.94000
181	1	51.00	3.29	0.000	0.000	2	0.97620	-8.880	33.60	4	1.06000	0.94000
182	1	51.00	3.29	0.000	0.000	2	0.97620	-8.880	33.60	4	1.06000	0.94000
183	1	51.00	3.29	0.000	0.000	2	0.97620	-8.880	33.60	4	1.06000	0.94000
184	1	0.00	0.00	0.000	0.000	2	0.98590	-4.310	154.00	2	1.06000	0.94000
185	1	0.00	0.00	0.220	-0.110	2	0.97870	-0.440	400.00	1	1.06000	0.94000
186	1	0.00	0.00	0.090	-0.210	2	1.04330	-4.170	154.00	2	1.06000	0.94000
187	1	46.50	6.57	0.000	0.000	2	1.03020	-7.900	33.60	4	1.06000	0.94000
188	1	46.50	6.57	0.000	0.000	2	1.03020	-7.900	33.60	4	1.06000	0.94000
189	1	0.00	0.00	0.270	-0.300	2	0.99920	2.130	400.00	1	1.06000	0.94000
190	1	0.00	0.00	0.000	0.000	2	1.03700	-3.390	154.00	2	1.06000	0.94000
191	1	0.00	0.00	0.000	0.000	2	0.99920	2.130	34.50	4	1.06000	0.94000
192	1	0.00	0.00	0.000	0.000	2	0.99920	2.130	34.50	4	1.06000	0.94000
193	1	0.00	0.00	0.000	0.000	2	0.98620	-5.470	154.00	2	1.06000	0.94000
194	1	0.00	0.00	0.000	0.000	2	0.99690	-4.250	154.00	2	1.06000	0.94000
195	1	42.75	7.70	0.000	0.000	2	0.94780	-6.090	34.50	4	1.06000	0.94000

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 196  1      0.00      0.00    0.010   -0.010   1  0.96610   -4.720   154.00  2    1.06000  0.94000
 197  1      0.00      0.00    0.000    0.000   1  0.96610   -4.720    31.50  4    1.06000  0.94000
 198  1      0.00      0.00    0.010   -0.060   1  0.96730   -4.740   154.00  2    1.06000  0.94000
 199  1      0.00      0.00    0.000    0.000   1  0.96730   -4.740    31.50  4    1.06000  0.94000
 200  2      0.00      0.00    0.000    0.000   1  1.01360    4.980    11.00  2    1.06000  0.94000
 201  2      0.00      0.00    0.000    0.000   1  0.98320    5.180    11.00  2    1.06000  0.94000
 202  2      0.00      0.00    0.000    0.000   1  0.98150    3.720    11.00  2    1.06000  0.94000
 203  2      0.00      0.00    0.000    0.000   1  1.00290    8.760    10.50  3    1.06000  0.94000
 204  2      0.00      0.00    0.000    0.000   1  1.00490    6.440    10.50  3    1.06000  0.94000
 206  2      0.00      0.00    0.000    0.000   1  1.01390    4.940    15.80  3    1.06000  0.94000
 207  2      0.00      0.00    0.000    0.000   1  1.01280    5.870    11.00  3    1.06000  0.94000
 208  2      0.00      0.00    0.000    0.000   1  1.01280    5.870    11.00  3    1.06000  0.94000
 209  2      0.00      0.00    0.000    0.000   1  1.00590    8.650    15.80  3    1.06000  0.94000
 210  2      0.00      0.00    0.000    0.000   1  1.04880    8.330    15.80  3    1.06000  0.94000
 211  2      0.00      0.00    0.000    0.000   1  1.00360    8.580    15.80  3    1.06000  0.94000
 212  2      0.00      0.00    0.000    0.000   1  0.99340    5.620    11.00  3    1.06000  0.94000
 213  2      0.00      0.00    0.000    0.000   2  1.00160    4.190    15.80  3    1.06000  0.94000
 214  2      0.00      0.00    0.000    0.000   2  1.00970    4.420    10.50  3    1.06000  0.94000
 215  2      0.00      0.00    0.000    0.000   2  1.01170    2.890    10.50  3    1.06000  0.94000
 216  2      0.00      0.00    0.000    0.000   2  1.01170    2.890    15.80  3    1.06000  0.94000
 217  2      0.00      0.00    0.000    0.000   2  1.01270    3.150    10.50  3    1.06000  0.94000
 218  2      0.00      0.00    0.000    0.000   2  1.01240    2.520    10.50  3    1.06000  0.94000
 219  2      0.00      0.00    0.000    0.000   2  1.01240    2.520    15.80  3    1.06000  0.94000
 220  2      0.00      0.00    0.000    0.000   2  1.01330    2.780    10.50  3    1.06000  0.94000
 221  2      0.00      0.00    0.000    0.000   2  1.00410    2.280    13.80  3    1.06000  0.94000
 222  2      0.00      0.00    0.000    0.000   2  0.98440    4.120    11.00  3    1.06000  0.94000
 223  2      0.00      0.00    0.000    0.000   2  0.98440    4.090    11.00  3    1.06000  0.94000
 224  2      0.00      0.00    0.000    0.000   2  0.98440    4.090    11.00  3    1.06000  0.94000
 225  2      0.00      0.00    0.000    0.000   2  0.99780    5.460    11.00  3    1.06000  0.94000
 205  3     21.46      0.00    0.000    0.000   1  1.00490   -0.370    10.50  3    1.06000  0.94000
];

%bus     Pg        Qg      Qmax     Qmin     Vsp      baseMVA  status    Pmax       Pmin
gen = [
   1   734.15   206.72   300.00  -250.00  1.00000   100.00    1       834.15     0.00
   2   300.00   275.84   300.00  -250.00  1.00000   100.00    1       400.00     0.00
   3   299.19   -49.06   500.00  -500.00  1.00000   100.00    1       399.19     0.00
 200    23.00     6.40    15.00    -8.00  1.01360   100.00    1       123.00     0.00
 201    23.00    -3.72    15.00    -8.00  0.98320   100.00    1       123.00     0.00
 202    11.00    -3.21    11.00    -6.00  0.98150   100.00    1       111.00     0.00
 203   101.00     3.25   113.00   -59.00  1.00290   100.00    1       201.00     0.00
 204    94.00     2.27   102.00   -56.00  1.00490   100.00    1       194.00     0.00
 205     0.00     0.01   102.00   -56.00  1.00490   100.00    1       330.40     0.00
 206   146.00    40.47   170.00  -100.00  1.01390   100.00    1       246.00     0.00
 207   146.00    31.97   136.00   -80.00  1.01280   100.00    1       246.00     0.00
 208   146.00    31.97   136.00   -80.00  1.01280   100.00    1       246.00     0.00
 209   155.00    -0.11   174.00   -82.00  1.00590   100.00    1       255.00     0.00
 210   152.00    82.00   174.00    82.00  1.01580   100.00    1       252.00     0.00
 211   152.00    -4.58   126.00   -79.00  1.00360   100.00    1       252.00     0.00
 212    50.00     1.58    28.00   -21.00  0.99340   100.00    1       150.00     0.00
 213   128.00    43.63   130.00   -60.00  1.00160   100.00    1       228.00     0.00
 214   150.00    62.88   164.00   -94.00  1.00970   100.00    1       250.00     0.00
 215   128.00    24.58   130.00   -60.00  1.01170   100.00    1       228.00     0.00
 216   128.00    24.58   130.00   -60.00  1.01170   100.00    1       228.00     0.00
 217   150.00    29.51   164.00   -94.00  1.01270   100.00    1       250.00     0.00
 218   128.00    21.48   130.00   -60.00  1.01240   100.00    1       228.00     0.00
 219   128.00    21.48   130.00   -60.00  1.01240   100.00    1       228.00     0.00
 220   150.00    25.88   164.00   -94.00  1.01330   100.00    1       250.00     0.00
 221    88.00     6.54    65.00   -45.00  1.00410   100.00    1       188.00     0.00
 222    33.00    -6.61    24.00   -22.00  0.98440   100.00    1       133.00     0.00
 223    33.00    -6.67    24.00   -22.00  0.98440   100.00    1       133.00     0.00
 224    33.00    -6.67    24.00   -22.00  0.98440   100.00    1       133.00     0.00
 225    64.00    -0.68    60.00   -37.00  0.99780   100.00    1       164.00     0.00
];
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%fbus tbus    r        x        b      ratea    rateb    ratec   ratio     angle  status
branch = [
   1   71  0.00060  0.00758  0.31585  1589.00  1334.00  2178.00  0.00000   0.000    1
   1  189  0.00063  0.00634  0.18659  1047.00   875.00  1431.00  0.00000   0.000    1
   2   71  0.00051  0.00643  0.26806  1589.00  1334.00  2178.00  0.00000   0.000    1
   3  117  0.00311  0.03150  0.92710  1047.00   875.00  1431.00  0.00000   0.000    1
   4   36  0.00373  0.01778  0.00766   182.00   153.00   250.00  0.00000   0.000    1
   4  200  0.01360  0.29952  0.00000    40.00    40.00    40.00  1.00000   0.000    1
   4  201  0.01360  0.29952  0.00000    40.00    40.00    40.00  1.00000   0.000    1
   4  202  0.01511  0.39948  0.00000    30.00    30.00    30.00  1.00000   0.000    1
   5    6  0.00134  0.07199  0.00000   150.00   150.00   150.00  0.98750   0.000    1
   5    6  0.00134  0.07199  0.00000   150.00   150.00   150.00  0.98750   0.000    1
   5   27  0.00049  0.00505  0.14459  1057.00   889.00  1431.00  0.00000   0.000    1
   6    7  0.01122  0.35118  0.00000    25.00    25.00    25.00  1.00000   0.000    1
   6   28  0.01379  0.04430  0.01526   132.00   110.00   180.00  0.00000   0.000    1
   6   29  0.01740  0.05587  0.01925   132.00   110.00   180.00  0.00000   0.000    1
   6   48  0.02224  0.07142  0.02461   132.00   110.00   180.00  0.00000   0.000    1
   6   61  0.02376  0.07630  0.02629   132.00   110.00   180.00  0.00000   0.000    1
   8    9  0.00579  0.19142  0.00000    63.00    63.00    63.00  1.00000   0.000    1
   8   10  0.02255  0.47462  0.00000    20.00    20.00    20.00  1.00000   0.000    1
   8   11  0.02255  0.47462  0.00000    20.00    20.00    20.00  1.00000   0.000    1
   8   51  0.00749  0.03571  0.01538   182.00   153.00   250.00  0.00000   0.000    1
   8   57  0.00005  0.00054  0.00034   408.00   342.00   560.00  0.00000   0.000    1
   8  105  0.02312  0.11021  0.04747   182.00   153.00   250.00  0.00000   0.000    1
  12   13  0.00281  0.15072  0.00000   100.00   100.00   100.00  1.00000   0.000    1
  12   14  0.00281  0.15072  0.00000   100.00   100.00   100.00  1.00000   0.000    1
  12   15  0.01127  0.06910  0.03135   204.00   171.00   280.00  0.00000   0.000    1
  12   18  0.01447  0.04647  0.01601   132.00   110.00   180.00  0.00000   0.000    1
  12   28  0.02427  0.07792  0.02685   132.00   110.00   180.00  0.00000   0.000    1
  12   63  0.00026  0.00161  0.00073   204.00   171.00   280.00  0.00000   0.000    1
  15   16  0.00281  0.15072  0.00000   100.00   100.00   100.00  1.00000   0.000    1
  15   17  0.00281  0.15072  0.00000   100.00   100.00   100.00  1.00000   0.000    1
  15   18  0.01047  0.03363  0.01159   132.00   110.00   180.00  0.00000   0.000    1
  15   39  0.01631  0.07773  0.03348   182.00   153.00   250.00  0.00000   0.000    1
  15   57  0.00669  0.05272  0.02513   247.00   206.00   336.00  0.00000   0.000    1
  18   19  0.00871  0.23970  0.00000    50.00    50.00    50.00  1.00000   0.000    1
  18   20  0.00281  0.15072  0.00000   100.00   100.00   100.00  1.00000   0.000    1
  18   21  0.00453  0.14954  0.00000    80.00    80.00    80.00  1.00000   0.000    1
  18   51  0.00935  0.03001  0.01034   132.00   110.00   180.00  0.00000   0.000    1
  18   51  0.00935  0.03001  0.01034   132.00   110.00   180.00  0.00000   0.000    1
  18   58  0.00324  0.02557  0.01219   247.00   206.00   336.00  0.00000   0.000    1
  18  121  0.03778  0.12132  0.04180   132.00   110.00   180.00  0.00000   0.000    1
  22   23  0.00871  0.23970  0.00000    50.00    50.00    50.00  1.00000   0.000    1
  22   24  0.01357  0.78560  0.00000    15.00    15.00    15.00  1.00000   0.000    1
  22   25  0.00617  0.02941  0.01267   182.00   153.00   250.00  0.00000   0.000    1
  22   29  0.01346  0.04321  0.01489   132.00   110.00   180.00  0.00000   0.000    1
  25   26  0.01122  0.35118  0.00000    25.00    25.00    25.00  1.00000   0.000    1
  25   36  0.01570  0.07482  0.03222   182.00   153.00   250.00  0.00000   0.000    1
  27   28  0.00080  0.04799  0.00000   250.00   250.00   250.00  0.97500   0.000    1
  27   31  0.00177  0.01811  0.51844  1057.00   889.00  1431.00  0.00000   0.000    1
  27   60  0.00098  0.01247  0.51950  1589.00  1334.00  2178.00  0.00000   0.000    1
  27   71  0.00199  0.02534  1.05561  1589.00  1334.00  2178.00  0.00000   0.000    1
  27  203  0.00185  0.10398  0.00000   125.00   125.00   125.00  1.00000   0.000    1
  28   41  0.00220  0.01350  0.00612   204.00   171.00   280.00  0.00000   0.000    1
  28   58  0.00895  0.07061  0.03366   247.00   206.00   336.00  0.00000   0.000    1
  28  204  0.00185  0.10398  0.00000   125.00   125.00   125.00  1.00000   0.000    1
  28  205  0.00185  0.10398  0.00000   125.00   125.00   125.00  1.00000   0.000    1
  29   30  0.01122  0.35118  0.00000    25.00    25.00    25.00  1.00000   0.000    1
  31   32  0.00185  0.10319  0.00000   125.00   125.00   125.00  1.00000   0.000    1
  31   33  0.00185  0.10319  0.00000   125.00   125.00   125.00  1.00000   0.000    1
  31   60  0.00004  0.00040  0.01152  1057.00   889.00  1431.00  0.00000   0.000    1
  34   35  0.00871  0.23970  0.00000    50.00    50.00    50.00  1.00000   0.000    1
  34   43  0.00922  0.04396  0.01893   182.00   153.00   250.00  0.00000   0.000    1
  36   37  0.01393  0.38352  0.00000    31.00    31.00    31.00  1.00000   0.000    1
  36   38  0.01393  0.38352  0.00000    31.00    31.00    31.00  1.00000   0.000    1
  36   48  0.01548  0.04972  0.01713   132.00   110.00   180.00  0.00000   0.000    1
  39   40  0.00871  0.23970  0.00000    50.00    50.00    50.00  1.00000   0.000    1
  41   42  0.00579  0.19142  0.00000    63.00    63.00    63.00  1.00000   0.000    1
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41	42	0.00579	0.19142	0.00000	63.00	63.00	63.00	1.00000	0.000	1
41	63	0.00760	0.04660	0.02114	204.00	171.00	280.00	0.00000	0.000	1
43	44	0.00871	0.23970	0.00000	50.00	50.00	50.00	1.00000	0.000	1
43	54	0.02832	0.09094	0.03134	132.00	110.00	180.00	0.00000	0.000	1
43	196	0.03423	0.10993	0.03788	132.00	110.00	180.00	0.00000	0.000	1
45	46	0.00570	0.18990	0.00000	63.00	63.00	63.00	1.00000	0.000	1
45	47	0.00570	0.18990	0.00000	63.00	63.00	63.00	1.00000	0.000	1
45	58	0.00020	0.00157	0.00075	247.00	206.00	336.00	0.00000	0.000	1
45	58	0.00020	0.00157	0.00075	247.00	206.00	336.00	0.00000	0.000	1
48	49	0.01122	0.35118	0.00000	25.00	25.00	25.00	1.00000	0.000	1
48	50	0.01109	0.68741	0.00000	16.00	16.00	16.00	1.00000	0.000	1
51	52	0.01109	0.68741	0.00000	16.00	16.00	16.00	1.00000	0.000	1
51	53	0.02255	0.47462	0.00000	20.00	20.00	20.00	1.00000	0.000	1
51	54	0.01109	0.03562	0.01227	132.00	110.00	180.00	0.00000	0.000	1
51	57	0.00766	0.03652	0.01573	182.00	153.00	250.00	0.00000	0.000	1
54	55	0.01122	0.35118	0.00000	25.00	25.00	25.00	1.00000	0.000	1
54	56	0.00871	0.23970	0.00000	50.00	50.00	50.00	1.00000	0.000	1
57	156	0.01129	0.05381	0.02318	182.00	153.00	250.00	0.00000	0.000	1
57	206	0.00091	0.04544	0.00000	220.00	220.00	220.00	1.00000	0.000	1
57	207	0.00112	0.05666	0.00000	180.00	180.00	180.00	1.00000	0.000	1
57	208	0.00112	0.05666	0.00000	180.00	180.00	180.00	1.00000	0.000	1
58	59	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
60	117	0.00111	0.01415	0.58945	1589.00	1334.00	2178.00	0.00000	0.000	1
60	209	0.00087	0.05434	0.00000	230.00	230.00	230.00	1.00000	0.000	1
60	210	0.00087	0.05434	0.00000	230.00	230.00	230.00	1.00000	0.000	1
60	211	0.00087	0.05434	0.00000	230.00	230.00	230.00	1.00000	0.000	1
61	62	0.01122	0.35118	0.00000	25.00	25.00	25.00	1.00000	0.000	1
61	62	0.01122	0.35118	0.00000	25.00	25.00	25.00	1.00000	0.000	1
63	64	0.00579	0.19142	0.00000	63.00	63.00	63.00	1.00000	0.000	1
63	65	0.00579	0.19142	0.00000	63.00	63.00	63.00	1.00000	0.000	1
63	212	0.00669	0.20556	0.00000	60.00	60.00	60.00	1.00000	0.000	1
66	105	0.00113	0.00362	0.00125	132.00	110.00	180.00	0.00000	0.000	1
66	195	0.00579	0.19142	0.00000	63.00	63.00	63.00	1.00000	0.000	1
66	195	0.00579	0.19142	0.00000	63.00	63.00	63.00	1.00000	0.000	1
67	69	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
67	171	0.00034	0.00153	0.03274	175.00	175.00	175.00	0.00000	0.000	1
67	171	0.00034	0.00153	0.03274	175.00	175.00	175.00	0.00000	0.000	1
68	70	0.00453	0.14954	0.00000	80.00	80.00	80.00	1.00000	0.000	1
68	173	0.00056	0.00601	0.10947	250.00	250.00	250.00	0.00000	0.000	1
71	72	0.00067	0.03785	0.00000	300.00	300.00	300.00	0.93750	0.000	1
71	73	0.00080	0.04799	0.00000	250.00	250.00	250.00	0.91250	0.000	1
71	73	0.00067	0.03785	0.00000	300.00	300.00	300.00	0.91250	0.000	1
71	86	0.00029	0.00366	0.15239	1589.00	1334.00	2178.00	0.00000	0.000	1
71	185	0.00006	0.00080	0.03325	1589.00	1334.00	2178.00	0.00000	0.000	1
72	74	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
72	128	0.00566	0.02699	0.01162	182.00	153.00	250.00	0.00000	0.000	1
72	128	0.00566	0.02699	0.01162	182.00	153.00	250.00	0.00000	0.000	1
73	75	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
73	113	0.00403	0.01923	0.00828	182.00	153.00	250.00	0.00000	0.000	1
73	147	0.00119	0.00941	0.00449	247.00	206.00	336.00	0.00000	0.000	1
73	147	0.00119	0.00941	0.00449	247.00	206.00	336.00	0.00000	0.000	1
73	186	0.00066	0.00679	0.00427	408.00	342.00	560.00	0.00000	0.000	1
73	186	0.00066	0.00679	0.00427	408.00	342.00	560.00	0.00000	0.000	1
76	77	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
76	135	0.00010	0.00112	0.02043	250.00	250.00	250.00	0.00000	0.000	1
76	135	0.00010	0.00112	0.02043	250.00	250.00	250.00	0.00000	0.000	1
78	79	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
78	80	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
78	81	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
78	85	0.00026	0.00161	0.00073	204.00	171.00	280.00	0.00000	0.000	1
78	85	0.00026	0.00161	0.00073	204.00	171.00	280.00	0.00000	0.000	1
82	84	0.00134	0.07332	0.00000	150.00	150.00	150.00	0.98750	0.000	1
82	84	0.00134	0.07332	0.00000	150.00	150.00	150.00	0.98750	0.000	1
82	127	0.00043	0.00443	0.12673	1057.00	889.00	1431.00	0.00000	0.000	1
82	213	0.00112	0.06666	0.00000	180.00	180.00	180.00	1.00000	0.000	1
82	214	0.00100	0.05999	0.00000	200.00	200.00	200.00	1.00000	0.000	1
83	124	0.00394	0.03107	0.01481	247.00	206.00	336.00	0.00000	0.000	1
83	128	0.00525	0.02505	0.01079	182.00	153.00	250.00	0.00000	0.000	1

83	128	0.00525	0.02505	0.01079	182.00	153.00	250.00	0.00000	0.000	1
83	179	0.00517	0.04079	0.01945	247.00	206.00	336.00	0.00000	0.000	1
83	215	0.00112	0.06666	0.00000	180.00	180.00	180.00	1.00000	0.000	1
83	216	0.00112	0.06666	0.00000	180.00	180.00	180.00	1.00000	0.000	1
83	217	0.00100	0.05999	0.00000	200.00	200.00	200.00	1.00000	0.000	1
84	85	0.00021	0.00129	0.00058	204.00	171.00	280.00	0.00000	0.000	1
84	85	0.00021	0.00129	0.00058	204.00	171.00	280.00	0.00000	0.000	1
84	218	0.00112	0.06666	0.00000	180.00	180.00	180.00	1.00000	0.000	1
84	219	0.00112	0.06666	0.00000	180.00	180.00	180.00	1.00000	0.000	1
84	220	0.00100	0.05999	0.00000	200.00	200.00	200.00	1.00000	0.000	1
85	129	0.00525	0.02505	0.01079	182.00	153.00	250.00	0.00000	0.000	1
85	129	0.00525	0.02505	0.01079	182.00	153.00	250.00	0.00000	0.000	1
85	159	0.00658	0.03135	0.01350	182.00	153.00	250.00	0.00000	0.000	1
85	159	0.00658	0.03135	0.01350	182.00	153.00	250.00	0.00000	0.000	1
85	221	0.00171	0.09485	0.00000	134.00	134.00	134.00	1.00000	0.000	1
86	87	0.00080	0.04799	0.00000	250.00	250.00	250.00	0.90830	0.000	1
86	88	0.00080	0.04799	0.00000	250.00	250.00	250.00	0.92500	0.000	1
86	127	0.00018	0.00233	0.09697	1589.00	1334.00	2178.00	0.00000	0.000	1
87	90	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
87	150	0.00169	0.00808	0.00348	182.00	153.00	250.00	0.00000	0.000	1
87	150	0.00169	0.00808	0.00348	182.00	153.00	250.00	0.00000	0.000	1
87	186	0.00339	0.01616	0.00696	182.00	153.00	250.00	0.00000	0.000	1
88	89	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
88	91	0.00102	0.00485	0.00209	182.00	153.00	250.00	0.00000	0.000	1
88	129	0.00264	0.01260	0.00543	182.00	153.00	250.00	0.00000	0.000	1
88	129	0.00264	0.01260	0.00543	182.00	153.00	250.00	0.00000	0.000	1
91	92	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
91	93	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
91	95	0.00025	0.00264	0.04817	250.00	250.00	250.00	0.00000	0.000	1
91	129	0.00190	0.00905	0.00390	182.00	153.00	250.00	0.00000	0.000	1
91	194	0.00186	0.00889	0.00383	182.00	153.00	250.00	0.00000	0.000	1
94	96	0.00453	0.14954	0.00000	80.00	80.00	80.00	1.00000	0.000	1
94	179	0.00022	0.00240	0.04379	250.00	250.00	250.00	0.00000	0.000	1
95	97	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
98	99	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
98	100	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
98	101	0.00141	0.01116	0.00532	247.00	206.00	336.00	0.00000	0.000	1
98	112	0.00066	0.00518	0.00247	247.00	206.00	336.00	0.00000	0.000	1
98	118	0.00298	0.02354	0.01122	247.00	206.00	336.00	0.00000	0.000	1
98	118	0.00298	0.02354	0.01122	247.00	206.00	336.00	0.00000	0.000	1
101	102	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
101	103	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
101	104	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
101	112	0.00145	0.01145	0.00546	247.00	206.00	336.00	0.00000	0.000	1
105	106	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
105	107	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
105	108	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
105	156	0.01139	0.05430	0.02339	182.00	153.00	250.00	0.00000	0.000	1
109	110	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
109	111	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
109	129	0.00366	0.01745	0.00752	182.00	153.00	250.00	0.00000	0.000	1
109	159	0.00356	0.01697	0.00731	182.00	153.00	250.00	0.00000	0.000	1
109	171	0.00180	0.00579	0.00199	132.00	110.00	180.00	0.00000	0.000	1
109	171	0.00180	0.00579	0.00199	132.00	110.00	180.00	0.00000	0.000	1
109	171	0.00028	0.00304	0.05546	250.00	250.00	250.00	0.00000	0.000	1
109	174	0.00034	0.00369	0.06714	250.00	250.00	250.00	0.00000	0.000	1
109	193	0.00034	0.00162	0.00070	182.00	153.00	250.00	0.00000	0.000	1
112	222	0.00884	0.26703	0.00000	45.00	45.00	45.00	1.00000	0.000	1
112	223	0.00884	0.26527	0.00000	45.00	45.00	45.00	1.00000	0.000	1
112	224	0.00884	0.26527	0.00000	45.00	45.00	45.00	1.00000	0.000	1
112	225	0.00327	0.17671	0.00000	86.00	86.00	86.00	1.00000	0.000	1
113	114	0.00453	0.14954	0.00000	80.00	80.00	80.00	1.00000	0.000	1
113	115	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
113	116	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
113	143	0.00028	0.00296	0.05400	250.00	250.00	250.00	0.00000	0.000	1
113	162	0.00028	0.00304	0.05546	250.00	250.00	250.00	0.00000	0.000	1
117	118	0.00080	0.04799	0.00000	250.00	250.00	250.00	0.95000	0.000	1
117	118	0.00080	0.04799	0.00000	250.00	250.00	250.00	0.95000	0.000	1

117	118	0.00080	0.04799	0.00000	250.00	250.00	250.00	0.95000	0.000	1
117	189	0.00039	0.00396	0.11662	1047.00	875.00	1431.00	0.00000	0.000	1
118	119	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
118	120	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
118	121	0.00610	0.03744	0.01699	204.00	171.00	280.00	0.00000	0.000	1
118	121	0.00610	0.03744	0.01699	204.00	171.00	280.00	0.00000	0.000	1
118	139	0.00173	0.01365	0.00651	247.00	206.00	336.00	0.00000	0.000	1
118	139	0.00173	0.01365	0.00651	247.00	206.00	336.00	0.00000	0.000	1
118	166	0.00378	0.02981	0.01421	247.00	206.00	336.00	0.00000	0.000	1
118	166	0.00378	0.02981	0.01421	247.00	206.00	336.00	0.00000	0.000	1
121	122	0.00453	0.14954	0.00000	80.00	80.00	80.00	1.00000	0.000	1
121	123	0.00453	0.14954	0.00000	80.00	80.00	80.00	1.00000	0.000	1
124	125	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
124	126	0.00125	0.06762	0.00000	160.00	160.00	160.00	1.00000	0.000	1
124	179	0.00117	0.00926	0.00441	247.00	206.00	336.00	0.00000	0.000	1
127	128	0.00080	0.04799	0.00000	250.00	250.00	250.00	0.97500	0.000	1
127	128	0.00080	0.04799	0.00000	250.00	250.00	250.00	0.97500	0.000	1
127	129	0.00080	0.04779	0.00000	250.00	250.00	250.00	0.92500	0.000	1
127	129	0.00080	0.04779	0.00000	250.00	250.00	250.00	0.92500	0.000	1
127	130	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
128	131	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
128	134	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
128	179	0.00298	0.01422	0.00612	182.00	153.00	250.00	0.00000	0.000	1
128	179	0.00298	0.01422	0.00612	182.00	153.00	250.00	0.00000	0.000	1
129	132	0.00185	0.10319	0.00000	125.00	125.00	125.00	1.00000	0.000	1
129	133	0.00185	0.10319	0.00000	125.00	125.00	125.00	1.00000	0.000	1
135	136	0.00453	0.14954	0.00000	80.00	80.00	80.00	1.00000	0.000	1
135	137	0.00453	0.14954	0.00000	80.00	80.00	80.00	1.00000	0.000	1
135	138	0.01122	0.35118	0.00000	25.00	25.00	25.00	1.00000	0.000	1
135	186	0.00032	0.00344	0.06276	250.00	250.00	250.00	0.00000	0.000	1
135	186	0.00031	0.00310	0.10431	360.00	360.00	360.00	0.00000	0.000	1
139	140	0.00453	0.14954	0.00000	80.00	80.00	80.00	1.00000	0.000	1
139	141	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
139	142	0.00453	0.14954	0.00000	80.00	80.00	80.00	1.00000	0.000	1
143	144	0.00871	0.23970	0.00000	50.00	50.00	50.00	1.00000	0.000	1
143	145	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
143	146	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
143	147	0.00021	0.00224	0.04087	250.00	250.00	250.00	0.00000	0.000	1
147	148	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
147	149	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
147	190	0.00119	0.00941	0.00449	247.00	206.00	336.00	0.00000	0.000	1
147	190	0.00119	0.00941	0.00449	247.00	206.00	336.00	0.00000	0.000	1
150	151	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
150	152	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
150	153	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
150	169	0.00031	0.00328	0.05984	250.00	250.00	250.00	0.00000	0.000	1
154	155	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
154	186	0.00034	0.00108	0.00037	132.00	110.00	180.00	0.00000	0.000	1
156	157	0.00579	0.19142	0.00000	63.00	63.00	63.00	1.00000	0.000	1
156	158	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
159	160	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
159	161	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
159	194	0.00203	0.00970	0.00418	182.00	153.00	250.00	0.00000	0.000	1
162	163	0.00453	0.14954	0.00000	80.00	80.00	80.00	1.00000	0.000	1
162	164	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
162	165	0.00871	0.23970	0.00000	50.00	50.00	50.00	1.00000	0.000	1
162	186	0.00042	0.00449	0.08174	250.00	250.00	250.00	0.00000	0.000	1
166	167	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
166	168	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
169	170	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
171	172	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
173	175	0.00453	0.14954	0.00000	80.00	80.00	80.00	1.00000	0.000	1
173	176	0.00453	0.14954	0.00000	80.00	80.00	80.00	1.00000	0.000	1
173	179	0.00073	0.00785	0.14304	250.00	250.00	250.00	0.00000	0.000	1
174	177	0.01088	0.29963	0.00000	40.00	40.00	40.00	1.00000	0.000	1
174	178	0.01088	0.29963	0.00000	40.00	40.00	40.00	1.00000	0.000	1
179	180	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1
179	181	0.00281	0.15072	0.00000	100.00	100.00	100.00	1.00000	0.000	1

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 179  182   0.00281  0.15072  0.00000   100.00   100.00    100.00  1.00000    0.000     1
 179  183   0.00281  0.15072  0.00000   100.00   100.00    100.00  1.00000    0.000     1
 179  184   0.00022  0.00240  0.04379   250.00   250.00    250.00  0.00000    0.000     1
 185  186   0.00080  0.04799  0.00000   250.00   250.00    250.00  0.91250    0.000     1
 185  186   0.00080  0.04799  0.00000   250.00   250.00    250.00  0.91250    0.000     1
 186  187   0.00281  0.15072  0.00000   100.00   100.00    100.00  1.00000    0.000     1
 186  188   0.00281  0.15072  0.00000   100.00   100.00    100.00  1.00000    0.000     1
 189  190   0.00080  0.04799  0.00000   250.00   250.00    250.00  1.00000    0.000     1
 189  191   0.00185  0.10319  0.00000   125.00   125.00    125.00  1.00000    0.000     1
 189  192   0.00185  0.10319  0.00000   125.00   125.00    125.00  1.00000    0.000     1
 196  197   0.01109  0.68741  0.00000    16.00    16.00     16.00  1.00000    0.000     1
 196  198   0.02731  0.08769  0.03022   132.00   110.00    180.00  0.00000    0.000     1
 198  199   0.08632  1.00423  0.00000     6.00     6.00      6.00  1.00000    0.000     1
];
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C. SUMMARY OF POWER-FLOW SOLUTIONS

C 1. SUMMARY OF THE POWER-FLOW SOLUTION OF THE 20-BUS IEEE SYSTEM

Solution Summary

Base MVA: 100 Tolerance: 1.000000e-003

Power-flow solution converged in 0.454104 seconds (in 410 iterations).

Bus Data

Bus No	Bus Code	Voltage Mag(pu)	Voltage Ang(deg)	Generation P(MW)	Generation Q(MVAR)	Load P(MW)	Load Q(MVAR)
1	2	1.020	16.63	750.00	150.70	-	-
2	2	1.020	16.63	750.00	150.70	-	-
3	1	1.008	12.44	0.00	0.00	-	-
4	1	1.005	0.30	0.00	0.00	-	-
5	1	0.982	-1.68	0.00	0.00	200.00	100.00
6	1	0.921	-7.68	0.00	0.00	1000.00	800.00
7	2	1.015	7.62	600.00	400.02	-	-
8	1	0.991	-0.18	0.00	0.00	-	-
9	1	0.954	-4.11	0.00	0.00	300.00	150.00
10	1	0.958	-2.96	0.00	0.00	-	-
11	1	0.932	-6.85	0.00	0.00	1200.00	700.00
12	2	0.972	-1.69	800.00	600.02	-	-
13	1	1.039	-0.75	0.00	0.00	-	-
14	1	1.039	-0.81	0.00	0.00	-	-
15	1	1.011	-2.26	0.00	0.00	-	-
16	1	0.997	-3.43	0.00	0.00	100.00	50.00
17	1	0.986	-2.18	0.00	0.00	-	-
18	1	0.961	-6.67	0.00	0.00	200.00	75.00
19	2	0.952	-7.07	100.00	5.02	200.00	75.00
20	3	1.050	0.00	248.86	186.79	-	-
			Total:	3248.86	1493.24	3200.00	1950.00

Branch Data

From Bus	To Bus	From Bus Injection P(MW)	From Bus Injection Q(MVAR)	To Bus Injection P(MW)	To Bus Injection Q(MVAR)	Loss P(MW)	Loss Q(MVAR)
3	1	-750.00	-94.45	750.00	150.70	0.00	56.25
3	2	-750.00	-94.45	750.00	150.70	0.00	56.25
3	4	930.04	57.51	-918.93	139.07	11.11	196.58
3	4	930.04	57.51	-918.93	139.07	11.11	196.58
3	7	569.96	-61.61	-566.73	110.14	3.24	48.53
4	5	675.71	482.98	-675.71	-448.51	0.00	34.47
4	8	94.59	133.58	-94.37	-130.93	0.21	2.65
4	15	148.63	-29.41	-147.95	36.22	0.68	6.81
5	6	409.05	216.12	-402.99	-161.60	6.06	54.52
5	6	409.05	216.12	-402.99	-161.60	6.06	54.52
5	17	66.66	-44.88	-66.59	45.69	0.07	0.80
6	9	-142.62	-57.49	143.73	68.63	1.11	11.14

6	11	-397.21	-258.83	398.09	267.64	0.87	8.82
6	19	-57.18	-120.87	57.75	125.50	0.57	4.63
7	8	553.26	89.36	-547.16	-13.15	6.10	76.21
7	10	613.47	185.07	-601.51	-65.51	11.96	119.56
8	9	641.53	385.39	-641.53	-327.82	-0.00	57.57
9	11	197.80	76.42	-196.57	-65.31	1.23	11.11
9	11	197.80	76.42	-196.57	-65.31	1.23	11.11
10	11	601.51	270.42	-601.51	-222.60	0.00	47.82
11	12	-800.00	-327.12	800.00	414.82	0.00	87.69
20	13	56.97	45.68	-56.97	-44.47	0.00	1.21
20	14	191.89	141.11	-191.89	-136.99	0.00	4.12
13	15	56.97	49.33	-56.66	-46.49	0.32	2.84
14	16	191.89	146.72	-190.27	-132.14	1.62	14.58
14	16	191.89	146.72	-190.27	-132.14	1.62	14.58
15	16	204.61	142.56	-204.61	-136.47	-0.00	6.09
16	17	-66.37	42.68	66.59	-40.80	0.22	1.88
16	18	231.36	119.56	-229.32	-102.50	2.05	17.07
16	19	129.88	77.75	-128.50	-66.22	1.38	11.53
18	19	29.32	33.05	-29.25	-32.52	0.06	0.53
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					Total:	68.88	1218.07

C 2. SUMMARY OF THE 225-BUS SYSTEM SOLUTION OF ISTANBUL REGION

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================================================================================
|                              Solution Summary                                |
================================================================================
 Base MVA:  100          Tolerance: 5.000000e-002

 Power-flow solution converged in 2.024027 seconds (in 10 iterations).

================================================================================
|                              Bus Data                                        |
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Bus No	Bus Code	Voltage Mag(pu)	Voltage Ang(deg)	Generation P(MW)	Generation Q(MVAR)	Load P(MW)	Load Q(MVAR)
1	2	1.000	3.17	734.15	206.52	-	-
2	2	1.000	1.46	300.00	275.83	-	-
3	2	1.000	8.53	299.19	-49.09	-	-
4	1	0.994	1.74	0.00	0.00	-	-
5	1	1.002	3.20	0.00	0.00	-	-
6	1	1.006	1.51	0.00	0.00	-	-
7	1	1.006	1.51	0.00	0.00	-	-
8	1	0.996	1.75	0.00	0.00	-	-
9	1	0.982	-1.87	0.00	0.00	32.51	5.33
10	1	0.996	1.75	0.00	0.00	-	-
11	1	0.996	1.75	0.00	0.00	-	-
12	1	0.992	0.15	0.00	0.00	-	-
13	1	0.982	-2.72	0.00	0.00	32.50	5.07
14	1	0.982	-2.72	0.00	0.00	32.50	5.07
15	1	0.984	-0.67	0.00	0.00	-	-
16	1	0.964	-5.85	0.00	0.00	57.00	9.48
17	1	0.964	-5.85	0.00	0.00	57.00	9.48
18	1	0.988	-0.48	0.00	0.00	-	-
19	1	0.967	-5.96	0.00	0.00	38.26	5.33
20	1	0.977	-3.89	0.00	0.00	38.26	5.33
21	1	0.976	-3.86	0.00	0.00	38.26	5.33
22	1	0.985	-0.58	0.00	0.00	-	-
23	1	0.966	-5.90	0.00	0.00	37.00	4.38
24	1	0.966	-6.42	0.00	0.00	12.35	1.51
25	1	0.987	-0.28	0.00	0.00	-	-
26	1	0.983	-3.45	0.00	0.00	15.24	0.00
27	1	1.003	3.44	0.00	0.00	-	-
28	1	1.005	1.45	0.00	0.00	-	-
29	1	0.993	0.17	0.00	0.00	-	-
30	1	0.982	-2.33	0.00	0.00	12.19	2.37
31	1	1.008	4.54	0.00	0.00	-	-
32	1	1.008	4.54	0.00	0.00	-	-
33	1	1.008	4.54	0.00	0.00	-	-
34	1	0.952	-5.12	0.00	0.00	-	-
35	1	0.926	-11.75	0.00	0.00	42.67	5.92
36	1	0.993	1.14	0.00	0.00	-	-
37	1	0.983	-1.21	0.00	0.00	10.50	1.92
38	1	0.983	-1.21	0.00	0.00	10.50	1.92
39	1	0.985	-0.73	0.00	0.00	-	-
40	1	0.985	-0.88	0.00	0.00	1.02	0.00
41	1	1.001	0.95	0.00	0.00	-	-
42	1	0.994	-1.23	0.00	0.00	39.63	5.92
43	1	0.961	-4.00	0.00	0.00	-	-
44	1	0.959	-5.97	0.00	0.00	13.21	0.00

45	1	0.992	-0.12	0.00	0.00	-	-
46	1	0.992	-0.12	0.00	0.00	-	-
47	1	0.992	-0.12	0.00	0.00	-	-
48	1	0.996	0.98	0.00	0.00	-	-
49	1	0.993	-0.87	0.00	0.00	9.14	0.57
50	1	0.989	-2.67	0.00	0.00	9.14	0.57
51	1	0.990	0.22	0.00	0.00	-	-
52	1	0.980	-2.41	0.00	0.00	6.50	1.21
53	1	0.983	-1.58	0.00	0.00	6.50	1.21
54	1	0.982	-0.95	0.00	0.00	-	-
55	1	0.982	-0.95	0.00	0.00	-	-
56	1	0.982	-0.95	0.00	0.00	-	-
57	1	0.997	1.81	0.00	0.00	-	-
58	1	0.992	-0.12	0.00	0.00	-	-
59	1	0.990	-1.45	0.00	0.00	15.11	1.18
60	1	1.008	4.57	0.00	0.00	-	-
61	1	0.998	0.63	0.00	0.00	-	-
62	1	0.987	-1.53	0.00	0.00	21.34	4.74
63	1	0.992	0.23	0.00	0.00	-	-
64	1	0.992	0.23	0.00	0.00	-	-
65	1	0.992	0.23	0.00	0.00	-	-
66	1	0.958	-2.89	0.00	0.00	-	-
67	1	0.985	-4.86	0.00	0.00	-	-
68	1	0.982	-4.40	0.00	0.00	-	-
69	1	0.954	-10.54	0.00	0.00	62.00	15.34
70	1	0.950	-10.06	0.00	0.00	62.00	15.34
71	1	0.980	0.42	0.00	0.00	-	-
72	1	1.008	-1.87	0.00	0.00	-	-
73	1	1.045	-3.10	0.00	0.00	-	-
74	1	1.005	-3.25	0.00	0.00	16.12	1.80
75	1	1.041	-4.38	0.00	0.00	16.12	1.80
76	1	1.042	-3.59	0.00	0.00	-	-
77	1	1.012	-9.24	0.00	0.00	69.09	15.99
78	1	0.999	-1.83	0.00	0.00	-	-
79	1	0.973	-7.16	0.00	0.00	60.20	13.31
80	1	0.973	-7.16	0.00	0.00	60.20	13.31
81	1	0.973	-7.16	0.00	0.00	60.20	13.31
82	1	0.975	-0.07	0.00	0.00	-	-
83	1	0.998	-1.22	0.00	0.00	-	-
84	1	1.000	-1.57	0.00	0.00	-	-
85	1	1.000	-1.75	0.00	0.00	-	-
86	1	0.970	-0.42	0.00	0.00	-	-
87	1	1.035	-4.43	0.00	0.00	-	-
88	1	1.005	-3.23	0.00	0.00	-	-
89	1	0.996	-5.47	0.00	0.00	26.00	4.93
90	1	1.027	-6.54	0.00	0.00	26.00	4.93
91	1	1.001	-3.49	0.00	0.00	-	-
92	1	0.971	-7.98	0.00	0.00	50.80	15.99
93	1	0.977	-9.04	0.00	0.00	62.99	11.26
94	1	0.985	-3.64	0.00	0.00	-	-
95	1	1.000	-3.56	0.00	0.00	-	-
96	1	0.962	-7.96	0.00	0.00	48.00	12.05
97	1	0.978	-7.78	0.00	0.00	48.00	12.05
98	1	1.006	-0.51	0.00	0.00	-	-
99	1	0.999	-2.43	0.00	0.00	22.38	3.53
100	1	0.999	-2.43	0.00	0.00	22.38	3.53
101	1	1.001	-1.03	0.00	0.00	-	-
102	1	0.981	-6.73	0.00	0.00	64.85	8.10
103	1	0.981	-6.73	0.00	0.00	64.85	8.10
104	1	0.981	-6.73	0.00	0.00	64.85	8.10
105	1	0.959	-2.80	0.00	0.00	-	-

106	1	0.949	-5.34	0.00	0.00	26.75	5.13
107	1	0.949	-5.34	0.00	0.00	26.75	5.13
108	1	0.949	-5.34	0.00	0.00	26.75	5.13
109	1	0.986	-4.74	0.00	0.00	-	-
110	1	0.961	-10.48	0.00	0.00	63.15	11.83
111	1	0.961	-10.48	0.00	0.00	63.15	11.83
112	1	1.003	-0.33	0.00	0.00	-	-
113	1	1.040	-3.61	0.00	0.00	-	-
114	1	1.029	-7.26	0.00	0.00	45.72	5.13
115	1	1.029	-7.29	0.00	0.00	45.72	5.13
116	1	1.029	-7.29	0.00	0.00	45.72	5.13
117	1	0.996	3.10	0.00	0.00	-	-
118	1	1.017	-0.08	0.00	0.00	-	-
119	1	1.003	-2.90	0.00	0.00	33.47	8.29
120	1	1.004	-2.80	0.00	0.00	32.39	7.70
121	1	1.009	-0.82	0.00	0.00	-	-
122	1	0.997	-4.03	0.00	0.00	37.85	5.77
123	1	0.997	-4.03	0.00	0.00	37.85	5.77
124	1	0.986	-3.52	0.00	0.00	-	-
125	1	0.973	-8.86	0.00	0.00	59.37	4.44
126	1	0.981	-5.90	0.00	0.00	59.37	4.44
127	1	0.968	-0.59	0.00	0.00	-	-
128	1	0.993	-2.47	0.00	0.00	-	-
129	1	1.004	-3.14	0.00	0.00	-	-
130	1	0.968	-0.59	0.00	0.00	-	-
131	1	0.957	-8.32	0.00	0.00	64.53	18.35
132	1	0.994	-6.43	0.00	0.00	55.59	7.40
133	1	0.994	-6.43	0.00	0.00	55.59	7.40
134	1	0.957	-8.32	0.00	0.00	64.53	18.35
135	1	1.042	-3.57	0.00	0.00	-	-
136	1	1.024	-6.71	0.00	0.00	39.41	10.15
137	1	1.024	-6.71	0.00	0.00	39.41	10.15
138	1	1.042	-3.57	0.00	0.00	-	-
139	1	1.014	-0.48	0.00	0.00	-	-
140	1	0.999	-3.59	0.00	0.00	37.00	8.33
141	1	0.999	-3.62	0.00	0.00	37.00	8.33
142	1	0.999	-3.59	0.00	0.00	37.00	8.33
143	1	1.040	-3.44	0.00	0.00	-	-
144	1	1.027	-6.99	0.00	0.00	27.70	3.75
145	1	1.033	-5.66	0.00	0.00	27.70	3.75
146	1	1.033	-5.66	0.00	0.00	27.70	3.75
147	1	1.040	-3.22	0.00	0.00	-	-
148	1	1.036	-6.22	0.00	0.00	37.53	0.89
149	1	1.036	-6.22	0.00	0.00	37.53	0.89
150	1	1.030	-4.95	0.00	0.00	-	-
151	1	1.001	-10.47	0.00	0.00	66.04	14.81
152	1	1.001	-10.47	0.00	0.00	66.04	14.81
153	1	1.001	-10.47	0.00	0.00	66.04	14.81
154	1	1.043	-3.48	0.00	0.00	-	-
155	1	1.017	-7.94	0.00	0.00	55.06	14.22
156	1	0.972	-1.17	0.00	0.00	-	-
157	1	0.960	-3.91	0.00	0.00	23.40	4.67
158	1	0.963	-3.33	0.00	0.00	23.40	4.67
159	1	0.993	-3.56	0.00	0.00	-	-
160	1	0.973	-7.75	0.00	0.00	47.00	9.86
161	1	0.973	-7.75	0.00	0.00	47.00	9.86
162	1	1.041	-3.65	0.00	0.00	-	-
163	1	1.028	-6.51	0.00	0.00	36.00	7.12
164	1	1.028	-6.54	0.00	0.00	36.00	7.12
165	1	1.018	-8.29	0.00	0.00	36.00	7.12
166	1	1.015	-0.40	0.00	0.00	-	-

167	1	1.007	-2.12	0.00	0.00	20.40	4.71
168	1	1.007	-2.12	0.00	0.00	20.40	4.71
169	1	1.029	-5.05	0.00	0.00	-	-
170	1	1.000	-9.81	0.00	0.00	57.00	15.88
171	1	0.985	-4.84	0.00	0.00	-	-
172	1	0.954	-10.05	0.00	0.00	57.00	15.88
173	1	0.983	-4.18	0.00	0.00	-	-
174	1	0.986	-4.83	0.00	0.00	-	-
175	1	0.972	-7.31	0.00	0.00	35.00	5.48
176	1	0.972	-7.31	0.00	0.00	35.00	5.48
177	1	0.965	-8.96	0.00	0.00	23.00	4.93
178	1	0.965	-8.96	0.00	0.00	23.00	4.93
179	1	0.986	-3.58	0.00	0.00	-	-
180	1	0.976	-8.15	0.00	0.00	51.00	3.29
181	1	0.976	-8.15	0.00	0.00	51.00	3.29
182	1	0.976	-8.15	0.00	0.00	51.00	3.29
183	1	0.976	-8.15	0.00	0.00	51.00	3.29
184	1	0.986	-3.58	0.00	0.00	-	-
185	1	0.979	0.28	0.00	0.00	-	-
186	1	1.043	-3.45	0.00	0.00	-	-
187	1	1.030	-7.18	0.00	0.00	46.50	6.57
188	1	1.030	-7.18	0.00	0.00	46.50	6.57
189	1	0.999	2.83	0.00	0.00	-	-
190	1	1.037	-2.67	0.00	0.00	-	-
191	1	0.999	2.83	0.00	0.00	-	-
192	1	0.999	2.83	0.00	0.00	-	-
193	1	0.986	-4.74	0.00	0.00	-	-
194	1	0.997	-3.52	0.00	0.00	-	-
195	1	0.948	-5.46	0.00	0.00	42.75	7.70
196	1	0.966	-4.09	0.00	0.00	-	-
197	1	0.966	-4.09	0.00	0.00	-	-
198	1	0.967	-4.12	0.00	0.00	-	-
199	1	0.967	-4.12	0.00	0.00	-	-
200	2	1.014	5.61	23.00	6.39	-	-
201	2	0.983	5.81	23.00	-3.73	-	-
202	2	0.982	4.35	11.00	-3.21	-	-
203	2	1.003	9.43	101.00	3.28	-	-
204	2	1.005	7.00	94.00	2.37	-	-
206	2	1.014	5.55	146.00	40.40	-	-
207	2	1.013	6.49	146.00	32.00	-	-
208	2	1.013	6.49	146.00	32.00	-	-
209	2	1.006	9.33	155.00	-0.10	-	-
210	2	1.049	9.01	152.00	82.01	-	-
211	2	1.004	9.25	152.00	-4.52	-	-
212	2	0.993	6.20	50.00	1.57	-	-
213	2	1.002	4.92	128.00	43.60	-	-
214	2	1.010	5.14	150.00	62.95	-	-
215	2	1.012	3.61	128.00	24.55	-	-
216	2	1.012	3.61	128.00	24.55	-	-
217	2	1.013	3.87	150.00	29.54	-	-
218	2	1.012	3.25	128.00	21.47	-	-
219	2	1.012	3.25	128.00	21.47	-	-
220	2	1.013	3.51	150.00	25.95	-	-
221	2	1.004	3.01	88.00	6.51	-	-
222	2	0.984	4.82	33.00	-6.60	-	-
223	2	0.984	4.78	33.00	-6.66	-	-
224	2	0.984	4.78	33.00	-6.66	-	-
225	2	0.998	6.15	64.00	-0.71	-	-
205	3	1.005	-0.37	-30.85	0.52	21.46	0.00
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			Total:	3842.49	862.19	3821.58	672.35

Branch Data

From Bus	To Bus	From Bus Injection P(MW)	From Bus Injection Q(MVAR)	To Bus Injection P(MW)	To Bus Injection Q(MVAR)	Loss P(MW)	Loss Q(MVAR)
1	71	639.05	227.74	-636.29	-192.85	2.76	34.89
1	189	95.10	3.90	-95.04	-3.33	0.06	0.57
2	71	300.00	289.23	-299.11	-278.06	0.89	11.17
3	117	299.19	-2.73	-296.41	30.93	2.78	28.20
4	36	56.83	-4.34	-56.70	4.92	0.12	0.58
4	200	-22.92	-4.73	23.00	6.39	0.08	1.66
4	201	-22.92	5.42	23.00	-3.73	0.08	1.68
4	202	-10.98	3.75	11.00	-3.21	0.02	0.54
5	6	83.74	-12.30	-83.69	14.84	0.05	2.54
5	6	83.74	-12.30	-83.69	14.84	0.05	2.54
5	27	-84.40	-16.15	84.44	16.52	0.04	0.37
6	7	-0.00	-0.00	0.00	0.00	0.00	0.00
6	28	2.48	0.80	-2.47	-0.80	0.00	0.00
6	29	44.84	10.62	-44.47	-9.45	0.36	1.17
6	48	15.56	8.83	-15.49	-8.61	0.07	0.23
6	61	21.48	4.73	-21.37	-4.36	0.11	0.36
8	9	32.58	7.50	-32.51	-5.34	0.07	2.15
8	10	-0.00	0.01	0.00	-0.01	0.00	0.00
8	11	-0.00	0.01	0.00	-0.01	0.00	0.00
8	51	74.19	2.00	-73.77	-0.02	0.42	1.98
8	57	-180.14	-23.19	180.16	23.37	0.02	0.18
8	105	73.38	21.39	-72.02	-14.90	1.36	6.48
12	13	32.53	6.76	-32.50	-5.06	0.03	1.69
12	14	32.53	6.76	-32.50	-5.06	0.03	1.69
12	15	21.54	7.23	-21.48	-6.87	0.06	0.36
12	18	23.59	1.48	-23.50	-1.22	0.08	0.26
12	28	-31.25	-7.32	31.50	8.14	0.25	0.82
12	63	-78.94	-11.64	78.96	11.75	0.02	0.10
15	16	57.10	14.90	-57.00	-9.49	0.10	5.42
15	17	57.10	14.90	-57.00	-9.49	0.10	5.42
15	18	-11.81	-5.99	11.83	6.05	0.02	0.06
15	39	1.02	-1.48	-1.02	1.49	0.00	0.00
15	57	-81.94	-10.67	82.41	14.38	0.47	3.71
18	19	38.40	9.16	-38.26	-5.33	0.14	3.83
18	20	38.30	7.69	-38.26	-5.33	0.04	2.36
18	21	38.33	7.67	-38.26	-5.33	0.07	2.34
18	51	-77.58	6.54	77.87	-5.61	0.29	0.93
18	51	-77.58	6.54	77.87	-5.61	0.29	0.93
18	58	-25.30	-13.69	25.33	13.90	0.03	0.22
18	121	-0.47	-17.53	0.59	17.91	0.12	0.38
22	23	37.13	7.94	-37.00	-4.38	0.13	3.56
22	24	12.37	2.81	-12.35	-1.51	0.02	1.30
22	25	-17.39	-1.91	17.41	2.00	0.02	0.09
22	29	-32.11	-7.69	32.26	8.17	0.15	0.49
25	26	15.27	0.85	-15.24	-0.00	0.03	0.84
25	36	-32.68	-0.70	32.85	1.52	0.17	0.82
27	28	74.81	-4.94	-74.76	7.55	0.04	2.61
27	31	-108.88	-15.94	109.09	18.12	0.21	2.18
27	60	-161.40	-25.89	161.66	29.21	0.26	3.31
27	71	210.93	80.17	-209.92	-67.34	1.01	12.82
27	203	-100.81	7.27	101.00	3.28	0.19	10.56
28	41	69.00	21.52	-68.88	-20.82	0.11	0.70
28	58	40.61	14.38	-40.44	-13.09	0.16	1.30
28	204	-93.84	6.74	94.00	2.37	0.16	9.10

28	205	30.87	0.46	-30.85	0.52	0.02	0.98
29	30	12.21	2.93	-12.19	-2.37	0.02	0.56
31	32	-0.00	0.00	0.00	-0.00	0.00	0.00
31	33	-0.00	0.00	0.00	-0.00	0.00	0.00
31	60	-109.09	9.43	109.09	-9.38	0.00	0.05
34	35	42.86	11.11	-42.67	-5.93	0.19	5.19
34	43	-42.86	-10.36	43.06	11.30	0.20	0.94
36	37	10.52	2.37	-10.50	-1.92	0.02	0.45
36	38	10.52	2.37	-10.50	-1.92	0.02	0.45
36	48	2.82	-8.57	-2.81	8.61	0.01	0.04
39	40	1.02	-0.00	-1.02	0.00	0.00	0.00
41	42	39.68	7.47	-39.63	-5.91	0.05	1.56
41	42	39.68	7.47	-39.63	-5.91	0.05	1.56
41	63	29.21	14.52	-29.13	-14.03	0.08	0.49
43	44	13.23	0.45	-13.21	0.00	0.02	0.45
43	54	-56.29	-3.36	57.27	6.49	0.98	3.13
43	196	0.01	-4.50	-0.00	4.52	0.01	0.02
45	46	-0.00	0.00	0.00	-0.00	0.00	0.00
45	47	-0.00	0.00	0.00	-0.00	0.00	0.00
45	58	0.00	0.23	-0.00	-0.23	0.00	0.00
45	58	0.00	0.23	-0.00	-0.23	0.00	0.00
48	49	9.15	0.87	-9.14	-0.57	0.01	0.30
48	50	9.15	1.16	-9.14	-0.57	0.01	0.59
51	52	6.51	1.52	-6.50	-1.21	0.01	0.31
51	53	6.51	1.42	-6.50	-1.21	0.01	0.21
51	54	57.65	5.76	-57.27	-4.55	0.38	1.22
51	57	-74.76	0.02	75.20	2.06	0.44	2.08
54	55	-0.00	0.00	0.00	-0.00	0.00	0.00
54	56	-0.00	0.00	0.00	-0.00	0.00	0.00
57	156	99.55	27.96	-98.33	-22.17	1.22	5.79
57	206	-145.80	-30.26	146.00	40.40	0.20	10.14
57	207	-145.76	-19.66	146.00	32.00	0.24	12.34
57	208	-145.76	-19.66	146.00	32.00	0.24	12.34
58	59	15.12	1.53	-15.11	-1.18	0.01	0.35
60	117	187.60	73.56	-187.16	-67.91	0.44	5.65
60	209	-154.79	13.00	155.00	-0.10	0.21	12.90
60	210	-151.76	-67.27	152.00	82.01	0.24	14.74
60	211	-151.80	16.99	152.00	-4.52	0.20	12.48
61	62	21.37	5.60	-21.34	-4.74	0.03	0.86
61	62	21.37	5.60	-21.34	-4.74	0.03	0.86
63	64	-0.00	0.00	0.00	-0.00	0.00	0.00
63	65	-0.00	0.00	0.00	-0.00	0.00	0.00
63	212	-49.83	3.64	50.00	1.57	0.17	5.21
66	105	-42.81	-9.43	42.83	9.51	0.02	0.08
66	195	42.81	9.73	-42.75	-7.72	0.06	2.01
66	195	42.81	9.73	-42.75	-7.72	0.06	2.01
67	69	62.13	22.09	-62.00	-15.34	0.13	6.75
67	171	-62.13	-19.65	62.13	19.69	0.01	0.03
67	171	-62.13	-19.65	62.13	19.69	0.01	0.03
68	70	62.20	22.12	-62.00	-15.36	0.20	6.76
68	173	-62.20	-16.54	62.23	16.80	0.02	0.26
71	72	109.98	-77.04	-109.86	83.70	0.12	6.66
71	73	319.59	-323.36	-318.87	364.91	0.72	41.55
71	73	319.59	-323.36	-318.87	364.91	0.72	41.55
71	86	398.90	233.43	-398.26	-225.29	0.64	8.14
71	185	305.44	136.20	-305.37	-135.27	0.07	0.93
72	74	16.13	2.20	-16.12	-1.81	0.01	0.39
72	128	96.90	94.16	-96.40	-91.74	0.51	2.42
72	128	96.90	94.16	-96.40	-91.74	0.51	2.42
73	75	16.13	2.17	-16.12	-1.80	0.01	0.37
73	113	53.07	13.12	-52.96	-12.60	0.11	0.53

73	147	58.91	92.25	-58.85	-91.74	0.07	0.52
73	147	58.91	92.25	-58.85	-91.74	0.07	0.52
73	186	199.29	23.33	-199.16	-22.07	0.12	1.25
73	186	199.29	23.33	-199.16	-22.07	0.12	1.25
76	77	69.23	23.39	-69.09	-15.98	0.14	7.41
76	135	-69.23	-23.34	69.23	23.37	0.00	0.03
76	135	-69.23	-23.34	69.23	23.37	0.00	0.03
78	79	60.31	19.38	-60.20	-13.32	0.11	6.06
78	80	60.31	19.38	-60.20	-13.32	0.11	6.06
78	81	60.31	19.38	-60.20	-13.32	0.11	6.06
78	85	-180.94	-57.05	180.99	57.34	0.05	0.29
78	85	-180.94	-57.05	180.99	57.34	0.05	0.29
82	84	69.49	-69.12	-69.43	72.78	0.07	3.66
82	84	69.49	-69.12	-69.43	72.78	0.07	3.66
82	127	207.44	120.28	-207.18	-117.60	0.26	2.68
82	213	-127.80	-31.45	128.00	43.60	0.20	12.15
82	214	-149.74	-47.38	150.00	62.95	0.26	15.57
83	124	130.13	23.10	-129.44	-17.64	0.69	5.45
83	128	173.73	4.49	-172.94	-0.69	0.80	3.80
83	128	173.73	4.49	-172.94	-0.69	0.80	3.80
83	179	101.53	17.96	-100.98	-13.61	0.55	4.36
83	215	-127.81	-13.49	128.00	24.55	0.19	11.06
83	216	-127.81	-13.49	128.00	24.55	0.19	11.06
83	217	-149.77	-15.87	150.00	29.54	0.23	13.67
84	85	475.46	-3.26	-475.23	4.72	0.24	1.46
84	85	475.46	-3.26	-475.23	4.72	0.24	1.46
84	218	-127.82	-10.52	128.00	21.47	0.18	10.96
84	219	-127.82	-10.52	128.00	21.47	0.18	10.96
84	220	-149.77	-12.41	150.00	25.95	0.23	13.54
85	129	180.42	-70.02	-179.43	74.71	0.98	4.69
85	129	180.42	-70.02	-179.43	74.71	0.98	4.69
85	159	201.69	6.43	-200.35	-0.05	1.34	6.38
85	159	201.69	6.43	-200.35	-0.05	1.34	6.38
85	221	-87.87	0.82	88.00	6.51	0.13	7.33
86	87	158.84	-141.63	-158.49	162.60	0.35	20.97
86	88	106.56	-75.01	-106.43	83.02	0.13	8.01
86	127	126.35	62.97	-126.31	-62.48	0.04	0.49
87	90	26.02	5.94	-26.00	-4.94	0.02	1.00
87	150	256.19	83.26	-255.61	-80.52	0.57	2.74
87	150	256.19	83.26	-255.61	-80.52	0.57	2.74
87	186	-119.96	-25.35	120.43	27.61	0.48	2.27
88	89	26.02	5.99	-26.00	-4.93	0.02	1.06
88	91	105.53	65.91	-105.37	-65.16	0.16	0.74
88	129	-22.27	16.16	22.28	-16.12	0.01	0.05
88	129	-22.27	16.16	22.28	-16.12	0.01	0.05
91	92	50.88	20.52	-50.80	-15.99	0.08	4.53
91	93	63.11	17.73	-62.99	-11.26	0.12	6.47
91	95	48.08	13.74	-48.07	-13.68	0.01	0.07
91	129	-71.85	-23.67	71.96	24.18	0.11	0.52
91	194	15.15	39.50	-15.11	-39.34	0.03	0.16
94	96	48.12	16.00	-48.00	-12.04	0.12	3.96
94	179	-48.12	-14.86	48.13	14.93	0.01	0.06
95	97	48.07	15.91	-48.00	-12.05	0.07	3.86
98	99	22.39	4.31	-22.38	-3.53	0.01	0.78
98	100	22.39	4.31	-22.38	-3.53	0.01	0.78
98	101	86.63	34.67	-86.51	-33.70	0.12	0.96
98	112	-53.93	49.26	53.97	-48.98	0.03	0.27
98	118	-77.49	-91.30	77.70	92.97	0.21	1.67
98	118	-77.49	-91.30	77.70	92.97	0.21	1.67
101	102	64.97	14.79	-64.85	-8.10	0.12	6.69
101	103	64.97	14.79	-64.85	-8.10	0.12	6.69

101	104	64.97	14.79	-64.85	-8.10	0.12	6.69
101	112	-108.42	-10.45	108.59	11.81	0.17	1.36
105	106	26.77	6.36	-26.75	-5.12	0.02	1.24
105	107	26.77	6.36	-26.75	-5.12	0.02	1.24
105	108	26.77	6.36	-26.75	-5.12	0.02	1.24
105	156	-51.14	-11.19	51.48	12.81	0.34	1.62
109	110	63.28	18.57	-63.15	-11.83	0.13	6.74
109	111	63.28	18.57	-63.15	-11.83	0.13	6.74
109	129	-171.23	-63.98	172.48	69.98	1.26	6.00
109	159	-120.75	-11.72	121.29	14.29	0.54	2.57
109	171	119.29	34.56	-119.24	-34.32	0.05	0.24
109	171	119.29	34.56	-119.24	-34.32	0.05	0.24
109	171	119.29	34.56	-119.24	-34.32	0.05	0.24
109	174	46.14	10.30	-46.13	-10.21	0.01	0.08
109	193	-0.00	-0.36	0.00	0.36	0.00	0.00
112	222	-32.90	9.72	33.00	-6.60	0.10	3.12
112	223	-32.90	9.77	33.00	-6.66	0.10	3.10
112	224	-32.90	9.77	33.00	-6.66	0.10	3.10
112	225	-63.87	7.99	64.00	-0.71	0.13	7.27
113	114	45.81	8.12	-45.72	-5.13	0.09	2.99
113	115	45.78	8.14	-45.72	-5.13	0.06	3.01
113	116	45.78	8.14	-45.72	-5.13	0.06	3.01
113	143	-105.44	19.53	105.47	-19.21	0.03	0.31
113	162	21.04	-25.46	-21.03	25.49	0.00	0.03
117	118	367.10	-136.15	-366.71	159.64	0.39	23.48
117	118	367.10	-136.15	-366.71	159.64	0.39	23.48
117	118	367.10	-136.15	-366.71	159.64	0.39	23.48
117	189	110.73	-89.56	-110.65	90.37	0.08	0.81
118	119	33.50	10.08	-33.47	-8.29	0.03	1.78
118	120	32.42	9.36	-32.39	-7.70	0.03	1.66
118	121	76.63	31.48	-76.43	-30.24	0.20	1.24
118	121	76.63	31.48	-76.43	-30.24	0.20	1.24
118	139	111.28	32.08	-111.17	-31.20	0.11	0.88
118	139	111.28	32.08	-111.17	-31.20	0.11	0.88
118	166	40.86	9.77	-40.82	-9.51	0.03	0.25
118	166	40.86	9.77	-40.82	-9.51	0.03	0.25
121	122	37.92	7.97	-37.85	-5.77	0.07	2.20
121	123	37.92	7.97	-37.85	-5.77	0.07	2.20
124	125	59.48	10.07	-59.37	-4.43	0.11	5.64
124	126	59.42	6.90	-59.37	-4.41	0.05	2.49
124	179	10.55	1.17	-10.55	-1.15	0.00	0.01
127	128	132.92	-100.44	-132.80	107.36	0.12	6.92
127	128	132.92	-100.44	-132.80	107.36	0.12	6.92
127	129	193.10	-155.49	-192.86	169.97	0.24	14.48
127	129	193.10	-155.49	-192.86	169.97	0.24	14.48
127	130	-0.00	0.01	0.00	-0.01	0.00	0.00
128	131	64.67	25.75	-64.53	-18.34	0.14	7.41
128	134	64.67	25.75	-64.53	-18.34	0.14	7.41
128	179	274.55	40.99	-273.39	-35.43	1.16	5.56
128	179	274.55	40.99	-273.39	-35.43	1.16	5.56
129	132	55.65	10.69	-55.59	-7.40	0.06	3.29
129	133	55.65	10.69	-55.59	-7.40	0.06	3.29
135	136	39.48	12.52	-39.41	-10.16	0.07	2.36
135	137	39.48	12.52	-39.41	-10.16	0.07	2.36
135	138	-0.00	0.00	0.00	-0.00	0.00	0.00
135	186	-148.19	-34.62	148.23	34.97	0.03	0.35
135	186	-148.19	-34.62	148.23	34.97	0.03	0.35
139	140	37.07	10.49	-37.00	-8.33	0.07	2.16
139	141	37.04	10.50	-37.00	-8.33	0.04	2.17
139	142	37.07	10.49	-37.00	-8.33	0.07	2.16
143	144	27.76	5.53	-27.70	-3.75	0.06	1.78

143	145	27.72	4.85	-27.70	-3.75	0.02	1.10
143	146	27.72	4.85	-27.70	-3.75	0.02	1.10
143	147	-188.67	8.72	188.74	-7.98	0.07	0.74
147	148	37.57	2.87	-37.53	-0.89	0.04	1.98
147	149	37.57	2.87	-37.53	-0.89	0.04	1.98
147	190	-205.03	96.82	205.31	-94.58	0.28	2.24
147	190	-205.03	96.82	205.31	-94.58	0.28	2.24
150	151	66.17	21.69	-66.04	-14.80	0.13	6.89
150	152	66.17	21.69	-66.04	-14.80	0.13	6.89
150	153	66.17	21.69	-66.04	-14.80	0.13	6.89
150	169	57.11	17.74	-57.10	-17.63	0.01	0.11
154	155	55.15	18.93	-55.06	-14.22	0.09	4.71
154	186	-55.15	-18.48	55.16	18.51	0.01	0.03
156	157	23.44	5.87	-23.40	-4.68	0.04	1.18
156	158	23.42	5.61	-23.40	-4.68	0.02	0.93
159	160	47.07	13.53	-47.00	-9.86	0.07	3.67
159	161	47.07	13.53	-47.00	-9.86	0.07	3.67
159	194	-15.08	-39.49	15.11	39.66	0.04	0.18
162	163	36.06	9.03	-36.00	-7.12	0.06	1.91
162	164	36.04	9.04	-36.00	-7.12	0.04	1.92
162	165	36.11	10.24	-36.00	-7.12	0.11	3.12
162	186	-87.17	-46.57	87.21	46.97	0.04	0.40
166	167	20.41	5.36	-20.40	-4.71	0.01	0.65
166	168	20.41	5.36	-20.40	-4.71	0.01	0.65
169	170	57.10	21.17	-57.00	-15.89	0.10	5.28
171	172	57.11	21.68	-57.00	-15.88	0.11	5.79
173	175	35.06	7.45	-35.00	-5.46	0.06	1.99
173	176	35.06	7.45	-35.00	-5.46	0.06	1.99
173	179	-132.35	-20.41	132.48	21.87	0.14	1.46
174	177	23.06	6.71	-23.00	-4.93	0.06	1.78
174	178	23.06	6.71	-23.00	-4.93	0.06	1.78
179	180	51.08	7.44	-51.00	-3.30	0.08	4.13
179	181	51.08	7.44	-51.00	-3.30	0.08	4.13
179	182	51.08	7.44	-51.00	-3.30	0.08	4.13
179	183	51.08	7.44	-51.00	-3.30	0.08	4.13
179	184	-0.00	-1.25	0.00	1.25	0.00	0.00
185	186	298.38	-283.51	-297.73	322.23	0.65	38.72
185	186	298.38	-283.51	-297.73	322.23	0.65	38.72
186	187	46.56	9.70	-46.50	-6.57	0.06	3.13
186	188	46.56	9.70	-46.50	-6.57	0.06	3.13
189	190	205.69	-72.20	-205.31	95.05	0.38	22.84
189	191	-0.00	0.00	0.00	-0.00	0.00	0.00
189	192	-0.00	0.00	0.00	-0.00	0.00	0.00
196	197	-0.00	0.00	0.00	-0.00	0.00	0.00
196	198	0.00	-1.34	0.00	1.34	0.00	0.00
198	199	-0.00	-0.00	0.00	0.00	0.00	0.00
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					Total:	52.84	1123.97

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