CONTINUATION POWER FLOW
AND VOLTAGE STABILITY IN POWER SYSTEMS

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AND VOLTAGE STABILITY IN POWER SYSTEMS

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ABSTRACT

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This thesis investigates an important power system phenomenon, voltage stability, by using continuation power flow method. Voltage collapse scenario is presented which can be a serious result of voltage instability and the parameters that affect voltage collapse are discussed.
In analyzing power system voltage stability, continuation power flow method is utilized which consists of successive load flows. This method is applied to a sample test system and Turkish Power System and load-voltage curves for several buses are obtained.

Keywords: Continuation Power Flow Method, Voltage Stability, Voltage Collapse

ÖZ

GÜÇ SİSTEMLERİNDE
SÜREGELEN GÜÇ AKIŞI VE GERİLİM STABİLİTESİ

KESKİN, Mehmet B.
Yüksek Lisans, Elektrik-Elektronik Mühendisliği Bölümü
Tez Yöneticisi: Prof. Dr. Arif ERTAŞ
Eylül 2007, 63 sayfa

Bu çalışma, süregelen güç akışı metodu ile güç sistemlerinde önemli bir olgu olan gerilim stabilitesini incelemektedir. Gerilim stabilitesinin bozulmasının bir sonucu olabilecek gerilim çöküntüsü anlatılmakta ve gerilim çöküntüsünü etkileyen faktörler tartışılmaktadır.
Güç sistemlerindeki gerilim stabilitesinin analizinde, ardışık yük akışlarından oluşan, süregelen güç akışı metodu kullanılmaktadır. Bu metod örnek bir test sistemine ve Türkiye Güç Sistemine uygulanarak birçok bara için yük-gerilim eğrileri elde edilmiştir.

Anahtar sözcükler: Süregelen Güç Akışı Metodu, Gerilim Stabilitesi, Gerilim Çöküntüsü

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CHAPTER 1

INTRODUCTION

Power systems operation become more important as the load demand increases all over the world. This rapid increase in load demand forces power systems to operate near critical limits due to economical and environmental constraints. The objective in power systems operation is to serve energy with acceptable voltage and frequency to consumers at minimum cost.

Reliability and security are also important parameters for power systems and should be satisfied. By reliability, it is meant that the system has adequate reserves in the face of changing energy demand. By security, it is meant that upon occurrence of a contingency, the system could recover to its original state and supply the same quality service as before. All these objectives can be achieved by proper planning, operation and control of power generation and transmission systems.

Investment costs of generation and transmission systems play a great role in a power market. In order to be competitive in power market, system has to be operated at critical limits since investment costs are high. Therefore, construction of new power plants and transmission lines and operation of existing ones should be carried out efficiently.

In addition, environmental constraints have negative effect on construction of new power plants and transmission lines. Great portion of the energy produced is consumed by big cities. Most of the time, it is impossible to build generation units near crowded cities which causes significant loss of energy due to long transmission lines.

Since generation and transmission units have to be operated at critical limits voltage stability problems may occur in power system when there is an increase in load demand. Voltage instability is one of the main problems in power systems. In voltage stability problem some or all buses voltages decrease due to insufficient power delivered to loads.

In case of voltage stability problems, serious blackouts may occur in a considerable part of a system. This can cause severe social and economic problems. In fact, more than 50 cases of voltage instability or voltage collapse were reported all over the world between 1965 and 1996. For example, a voltage collapse in the North American Western Systems Coordinating Council system on July 2, 1996, resulted in service interruptions to more than 6 million people [1]. When the necessity of electricity to industry and community in all fields of the life is considered, the importance of a blackout can be understood more easily. Therefore, special analysis should be performed in order to examine the voltage stability in power systems.

In Chapter 2, voltage stability and voltage collapse phenomena are described. Then in Chapter 3, continuation power flow method, one of the methods used in voltage stability analysis, is introduced.

In Chapter 4, continuation power flow method is applied to a 5-bus test system [2] and effects of compensation, transmission line reactance and adding a new generating unit are presented by analyzing bus voltage profiles that show the relationship between power and voltage. As a final step, continuation power flow method is applied to the Turkish Power System and several bus voltage profiles are obtained and plotted in order to analyze voltage stability of buses located in different regions of Turkey.

CHAPTER 2

VOLTAGE STABILITY

Power system stability can be divided into two as voltage stability and rotor angle stability. Rotor angle stability is the ability of interconnected synchronous machines of a power system to remain in synchronism [3]. In this kind of stability, power-angle equations are handled since power output of a synchronous machine varies as its rotor oscillates.

2.1 Definition of Voltage Stability

Voltage stability is the ability of a power system to maintain steady acceptable voltages at all buses in the system under normal operating conditions and after being subjected to a disturbance [3].

Voltage stability can be attained by sufficient generation and transmission of energy. Generation and transmission units have definite capacities that are peculiar to them. These limits should not be exceeded in a healthy power system. Voltage stability problem arises when the system is heavily loaded that causes to go beyond limitations of power system. A power system enters a state of voltage instability when a disturbance, increase in load demand power or change in system condition causes a progressive and uncontrollable decline in voltage. The main factor causing instability is the inability of the power system to meet the demand for reactive power [3].

2.2 Factors Affecting Voltage Stability

The main reason for voltage instability is the lack of sufficient reactive power in a system. Generator reactive power limits and reactive power requirements in transmission lines are the main causes of insufficient reactive power.

2.2.1 Reactive Power Limits of Generators [4]

Synchronous generators are the main devices for voltage control and reactive power control in power systems. In voltage stability analysis active and reactive power capabilities of generators play an important role. The active power limits are due to the design of the turbine and the boiler. Therefore, active power limits are constant.

Reactive power limits of generators are more complicated than active power limits. There are three different causes of reactive power limits that are; stator current, over-excitation current and under-excitation limits. The generator field current is limited by over-excitation limiter in order to avoid damage in field winding. In fact, reactive power limits are voltage dependent. However, in load flow programs they are taken to be constant in order to simplify analysis.

2.2.2 Transmission Lines [1]

Transfer of active and reactive power is provided by transmission lines. Since transmission lines are generally long, transfer of reactive power over these lines is very difficult due to significant amount of reactive power requirement.

The characteristics of voltage stability and the effect of transmission lines are illustrated by 2-bus simple test system that is shown in Figure 2.1.

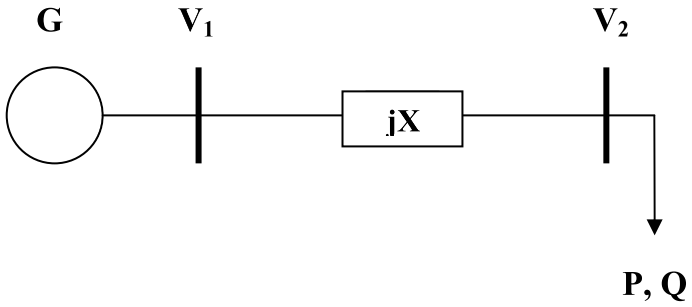

Figure 2.1. Single line diagram of a 2-Bus Test System

The active and reactive power delivered to load bus can be written as

$$P = \frac{V_1 V_2}{X} \sin \delta \tag{2.1}$$

$$Q = \frac{V_1 V_2}{X} \cos \delta - \frac{V_2^2}{X} \tag{2.2}$$

where δ is the angle difference between sending and receiving end buses voltages, X is the reactance of the transmission line.

Eliminating δ and solving Equation 2.1 and 2.2 for V_2 yields Equation 2.3.

$$V_2 = \sqrt{\frac{V_1^2}{2} - QX \pm X\sqrt{\frac{V_1^4}{4X^2} - P^2 - Q\frac{V_1^2}{X}}} \tag{2.3}$$

In order to attain a real solution for V_2 Equation 2.4 should be satisfied.

$$\frac{V_1^4}{4X^2} - P^2 - Q\frac{V_1^2}{X} \geq 0 \tag{2.4}$$

Substituting the short circuit power at the receiving end, $S_{sc} = V_1^2 / X$

$$\left(\frac{S_{sc}}{2}\right)^2 \geq P^2 + QS_{sc} \tag{2.5}$$

The maximum possible transfer of active power is $S_{sc}/2$ (for Q = 0) and the maximum possible transfer of reactive power is $S_{sc}/4$ (for P = 0). Since $(S_{sc}/2)>(S_{sc}/4)$, it can be concluded that transfer of reactive power is more difficult than transfer of active power and as it is observed from Equations 2.1 and 2.2 transfer of power is inversely proportional to line reactance.

Overhead lines either absorb or supply reactive power, depending on the load current. They generate reactive power under light load since their production due to the line shunt capacitance exceeds the reactive power requirement in the transmission line due to the line impedance. Under heavy load, they absorb more reactive power than they produce.

Underground cables produce reactive power since the power requirement never exceed the production due to their high shunt capacitance under all operating conditions. Since they produce reactive power, a definite amount of reactive power demand of loads is met by the power produced by underground cables. Thus, the possibility of seeing voltage stability problem in buses decreases.

2.3 Voltage Collapse [3]

Voltage collapse is the process by which the sequence of events accompanying voltage instability leads to a low unacceptable voltage profile in a significant part of system.

When a power system is subjected to a sudden increase of reactive power demand, the required demand is met by the reactive power reserves supplied from generators and compensation devices. Most of the time, this can be achieved since there are sufficient reserves. Sometimes, it is not possible to meet this rapid increase in demand due to combination of events and system conditions. Thus, voltage collapse and a major breakdown of part or all of the system may occur.

Typical scenario of a voltage collapse can be summarized as follows:

- Some of the large generating units near load centers can be out of service due to abnormal operating conditions. This reduces reactive power supplied and some transmission lines are heavily loaded so as to carry sufficient reactive power to problematic parts of the grid.
- Loss of a heavily loaded transmission line due to a fault causes additional loading on the remaining adjacent lines. This increases the reactive power requirement in lines since reactive power requirement increases rapidly for loads above surge impedance loading. Thus, reactive power demand in the system augments.
- The load voltages decrease because of extra reactive power demand. This causes a decrease in load demand. The voltage control system of generators restores terminal voltage by increasing field excitation. The

additional reactive power flow through transformers and transmission lines causes increased voltage drop across each of these elements.

- The voltage reduction in transmission system is reflected to distribution system. Substation transformers restore voltages by tap changing in a few minutes depending on time delay of tap changing. With each tap change operation voltage and thereby load increases resulting in increase in reactive power demand. When transmission lines are loaded above surge impedance loading, each MVA increase causes great amount of reactive power requirement in systems.
- As a result of tap changing operations, the reactive power output of generators increase. When the generator hits the reactive power capability limit, the terminal voltage decreases. Its sharing of reactive power is transferred to other generators, leading to overloading of more generators. The process eventually leads to voltage instability and voltage collapse.

2.4 Countermeasures against Voltage Instability

There are some countermeasures that can be taken against voltage instability. Automatic voltage regulators (AVRs), under-load tap changers (ULTCs) and compensation devices are common ways to keep bus voltage magnitude in acceptable ranges.

2.4.1 Generator AVRs [3]

Generator AVRs are the most important means of voltage control in a power system. Under normal conditions the terminal voltages of generators are maintained constant. When there exist voltage stability problem due to reactive power demand, generators can supply more power to system in the range of field current limits. AVRs act on the exciter side of synchronous generators. The exciter supplies the field voltage in the field winding. Within the capability limits of the generator, it can regulate the bus voltage.

2.4.2 Under-Load Tap Changers [3]

Transformers enable utilization of different voltage levels across the system. In addition to voltage transformation, transformers are often used for control of voltage and reactive power flow. Therefore, practically all transformers used for bulk power transmission and many distribution transformers have taps in windings in order to change the turns ratio.

From the power system aspect, changing the ratio of transformer is required to compensate for variations in system voltages. There are two types of tap-changing ways that are off-load tap changing and under-load tap changing. Off-load tap changing requires transformer to be inactivated. It is used when long-term variations are considered such as; seasonal changes.

The ULTC is used when the ratio has to be changed frequently due to simultaneous changes in load such as; daily variations. Therefore, in order to maintain voltage stability ULTCs are often used. Generally, taps allow the ratio to vary in the range of ±10% to ±15%.

2.4.3 Compensation Devices [3]

Reactive compensation devices are usually added to supply or absorb reactive power and thereby control the reactive power balance in a desired manner.

Shunt capacitors, shunt reactors, synchronous condensers and static var compensators are used for these purposes.

2.4.3.1 Shunt Capacitors

Shunt capacitors are used to compensate for the reactive power requirement in transmission and to ensure acceptable voltage levels during heavy loading conditions. Capacitor banks of appropriate sizes are connected either directly to bus or tertiary winding of the main transformer. Switching of capacitor banks provides a convenient means of controlling transmission bus voltages. They are normally distributed throughout the system in order to minimize losses and voltage drops.

Shunt capacitors are also used in distribution systems. They generate reactive power and correct the receiving end power factor. The objective of power factor correction is to provide reactive power close to point where it is being consumed, rather than supply it from remote sources. Compensation by shunt capacitors increases the transfer limit of power to the loads. Therefore, it helps to prevent voltage collapse for many loading conditions.

2.4.3.2 Series Capacitors

Series capacitors are connected in series with the transmission line to compensate for the inductive reactance of the line. This reduces the reactance of the transmission line between the generation and load bus. Therefore, the maximum power that can be transferred increases and it reduces the reactive power requirement of the line. Since series capacitors permit economical loading of long transmission lines they are used frequently in power systems.

2.4.3.3 Shunt Reactors

Shunt reactors are used to compensate for the effects of line capacitance. They absorb reactive power from system. In case of unacceptable voltage rises they are activated so as to limit voltage rise. In fact, it is not a countermeasure taken against voltage collapse. Especially under light loading conditions, they are used in order to prevent over-voltages since transmission lines produce reactive power under light loading conditions. During heavy loading conditions, they may have to be disconnected.

2.4.3.4 Synchronous Condensers

A synchronous condenser is a synchronous machine running without a prime mover or a mechanical load. By controlling the field excitation, it can be made to either generate or absorb reactive power. They can automatically adjust the reactive power output to maintain constant terminal voltage with a voltage regulator. They are often connected to tertiary windings of transformers. However, they are not preferred frequently due to their high prices and operating costs.

2.4.3.5 Static Var Systems

Static var compensators are shunt-connected static generators or absorbers whose outputs are varied so as to control specific parameters of the electric power system. Static var systems are capable of controlling individual phase voltages of the buses to which they are connected. Generally, thyristor controlled circuits are used in these systems. A static var system is ideally suited for applications requiring direct and rapid control of voltage.

2.4.4 Other Measures

Load shedding is another method to keep power system voltage stable. Load shedding means cutting off energy to some loads when there is supply-demand problem in a system. This method is considered if all other means are exhausted. It can be done either manually or automatically. Manual load shedding is preferred for voltage stability problems seen in long-term, whereas automatic load shedding for problems seen in short-term..

Another way to keep system voltage stable, new generators can be activated. However, these generating units should be fast starting units. In other words, they can be activated in a few minutes since it is possible to face with stability problems in short time duration. In order to solve this, spinning reactive power reserves must be ensured by operating generators. Spinning reserves are the on-line reserve capacities that are synchronized to power system.

In addition, coordination of protection and control devices are important in prevention of voltage collapse since lack of coordination is one of the causes of voltage collapse.

CHAPTER 3

ANALYSIS OF VOLTAGE STABILITY

The most common methods used in voltage stability analysis are continuation power flow, point of collapse, minimum singular value and optimization methods. In this study, continuation power flow method, widely used in voltage stability analysis, is utilized in order to analyze voltage stability of power systems. Voltage stability can be analyzed by using bifurcation theory.

3.1 Bifurcation Theory [5, 6]

Bifurcation theory is used to describe changes in the qualitative structures of the phase portrait when certain system parameters change. Local bifurcations can be studied by analyzing the vector differential equations near the bifurcation equilibrium points. Voltage collapse in power systems can be predicted by identifying parameter values that lead to saddle-node bifurcations. In order to present the characteristic of bifurcation, Equation 3.1 is considered.

$$f(x,\lambda) = \dot{x} = \lambda - x^2 \tag{3.1}$$

In differential Equation 3.1, x is the state variable and λ is a parameter. There is a point called equilibrium point where $f(x_o,\lambda_o) = 0$. For this value of λ the linearization of $f(x, \lambda)$ is singular.

Figure 3.1 is obtained for $f(x, \lambda)$, as λ changes. When $\lambda=0$ there is a saddle-node point. For $\lambda<0$, there is no equilibrium whereas for $\lambda>0$ there are two equilibrium points as stable and unstable points.

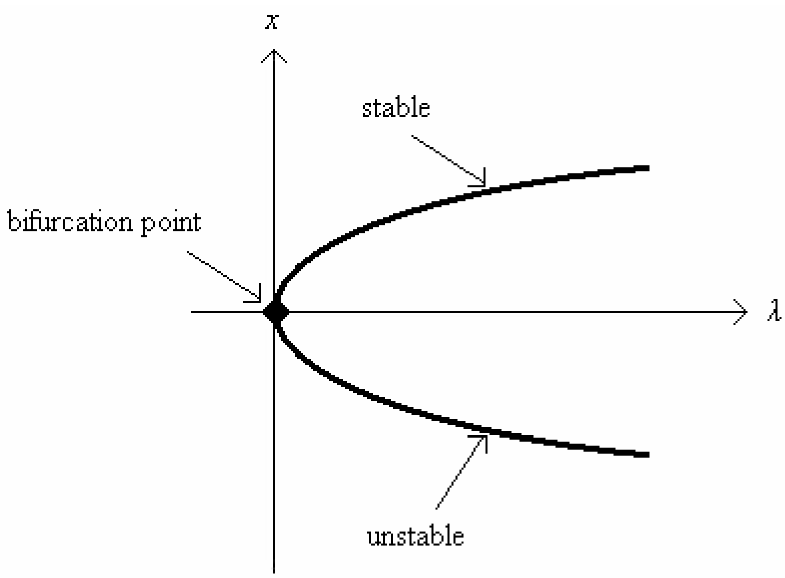

Figure 3.1: Bifurcation diagram for $f(x, \lambda)$

The shape of the diagram shown in Figure 3.1 is quite similar to the bus voltage versus load parameter curves that are obtained in the following chapters.

3.2 Continuation Power Flow

The Jacobian matrix of power flow equations becomes singular at the voltage stability limit. Continuation power flow overcomes this problem. Continuation power flow finds successive load flow solutions according to a load scenario.

It consists of prediction and correction steps. From a known base solution, a tangent predictor is used so as to estimate next solution for a specified pattern of load increase. The corrector step then determines the exact solution using Newton-Raphson technique employed by a conventional power flow. After that a new prediction is made for a specified increase in load based upon the new tangent vector. Then corrector step is applied. This process goes until critical point is reached. The critical point is the point where the tangent vector is zero. The illustration of predictor-corrector scheme is depicted in Figure 3.2.

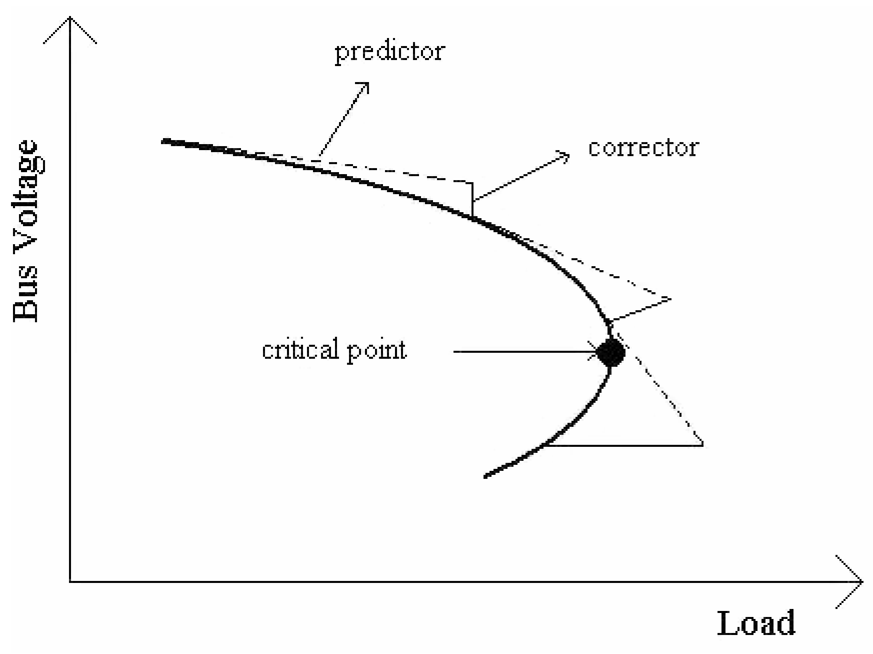

Figure 3.2: Illustration of prediction-correction steps

In continuation load flow, first power flow equations are reformulated by inserting a load parameter into these equations [7].

3.2.1 Mathematical Reformulation

Injected powers can be written for the i^{th} bus of an n-bus system as follows [8]:

$$
\begin{aligned}
P_i &= \sum_{k=1}^{n} |V_i||V_k|(G_{ik}\cos\theta_{ik} + B_{ik}\sin\theta_{ik}) \\
Q_i &= \sum_{k=1}^{n} |V_i||V_k|(G_{ik}\sin\theta_{ik} - B_{ik}\cos\theta_{ik})
\end{aligned}
\tag{3.2}
$$

$$P_i = P_{Gi} - P_{Di},\ \ Q_i = Q_{Gi} - Q_{Di} \tag{3.3}$$

where the subscripts G and D denote generation and load demand respectively on the related bus.

In order to simulate a load change, a load parameter λ is inserted into demand powers P_{Di} and Q_{Di}.

$$
\begin{aligned}
P_{Di} &= P_{Dio} + \lambda(P_{\Delta base}) \\
Q_{Di} &= Q_{Dio} + \lambda(Q_{\Delta base})
\end{aligned}
\tag{3.4}
$$

P_{Dio} and Q_{Dio} are original load demands on i^{th} bus whereas $P_{\Delta base}$ and $Q_{\Delta base}$ are given quantities of powers chosen to scale λ appropriately. After substituting new demand powers in Equation 3.4 to Equation 3.3, new set of equations can be represented as:

$$F(\theta, V, \lambda) = 0 \tag{3.5}$$

where θ denotes the vector of bus voltage angles and V denotes the vector of bus voltage magnitudes. The base solution for λ=0 is found via a power flow. Then, the continuation and parameterization processes are applied [9, 10].

3.2.2 Prediction Step

In this step, a linear approximation is used by taking an appropriately sized step in a direction tangent to the solution path. Therefore, the derivative of both sides of Equation 3.5 is taken.

$$F_\theta d\theta + F_V dV + F_\lambda d\lambda = 0$$

$$\begin{bmatrix} F_\theta & F_V & F_\lambda \end{bmatrix} \begin{bmatrix} d\theta \\ dV \\ d\lambda \end{bmatrix} = \underline{0} \tag{3.6}$$

In order to solve Equation 3.6, one more equation is needed since an unknown variable λ is added to load flow equations. This can be satisfied by setting one of the tangent vector components to +1 or -1 which is also called continuation parameter. Setting one of the tangent vector components +1 or -1 imposes a non-zero value on the tangent vector and makes Jacobian nonsingular at the critical point. As a result Equation 3.6 becomes:

$$\begin{bmatrix} F_\theta & F_V & F_\lambda \\ & \underline{e_k} & \end{bmatrix} \begin{bmatrix} d\theta \\ dV \\ d\lambda \end{bmatrix} = \begin{bmatrix} 0 \\ \pm 1 \end{bmatrix} \tag{3.7}$$

where $\underline{e_k}$ is the appropriate row vector with all elements equal to zero except the k^{th} element equals 1. At first step λ is chosen as the continuation parameter. As the process continues, the state variable with the greatest rate of change is selected as continuation parameter due to nature of parameterization. By solving Equation 3.7, the tangent vector can be found. Then, the prediction can be made as follows:

$$\begin{bmatrix} \theta \\ V \\ \lambda \end{bmatrix}^{p+1} = \begin{bmatrix} \theta \\ V \\ \lambda \end{bmatrix}^{p} + \sigma \begin{bmatrix} d\theta \\ dV \\ d\lambda \end{bmatrix} \tag{3.8}$$

where the subscript "p+1" denotes the next predicted solution. The step size σ is chosen so that the predicted solution is within the radius of convergence of the corrector. If it is not satisfied, a smaller step size is chosen.

3.2.3 Correction Step

In correction step, the predicted solution is corrected by using local parameterization. The original set of equation is increased by one equation that specifies the value of state variable chosen and it results in:

$$\begin{bmatrix} F(\theta, V, \lambda) \\ x_k - \eta \end{bmatrix} = [0] \tag{3.9}$$

where x_k is the state variable chosen as continuation parameter and η is the predicted value of this state variable. Equation 3.9 can be solved by using a slightly modified Newton-Raphson power flow method.

3.2.4 Parameterization

Selection of continuation parameter is important in continuation power flow. Continuation parameter is the state variable with the greatest rate of change. Initially, λ is selected as continuation parameter since at first steps there are small changes in bus voltages and angles due to light load. When the load increases after a few steps the solution approaches the critical point and the rate of change of bus voltages and angles increase. Therefore, selection of continuation parameter is checked after each corrector step. The variable with the largest change is chosen as continuation parameter. If the parameter is increasing +1 is used, if it is decreasing -1 is used in the tangent vector in Equation 3.7.

In order to summarize the whole continuation power flow process, a flow chart is presented in Figure 3.3.

The continuation power flow is stopped when critical point is reached as it is seen in the flow chart. Critical point is the point where the loading has maximum value. After this point it starts to decrease. The tangent component of λ is zero at the critical point and negative beyond this point. Therefore, the sign of $d\lambda$ shows whether the critical point is reached or not.

3.3 Continuation Method without Parameterization

Although parameterization is necessary to guarantee the non-singularity of Jacobian matrix in power flow equations, the continuation equations of the corrector step can be shown nonsingular at the collapse point [6].

In this method, continuation power flow is applied without changing continuation parameter. Load parameter λ is selected as continuation parameter in all prediction and correction steps. The non-singularity of Jacobian in this method can be obtained by reducing step size σ as the solution approaches to critical point. In this study, continuation power flow method without parameterization is utilized so as to analyze the voltage stability of systems since it gives satisfactory results.

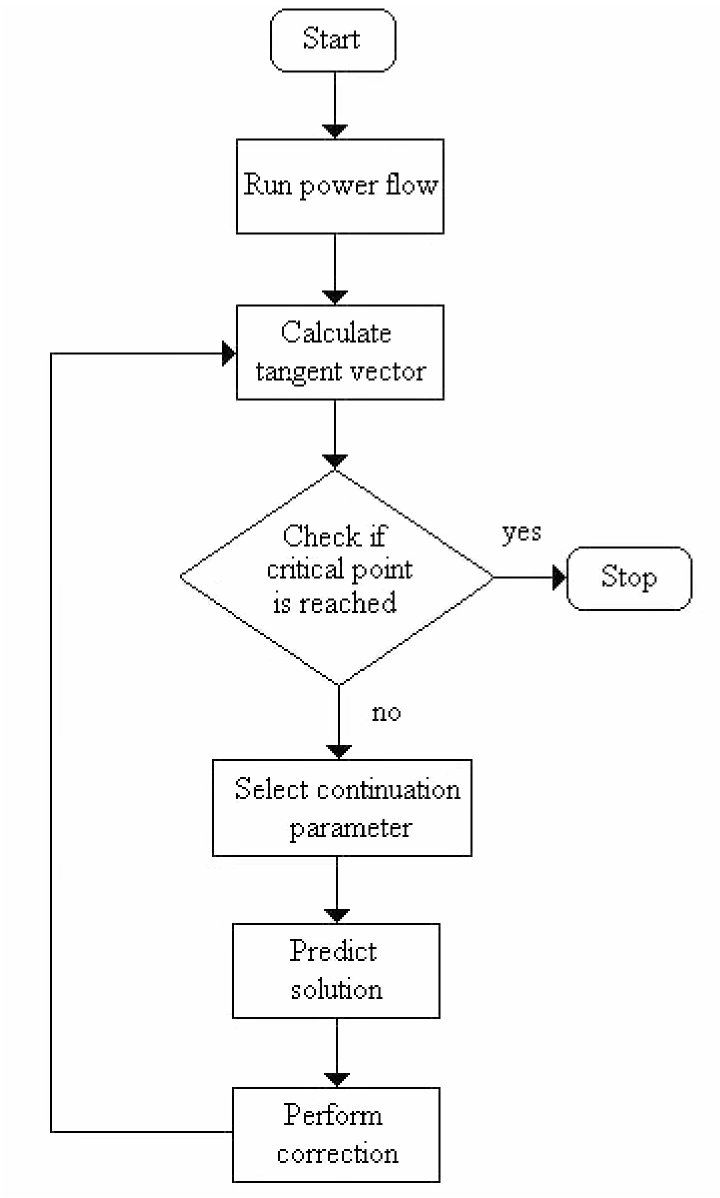

Figure 3.3: Flow chart for continuation power flow [7]

3.4 Continuation Power Flow Program-Uwpflow

Uwpflow is a voltage stability analysis program utilizing continuation power flow method. Program was developed in C and C++ and it has no limitations on system size. The program can be obtained from [11] for educational purposes.

3.4.1 Input Data

WSCC/BPA/EPRI formats or IEEE Common format can be used as input data format in Uwpflow [12]. Some additional data files are required for continuation power flow that can be obtained from original power flow data.

3.4.2 Running of Program

Uwpflow program is simply run by entering commands of options given in the manual into command line. A standard power flow or continuation power flow with various options can be made with this program. Detailed description of program and options can be seen in Appendix A.

In continuation power flow, PV curves of defined buses can be plotted. In addition, by using relevant commands, program outputs data in Matlab file format.

CHAPTER 4

APPLICATION OF CONTINUATION POWER FLOW METHOD

The method presented in Chapter 3 is applied first to a 5-bus sample test system and then Turkish power system by using Uwpflow computer program.

4.1 5-Bus Sample Test System

Sample test system consists of 5 buses, 2 generators, 6 transmission lines and 5 loads. The single line diagram of 5-bus test system is shown in Figure 4.1 [2]. The IEEE common format data of this system can be seen in Appendix B (Table B-1).

In this test system, Birch bus is chosen as swing bus, Maple is voltage control bus, Elm, Pine and Oak buses are load buses. Load flow input includes bus demand powers, bus voltages, reactive power generation limits of generators, active power generation of Maple bus and transmission lines resistance, reactance and charging values. First, a standard power flow is performed using Uwpflow program. The power flow result which is consistent with the result given in [2] can be seen in Appendix B (Table B-2).

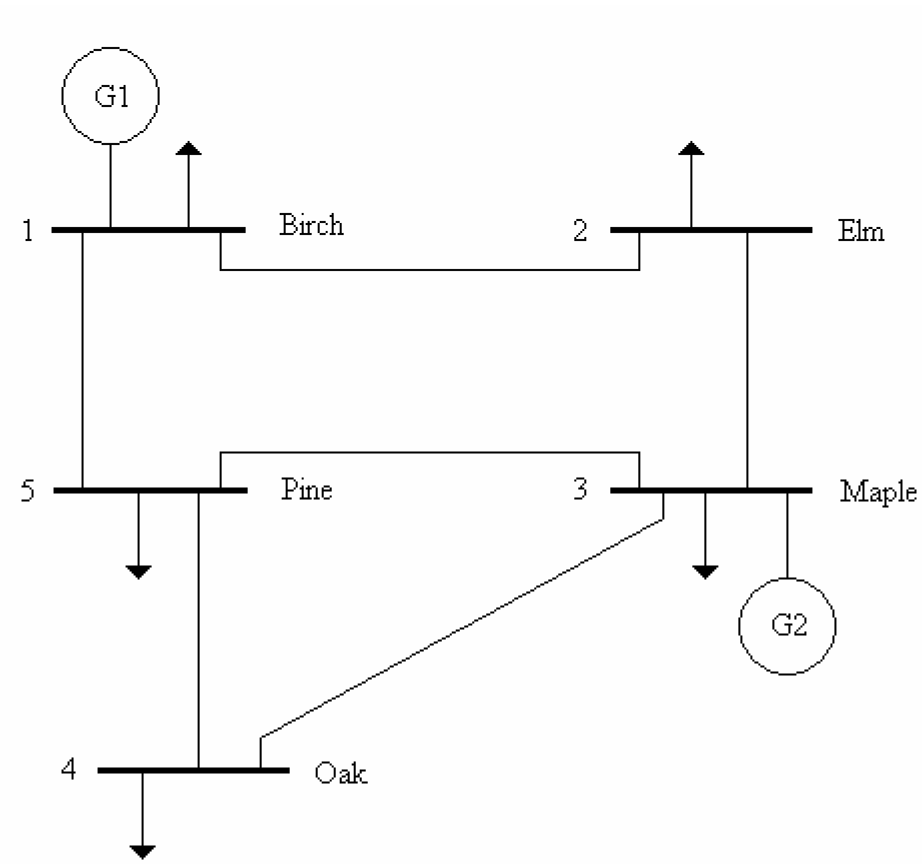

Figure 4.1: Single-line diagram of 5-Bus Test System

Continuation power flow method is applied to sample test system and voltage profiles of 5 buses are obtained. Bus voltages are plotted with respect to the load parameter in Figure 4.2. As the load parameter is increased, bus voltages of load buses decrease as it is expected.

When Figure 4.2 is examined it can be seen that the most reduction in bus voltages occurs in Oak bus. It can be concluded from this result that Oak bus is the weakest bus in this sample system. In fact, it may be predicted before simulation since Oak bus is supplied through slightly longer transmission lines with higher reactance when compared to other buses. Long transmission lines affects voltage stability negatively as it is mentioned in previous chapters.

The ratio $|dV_i/dP_{total}|$ is taken as voltage stability sensitivity factor where dP_{total} and dV_i are respectively total active load change and per unit voltage change in i^{th} bus in the system. Since the denominators in this ratio are the same for all buses, the differential change in bus voltages can be taken as voltage stability sensitivity factor. Table 4.1 shows the buses voltage sensitivity factors.

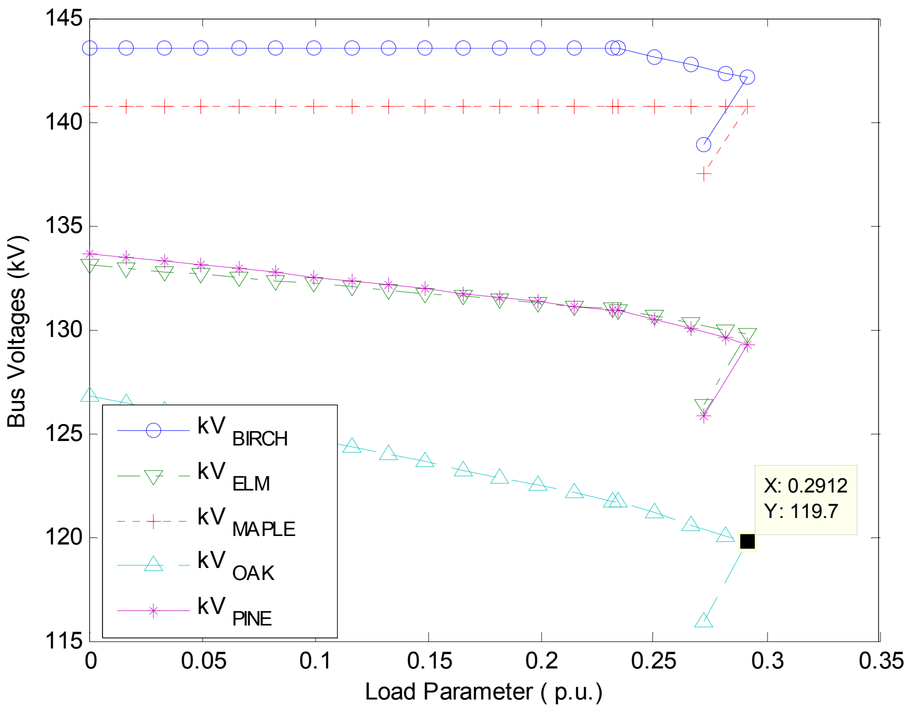

Figure 4.2: Voltage profiles of 5-Bus Test System

Table 4.1: Voltage sensitivity factors of 5-Bus Test System

Bus Name	**Voltage Sensitivity Factor**
BIRCH	0.02261
ELM	0.02452
MAPLE	0.02331
OAK	0.02708
PINE	0.02489

The bus with the highest voltage sensitivity factor can be thought as the weakest bus in a system. Weakest bus is more sensitive to load changes. In other words, the load connected to this bus is affected more than other loads in case of an unexpected load increase. Thus, Oak bus is the weakest bus in this sample system when Table 4.1 is considered.

The continuation power flow result is given in Appendix B (Table B-3). As it is seen in Table B-3 reactive power generations are written as "150H" that means both generators hit their reactive power generating limits 150 MVAR.

The increase in loads with the insertion of load parameter causes generators to reach their generating capacities and forces to exceed limits. Since it is not possible to exceed these limits, sample system looses its voltage stability at the critical point where the load parameter value is 0.2912 as seen in Figure 4.2. The critical point can be taken as voltage collapse point. System becomes voltage unstable beyond this point and voltage decreases rapidly due to requirement of reactive power in the system.

4.1.1 Effect of Compensation on Voltage Stability

In order to demonstrate the effect of compensation in voltage stability, shunt capacitor banks ranging from 0.1 to 0.3 pu in 0.1 pu steps are connected respectively to Oak bus and continuation power flow is performed for all cases. It is expected to see the critical point at the highest loading level in capacitor bank with 0.3 pu case.

Figure 4.3 shows the voltage profiles for base and other three cases of Oak bus obtained in continuation power flows. It is obviously seen that maximum loading point increases as compensation value increases.

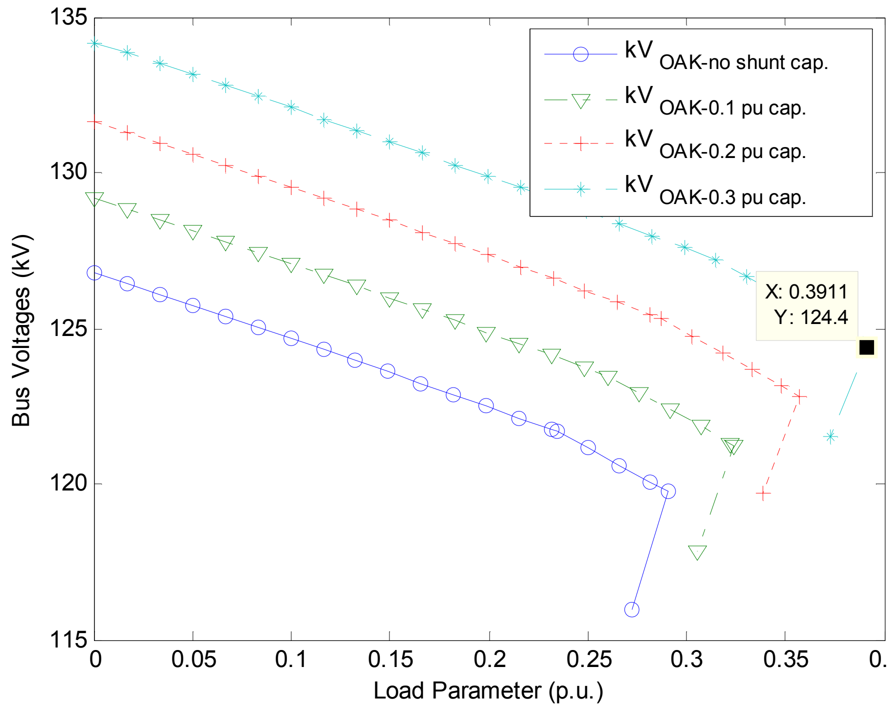

Figure 4.3: Voltage profiles of Oak Bus for different compensation cases

In the base case, load parameter is 0.2912 whereas in 0.3 pu shunt compensation case it increases to 0.3911. Adding shunt capacitor to power system enhances the voltage stability limits. Therefore, for some situations it prevents voltage collapse.

Adding a shunt capacitor to Oak bus improves the voltage stability limit not only in Oak bus but also in other buses. Table 4.2 shows the voltage sensitivity factors of buses for the 0.3 pu shunt capacitor case.

Table 4.2: Voltage sensitivity factors of 5-Bus Test System for 0.3 pu shunt capacitor case

Bus Name	**Voltage Sensitivity Factor**
BIRCH	0.01672
ELM	0.01806
MAPLE	0.01735
OAK	0.01956
PINE	0.01850

When voltage sensitivity factors in Table 4.1 and Table 4.2 are compared it is seen that factors in all buses decrease in the latter case which shows the enhancement in voltage stability.

In addition, when both bus voltages and factor percent changes are compared for buses individually it can be concluded that the most enhancement in voltage stability occurs in Oak bus. It is an expected result since shunt capacitor is connected to Oak bus. In fact, it proves the importance of local compensation. Due to the requirement of reactive power in transmission lines, most of the time local compensation is preferred in order to improve voltage stability.

4.1.2 Effect of Line Reactance on Voltage Stability

After presenting the effect of compensation, transmission line reactance effect on voltage stability is presented by performing continuation power flow for different line reactance values.

In order to analyze the effect of transmission lines reactance, again the weakest bus in the system, Oak bus is observed by performing continuation power flows for different line reactance values between Maple and Oak bus, X_{3-4}.

Similar to compensation cases analysis, four continuation power flows are done for X_{3-4}, $0.8X_{3-4}$, $0.6X_{3-4}$ and $0.4X_{3-4}$ and voltage profiles of Oak bus are observed for these cases. In these cases, it is expected to see a better voltage profile as line reactance decreases since transmission line reactance cause significant amount of reactive power requirement in systems

Figure 4.4 shows the voltage profiles for different line reactance values for X_{3-4} which is the line reactance of transmission line between Oak and Maple buses. As it is seen in Figure 4.4, load parameter in critical point increases as line reactance X_{3-4} decreases. Load parameter for $0.4X_{3-4}$ case is approximately 0.35. It means that Oak bus lose its voltage stability after this critical point which is greater than the base case.

In practical, it is possible to change reactance of transmission line by adding series capacitors. Normally, transmission line parameters depend on system requirements and environmental constraints.

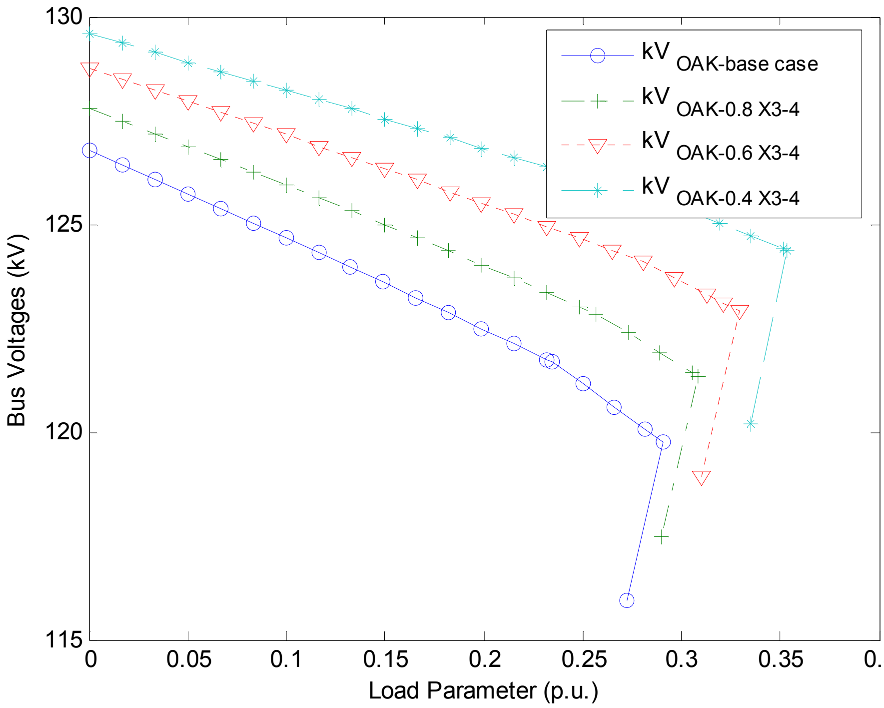

Figure 4.4: Voltage profiles of Oak Bus for different X_{3-4} reactance cases

Table 4.3 shows the voltage sensitivity factors for $0.4X_{3-4}$ case. When it is compared with the base case, it is seen that voltage sensitivity factors increase when line reactance decreases. However, this fact does not mean that voltage stability in buses get worse as line reactance decreases since voltage profiles seen in Figure 4.4 proves the enhancement. Therefore, in voltage stability analysis both voltage profiles and sensitivity factors should be taken into account in order to obtain more reliable results.

Table 4.3: Voltage sensitivity factors of 5-Bus Test System for $0.4X_{3-4}$ reactance case

Bus Name	**Voltage Sensitivity Factor**
BIRCH	0.02580
ELM	0.02821
MAPLE	0.02655
OAK	0.02949
PINE	0.02806

4.1.3 Effect of A New Generator on Voltage Stability

Lastly, a new generator is thought to be connected to Maple bus in sample system by increasing the reactive power limit of the generator connected to Maple bus.

Figure 4.5 shows the voltage profiles of buses for the case new generator that has 100 MVAR generating capacity is added to system. When it is compared with Figure 4.2 it is easily seen that critical point moves to right in new case.

Since reactive power generating limit of whole system increases by adding a generator, system can keep bus voltages stable for higher loadings when compared with base case.

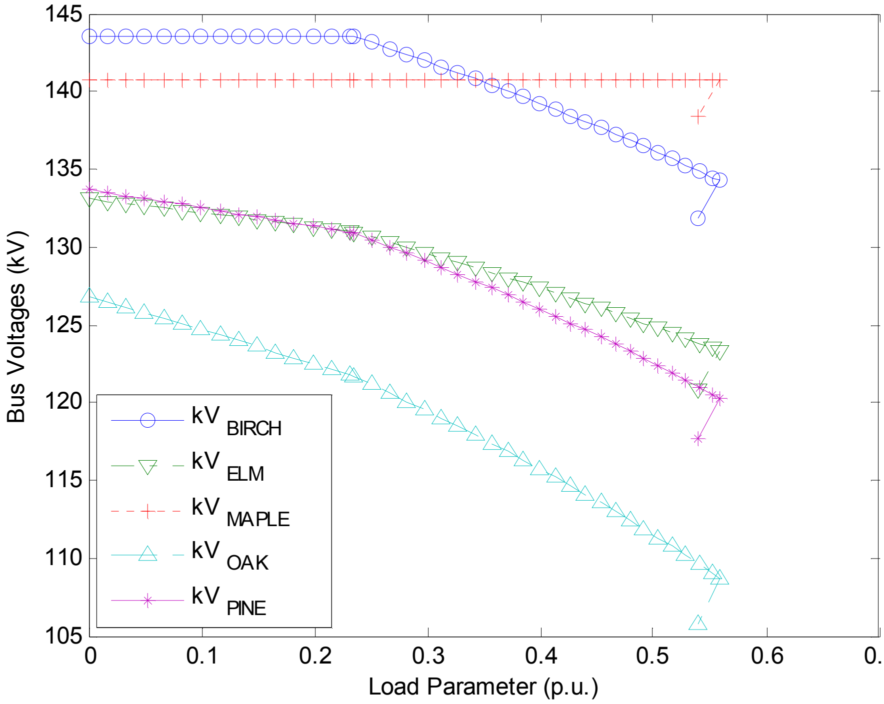

Figure 4.5: Voltage profiles of 5-Bus Test System with a new generator

When Figure 4.2 and 4.5 are compared, an important point is seen in voltage profiles that do not change. This point corresponds to the load parameter value 0.24, where there exists a slightly sharp voltage decrease. These sharp turning points in voltage profiles represent the arrival of reactive power generating limits of generators. In the first turning point, the reactive power generating limit of Birch generator is reached. Since reactive power generating limit of Birch generator is the same for both cases, this turning point remains the same.

The second turning point, which is also called critical loading point, is the arrival of reactive power generating limit of Maple generator. Since generating limit of Maple generator is increased by 100 MVAR, critical loading point moves towards right in voltage profiles plots with respect to load parameter. Table 4.4 presents the new voltage sensitivity factors.

Table 4.4: Voltage sensitivity factors of 5-Bus Test System with a new generator case

Bus Name	Voltage Sensitivity Factor
BIRCH	0.01681
ELM	0.01797
MAPLE	0.01660
OAK	0.02131
PINE	0.01889

4.2 Turkish Power System

In the analysis of Turkish Power System, load flow data which is obtained by Tubitak-Uzay in July 2005 is utilized. The load flow data is in IEEE common format. There are 1000 buses and 1477 branches on line in the system and G-4ELB11 bus is chosen as slack bus.

There are 21 areas in Turkish Power System. The locations of areas are shown in Appendix C. Continuation power flow is performed by considering voltage profiles of buses from each of these areas. In the continuation power flow analysis of Turkish Power System AC system controls such as tap changers are turned off.

First, Babaeski, Hadimkoy, Bolu and Yalova buses are considered that are in the areas from 1 to 4 respectively. Figure 4.6 shows the voltage profiles of these buses.

It is seen in Figure 4.6 that after the point where λ is 0.3061, bus voltages start to decrease due to insufficient power generation. This point is critical point for the whole system under defined operating conditions. After this point, system enters into an unstable condition which can cause voltage collapse.

When the voltage profiles of buses are compared, Babaeski bus seems to be the strongest and Yalova bus seems to be the weakest bus in voltage stability aspect. The increase in load affects Yalova and Bolu buses more than other buses and causes more voltage reduction compared to other two buses.

Obviously, geographical locations of these buses play an important role in this result since they affect the transmission line reactances. Long transmission lines causes high reactance and thereby reactive power requirement under heavy load.

Table 4.5 presents the voltage sensitivity factors, dV_i component of tangent vector at critical point. Voltage sensitivity factors confirm the comment that is done by analyzing voltage profiles. Yalova bus has a higher voltage sensitivity factor than other buses that makes it the weakest bus in this case.

Babaeski bus is the strongest bus as it is observed from voltage sensitivity factor and voltage profile. In fact, it is an expected result since there are huge generating units such as Hamitabad natural gas power plant in this area.

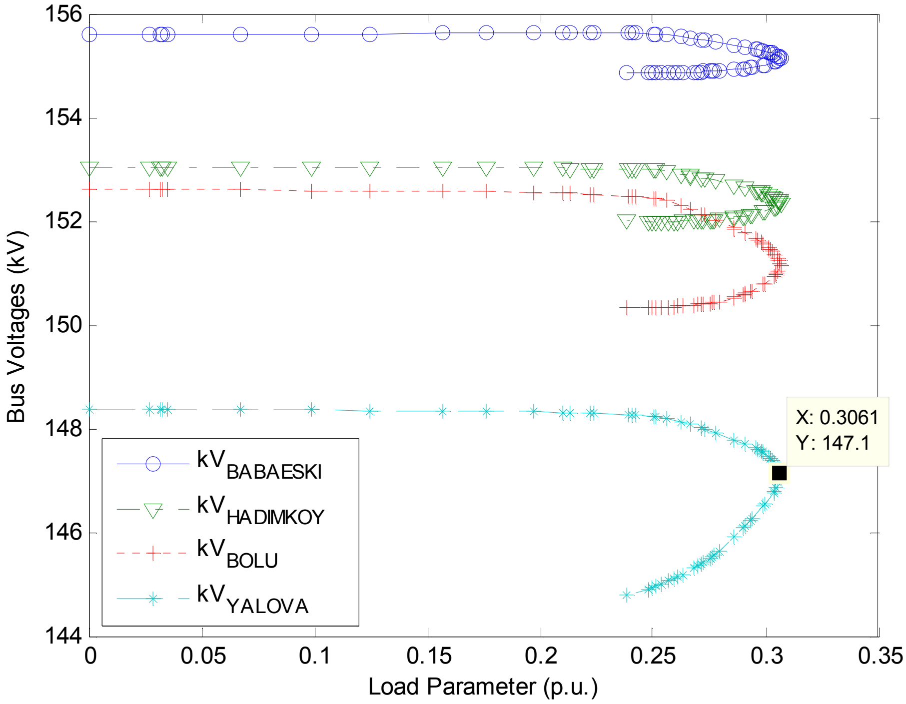

Figure 4.6: Voltage profiles of 4 Buses in areas from 1 to 4 in Turkish Power System

Table 4.5: Voltage sensitivity factors of 4 Buses in areas from 1 to 4 in Turkish Power System

Bus Name	**Voltage Sensitivity Factor**
BABAESKI	0.00099
HADIMKOY	0.00130
BOLU	0.00286
YALOVA	0.00403

In the second continuation power flow analysis, voltage profiles of Ezine, Seyitomer, Alacati and Usak buses are plotted. Figure 4.7 shows the voltage profiles of these buses that are in areas from 5 to 8 respectively.

It is observed in Figure 4.7 that voltage reduction after critical point is more in Alacati bus than the other three buses. Therefore, Alacati bus can be taken as weakest bus in this case. The distance between the generating units and Alacati bus determines this fact.

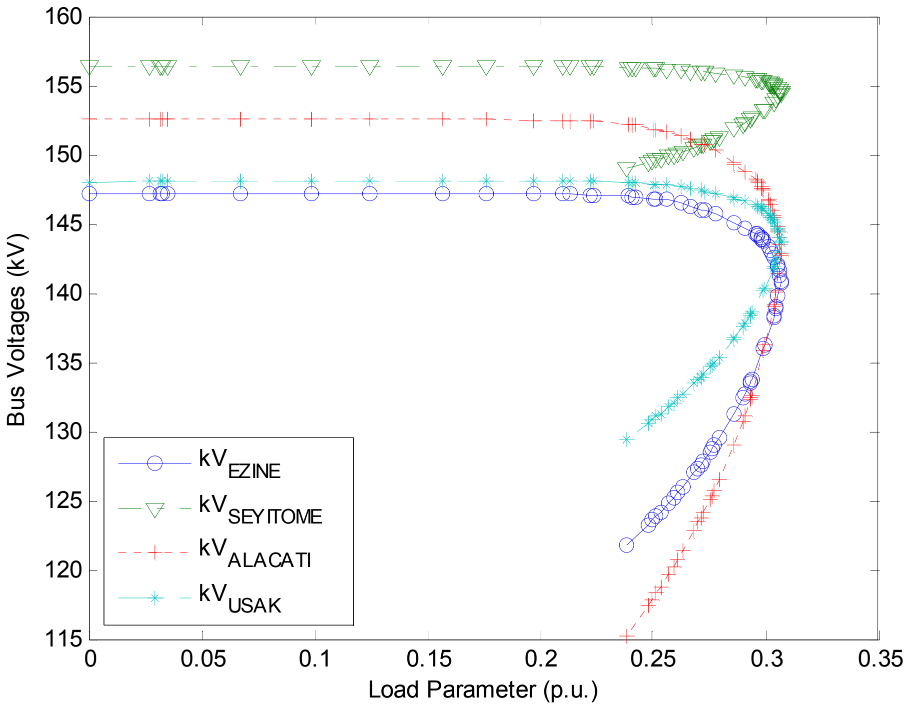

Figure 4.7: Voltage profiles of 4 Buses in areas from 5 to 8 in Turkish Power System

In contrary to Alacati bus, Seyitomer bus is directly connected to a generating bus. In fact, there are two more generating units on-line in Seyitomer which is connected to Seyitomer bus through short transmission lines.

The generating units near Seyitomer make this bus the strongest bus in voltage stability point of view. Voltage sensitivity factors shown in Table 4.6 are also consistent with this claim. Seyitomer bus has the lowest voltage sensitivity factor meaning that this bus is more voltage stable than other three buses.

Table 4.6: Voltage sensitivity factors of 4 Buses in areas from 5 to 8 in Turkish Power System

Bus Name	**Voltage Sensitivity Factor**
EZINE	0.03488
SEYITOMER	0.00918
ALACATI	0.05076
USAK	0.02538

In the third analysis, Datca, Manavgat, IsdemirA and Golbasi buses are considered that are in areas from 9 to 12 respectively. Figure 4.8 presents the voltage profiles of these buses.

In the fourth analysis, voltage profiles of Turhal, Hirfanli, Karaman and Sandikli buses are plotted and shown in Figure 4.9. Lastly, Boyabat, Artvin, Erzurum, Elbistan and Cizre buses that are from the remaining areas are considered and their voltage profiles are presented in Figure 4.10.

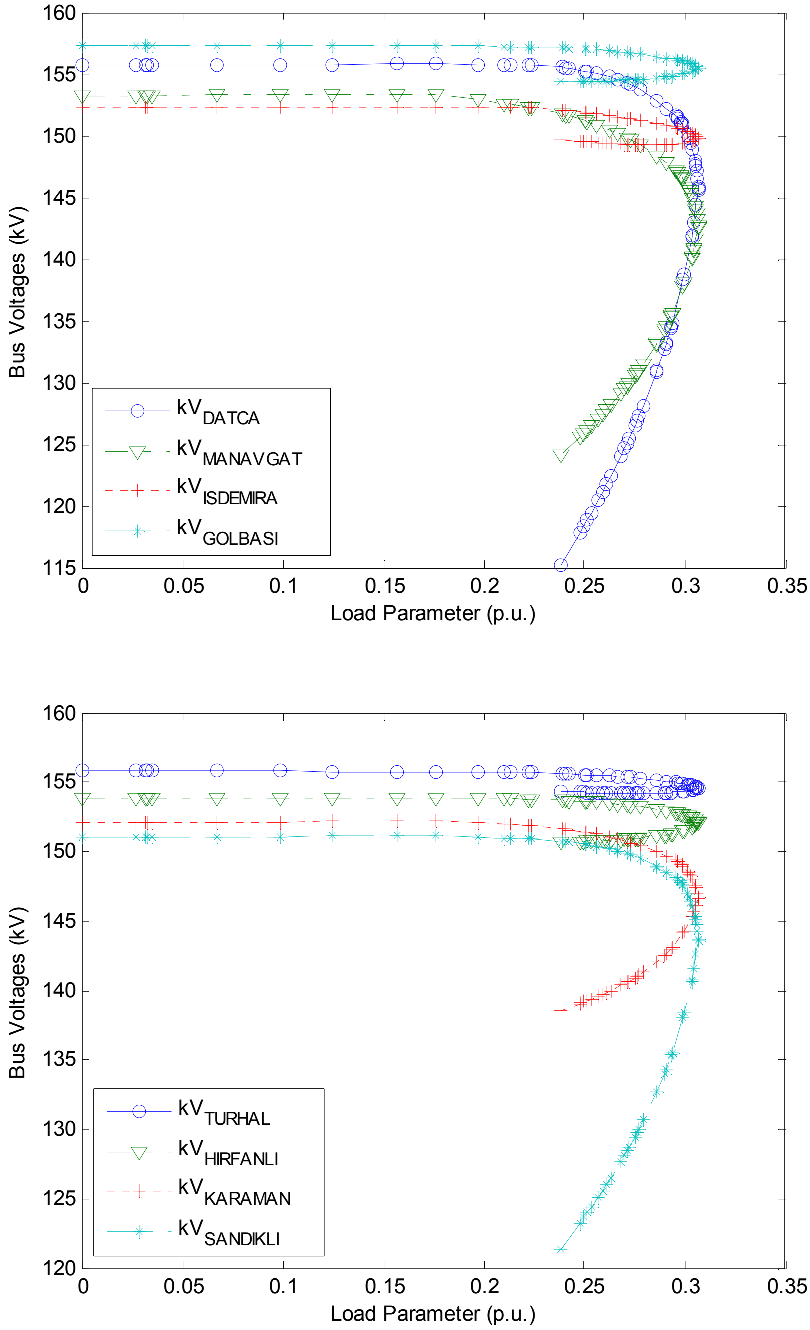

Figure 4.8-4.9: Voltage profiles of 8 Buses in areas from 9 to 12 and 13 to 16 in Turkish Power System

When Figures 4.8, 4.9 and 4.10 are analyzed again geographical locations seem to be a distinguishing factor in voltage profile characteristics. The buses that are near generating units compared to other buses have better voltage profiles.

Table 4.7 shows the voltage sensitivity factors of the buses whose voltage profiles are plotted in last three analyses. It shows that it is not always possible to comment on voltage stability of a system only by considering only voltage sensitivity factors. Figure 4.10 shows that Cizre bus may face with serious voltage magnitude problems in case of an unexpected load increase even before the critical point is reached. Therefore, in voltage stability analysis both load parameter-voltage curves and voltage sensitivity factors should be considered.

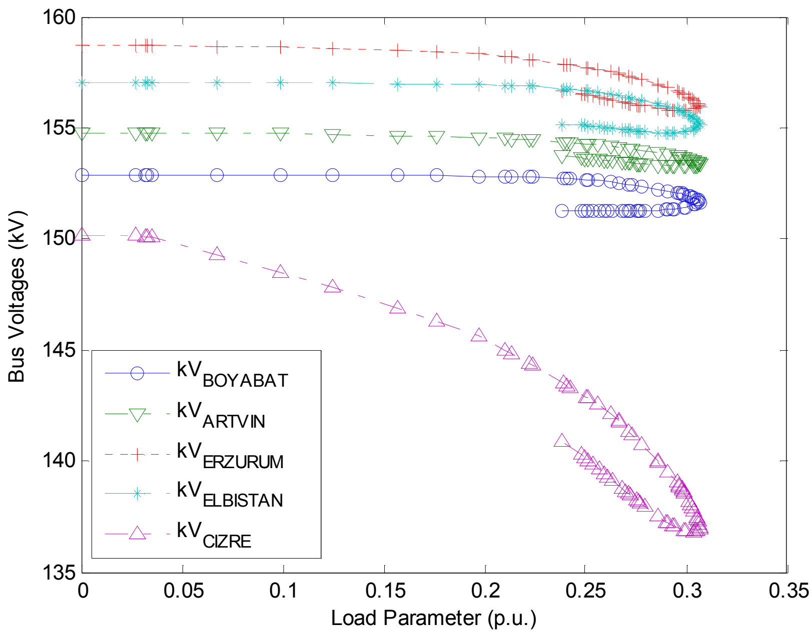

Figure 4.10: Voltage profiles of 4 Buses in areas from 17 to 21 in Turkish Power System

Table 4.7: Voltage sensitivity factors of 13 Buses in areas from 9 to 21 in Turkish Power System

Bus Name	**Voltage Sensitivity Factor**
DATCA	0.05388
MANAVGAT	0.03594
ISDEMIRA	0.00366
GOLBASI	0.00392
TURHAL	0.00194
HIRFANLI	0.00437
KARAMAN	0.01922
SANDIKLI	0.04038
BOYABAT	0.00209
ARTVİN	0.00107
ERZURUM	0.00202
ELBISTAN	0.00276
CIZRE	0.00411

The steady decrease in Cizre bus voltage as load parameter increases can be explained by the lack of transmission lines. Especially, in the East and Southeast regions of Turkey, there are fewer transmission lines when compared to west region. Therefore, power transmission capacity is limited in East region which may cause voltage stability problems.

The analysis of Turkish Power System can further be expanded by considering average load bus voltage sensitivity factors of the buses belonging to the same area. Table 4.8 shows the average bus voltage sensitivity factors of the corresponding areas. Voltage sensitivity factors of all load buses and area data of buses are given in Appendix D.

It is observed from Table 4.8 that Area-1 is the strongest region in voltage stability point of view. It has the lowest average voltage sensitivity factor. It is expected since there are important generating units in this region.

Area-9 seems to be the weakest region in voltage stability aspect since its average voltage sensitivity factor is greater than other areas. This is the result of long transmission lines from generating units to loads.

Area-21 is seen to be more voltage stable than most of other areas when only average voltage sensitivity factor is considered. However, when voltage profiles of buses are considered in this area such as Cizre bus in Figure 4.10, it can be concluded that this area is weak when compared to other areas.

Table 4.8: Average voltage sensitivity factors of buses in corresponding areas from 1 to 21 in Turkish Power System

Area	**Average VSF**	**Area**	**Average VSF**
Area-1	0.00084	Area-12	0.00299
Area-2	0.00141	Area-13	0.00270
Area-3	0.00385	Area-14	0.00398
Area-4	0.00791	Area-15	0.02118
Area-5	0.01649	Area-16	0.01660
Area-6	0.00990	Area-17	0.00148
Area-7	0.04198	Area-18	0.00098
Area-8	0.03463	Area-19	0.00197
Area-9	0.04805	Area-20	0.00379
Area-10	0.03976	Area-21	0.00316
Area-11	0.00636		

CHAPTER 5

CONCLUSION

In this thesis, voltage stability phenomena and continuation power flow method, frequently used in voltage stability analysis of power systems, are presented.

The presented method is applied to 5-Bus sample test system. Voltage stability sensitivity factors and bus voltage versus load parameter curves are obtained for several scenarios by using a software called Uwpflow [11].

The effect of compensation is discussed by adding shunt capacitors in different per unit values to the bus defined in sample system. It is observed from voltage profiles and voltage sensitivity factors that adding shunt capacitor to a bus enhances the voltage stability of whole buses in sample system. Addition of a shunt capacitor supplies more reactive power to system. Thus, critical point occurs in higher loading levels and the magnitudes of bus voltages increase.

In addition, effect of line reactance on voltage stability is studied by performing three continuation power flows to sample system. Voltage profiles for different line reactance cases prove the enhancement in voltage stability. As line reactance decreases, reactive power demand decreases and bus voltages show better voltage profiles. In this case voltage sensitivity factors of buses increase which is not consistent with the result obtained from voltage profiles. Therefore, this case shows that in voltage stability analysis both voltage profiles and voltage sensitivity factors should be considered.

The effect of adding a new generating unit is also observed in sample test system. Adding a new generator improves the voltage stability of sample system since total power generation increases.

In voltage stability analysis of Turkish Power System, several bus voltage profiles from different areas are plotted. Voltage sensitivity factors of all load buses obtained from continuation power flows are presented in Appendix D.

Voltage profiles depict that buses close to generating units have better voltage characteristics than other buses. The buses in the Northwest region of Marmara are the strongest buses in Turkish Power System when voltage profiles are examined in voltage stability aspect. Smaller voltage sensitivity factors in these buses also support this claim.

The voltage profiles of the buses in Southwest and Southeast regions show that they may face with voltage stability problems in heavy loading situations. In Southwest region, bus voltages generally decrease significantly after the critical point which is an event observed in weak buses. In Southeast region, bus voltages starts to decrease in great amounts even before critical point is reached which proves the weakness of the buses in this region in voltage stability point of view.

As a future work, the effect of under load tap changers on voltage stability can be studied. They can not alter the critical loading parameter value but they can adjust the bus voltage magnitude in the range allowed in case of a voltage stability problem.

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APPENDIX A

UWPFLOW PROGRAM DESCRIPTION

AC/DC Power Flow (c)1991 C. Canizares and F. Alvarado

Usage: pflow [-aAbBcCFGhHiIjJkKlLMnNpPqQrRstTvVwW] [<]input_file [>]output_file

The input file could be in WSCC format or IEEE common format for the AC system. The program writes the solution into the output file in ASCII. It can also write (-W option) the solved case in a file in IEEE common format (the HVDC links are written in ETMSP format). The AC/DC power flow is solved with simultaneous N-R, allowing for asynchronous systems, Area interchange, remote voltage control, and regulating transformers (LTCs and phase shifters).

Options:

-a	Turns off tap and angle limits in regulating transformers.
-A	Turns off interchange Area control.
-b	Solve base case before changing the loading factor lambda.
-Bnum	PQ bus number 'num' where the voltage is fixed in order to find the loading factor (lambda) for voltage collapse studies. Must be used with -K and -v options.
-cfile	Increases the loading factor lambda using a modification of Iba's homotopy continuation method for finding voltage profiles. The output (optional 'file') is a list of 8 random AC voltages plus 3 additional variables for each DC bus. Must be used with -K option.
-Cfile	Point of Collapse studies, i.e., find the maximum loading factor lambda for a given generation and load direction. The base case loading can be initialized using the -L option; nevertheless, the program calculates an initial loading of the system before the PoC method is applied. The left eigenvector is written in 'file' (optional). Must be used with -K option.

-Fval Stability/sparsity value 'val' for factorization (def. 0.01). A value of 0 means choose a pivot based on sparsity only; a value of 1 means choose a pivot based on stability only.

-G Do not enforce Q limits during the iteration process. The limits will be applied after a base solution has been found.

-h Prints this message in standard output.

-Hfile Increases the loading factor lambda using a parameterized homotopy continuation method for finding voltage profiles. The output (optional 'file') is a list of 8 random AC voltages plus 3 additional variables for each DC bus. Must be used with -K option.

-ifile List of bus numbers and names in 'file' for printing voltage profiles with the -H option. The input format is: BusNumber BusName; use zero when either the number or the name are unknown. If BusName has spaces, wrap it in double or single quotes.

-I Input data in IEEE common format.

-kval Factor 'val' used in the homotopy continuation method for finding the increments in the loading factor lambda (def. 1). Must be used with the -H option.

-Kfile Read generation and load distribution factors from 'file'. The data is all p.u. and must be separated by spaces, i.e., BusNumber BusName DPg DPl DQl. If the input variables are unknown give them a value of zero. The generation factors are normalized for each Area, i.e., ||Pg||=1 in each Area. Buses not in the list are assumed to have zero distribution factors. If BusName has spaces, wrap it in double or single quotes.

-jfile Write the Jacobian of the solved case in I J VALUE format in 'file.jac'. The equation mismatches and the system variables are also written in 'file.mis' and 'file.var', respectively. If no 'file' is given the program writes to standard output.

-Jfile Similar to -j option, but in this case the Jacobian corresponds to the system without the loading factor as a variable.

-lfile Write standard error output to 'file' (log file).

-Lval Loading factor 'val' (def. 0). Simulates load changes in conjunction with the load distribution factors (-K option).

-Mnum Number 'num' of max. N-R iterations, overriding input data(default 50).

-n Turns off all AC system limits.

-N Turns off all AC system controls.

-p Turns off P and Q limits in regulating transformers.

-P Turns off P and Q control by regulating transformers.

-q Turns off Q limits in PV buses.

-Q Turns off remote voltage generator control. The generators will just control their terminal voltage to its initial value.

-r Turns off V limits in regulating transformers and PV buses.

-R Turns off V control by regulating transformers.

-s Suppress ASCII output_file.

-ttol If the relative error of two consecutive iteration mismatches is larger than 'tol', voltage limits and regulating transformer limits are applied (default 0.1).

-Ttol P.U. tolerance 'tol' for N-R method (default 1e-4).

-vmag Voltage magnitude 'mag' at the first PQ bus (unless otherwise specified by -B option) to find the corresponding loading factor for voltage collapse studies. Must be used with -K option.

-Vfile Read initial guesses for AC bus voltages from 'file'. The data must be separated by spaces, i.e., BusNumber BusName V_mag V_ang(deg). If the input variables are unknown give them a value of zero. Buses not in the list are given a flat start. If BusName has spaces, wrap it on double or single quotes.

-wfile Write solved case into 'file' in IEEE CARD common format. If no 'file' is given the program writes to standard output.

-Wfile Similar to -w option, but the solved case is written in IEEE TAPE common format.

Sample Command Used in Analysis

uwpflow -I trsistem.cf -Ktrsistem.k -ctrsistemvp.m -m –N –S0.8 -ltrsistem.lg4 trsistem.pf3 -k0.2 -itrsistem.vp

APPENDIX B

5-BUS SAMPLE SYSTEM DATA AND LOAD FLOW RESULTS

Table B-1: Load Flow Data for 5-bus test system

C	5-BUS SAMPLE AC TEST SYSTEM:																					
C	IEEE Common Format File																					
	26/04/79 THE POWER COMPANY						100.0 1979 S 5-BUS TEST SYSTEM															
BUS DATA FOLLOWS								5 ITEMS														
C		Name				V(pu)	V(θ)	Pl	Ql	Pg	Qg	Base	Vd	Qmax	Qmin							
	1	BIRCH	1	1	3	1.0400	0.00	65.00	30.00	0.00	0.00	138.00	1.0400	150.00	-10.00	0.00	0.00	0	1			
	2	ELM	1	1	0	1.0000	0.00	115.00	60.00	0.00	0.00	138.00	0.0000	0.00	0.00	0.00	0.00	0	2			
	3	MAPLE	1	1	2	1.0200	0.00	70.00	40.00	180.00	0.00	138.00	1.0200	150.00	-10.00	0.00	0.00	3	3			
	4	OAK	1	1	0	1.0000	0.00	70.00	30.00	0.00	0.00	138.00	0.0000	0.00	0.00	0.00	0.00	0	4			
	5	PINE	1	1	0	1.0000	0.00	85.00	40.00	0.00	0.00	138.00	0.0000	0.00	0.00	0.00	0.00	0	5			
-999																						
BRANCH DATA FOLLOWS								6 ITEMS														
C							R (pu)	X(pu)	B(pu)													
	1	2	1	1	1	0	0.0042	0.1680	0.041	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1
	1	5	1	1	1	0	0.0310	0.1260	0.031	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2
	2	3	1	1	1	0	0.0310	0.1260	0.031	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3
	3	4	1	1	1	0	0.0840	0.3360	0.082	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4
	3	5	1	1	1	0	0.0530	0.2100	0.051	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5
	4	5	1	1	1	0	0.0630	0.2520	0.061	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6
-999																						
LOSS ZONES FOLLOWS								0 ITEMS														
-99																						
INTERCHANGE DATA FOLLOWS									0 ITEMS													
-9																						
TIE LINES FOLLOW								0 ITEMS														
-999																						
END OF DATA																						

Table B-2: Load flow result of 5-bus test system

A	i	Bus	V(pu)	V(kV)	Pg(MW)	Pload	Pshunt|	j	Bus	C	Pij	Plosses	|Iij|(A)
n		Name	d(deg)	d(rad)	Qg(MVAR)	Qload	Qshunt|		Name	r	Qij	Qlosses	
0	1	BIRCH	1.0400	143.52	232.23	65.00	0.00	5	PINE	1	96.42	3.13	417.69
			0.00	0.0000	109.65	30.00	0.00				38.51	9.58	
								2	ELM	1	70.80	0.27	329.41
											41.14	6.55	
0	2	ELM	0.9736	134.36	0.00	115.00	0.00	3	MAPLE	1	-44.47	0.83	220.06
			-6.64	-0.1159	0.00	60.00	0.00				-25.41	0.31	
								1	BIRCH	1	-70.53	0.27	337.57
											-34.59	6.55	
0	3	MAPLE	1.0200	140.76	180.00	70.00	0.00	5	PINE	1	24.41	0.49	121.37
			-3.84	-0.0670	100.53	40.00	0.00				16.72	-3.08	
								4	OAK	1	40.29	1.71	181.15
											18.09	-0.88	
								2	ELM	1	45.30	0.83	213.65
											25.72	0.31	
0	4	OAK	0.9203	127.00	0.00	70.00	0.00	5	PINE	1	-31.43	0.79	151.40
			-10.97	-0.1915	0.00	30.00	0.00				-11.03	-2.29	
								3	MAPLE	1	-38.57	1.71	195.43
											-18.97	-0.88	
0	5	PINE	0.9683	133.62	0.00	85.00	0.00	4	OAK	1	32.21	0.79	144.21
			-6.22	-0.1085	0.00	40.00	0.00				8.73	-2.29	
								3	MAPLE	1	-23.92	0.49	134.17
											-19.80	-3.08	
								1	BIRCH	1	-93.30	3.13	422.05
											-28.93	9.58	

Table B-3: Continuation power flow result of 5-bus test system

A	i	Bus	V(pu)	V(kV)	Pg(MW)	Pload	Pshunt	j	Bus	C	Pij	Plosses	|Iij|(A)
n		Name	d(deg)	d(rad)	Qg(MVAR)	Qload	Qshunt		Name	r	Qij	Qlosses	
0	1	BIRCH	1.0068	138.94	197.82	82.71	0.00	5	PINE	1	73.90	2.78	392.26
			0.00	0.0000	150.00H	38.17	0.00				58.73	8.45	
								2	ELM	1	41.21	0.20	279.30
											53.09	4.06	
0	2	ELM	0.9154	126.33	0.00	146.33	0.00	3	MAPLE	1	-105.31	4.35	497.21
			-4.16	-0.0727	0.00	76.34	0.00				-27.32	14.85	
								1	BIRCH	1	-41.02	0.20	292.15
											-49.03	4.06	
0	3	MAPLE	0.9963	137.48	333.48	89.07	0.00	5	PINE	1	69.59	2.98	310.04
			3.69	0.0644	150.00H	50.90	0.00				24.65	7.16	
								4	OAK	1	65.16	4.71	305.37
											32.28	11.88	
								2	ELM	1	109.66	4.35	493.40
											42.17	14.85	
0	4	OAK	0.8403	115.96	0.00	89.07	0.00	5	PINE	1	-28.62	0.95	167.75
			-9.32	-0.1626	0.00	38.17	0.00				-17.77	-0.89	
								3	MAPLE	1	-60.45	4.71	317.64
											-20.40	11.88	
0	5	PINE	0.9116	125.80	0.00	108.16	0.00	4	OAK	1	29.57	0.95	156.27
			-4.65	-0.0812	0.00	50.90	0.00				16.88	-0.89	
								3	MAPLE	1	-66.61	2.98	316.08
											-17.49	7.16	
								1	BIRCH	1	-71.12	2.78	399.73
											-50.28	8.45	

APPENDIX C

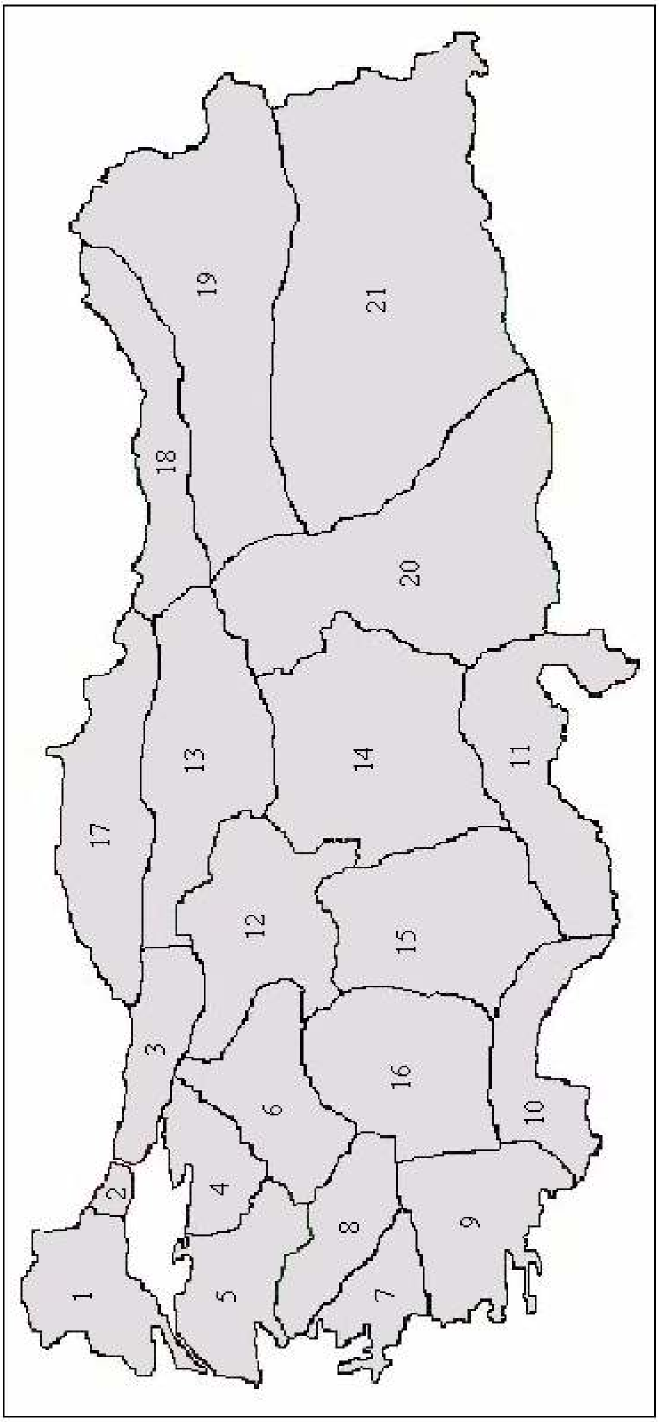

Figure C-1: Areas of Turkish Power System

APPENDIX D

VOLTAGE SENSITIVITY FACTORS OF LOAD BUSES IN TURKISH POWER SYSTEM

Bus No	Bus Name	Area	VSF	Bus No	Bus Name	Area	VSF
V1100	4BABAESK	1	0.00110	V1203	4HABIPLR	2	0.00233
V1101	4UNIMRDG	1	0.00107	V1204	AKSARY_A	2	0.00149
V1102	4HAMIT	1	0.00112	V1206	AMBAR_2A	2	0.00126
V1103	BABAESKI	1	0.00100	V1207	AMBAR_2B	2	0.00108
V1104	TRAKYADG	1	0.00037	V1208	ATISALNA	2	0.00194
V1105	BOTASME	1	0.00037	V1209	BAGCILRB	2	0.00150
V1106	B.CEKMEC	1	0.00103	V1210	B.DUZU	2	0.00123
V1107	B.KARIST	1	0.00059	V1211	DAVUTPSA	2	0.00150
V1108	CERKEZKO	1	0.00051	V1212	ESENYURT	2	0.00117
V1109	CORLU	1	0.00056	V1213	ETILER	2	0.00256
V1110	EDIRNE	1	0.00103	V1214	ALIBEY_A	2	0.00218
V1111	EDIRNECM	1	0.00103	V1215	ALIBEY_B	2	0.00256
V1112	GELIBOLU	1	0.00076	V1216	HADIMKOY	2	0.00130
V1113	HAMIT	1	0.00084	V1217	IKITEL_A	2	0.00180
V1114	HAVSA	1	0.00102	V1218	IKITEL_B	2	0.00149
V1115	KESAN	1	0.00076	V1219	HABIP_A	2	0.00142
V1116	KIRKLARE	1	0.00102	V1220	KASIMPAS	2	0.00218
V1117	KIYIKOY	1	0.00051	V1221	KUCUKKOA	2	0.00220
V1118	K.LIMANI	1	0.00077	V1222	LEVENT	2	0.00256
V1119	LULEBURG	1	0.00080	V1223	MASLAK	2	0.00256
V1120	MALKARA	1	0.00075	V1224	SAGMALCI	2	0.00158
V1121	PINARHIS	1	0.00102	V1225	SILAHTAR	2	0.00257
V1122	TEGESAN	1	0.00049	V1226	SISLI_A	2	0.00257
V1123	TEKIRDAG	1	0.00057	V1227	S.MURAT	2	0.00145
V1124	UZUNKOP	1	0.00088	V1228	TOPKAP_B	2	0.00149
V1125	SILIVRI	1	0.00064	V1229	TOPKAP_A	2	0.00155
V1127	ULAS	1	0.00056	V1230	VELIEFEA	2	0.00150
V1129	AKCANSA	1	0.00103	V1231	YILDIZ_A	2	0.00218
V1131	4KAPTAN	1	0.00107	V1232	YILDIZ_B	2	0.00257
V1133	ZORLULUL	1	0.00058	V1233	AMBARFO	2	0.00129
V1200	4AMBARLI	2	0.00153	V1234	Y.BOSN_B	2	0.00139
V1201	4ALIBEY	2	0.00237	V1236	Y.BOSN_A	2	0.00150
V1202	4IKITELL	2	0.00191	V1237	VELIEFEB	2	0.00144

V1238	HABIP_B	2	0.00226	V1335	UMRANIYE	3	0.00282
V1239	BAHCELI	2	0.00150	V1336	VANIKOY	3	0.00282
V1240	ICDAS	2	0.00132	V1337	YARIMCA1	3	0.00323
V1241	BAHCESEH	2	0.00125	V1338	YARIMCA2	3	0.00339
V1242	TASOLUK	2	0.00143	V1339	GOZTEPE	3	0.00279
V1243	4YILDIZ	2	0.00236	V1340	BUYUKBKA	3	0.00264
V1244	ALTINTP	2	0.00218	V1342	ENERJISA	3	0.00263
V1245	BAGCILRA	2	0.00151	V1343	4ADAPADG	3	0.00358
V1248	4ATISALA	2	0.00209	V1344	ICMELER	3	0.00213
V1249	ATISALNB	2	0.00160	V1346	KUZULUK	3	0.00376
V1253	YENIKAPI	2	0.00147	V1347	GEBZEOSB	3	0.00206
V1254	AKSAHADI	2	0.00130	V1348	HYNDAI	3	0.00329
V1300	4ADAPAZA	3	0.00411	V1349	ADAPAZ_B	3	0.00336
V1303	4AKYAC3	3	0.00339	V1350	COLAK_B	3	0.00163
V1304	4AKYAC4	3	0.00388	V1351	GEBZE_B	3	0.00311
V1305	4GEBZE	3	0.00321	V1352	PASAKO_B	3	0.00270
V1306	4OSMANCA	3	0.00340	V1353	SAKARYA	3	0.00336
V1307	4PASAKOY	3	0.00286	V1354	ISAKOY	3	0.00313
V1308	4UMRANIY	3	0.00291	V1355	FORDOTO	3	0.00296
V1309	ADAPAZA3	3	0.00426	V1356	BOLUCIM	3	0.00278
V1310	ADAPAZ_A	3	0.00439	V1358	4IZMIT	3	0.00475
V1311	AKCAKOCA	3	0.00267	V1359	EDISON	3	0.00256
V1312	BOLU	3	0.00286	V1361	AYRILCES	3	0.00280
V1313	BOLU2	3	0.00280	V1362	ISTMALTP	3	0.00251
V1314	COLAK_A	3	0.00148	V1399	4GEBZEDG	3	0.00360
V1315	DILISKEL	3	0.00170	V1400	4BURSA	4	0.01015
V1316	DUDULLU	3	0.00295	V1401	AKCALAR	4	0.01261
V1317	GEBZE_A	3	0.00229	V1402	ASILCELI	4	0.00428
V1318	HENDEK	3	0.00398	V1403	BURSA3	4	0.00506
V1319	IZMIT1	3	0.00274	V1404	BURSAMER	4	0.00534
V1320	KARASU	3	0.00331	V1405	BURSSN_A	4	0.00868
V1321	KARTAL	3	0.00239	V1406	DEMIRTAS	4	0.00398
V1322	KAYNARCA	3	0.00337	V1407	DOKTAS	4	0.00432
V1323	KAYNASLI	3	0.00309	V1408	GEMLIK	4	0.00438
V1324	KOSEKOY	3	0.00276	V1409	INEGOL	4	0.00702
V1325	KUCUKBAK	3	0.00277	V1410	KARAMURS	4	0.00335
V1326	KURTKOY	3	0.00235	V1412	KESTEL	4	0.00541
V1327	K.CELIK	3	0.00192	V1413	M.KEMALP	4	0.01496
V1328	MUDURNU	3	0.00323	V1414	ORHANELI	4	0.01053
V1329	NUHCIM	3	0.00298	V1415	YALOVA	4	0.00403
V1330	OSMANCA	3	0.00326	V1416	YENISEHI	4	0.00565
V1331	SELIMIYE	3	0.00281	V1417	4BURSADG	4	0.00787
V1332	SILE	3	0.00313	V1418	BURSDG_A	4	0.00370
V1333	SOGANLIK	3	0.00265	V1419	OTOSANST	4	0.00467
V1334	TUZLA	3	0.00195	V1420	BESEVLER	4	0.00882

V1423	GORUKLE	4	0.01006	V1620	TUNCBL_A	6	0.00952
V1424	KARACABY	4	0.01443	V1621	YENICEHS	6	0.00442
V1425	ENTEK	4	0.00356	V1622	YENITUNC	6	0.01333
V1426	BURSDG_B	4	0.00411	V1623	Y.GEDIZ	6	0.02302
V1427	BURSSN_B	4	0.00583	V1624	ESKISEH3	6	0.00656
V1435	BOSEN	4	0.00567	V1625	PAMUKOVA	6	0.00520
V1500	4BALIKES	5	0.02498	V1626	SIMAV	6	0.02323
V1501	BALIKES2	5	0.02683	V1628	AKBOZUYU	6	0.00510
V1502	BALIKESI	5	0.03116	V1700	4ALIAGA	7	0.04150
V1503	BALISEKA	5	0.03307	V1701	4ISIKLAR	7	0.04241
V1504	BANDIRM3	5	0.02018	V1702	4UZUNDER	7	0.04458
V1505	BANDIRM2	5	0.02191	V1703	ALACATI	7	0.05076
V1506	BIGA	5	0.02881	V1704	ALCUK	7	0.04251
V1507	CAN	5	0.03072	V1705	ALIAGA_A	7	0.04246
V1508	CANAKCMT	5	0.03438	V1706	ALIAGA_B	7	0.04575
V1509	CANAKKAL	5	0.03419	V1707	ALMAK	7	0.04252
V1510	AKCAY	5	0.03745	V1708	ARSLANLA	7	0.05355
V1511	EDREMIT2	5	0.03759	V1709	BORNOVA	7	0.04857
V1512	EZINE	5	0.03488	V1710	BOSTANLI	7	0.04715
V1513	GOBEL	5	0.01654	V1711	BOZYAKA	7	0.04918
V1514	GONEN	5	0.02920	V1712	BUCA	7	0.04909
V1515	NARLIKOY	5	0.02383	V1713	BAHRIBAB	7	0.04920
V1516	CANTS	5	0.03072	V1714	EBSO	7	0.04682
V1517	CANENJSA	5	0.03438	V1715	G.YALI	7	0.04913
V1518	4KARABIG	5	0.00800	V1716	HABAS	7	0.04248
V1600	4SEYITOM	6	0.01470	V1717	EGEMETAL	7	0.04246
V1601	4TUNCBIL	6	0.01318	V1718	HATAY	7	0.04917
V1602	ALPU	6	0.00701	V1719	HILAL	7	0.04925
V1603	ALTINTAS	6	0.01319	V1720	ILICA	7	0.04912
V1604	BIGADIC	6	0.02450	V1721	ISIKLA_A	7	0.04898
V1605	BILORSA	6	0.00641	V1723	KARSIYAK	7	0.04715
V1606	BOZUYUK	6	0.00523	V1724	K.BAGLAR	7	0.04905
V1607	CIFTELER	6	0.00766	V1725	K.PASA	7	0.04719
V1608	DEMIRCI	6	0.02327	V1726	ODEMIS	7	0.05617
V1609	DURSUNBE	6	0.02047	V1727	PETKIM2	7	0.04564
V1610	EMET	6	0.01748	V1728	PIYALE	7	0.04859
V1611	ESKISEH1	6	0.00666	V1729	SEMIKLER	7	0.04712
V1612	ESKISEH2	6	0.00653	V1730	TAHTALI	7	0.04942
V1613	KIRKA	6	0.00836	V1731	TIRE	7	0.05565
V1614	KUTAHYA	6	0.01062	V1732	ULUCAK	7	0.04680
V1615	K.AZOT	6	0.01062	V1733	URLA	7	0.05042
V1616	PASALAR	6	0.00582	V1734	UZUNDERE	7	0.04895
V1617	SEYITOME	6	0.00919	V1735	VIKING	7	0.04486
V1618	SOGUT	6	0.00549	V1737	UNIVERSI	7	0.04771
V1619	TUNCBL_B	6	0.01318	V1738	4ALIADG	7	0.04151

V1740	ALIAGOSB	7	0.04349	V1926	SARAYKOY	9	0.04852
V1741	ISIKLA_B	7	0.04741	V1927	SOKE	9	0.05568
V1742	ALIAGA2	7	0.04583	V1928	TEFENNI	9	0.04705
V1743	HABAS2	7	0.04247	V1929	YATAGAN	9	0.05157
V1800	4SOMA	8	0.03296	V1930	YENIKOY	9	0.05029
V1801	AKHISAR	8	0.04110	V1931	4DENIZLI	9	0.04406
V1802	ALASEHIR	8	0.04343	V1932	DENIZLI	9	0.04793
V1803	AYVALIK	8	0.03958	V1934	TAVAS	9	0.04992
V1804	BERGAMA	8	0.03997	V1937	CINE	9	0.05366
V1805	DEMIRKOP	8	0.04420	V1938	ESEN2	9	0.05035
V1806	MANISA	8	0.04684	V2000	4OYMAPIN	10	0.03075
V1807	MANISOSB	8	0.04743	V2001	4VARSAK	10	0.03799
V1808	SALIHLI	8	0.04522	V2002	AKSU	10	0.04441
V1809	SOMA_B	8	0.03615	V2003	ALANYA1	10	0.03790
V1810	TURGUTLU	8	0.04670	V2004	ANT.OSB	10	0.04372
V1811	USAK	8	0.02538	V2005	ANT.SB	10	0.04424
V1812	SARUHANL	8	0.04546	V2006	A.KEMER	10	0.04510
V1813	USAKOSB	8	0.02941	V2007	BELEK	10	0.04524
V1814	SOMA_A	8	0.03629	V2008	FERROKRM	10	0.04382
V1900	4KEMERKO	9	0.04576	V2009	FINIKE	10	0.04718
V1901	4YATAGAN	9	0.04547	V2011	KEPEZHS	10	0.04382
V1902	4YENIKOY	9	0.04587	V2012	MANAVGAT	10	0.03594
V1903	ACIPAYAM	9	0.04765	V2013	OYMAPINA	10	0.03461
V1904	ADIGUZEL	9	0.04638	V2014	VARSAK	10	0.04360
V1905	AKBUK	9	0.05229	V2018	KAS	10	0.04878
V1906	AYDIN	9	0.05535	V2100	4ADANA	11	0.00669
V1907	BODRUM	9	0.05248	V2101	4ERZIN	11	0.00532
V1908	BOZKURT	9	0.04727	V2102	AKBELEN	11	0.00425
V1909	CIVRIL	9	0.04525	V2104	ANAMUR	11	0.01065
V1910	DALAMAN	9	0.05005	V2105	ANTAKYA1	11	0.00383
V1911	DATCA	9	0.05388	V2106	ANTAKYA2	11	0.00382
V1912	DENIZCIM	9	0.04785	V2107	ASLANTAS	11	0.00288
V1913	DENIZLI2	9	0.04827	V2108	BAHCE	11	0.00256
V1914	DENIZLI3	9	0.04867	V2109	BERKEHS	11	0.00214
V1915	FETHIYE	9	0.05045	V2110	CATALAN	11	0.00215
V1916	GERMENCI	9	0.05514	V2111	CEYHAN1	11	0.00400
V1917	JEOTERMA	9	0.04852	V2112	CEYHAN2	11	0.00388
V1918	KEMERHS	9	0.05196	V2113	CIHADIYE	11	0.00495
V1919	KEMERKOY	9	0.05030	V2114	ERDEMLI	11	0.00441
V1920	KORKUTEL	9	0.04568	V2115	ERZIN_A	11	0.00389
V1921	KUSADASI	9	0.05577	V2116	ISDEMIRA	11	0.00366
V1922	MARMARIS	9	0.05359	V2117	IKIZLER	11	0.00376
V1923	MILAS	9	0.05162	V2118	INCIRLIK	11	0.00462
V1924	MUGLA	9	0.05171	V2119	ISKENDE1	11	0.00376
V1925	NAZILLI	9	0.05287	V2120	ISKENDE2	11	0.00377

V2122	KADINCI1	11	0.00419	V2210	BASTAS	12	0.00360
V2123	KADINCI2	11	0.00418	V2211	BEYLIKKO	12	0.01420
V2124	KADIRLI	11	0.00277	V2212	BEYPAZAR	12	0.00284
V2125	KARAHAN	11	0.00401	V2213	CANKAYA	12	0.00391
V2126	KARAISA	11	0.00295	V2214	CAYIRHAN	12	0.00260
V2127	KOZAN	11	0.00319	V2215	EMIRLER	12	0.00392
V2128	MISIS	11	0.00437	V2216	ESENBOGA	12	0.00343
V2129	M.TERMIK	11	0.00387	V2217	4BAGLUM	12	0.00322
V2130	NACARLI	11	0.00366	V2218	GOLBASI	12	0.00391
V2131	OSMANIYE	11	0.00358	V2219	HACILAR	12	0.00362
V2132	PAYAS	11	0.00368	V2220	KALECIK	12	0.00335
V2133	ADANA	11	0.00500	V2221	KAPULUKA	12	0.00360
V2134	SEYHAN	11	0.00376	V2222	KIRIKKAL	12	0.00365
V2135	SIRHS	11	0.00194	V2223	MACUNKOY	12	0.00346
V2136	TARSUS	11	0.00343	V2224	MALTEPE1	12	0.00349
V2137	TASUCU	11	0.00603	V2225	MALTEPE2	12	0.00363
V2138	TOROSLAR	11	0.00446	V2226	MAMAK	12	0.00353
V2139	YAKAKOY	11	0.00368	V2227	OVACIK	12	0.00346
V2140	YUMURTA	11	0.00388	V2228	POLATLI	12	0.01123
V2141	ZEYTINLI	11	0.00294	V2229	SARIYAR	12	0.00232
V2142	4SUGOZU	11	0.00584	V2230	SINCAN_A	12	0.00340
V2143	BADANA66	11	0.00411	V2231	UMITKOY	12	0.00317
V2145	INCIR66	11	0.00458	V2233	IMRAHO_A	12	0.00392
V2146	D.ADNA66	11	0.00424	V2234	SINCAN_B	12	0.00334
V2147	SEYHAN66	11	0.00410	V2235	TEMELI_A	12	0.00613
V2148	SEHIT66	11	0.00412	V2236	TEMELI_B	12	0.00223
V2149	TARSUS66	11	0.00399	V2239	BEYLKDDY	12	0.01420
V2150	M.TERM66	11	0.00400	V2240	SAZAK	12	0.01421
V2152	YK_ENJSA	11	0.00368	V2241	K.KALEMB	12	0.00367
V2153	G.ADANA	11	0.00482	V2242	IMRAHO_B	12	0.00356
V2156	MERSIN2	11	0.00425	V2244	BSTASDMY	12	0.00360
V2158	ZY_ENJSA	11	0.00275	V2245	SNCNZORL	12	0.00334
V2159	YAZICI	11	0.00378	V2300	4CAKAYA1	13	0.00131
V2161	MRSNTR66	11	0.00417	V2301	4CAKAYA2	13	0.00065
V2162	YUREGI66	11	0.00464	V2302	4CAKAYA3	13	0.00231
V2163	MIHMAN66	11	0.00478	V2303	4CANKIRI	13	0.00241
V2167	TASUSEKA	11	0.00603	V2304	4KAYABAS	13	0.00201
V2200	4CAYIRHA	12	0.00263	V2305	AKDAGMAD	13	0.00271
V2201	4GOKCEKA	12	0.00745	V2306	ALACA	13	0.00300
V2202	4GOLBASI	12	0.00396	V2307	ALMUS	13	0.00092
V2205	4SINCAN	12	0.00357	V2308	AMASYA	13	0.00220
V2206	4TEMELLI	12	0.00415	V2309	BOGAZLIY	13	0.00446
V2207	AKKOPRU	12	0.00349	V2310	CANKIRI2	13	0.00269
V2208	ANKARASA	12	0.00343	V2311	CORUM	13	0.00245
V2209	BALGAT	12	0.00363	V2312	CORUM2	13	0.00257

V2313	ERBAA	13	0.00095	V2431	TAKSAN	14	0.00431
V2314	KAYABASI	13	0.00220	V2432	TUMOSAN	14	0.00480
V2315	KOKLUCE	13	0.00064	V2433	YESILHIS	14	0.00490
V2316	KURSUNLU	13	0.00254	V2434	CAMLICA1	14	0.00404
V2317	SARKISLA	13	0.00314	V2435	DERINKUY	14	0.00471
V2318	SIZIR	13	0.00314	V2436	KESDUMY1	14	0.00401
V2319	SORGUN	13	0.00341	V2437	KESDUMY2	14	0.00402
V2320	TOKAT	13	0.00161	V2438	ZORLUKYS	14	0.00403
V2321	TURHAL	13	0.00195	V2500	4CASEYDI	15	0.02637
V2322	YERKOY	13	0.00371	V2501	4SEYDISE	15	0.02111
V2323	YIBITAS	13	0.00354	V2502	AKSEKI	15	0.02234
V2324	YOZGAT	13	0.00339	V2503	CIHANBEY	15	0.01062
V2325	TOKATOSB	13	0.00172	V2504	LADIK	15	0.01692
V2327	YAMULA	13	0.00409	V2505	CUMRA	15	0.02008
V2400	4AGACC1	14	0.00393	V2506	GEZENDE	15	0.01598
V2401	4AGACC2	14	0.00655	V2507	KARAMAN	15	0.01922
V2402	4AGACC3	14	0.00393	V2508	KARAPINR	15	0.02001
V2403	4AGACC4	14	0.00655	V2509	KONYA1	15	0.02059
V2404	4AVANOS	14	0.00291	V2510	KONYA2	15	0.02048
V2405	4AVANOS2	14	0.00302	V2511	KONYA3	15	0.01931
V2406	4CAAVAN1	14	0.00361	V2512	K.EREGLI	15	0.02006
V2407	4CAAVAN2	14	0.00216	V2513	SEYDISEH	15	0.02230
V2408	4CAAVAN3	14	0.00238	V2516	ALTINEKI	15	0.01405
V2409	4CAAVAN4	14	0.00362	V2517	KARASI66	15	0.02035
V2410	4CAKAYS1	14	0.00268	V2518	4KONYA	15	0.01677
V2411	4CAKAYS2	14	0.00268	V2519	KONYA4	15	0.01945
V2412	4KAYSERI	14	0.00327	V2520	KIZOREN	15	0.01967
V2413	4YESILHI	14	0.00562	V2521	KARAMOSB	15	0.01940
V2414	AVANOS	14	0.00432	V2522	BEYSEHIR	15	0.02360
V2415	BOR	14	0.00475	V2524	AB.HOY	15	0.02047
V2416	CINKUR	14	0.00408	V2525	AB.HOY66	15	0.02033
V2417	HIRFANLI	14	0.00437	V2526	GOKSU66	15	0.02037
V2418	KALABA	14	0.00441	V2527	BIRKAPIL	15	0.01599
V2419	KAYSEKAP	14	0.00371	V2600	AFYON	16	0.01439
V2420	KAYSERI1	14	0.00393	V2601	AFYON2	16	0.03230
V2421	KAYSERI2	14	0.00386	V2602	AKSEHIR	16	0.02510
V2422	KAYSESAN	14	0.00403	V2603	BARLA	16	0.00710
V2423	KESIKKOP	14	0.00399	V2604	BUCAK	16	0.00380
V2424	KIRSEHIR	14	0.00415	V2605	BURDUR	16	0.00522
V2425	MISLIOVA	14	0.00480	V2606	CAYSEKA	16	0.03243
V2426	NEVSEHI2	14	0.00434	V2607	EGIRDIR	16	0.00544
V2427	NIGDE	14	0.00481	V2608	EMIRDAG	16	0.02599
V2428	PETLAS	14	0.00418	V2609	ISPARTA	16	0.00598
V2429	SENDIREM	14	0.00452	V2610	KARACAO1	16	0.00267
V2430	S.KOCHIS	14	0.00452	V2611	KECIBOR	16	0.00523

V2612	KOVADA2	16	0.00396	V2740	SAMSUN3	17	0.00105
V2613	KULEONU	16	0.00635	V2745	YENICA66	17	0.00107
V2614	SANDIKLI	16	0.04038	V2748	INEBOLU	17	0.00169
V2615	S.K.AGAC	16	0.02521	V2749	CAYCUM66	17	0.00122
V2616	YUNAK	16	0.02535	V2750	KARABU66	17	0.00150
V2618	KARACAO2	16	0.00235	V2751	KOPRUBAS	17	0.00263
V2623	4AFYON	16	0.01880	V2752	KASTAOSB	17	0.00186
V2700	ONDOKMAY	17	0.00110	V2800	4TIREBOL	18	0.00103
V2701	4ALTINKA	17	0.00114	V2801	ARDESEN	18	0.00085
V2702	4CARSAMB	17	0.00106	V2802	ARSIN	18	0.00102
V2703	4EREGLI	17	0.00303	V2803	ARTVIN	18	0.00107
V2704	4H.UGUR	17	0.00099	V2804	CAKMAKKA	18	0.00088
V2705	ALTINKAY	17	0.00108	V2805	CAYELI	18	0.00091
V2706	AYANCIK	17	0.00148	V2806	DOGANKEN	18	0.00099
V2707	BAFRA	17	0.00109	V2807	GIRESUN	18	0.00105
V2708	BARTIN	17	0.00100	V2808	GOLKOY	18	0.00105
V2709	BOYABAT	17	0.00209	V2809	HOPA	18	0.00069
V2710	CARSAMBA	17	0.00098	V2810	IYIDERE	18	0.00098
V2711	CAYCUMA	17	0.00101	V2811	KURTUNHS	18	0.00105
V2712	CIDE	17	0.00133	V2812	OLTU	18	0.00102
V2713	DERBNTHS	17	0.00104	V2813	ORDU	18	0.00104
V2714	ERDEMIR	17	0.00168	V2814	RIZE	18	0.00102
V2715	EREGLI2	17	0.00175	V2815	TIREBOL2	18	0.00104
V2716	GERKONSA	17	0.00248	V2816	TORTUM	18	0.00102
V2717	ISMETPAS	17	0.00225	V2817	TORTUM66	18	0.00089
V2718	KARABUK	17	0.00180	V2819	TRABZON	18	0.00103
V2719	KARGI	17	0.00224	V2820	UNYE	18	0.00103
V2720	KASTAMON	17	0.00200	V2821	FATSA	18	0.00103
V2721	KURE	17	0.00170	V2826	MURATLI	18	0.00054
V2722	LACIM	17	0.00168	V2831	IKIZDE66	18	0.00042
V2723	MERZIFON	17	0.00214	V2832	IYIDER66	18	0.00073
V2724	SAFRANBO	17	0.00167	V2835	UZDMY166	18	0.00089
V2725	SAMSUN1	17	0.00110	V2841	UZUNDR66	18	0.00094
V2726	SAMSUN2	17	0.00105	V2900	4ERZURUM	19	0.00205
V2727	SINOP	17	0.00137	V2901	AGRI	19	0.00270
V2728	S.UGURLU	17	0.00092	V2902	ARDAHAN	19	0.00151
V2729	TASKOPRU	17	0.00205	V2903	ASKALE	19	0.00190
V2730	TOSYA	17	0.00227	V2904	BAYBURT	19	0.00166
V2731	VEZIRKOP	17	0.00213	V2905	CILDIR	19	0.00191
V2732	YENICATA	17	0.00076	V2906	DOGUBEYA	19	0.00258
V2733	ZONGULDA	17	0.00076	V2907	ERZINCAN	19	0.00185
V2735	ERDEMIR2	17	0.00175	V2908	CAMLIGOZ	19	0.00085
V2737	AKSAMB	17	0.00105	V2909	ERZURUM	19	0.00202
V2738	EREGLI66	17	0.00175	V2910	ERZURUM2	19	0.00205
V2739	CENGIZMB	17	0.00105	V2911	ERZ.OSB	19	0.00091

V2912	GUMUSHAN	19	0.00175	V3032	KAHTA	20	0.00381
V2914	HINIS	19	0.00203	V3033	KANGAL	20	0.00203
V2915	HORASAN	19	0.00211	V3034	KARAKAYA	20	0.00288
V2916	IGDIR	19	0.00251	V3035	KEBAN	20	0.00220
V2917	KARS	19	0.00213	V3036	KILAVUZ	20	0.00420
V2918	KILICKAY	19	0.00085	V3037	KILIS	20	0.00479
V2919	KUZGUNHS	19	0.00195	V3038	KIZILTEP	20	0.00415
V2920	PULUMUR	19	0.00189	V3039	K.MARAS	20	0.00429
V2921	REFAHIYE	19	0.00091	V3040	MALATYA	20	0.00347
V2922	SUSEHRI	19	0.00090	V3041	MALATYA2	20	0.00327
V2923	TERCAN	19	0.00190	V3042	MALORSA	20	0.00375
V2926	ERZURU66	19	0.00119	V3043	MENZELET	20	0.00409
V2927	ASKALECM	19	0.00190	V3044	NARLI	20	0.00446
V3000	4ANDIRIN	20	0.00408	V3045	PINARBAS	20	0.00279
V3001	4ATATURK	20	0.00424	V3046	PS4A	20	0.00428
V3002	4ELBIS	20	0.00252	V3047	PS4B	20	0.00446
V3003	4ELBIS2	20	0.00267	V3048	PS5	20	0.00463
V3004	4GOKCA1	20	0.00613	V3049	SIVAS	20	0.00181
V3005	4GOKCA2	20	0.00419	V3050	SIVEREK	20	0.00363
V3006	4GOKCA3	20	0.00613	V3051	SURUC	20	0.00470
V3007	4GOKCA4	20	0.00419	V3052	S.URFA	20	0.00458
V3008	4G.ANTEP	20	0.00451	V3053	TELHAMUT	20	0.00460
V3009	4KANGAL	20	0.00177	V3054	URFACIM	20	0.00455
V3010	4KARAKAY	20	0.00254	V3055	VIRANSEH	20	0.00453
V3011	4KEBAN	20	0.00190	V3056	YARDIMCI	20	0.00470
V3012	4SIVAS	20	0.00192	V3057	ZARA	20	0.00140
V3013	ADIYACMT	20	0.00428	V3058	URFAHES	20	0.00451
V3014	ADIYAMAN	20	0.00413	V3059	4URFA	20	0.00414
V3015	AKCAKALE	20	0.00474	V3060	DOGANKOY	20	0.00432
V3016	ANDIRIN	20	0.00252	V3061	KARKAMIS	20	0.00462
V3017	ATATURK	20	0.00442	V3062	KILILI	20	0.00428
V3018	ATATURK1	20	0.00438	V3063	SURFAOSB	20	0.00462
V3019	A.GOLBAS	20	0.00412	V3064	BIRECKHS	20	0.00461
V3020	BIRECIK	20	0.00462	V3065	4BIRECIK	20	0.00432
V3021	CIRCIP	20	0.00453	V3066	4KIZILTP	20	0.00363
V3022	DARENDE	20	0.00262	V3067	DIKMEN	20	0.00416
V3023	DEMIRDAG	20	0.00190	V3068	ELB_BTES	20	0.00279
V3024	ELBISTAN	20	0.00276	V3069	4KEBANHS	20	0.00183
V3025	FEVZIPAS	20	0.00337	V3070	4ELBS2TS	20	0.00262
V3026	G.ANTEP1	20	0.00474	V3073	PEKMEZLI	20	0.00468
V3027	GOKSUN	20	0.00337	V3074	4HILVAN	20	0.00337
V3028	G.ANTEP2	20	0.00472	V3076	KISIK	20	0.00395
V3029	G.ANTEP3	20	0.00475	V3077	KISIKDMY	20	0.00396
V3030	G.ANTEP4	20	0.00476	V3078	KIRLIK	20	0.00461
V3031	HASANCEL	20	0.00243	V3079	KARAKECI	20	0.00401

V3080	KARGILIK	20	0.00252
V3100	4DIYARBA	21	0.00287
V3101	4OZLUCE	21	0.00203
V3102	ADILCEVA	21	0.00350
V3103	BAGISLI	21	0.00391
V3104	BATMAN	21	0.00363
V3105	BATMANHS	21	0.00341
V3106	BINGOL	21	0.00273
V3107	DICLEHS	21	0.00185
V3108	DIYAR2	21	0.00305
V3109	DIYAR3	21	0.00297
V3110	DODAN	21	0.00377
V3111	ELAZIG	21	0.00235
V3112	ENGIL	21	0.00374
V3113	ERCIS	21	0.00339
V3114	ERGANI	21	0.00233
V3115	ETIFOSFA	21	0.00365
V3116	FERROKRO	21	0.00245
V3117	HAZAR1	21	0.00232
V3119	K.KIZIHS	21	0.00203
V3120	LICE	21	0.00305
V3121	MADEN	21	0.00233
V3122	MARDIN	21	0.00407
V3123	MERCAN	21	0.00180
V3124	MUS	21	0.00329
V3125	OZLUCE	21	0.00250
V3126	PS3	21	0.00421
V3127	PS3A	21	0.00407
V3128	PS4	21	0.00400
V3129	SIIRT	21	0.00383
V3130	SIIRTCIM	21	0.00380
V3131	TATVAN	21	0.00356
V3132	TUNCELI	21	0.00197
V3133	ULUDERE	21	0.00427
V3134	VAN	21	0.00367
V3135	CIZRE	21	0.00411
V3136	BISMIL	21	0.00334
V3137	CAG-CAG	21	0.00406
V3138	4BATMAN	21	0.00325
V3139	BATMAN2	21	0.00363
V3140	HAKKARI	21	0.00392
V3143	SILVAN	21	0.00335
V3145	KONAKTEP	21	0.00186
V3146	DIYAR4	21	0.00298
V3147	KHOLDING	21	0.00223
V3148	HAZAR2	21	0.00231
V3149	KHOLDUMY	21	0.00223
V3150	UZUNCAYI	21	0.00210
V3151	SIRNAK	21	0.00410
V3156	4DUMYGRC	21	0.00340
V3159	BATMANMB	21	0.00362
V3160	KARKEY	21	0.00421