Analysis of Transmission Congestion Using Power-Flow Solutions

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Abstract: - Transmission congestion has become a new challenge in an open-access environment of electric transmission networks. In today's world, electric power networks have been so much loaded that such a case has never been observed before. Due to overloading, transmission lines of the networks are congested. Under these circumstances, management of transmission congestion is a crucial task for successful operation of power systems. Our specific problem is to detect load centers or cities that are not congested for power transmission from a specific power plant such as newly-built wind farms and small size hydro dams.

In this study, we analyze transmission congestion using power-flow solutions for various load and generation levels. Under the condition that additional generation is supplied and the corresponding load is demanded, we run the power-flow program that we have developed. After obtaining the base case solution of the power flow, we select a candidate bus from load buses to apply incremental changes in real and reactive power. In order to assess the real and reactive power capacities of the candidate bus, we plot the P-V curve and the Q-V curve for the candidate bus. As a result of this process, we have the real and reactive power capacities of the candidate bus and information about the congested parts of the power network. Therefore, we provide such information for power utilities to manage power efficiently and power marketers to sell power economically.

Keywords: **-** Transmission Congestion, Power Flow, P-V Curve, Q-V Curve, Deregulation

1 Introduction

Deregulation in electric power power industry has become very popular in many countries around the world, since energy resources are utilized efficiently without rigorous regulations and in an open-access environment, consumers are allowed to choose their provider for electric energy. Power flow due to increasing transactions can cause transmission lines to be overloaded. The inability of transmission lines to deliver power under some loading conditions is called transmission congestion. Increase in power demand and generation usually results in congestion unless transmission networks are upgraded or transactions are coordinated.

The vast information about transmission congestion has been reported by the US Department of Energy [1]. Economical impacts of congestion have been studied by many researchers [2]-[6]. However, this paper is concerned with the technical anaysis of the congestion based on the power flow through the transmission network.

Power generation from renewable energy sources has been increasing in the world. Therefore, electric power networks are grown up quickly. However, power transmission lines are not expanded as the same pace. When a new power plant is added to a power system, it may have positive or negative impacts, depending on where the new generator will be installed and what the new amount of its capacity will be [6]. By analysis of transmission congestion, we assess the impacts of a new generator or generators added to the system because of energy demand.

Deregulation sometimes results in congestion problems. In the current deregulated environment of power systems, many countries have been faced with the congestion problem, which may lead to various other problems such as voltage instability, blackouts, and machine hunting. Under these circumstances, information about congestion is indispensable.

Our specific problem is to detect load centers or cities that are not congested for power transmission from a specific power plant such as a newly-built wind farms, small size hydro dams. In this study, we use the 225-

bus system of Istanbul Region. For our research study, we need power-flow solutions of the given systems. In order to assess real and reactive power capacities of candidate buses from load buses, we draw P-V and Q-V curves of each candidate bus. As a result of this process, we have the real and reactive power limits of candidate buses and the congested parts of these power networks.

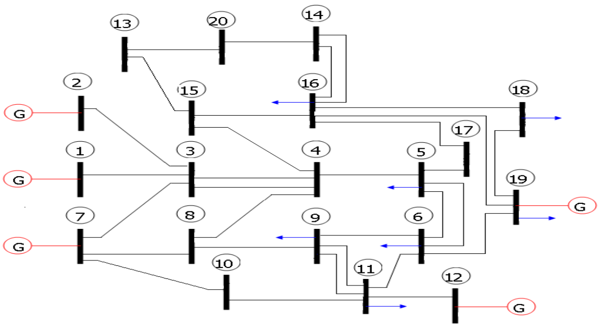

Figure 1-a. One-line diagram of a 20-bus system

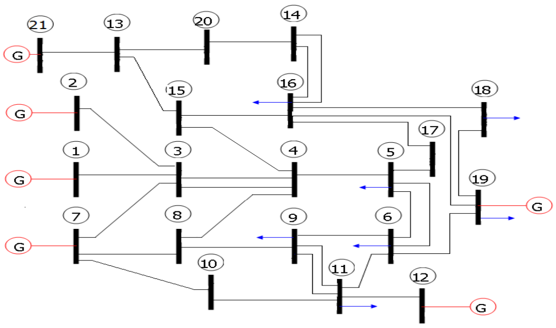

Figure 1-b. One-line diagram of the system with a new generator bus added

2 Methodologies

In this study, we use the 225-bus system of Istanbul Region. In Figure 2, one-line diagram of the 225-bus system of Istanbul Region is given. Our goal of this study is that how a power system is affected when a new generator is added to the system. To achieve what we promise for an extended power system with new additions, we first modify the power system data based on changes in demand, generation, and network. In order to do so, we add the new bus to the current network and increase the generation and demand. Subsequently, network and bus data are updated automatically. In this way, data become ready for running the power-flow program. Via this program, we reach the power-flow solutions. We code the power-flow program in MATLAB 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 with the tolerance of 0.001 p.u. Also note that the reactive power limits of generator buses are taken into account in the solutions [7], [8]. In Figure 3-a and 3-b, flowchart for power-flow program and Newton-Raphson algorithm is given.

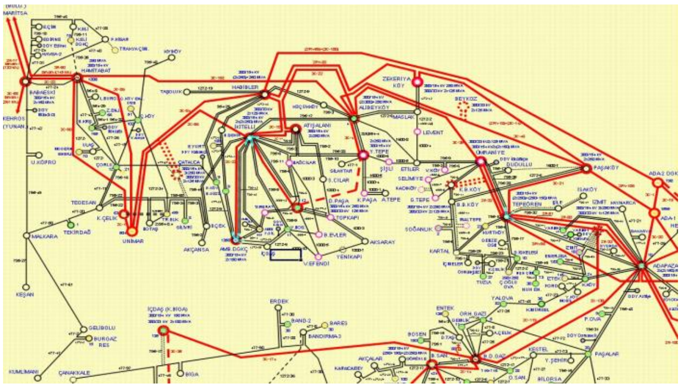

Figure 2. One-line diagram of the 225-bus system of Istanbul Region (Courtesy of TEİAŞ)

We assess the real and reactive power limits via P-V and Q-V curves. P-V and Q-V curves can be readily calculated using power-flow program. As a result of this process, we have the real and reactive power limits of candidate buses and the congested parts of these power networks. 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. In order to draw the P-V curve for a candidate bus, we increase real power by 0.75 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 [9]. Using these values, the P-V curve is drawn for the real power and the voltage magnitude 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. In Figure 3-c, flowchart for plotting P-V and Q-V curves is given.

In Figure 4-a and 4-b, using the methodology for generating P-V and Q-V curves which we discuss above, we generate P-V and Q-V curves for load bus 9 of the 225-bus system of Istanbul Region. The real and reactive power limits of this bus are easily obtained from these figures.

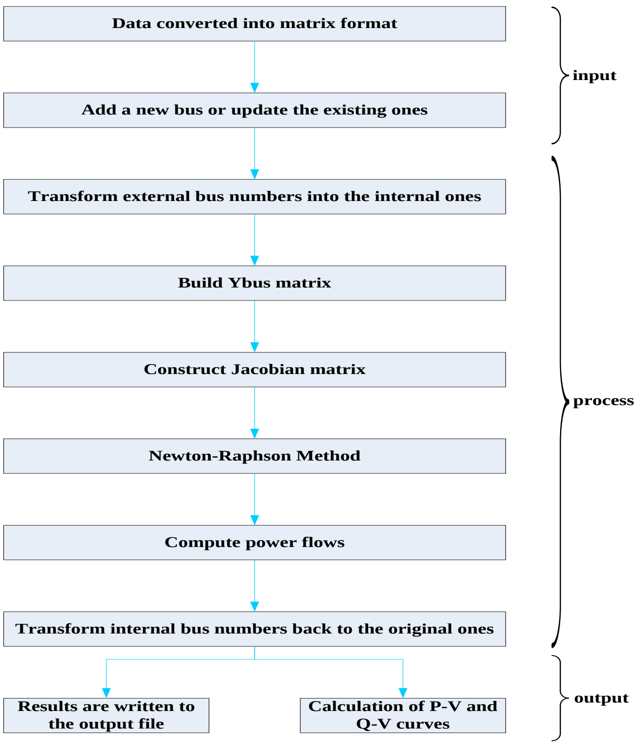

Figure 3-a. Flowchart for Power-Flow Program

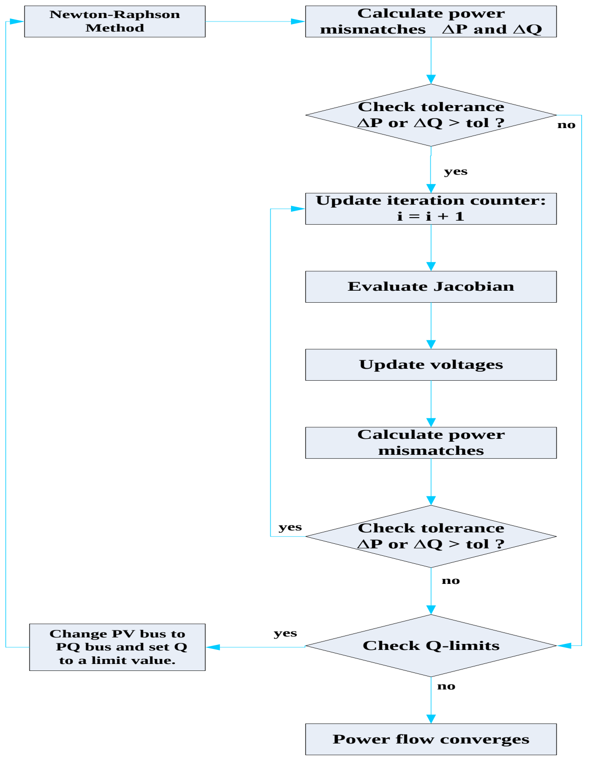

Figure 3-b. Flowchart for Newton-Raphson Algorithm

3 Conclusions

We observe the congestion effects of newly-added generator to the power system by this study. For example, a utility company would like to sell power to some load centers or cities. However, it is not that simple to transfer power between utility company regarding consumption centers if the transmission lines become congested under new loading conditions. In such a case, our study provides the utility company with the information that whether or not the transmission system turns out to be congested. This work provides information for utilities to manage the power grid effectively and power investors to invest in correct resources at correct places.

Throughout the power-flow solutions, we obtain interesting points after the nose in the P-V and Q-V curves of some buses. A general belief in power system management is that after a power-flow solution misses the convergency, the system solution does not converge again. However, the behavior of the points after the nose of the curve in the figures above is contrary to that general belief; interestingly enough, such convergence can occur after divergence. These results suggest us analyse these curves mathematically indetails to understand the behaviour of these points as a further study.

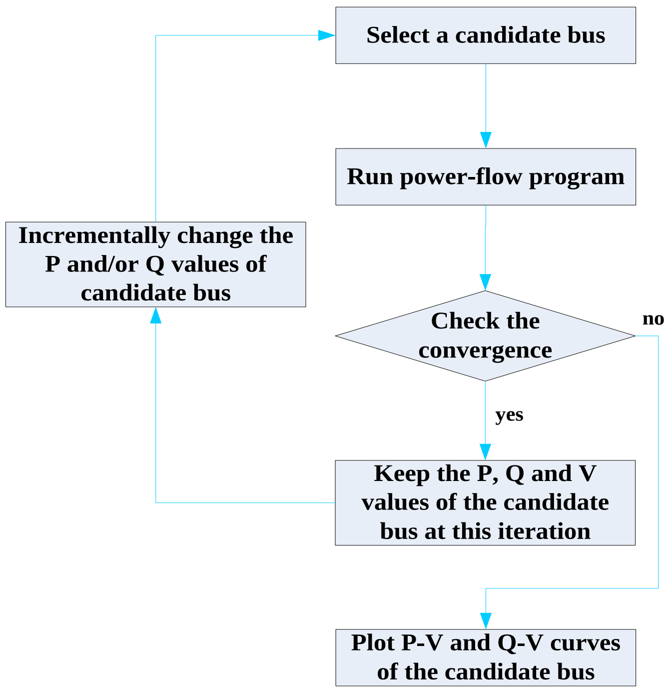

Figure 3-c. Flowchart for Plotting P-V and Q-V Curves

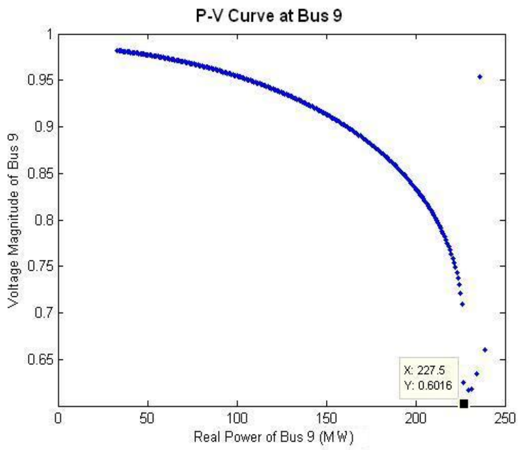

Figure 4-a. P-V Curve at Bus 9

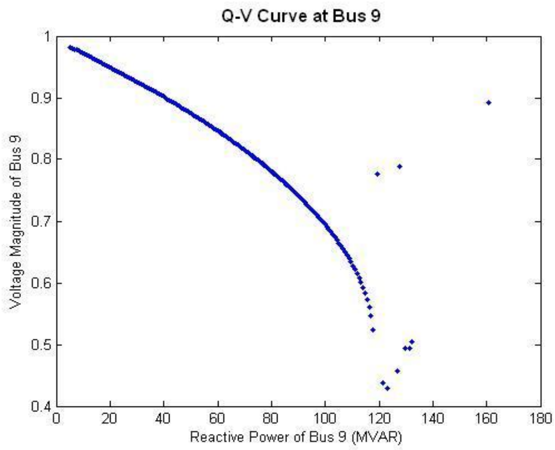

Figure 4-b. Q-V Curve at Bus 9

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