**Introduction**

In this work, a load flow analysis will be performed on a power system composed of 5 bars, 6 transmission lines and two reactive compensators. By means of two iterative methods, the system voltages will be determined for certain defined load values, and the results obtained by both methods will be compared. The use of the Newton-Raphson and Gauss-Seidel methods in power systems is quite famous for its simplicity and accuracy. However, both methods differ in the solutions offered and in the number of iterations required.

**Problem 1**

**Part i)**

The node admittance matrix is ​​known to be an essential factor in power system analysis since it represents "the skeleton" that composes it. Through this matrix, you can know the data of the lines, transformers, system size and other parameters of interest.

A transmission line impedance is defined basing on its resistance and reactance as:

The inverse of this values is known as the admittance as is defined as function of the conductance and susceptance:

The nodal admittance matrix, defined as a matrix that contains all the admittances of the system is defined as:

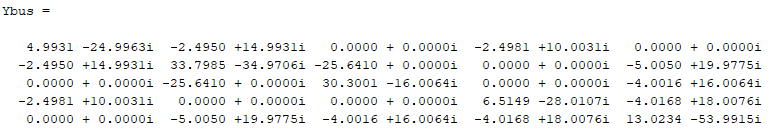
For where n is the number of buses in the system. is the equivalent admittance connected to the bus , while is the equivalent admittance of the line connected between the bus and , and is defined as:

For the 5-bus system studied in this paper, the nodal admittance matrix will ba a matrix of size . It’s important to know that the admittance for buses that doesn’t have a direct connection is zero. This is because between these buses, there is an open circuit, and an open circuit has an infinite impedance. So:

The 5-bus system nodal admittance matrix is:

It is important to know that the nodal admittance matrix is symmetrical. This because:

For the 5-bus system, the Ybus admittance matrix is the following:



**Part ii)**

Newton-Raphson method

For this part, only two iterations will be made using Newton-Raphson method. The following table presents the resulting voltages and generation after two iterations were made:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Bus** |  |  |  |  |  |  |  |
| 1 | 1.01 | 0.0 | 0.0 | 0.0 | 0.8517 | 0.3864 | 0.0 |
| 2 | 0.9915 | -0.0250 | 0.6 | 0.35 | 0.0 | 0.0 | 0.0 |
| 3 | 0.9756 | -0.0561 | 0.7 | 0.42 | 0.0 | 0.0 | 0.18 |
| 4 | 0.9853 | -0.0360 | 0.8 | 0.50 | 0.0 | 0.0 | 0.15 |
| 5 | 1.0 | -0.0184 | 0.65 | 0.36 | 1.9 | 0.9317 | 0.0 |

Gauss-Seidel method

The following results correspond to the solution of the 5-bus system after two iterations of the Gauss-Seidel method:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Bus** |  |  |  |  |  |  |  |
| 1 | 1.01 | 0.0 | 0.0 | 0.0 | 0.8820 | -0.0672 | 0.0 |
| 2 | 0.9796 | -0.0157 | 0.6 | 0.35 | 0.0 | 0.0 | 0.0 |
| 3 | 0.9539 | -0.0311 | 0.7 | 0.42 | 0.0 | 0.0 | 0.18 |
| 4 | 0.9857 | -0.0246 | 0.8 | 0.50 | 0.0 | 0.0 | 0.15 |
| 5 | 1.0 | -0.0056 | 0.65 | 0.36 | 1.9 | 1.4330 | 0.0 |

**Part ii)**

Newton-Raphson Method

The following results were obtained doing a Load Flow using the Newton-Raphson method. The parameters and resulting iterations are shown in the following table:

|  |  |  |
| --- | --- | --- |
| **Max. Iterations** | **Iterations Obtained** | **Tolerance** |
| 5000 | 7 |  |

The results of voltages, generation, angles, and all other desired parameters of the power system are:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Bus** |  |  |  |  |  |  |  |
| 1 | 1.01 | 0.0 | 0.0 | 0.0 | 0.8688 | 0.3947 | 0.0 |
| 2 | 0.9913 | -0.0258 | 0.6 | 0.35 | 0.0 | 0.0 | 0.0 |
| 3 | 0.9742 | -0.0581 | 0.7 | 0.42 | 0.0 | 0.0 | 0.18 |
| 4 | 0.9847 | -0.0370 | 0.8 | 0.50 | 0.0 | 0.0 | 0.15 |
| 5 | 1.0 | -0.0195 | 0.65 | 0.36 | 1.9 | 0.9865 | 0.0 |

The line flows are presented in the following table:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Line** |  |  |  |  |  |  |
| 1-2 | 0.4387 | -0.4361 | 0.0026 | 0.2235 | -0.2080 | 0.0154 |
| 1-4 | 0.4381 | -0.4319 | 0.0063 | 0.2824 | -0.2573 | 0.0251 |
| 2-3 | 1.0199 | -0.605 | 0.0593 | -0.6746 | 0.6746 | 0.0 |
| 2-5 | -0.1639 | 0.1645 | 0.000 | -0.1420 | 0.1442 | 0.0023 |
| 3-5 | -0.7 | 0.7138 | 0.0138 | -0.6 | 0.6552 | 0.0552 |
| 4-5 | -0.3681 | 0.3717 | 0.0036 | -0.3927 | 0.4088 | 0.0162 |

Gauss-Seidel Method

The following results were obtained doing a Load Flow using the Gauss-Seidel method. The parameters and resulting iterations are shown in the following table:

|  |  |  |
| --- | --- | --- |
| **Max. Iterations** | **Iterations Obtained** | **Tolerance** |
| 5000 | 68 |  |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Bus** |  |  |  |  |  |  |  |
| 1 | 1.01 | 0.0 | 0.0 | 0.0 | 0.8790 | 0.1824 | 0.0 |
| 2 | 0.9886 | -0.0911 | 0.6 | 0.35 | 0.0 | 0.0 | 0.0 |
| 3 | 0.9617 | -0.10 | 0.7 | 0.42 | 0.0 | 0.0 | 0.18 |
| 4 | 0.9839 | -0.0678 | 0.8 | 0.50 | 0.0 | 0.0 | 0.15 |
| 5 | 1.0 | -0.0675 | 0.65 | 0.36 | 1.9 | 1.1622 | 0.0 |

From the above tables it can be seen that the Newton-Raphson method converges fastest (in fewer iterations). The Newton-Raphson method, for a tolerance of converged in just 7 iterations while the Gauss-Seidel method, for the same tolerance, converged in 68 iterations (almost 10 times the number of iterations than Newton-Raphson).

The different approaches used by both methods require that one of them be more effective than another. In this work it was determined that the Newton-Raphson method is more effective when converges in fewer iterations. In addition, Newton-Raphson makes his analysis by using the Jacobian matrix, so the results obtained by this method are accepted as more accurate.

For planning, it’s required to known the technical/operational criteria of the system. For example, the limits of voltages, generators, reactive injection, etc. The voltage values are typically set at . This means that all the voltages of the system are between the range. However, the voltage of bus 3 is close to the lower bound, so a higher compensator is required in that bus.