Load Flow Analysis of Khwaja Fareed University of Engineering and Information Technology Rahimyar Khan, Pakistan

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Abstract—Load flow analysis is one of the most important aspects of power system planning and operation. To determine the magnitude of voltages, currents, real and reactive power at each node, load flow analysis is necessary. In the buses of the electrical networks, two parameters are known and two are unknown. To find these parameters the mathematical modeling is done. The Newton Raphson method is used for the solution of mathematical equations of these electrical networks. This method was chosen because it is most appropriate and widely used. Small electric networks can be analyzed by manual calculations but it is very difficult to analyze large electric networks by this method [18]. To analyses large electric networks we used PSS SINCALL software. The KFUEIT Rahim Yar Khan consist of two electrical networks i.e. current electric network and future electric network. These networks are modeled on PSS SINCAL software. In the current electric network six transformers of different ratings supplying power to the different departments of the university. The load profile of those departments are extracted by installing the PQ analyzer at all load points to examine the magnitude of real and reactive power is being consumed. On the base of our model results, we have also provided suggestion to compensate the reactive power. The future 1st phase of the electrical network will consist of twelve transformers. The independent feeder of 4.6 MW will feed the university in future. This thesis mainly focuses on the analysis of current electric network which is helpful in designing of future electric network of the university.

Keywords—Load flow analysis, Newton Raphson Method, PSS SINCALL, Real Power, Reactive Power.

I. INTRODUCTION

The Khwaja Fareed University of Engineering and Information Technology, Rahim Yar Khan was established in 2014, initially, university started its administrative operations and academic activities mainly in the premises of Government College of Technology, Rahim Yar Khan. Later, University moved to its own campus in January 2016 and at that time university construction was only 20% completed. Classes were conducted in admin block and university electricity plugged in with two transformers of 100 kVA. These transform-ers were supplying electricity to admin block, VC office, library, and cafeteria. With the passage of time, few buildings were completed like Civil block and Security office. So the demand of electricity of the university was increased. To meet this demand more transformers were installed in university. Currently, six transformers are supplying electric power to the different departments of university. Name of these transformers are labeled according to their position and demand for each department. Load on the cur-rent network has been increasing and in future, this network will not fulfill the demand of electricity of the university. To counter this problem, the administration of the university decided the future planning of electricity of the university. The NESPAC Company has modeled the electrical design of the university for future. In future 1st phase, 12 trans-formers will be installed. The university has two electrical networks i.e current and future electrical networks. Currently, the different departments of the university are electrically switched by 11 kV feeder having six transformers. In the future, different departments of the university will be electrically switched by an independent 11 kV feeder having twelve transformers. Load flow analysis is basically a numerical analysis of an interconnected system when power flow through the system. This analysis is performed for the
steady-state operation of power system whose target is to determine the magnitude of the voltages, current, phase angle, active and reactive power magnitude under given load condition. It is required for proper planning and the stable operation of the system [17]. The objective of load flow analysis is to reduce the operation cost, voltage magnitude on the buses remain close to the required limit and stability of system in all conditions. In this analysis the percentage or per unit system is used, by per unit system the overall AC power system parameter magnitude realization is easy, the AC parameters are active power, reactive power, voltage and voltage angles. For the solution of the power system, the admittance matrix is used because the sparse techniques in this matrix make this easy for calculations. Admittance matrix is easy to solve because many zeros are present in this matrix and this calculation is done on super or large computational computers with a number of iterations [7], [4]. We have modelled current and future electrical models on PSS SINCALL software. With the help of these electrical model results we have provided suggestion to compensate reactive power which is helpful to reduce electric bill of the university [5].

A. Literature review

To solve the interconnected electrical network, the mathematical model is necessary for its solution. So, mathematical modeling is a basic of load flow analysis, it is also used in optimal power flow, fault analysis and contingency analysis. The electrical network consist of transmission lines, generators and transformers. So, these networks elements have impedance. This electrical network consist of nodal admittance matrix or nodal impedance matrix. There are thousands of nodes in large electrical network, so a effective mathematical modeling is necessary [15]. These methods have great influence on describing and analyzing the modern power system. The nodal admittance matrix method is sparse and large. As there are a large number zeros in the nodal admittance method so computational effectiveness increments. In this analysis the percentage or per unit system is used, in per unit system the realization of magnitude of overall AC power system i.e active power, reactive power, voltage and voltage angles is easy. To solve the large matrix many techniques but two technique are widely used i.e Gauss Seidel and Newton Raphson. The most accurate and popular technique is Newton Raphson for the solution the power system [18]. A node in power system is connected with one or many lines or load or generators. In a power system network the bus is associated with the four quantities, active power, reactive power, voltage and phase angle of voltage [6]. The two parameters of bus are known and the remaining two are determined by the solution of equations. There are two methods to analyze the electric network and form the admittance matrix and impedance matrix i.e. Node Voltage method and Loop Current method. There are two methods to analyze the electric network and form the admittance matrix and impedance matrix i.e. Node Voltage method and Loop Current method. Nodal analysis provide a general procedure for analyzing circuits using node voltages as the circuits variables. In the nodal equation method, the network elements are often represented in admittance. The electrical network contain two generator, load and five nodes with six branches. The reference node is ground node and the equation are written by Kirchhoff current law [18]. Loop analysis provide another general procedure for analyzing circuits, using mesh current as the circuit variables. In the following the network shown in figure is used again to illustrate the basic principle of analyzing the electric network by the loop current equations. In the loop equation method, the network elements are often represented in impedance [18]. There are two different methods to solve the non-linear equations. Guass Seidal Method was named after the German mathematicians Carl Friedrich Gauss and was upgraded by Philipp Ludwig von Seidel. This method is defined for matrices with non-zero diagonal elements, but converges only if the matrix is either symmetric or positive definite or diagonally dominant [5]. The Gauss-Seidel (GS) technique is an iterative technique to solve a set of non-linear algebraic equations. Initially a solution vector is assumed [12]. The revised value of this particular variable is obtained by evaluating an equation by substituting in it the present values of other variables. The same procedure is followed for all other variables completing one full iteration. This process is then repeated till the solution vector converges within a permissible error limits. The degree of convergence is quite sensitive to the initial values that are assumed [1]. Newton Raphson Method was named after Isaac Newton and Joseph Raphson. The origin and formulation of Newton-Raphson method was dated back to late 1960s. It is an iterative method which approximates a set of non-linear simultaneous equations to a set of linear simultaneous equations using Taylor series expansion [11] and the terms are limited to the first approximation [16]. It is the most iterative method used for the load flow because its convergence characteristics are relatively more powerful compared to other alternative processes and the reliability of Newton-Raphson approach is comparatively good since it can solve cases that lead to divergence with other popular processes. If the assumed value is near the solution, then the result is obtained very quickly, but if the assumed value is farther away from the solution then the method may take longer to converge [13].

B. Methodology

We have used PSS SINCAL software in our project. Load flow analysis is the most important and essential approach to investigate the problems in power system operation and planning. Electrical networks consist of many nodes, transformers and different types of loads. To solve these networks many techniques are used i.e. Gauss-Seidel and Newton Raphson. In these techniques, many iterations performed for the accuracy of results. Fast or supercomputer required for computation process of large networks. In this project, N-R technique is used to solve the current and future network of the university. The software used in this project is PSS SINCAL which is invented by Siemens and it is simulation-based software. PSS SINCAL (SIEMENS Network Calculation) software provides us with extensive functions for the planning of different networks. The program has a number of highly specialized simulation methods for electrical network and pipe network that provide the best possible support when you create, interactively administer and analyze networks. He tool which we have used in the load flow analysis of KFUEIT Rahim Yar Khan is mainly PQ analyzer. The PQ analyzer can measure nine electric parameters at a time i.e. the active, reactive, apparent power, voltage, voltage angle and current.
on each phase etc. The PQ analyzer has SD card which stores the data with respect to time in an excel sheet. The user can take these values for analysis and get results.

Equation 2.1:
\[ y_4(V_2 - V_1) + y_5(V_3 - V_1) - y_6(V_4) = 0 \]
\[ y_1(V_4 - V_2) + y_5(V_3 - V_2) - y_4(V_1 - V_2) = 0 \]
\[ y_2(V_5 - V_3) + y_5(V_2 - V_3) - y_3(V_1 - V_3) = 0 \]
\[ y_1(V_4 - V_2) = l_1 \]
\[ y_2(V_5 - V_3) = l_2 \]

Equation 2.2:
\[ Y_{11} = y_4 + y_5 + y_6 \]
\[ Y_{22} = y_1 + y_3 + y_5 \]
\[ Y_{33} = y_2 + y_3 + y_5 \]
\[ Y_{44} = y_1 \]
\[ Y_{55} = y_2 \]

Equation 2.3:
\[ Y_{12} = Y_{21} = y_4 \]
\[ Y_{13} = Y_{31} = y_5 \]
\[ Y_{23} = Y_{32} = y_3 \]
\[ Y_{24} = Y_{42} = y_1 \]
\[ Y_{35} = Y_{53} = y_2 \]

Equation 2.4:
\[ l = YV \]

Equation 2.5:
\[ (Z_4 + Z_5 + Z_6)l_1 + (Z_4)l_2 - (Z_4)l_3 = V_4 \]
\[ (Z_5)l_1 + (Z_5 + Z_6)l_2 + (Z_5)l_3 = V_5 \]
\[ (-Z_4)l_1 + (Z_5)l_2 + (Z_4 + Z_5)l_3 = 0 \]

C. Results

Basically, university has two electrical networks i.e. current and future electrical network. We have load profile of current electrical network so we have been discussed the outcomes of current electrical network in detail. We do not have the load profile of future electrical network so we have mentioned the assumed peak load of every transformer of future electrical network. There are following outcomes of current electric network. It includes power consumption of each transformer in the form of graph with respect to time. It includes the graph of both active and reactive power of each transformer separately. In these graphs there is low peak for continues 24 hours which shows there is holiday in the university on that day. The only load on that day would be lighting load. From the load profile of EE it is found that load of EE is the 24.39% of the 200 kVA transformer during peak and off-peak hours. This data is taken from the load profile of EE, ME and admin with different dates and time. When the weekly load profile of this 200 kVA transformer inserted in PSS SINCAL software, we got the following active power and reactive power graphs. These graphs represent the magnitude of power with respect to time.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Transformers</th>
<th>Ratings</th>
<th>Supplying</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Admin(I)</td>
<td>200 kVA</td>
<td>EE+ME engineering and admin block</td>
</tr>
<tr>
<td>2</td>
<td>Admin (II)</td>
<td>100 kVA</td>
<td>Admin Block</td>
</tr>
<tr>
<td>3</td>
<td>Civil engineering</td>
<td>100 kVA</td>
<td>Civil engineering</td>
</tr>
<tr>
<td>4</td>
<td>Project and ICT</td>
<td>50 kVA</td>
<td>Project and ICT</td>
</tr>
<tr>
<td>5</td>
<td>Transport</td>
<td>50 kVA</td>
<td>Transport and Reception office</td>
</tr>
<tr>
<td>6</td>
<td>Security office</td>
<td>100 kVA</td>
<td>Security control office and faculty hostel</td>
</tr>
</tbody>
</table>
Figure 1. The Current electric network which has been modeled on PSS SINCAL software

Figure 2. Load Distribution of different transformers of current Electric Network

Figure 3. Load percentage of different transformers
TABLE 2. FUTURE ELECTRIC NETWORK TRANSFORMER RATING

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Transformers Rating</th>
<th>Supplying</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>630 kVA</td>
<td>Electrical Engineering</td>
</tr>
<tr>
<td>2</td>
<td>630 kVA</td>
<td>Mechanical Engineering</td>
</tr>
<tr>
<td>3</td>
<td>630 kVA</td>
<td>Civil Engineering</td>
</tr>
<tr>
<td>4</td>
<td>630 kVA</td>
<td>Basics Sciences &amp; Humanities</td>
</tr>
<tr>
<td>5</td>
<td>630 kVA</td>
<td>CS and IT</td>
</tr>
<tr>
<td>6</td>
<td>630 kVA</td>
<td>ICT &amp; Computer engineering</td>
</tr>
<tr>
<td>7</td>
<td>400 kVA</td>
<td>Chemical Department</td>
</tr>
<tr>
<td>8</td>
<td>200 kVA</td>
<td>Staff Residence</td>
</tr>
<tr>
<td>9</td>
<td>200 kVA</td>
<td>Faculty Hostel</td>
</tr>
<tr>
<td>10</td>
<td>200 kVA</td>
<td>Boys Hostel</td>
</tr>
<tr>
<td>11</td>
<td>200 kVA</td>
<td>Library</td>
</tr>
<tr>
<td>12</td>
<td>200 kVA</td>
<td>Masjid</td>
</tr>
</tbody>
</table>

Figure 4. Future electric network on Google map

The future electric network modeled on PSS-SINCAL software according to the transformer rating which is shown in given fig.
Maximum magnitude of active power (P) in peak hour is 110.8 kW and minimum magnitude of power in off-peak hours is 10.3 kW.

Maximum magnitude of reactive power (Q) in peak hours is 54.62 kVAR and minimum magnitude of power in off-peak hours is 2.8 kVAR. When the weekly load profile of this 100 kVA transformer inserted in PSS SINCAL software, we got the graphs of active and reactive power.

Maximum magnitude of the active power (P) in peak hours is 52.5 kW and minimum magnitude of this power in off-peak hours is 4.9 kW.

Maximum magnitude of reactive power (Q) in peak hours is 16.14 kVAR and minimum magnitude of this power in off-peak hours is 1.5 kVAR. Load of this transformer is 9% of the total load of university. When the weekly load profile of this 50 kVA transformer inserted in PSS SINCAL software, we got the graphs of active and reactive power which are shown below in the figure.
Maximum magnitude of the active power (P) in peak hours is 22.74 kW and minimum magnitude of this power in off-peak hours is 2.1 kW.

Maximum magnitude of reactive power (Q) in peak hours is 11.21 kVAR and minimum magnitude of this power in off-peak hours is 1.0 kVAR. Load on this transformer is 4% of the total load of university. When the weekly load profile of this 100 kVA transformer inserted in PSS SINCAL software, we got the graphs of active and reactive power which are shown below in the figure. Maximum magnitude of the active power (P) in peak hours is 9.49 kW and minimum magnitude of this power in off-peak hours is 1.0 kW.

Maximum magnitude of reactive power (Q) in peak hours is 4.68 kVAR and minimum magnitude of this power in off-peak hours is 0.4 kVAR. Load of this transformer is 9% of the total load of university. When the weekly load profile of this 50 kVA transformer inserted in PSS SINCAL software, we got the graphs of active and reactive power which are shown below in the figure.

Maximum magnitude of the active power (P) in peak hours is 23.4 kW and minimum magnitude of this power in off-peak hours is 2.2 kW.

Maximum magnitude of reactive power (Q) in peak hours is 11.53 kVAR and minimum magnitude of this power in off-peak hours is 1.1 kVAR. Future electric network consists of twelve transformers of different ratings whose expected peak load are given below in the table 3.
TABLE 3. CURRENT NETWORK POWER CALCULATION AT DIFFERENT POWER FACTORS

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Transformers Rating</th>
<th>Supplying</th>
<th>Peak load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>630 kVA</td>
<td>Electrical Engineering</td>
<td>393 kW</td>
</tr>
<tr>
<td>2</td>
<td>630 kVA</td>
<td>Mechanical Engineering</td>
<td>396 kW</td>
</tr>
<tr>
<td>3</td>
<td>630 kVA</td>
<td>Civil Engineering</td>
<td>434 kW</td>
</tr>
<tr>
<td>4</td>
<td>630 kVA</td>
<td>Basics Sciences &amp; Humanities</td>
<td>393 kW</td>
</tr>
<tr>
<td>5</td>
<td>630 kVA</td>
<td>CS&amp;IT</td>
<td>360 kW</td>
</tr>
<tr>
<td>6</td>
<td>630 kVA</td>
<td>ICT &amp; Computer engineering</td>
<td>393 kW</td>
</tr>
<tr>
<td>7</td>
<td>400 kVA</td>
<td>Chemical Department</td>
<td>253 kW</td>
</tr>
<tr>
<td>8</td>
<td>200 kVA</td>
<td>Staff Residence</td>
<td>160 kW</td>
</tr>
<tr>
<td>9</td>
<td>200 kVA</td>
<td>Faculty Hostel</td>
<td>148 kW</td>
</tr>
<tr>
<td>10</td>
<td>200 kVA</td>
<td>Boys Hostel</td>
<td>152 kW</td>
</tr>
<tr>
<td>11</td>
<td>200 kVA</td>
<td>Library</td>
<td>140 kW</td>
</tr>
<tr>
<td>12</td>
<td>200 kVA</td>
<td>Masjid</td>
<td>150 kW</td>
</tr>
</tbody>
</table>

The demand of this reactive power is mainly originated from inductive load connected to the system. These inductive loads are generally electromagnetic circuit of electric motors, electrical transformers, inductance of transmission and distribution networks, induction furnaces, fluorescent lightings etc. [2]. This reactive power should be compensated properly otherwise, there would be losses in the system. It could be done by many ways but here we are going to use capacitor bank [3]. We have calculated the peak values of active, reactive and apparent power from the results of current electric network at every transformer which are given in the table [3]. We can compensate reactive by using capacitor bank. The capacitor bank by JKCN Company having model name BAM11-100-1W of 100kVAR rating at 11kV line is suggested to the university [8].

TABLE 4. CURRENT NETWORK POWER CALCULATION AT DIFFERENT POWER FACTORS

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Transformer</th>
<th>At power factor 0.87</th>
<th>At power factor 0.95</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>P</td>
<td>Q</td>
</tr>
<tr>
<td>1</td>
<td>Admin I</td>
<td>110.8</td>
<td>62.79</td>
</tr>
<tr>
<td>2</td>
<td>Admin II</td>
<td>52.54</td>
<td>29.77</td>
</tr>
<tr>
<td>3</td>
<td>Civil</td>
<td>32.74</td>
<td>18.55</td>
</tr>
<tr>
<td>4</td>
<td>ICT</td>
<td>22.74</td>
<td>12.89</td>
</tr>
<tr>
<td>7</td>
<td>Total</td>
<td>251.7</td>
<td>142.63</td>
</tr>
</tbody>
</table>

By improving power factor load angle between voltage and current can be reduced. This can reduce the reactive power and as a result apparent power also reduced [10].

![Figure 18. Comparison of power triangle at two different power factors of current network](image)

In future electric network results, we have mentioned the peak values of active power. By using these values we have calculated the peak values of active, reactive and apparent power which are given below in the table. We can compensate the reactive power by using capacitor banks [14]. Four capacitor banks by JKCN company having model name BAM11-250-1W of 250kVAR rating at 11kV line is suggested to the university [8].
TABLE 5. FUTURE NETWORK POWER CALCULATION AT DIFFERENT POWER FACTOR

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Transformers</th>
<th>At power factor 0.87</th>
<th>At power factor 0.95</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Electrical</td>
<td>393</td>
<td>451.72</td>
</tr>
<tr>
<td>2</td>
<td>Mechanical</td>
<td>396</td>
<td>455.17</td>
</tr>
<tr>
<td>3</td>
<td>Civil</td>
<td>434</td>
<td>498.85</td>
</tr>
<tr>
<td>4</td>
<td>CS and IT</td>
<td>360</td>
<td>413.79</td>
</tr>
<tr>
<td>5</td>
<td>ICT</td>
<td>393</td>
<td>451.72</td>
</tr>
<tr>
<td>6</td>
<td>Basic Science</td>
<td>393</td>
<td>451.72</td>
</tr>
<tr>
<td>7</td>
<td>Chemical</td>
<td>253</td>
<td>290.80</td>
</tr>
<tr>
<td>8</td>
<td>Staff Residence</td>
<td>160</td>
<td>183.91</td>
</tr>
<tr>
<td>9</td>
<td>Faculty Hostel</td>
<td>148</td>
<td>170.11</td>
</tr>
<tr>
<td>10</td>
<td>Boys Hostel</td>
<td>152</td>
<td>174.71</td>
</tr>
<tr>
<td>11</td>
<td>Library</td>
<td>140</td>
<td>160.92</td>
</tr>
<tr>
<td>12</td>
<td>Masjid</td>
<td>150</td>
<td>172.41</td>
</tr>
<tr>
<td>13</td>
<td>Total</td>
<td>3372</td>
<td>3875.8</td>
</tr>
</tbody>
</table>

By improving power factor load angle between voltage and current can be reduced. This can reduce the reactive power and as a result apparent power also reduced.

Figure 19. Comparison of power triangle at two different power factors of future network

D. Conclusion

This project introspects on the electric network of the university i.e either it is current or future network of the university. In this project, the load flow analysis is analyzed on the current electrical network of KFUEIT Rahim Yar Khan for its stable operation. For voltage stability in the university the reactive power (Q) controlling is necessary and for maximum active power in a system the power factor close to 1 required. The load profile of transformers extracted by installing the PQ analyzer in different departments and the necessary parameters measured by the PQ analyzer. Transformers in the network has different share in supplying the power to the total demand of university. The load profile of transformers reveals the percentage value in the total load of the university. University both networks has been modeled on the PSS SINCAL software. In this software Newton Raphson (NR) method used to solve the network with multiple iterations to get the accurate results. New-ton Raphson (NR) method is most accurate than any other method. Weekly load profile of current electric network inserted in the PSS SINCAL software and got the values of active power, reactive power, voltage and phase angle. Graphs of magnitude of active and reactive power with respect to time extracted. Current and future electric networks displayed on the map of the university. Total reactive power has been estimated by the load profile. University electricity bills can be reduced by controlling the amount of reactive power.

E. Future Work

Based upon results and conclusion of the present network can be extended by reducing the reactive power of the system which will improve the power factor to reduce the utility power bills. This can be done by installing the capacitor bank of suitable ratings. Most of the utility bills are influenced by the kVAR usage. The present network can be merged with the renewable source i.e. solar system. It is also in the plan of university to install the solar system in university, the prototype for installation of solar panels is designed on roof of the department of Mechanical Engineering. Our current network results can be official document of university in which anyone can see its preliminary networks load profile.
F. Acknowledgement

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References