



Research Article

LOAD FLOW ANALYSIS OF JAMSHORO THERMAL POWER STATION (JTPTS) PAKISTAN USING MATLAB PROGRAMMING

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ABSTRACT

This effort aims to analyze the active and reactive power flows, line losses, voltage profile and magnitude of angle at different buses of JTPTS. This investigation is carried out for economical scheduling, proper future planning, and operation control. It involves iterative methods, which creates problems analytically, particularly if the size of systems is large. Additionally, it consumes more time in comparison to other methods. Thus, MATLAB programming software package developed by authors is used for above stated enquiry.

INTRODUCTION

Load flow analysis assures the transmission of power from generating units to end users (customers) involving substation, in an economic, stable and reliable way (Guile and Paterson, 1977; Stevenson, 1982). Whereas the traditional methods involves iterative tools to solve these problems. It can be either Gauss-Siedel (GS) method or Newton Raphson (NR) method (Tinney and Hart, 1967; Tinney and Hart, 1967). A necessary condition is developed by power flow analysis for power system design and operation. For the analysis of large power systems, notable research has already been carried out in the formation of load flow computer programs. When the given system is characterized by radial distribution including large number of buses and feeders, then convergence issues may occur in these general purpose programs. Hence, it becomes implicit to introduce exceptionally optimized program for stated distribution studies (Carpentier, 1979). Most important knowledge obtained from load flow analysis is the voltage profile of the system. In case the system voltage deviates too much, then expected outcomes lead to more real power loss and at certain cases possible voltage collapse if the deviation is so large (Sun et al., 1984; Klingman and Himmelblau, 1964).

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The indispensable factor is running cost of electrical energy for the operation of economic power systems and this is naturally high due to interconnected systems, so load flow analysis plays a vital role in this area (Das et al., 1991; Rahman and Jasmon, 1995). There is no doubt that if small percentage of saving is achieved, it would result in considerable reduced running cost as well as low fuel consumption. The key requirement in obtaining minimum running cost generating units is economic load dispatch. To overcome the problem of economic dispatch, the generating units be arranged in such a way that committed units should supply the given proper load in the optimal manner, instead of involving all units in the array of system (Ghosh and Das, 1999). Currently, modern system theory and optimization technique are used to reduce running cost with optimum economical operation.

LOAD FLOW OVER VIEW

- Load Flow Analysis is an essential tool in the early planning of new power networks or in the extension of given power system such as; introducing new generating unit in system to meet increased load demand and also in developing new transmission lines.
- The solution of power flow analysis gives the magnitude and phase angle of voltage at the different buses. Hence

power is being injected at buses and line losses at different stages of interconnecting system.

- Load Flow Analysis is very much helpful for selecting the proper site and maximum operating capacity of given generating stations, grid stations and incoming transmission lines.
- One condition for Load Flow Analysis is that voltage at certain buses should be kept within the defined standard range and second condition is that Load Flow Study Should ensures that system transmission losses are minimized.
- Load Flow Analysis assures that system operation with respect to fuel cost to produce the required power is economical.
- Lines losses can be calculated and with this information a reference limit usually called stability or thermal limit, can be set to avoid over loading of lines.

LOAD FLOW ANALYSIS

Load Flow Analysis is an essential tool for designing the extension of power system as well as ensuring the convenient performance of existing System. In this analysis Bus Classification is taken into consideration

Bus Classification

A bus is nodal point, at which one or number of loads, one or number of lines and generating units are connected. In the electrical power system, four electrical quantities are used to characterize the buses like; magnitude of active (P) and reactive (Q) powers, magnitude (V) and phase angle (Θ) of voltage in the power flow problems. From these four quantities, two quantities are normally specified and other two quantities are needed to be calculated through some specific algorithm for equations solution. In the Load Flow Studies we make assumption that system load is constant and it is specified by its active and reactive powers utilization.

Slack or Swing Bus

At this bus voltage magnitude (V) and phase angle (Θ) are specified and active (P) and reactive (Q) powers are needed to be determined. Since at any bus without the information of voltage profile, the losses in system cannot be calculated. The slack bus supplies the difference between the total system load plus losses and the sum of the complex powers at remaining buses. Since initially the losses in the system are unknown before calculation, so one bus in the system is such that its powers are unspecified so that after the calculation, it could be able to supply the losses. Normally the bus which is connected with largest generating unit is taken as Swing bus, so small variation can be encountered (Jamali et al., 2006)

Load bus

At this bus actual load is connected and their active (P) and reactive (Q) powers are specified and voltage magnitude (V) and phase angle (Θ) are required to be calculated. This bus is also called PQ bus (Jamali et al., 2006).

Voltage Controlled Bus

It the generator bus where voltage profile can be maintained by adjusting the excitation of generator and active power injected at bus can be controlled by adjusting the mechanical power input of generating unit. This bus is also called PV bus (Jamali et al., 2006).

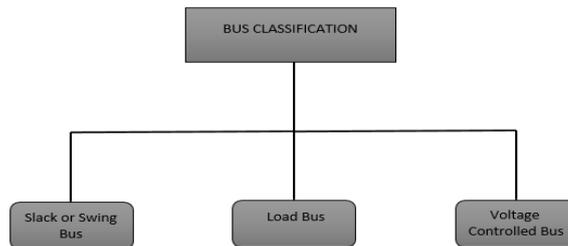


Figure 1. Bus Classification

POWER FLOW SOLUTION

According to Power System Engineering, Power flow Analysis (also known as Load Flow Analysis), is actually I numerical analysis which involves the various AC Power forms, applied to Power System with the help of one line diagram and per unit system, unlike common circuit analysis, in which current and voltage are taken into account. Load Flow analysis is carried out when the system is n steady state. Different iterative methods are used to solve Load Flow Problems, but here we consider just two of them.

Guass-Siedel Method

- Consider a non-linear equation $f(x)=0$
- Rearrange $f(x)$ so that $x=g(x)$, $f(x)=x-g(x)$ or $f(x)=g(x)-x$
- Guess an initial estimate of $x=x^k$
- Use iteration , obtain next x value as $x^{(k+1)}=g(x^k)$
- Criteria for Accuracy $|X^{(k+1)}-x^{(k)}| \leq \epsilon$
- ϵ is the required Accuracy

Current flow into bus is given by;

$$I_i = V_i \sum_{j=0}^n Y_{ij} - \sum_{j=1}^n Y_{ij} V_j \quad j \neq i \tag{1}$$

Now expressing I_i in terms of P and Q;

$$I_i = (P_i - jQ_i) / V_i^* \tag{2}$$

We also know that

$$I = YV \tag{3}$$

Now the load flow equation becomes

$$(P_i - jQ_i) / V_i^* = V_i \sum_{j=0}^n Y_{ij} - \sum_{j=1}^n Y_{ij} V_j \tag{4}$$

With the help of above equation (4), voltages of buses can be calculated. Load Flow Problems results in an algebraic nonlinear equations which must be solved by iteration methods. In equation (1), Y is the admittance matrix and V_i is the bus voltage and in equation (2), P_i and Q_i are the active and reactive powers injected at the bus.

For the swing bus equation for bus voltage cannot be formulated, because its voltage is already being known. But for P_i

$$P_i^{(k+1)} = \text{Re}\{V_i^{*(k)} [V_i^{(k)} \sum_{j=0}^n Y_{ij} - \sum_{j=1}^n Y_{ij} V_j^{(k)}]\} \quad (5)$$

For the PQ bus, since P and Q are known, so equation for voltage would be

$$V_i^{(k+1)} = \frac{(P_i^{sch} - jQ_j^{sch}) / V_i^* + \sum Y_{ij} V_k^{(k)}}{\sum Y_{ij}} \quad (6)$$

For the PV bus, the equation for reactive power will be

$$Q_i^{(k+1)} = -\text{Im}\{V_i^{*(k)} [V_i^{(k)} \sum_{j=0}^n Y_{ij} - \sum_{j=1}^n Y_{ij} V_j^{(k)}]\} \quad (7)$$

In order to decide whether further iterations would be needed or not, we would calculate the error, by having subtraction of new value from old and certain tolerance is being set to end the number of iterations. To accelerate the convergence, using the following approximation after new V_i is obtained

$$V_i^{(k+1)} = V_i^{(k)} + \alpha(V_i^{old} - V_i^{new}) \quad (8)$$

Where α is in the range of between 1.3 to 1.7

Newton-Raphson Method

Algorithm for Newton Raphson Method is

$$c^{(k)} = c - f(x^{(k)}) \quad (9)$$

$$x^{(k)} = c^{(k)} / \left(\frac{df}{dx}\right)^{(k)} \quad (10)$$

$$x^{(k+1)} = x^{(k)} + x^{(k)} \quad (11)$$

Newton Raphson Method procedure for solving n variables

$$f_1(x^{(0)} + \Delta x^{(0)}) = f_1(x^{(0)}) + \left(\frac{df_1}{dx_1}\right)^{(0)} \Delta x_1^{(0)} + \left(\frac{df_1}{dx_2}\right)^{(0)} \Delta x_2^{(0)} + \dots + \left(\frac{df_1}{dx_n}\right)^{(0)} \Delta x_n^{(0)} = c_1 \quad (12)$$

$$f_2(x^{(0)} + \Delta x^{(0)}) = f_2(x^{(0)}) + \left(\frac{df_2}{dx_1}\right)^{(0)} \Delta x_1^{(0)} + \left(\frac{df_2}{dx_2}\right)^{(0)} \Delta x_2^{(0)} + \dots + \left(\frac{df_2}{dx_n}\right)^{(0)} \Delta x_n^{(0)} = c_2 \quad (13)$$

$$f_n(x^{(0)} + \Delta x^{(0)}) = f_n(x^{(0)}) + \left(\frac{df_n}{dx_1}\right)^{(0)} \Delta x_1^{(0)} + \left(\frac{df_n}{dx_2}\right)^{(0)} \Delta x_2^{(0)} + \dots + \left(\frac{df_n}{dx_n}\right)^{(0)} \Delta x_n^{(0)} = c_3 \quad (14)$$

Rearranging equations (12), (13) and (14) in the matrix form

$$\begin{bmatrix} c_1 - f_1 \\ c_2 - f_2 \\ c_n - f_n \end{bmatrix} = \begin{bmatrix} df_1/dx_1 & df_1/dx_2 & df_1/dx_n \\ df_2/dx_1 & df_2/dx_2 & df_2/dx_n \\ df_n/dx_1 & df_n/dx_2 & df_n/dx_n \end{bmatrix} \begin{bmatrix} \Delta x_1 \\ \Delta x_2 \\ \Delta x_n \end{bmatrix}$$

The above matrix form can be written as;

$$C^{(k)} = J^{(k)} X^{(k)}$$

Where $J^{(k)}$ is called Jacobian matrix

Gauss-Siedel Method has a linear characteristic of convergence and also computation time per iteration is less unlike that of

Newton Raphson method. In Gauss-Siedel method rectangular co-ordinate system is used. The selection of Swing bus is critical in Gauss-Siedel Method.

SYSTEM DESCRIPTION

Figure.02 shows the main one line diagram of Thermal Power Station Jamshoro. The Load study diagram of Thermal Power Station Jamshoro for Power flow analysis is shown in Figure 02, with four generating units, from which three are of 210 MW China based with generation voltage of 15.75 kV, 50 Hz, with ramping rate of 1.0 MW/min and require 6 hours to synchronize with system and one unit is of 250 MW Japan based with generation voltage of 16.5 kV, 50 Hz, with ramping rate of 2.0 MW/min and requires 12 hours to synchronize with system. Just for simplification we have merged here three china units in one big unit and is shown by G2 in the Figure. 02 which is connected to bus number 2, while 250 MW Japanese units is represented by G1 which is connected to bus number 3.

Here the 100 MVA is taken as base power and 15 kV is taken as base voltage. Since Jamshoro Thermal power Station supplies the power to different cities of Pakistan like; Karachi, Hyderabad, Jamshoro, Dadu, Hala, Lakhra, with the help of fourteen transmission lines, there lump summed load which is actually demanded from Jamshoro Power Plant is calculated to be approximately 600 MW with 200 MVar reactive power demand. This lumped load is connected at bus number 2. Since bus number one is chosen as slack bus and connected with generator, whose power can regulated to balance the load demand and the line losses. Since the lines have impedance as marked on these lines, so they cause line losses, which should be taken into consideration while performing Load flow studies

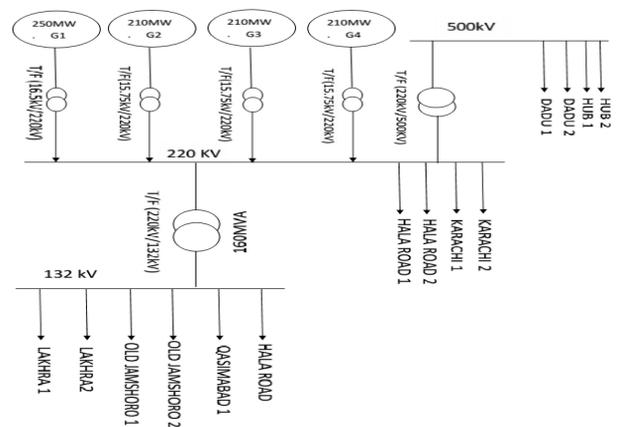


Figure 2. Main One Line Diagram of Jamshoro Thermal power station

LOAD FLOW STUDY TEST RESULTS

Load Flow Analysis is performed Thermal power station system as shown in figure.02. The MATLAB program is written to calculate the voltages, active and reactive powers at every bus of the system for every iteration.

MATLAB program for Forming Ybus Matrix and Gauss-Siedel load flow are written in appendix. After simulating the program, it displays results i.e; voltage, active and reactive power losses and line losses. The Results of MATLAB program for Jamshoro Thermal Power System are

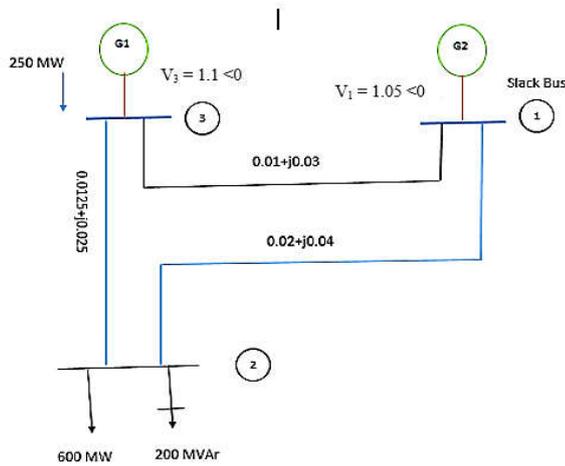


Figure 3. Load Study Diagram of Jamshoro Thermal Power Station

$$\begin{aligned}
 V_2^{(1)} &= 0.98461 - j0.05229 Q_3^{(1)} = 1.258 V_3^{(1)} = 1.1783 - j0.006170 \\
 V_2^{(2)} &= 0.98112 - j0.053428 Q_3^{(2)} = 1.48759 V_3^{(2)} = 1.19974 - j0.00829 \\
 V_2^{(3)} &= 0.98071 - j0.055327 Q_3^{(3)} = 1.52902 V_3^{(3)} = 1.19963 - j0.00931 \\
 V_2^{(4)} &= 0.98065 - j0.055328 Q_3^{(4)} = 1.54381 V_3^{(4)} = 1.19962 - j0.00972 \\
 V_2^{(5)} &= 0.98062 - j0.055542 Q_3^{(5)} = 1.55598 V_3^{(5)} = 1.19961 - j0.00991 \\
 V_2^{(6)} &= 0.98061 - j0.055541 Q_3^{(6)} = 1.55941 V_3^{(6)} = 1.19960 - j0.00999 \\
 V_2^{(7)} &= 0.98059 - j0.055539 Q_3^{(7)} = 1.56079 V_3^{(7)} = 1.19960 - j0.0100
 \end{aligned}$$

The process is continued and solution is converged with an accuracy of 5×10^{-5} pu

The final values after so many iterations is précised to be

$$\begin{aligned}
 V_2 &= 0.98112 \angle -2.3957^\circ \text{ pu} \\
 S_3 &= 2.5 + j1.5095 \text{ pu} \\
 V_3 &= 1.1 \angle -0.3^\circ \text{ pu} \\
 S_1 &= 4.08 - j1.35 = 408 \text{ MW} + j155 \text{ MVar}
 \end{aligned}$$

The line flows are

$$\begin{aligned}
 S_{12} &= 3.25 + j1.01 = 325 \text{ MW} + j101 \text{ MVar} \\
 S_{13} &= 83 + j0.54 = 83 \text{ MW} + j54 \text{ MVar} \\
 S_{21} &= -3.02 - j1.02 = -302 \text{ MW} - j102 \text{ MVar} \\
 S_{31} &= -0.71 - j0.34 = -71 \text{ MW} - j34 \text{ MVar} \\
 S_{23} &= -2.98 - j0.98 = -298 \text{ MW} - j98 \text{ MVar} \\
 S_{32} &= 3.21 + j1.24 = 321 \text{ MW} + j124 \text{ MVar}
 \end{aligned}$$

Conclusion

Load flow or Power Flow analysis is an essential tool for determining the economical operation of the existing power system and also planning its future extension on the increased load demand basis. The main knowledge obtained from the load flow study is the magnitude and phase angle of voltage at each bus and active and reactive power flows in each line connection to bus. In this paper we have formulated the algorithm and designed the MATLAB coding for the load flow analysis of Jamshoro Thermal Power station.

MATLAB programming for bus admittance matrix and Gauss Siedel method for given power plant is being developed in appendix. The voltage magnitude and phase angles for the different buses of Jamshoro Thermal Power station are being calculated for different reactance loading. From this analysis, it is concluded that increasing the impedance loading, result would be high voltage regulation.

Moreover, we have also observed that the combine rating of three units at bus 1 is 630MW but they supply only there 408MW, because the power plant is thermal one and its efficiency decreases with its ages so alternators connected are not working at their full efficiency. In Future if given power plant is recommissioned then a larger load than 600 MW can be connected and the impedance loading of lines can be improved because now the line losses are also larger. Since Gauss-Siedel method is simple in calculation and easy to execute, but as the number of buses increases, the number of iterations increases. While in Newton Raphson method, the calculations are bit difficult, but the number of iterations are less even for greater number of buses.

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Appendix

```

%Function ybus
function(yb,ych)=ybus
% The Linr Impedances are
zz=(0 0.02+j0.04 0.01+j0.03
    0.02+j0.04 0 0.0125+j0.025
    0.01+j0.03 0.0125+j0.025 0)
% The ybus matrix is formed here
for i=1:3
    for j=1:3
        if zz(I,j)==0
            yb(I,j)=0;
        else
            yb(i,j)=-1/zz(I,j);
        end
    end
end
for i=1:3
    ysum=0;
    csum=0;
    for j=1:3
        ysum=ysum+yb(i,j);
        csum=csum+yb(i,j);
    end
    yb(i,j)=csum-ysum;
end

% Program Load Flow_Gauss-Siedel
clear all
d2r=pi/180; w=100*pi;

% The ybus Matrix is

(ybus,ych)=ybus;
g=real(ybus); b=imag(ybus);

% The given parameters and conditions are
P=(4.08;-6.0;2.5);

```

```

q=(1.85;-2;1.5095);
th=(0;0;0);
v=(mv(1);mv(2);mv(3));
acc=input('Enter the acceleration constant:');
del=1; indx=0;
% The Guass-Siedel Iterations starts here
while del>1e-5

```

```

% P-Q bus
for i=1:2
tmp1(p(i)-j*q(i)/conj(v(i)));
tmp2=0;
for k=1:3
for (i==k)
tmp2=tmp2+0;
else
tmp2=tmp2+ybus(i,k)*v(k);
end
end
vt=(tmp1-tmp2)/ybus(i,i);
v(i)=v(i)+acc*(vt-v(i));
end

```

```

% P-V bus
q3=0;
for i=1:3
q3=q3+ybus(3,i)*v(i);
end
q3=imag(conj(v(5))*);
tmp=(p(3)-jq(3))/conj(v(3));
tmp2=0;
for k=1:2
tmp2=tmp2+ybus(3,k)*v(k);
end
vt=(tmp1-tmp2)/ybus(3,3);
v(3)=abs(v(3))*vt/abs(vt);

```

% Calculate P and Q

```

for i=1:3
sm=0;
for k=1:3
sm=sm+ybus(i,k)*v(k);
end
s(i)=conj(v(i))*sm;
end

```

```

% The mismatch
delp=p-real(s);
delq=q+imag(s);

```

```

delpq=(delp(1:3);delq(1:2));
del=max(abs(delpq));
indx=indx+1;
if indx==1
pause
end
end

```

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