APPORTIONING THE TRANSMISSION LOSS IN POWER NETWORK TO INDIVIDUAL LOADS AND GENERATOR

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By

Mohd Rushahidi Bin Khalid

Final Report
Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
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CERTIFICATION OF APPROVAL

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TRONOH, PERAK

June 2010

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Mohd Rushahidi Bin Khalid

ABSTRACT

Continuing trend towards deregulation and unbundling of transmission services has resulted in the need to assess what the impact of a particular generator or load is on the power system. A new method of tracing the flow of electricity in meshed electrical networks is proposed which may be applied to both real and reactive power flows. The method allows assessment of how much the real and reactive power output from a particular station goes to a particular load. It is also allows the assessment of contribution of individual generators or loads to individual line flows. A loss-apportioning algorithm has also been introduced which allows the breakdown of the total transmission loss into components to be allocated to individual loads or generators. The method can be useful in providing additional insight into power system operation and can be used to modify existing tariff of charging for transmission loss, reactive power and transmission services [2].

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CHAPTER 1

INTRODUCTION

1.1 Background of study

The mesh structure of high-voltage transmission networks provides a large number of possible routes by which electrical power can flow from the source (generators) to the sinks (loads). Tracing the connections using the load flow program is not possible as changing a demand or generation at any node would result in corresponding change of generation coming from the marginal (swing) plant. Hence, the conventional wisdom is that with an integrated system it is not possible to trace electricity from a particular generator to a particular supplier. It is only possible to determine relation between the generators (or loads) and the flow in transmission lines by means of sensitivity analysis, that is by determining how a change in a nodal generation/demand influences the flow in a particular line [2].

Recently, the question of tracing electricity was of a limited interest. The electrical supply industry tended to be integrated vertically almost everywhere and power exchanges between utilities were determined by contracts. Since the 1980's, however, the increased deregulation of the industry is almost every corner of the world has posed many new question to electrical engineers. It is widely recognised that the proper regulatory framework of the transmission is of a vital importance as the market power through control of transmission is the single greatest impediment to competition [2]. In this context, the problem of tracing electricity gains importance as its solution could enhance the transparency in the operation of the transmission system.

1.2 Problem statement

Long transmission lines are required to transmit power from remote generation sites to the population centers. The stability of the transmission system depends on the power flows through the transmission line, but load at the buses never static and always changes, either increasing or decreasing according to the system requirement [3]. Electrical loads both generate and absorb reactive power. They are inductive in nature and consumed a lot of reactive power from the transmission lines. Hence there is voltage drop on the line. So, it is clear that there will be the sending end and the receiving end voltages magnitude variation, as well as phase difference, is created.

Therefore it is important to trace the flow of electricity (Real and Reactive Power) in the power networks. The method that we shall use for the power tracing in meshed electrical network, allows the assessment of how much of real and reactive power output from a particular station goes to a particular load. Through this we can modify the existing tariffs of charging for transmission loss, reactive power and transmission services into the power networks.

1.3 Objective and scope of studies

Since there are many methods have been presented, the study is on one of the method to allocate the transmission loss to loads and generators. In this case, loss allocation method has been chosen and its algorithm will be used to be tested to prove it whether this method is efficient and practical enough for real time application or not. However, the test will be conducted by using MATLAB program. It is impracticable to test it at the grid since it will interrupt the system for the customers and will cost losses in millions of dollars even for short time.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory

The purposed electricity tracing method is topological in nature that is it deals with a general transportation problem of how the flows are distributed in a meshed network. An assumption is made in order to make it easy to trace the problem. The network is assumed to be connected and describe by a set of n does, m directed links (transmission lines or transformers), 2m flows (at both end of each link) and a number of sources (generators) and sinks (loads) connected to the nodes [2].

Practically, the only requirement for the input data is that Kirchhoff's Current Law must be satisfied for all the nodes in the network. The method is applicable to real and reactive power flows and direct current. Neglecting the Kirchhoff's Voltage Law has been already used to obtain the flows [2].

The main principle used to trace the flow of electricity will be that of proportional sharing. To be more specific, the total power flow through nodes inflow will always be equal to outflows. It is also to be assumed that the network node is a perfect mixer of incoming flows so that it is impossible to tell which particular inflowing electron goes into which particular outgoing line. This is to agree with common sense that electricity is indistinguishable [2].

2.1.1 Tracing Electricity using Power Flow Tracing

As mentioned in the main theory, the basic principle used to trace the flow of electricity in the transmission network is the proportional sharing. The principle basically amounts to assuming that any network node is a perfect mixer of incoming flows. Proportional sharing principle is fair as it treats all the incoming and out-flowing in the same way without any discrimination [2]. Let consider a node showed in Figure 1 where four lines are connected to node i, two with inflows and two with outflows.

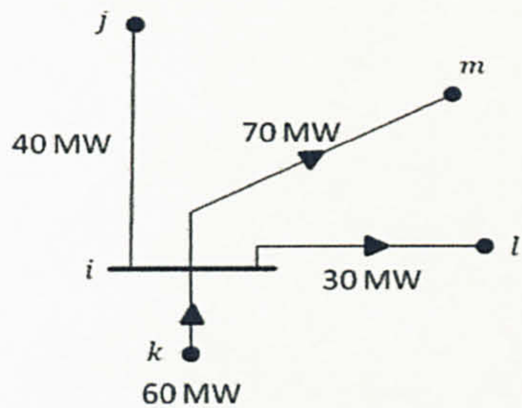

Figure 1: Proportional sharing principle

The total power associated with the node i, P_i is the sum of inflow or outflow in node i. Thus P_i is 100 MW of which 40% is supplied by the line $j - i$ and 60% by line $k - i$.

It is to be assumed that each MW leaving the node contains the same proportion of inflows to the total node power. Hence, the 70 MW outflows in line $i - m$ consist of $70 \times {}^{40}/_{100} = 28\,MW$ supplied by the line $j - i$ and $70 \times {}^{60}/_{100} = 42\,MW$ supplied by the line $k - i$. Similarly, the 30 MW outflows in the line $i - l$ consist of

$30 \times {}^{40}/_{100} = 12\,MW$ supplied by the line $j - i$ and $30 \times {}^{60}/_{100} = 18\,MW$ supplied by the line $k - i$.

2.1.2 Power Flow Tracing using Average Line Flows

Tracing electricity can be seen as transportation problem of determining how the power injected by the generators is distributed between lines and loads of the network. The algorithm discussed below is applicable only on lossless network wherein power flows at the beginning and end of each transmission line are equal. The simplest way of obtaining lossless flows from the lousy ones is by assuming that a line flow is an average over the sending-end and receiving-end flows and by adding half of the line loss as load at each terminal node of the line [2]. Consider an example from Figure 2. The power flow results are marked in the figure. A number on the top or the left of a line indicates a real power flow, while a number below or to the right of the line indicates a reactive power flow.

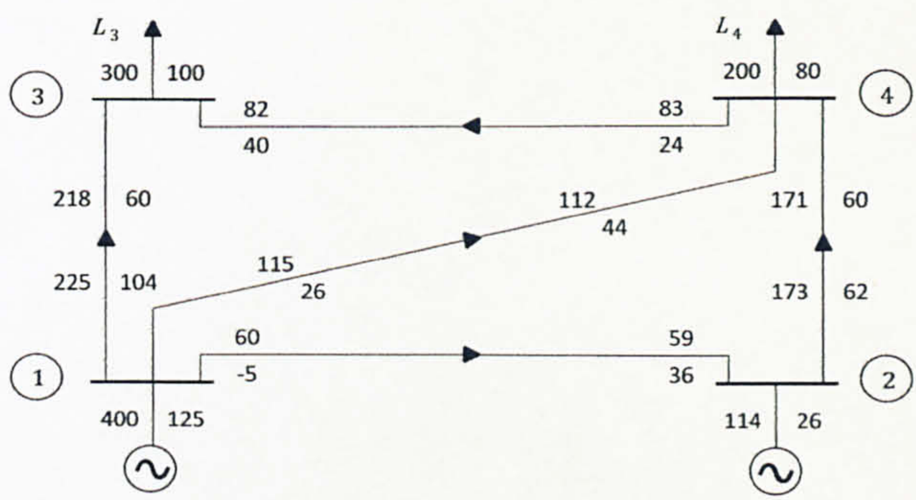

Figure 2: AC power flow in four-node network

Using a real power flow, an average of the loss is calculated in each of every line in the power networks. Figure 3 shows a lossless real power flow obtained from the average power from Figure 2.

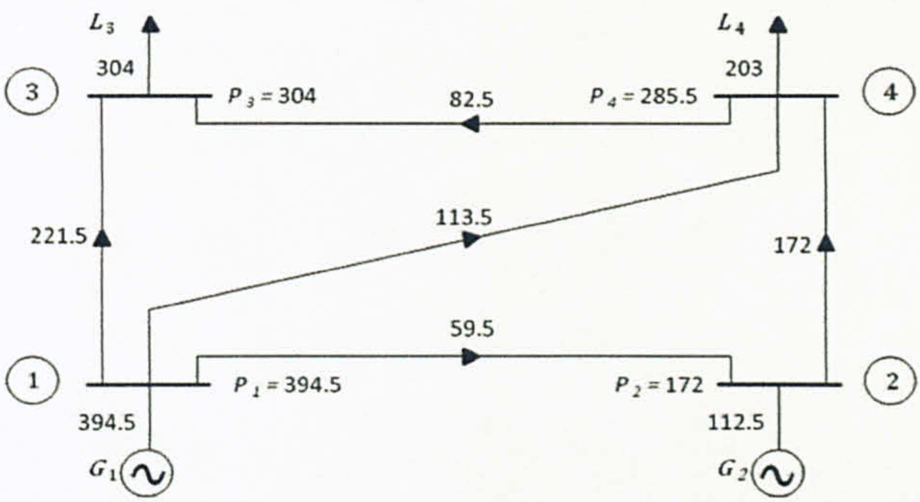

Figure 3: Lossless power flow

The algorithm for tracing the flow of electricity will be derived into 2 parts. The upstream algorithm will look at the balance of nodal inflows while the downstream algorithm will look at the balance of nodal outflows.

2.1.3 Tracing Electricity using Gross Flows

An interesting version of electricity tracing method which is obtained by assuming that the system is fed with actual generation and no power is lost in the network. This will require then modifying the nodal demands but will leave the nodal generations unchange [2]. Let's take the Figure 1 as an example:

To understand it further, let takes an example:

Consider the line 2 – 4 which carries 173 MW at the sending end and 171 MW at the receiving end. The line loss of 2 MW can be added to the receiving end flow to give a gross line flow of 173 MW so that the modified flow at both end are the same. The same method is applied to all lines at the busses as shown if Figure 4.

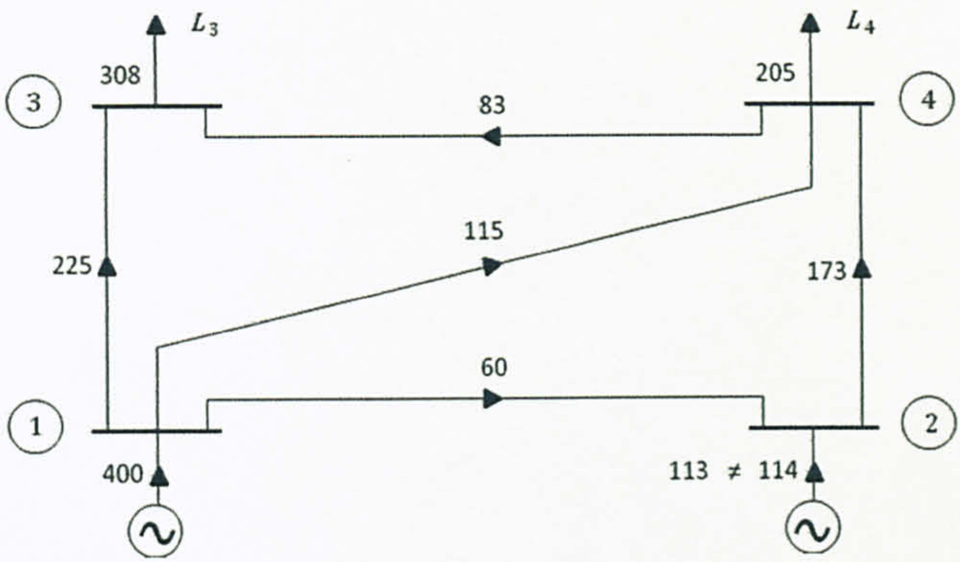

Figure 4: Gross power flow

As the result above gives unequal value to the actual power from generator 2 thus, the resultant power flows will not satisfy the Kirchhoff's Current Law. Do not forget that the method used in gross flows analysis is by assuming that **the system is fed with actual generation and no power loss in the network** [2]. To understand this further, again consider line 2 – 4. The 173MW at the sending end is not the 'true' gross flow as 1MW out of power reaching node 2 had already been lost in line 1 – 2. Hence the true gross flow in line 2 – 4 is not 173MW but 173MW + 1MW = 174MW. A question has arise why does we need to add 1 at line 2 – 4 and not the line 1 – 2. The answer is the only bus that does not follow the Kirchhoff Current Law is bus 2 where the total power inflow is not equal to outflows. Thus, it is necessary to add 1 MW at bus two to give a balance power. It can be choose to add the 1 MW to line impedance $2 - 4$ or line impedance $1 - 2$. The power flow analysis then can be simplified as Figure 5.

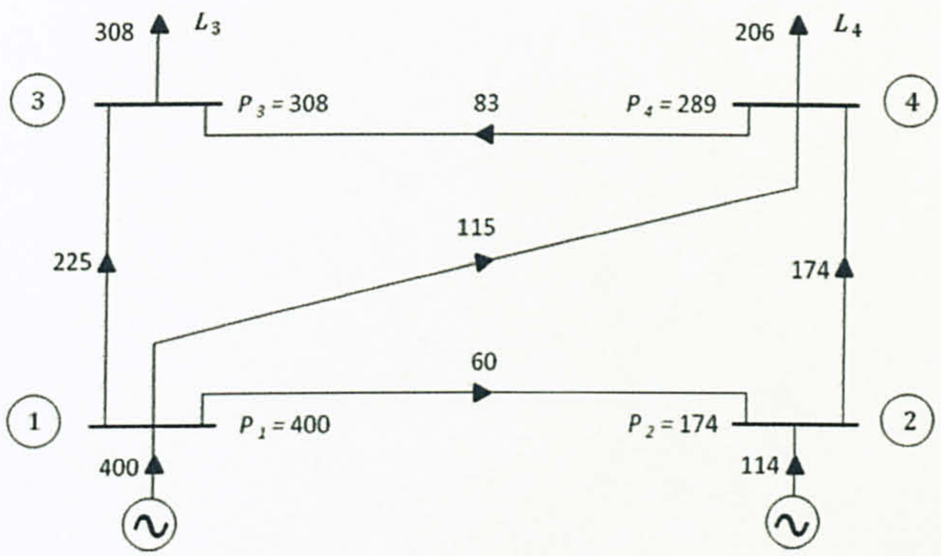

Figure 5: Balance gross power flow

Once the gross power flow satisfy Kirchhoff's Current Law and is calculated, it is then straight forward to apply the electricity tracing method. Take note that this method also require upstream and downstream algorithm.

2.1.4 Loss Allocation Algorithm

Another variation of the loss allocation method presented in gross flow analysis can be developed which use explicitly line losses in its formulation and introduces a concept of nodal losses. The resulting algorithm is a generalisation of the loss allocation method applicable only to radial distribution networks [2]. This method is an adaptation from the gross flow analysis where the theory is the same. However, the difference is that loss allocation applying calculation on the power loss in the transmission line and can only find the loss at the loads in the networks. The advantage of this approach is that it gives additional insight into the electricity tracing algorithm and it allows modifying the loss sharing formulas.

CHAPTER 3

METHODOLOGY

3.1 Methodology

Using the loss allocation method, the algorithm of this method will be implemented. Since it is impracticable to test it at the grid since it will interrupt the system for the customers and will cost losses in millions of dollars even for short time, a simulation for this test is necessary. The test will be conducted using MATLAB software. However, a further study on this method is necessary to understand its algorithm and advantages. Recently, many methods have been purposed on the internet and it is a best approach to read the report from the researcher from all over the world. The power system text book is also necessary in order to give more understanding on the algorithm regarding to the method studied because the report from the researchers mostly an advance algorithm. It is a good start to make the text book as the reference since it will show the basic of the power tracing algorithm. With this, it will be easy to understand the algorithm used in the method mentioned.

Using the MATLAB simulation, the network will be created to test the method. Either it is a simple network or complex network it will be tested base on the method mentioned by using MATLAB. The values of the power transferred to the network and power received will be random yet rational. The coding to write an algorithm for MATLAB will be referred to MATLAB text book. The end result will be show either to the value of the power loss calculated or the graph from the coding. The methodology flow chart will be shown in Figure 6 to give an overall view of the project.

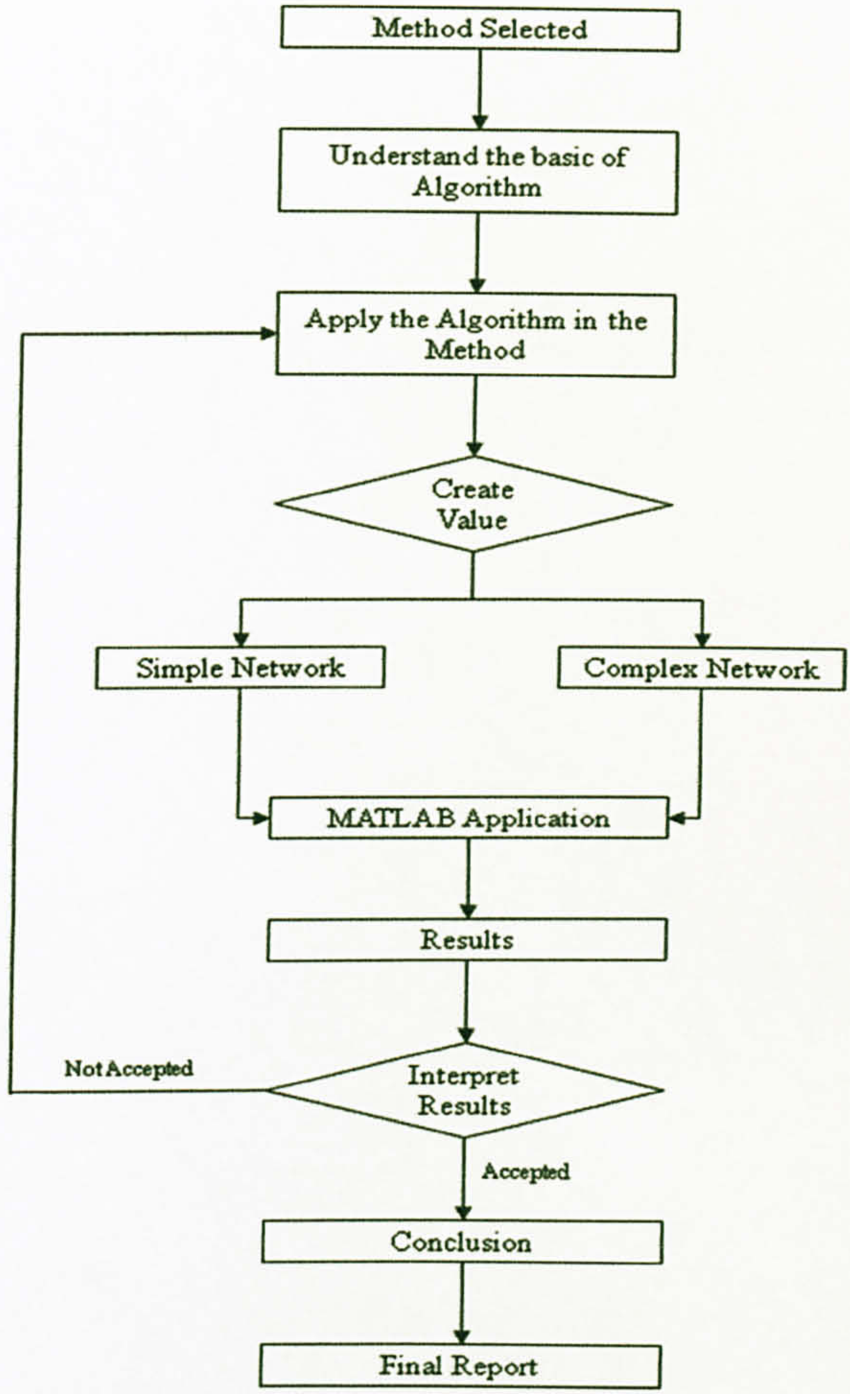

Figure 6: Methodology flow diagram

3.1.1 Average Line Flow Algorithm

Upstream-looking Algorithm:

Let there be n nodes in the network. In the upstream-looking algorithm the power ***inflows*** in the line connected at a node are considered. In node i, P_{j-i} is the power that flows from node j to node i. Considering the inflows, node power P_i can be written as:

$$P_i = P_{Gi} + \sum_{j \in \alpha iu} P_{j-i} \tag{1}$$

where αiu is the set of nodes supplying power directly to the node i. Here $P_i = c_{ji} P_j$ where,

$$c_{ji} = {P_{j-i}}/{P_j} \tag{2}$$

Substituting eq. (2) into eq. (1) yield

$$P_i = P_{Gi} + \sum_{j \in \alpha iu} c_{ji} \, P_j \tag{3}$$

On arrangement

$$P_i - \sum_{j \in \alpha iu} c_{ji} \, P_j = P_{Gi} \tag{4}$$

The above equation can be written in matrix form as

$$A_u \begin{bmatrix} P_1 \\ P_2 \\ \vdots \\ P_n \end{bmatrix} = \begin{bmatrix} P_{G1} \\ P_{G2} \\ \vdots \\ P_{Gn} \end{bmatrix} \tag{5}$$

Where A_u is the $(n \times n)$ upstream distribution matrix. The (i, j) element of A_u is given by

$$\lfloor A_u \rfloor_{ij} = \begin{cases} 1 & for\ i = j \\ -c_{ji} = -\frac{P_{j-i}}{P_j} & for\ j \in \alpha iu \\ 0 & otherwise \end{cases} \tag{6}$$

$$\begin{bmatrix} P_1 \\ P_2 \\ \vdots \\ P_n \end{bmatrix} = [A_u^{-1}] \begin{bmatrix} P_{G1} \\ P_{G2} \\ \vdots \\ P_{Gn} \end{bmatrix} \tag{7}$$

Individual node powers can be written as

$$P_i = \sum_{k=1} [A_u^{-1}]_{ik}\ P_{Gk} \tag{8}$$

Note that the above node power P_i is also equal to the sum of load demand P_{Li} and the outflows in the lines connected to node i. Thus,

$$P_i = P_{Li} + \sum_{l \in \alpha id} P_{il} \tag{9}$$

where αid is the set of nodes receiving power from node i. The outflow power P_{i-l} can be calculated using proportional sharing principle as

$$P_{i-l} = \frac{P_{i-l}}{P_i} P_i \tag{10}$$

Using Eq. (8)

$$P_{i-l} = \frac{P_{i-l}}{P_i} \sum_{k=1}^{n} [A_u^{-1}]\, P_{Gk} \tag{11}$$

Eq. 11 allows one to determine how line flows are supplied from individual generators. Further, it is to be noted that $\left({P_{i-l}}/{P_i}\right) [A_u^{-1}]_{ik}\, P_{Gk}$ will give the contribution of the k^{th} generator for the outflow power P_{i-l}.

Similar to the outflow power, the load demand P_{Li} can also be calculated using proportional sharing principle as

$$P_{Li} = \frac{P_{Li}}{P_i} P_i \tag{12}$$

Using eq. (8)

$$P_{Li} = \frac{P_{Li}}{P_i} \sum_{k=1}^{n} [A_u^{-1}]_{ik}\, P_{Gk} \tag{13}$$

it is noted that $\left({P_{Li}}/{P_i}\right) [A_u^{-1}]_{ik}\, P_{Gk}$ will give the contribution of the k^{th} generator for the load power P_{Li}.

The upstream-looking algorithm is not applied to the network shown in Figure 3. Matrix A_u is constructed first where i varies from 1 to 4 and j should cover the nodes supplying power directly to node i. Table 1 below shows the j values for different values of i.

Table 1: j values for different values of i

i	j values
1	-----
2	1
3	1, 4
4	1, 2

$$A_u(2,1) = -\frac{P_{1-2}}{P_1} = -\frac{59.5}{394.5} = -0.1508$$

$$A_u(3,1) = -\frac{P_{1-3}}{P_1} = -\frac{221.5}{394.5} = -0.5615$$

$$A_u(3,4) = -\frac{P_{4-3}}{P_4} = -\frac{82.5}{285.5} = -0.2890$$

$$A_u(4,1) = -\frac{P_{1-4}}{P_1} = -\frac{113.5}{394.5} = -0.2877$$

$$A_u(4,2) = -\frac{P_{2-4}}{P_2} = -\frac{172}{172} = -1$$

Thus

$$A_u = \begin{bmatrix} 1 & 0 & 0 & 0 \\ -0.1508 & 1 & 0 & 0 \\ -0.5615 & 0 & 1 & -0.2890 \\ -0.2877 & -1 & 0 & 1 \end{bmatrix}$$ And hence

$$[A_u{}^{-1}] = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0.1508 & 1 & 0 & 0 \\ 0.6882 & 0.2890 & 1 & 0.2890 \\ 0.4385 & 1 & 0 & 1 \end{bmatrix}$$

Using

$$P_{i-l} = \frac{P_{i-l}}{P_i}\sum_{k=1}^{n}[A_u^{-1}]\,P_{Gk} \tag{14}$$

Contribution of generators for the outflow power can be calculated. The result will be discussed in Chapter 4.

3.1.2 Gross Flow Algorithm

Upstream-looking Algorithm:

By using an assumption of proportional sharing, the algorithm of gross flow can be written as

$$P_i^{(gross)} - \sum_{j\in\alpha_i^{(u)}} \frac{P_{j-i}^{(gross)}}{P_j^{(gross)}} P_i^{(gross)} \qquad Or \qquad [A_u]P_{gross} = P_G \tag{15}$$

where P_{gross} , is the unknown vector of gross nodal flows and $[A_u]$ is the upstream distribution matrix calculated from the actual not modified flows.

Once gross nodal flow has been determined, the gross line flows and gross demand can also be founding using the proportional sharing principle. The gross flow in line $i - l$ is:

$$P_{i-l} = \frac{P_{i-l}}{P_i}\sum_{k=1}^{n}[A_u^{-1}]_{ik}\,P_{Gk}$$

While the gross demand can be calculated as

$$P_{Li} = \frac{P_{Li}}{P_i}\sum_{k=1}^{n}[A_u^{-1}]_{ij}\,P_{Gk} \tag{16}$$

The equation is important as it shows what would be load demand at a given node if a lossless network was fed with the actual generation.

Table 2: j values for different values of i

i	j values
1	-----
2	1
3	1, 4
4	1, 2

$$A_u(2,1) = -\frac{P_{1-2}^{(gross)}}{P_1^{gross}} = -\frac{60}{400} = -0.1500$$

$$A_u(3,1) = -\frac{P_{1-3}^{(gross)}}{P_1^{gross}} = -\frac{225}{400} = -0.5625$$

$$A_u(3,4) = -\frac{P_{4-3}^{(gross)}}{P_4^{gross}} = -\frac{83}{289} = -0.2872$$

$$A_u(4,1) = -\frac{P_{1-4}^{(gross)}}{P_1^{gross}} = -\frac{115}{400} = -0.2875$$

$$A_u(4,2) = -\frac{P_{2-4}^{(gross)}}{P_2^{gross}} = -\frac{174}{174} = -0.1000$$

Thus

$$A_u = \begin{bmatrix} 1 & 0 & 0 & 0 \\ -0.1500 & 1 & 0 & 0 \\ -0.5625 & 0 & 1 & -0.2872 \\ -0.2875 & -1 & 0 & 1 \end{bmatrix} \text{ And hence}$$

$$A_u^{-1} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0.1500 & 1 & 0 & 0 \\ 0.6882 & 0.2872 & 1 & 0.2872 \\ 0.4375 & 1 & 0 & 1 \end{bmatrix}$$

The result will be discussed in Chapter 4

3.1.3 Loss allocation algorithm

The advantage of this approach is that it gives additional insight into the electricity tracing algorithm presented in gross flow analysis. Consider again the gross nodal power

$$P_i^{(gross)} = P_i + \Delta P_i^{(gross)} \tag{17}$$

where $\Delta P_i^{(u)}$ is an unknown upstream nodal loss. Now consider $P_{i-j}^{(gross)} = P_{j-i}^{(gross)}$ in line $j-i$ supplying node i. $P_{i-j}^{(gross)} > P_{i-j}$ because some of the loss incurred in other lines supplying line $j-i$ is passed over to that line. This can be expressed as

$$\left|P_{i-j}^{(gross)}\right| = \left|P_{i-j}\right| + \Delta P_{i-j} + P_{(i-j)}^{(u)} \tag{18}$$

ΔP_{i-j} is the transmission loss in line $j-i$

It is necessary to assume a principle on which the nodal loss in the upstream breaks down into component $\Delta P_{j-i}^{(u)}$. The only requirement which must be met is that the sum of individual component must give the nodal loss, that is $\Delta P_j^{(u)} = \sum_{i\in\alpha_{j(d)}} \Delta P_{j-i}^{(u)} + \Delta P_{Lj}$ where ΔP_{Lj} is the component allocated in the j^{th} load [2]. This can be express as

$$\Delta P_{j-i}^{(u)} = \frac{\left|P_{j-i}\right|}{P_j} \Delta P_j^{(u)} \quad \& \quad \Delta P_{Lj} = \frac{P_{Lj}}{P_j} \Delta P_j^{(u)} \tag{19}$$

Equation (17) can be written as

$$P_i + \Delta P_i^{(u)} = \sum_{j\in\alpha_i^{(u)}} \left(|P_{i-j}| + \Delta P_{j-i} + \frac{|P_{j-i}|}{P_j} \Delta P_j^{(u)} \right) + P_{Gi} \tag{20}$$

Equation (18) can be simplifies to

$$\Delta P_i^{(u)} - \sum_{j\in\alpha_i^{(u)}} \frac{|P_{j-i}|}{P_j} \Delta P_j^{(u)} = \sum_{j\in\alpha_i^{(u)}} \Delta P_{i-j} \tag{21}$$

or

$$A_u \Delta P_{node}^{(u)} = \Delta P_{line}^{(u)}$$

(19) can be written in matrix form as

$$\begin{bmatrix} \Delta P_{node(1)}^{(u)} \\ \Delta P_{node(2)}^{(u)} \\ \vdots \\ \Delta P_{node(n)}^{(u)} \end{bmatrix} = [A_u]^{-1} \begin{bmatrix} P_{line(1)}^{(u)} \\ P_{line(2)}^{(u)} \\ \vdots \\ P_{line(n)}^{(u)} \end{bmatrix} \tag{22}$$

A_u is the previously defined upstream distribution matrix and $\Delta P_{node}^{(u)} = P_{gross} - P$ is the vector of unknown upstream nodal losses and $\Delta P_{line}^{(u)}$ is the vector which i^{th} element is equal to the sum of losses in all the lines supplying directly to node i. Solving equation (20) will gives the unknown vector $\Delta P_{node}^{(u)}$ and the final allocation of the total transmission loss to the individual loads is obtained from the equation (18).

CHAPTER 4

RESULT AND DISCUSSION

4.1 Results and Discussion

Before going on further onto the results, there are 5 results obtained by applying the methods mentioned in chapter 3 with subtopics of 3.1.1 and 3.1.2. These results can be used in the future for different approach. Since this project falls under the *Loss Allocation Algorithm*, this method is the primary method to be tested and implies to the title of this project.

Regarding to *Loss Allocation Algorithm* tests, it will be for the *Small System Network* (4-bus systems) and *Complex System Network* (14-bus systems). This test is conducted by using the data given by IEEE for 4 bus systems and 14 bus systems. The *Newton Raphson method* needs to be applied in this case and the results of line to line data is used to be applied on *Loss Allocation Algorithm*. Then the total power loss computed in *Newton Raphson Method* and *Loss Allocation Algorithm* is compared.

4.1.1 Average Line Flow Algorithm

The hand calculation is approximately equal to the result obtained from MATLAB. The only work to be completed is to apply some coding in MATLAB to perform calculation to calculate how much the incoming power flow from one bus to another bus and how much the outgoing power flow from one bus to another bus. The result obtained from MATLAB is shown in Figure 7:

```
>> A = [ 1 0 0 0; -0.1508 1 0 0; -0.5615 0 1 -0.2890; -0.2877 -1 0 1 ];
>> A = inv(A)

A =

    1.0000         0         0         0
    0.1508    1.0000         0         0
    0.6882    0.2890    1.0000    0.2890
    0.4385    1.0000         0    1.0000

>> B = [ 394.5; 172; 0; 0 ];
>> A * B

ans =

  394.5000
  231.4906
  321.2134
  344.9882

>>
```

Figure 7: MATLAB results for average power flow

Table 3: Power distributed from P_{G1} and P_{G2} to the lines (Average power flow)

Total i flow	Line i - l	From P_{G1}	From P_{G2}
59.50	1 – 2	$\frac{59.5}{394.5} \times 1 \times 394.5 = 59.50$	$\frac{59.5}{394.5} \times 0 \times 112.5 = 0$
221.50	1 – 3	$\frac{221.5}{394.5} \times 1 \times 394.5 = 221.50$	$\frac{221.5}{394.5} \times 0 \times 112.5 = 0$
113.50	1 – 4	$\frac{113.5}{394.5} \times 1 \times 394.5 = 113.50$	$\frac{113.5}{394.5} \times 0 \times 112.5 = 0$
171.99	2 – 4	$\frac{172}{172} \times 0.1508 \times 394.5 = 59.49$	$\frac{172}{172} \times 1 \times 112.5 = 112.50$
82.5	4 – 3	$\frac{82.5}{285.5} \times 0.4385 \times 394.5 = 49.99$	$\frac{82.5}{285.5} \times 1 \times 112.5 = 32.51$

Using

$$\frac{P_{Li}}{P_i}\left[A_u{}^{-1}\right]_{ik} P_{Gk}$$

Contribution of generators to meet the load powers can be calculated. The result is shown in Table 4 below:

Table 4: Power distributed from P_{G1} and P_{G2} to the loads (Average power flow)

Load	From P_{G1}	From P_{G2}	Total Load Power
L_3	$\frac{304}{304} \times 0.6882 \times 394.5 = 271.49$	$\frac{304}{304} \times 0.289 \times 112.5 = 32.51$	304
L_4	$\frac{203}{285.5} \times 0.4385 \times 394.5 = 123.00$	$\frac{203}{285.5} \times 1 \times 112.5 = 79.99$	202.99
Total	394.49	112.5	507

As one can see that the result obtained ≈ result calculated by hand calculation.

4.1.2 Gross Flow Algorithm

The result shows the method can be used as its final calculation is equal with the value done by hand calculation.

```
>> A = [ 1 0 0 0; -0.1500 1 0 0; -0.5625 0 1 -0.2933; -0.2875 -1 0 1 ];
>> A = inv(A)

A =

    1.0000         0         0         0
    0.1500    1.0000         0         0
    0.6908    0.2933    1.0000    0.2933
    0.4375    1.0000         0    1.0000

>> B = [ 400; 114; 0; 0 ];
>> A * B

ans =

  400.0000
  174.0000
  309.7637
  289.0000
```

Figure 8: MATLAB results for gross flow

Using equation

$$\frac{P_{i-l}}{P_l}\sum_{k=1}^{n}[A_u{}^{-1}]_{ik}P_{Gk} \qquad for\ all \in \alpha_i{}^{(d)}$$

Table 5: Power distributed from P_{G1} and P_{G2} to the lines (Gross flow)

Total i flow	Line i − l	From P_{G1}	From P_{G2}
60	1 − 2	$\frac{60}{400}\times 0\times 400 = 0$	$\frac{60}{400}\times 0\times 114 = 0$
225	1 − 3	$\frac{225}{400}\times 1\times 400 = 225$	$\frac{225}{400}\times 0\times 114 = 0$
115	1 − 4	$\frac{115}{400}\times 1\times 400 = 115$	$\frac{115}{400}\times 0\times 114 = 0$
173	2 − 4	$\frac{173}{173}\times 0.15\times 400 = 60$	$\frac{173}{173}\times 1\times 114 = 114$
83	4 − 3	$\frac{83}{283}\times 0.4375\times 400 = 51.3$	$\frac{83}{283}\times 1\times 114 = 33.4$

Using Eq. (16)

Contribution of generators to meet the load powers can be calculated. The result is shown below:

Table 6: Power distributed from P_{G1} and P_{G2} to the loads (Gross flow)

Load	From P_{G1}	From P_{G2}	Total Load Power
L_3	$\frac{300}{300}\times 0.6908\times 400 = 276.32$	$\frac{300}{300}\times 0.2933\times 114 = 33.44$	309.76
L_4	$\frac{200}{283}\times 0.4375\times 400 = 123.67$	$\frac{200}{283}\times 1\times 114 = 80.57$	204.24
Total	400	114	514

As one can see that the result obtained ≈ result calculated by hand calculation.

4.1.3 Loss Allocation Algorithm

The result obtained is approximately equal with the method use in gross flow. As expected that this method can also be used to trace electricity on how much the power contributed from load 1 and load 2 to each transmission line.

$$\Delta P_{line}^{(u)} = \begin{bmatrix} 0 \\ 60 - 59 = 1 \\ (225 - 218) + (83 - 82) = 8 \\ (115 - 112) + (173 - 171) = 5 \end{bmatrix}$$

Using equation (22)

$$\begin{bmatrix} \Delta P_{node(1)}^{(u)} \\ \Delta P_{node(2)}^{(u)} \\ \vdots \\ \Delta P_{node(n)}^{(u)} \end{bmatrix} = [A_u]^{-1} \begin{bmatrix} P_{line(1)}^{(u)} \\ P_{line(2)}^{(u)} \\ \vdots \\ P_{line(n)}^{(u)} \end{bmatrix}$$

$$\begin{bmatrix} P_1^{(u)} \\ P_2^{(u)} \\ P_3^{(u)} \\ P_4^{(u)} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0.15 & 1 & 0 & 0 \\ 0.6908 & 0.2933 & 1 & 0.2933 \\ 0.4375 & 1 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 1 \\ 8 \\ 5 \end{bmatrix} = \begin{bmatrix} 0 \\ 1 \\ 9.7598 \\ 6 \end{bmatrix}$$

For further calculation from equation above, the MATLAB calculation has been performs and shown as in Figure 9.

```
>> A = [ 1 0 0 0; -0.1500 1 0 0; -0.5625 0 1 -0.2933; -0.2875 -1 0 1 ];
>> A = inv(A)
 A =

    1.0000         0         0         0
    0.1500    1.0000         0         0
    0.6908    0.2933    1.0000    0.2933
    0.4375    1.0000         0    1.0000

>> dP = [ 0; 1; 8; 5 ]

dP =

     0
     1
     8
     5

>> A * dP

ans =

         0
    1.0000
    9.7598
    6.0000

>>
```

Figure 9: MATLAB result for Loss Allocation algorithm

Based on the A_u matrix calculated earlier in gross flow, the result of the total transmission loss to the individual loads is computed.

Table 7: Power loss at the loads (Loss allocation)

Load	Loss
L_3	$\frac{300}{300} \times 9.76 = 9.76$
L_4	$\frac{200}{283} \times 6 = 4.24$
Total loss	14

The result show loss allocation gives equal result with average line flow and gross flow.

The Loss Allocation algorithm is chosen in this project. Bear in mind that there will be two tests conducted which is 4 bus system and 14 bus system as simple power network and complex power network respectively.

The previous result shows the fixed data to be calculated using the loss allocation algorithm. To make it where people can have the data viewed and edited, the MATLAB program must have the input data prior to the easy used program. In order to do so, the M-file is necessity in this program. User can view and edit the input data inside the M-file to be calculated using Loss Allocation algorithm. After viewing and editing the input data, another M-file to calculate Loss Allocation algorithm must be introduced. The reason separating these two files is to less the time taken in order to do the computation using algorithm mentioned just now. Then the result is viewed by creating another M-file specifically to view the result in MATLAB command window. The flow chart of this process is viewed in Figure 10.

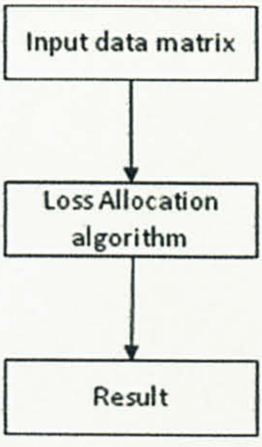

Figure 10: MATLAB M-file flow chart process

Starting with 4 bus system, the input data matrix is organized in proper element to make the coding possible for the number of bus from two to infinity. The input data in MATLAB M-file is shown in Figure 11.

```
%                               4-bus System IEEE
%                         Bus   Bus    ni     nj    Generation    Load
%                    no   ni    nj     MVA    MVA      MVA        MVA
LAlinedata = [       1    1     1      0      0        400        0
                     2    1     2      60     59       0          0
                     3    1     3      225    218      0          0
                     4    1     4      115    112      0          0
                     5    2     1      0      0        0          0
                     6    2     2      0      0        114        0
                     7    2     3      0      0        0          0
                     8    2     4      173    171      0          0
                     9    3     1      0      0        0          0
                     10   3     2      0      0        0          0
                     11   3     3      0      0        0          300
                     12   3     4      0      0        0          0
                     13   4     1      0      0        0          0
                     14   4     2      0      0        0          0
                     15   4     3      83     82       0          0
                     16   4     4      0      0        0          200 ]

Pline = [ 0; 1; 8; 5 ];

lfAmat %go to other mfile to execute function
```

Figure 11: Input data in M-file (4 bus system)

In Column 1 of the matrix, the value is not a significant to the data because the number is representing how many rows in the matrix have. In column 2, the values are for the bus sending end and for column 3 is bus receiving end. In column 4, the values are receiving end real power at a particular bus and for column 5 is the real power for sending end. Generation real power also has significant in the algorithm thus the value for real power generation is set at column 5. Column no 6 refers to the value of real power at the load.

Users can alter the data to be less or more bus system by looking at the '*ni*' and '*nj*'. If wanted to add the buses, just introduce the bus of n^{th} element into the matrix and key in the data. The more data the more lines will have. Once setting all the data, the data which is named in the form of matrix is called 'LAlinedata' will be send to another program to be calculated. The other program is called 'lfAmat' where the Loss Allocation algorithm is made. The M-file for the Loss Allocation algorithm is shown in Figure 12.

```
ni = LAlinedata(:,2); nj = LAlinedata(:,3); nA = max(max(ni),max(nj));
rpwi = LAlinedata(:,4); rpwj = LAlinedata(:,5); rpwgen =
LAlinedata(:,6);
rpwload = LAlinedata(:,7);
nA = max(max(ni), max(nj));
%Abus = zeros(nA,nA);
size(rpwi); %create a size of 16x1 matrix
value = ans(1); %value = 16
Abus = zeros(nA,nA);

Abus = reshape(rpwi,nA,nA); %shape the matrix by nA x nA
Abus1 = Abus(:,1)./400; %all row and 1st column divided by 400
Abus2 = Abus(:,2)./173; %all row and 1st column divided by 173
Abus3 = Abus(:,3)./300; %all row and 1st column divided by 300
Abus4 = Abus(:,4)./283; %all row and 1st column divided by 283
Abus = horzcat(Abus1,Abus2,Abus3,Abus4); %concatenation of 4x4 matrix
Abus = Abus * -1; % all the element is times -1
Abus = Abus + eye(4); % add the result with diagonal of 1
Abus = inv(Abus) %taking the inverse of the result
dP = Abus * Pline % taking the product of result and data


lossb1 = 400/400 * dP(1,:) %product of total power at bus 1
lossb2 = 173/173 * dP(2,:) %product of total power at bus 2
lossb3 = 300/300 * dP(3,:) %product of total power at bus 3
lossb4 = 200/283 * dP(4,:) %product of total power at bus 4

Tloss = lossb4 + lossb3 %total power loss
```

Figure 12: Loss Allocation algorithm in M-file (4 bus system)

This Loss Allocation algorithm is done in few steps. From Figure 9, the value must be defined first from the input data from Figure 8. Then after defined it, the values need to be used in the algorithm. Since the algorithm consist of matrix (eq. 22), the element positioning in the new matrix is reshape to be m x m matrix from the data of column 4. After that the computation continues by summing the off diagonal element and diagonal element. From eq. 22, $\Delta P_{node}^{(u)}$ is defined and the difference in sending end and receiving end is computed. Then the loss allocation is computed by having the product of the two matrixes. Figure 13 shows the flow of the algorithm.

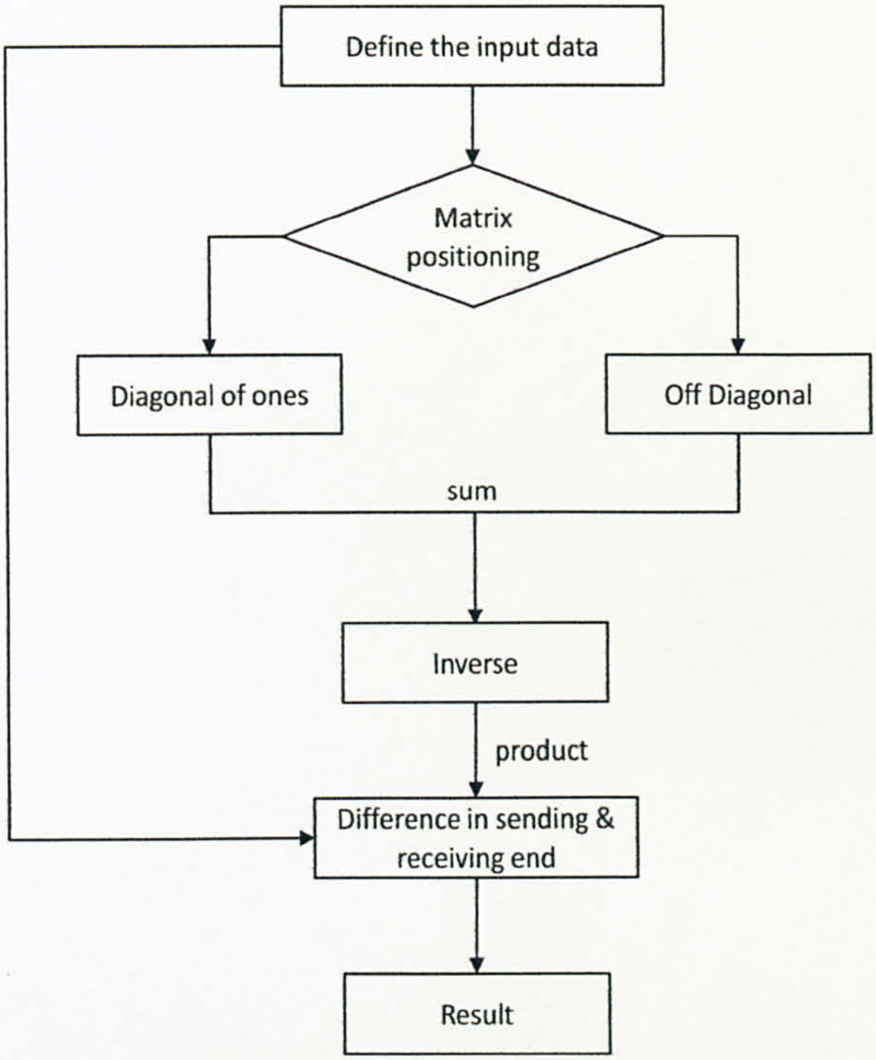

Figure 13: Loss Allocation algorithm flow

Once the data has been calculated the result shows exactly the same as the hand calculation. To run this program, one must define the location of program folder. Figure 14 shows the steps taken to run the program to see the result.

```
>> %find the location of the project folder
>> addpath 'D:\4th2nd(final) sem\FYP Source Code\Projek\loss
allocation\4 bus system'
>> %run IEEE4 to make computation
>> IEEE4

dP =

         0
    1.0000
    9.7597
    6.0000


lossb1 =

     0

lossb2 =

     1

lossb3 =

    9.7597

lossb4 =

    4.2403

Tloss =

    14
>>
```

Figure 14: Steps to run the program and the result

As the result tells, at the slack bus (bus 1) no loss is occurred and at bus 2, there are 1MW loss occurred during the transmission. However, at bus 3 and 4, it is clear that the load loss has occurred and the total of the load loss is 14 as the hand calculation shows. Thus, the result is equal with hand calculation.

For 14 bus system, Newton Raphson method is used to find the data of line-to-line power as mentioned in subtopic 4.1. This is because the data provided by IEEE is in per-unit. Once obtaining the line to line data as well as the total power loss of Newton *Raphson method*, the *Loss Allocation* is computed. The flow of the coding is the same as 4-bus system but the only difference is more input introduce in 14-bus system. If 4-bus system can create 4×4 matrix which gives 16 lines of input data (still can be computed), but 14-bus system will have to create 14×14 matrix which gives 196 lines of input data. That matrix magnitude of that scale is difficult to compute by hand calculation.

The 14 bus system data is obtained by IEEE and the coding to compute *Newton Raphson method* is obtained from Power System Analysis by Hadi Saadat [5]. Since this project want to apply *Loss Allocation algorithm* fully and the 14 bus system is quite long for results, we will not go onto details on the Newton Raphson but just taking it total power loss (active power only) to be compared to total loss of *Loss Allocation algorithm.*

The result of Newton Raphson method gives:

```
Total loss                              13.455   26.977
```

The Loss Allocation input data for 14-bus system is shown on Appendix A:

As one can see, the more the bus numbers more lines the input data will be which the only problem for this is coding approaches. It is due to lack of knowledge in MATLAB syntax and difficulties in setting the condition to do the computation.

However, the algorithm is no different from 4 bus system just that a few lines are added in order to satisfy the 14 bus system requirement. The algorithm is as in Appendix B.

As we mentioned before, the steps is all the same and just add a few more line to satisfy the requirement of 14 bus system. Ones can compare it with 4 bus system and can simply put the coding is quite simple (time effective) for the processor to process the data.

As for the results, it is quite good as the difference in power mismatch between Newton Raphson method and Loss allocation is very small. The result would be as in Appendix C. However, for quick reference for the result, the table below shows the simplified results for the 14-bus system.

Table 8: Simplified result for 14-bus system

N Node for *N*=1,2,3…	$\Delta P_{node(N)}^{(u)}$ for N =1,2,3… (MW)
1	0
2	0.4834
3	5.5254
4	3.0024
5	0.3081
6	0.4540
7	0
8	0
9	1.5157
10	0.4822
11	0.1690
12	0.0633
13	0.1598
14	1.3287
Total	13.4919

As we can see, the total powers mismatch from Newton Rahpson's method and loss allocation is $13.4919 - 13.455 = 0.0369$ mismatch.

CHAPTER 5

CONCLUSION AND RECOMENDATION

5.1 Conclusion and Recomendation

The result of the 3 methods use to trace electricity has been obtained and compare. It shows that the results obtained is approximately the same as using the different algorithm to compute the power that has been contributed at generation one and generation two to every transmission line as well as it also can be obtained from load one and load two to every transmission line. This method (loss allocation) has been confirmed can be used in tracing the electricity for the simple network (4 bus system) and complex network (14 bus system). Using the basis of this algorithm and apply it into MATLAB have give the loss allocation advantages in many ways over Newton Raphson.

1. Time effective:

   The computation doesn't involves looping in MATLAB coding but it involves built in function inside MATLAB and it has gives the boost in time computation of the data.

2. Contribution of individual load.

   The contribution of individual loads can be computed and gives more insight to how much power loss at particular bus.

As for the disadvantages, this method requires Newton Raphson to gain the line-to-line data because this algorithm cannot be computed in per-unit but real power. That's the only disadvantage it has.

The conclusion, I conclude that this method gives additional insight in identifying the contribution of individual load and generator where Newton Raphson cannot provided.

As for the recommendation, this coding approach can still be modified to use only the necessary data compared in this project. As we can see from the data input, there are too many unnecessary data that contains zero variables inside it. Perhaps by using another approach to modify the coding will help eliminate the unnecessary data.

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APPENDICES

APPENDIX A

THE LOSS ALLOCATION INPUT DATA FOR 14-BUS SYSTEM (LAlinedata)

```
%                        14-bus System IEEE
%                   Bus   Bus    ni       nj       Generation    Load
%              no   ni    nj     MVA      MVA        MVA         MVA
LAlinedata = [  1    1     1     0.0      0.0       232.453       0.0
                2    1     2    156.88   152.50       0.0         0.0
                3    1     3     0.0      0.0         0.0         0.0
                4    1     4     0.0      0.0         0.0         0.0
                5    1     5    75.51    72.75        0.0         0.0
                6    1     6     0.0      0.0         0.0         0.0
                7    1     7     0.0      0.0         0.0         0.0
                8    1     8     0.0      0.0         0.0         0.0
                9    1     9     0.0      0.0         0.0         0.0
               10    1    10     0.0      0.0         0.0         0.0
               11    1    11     0.0      0.0         0.0         0.0
               12    1    12     0.0      0.0         0.0         0.0
               13    1    13     0.0      0.0         0.0         0.0
               14    1    14     0.0      0.0         0.0         0.0
               15    2     1     0.0      0.0         0.0         0.0
               16    2     2     0.0      0.0        40.0        21.7
               17    2     3    73.24    70.91        0.0         0.0
               18    2     4    56.13    54.45        0.0         0.0
               19    2     5    41.52    40.61        0.0         0.0
               20    2     6     0.0      0.0         0.0         0.0
               21    2     7     0.0      0.0         0.0         0.0
               22    2     8     0.0      0.0         0.0         0.0
               23    2     9     0.0      0.0         0.0         0.0
               24    2    10     0.0      0.0         0.0         0.0
               25    2    11     0.0      0.0         0.0         0.0
               26    2    12     0.0      0.0         0.0         0.0
               27    2    13     0.0      0.0         0.0         0.0
               28    2    14     0.0      0.0         0.0         0.0
               29    3     1     0.0      0.0         0.0         0.0
               30    3     2     0.0      0.0         0.0         0.0
               31    3     3     0.0      0.0         0.0        94.2
               32    3     4     0.0      0.0         0.0         0.0
               33    3     5     0.0      0.0         0.0         0.0
               34    3     6     0.0      0.0         0.0         0.0
               35    3     7     0.0      0.0         0.0         0.0
               36    3     8     0.0      0.0         0.0         0.0
               37    3     9     0.0      0.0         0.0         0.0
               38    3    10     0.0      0.0         0.0         0.0
               39    3    11     0.0      0.0         0.0         0.0
               40    3    12     0.0      0.0         0.0         0.0
               41    3    13     0.0      0.0         0.0         0.0
               42    3    14     0.0      0.0         0.0         0.0
```

43	4	1	0.0	0.0	0.0	0.0
44	4	2	0.0	0.0	0.0	0.0
45	4	3	23.66	23.29	0.0	0.0
46	4	4	0.0	0.0	0.0	47.8
47	4	5	0.0	0.0	0.0	0.0
48	4	6	0.0	0.0	0.0	0.0
49	4	7	28.07	28.07	0.0	0.0
50	4	8	0.0	0.0	0.0	0.0
51	4	9	16.08	16.08	0.0	0.0
52	4	10	0.0	0.0	0.0	0.0
53	4	11	0.0	0.0	0.0	0.0
54	4	12	0.0	0.0	0.0	0.0
55	4	13	0.0	0.0	0.0	0.0
56	4	14	0.0	0.0	0.0	0.0
57	5	1	0.0	0.0	0.0	0.0
58	5	2	0.0	0.0	0.0	0.0
59	5	3	0.0	0.0	0.0	0.0
60	5	4	61.67	61.16	0.0	0.0
61	5	5	0.0	0.0	0.0	7.6
62	5	6	44.09	44.09	0.0	0.0
63	5	7	0.0	0.0	0.0	0.0
64	5	8	0.0	0.0	0.0	0.0
65	5	9	0.0	0.0	0.0	0.0
66	5	10	0.0	0.0	0.0	0.0
67	5	11	0.0	0.0	0.0	0.0
68	5	12	0.0	0.0	0.0	0.0
69	5	13	0.0	0.0	0.0	0.0
70	5	14	0.0	0.0	0.0	0.0
71	6	1	0.0	0.0	0.0	0.0
72	6	2	0.0	0.0	0.0	0.0
73	6	3	0.0	0.0	0.0	0.0
74	6	4	0.0	0.0	0.0	0.0
75	6	5	0.0	0.0	0.0	0.0
76	6	6	0.0	0.0	0.0	11.2
77	6	7	0.0	0.0	0.0	0.0
78	6	8	0.0	0.0	0.0	0.0
79	6	9	0.0	0.0	0.0	0.0
80	6	10	0.0	0.0	0.0	0.0
81	6	11	7.35	7.3	0.0	0.0
82	6	12	0.0	0.0	0.0	0.0
83	6	13	0.0	0.0	0.0	0.0
84	6	14	0.0	0.0	0.0	0.0
85	7	1	0.0	0.0	0.0	0.0
86	7	2	0.0	0.0	0.0	0.0
87	7	3	0.0	0.0	0.0	0.0
88	7	4	0.0	0.0	0.0	0.0
89	7	5	0.0	0.0	0.0	0.0
90	7	6	0.0	0.0	0.0	0.0
91	7	7	0.0	0.0	0.0	0.0
92	7	8	0.0	0.0	0.0	0.0
93	7	9	28.07	28.07	0.0	0.0

94	7	10	0.0	0.0	0.0	0.0
95	7	11	0.0	0.0	0.0	0.0
96	7	12	0.0	0.0	0.0	0.0
97	7	13	0.0	0.0	0.0	0.0
98	7	14	0.0	0.0	0.0	0.0
99	8	1	0.0	0.0	0.0	0.0
100	8	2	0.0	0.0	0.0	0.0
101	8	3	0.0	0.0	0.0	0.0
102	8	4	0.0	0.0	0.0	0.0
103	8	5	0.0	0.0	0.0	0.0
104	8	6	0.0	0.0	0.0	0.0
105	8	7	0.0	0.0	0.0	0.0
106	8	8	0.0	0.0	0.0	0.0
107	8	9	0.0	0.0	0.0	0.0
108	8	10	0.0	0.0	0.0	0.0
109	8	11	0.0	0.0	0.0	0.0
110	8	12	0.0	0.0	0.0	0.0
111	8	13	0.0	0.0	0.0	0.0
112	8	14	0.0	0.0	0.0	0.0
113	9	1	0.0	0.0	0.0	0.0
114	9	2	0.0	0.0	0.0	0.0
115	9	3	0.0	0.0	0.0	0.0
116	9	4	0.0	0.0	0.0	0.0
117	9	5	0.0	0.0	0.0	0.0
118	9	6	0.0	0.0	0.0	0.0
119	9	7	0.0	0.0	0.0	0.0
120	9	8	0.0	0.0	0.0	0.0
121	9	9	0.0	0.0	0.0	29.5
122	9	10	5.23	5.21	0.0	0.0
123	9	11	0.0	0.0	0.0	0.0
124	9	12	0.0	0.0	0.0	0.0
125	9	13	0.0	0.0	0.0	0.0
126	9	14	9.43	9.31	0.0	0.0
127	10	1	0.0	0.0	0.0	0.0
128	10	2	0.0	0.0	0.0	0.0
129	10	3	0.0	0.0	0.0	0.0
130	10	4	0.0	0.0	0.0	0.0
131	10	5	0.0	0.0	0.0	0.0
132	10	6	0.0	0.0	0.0	0.0
133	10	7	0.0	0.0	0.0	0.0
134	10	8	0.0	0.0	0.0	0.0
135	10	9	0.0	0.0	0.0	0.0
136	10	10	0.0	0.0	0.0	9.0
137	10	11	0.0	0.0	0.0	0.0
138	10	12	0.0	0.0	0.0	0.0
139	10	13	0.0	0.0	0.0	0.0
140	10	14	0.0	0.0	0.0	0.0
141	11	1	0.0	0.0	0.0	0.0
142	11	2	0.0	0.0	0.0	0.0
143	11	3	0.0	0.0	0.0	0.0
144	11	4	0.0	0.0	0.0	0.0

145	11	5	0.0	0.0	0.0	0.0
146	11	6	0.0	0.0	0.0	0.0
147	11	7	0.0	0.0	0.0	0.0
148	11	8	0.0	0.0	0.0	0.0
149	11	9	0.0	0.0	0.0	0.0
150	11	10	3.80	3.79	0.0	0.0
151	11	11	0.0	0.0	0.0	3.5
152	11	12	0.0	0.0	0.0	0.0
153	11	13	0.0	0.0	0.0	0.0
154	11	14	0.0	0.0	0.0	0.0
155	12	1	0.0	0.0	0.0	0.0
156	12	2	0.0	0.0	0.0	0.0
157	12	3	0.0	0.0	0.0	0.0
158	12	4	0.0	0.0	0.0	0.0
159	12	5	0.0	0.0	0.0	0.0
160	12	6	0.0	0.0	0.0	0.0
161	12	7	0.0	0.0	0.0	0.0
162	12	8	0.0	0.0	0.0	0.0
163	12	9	0.0	0.0	0.0	0.0
164	12	10	0.0	0.0	0.0	0.0
165	12	11	0.0	0.0	0.0	0.0
166	12	12	0.0	0.0	0.0	6.1
167	12	13	1.61	1.61	0.0	0.0
168	12	14	0.0	0.0	0.0	0.0
169	13	1	0.0	0.0	0.0	0.0
170	13	2	0.0	0.0	0.0	0.0
171	13	3	0.0	0.0	0.0	0.0
172	13	4	0.0	0.0	0.0	0.0
173	13	5	0.0	0.0	0.0	0.0
174	13	6	0.0	0.0	0.0	0.0
175	13	7	0.0	0.0	0.0	0.0
176	13	8	0.0	0.0	0.0	0.0
177	13	9	0.0	0.0	0.0	0.0
178	13	10	0.0	0.0	0.0	0.0
179	13	11	0.0	0.0	0.0	0.0
180	13	12	0.0	0.0	0.0	0.0
181	13	13	0.0	0.0	0.0	13.5
182	13	14	5.64	5.59	0.0	0.0
183	14	1	0.0	0.0	0.0	0.0
184	14	2	0.0	0.0	0.0	0.0
185	14	3	0.0	0.0	0.0	0.0
186	14	4	0.0	0.0	0.0	0.0
187	14	5	0.0	0.0	0.0	0.0
188	14	6	0.0	0.0	0.0	0.0
189	14	7	0.0	0.0	0.0	0.0
190	14	8	0.0	0.0	0.0	0.0
191	14	9	0.0	0.0	0.0	0.0
192	14	10	0.0	0.0	0.0	0.0
193	14	11	0.0	0.0	0.0	0.0
194	14	12	0.0	0.0	0.0	0.0
195	14	13	0.0	0.0	0.0	0.0

```
              196   14   14     0.0     0.0         0.0         14.9 ];

Pline = [ 0; 4.29; 2.7; 2.19; 3.67; 0; 0; 0; 0; 0.03; 0.06;...
0.08; 0.21; 0.05 ];

lfAmat
```

APPENDIX B

LOSS ALLOCATION ALGORITHM CODING FOR14-BUS SYSTEM (LfAmat)

```
ni = LAlinedata(:,2); nj = Lalinedata(:,3); nA = max(max(ni),max(nj));
rpwi = Lalinedata(:,4); rpwj = Lalinedata(:,5); rpwgen =
Lalinedata(:,6);
rpwload = Lalinedata(:,7);
nA = max(max(nj), max(nj));
size(rpwi); %create a size of 16x1 matrix
value =ans(1); %value = 16
Abus = reshape(rpwi,nA,nA);
Abus1 = Abus(:,1)./232.39;
Abus2 = Abus(:,2)./192.59;
Abus3 = Abus(:,3)./94.57;
Abus4 = Abus(:,4)./115.61;
Abus5 = Abus(:,5)./113.36;
Abus6 = Abus(:,6)./44.9;
Abus7 = Abus(:,7)./28.07;
Abus8 = Abus(:,8);
Abus9 = Abus(:,9)./44.15;
Abus10 = Abus(:,10)./9;
Abus11 = Abus(:,11)./7.3;
Abus12 = Abus(:,12)./7.71;
Abus13 = Abus(:,13)./1.61;
Abus14 = Abus(:,14)./14.9;
Abus = horzcat(Abus1,Abus2,Abus3,Abus4,Abus5,Abus6,Abus7,Abus8,Abus9,...
Abus10,Abus11,Abus12,Abus13,Abus14); %contenation of 14 columns

Abus = Abus * -1; % all the element is times -1
Abus = Abus + eye(14); % add the result with diagonal of 1
Abus = inv(Abus); %taking the inverse of the result
dP = Abus * Pline ; % taking the product of result and data

lossb1 = 232.453/232.453 * dP(1,☺ %product of total power at bus 1
lossb2 = 21.7/192.59 * dP(2,☺ %product of total power at bus 2
lossb3 = 94.2/94.57 * dP(3,☺ %product of total power at bus 3
lossb4 = 47.8/94.57 * dP(4,☺ %product of total power at bus 4
lossb5 = 7.6/113.36 * dP(5,☺ %product of total power at bus 5
lossb6 = 11.20/44.09 * dP(6,☺ %product of total power at bus 6
lossb7 = 0 * dP(7,☺ %product of total power at bus 7
lossb8 = 0 * dP(8,☺ %product of total power at bus 8
lossb9 = 29.5/44.15 * dP(9,☺ %product of total power at bus 9
lossb10 = 9/9 * dP(10,☺ %product of total power at bus 10
lossb11 = 3.5/7.3 * dP(11,☺ %product of total power at bus 11
lossb12 = 6.1/7.71 * dP(12,☺ %product of total power at bus 12
lossb13 = 13.5/19.15 * dP(13,☺ %product of total power at bus 13
lossb14 = 14.9/14.9 * dP(14,☺ %product of total power at bus 14
```

```
Tloss =
lossb2+lossb3+lossb4+lossb5+lossb6+lossb7+lossb8+lossb9+lossb10...
                          +lossb11+lossb12+lossb13+lossb14
```

APPENDIX C

LOSS ALLOCATION RESULTS FOR 14-BUS SYSTEM (IEEE14)

```
>> addpath 'D:\4th2nd(final) sem\FYP Source Code\Projek\loss
allocation\14 bus system'
>> IEEE14

lossb1 =

     0

lossb2 =

    0.4834

lossb3 =

    5.5254

lossb4 =

    3.0024

 lossb5 =

    0.3081

lossb6 =

    0.4540

lossb7 =

     0

lossb8 =

     0

lossb9 =

    1.5157

lossb10 =
```

```
    0.4822

lossb11 =

    0.1690

lossb12 =

    0.0633

lossb13 =

    0.1598

lossb14 =

    1.3287

Tloss =

   13.4919
>>
```