**Proceedings of the**
**International Conference on Mechanical Engineering 2007**
**(ICME2007) 29- 31 December 2007, Dhaka, Bangladesh**

**ICME07-AM-41**

# DECISION MAKING ON LOAD CONNECCTION FROM DIFFERENT SUBSTATIONS OF SPECIFIC CAPACITY ON THE BASIS OF MINIMUM TRANSMISSION LOSS

**Sikder Mainul Hasan[1] and Md. Siful Islam[2]**

[1] Dept. of IEM, Khulna University of Engineering & Technology, Khulna 920300,
[2] Khulna Power Station(BPDB), Goal Para, Khulna 9000.

## ABSTRACT

To connect large electric loads of certain MW demand, the REB constructs high tension line (33 KV/11 KV) from substation to load end. The transmission loss of electricity from substation to load-end depends on line length, quantity of load, resistance of wire etc. If in an area there exists some newly constructed large electric loads of various demands and there exists facilities and if load connection is possible from different substations of specific capacity, it would be more viable to give connection according to lowest transmission loss. Paper indicates three substations are available to connect four large loads (Cold storage, cement factory, fertilizer factory & textile mill) existing in different location of Jessore district. A countable amount of transmission loss may be reduced if the connections are given on the basis of lowest transmission loss determined by transportation model. An education version software TORA was used for transportation model analysis and subsequent decision making on load connection.

**Keywords:** Transportation Model, Transmission Loss, Load Connection

## 1. INTRODUCTION

The transportation model is a special class of linear programming that deals with shipping a commodity from sources to destinations. The objective is to determine the shipping schedule that minimizes the total shipping cost while satisfying supply and demand limits [1]. The model assumes that the shipping cost is proportional to the number of units shipped on a given route.

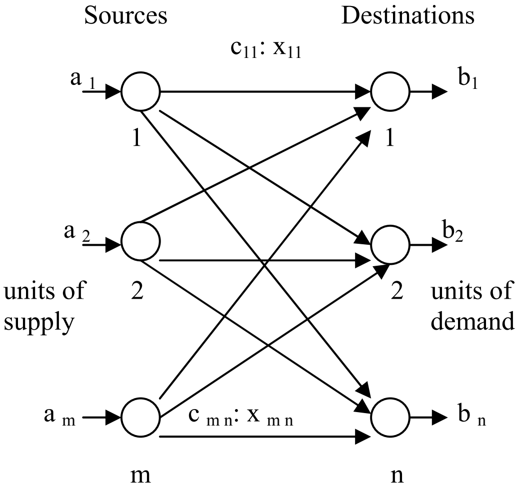


Figure 1.1: Representation of the transportation model with node and arcs.

The general problem is represented by the network in Figure 1.1. There are m **sources** and n **destinations**, each represented by a **node**. The **arcs** represent the routes linking the sources and the destinations. Arc (i,j) joining source i to destination j carries two pieces of information : the transportation cost per unit, $c_{ij}$, and the amount shipped, $x_{ij}$. The amount of supply at source i is $a_i$, and the amount of demand at destination j is $b_j$. The objective of the model is to determine the unknowns $x_{ij}$ that will minimize the total transportation cost while satisfying all the supply and demand restrictions.

### 1.1 The Transportation Algorithm

The transportation algorithm is based on the assumption that the model is **balanced,** meaning that the total demand equals the total supply [2] & [3]. The transportation algorithm is explained by the following example:

Let $x_{ij}$ represents the amount transported from source i to destination j; then the LP model representing the transportation problem is given normally as

$$\text{minimize } z = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij} x_{ij}$$

subject to

$$\sum_{j=1}^{n} x_{ij} \le a_i \qquad i = 1, 2, \ldots\ldots\ldots, m$$

$$\sum_{i=1}^{m} x_{ij} \ge b_i \qquad j = 1, 2, \ldots\ldots\ldots, n$$

$$x_{ij} \ge 0 \text{ for all i and j}$$

the first set of constraints stipulates that the sum of the shipments from a source cannot exceed its supply; similarly the second set requires that the sum of the shipments to a destination must satisfy its demand.

The model just described implies that the total supply $\sum_{i=1}^{m} a_i$ must at least equal the total demand $\sum_{j=1}^{n} b_j$. When the total supply demand equals the total demand ($\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j$), the resulting formulation is called a balanced transportation model. It differs from the model above only in the fact that all constraint are equation; that is

$$\sum_{j=1}^{n} x_{ij} \le a_i \qquad i = 1, 2, \ldots\ldots, m$$

$$\sum_{i=1}^{m} x_{ij} \ge b_i \qquad j = 1, 2, \ldots\ldots, n$$

in real life it is not necessarily true that supply equal demand or, for that matter, exceed it. However a transportation model can always be balanced. If the model is unbalanced, we can always augment it with a dummy source or a dummy destination to restore balance. When demand exceeds the supply, a dummy source is added to balance the transportation model. In this case, the unit transportation cost from the dummy plant to the destinations is zero because the plant does not exist.

Table 2.1: Distances from the different substations to different loads

| | NOA PARA | BASU NDIA | RAJA RHAT | JESSO RE | DUM MY | CAPA CITY |
|---|---|---|---|---|---|---|
| MONI RAM PUR | 25km | 37km | 15km | 22km | 0Km | 8MW |
| NOAP ARA | 5km | 15km | 20km | 24km | 0Km | 8MW |
| BASU NDIA | 12km | 3km | 8km | 12km | 0Km | [ 4MW |
| Demand | 4 | 5 | 4 | 3 | 4 | |

## 2. DESCRIPTION OF THE PROBLEM

There are three substations named as Monirampur, noapara, and Basundia of Jessore district of capacity 8MW, 8MW and 4MW respectively. The loads at the location of Noapara, Basundia, Rajarhat, and Jessore of demand 4MW, 5MW, 4MW and 3MW are to be connected from the above mentioned substations. The distances from the different substations to different loads are given in Table 2.1

## 3. FORMATION OF TRANSPORTATION ALGORITHM

To construct the transportation algorithm, it is necessary to calculate the per unit transmission loss. If 1 MW load is connected to a line of 1km length, the line loss is 3.87 KW (see calculation). The line lengths from different substations to different loads are different, so the losses of per MW transmission through different routes are also different. The per MW transmission loss of different routes are shown in the Table 3.1

Table 3.1: Per MW transmission loss of different routes

| | NOAP ARA | BASU NDIA | RAJA RHAT | JESSO RE | DUM MY | CAPA CITY |
|---|---|---|---|---|---|---|
| MONI RAMP UR | 96.75 | 143.19 | 58.05 | 85.14 | 0 | 8 |
| NOAP ARA | 19.35 | 58.05 | 77.4 | 92.88 | 0 | 8 |
| BASU NDIA | 46.44 | 11.61 | 30.96 | 46.44 | 0 | 4 |
| Dem. In MW | 4 | 5 | 4 | 3 | 4 | |

To find the starting solution of the algorithm, there are three methods.

1) North west corner method 2) Least cost method and 3) Vogel's approximation method.

Here least cost method is used to solve the algorithm.

### 3.1 Least-Cost Method

The Least-cost method finds a better starting solution by concentrating on the cheapest routes [4]. The method starts by assigning as much as possible to the cell with the smallest unit cost. Next, the satisfied row or column is crossed out and the amounts of supply and demand are adjusted accordingly. If both a row and a column are satisfied simultaneously, only one is crossed out. Next, look for the uncrossed out cell with the smallest unit cost and repeat the process until exactly one row or column is left uncrossed out.

The least-cost method is applied in Table 3.1 to find out the starting solution. The starting solution is shown in the table below:

Table 3.2: Starting solution least-cost method

| | NOA PARA | BASU NDIA | RAJA RHAT | JESSO RE | DUM MY | CAPA CITY |
|---|---|---|---|---|---|---|
| MONI RAM PUR | 96.75 | 143.19 **1** | 58.05 **4** | 85.14 **3** | 0 | 8MW |
| NOAP ARA | 19.35 **4** | 58.05 | 77.4 | 92.88 | 0 **4** | 8MW |
| BASU NDIA | 46.44 | 11.61 **4** | 30.96 | 46.44 | 0 | [ 4MW |
| Demand | 4 | 5 | 4 | 3 | 4 | |

Actually line loss does not increases proportionally to the load. For example, if 1 MW load is connected to 1 km line, the line loss is 3.87 KW, which is 62 KW not 15.48 (4*3.87=15.48) KW for 4 MW load. Therefore, line loss is calculated for different loads. Though load of different ratings are connected to line, the per MW transmission loss is not taken as 3.87 KW instead average 14.04 KW (see calculation).

Taking 14.04 KW loss for per Mw load transmission the table 3.2 becomes Table 3.3:

Table 3.3: starting solution

| | NOA PARA | BASU NDIA | RAJA RHAT | JESSO RE | DUM MY | CAPA CITY |
|---|---|---|---|---|---|---|
| MONI RAM PUR | 351 | 519.48 **1** | 210.6 **4** | 308.88 **3** | 0 | 8MW |
| NOAP ARA | 70.2 **4** | 210.6 | 280.8 | 336.96 | 0 **4** | 8MW |
| BASU NDIA | 168.4 | 42.12 **4** | 112.32 | 168.4 | 0 | [ 4MW |
| Demand | 4 | 5 | 4 | 3 | 4 | |

If the loads mentioned in the problem are connected from the substations according with the starting solution of table 3.3, the total line loss will be:

Total loss =4×70.2 + 1×519.48+ 4×42.12 + 4×210.6+ 3×308.88= 2737.8KW= 2737.8×24×30=1971216 Kwh.

The final solution by TORA software is shown in Table : TORA 3. If the loads are rearranged in another way (random order) described in table 3.3 , say in the following way in Table 3.4,

Table: 3.4: Final solution by TORA software

| | NOA PARA | BASU NDIA | RAJA RHAT | JESSO RE | DUM MY | CAPA CITY |
|---|---|---|---|---|---|---|
| MONI RAM PUR | 351 **4** | 519.48 **4** | 210.6 | 308.88 | 0 | 8MW |
| NOAP ARA | 70.2 | 210.6 **1** | 280.8 **4** | 336.96 **3** | 0 | 8MW |
| BASU NDIA | 168.4 | 42.12 | 112.32 | 168.4 | 0 **4** | [ 4MW |
| Demand | 4 | 5 | 4 | 3 | 4 | |

The monthly line loss for the arrangement of Table 3.4 =(4×351 + 4×519.48 + 1×210.6+ 4×280.8+ 3×336.96+ 4×0= 5826.6KW) ×24×30= 4195152 Kwh.

## 4. CALCULATION

The conductor used to construct the line is 4 knot ACSR. The resistance of the wire is 0.38Ω/km.

Power (P)=$\sqrt{3} \times V_L \times I_L \times Cos\Theta$

If the substation's transformer secondary is Y connected and 1 MW load is connected with 11KV line of length 1km then,

$\sqrt{3} \times 11000 \times I_L \times 0.9 = 1000000$ [P.F, Cosθ=0.9]

$\therefore I_L = 58.31$ Ampere.

Line loss (length of line = 1 km) due to 1 MW load,

$P = 3 \times I^2 \times R = 3 \times (58.31)^2 \times 0.38 = 3.87$ KW [multiplied by 3 for 3 phases]

To get line loss for 1Mwh transmission through different routes of length 3km, 5km, 8km, 12km, 15km, 20km, 22km, 24km, 25km & 37km mentioned in the problem, 3.87KW is multiplied by the respective length of the line and the loss is 11.61KW, 19.35KW, 30.96W, 46.44KW, 58.05KW, 77.4KW, 85.14KW, 92.88KW, 96.75KW, 143.19KW.

Kilowatt-hour loss for 1 Megawatt hour transmission through different routes is found by multiplying these Kilowatt losses with hour **(used in table3.2).**

Actually only 1MW load is not connected with the different lines, so line loss must be calculated for different Megawatt loads. For 1 MW load with 1km line length the loss is 3.87KW (calculated before). Similarly for 2 MW, 3 MW, 4 MW, & 5 MW, the line loss is 15.5 KW,34.89 KW,62 KW,96.93KW respectively. It is seen that line loss is not proportional with loads, so average loss per MW transmission loss should be calculated on the basis of connected loads given in table 3.2.

From table 3.2 the load connected from different substations are 1MW, 3MW, 4MW, 4MW & 4MW. Therefore, average per MW loss = (3.87+62+62+62+34.89)KW/(1+3+4+4+4)MW= 14.04KW. Taking this 14.04KW loss per MW per km into consideration, the per MW loss of various routes will be calculated and the losses are42.12 KW,70.2 KW,112.32 KW,168.48 KW,210.6 KW,280.8 KW,308.88 KW,336.96 KW,351 KW &519.48 KW.

## 5. SOLUTION OF THE PROBLEM BY TORA SOFTWARE

The developed model of transportation problem of load connection was solved by TORA software. The results has been shown below.

Table: TORA 1

TRANSPORTATION MODEL

Title: Transmission Loss Calculation
Size:(3 x 5)
Original data

| | D1 | D2 | D3 | D4 | D5 | SUPPLY |
|---|---|---|---|---|---|---|
| S1 | 351 | 519.48<br>1 | 210.6<br>4 | 308.88<br>3 | 0 | 8 |
| S2 | 70.2<br>4 | 210.6 | 280.8 | 336.96 | 0<br>4 | 8 |
| S3 | 168.48 | 42.12<br>4 | 112.32 | 168.48 | 0 | 4 |
| DEMAND | 4 | 5 | 4 | 3 | 4 | |

~**************~

Table: TORA 2

OPTIMUM TRANSPORTATION SOLUTION

Title: Transmission Loss Calculation
Size:(3 x 5)
Final iteration no: 2
Total Loss =2428.9199

| From | To | Amount | Unit Loss | Route Loss |
|---|---|---|---|---|
| S1 | D1 | 0 | 351.00 | 0.00 |
| | D2 | 0 | 519.48 | 0.00 |
| | D3 | 4 | 210.60 | 842.40 |
| | D4 | 3 | 308.00 | 926.64 |
| | D5 | 1 | 0.00 | 0.00 |
| S2 | D1 | 4 | 70.20 | 280.80 |
| | D2 | 1 | 210.60 | 210.60 |
| | D3 | 0 | 280.80 | 0.00 |
| | D4 | 0 | 336.96 | 0.00 |
| | D5 | 3 | 0.00 | 0.00 |
| S3 | D1 | 0 | 168.48 | 0.00 |
| | D2 | 4 | 42.12 | 168.48 |
| | D3 | 0 | 112.32 | 0.00 |
| | D4 | 0 | 168.48 | 0.00 |
| | D5 | 0 | 0.00 | 0.00 |

Summary of Transportation Loss

| Node | Supply/Demand | Total Loss | Av. Loss/unit |
|---|---|---|---|
| S1 | 8 | 1769.04 | 221.13 |
| S2 | 8 | 491.40 | 61.42 |
| S3 | 4 | 168.48 | 42.12 |
| D1 | 4 | 280.80 | 70.20 |
| D2 | 5 | 379.08 | 75.82 |
| D3 | 4 | 842.40 | 210.60 |
| D4 | 3 | 926.64 | 308.88 |
| D5 | 4 | 0.00 | 0.00 |

End of solution summary

## 6. CONCLUSION

If the load connection is given randomly, for instance like

Table: TORA 3

TRANSPORTATION MODEL

Title: Transmission Loss Calculation
Size:(3 x 5)
Final Iteration No: 2
Total Loss = 2428.9199

```
                                                               Ui
   D1       D2       D3       D4        D5   SUPPLY
  |--------|-------|-------|-------|-------|-------|
  |351     |519.48 |210.6  |308.88 |0      |    0.00
S1|        |       |  4    |  3    |  1
  |        |       |       |       |       | 8
  |-280.80 |-308.88|   0.00|   0.00|   0.00|
  |--------|-------|-------|-------|-------|
  |70.2    |210.6  |280.8  |336.96 |0      |    0.00
  |        |       |
S2|    4   |   1   |       |       |  3    |  8
     0.00  |   0.00| -70.20  -28.08|   0.00|
  |--------|-------|-------|-------|-------|
  |168.48  |42.12   112.32  168.48   0         -168.48
S3         |  4    |       |       |       |  4
  | -266.76|-0.00  |-70.20   -28.08|-168.48
  |--------|-------|-------|-------|-------|
Vj  70.20    210.6  210.6   308.88  V5=0.00
DEMAND 4       5      4      3       4
```

Table 3.4 the line loss would be 4195152 Kwh. If there is no load shedding over the month, the total unit consumed by the consumers will be, 16×1000×24×30=115200000 Kwh. In this case the line loss will be (4195152/115200000)×100=36.41%., which is significantly high and therefore objectionable. Again if we consider the starting solution (using least cost method Table 3.3) the percentage loss would be (2737.8/16000)*100= 17.11%. By successive iteration we get final solution (by TORA) and the table is given in Table: TORA 3. Considering this final solution the percentage loss would be (2428.91/16000)*100= 15.18%..Whatever be the arrangements to give connections of the loads mentioned in the problem from specified substations, the loss will never be less than 15.18% and this is abruptly high because the standard 11 KV losses in the power distribution system is tried to maintain within only 4.6% [5]. So it will not be viable to construct all 11 kv lines to connect the loads from existing substations. If the calculated loss by transportation model is within the standard limit (4.6%), the connection will be given by constructing 11 kv line according to arrangement in Table: TORA 3.

Table 5: Depicts individual Load's Transmission Loss

| Name of Loads | Name of Substations | Percentage Line Loss |
|---|---|---|
| Noapar (D1) | Noapara (S2) | 280/4000= 7% |
| Basundia (D2) | Noapara (S2)+ Basundia (S3) | 210/1000=21% & 168/4000= 4.2% |
| Rajarhat (D3) | Monirampur (S1) | 842/4000= 21.05% |
| Jessore (D4) | Monirampur (S1) | 926.64/3000= 30.88% |
| Dummy (D5) | | |

Alternately we can revise the percentage line loss considering individual load connection according to Table: TORA 2. The percentage table is shown is Table 5

From the statistics of Percentage Line Loss in Table 5, it is evident that the Line Rajarhat~Monirampur and Jessore ~ Monirampur would not be feasible since line loss is very high. Therefore, a new 33/11 kv substation must be constructed near the above mentioned loads (Rajarhat & Jessore ). The line (Noapara~Noapara) can be considered favorably since the loss is very close to standard limit, provided that other conditions is also favorable. The load of Basundia is shared by Noapara & Basundia substation which is not technically permissible(if one substation fails, the other will be overloaded).The line loss of Basundia ~ Basundia is only 4.2% which is below the standard limit, so Basundia substation can be upgraded and then connection is given.

## 7. REFERENCES


1. HAMDY A. TAHA “Operations Research: An Introduction”, 5th ed., 1995
2. H. Taha “Computer Algorithms for OPERATIONS REASEARCH”, 6th ed., 1997
3. Gupta P. K. and Mohan M “Problems in Operations Research” 8th ed., 1998
4. Winston L. W. “Operations Research- applications and algorithms ” 4th ed., 2003
5. Mr. Abul Bashar, Staking Engineeri, ECBL, JPBS 2, Jessore.


## 8. NOMENCLATURE

| Symbol | Meaning | Unit |
|---|---|---|
| KV | KiloVoltage | - |
| KW | Killo Watt(Power) | Watt |
| LP | Linear Programming | - |
| Ω | Resistance | Ohm |
| MW | Mega watt(Power) | Watt |
| ACSR | Aluminum Conductor Steel Reinforced | - |