Electricity Demand Load Forecasting for a Remote Area of Bangladesh

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Abstract: *Load forecasting of a rustic area where grid connection does not exist is a process of calculating the required electric load using a method named Matrix Analysis. In our neighbor country India meet their clients need but in Bangladesh which is most densely populated country in the world. Most of the people of Bangladesh live in below poverty level. In Bangladesh almost 66 percent people access the grid connection but more than 45 percent people of rural area in Bangladesh does not get the grid connection. It can be seen from the calculated amount the number of people who does not access grid power supply yet now is more than 34 percent. This is not expected actually. According to blessing of electric supply we can get better life style.*

Keywords: *Potential Load Explanation, Matrix Analysis, Deprived Area, Bangladesh, Moheskhali, ST. Martin.*

I. Introduction

The infrastructure of power Generation Company in Bangladesh is not sufficient capacity of need basis. Due to having insufficient power connection in Bangladesh we have to use properly so we have to calculate how much electricity is needed area basis. Size of the power industry in Bangladesh is still small with only 12,000 MW installed capacity (grid) compare to the huge population of 160 million. Economy of Bangladesh is in transition from agriculture to industry. Since 90's GDP growth rate was very stable and resilient with all internal and external shocks. In the last two decades, GDP growth rate was around6 percent and Bangladesh is expecting more than 7 percent GDP growth in coming years. Enhanced economic activities and expansion of rural electrification have created increasing electricity demand in the power market of Bangladesh. The per capita power consumption in Bangladesh is 9.30 GW in 2016 but only 66 percent people of this developing country is accessing the benefit of grid connectivity. It can be said without any doubt that the people of Bangladesh is very corrupted in administration level, system losses, become late to complete new power station, making lowest efficiency of power station, electricity theft, collapsing and having insufficient amount for maintaining the power station. The government of Peoples Republic of Bangladesh has taken some initiatives to solve the problem. Fig 1 shows power plant generation capacity expansion plans from 2010 to 2025 & Grid Map of Bangladesh.

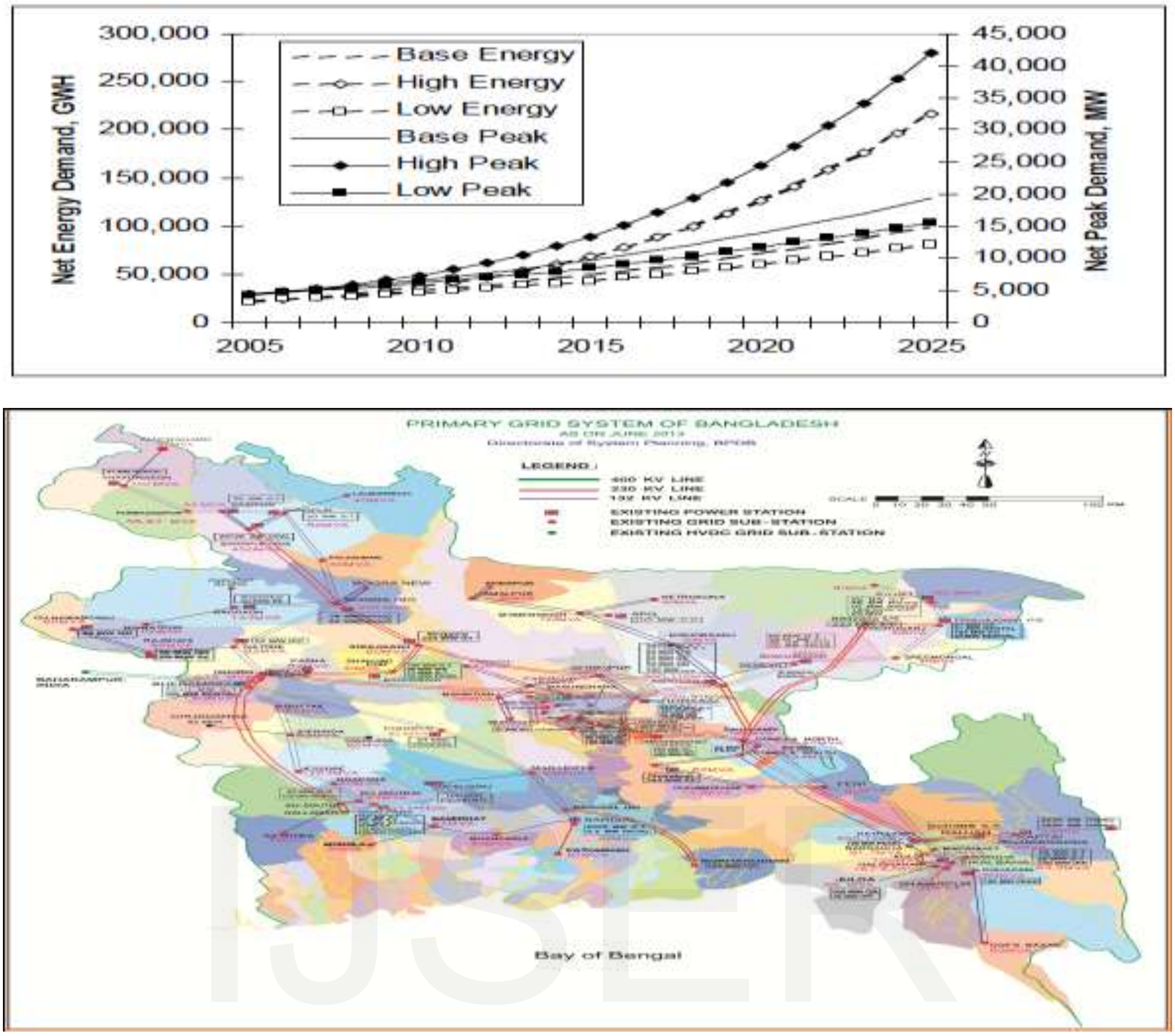

Figure: 1 Power plant generation capacity expansion plans & Grid Map of Bangladesh

Using this techniques researcher can find the resulting solution of required power supply in any remote area all over the world.

1.1 Power sector of Bangladesh

Power sector development of Bangladesh in recent years is quite remarkable. Installed power generation capacity was doubled and number of consumers increases from 12 million to 18 millions in the last five years. In 2015, 66 % of the total population has direct access to grid electricity and per capita electricity consumption was around 251 kWh, which is one the lowest in the world. But it is important to note that rate of people getting direct access to electricity is increasing. Per capita electricity consumption is also on increasing trend. By this time, distribution utilities have expanded their services to more than 60,000 villages. Though installed capacity was 12,000 MW, actual maximum peak generation of 8,200 MW in 2015 against demand of more than 9,000 MW indicates that system is facing rolling blackouts in hot summer days due to some bottlenecks exists in transmission and distribution system. Though load-shedding has reduced substantially but still this sector is struggling to supply quality electricity to its customers. Power sector is also struggling with increasing per unit supply cost due to increasing oil based electricity generation.

Table 1: Power Sector at a Glance

1.	Installed Generation Capacity(grid) (June 2016)	12,365MW
2.	Maximum Demand in FY 2016	9,600 MW
3.	Maximum generation so far (30June, 2016)	9,036 MW
4.	Energy Generation (kWh)	45,836 M kWh
5.	Transmission Line (400 kV 230 kV & 132 kV)	9,700 km
6.	Distribution Line (33 KV and below)	3,26,000 km
7.	No. of Consumers	18 Million
8.	Transmission and Distribution Losses	13.55 %
9.	Village Electrification (no.)	60,000
10.	Access to Grid Electricity	66 %
11.	Per capita Electricity Consumption (Grid)	251 kWh

Source: System Planning, BPDB

II. Background study of the work

According to grid map of Bangladesh there is still many isolated area in where electricity is unavailable. So when a step will be taken to add those areas to national grid than some sequence of work must take. At first an area must be taken which is similar to those isolated area so that it can be comparable. Than load of those isolated area will be forecast using various method of analysis. We have chosen the pair of Maheshkhali and Kutubdia based on their occupation:

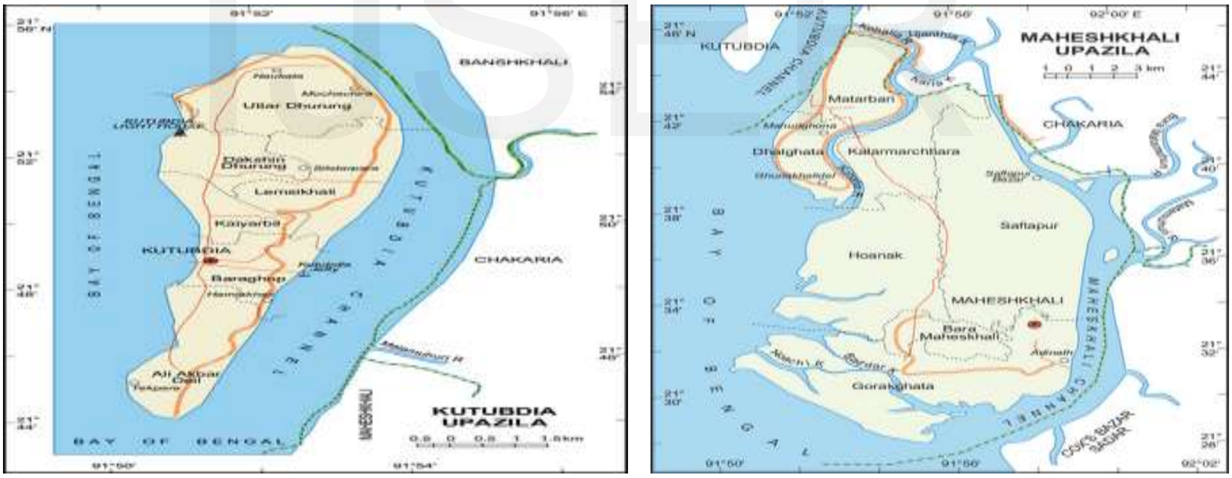

Figure: 2 Map of Kutubdia & Maheshkhali

Kutubdia --- Main occupations Agriculture 32%, fishing 4.67%, agricultural laborer 24%, commerce 11.88%, service 3.94%
Maheshkhali --- Main occupations Agriculture 23%, fishing 6%, agricultural laborer 25%, commerce 13.78%, service 6.08%
In here Kutubdia is off grid area or remote area while Maheskhali is on grid area.

III. Inverse Matrix Analysis

Matrix analysis is an important technique to analysis and calculates the required load of an inaccessible area in Bangladesh and also all over the world. During calculate the load

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researcher have to consider four areas of loads such as Domestic Load, Industrial Load, Commercial Loads and Irrigation Load. Those are described in below:

3.1. Domestic loads

Domestic load consists of lights, fans, refrigerators, heaters, television, small motors for pumping water etc. Most of the residential load occurs only for some hours during the day (i.e., 24 hours) e.g., lighting load occurs during night time and domestic appliance load occurs for only a few hours. For this reason, the load factor is low (10% to 12%).

The domestic load, LD may then be expressed as,

L_D (t) = f_1 (P (t), L_R (t), P_1 (t))

Where, P (t) = Population at time t, L_R (t) = Adult literacy rate at time t, P_I (t) = Per capita income at time t.

3.2. Industrial Loads

Industrial load consists of load demand by industries. The magnitude of industrial load depends upon the type of industry. Thus small scale industry requires load up to 25 kW, medium scale industry between 25kW and 100 kW and large-scale industry requires load above 500 kW. Industrial loads are generally not weather dependent.

This industrial load L_I can be calculated as, $L_1(t)= f_2(P_1(t),R_L(t),D_T(t),A_L(t))$

Where, R_L (t) = Inland communication length in per unit area at time t, D_T (t) = Distance from local town, A_L (t) = Agricultural land in percent of total area at time t.

3.3. Commercial Loads

The commercial load mainly depends on per capita income, inland communication in per unit area and distance from local town. The commercial load, L_C may then be expressed as,

L_C (t) = f_3 (P_I(t), R_L(t), D_T(t))

3.4. Irrigation Loads

This type of load is the electric power needed for pumps driven by motors to supply water to fields. Generally this type of load is supplied for 12 hours during night.

This industrial load L_{IR} can be calculated as, L_{IR} (t) = f_4 (A_L(t), P_I(t))

The total electrical load demand, L (t) in an isolated area is the sum of the above four loads. That is, L (t) =$L_D(t)+L_I(t) +L_C(t)+L_{IR}(t)$

Therefore, the load of an isolated area can be expressed as $L(t)=f(P(t),L_R(t),P_I(t), R_L(t), A_L(t),D_T(t))$

However, the equation is given above explain the load function of six time dependent variables, all of those variables will not contribute likewise to the electricity generation of load. Let X_1, X_2, X_3, X_4, X_5, and X_6 represent the weighting factors by which each time varying factor P(t), L_R(t), P_I(t), R_L(t), A_L(t), and D_T(t) respectively contributes towards the load growth. The weighting factors, [X] are also random in nature. They may vary with different areas. Now the load and weight factors [X] can be expressed as,

$$[L(t)] = [X] \times \begin{pmatrix} P(t) \\ L_R(t) \\ P_I(t) \\ R_L(t) \\ A_L(t) \\ D_T(t) \end{pmatrix} \qquad [X] = [L_T] \times \text{Pinv} \begin{pmatrix} P(t) \\ L_R(t) \\ P_I(t) \\ R_L(t) \\ A_L(t) \\ D_T(t) \end{pmatrix}$$

To calculate, the value of these weighted factor, the past history of the considered area need to be known. One more option is that one can consider an area whose behaviors are similar to that of the isolated area. This is what, is the main contribution of this work. This will be clarified through the practical implementation of the proposed method.

IV. Collected data

The data was collected from Saint Martin Island, Moheskhali, Kutubdia and Chakaria which was located at Cox-Bazar District in Bangladesh. The researcher had collected their calculative data from Upazilla Nirbahi Officer's Office. Researcher also collect the time invariant data like rate of population, per capital income, their life expectancy rate, adult literacy rate, number of agricultural land, their communication process, transport system. After collect required data from UNO office researcher had gone to REB office at Moheskhali and Chakaria for acquiring the maximum and average load of power consumption. After then our research team went to Bangladesh Statistical Bureau to get more reliable data and to get a clear concept about per capital income. The data we collected form UNO and REB office form those areas are given below.

Table 2: The data we collected from UNO of Moheskhali, Kutubdia, Chakaria and Saint Martin is given below:

Collected Data from UNO	Moheskhali (on grid)	Kutubdia (off -grid)	Chakaria (on-grid)	St.Martin (off-grid)
Population	321221	125280	474321	6704
Adult literacy rate	30.18%	35%	47.8%	18.8%
Per capital income	4808.89 taka	4884.49 taka	4854.95 taka	4671.65 taka
In land communication strength	284.85 km	245.13 km	180.71 km	5.575 km
Agricultural land	5275.26 hectors	8903.22 hectors	27141 hectors	115 hectors
Distance from main land	89.3 km	91 km	50 km	116 km

Table 3: Average Demand/Load of Maheshkhali Upazila (Cox's Bazar) from 2013-2016 by month

Month & Year ⇩ ⇨	Average Demand/Load			
	2016	**2015**	**2014**	**2013**
January	1648	1527	1301	1171
February	1611	1501	1353	1270
March	1583	1471	1365	1372
April	1653	1607	1370	1477
May	1563	1605	1453	1466
June	1734	1462	1554	1382
July	1678	1594	1572	1408
August	1659	1501	1420	1431
September	1401	1648	1457	1514
October	1689	1709	1462	1483
November	1557	1536	1427	1407
December	1571	1521	1310	1384

Table 4: Maximum Demand/Load of Maheshkhali Upazila (Cox's Bazar) from 2013-2016 by month

Month & Year ⇩ ⇨	Maximum Demand/Load			
	2016	**2015**	**2014**	**2013**
January	3661	3397	2897	2601
February	3575	3335	3008	2829
March	3513	3268	3036	3050
April	3675	3573	3046	3281
May	3468	3567	3231	3259
June	3854	3244	3254	3073
July	3732	3544	3504	3129
August	3688	3336	3158	3183
September	3111	3664	3244	3363
October	3752	3797	3251	3297
November	3461	3414	3167	3124
December	3491	3382	2908	3077

V. Calculated Data

5. 1. Inverse Matrix Analysis

It is not possible to commit inverse of non-square matrix. To solve this problem Authors can be used new term of **pinv.** When referring to a matrix, the term **pseudo inverse**, without further specification, is often used to indicate the Moore–Penrose **pseudo inverse**. In mathematics, and in particular linear algebra, a **pseudo inverse** A^{+} of a matrix A is a generalization of the inverse matrix.

The pseudo inverse facilitates the statement and proof of results in linear algebra. So putting pinv we get the value of X corresponding average load.

Table 5: Value of X corresponding average load

Month of 2016	X1	X2	X3	X4	X5	X6
January	0.0052	0	0.0001	0	0.0001	0
February	0.0051	0	0.0001	0	0.0001	0
March	0.0048	0	0.0001	0	0.0001	0
April	0.0050	0	0.0001	0	0.0001	0
May	0.0048	0	0.0001	0	0.0001	0
June	0.0055	0	0.0001	0	0.0001	0
July	0.0053	0	0.0001	0	0.0001	0
August	0.0052	0	0.0001	0	0.0001	0
September	0.0045	0	0.0001	0	0.0001	0
October	0.0054	0	0.0001	0	0.0001	0
November	0.0049	0	0.0001	0	0.0001	0
December	0.0048	0	0.0001	0	0.0001	0

$$[X] = [L_T] * Pinv \begin{bmatrix} P(t) \\ L_R(t) \\ P_I(t) \\ R_L(t) \\ A_L(t) \\ D_T(t) \end{bmatrix}$$

Then from the value of X we get the estimated value of Kutubdia

Table 6: Estimated average load of kutubdia

Month of 2016	Average load (KW)	Month of 2016	Month of 2016	Month of 2016	Average load (KW)
January	643.1581	May	609.9654	September	546.7039
February	628.7095	June	676.7414	October	659.1687
March	617.7754	July	655.2637	November	608.4034
April	645.5011	August	648.2347	December	613.0894

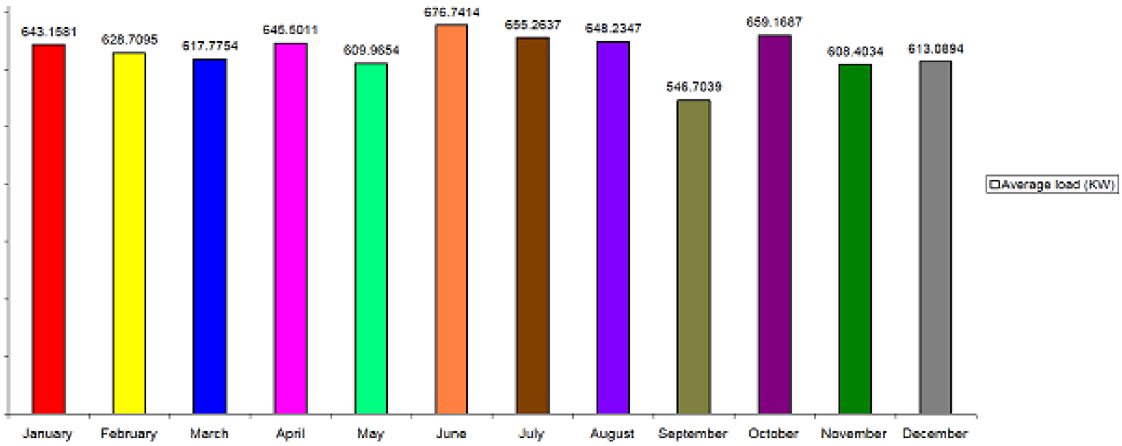

Fig 3: the graphical bar diagram of estimated average load Kutubdia

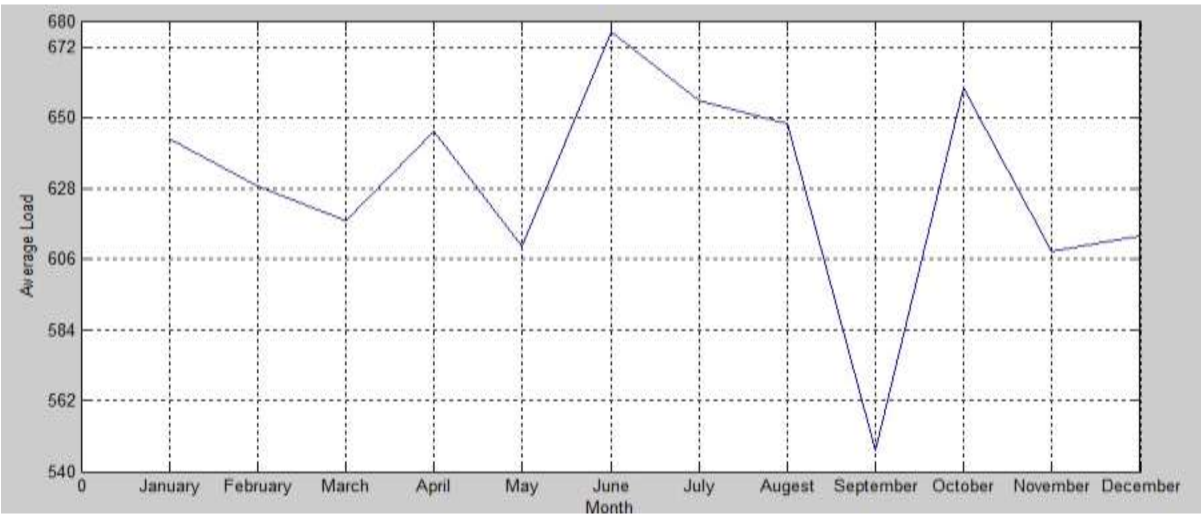

Fig 4: the graphical line diagram of estimated average load Kutubdia

Similarly value of X corresponding maximum load

Table 6 Value of X corresponding maximum load

Month of 2016	X1	X2	X3	X4	X5	X6
January	0.0113	0	0.0002	0	0.0002	0
February	0.0112	0	0.0002	0	0.0002	0
March	0.0110	0	0.0002	0	0.0002	0
April	0.0114	0	0.0002	0	0.0002	0
May	0.0109	0	0.0002	0	0.0002	0
June	0.0121	0	0.0002	0	0.0002	0
July	0.0115	0	0.0002	0	0.0002	0
August	0.0116	0	0.0002	0	0.0002	0
September	0.0098	0	0.0002	0	0.0002	0
October	0.0117	0	0.0002	0	0.0002	0
November	0.0108	0	0.0002	0	0.0002	0
December	0.0110	0	0.0002	0	0.0002	0

Then from the value of X we get the estimated value of Kutubdia

Table 7: Estimated maximum load of Ktubdia

Month of 2016	Maximum Load (KW)	Month of 2016	Maximum Load (KW)	Month of 2016	Maximum Load (KW)
January	1429.2	May	1354.7	September	1214.6
February	1396.4	June	1504.6	October	1464.8
March	1372.2	July	1457	November	1351.1
April	1434.7	August	1440.6	December	1362.9

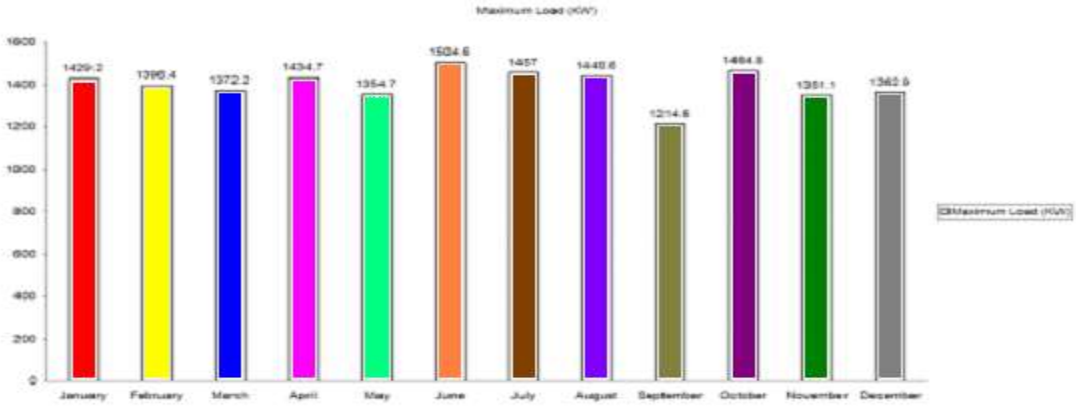

Fig 5: the graphical bar diagram of estimated maximum load Kutubdia

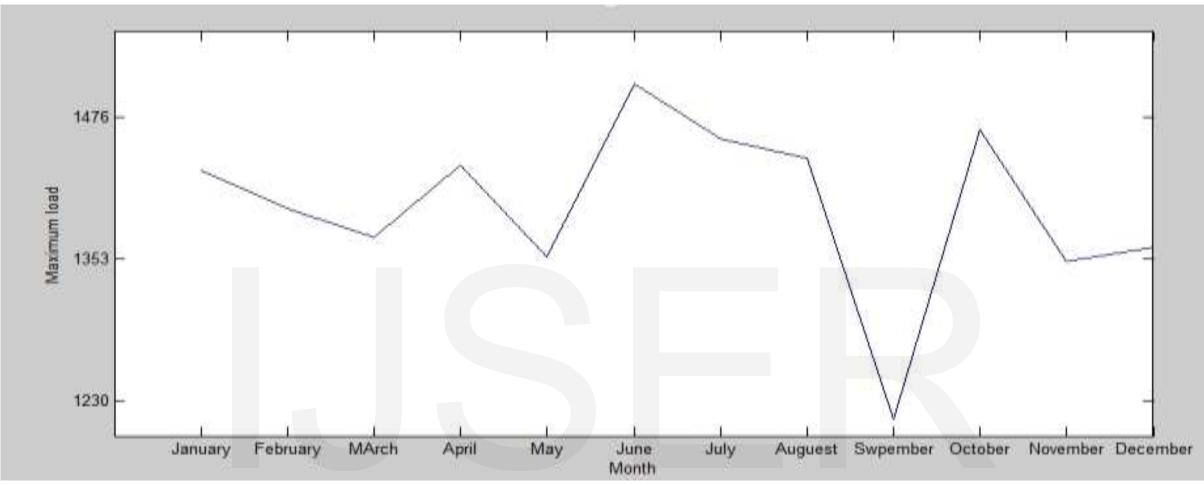

Fig 6: the graphical line diagram of estimated maximum load Kutubdia

Calculation of average and maximum load of Saint Martin

Table 8: Average Demand/Load of ChakoriaUpazila (Cox's Bazar) from 2013-2016

Month & Year ⇩ ⇒	Average Demand/Load			
	2016	**2015**	**2014**	**2013**
January	3801 K.W	3801K.W	3602 K.W	3303 K.W
February	3751	3705	3751	3352
March	4001	2901	3502	3352
April	3803	3903	3403	3803
May	3604	3353	3802	3902
June	3604	3303	3453	3803
July	3801	3501	4052	3451
August	3802	4002	3752	3352
September	3698	3648	3999	3601
October	3749	3198	3100	3701
November	3601	3300	3750	3650
December	3599	3749	3750	3951

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Table 10: Calculating factors X of load growth deciding variables for average demand of ST. Martin.

Months of 2016	X_1	X_2	X_3	X_4	X_5	X_6
January	0.0088	0	0.0001	0	0.0005	0
February	0.0089	0	0.0001	0	0.0005	0
March	0.0092	0	0.0001	0	0.0005	0
April	0.0088	0	0.0001	0	0.0005	0
May	0.0084	0	0.0001	0	0.0005	0
June	0.0083	0	0.0001	0	0.0005	0
July	0.0088	0	0.0001	0	0.0005	0
August	0.0086	0	0.0001	0	0.0005	0
September	0.0091	0	0.0001	0	0.0005	0
October	0.0090	0	0.0001	0	0.0005	0
November	0.0083	0	0.0001	0	0.0005	0
December	0.0084	0	0.0001	0	0.0005	0

Table 11: Estimated Average Load for ST. Martin

Months of 2016	Average Load(KW)	Months of 2016	Average Load(KW)
Jan	53.9549	July	53.9549
Feb	53.2450	Aug	53.9549
Mar	56.7946	Sep	52.5350
Apr	53.9549	Oct	53.2450
May	51.1152	Nov	51.1152
June	51.1152	Dec	51.1152

Table 12: Calculating factors X of load growth deciding variables for maximum demand for ST.Martin.

Months of 2016	X_1	X_2	X_3	X_4	X_5	X_6
January	0.0080	0	0.0001	0	0.0005	0
February	0.0078	0	0.0001	0	0.0005	0
March	0.0085	0	0.0001	0	0.0005	0
April	0.0080	0	0.0001	0	0.0005	0
May	0.0077	0	0.0001	0	0.0004	0
June	0.0076	0	0.0001	0	0.0004	0
July	0.0080	0	0.0001	0	0.0005	0
August	0.0081	0	0.0001	0	0.0005	0
September	0.0078	0	0.0001	0	0.0004	0
October	0.0079	0	0.0001	0	0.0005	0
November	0.0077	0	0.0001	0	0.0004	0
December	0.0076	0	0.0001	0	0.0004	0

Table 13: Estimated Maximum Load for ST.Martin.

Months of 2016	Maximum Load(KW)	Months of 2016	Maximum Load(KW)
January	59.8473	July	58.5411
February	59.3646	August	58.3707
March	61.4944	September	60.6993
April	58.6689	October	60.6283
May	56.2977	November	55.3890
June	55.8575	December	57.0766

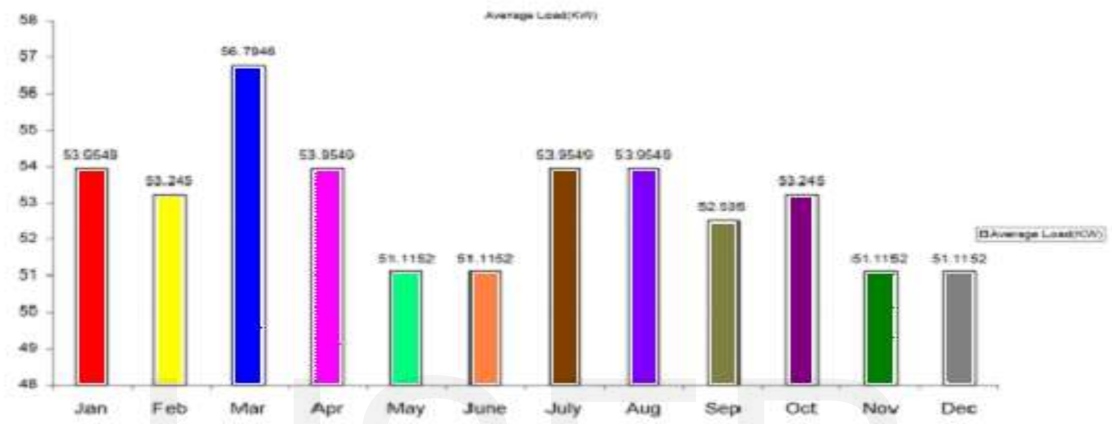

Figure 7: Forecasted average demands (KW) of an isolated area, ST.Martin

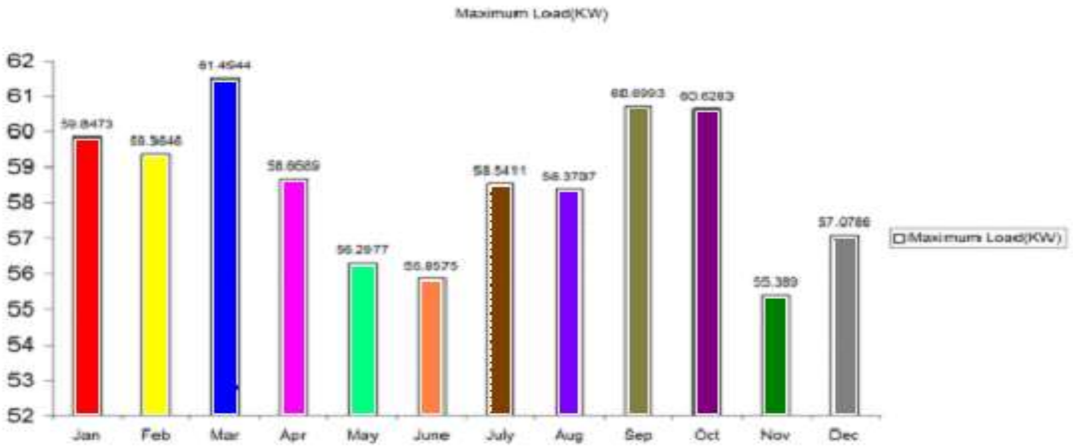

Figure 8: Forecasted maximum demands (KW) of an isolated area, ST.Matin

VI. Results and Conclusion

In the matrix analysis system researcher applied successfully suitable techniques for calculating potential explanation of power supply. When research investigator tries to find the result the team was dependent on only UNO office's data. The accuracy level is laid o the performance level of the data of UNO office as the research team use their entire data. The maximum number of Power Generation Company like Rural Electrification Board (REB) uses the digital copy but UNO office provides manual data. If they provide digital evidence many researcher will developed this types of techniques more accurately. The received data is almost oldest and they had no uses in modern day. To be concluding it is more efficient to calculate first the required load of an area then should implement the power station. That will help us to prevent the unnecessary consumption of electricity and blackouts of power.

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