CHAPTER 5

LONG TERM DISTRIBUTION NETWORK IMPROVEMENT PLAN IN LAE AREA

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5.1 DISTRIBUTION NETWORK REINFORCEMENT PLAN FOR 2030

[Purpose of creating a master plan]

The role of distribution systems is to supply electricity to customers.

They chiefly include high- and low-voltage lines, distribution transformers and utility poles, and are installed in a net pattern.

It is necessary that they are upgraded as new demand arises or the power consumption in their service area increases.

In other words, there is no need for reinforcing D/Ls where there is no new demand or increase in existing load in the area. Specific reinforcement measures depend on what kind of demand has grown.

Unlike T/Ls, S/Ss and other power-related facilities, distribution systems supply electricity directly to customers; that means the systems are susceptible to the characteristics of demand in the supply area. How to reinforce the systems, therefore, differs according to the scale of demand growth. This chapter attempts to formulate a long-term reinforcement plan with a focus on S/Ss and D/Ls based on predictions of demand increases on a relatively large scale.

The maximum capacity of distribution systems per line is usually standardized from the viewpoint of system building and operational efficiency.

In developing a 2030 master plan for the Lae area, JICA Study Team used the system building standards recommended in the Electricity Distribution Network Immediate Improvement Plan for Year 2020 as the basis.

A master plan for improving distribution systems needs to ensure stable supply of electricity with cost-minimum equipment for future electricity demand. As such, a master plan for the Lae area shall be aimed at building and improving systems at a bare-minimum level in order to satisfy future demand scenarios in the Lae area in 2030.

Specifically speaking, the master plan is a line diagram indicating distribution routes, proposing construction works needed for satisfying new demand.

As mentioned above, distribution systems serve demand directly, and thus exact future demand points were beyond prediction at the time of developing a master plan. Alternatively, JICA Study Team estimated demand increases in a relatively rough manner, and designed trunk routes based on that assumption.

More specifically, JICA Study Team divided the supply area of each S/S into blocks, and drew a supply route to each block on a diagram. These diagrams collectively act as a master plan. A 2030 master plan for the Lae area was developed in the following steps.

[Steps of developing a 2030 Lae master plan]

Step 1 Estimate future demand in 2030.

Step 2 Examine the feasibility of satisfying the demand forecast with existing S/Ss.

Step 3 If deemed feasible, draw a new D/L diagram as a master plan.

Step 3-1 If deemed unfeasible, elaborate a S/S reinforcement plan (an addition of transformers, establishment of a new S/S, etc.)

The formulation of a 2030 Lae master plan builds upon the assumption of having three S/Ss in the area, Milford, Taraka and Erap S/Ss, as it had already been concluded that adding transformers to the first two stations combined with constructing a new S/S in Erap would be the lowest-cost solution to the power supply in the Lae area in 2030. The following explains the specific process.

(1) Determine the total demand in the entire Lae area and the supply areas.

(2) Determine which S/S to use and its supply area based on future power system planning.

(3) Estimate the load per block in the supply area of each S/S.
In this step, the estimated load is allocated to certain blocks with consideration given to the type of demand in each block today.
The number of D/Ls needed is determined based on the estimated load in each block.

(4) Develop a future feeder route on the assumption that existing secondary roads will be extended, because, though a future route is usually determined based on the current feeder route in the light of future road planning and the like, there is no clearly established road planning.

JICA Study Team formulated a 2030 master plan for the Lae area using this approach.

5.1.1 Outlook on Future Demand and the Supply Areas of the Three Substations in the Lae Area in 2030

(1) Future demand in the entire Lae area

Table 5.1-1 presents the results of calculating the load of each of the three S/Ss in the Lae area using demand forecasts for the Ramu system in 2030.

Typically, future demand is estimated with respect to the active power (MW) to be consumed, which is provided in Row (A) of Table 5.1-1. On the other hand, the load incurred in relation to the demand requires attention to not only the active power (MW) to be consumed but reactive power (MVar). Thus, the capacity of power equipment which satisfies the estimated demand must be large enough to respond to reactive power (MVar) as well. Row (B) denotes the apparent power (MVA) assessed with the PF (reactive power) being 0.85. Likewise, Row (C) represents the apparent power (MVA) assessed with the PF being 0.90.

Table 5.1-1 Demand Forecast for Lae Area until 2030

	Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Demand Load (MW) (A)	Milford	21	23	24	27	29	32	34	37	40	43	46	46	50	53	57	61
	Taraka	19	20	22	24	27	29	30	33	36	39	42	41	44	47	51	54
	Nadzab/Erap	0.3	0.3	0.3	0.3	0.3	0.3	3	3	3	3	3	10	10	10	10	10
	Total	40.3	43.3	46.3	51.3	56.3	61.3	67	73	79	85	91	97	104	111	118	125
Apparent Power (MVA) (Converted by PF=0.85) (B)	Milford	25	27	28	31	35	38	40	43	47	51	55	54	59	63	67	71
	Taraka	22	24	25	28	31	34	36	39	42	45	49	48	52	56	60	64
	Nadzab/Erap	0.4	0.4	0.4	0.4	0.4	0.4	3.5	3.5	3.5	3.5	3.5	11.8	11.8	11.8	11.8	11.8
	Total	44.4	51.4	53.4	59.4	66.4	72.4	79.5	85.5	92.5	99.5	107.5	113.8	122.8	129.8	138.8	147
Apparent Power (MVA) (Converted by PF=0.9) (C)	Milford	24	25	27	30	33	36	38	41	44	48	52	51	55	59	63	68
	Taraka	21	23	24	27	29	32	34	37	40	43	46	46	49	53	56	60
	Nadzab/Erap	1	1	1	1	1	1	3	3	3	3	3	11	11	11	11	11
	Total	46	49	52	57	63	69	74	81	87	94	101	108	116	123	131	139

Source: JICA Study Team

As evident in Table 5.1-1, electricity demand in the Lae area will grow three-fold by 2030. In this scenario, the total load at the Taraka and Milford S/Ss in the same year will be 115MW. This increase results from an expansion of the scope of the current supply areas and also from an increase in the load within these areas.

Accordingly, the following subsections discuss the supply area of each S/S today and the demand in each supply area forecasted for 2030.

(2) Overview of the supply areas

1) Today's supply area

JICA Study Team conducted a survey on the current supply areas and our findings are outlined in Fig. 5.1-1.

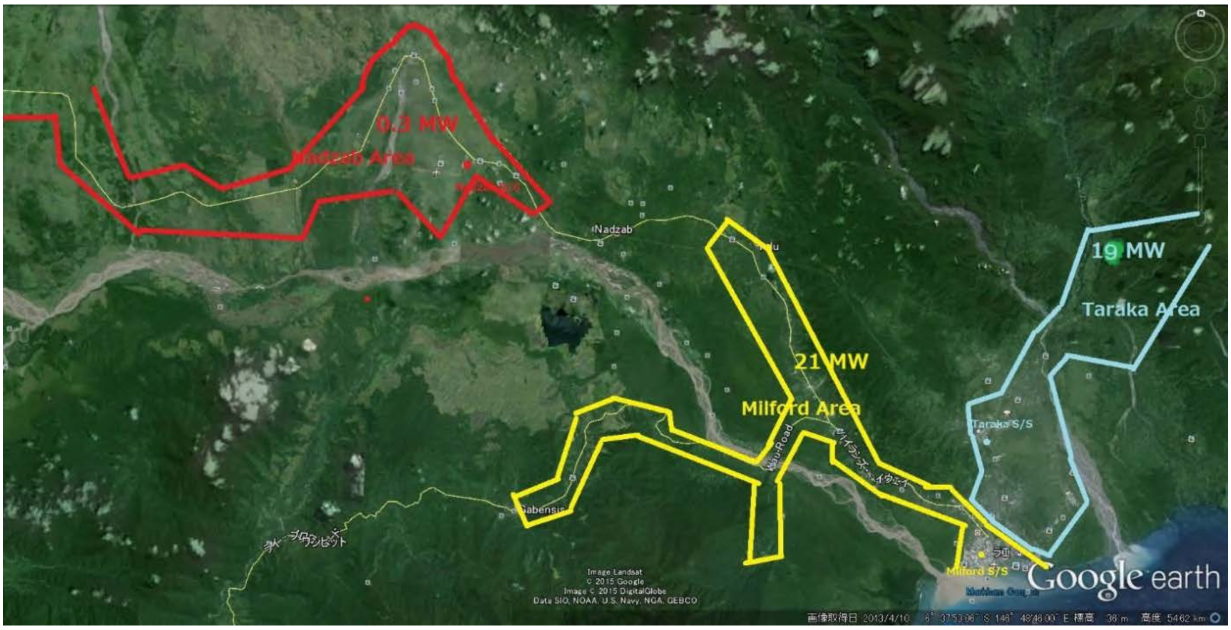


Fig. 5.1-1 Supply Area of Each Substation in 2015

Source: JICA Study Team

The three S/Ss in the Lae area (Milford, Taraka, Nadzab) respectively supply electricity to the areas as indicated in Fig. 5.1-1.

In between the Nadzab Airport along the Highland Highway and the City of Lae extends an unelectrified area.

2) Supply area in 2030

At a point in 2030, the Nadzab S/S will have been abolished because it will hinder the operations of the Nadzab Airport as an international airport, and the Erap S/S will have been built as a substitute. The supply area in 2030 is estimated as shown in Fig. 5.1-2, in response to such changes in demand.

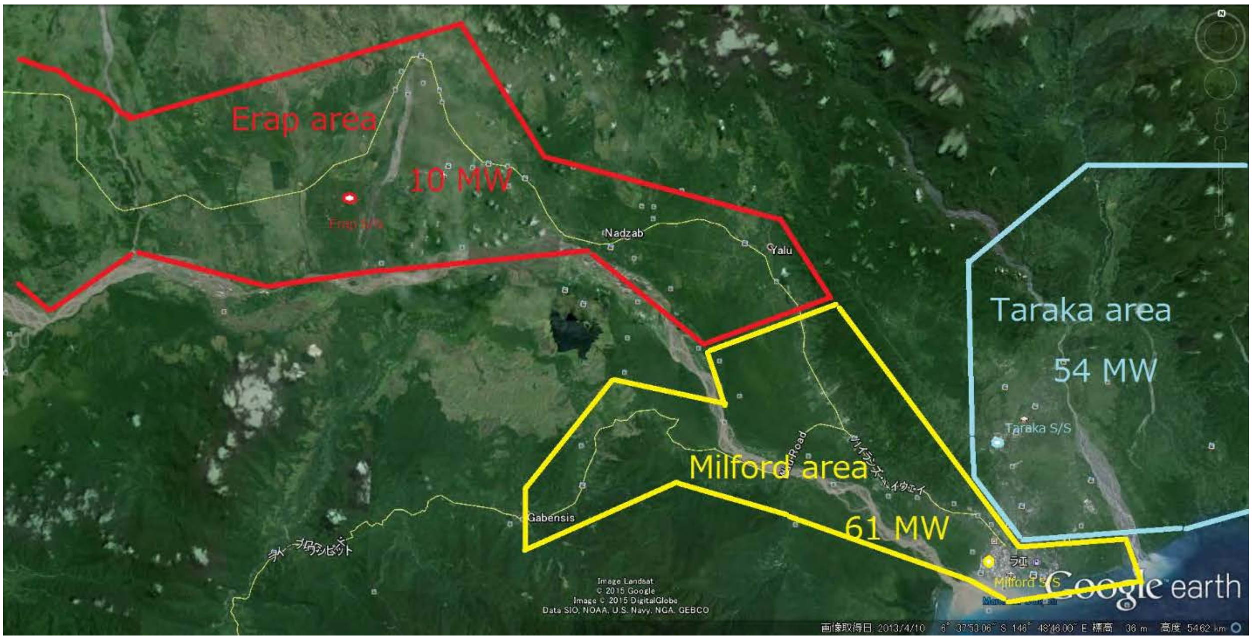


Fig. 5.1-2 Supply Area for Each Substation in 2030

Source: JICA Study Team

The most noticeable difference from the status quo is that the unelectrified area in between the City of Lae and the Nadzab Airport will have access to electricity. This area will likely be covered by an extension of the D/L running from the Erap S/S to the City of Lae along the Highland Highway.

The planned distribution voltage of the Erap S/S is either 22kV or 33kV. These figures are used in districts with low load density in accordance with the PPL standards. At present, the D/L leading from the Nadzab S/S is 11kV, and it supplies power at the airport before being stepped up to 22kV.

The line carries 22kV from the transforming point to the Mutzing Station for about 80 kilometers. There are 38 transformers along the way, supplying electricity to customers.

If the distribution voltage of the Erap S/S is set as 33kV, all these other systems must be upgraded to accommodate 33kV. If the voltage is determined as 22kV, the current systems may be used as they are.

In conclusion, the distribution voltage at the Erap S/S should be 22 kV.

In this Study, JICA Study Team assumed the voltage as 22kV.

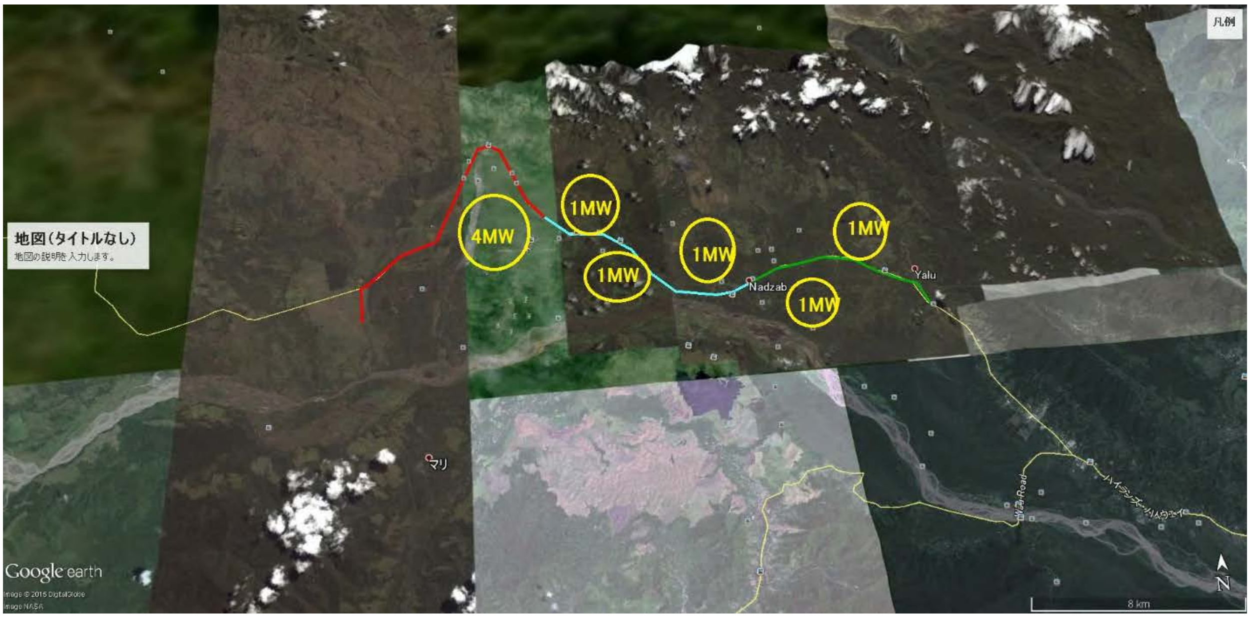


Fig. 5.1-3 Load Distribution in the Erap Supply Area in 2030

Source: JICA Study Team

The load distribution in the supply area of the Erap S/S in 2030 is forecasted in Fig. 5.1-3.

As two 22kV feeder lines will be used to cover such load, the current-carrying capacity is deemed as sufficient.

Meanwhile, the distribution system shown in Fig. 5.1-4 is envisioned for the Erap S/S to satisfy the load in the airport and city directions. As Fig. 5.1-4 suggests, the network is planned to have long distance, with the longest distance of Line No. 1 being 27 km and that of Line No. 2 being 37 km. One needs to study the possibility of a voltage deviation at the line end for such a network.

JICA Study Team conducted an assessment on potential drops for the normal operation system as well as the emergency system (a relief system using other networks) as follows.

Potential drops during normal-time operation and in case of emergency on model networks were calculated as follows based on the load distribution given in Fig. 5.1-4.

Fig. 5.1-4 shows operation of normal time.
Fig. 5.1-5 shows operation of emergency time.

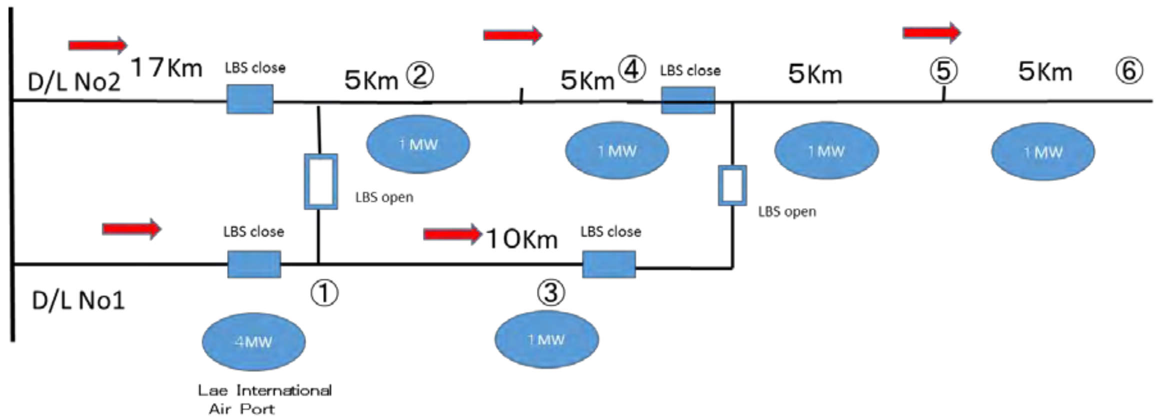


Fig. 5.1-4 Operation of Normal Time

Source: JICA Study Team

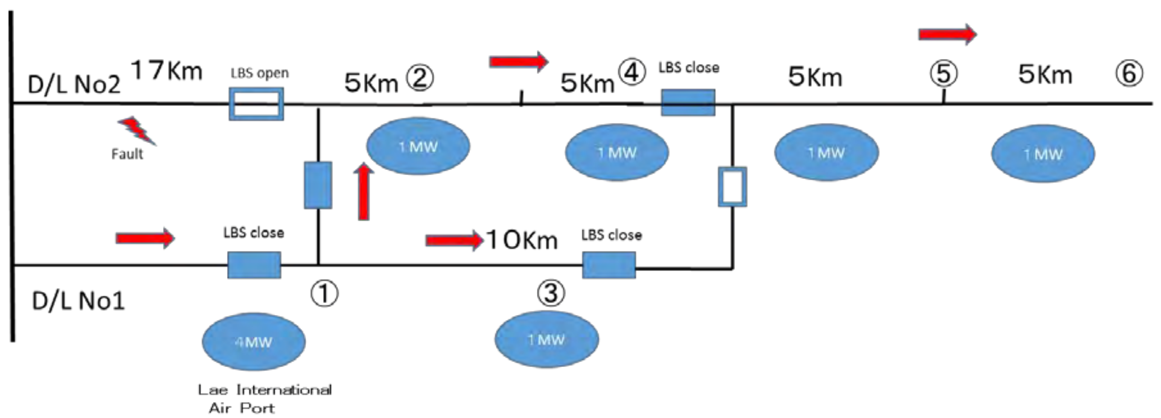


Fig. 5.1-5 Operation of Emergency Time

Source: JICA Study Team

The potential drops in both cases are calculated as follows:

Table 5.1-2 Voltage Drop Calculation Result

D/L No.1	point	①	③				
	load current(A)	195	39				
	Voltage drop (▲V)	872	974				
	Voltage(V)	21128	21026				
D/L No.2	point	②	④	⑤	⑥		
	load current	156	117	78	39		
	Voltage drop (▲V)	903	1056	1159	1210		
	Voltage	21097	20944	20841	20790		
Emergency	point	①	②	③	④	⑤	⑥
	load current	351	195	156	117	78	39
	Voltage drop (▲V)	1569	1826	2031	2185	2287	2339
	Voltage	20431	20174	19969	19815	19713	19661

Source: JICA Study Team

With respect to the normal operation system, the potential drop poses no problem as to D/L No.1, while it becomes five percent above the standard level at places along D/L No.2. The supply voltage, however, may be maintained within the controllable range, as the voltage departing from the S/S may be adjusted in the range of ±11% or so.

On the other hand, the voltage drop with the emergency system becomes 10% above the standard level or greater from place to place.

That may result in a deviation of the supply voltage from the standard in the emergency system, if the load on the Erap S/S and/or around the boundary between the Milford and Erap S/Ss increases.

From above, the demand forecasts generated herein should be reviewed in around 2025, and if the load exceeds the estimated demand, one has to look at the possibility of increasing the number of lines or building a new S/S.

In our study, the option of building a new S/S by 2030 is excluded.

Consequently, the boundary between the Milford and Erap S/Ss, a point approximately 20 km distant from the Milford S/S, is considered to be the limit of the Milford load area.

Incidentally, mutual relief between the two S/Ss in case of a transformer accident is not taken into account.

3) Boundary between the supply areas of Taraka and Milford Substations in 2030

The areas covered by the Milford and Taraka S/Ss in 2030 will likely be as drawn in Fig. 5.1-6, when giving consideration to future load and regarding major linear features, such as roads and rivers, as the boundary between the D/Ls.

The red line represents the boundary today, and the green line represents that in 2030.

The border of the Milford supply area is estimated to expand northward a little in the west and east parts.

In the future demand scenario for 2030, the loads on the Taraka and Milford S/Ss will both grow three times; the number of D/Ls must be raised in response to the higher demand densities.

As a result, the supply area per D/L becomes smaller, and it needs to be restructured accordingly.

Additionally, the supply area of the Milford S/S in 2030 will be smaller in the north and expanded in the northwest direction.

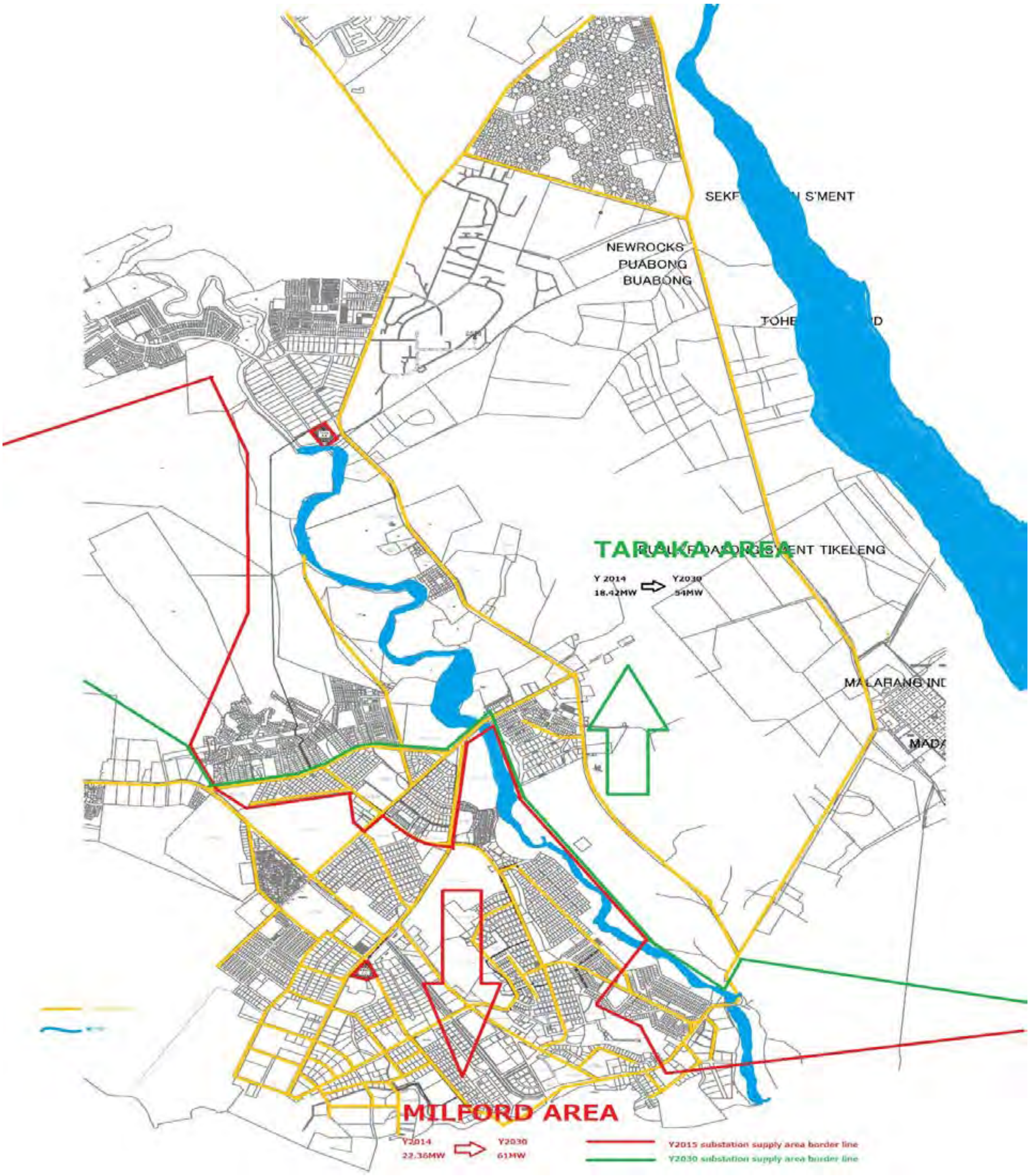


Fig. 5.1-6 Boundary between Taraka and Milford Supply Area

Source: JICA Study Team

5.1.2 Demand Forecast by Block

Creating a master plan for distribution systems requires data on load distribution within the supply area.

As such, JICA Study Team divided the supply area of each S/S into blocks, and estimated future demand per block.

The area covered by each S/S is split into four blocks, based on the demarcation between the two S/Ss presented in Fig. 5.1-6 and the existing D/Ls in place today. That means the area comprised of the blocks does not correspond exactly to the current supply area.

5.1.2.1 Current Status of Blocks

The current load of the Taraka and Milford S/Ss is distributed among the blocks.

The current load on the two S/Ss is 40.3MW in total.

In distributing this load to the eight blocks, JICA Study Team took the following process since the coverage of each S/S in 2030 is not the same as today.

1) The total load of 40.7MW was allocated proportionally to the two S/Ss and D/Ls.
2) The load allocated to each D/L was allocated proportionally to the transformers based on their capacity.
3) The load in each block was summed up.

Table 5.1-3 tabulates the results of the above calculation.

Table 5.1-3 Transformer Capacity of Each Block and the Load Distribution

D/L	M1	M2	M3	M4	M5	M6	Milford Total	T1	T2	T3	T4	T5	Taraka Total	Total
KIOSK type (kVA)	2,350	4,100	5,250	4,450	4,150	0	20,300	3,200	5,300	0	3,800	500	12,800	33,100
Pad mounted Transformer (kVA)	7,500	1,900	3,300	2,300	500	0	15,500	1,000	2,400	600	11,000	1,250	16,250	31,750
Pole mounted Transformer (KVA)	2,300	2,500	4,000	6,300	5,900	5,010	26,010	2,100	3,675	2,600	7,050	1,300	16,725	42,735
Total (KVA)	12,150	8,500	12,550	13,050	10,550	5,010	61,810	6,300	11,375	3,200	21,850	3,050	45,775	107,585
Max. Load (kW)	4,452	3,115	4,599	4,782	3,866	1,836	22,650	2,491	4,498	1,265	8,641	1,206	18,101	40,750

Source: JICA Study Team

The load power of each block is as provided in Table 5.1-4.

Table 5.1-4 Load of Each Block

	Supply area (km^2)	2015 load (MW)	2015 load density (kW/km^2)	Transformer capacity (kVA)	Zone characteristic
T1 Block	13.95	5.5	0.39	17,675	Industry, School, Residence
T2 Block	0.15	1.0	6.67	2,000	Industry, Residence
T3 Block	4.01	4.0	1.00	15,050	Industry, School, Residence
T4 Block	3.73	2.0	0.54	3,300	Industry, Residence
Taraka subtotal	**21.84**	**12.5**	**0.57**	**38,025**	
M1 Block	4.23	12.4	2.93	25,310	Commerce, Residence
M2 Block	1.85	9.2	4.97	28,950	Heavy Industry, Commerce
M3 Block	2.79	4.0	1.43	11,100	Heavy Industry, Residence
M4 Block	4.99	2.6	0.52	4,200	Industry, Residence
Milford Total	**13.86**	**28.2**	**2.03**	**69,560**	
Total	**35.7**	**40.7**	**1.14**	**107,585**	

Source: JICA Study Team

Fig. 5.1-7 is an illustration of Table 5.1-4.

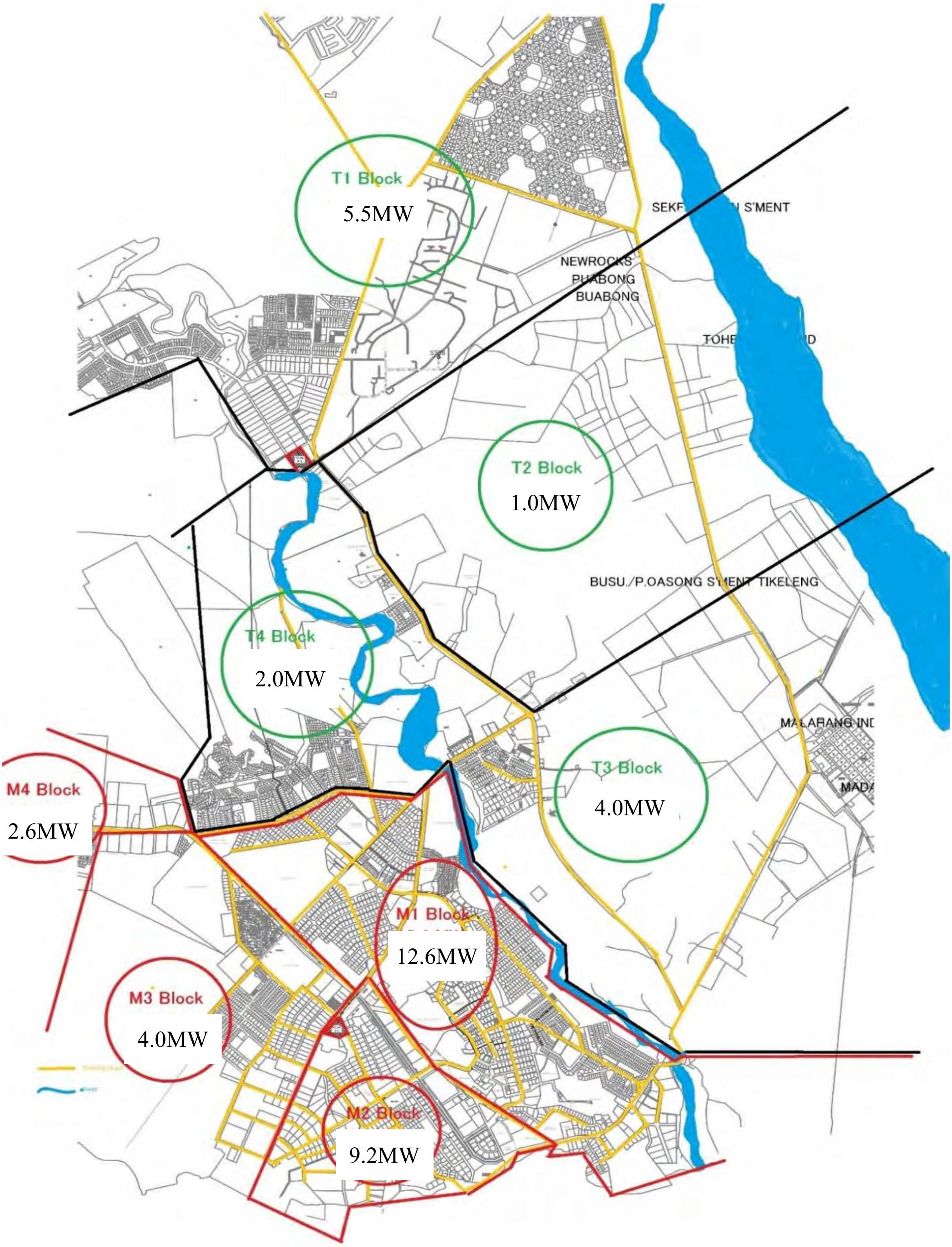


Fig. 5.1-7 Demand for Each Block in 2015

Source: JICA Study Team

In addition, Fig. 5.1-8 below outlines the present supply areas.

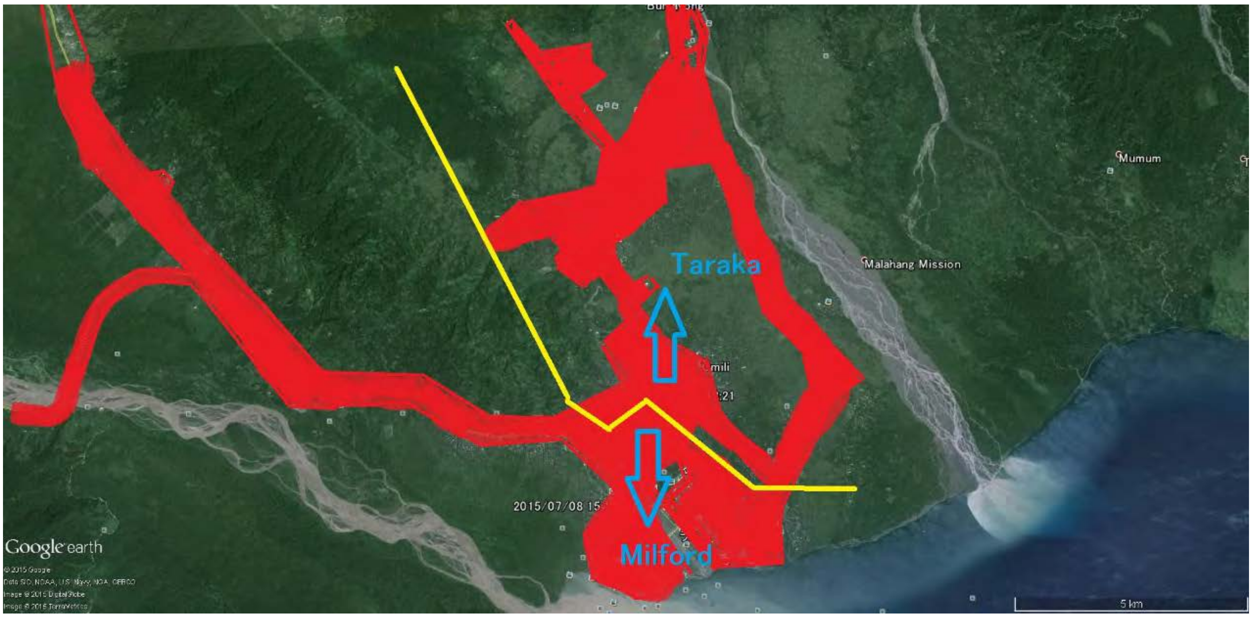


Fig. 5.1-8 Overview of the Current Supply Area

Source: JICA Study Team

Fig. 5.1-8 clearly shows that there extends a large undeveloped area in the middle of the Taraka supply area and thus suggests that it will very likely be developed in the future.

In the meantime, the coverage of the Milford S/S mainly consists of developed land. Possible demand increases in the future, therefore, will come mainly from grown power consumption of the existing load.

New load may arise in surrounding undeveloped areas, specifically the open space in the east and the vacant land along the Highland Highway.

Demand growth in a place almost completely developed comes mainly from a rise in the load density level.

Demand growth in an area undergoing the development phase, like the Lae area, is a mixture of two factors: i) added loads resulting from the development of undeveloped areas; and, ii) higher densities of existing load.

JICA Study Team calculated future load power using these two approaches.

5.1.3 Calculation of Demand per Block

(1) Calculating an increment to existing load

Table 5.1-5 Installed Capacity of Distribution Transformer by Type

Feeder No	Milford Total			Taraka Total			Grand Total		
Type of Transformer	Tr Capacity (kVA)	Dedicated Tr Capacity (kVA)	Dedicated Tr Ratio (%)	Tr Capacity (kVA)	Dedicated Tr Capacity (kVA)	Dedicated Tr Ratio (%)	Tr Capacity (kVA)	Dedicated Tr Capacity (kVA)	Dedicated Tr Ratio (%)
KIOSK type	20,300	20,300	100%	12,800	12,800	100%	33,100	33,100	100%
Pad mounted Tr.	15,500	15,500	100%	16,250	16,250	100%	31,750	31,750	100%
Pole Mounted Tr.	26,010	2,830	11%	16,725	5,900	35%	42,735	8,730	20%
Total	**61,810**	**38,630**	**62%**	**45,775**	**34,950**	**76%**	**107,585**	**73,580**	**68%**

Table 5.1-5 lists the combined capacity of the transformers installed along all the D/Ls of the Milford and Taraka S/Ss by type along with the total capacity of dedicated transformers alone. A dedicated transformer serves a particular customer only and does not provide electricity to any other customers. The cost of installing such a transformer is fully borne by the customer; likewise, any cost associated with replacing a larger-capacity transformer at some point in the future due to additional load at the customer needs to be borne by the customer. Dedicated transformers, therefore, are typically of sufficiently-large capacity from the start with a view to possible increases in demand in the future.

The installed capacity of dedicated transformers accounts for nearly 70% of the total capacity of distribution transformers in the supply areas of the Taraka and Milford S/Ss.

In estimating future demand of the existing load, JICA Study Team used 80% as the utilization rate of transformers.

Table 5.1-6 presents the results of our estimation.

Table 5.1-6 Demand by the Growth of the Existing Load

Block	2015 Demand (MW)	Transformer Capacity (kVA)	2030 demand of the existing load (MW)	Zone characteristic
T1	5.5	17,675	9.5	Industry, School, Residence
T2	1.0	2,000	1.1	Industry, Residence
T3	4.0	15,050	8.1	Industry, School, Residence
T4	2.0	3,300	2.0	Industry, Residence
Taraka subtotal	12.5	38,025	20.7	
M1	12.4	25,310	13.4	Commerce ,Residence
M2	9.2	28,950	15.5	Heavy Industry, Commerce
M3	4.0	11,100	5.9	Heavy Industry, residence
M4	2.6	4,200	2.2	Industry, Residence
Milford subtotal	28.2	69,560	37.0	
Total	**40.7**	**107,585**	**57.7**	

Source: JICA Study Team

(2) Calculating new load

In calculating new demand, JICA Study Team assumed that there would be certain areas newly developed by 2030, and multiplied the area of such new development with the load density in the same block as of 2015.

Table 5.1-7 shows the results of our calculation.

Table 5.1-7 Demand by New Development Load

Block	New development area (km^2)	2030 supply area (km^2)	2015 Load (MW)	2015 load density (kW/km^2)	New load (MW)	Zone characteristic
T1	9.3	23.2	5.5	0.4	3.7	Industry, School, Residence
T2	10.8	10.9	1.0	6.7	11.1	Industry, Residence
T3	7.1	11.1	4.0	1.0	7.1	Industry, School, Residence
T4	1.2	4.9	2.0	0.5	0.6	Industry, Residence
Taraka subtotal	**28.3**	**50.2**	**12.5**			
M1	1.1	5.4	12.4	2.9	3.3	Commerce ,Residence
M2	0.9	2.7	9.2	5.0	4.3	Heavy Industry, Commerce
M3	1.2	4.0	4.0	1.4	1.7	Heavy Industry, residence
M4	3.0	8.0	2.6	0.5	1.6	Industry, Residence
Milford subtotal	**6.2**	**20.0**	**28.2**			
Total	**34.5**	**70.2**	**40.7**		**33.3**	

Source: JICA Study Team

(3) Estimated load sum

A sum of the increased demand of the existing load (Table 5.1-6) and the additional load in newly-developed areas (Table 5.1-7) derived above is given in Table 5.1-8 below.

Table 5.1-8 Total Demand of Each Block

Block	2015 Load (MW)	2030 demand of the existing load (MW)	New Load (MW)	total (MW)	Zone characteristic
T1	5.5	9.5	3.7	13.2	Industry, School, Residence
T2	1.0	1.1	11.1	12.2	Industry, Residence
T3	4.0	8.1	7.1	15.2	Industry, School, Residence
T4	2.0	2.0	0.6	2.6	Industry, Residence
Taraka	***12.5***	***20.7***	***22.5***	***43.2***	
M1	12.4	13.4	3.3	16.7	Commerce, Residence
M2	9.2	15.5	4.3	19.8	Heavy Industry, Commerce
M3	4.0	5.9	1.7	7.6	Heavy Industry, residence
M4	2.6	2.2	1.6	3.8	Industry, Residence
Milford	***28.2***	***37.0***	***10.8***	***47.8***	
Total	**40.7**	**57.7**	**33.3**	**91.0**	

According to Table 5.1-8, the combined load of the Taraka and Milford S/Ss in 2030 is 91.0MW, approximately 24MW below the demand forecast of 115MW (Table 5.1-1).

Based on these numbers, JICA Study Team made adjustment to the load of each block by incorporating information on development plans and so forth.

5.1.3.1 Adjustment of Taraka Blocks

(1) Adjustment of T1 Block

T1 Block is situated in the north of Taraka S/S, where the current load includes an industrial compound, pumping station, university, military barracks, and houses.

Fig. 5.1-9 Overview of T1 Block

Source: JICA Study Team

Fig. 5.1-9 is a satellite image over T1 Block.
The zones surrounded by red line correspond to the current load areas.
This image shows that there are many vacant lots in the industrial compound and undeveloped flatlands in the zones with light blue line. In the future, the industrial compound will likely have more tenant factories and the undeveloped flatlands will be developed.

The characteristics of this block are summarized as follows.

[Geographical conditions]

- Close to the urban area of Lae, only 5 km away.
- The west section of the access road, or the Independent Drive running from west to east, is paved up to the industrial area.
- The access road, or the East Independent Drive, is paved up to the Marahan Industrial Area.

- The east section of the Independent Drive was paved up to the entrance of the residential area in June 2015.

[Predictions]

- The access to the urban area of Lae will be significantly improved as a result of road development.
- The areas in the south of the military garrison and the flat areas on the east side of the river (with a new bridge to be constructed) do not require large-scale land preparation, and hence may be developed with relatively-low cost.
- The east section of the river is narrower than the downstream, which makes it easy to build a bridge, and is likely to be developed.
- More industrial estates and residential areas will be developed.

Fig. 5.1-10 Vacant lot in T1 Block Industrial Zone

Fig. 5.1-11 Vacant Lot in South Region of Military Garrison

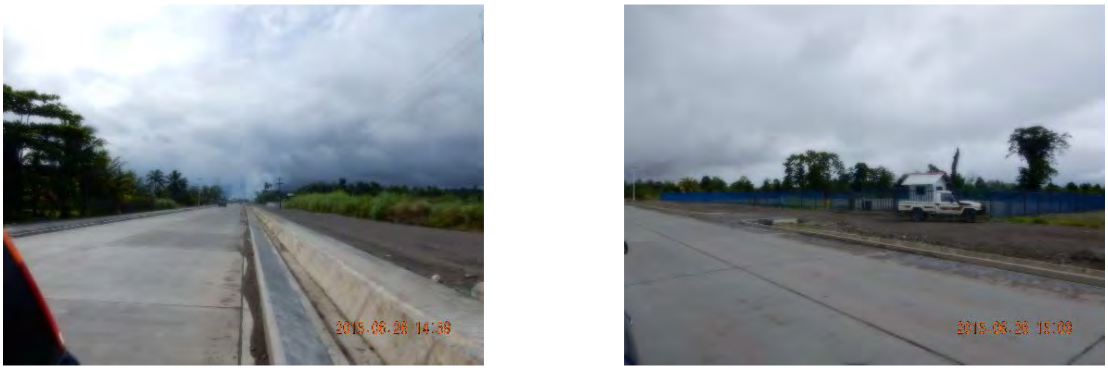


Fig. 5.1-12 Vacant Lot along East Independent Road

Source: JICA Study Team

Table 5.1-9 T1 Block Total of the Existing Load and New Development Areas (Assumed value of T1 Block)

	2015 load (MW)	2030 demand of the existing load (MW)	New Load (MW)	Total (MW)	Zone characteristics
T1	5.5	9.5	3.7	13.2	Industry, School, Residence

Source: JICA Study Team

Adjustment: At the time of this report, there is no specific development plan or ongoing development works in this block, but a new demand of 6.9MW is envisioned for the year 2030.
Accordingly, the load power in this block as of 2030, i.e., a combination of an increase in unit consumption of the current load and newly added load, is considered to be 13.2MW.

(2) Adjustment of T2 Block

T2 Block is situated in the southeast of Taraka S/S, where the current load includes Lae Biscuit, small plants, and some houses. Thus, the demand density is low.

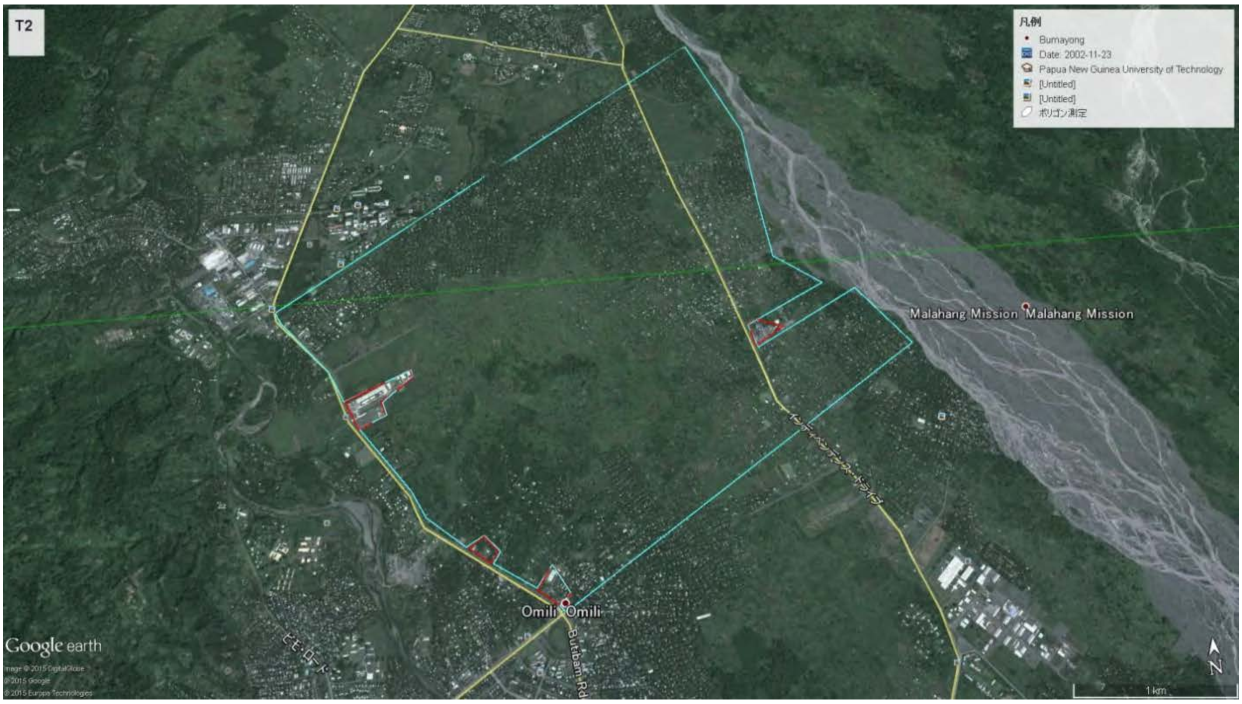


Fig. 5.1-13 Overview of T2 Block

Source: JICA Study Team

Fig. 5.1-13 is a satellite image over T2 Block.
The zones surrounded by red line correspond to the current load areas.
Fig. 5.1-13 conspicuously shows open spaces in the areas indicated with light blue line, and these undeveloped flat lands will likely be developed.

[Geographical conditions]

- Close to the urban area of Lae, only 3 km away.
- The west section of the access road, or the Independent Drive running from west to east, is paved up to the industrial area.
- The access road, or the East Independent Drive, is paved up to the Marahan Industrial Area.
- The east section of the Independent Drive was paved up to the entrance of the residential area in June 2015.

[Predictions]

- The access to the urban area of Lae will be significantly improved owing to road development.
- More industrial estates and residential areas will be developed.
- A new factory in the northwest vacant lot of the Marahan Industrial Area starts operation.
- New factories will first emerge in the vacant lots along the Independent Road running from west to east, followed by the development of an access road to the central part, which propels the development of more factories and houses.

Fig. 5.1-14 Lae Biscuit

Fig. 5.1-15 Vacant Lot along East Independent Road

Source: JICA Study Team

Table 5.1-10 Total Load of the Existing Load and New Development Areas (Assumed value of T2 Block)

	2015 load (MW)	2030 demand of the existing load (MW)	New Load (MW)	Total (MW)	Zone characteristic
T2	1.0	1.1	11.0	12.2	Industry, Residence

Source: JICA Study Team

Adjustment: The yellow zones in Fig. 5.1-16 are already prepared now.
As factories may likely be sited here in coming years, JICA Study Team made adjustment to these areas.
The total load of these two sites is estimated at 3MW or so, based on the actual load of adjoining Lae Biscuit. Thus, the total load power of T2 Block is estimated at 15.2MW, adding 3MW above to the total (MW) in Table 5.1-10.

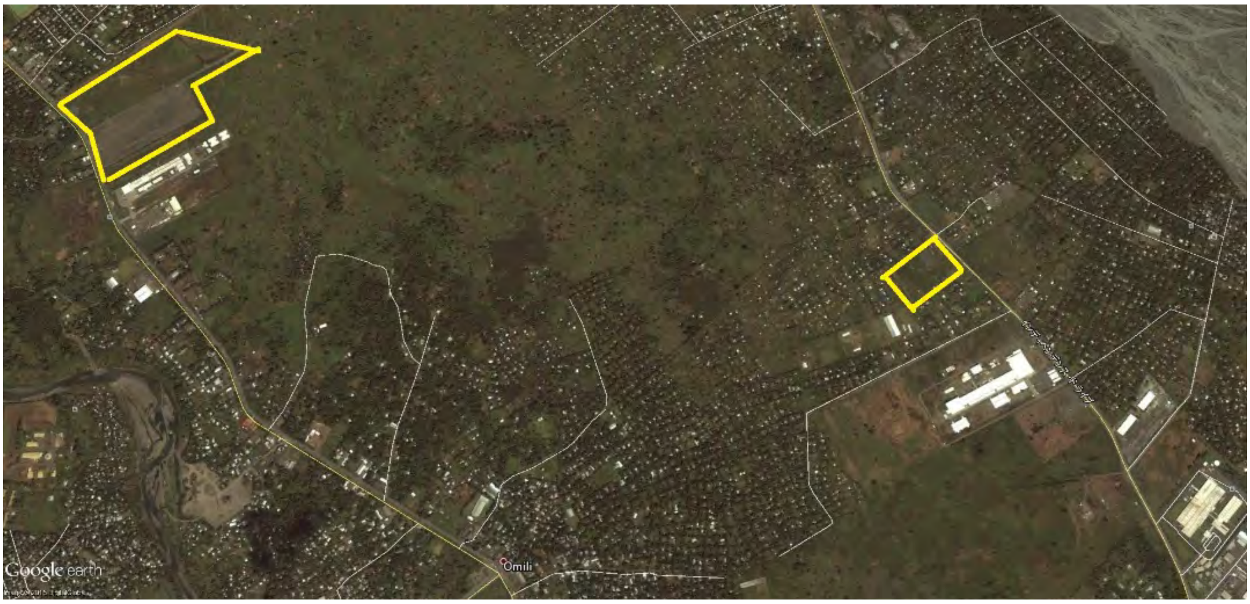


Fig. 5.1-16 Construction Sites in T2 Block

Source: JICA Study Team

(3) Adjustment of T3 Block

T3 Block is situated in the southeast of Taraka S/S, where the current load includes the Marahan Industrial Area, schools and houses.

Fig. 5.1-17 is a satellite image over T3 Block.

The zones surrounded by red line correspond to the current load areas. Those indicated with light blue line are undeveloped, open spaces.
The vacant lots in the industrial park and the undeveloped flatland will likely be developed in the future.

[Geographical conditions]

- Close to the urban area of Lae, only 2 km away.
- The access road is paved (in part.)
- No access road to the inside.
- Open space exists behind the Marahan Industrial Area.

[Predictions]

- More factories are built resulting from the development of areas surrounding the industrial complex.
- More houses and industrial parks are built resulting from the redevelopment based on the past development plan.
- The industrial complex is expanded in the back of the premises.

Fig. 5.1-17 Overview of T3 Block

Source: JICA Study Team

Fig. 5.1-18 Vacant Lot along East Independent Road

Fig. 5.1-19 Vacant Lot along West Independent Road

Source: JICA Study Team

Table 5.1-11 Total Load of the Existing Load and New Development Areas (Assumed value of T3 Block)

	2015 load (MW)	2030 demand of the existing load (MW)	New Load (MW)	Total (MW)	Zone characteristic
T3	4.0	8.1	7.1	15.2	Industry, Residence, Schools

Source: JICA Study Team

Adjustment: The yellow zones in Fig. 5.1-20 are already prepared now.
Building construction is going on in Site A, which consumes electricity. The land in Site B has been prepared. JICA Study Team assumed a total load increase of about 3MW in these two locations. Thus, the total load power of T3 Block is estimated at 18.2MW, adding 3MW above to the total (MW) in Table 5.1-11.

Fig. 5.1-20 Construction Place of T3 Block

Source: JICA Study Team

(4) Adjustment of T4 Block

T4 Block is situated in the southwest of Taraka S/S, where the current load includes factories and houses.
This block is occupied by hills in the west, where water for the City of Lae comes from, and crossed by the river in the middle; thus there is not as much open space for development as other blocks.

Fig. 5.1-21 is a satellite image over T4 Block.
The zones surrounded by red line correspond to the current load areas.
In the future, industrial parks may be developed in the norther part of the block, where open space stands out.

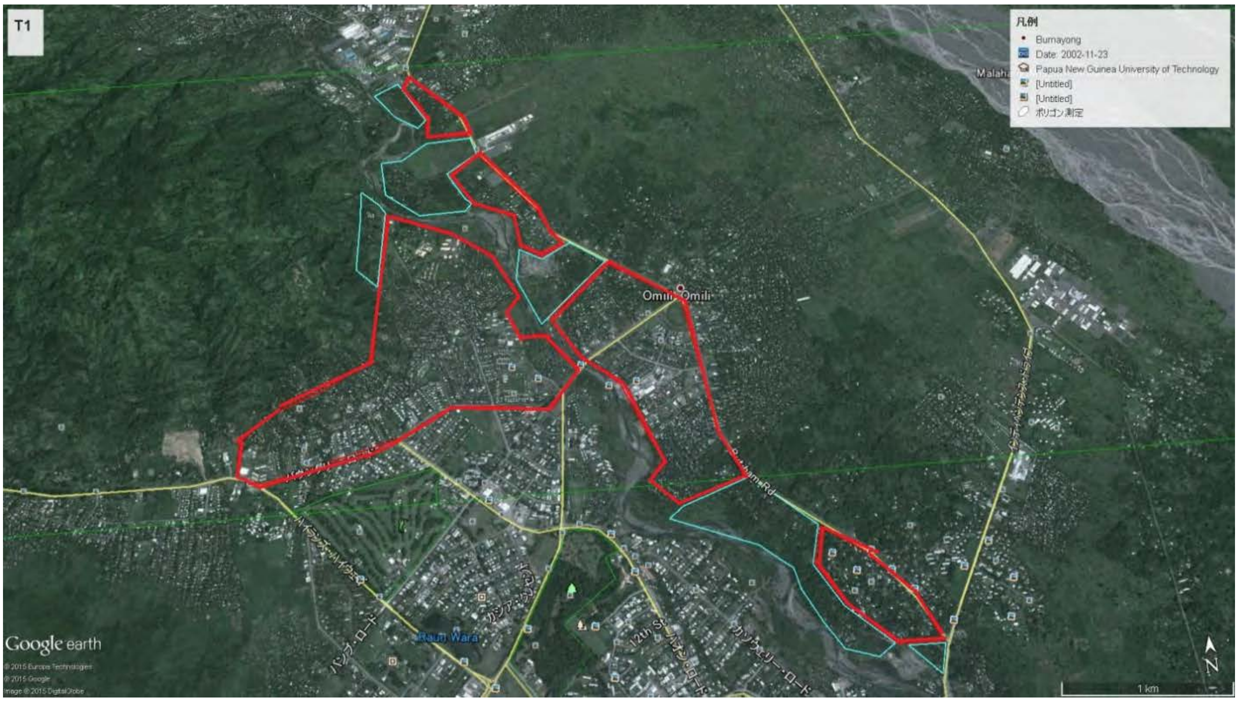


Fig. 5.1-21 Overview of T4 Block

Source: JICA Study Team

[Geographical conditions]

- Close to the urban area of Lae, only 2 km away.
- The access road is paved (in part).
- The mountainous area in the west is under development.
- The Bumbu Road is expanded and has started being paved.

[Predictions]

- With some progress in the development of the open space in the mountainous area in the west, more factories will appear.
- More factories will be established in the open space along the Independent Road.
- The industrial complex is expanded in the back of the premises.
- A shopping center may be developed in the open space in the middle of the already-developed area.
- The access road in the southern part of the block is still unpaved; paving this section will accelerate the development of this area.

Fig. 5.1-22 Vacant Lot along East Independent Road

Fig. 5.1-23 Vacant Land in the Pre-developed Areas

Source: JICA Study Team

Table 5.1-12 Total Load of the Existing Load and New Development Areas (Assumed value of T4 Block)

	2015 load (MW)	2030 demand of the existing load (MW)	New Load (MW)	Total (MW)	Zone characteristic
T4	2.0	2.0	0.6	2.6	Industry, Residence, Commerce

Source: JICA Study Team

Fig. 5.1-24 Overview of T4 Block

Source: JICA Study Team

Adjustment: The yellow zones in Fig. 5.1-24 are already prepared now.
The foundation work of a building has already begun in Site A.
The land in Sites B and C has been prepared, where new load is to occur immediately.
Site D is left vacant at the time of this report but requires no land preparation; new load may occur anytime soon.

Assuming that the loads here as 3MW in Site A and a total of 4MW in Sites B, C and D, emerging load will be 7MW in total. Thus, the total load power of T4 Block is estimated at 9.6MW, adding 7MW above to the total (MW) in Table 5.1-12.

5.1.3.2 Adjustment of Milford Blocks

(1) Adjustment of M1 Block

M1 Block is situated in the northeast of Milford S/S, where the current load consists of urban functions of the City of Lae, such as administrative installations, commercial buildings, hotels and hospitals, as well as houses, universities, industrial parks, and so forth. In other words, this block has already been fairly developed.

Fig. 5.1-25 is a satellite image over M1 Block.
The zones surrounded by red line correspond to the current load areas.
More houses and factories may emerge centering on the open space in the eastern part of the block.

[Geographical conditions]

- The center of the City of Lae
- Offices, hotels and shopping centers are concentrated in the middle.
- Factories cluster in the southeastern part.
- Dense residential areas near the perimeter.

[Predictions]

- Commercial buildings and hotels will be built in the open space in the Top Town District.
- The undeveloped flatland on the east side of the Bumbu River, shown in light blue in Fig. 5.1-25, will be developed.
- Unit consumption in Top Town will significantly grow due to an emergence of, most notably, commercial buildings and recreation facilities.
- Underground distribution systems could be employed in this area.

Fig. 5.1-25 Overview of M1 Block

Source: JICA Study Team

Fig. 5.1-26 Vacant Lot along East Independent Road

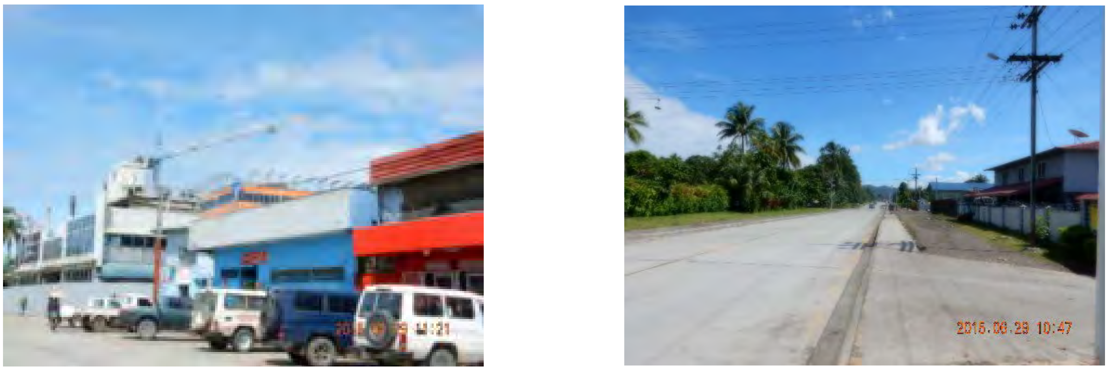


Fig. 5.1-27 Vacant Land in the Pre-developed Areas

Source: JICA Study Team

Table 5.1-13 Assumed Value of M1 Block Source

	2015 load (MW)	2030 demand of the existing load (MW)	New Load (MW)	Total (MW)	Zone characteristics
M1	12.4	13.4	3.3	16.7	Residence, Commerce

Source: JICA Study Team

Adjustment: The shopping center under renovation in Top Town is supposed to receive electricity from the existing transformer.
Although the load density in Top Town is high, a sufficient margin is already counted as a possible growth of the existing load in M1 Block as a whole.
Thus, no adjustment is needed here, and the total load power of M1 Block is estimated at 16.7MW, as given as the total (MW) in Table 5.1-13.

(2) Adjustment of M2 block

M2 Block is situated in the southeast of Milford S/S, where the current load includes factories (chiefly heavy industrial works), and some commercial buildings. This block has the highest load density in the City of Lae.

Fig. 5.1-28 is a satellite image over M1 Block. The zones surrounded by red line correspond to the current load areas.

Construction of a shopping center is planned in the vast open space in the eastern part of the block, a former airfield site.
More heavy-industry plants may be built in the open lots within the existing load areas.
The cement company operating in this block has a project of doubling the capacity of its production equipment in ten years' time.
The block may well stay as the center of heavy industry of the City of Lae into the future.

Fig. 5.1-28 Overview of M2 Block

Source: JICA Study Team

[Geographical conditions]

- The center of heavy industry of the City of Lae.
- A container yard exists surrounded by factories that process imported materials, warehouses to store imports, and other companies and organizations.
- The central market of the Lae area is situated.
- Factories still have additional space in their premises.

[Predictions]

- A shopping center will be developed in the former airfield site.
- Increases in the load are easily predictable due to the high possibility for existing factories to expand their facilities.

Fig. 5.1-29　Vacant Lot along East Independent Road

Fig. 5.1-30　Vacant Land in the Pre-developed Areas

Source: JICA Study Team

Table 5.1-14　Assumed Value of M2 Block

	2015 load (MW)	2030 demand of the existing load (MW)	New Load (MW)	Total (MW)	Zone characteristics
M2	9.2	15.5	4.3	19.8	Heavy industry, commerce

Source: JICA Study Team

Adjustment: The yellow zones in Fig. 5.1-31 (A, B), the former airfield, are already prepared but left open at the time of this report.
A shopping center project is in progress in Site A, and it is partially completed.
Site B has been used as a temporary container storage yard, but may likely turn into factory and hopping center sites.
The sum total of the load is assumed as more or less than 3MW.
Thus, the total load power of M2 Block is estimated at 22.8MW, adding 3MW above to the total (MW) in Table 5.1-14.

Fig. 5.1-31 Overview of M2 Block

Source: JICA Study Team

(3) Adjustment of M3 Block

M3 Block is situated in the west of Milford S/S, where the current load mainly includes large-, medium- and small-sized factories with some shops and houses.

Fig. 5.1-32 Overview of M3 Block

Source: JICA Study Team

Fig. 5.1-32 is a satellite image over M3 Block.

The zones surrounded by red line correspond to the current load areas. Those indicated with light blue line are areas to be developed.

More heavy-industry installations, starting with a new container terminal, may be built in the future.

This block is expected to develop gradually into the center of heavy industry of the City of Lae.

[Geographical conditions]

- Heavy industries and imports warehouses.
- With a new container terminal future development is foreseeable.
- No access road to the new terminal.
- Factories have additional space for expansion within their premises.

[Predictions]

- With the start of operation of the new container terminal, similar factories and plants present in M2 Block will emerge in the peripheral areas.
- Container warehouses will spread on the fringe.
- The area may become the center of industry of the City of Lae.


Fig. 5.1-33 Vacant Lot along East Independent Road

Fig. 5.1-34 Vacant Land in the Pre-developed Areas

Source: JICA Study Team

Table 5.1-15 Assumed Value of M3 Block

	2015 load (MW)	2030 demand of the existing load (MW)	New Load (MW)	Total (MW)	Zone characteristics
M3	4.0	5.9	1.7	7.6	Heavy industry, commerce

Source: JICA Study Team

Adjustment: The new container terminal, indicated in yellow in Fig. 5.1-36, has already been completed. The next step is to install container cranes and other equipment. As the size of the yard is said to be five times that of the existing yard and the demand is 1MW, the demand here is assumed as 5MW.
Thus, the total load power of M3 Block is estimated at 12.6MW, adding 5MW above to the total (MW) in Table 5.1-15.

Fig. 5.1-35 Overview of M3 Block

Source: JICA Study Team

(4) Adjustment of M4 Block

M4 Block is situated in the west of Milford S/S, where the current load mainly includes villages and factories along the Highland Highway running from the City of Lae to the Nadzab Airport.

Fig. 5.1-36 is a satellite image over M4 Block.

The zones surrounded by red line correspond to the current load areas.

At the time of this report, the Highland Highway is undergoing expansion works to improve access to the Nadzab Airport. Some open space along the highway has already been prepared with plans of building a new industrial park and factories. Meanwhile, one of the existing factories, Table Bird, has applied for increasing its contract demand; but a rapid load change of operating equipment poses a concern over voltage dipping.

The light blue area will likely develop rapidly; more industrial estates and residential areas are expected to be developed there.

Fig. 5.1-36 Overview of M4 Block

Source: JICA Study Team

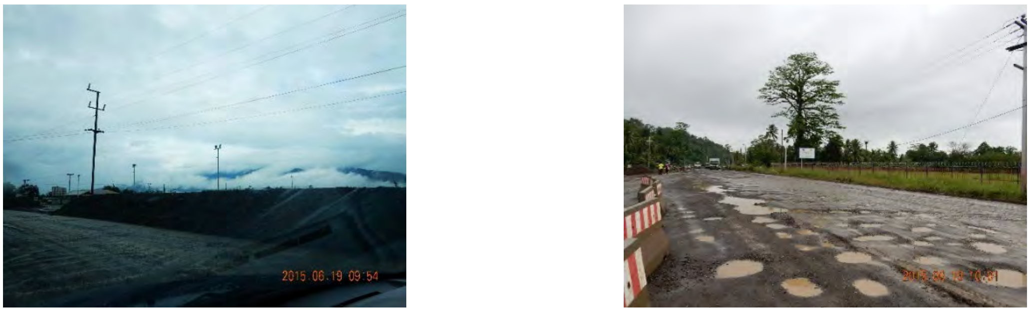


Fig. 5.1-37 Vacant Lot along East Independent Road

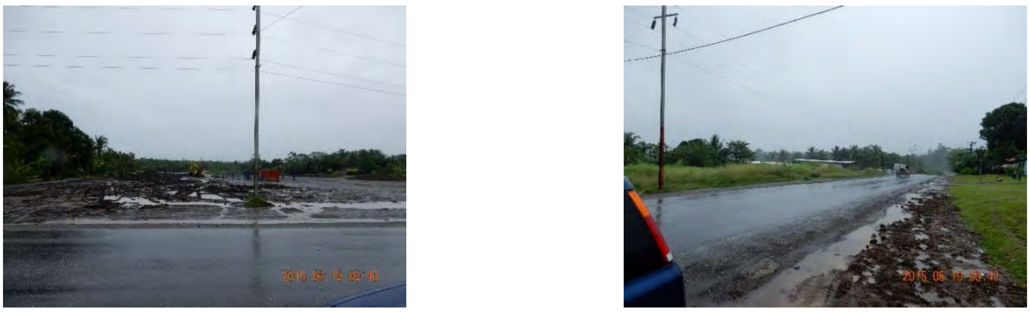


Fig. 5.1-38 Vacant Land in the Pre-developed Areas

Source: JICA Study Team

At the time of this report, there are several plans of developing industrial parks along the above said road, and requests for power supply are coming in.

[Geographical conditions]

- Small-sized factories and residential buildings are dispersed along the Highland Highway stretching from the City of Lae to the airport.
- Land preparation work of a fairly large scale takes place in the open space along the highway.
- Works to expand the Highland Highway are going on.

[Predictions]

- Several industrial parks will be established along the highway.
- Industrial parks and residential zones will be developed along the Wau Road, which branches out from the highway.

Table 5.1-16 Assumed Value of M4 Block

	2015 load (MW)	2030 demand of the existing load (MW)	New Load (MW)	Total (MW)	Zone characteristics
M4	2.6	2.2	1.6	3.8	Industry, Residence

Source: JICA Study Team

Adjustment: Since there is a business inquiry for an industrial estate in the yellow site in Fig. 5.1-39, the demand there is assumed as about 3MW.
Thus, the total load power of M4 Block is estimated at 6.8MW, adding 3MW above to the total (MW) in Table 5.1-16.

Fig. 5.1-39 Overview of M4 Block

Source: JICA Study Team

5.1.3.3 Demand Forecast for Erap (Nadzab) Substation

(1) Prediction of demand in the coverage of the substation

The load of Erap (Nadzab) S/S consists of the Nadzab Airport and houses along the Highland Highway.
There is only one D/L from the S/S, stretching in two directions, westward and eastward.
One section of the feeder line is installed along the Highland Highway toward the City of Lae.
The other section goes through the airport, then runs westward after stepped up to 22 kV.
The westward line ends in Mutsing, approximately 80 kilometers away.
The current load power of this feeder is 0.3MW, comprising 0.2MW of the airport and 0.1MW of the villages along the Highland Highway.
Fig. 5.1-40 maps the current high-voltage transmission routes.

In view of the existing load explained above, JICA Study Team distributed the future demand envisioned for 2030 in the Nadzab supply area, as exhibited in Fig. 5.1-41. In conjunction with an increased voltage of the Erap Switchyard, an Erap S/S with 132/22kV and 10MVA will have been established by 2030; consequently, the current load of the Nadzab S/S will be transferred to the Erap S/S. The supply area and the load therein shown in Fig. 5.1-41 will be served by the new S/S.

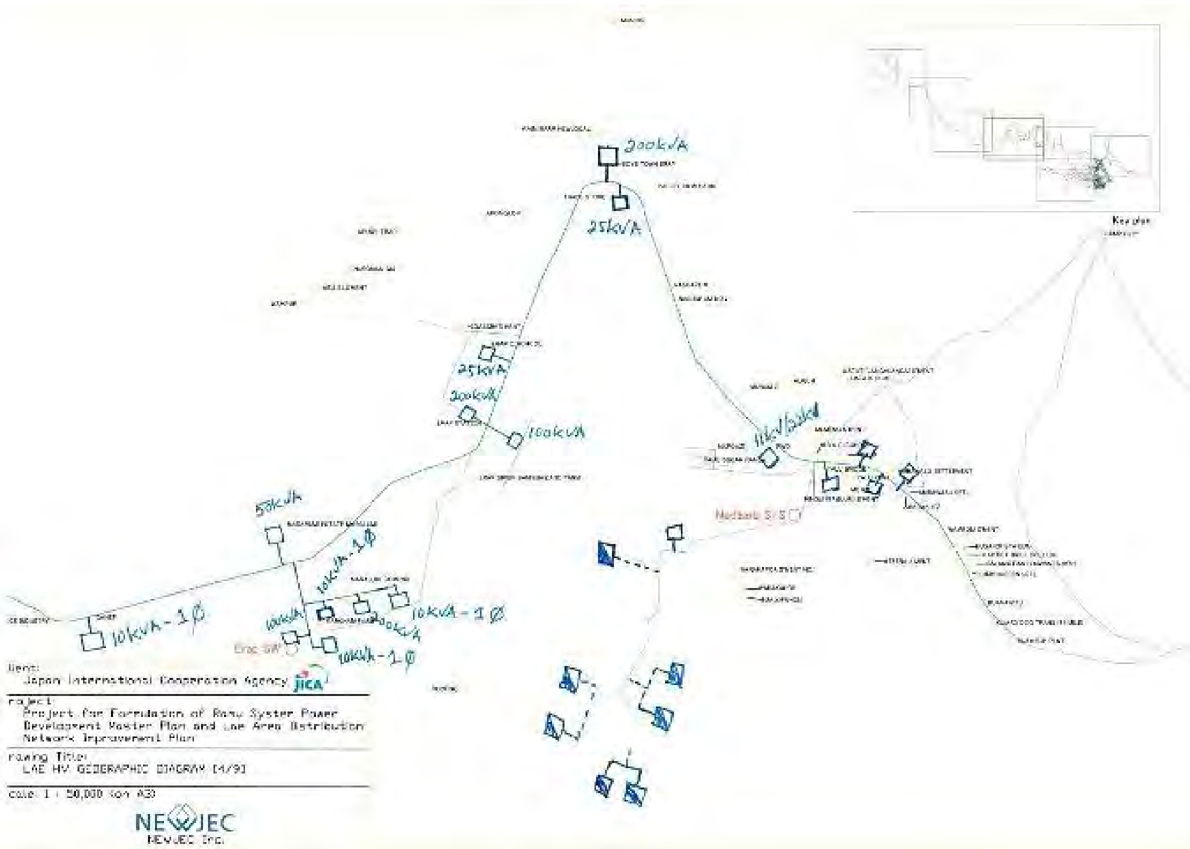


Fig. 5.1-40 (1) Single Line Diagram of the Distribution Feeder from Nadzab Substation

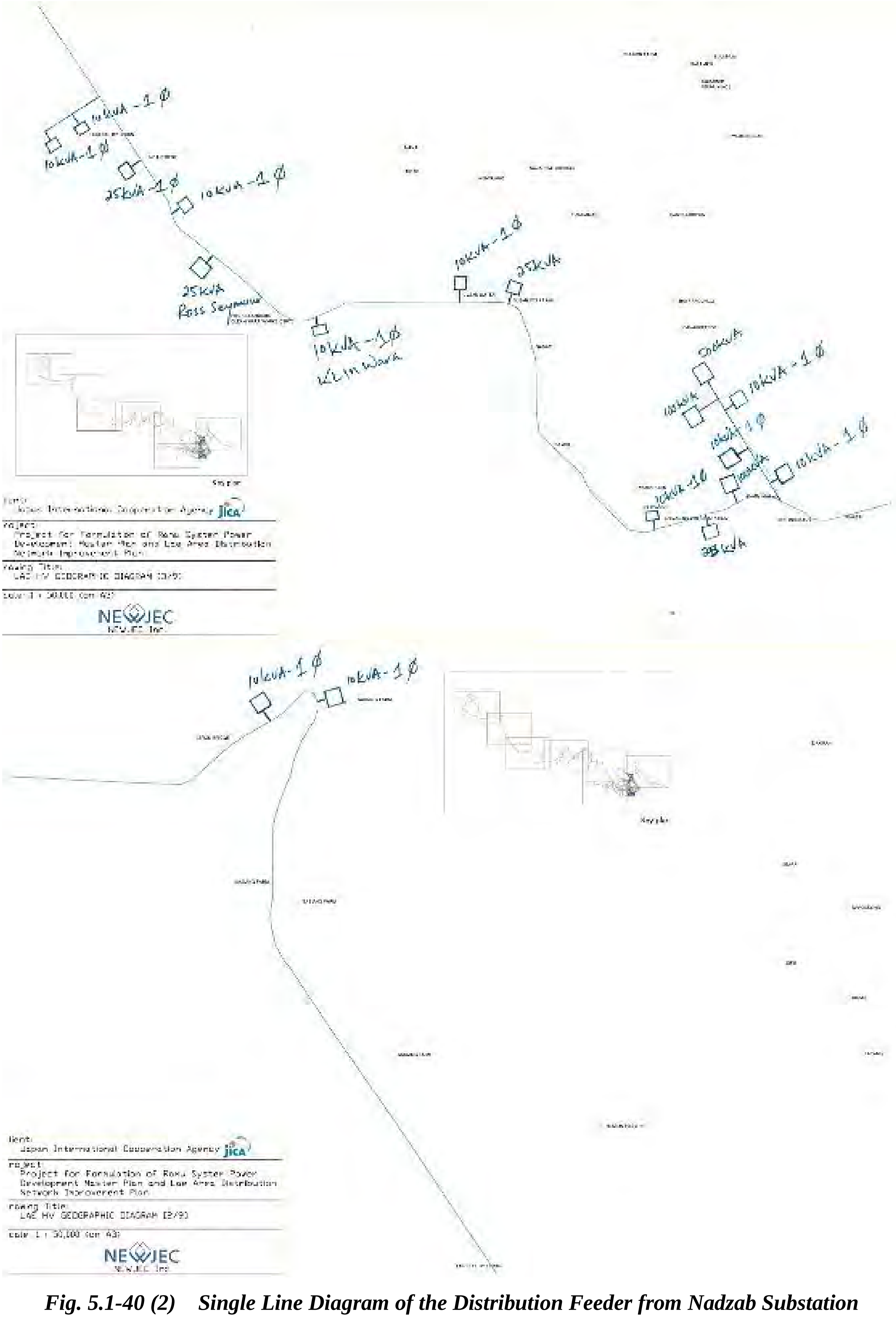


Fig. 5.1-40 (2)   Single Line Diagram of the Distribution Feeder from Nadzab Substation

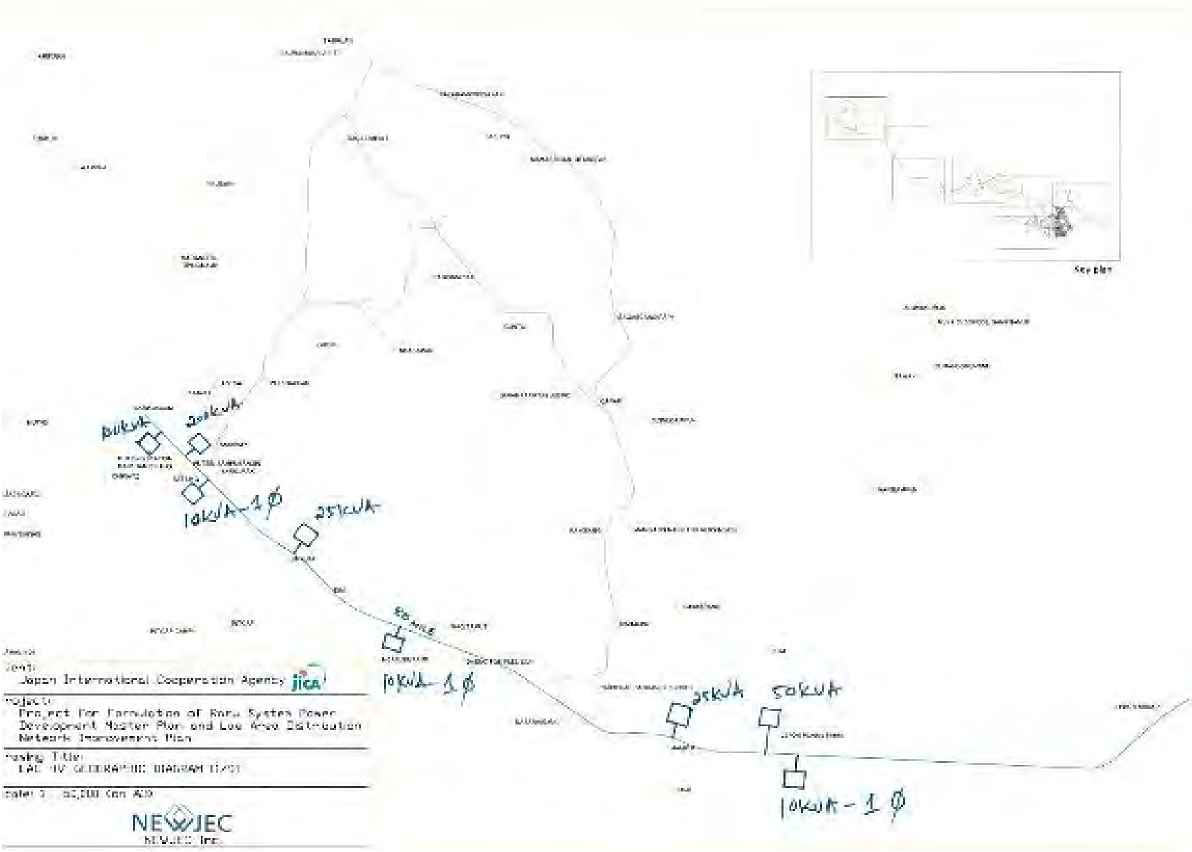


Fig. 5.1-40 (3)   Single Line Diagram of the Distribution Feeder from Nadzab Substation

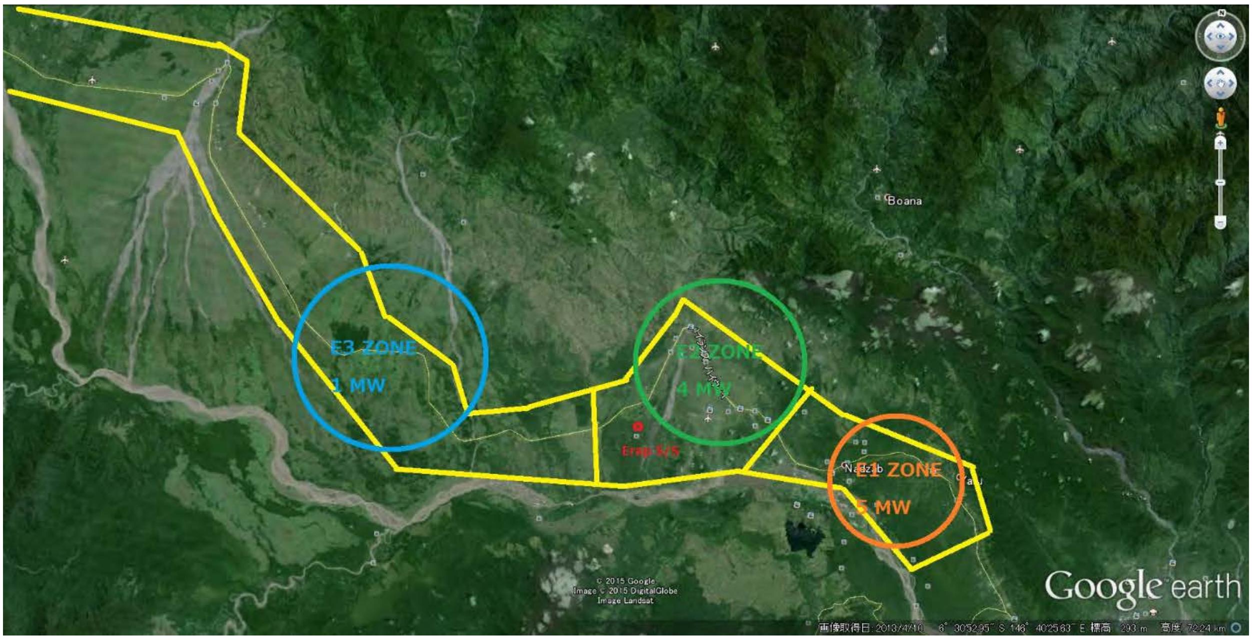


Fig. 5.1-41   Overview of the Supply Area of Erap Substation

Source: JICA Study Team

(2) Power supply plan in association with the renovation of the Nadzab Airport

The previous section forecasted future demand by means of macroscopic examination in the Lae area. In the region in question, however, the Nadzab Airport has a renovation plan, and an increase in its electricity demand in the coming years has become more visible. At the same time, PPL positions the Nadzab Airport, once renovated, as an important load point, and pays particular attention to assuring reliability of satisfying this load.

JICA Study Team studied how to meet the future demand of the airport that has become more seeable while maintaining supply reliability.

1) Electricity demand of the airport

The Final Report on the Preparatory Survey for the Nadzabu (Lae) Airport Improvement Project in Papua New Guinea, a JICA report issued in March 2015, states that the renovation project at the Nadzab Airport is slated for commencing in 2018 and completing at the end of 2020.

Additional power demand will arise in conjunction with this project. This refers to not only the load facilities at the airport but electricity needed for construction works prior to the completion of the project.

Table 5.1-17 summarizes expected demand by facility of the Nadzab Airport.

The capacity of existing electric equipment is seemingly 1200 kVA, but the actual demand is 200 kW. According to the aforementioned report, the airport installation, once renovated, will have a passenger terminal building and a control tower, which have the capacities of 1,700kVA and 1,400kVA, respectively. Assuming that the power demand of these facilities accounts for 80% of the installed capacity, they will be needing 1400 kW and 1100 kW, respectively. Plus, 800 kW is needed for construction works during the renovation period.

Incidentally, the passenger terminal building and the control tower will each be furnished with two emergency generators, from the standpoint of supply reliability assurance. The capacity of these generators is about a half of the installed capacity. This is one of the reasons why the airport plans to receive electricity from PPL with a single feeder line.

Table 5.1-18 presents power demand of the airport by year derived based on the renovation schedule and the power demand described above.

As understood from Table 5.1-18, the load power of the airport remains the same as today at 200 kW up to 2017, and jumps to 1000 kW in 2018, reflecting power needs for construction. The renovation project is scheduled to be completed by the end of year 2020, during which the parts of the airport facilities already completed will be operational in parallel with existing facilities while some works will still be in process. The power needed for the operation of the airport and the construction works will reach 3500 kW at the maximum. The demand will return to normal at 2500 kW in 2021, when the project is completed.

Table 5.1-17 Electric Facilities and Future Demand at the Nadzab Airport

Facility	Installed capacity (planned) (kVA)	Expected load (kW)	Schedule
Passenger terminal (new)	1,700	1,400	From the end of 2020
Control tower	1,400	1,100	From the end of 2020
Electricity for construction		800	From 2018 to the end of 2020
Passenger terminal (old)	1,200	200	Until the end of 2020
Standby generator (for terminal bldg.)	2,000 × 2		
Standby generator (for control tower)	350 × 2		

Table 5.1-18 Annual Electricity Demand of Airport Facilities

Year	2015	2016	2017	2018	2019	2020	2021	2022~
Load	200	200	200	1,000	1,000	3,500	2,500	2,500

2) Power supply equipment at the Nadzab Substation

The Nadzab S/S operates relatively close to the Nadzab Airport today. This S/S receives power from the Taraka S/S via a single 66 kV T/L. This line has experienced many failures, and there is no backup equipment for emergency in the coverage of the Nadzab S/S. For this, assuring the reliability of power supply to the Nadzab Airport has been one of the important challenges PPL tackles.

The transformer capacity at the Nadzab S/S is 1.0 MVA. A single 11 kV feeder leads from this transformer and provides power to the Nadzab Airport and customers in the vicinity. The load of the D/L in 2015 has been approximately 0.3MW. Thus, the existing equipment can stand to meet the demand for the following two years.

3) Power supply planning

Shown in Table 5.1-18 is an equipment expansion schedule along with a demand forecast based on the load at the Nadzab Airport.

A comparison between the demand forecasts given in Table 5.1-1 and Table 5.1-18 reveals that an increase in the load is observed two years earlier in the latter, exceeding the current transformer capacity at the Nadzab S/S in 2018. This increase is caused by the airport renovation project.

Although the increase will entail a 10% excess of the transformer capacity at the Nadzab S/S, the current capacity may still be considered sufficient. Whether or not to upgrade the transformer capacity may be determined in the course of monitoring the actual peak load power.

The load power of the S/S in 2020 is expected to be 3.6MW, as the old and new facilities will be used in parallel during that year. At that time, the transformer at the Nadzab S/S will have to be upgraded.

In the meantime, the Erap Switchyard, located several kilometers west of the Nadzab S/S, will have the voltage increase works completed in 2020. There is a plan to co-locate a distribution S/S (Erap S/S) in the same site. The above-studied load increase, therefore, will be supplied by transformers to be newly installed at the Erap S/S. The new S/S will be equipped with two 22 kV, 10 MVA transformers, so as to accommodate future load and assure power supply even in case where one bank fails. In consequence, the 11 kV feeder line leading from the Nadzab S/S will be boosted to 22 kV and connected to the Erap S/S.

Incidentally, the actual time of completion of the Erap S/S may make it difficult to respond to the foreseeable load increment in 2020. In such a case, an addition of a transformer at the Nadzab S/S will have to be studied as an ad-hoc measure.

Although the Nadzab Airport will still be receiving electricity from PPL via a single D/L, it has a plan to have standby generators; thus, the reliability of power supply will be maintained to a certain extent. On the other hand, the PPL side has an option of introducing two 22 kV feeder lines to the airport. The utility has a plan to lay two D/Ls in the eastern direction from the Erap S/S, where the Nadzab Airport is situated (Fig. 5.1-4). If the two lines are connected to the airport and a switchgear to change over between the normal system and the emergency system is installed near the power receiving point, the airport will have a power supply system capable of ensuring emergency power supply in case of a single-line accident.

Table 5.1-19 Future Demand and Equipment Planning based on the Load at the Nadzab Airport

Year	Demand		Installed capacity		No. of lines	Equipment to be installed
	Airport	Whole area	Nadzab S/S	Erap S/S		
2015	0.2	0.30	1.0		1	
2016	0.2	0.3	1.0		1	
2017	0.2	0.3	1.0		1	
2018	1.0	1.1	1.0		1	
2019	1.0	1.1	1.0		1	
2020	3.5	3.6		20.0	2	Two 10-MVa transformers at Erap S/S, one feeder line, voltage increase of feeder line to 22 kV
2021	2.5	3.0		20.0	2	
2022	2.5	3.0		20.0	2	
2023	2.5	3.0		20.0	2	
2024	2.5	3.0		20.0	2	
2025	2.5	3.0		20.0	2	
2026	2.5	10.0		20.0	2	Extension of feeder line
2027	2.5	10.0		20.0	2	
2028	2.5	10.0		20.0	2	
2029	2.5	10.0		20.0	2	
2030	2.5	10.0		20.0	2	

5.1.4 Conclusion

JICA Study Team calculated the load at each of the Milford, Taraka, and Erap S/Ss in 2030, and the demand at each S/S derived from the calculation is summarized in Fig. 5.1-42.

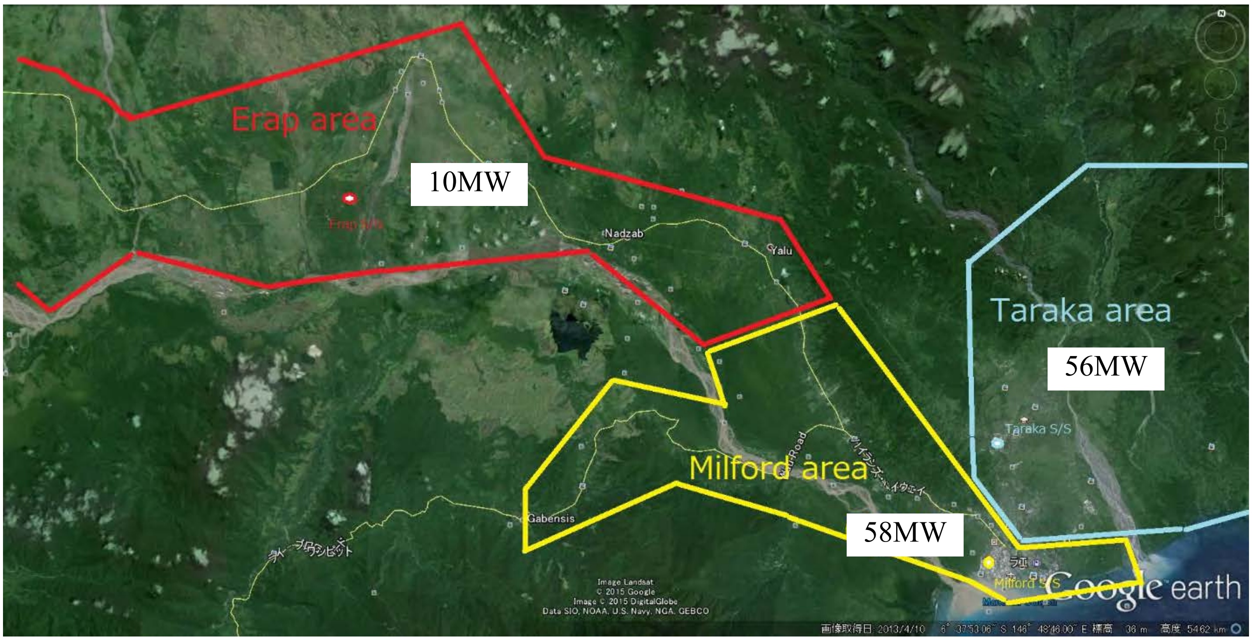


Fig. 5.1-42 Overview of Each Substation's Supply Area in 2030

Source: JICA Study Team

The load in each block segmented in the Taraka and Milford supply areas is shown below.

Table 5.1-20 Demand of Each Block in Taraka and Milford Substations in 2030

Block	2030 Supply Area (km^2)	2015 load (MW)	2015 load density (kW/km^2)	2030 load for existing customers (MW)	New load (MW)	Total load (MW)	Correction load (MW)	Total (MW)	2030 load density (kW/km^2)	Zone characteristics
T1	23.2	5.5	0.39	9.5	3.7	13.2	0	13.2	0.6	Industry, school, residence
T2	10.9	1.0	6.67	1.1	11.1	12.2	3	15.2	1.4	Industry, residence
T3	11.1	4.0	1.00	8.1	7.1	15.2	3	18.2	1.6	Industry, school, residence
T4	4.9	2.0	0.54	2.0	0.6	2.6	7	9.6	2.0	Industry, residence
Taraka Subtotal	**50.2**	**12.5**	**8.6**	**20.7**	**22.5**	**43.2**	**13**	**56.2**	**1.1**	
M1	5.4	12.4	2.93	13.4	3.3	16.7	0	16.7	3.1	commerce, residence
M2	2.7	9.2	4.97	15.5	4.3	19.8	3	22.8	8.4	Commerce, heavy industry
M3	4.0	4.0	1.43	5.9	1.7	7.6	5	12.6	3.2	Heavy industry, residence
M4	8.0	2.6	0.52	2.2	1.6	3.8	3	6.8	0.8	Industry, residence
Milford Subtotal	**20.0**	**28.2**	**9.9**	**37.0**	**10.8**	**47.8**	**11**	**58.8**	**2.9**	
Total	**70.2**	**40.7**	**18.5**	**57.7**	**33.3**	**91.0**	**24**	**115.0**	**1.6**	

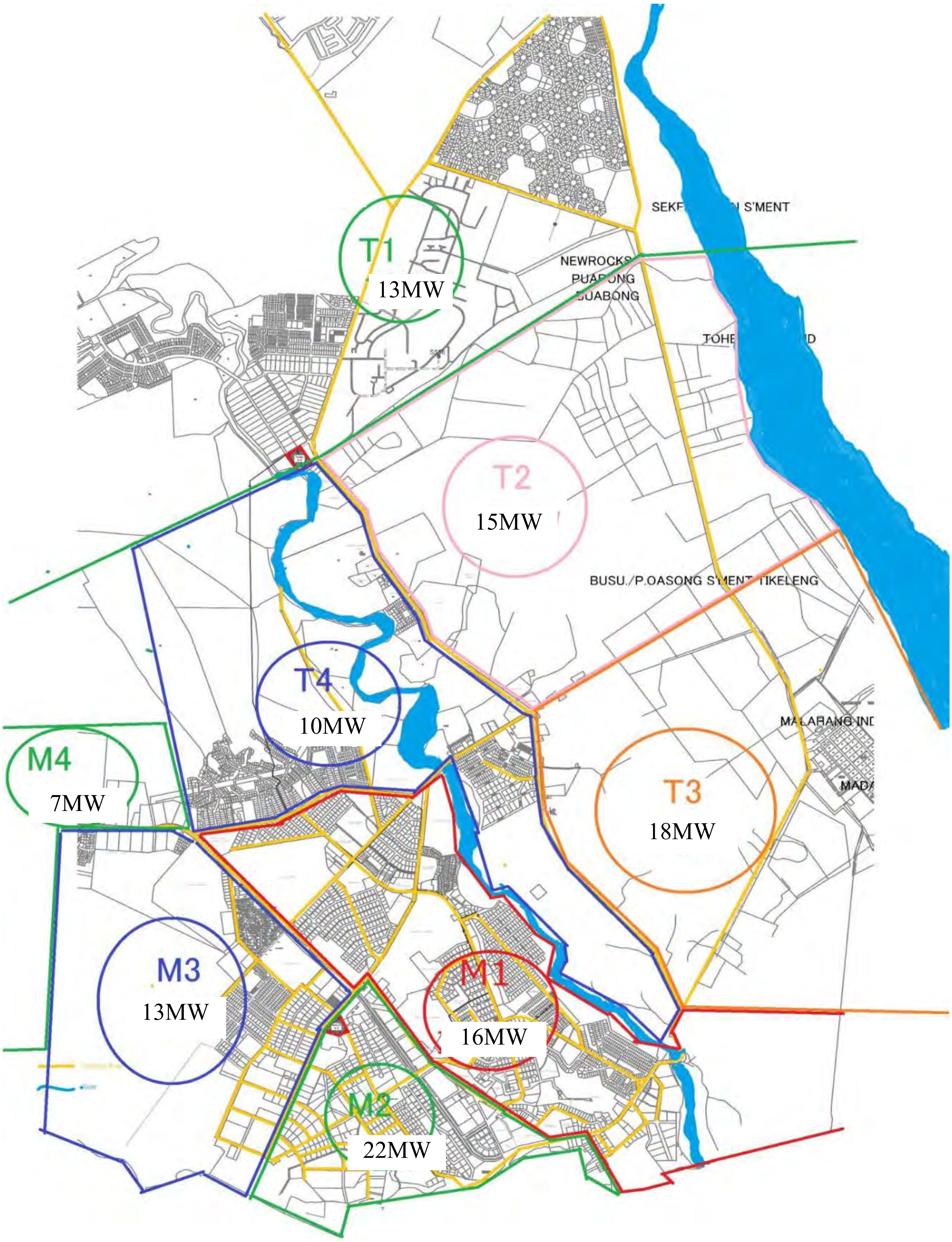


Fig. 5.1-43 Demand of Each Block in 2030

5.1.4.1 Number of Distribution Lines in 2030 based on Power Demand Forecasts in the Lae Area

JICA Study Team then calculated the number of D/Ls needed for serving the expected 2030 demand in each block.

In performing such calculations, the power factor has significant impact on the transmission capacity per line. While the power factor of load to the D/L is specified as 0.9 in PPL's grid code, our measurements found that it is 0.85. Hence, JICA Study Team applied 0.85 as the power factor, a more rigorous condition in calculating the line current, when studying the necessary number of feeder lines.

(1) Number of required distribution lines by year

JICA Study Team calculated the necessary number of lines by year based on the future annual demand envisioned until 2030.

Table 5.1-21 Results of Calculating the Required Number of Distribution Lines

	Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Demand Load (MW) (A)	Milford	20	21	23	24	27	29	32	34	37	40	43	46	46	50	53	57	61
	Taraka	18	19	20	22	24	27	29	30	33	36	39	42	41	44	47	51	54
	Nadzab/Erap	0.3	0.3	0.3	0.3	0.3	0.3	0.3	3	3	3	3	3	10	10	10	10	10
	Total	39	41	43	46	51	56	62	67	73	79	85	91	97	104	111	118	125
Apparent power (MVA) (Converted by PF=0.85) (B)	Milford	24	25	27	28	31	35	38	40	43	47	51	55	54	59	63	67	71
	Taraka	21	22	24	25	28	31	34	36	39	42	45	49	48	52	56	60	64
	Nadzab/Erap	0.4	0.4	0.4	0.4	0.4	0.4	0.4	3.5	3.5	3.5	3.5	3.5	11.8	11.8	11.8	11.8	11.8
	Total	45	48	51	54	60	66	73	79	86	93	100	107	115	122	130	139	147
Transformer Capacity (MVA) (C)	Milford	50	50	50	50	50	50	50	50	50	50	50	90	90	90	90	90	90
	Taraka	40	40	40	40	40	40	40	70	70	70	70	70	70	70	70	70	90
	Nadzab/Erap	1	1	1	1	1	1	1	20	20	20	20	20	20	20	20	20	20
	Total	91	91	91	91	91	91	91	140	140	140	140	180	180	180	180	180	200
Max. load of D/L (MVA) (D)	Milford	30	32	34	36	40	44	48	50	55	60	64	69	69	74	80	85	91
	Taraka	27	29	30	32	36	40	43	45	49	53	58	62	61	66	71	76	81
	Nadzab/Erap	0.4	0.4	0.4	0.4	0.4	0.4	0.4	4	4	4	4	4	15	15	15	15	15
	Total	58	61	65	69	76	84	92	100	109	117	127	136	145	155	166	176	187
Required No of D/L (PF=0.85) (E)	Milford	5	5	6	6	6	7	8	8	9	9	10	11	11	12	12	13	14
	Taraka	5	5	5	5	6	6	7	7	8	8	9	10	10	10	11	12	13
	Nadzab/Erap	1	1	1	1	1	1	1	1	1	1	1	1	3	3	3	3	3
	Total	11	11	12	12	13	14	16	16	18	18	20	22	24	25	26	28	30

JICA Study Team used the following formula to calculate the necessary number of feeder lines (E).

$$(E) = (A) / (B) \times (D.F) / (Pn)$$

Where (A) is the active power (MW), (B) is the power factor, (D.F) is the diversity factor of feeder line (the actual measurement taken by the study team (1.27)), and (Pn) is the rated capacity per D/L (the figure used in the concept design of distribution network (6.7MVA.))

The solution from this formula simply suggests that this number of lines is theoretically required at the minimum. There is no problem with the Milford S/S having six lines today.

(2) Number of distribution lines per block needed in 2030

JICA Study Team calculated the necessary number of feeder lines to satisfy the expected demand of each block in 2030. Here again, the above formula was used, and the results are provided in Table 5.1-21.

Table 5.1-22 Required Circuit Number for Each Block

Year	2015			2030		
Block No.	Load (MW)	Required distribution line number	Reasonable distribution line number	Load (MW)	Required distribution line number	Reasonable distribution line number
T1	5.5	2	3	16.0	4	13
T2	1.0	1		12.0	3	
T3	4.0	1		16.0	4	
T4	2.0	1		10.0	3	
Taraka subtotal	*12.5*	*5*	*3*	*54.0*	*14*	*13*
M1	12.4	3	7	16.0	4	14
M2	9.2	3		20.0	5	
M3	4.0	1		14.0	4	
M4	2.6	1		11.0	3	
Milford subtotal	*28.2*	*8*	*7*	*61.0*	*16*	*14*
Grand total	**40.7**	**13**	**10**	**115.0**	**30**	**27**

Note: The areas covered by the blocks in Table 5.1-21 do not correspond to the supply area of each S/S today (2015).
The total number of D/Ls obtained by summing up the necessary numbers of lines for the blocks is not the same as the optimal number of lines calculated based on the total demand in the S/S coverage.

Prerequisite 1: In cases where any two blocks are separated by mountains, rivers, or other natural obstacles so that interchange between the two blocks is not feasible, additional lines are to be laid based on these numbers.

Prerequisite 2: Wherever feasible, interchange between blocks is the option.
In this case, the number of lines is to be coordinated among blocks when designing the D/L configuration, in order to minimize the number of lines.
With respect to the Milford and Taraka S/Ss, interchange among the blocks is deemed feasible.

A 2030 master plan shall be created based on the numbers provided in Table 5.1-21.
In actuality, the numbers will not jump from the current level right up to the numbers in 2030.
The load will gradually grow toward 2030.
That being the case, JICA Study Team studied the creation of a master plan using the following approach.

i) Examine the feasibility of supplying power to the additional load using the existing D/Ls.
If feasible, assume the use of the existing D/Ls.

ii) If not, examine whether additional lines need to be put in place to meet the total load in the entire S/S coverage.
If deemed negative, consider the possibility of serving the demand by transferring the extra load to a neighboring D/L.

iii) If additional lines are needed, a new D/L is to be installed.

By repeating this process, step by step, JICA Study Team ensured that increments to the load onto D/Ls will be fully covered.

Note, however, that additional load points are predicted as to each block in this examination, and JICA Study Team developed a master plan at that level.

(3) Number of distribution lines to each block in 2030

JICA Study Team examined the routing of the lines based on the expected road network in 2030 based on Fig. 5.1-44.

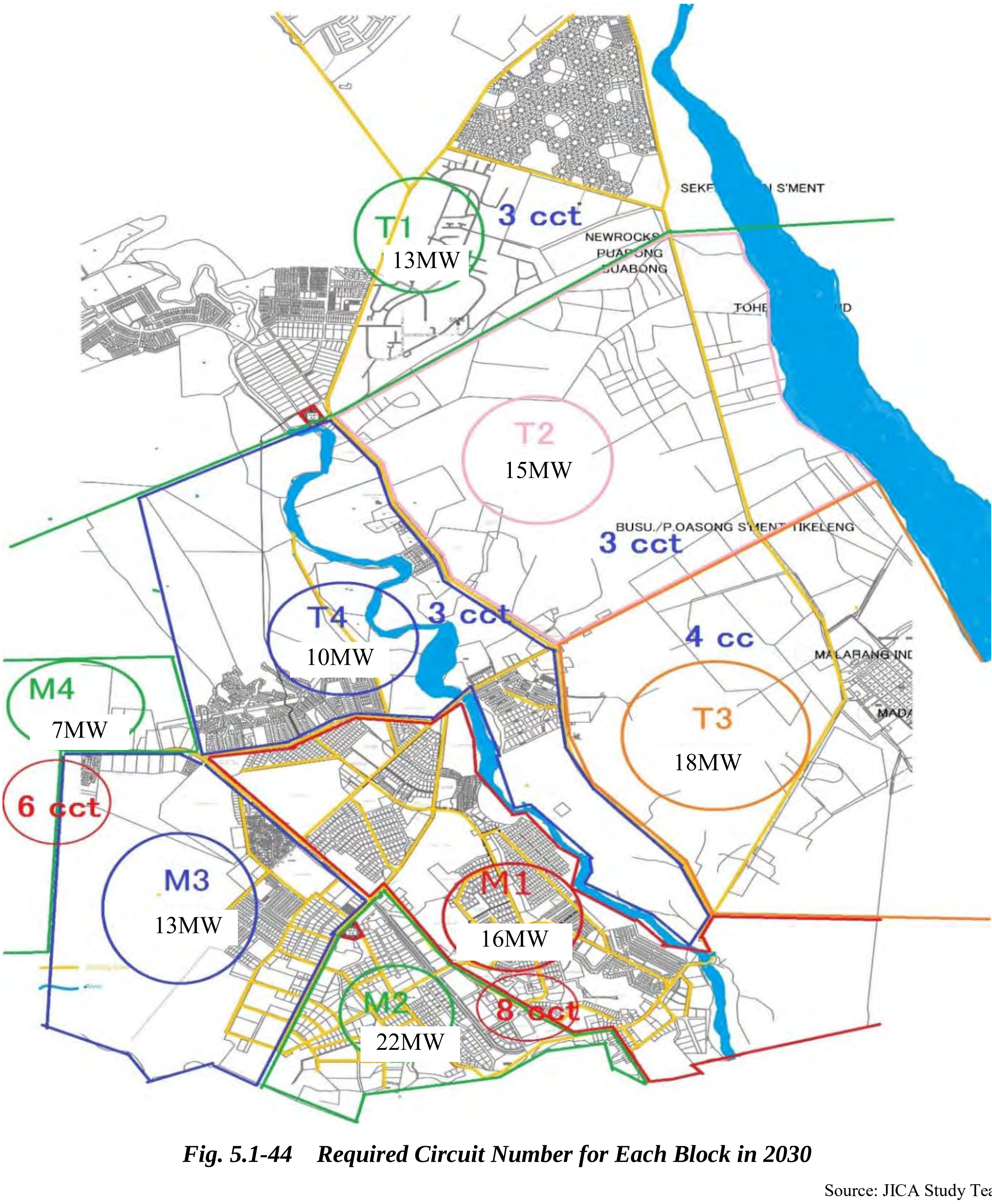


Fig. 5.1-44 Required Circuit Number for Each Block in 2030

Source: JICA Study Team

JICA Study Team examined the routing of the lines based on the expected road network in 2030 based on Fig. 5.1-44.

In view of the current road network, new roads indicated in green in Fig. 5.1-45 will at least be constructed by 2030. Furthermore, the Highland Highway, connecting the City of Lae and the Nadzab Airport, will be widened to a six-lane road.

Trunk D/Ls leading to the individual blocks will basically be routed along such main roads.

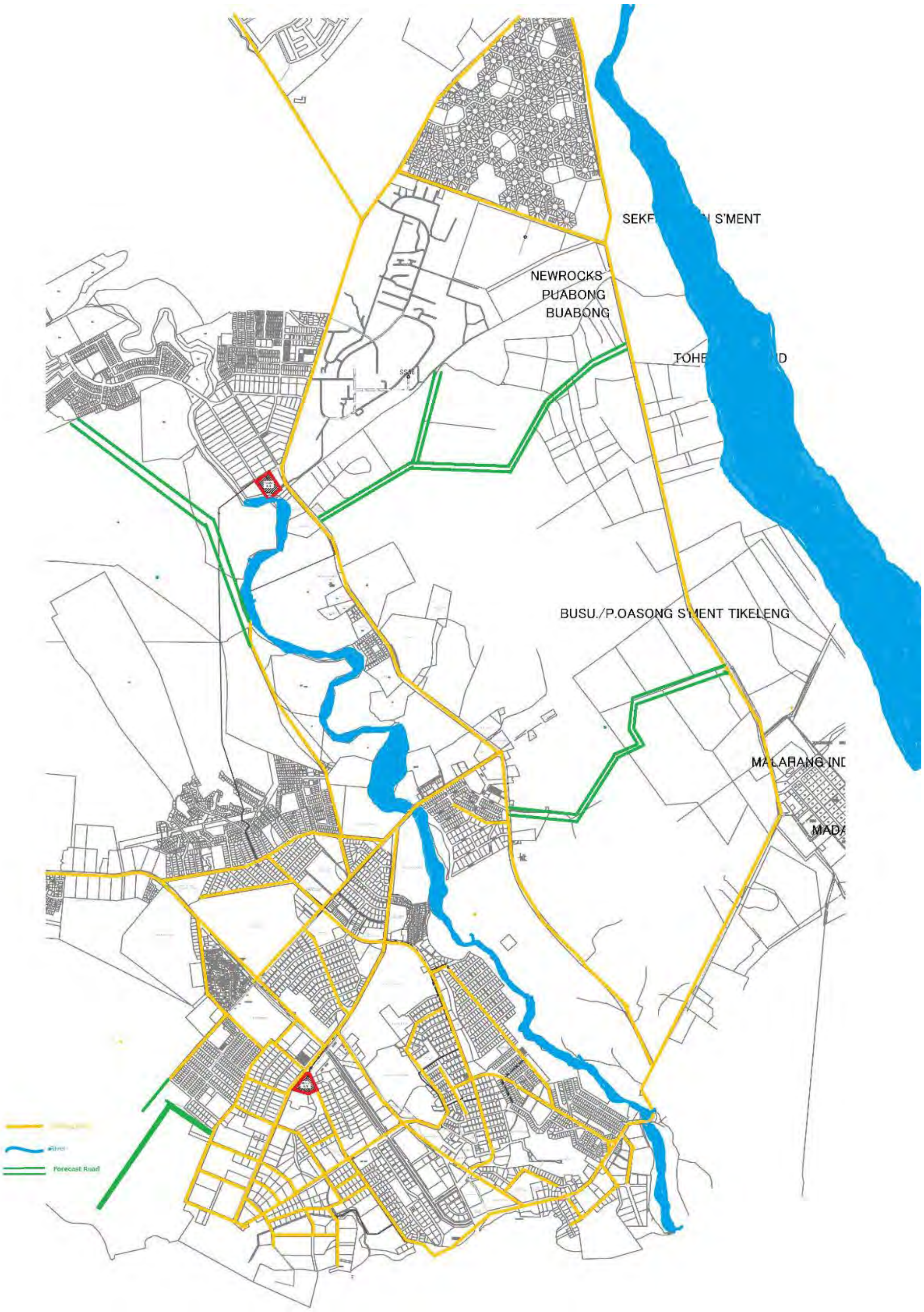


Fig. 5.1-45 Assumed Plan of Road Construction

(4) 2030 Master Plan

Fig. 5.1-44 presents the number of feeder lines needed for meeting the expected demand of each block of the Taraka or Milford S/S coverage in 2030. Fig. 5.1-46 exhibits a concrete map of trunk feeder routes from the two S/Ss to their constituent blocks.

JICA Study Team performed the study on trunk feeder routes on the following conditions.

i) D/Ls are basically overhead lines.

ii) One pole shall carry two lines at the maximum. Where an installation of more lines is needed, overhead cabling shall be applied.

iii) Routes shall be secured on both roadsides.

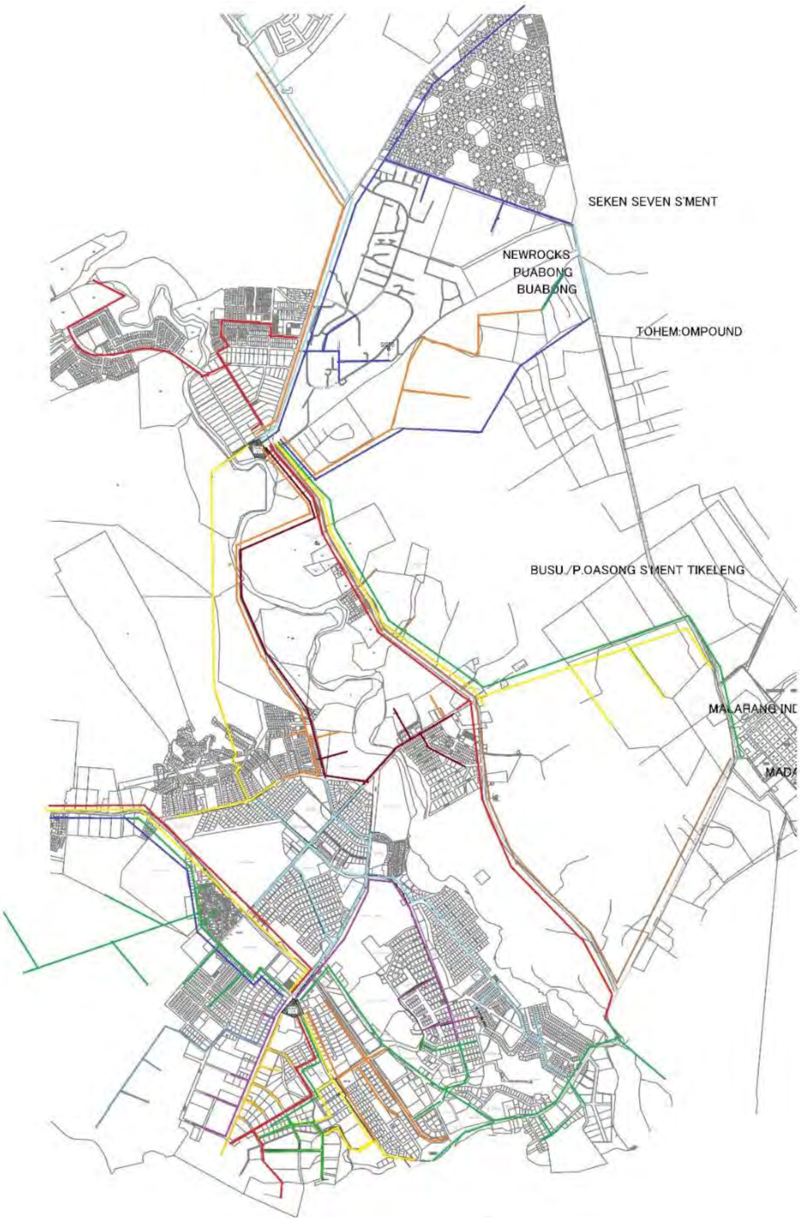


Fig. 5.1-46 Route Map of Distribution Feeders for Taraka and Milford Substation in 2030

5.2 INTRODUCTION OF NEW TECHNOLOGIES FOR THE DISTRIBUTION NETWORK

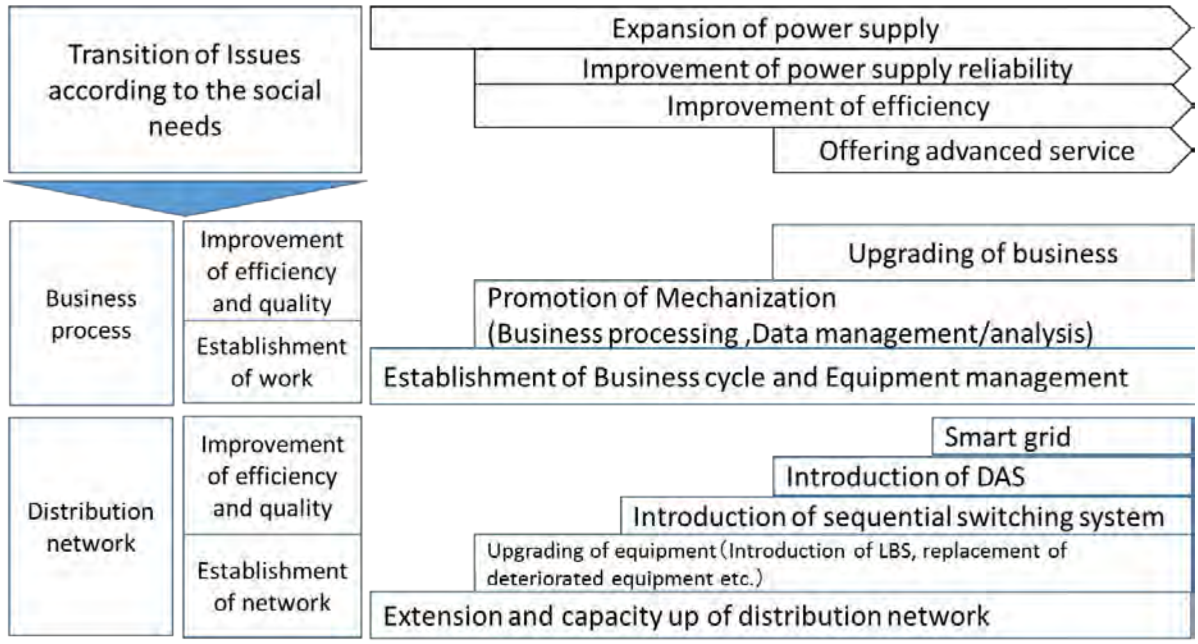
5.2.1 Technologies for Advanced Distribution Network Operation

As the demand for electric power grows towards the future, higher-quality power supply will be a more important issue for PPL. At the same time, continuous efforts for cost reduction will be required.

At the power distribution department, efforts for the construction of the distribution network have focused on the expansion and reinforcement of equipment to meet the growth of power demand. From the medium-to-long-term point of view, it will be more important to respond to the higher social requirements for power supply such as improved reliability, efficiency, and service, as outlined in Fig. 5.2-1.

To satisfy these needs, continuous improvement of the business process to enhance operational efficiency, accuracy, and service levels will be crucial. It will also be necessary to upgrade distribution network operation by expanding and renovating facilities and introducing new technologies stepwise.

In this section JICA Study Team give an overview of the sequential switching system, distribution automation system (DAS), and smart grid as basic technical steps for the progress of distribution system operations. These systems and their introduction to the Lae area are outlined based on the present situation of the power distribution towards the future up to around 2030. JICA Study Team also present views on the undergrounding of D/Ls to meet social requirements in the future.



Source: JICA Study Team

Fig. 5.2-1 Outline of Issues and Assumed Measures in the Distribution Department according to the Transition of Social Needs

5.2.2 Distribution Automation System (DAS)

(1) Assumption on the introduction of DAS for the PPL Lae area

DAS is in general a system that enables the supervision, control, and switching of the distribution network from a base operation office through a communication network. In some cases, the system is developed to have further advanced functions such as remote reading, demand side management (DSM), line voltage control, and monitoring and control of distributed generators.

Following is an overview of the effects assumed when examining the introduction of a DAS in the Lae area.

1) Improved efficiency for distribution network capacity

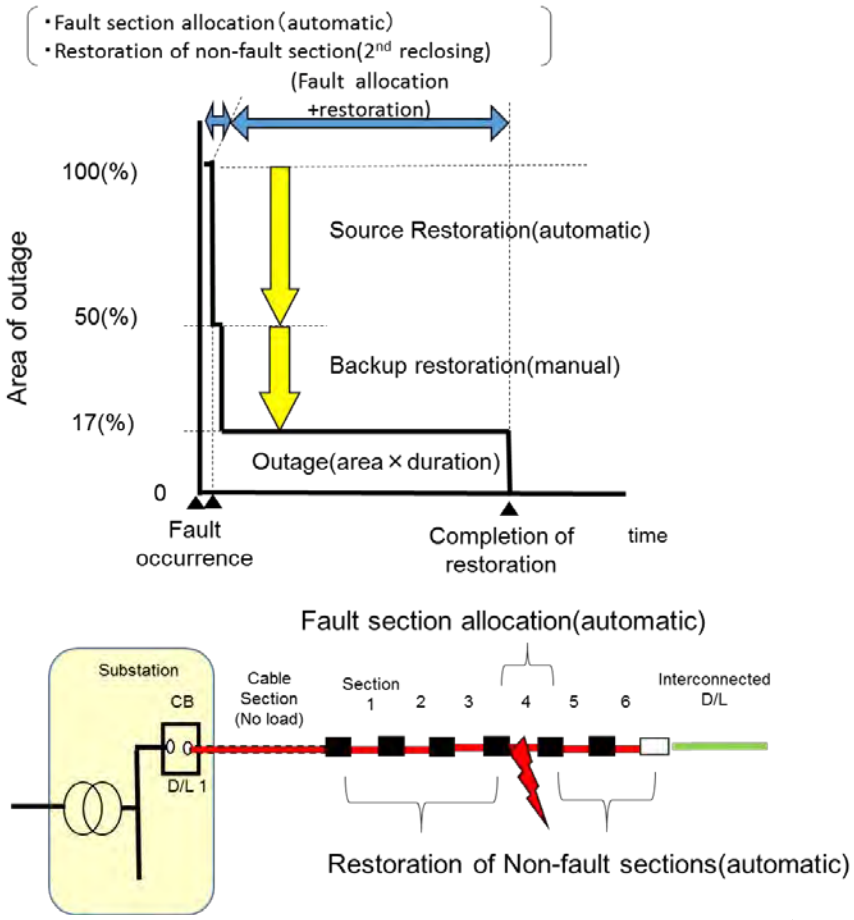
When a fault occurs in a D/L, load switching can be available not only from the neighboring lines but also from further lines around the lines using the remote switching function of the LBS. This function can suppress the capacity for backup in each distribution to a lower level, which increases the regular network operation capacity to a higher level.

2) Improved efficiency of network operation work

Using a remote function for voltage and current monitoring and LBS operation for the office, operation, and measurement works on the site may be faster and more effective.

3) Improved supply reliability

An overview of the restoration based on a DAS is shown in Fig. 5.2-2. The function of the sequence switching system is basically used to restore power to no-fault sections. However, the procedure for network switching may be more flexibly handled by automatic calculation than by manual examination when faults occur with high feeder current or faults occur in multiple D/Ls.

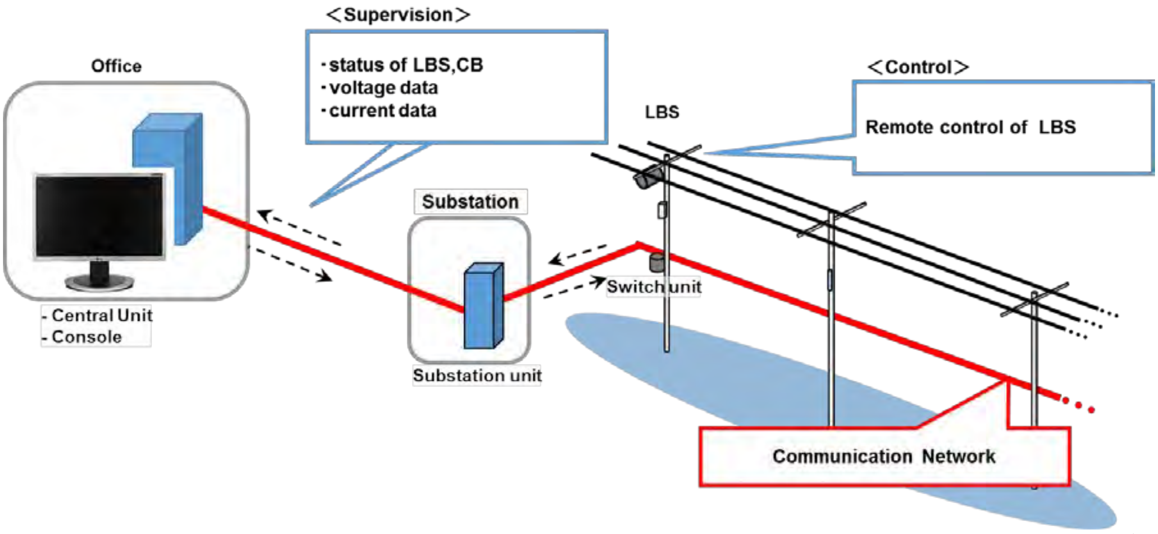


Source: JICA Study Team

Fig. 5.2-2 Overview of the Restoration using a DAS

(In this example, up to six LBS's are added per D/L)

The general configuration of the DAS is shown in Fig. 5.2-3. An overview of the features of each piece of equipment as shown in Table 5.2-1. An example of the business functions included in the system is shown in Table 5.2-2. The actual function and performance has to be examined by clarifying the needs in practical operation work.



Source: JICA Study Team

Fig. 5.2-3 General Configuration of the DAS

Table 5.2-1 Overview of the Features of the DAS Equipment

Item	Installation locations	Main features
Central unit	Office (network operation)	- Distribution network data management - Monitoring and control of the network
Console	Ditto	- Display for the status of network - Interface for system operation and data maintenance
Communication line	Between each units	Signal transmission
Substation unit	Substation	Transmission of substation status information
Switch unit	Controlled LBS	Transmission of LBS status information and LBS operation signal

Source: JICA Study Team

Table 5.2-2 Function of the Central Unit (example)

Subject	Examples of functions
Super vision of network	-Monitoring of operational conditions of the S/Ss and LBS's -Monitoring of the circumstance of fault
System operation	- Operation of the LBS's - Fault recovery operations
Load switch calculation	-Study of load switching -Calculation of line voltage and current
Equipment settings	Manual setting of the LBS's
Record and report	Load data, status changes, operation records
Simulation	System operations training
Data maintenance	Registration and revision of network data

Source: JICA Study Team

(2) View for the introduction of DAS to the Lae area distribution network

The introduction of a DAS seems premature in the years leading up to 2030, for the following reasons.

1) Insufficient business management capability and technological level for system maintenance

The DAS function can only be sufficiently utilized by constructing a high-quality facility data management system and providing timely data updates. Data on network operations must be reflected to ensure the results of switching, construction, and so on.

In the Lae area, the bases for the facility management work such as network drawings and the load management of distribution transformers have not yet been sufficiently developed. As such, an important precondition for DAS introduction is not yet met. This situation is expected to gradually improve, but it will take a long time to stabilize the accuracy of facility management data and the quality of the work process.

The DAS consists of many kinds of components such as a central unit including software, a communication network, a S/S unit, and a switch unit. The categories of technical skills required for their operation and maintenance are quite different from those for conventional power distribution. When some malfunction occurs in the system, PPL must be able to narrow down the cause of the problem and grasp the malfunction events smoothly through its own efforts. For this reason, a work system to support DAS must be established and a substantial amount of technical training has to be carried out.

Yet even the maintenance works for the existing distribution facility in the Lae area are insufficiently carried out as of now. The circumstances are therefore inappropriate for introducing a large facility with a technology as new as DAS. The efforts required in the existing work system are too prohibitive even now. The introduction of a DAS can be examined more practically and concretely when the situation improves.

Note that if a DAS was introduced before the establishment of the basic conditions JICA Study Team describe, the result might include not only insufficient system utilization, but also a worsening of the effects and quality of usual works due to excessive workloads and improper system operation.

2) Uncertain effects of a DAS introduction

The basic form of network operation work is not yet established in the Lae area and there are not enough data to estimate the effects of improved work efficiency or an improved rate of network capacity utilization.

As for the distribution reliability, the introduction of a sequential switching system can considerably improve reliability in the Lae area under consideration compared to the present level. Further effects from the introduction of a DAS would therefore be less substantial. A DAS may help the operator in the event of, for example, a S/S bank fault or multiple D/L fault, but the number of such cases is small compared to other cases.

3) Low investment priority for the DAS

To improve the majority of blackout incidents that PPL faces at present, investment for improvement of issues such as ‘demand and supply balance’ and ‘construction of transmission and S/S network’ is preferentially carried out.

Since issues in power distribution are rather small in comparison, it seems basically hard for PPL to investigate for the improvement of power distribution sector. The introduction of DAS also seems difficult in this situation, because the effect is unclear in spite of the large budget for the system introduction.

(3) Preparation for the introduction of a DAS in the future

As mentioned above, the introduction of a DAS to the Lae area is considered premature. However, the following efforts for the improvement of distribution network operation in the meantime are also necessary for the preparation of DAS introduction in the longer-term future.

1) Improvement of network operation skills

At present, the distribution network in the Lae area is operated by manual operation of the ABS's with the network in a no-charged condition. The introduction of manual LBS's under a short-term distribution network improvement plan enables the operation of LBS's in a power-on condition. Plans also call for the introduction of a sequential switching system in the network.

The operation and switching skills for such a basic distribution network will also be very important as base skills when the DAS is introduced in the network in the future. It is therefore necessary to develop the ability of operators and field workers in the distribution network department over a sufficient period.

2) Establishment of a work process for distribution facility data management

Distribution facility data management is an important work directly linked to the quality of power distribution. As such, it should be a focus of emphasis going forward. The timely updating of network data is not only essential for maintaining the quality of the distribution system operation work, but also for setting up and establishing the work process as soon as possible as a premise for the introduction of the DAS.

5.2.3 Smart Grid

(1) Assumptions on the introduction of Smart grid for the PPL Lae area

The aim when creating "a smart grid" is generally to construct a power system with high efficiency, high quality, and high reliability through the integration and utilization of information on distributed power such as PV and information on customers through the use of Information Technology (IT), for integrated operation with an existing power system consisting of concentrated power sources and T/Ls.

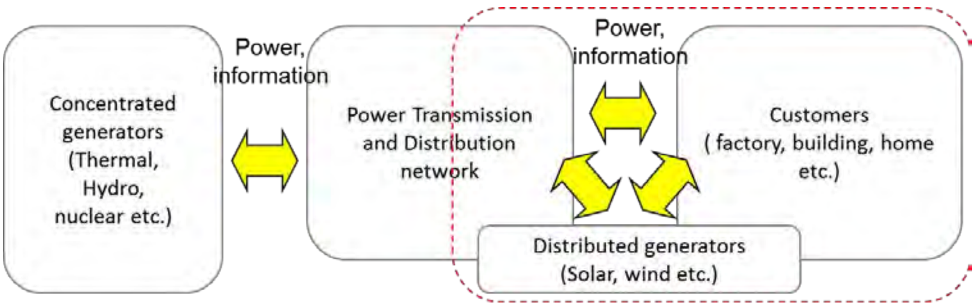


Fig. 5.2-4 Conceptual Drawing of a Smart Grid

Source: "Research report on low-carbon energy supply system"

An overview of technologies adaptable for a smart grid is shown in Table 5.2-3. Most of the items shown are underdeveloped as of now, with a few exceptions such as the remote metering system, but they are expected to be operative in the future.

Table 5.2-3 Overview of Possible Technologies for a Smart Grid

Category	Technology
(1) Distribution network monitoring and control technology	- Wide-area monitoring and control - Cooperative system of dispersed generation and consumers Cooperative control systems with renewable energy Battery systems for grid Local energy management systems Distribution automation system
(2) Demand-side energy management technology	Energy management system technology - Energy management system for homes, buildings, and factories - Demand response, smart home appliances - Interconnection technology of electric vehicle
(3) Advanced technology enabling effective operation of the power system	- Superconducting power transmission, high-voltage DC transmission - Power electronics application equipment
(4) Advanced interface technology	- Power conditioner technology - AMI, smart metering

Source: NEDO “Renewable Energy Technology White Paper"

With the use of technologies such as these, the introduction of the following systems can be assumed in the Lae area in the future.

1) Remote automatic meter reading system

This system may be utilized not only for the improvement of efficiency of meter reading work and power theft prevention, but also for the facility management work such as distribution transformer load management using collected load data.

2) Distribution network monitoring and equipment control system for power quality assurance

There are many vacant spaces in the suburbs of the Lae area and good prospects for the high growth of dispersed-type renewable energy generation. If too many dispersed-type renewable energy generation facilities are interconnected to the distribution network, bad effects such as voltage raise and current disturbance may occur due to unstable power generation characteristics. As a countermeasure, the introduction of a system with advanced technologies for distribution network monitoring and equipment control can be expected to assure the quality of the power supply in the future.

(2) View for the introduction of smart grid for the Lae area

A smart grid is generally constructed on the base of an existing DAS with necessary functions added or extended. As described in Section 5.2.2, the introduction of a DAS in the Lae area by the year 2030 would be considered premature. The same applies to the introduction of a smart grid.

When PPL examines the introduction of DAS in the future, however, some of the smart grid technology described above may be in practical use. Steps should thus be taken now to survey the status of technical development and examine DAS functions appropriate for a smart grid of the present.

5.2.4 Undergrounding of Distribution Lines

(1) Present status of undergrounding of distribution lines in the Lae area

Only limited parts of the distributions lines in the Lae area are constructed underground, such as the leader cables for distribution feeders from S/Ss, cables from overhead lines to transformers mounted on the ground for low-voltage power supply, etc. Underground D/Ls that cover designated wide areas along main roads, for example, are not yet constructed. The system and equipment for maintaining the facilities of underground D/Ls are also still lacking.

(2) View for the introduction of undergrounding of distribution lines to the Lae area

The undergrounding of D/Ls is a measure introduced based the social needs such as the need for space for safe and comfortable passage, the prevention of urban disasters, and improved urban landscapes. For the Lae area, however, the issues described below have to be considered.

1) High construction costs

- Construction costs are higher than those for overhead lines.
- There is also a possibility of further construction costs for frequent road excavations to supply new customers. The demand for power supply is expected to increase in the future.

2) Risk for assurance of distribution reliability

Undergrounding distribution network is generally designed to assure reliability using alternate feeder systems, loop systems, etc. But if skills for the maintenance and reserved equipment are insufficient, there is a risk that high time burdens will be incurred for fault location and restoration works on the cables and equipment.

3) Workload for the construction and maintenance of undergrounded distribution lines

Additional workforce, technical training, and equipment are necessary for the construction and maintenance of long span conductors, cables, and manholes. If the demands on the existing work are excessive, there is a risk that the present work situation will worsen.

Stable and reliable power supply at a low cost is now strongly required in PPL, and the basic requirements do not seem to easily change. Considering this situation and the issues for construction and maintenance, the undergrounding of D/Ls is not a preferable measure in the years leading up to 2030.

If some entity requests landscape improvement, measures using overhead lines should be examined. For example, the removal of poles and overhead lines in the target area could be enabled by a detour of the trunk line route or by changing the route of the service line from the main street to the side street.

CHAPTER 6

INITIAL ENVIRONMENTAL EXAMINATION (IEE) FOR THE LAE AREA DISTRIBUTION NETWORK IMPROVEMENT PLAN

CHAPTER 6 INITIAL ENVIRONMENTAL EXAMINATION (IEE) FOR THE LAE AREA DISTRIBUTION NETWORK IMPROVEMENT PLAN

6.1 DESCRIPTION OF THE PROJECT

6.1.1 Improvement of the Electricity Supply Reliability: Immediate Improvement Plan

In order to maintain stabilized supply of electricity for the city of Lae, where large to small size business activities are rapidly emerging, electricity distribution system within the city is in need of rehabilitation and renew where required in order to improve supply reliability.

While it is important to improve distribution system, breakdown of D/L is relatively low as its percent share is slightly less than 12 % based on the above figures. Thus in order to establish urgent and short term distribution network improvement plan, JICA Study Team has focused on the reduction of electricity outage and its duration.

Based on the outage records maintained with PPL local office of Lae City from October 2013 to September 2014, there have been 1) 1,578 cases of generator breakdown; 2) 313 cases of T/L breakdown; 3) 582 cases of generator and/or transmission system breakdown; 4) 343 cases of D/L breakdown; and 5) 103 cases of other causes.

Out of 343 distribution network fault cases, 1) defect of facilities is accounted for 30 %; 2) natural cause being 1 %; and 3) Outage from function of electric relay and other unknown causes. Electricity outage causes such as deterioration of electric lines, cause of thunders and lightning, salt contamination etc. are not possible to statistically analyzed. Thus JICA Study Team has concluded that the reduction of outage is a key factor for the improvement of supply reliability of electricity and that it has to be achieved as soon as possible. Outage reduction plan based on the 2016 electricity demand is as follows:

1) Replacement of the existing small size conductors of 11 KV D/Ls to the standard size Grape conductors (based on the Australian Standard);

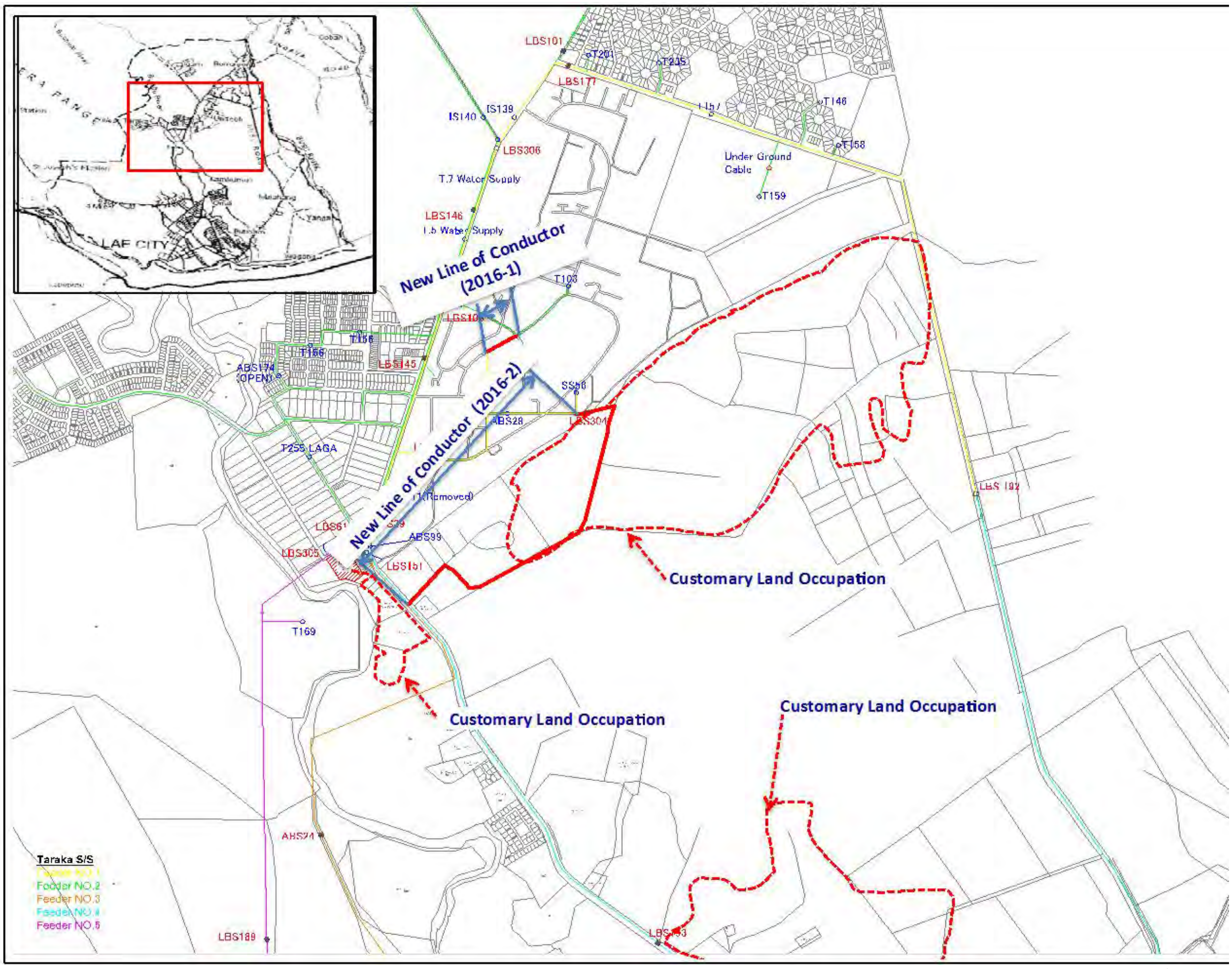
2) Replacement/upgrading of ABS and IS on the existing 11 KV D/Ls in order to avoid malfunctioning of the switching system;

3) Re-configuration of 11KV distribution network and expansion of network system i.e. a number of new D/Ls are constructed in the areas where there is no D/L at present as per Fig. 6.1-1 and Fig. 6.1-2; and

4) Replacement/upgrading of 11KV distribution facilities i.e. using grape conductors, circuit breakers within the Milford Substation of PPL in Lae City, and replacement of current transformers in order to improve feeder capacity of the electricity supply.

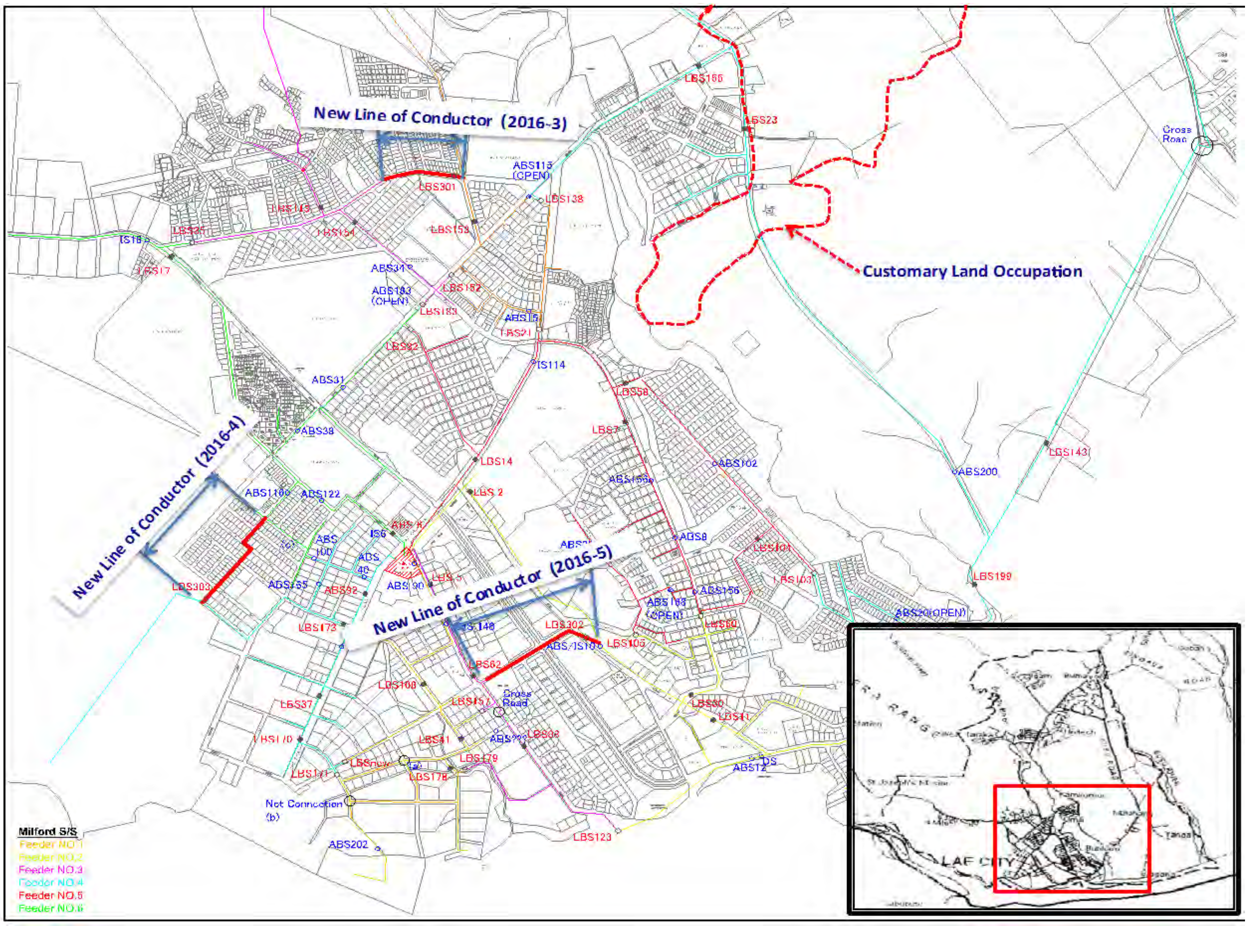
The area subject to the immediate improvement of electricity supply reliability as of 2016 is shown in thick lines in terms of new line of conductor construction works i.e. above activities of 3) on Fig. 6.1-1 and Fig. 6.1-2.

Thin line on Fig. 6.1-1 and Fig. 6.1-2 indicates the existing D/Ls in need of the above activities of 1), 2) and 4).



Source: JICA Study Team

Fig. 6.1-1 Electricity Distribution Network Improvement Plan: Immediate Improvement Plan – Northern Half of the Urban Area of Lae City



Source: JICA Study Team

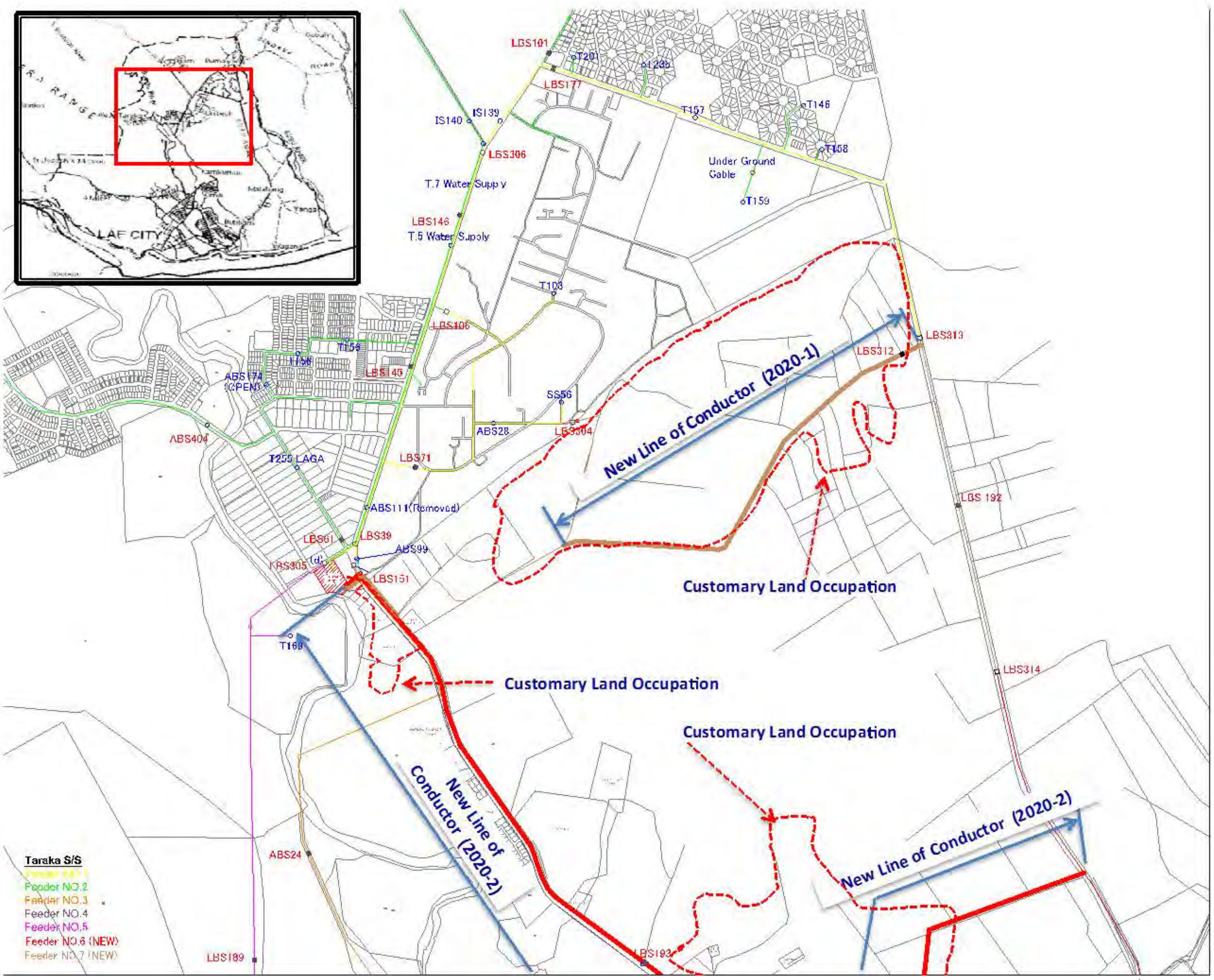
Fig. 6.1-2 Electricity Distribution Network Improvement Plan: Immediate Improvement Plan - Southern of the Urban Area of Lae City

6.1.2 Improvement of the Electricity Supply Capacity Plan: Year 2020 Improvement Plan

During the five-year period between 2016-2020, because of the anticipated increase of electricity demand during this period might increase because of the rapid economic development could take place, new lines of conductor construction works should become necessary. Thereby the increase of electricity supply capacity should be able to meet anticipated demands by the year 2020. It is therefore the Target Year 2020 Plan for the distribution network is necessary to elaborate.

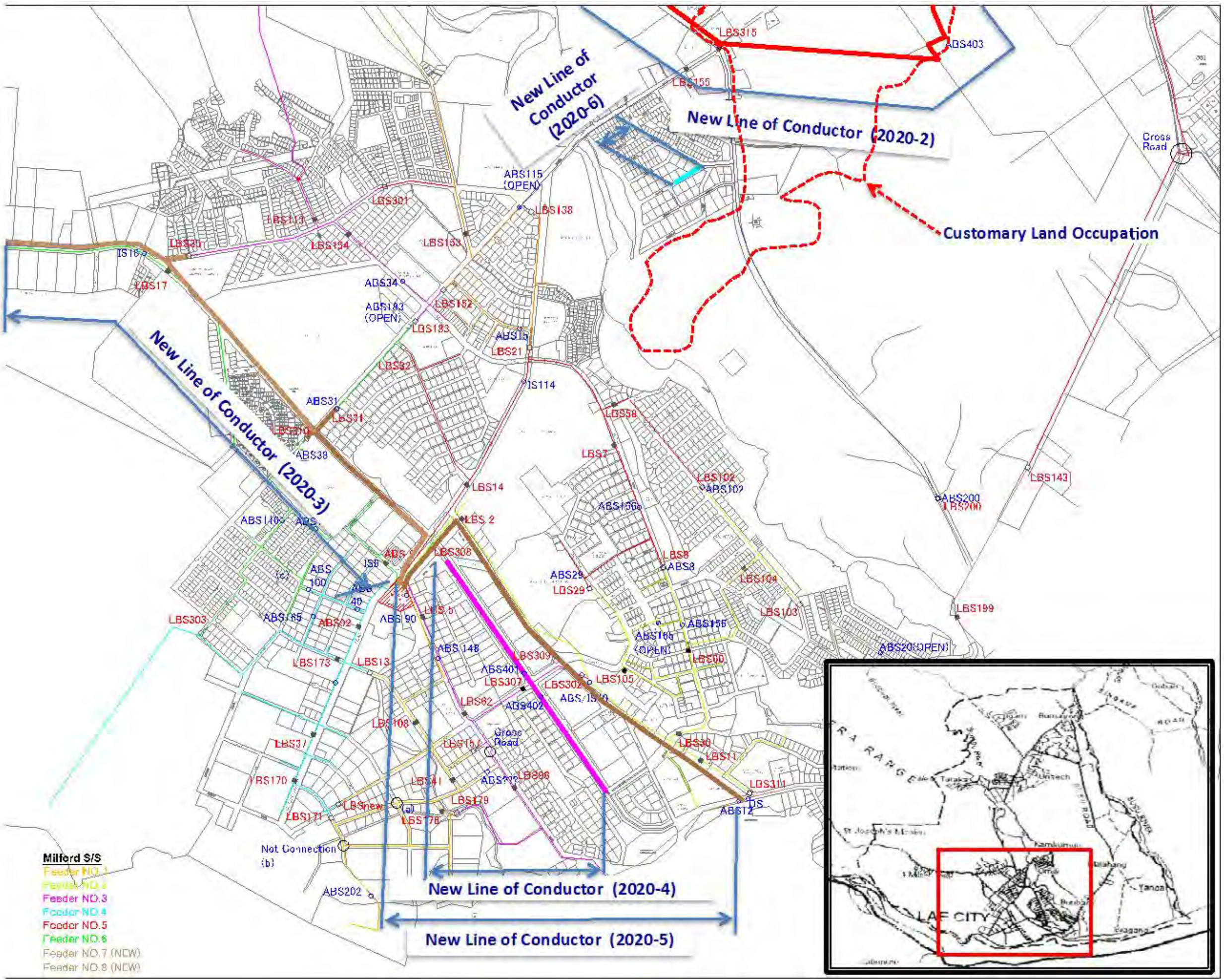
Within the framework of the plan, the activity of 3) as well as the activity 4) described in the previous section should therefore take place. Fig. 6.1-3 and Fig. 6.1-4 show the area of the Year 2020 Improvement Plan of the distribution network within the urban area of Lae City.

Thick lines indicate new lines of conductor construction works necessary to meet the electricity demand. New construction works should also cater for emergency of electricity supply outages. Thin lines indicate that the existing lines of 11 kV should be replaced or upgraded with the products of appropriate standard. Upgrading of the facilities of Milford Substation should also be carried out.



Source: JICA Study Team

Fig. 6.1-3 Lae City Electricity Distribution Network Improvement Plan: Year 2020 Plan - Northern Half of the Urban Area of Lae City



Source: JICA Study Team

Fig. 6.1-4 Lae City Electricity Distribution Network Improvement Plan: Year 2020 Plan – Southern Half of the Urban Area of Lae City

6.1.3 Improvement of the Electricity Supply Capacity Plan: Year 2030 Improvement Plan

Details of the Year 2030 development plan are described in Chapter 5. Since electricity lines are installed along the roads developed within the boundaries of urban area of Lae City, appropriate distribution design cannot be carried out at this stage because of the lack of road network.

As is shown in a number of illustrations in Chapter 5, there will be three large areas of electricity supply in Lae as follows:

a. Nadzav Supply Area;
b. Milford Supply Area; and
c. Taraka Supply Area.

Within each electricity supply area, there will be a large number of patches of electricity supply area shown in blue lines in the satellite images in Chapter 5 subject to further development.

Assuming that all of the electricity D/Ls are installed within the road reserve of which Lae City's urban development including its road network within the urban area as well as the road leading to Nadzav Airport are subject to further planning and development, environmental impacts induced by the D/L improvement works for the Year 2030 should remain the same as that of the Year 2020.

6.2 BASELINE FEATURES OF LAE CITY AND ITS SURROUNDING AREAS

6.2.1 Geography of Urban Development

As per Fig. 6.2-1, the city of Lae is located along the coast of the Huon Gulf, which is bordering the south of the city. The city boasts of having the largest wharf in PNG, with the deep sea harbor which allows for ocean liners to berth and discharge their cargoes. Currently, the Warf is undergoing redevelopment program, which will make it the largest seaport in PNG and the South Pacific Region. The coastline also offers a beautiful bay at a location called “the Voco Point”, which a coastal wharf is located to provide services for the coastal boats. Also between the Main Wharf and the Voco Point is another wharf, which services for the fishing boats, both overseas and local.

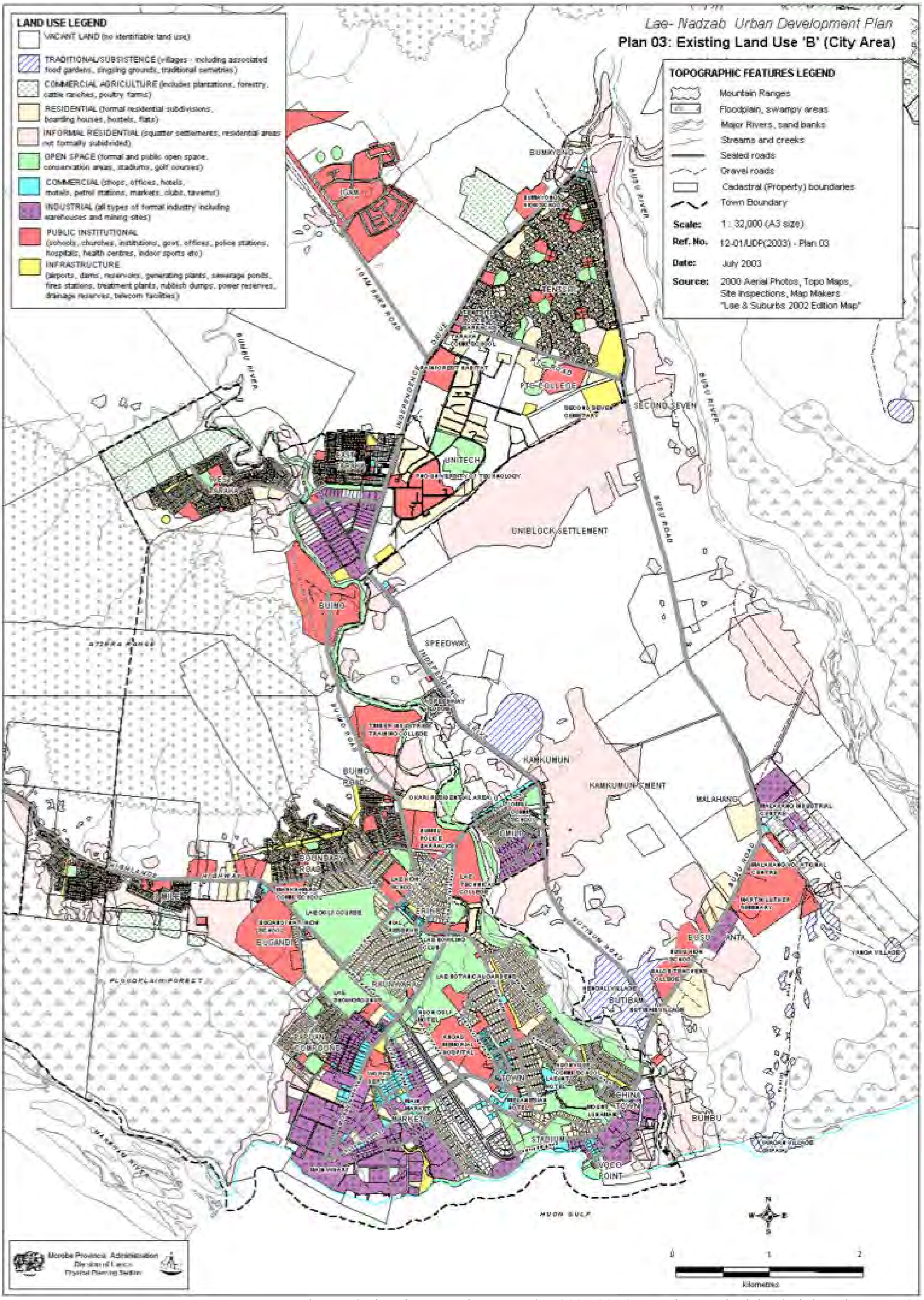
To the east and west are two fast flowing rivers of Busu River and Bumsu River respectively. Bumbu River runs meanderingly through the southern area of Lae City, commencing at the head of the Adzera Mountain Range, down to the West and East Taraka, to Kamkumung, to Butibam, to Bumbu Settlement before it drains into the coastline of Huon Gulf.

These rivers caused the major damage to the city in 1992. The river is still a threat to the properties along the river, as well as the residents, particularly during the wet season every year. Thus there has been a plan put in place by Lae City Council called “the Bumbu River Mitigation Project” to counter and manage the river in order to safeguard the properties as well as the residents along the river.

Lae City has 137 kilometers of roads. The national government of PNG is responsible for the maintenance of the Independence Drive, the Markham Road, and the Milford Haven Road, while Lae City Council maintains the rest of the roads in the city.

There are a number of customary land occupation scattered around the urban area of Lae City as is shown in light pink shaded areas as per Fig. 6.2-1. These are the areas occupied by the inflow migrants from the rural areas during the past decades before appropriate land use plan is laid out.

Because of the old airfield remaining relatively intact in the middle of Lae City, configuration of the urban area in Lae remains unique i.e. the area to the east of airfield generally developed for administration center and residential area on ridge dividing Busu River alluvial plane and Bunsu River alluvial plane. To the west of airfield is the commercial area of Lae while to the north new urban development area development is anticipated.



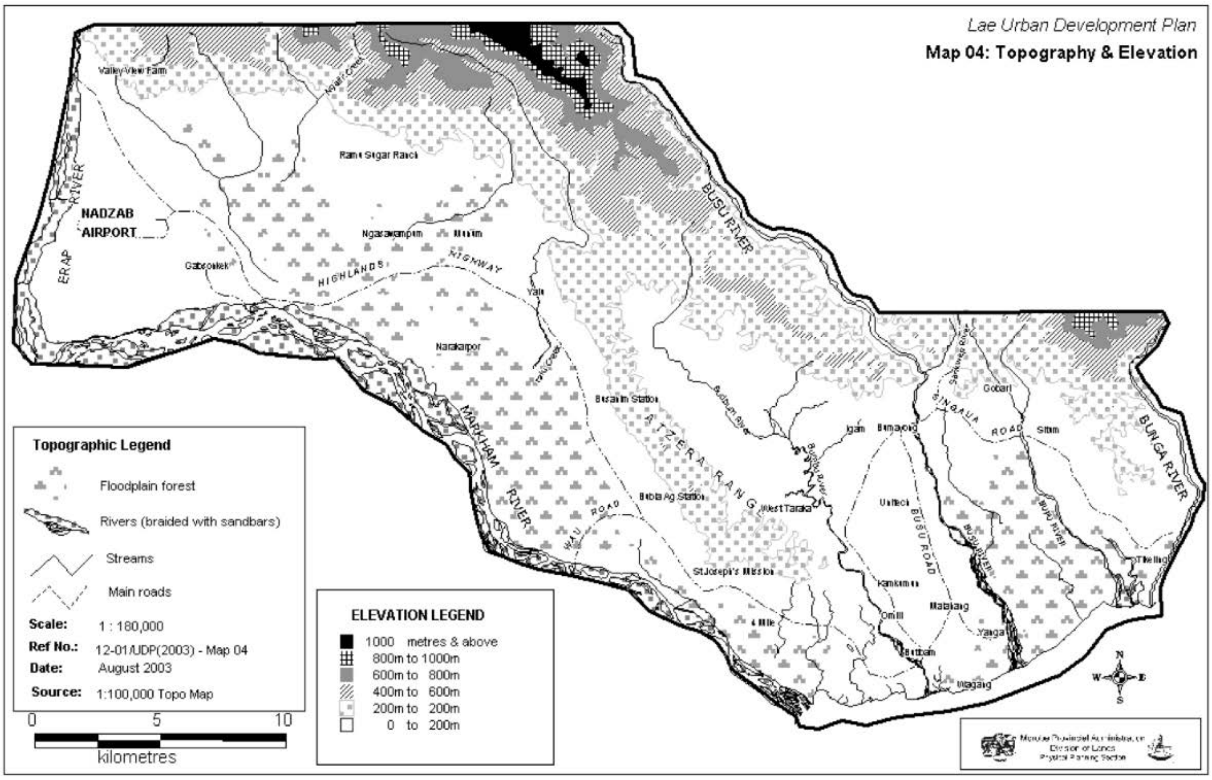
Source: lae-Nadzab Urban Development Plan 2005-2016, Morobe Provincial Administration, Nov.2003

Fig. 6.2-1 Urban Development Area of Lae City

6.2.2 Topography of Lae and its Surrounding Area

Topography of Lae and its surrounding area as per Fig. 6.2-2 shows that Lae City is facing Pacific Ocean to the south and foothills of highlands up to 200 masl to the north. Outside of the city is generally occupied by swamp area and flat to the east of Busu River. To the west of the city also lies swamp area between Markham River and Bunsu River and it stretches out to the area near Nadzab Airport located on the western end of the rural Lae City surrounding area.

Bunsu River and Busu River are two rivers causing flood events to the alluvial place on which Lae City sits. These two rivers are left as naturally formed river banks do not provide appropriate protection to Lae City. This is one of the reasons the city administration and residential areas have been historically developed on the ridges running generally north to south of the city.

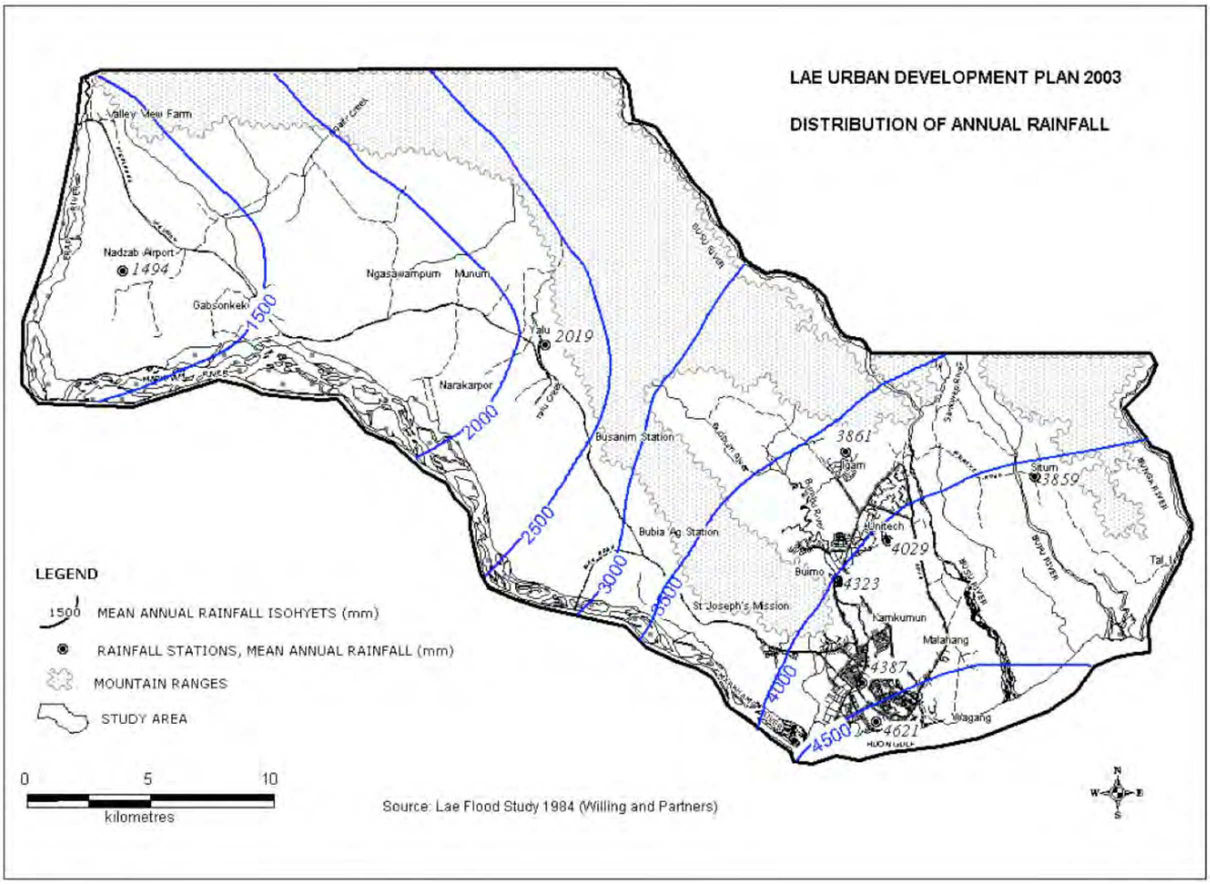


Source: Lae-Nadzab Urban Development Plan 2005-2016, Morobe Provincial Administration, Nov.2003

Fig. 6.2-2 Topography of Lae and its Surrounding Area

6.2.3 Rainfall Patterns

Rainfall patterns are year-round i.e. generally 15 days of rainfall each month. As per Fig. 6.2-3, the Lae City receives 4,500 mm of rain per annum while the western end of the surrounding area receives 1,500 mm per annum. The difference of rainfall amount within 30 km of distance between the urban center and the rural area to the west of surrounding area of Lae City is very unique that the city's rainfall pattern is classified as seen in rain forest while dry savannah is seen next to the rainforest patterns of precipitation.



Source: Lae-Nadzab Urban Development Plan 2005-2016, Morobe Provincial Administration, Nov.2003

Fig. 6.2-3 Precipitation of Lae and its Surrounding Area

6.2.4 Bio-zoological Environment

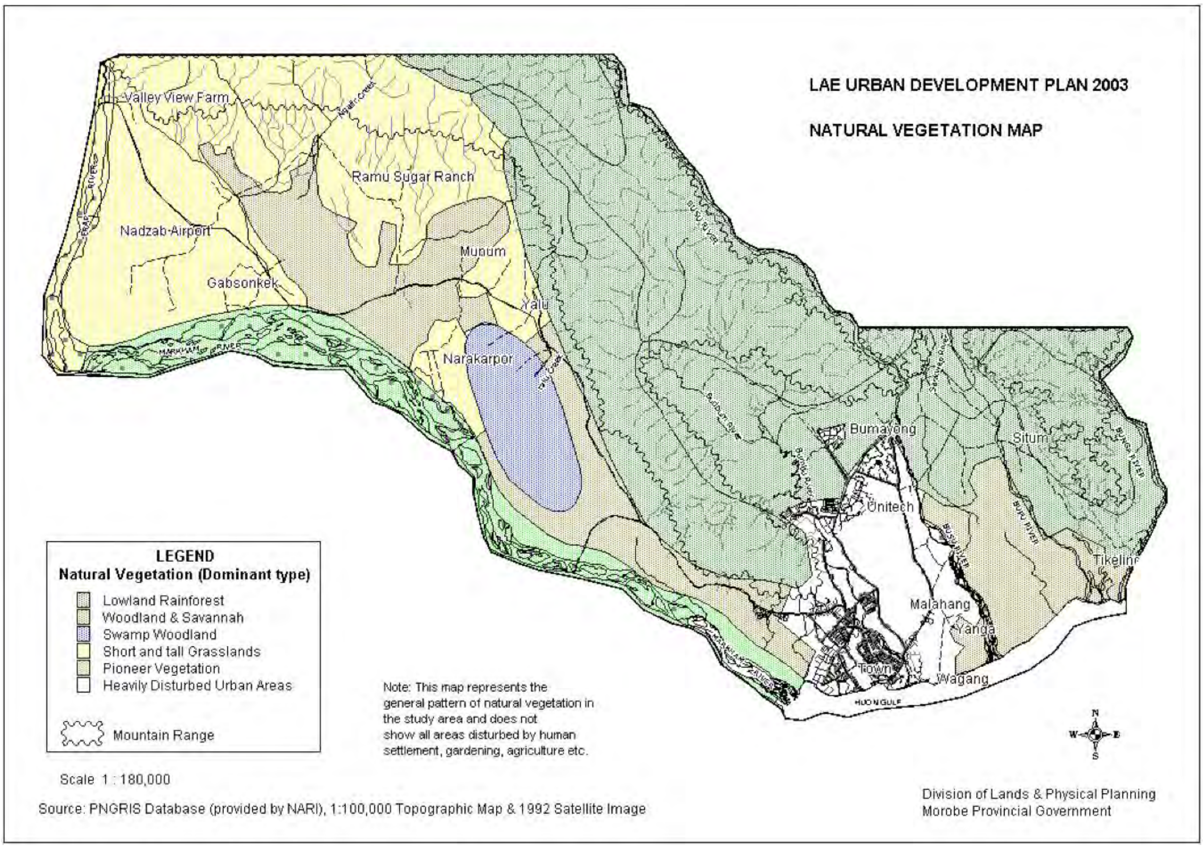
As has been describe above, and as per Figure rainfall patterns forming rain forest vegetation is seen in the area generally higher elevation areas of the surrounding areas of Lae City.

While probably the northern half of Lae City's urban area was covered by lowland rainforest, it has been cleared for settlement area during the past decades. While also possible to state that the southern half of the urban area of Lae City was covered with thick vegetation during the past centuries, urban development took over the area of wetland and savanna vegetation during the past decades.

Swamp woodland and savannah vegetation still remains intact to the east of Busu River and to the west of Bunsu River.

Lae is strategically located for research on fauna and flora in PNG. It is in the centre of pristine rain forests and where the world's biodiversity is found. There are also in the nearby area that there are diverse aquatic and terrestrial biomes. Thus abundant flora and fauna can be found on nearby isolated islands, coral reefs, untouched rainforests, mountainous regions, valleys, mangrove and coastline habitats.

PNG has 7% of the biological diversity of the world and is considered the richest island on the planet in terms of flora. There are nearly 15,000 species of plants, 750 bird species, and 240 species of mammals. Mammal species that are possible to find in the surrounding areas of Lae City, especially in the wetland forest area are also found occasionally in the foothills of the Highlands.



Source: lae-Nadzab Urban Development Plan 2005-2016, Morobe Provincial Administration, Nov.2003

Fig. 6.2-4 Vegetation of Lae and its Surrounding Area

A Rainforest Habitat has been set up for educational purposes on the University of Technology Campus in Lae. It is over 3,000 sq. m in area and displays of nearly 15,000 native and exotic plants, 21 species of birds including the magnificent Raggiana Bird of Paradise as well as crocodiles, cassowaries, tree kangaroos, lizards, butterflies, turtles, frogs and fishes.

The Lae City is also known as a Garden City. This name derived basically from the Botanical Garden of the City as well as the trees and flowers that line up along the roads and properties within the City. Some of the selected wildlife and features of vegetation are shown in Fig. 6.2-5.

The marine life in the tropical waters of the Huon Gulf are also abundant with marine life. In the sea within a few kilometers of Lae it is not uncommon to see dolphins, saltwater crocodiles and turtles.


Victoria crowned pigeon


Southern Cassowary


Reproduced Rainforest


Tree-climbing Kangaroo

Source: Morobe Provincial Government (http://www.morobepng.com/id25.html)

Fig. 6.2-5 Plant and Wildlife in the Natural Environment Reproduced in University of Technology, Lae

6.2.5 Socio-economic Environment

(1) General Economic Activities

Lae is located at the start of the Highlands Highway, which is the main land transport corridor to and from the Highlands region linking the coastal area and the delta of the Markham River. Lae holds the largest cargo port of the country and is the industrial city PNG. The city is known as the Garden City and home of the University of Technology.

Halla Cement Factory, Trukai Rice Industry, SP Brewery, South Pacific Steel, to name a few. Lae has the largest seaport in PNG. It is also strategically important supply centre for all Highlands, New Guinea Islands, Southern and, the Momase regions.

Traditional agricultural activities are coffee, cocoa, copra, sugar, pineapples, banana, peanuts, taro, rice, cattle/livestock, and fishing. Gold mining is also one of the important economic activities. In recent years, oil and natural gas, vanilla and other spices, cashew nuts, oil palm, fish/wildlife farming, eco-tourism and horticulture are emerging economic activities. Economic growth in 2007 was 2.5 %.

Lae being the second biggest city is the industrial centre of PNG and is where the largest export port in PNG is located. It is strategically located in that it can supply goods to Highlands, Islands Regions, Southern and Momase regions. Large businesses established in the city include; 1) Halla Cement; 2) Trukai Rice; 3) SP Brewery; 4) South Pacific Steel; 5) Papindo Group Of Companies; 6) Prima Small Goods; and 7) Lae Biscuit Factory.

Members of the Lae Chamber of Commerce and Industry control business investments in Lae. The business activities they engaged in are; mechanizing, wholesale, catering, hotel industries, real estate, food and beverages, pharmaceuticals, banking, legal, accountings and business consultancy, electrical works, building, shipping, airlines industries, motor vehicle and fuels.

The economic prospects for Lae in the next couple of years will be boasted by the mining activities of the two potential mines in Bulolo District’s Wafi Golpu Gold and Copper mines in Hamata and Hidden Valley. These mines will be managed by Morobe Mining Joint Ventures Ltd and the Frabelle (PNG) Ltd, one of the tuna canning factories in Tae. Palm oil is another potential investment opportunity while tourism development has not been fully developed to date.

Lae and Morobe Province contributes immensely to the economy of PNG and will continue to do so in many years ahead. Increasing economic activities and population growth makes Lae the most ideal place in PNGa to invest.

(2) Population and Ethnography

Lae is the provincial center of Morobe Province and its population is 119,178 according to 2011 national Census. It is PNG’s second largest and industrial city in PNG. From a population of 78,692 according to the National Census 2000, city’s population has grown by 51 % during the 11 year period from 2000 to 2011.

Lae is linked to the rest of PNG by air, sea and land transport, and telecommunications network. It is situated on the shores of the pristine Huon Gulf, Six Degrees South of the Equator. The mountainous Finnistere, Sarawagat and Rawlingand ranges to the Northern Extension of Owen Stranley Range with the highest peak of Mt Bangita rises at 13,000 above the sea level.

Establishment of Lae is originally from a tiny patrol post and mission station before the 1920s Wau

Gold Rush. During the post war the Australian Neo-colonial administration shifted its headquarters from Morobe Patrol Post to Salamaua. The gold rush township of Wau transformed it into a major port and industrial centre of present Lae.

(3) Local Administration System

The Lae City Council is known as Lae Urban Local-Level Government (LLG). It is an Urban Municipal Authority, responsible for the policy decisions, management and administration of the City, by way of providing the municipal services to the residents of the City.

Head of the Lae Urban LLG is termed as Lord Mayor who is elected by the local people along with six elected and three nominated councilors. Six elected councilors represent the six wards of the City. Three nominated councilors represent the Chamber of Commerce, the Workers Federation Union, and the Women, Youth and Churches. The city council makes decisions on the policy issues relating to affairs of the city's economic development.

Lae city aims to become one of the garden cities of Asia Pacific Region by creating a modern, safe, vibrant city, with a strong economy, whilst enhancing its cultural heritage, and by developing a healthy, well educated, and harmonious community.

6.2.6 Socio-economic Conditions of Morobe Province

(1) Population

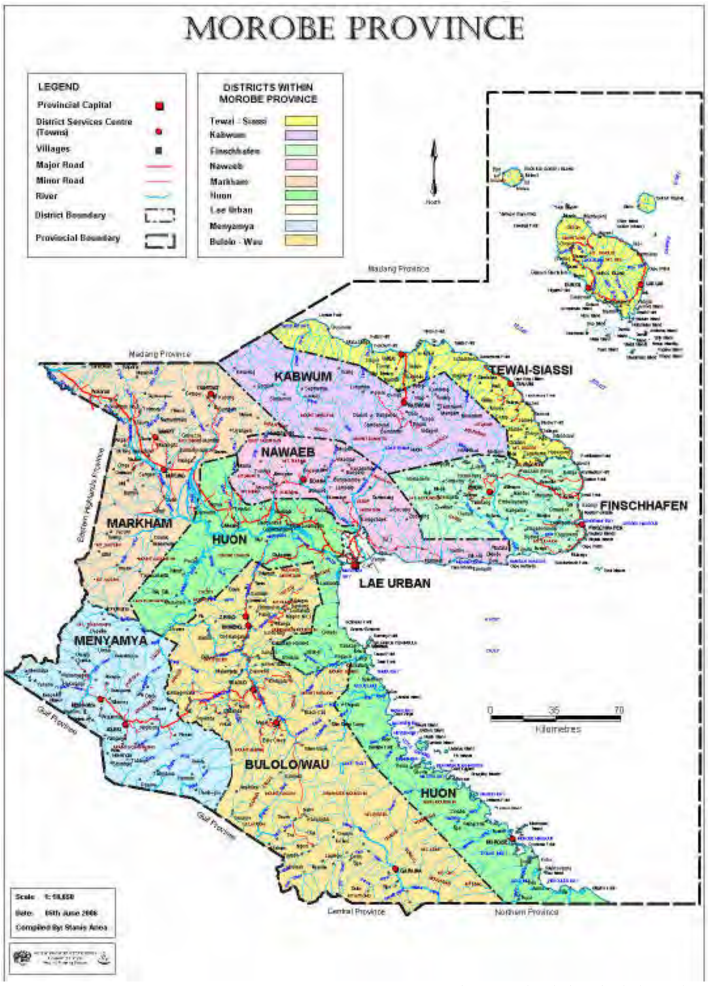
Outside of Lae lies Huon District to the south and Nawaeb District to the north, both of them being districts forming Morobe Province, which has the highest provincial population of 671,521. This is 9.2 % of the total population of PNG as a result of 2011 National Census. It is one of the densely populated provinces in PNG.

The population of Morobe province comprises of younger people than matured and economically active people. In other words, 80% of the non-working population is dependent of only 20% of the workforce population. The population growth rate is 2.8 % per annum while its economy grows at 2.7 % per annum.

(2) Socio-economic Conditions of Morobe Province

Reflecting the population growth is the lack of social services and infrastructure development. Currently Moreobe Province is suffers from: 1) Increased urban drift and rising squatter settlement issues leading to social disorder; 2) Increasing illiterate population i.e. more spaces in classrooms and teachers for increasing illiterate population; 3) HIV/Aids and other health issues are increasing i.e. Increase of health facilities and health-care staff are in needs; 4) Lack of income per capita compatible to the increase of prices; and 4) Deteriorating road networks and other utility services such as telephone, electricity water and drainage systems;

The economy in Morobe at present is better than it has been for many years as there have been a number of development projects such as new gold mines, fisheries projects, agricultural projects and government initiatives for improvement of infrastructure development. On the other hand, rural Morobe is endowed with rich natural resources, and diverse flora and fauna. Traditional economic activities such as coffee, cocoa, cattle, and logging are thriving while the emerging activities of gold and copper mining, tuna fishing, and oil exploration are emerging. Fig. 6.2-6 shows administrative boundaries of Morobe Province and the location of Lae.



Source: Morobe Provincial Administration

Fig. 6.2-6 Administrative Boundaries of Moreobe Province

(3) Population

Morobe Province stretches from the Sarawaget Range in the north along the Huon Peninsula to the east. Markham Valley stretches through the center of province. The Bulolo and Watut Valleys run north to south, with the Ekuti and Owen Stanley Ranges in the south. Those living in the Markham and Watut Valley earn high agricultural incomes from the sale of betel nut and fresh food. Moderate incomes are earned from fish, food, coconut and betel nut in the coastal areas around Lae. Remote areas earn very low incomes. Other sources of income are also available from mining near Wau, forestry near Bulolo and cattle in the Markham Valley.

The Highlands Highway and a road between Lae and Wau provide reasonable access in the province. Roads along the Huon Peninsula do not connect to Lae. The areas in the north of the province in Kabwum Distict and south of the province, around Garaina are very remote and accessibility by road is limited. A brief description of the province is as follows:

Provincial headquarters	:	Lae
Number of districts	:	Bulolo, Finschhafen, Huon Gulf, Kabwum, Lae, Markham, Menyamya, Nawae, Tewai Siassi

Number of LLGs	:	33
Number of wards	:	547
Population	:	Total 674,810 (Male / Female Ratio: 51.2 % / 48.8 %)
No. of Households	:	130,109
Area (km²)	:	33,705
Literacy rate (%)	:	Total 63.6% (Male / Female Ratio: 60.2% - 39.8%)
Economic Activities	:	Food crops 69.2% Betel nut 59.4 % Coffee 45.7 % Coconut 36.9 % Livestock 34.5%
Electricity Customers	:	12,136

As the number of electricity customers of 9.1 % of the total population in the province indicates that the province's economic activities linked to commerce and industry is comparatively high while there are yet to develop in the future in terms of the home-use of electricity for education.

(4) Regional Traditions and Culture

Morobe Province is a home to a number of interesting cultural and archeological sites - located on the Huon Peninsular are two sites of 1) Bobongara being the oldest archeological site in the Pacific. It consists of stone axes found on the edge of a relict uplifted lagoon which was occupied more than 400,000 years ago; and 2) the Huon Terraces are a "staircase" of ancient coral reefs and is one of the most remarkable examples of an uplifted marine terrace in the Pacific.

Linguistically, there are 171 different languages with 27 language families are used over and above English as common language. English & Tok Pigin is the common languages in the urban areas and tok ples (distinctly different languages of each village) spoken in the rural and remote areas.

There are distinct languages spoken within the province, with English & Tok Pigin the common languages in the urban areas and with tok ples (distinctly different languages of each village) spoken in the rural and remote areas.

There are about 34 tribal and cultural groups in the province. They range from the Yupna tribe of the high mountains in the Finisterre Range near Madang Provincial Border; the two groups of people; the Liewompa group of people who occupied the Lae region; whilst the Anga people, (fierce bowmen known as Kukukuku warriors), lived nomadic lives in the central mountains.

The grassland mountainous areas near the Papuan Border of Gulf Province are inhabited by the Anga (Kukukuku) people of Menyamya. The region retains its cultural heritage and uniqueness and virtually untouched by modern society. The people of Markham Valley Plain and those from the coastal regions near Lae are tall in height.

The origin of the people of Morobe is unknown. Their origins have been determined by the oral history, customs, and beliefs of Morobeans that were handed down the generations by word of mouth and have become vague over centuries. Archaeologists assume Morobeans originated from Southern Asia who traveled through Indonesia to New Guinea and that several waves of migrant swept through the region thousands of years ago. The present ethnological state of the province suggests that these migrants may have passed through the region over a long period.

6.3 ENVIRONMENTAL POLICY OF PNG AND ITS LAWS AND REGULATIONS

6.3.1 Environmental Laws in PNG

(1) Outline of the Environmental Act 2000

The GoPNG has been working on which consolidation of the environmental laws and regulations have been made at the turn of the century. As is stated in the next section, Environmental Impact Assessment (EIA) laws and regulations have been improved in the Year 2000. However, there has been no adaptation of SEA to date. Thus Conservation and Environment Protection Authority (CEPA) considers to introducing Strategic Environmental Assessment (SEA) concept in the near future. The EIA branch of CEPA will deal with SEA introduction in the future.

It is one of the obligations of the Study that principle and methodology of SEA has to be applied. Thus within the framework of the Study, one of the prevailing methodologies of SEA generally employed by WB, IFC or ADB will be selected in order to meet the requirement of the Study. Details of SEA principle and methodology are described in Section 8.3.

(2) Environmental Act 2000

The legal framework related to the laws and regulations concerning the environment impacts caused by projects. It also provides the appropriate level of environmental mitigation measures and secure its implementation by monitoring through the regulatory process.

The Environmental Act 2000 came into force in 2004 by integrating previous three different legislations such as i) Environmental Planning Act; ii) Environmental Contaminant Act; and iii) Water Resources Management Act. The Act states the environmental protection and promotes sustainable development as follows:

- To provide for the protection of environment in accordance with the Fourth National Goal and Directive Principle of the Constitution
- To regulate the environmental impacts of development activities in order to promote sustainable development of the environment and economic, social and physical well-being of people by safeguarding the life supporting capacity of air, water, soil and ecosystems for present and future generations and avoiding, remedying and mitigation of any adverse effects of activities on the environment
- To provide the protection for the environment from environmental harm
- To provide the management of natural water resources and the responsibility for their management

(3) Environmental Regulations

The Act is a main legal instrument that regulates environmental impact assessment and management in PNG. Under the Act 2000, five regulations as listed below were enacted in 2002. Each regulation deals with EIA and licensing procedures as a comprehensive part of the Act.

- Environmental Regulation 2002 (Procedures)
- Environmental Regulation 2002 (Permits and Transitional)
- Environmental Regulation 2002 (Prescribed Activities)
- Environmental Regulation 2002 (Fee and Charge)
- Environmental Regulation 2002 (Water Quality Criteria)

(4) EIA Guidelines

There are a number of guidelines put out in 2004 as a result of the enactment of the Environmental Act 2000 as follows:

- Guidelines for Preparation of Environmental Inception Report, 2004
- Guidelines for Conduct of Environmental Impact Assessment & Preparation of Environmental Impact Statement 2004
- Notification of Preparatory Work in Level-2 and Level-3 Activities, 2004
- Guidelines for Submission of an Application for an Environment Permit to Discharge Waste, 2004
- Technical Guidelines for Noise, Air and Water & Land Discharges 2004
- Technical Guidelines for Air Discharge 2004
- Technical Guidelines for Water & Land Discharges 2004

(5) Environmental Protection Authority Act

The Act commenced retrospectively on 2014.12.01. CEPA has therefore been created and has taken over administration of the Environment Act, the Conservation Areas Act, the Fauna (Protection and Control) Act, the International Trade (Fauna and Flora) Act and the Crocodile Trade (Protection) Act.

(6) Environmental Amendment Act

The Environment (Amendment) Act 2014 also commenced on 2014.12.01. The amendments to the Environment Act are set to commence in two phases. First, the consequential amendments in connection with the creation of CEPA and, second, the more substantial amendments to the Environment Act that relate to the permitting process and the classification of activities.

- Fauna Act (Protection and Control) 1966
- National Parks Act 1982
- Conservation Areas Act 1978

(7) Environmental Standard

The regulation of specific values for Suspended Particle Matters (SPM), SOx, NOx for air pollution and BOD, COD in water pollution is one of the important tools in order to administer environmental conditions of the country. However, CEPA does not have regulations for the specific values of standard for air and water quality management. Thus Monitoring and Compliance Branch of the Environmental Protection Division of CEPA supervises implementation of the environment permit and environmental management plan in terms of air and water quality control.

(8) Environment (Fees and Charges) Regulation 2002

Procedures for permit fees and charges for environmental impact assessment and permit, water use, discharges to water and disturbed area runoff are regulated by this regulation. Fees and charges are set by DEC.

(9) Environment (Permits and Transitional) Regulation 2002

This regulation defines procedures for applications for, processing of, appeals against, and compliance with, environmental permits.

(10) Environment (Prescribed Activities) Regulation 2002

Guidelines used for determining whether the Study will be a level I, II or III activity.

(11) Environment (Procedures) Regulation 2002

Procedures of the Environment Council (who will provide advice to the Minister on the EIS) are regulated by this regulation.

(12) Environment (Water Quality Criteria) Regulation 2002

Permit required to set a mixing zone, the boundary at which prescribed water quality criteria have to meet if any project intervention is likely to disturb water quality.

(13) Fauna (Protection and Control) Act 1966

This act regulates and requires measures to prevent poaching of wildlife by the workforce.

(14) Conservation Areas Act 1978

This Act provides for the preservation of the environment and of the natural and/or cultural inheritance by the conservation of sites and areas having particular biological, geological, historic, scientific or social importance and the management of those sites and areas.

The Minister may refer any proposals for development to the National Conservation Council (formed under the Act) to consider any development affecting, or in the vicinity of a conservation area, and to assist the Minister on the formulation of rules applicable to conservation areas.

(15) International Trade (Fauna and Flora) Act 1979

This Act requires measures to prevent poaching of wildlife by the workforce specifically trained and established under this Act. It also provides power to regulate trading fauna and flora of nationally and internationally important to and from PNG.

6.3.2 Agency for the Environmental Conservation and Management

(1) Implementing Agency for the Environmental Conservation and Management

CEPA of PNG has replaced the previous DEC. CEPA is now the government agency responsible for administering the Environment Act 2000, the Conservation Areas Act (Chapter 362), the Fauna (Protection and Control) Act (Chapter 154), the International Trade (Fauna and Flora) Act (Chapter 391) and the Crocodile Trade (Protection) Act (Chapter 213).
Within the framework of these laws, CEPA manages natural resources and the environmental quality in order to enforce related regulations. It is the body of which Environment Act must be appropriately enforced, including environment permit applications from the government and private organizations. It also collect fees and charges related to the enforcement of the environmental laws. CEPA is composed of three divisions as follows:

- Policy Coordination and Evaluation Division
- Sustainable Environment Management Division
- Environment Protection Division

(2) Role of the Director of CEPA

The Director of CEPA has the authority to administer the Act and issues environmental permits as prescribed in the Section 16 of the Act.

(3) Role of Environmental Council

An environment council is established for the purpose of reviewing the Director's decision and also for providing advice to the Minister as prescribed in the Section 19 of the Act.

(4) Role of Environmental Protection Division

The Environment Protection Division of CEPA has three separate branches as follows:

- EIA Branch
- Environmental Permit Branch
- Monitoring & Compliance Branch

The above three branches are responsible for environmental assessment and issuance of permits. EIA Branch is responsible for dealing with the Level 3 (equivalent to Category A of the classification system within the framework of JICA Guidelines) project proposals that require detailed environment impact assessment. Environmental Permit Branch is responsible for processing the Environment Permit application for any development project under Level 2A, Level 2B and the Level 3.

Environmental Monitoring & Compliance Branch is responsible for ensuring the enforcement of environment permit conditions that the contents of application are met these conditions. The branch further ensures the project activities are periodically audited.

6.3.3 Procedures for Environmental Permit and EIA in PNG

(1) Categorization of Projects

Under the Environment Act 2000, project proponent is required to submit Environmental Impact Statement (EIS) obligatory to obtain Environmental Permit before its implementation.

The projects are prescribed on the basis of the classification in the Environment Regulation 2002 (Prescribed Activities). Activities are categorized into three levels based on the project size or environmental impact level. When a level 2 or level 3 activities are carried out, the Environmental Permit is required.

1) Level 1 Activity

Level 1 activity is assumed to have very low risk of causing environmental impacts. Application for an environmental permit is not required. According to the regulation, Level 1 activity is those that are not prescribed as Level 2 or level 3 activities. The specific activities categorized as Level 1 is shown as follows:

- Hydroelectric plant with a capacity of less than 2 MW is a Level 1 activity. If those are in conflict with the sensitivity of the environment, Level 2A activity is applied;
- Fuel burning power stations with a capacity of less than 5MW is a Level 1 activity. If those are in conflict with the sensitivity of the environment, Level 2A activity is applied;

- Fuel burning appliances including furnaces and boilers with a rated thermal output of less than 20MW is a Level 1 activity. If those are in conflict with the sensitivity of the environment, Level 2A activity is applied;

- Construction of electricity T/Ls less than 10 km in length is a Level 1 activity. If those are in conflict with the sensitivity of the environment, Level 2A activity is applied; and

- Construction of electricity D/Ls is a Level 1 Activity.

According to the Environmental Officer in PPL, there has been no EIS submission for the D/L projects in PPL.

2) Level 2 Activity

Level 2 activities are those that have potential to cause environmental harm. Such activities are divided into two categories of Level 2A and Level 2B.

Level 2A activities are expected to cause relatively lower potential risk than Level 3. Level 2A activities are not required application of permit for approval i.e. no submission of EIS is required. Level 2A would include mining exploration and minor forest activities. There is no prescription of the power sector projects if they are categorized in Level 2A.

Level 2B activities are expected to cause higher potential risk than Level 2A. Level 2B activities are required permit approval process with submission of an EIS. However, Level 2B category does not need to prepare a full EIS level assessment upon application for an environment permit.

Level 2B involves manufacturing, chemical processes and mid-sized mining. As for the power sector, Level 2B includes the following activities as prescribed in the regulation:

- Hydroelectric plants with a capacity of more than 2 MW;
- Fuel burning power stations with a capacity of more than 5MW;
- Fuel burning appliances including furnaces and boilers with a rated thermal output of 20MW;
- Damming or diversion of rivers or streams; and
- Construction of electricity T/Ls greater than 10 km in length

These prescription means that activities, which divert runoff from original rivers or stream such as run-off-river type hydropower plant, whatever the length of diverted sections, are categorized as Level 2B.

3) Level 3 Activity

Level 3 activities are defined that it is essentially those projects of national importance and that it causes serious environmental and social impacts. These activities are subject to produce a fully studied EIS.

Level 3 activities are generally the type of industrial activities, such as manufacturing, large-scale mining, industrial waste disposal and projects causes a large number of resettlement. As for power production sector, Level 3 activities include the following activities:

- Major hydropower schemes or water supply reservoirs inundating an area greater than 5 km^2; and

- Activities that may result in a significant risk of serious or material environmental impacts within Wildlife Management Areas, Conservation Areas, National Parks and Protected Areas.

(2) Application of Environmental Permit and Its Screening

All project proponents should submit notification for preparatory works of projects. The Level 2 and 3 categorized projects should obtain Environmental Permit before the start of project implementation. Process of the Environmental Permit in PNG is as follows:

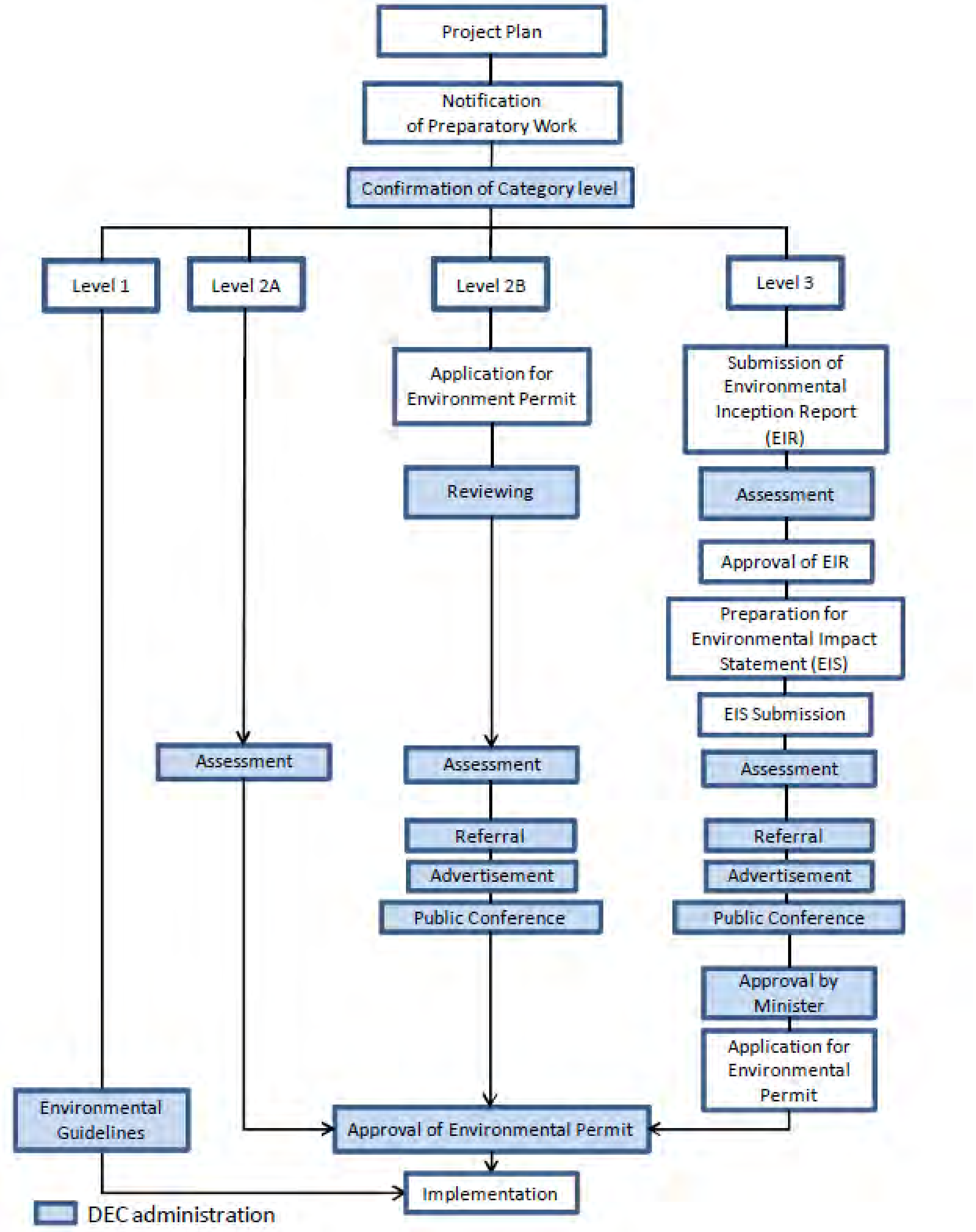
- Project proponents should register the intention to carry out preparatory work to the CEPA, at least one month prior to the preparation works;
- After confirmation of the Categories in Levels 1-3 by the CEPA, proponent should submit Environmental Inception Report (EIR), which shows listing the issues to be covered in the EIS;
- After the approval of EIR, the proponent should submit EIS; and
- When the EIS is approved by the Minister, final application for the Environmental Permit can be processed.

Since the Project is classified as Level 1 activity according to the Environmental Laws and Regulations in PNG, no procedure for application of environmental permit is required.

(3) EMP, RAP and Biodiversity Offset Plan

Environmental Management Plan (EMP) should be attached to EIS of Level 2B or Level 3 activities only.

D/L Netword Improvement Plan for Lae City since there is no part of the project area that falls under Level 2B or Level 3 activities. Thus these documents are not required when the Project is implemented as it is classified as Level 1 activity. Flow of Level 1 Activity within the framework of PNG's environmental impact assessment is shown in Fig. 6.3-1.



Source: CEPA, Dept. of Environment and Conservation, PNG

Fig. 6.3-1 Environmental Regulatory Process of PNG

(4) Procedure for Application of Environmental Impact Assessment

The procedures of environmental impact assessment is described in the section 51(1) of the Environmental Act 2000 as follows:

- Submission of an EIR setting out the issues to be covered in the EIS;
- Submission of an EIS setting out the physical and social environmental impacts, which are likely to result from the carrying out of the project activity;
- Assessment and public review of the EIS;
- Acceptance of the EIS by the Director;
- In reference to the EIS, assessment report and other materials are sent to the Minister;
- The Minister further calls for which the Environmental Management Council further makes assessment of the report;
- Recommendations by the Environmental Management Council are sent to the Minister; and
- The Minister approves the EIS in principle.

Assessment for Level 2A category is processed within 30 days, while for Level 2B category, 90 days is required for the approval process after the submission of application.

After EIS assessment for 6 month, Environmental Management Council consisting of 5 experts approves the submission and then Minister's approval is issued for the Environment Permit. Figure 8.2.1 shows general process of EIA. Fig. 6.3-1 shows general process of environmental permit application and the process of EIS.

(5) Resettlement Framework

While there are no provisions of policies, laws and regulations for involuntary resettlement provided in the environmental impact assessment laws and regulations in PNG, Asian Development Bank (ADB) prepared a project report of **"Papua New Guinea: Power Sector Development Plan"** in April 2009 which includes "**Social Safeguards**" in its Appendix F and that there is a provision of **"Resettlement Framework"**.

Within the framework of the D/L Netword Improvement Plan for Lae City there is no person involved in the resettlement.

(6) Land Acquisition for the Project

1) Land Tenure System in PNG

The land tenure system in PNG is classified into two categories. One is Alienated Land, which is managed by the Government as leasehold land. The other is Customary Land, which belongs to a citizen or a group of citizens traditionally maintained their own territory. Customary Land shares about 97 % of the total area of PNG and Alienated Land shares 3%.

Land Act 1996 stipulates that there are two (2) types of land acquisition process, which are i) Compulsory Acquisition; and ii) Agreed Land Acquisition.

Since Lae City area is PNG's lease-hold area, D/L network improvement plan does not cause any land issues. However, as electricity pole installation work could take place outside of the road boundary, appropriate negotiation taking into account of Customary Land Tenure System should be implemented. It is particularly important to respect and deals with a group of people forming Incorporated Land Groups.

2) Characteristics of Customary Land

The key characteristics of customary land tenure system are described as follows:

- Appropriate for traditional needs - established and well understood by users;
- Responsive to internal pressure - i) flexible and controlled by landowners; and ii) less responsive to external impacts;
- Ownership by the Clan; individual members have rights to use and occupy land based on verbal agreement and conventionality at the level of each Clan;
- The Clan sets aside land for meetings, signings, feasts, rituals and sports, etc.;
- The Incorporated Land Group (ILG) within the community resolves all land issues. There is no individual registration of land in PNG. All land is registered in the name of ILG;
- There are thousands of ILGs in the country. Each ILG has a certificate of registration. Once the ILG is registered and claims possession of land, then no other person can claim ownership of the land.
- The Land Department does not involve in the process. Disputes are settled in civil court.
- Another source of conflicts is buffer zones, where generally no Clan owns the land because it lies between generalized landmark boundaries. Nevertheless, if there is development, disputes naturally arise as to which clan owns those tracts of land.

(7) Land Use in PPL Projects

1) Type of Land Usage in PPL Projects

- The lands, which are in need of the main facilities of electric power development projects such as dams, P/S, S/S are acquired with monetary payment based on the agreement. The payment is settled by negotiation between PPL and landowners based on the market price. The ownership is then transferred to the Government.
- The lands, which are in need of the right of way (Right of Way (ROW)) of power lines and foundations of towers of T/Ls and access roads for dams, P/S, and S/S, are utilized by fee payment with an agreement. The agreement is called the Access Agreement, while the agreement of the access road is called as Lease Agreement. The ownership is not transferred.
- The Access Agreement is like so called easement agreement. However, there are no internal guidelines in PPL for the usage limitation of landowner. The usage limitation for building houses or glowing crops and trees are not prescribed in the agreement. When trees become high after years, PPL will just clear those trees without compensation. However, there are cases that PPL compensates again for clearance of glowing coffee in Highland areas.
- The land, which is needed for ROW of power line and foundations of pole of D/Ls and access road for T/Ls, are utilized by no fee payment. PPL regards that landowners have benefits from the D/Ls and access road for T/Ls.
- The crops, trees, house and so force upon the above mentioned areas are compensated. After payment for compensation, PPL clears the crops and trees grown in the land subject to acquisition.

2) Price of Land Acquisition

The price of land acquisition is decided by negotiation between the landowner organization of ILG and PPL at the market price.

3) Access Agreement

The Access Agreement is a kind of an agreement of the right of usage for the foundations of towers of T/Ls or access roads, which are not prescribed in the PNG laws and regulations while it has been commonly used in power development like PPL implements, or telephone company of PNG.

The payment fee is decided according to the negotiation between the owner and PPL with characteristic of local condition. Payment may be one time or annual payment. One example shows that the unit price of 132kV T/L foundation is 160 kina/km^2 as of 2014, while the unit price of pole of telephone company is 10,000 kina/km^2

4) Compensation for Crops and Trees

PPL compensates crops and trees according to the unit prices which are established by Valuer General's Office

The latest unit prices schedule has been published in 2008. These unit prices in the following year are announced by the Valuer in the regions based on the commodity price growth rate in the "Value General Price Schedule for Acquisition of Trees and Plants of All Region". It is published by the Valuer Generals Office of the Department of Lands.

5) Landownership in City Areas

In principal, PNG government owns the lands in city areas such as Port Moresby and Lae. These areas are termed as "State Lease Land". However, the local clan still own lands in these cities as their traditional rights are maintained. Thus land users pay annual lease fee to the government in return the government pays annual lease fee to the traditional landowners.

Electricity distribution improvement projects generally does not cause dispute over the use of land for ROW as road or private user of land generally accept such projects.

6) Disputes over Compensation

Responsible unit for land acquisition in PPL is Cooperate Services Group, Community Support Service Unit (CSS). There have been a number of claims for resettlement and land acquisition related to the projects implemented by PPL during 40 years. These claims are mainly for compensation of the resettlement caused by Yonki Dam and Sirinvnu Dam.

(8) Land Disputes in PNG

PNG has a complex land tenure system. Difficulties arise when land is required by the state for which developers for the construction of public infrastructure and major resources extraction, agricultural, industrial and commercial projects are planned. Therefore a mechanism of ILG has been devised to allow local landowners to organize themselves, and register their land before negotiating with the project developers and the State. Major land disputes in PNG as of 2016 are shown as follows:

- Lae Port Extension Phase 2 causing resettlement is under study for environmental permit;

- Stanly Gas Pipeline Project in Western Highlands Province causing resettlement is under study for environmental permit;
- Ram Nico mining is under protest from the residents; and
- Additional compensation is claimed after fulfillment of agreements in the projects such as Yonki dam, Syrinumu dam, and a number of mining projects.

CEPA made advises to avoid land disputes as 1) The land disputes usually occur if early consultation on landowner issues are not addressed properly. Prior to obtaining permit or license from relevant government agencies including CEPA, the developer should come to agree with landowner; 2) Agreement or Minutes of Understanding (MOU) with landowners upon land acquisition or resettlement for preparing the development project provides peaceful resolution; 3) Social Mapping Studies should be carried out in order to identify the actual landowners of the project site.

(9) Local Government Involvement

CEPA makes reference of the EIS to the relevant local authorities such as Province and District in terms of the implementation of the project including land acquisition. Local Authorities such as LLGs and wards should get involved in terms of the assessment of EIS at the time of public hearing.

Local government is entitled to register disagreement of the contents of EIS at anytime before sighing the approval of Environmental Permit.

(10) Disclosure of Project Information and Public Consultation

There is a provision of information disclosure in the Environment Act 2000. CEPA will facilitate a public conferences and presentation during the public review process stage of EIA. EIS documents are open to public reading upon notification issued by the Director of CEPA. The project proponent bears the associated cost of public conferences.

CEPA will chair the public conference. EIA laws and regulations provide no specific number of times of the public conference. However, depending on the accessibility, logistics and the project proposal’s scope, any number of times of public conference would be requested to hold to the project proponent by CEPA.

After receiving the EIS, the Director of the CEPA issue an official letter requesting to the project proponent to hold a session of public hearing for those that are likely to be affected by the project activities.

Public hearing should be held with each different group of affected people such as displaced people, people affected only by land acquisition i.e. absentee landowners, downstream communities and upstream communities that are affected by the project activities.

6.4 IEE FOR THE DISTRIBUTION NETWORK IMPROVEMENT PLAN

6.4.1 PPL's Policy on the Installation of Distribution Lines

PPL maintains the following policies for installation of D/Ls, not only limited to but including urban areas where demand of electricity is much concentrated:

1) In urban areas, D/Ls are to be located on public road wherever possible. Access to construct and maintain these lines are therefore by arrangement with the local authorities only with no other third party required to be involved. In particular PPL has the authority to clear any tree growth that is impinging on the distribution infrastructure;

2) In urban areas, should D/Ls encroach on to privately owned properties, PPL will have in place formally executed access agreements;

3) Rural Electrification D/Ls are to be constructed within road easements wherever possible. Even if customary land is encroached on by the distribution infrastructure, PPL will not purchase any land outright for the project to proceed;

4) PPL will have in place formal Community Line Maintenance and Access Agreements with local communities. The feature of these agreements is that nominal agreed fixed price payments will be paid at agreed time intervals for the D/L corridor to be maintained with specified low vegetation allowed only;

5) Prior to construction of rural electrification projects funded by PPL, PPL will have in place a public awareness program with a particular emphasis on community benefits and the long term Community Line Maintenance and Access Agreements that will be put in place; and

6) For Rural Electrification projects funded by PPL, one off compensation payments for damaged economic trees and cash crops will be paid in accordance with PPL's Management of Tree Compensation Payments Policy.

As above, PPL has a clearly established policy on the compensation related to the D/L construction works. PPL would make commitment to hold public participation dialogues as D/L development plan is carried out. Where D/L has to go through rural areas, Community Line Maintenance and Access Agreements is made. PPL usually makes an agreement with a group of local residents formed as an indigenous organization in order to deal the land issues. Thus the agreement becomes an important tool for negotiation of the rural electrification plan.

6.4.2 Area of Electricity Distribution Network Improvement Plan for Lae City

(1) Immediate Improvement Plan

Fig. 6.1-1 and Fig. 6.1-2 show the suggested plan of the electricity distribution plan in terms of the improvement of supply reliability for Lae City for immediate improvement plan. As is described in the Section 6.1, the following activities take place:

1) Replacement of the existing small size conductors of 11 KV D/Ls to the standard size Grape conductors (based on the Australian Standard);

2) Replacement/upgrading of ABS and IS on the existing 11 KV D/Ls in order to avoid malfunctioning of the switching system;

3) Re-configuration of 11KV distribution network and expansion of network system i.e. a number of new D/Ls are constructed in the areas where there is no D/L at present as per Fig. 6.1-1 and Fig. 6.1-2; and

4) Replacement/upgrading of 11KV distribution facilities using grape conductors, circuit breakers within the Milford Substation of PPL in Lae City, and replacement of current transformers in order to improve feeder capacity of the electricity supply.

(2) Year 2020 Plan

Fig. 6.1-3 and Fig. 6.1-4 show the suggested plan for Distribution Network Improvement Plan in Lae City in terms of the Year 2020 improvement plan. As is described in the Section 6.1, the following activities take place:

1) Re-configuration of 11KV distribution network and expansion of network system i.e. a number of new D/Ls are constructed in the areas where there is no D/L at present as per Fig. 6.1-3 and Fig. 6.1-4; and

2) Replacement/upgrading of 11KV distribution facilities using grape conductors, circuit breakers within the Milford Substation of PPL in Lae City, and replacement of current transformers in order to improve feeder capacity of the electricity supply.

(3) Year 2030 Plan

As per the description of Chapter 5, all of D/Ls are installed as follows:

1) Lae City's urban development works are carried during the next 15 years including road networks; and

2) Upon completion of the construction works of road installation of electricity poles and D/Ls are carried out.

Assuming that all of the electricity distribution poles and electric cables are installed within the road reserve, environmental impacts induced by the D/L improvement works for the Year 2030 should remain the same as that of the Year 2020.

6.4.3 Initial Environmental Examination

Based on JICA's Environment and Social Considerations Guidelines (2010), checklist system has been employed in order to carry out IEE for the Electricity Distribution Network Improvement Plan for Lae City in terms of the immediate improvement plan is shown in Table 6.4-1 while Table 6.4-2 shows that of the Year 2020 improvement plan.

The areas of customary land occupation shown in the Fig. 6.1-1 are the areas where local residents moved in to Lae City's urban areas from the rural areas during the past decades. They are generally considered as squatters while some of them are obtaining residential status over years. However, while the construction length on the road of 1,995 m of the "2016-2" within the framework of Immediate Improvement Plan goes into the customary occupation area, no part of the private land of local residents are necessary to acquire for the Plan.

PPL's policy on the D/L construction work clearly states that participatory meeting with the local people is held at each locality in the event D/L construction work takes place.

Table 6.4-1 Environmental Checklist: Improvement of Supply Reliability for Lae City – Immediate Improvement Plan

Check Item \ Target Year		Immediate Improvement Plan				
		2016-1 (L=167m)	2016-2 (L=1,995m)	2016-3 (L=406m)	2016-4 (L=656m)	2016-5 (L=608m)
Permits and Approvals	EIA and Env. Permit	Level 1	Level 1	Level 1	Level 1	Level 1
	Explanation to Public	Level 1	Level 1	Level 1	Level 1	Level 1
Anti-pollution Measures	Air Quality	n/a	n/a	n/a	n/a	n/a
	Water Quality	n/a	n/a	n/a	n/a	n/a
	Waste	n/a	n/a	n/a	n/a	n/a
	Soil Contamination	n/a	n/a	n/a	n/a	n/a
	Noise and Vibration	n/a	n/a	n/a	n/a	n/a
	Subsidence	n/a	n/a	n/a	n/a	n/a
	Odor	n/a	n/a	n/a	n/a	n/a
	Sediment	n/a	n/a	n/a	n/a	n/a
Natural Environment	Protected Areas	n/a	n/a	n/a	n/a	n/a
	Ecosystem	n/a	n/a	n/a	n/a	n/a
	Hydrology	n/a	n/a	n/a	n/a	n/a
	Topography	n/a	n/a	n/a	n/a	n/a
	Geology	n/a	n/a	n/a	n/a	n/a
	Abandoned Sites	n/a	n/a	n/a	n/a	n/a
Social Environment	Resettlement	n/a	n/a	n/a	n/a	n/a
	Livelihood	n/a	n/a	n/a	n/a	n/a
	Living Standards	n/a	n/a	n/a	n/a	n/a
	Heritage Sites	n/a	n/a	n/a	n/a	n/a
	Landscape	n/a	n/a	n/a	n/a	n/a
	Ethnic Minorities	n/a	n/a	n/a	n/a	n/a
	Working Conditions	n/a	n/a	n/a	n/a	n/a
	Occupational Safety	n/a	n/a	n/a	n/a	n/a
Others	Impacts During Construction Period	n/a	n/a	n/a	n/a	n/a
	Accident Prevention Measures	n/a	n/a	n/a	n/a	n/a
	Monitoring	n/a	n/a	n/a	n/a	n/a

Note: 1) "Level 1" denotes "The items is classified as Level 1 activity" according to the Environmental Law 2000 of PNG i.e. EIA/permit not required.
2) "n/a" denotes "not appricable" i.e. no negative impact takes place.

Source: JICA Study Team

The areas of customary land occupation shown in the Fig. 6.1-3 are the areas where local residents moved in to Lae City's urban areas from the rural areas during the past decades. They are generally considered as squatters while some of them are obtaining residential status over years. However, while the construction length on the road of 2,338 m of the "2020-1" and 5,700 m of the "2020-2" within the framework of Immediate Improvement Plan goes into the customary occupation area, no part of the private land of local residents are necessary to acquire for the Plan.

PPL's policy on the D/L construction work clearly states that participatory meeting with the local people is held at each locality in the event D/L construction work takes place.

Table 6.4-2 Environmental Checklist: Improvement of Supply Reliability for Lae City – Year 2020 and 2030 Improvement Plan

	Target Year	Year 2020 Improvement Plan					
Check Item		2020-1 (L=2,338m)	2020-2 (L=5,700m)	2020-3 (3,304m)	2020-4 (1,436m)	2020-5 (L=2,519m)	2020-6 (L=154m)
Permits and Approvals	EIA and Env. Permit	Level 1	Level 1	Level 1	Level 1	Level 1	Level 1
	Explanation to Public	Level 1	Level 1	Level 1	Level 1	Level 1	Level 1
Anti-pollution Measures	Air Quality	n/a	n/a	n/a	n/a	n/a	n/a
	Water Quality	n/a	n/a	n/a	n/a	n/a	n/a
	Waste	n/a	n/a	n/a	n/a	n/a	n/a
	Soil Contamination	n/a	n/a	n/a	n/a	n/a	n/a
	Noise and Vibration	n/a	n/a	n/a	n/a	n/a	n/a
	Odor	n/a	n/a	n/a	n/a	n/a	n/a
Natural Environment	Protected Areas	n/a	n/a	n/a	n/a	n/a	n/a
	Ecosystem	n/a	n/a	n/a	n/a	n/a	n/a
	Hydrology	n/a	n/a	n/a	n/a	n/a	n/a
	Topography	n/a	n/a	n/a	n/a	n/a	n/a
	Geology	n/a	n/a	n/a	n/a	n/a	n/a
	Sediment	n/a	n/a	n/a	n/a	n/a	n/a
	Subsidence	n/a	n/a	n/a	n/a	n/a	n/a
	Disposal Site	n/a	n/a	n/a	n/a	n/a	n/a
Social Environment	Resettlement	n/a	n/a	n/a	n/a	n/a	n/a
	Livelihood	n/a	n/a	n/a	n/a	n/a	n/a
	Living Standards	n/a	n/a	n/a	n/a	n/a	n/a
	Heritage Sites	n/a	n/a	n/a	n/a	n/a	n/a
	Landscape	n/a	n/a	n/a	n/a	n/a	n/a
	Ethnic Minorities	n/a	n/a	n/a	n/a	n/a	n/a
	Working Conditions	n/a	n/a	n/a	n/a	n/a	n/a
	Occupational Safety	n/a	n/a	n/a	n/a	n/a	n/a
Others	Impacts During Construction Period	n/a	n/a	n/a	n/a	n/a	n/a
	Accident Prevention Measures	n/a	n/a	n/a	n/a	n/a	n/a
	Monitoring	n/a	n/a	n/a	n/a	n/a	n/a

Note: 1) "Level 1" denotes "The items is classified as Level 1 activity" according to the Environmental Law 2000 of PNG i.e. EIA/permit not required.
2) "n/a" denotes "not appricable" i.e. no negative impact takes place.

Source: JICA Study Team

CHAPTER 7

FINANCIAL AND ECONOMIC ANALYSIS OF DISTRIBUTION NETWORK IMPROVEMENT PLAN

CHAPTER 7 FINANCIAL AND ECONOMIC ANALYSIS OF DISTRIBUTION NETWORK IMPROVEMENT PLAN

7.1 SHORT TERM DISTRIBUTION NETWORK IMPROVEMENT PLAN

7.1.1 Impact of Project

Short term distribution network improvement project was planned with the objective to improve the reliability of power supply, specifically to reduce the duration of blackout. Firstly, the effect of reduction of blackout duration made possible by the Project is explained.

In the Project, LBSs will be installed in place of present ABSs, new interconnection lines added, and trunk line conductors replaced with ones of larger capacity. In the present system, when an accident occurred on a segment somewhere in the feeders, the location of the accident is searched and identified first, followed by disconnection of the feeder at somewhere upstream of the accident. The blackout of the downstream of the disconnection continues for the whole duration of the remedy work. After the implementation of the Project, the disconnection will be limited for the segment where the accident occurred, and the power in the downstream will be restored even while the remedy work is being carried out. In this way the earlier recovery of power is realized on some segments of the feeder, which reduces the blackout time in the system, as explained in Chapter 4.

Reduction of blackout time contributes to the cut of lost income and to the additional electricity sales and revenue. On the other hand, the users of electricity will benefit from the reduction of blackout time in various ways, such as;

1) Reduction of down time and loss of production in the industries,
2) Reduction of loss due to the interruption of production, additional cost of resuming the production, waste produced due to blackout of power,
3) Reduction of cost incurred in provision and operation of back-up power, etc.

Considering the frequency of occurrence of blackout in Ramu System, industrial enterprises are all equipped with back-up power facilities, and the loss of production are minimized by running their own generating facilities. Benefit 2) above depends on both the frequency and duration of blackout, but the frequency of occurrence of blackout cannot be reduced by the Project. For the same reason, industrial enterprises would not do without their own generators until the frequency of blackout becomes very low. Therefore, most of the benefit of the Project can be represented by reduction of cost incurred in operation of back-up power, specifically the fuel cost of their own generators.

To evaluate the impact quantitatively, the energy additionally supplied due to the Project was estimated in the first place.

Suppose there is a feeder line represented by the simple figure below. The feeder is segmented into three, by LBSs at "+" locations in the figure.

```
                          Seg.1        Seg.2        Seg.3
Substation  →   + ——————— + ——————— + ——————— +   ←from other feeder
```

Fig. 7.1-1 Illustration of Segmentation of Feeder by LBS

The installation of LBSs will change the duration of blackout, subject to which segment the accident occurred on, as shown in the table below.

Table 7.1-1 Differences in Duration of Blackout before/after Installation of LBS

Location of Accident	Before Installation	After Installation	Difference
Segment 1	Blackout continues on segment 1, 2 and 3	Blackout continues on segment 1	Earlier recovery in segment 2 and 3
Segment 2	Blackout continues on segment 2 and 3	Blackout continues on segment 2	Earlier recovery in segment 3
Segment 3	Blackout continues on segment 3	Blackout continues on segment 3	None

Assuming that the probabilities that an accident occur on segment 1, 2 and 3 are even, the total probability of earlier recovery of power can be obtained as shown in the table below.

Table 7.1-2 Probability of Earlier Recovery of Power by Installation of LBS

Location of Accident	Probability of Earlier Recovery= Probability of Occurrence of Accident x load on the segment recovered earlier	Total
Segment 1	1/3 × 2/3 = 2/9	2/9 + 1/9 + 0 = 1/3
Segment 2	1/3 × 1/3 = 1/9	
Segment 3	1/3 × 0 = 0	

The facts on blackout due to accidents on the feeders in Lae area are known from the records to be;

Annual occurrence of blackout	123 times
Average duration of blackout	7.6 hours
Average load on one feeder	2.1 MW

The effect of reduction of blackout duration is not for the whole 7.6 hours: it is instead the time after the earlier recovery. Therefore, the reduction of blackout duration can be estimated by the average duration subtracted by the average time required in the identification of accident location and the disconnection of that segment, which was set to be one hour, the assumption made from verbal information obtained in interviews as there were no specific records about this time.

The energy supplied additionally to customers due to the Project is thus estimated by the calculation shown below;

[Probability of earlier recovery] × [Frequency of occurrence of blackout]
× [average reduction of blackout duration] × [average load]
= 1/3 × 123 × (7.6-1) × 2.1 = 568.26 MWh

7.1.2 Financial Evaluation

The Project was evaluated from PPL's perspective.

(1) Investment Cost

Installation of LBS

The cost of installation of LBSs was estimated as discussed in Section 4.2 above, which is repeated in the table below.

Table 7.1-3 Installation Cost of LBS

Item	Quantity	Unit Price	Amount (kina)
Material cost (LBS)	59 Units	40,000 kina/unit	2,360,000
Cost of transportation (POM to Lae) and installation	10%	(Material cost)	236,000
Cost of Supervisor by manufacturer	30 Days	3333 kina/day	100,000
Cost of Supervisor's Trip	2 Trips	6,667 kina/trip	13,333
Subtotal			***2,709,333***
Contingency (10%)			270,933
Total			**2,980,266**

To make financial cost, generation-skipping tax (GST) 10% is added to the amount above.

Construction of New Interconnection Lines

The cost of constructing new interconnection lines was estimated as discussed in Section 4.2 above, which is repeated in the table below.

Table 7.1-4 Installation Cost of Interconnection Lines

Item	Quantity	Unit Price	Amount (kina)
Distribution General Cost Estimate, Urban Setting (Medium Voltage 3-phase, including Labor, Transport & Accommodation)	3.83 km	90,000 kina/km	344,700
Material cost (Grape Conductor, 3 phases)	12.60 km	6,000 kina/km	75,600
Subtotal			***420,300***
Contingency (10%)			42,030
Total			**462,330**

GST 10% is added to the amount above.

Replacement of Conductors with Higher Capacity

The cost of replacement of conductors was estimated as discussed in Section 4.2 for 15.11km long trunk lines.

Table 7.1-5 Installation Cost of High Capacity Trunk Lines

Item	Quantity	Unit Price	Amount (kina)
Distribution General Cost Estimate, Urban Setting (Medium Voltage 3-phase, including Labor, Transport & Accommodation)	15.11 km	90,000 kina/km	1,359,900
Material cost (Grape Conductor, 3 phases)	49.90 km	6000 kina/km	299,400
Subtotal			***1,659,300***
Contingency (10%)			165,930
Total			**1,825,230**

The trunk line in question requires the replacement of conductors, or increase of capacity, to function as part of this project. This trunk line passes through the areas where rapid increase in electricity demand is expected and the capacity of the conductors used will become soon insufficient. The cost of replacement of conductors will have to be borne by the developers of the areas when they apply for new connections, as stipulated in ERC. Therefore, the increase of conductor capacity is a pre-requisite of the Project and its cost is not included in the project cost.

The financial cost of the Project is summarized in the table below.

Table 7.1-6 Investment Cost of Short Term Distribution Improvement Plan

Description	Cost
1) Introduction of LBSs	2,980,266
2) Construction of Interconnection	462,330
tax (GST 10%)	344,260
Total	3,786,856

Unit: Kina

As for the cost of operation and maintenance of the equipment installed in the Project, there would be no cost incurred in addition to the current OM cost. However, to supply energy additionally, there will be additional generation of energy necessary. Therefore, the cost of generation for the energy additionally supplied should be included as part of the financial cost of the Project. From the analyses described in the previous section, the average generation cost as a weighted average of hydro and thermal power generation in Ramu System was calculated at Kina 0.09101 per kWh.

Meanwhile, the energy generated additionally would not be 568.26 MWh mentioned in Section 7.1.1, but the generation end energy before the energy loss in the System. The System loss calculated for 2014 was 23.6 %, and necessary energy additionally generated should be 743.80 MWh.

(2) Additional Sales by Project

As mentioned above, there would be additional sales of energy due to the Project, which was estimated to be 568.26 MWh per year. Meanwhile, the average tariff in Ramu System calculated for 2014 was toea73.2 per kWh.

The product of these two values will be the additional financial income due to the Project.

(3) Financial Analysis

Financial analysis compares its product, Financial Internal Rate of Return (FIRR) with an index of the cost of capital provision, Weighted Average Cost of Capital (WACC).

FIRR calculated here was a Project IRR, which is obtained through the comparison of financial expenditures and financial income for 25 years (plus one year of project implementation period), without identifying the composition of capital sources.

WACC, on the other hand, was calculated with the assumptions such as,

Capital composition	Loan: 70% at interest rate 9%, Own fund: 30% at the expected dividend rate 15%
Corporate tax rate	30%
Annual inflation rate	5%

WACC obtained was 2.4% as shown in the table below. The Project should produce an FIRR higher than this to be financially viable.

Table 7.1-7 Calculation of WACC

Component	Loan	Equity
Proportion	70%	30%
Nominal Cost (Interest rate & return)	9.00%	15.00%
Income Tax Rate	30%	
Tax-adjusted Nominal Cost	6.30%	10.50%
Inflation Rate	5.00%	5.00%
Real Cost	1.24%	5.24%
Weighted component of WACC	0.87%	1.57%
WACC	2.4%	

Other variables set for the analysis were;

Evaluation period	25 years
Price estimation year	2014

The FIRR obtained was 7.8 %.

The FIRR is well above WACC, and the Project is shown to be financially viable to the project proponent, PPL.

The calculation of FIRR is presented together with that of Economic Internal Rate of Return (EIRR) in the table exhibited in the end of this section.

7.1.3 Economic Evaluation

Economic evaluation is different from financial evaluation in that it is a comparison between the economic cost and benefit of the Project to show if the Project brings about a positive impact to the regional economy of PNG.

(1) Economic Cost of Investment

In financial evaluation, the financial cost of the investment was obtained by adding a tax (GST) to the project cost estimated in 4.2 above. Tax is a transfer of money within the PNG economy, therefore, is not included in the economic cost of the Project. Also, other cost elements such as labor cost should be evaluated at shadow prices which reflect the opportunity costs of that good or service. Labor cost in particular may entail distortion of the market, with relatively large discrepancy between its market price and opportunity cost. This can be solved by using a standard conversion factor (SCF), multiplying the market pricy by SCF to obtain the opportunity cost. However, in the evaluation of the economic cost here, the market price (the estimated cost) was used as it is, to be on a conservative side.

Aside from the investment cost, there will be a cost necessary to generate the additional energy to be supplied to customers every year. This cost was assumed at the same value as in the financial cost.

(2) Economic Benefit of Project

As discussed in Section 7.1.1 above, the benefit of the project is the reduction of the duration of blackouts, which accrues to customers in the form of the reduction of own generation cost. This reduction was estimated as shown below.

1) Thermal efficiency of generating units owned by customers was assumed to be the same as the average thermal efficiency of PPL's diesel power plants,

2) The fuel prices should be evaluated by regional market prices, which are in general higher than the PPL's procurement prices for the bulk purchase.

Market prices of fuel are published by ICCC on monthly basis. ICCC's published prices were compared with PPL's purchase prices in Lae for the period of December 2013 to December 2014, and the average ratio of ICCC's market prices to PPL's Lae prices was found to be 1.27. This ratio was multiplied to PPL's average diesel generation cost for Ramu System, and the unit cost Kina 1.0097 per kWh was obtained.

The economic benefit of the Project was evaluated as the reduction of own generation cost calculated by using the values mentioned above.

(3) Economic Analysis

Economic analysis compares its product, EIRR with an index of the socially expected return on projects, Social Discount Rate (SDR). EIRR was obtained through the comparison of economic cost and benefit for 25 years (plus one year of project implementation period). Also, Economic Net Present Value (ENPV) was calculated by balances of economic benefit and cost for the whole period discounted with SDR. The SDR chosen for the analysis was 12 %.

Obtained EIRR and ENPV were as follows,

EIRR = 14.2%
ENPV = K 526,000

This result shows that the Project will be beneficial to the regional economy of PNG.

Short-term Distribution Project Financial and Economic Analysis

Project Cost		
1) Introduction of LBSs	2,980,266	K
2) Construction of Interconnection	462,330	K
tax (GST 10%)	*344,260*	K
total	3,786,856	K
OM Cost		
OM Cost Fixed (nothing additional)	0.0000	
OM Cost Variable (generation cost)	0.0910	K/kWh
Assumptions for Financial Analysis		
Energy additionally required (sold)	568.26	MWh
Loss	23.60%	
Energy additionally generated	743.80	MWh
OM Cost (=Generation cost)	67.7	K1,000
Average tariff	0.7320	K/kWh
Revenue	416.0	K1,000
WACC		
Component	Loan	Equity
Proportion	70%	30%
Nominal Cost (Interest rate&return)	9.00%	15.00%
Income Tax Rate	30%	
Tax-adjusted Nominal Cost	6.30%	10.50%
Inflation Rate	5.00%	5.00%
Real Cost	1.24%	5.24%
Weighted component of WACC	0.87%	1.57%
WACC	2.4%	
Assumptions for Economic Analysis		
Cost of Alternative Generation	1.0097	K/kWh
Annual Economic Benefit	573.7	K1,000
Standard Conversion Factor	1	
Social Discount Rate (SDR)	12.0%	

		Financial Schedule (simple Cash Flow)				Economic Schedule			
	Year	Investment cost	OM Cost	Energy Sales	Balance	Benefit	Cost	Balance	Discounted
-1									
0		-3,786.9			-3,786.9		-3,442.6	-3,442.6	-3,442.6
1			-67.7	416.0	348.3	573.7	-67.7	506.1	451.8
2			-67.7	416.0	348.3	573.7	-67.7	506.1	403.4
3			-67.7	416.0	348.3	573.7	-67.7	506.1	360.2
4			-67.7	416.0	348.3	573.7	-67.7	506.1	321.6
5			-67.7	416.0	348.3	573.7	-67.7	506.1	287.1
6			-67.7	416.0	348.3	573.7	-67.7	506.1	256.4
7			-67.7	416.0	348.3	573.7	-67.7	506.1	228.9
8			-67.7	416.0	348.3	573.7	-67.7	506.1	204.4
9			-67.7	416.0	348.3	573.7	-67.7	506.1	182.5
10			-67.7	416.0	348.3	573.7	-67.7	506.1	162.9
11			-67.7	416.0	348.3	573.7	-67.7	506.1	145.5
12			-67.7	416.0	348.3	573.7	-67.7	506.1	129.9
13			-67.7	416.0	348.3	573.7	-67.7	506.1	116.0
14			-67.7	416.0	348.3	573.7	-67.7	506.1	103.5
15			-67.7	416.0	348.3	573.7	-67.7	506.1	92.5
16			-67.7	416.0	348.3	573.7	-67.7	506.1	82.5
17			-67.7	416.0	348.3	573.7	-67.7	506.1	73.7
18			-67.7	416.0	348.3	573.7	-67.7	506.1	65.8
19			-67.7	416.0	348.3	573.7	-67.7	506.1	58.8
20			-67.7	416.0	348.3	573.7	-67.7	506.1	52.5
21			-67.7	416.0	348.3	573.7	-67.7	506.1	46.8
22			-67.7	416.0	348.3	573.7	-67.7	506.1	41.8
23			-67.7	416.0	348.3	573.7	-67.7	506.1	37.3
24			-67.7	416.0	348.3	573.7	-67.7	506.1	33.3
25			-67.7	416.0	348.3	573.7	-67.7	506.1	29.8
									[figures in Kina 1,000]
Project IRR (FIRR)					7.8%				
EIRR								14.2%	
Economic NPV									526

7.2 SHORT TERM DISTRIBUTION NETWORK IMPROVEMENT PLAN WITH SEQUENTIAL SWITCHING

7.2.1 Impact of Project with SSS

In this section, we consider the effect of the short term distribution network improvement project discussed in the previous section 7.1 expanded with the additional introduction of Sequential Switching System (hereinafter referred to as "SSS").

The effect is already outlined in Section 4.2.2. Specifically, the impact to be added by the introduction of SSS is explained in two variables;

- Fault segment can be located in shorter time,

- The power along the segment(s) on the source side (substation side) of the fault segment can be restored in very short time.

For the analysis of the impact, two variables were added while the method is basically the same, which is explained below.

First we define time variables related to restoration of power;

- Time Necessary for Physically Fixing Fault (present Blackout Duration): A,
- Time Necessary for Locating Fault without SSS: B,
- Time Necessary for Locating Fault with SSS: b,
- Time Necessary for Restoring Power along Substation Side with SSS: c,

We use the same model of feeder.

```
                         Seg.1          Seg.2          Seg.3
Substation   →   + ———————— + ———————— + ———————— +   ←from other feeder
```

Suppose a fault occurs in Segment 1. The time required for restoration of power along each segment can be expressed with variables introduced above,

	without Project	with project	Effect of project
Seg.1	A	A	nil
Seg.2	A	b	A-b
Seg.3	A	b	A-b
total	3A	A+2b	2(A-b)

If a fault occurs in Segment 2, then the time required for restoration of power along each segment are,

	without Project	with project	Effect of project
Seg.1	B	c	B-c
Seg.2	A	A	nil
Seg.3	A	b	A-b
total	2A+B	A+b+c	(B-c+A-b)

If a fault occurs in Segment 3, similarly,

	without Project	with project	Effect of project
Seg.1	B	c	B-c
Seg.2	B	c	B-c
Seg.3	A	A	nil
total	A+2B	A+b+c	2(B-c)

As the probability of a fault occurring on each of Segment 1, 2 and 3 is 1/3, we have the expectation of average reduction of blackout duration as;

[A + B – b - c].

Having a variable P stands for the power (load) of the feeder (then the load along one segment is 1/3P), we have the expectation of the energy provided additionally due to the project with SSS, for one incident of blackout as;

1/3 • P • [A + B – b - c].

Then we find the quantitative impact of the project with SSS, that is the energy supplied additionally to customers, as in the formula shown below;

[Expectation of Energy Supplied Additionally]
= [frequency of Occurrence of Blackout] x 1/3 • P • [A + B – b - c]

Assuming the variables;

P : Power(Load) of the feeder	2.1	[MW]
A : Average Duration of Blackout	7.6	[hr]
B : Time for Locating Fault	1.0	[hr]
b : Time for Locating Fault with SSS	0.5	[hr]
c : Time for Restoring Power on SS Side	0.017	[hr] (= 1 minute)

we obtain

[Expectation of Energy Supplied Additionally] = 696.0 [MWh].

This method is perfectly compatible with the analysis in Section 7.1.1 if we redefine the time variables as B = b = c.

7.2.2 Financial and Economic Evaluation

(1) Investment Cost

The project cost is increased from that without the introduction of SSS.

Table 7.2-1 Investment Cost of Short Term Distribution Improvement Plan with SSS

Description	Cost
1) Introduction of LBSs	2,980,266
2) Intro. of Sequential Switching	851,366
3) Construction of Interconnection	462,330
tax (GST 10%)	429,396
Total	4,723,358

Unit: Kina

(2) Additional Sales by Project

As mentioned above, the additional sales of energy due to the Project is increased from that without the introduction of SSS to 696.0 MWh.

(3) Financial Analysis

Other than the investment cost and the additional energy, all the other things are the same as in the financial analysis for the project without SSS.

The FIRR obtained was 7.6 %, slightly lower than the one for the project without SSS but the conclusion is the same: the Project with SSS is financially viable to the project proponent, PPL.

The calculation of FIRR is presented together with that of EIRR in the table exhibited in the end of this section.

(4) Economic Analysis

Economic evaluation of the Project with SSS is very much similar to the one for the Project without SSS. Therefore, only the results are shown below;

EIRR = 13.9 %
ENPV = K 567,000

The EIRR is a little lower than that for Project without SSS, but the ENPV is a little expanded by the larger size (the investment cost) of the Project with SSS.

Short-term Distribution Project with SSS: Financial and Economic Analysis

Project Cost		
1) Introduction of LBSs	2,980,266	K
2) Intro. of Sequencial Switching Sys.	851,366	K
3) Construction of Interconnection	462,330	K
tax (GST 10%)	*429,396*	K
total	4,723,358	K
OM Cost		
OM Cost Fixed (nothing additional)	0.0000	
OM Cost Variable (generation cost)	0.0910	K/kWh
Assumptions for Financial Analysis		
Energy additionally required (sold)	695.975	MWh
Loss	23.60%	
Energy additionally generated	910.96	MWh
OM Cost (=Generation cost)	82.9	K1,000
Average tariff	0.7320	K/kWh
Revenue	509.5	K1,000
WACC		
Component	Loan	Equity
Proportion	70%	30%
Nominal Cost (Interest rate&return)	9.00%	15.00%
Income Tax Rate	30%	
Tax-adjusted Nominal Cost	6.30%	10.50%
Inflation Rate	5.00%	5.00%
Real Cost	1.24%	5.24%
Weighted component of WACC	0.87%	1.57%
WACC	2.4%	
Assumptions for Economic Analysis		
Cost of Alternative Generation	1.0097	K/kWh
Annual Economic Benefit	702.7	K1,000
Standard Conversion Factor	1	
Social Discount Rate (SDR)	12.0%	

	Financial Schedule (simple Cash Flow)				Economic Schedule			
Year	Investment cost	OM Cost	Energy Sales	Balance	Benefit	Cost	Balance	Discounted
-1								
0	-4,723.4			-4,723.4		-4,294.0	-4,294.0	-4,294.0
1		-82.9	509.5	426.5	702.7	-82.9	619.8	553.4
2		-82.9	509.5	426.5	702.7	-82.9	619.8	494.1
3		-82.9	509.5	426.5	702.7	-82.9	619.8	441.2
4		-82.9	509.5	426.5	702.7	-82.9	619.8	393.9
5		-82.9	509.5	426.5	702.7	-82.9	619.8	351.7
6		-82.9	509.5	426.5	702.7	-82.9	619.8	314.0
7		-82.9	509.5	426.5	702.7	-82.9	619.8	280.4
8		-82.9	509.5	426.5	702.7	-82.9	619.8	250.3
9		-82.9	509.5	426.5	702.7	-82.9	619.8	223.5
10		-82.9	509.5	426.5	702.7	-82.9	619.8	199.6
11		-82.9	509.5	426.5	702.7	-82.9	619.8	178.2
12		-82.9	509.5	426.5	702.7	-82.9	619.8	159.1
13		-82.9	509.5	426.5	702.7	-82.9	619.8	142.0
14		-82.9	509.5	426.5	702.7	-82.9	619.8	126.8
15		-82.9	509.5	426.5	702.7	-82.9	619.8	113.2
16		-82.9	509.5	426.5	702.7	-82.9	619.8	101.1
17		-82.9	509.5	426.5	702.7	-82.9	619.8	90.3
18		-82.9	509.5	426.5	702.7	-82.9	619.8	80.6
19		-82.9	509.5	426.5	702.7	-82.9	619.8	72.0
20		-82.9	509.5	426.5	702.7	-82.9	619.8	64.3
21		-82.9	509.5	426.5	702.7	-82.9	619.8	57.4
22		-82.9	509.5	426.5	702.7	-82.9	619.8	51.2
23		-82.9	509.5	426.5	702.7	-82.9	619.8	45.7
24		-82.9	509.5	426.5	702.7	-82.9	619.8	40.8
25		-82.9	509.5	426.5	702.7	-82.9	619.8	36.5
								[figures in Kina 1,000]
Project IRR	(FIRR)			7.6%				
EIRR							13.9%	
Economic NPV								567

CHAPTER 8

TECHNICAL GUIDANCE FOR DISTRIBUTION NETWORK

CHAPTER 8 TECHNICAL GUIDANCE FOR DISTRIBUTION NETWORK

8.1 SELECTION OF OJT SITE AND WORK PLANNING

8.1.1 Purpose of OJT

The purpose of the OJT (on-the-job training) in this Project is to have the distribution team in Lae acquire the technical skills and maintenance items currently thought to be insufficient for the maintenance and management of the distribution network. To achieve the purpose effectively with a limited teaching period and advisory personnel, the technical skills and maintenance items are selected with care based on the problems revealed by the site survey in addition to the initial assumptions.

8.1.2 Selection of OJT Site

Among the distribution network sites in the Lae area (Lae city, Nadzab, Erap, and Taraka), the distribution network in Lae city, a demand center with dense network activity, is selected as OJT site. Increase of the demand for future 2030 is expected in Lae city, as described in the long-term distribution plan. It is therefore necessary to construct new distribution lines accordingly. There are many kinds of customers, and the new offer for connection is expected in Lae area. In view of this, and the OJT contents described later, the Lae area can be regarded as an appropriate OJT site.

8.1.3 Work Plan

The following items were planned in the initial stage of this survey

[Initial plan]

- ✓ To offer advice on voltage control and power factor management, etc.
- ✓ To instruct how to put priority order on each feeder in consideration of feeder load
- ✓ To instruct purpose of use and basis motion of every protection relay instruments
- ✓ To instruct concept of preventive maintenance and predictive maintenance
- ✓ To develop regulations related to distribution network operation

However, as the survey of the distribution network in the Lae area (mainly described in Chapter 2) proceeded, facts that were unforeseen and different from the initial assumptions were revealed.

Under these circumstances, in order to perform effective OJT that matches the actual conditions of the distribution network in the Lae area, technical guidance items to be carried out in this OJT are selected with care. Specifically, the need for the implementation of items assumed in the initial plan is determined based on the results of our site survey. The results are shown in Table 8.1-1.

Table 8.1-1 Consideration of Work Plan

Initial plan	Actual condition of the distribution network in Lae	Selection of work plan
To offer advice on voltage control and power factor management, etc.	The Power Factor was actually measured in each feeder. The results range from 0.81~0.90. (Pr2 P.2-91). On the other hand, FYPDP states the following: Distribution Capacitors will be employed where required to (omission) maintain a power factor of at least 0.90 at the originating point of the feeder. (P.33) PPL understands that the electricity price plan to improve the PF (If the PF is poor, a penalty is imposed) is effective. However, there are no such plans.	According to the result of the PF measurement and the site survey, PPL cannot take effective measures to improve the PF. It will be necessary to offer advice on power factor management. → "necessary"
	Voltage in the substation is automatically regulated by a tap changer in the main transformer. (Part B 2-104&108) The voltage at the 11kV bus in the substation is controlled within the limits of normal operation.	According to the result of voltage measurement, there is no significant problem in voltage control. Priority is low. → "not necessary"
To instruct how to put priority order on each feeder in consideration of feeder load	When implementing load shedding, PPL put priority order on each feeder (Part A 7-26, Part B 2-37). The PNG Grid Code describes "Automatic Under Frequency Load Shedding" (AUFLS) to cut off each feeder according to the priority determined beforehand.	According to the result of the site survey, there is no significant problem in the order of priority on each feeder in terms of feeder load. Moreover this AUFLS to the feeders will not be necessary after the power source and load are balanced in the future. → "not necessary"
To instruct purpose of use and basis motion of every protection relay instruments	The overview of the distribution line protection system of the Lae area indicated above shows no problems in terms of configuring the protection system equipment. (Part B 2-40)	According to the result of the site survey, there is no significant problem in the protection relay system. Priority is low. → "not necessary"
To instruct concept of preventive maintenance and predictive maintenance	There are no concepts of preventive maintenance and predictive maintenance[1]. Only breakdown maintenance is carried out.	Preventive maintenance is assumed to be premature for PPL, considering its management of the distribution network. It appears that it would be difficult to apply predictive maintenance to the distribution network because there are almost no examples. → "not necessary"
To develop regulations related to distribution network operation	When a distribution line fault occurs, power is not sent from the neighboring section. That situation will be improved by the Short-term distribution network improvement plan (Part B, Chapter 4)	It will be necessary to instruct trainees on the method of operation accompanied by the installation of the new LBS in the short-term distribution network improvement plan. → "necessary"
New necessary item (To instruct trainees on appropriate response to connection offers from new customers and management in load distribution transformers)	The main incentive to enhance the distribution network is generally not to increase energy (Wh) but to increase power (W). One of the most important matters in the distribution network is standardization (capacity per one feeder, etc.). In the enhancement of facilities, it will be important to manage the number of HV Feeders, distribution transformers, and so on according to the increase of power (W). From a long-term viewpoint, the current enhancement of the Lae distribution network cannot be considered rational, because the network enhancement takes place after a problem occurs.	The long-term plan to enhance the distribution network is made based on assumed demand in 2030. Appropriate response to connection offers from new customers will be indispensable. → "necessary"
		Management in load distribution transformers is not properly carried out by PPL → "necessary"

1 Predictive maintenance (PdM) techniques are designed to help determine the condition of in-service equipment in order to predict when maintenance should be performed. This approach promises cost savings over routine or time-based preventive maintenance, because tasks are performed only when warranted. However it is necessary to evaluate the condition of equipment by performing periodic or continuous (online) equipment condition monitoring. (Reference : https://en.wikipedia.org/wiki/Predictive_maintenance)

As a result of Table 8.1-1, the following items are selected in this OJT

[Work plan after site survey]

- ✓ To offer advice on power factor management.
- ✓ To develop regulations related to distribution network operation
- ✓ To instruct trainees on appropriate response to connection offers from new customers
- ✓ To instruct trainees on management in load distribution transformers

Based on the above work plan after the site survey, concrete contents and a detailed schedule for OJT will be arranged at the next 6th site survey through discussion with PPL. As mentioned in the overall schedule, the OJT was conducted from May to June 2016.

8.2 ON-THE-JOB TRAINING

8.2.1 First OJT

First OJT consisted of on-site training of power quality data measurement and training in the class. This OJT was conducted on March 2016.

(1) On-site training

On-site training for data measurement was conducted in the sites of Lae area. The measurement work is a series of work that consist of installation and remove of measuring equipment, measurement, collection of data. The way of setting sensors for current and voltage measurement according to the condition of the site equipment was explained.
Through several times of measurement training at Taraka substation and Lae city sites in the 1st OJT, the trainee came to carry out the measurement almost by themselves.

< Outline of the data measurement training >

- Measuring equipment:	power quality analyzer, Hioki PW3198: two sets
- Site of measurement:	substation (Taraka) and distribution transformers (markets, communication carrier etc.)
- Measured items:	power factor, active power, reactive power

Fig. 8.2-1 Measurement at Taraka Substation

Fig. 8.2-2 Measurement at a Transformer

(2) Training in the class

Lecture and exercise on the outline of pf management and the basic calculation on pf improvement were conducted to make the trainee understand the benefit of pf improvement.

1) Outline of pf management

- Definition of pf
- Causes of low pf
- Benefit of pf improvement
- Measure for pf improvement
- Reflection of pf for the electrical bill (example in Japan)

2) Theory of calculation on pf improvement (single load system model)

- Calculation of current, power loss, voltage drop in the model 11kV distribution system (single load)
- Calculation of effect of pf improvement (reduction of power loss and voltage drop)
- Calculation of pf at the distribution feeder (using active power and reactive power indicated on the substation relay panel)

3) Practice of calculation on pf improvement (single load system model)

- Comparison of the effect of pf improvement by the model condition; load capacity and distance from the substation.
- Calculation of the capacity of reactive power compensation equipment required to improve the value of pf.
- Cost effect evaluation on pf improvement (model calculation of equipment cost vs. cost reduction of loss kWh using assumed cost)

4) Outline of regulations related to distribution network operation

- Load distribution of each existing distribution power line.

5) Outline of appropriate response to connection offers from new customers

- Necessity of load management of existing distribution transformer
- Management of measurement load data of distribution transformer.
- Several trainees explained about the calculation process of the power loss and voltage drop in the model distribution line. Though there were some minor mistakes in their calculations, the process of calculation was well understood.
- Load data measured at an OJT site was used for the calculation practice to help understanding the change of the customer’s load operation condition presumed from the load curve.

8.2.2 Second OJT

Second OJT was conducted on June 2016.

(1) On-site training of data measurement (checking the assignment for PPL)

PPL conducted on-site measurement by their efforts for the assignment after 1st OJT. The result of their activity was checked in the 2nd OJT.

1) Result of the on-site measurement by the trainees

In the period between 1st and 2nd OJT, on-site measurement was carried out at the place as in below.

- Substation feeder — 2 lines (at Taraka substation)
- Distribution transformer (Customer) — 5 places (Large load customers such as factories and supermarkets)

Collection, saving and exportation of the data to the excel format were carried out without problem. There were some load data recorded in negative value which caused by setting a sensor for opposite direction. Trainees noticed the error when checking the recorded data and corrected the sensor setting so the data was measured normally after the correction.

2) Processing of collected data

The trainee made a presentation about load data measured on-site (Fig. 8.2-3). A Load curve graph with pf transition drawn by using MS excel (Fig. 8.2-4) was shown. Explanation for the graph was as follows.

- This distribution line, Taraka#4, has a long trunk line and heavy load so the voltage drop and loss in the HV line tends to be large.
- The peak load of the day was recorded in the evening.
- The value of pf at the feeder point is in relatively narrow range of 0.82 to 0.88 which is a result of the similar fluctuation tendency of active power and reactive power.
- As for the average value of pf, measured value of pf=0.85 satisfies the standard lower limit of pf=0.8 so not an urgent issue for now but it should be improved to 0.9 in the future.

Fig. 8.2-3 Presentation on the Measured Data

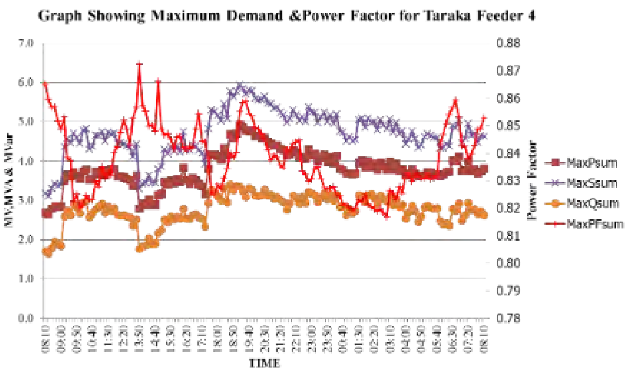


Fig. 8.2-4 Example of a Load Curve (Taraka #4)

Through checking the action for the assignment, it is shown that the PPL trainees have learned the skills for carrying out measurement and processing of the data.

(2) Training in the class

Aiming enhancement of the trainee's ability for technical investigation concerned to pf improvement, the 2nd OJT in the class was conducted mainly with the lecture and practice of calculation on pf improvement using more complexed system model than that in the 1st OJT.

1) Data processing of measured data

- Graph chart of the measured data (load curve and pf curve),
- Information from the load data,
- Characteristic values of the load data,
- Reactive power of compensation necessary for the target pf value.

2) Theory and practice of calculation on pf improvement (two loads system model)

- Comparison of the effect of pf improvement by model condition; capacity and position (end concentrated / load point) of the shunt capacitor installation,
- Notice for over compensation of reactive power in the distribution line which can induce leading current causing voltage rise and increase in power loss.

3) Theory and practice of calculation on pf improvement (three loads system model)

The way of examination for the two loads system model was developed for the three loads model.

4) Theory and practice of calculation on pf improvement (using MS excel system model)

Calculation work of pf gets complicated as the number of loads in the distribution system increases. Therefore, calculation method by simple modeling of distribution system using MS excel was introduced in the 2nd OJT which enables the execution of this work effectively. Items explained were as follows.

- Theoretical formula for model calculation,
- Assumptions for the modeling,
- Calculation procedure in MS excel,
- Procedure of modeling (example of Taraka#4).

5) Case study

A comparative review of measures for a voltage drop issue in a model distribution line was examined.

6) Future work for the improvement of pf

- Technical support for the improvement of pf in customers' load,
- Rational design for installation of shunt capacitors,
- Maintenance of distribution equipment data and load data which are the base of technical study of pf improvement.

Fig. 8.2-5 Training in the Class
(Explanation by a trainee on a calculation practice)

Through the OJT as described in above, technical skill of the trainee for quantitative examination on pf improvement had been enhanced. As a result of it, for the improvement of pf in the future, significance of such items as technical study and maintenance of base data were also understood.

8.2.3 Third OJT

Third OJT was conducted on July 2016.

In addition to the overall review of OJT, following training items were conducted in the third OJT;

- Training of load change in distribution line,
- Lecture about future work regarding load data including update of the data,
- Training of load managing including consideration by utilizing the data,
- Preparation of the management sheet of distribution transformers.

8.3 CONCLUSION OF ON-THE-JOB TRAINING

Through the OJT, basic skills and knowledges for the maintenance and management of the distribution network was improved as follows, which would help carrying out the work in PPL distribution team in Lae more effectively.

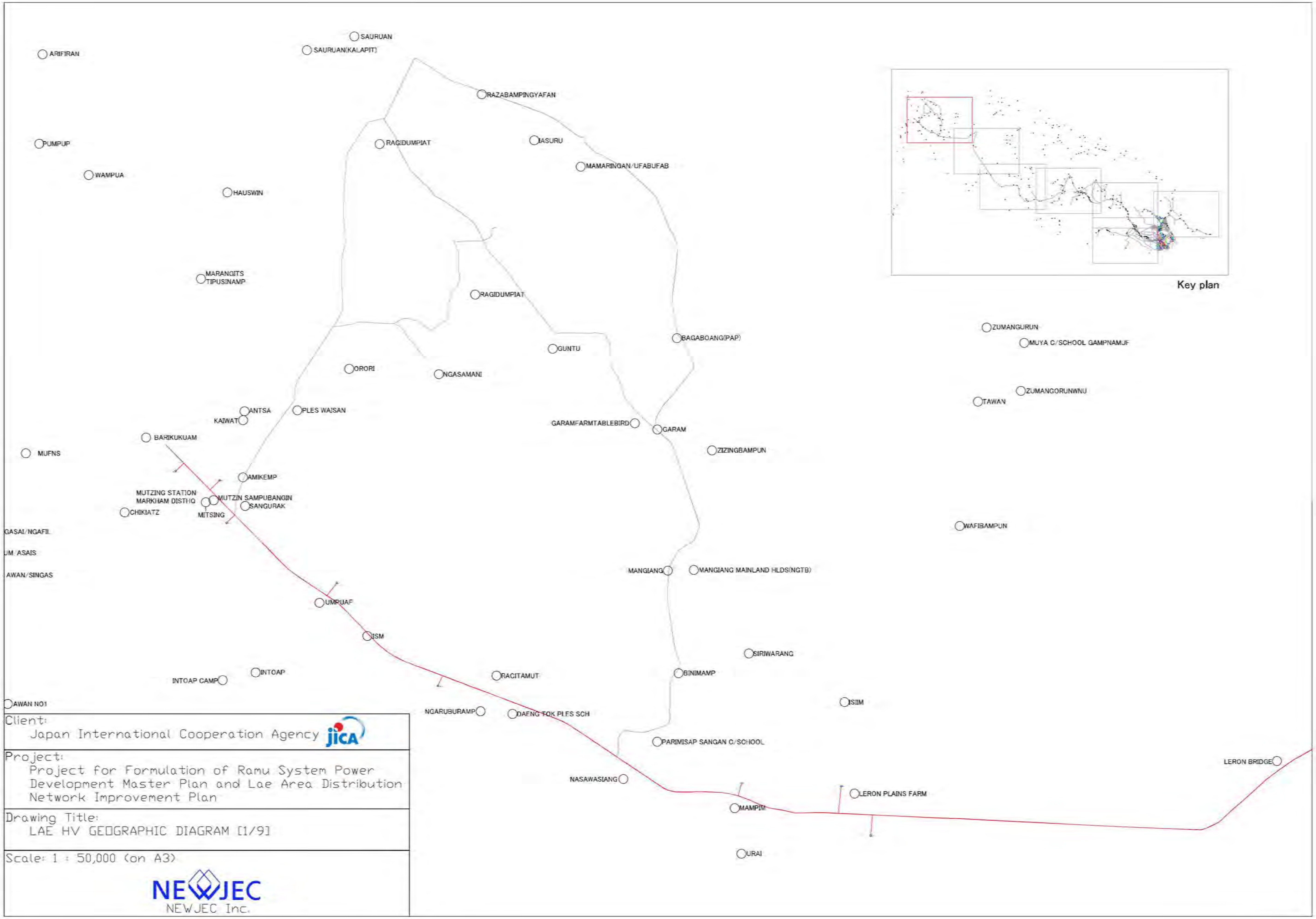
1) Through the on-site training, trainees of PPL had learned the skill for carrying out data measurement and data processing concerned to the maintenance and management of the distribution network.

2) Through the training in the class, they had learned the benefit of distribution network improvement and their ability for the technical study to estimate the effect had been improved. Consequently, they had also recognized the significance of the efforts for the improvement of the maintenance and management of distribution network in the future.

APPENDIX-B

Appendix B-1

The H.V. Geographic Operating Diagram in Rural Area (Draft)



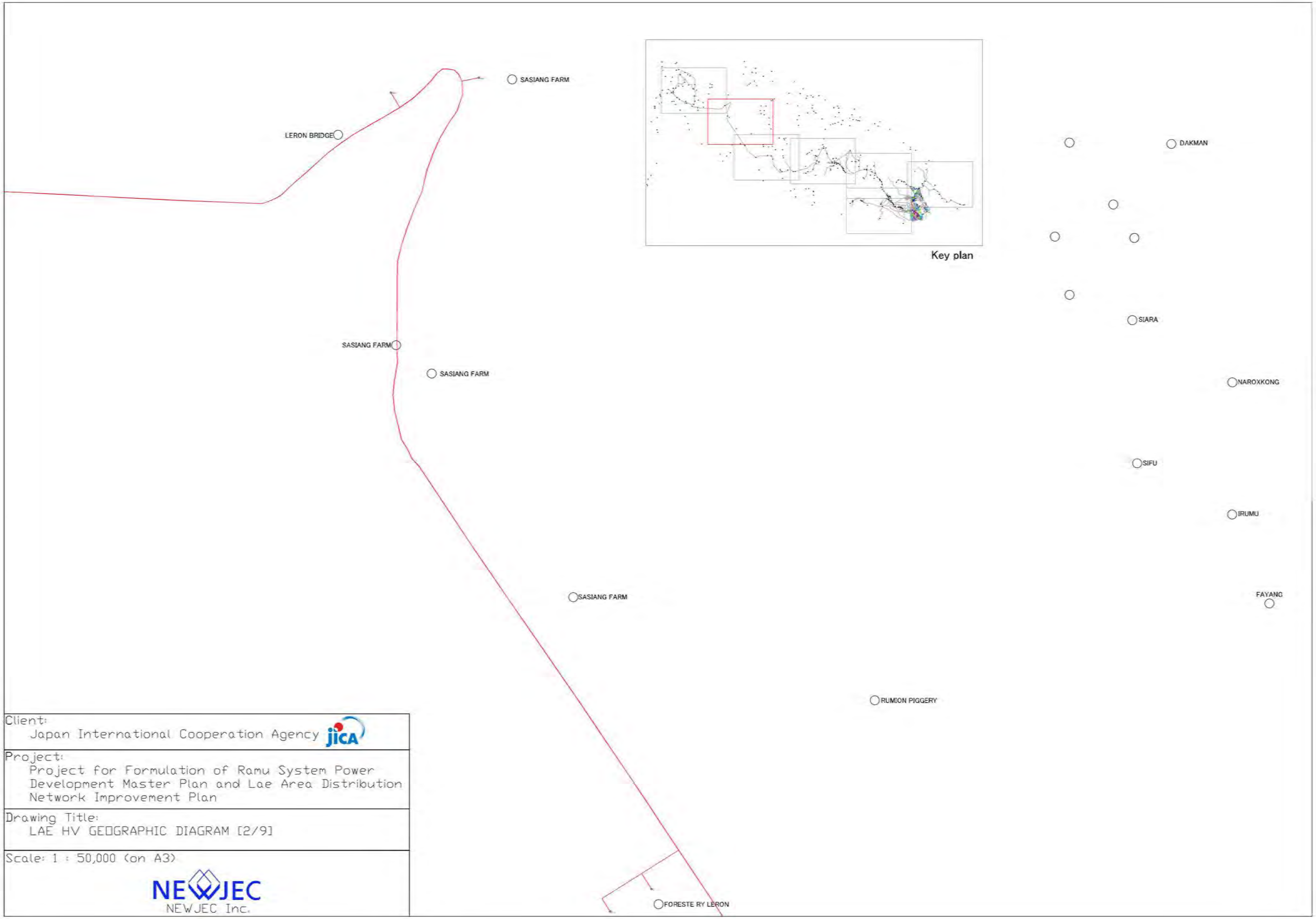
Client:
Japan International Cooperation Agency

Project:
Project for Formulation of Ramu System Power Development Master Plan and Lae Area Distribution Network Improvement Plan

Drawing Title:
LAE HV GEOGRAPHIC DIAGRAM [1/9]

Scale: 1 : 50,000 (on A3)

NEWJEC Inc.



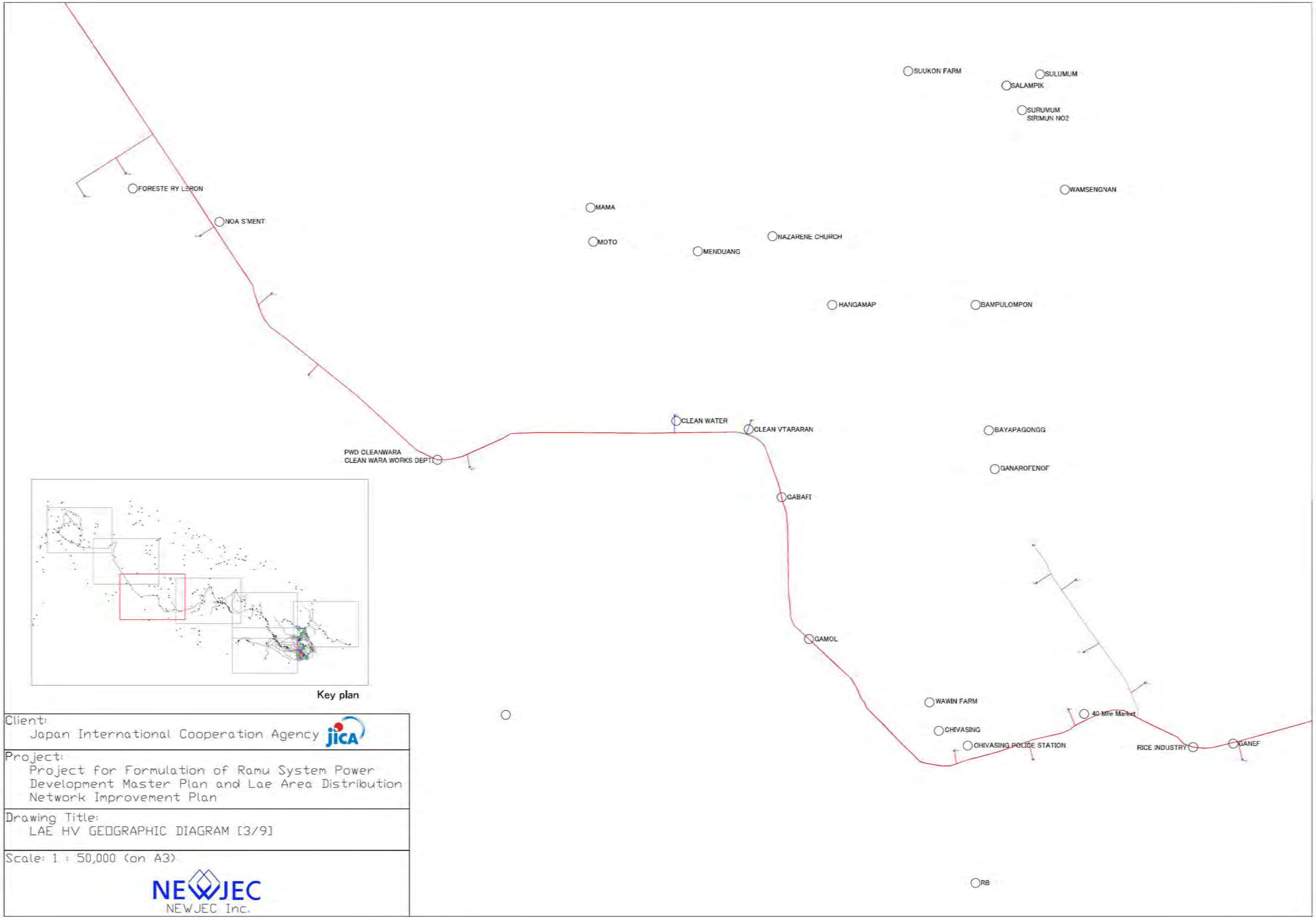
Client:
Japan International Cooperation Agency JICA

Project:
Project for Formulation of Ramu System Power Development Master Plan and Lae Area Distribution Network Improvement Plan

Drawing Title:
LAE HV GEOGRAPHIC DIAGRAM [2/9]

Scale: 1 : 50,000 (on A3)

NEWJEC
NEWJEC Inc.



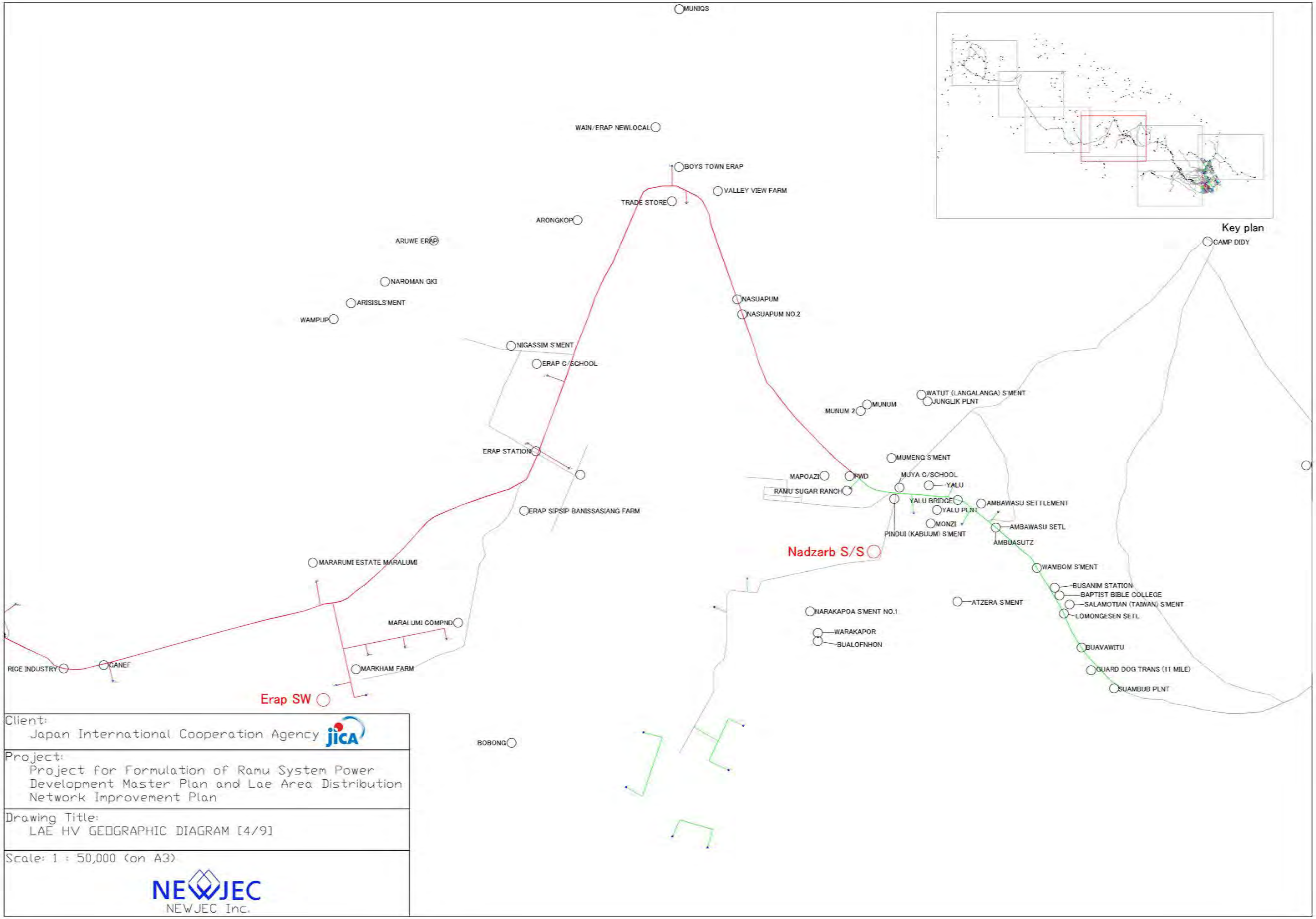
Client:
Japan International Cooperation Agency

Project:
Project for Formulation of Ramu System Power Development Master Plan and Lae Area Distribution Network Improvement Plan

Drawing Title:
LAE HV GEOGRAPHIC DIAGRAM [3/9]

Scale: 1 : 50,000 (on A3)

NEWJEC Inc.



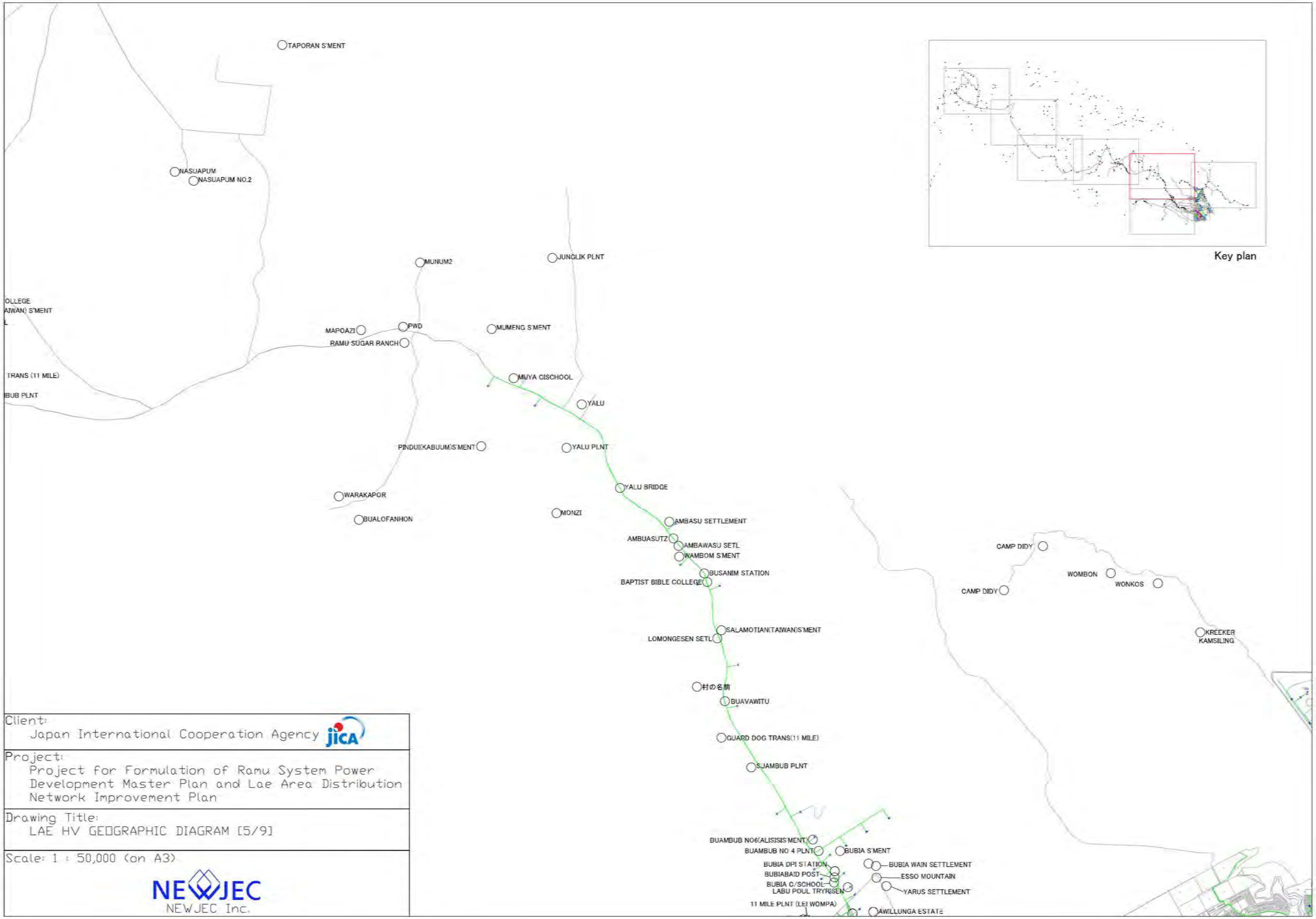
Client:
Japan International Cooperation Agency

Project:
Project for Formulation of Ramu System Power Development Master Plan and Lae Area Distribution Network Improvement Plan

Drawing Title:
LAE HV GEOGRAPHIC DIAGRAM [4/9]

Scale: 1 : 50,000 (on A3)

NEWJEC Inc.



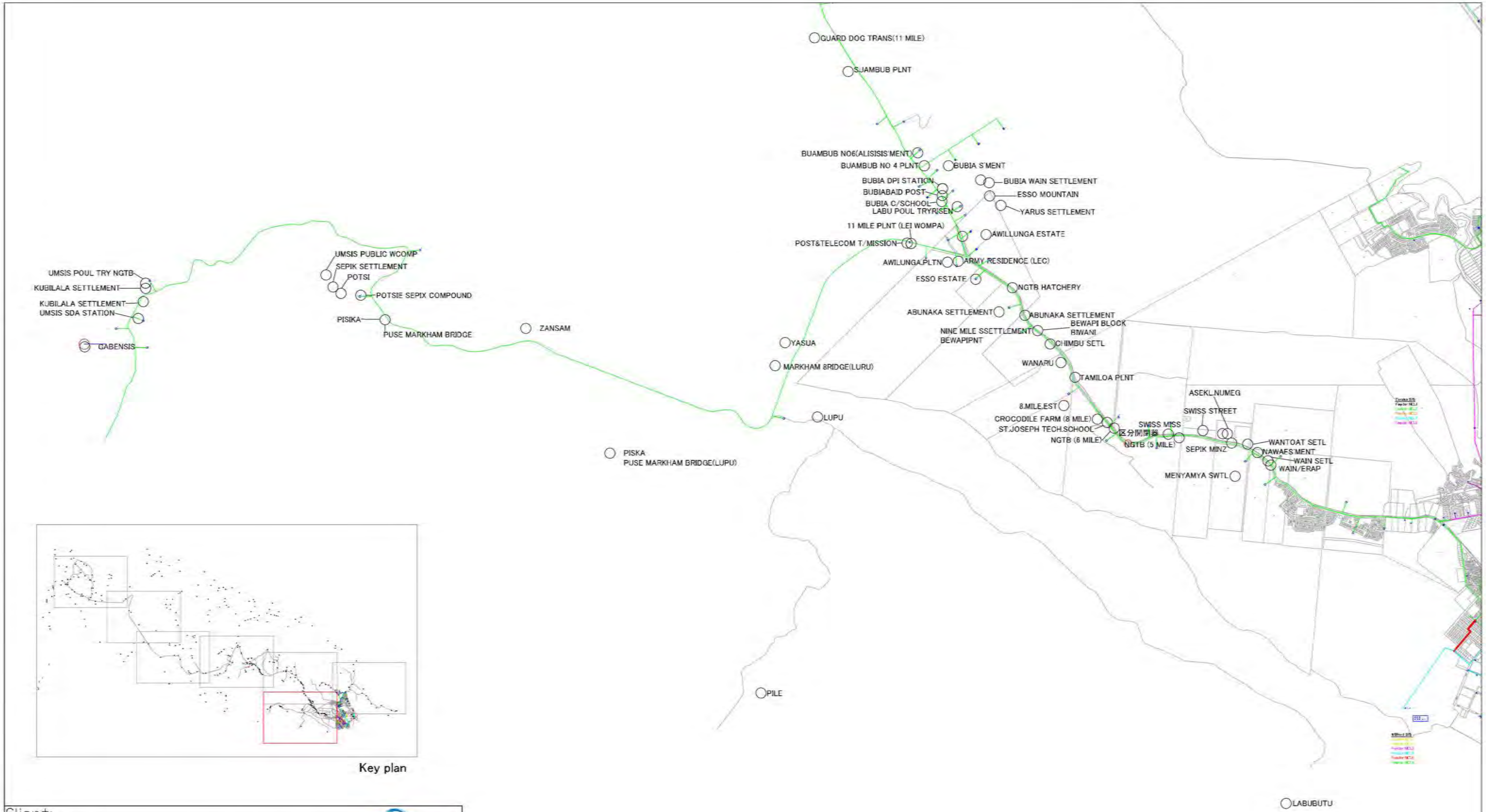
Client:
Japan International Cooperation Agency JICA

Project:
Project for Formulation of Ramu System Power Development Master Plan and Lae Area Distribution Network Improvement Plan

Drawing Title:
LAE HV GEOGRAPHIC DIAGRAM [5/9]

Scale: 1 : 50,000 (on A3)

NEWJEC
NEWJEC Inc.



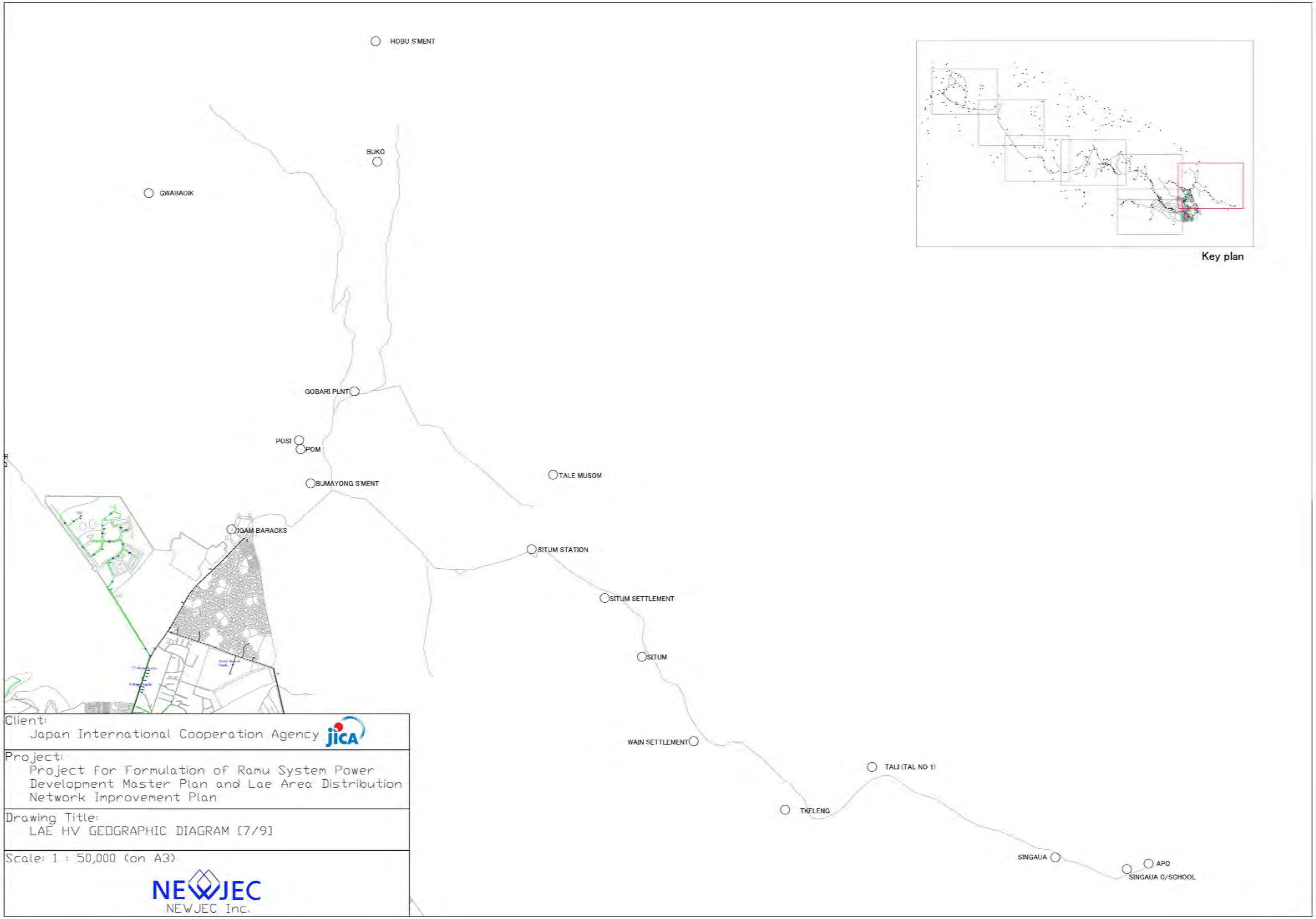
Client:
Japan International Cooperation Agency

Project:
Project for Formulation of Ramu System Power Development Master Plan and Lae Area Distribution Network Improvement Plan

Drawing Title:
LAE HV GEOGRAPHIC DIAGRAM [6/9]

Scale: 1 : 50,000 (on A3)

NEWJEC
NEWJEC Inc.



Client:
Japan International Cooperation Agency

Project:
Project for Formulation of Ramu System Power Development Master Plan and Lae Area Distribution Network Improvement Plan

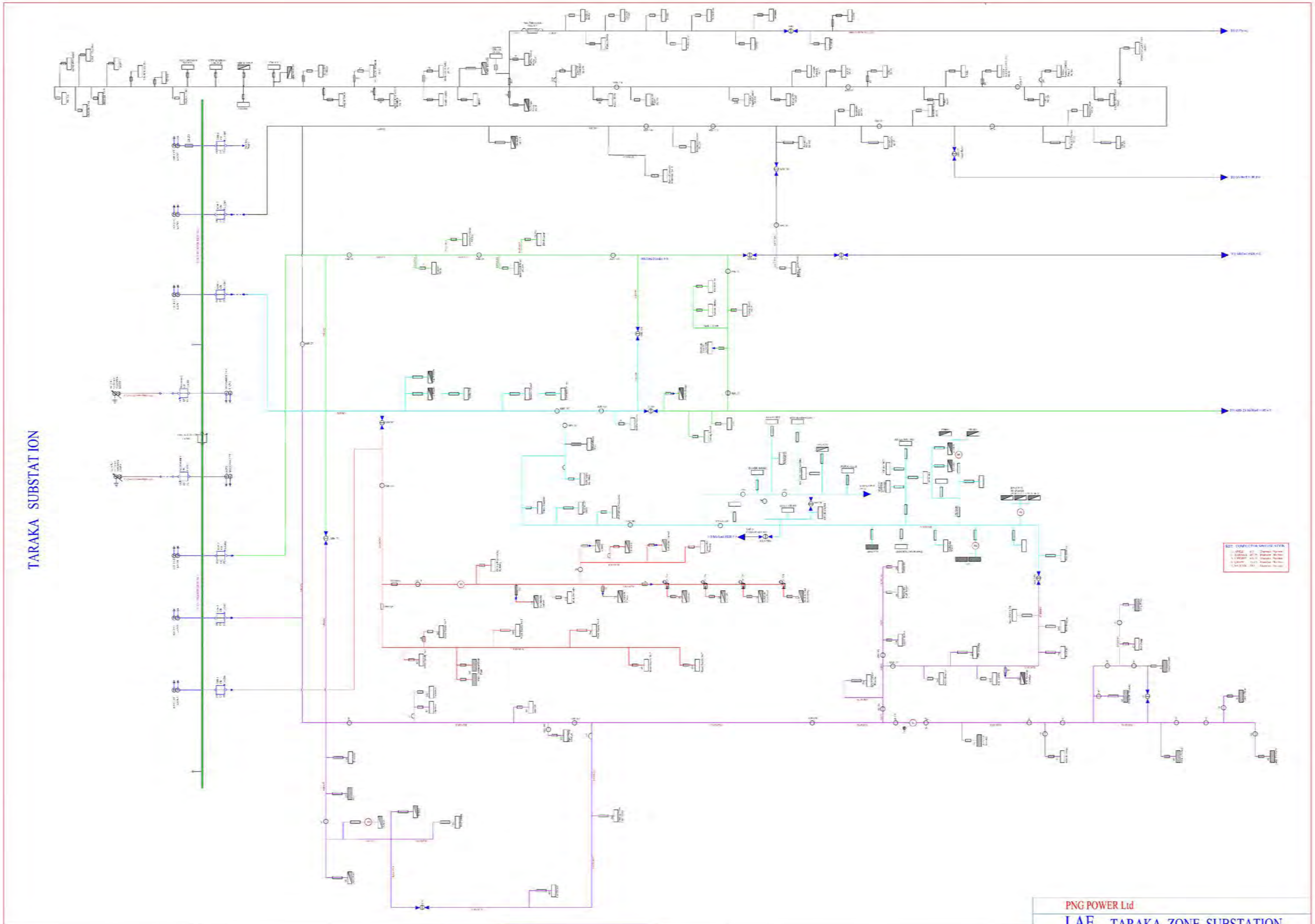
Drawing Title:
LAE HV GEOGRAPHIC DIAGRAM [7/9]

Scale: 1 : 50,000 (on A3)

NEWJEC
NEWJEC Inc.

Appendix B-2

Single-line Diagram provided by PPL Lae



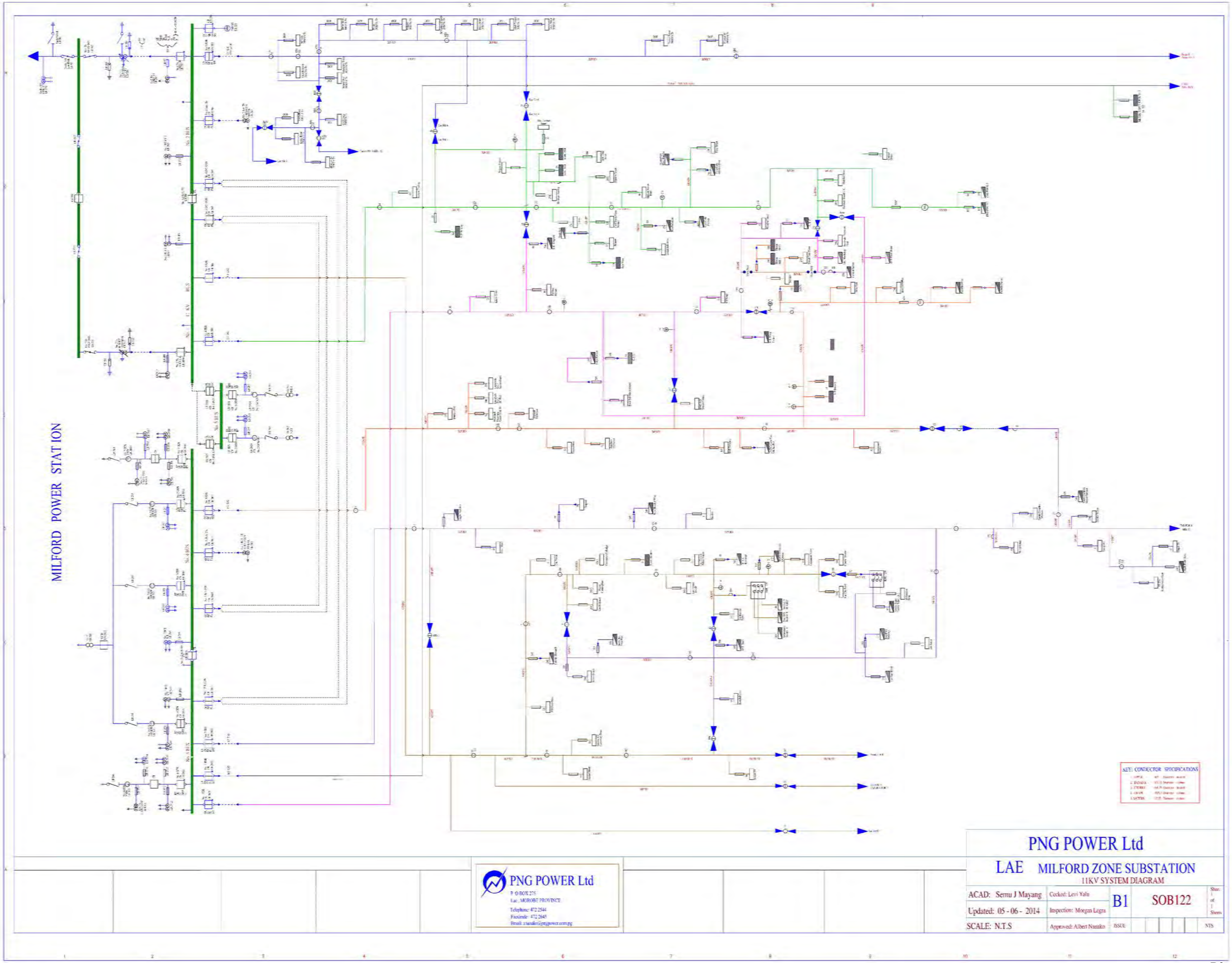
PNG POWER Ltd
P O BOX 275
Lae , MOROBE PROVINCE
Telephone: 472 2544
Facsimile: 472 2645

PNG POWER Ltd

LAE TARAKA ZONE SUBSTATION

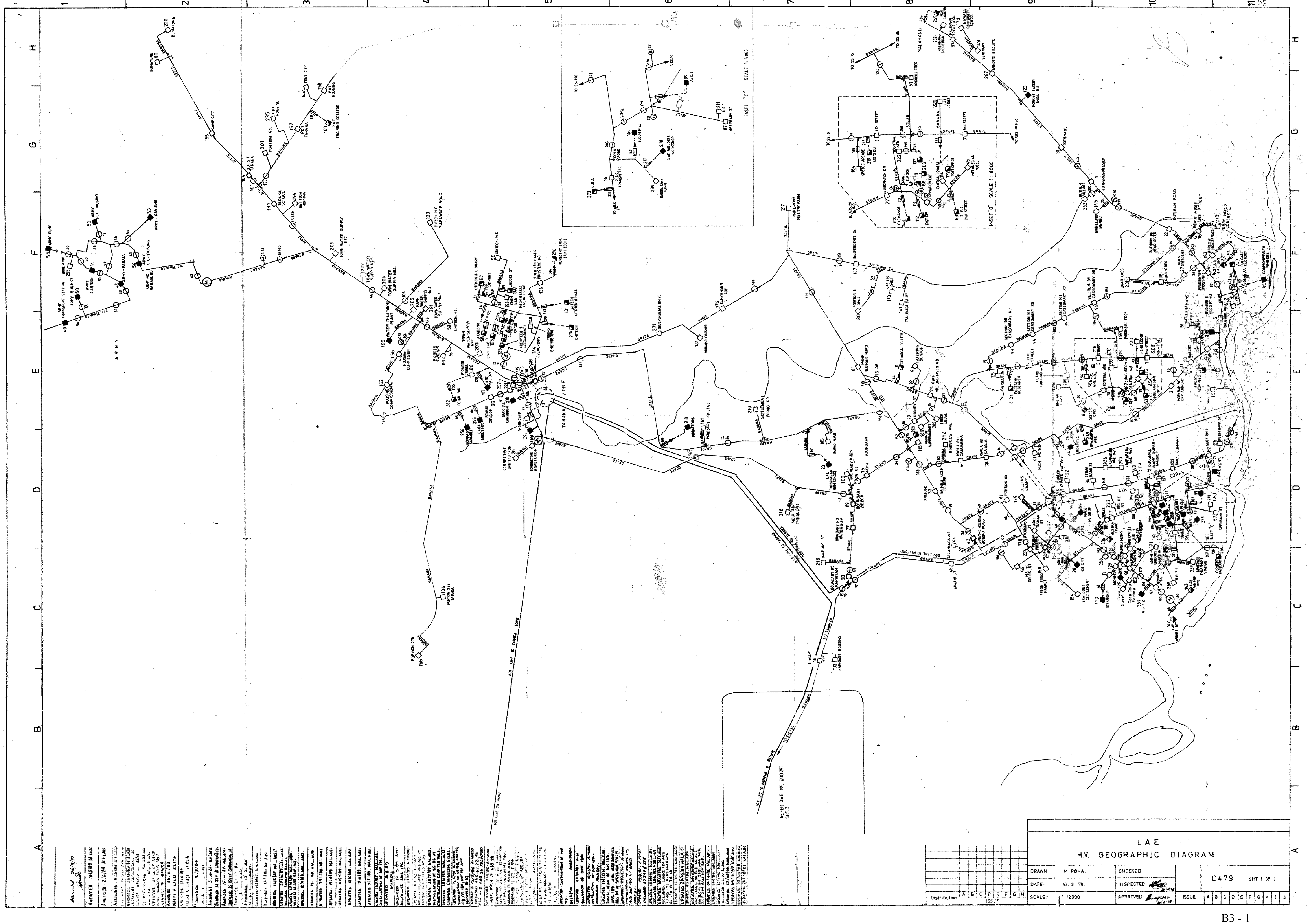
11KV SYSTEM DIAGRAM

Acad: Semu J Mayang	Checked: Levi Yale	B1	SOB122
DATE: 28 - 05 - 2014	Inspected: Morgan Logra		
SCALE: N.T.S	Approved: Albert Nanaki	ISSUE	


MILFORD POWER STATION
KEY: CONDUCTOR SPECIFICATIONS
PNG POWER Ltd
P O BOX 275
Lae, MOROBE PROVINCE
Telephone: 472 2544
Facsimile: 472 2645
PNG POWER Ltd
LAE
MILFORD ZONE SUBSTATION
11KV SYSTEM DIAGRAM
ACAD: Semu J Mayang
Cecked: Levi Yalu
Updated: 05 - 06 - 2014
Inspection: Morgan Legra
SCALE: N.T.S
Approved: Albert Nanako
ISSUE
B1
SOB122
NTS

Appendix B-3

Geographic Operating Diagram as of Year 2000



LAE
H.V. GEOGRAPHIC DIAGRAM
DRAWN: M. POHA.
CHECKED:
DATE: 10. 3. 78.
INSPECTED:
SCALE: 1:12000
APPROVED:
D479 SHT 1 OF 2
ISSUE A B C D E F G H I J
Distribution A B C D E F G H
ISSUE
INSET "B" SCALE 1:8000
INSET "C" SCALE 1:4000
ARMY
TARAKA ZONE

Appendix B-4

Breakdown of the Lengths of the Distribution Network in Lae

	Neme of feeder	(From)	(to)	Length	Conductor Code
1	**Taraka Fdr. NO.1**			**3,972 m**	
		Taraka S/S	Near IS138	2,398 m	Banana
		Near ABS28		1,005 m	Banana
			SS56	569 m	Banana
2	**Taraka Fdr. NO.2**			**18,160 m**	
		Taraka S/S	Near ABS56	6,599 m	Grape
		Near ABS61	ABS174	1,025 m	Grape
		ABS174	branch	1,044 m	Grape
		Near T255		3,212 m	Grape
		Near T255		403 m	Grape
		Near T255		367 m	Grape
		Near T255		178 m	Grape
		Near ABS106		814 m	Grape
		Near ABS145		89 m	Grape
		Near ABS139		296 m	Apple
		Near ABS139		79 m	Apple
		Branch	IS139	133 m	Banana
		IS139	ABS177	408 m	Apple
		ABS177	Corner	1,813 m	Banana
		Corner	ABS192	1,700 m	Cherry
3	**Taraka Fdr. NO.3**			**6,478 m**	
		Taraka S/S	Near AB153	4,301 m	Grape
		ABS115	ABS138	1,623 m	Grape
		ABS152		54 m	Grape
		ABS21		81 m	Grape
				211 m	Grape
				123 m	Grape
				85 m	Grape
4	**Taraka Fdr. NO.4**			**17,361 m**	
		Taraka S/S	Near ABS155	3,127 m	Grape
		Near ABS200	ABS115	4,396 m	Grape
		Near ABS115	IS138	48 m	Grape
		ABS143	Near ABS103	2,545 m	Grape
			ABS20	708 m	Grape
		ABS20		297 m	Grape
			ABS52	592 m	Grape
		ABS192	ABS143	5,299 m	Cherry
		ABS103	Branch	349 m	Banana
5	**Taraka Fdr. NO.5**			**6,127 m**	
		Taraka S/S	Near ABS113	3,626 m	Grape
			T169	194 m	Grape
		ABS35		999 m	Grape
		Near ABS113		336 m	Grape
		IS154	ABS34	777 m	Grape
		ABS183	ABS152	195 m	Grape
6	**Milford Fdr. NO.1**			**4,787 m**	
		Milford S/S	Near ABS41	1,304 m	Grape
		Near ABS100	ABS13	222 m	Grape
		ABS new		673 m	Grape
		ABS 157		162 m	Grape
		Near ABS 171	ABS ???	771 m	Grape
		Not connection (b)		550 m	Grape
		ABS 171		810 m	Grape
		Not connection (a)		241 m	Grape
				54 m	Grape
7	**Milford Fdr. NO.2**			**6,876 m**	
		Milford S/S	ABS52	3,100 m	Grape
		-	ABS2	95 m	Grape
		ABS123	-	870 m	Grape
		ABS60	-	999 m	Grape
		ABS105		674 m	Grape
		ABS30		499 m	Grape
		ABS210		224 m	Grape
		Near ABS210		415 m	Grape

	Neme of feeder	(From)	(to)	Length	Conductor Code
8	**Milford Fdr. NO.3**			**3,999 m**	
		Milford S/S	Cross Road	1,040 m	Grape
		Cross Road	ABS123	936 m	Grape
		Near ABS62		35 m	Grape
		ABS157		69 m	Grape
		ABS179		592 m	Grape
		ABS179		499 m	Grape
		ABS178		37 m	Grape
		Point (a)		241 m	Grape
		Point (b)		550 m	Grape
9	**Milford Fdr. NO.4**			**6,067 m**	
		Milford S/S	IS92	277 m	Grape
		IS92	Near ABS170	1,046 m	Grape
		ABS13		2,376 m	
		Near ABS40	ABS100	301 m	Grape
		Near IS6		232 m	Grape
		Near ABS165		542 m	Grape
				47 m	Grape
		Near ABS37		603 m	Grape
				185 m	Grape
				110 m	Grape
		ABS171		262 m	Grape
		ABS new		86 m	Grape
10	**Milford Fdr. NO.5**			**8,157 m**	
		Milford S/S	ABS60	3,174 m	Grape
		ABS32	Near ABS14	766 m	Grape
		ABS32		232 m	Grape
		Near ABS166	ABS105	963 m	Grape
		Near ABS29		232 m	Grape
		Near ABS8		150 m	Grape
		ABS168		184 m	Grape
		ABS168		44 m	Grape
		Near ABS168		112 m	Grape
		Near ABS105		298 m	Grape
		ABS58	ABS103	1,528 m	Banana
		Near ABS104		474 m	Banana
11	**Milford Fdr. NO.6**			**15,829 m**	
		Milford S/S	Sectionalizer	6,596 m	Grape
		Near ABS122		248 m	Grape
			ABS38	163 m	Grape
		Near ABS38		201 m	Grape
		Near ABS31	ABS183	748 m	Grape
			ABS32	32 m	Grape
		ABS38		760 m	Grape
		Branch	ABS35	160 m	Grape
		Near 116		259 m	Grape
		ABS165		409 m	Grape
		ABS100		39 m	Grape
				364 m	Grape
		Sectionalizer	Tei Tr. (11/22kV)	850 m	
		Tei Tr. (11/22kV)	MUYA	1,540 m	
		Tei Tr. (11/22kV)	(22kV Line)	3,460 m	
12	**Nadzab Fdr. NO.1**			**91,100 m**	
		Nadzab S/S	Tei Tr. (11/22kV)	1,000 m	
		Tei Tr. (11/22kV)	for Lae	5,100 m	
		Tei Tr. (11/22kV)	Muting(22kV Line)	85,000 m	

Appendix B-5

Distribution Transformer List provided from PPL Lae

Feeder ID	Sub Station No	Type	Location
Lae 1	1	Aerial Tx	
	2	Kiosk	
	3	Aerial Tx	
	4	Kiosk	
	5	Aerial Tx	
	6	Kiosk	
	7	Kiosk	
	8	Aerial Tx	
	9	Ground Sub	
	10	Kiosk	
	11	Aerial Tx	
	12	Kiosk	
	13	Aerial Tx	
	14	Kiosk	
	15	Kiosk	
	16	Aerial Tx	
	17	Ground Sub	
Lae 2	1	Kiosk	Niugini Builders Yard
	2	Aerial Tx	Huon Gulf Motel
	3	Ground Sub	Angau Hospital
	4	Kiosk	Angau Hospital
	5	Aerial Tx	Theodist
	6	Kiosk	BSP Commercial Bank
	7	Kiosk	AAA Apartments
	8	Aerial Tx	Mt Lunaman
	9	Aerial Tx	Outdoor Stadium Complex
	10	Kiosk	Indoor Stadium Complex
	11	Ground Sub	Asiawe Village
	12	Aerial Tx	Bus Stop
	13	Aerial Tx	PNG Forest Product
	14	Aerial Tx	Vocco Point
	15	Aerial Tx	Opposite Kumho Tyres
	16	Kiosk	Colgate Palmolive
	17	Kiosk	Lae Intenational Hotel
	18	Aerial Tx	Huon Road
	19	Kiosk	Post Office
	20	Aerial Tx	Melanesian Hotel
	21	Kiosk	IPI Building
Lae 3	1	Aerial Tx	21C
	2	Aerial Tx	ANZ Bank

Feeder ID	Sub Station No	Type	Location
Lae 4	3	Aerial Tx	
	4	Aerial Tx	TE PNG
	5	Aerial Tx	Main Market Area
	6	Aerial Tx	Orica
	7	Aerial Tx	
	8	Aerial Tx	
	9	Aerial Tx	
	10	Kiosk	LNG Yard
	11	Aerial Tx	Honnale Guest House Junction
	12	Kiosk	SP Brewery
	13	Kiosk	SP Brewery
	14	Kiosk	SP Brewery
	15	Ground Sub	Territory Packaging
	16	Kiosk	Amapack
	17	Kiosk	Amapack
	18	Kiosk	Frabelle
	19	Kiosk	Frabelle
	20	Aerial Tx	Markham Culvert
	21	Kiosk	Lae Builders Workshop
	22	Kiosk	Flour Mill
	23	Aerial Tx	Niugini Oil Company
	1	Aerial Tx	Stevens Store
	2	Ground Sub	Works Dept Office
	3	Aerial Tx	
	4	Aerial Tx	Metier Contractors
	5	Aerial Tx	
	6	Aerial Tx	PPL SOQ
	7	Aerial Tx	
	8	Aerial Tx	Papua Compound
	9	Aerial Tx	
	10	Aerial Tx	
	11	Ground Sub	Horni Brook
	12	Aerial Tx	
	13	Kiosk	Tidal Basin
	14	Aerial Tx	Hasting Deering
	15	Aerial Tx	Courts
	16	Aerial Tx	
	17	Kiosk	
	18	Aerial Tx	
	19	Aerial Tx	

Feeder ID	Sub Station No	Type	Location
Lae 4	20	Kiosk	
	21	Aerial Tx	
	22	Kiosk	Coca Cola
	23	Kiosk	Coca Cola
	24	Kiosk	
	25	Kiosk	Trukai Industries
	26	Aerial Tx	
	27	Aerial Tx	
	28	Aerial Tx	
	29	Aerial Tx	
	30	Kiosk	PNG Ports
	31	Kiosk	PNG Ports
Lae 5	1	Aerial Tx	Kwila Road
	2	Aerial Tx	Kwila Road
	3	Aerial Tx	Puma Energy-Eriku
	4	Aerial Tx	
	5	Kiosk	FRI
	6	Aerial Tx	
	7	Aerial Tx	
	8	Aerial Tx	Coronation College
	9	Aerial Tx	Hotel Morobe
	10	Kiosk	Angau Nursing Quarter
	11	Aerial Tx	Opposite PPL Office-Town
	12	Aerial Tx	Police Station-Town
	13	Kiosk	Telikom PNG
	14	Kiosk	Morobe Provincial HQ
	15	Aerial Tx	Tutumang House
	16	Aerial Tx	
	17	Aerial Tx	Lae Hotel
	18	Kiosk	SVS-Big V
	19	Kiosk	8 Six Shop
	20	Kiosk	Vele Lumana Building
	21	Aerial Tx	Big Rooster-Town
	22	Kiosk	Food Mart
	23	Aerial Tx	Central Courts
	24	Aerial Tx	Court House Area
	25	Aerial Tx	
	26	Aerial Tx	
	27	Aerial Tx	East West 1 Yard

Feeder ID	Sub Station No	Type	Location
Lae 6	1	Aerial Tx	St Paul's Primary School
	2	Aerial Tx	Susu Mama Clinic
	3	Aerial Tx	Salamanda/Show Ground
	4	Aerial Tx	Salamanda Residents
	5	Aerial Tx	Golf Club
	6	Aerial Tx	Papua Compound
	7	Aerial Tx	Jawani Street
	8	Aerial Tx	212 Residents
	9	Aerial Tx	
	10	Aerial Tx	
Taraka 1	1	Aerial Tx	Unitech Mining Eng Dept
	2	Kiosk	Unitech Stds Dining Hall
	3	Aerial Tx	Unitech Male Stds Dormitory
	4	Kiosk	Unitech Forestry Dept
	5	Kiosk	Unitech Electrical Eng Dept
	6	Kiosk	Unitech Stds Library
	7	Aerial Tx	Unitech Cooks Compound
	8	Aerial Tx	Staff Residents Area
	9	Kiosk	Unitech Female Dormitory
	10	Kiosk	Unitech Language & Surveying Dept
	11	Kiosk	Unitech Duncanson Hall
	12	Kiosk	Unitech Business & Building Dept
	13	Kiosk	Civil Eng Dept
	14	Aerial Tx	Water Pump No. 1
	15	Aerial Tx	Water Pump No. 2
	16	Kiosk	Water Treatment Plant
	17	Aerial Tx	Water Pump No. 3
	18	Aerial Tx	Water Pump No. 4
	19	Aerial Tx	Water Pump No. 5
	20	Aerial Tx	Water Pump No. 6
Taraka 2	1	Aerial Tx	Cummings Taraka
	2	Aerial Tx	
	3	Kiosk	Atlas Steel
	4	Aerial Tx	
	5	Kiosk	Colorpack
	6	Aerial Tx	
	7	Aerial Tx	
	8	Aerial Tx	
	9	Aerial Tx	Unitech Staff Residents
	10	Aerial Tx	Unitech Area 5 Residents

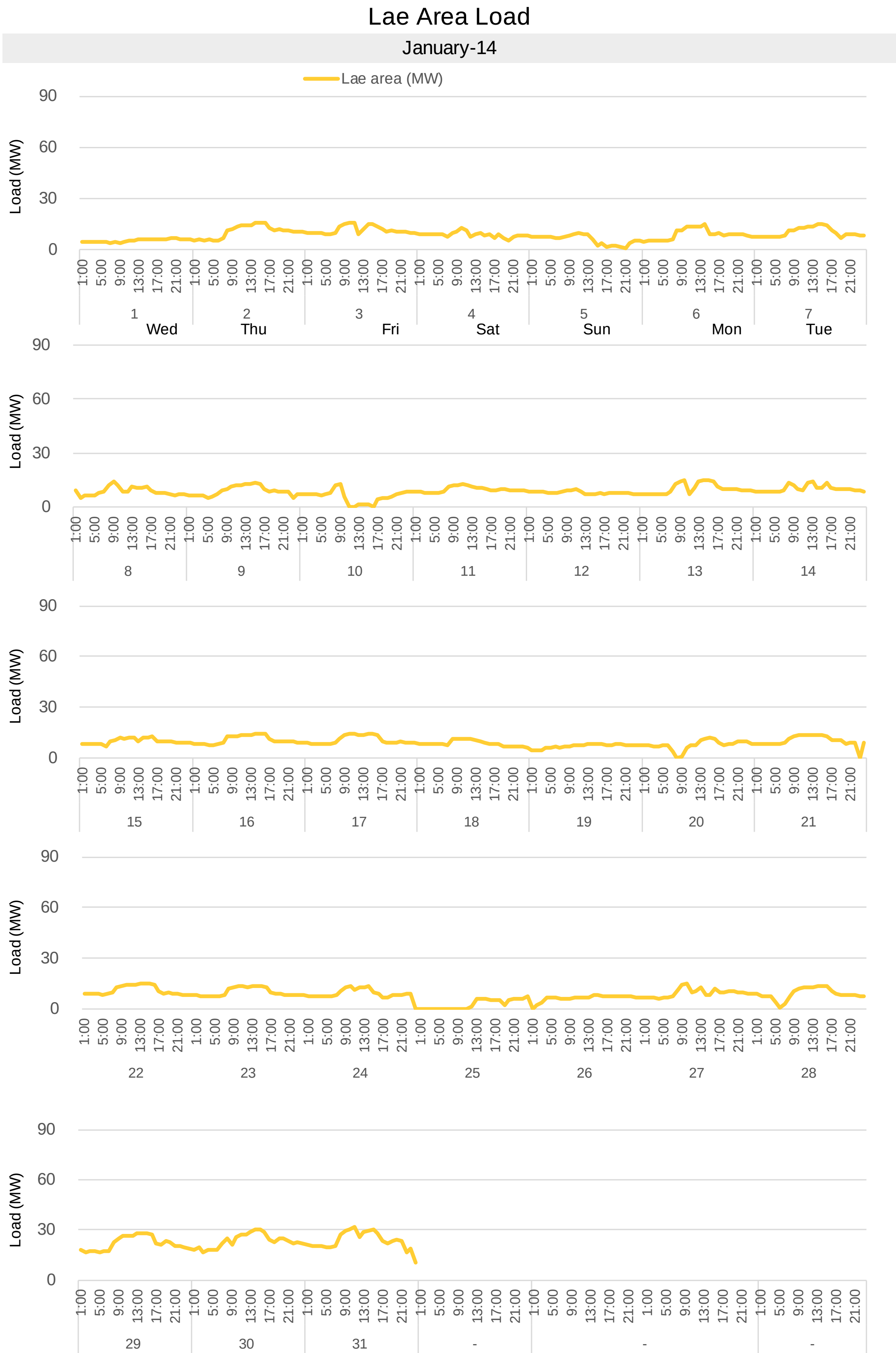
Feeder ID	Sub Station No	Type	Location
Taraka 2	11	Aerial Tx	Unitech Area 5 Residents
	12	Aerial Tx	
	13	Aerial Tx	
	14	Aerial Tx	
	15	Kiosk	Telikom PNG College
	16	Aerial Tx	
	17	Aerial Tx	
	18	Aerial Tx	Tent City
	19	Aerial Tx	Back Road
	20	Aerial Tx	Bumayong Secondary School
	21	Aerial Tx	Bumayong Centre
	22	Aerial Tx	Igam Road
	23	Aerial Tx	Igam Gate Market
	24	Kiosk	Igam Barracks
	25	Kiosk	Igam Barracks
	26	Kiosk	Igam Barracks
	27	Kiosk	Igam Barracks
	28	Kiosk	Igam Barracks
	29	Aerial Tx	
	30	Aerial Tx	East Taraka Housing
	30	Aerial Tx	West Taraka Road
	31	Aerial Tx	West Taraka
Taraka 3	1	Ground Sub	Abattoir
	2	Aerial Tx	Timber College
	3	Aerial Tx	Bundu Camp
	4	Aerial Tx	Gurney Street
	5	Aerial Tx	Papindo Supermarket Eriku
	6	Aerial Tx	Raumai 18 Eriku
	7	Aerial Tx	Digicel Office Eriku
	8	Aerial Tx	Makati Village
	9	Aerial Tx	Polytech
	10	Kiosk	Polytech
Taraka 4	1	Kiosk	Lae Biscuit Company
	2	Kiosk	Lae Biscuit Company
	3	Aerial Tx	Speedway
	4	Aerial Tx	Boinamo Gravel
	5	Aerial Tx	Kamkumung Village
	6	Aerial Tx	Kamkumung Market
	7	Aerial Tx	
	8	Aerial Tx	

Feeder ID	Sub Station No	Type	Location
Taraka 4	9	Aerial Tx	
	10	Aerial Tx	Butibam Village
	11	Aerial Tx	Bumbu Compound
	12	Aerial Tx	
	13	Aerial Tx	
	14	Aerial Tx	
	15	Kiosk	PNG Ready Mix
	16	Aerial Tx	
	17	Kiosk	Nestle
	18	Aerial Tx	
	19	Aerial Tx	
	20	Aerial Tx	
	21	Aerial Tx	Chinese Club
	22	Aerial Tx	
	23	Aerial Tx	Balop Teachers College
	24	Ground Sub	Paradise Foods Ltd
	25	Aerial Tx	
	26	Aerial Tx	Martin Luther Seminary
	27	Aerial Tx	
	28	Aerial Tx	
	29	Aerial Tx	
	30	Aerial Tx	Yanga
	31	Aerial Tx	Malahang Technical High School
	32	Aerial Tx	
	33	Kiosk	
	34	Kiosk	
	35	Aerial Tx	
	36	Kiosk	
	37	Kiosk	
	38	Ground Sub	IFC
	39	Ground Sub	IFC
	40	Kiosk	
	41	Kiosk	
	42	Aerial Tx	
	43	Kiosk	Majestic Sea Foods
	44	Kiosk	Majestic Sea Foods
	45	Kiosk	Majestic Sea Foods
	46	Aerial Tx	Back Road

Feeder ID	Sub Station No	Type	Location
Taraka 5	1	Kiosk	
	2	Kiosk	Shorncliff Workshop
	3	Aerial Tx	Buimo Correctional Service
	4	Aerial Tx	Boundary Road
	5	Aerial Tx	1 Mile
	6	Aerial Tx	1 Mile
	7	Aerial Tx	Huon Road
	8	Aerial Tx	Eriku Shopping Centre
	9	Kiosk	Andersons Foodland Eriku

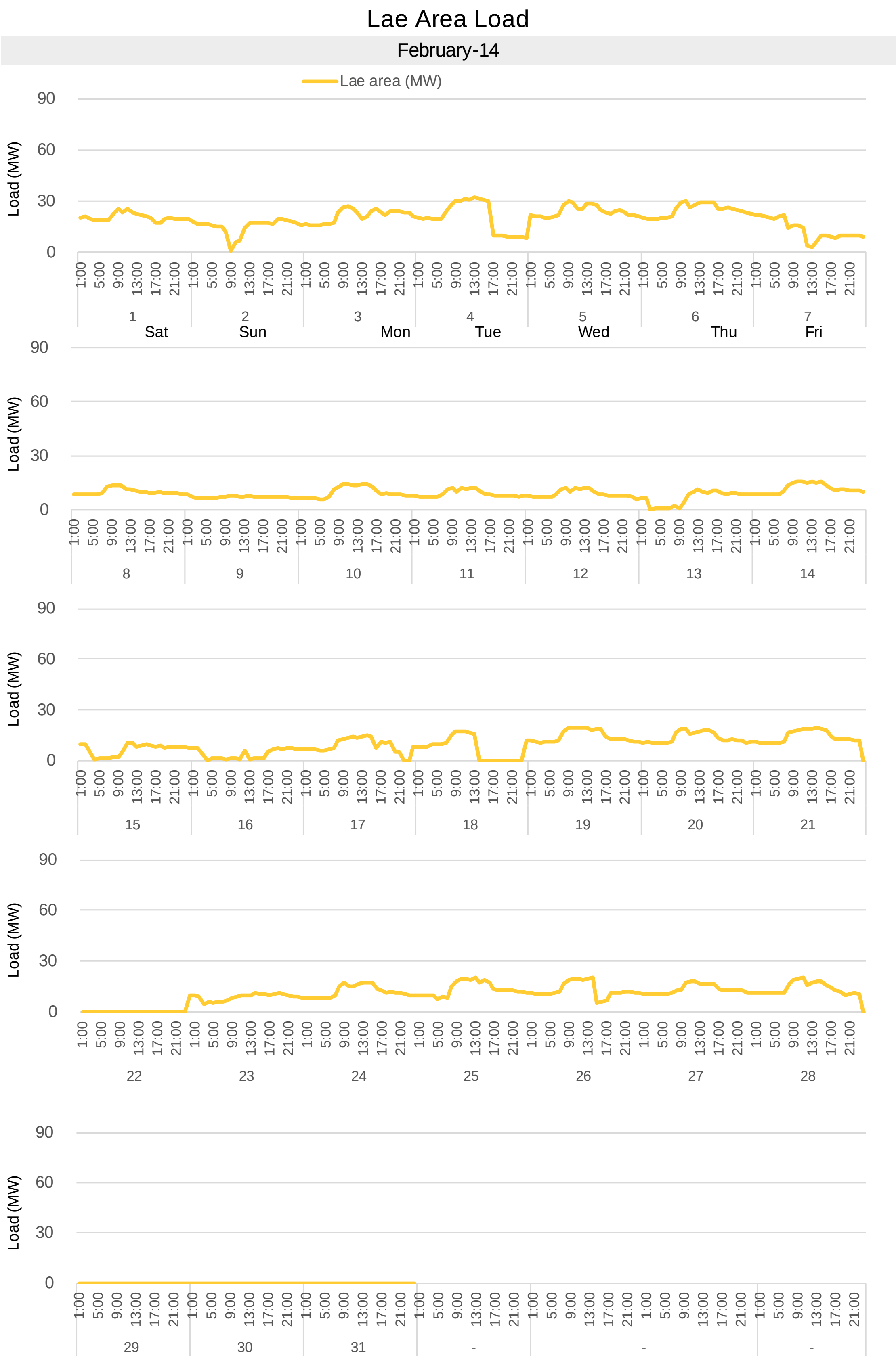
Appendix B-6

Detailed Graphs of Power Demand per Feeder

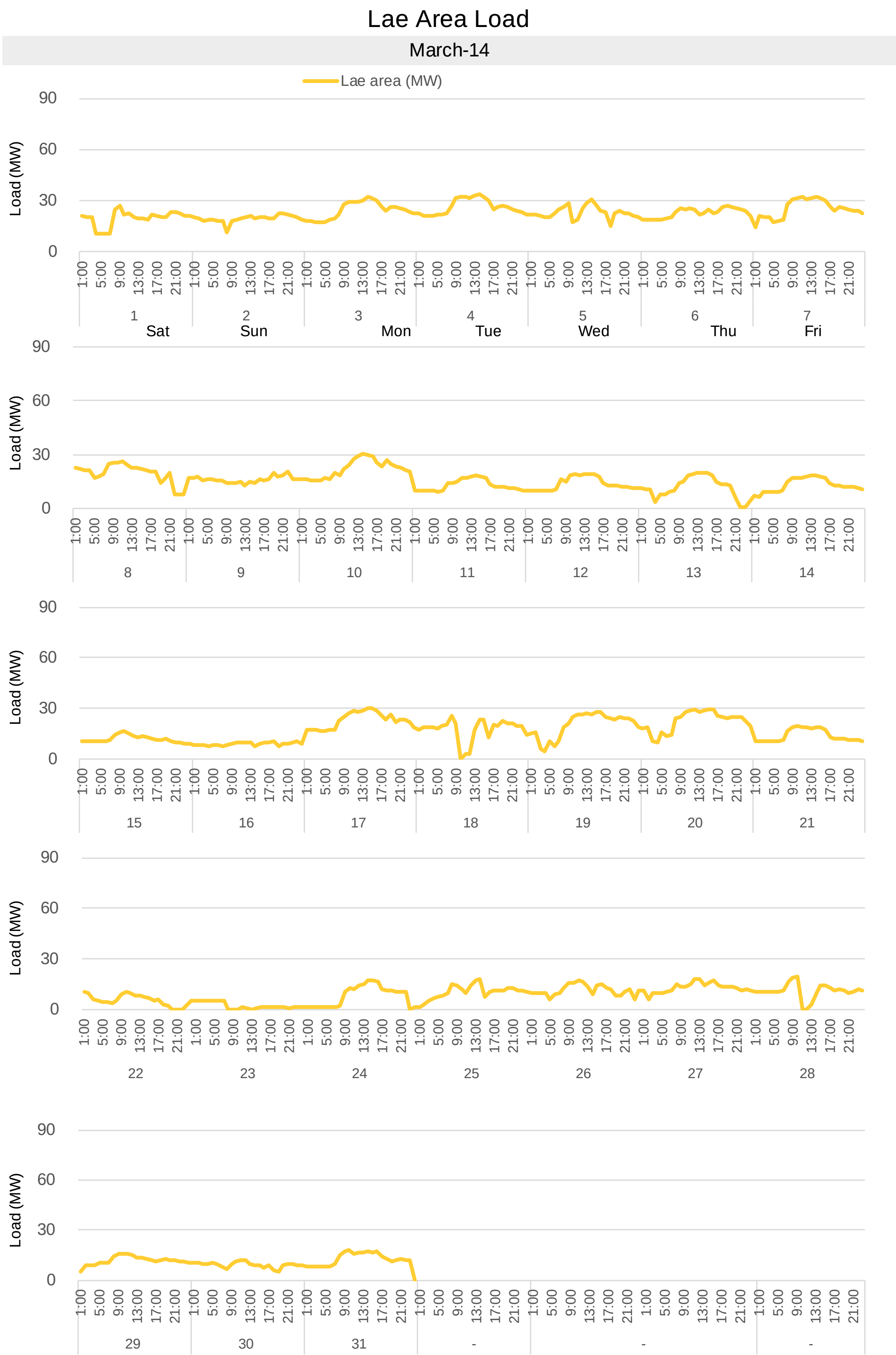


Max.(MW)
31.37

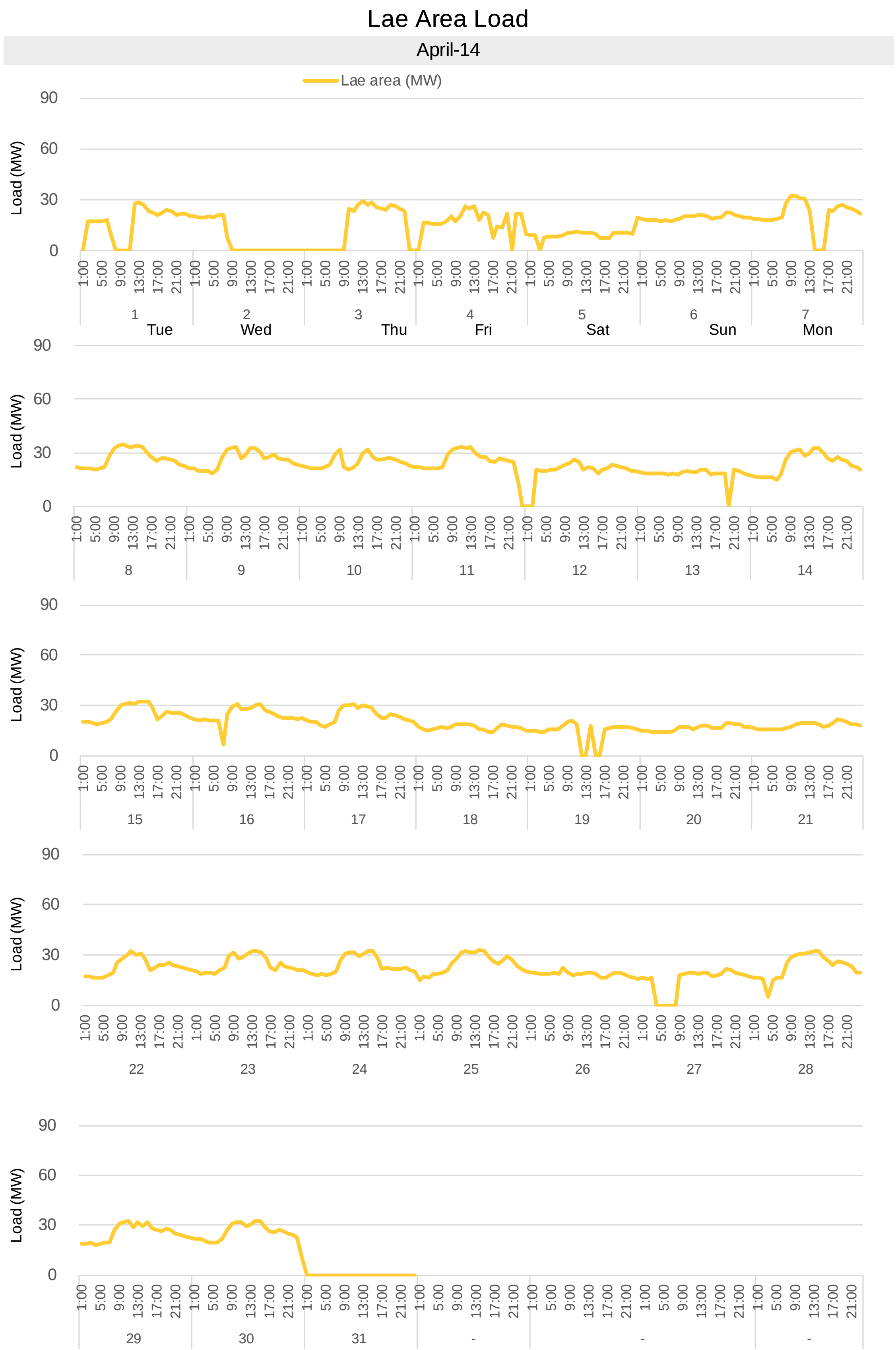
Ave.(MW)
10.41



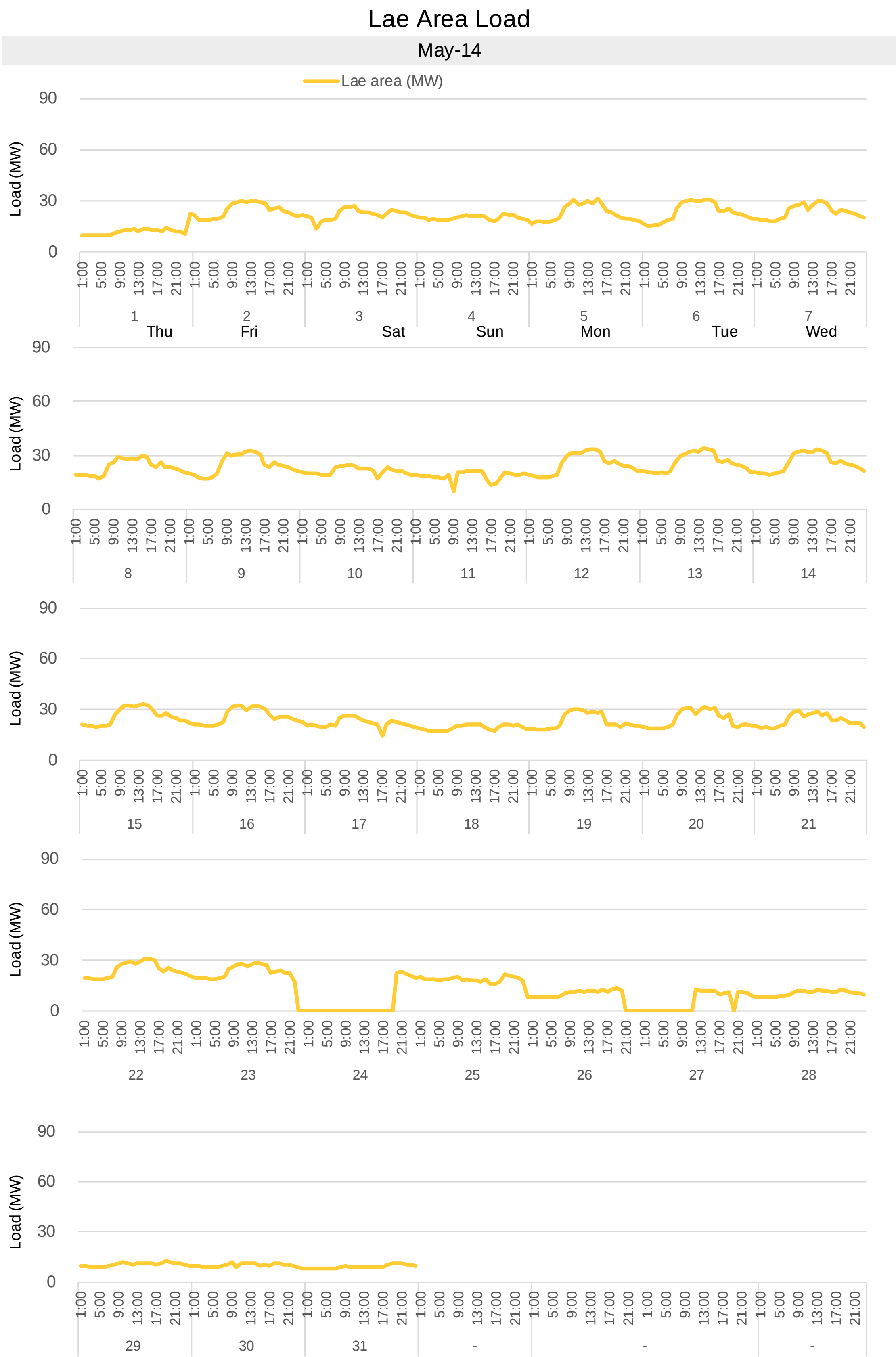
Max.(MW)	Ave.(MW)
32.43	13.15



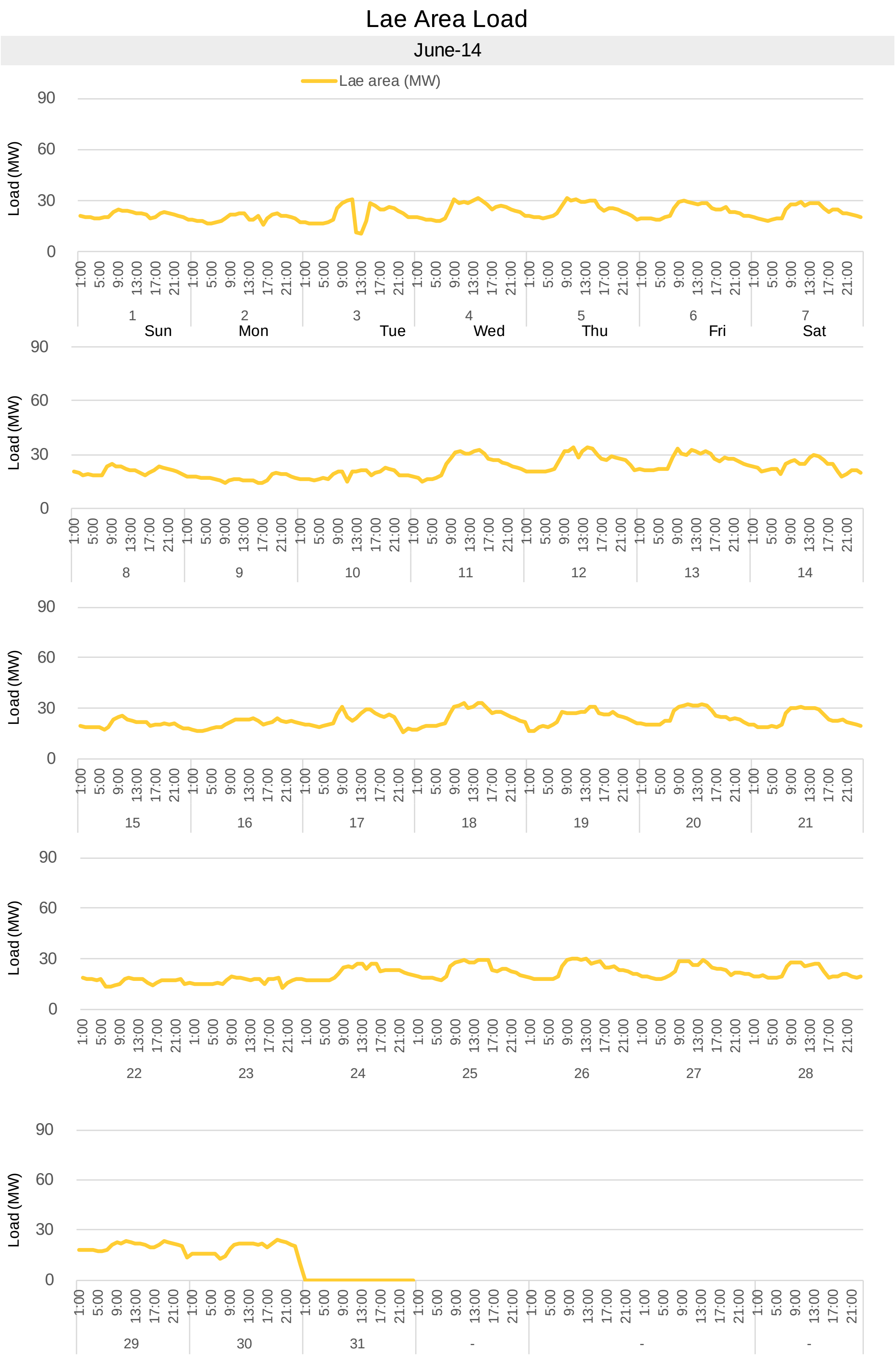
Max.(MW)	Ave.(MW)
33.43	15.84



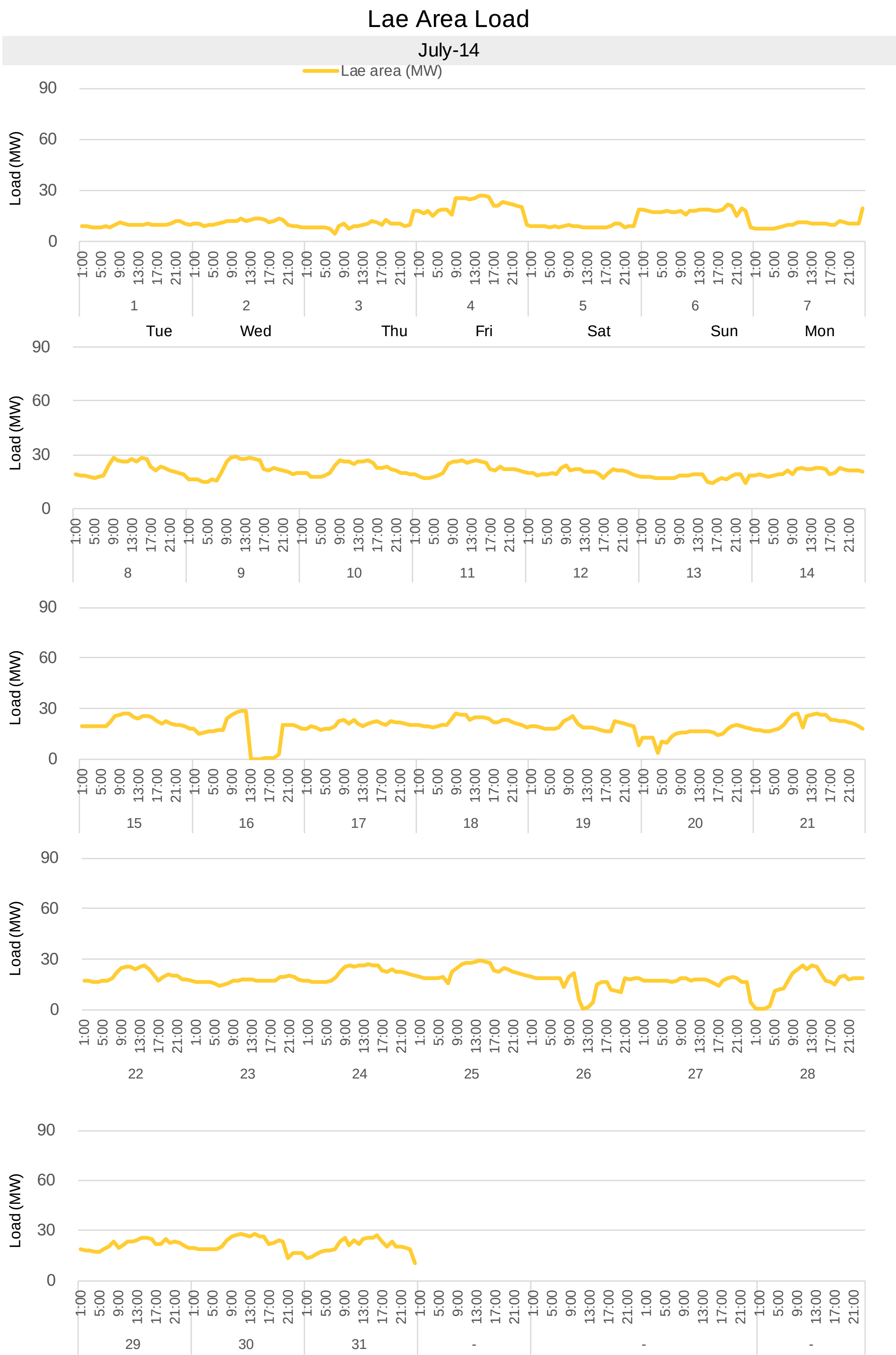
Max.(MW)	Ave.(MW)
34.58	21.22



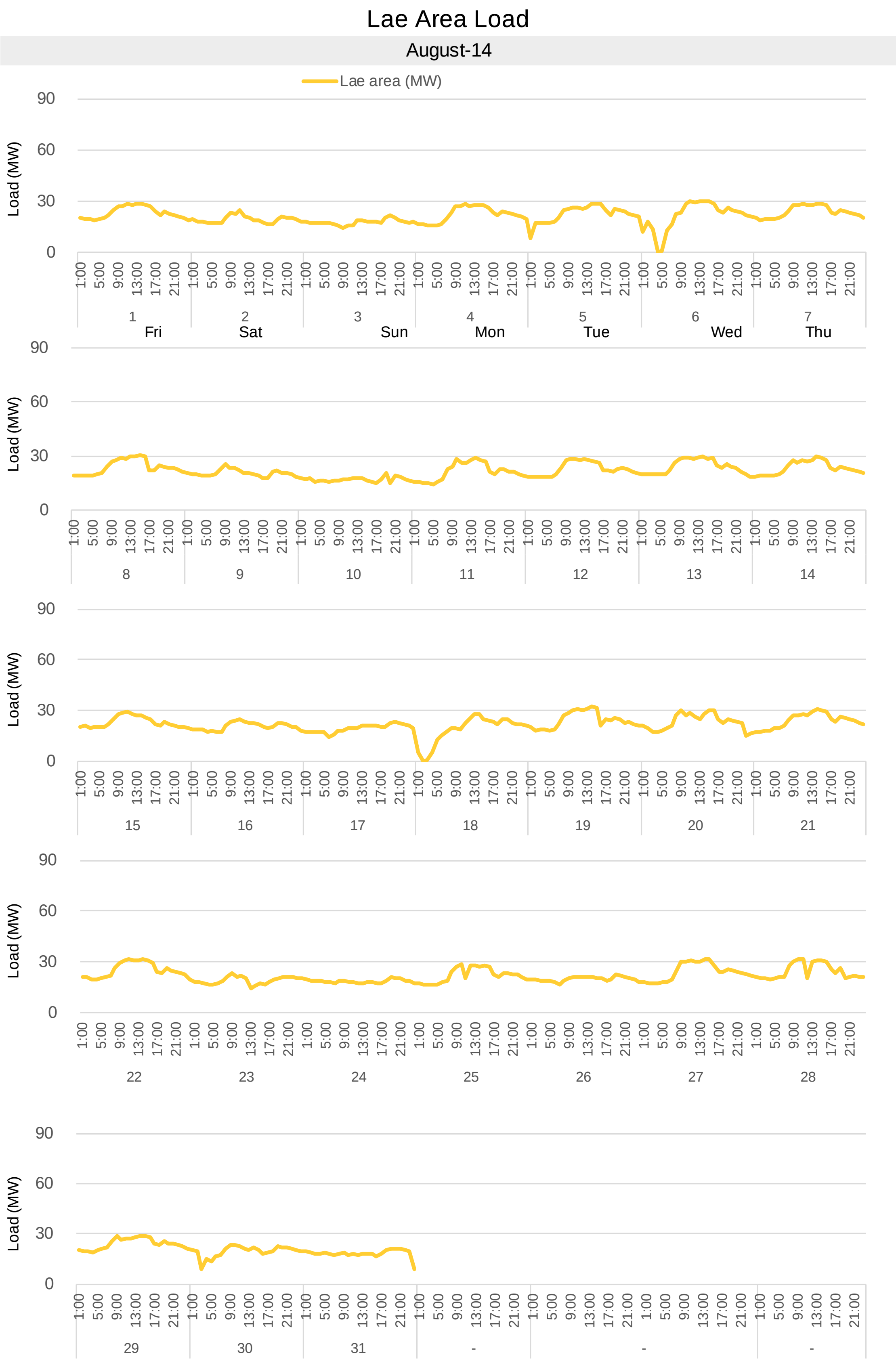
Max.(MW)	Ave.(MW)
34.02	20.25



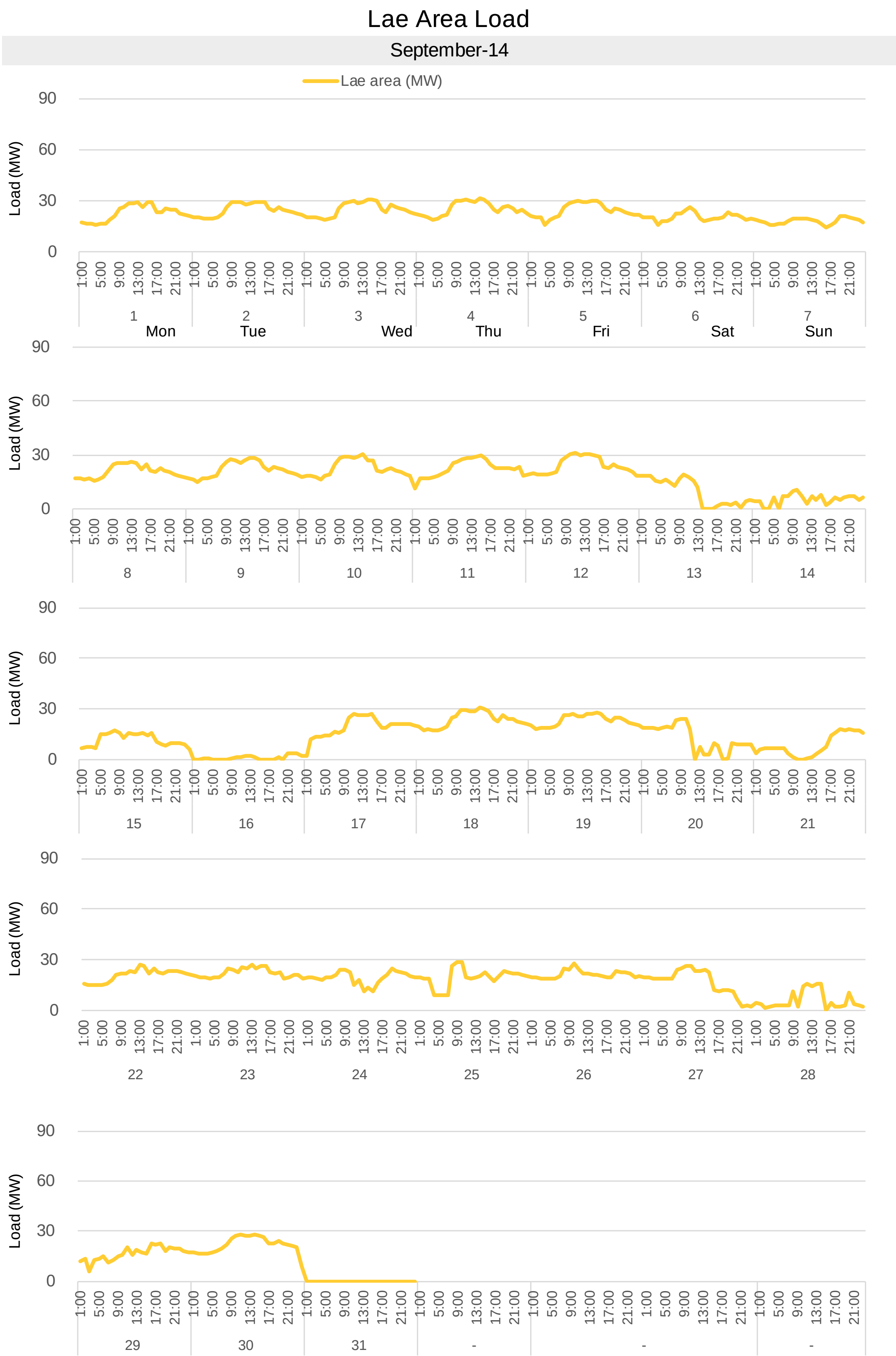
Max.(MW)	Ave.(MW)
34.04	22.34



Max.(MW)	Ave.(MW)
29.01	18.42

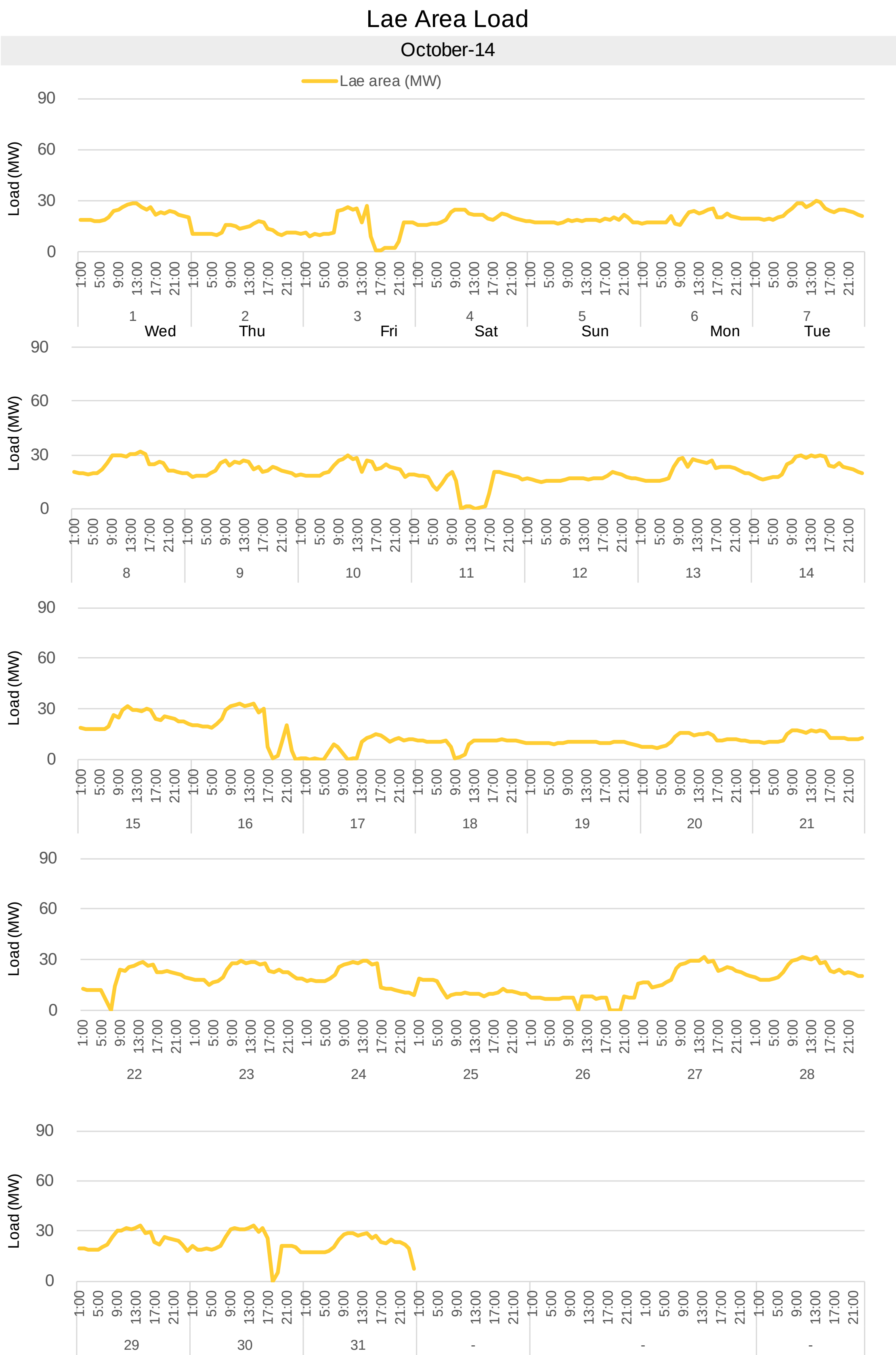


Max.(MW)	Ave.(MW)
32.54	21.77

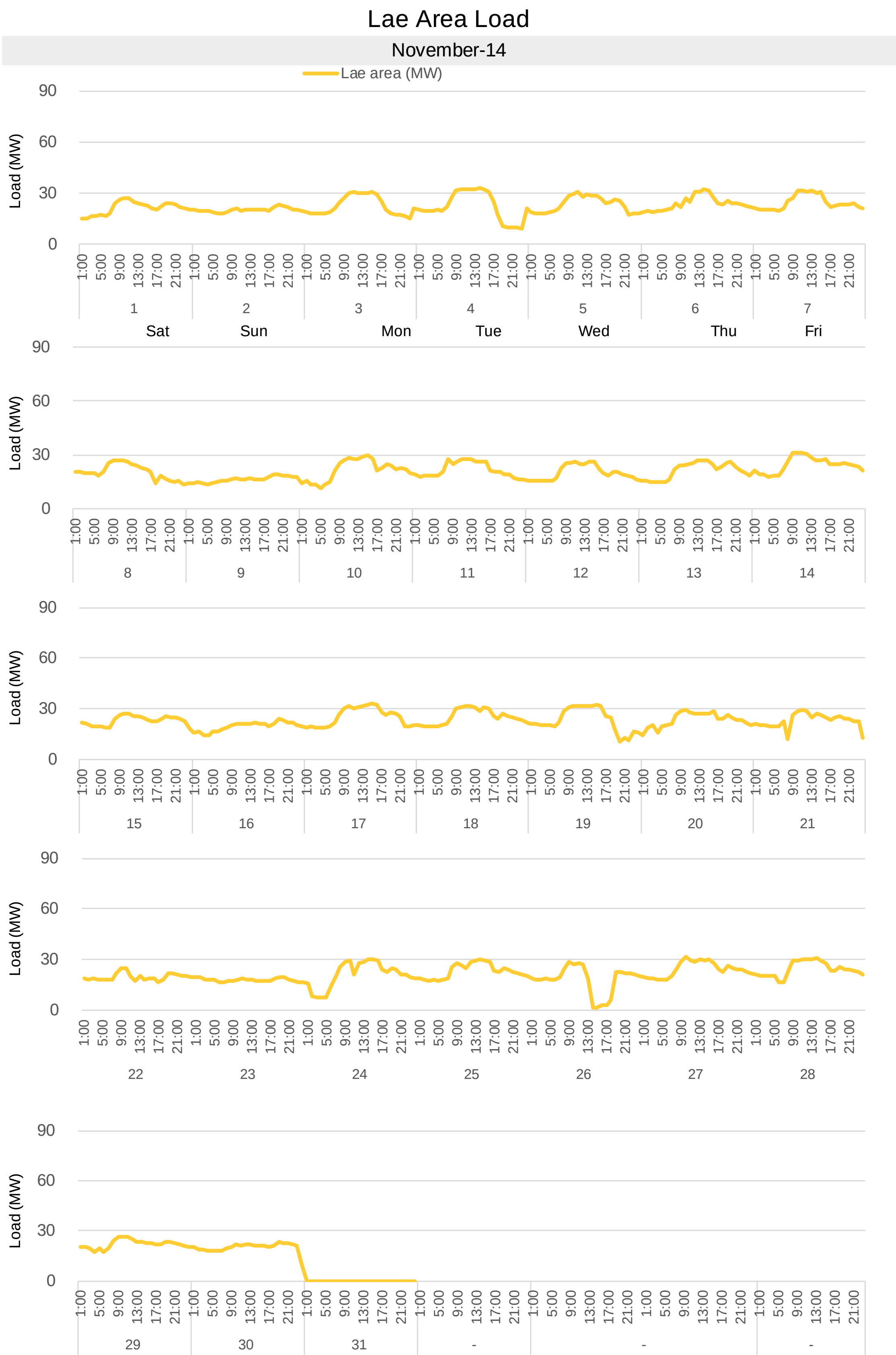


Max.(MW)
31.23

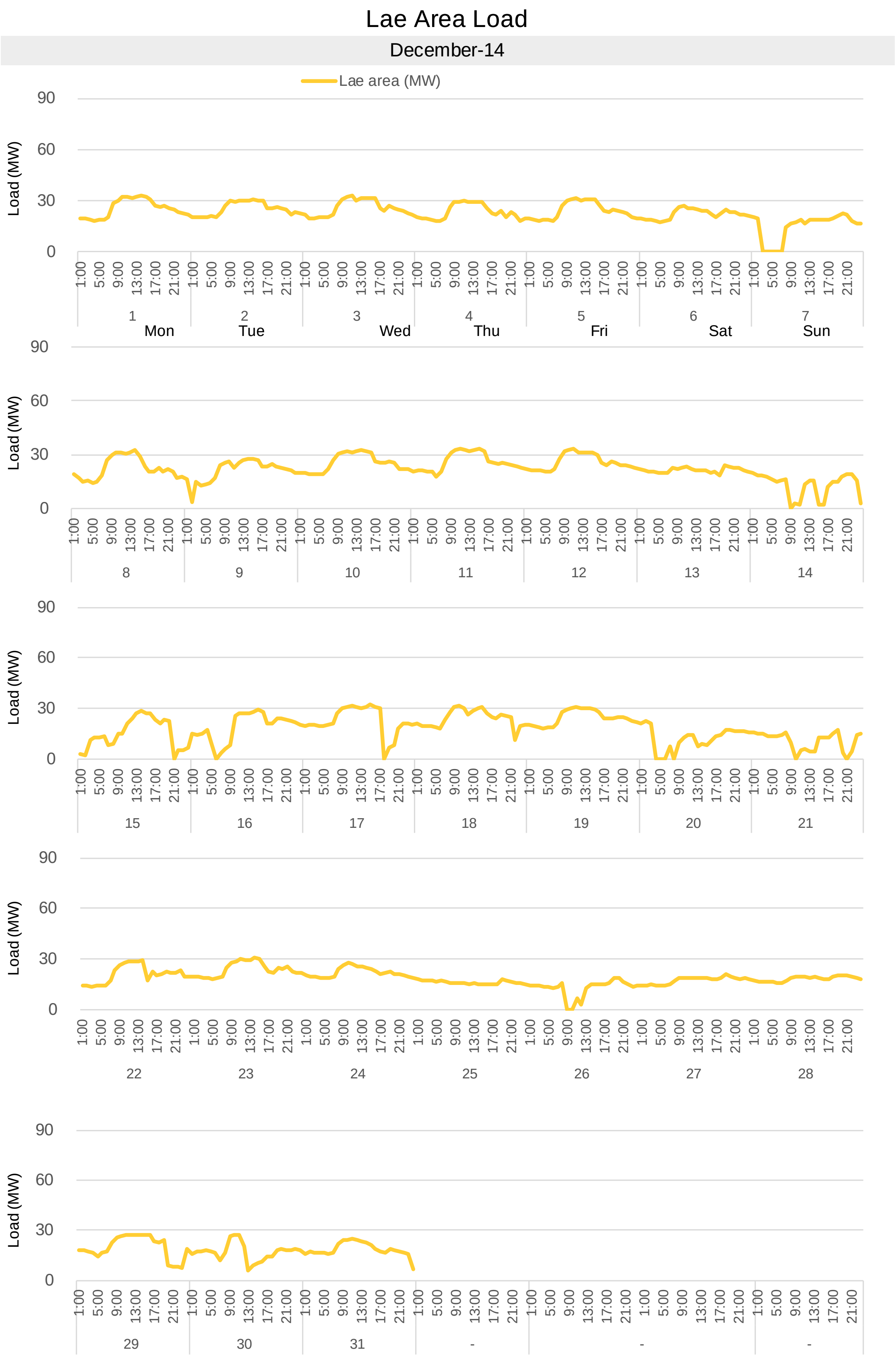
Ave.(MW)
18.94



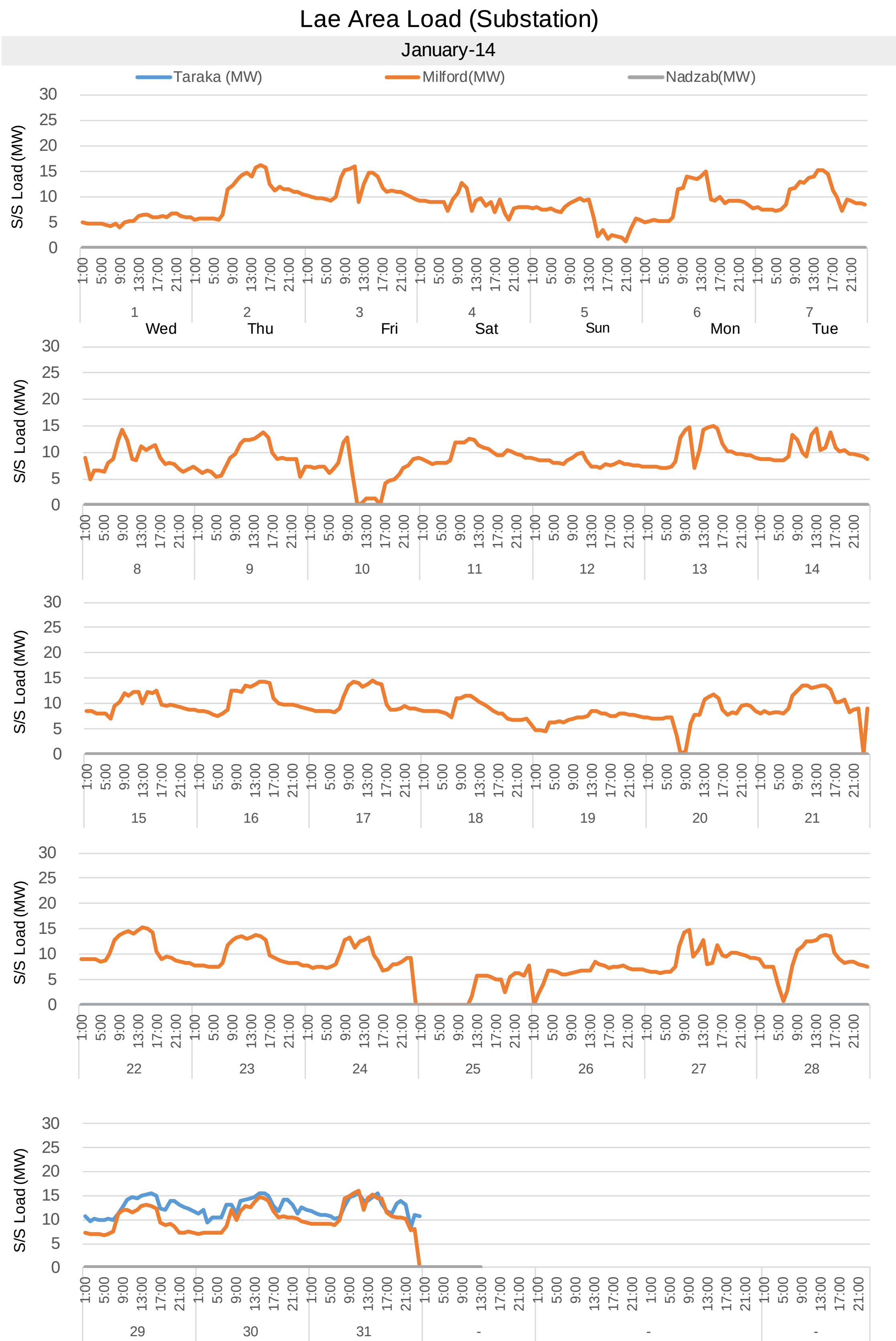
Max.(MW)	Ave.(MW)
33.18	18.70



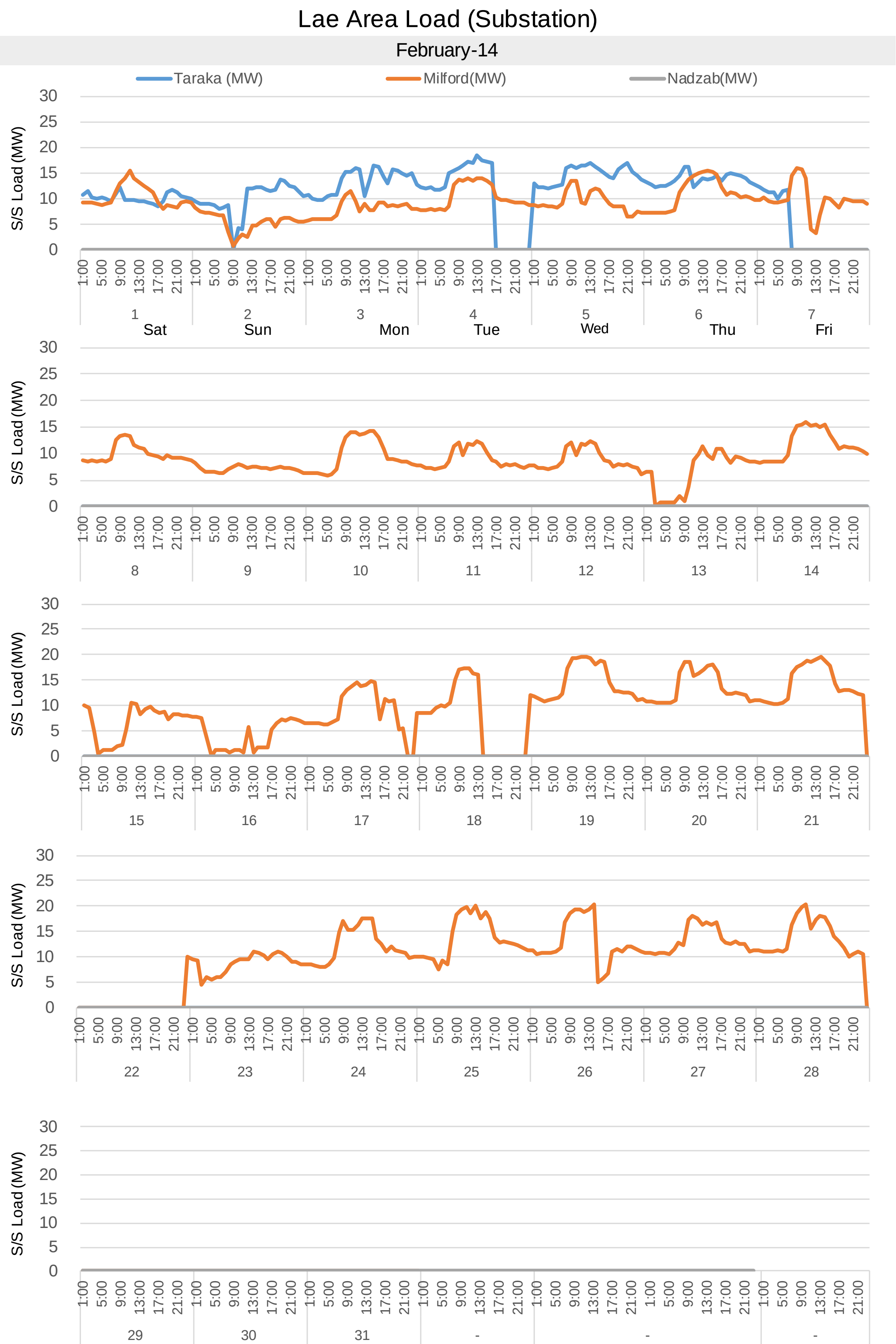
Max.(MW)	Ave.(MW)
32.77	21.97



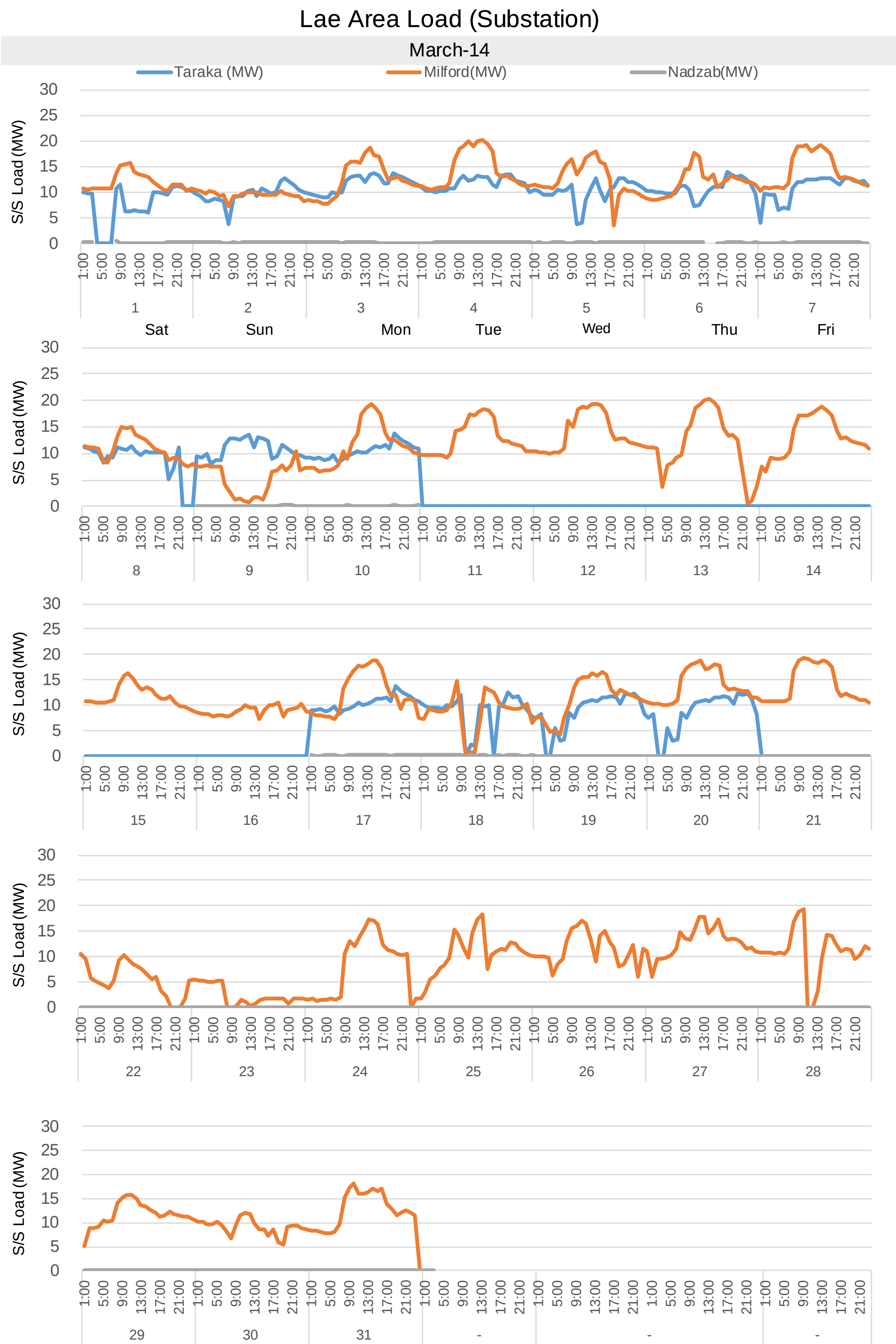
Max.(MW)	Ave.(MW)
33.24	20.79



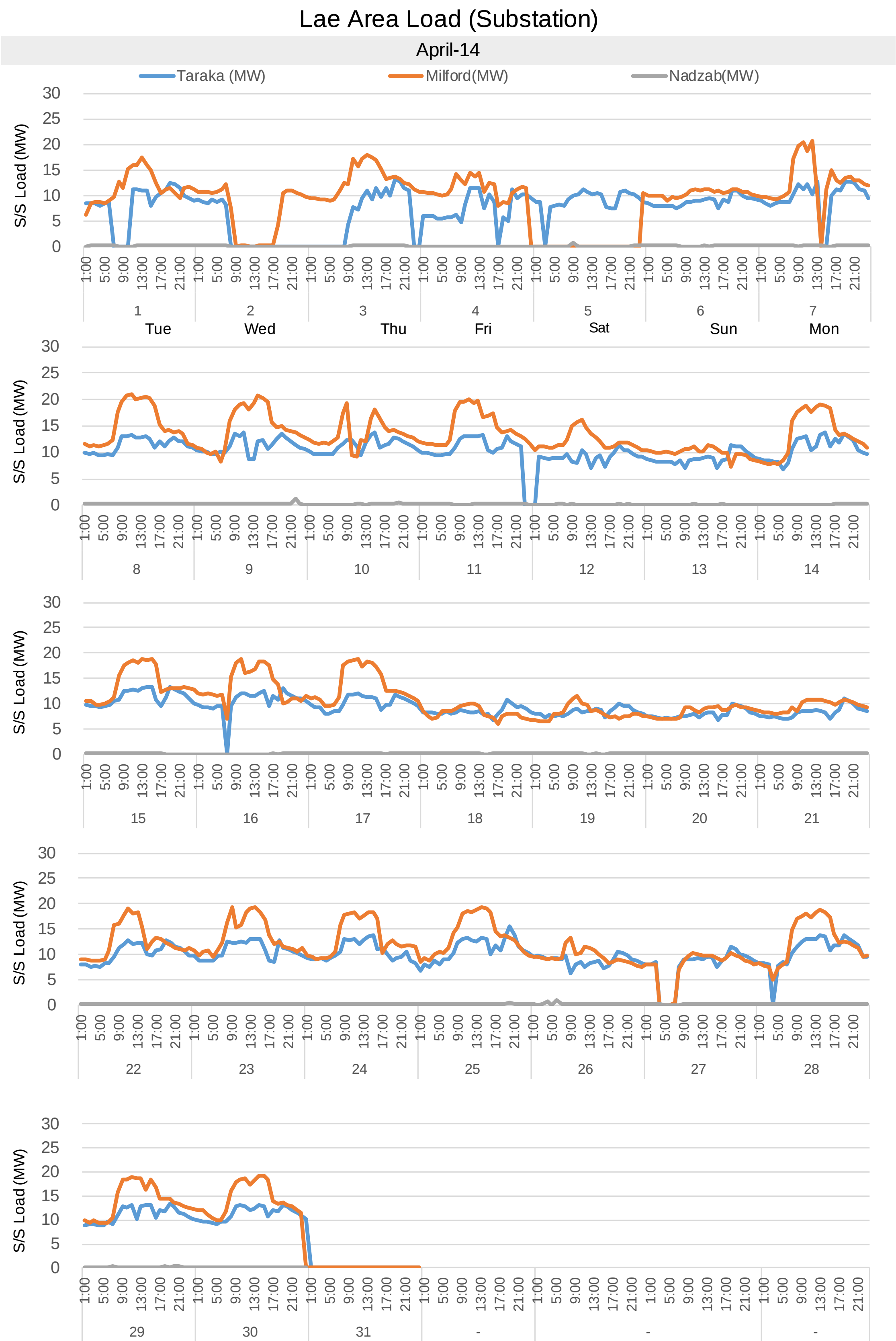
S/S	Taraka	Milford	Nadzab	Max.
Max. Load (MW)	15.49	16.11	0.00	16.11
Ave. Load (MW)	12.59	9.18	-	



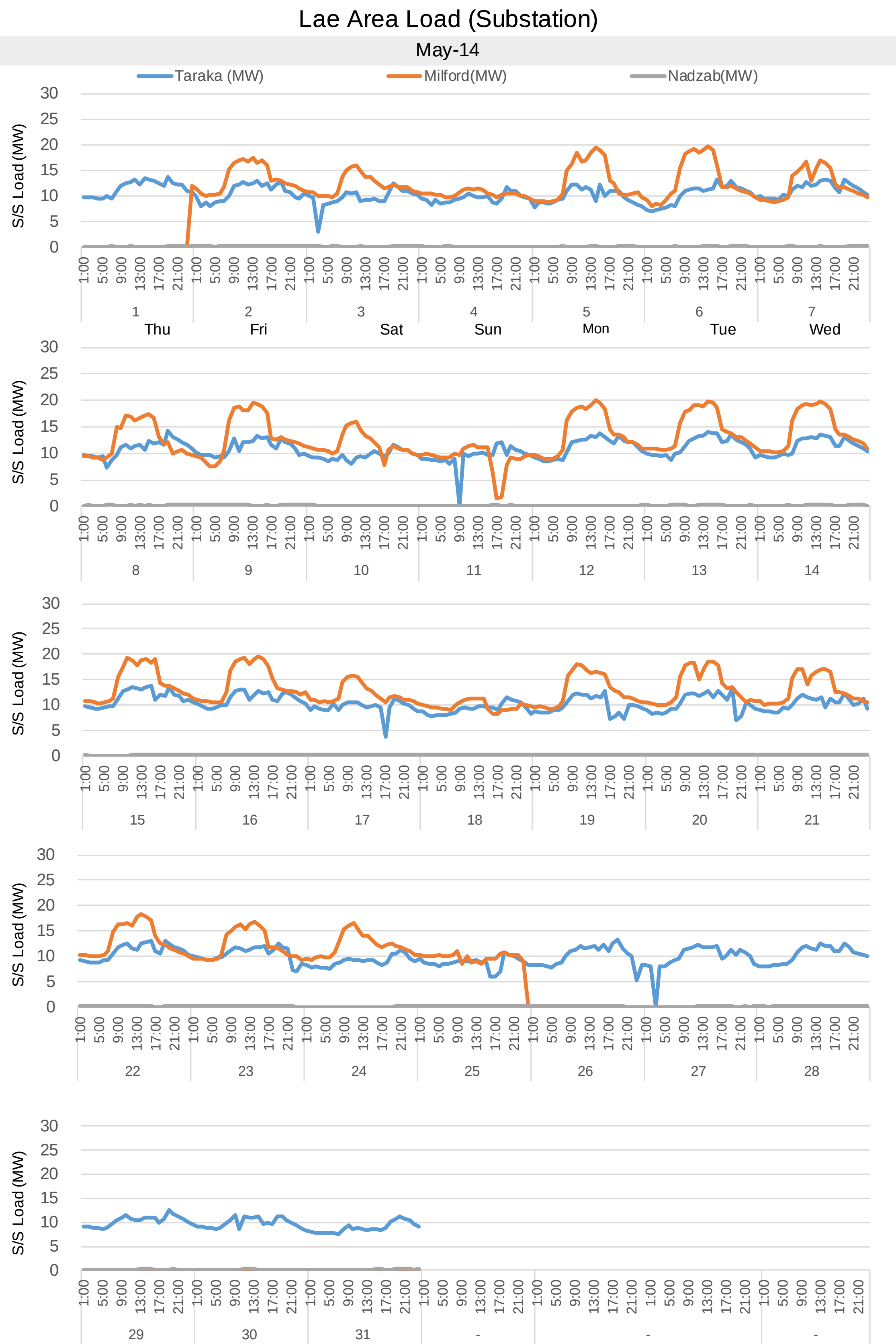
S/S	Taraka	Milford	Nadzab	Max.
Max. Load (MW)	18.42	20.40	0.00	20.40
Ave. Load (MW)	12.73	10.29	0.00	



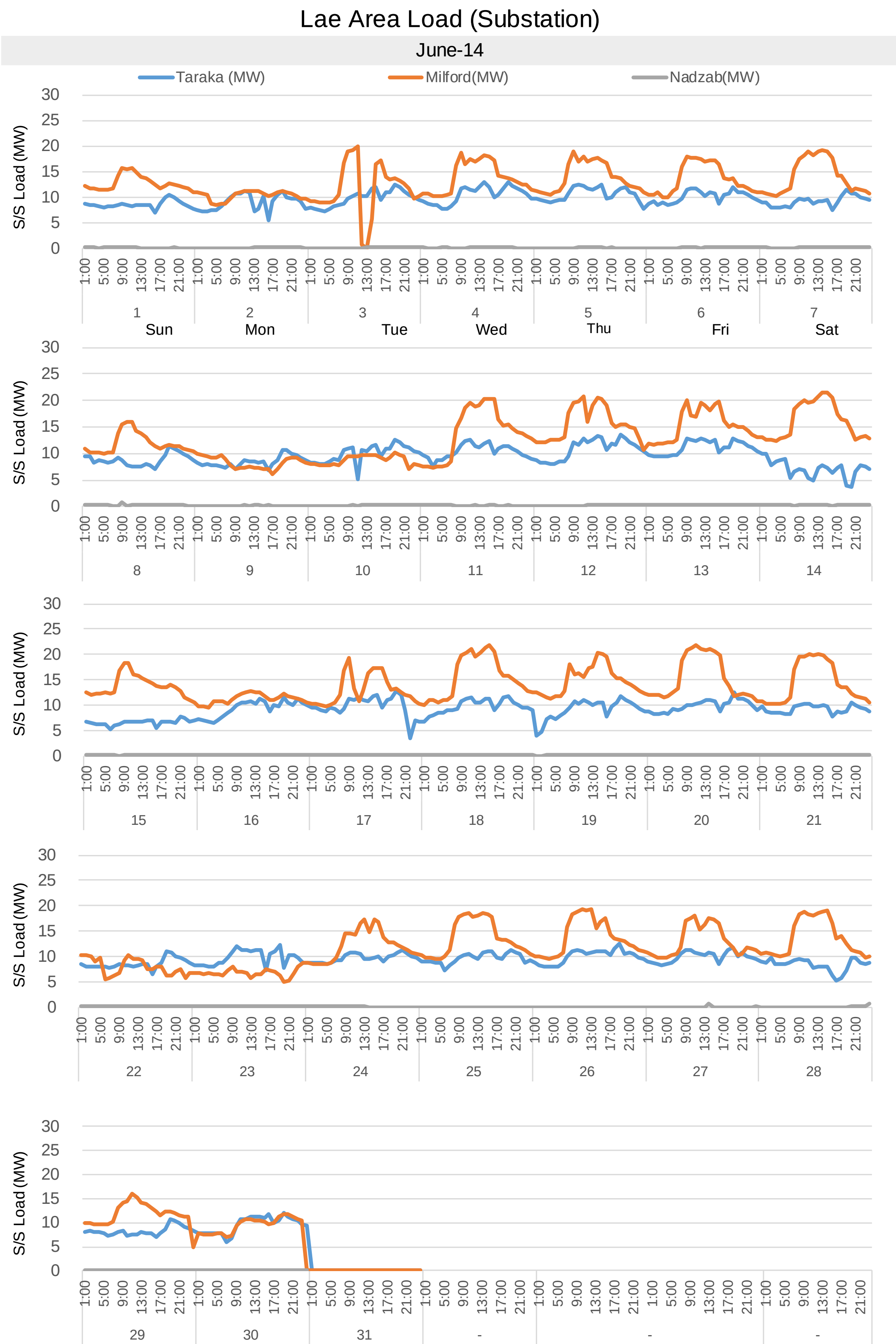
S/S	Taraka	Milford	Nadzab	Max.
Max. Load (MW)	13.95	20.21	0.47	20.21
Ave. Load (MW)	10.32	11.22	-	



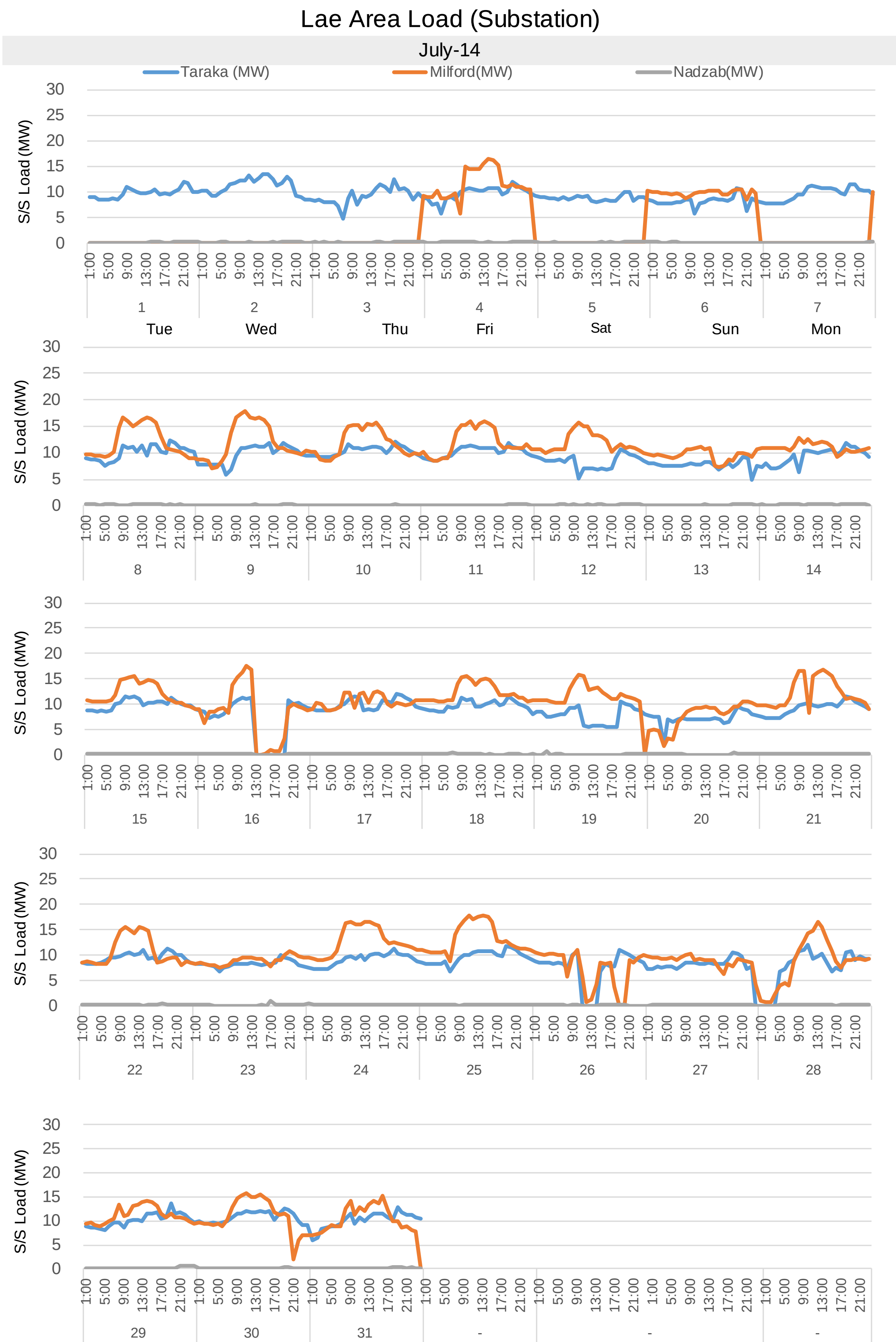
S/S	Taraka	Milford	Nadzab	Max.
Max. Load (MW)	15.54	21.09	0.99	21.09
Ave. Load (MW)	10.01	12.06	0.20	



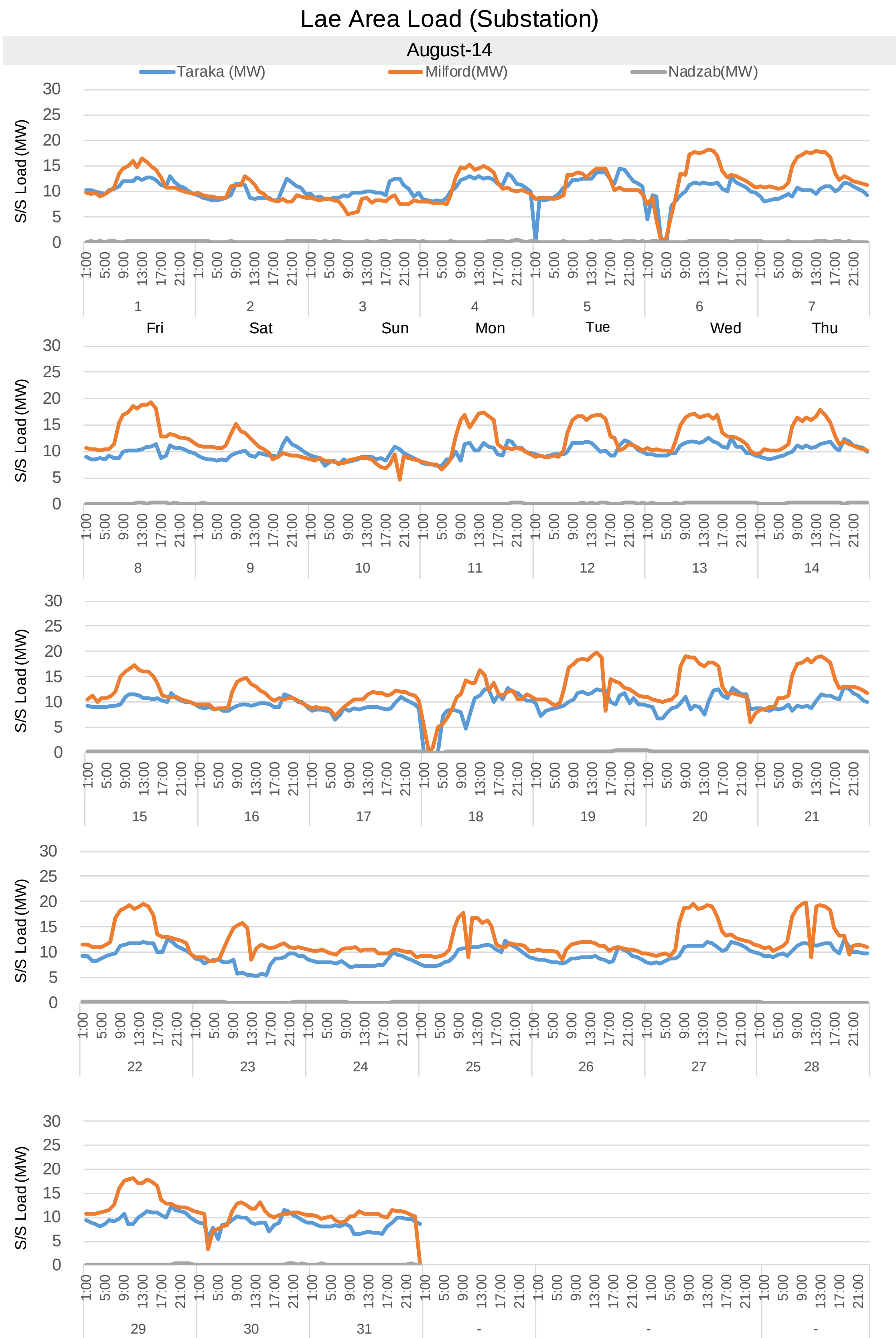
S/S	Taraka	Milford	Nadzab	Max.
Max. Load (MW)	14.22	20.12	0.35	20.12
Ave. Load (MW)	10.33	12.58	0.18	



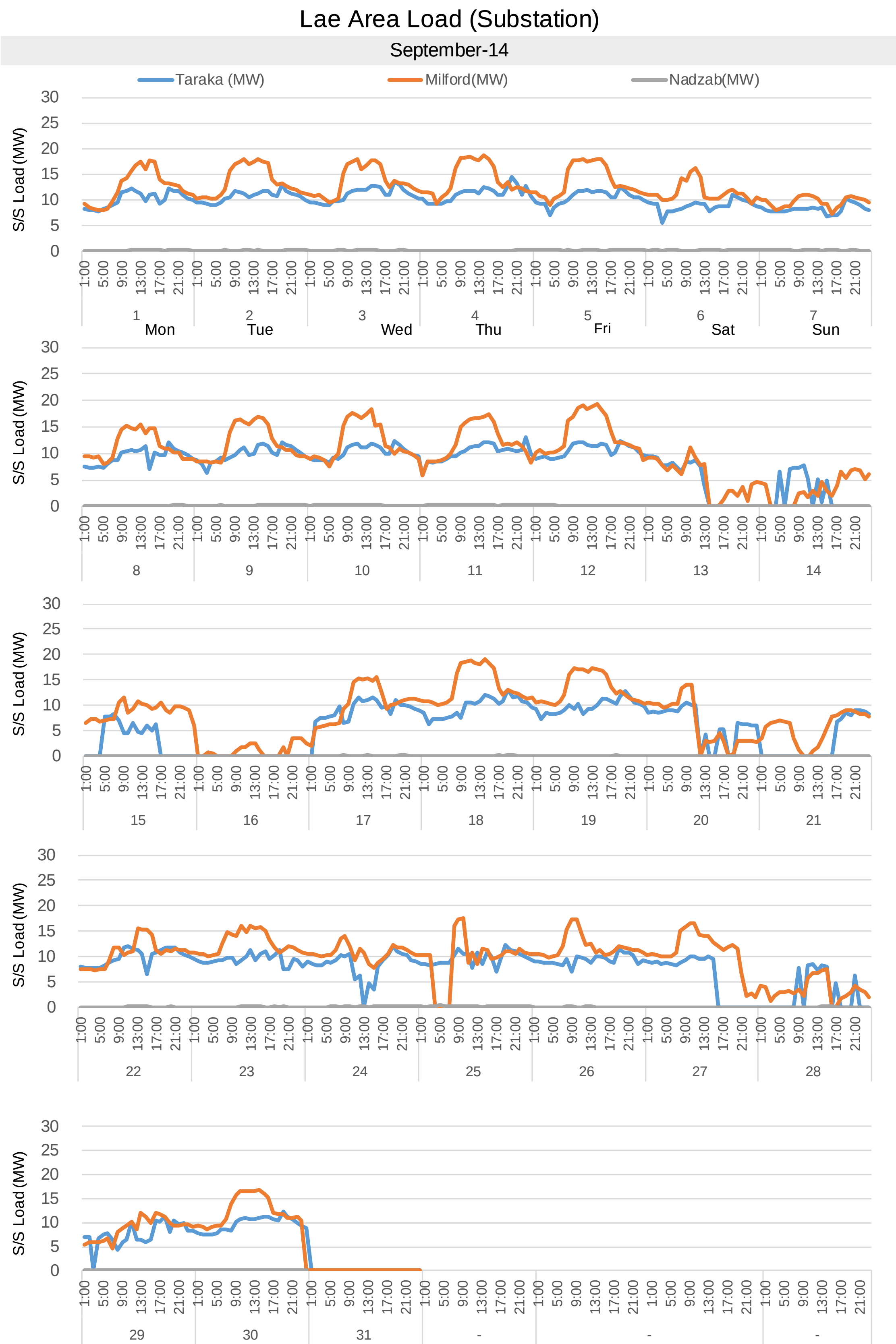
S/S	Taraka	Milford	Nadzab	Max.
Max. Load (MW)	13.44	21.94	0.84	21.94
Ave. Load (MW)	9.43	12.76	0.19	



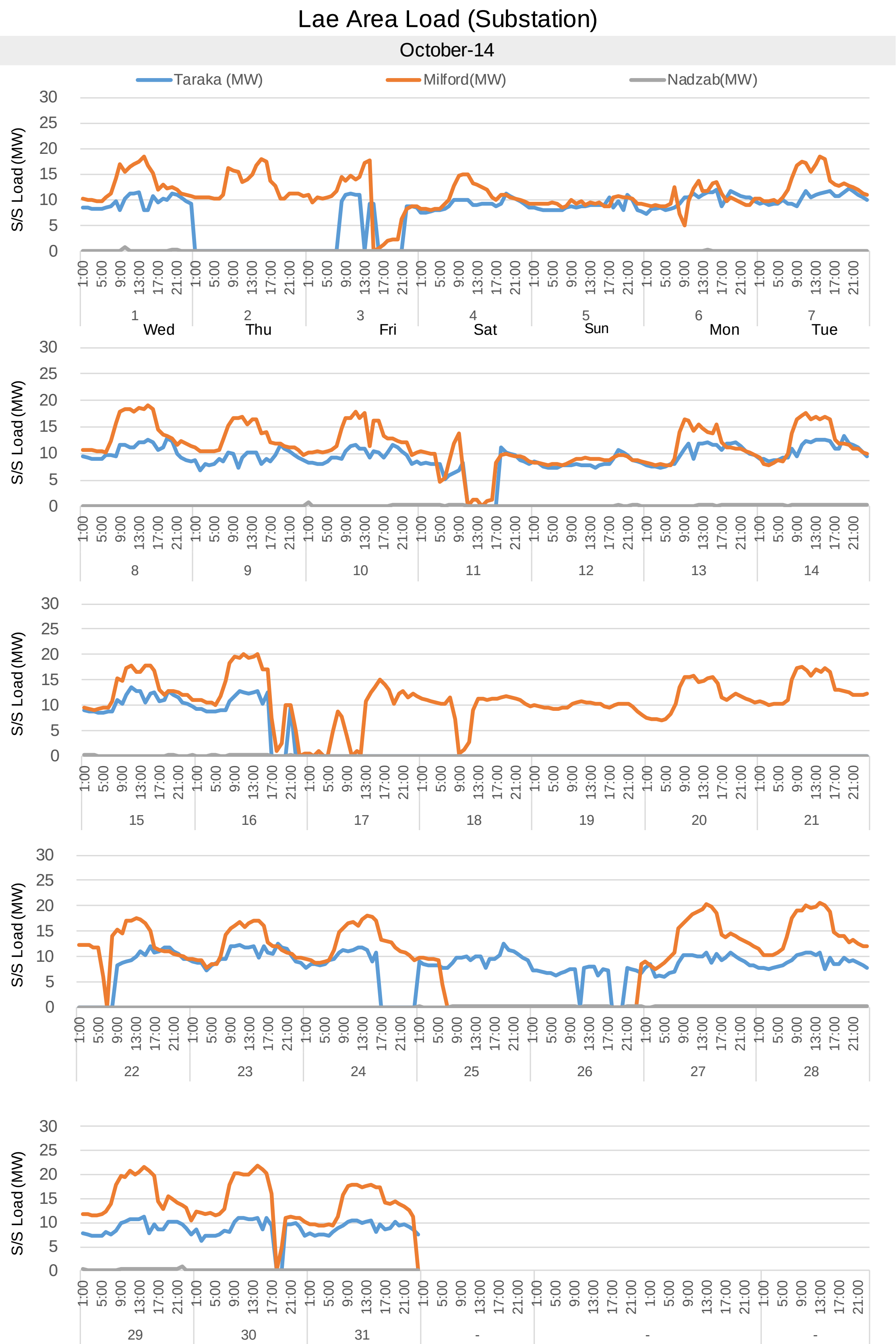
S/S	Taraka	Milford	Nadzab	Max.
Max. Load (MW)	13.53	17.92	0.98	17.92
Ave. Load (MW)	9.37	10.85	0.19	



S/S	Taraka	Milford	Nadzab	Max.
Max. Load (MW)	14.44	19.86	0.59	19.86
Ave. Load (MW)	9.81	11.88	0.21	

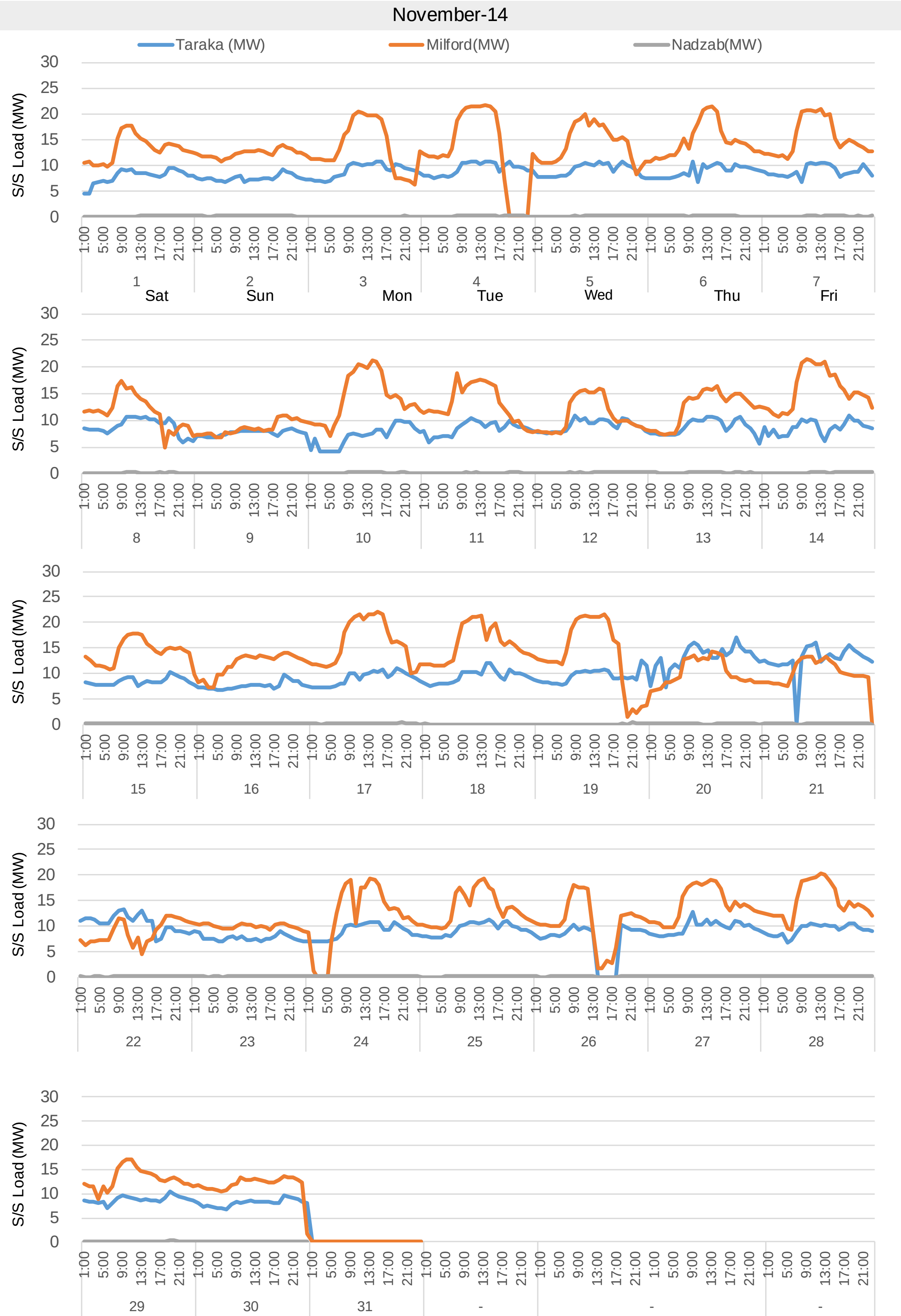


S/S	Taraka	Milford	Nadzab	Max.
Max. Load (MW)	14.60	19.28	0.46	19.28
Ave. Load (MW)	9.48	10.76	0.16	

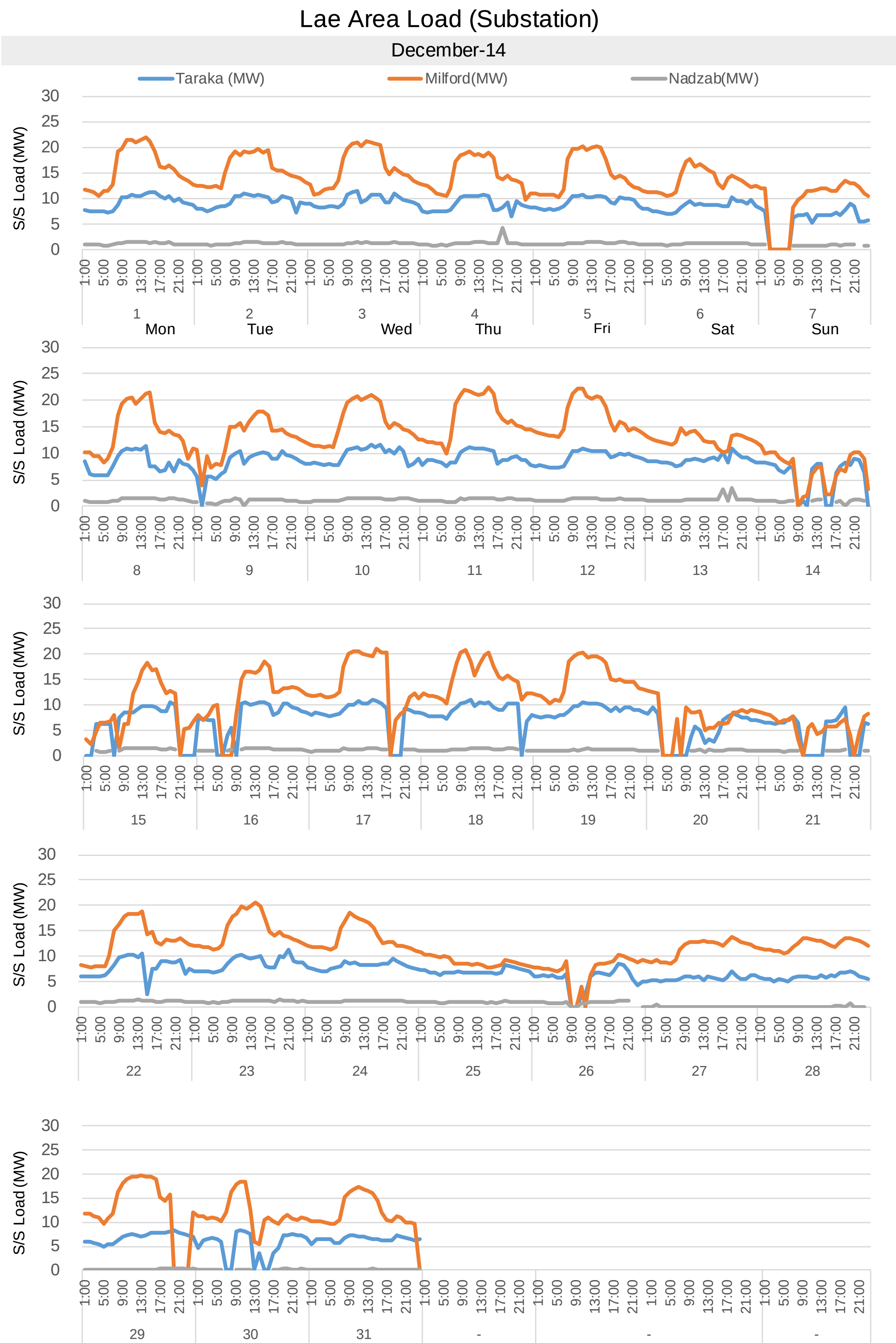


S/S	Taraka	Milford	Nadzab	Max.
Max. Load (MW)	13.44	21.85	0.81	21.85
Ave. Load (MW)	9.51	12.07	0.17	

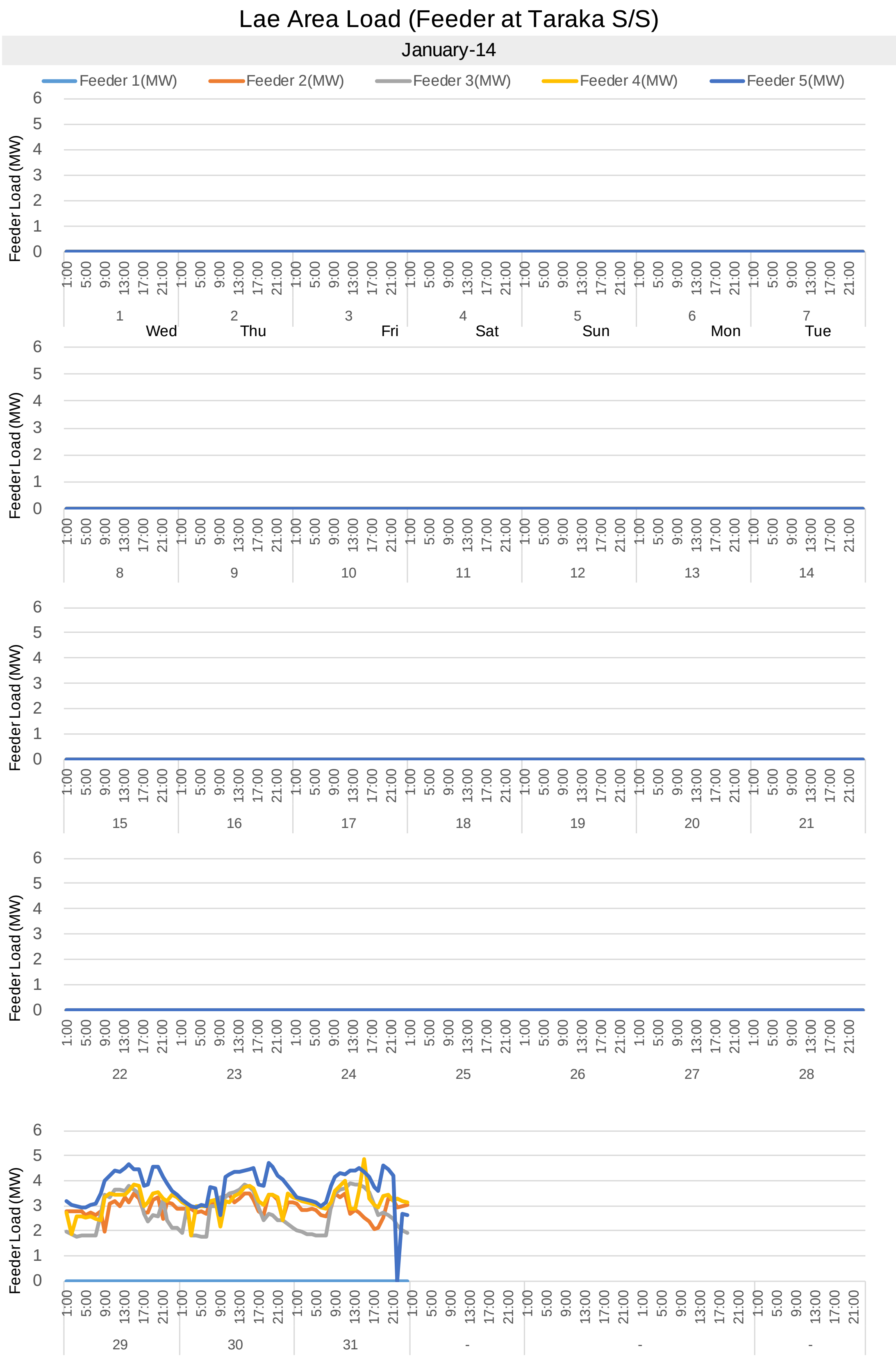
Lae Area Load (Substation)



S/S	Taraka	Milford	Nadzab	Max.
Max. Load (MW)	16.99	22.14	0.41	22.14
Ave. Load (MW)	9.06	13.02	0.19	

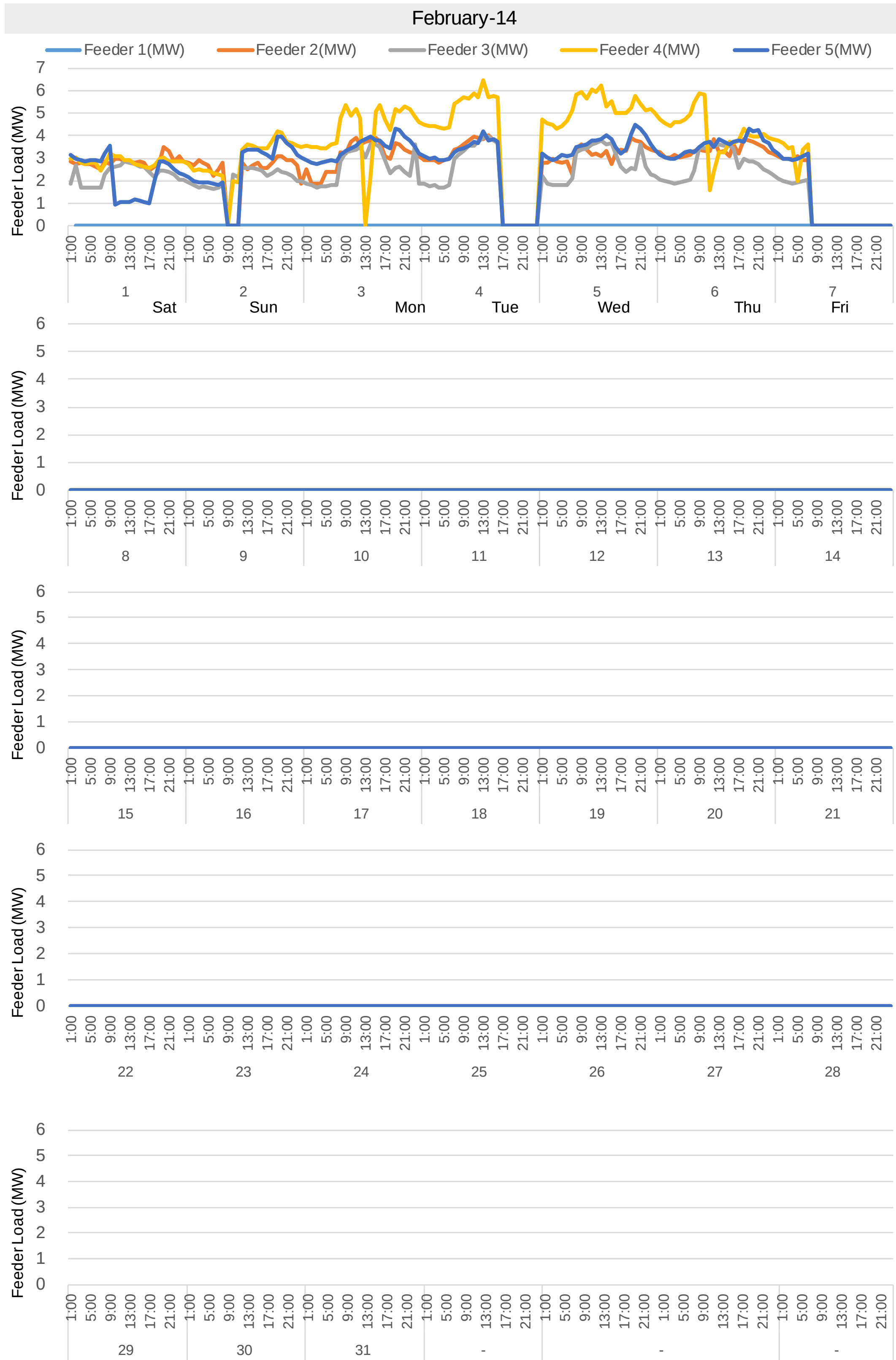


S/S	Taraka	Milford	Nadzab	Max.
Max. Load (MW)	11.63	22.36	0.92	22.36
Ave. Load (MW)	8.10	12.97	0.20	

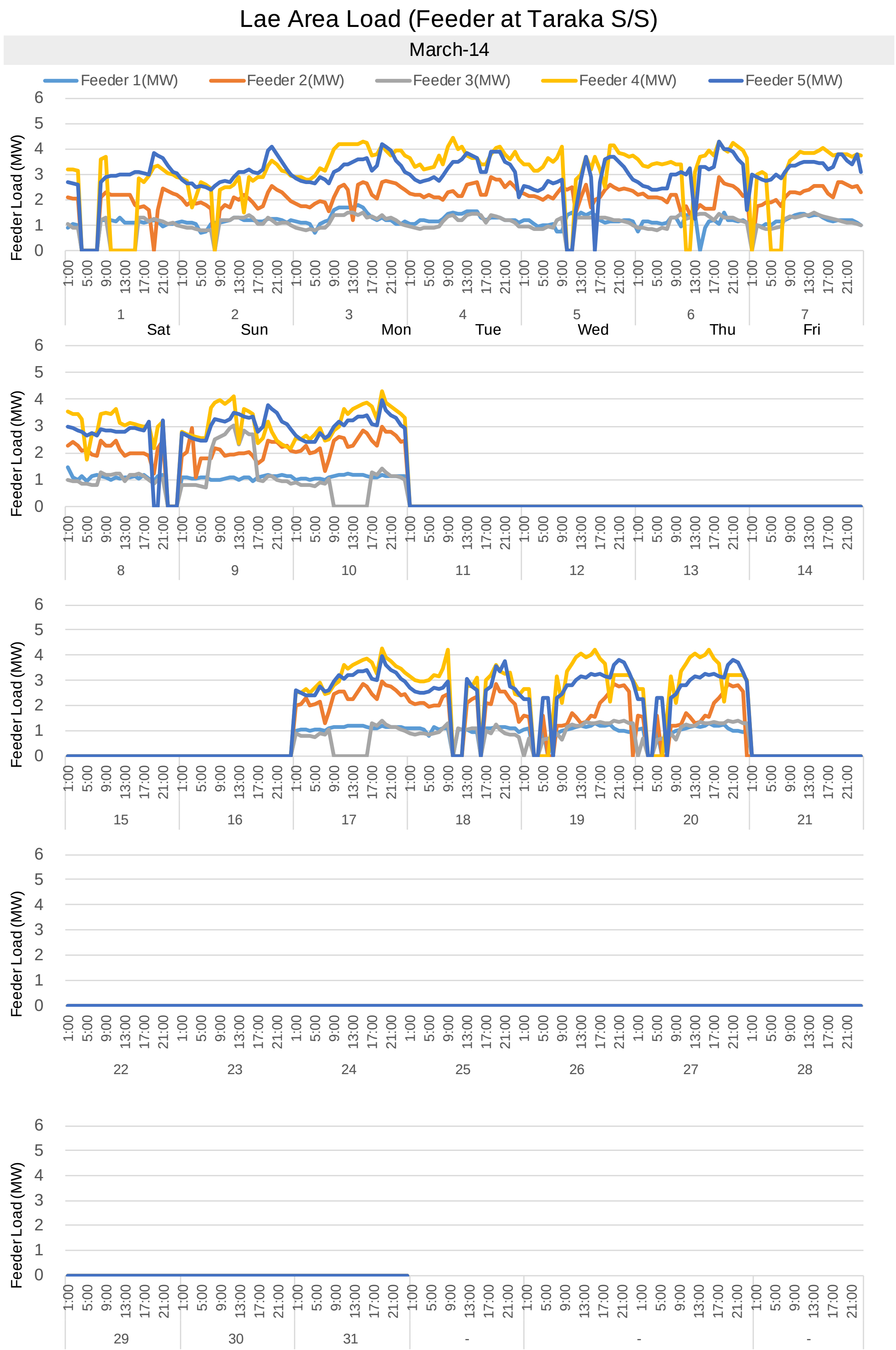


Feeder	No.1	No.2	No.3	No.4	No.5		Max.
Max. Load (MW)	-	3.51	3.89	4.88	4.70		4.88
Ave. Load (MW)	-	2.95	2.72	3.18	3.79		3.79

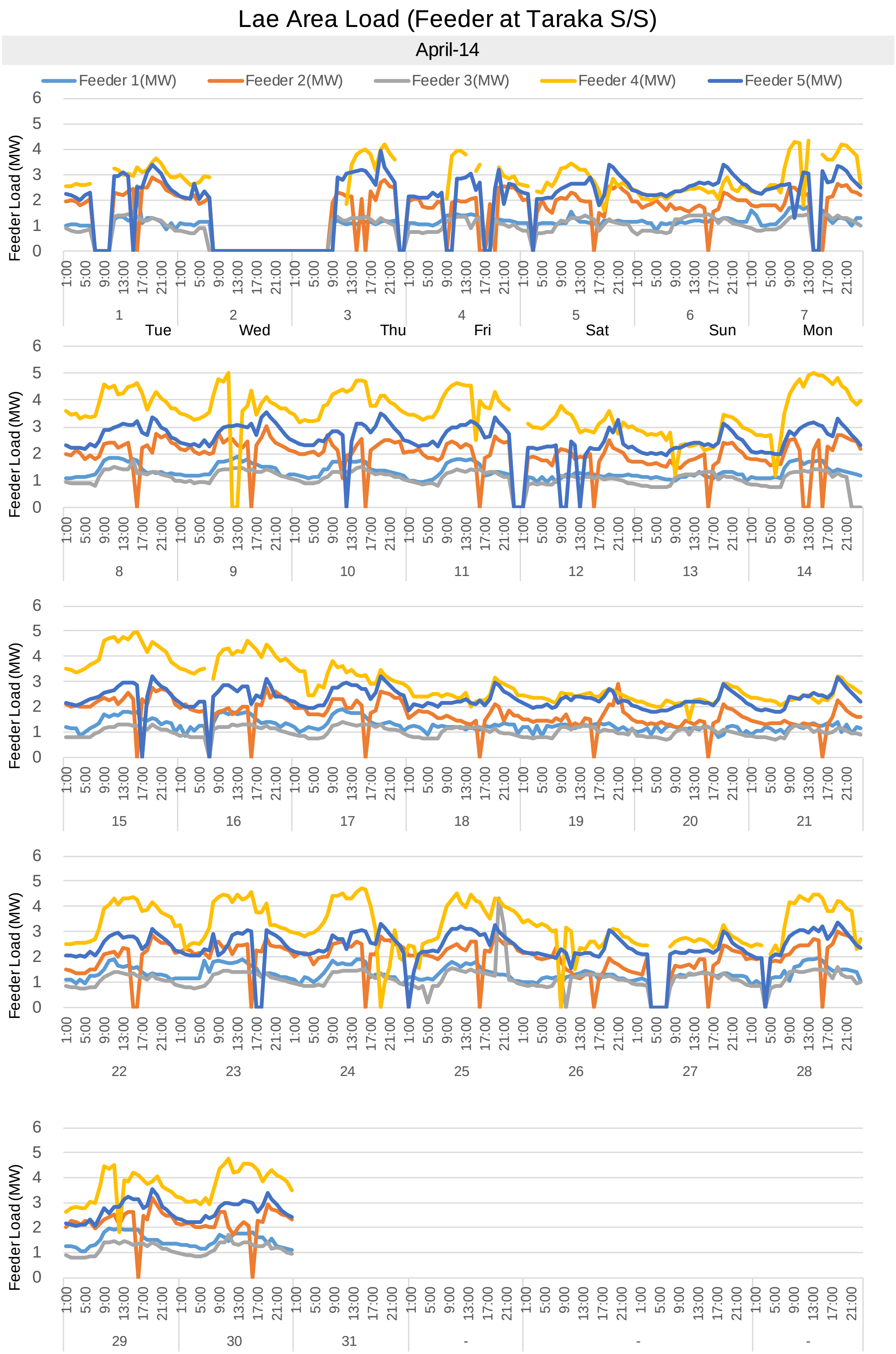
Lae Area Load (Feeder at Taraka S/S)



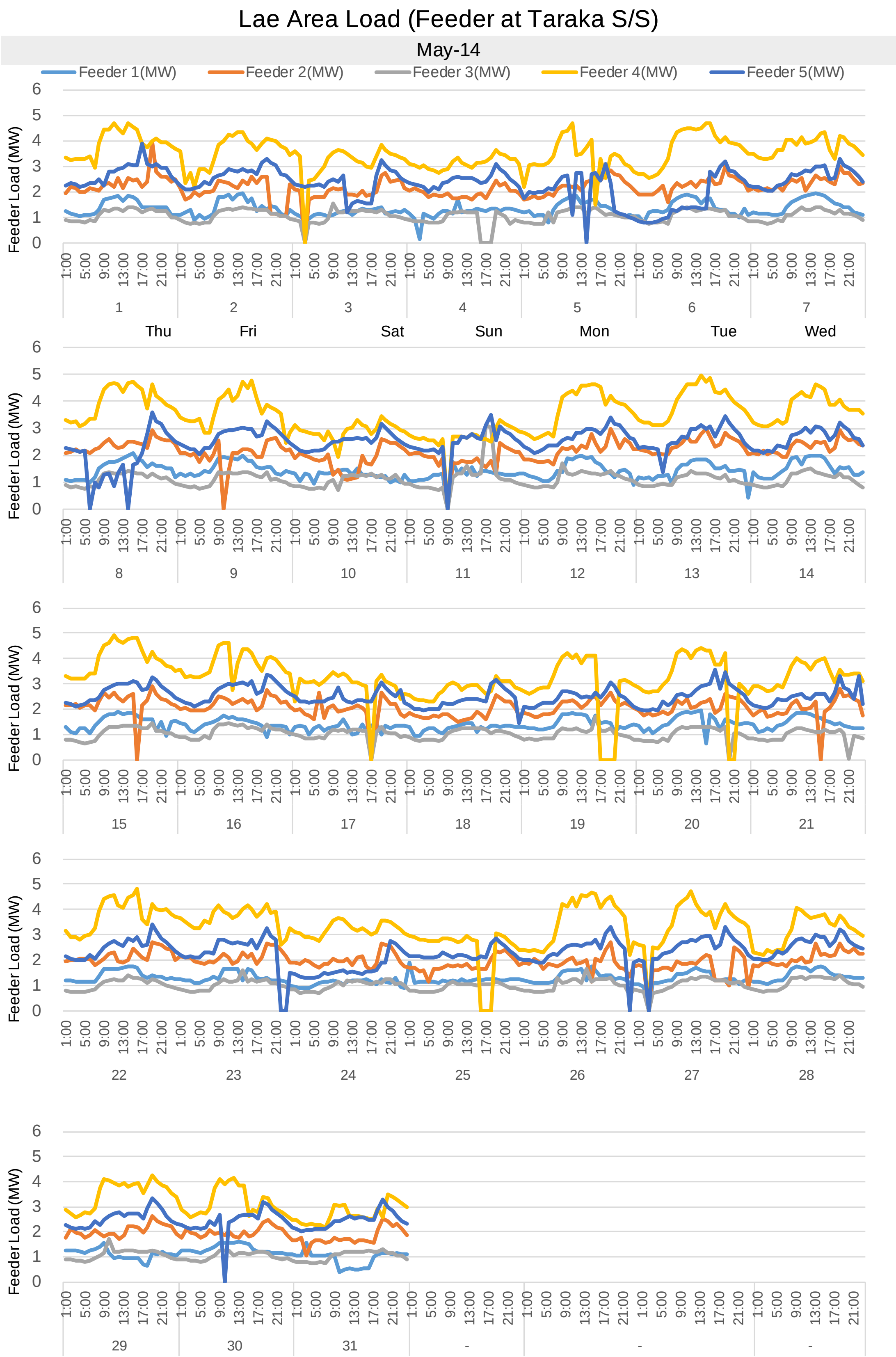
Feeder	No.1	No.2	No.3	No.4	No.5		Max.
Max. Load (MW)	-	3.99	3.94	6.45	4.47		6.45
Ave. Load (MW)	-	3.09	2.53	4.06	3.16		4.06



Feeder	No.1	No.2	No.3	No.4	No.5		Max.
Max. Load (MW)	1.80	2.98	3.04	4.45	4.31		4.45
Ave. Load (MW)	1.15	2.15	1.16	3.31	3.04		3.31

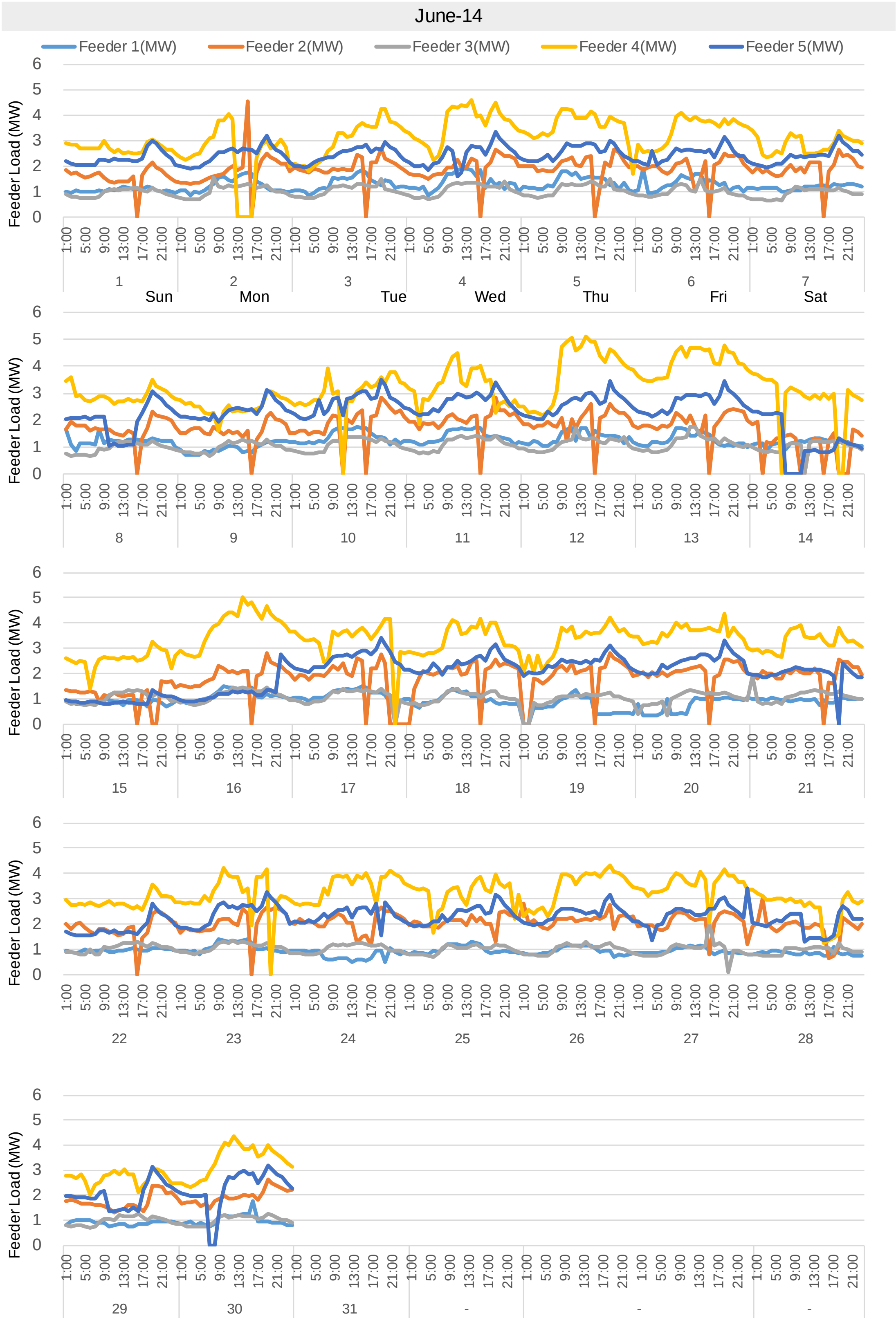


Feeder	No.1	No.2	No.3	No.4	No.5		Max.
Max. Load (MW)	2.54	3.19	4.31	5.02	3.96		5.02
Ave. Load (MW)	1.31	2.05	1.11	3.26	2.53		3.26

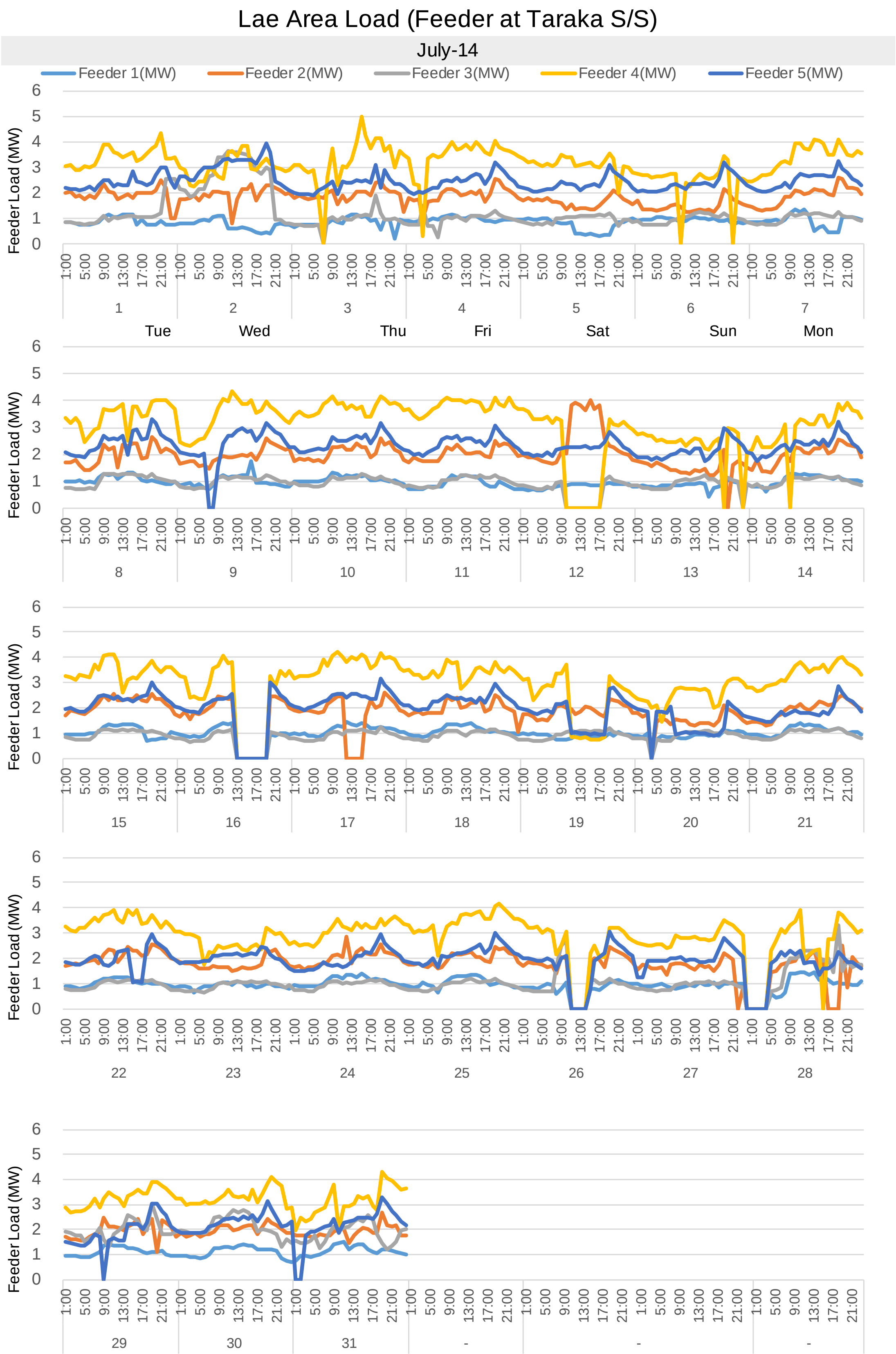


Feeder	No.1	No.2	No.3	No.4	No.5		Max.
Max. Load (MW)	2.06	3.92	3.13	4.98	3.88		4.98
Ave. Load (MW)	1.35	2.10	1.08	3.45	2.46		3.45

Lae Area Load (Feeder at Taraka S/S)

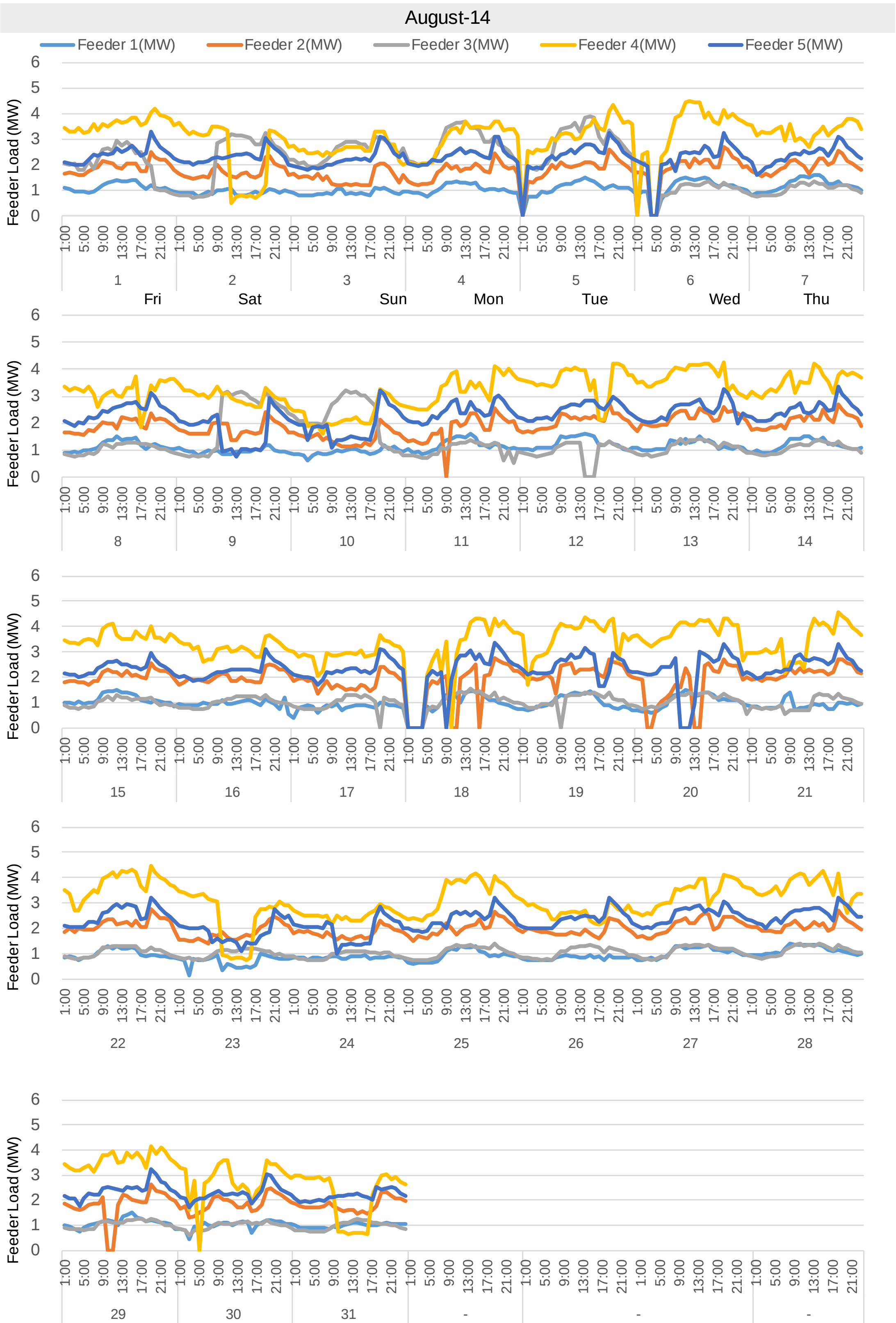


Feeder	No.1	No.2	No.3	No.4	No.5		Max.
Max. Load (MW)	1.90	4.52	2.05	5.09	3.51		5.09
Ave. Load (MW)	1.09	1.96	1.05	3.24	2.27		3.24

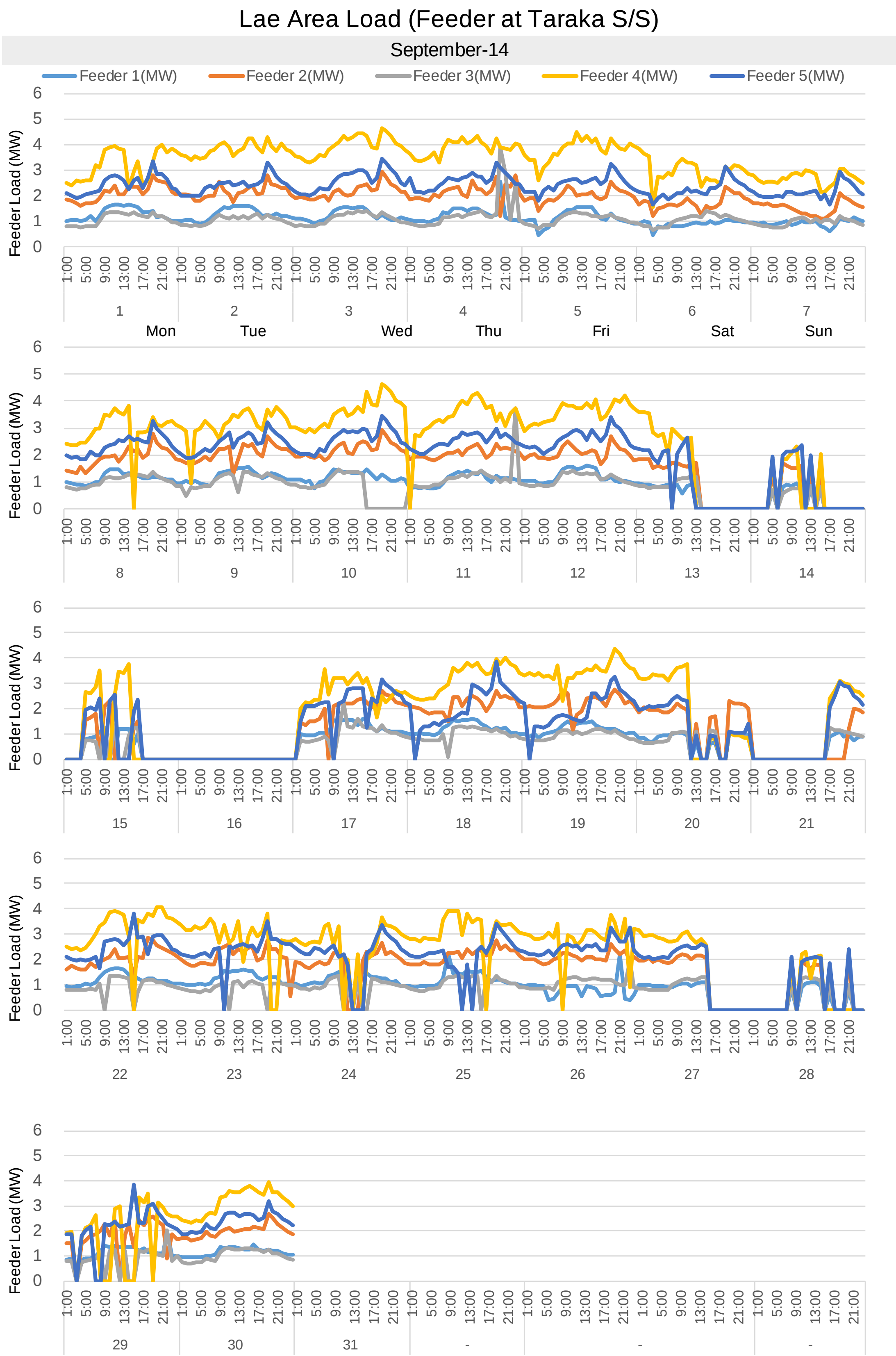


Feeder	No.1	No.2	No.3	No.4	No.5		Max.
Max. Load (MW)	1.77	4.02	3.62	4.99	3.96		4.99
Ave. Load (MW)	0.99	1.93	1.16	3.19	2.23		3.19

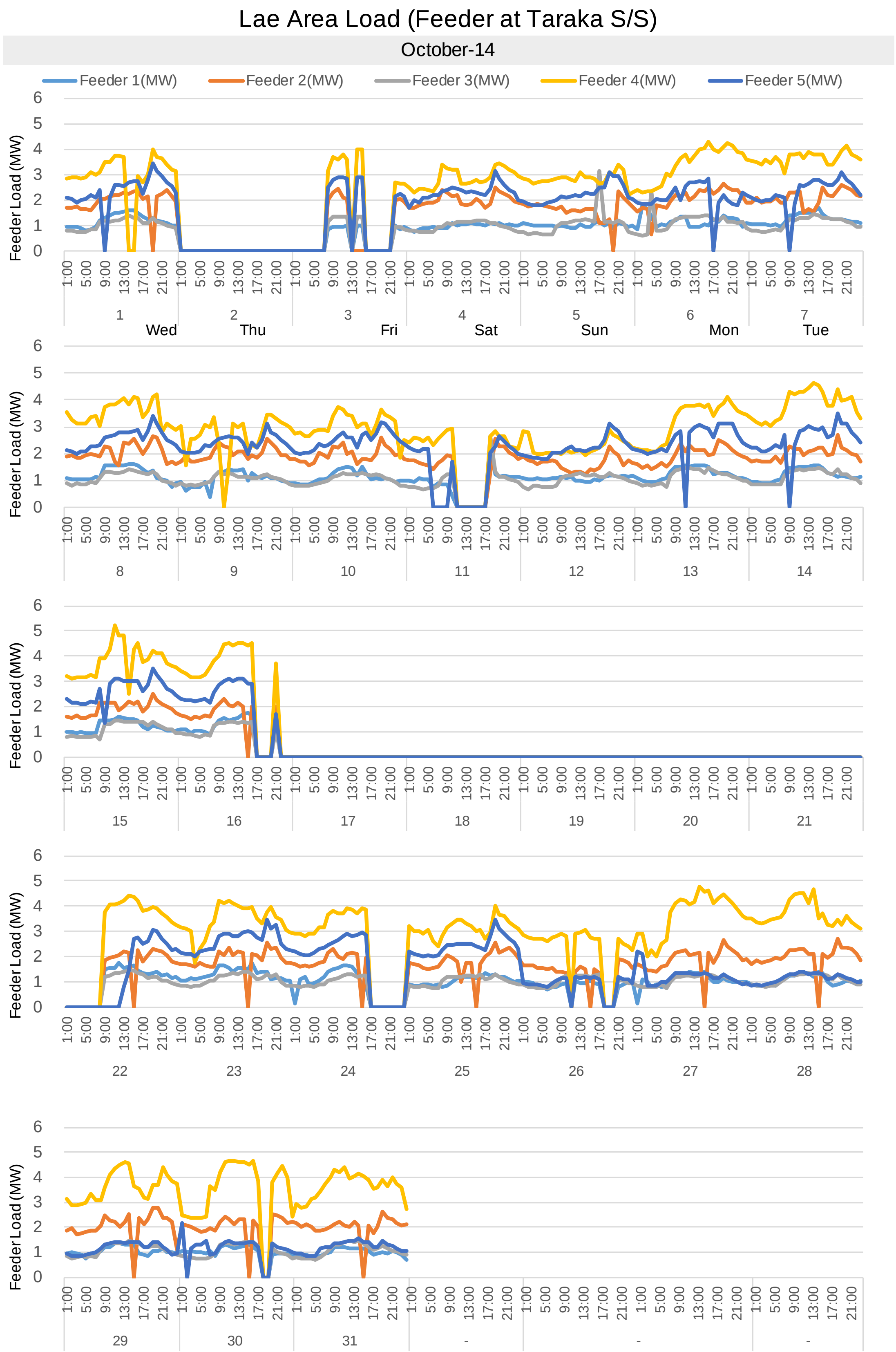
Lae Area Load (Feeder at Taraka S/S)



Feeder	No.1	No.2	No.3	No.4	No.5		Max.
Max. Load (MW)	1.61	2.76	3.89	4.58	3.37		4.58
Ave. Load (MW)	1.04	1.94	1.37	3.19	2.34		3.19

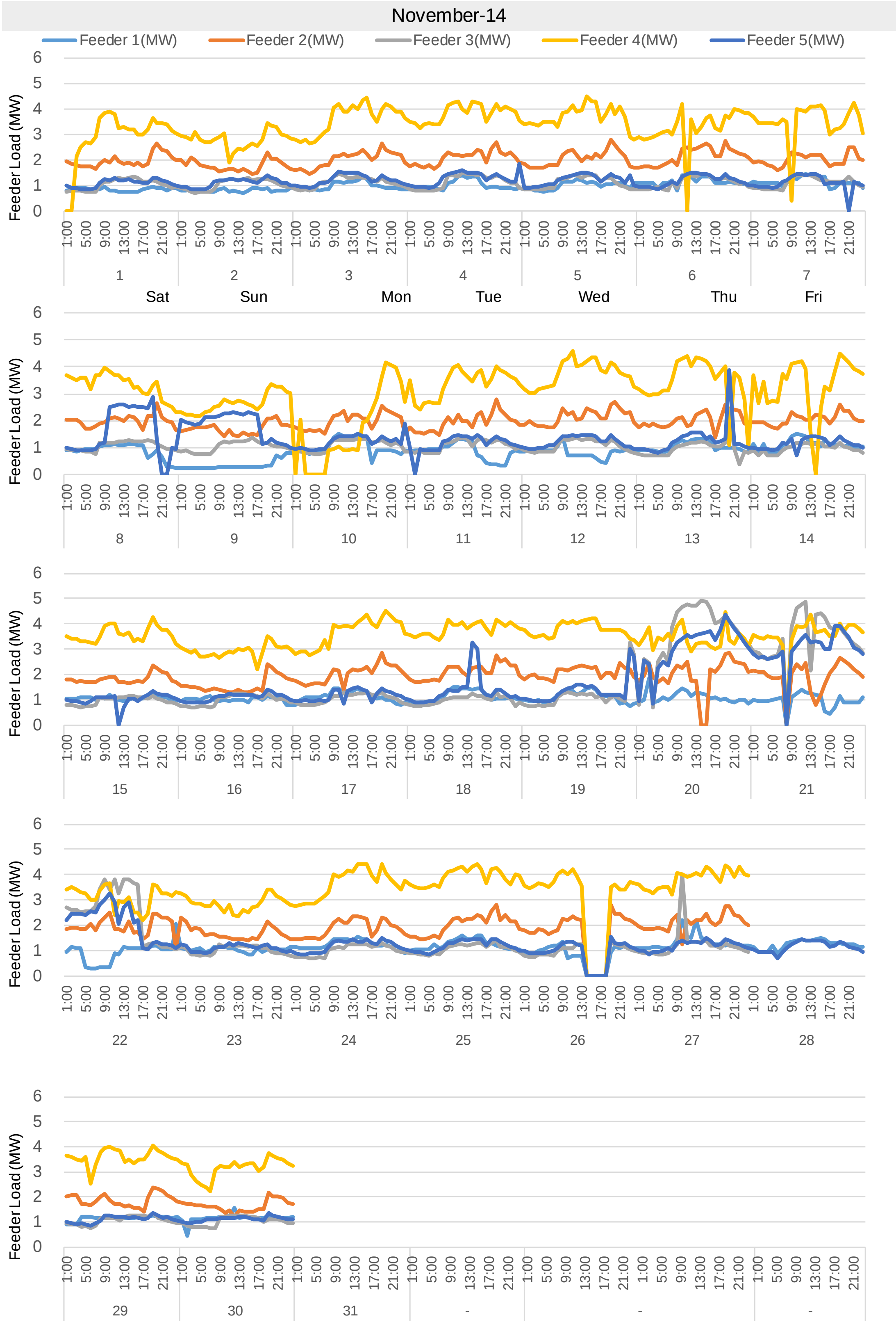


Feeder	No.1	No.2	No.3	No.4	No.5		Max.
Max. Load (MW)	2.56	2.93	3.89	4.62	3.85		4.62
Ave. Load (MW)	1.13	2.02	1.06	3.20	2.38		3.20

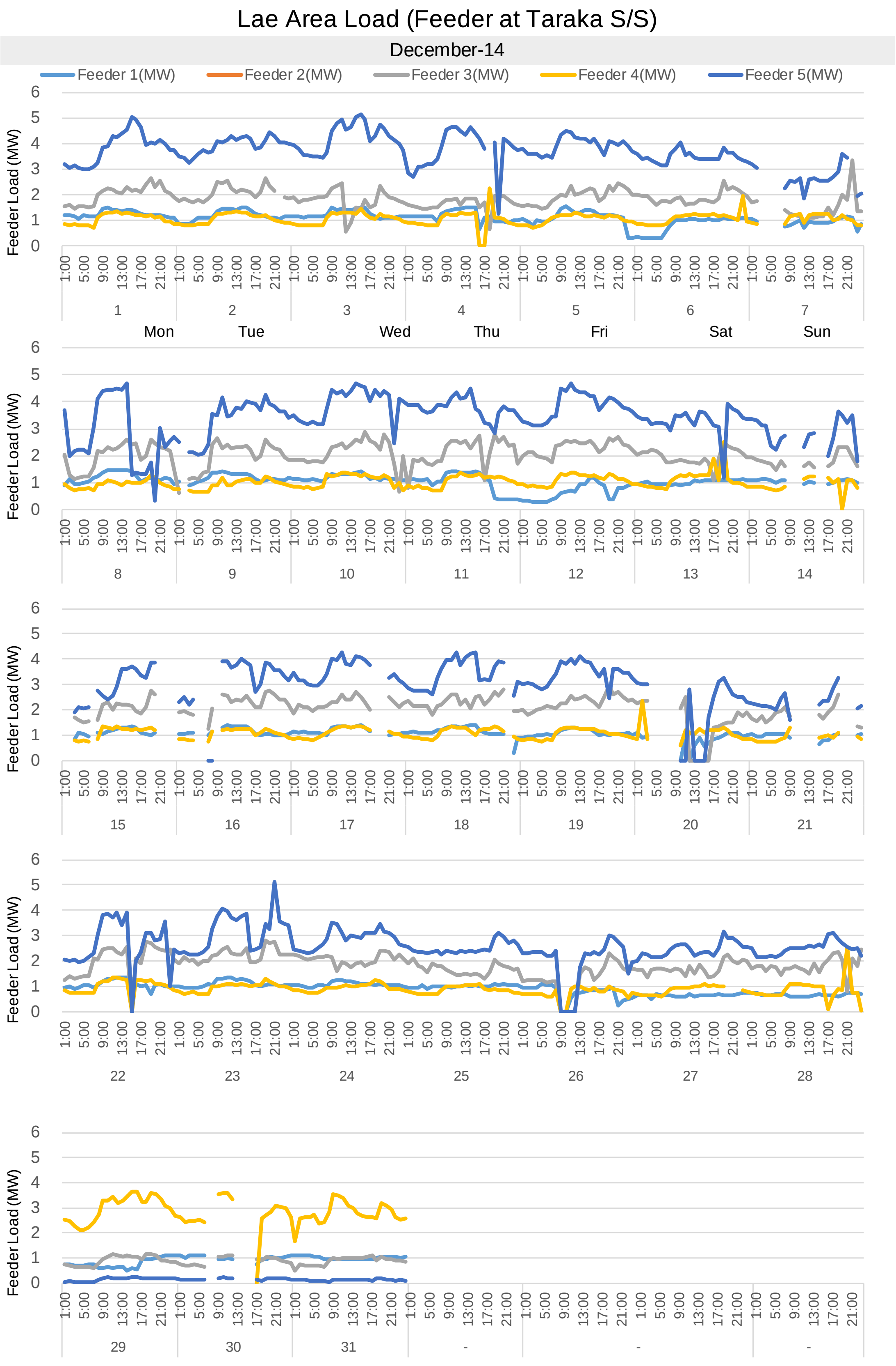


Feeder	No.1	No.2	No.3	No.4	No.5		Max.
Max. Load (MW)	2.39	2.77	3.13	5.20	3.51		5.20
Ave. Load (MW)	1.14	1.96	1.09	3.33	2.13		3.33

Lae Area Load (Feeder at Taraka S/S)

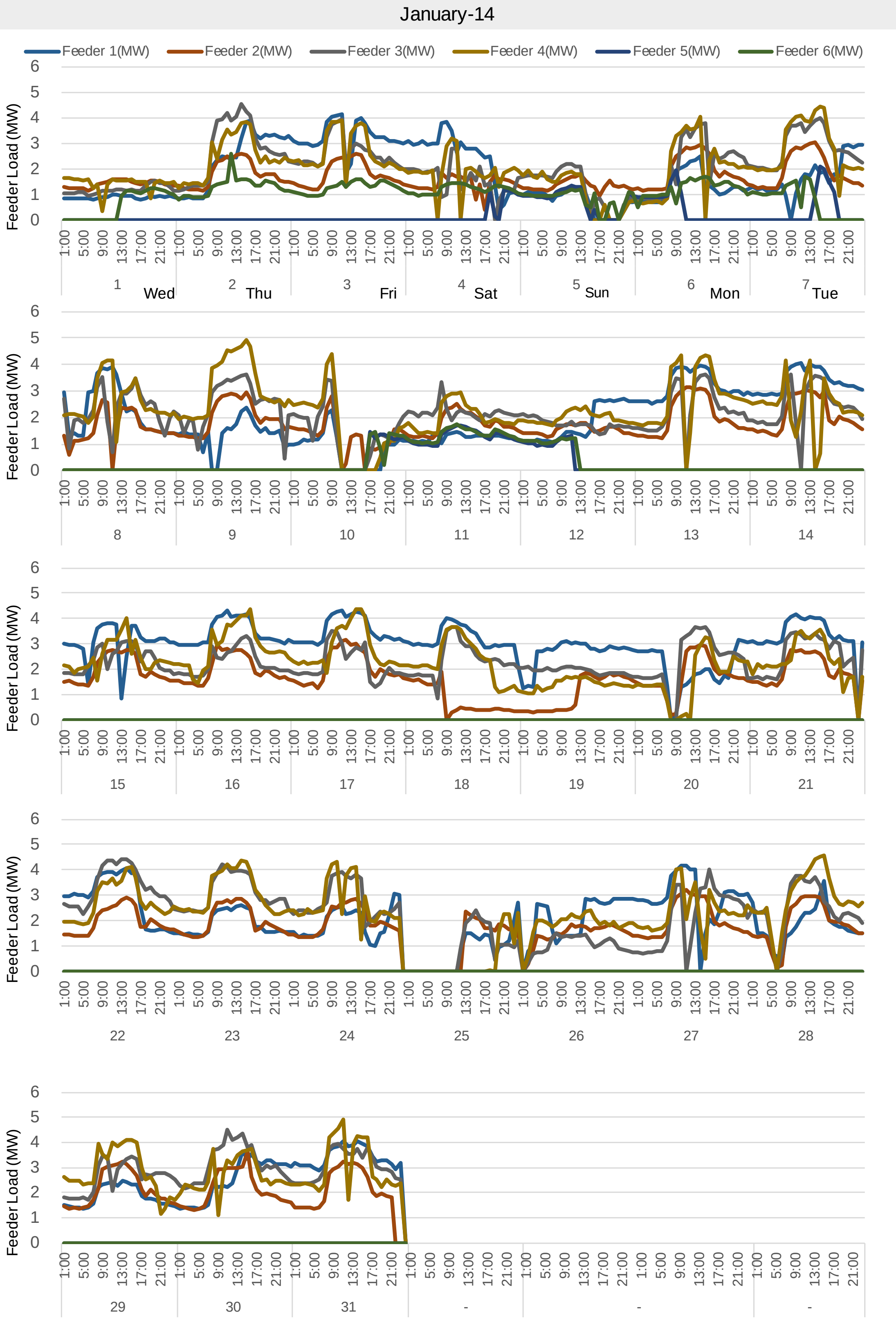


Feeder	No.1	No.2	No.3	No.4	No.5		Max.
Max. Load (MW)	2.23	2.86	4.94	4.59	4.37		4.94
Ave. Load (MW)	1.04	1.97	1.29	3.44	1.39		3.44

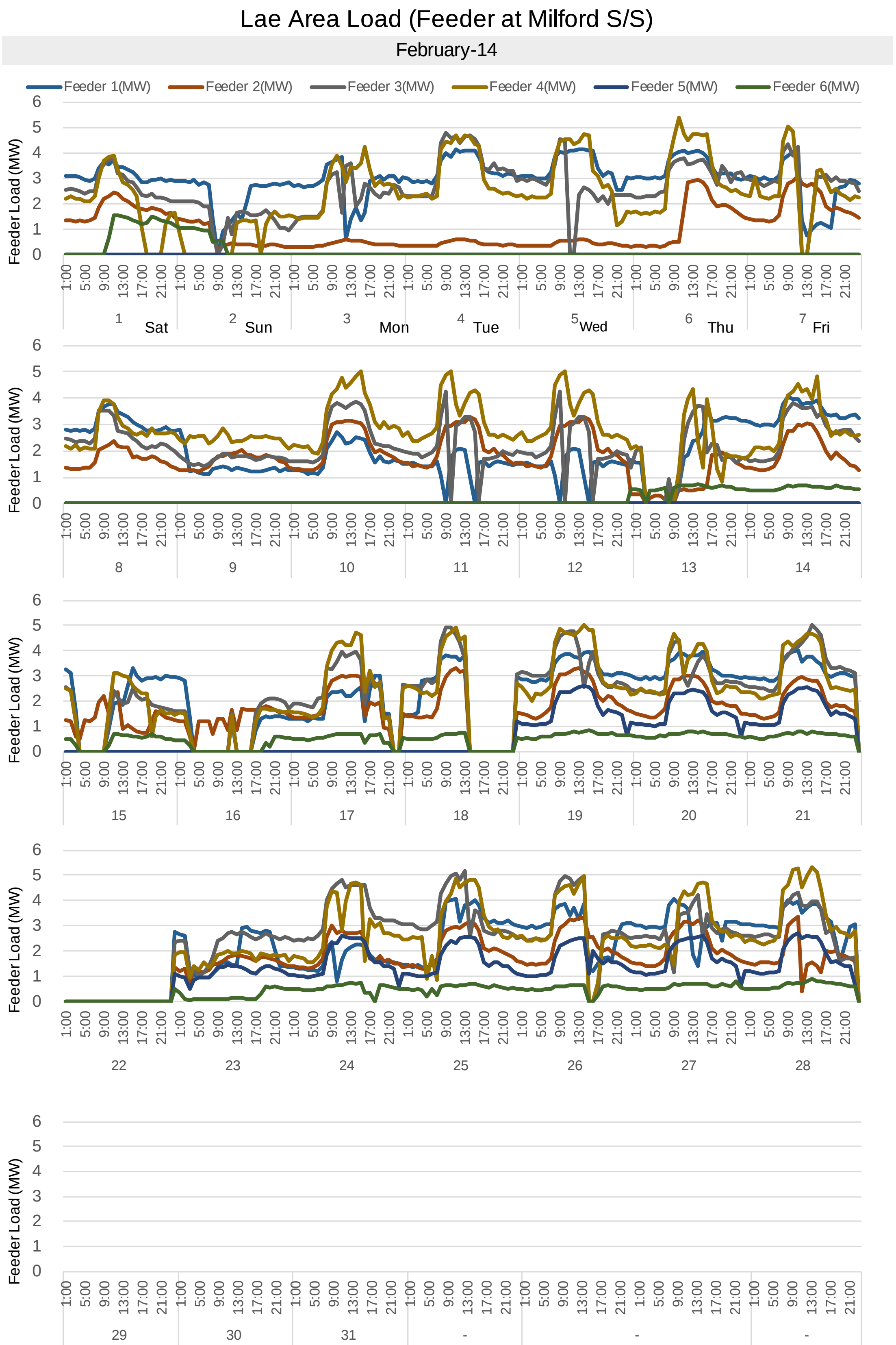


Feeder	No.1	No.2	No.3	No.4	No.5		Max.
Max. Load (MW)	1.54	3.35	2.54	5.14	4.26		5.14
Ave. Load (MW)	1.02	1.98	1.01	3.21	1.00		3.21

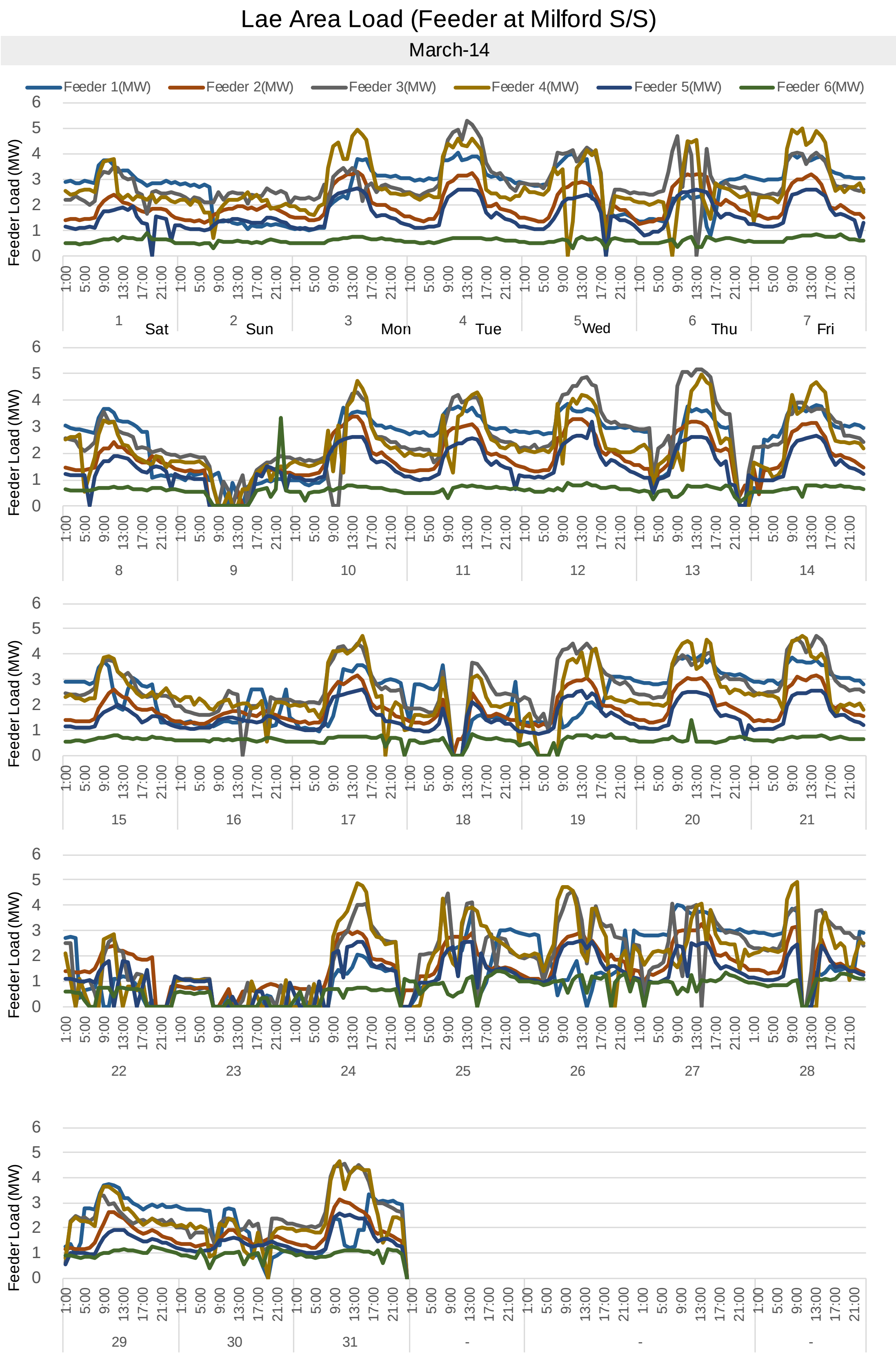
Lae Area Load (Feeder at Milford S/S)



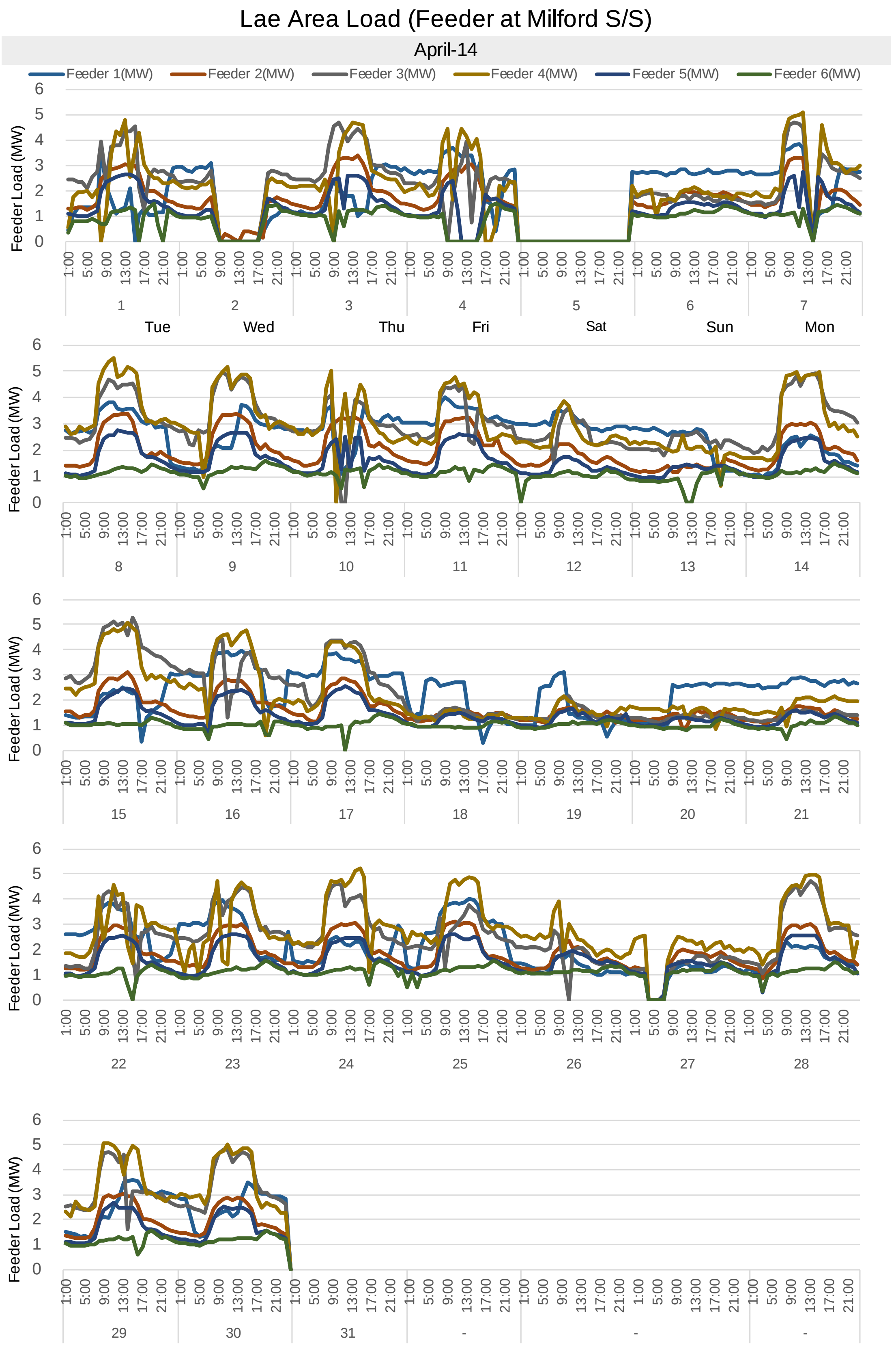
Feeder	No.1	No.2	No.3	No.4	No.5	No.6	Max.
Max. Load (MW)	4.42	4.38	4.59	5.08	2.23	3.34	5.08
Ave. Load (MW)	2.39	1.81	2.38	2.49	1.21	1.25	2.49



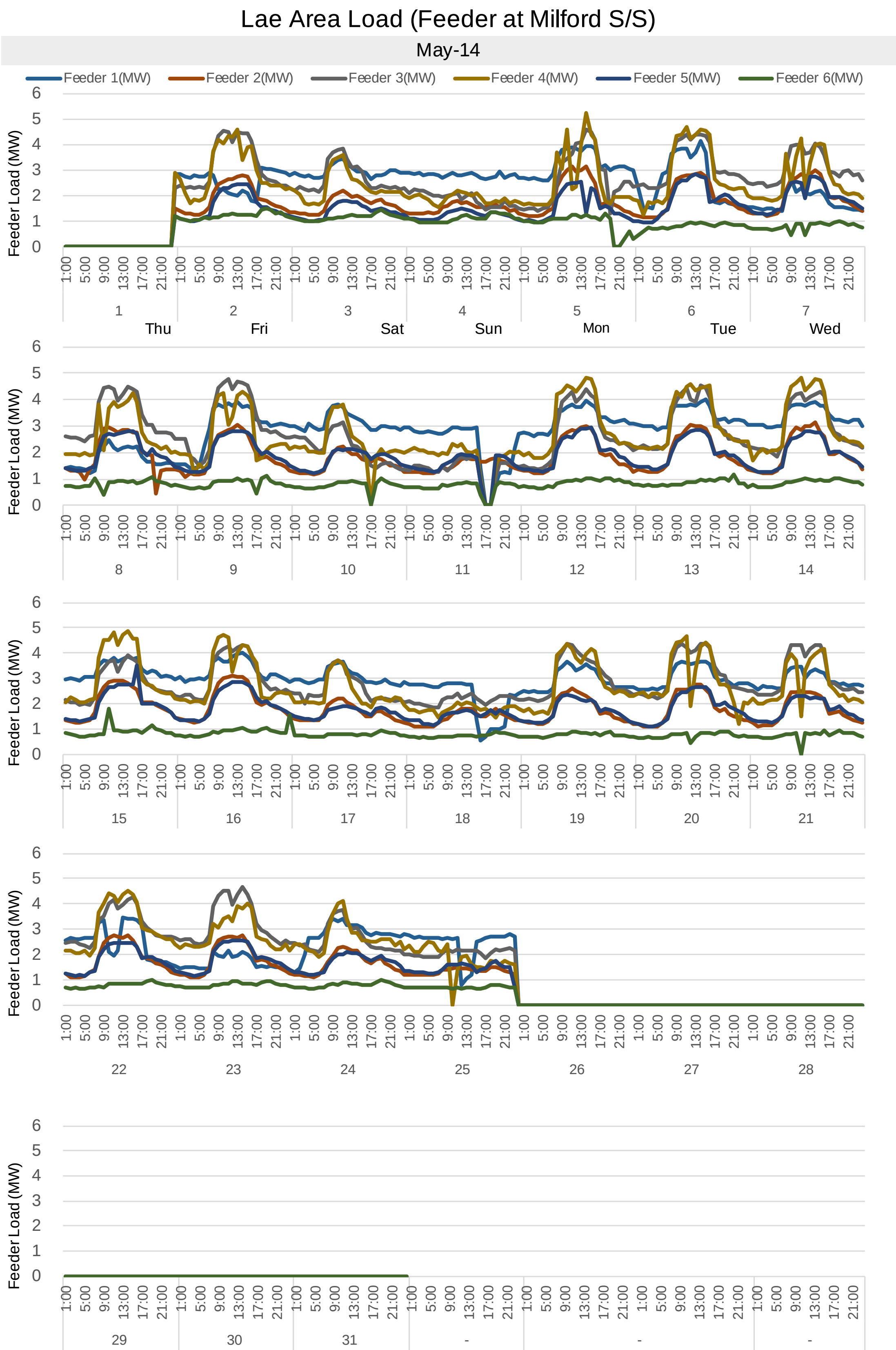
Feeder	No.1	No.2	No.3	No.4	No.5	No.6	Max.
Max. Load (MW)	4.21	3.41	5.38	6.01	2.90	1.62	6.01
Ave. Load (MW)	2.68	1.67	2.75	2.90	1.64	0.63	2.90



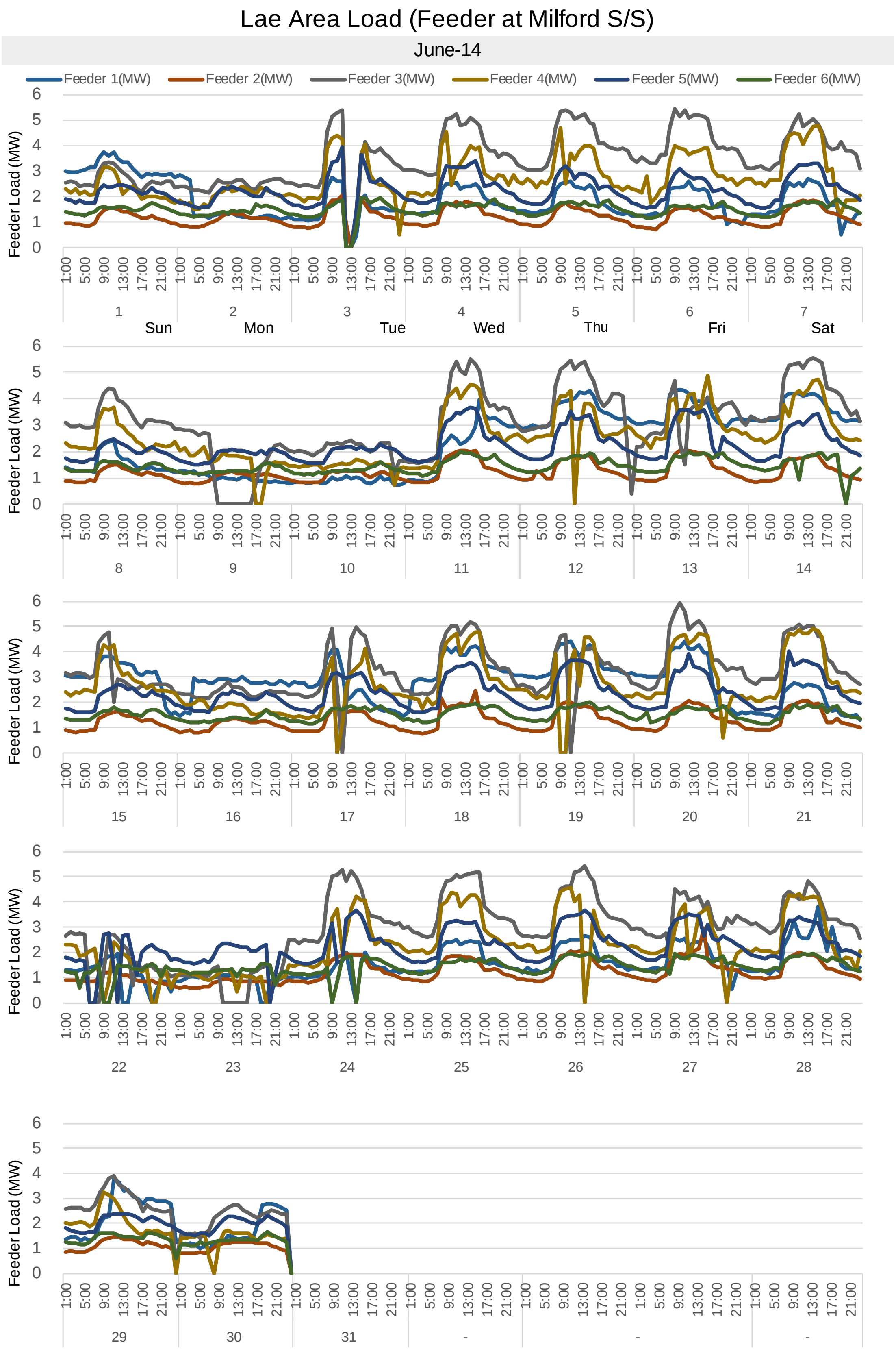
Feeder	No.1	No.2	No.3	No.4	No.5	No.6	Max.
Max. Load (MW)	4.12	3.46	5.41	5.81	3.95	1.48	5.81
Ave. Load (MW)	2.45	1.88	2.78	2.63	1.59	0.73	2.78



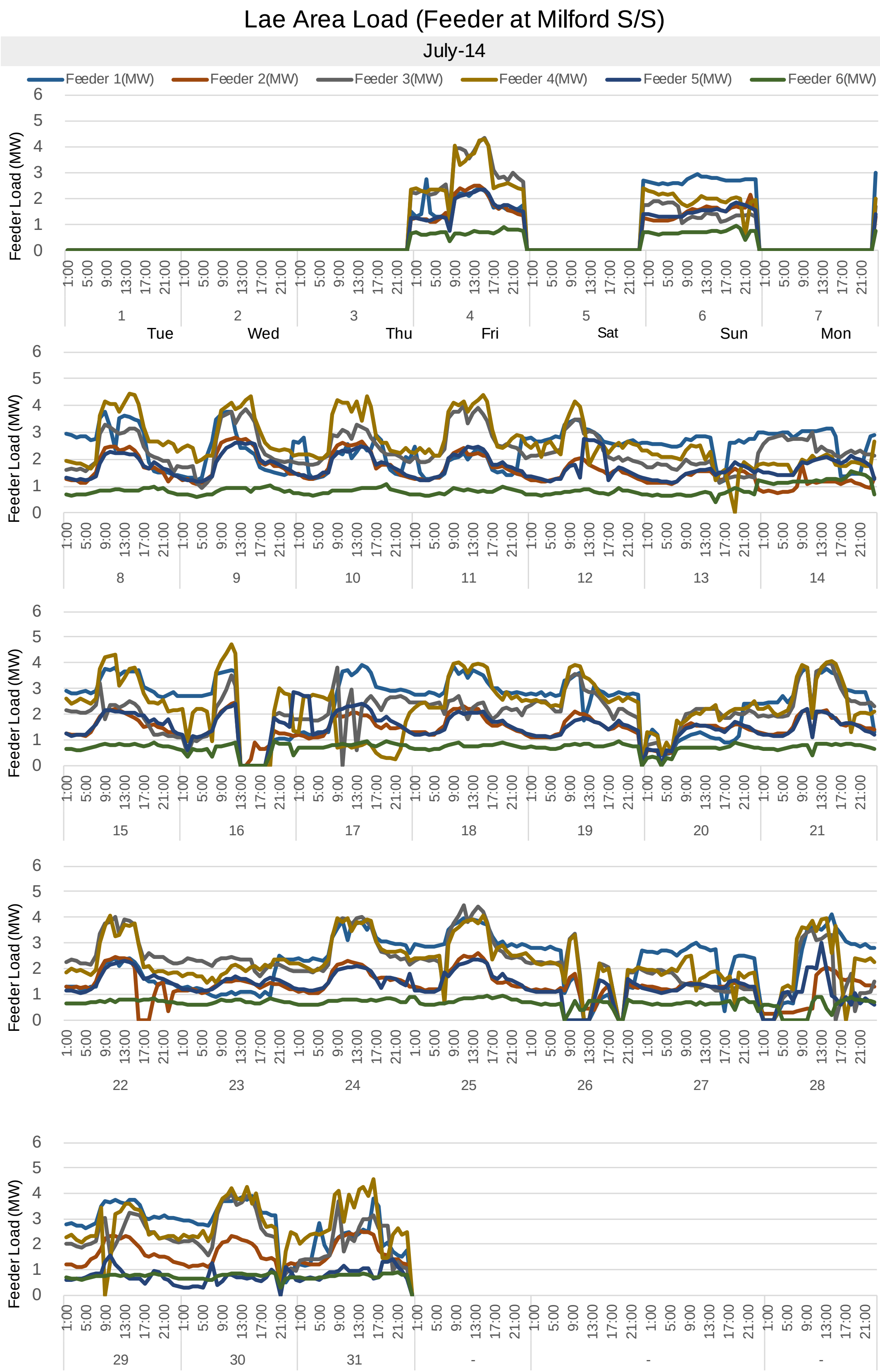
Feeder	No.1	No.2	No.3	No.4	No.5	No.6	Max.
Max. Load (MW)	4.07	3.45	5.30	5.56	2.79	1.62	5.56
Ave. Load (MW)	2.37	1.87	2.68	2.78	1.56	1.12	2.78



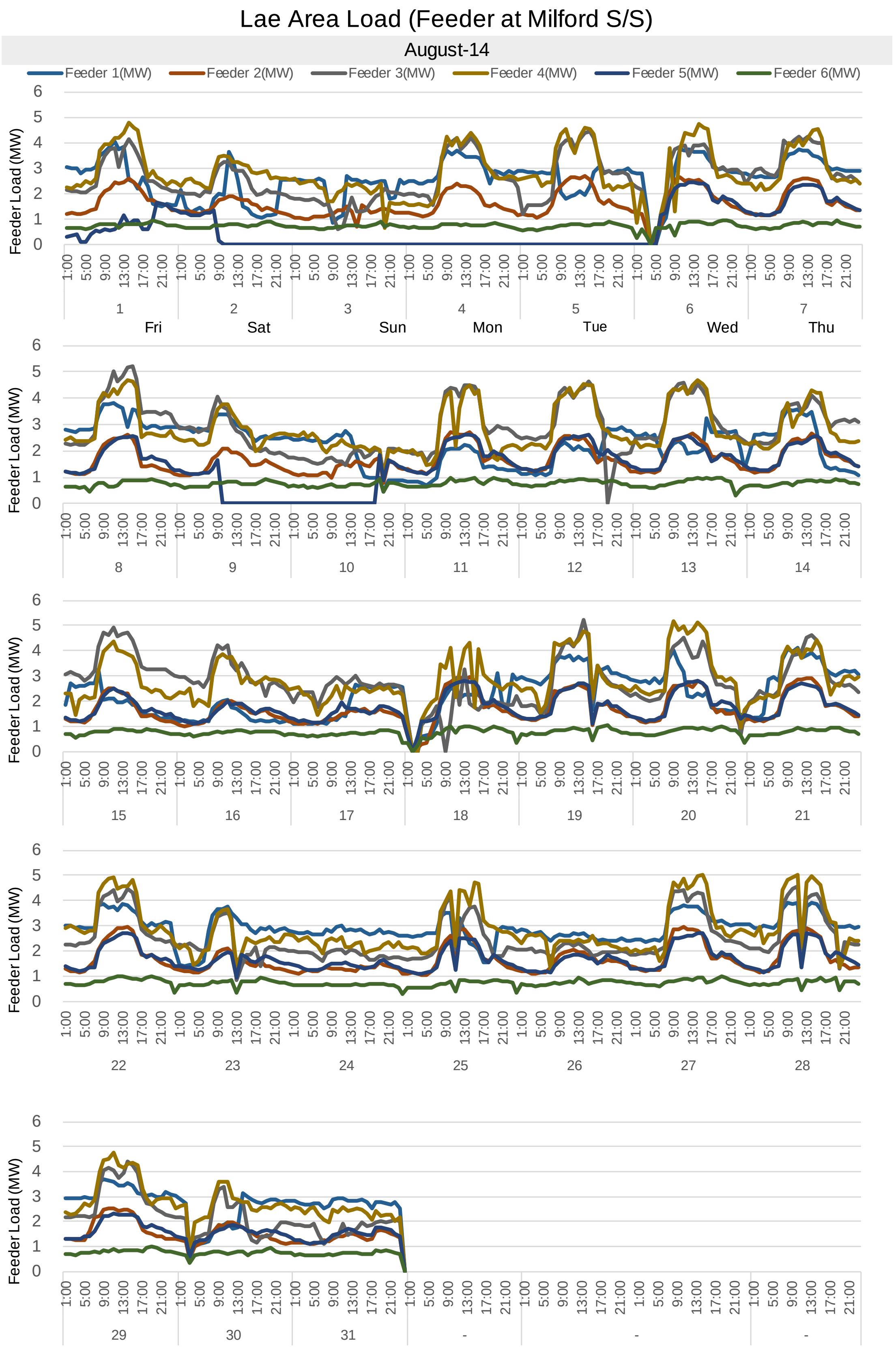
Feeder	No.1	No.2	No.3	No.4	No.5	No.6	Max.
Max. Load (MW)	4.56	3.17	4.79	5.93	4.53	2.64	5.93
Ave. Load (MW)	2.77	1.80	2.79	2.68	1.77	0.87	2.79



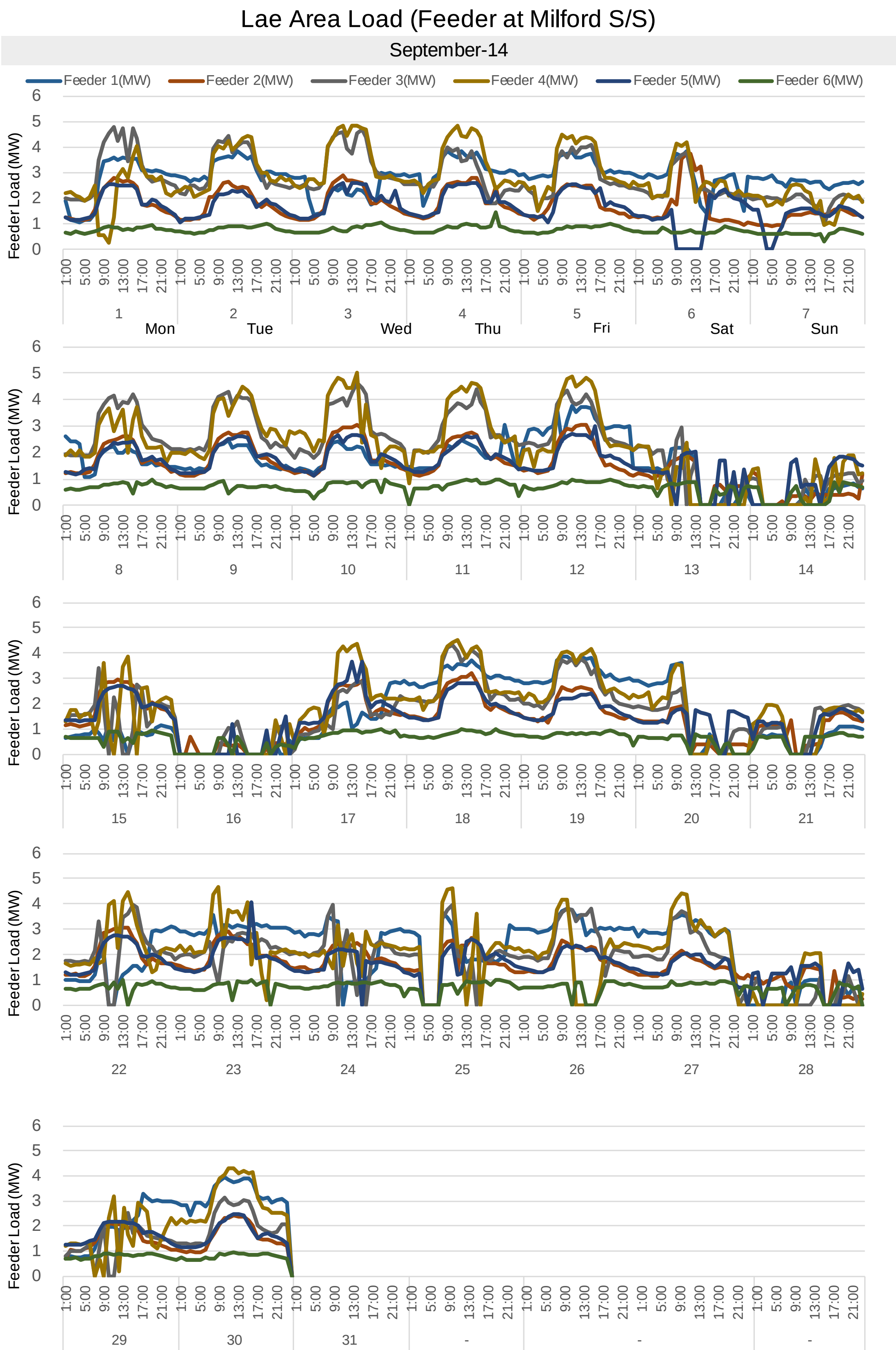
Feeder	No.1	No.2	No.3	No.4	No.5	No.6	Max.
Max. Load (MW)	4.45	4.01	6.05	5.08	4.56	2.35	6.05
Ave. Load (MW)	2.18	1.23	3.28	2.58	2.29	1.49	3.28



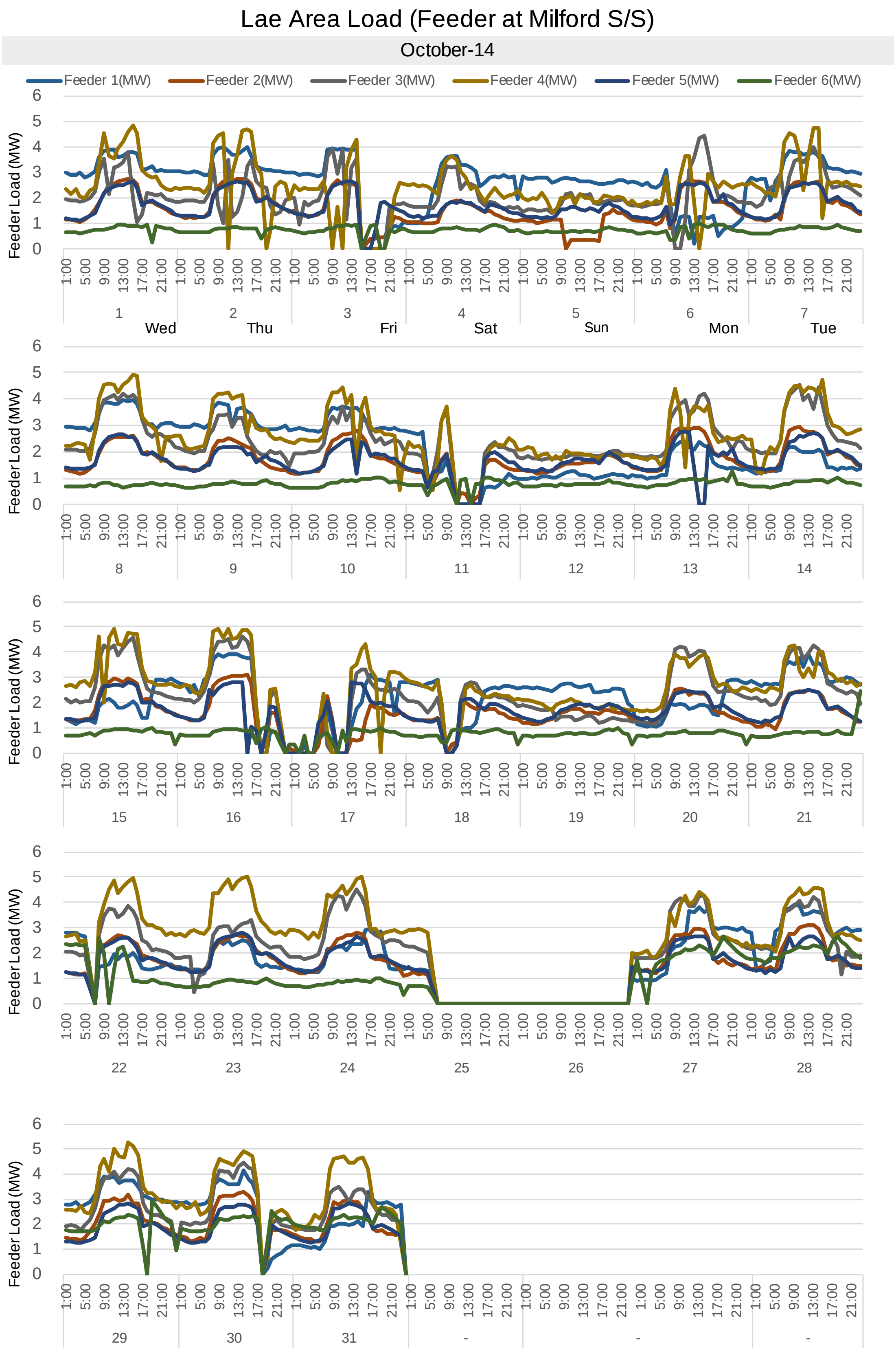
Feeder	No.1	No.2	No.3	No.4	No.5	No.6	Max.
Max. Load (MW)	4.53	2.82	4.48	4.86	3.11	1.57	4.86
Ave. Load (MW)	2.49	1.54	2.33	2.58	1.52	0.77	2.58



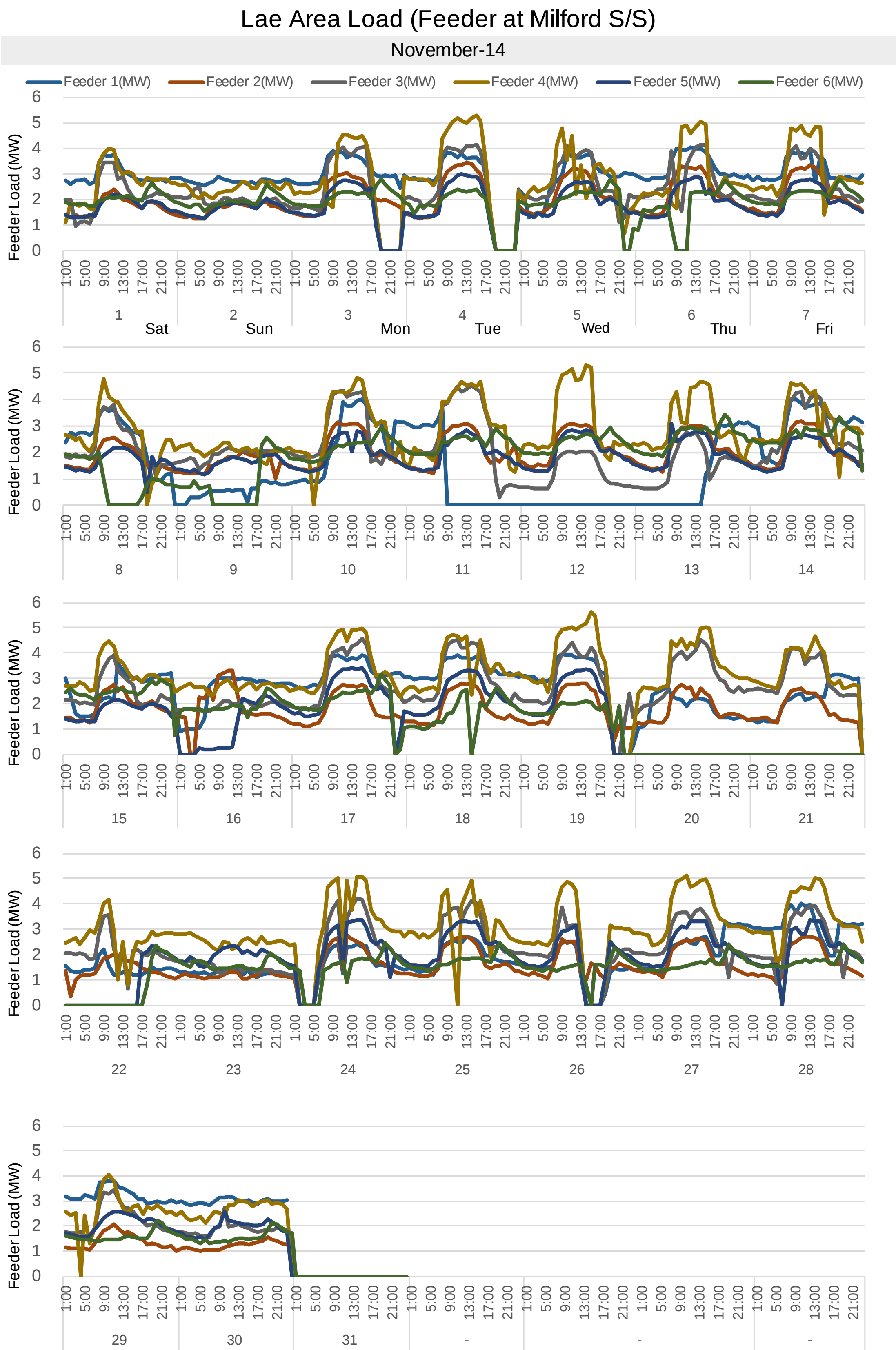
Feeder	No.1	No.2	No.3	No.4	No.5	No.6	Max.
Max. Load (MW)	4.18	3.05	5.90	5.98	2.85	1.08	5.98
Ave. Load (MW)	2.54	1.67	2.72	2.89	1.70	0.77	2.89



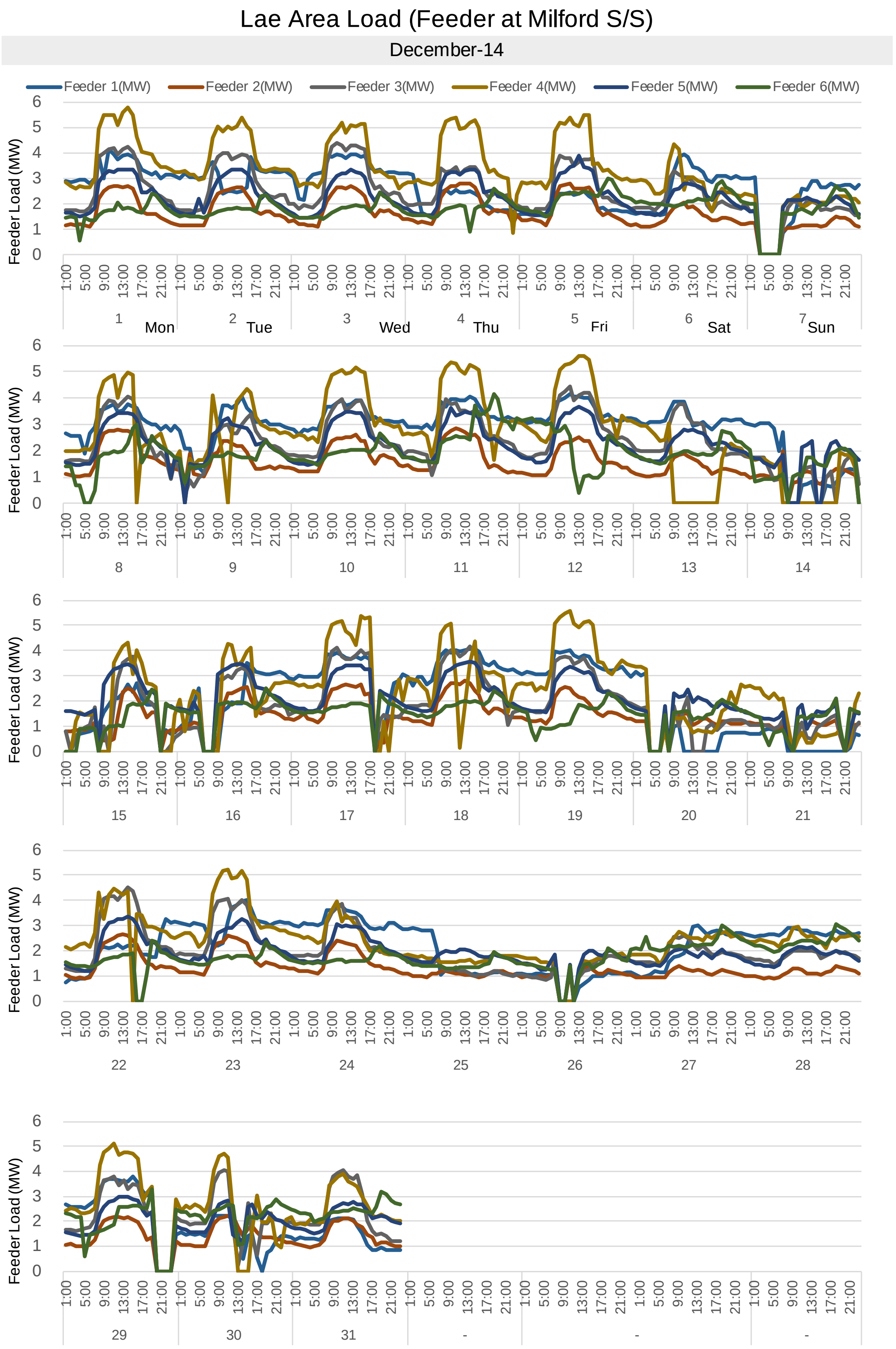
Feeder	No.1	No.2	No.3	No.4	No.5	No.6	Max.
Max. Load (MW)	4.10	3.84	5.06	5.11	4.51	1.94	5.11
Ave. Load (MW)	2.38	1.66	2.44	2.71	1.79	0.78	2.71



Feeder	No.1	No.2	No.3	No.4	No.5	No.6	Max.
Max. Load (MW)	4.48	3.35	4.65	5.35	3.51	2.94	5.35
Ave. Load (MW)	2.44	1.78	2.54	2.95	1.82	1.04	2.95



Feeder	No.1	No.2	No.3	No.4	No.5	No.6	Max.
Max. Load (MW)	4.13	3.48	4.85	5.81	4.21	3.43	5.81
Ave. Load (MW)	2.57	1.85	2.45	3.12	2.02	1.98	3.12



Feeder	No.1	No.2	No.3	No.4	No.5	No.6	Max.
Max. Load (MW)	4.38	3.00	4.65	5.79	4.28	4.25	5.79
Ave. Load (MW)	2.60	1.54	2.31	3.00	2.21	1.91	3.00

Appendix B-7

Power Quality Measurement Graphs

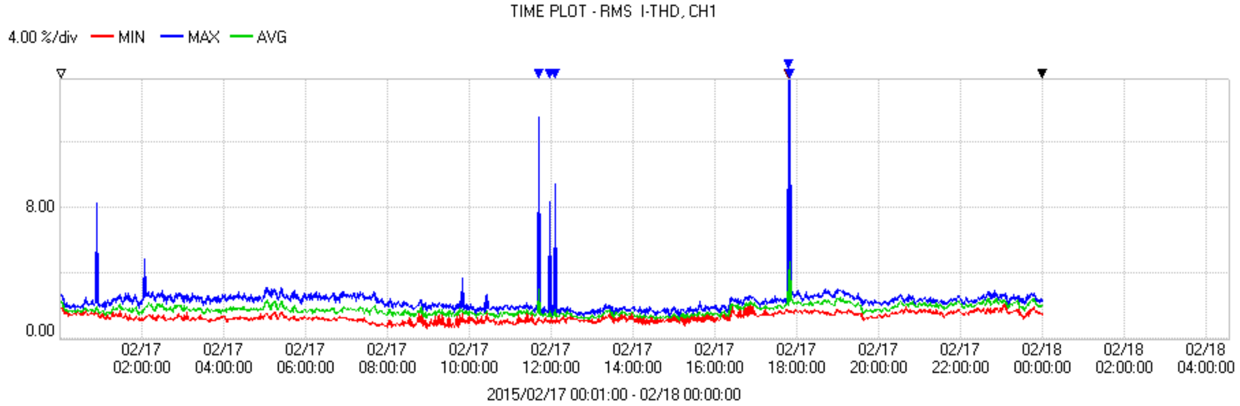
Preliminary Measurement

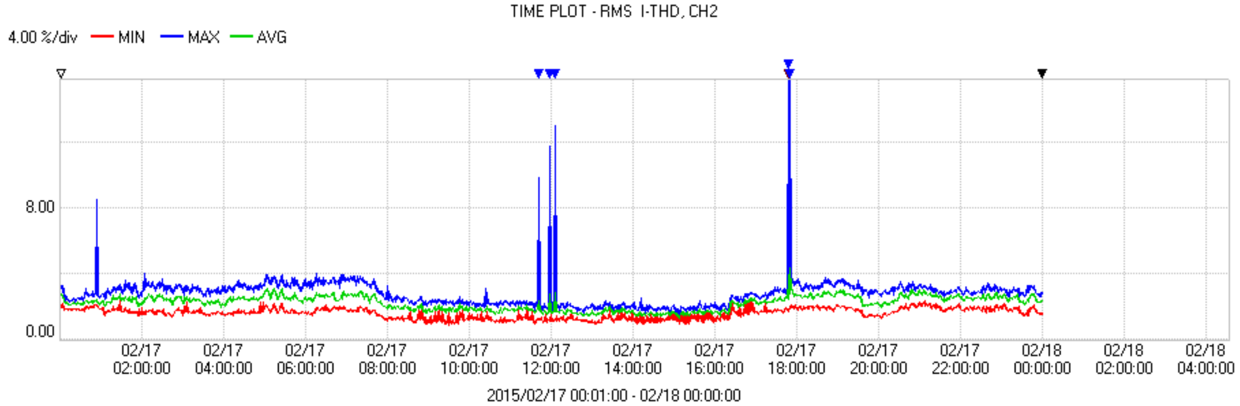
Lomg Term Measurement

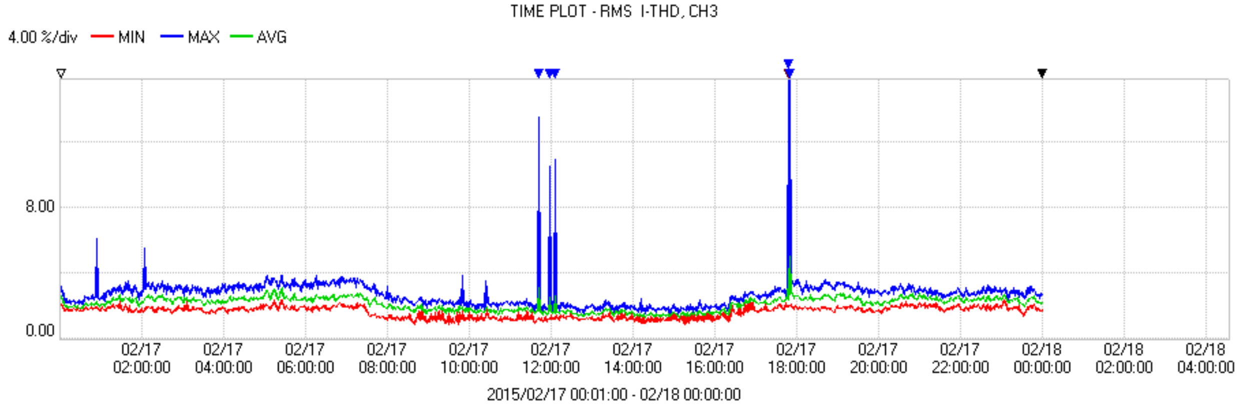
M#	:	Milford substation Feeder #
T#	:	Taraka substation Feeder #
Ithd	:	Total harmonic current distortion factor
IharmH	:	High-order harmonic current component
Uthd	:	Total harmonic voltage distortion factor
UharmH	:	High-order harmonic voltage component

PRELIMINARY MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : M1
Duration : 17/February/2015 00:00 – 18/February/2015 00:00

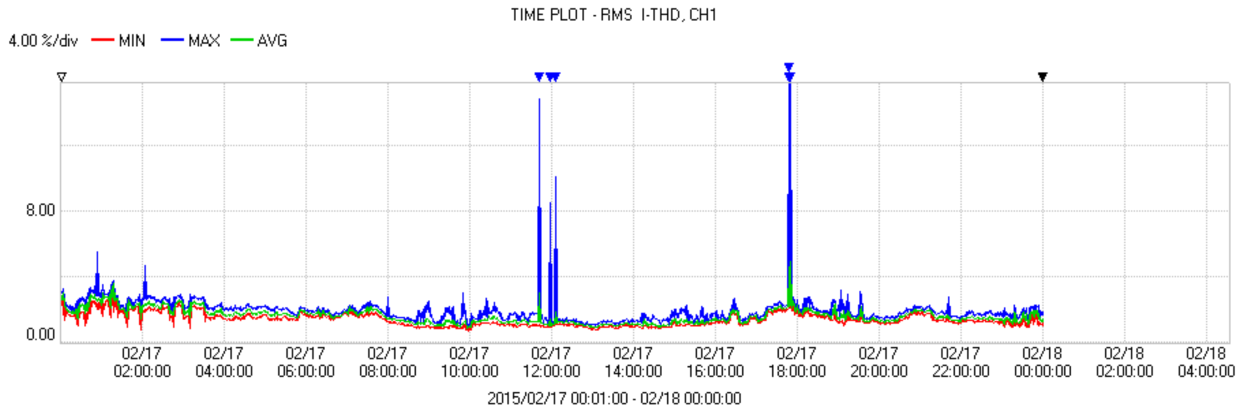


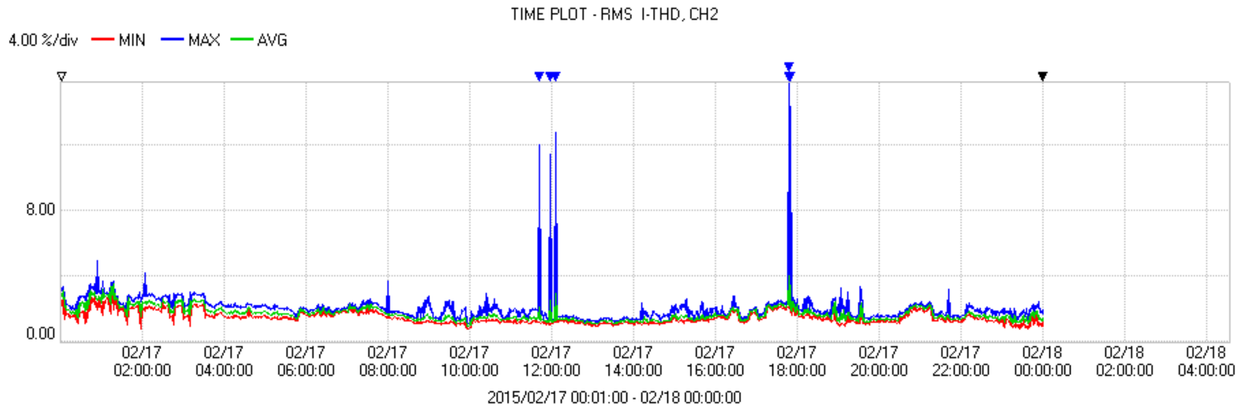


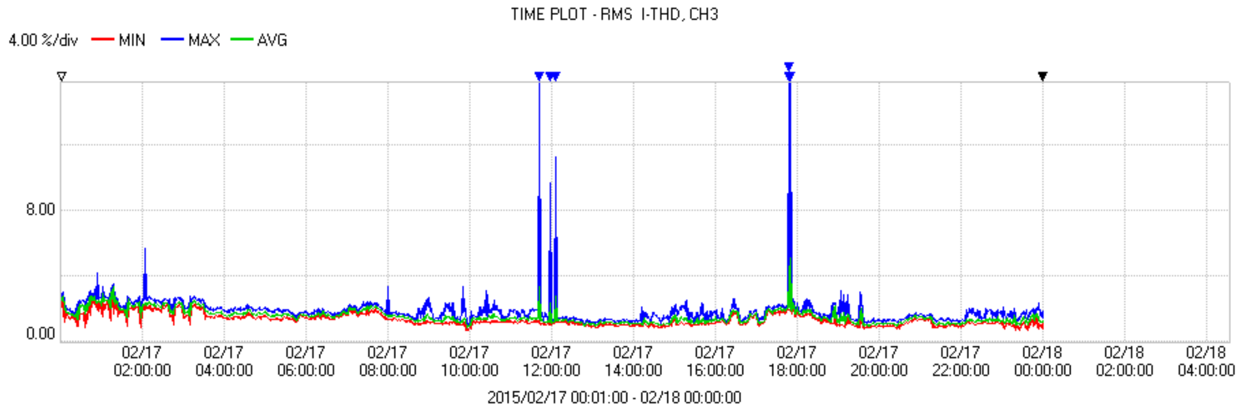


PRELIMINARY MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : M2
Duration : 17/February/2015 00:00 – 18/February/2015 00:00

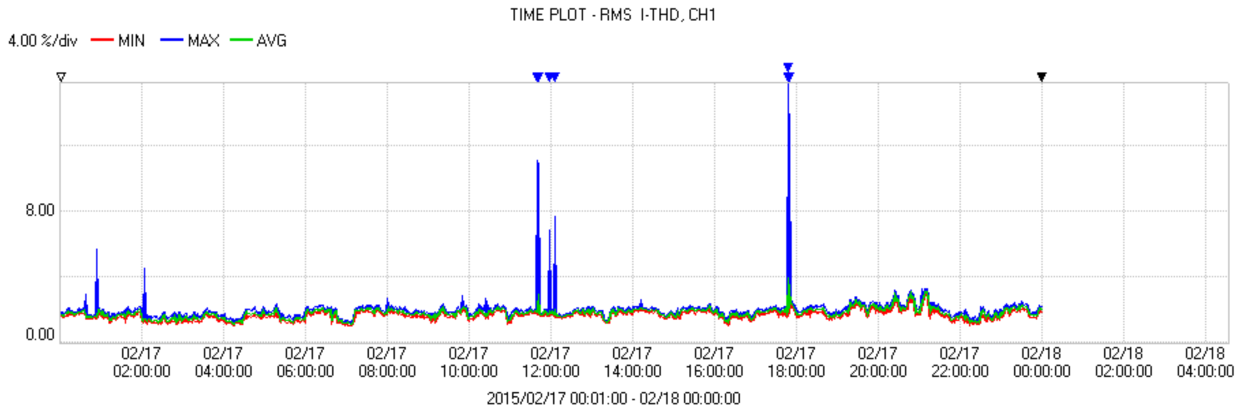


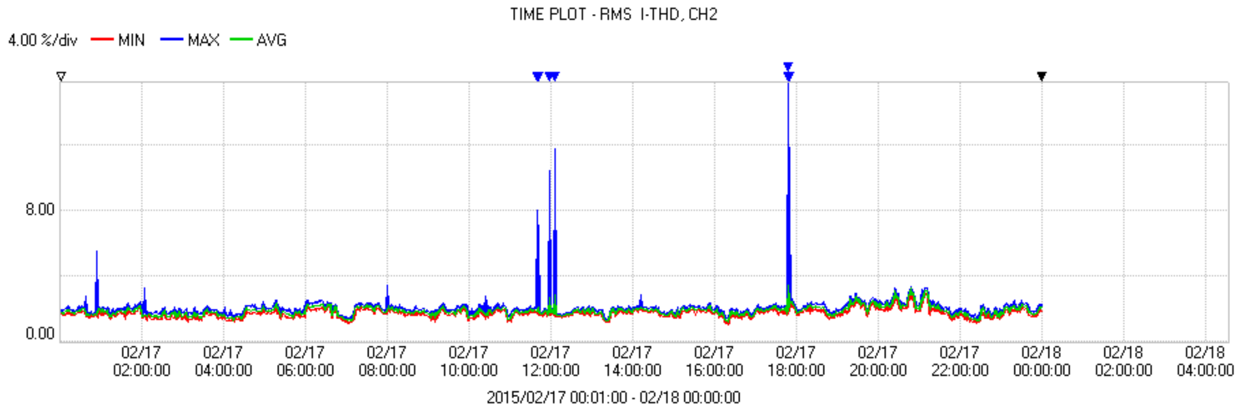


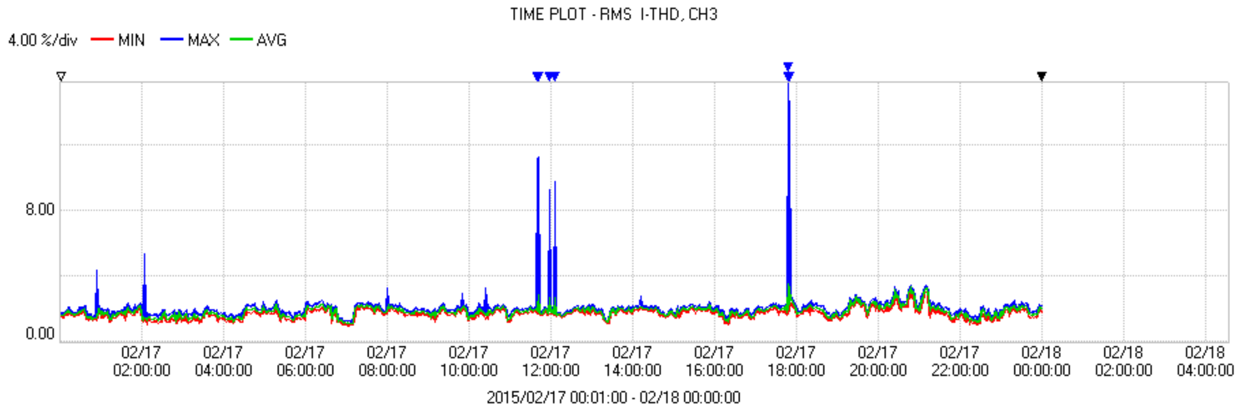


PRELIMINARY MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : M3
Duration : 17/February/2015 00:00 – 18/February/2015 00:00

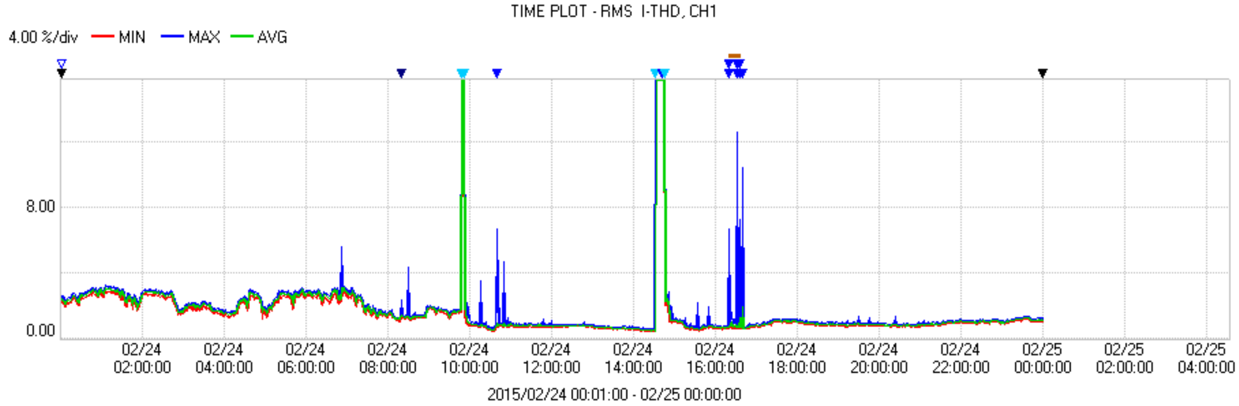


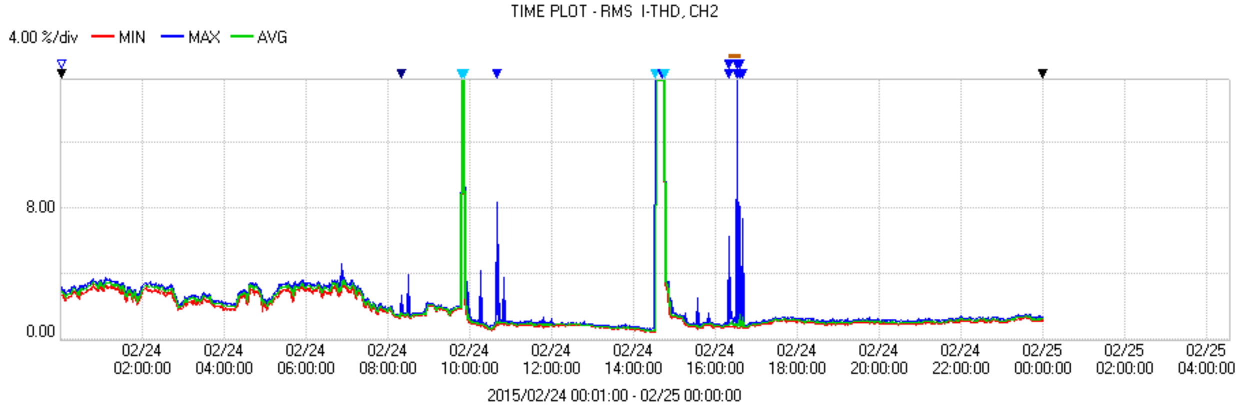


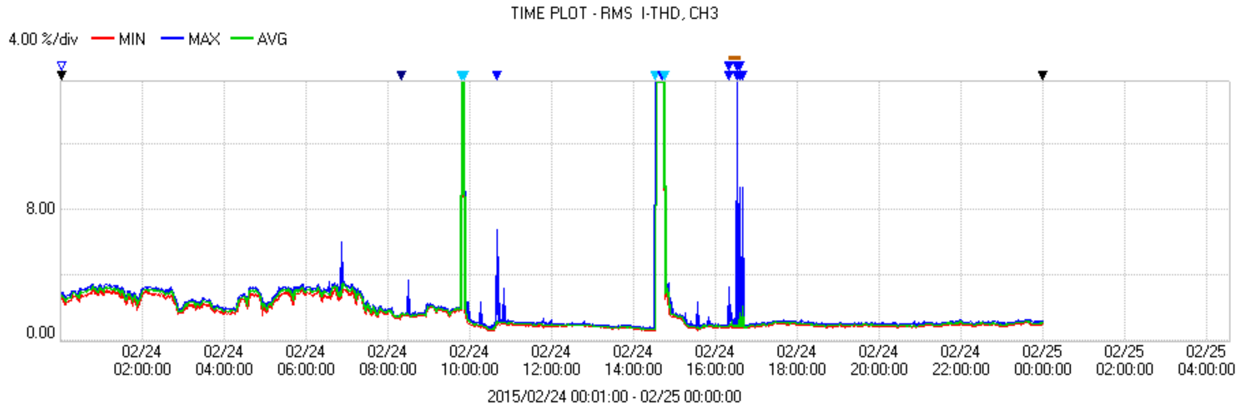


PRELIMINARY MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : M4
Duration : 24/February/2015 00:00 – 25/February/2015 00:00

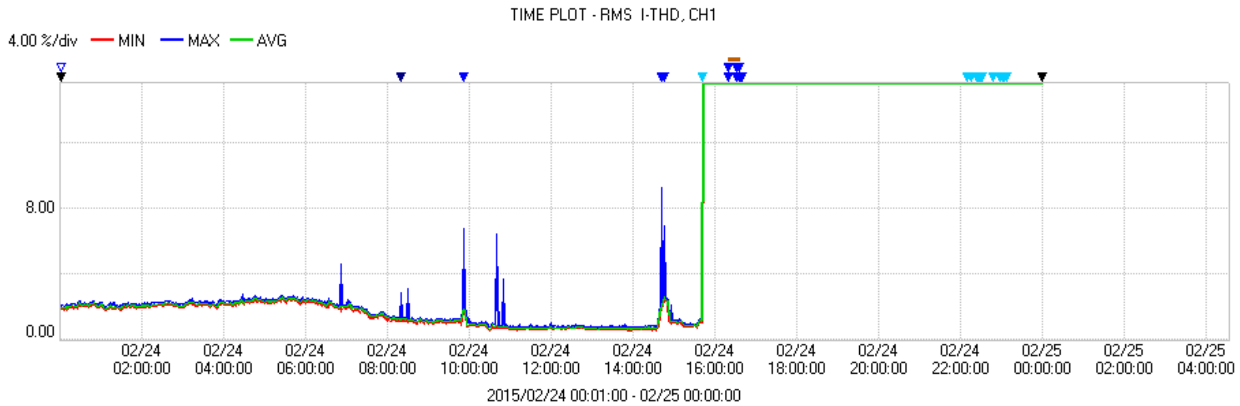


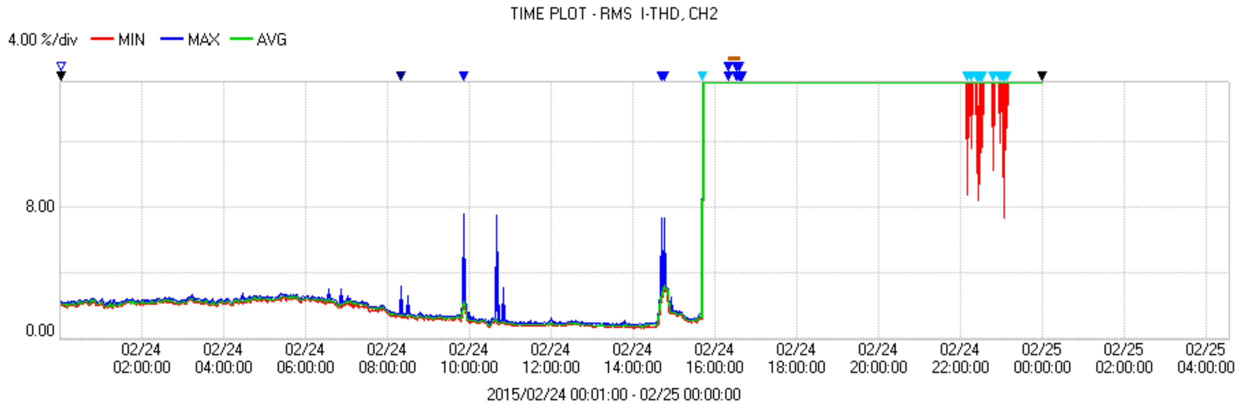


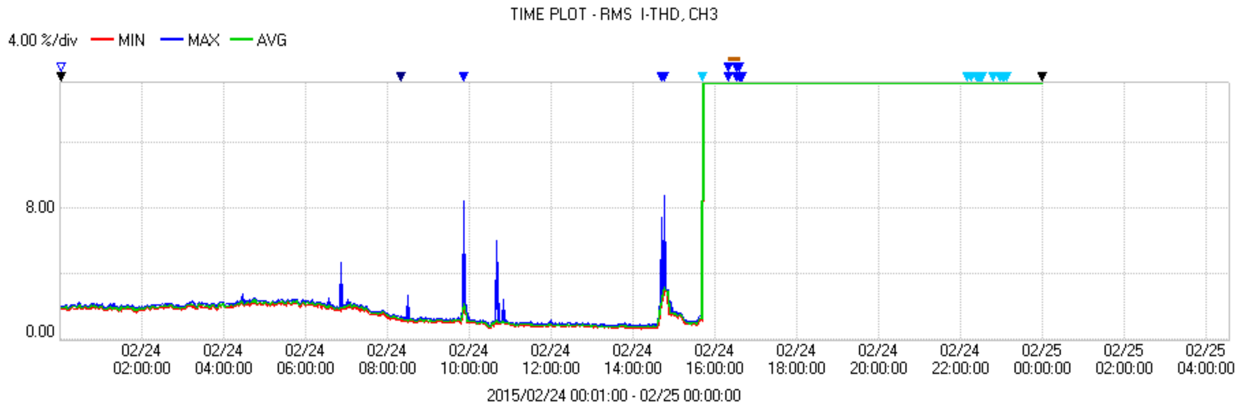


PRELIMINARY MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : M5
Duration : 24/February/2015 00:00 – 25/February/2015 00:00

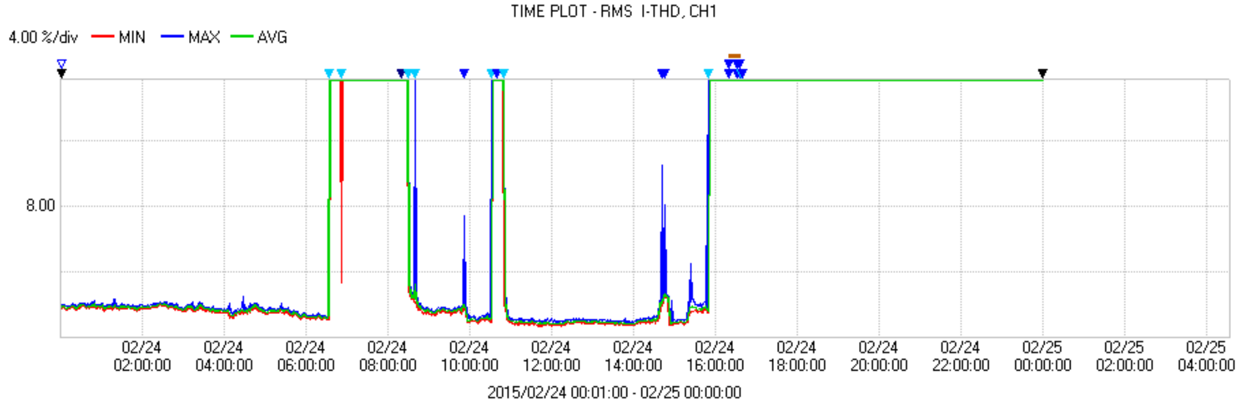


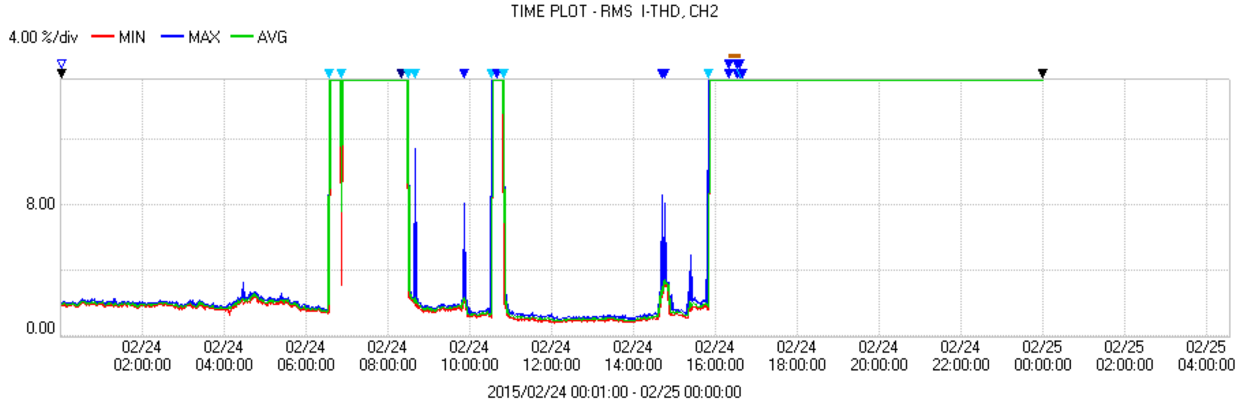


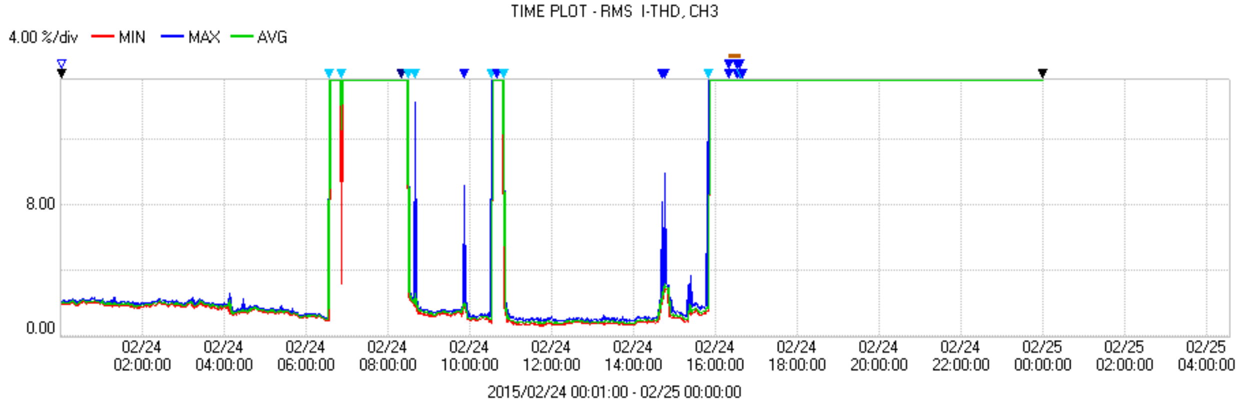


PRELIMINARY MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : M6
Duration : 24/February/2015 00:00 – 25/February/2015 00:00

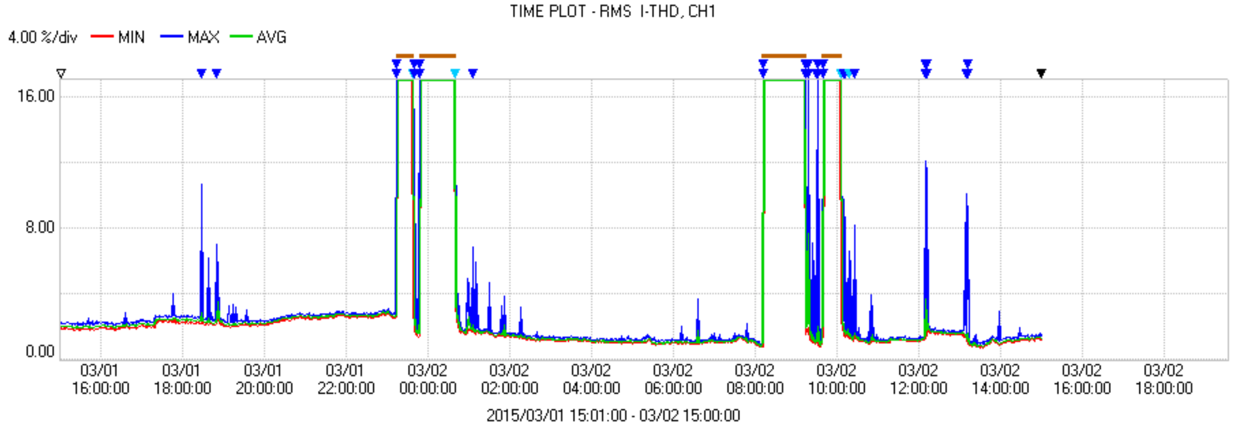


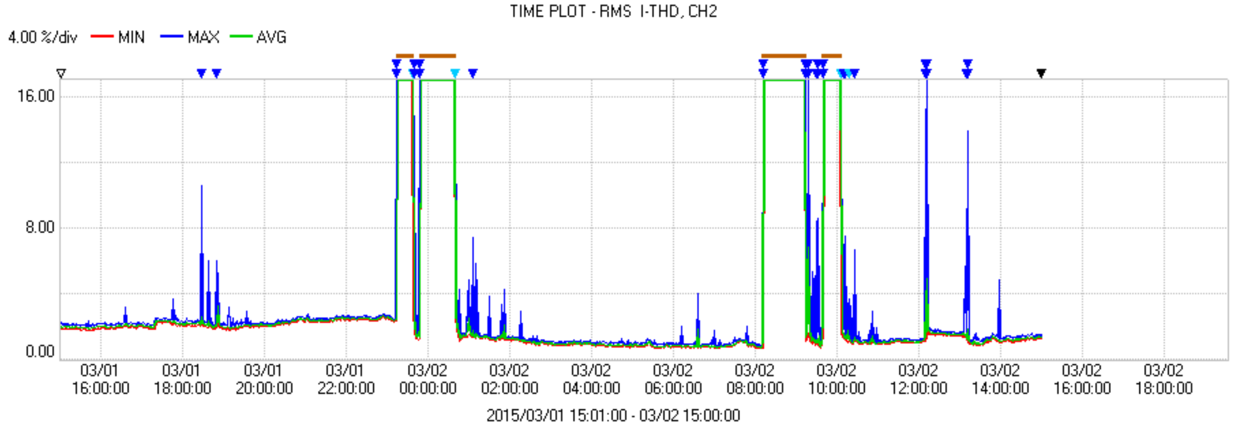


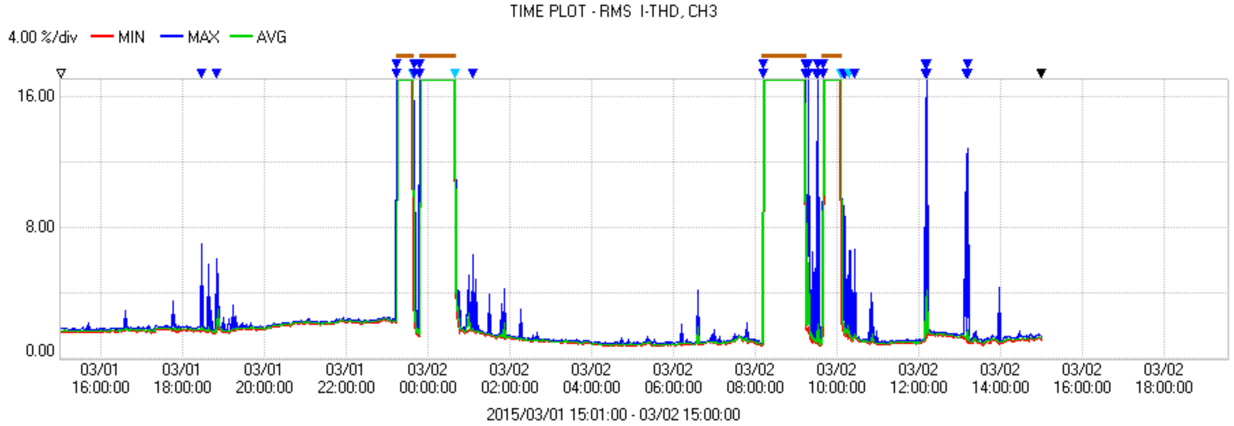


PRELIMINARY MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : T1
Duration : 1/March/2015 15:00 – 2/March/2015 15:00

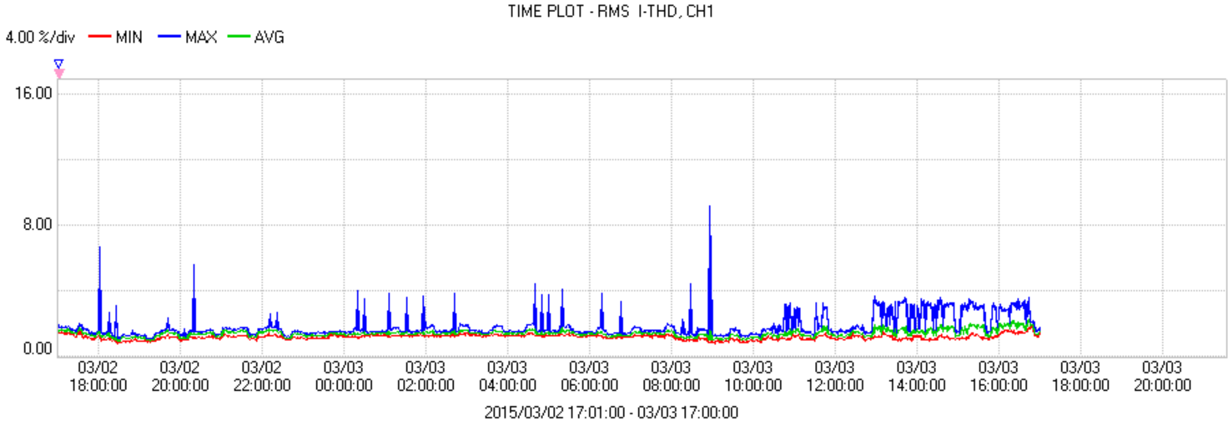


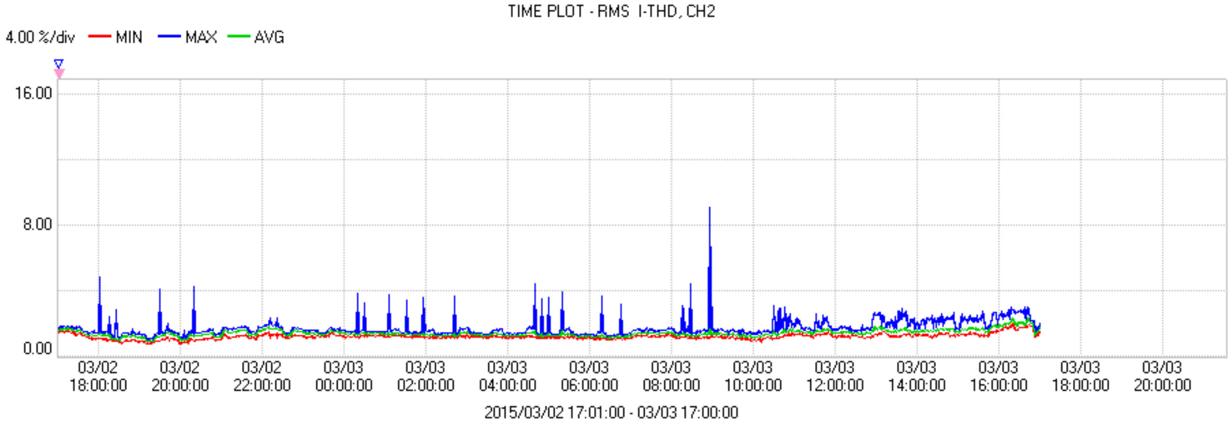


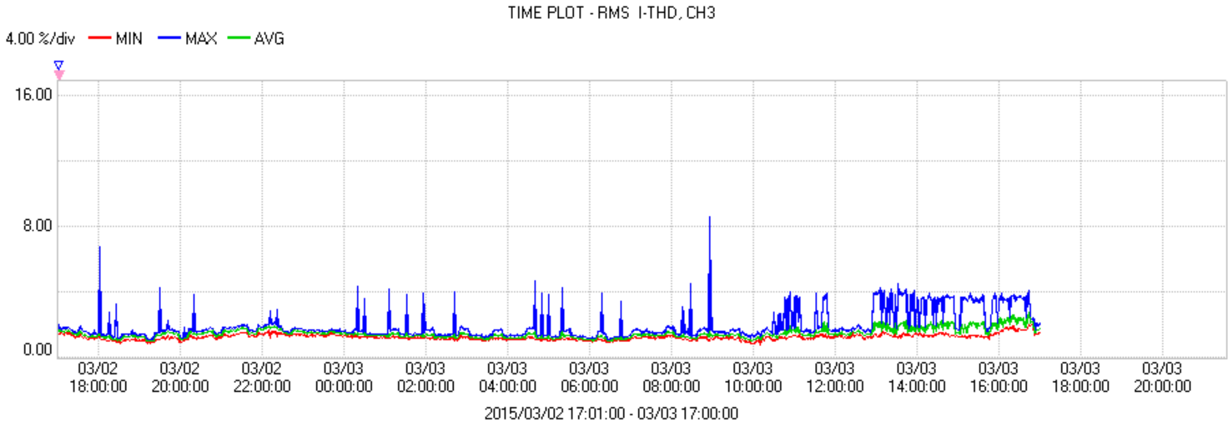


PRELIMINARY MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : T2
Duration : 2/March/2015 17:00 – 3/March/2015 17:00

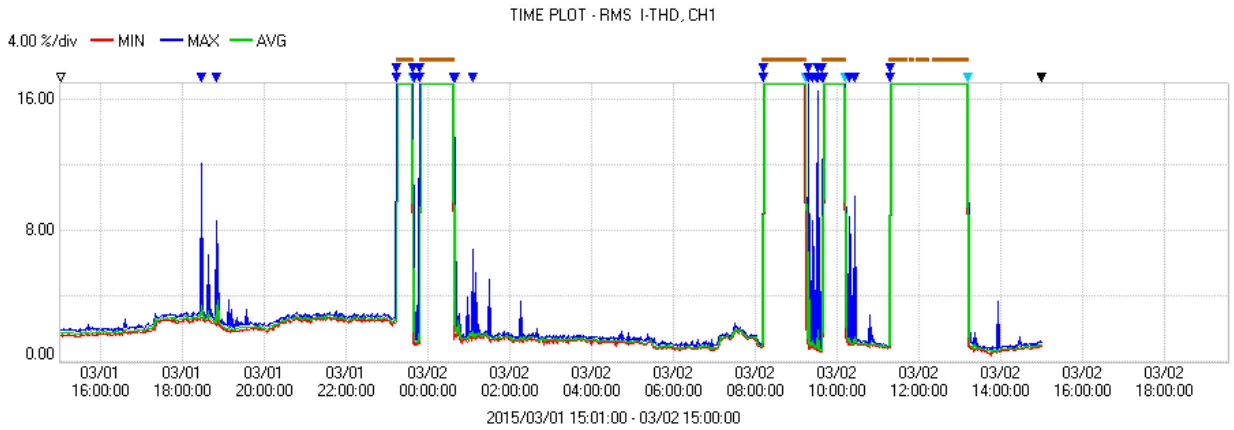


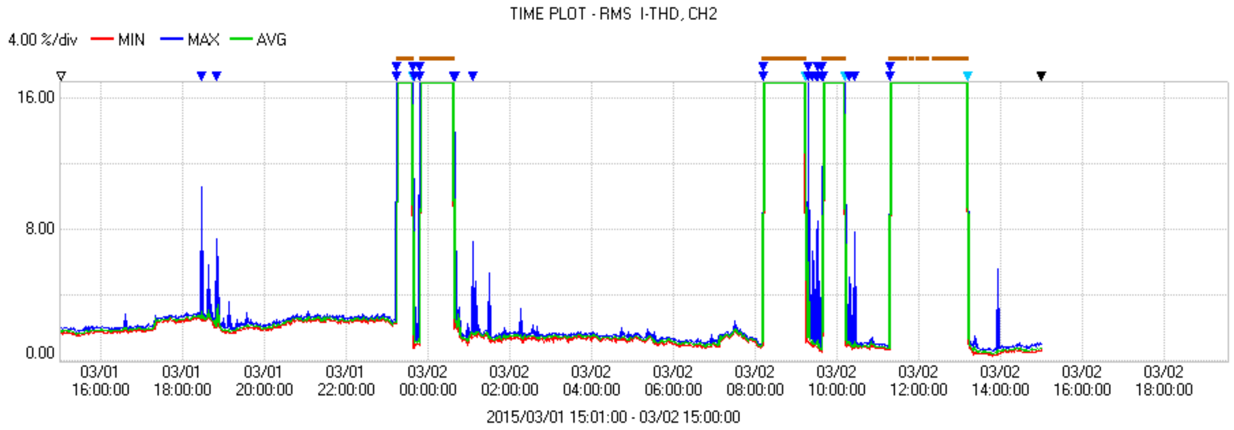


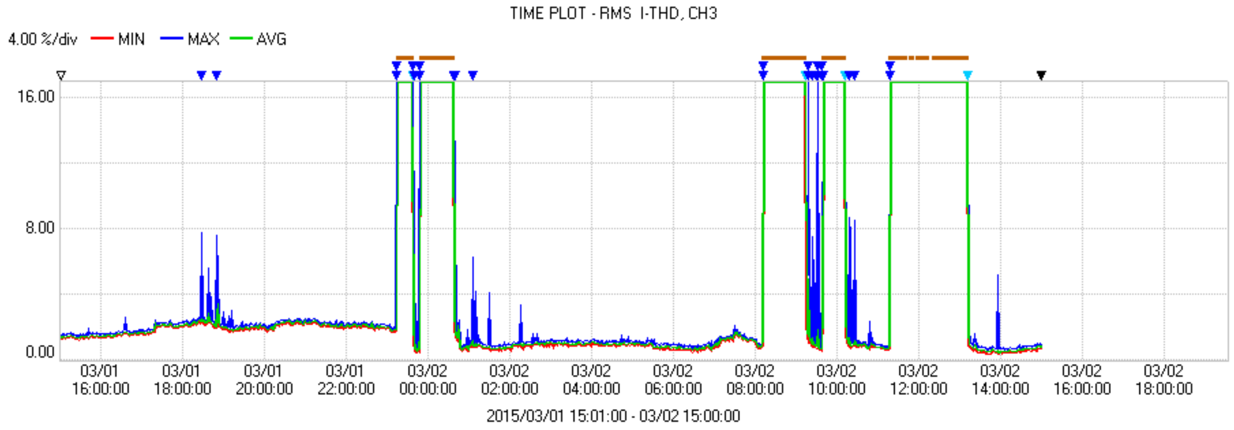


PRELIMINARY MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : T3
Duration : 1/March/2015 15:00 – 2/March/2015 15:00

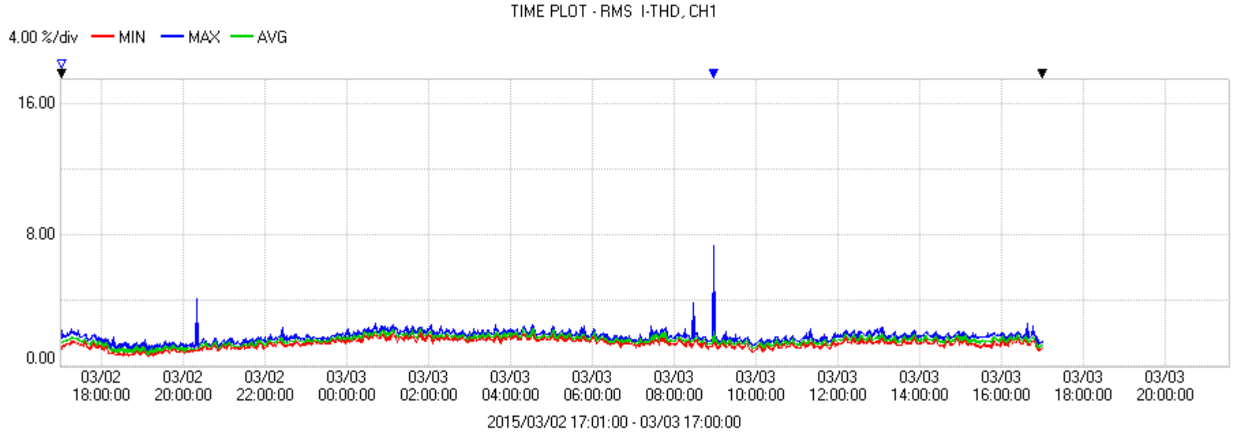


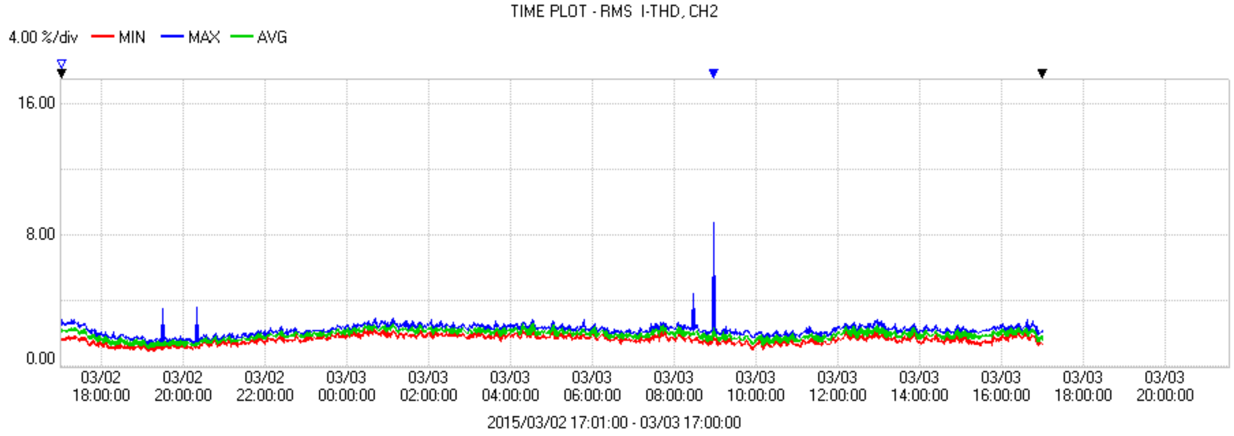


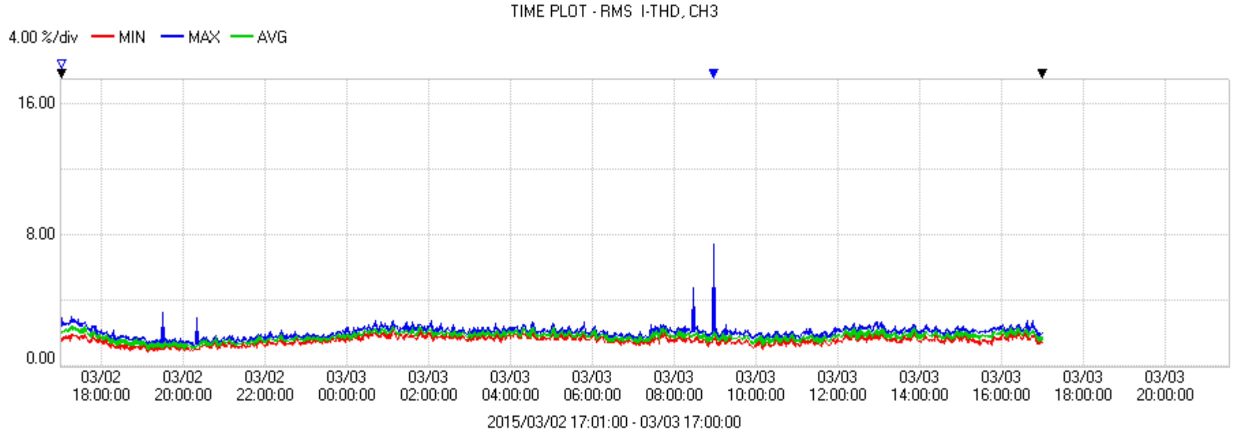


PRELIMINARY MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : T4
Duration : 2/March/2015 17:00 – 3/March/2015 17:00

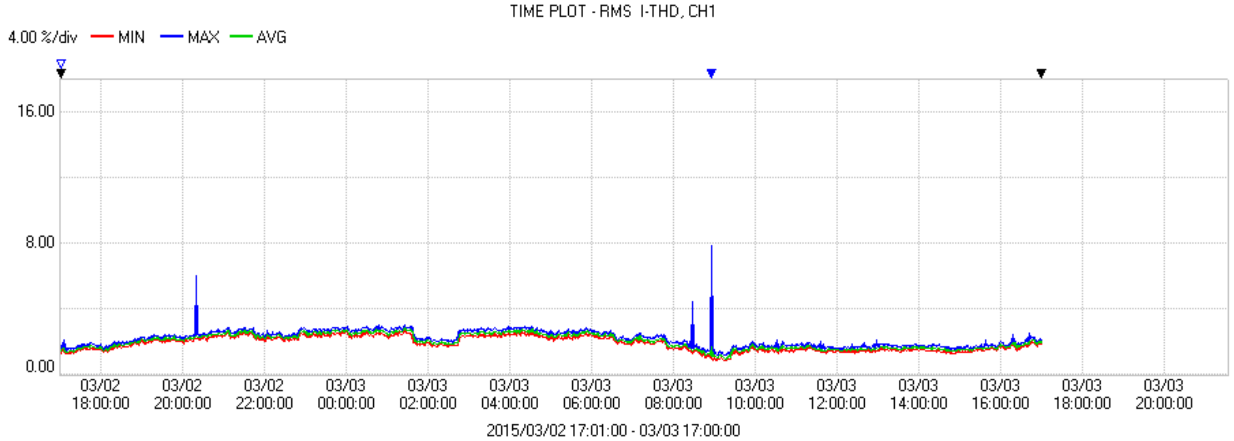


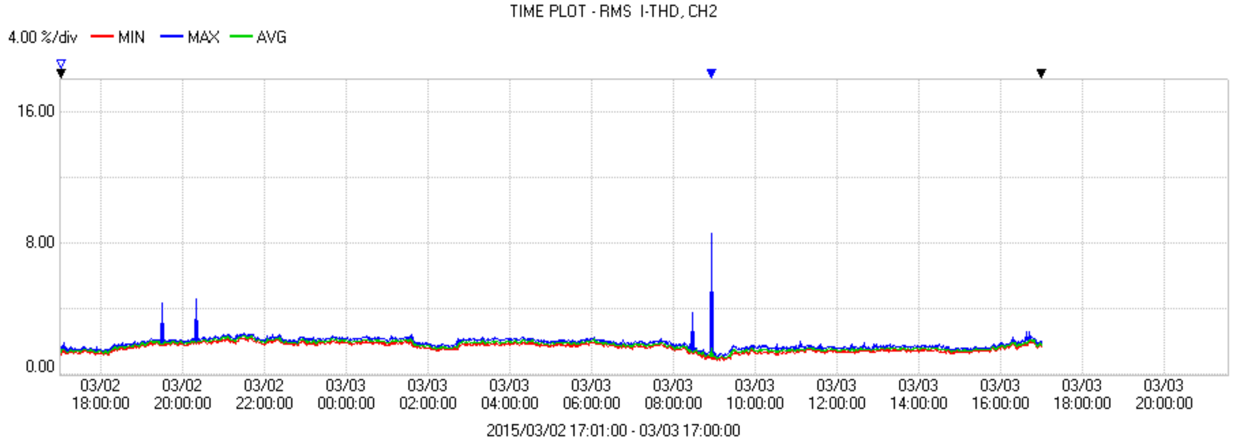


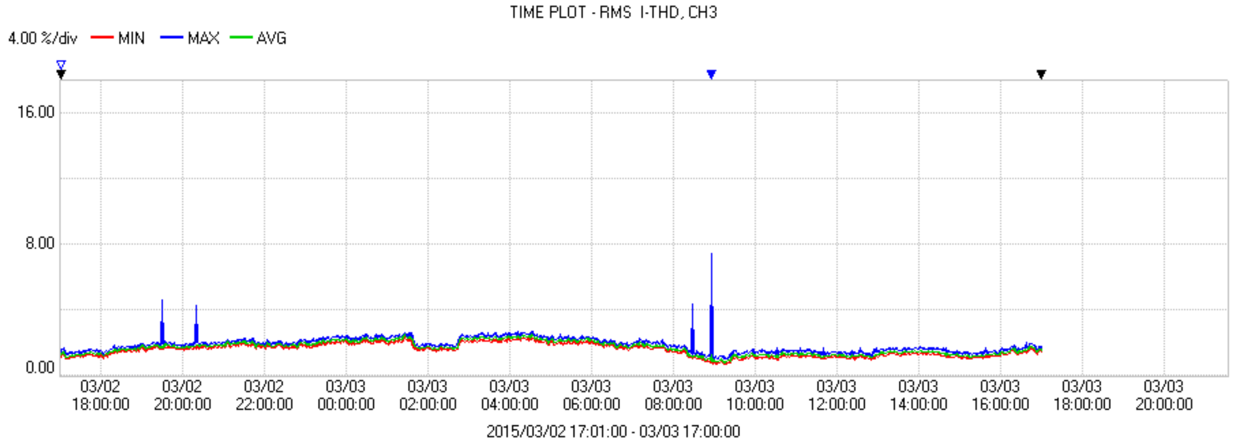


PRELIMINARY MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : T5
Duration : 2/March/2015 17:00 – 3/March/2015 17:00

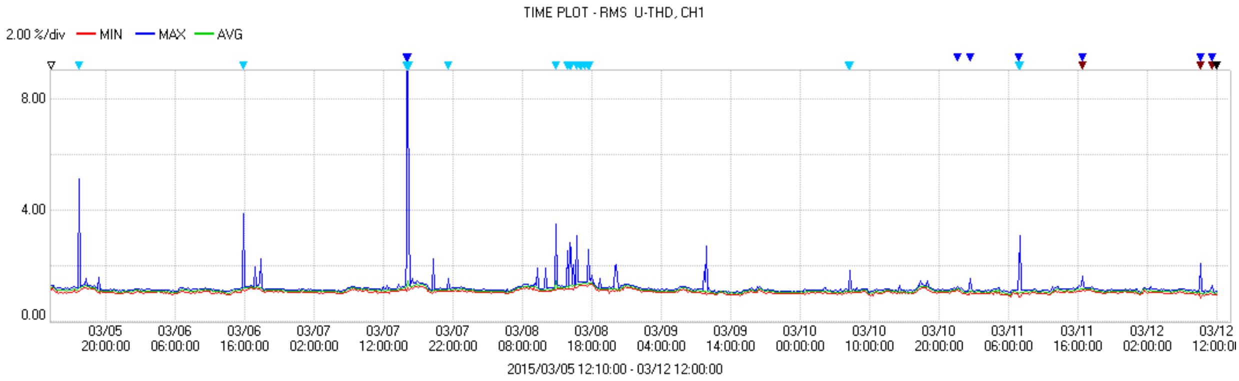


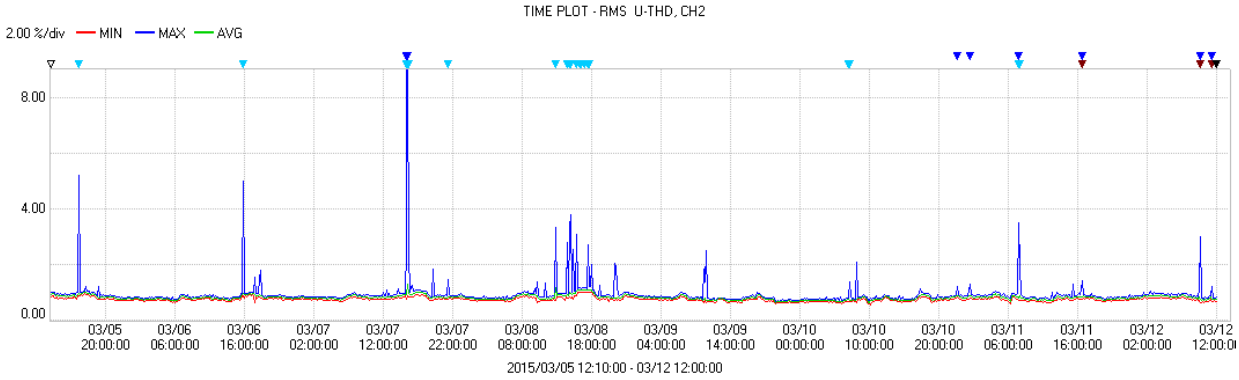


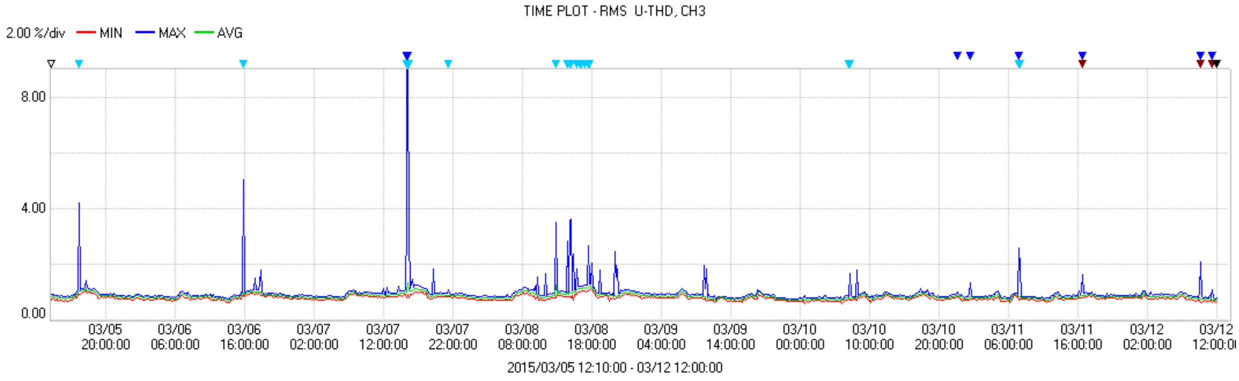


LONG TERM MEASUREMENT

Measurement Item : Uthd (CH1, CH2, CH3)
Measuring Point : Milford substation 11kV bus
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

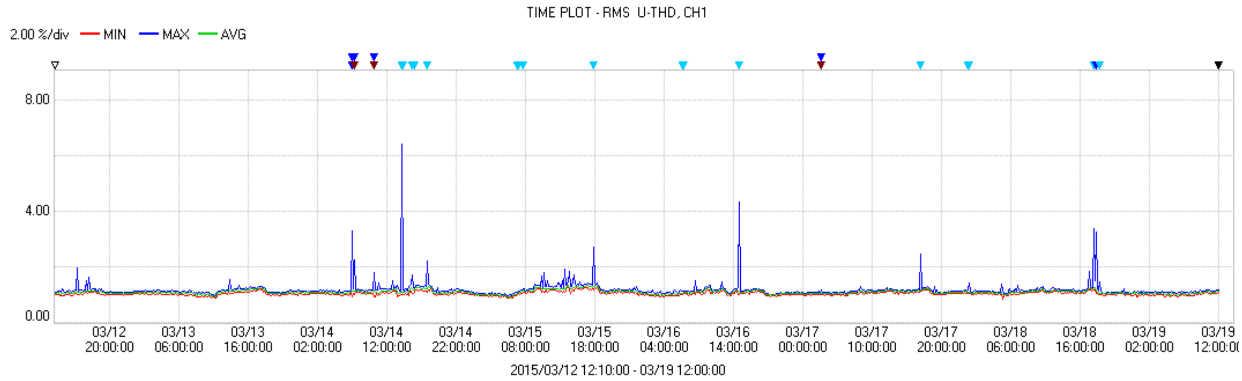


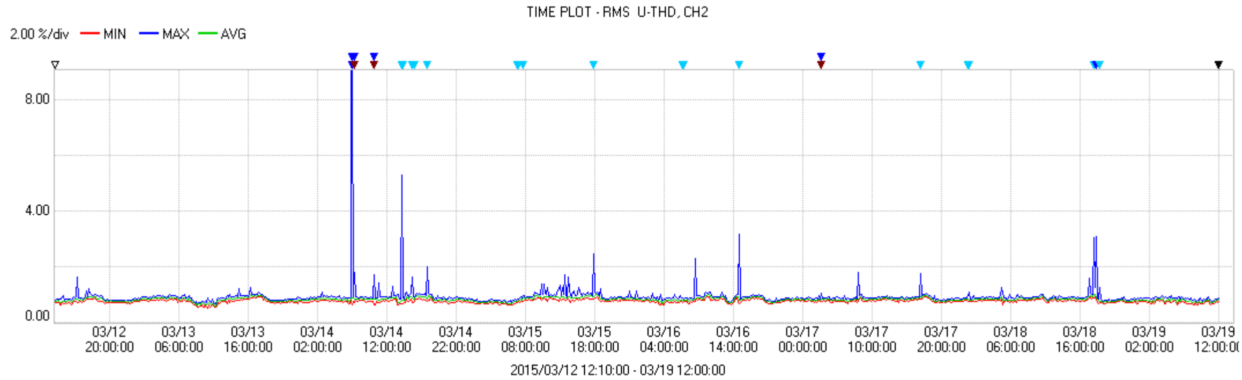


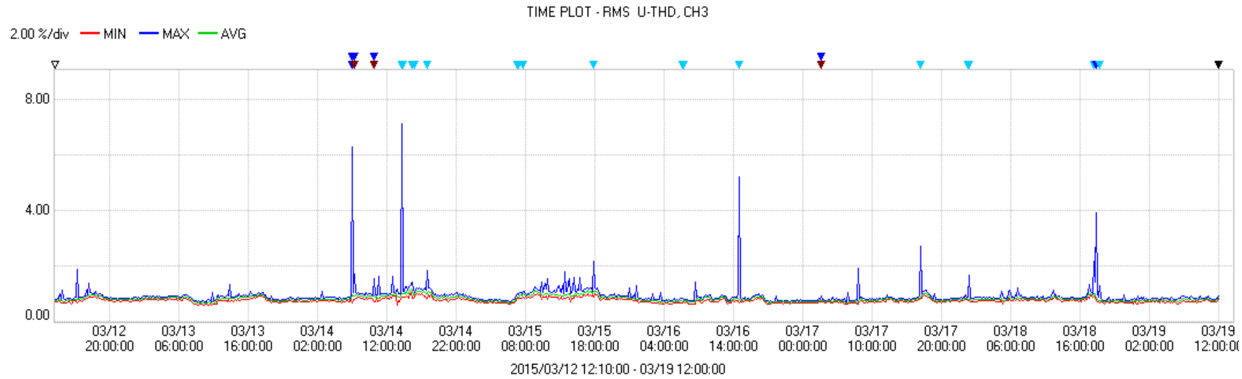


LONG TERM MEASUREMENT

Measurement Item : Uthd (CH1, CH2, CH3)
Measuring point : Milford substation 11kV bus
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

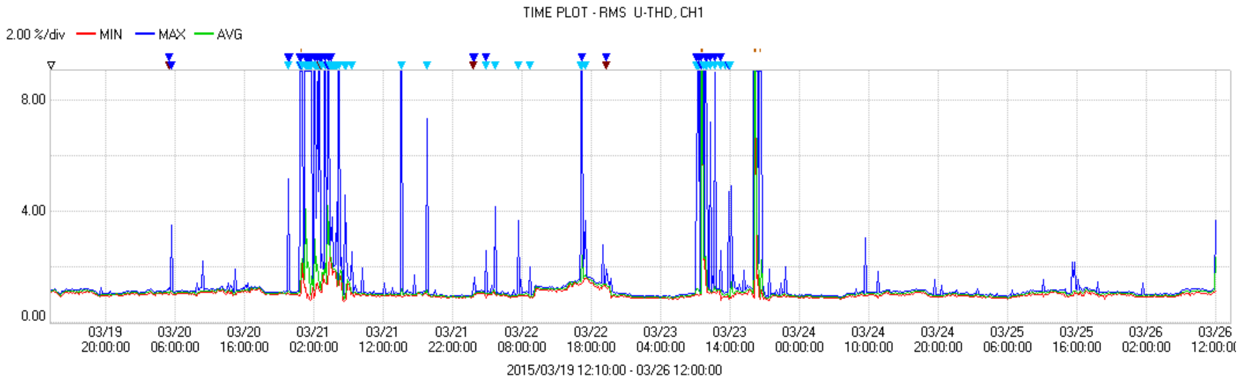


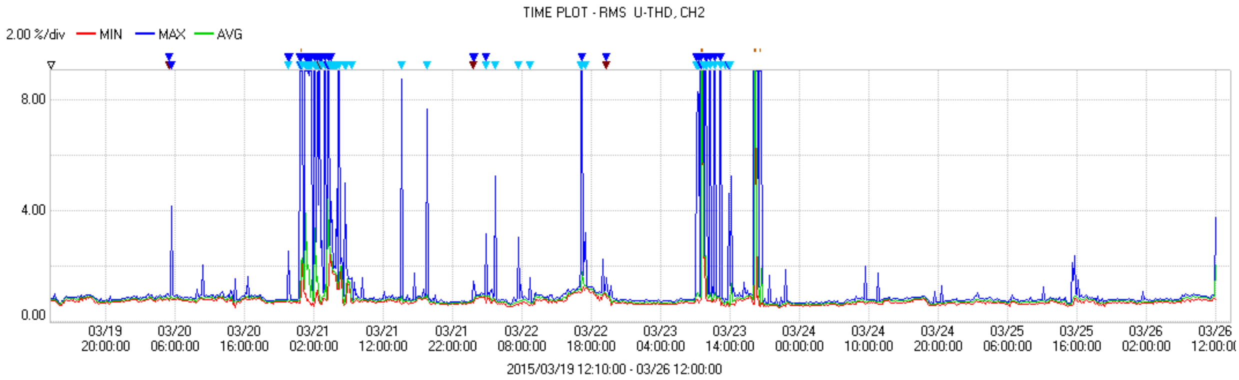


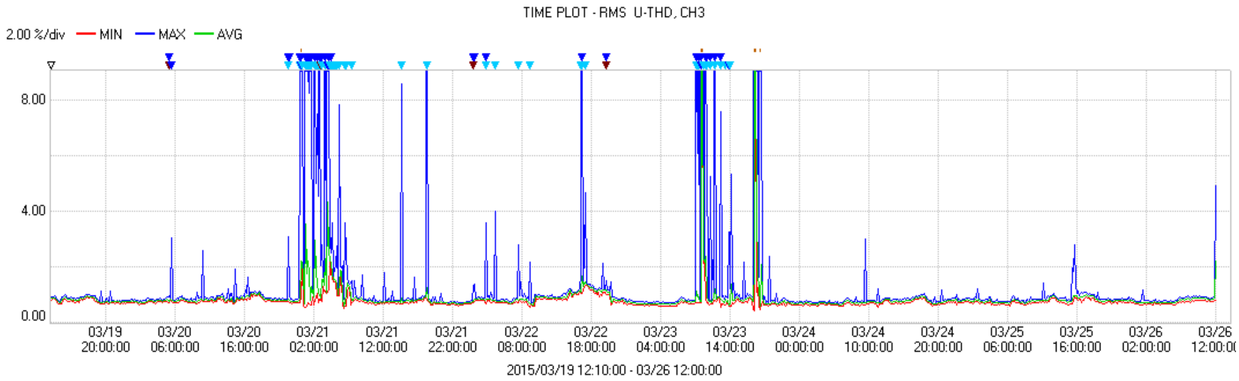


LONG TERM MEASUREMENT

Measurement Item : Uthd (CH1, CH2, CH3)
Measuring point : Milford substation 11kV bus
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

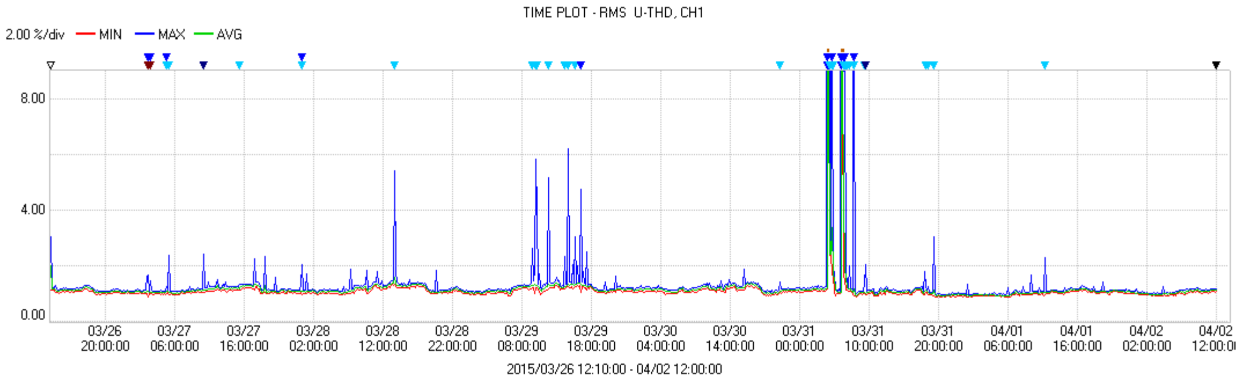


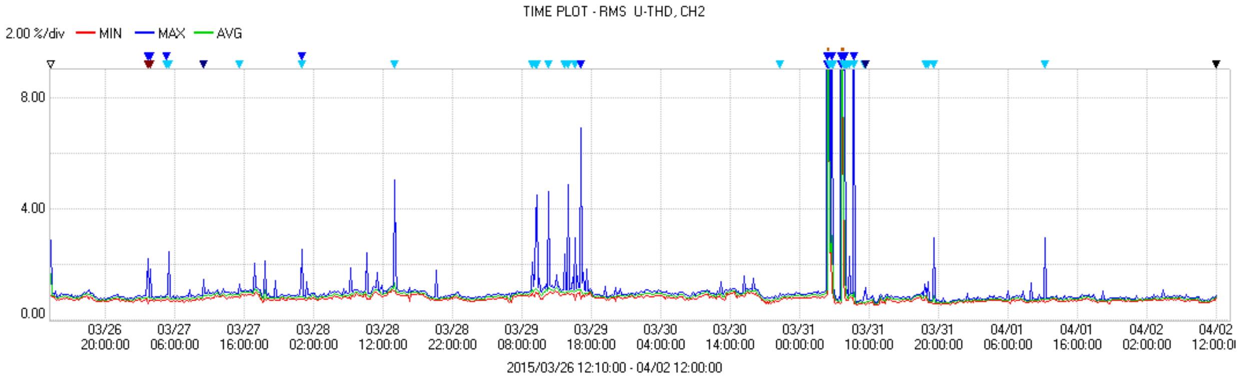


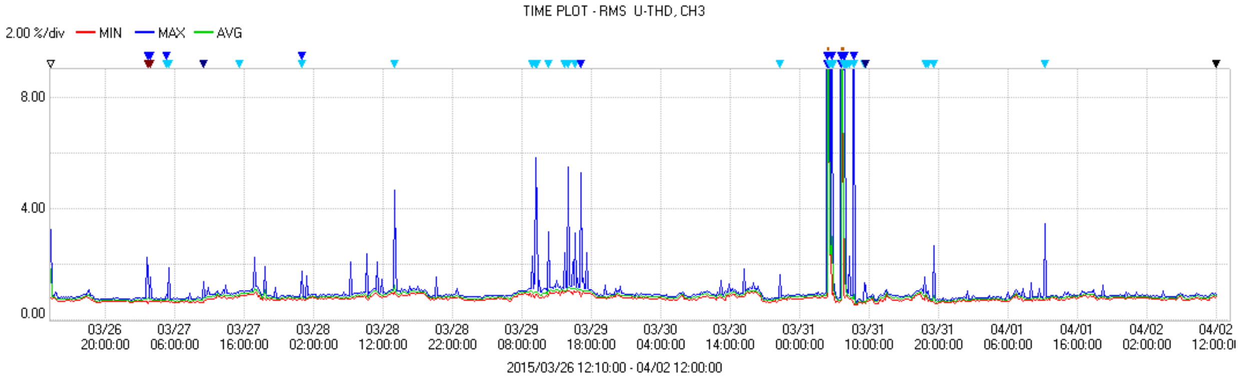


LONG TERM MEASUREMENT

Measurement Item : Uthd (CH1, CH2, CH3)
Measuring point : Milford substation 11kV bus
Duration : 26/March/2015 12:00 – 2/April/2015 12:00

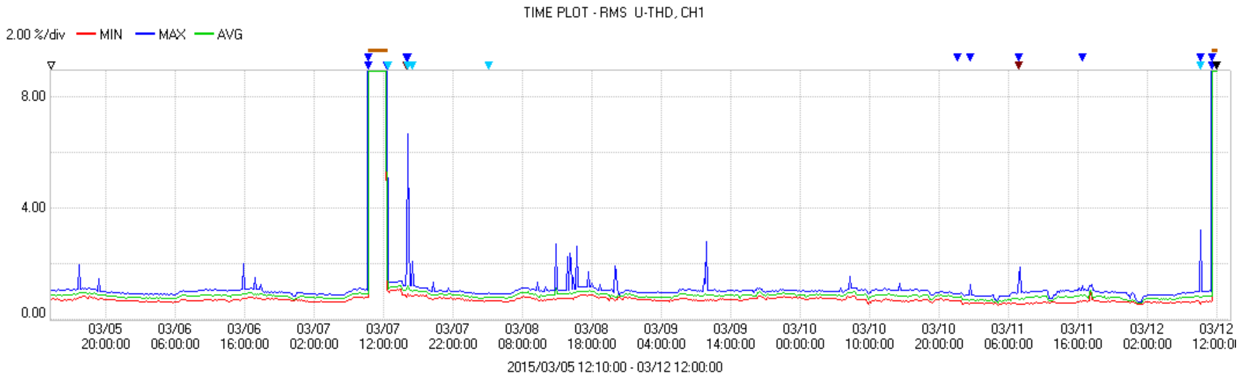


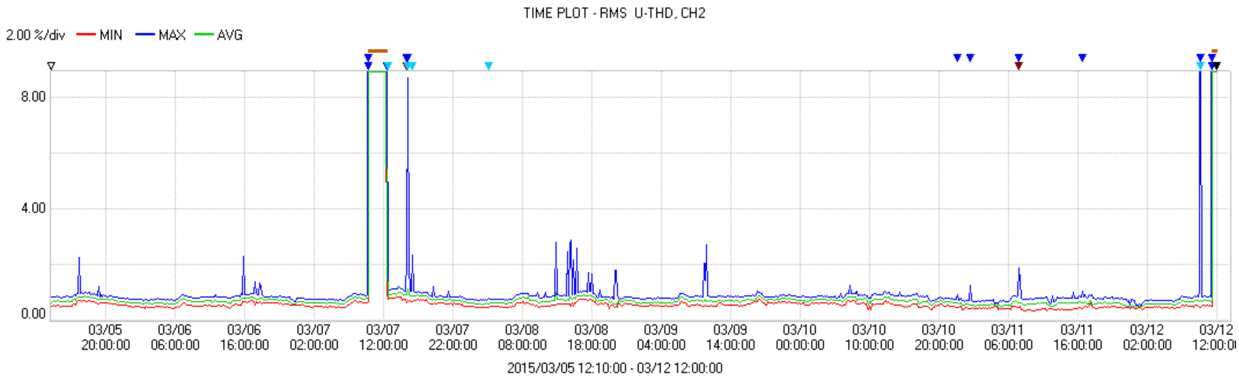


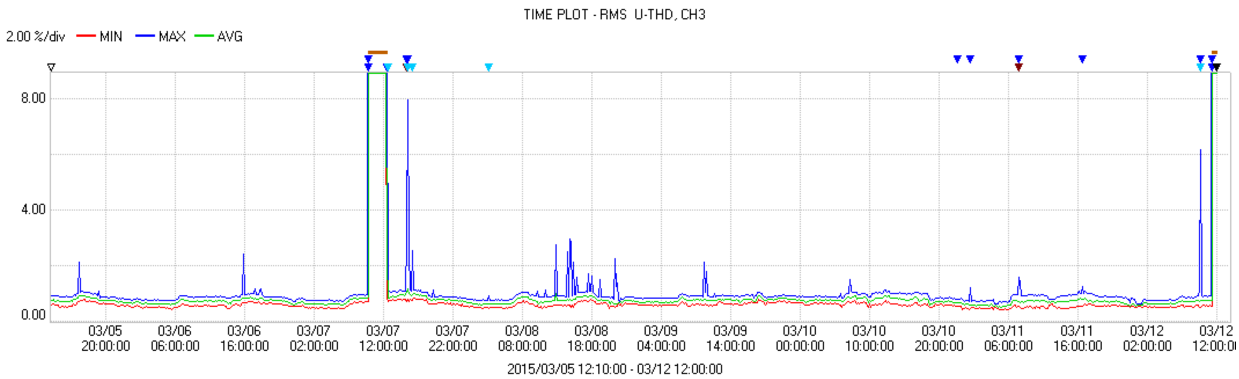


LONG TERM MEASUREMENT

Measurement Item : Uthd (CH1, CH2, CH3)
Measuring Point : Taraka substation 11kV bus
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

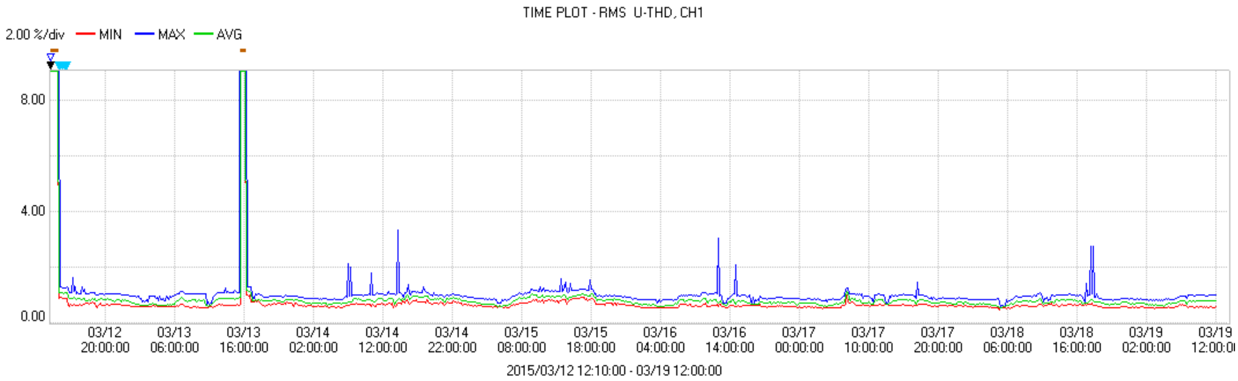


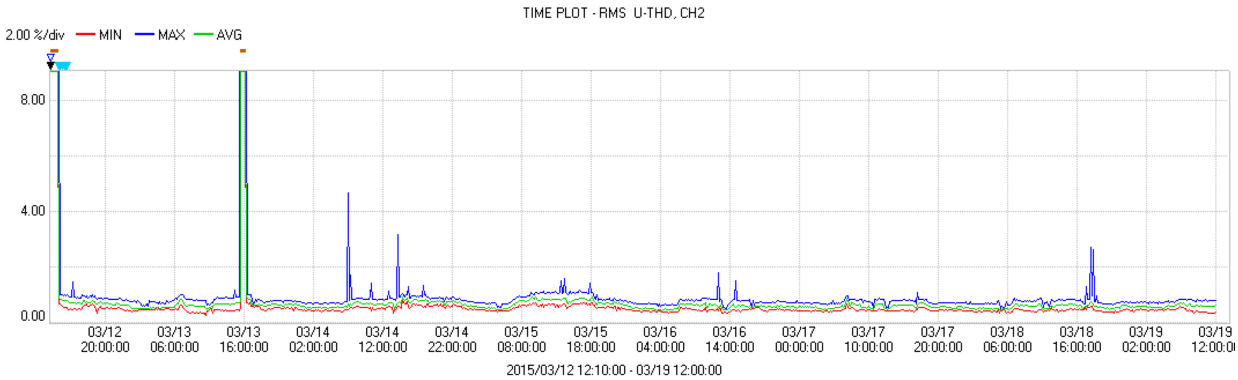


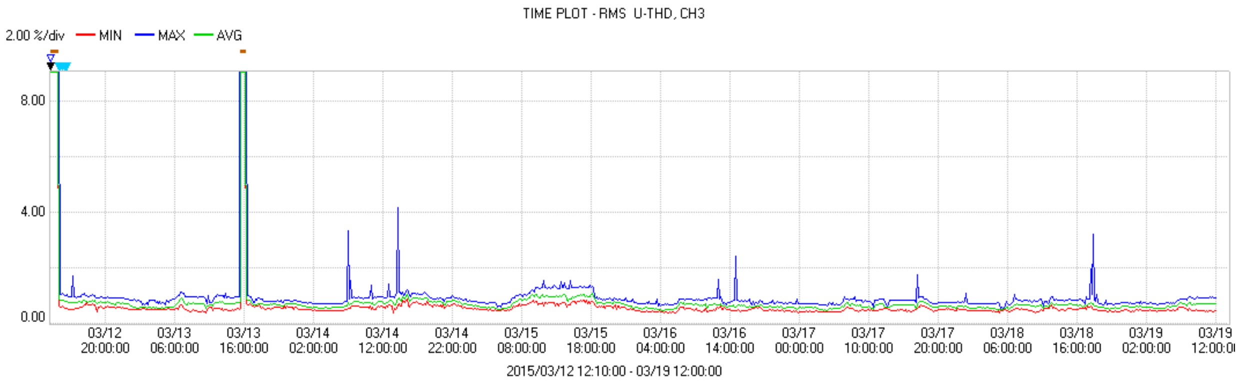


LONG TERM MEASUREMENT

Measurement Item : Uthd (CH1, CH2, CH3)
Measuring point : Taraka substation 11kV bus
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

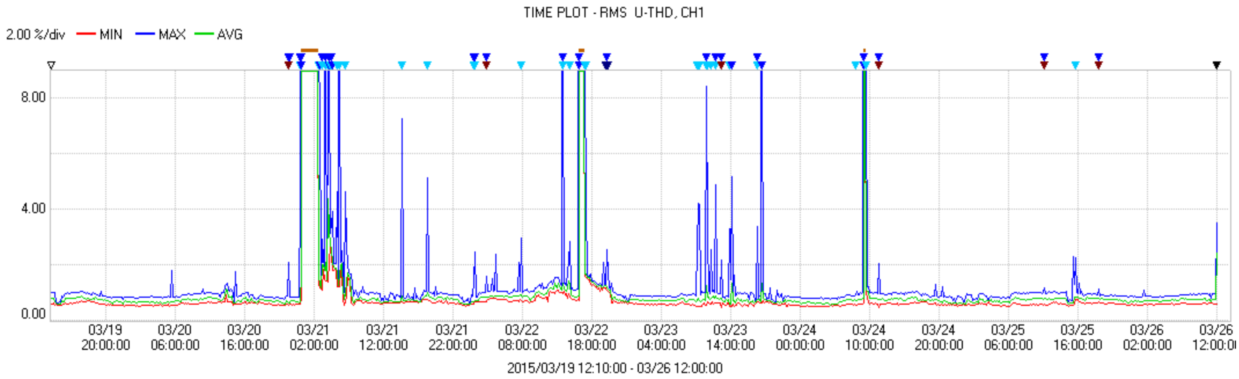


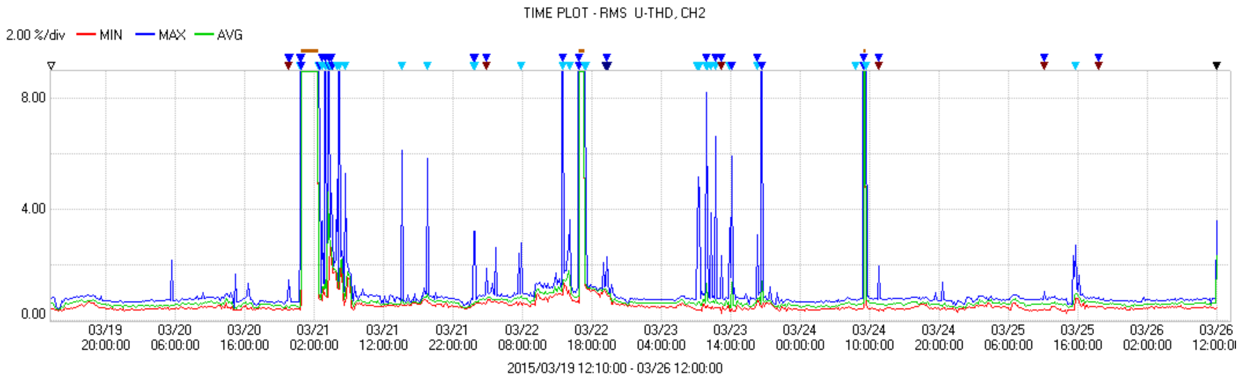


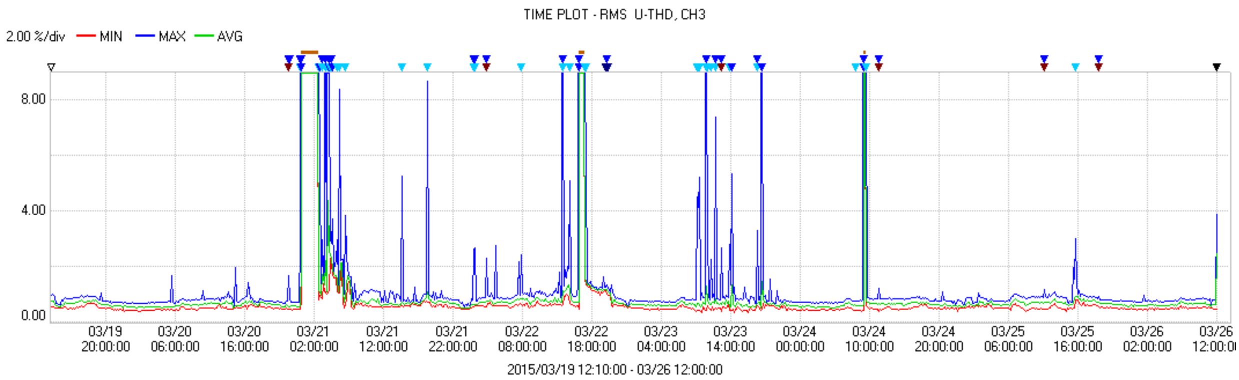


LONG TERM MEASUREMENT

Measurement Item : Uthd (CH1, CH2, CH3)
Measuring point : Taraka substation 11kV bus
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

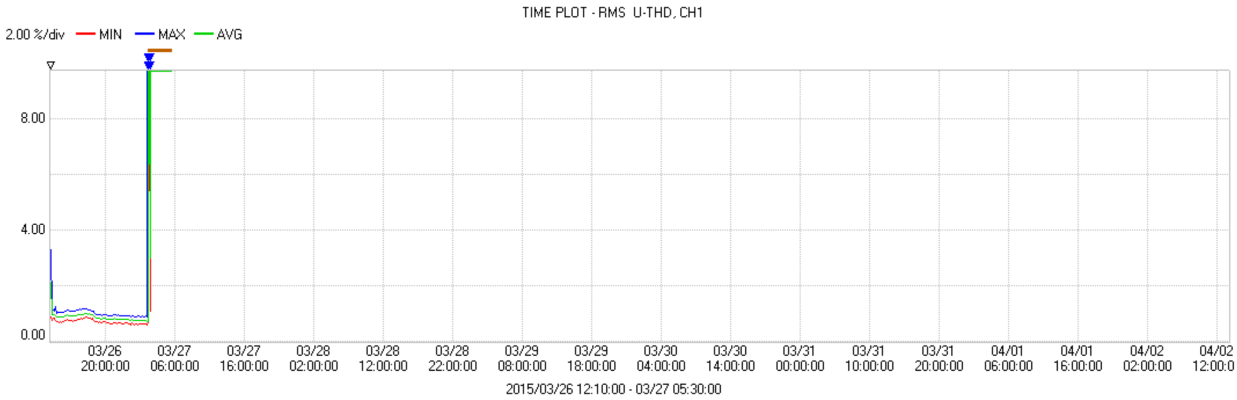


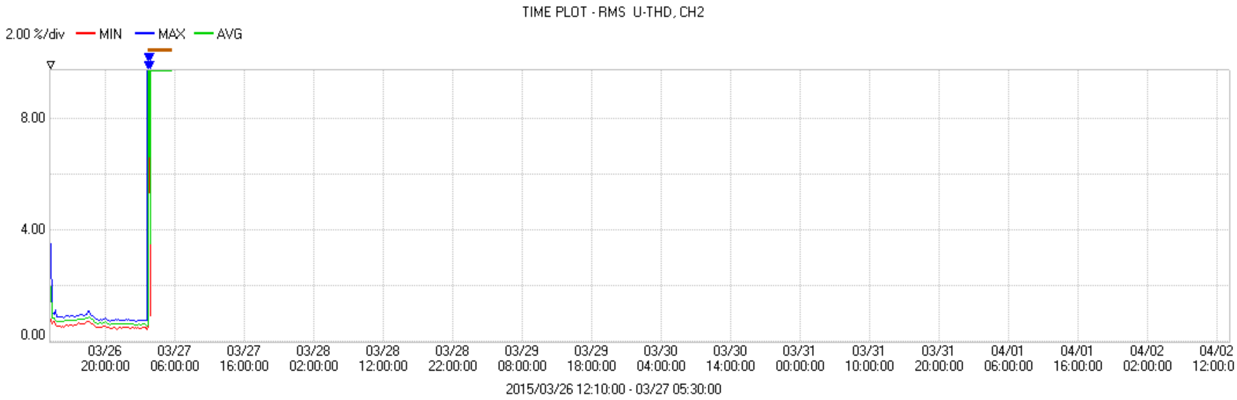


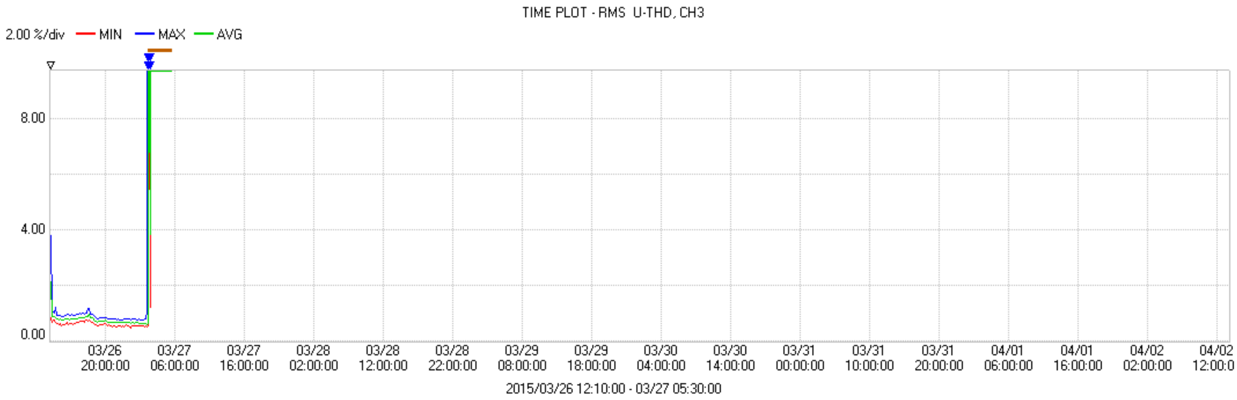


LONG TERM MEASUREMENT

Measurement Item : Uthd (CH1, CH2, CH3)
Measuring point : Taraka substation 11kV bus
Duration : 26/March/2015 12:00 – 27/March/2015 05:30

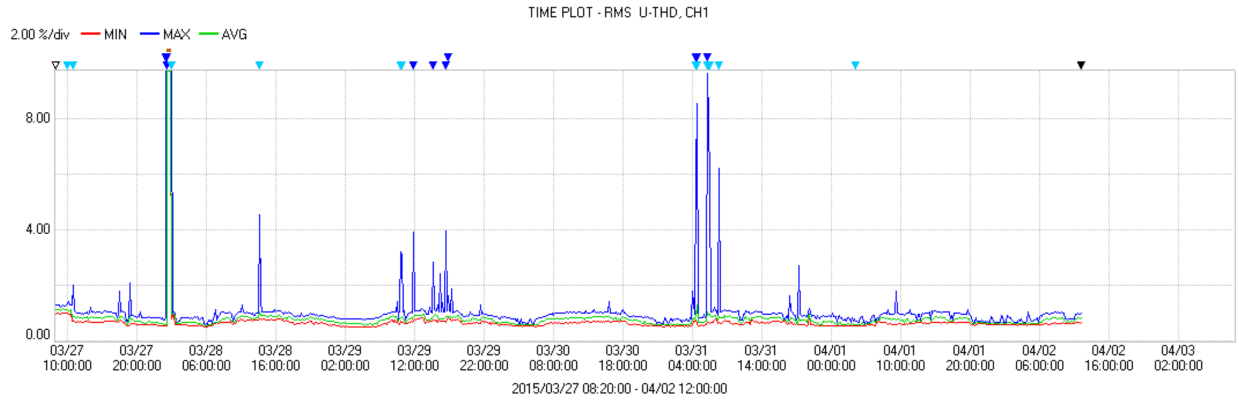


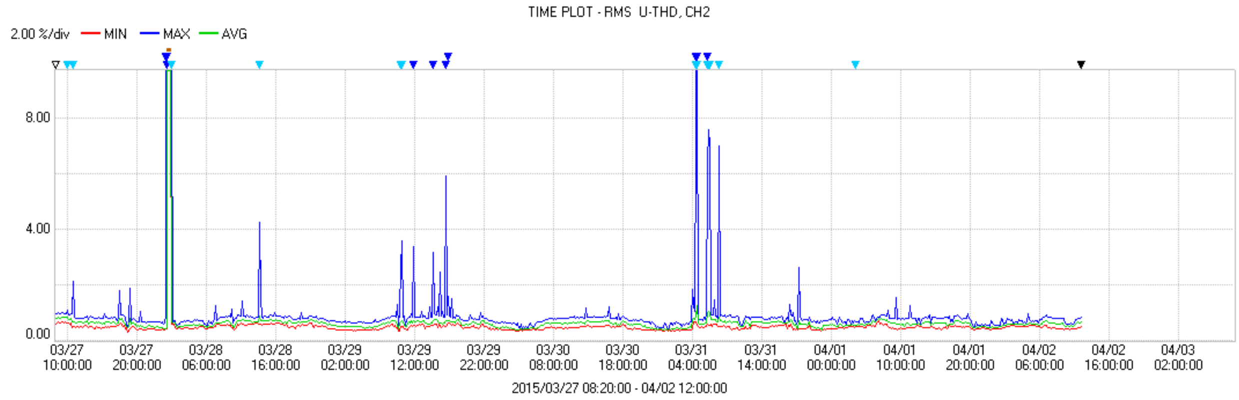


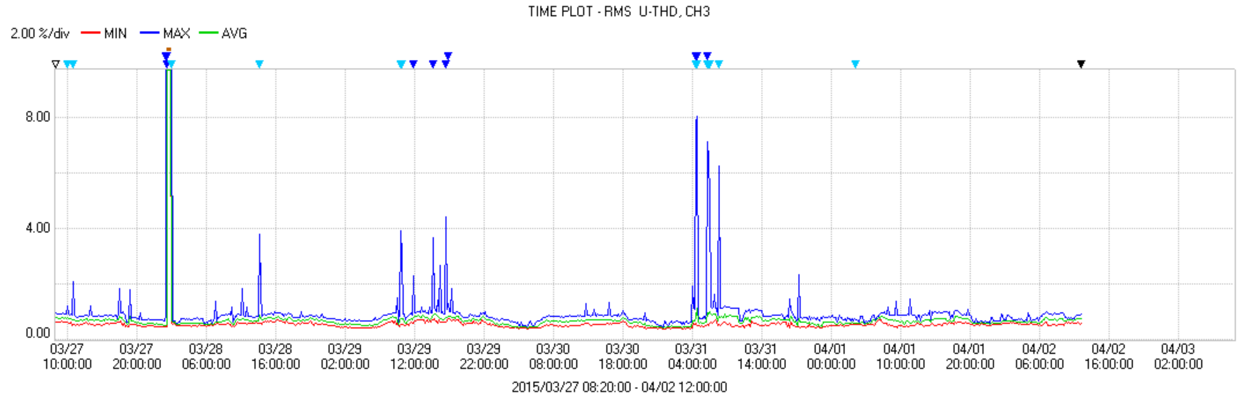


LONG TERM MEASUREMENT

Measurement Item : Uthd (CH1, CH2, CH3)
Measuring point : Taraka substation 11kV bus
Duration : 27/March/2015 08:20 – 2/April/2015 12:00

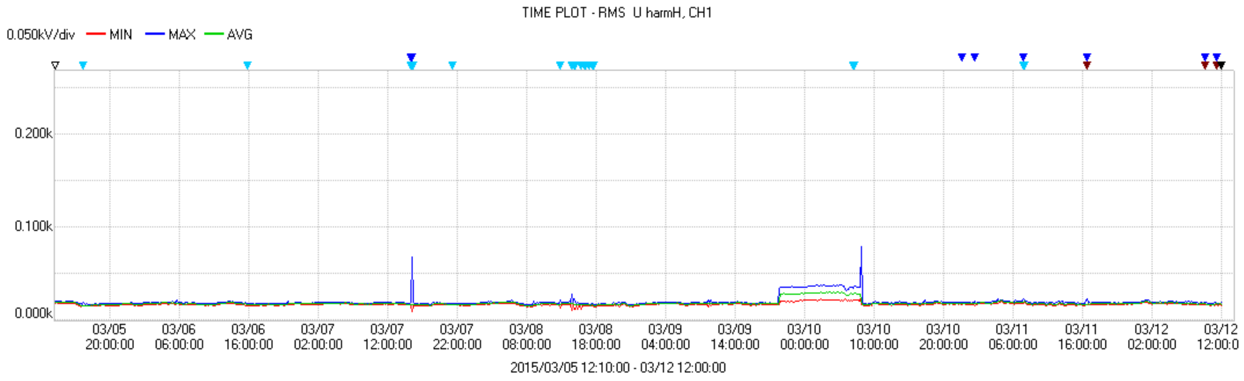


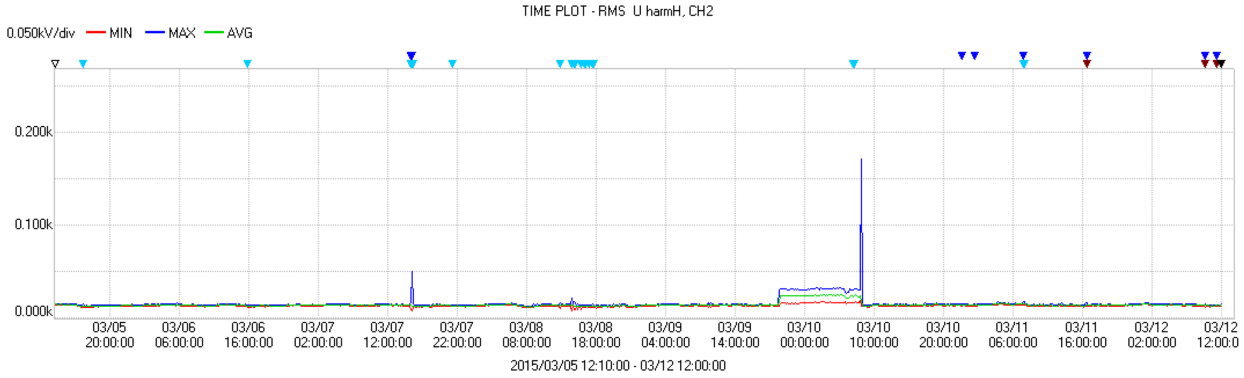


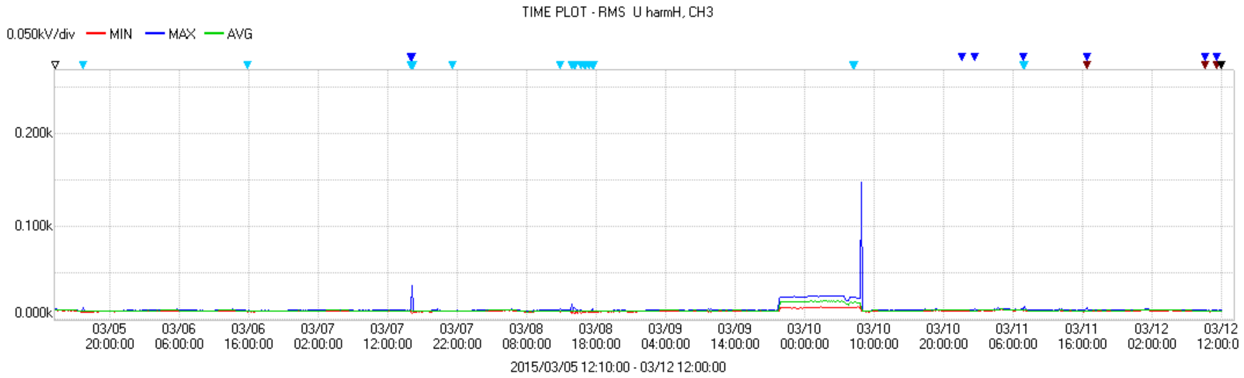


LONG TERM MEASUREMENT

Measurement Item : UharmH (CH1, CH2, CH3)
Measuring Point : Milford substation 11kV bus
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

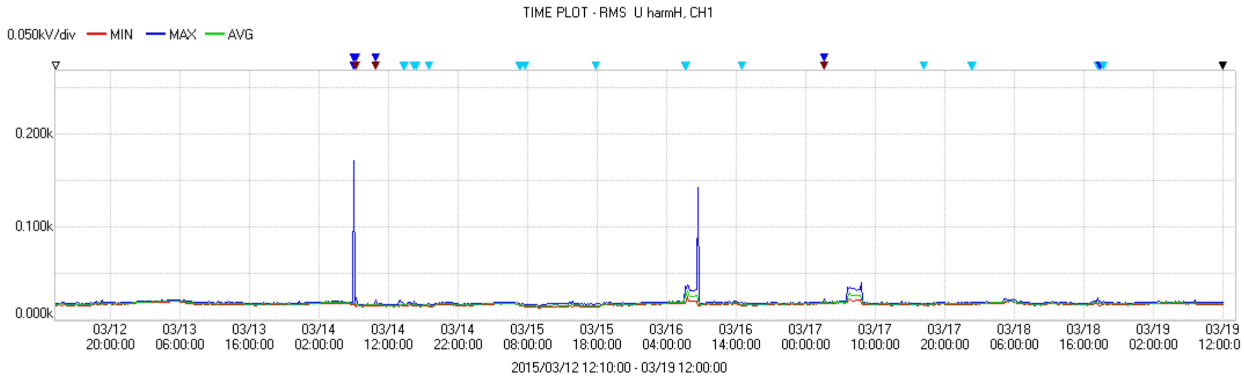


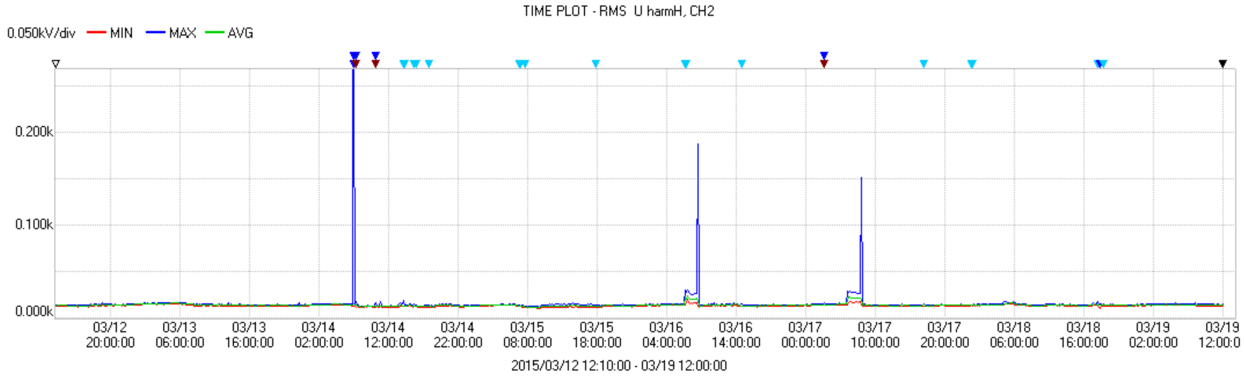


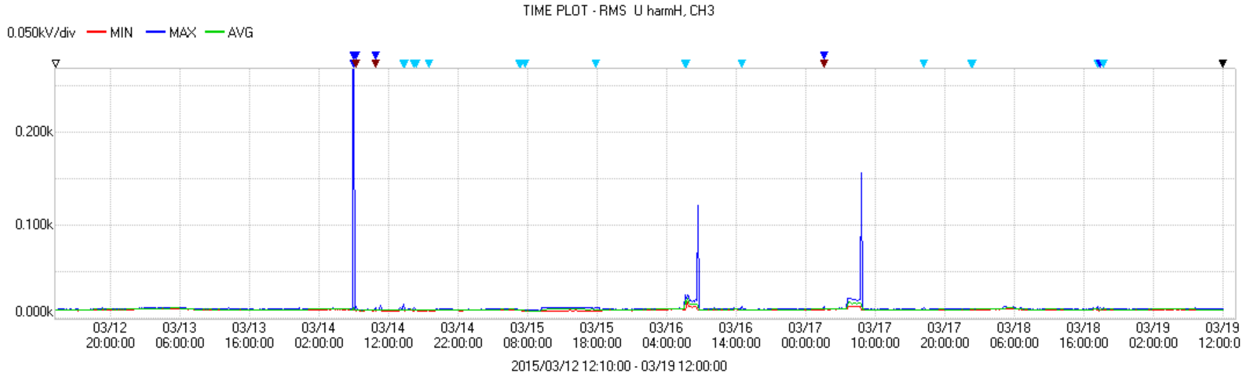


LONG TERM MEASUREMENT

Measurement Item : UharmH (CH1, CH2, CH3)
Measuring point : Milford substation 11kV bus
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

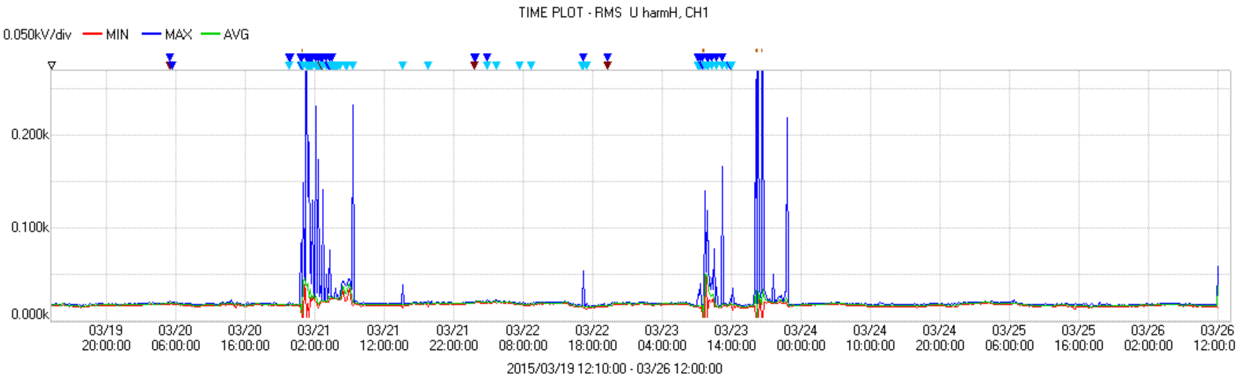


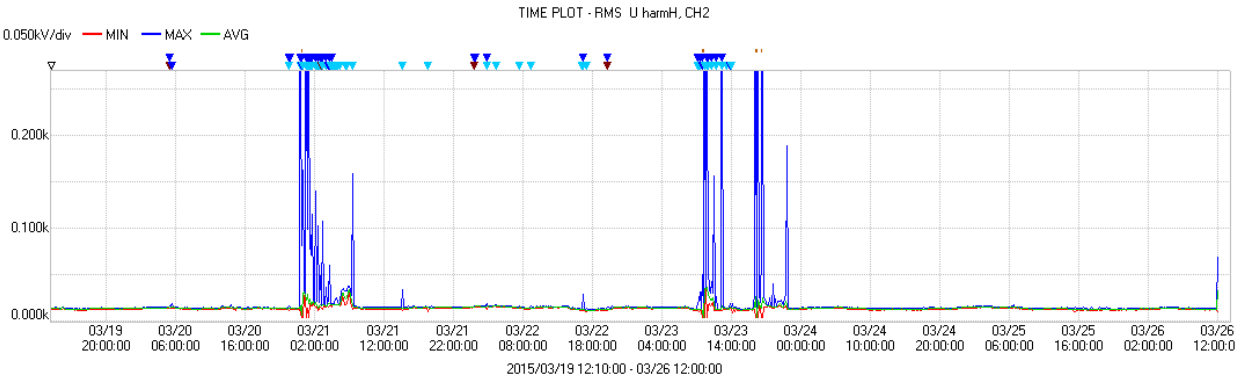


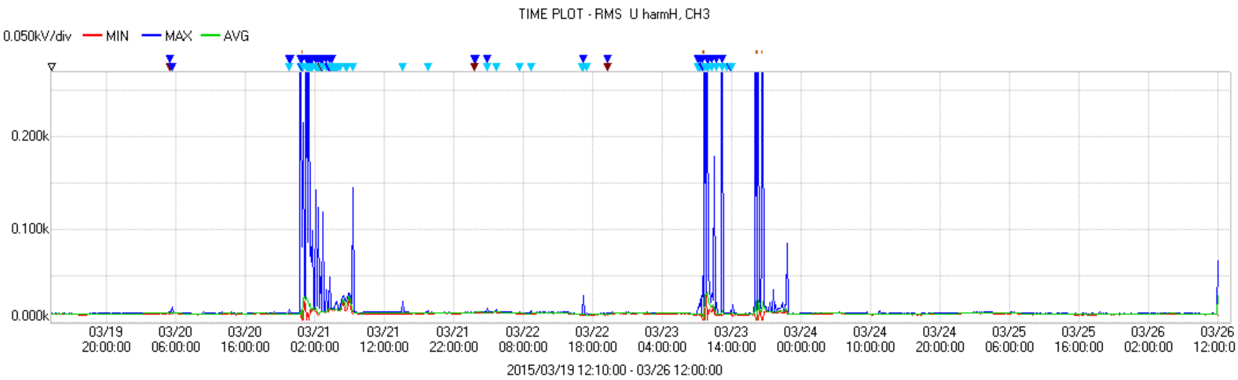


LONG TERM MEASUREMENT

Measurement Item : UharmH (CH1, CH2, CH3)
Measuring point : Milford substation 11kV bus
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

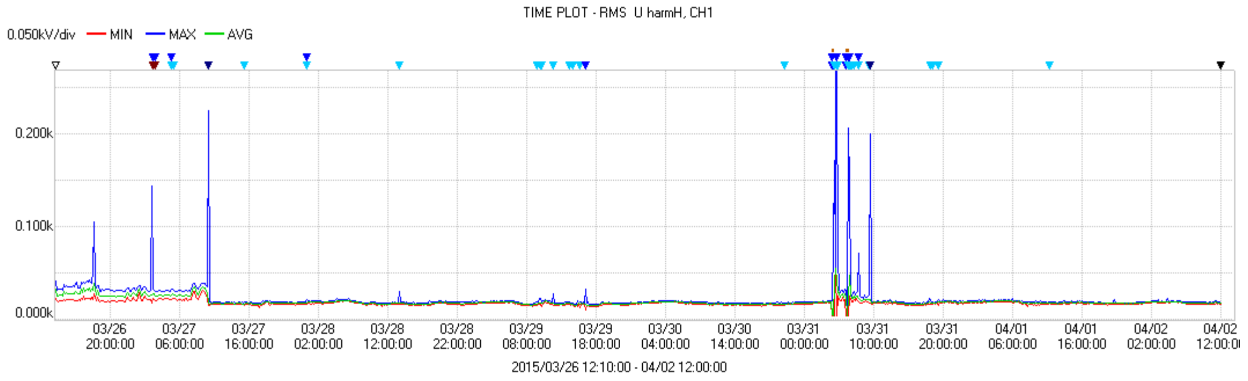


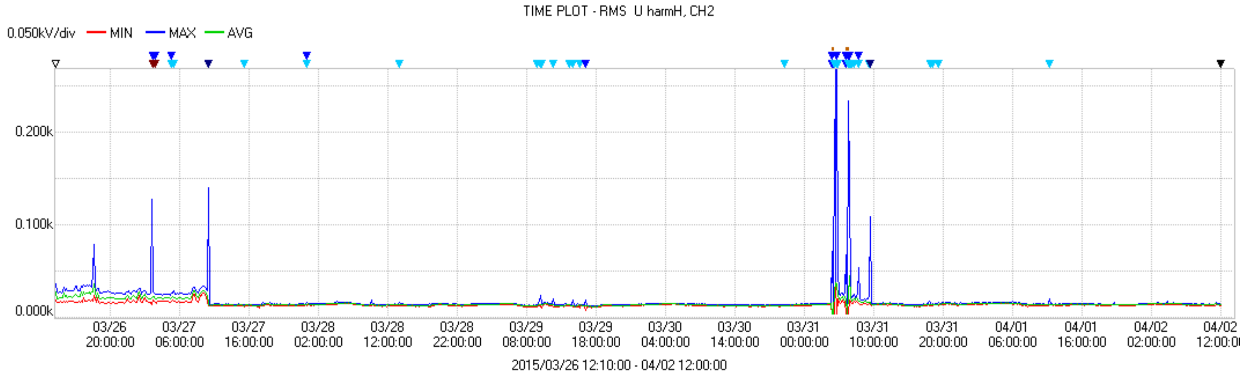


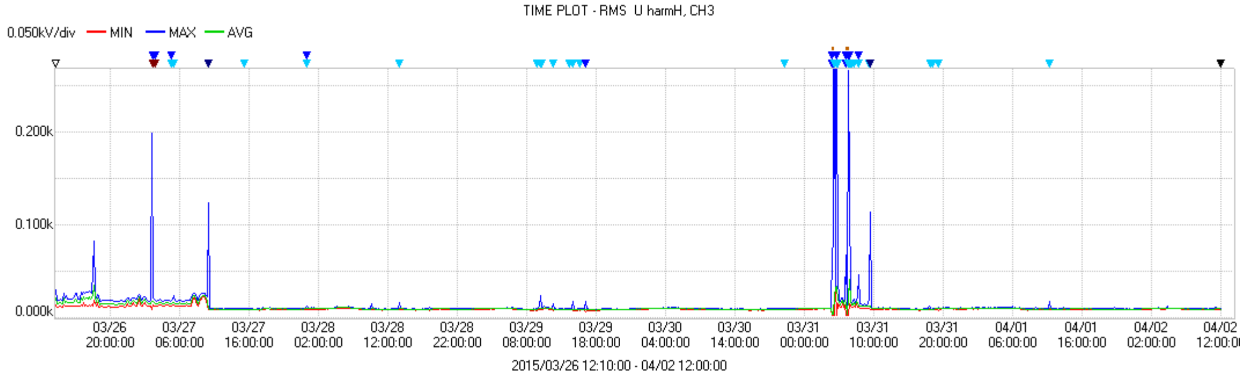


LONG TERM MEASUREMENT

Measurement Item : UharmH (CH1, CH2, CH3)
Measuring point : Milford substation 11kV bus
Duration : 26/March/2015 12:00 – 2/April/2015 12:00

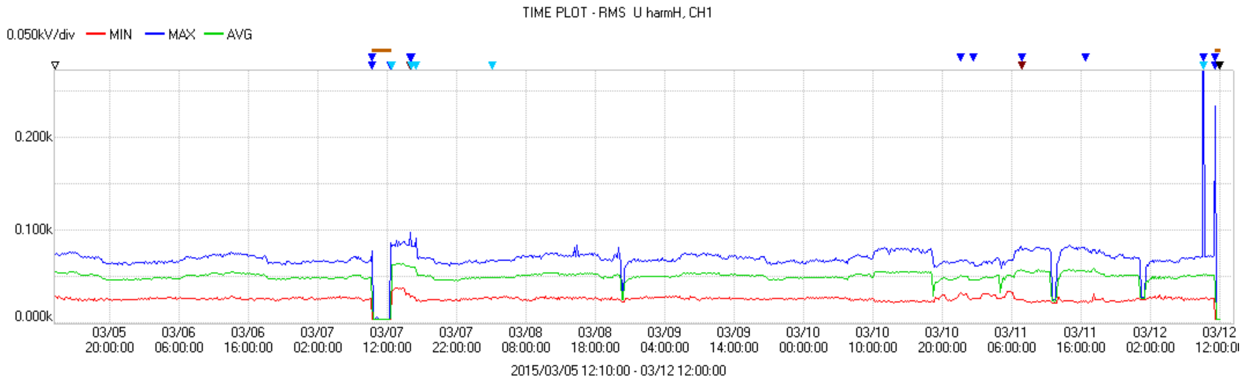


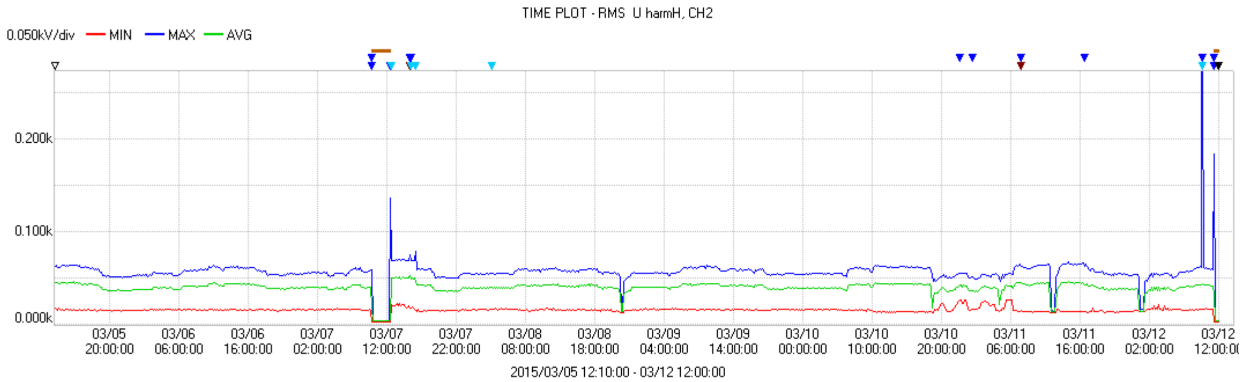


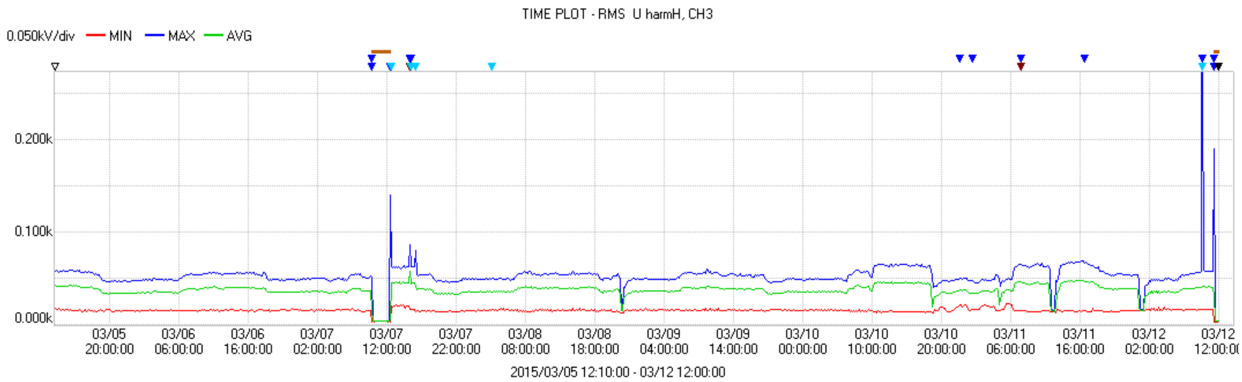


LONG TERM MEASUREMENT

Measurement Item : UharmH (CH1, CH2, CH3)
Measuring Point : Taraka substation 11kV bus
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

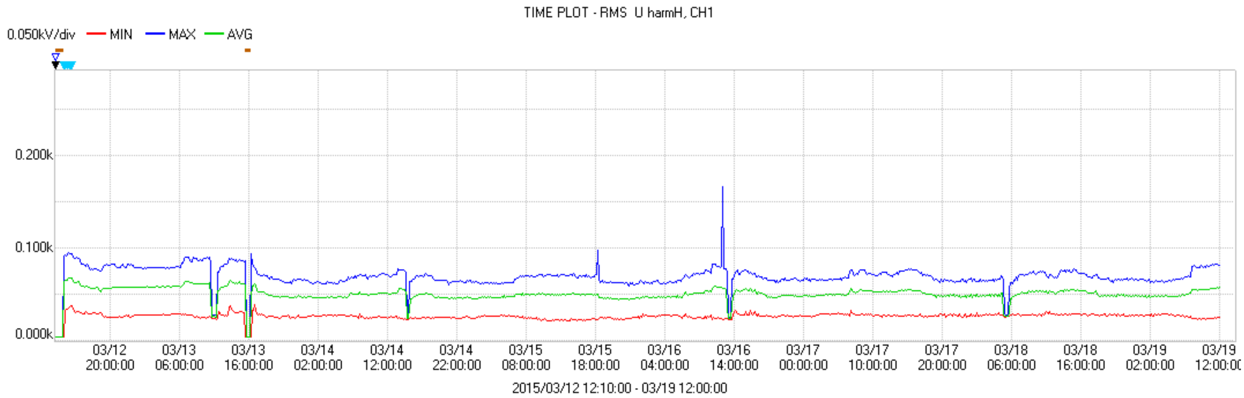


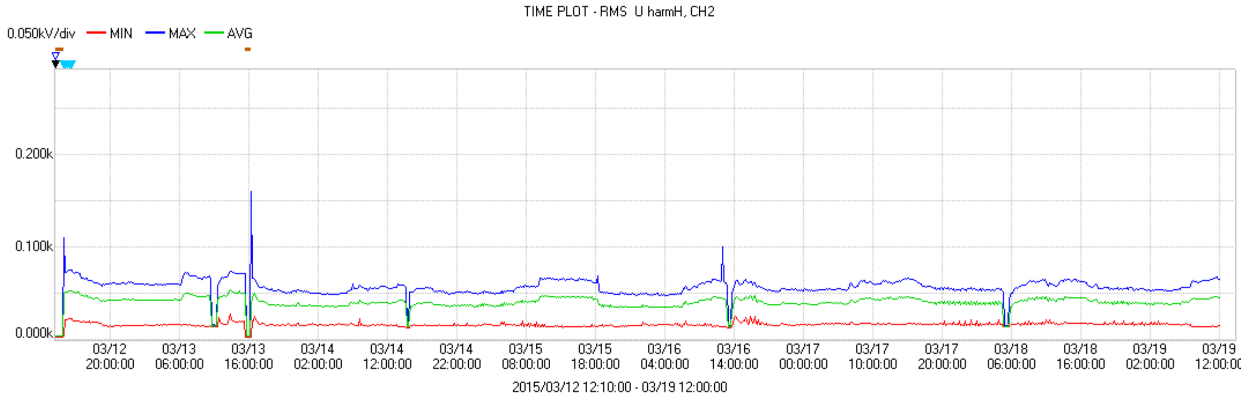


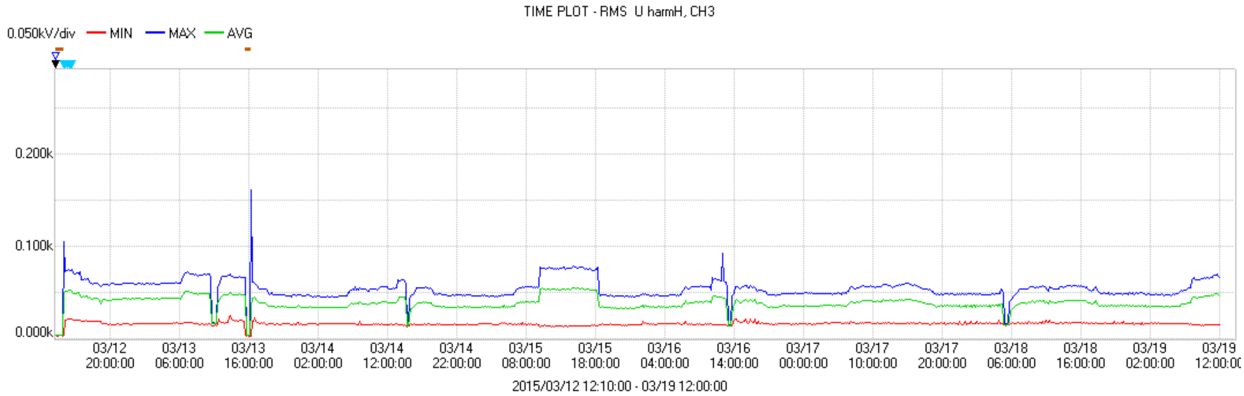


LONG TERM MEASUREMENT

Measurement Item : UharmH (CH1, CH2, CH3)
Measuring point : Taraka substation 11kV bus
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

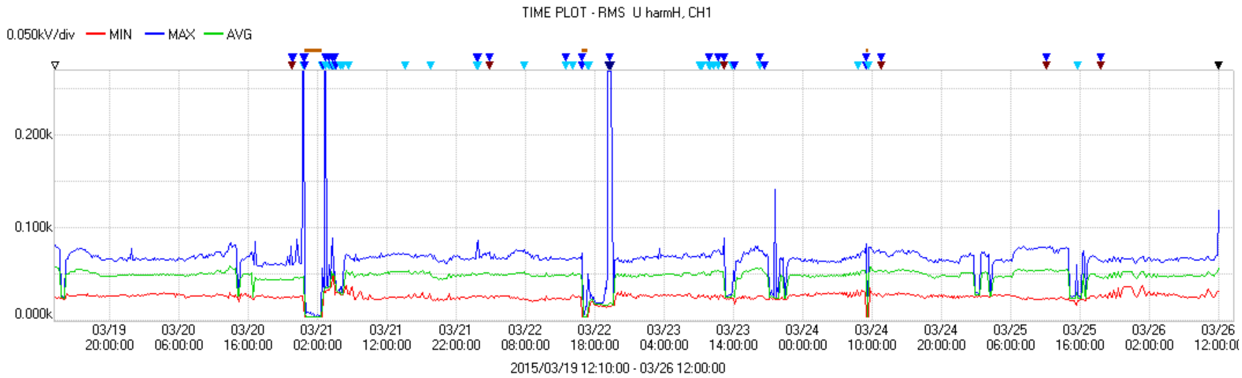


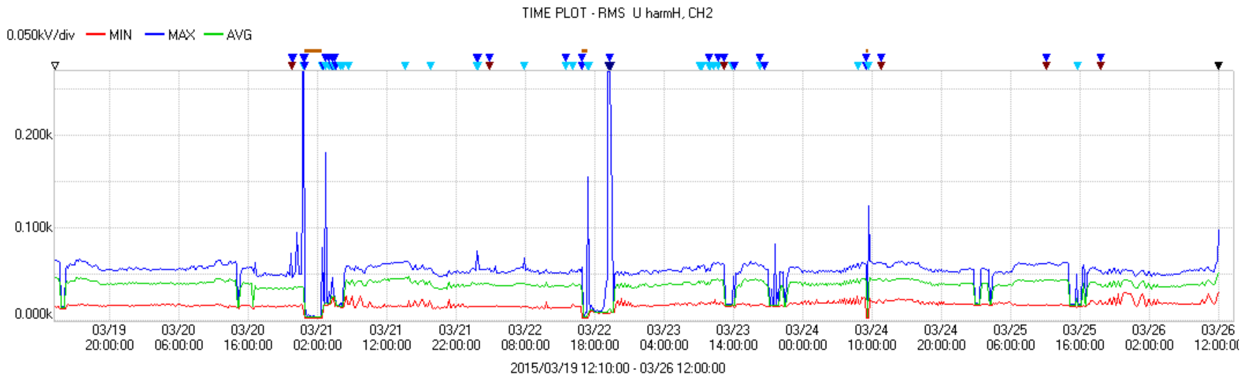


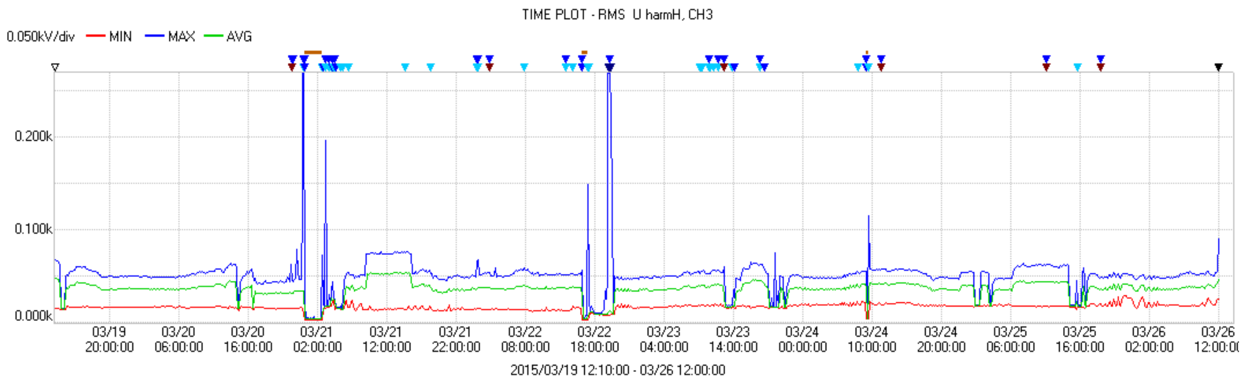


LONG TERM MEASUREMENT

Measurement Item : UharmH (CH1, CH2, CH3)
Measuring point : Taraka substation 11kV bus
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

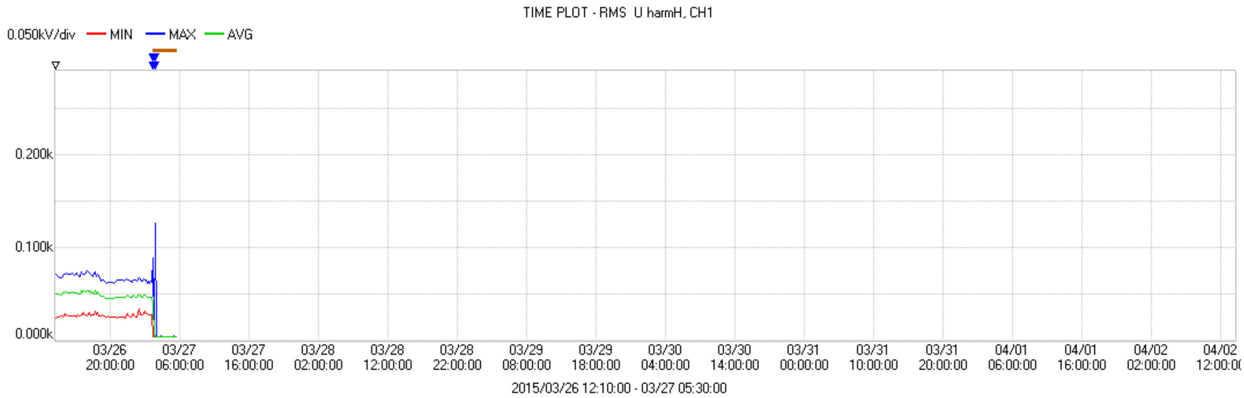


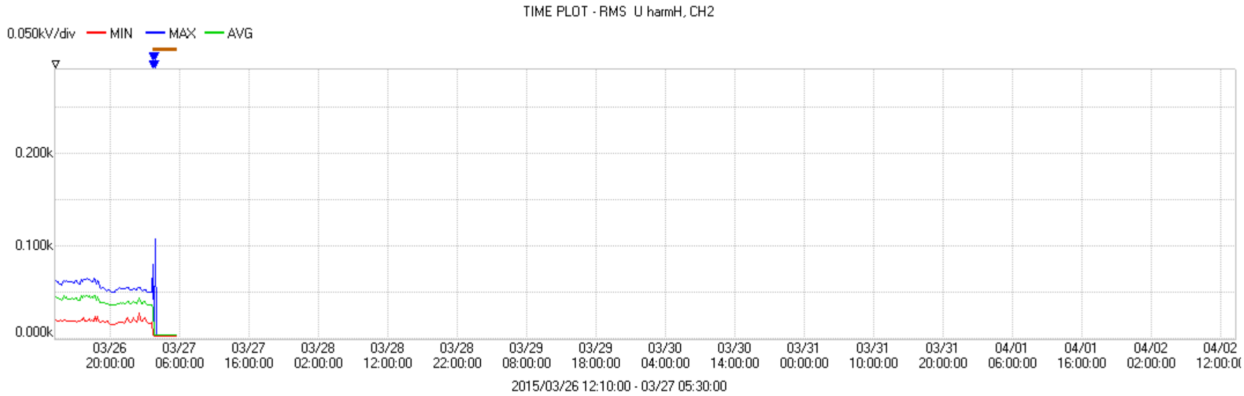


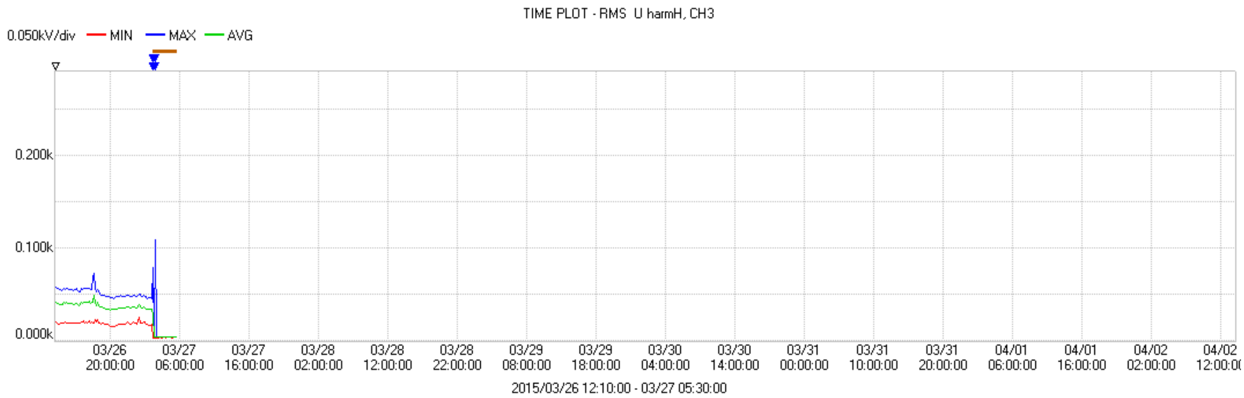


LONG TERM MEASUREMENT

Measurement Item : UharmH (CH1, CH2, CH3)
Measuring point : Taraka substation 11kV bus
Duration : 26/March/2015 12:00 – 2/March/2015 05:30

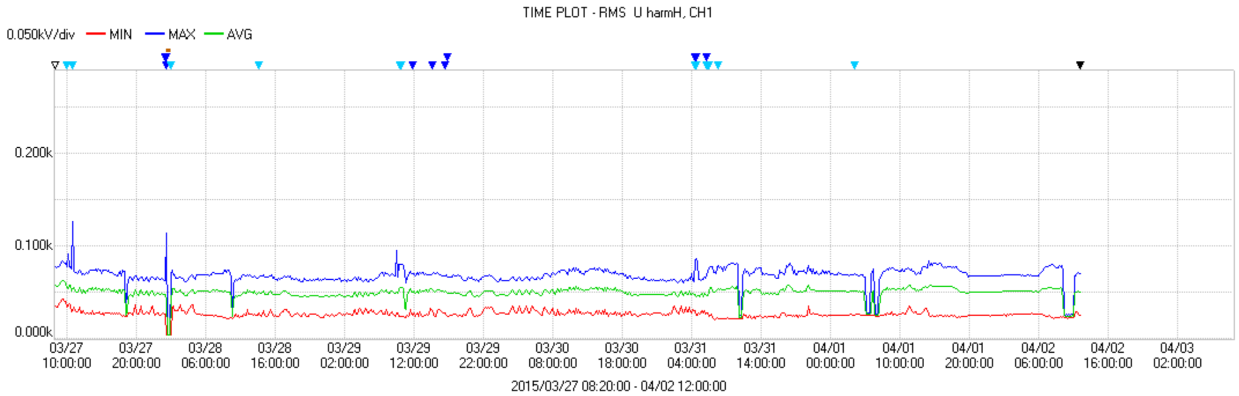


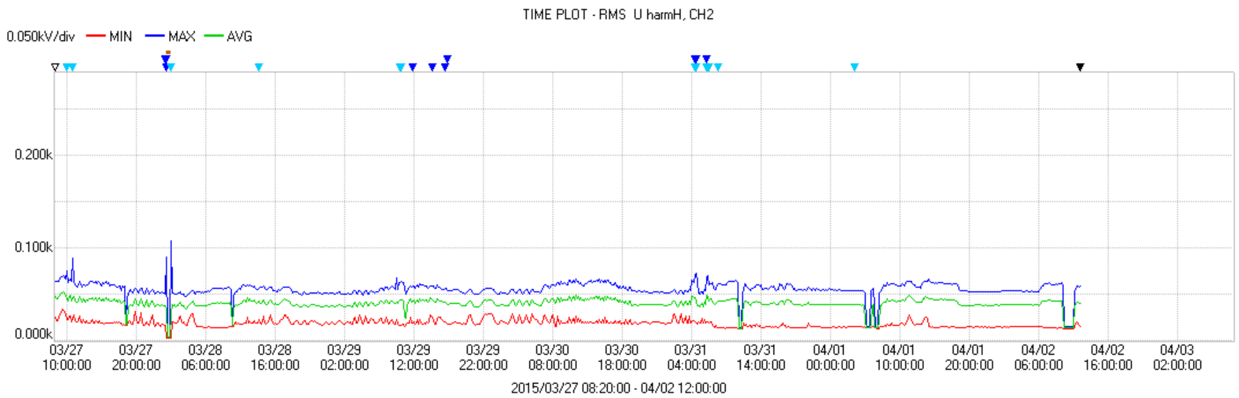


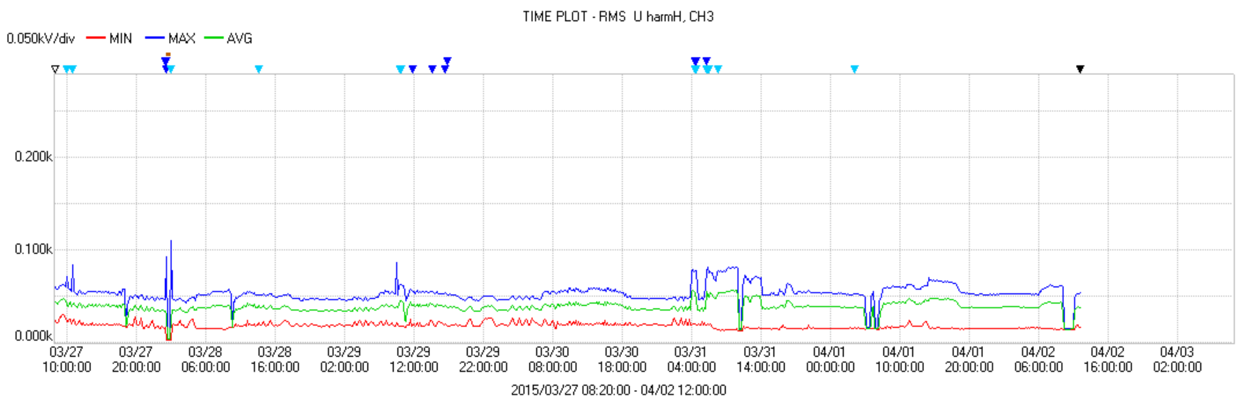


LONG TERM MEASUREMENT

Measurement Item : UharmH (CH1, CH2, CH3)
Measuring point : Taraka substation 11kV bus
Duration : 27/March/2015 08:20 – 2/April/2015 12:00

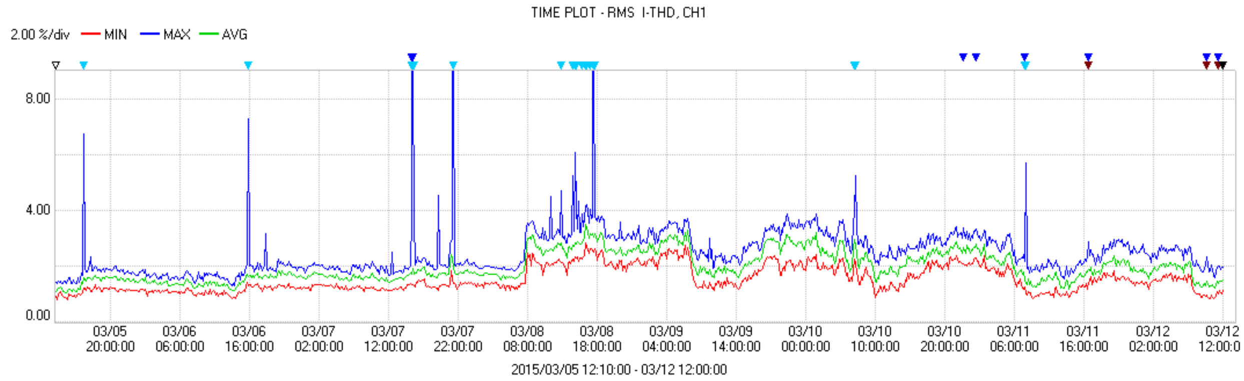


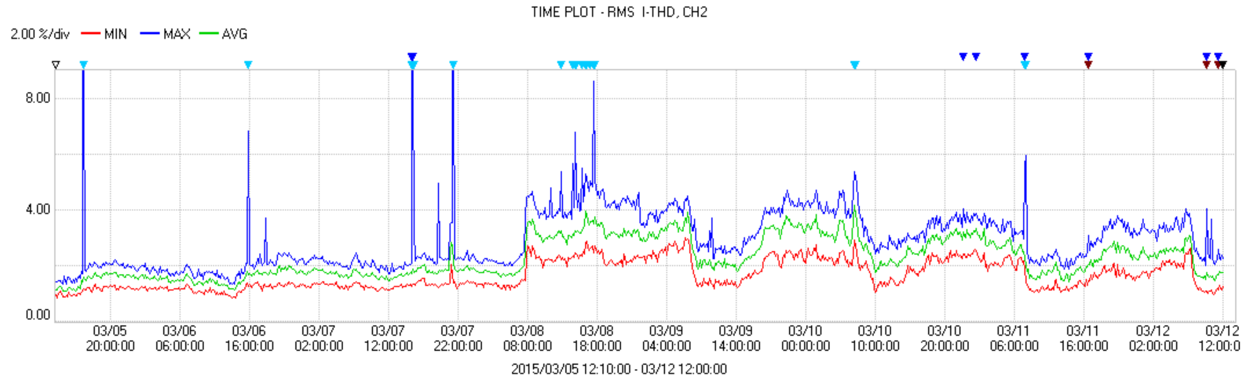


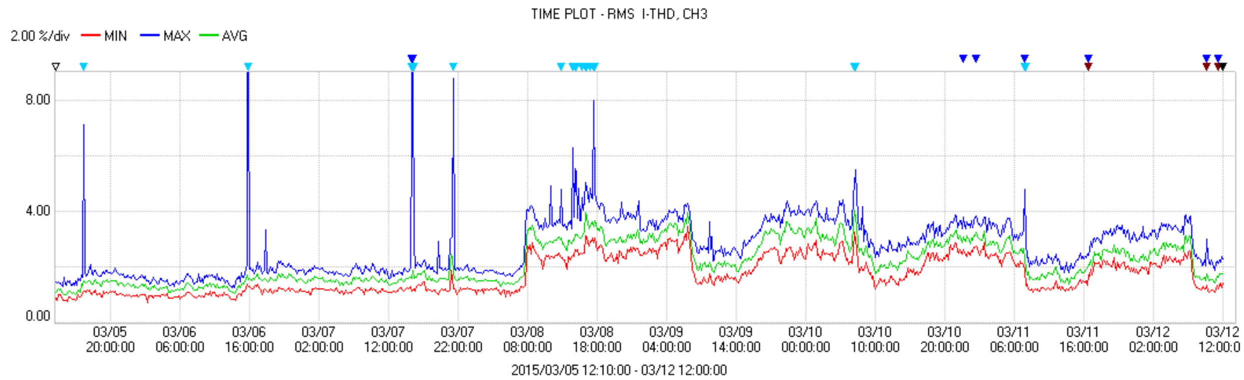


LONG TERM MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : M1
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

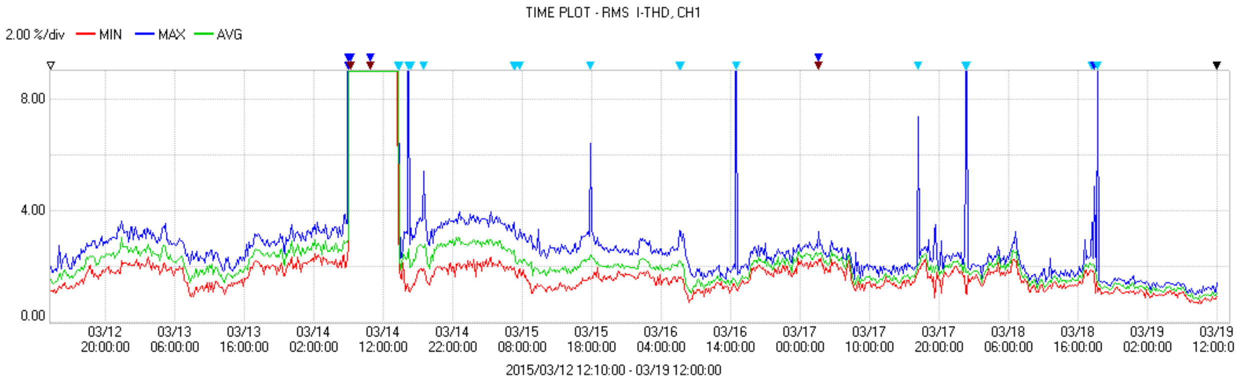


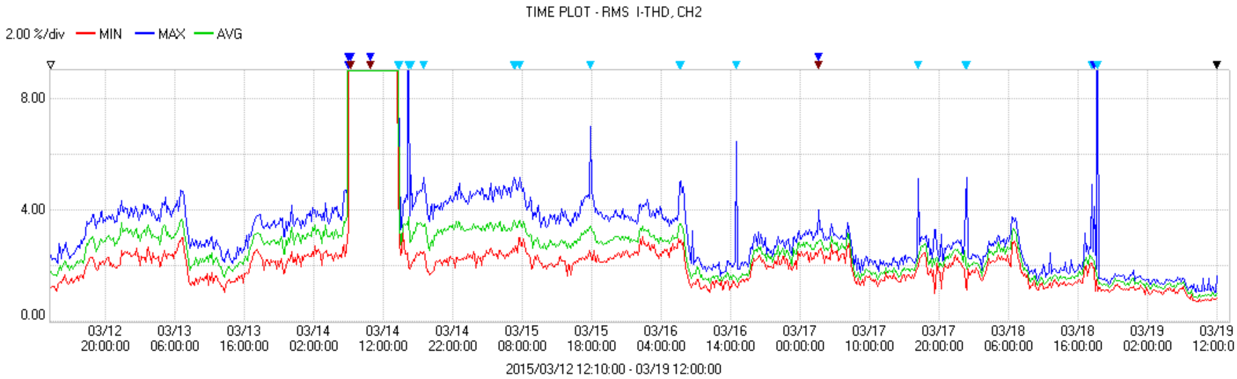


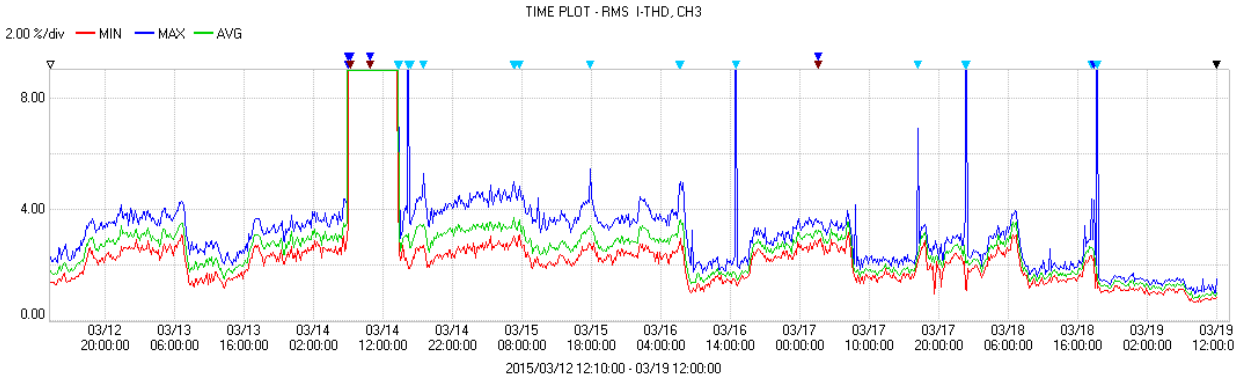


LONG TERM MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : M1
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

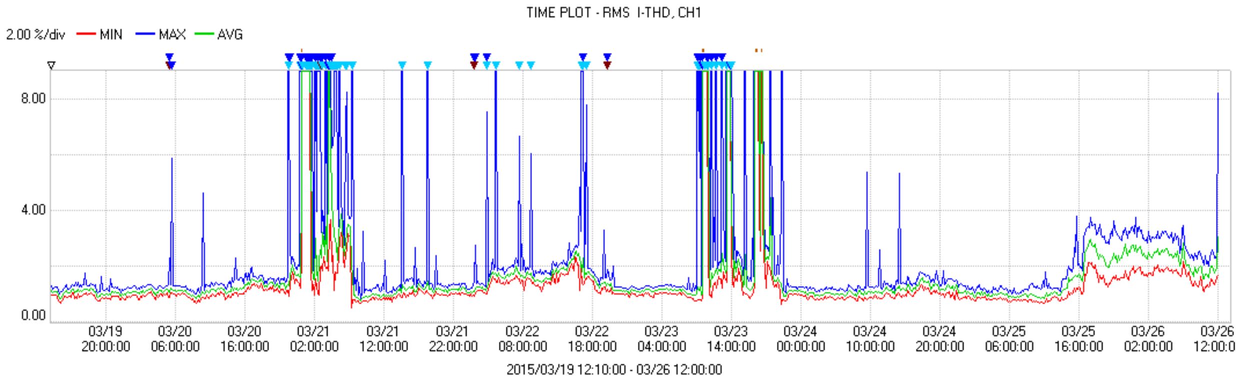


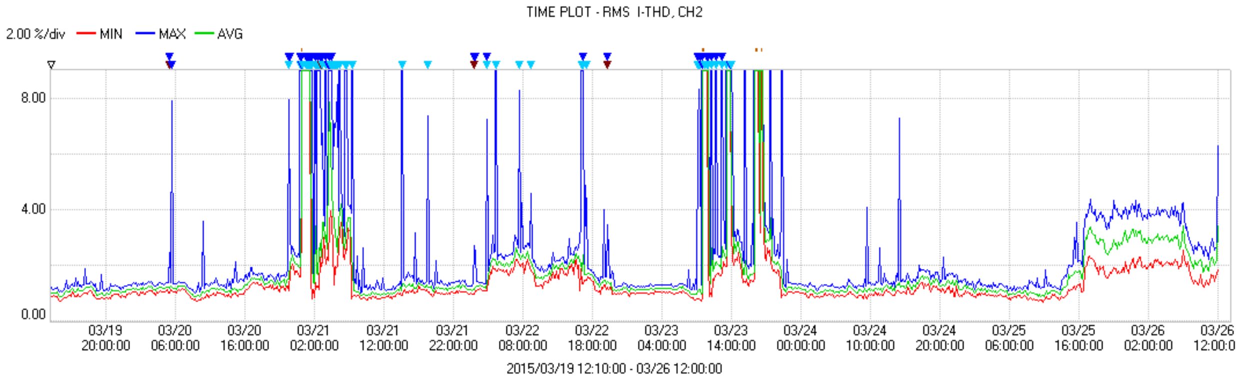


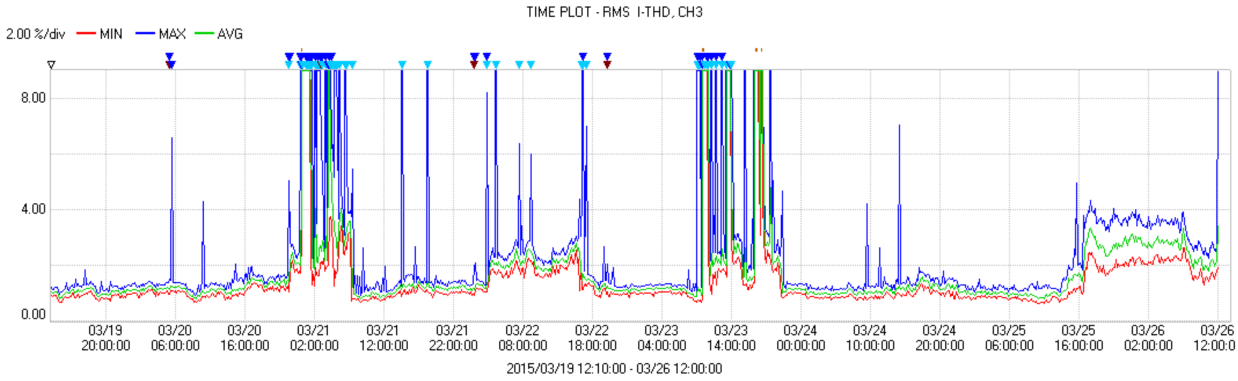


LONG TERM MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : M1
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

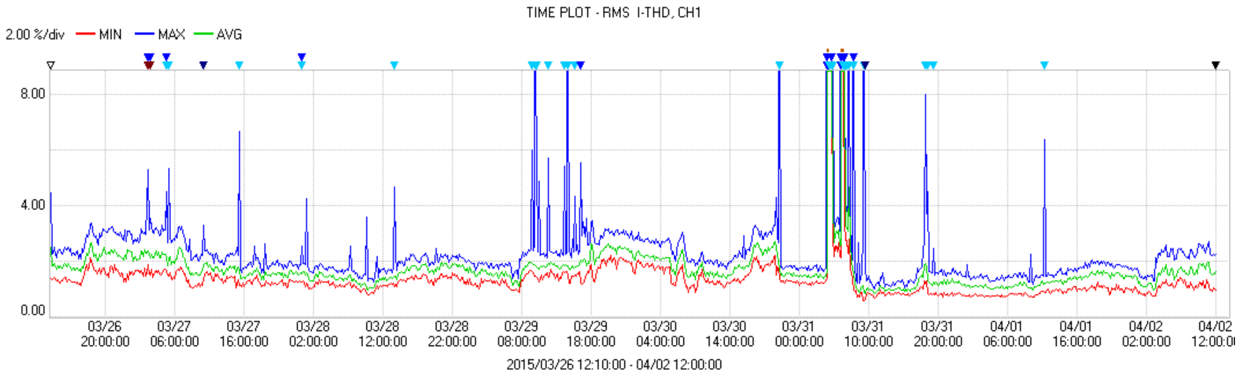


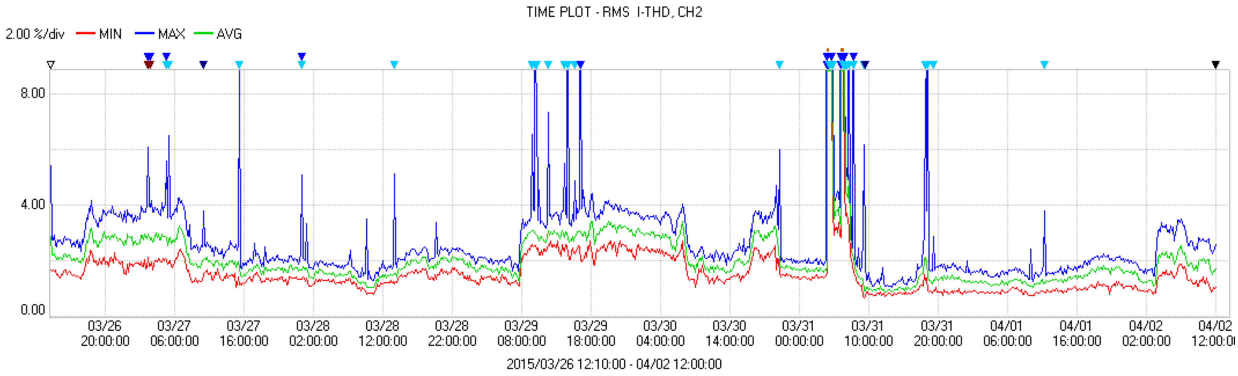


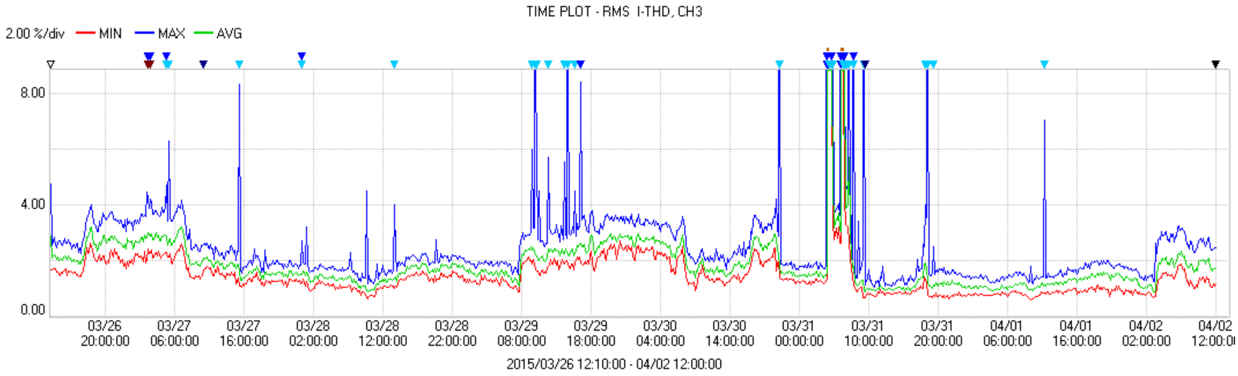


Long Term Measurement

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : M1
Duration : 26/March/2015 12:00 – 2/April/2015 12:00

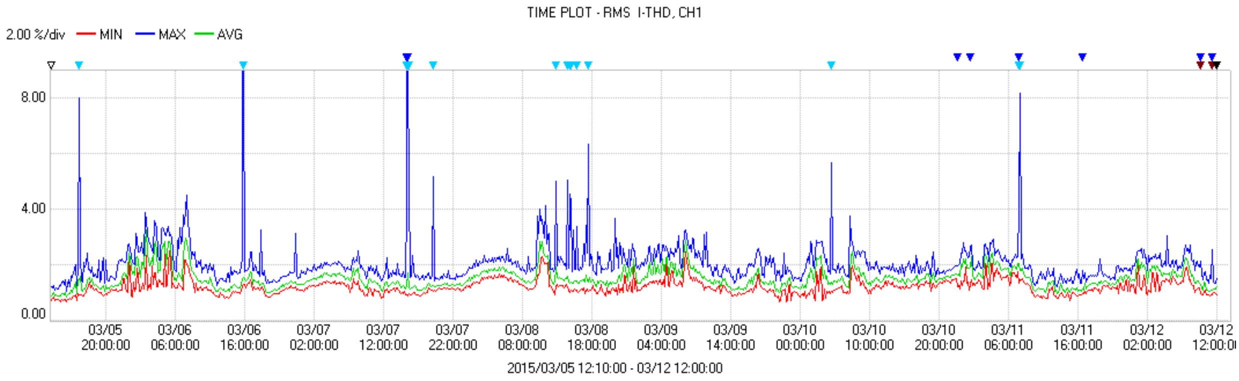


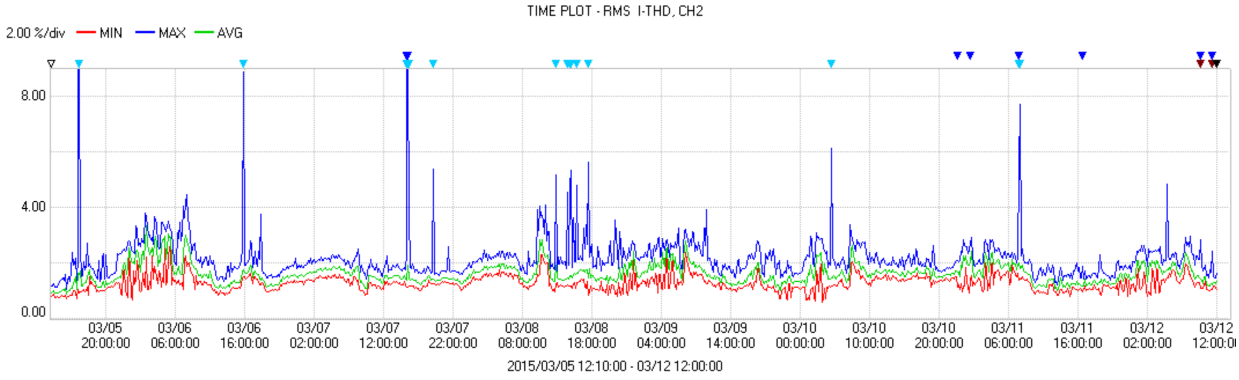


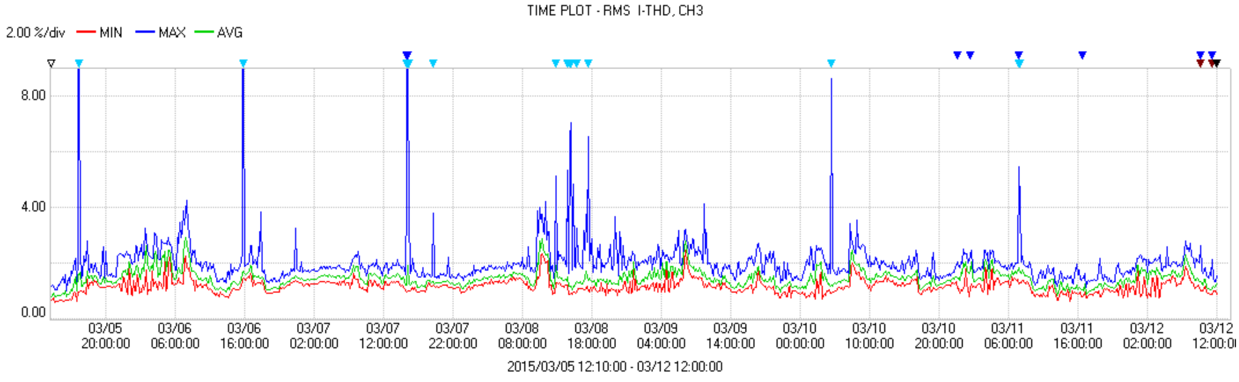


LONG TERM MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : M2
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

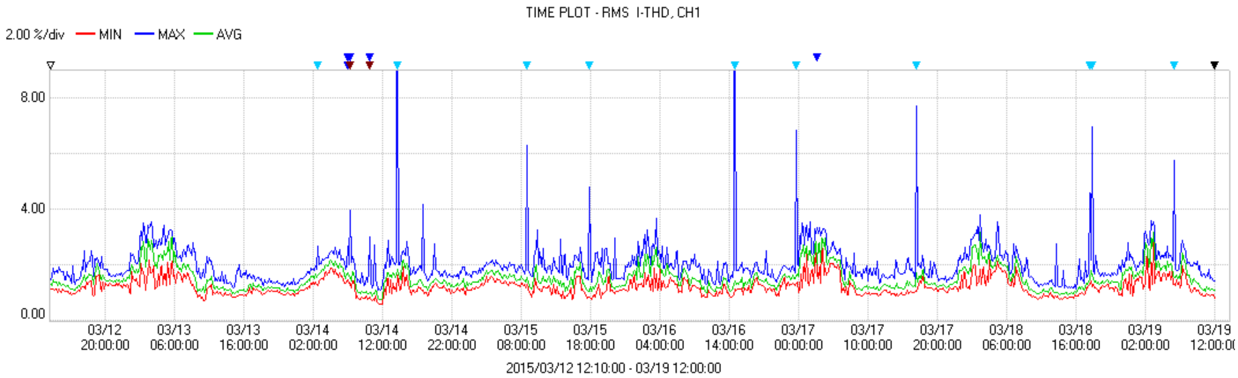


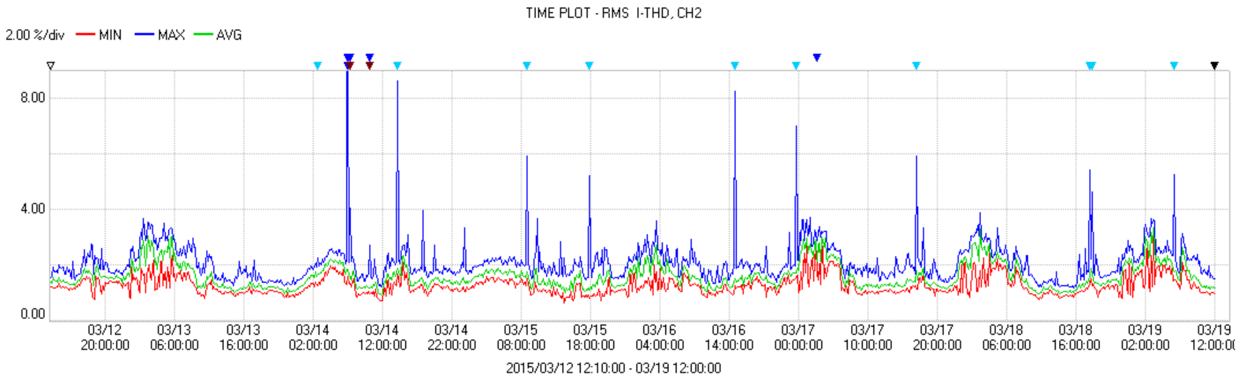


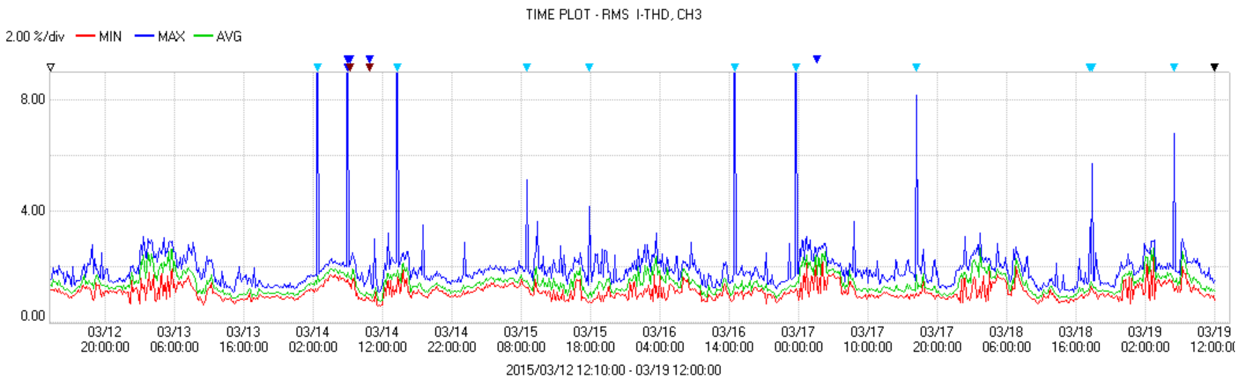


LONG TERM MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : M2
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

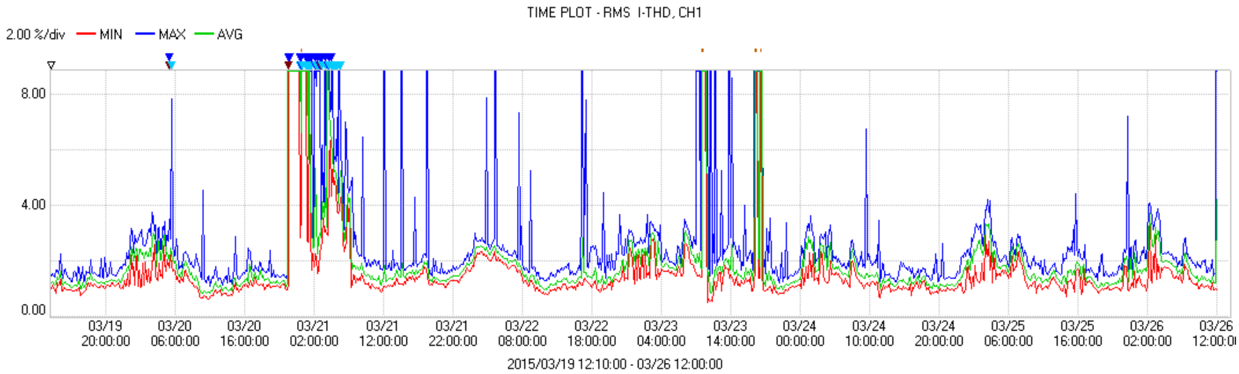


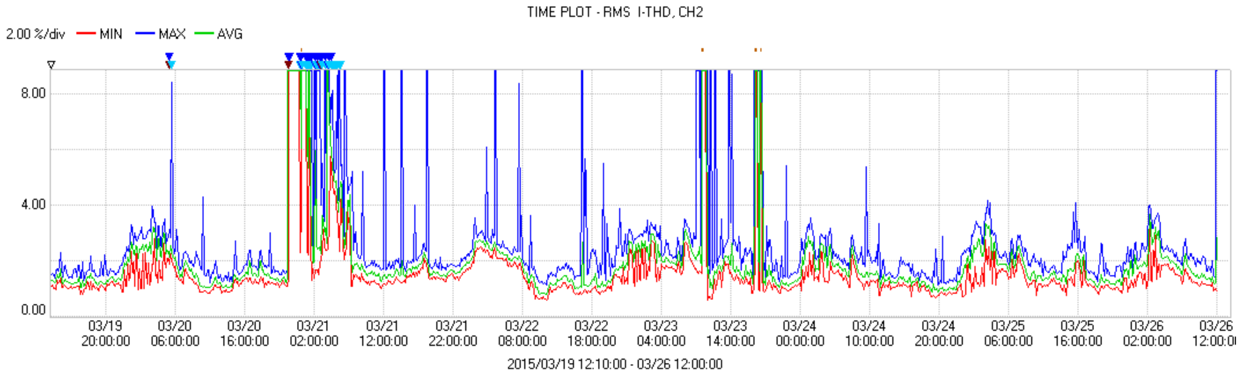


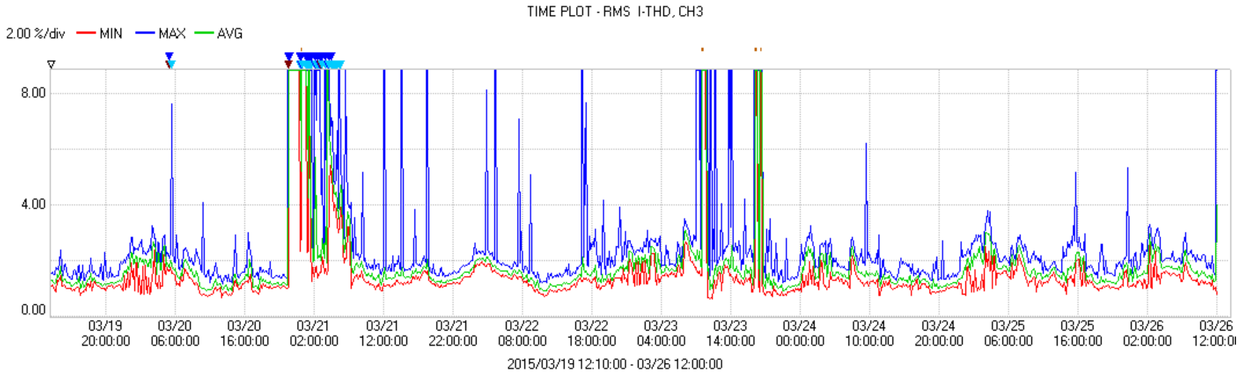


LONG TERM MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : M2
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

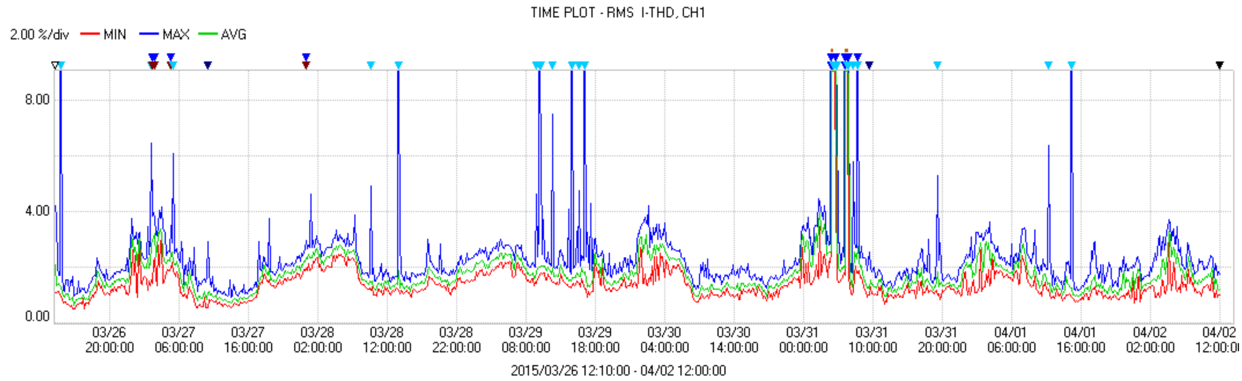


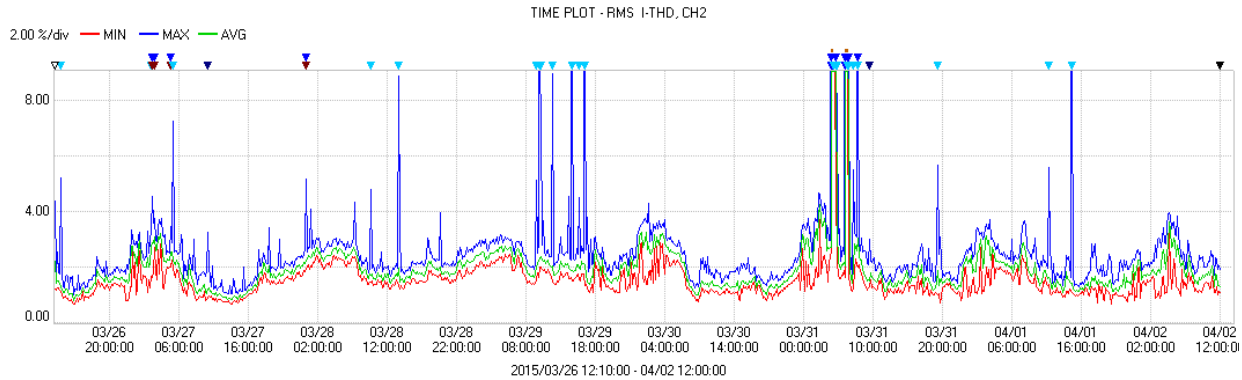


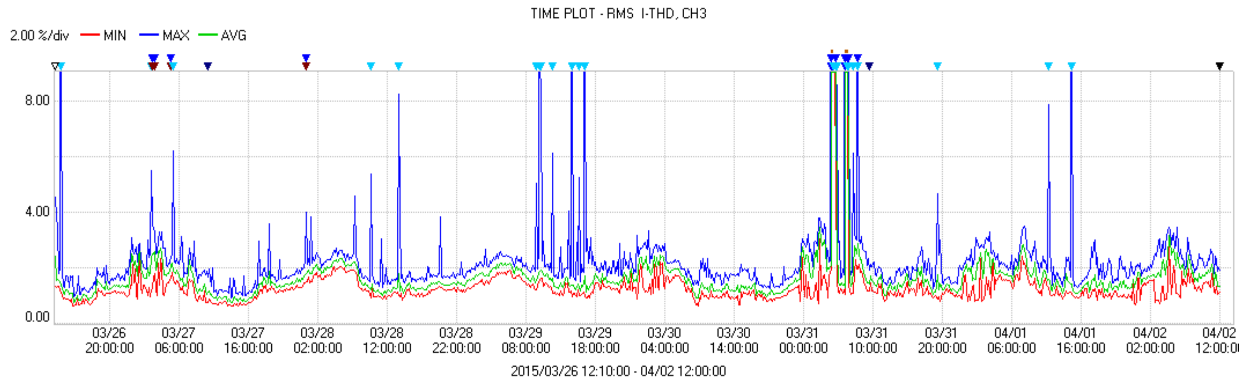


LONG TERM MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : M2
Duration : 26/March/2015 12:00 – 2/April/2015 12:00

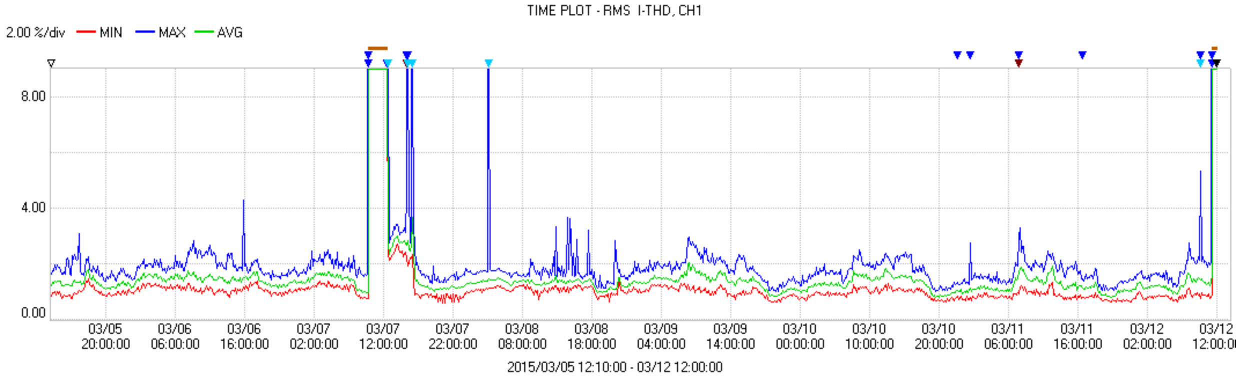


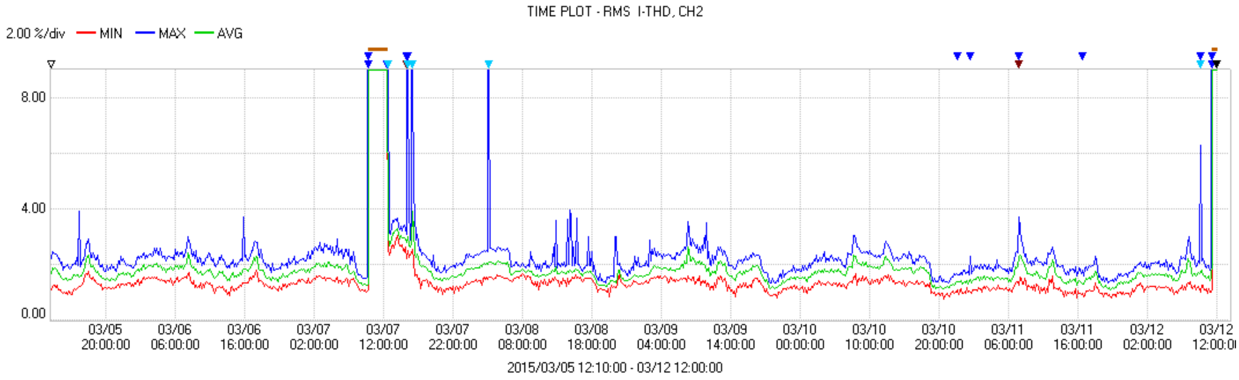


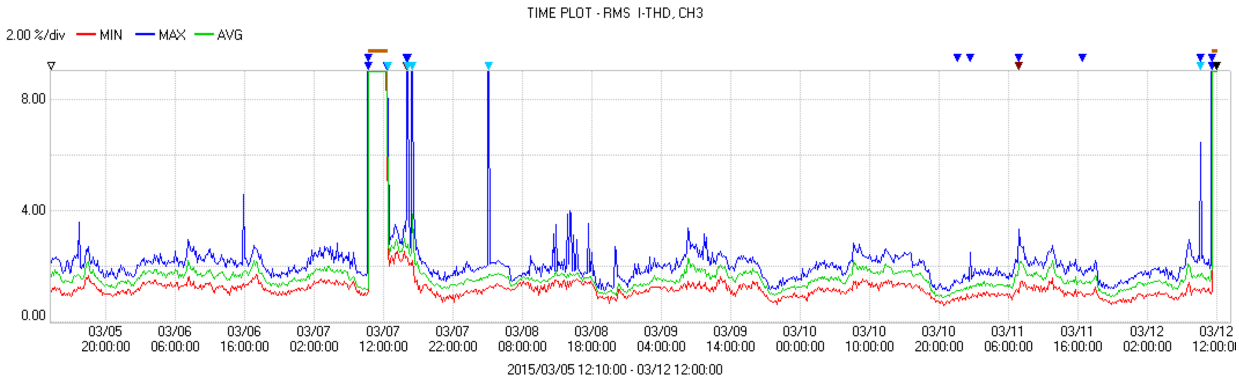


LONG TERM MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : T4
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

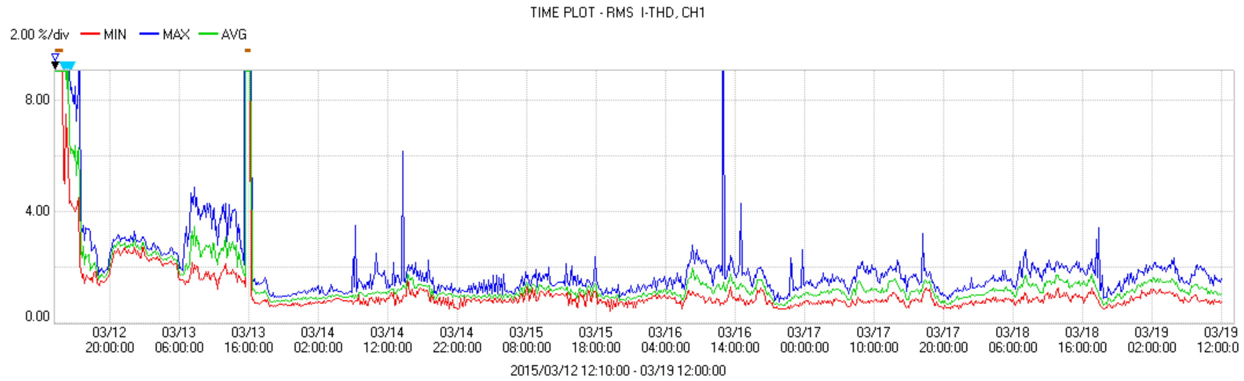


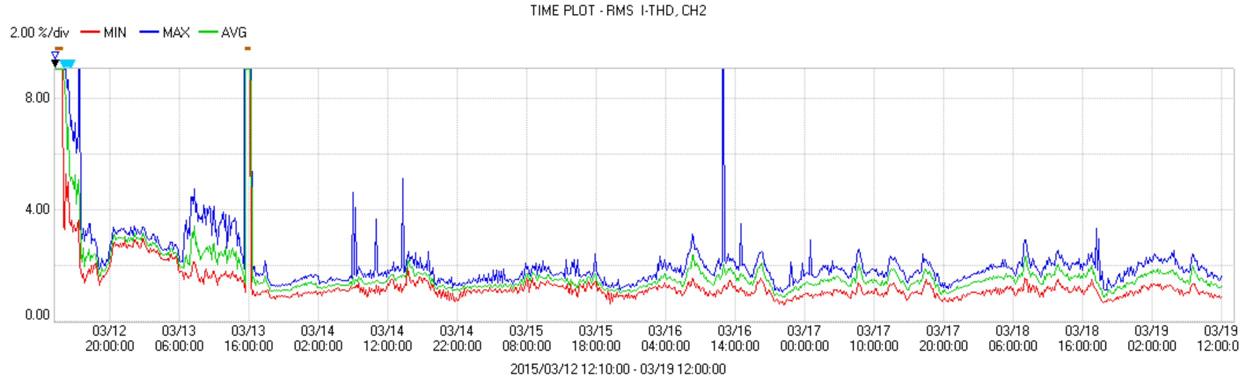


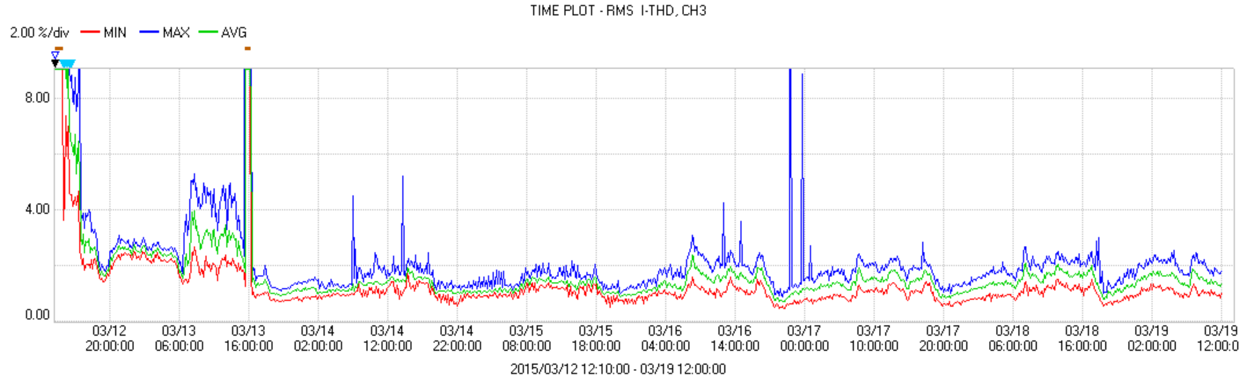


LONG TERM MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : T4
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

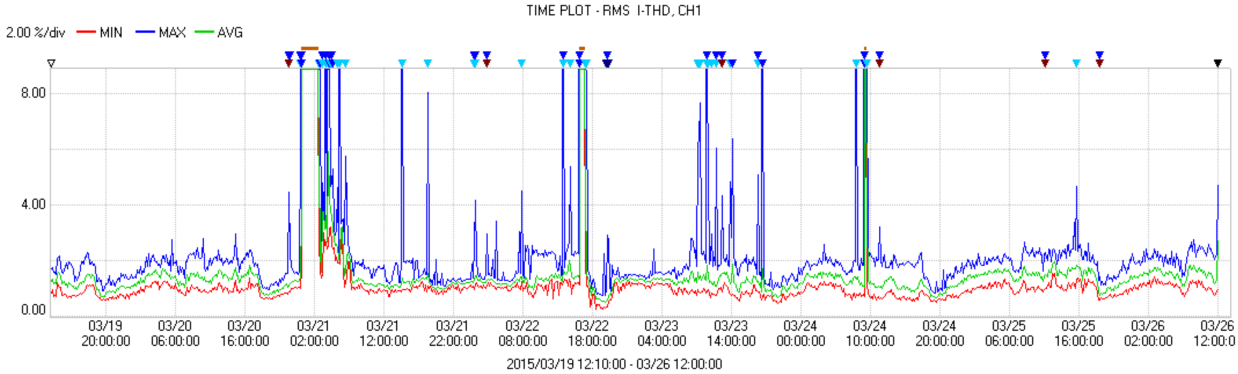


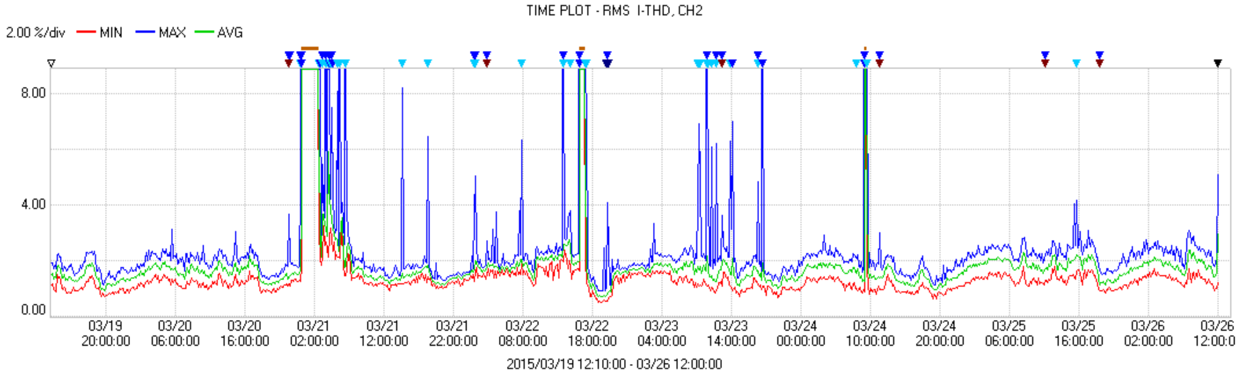


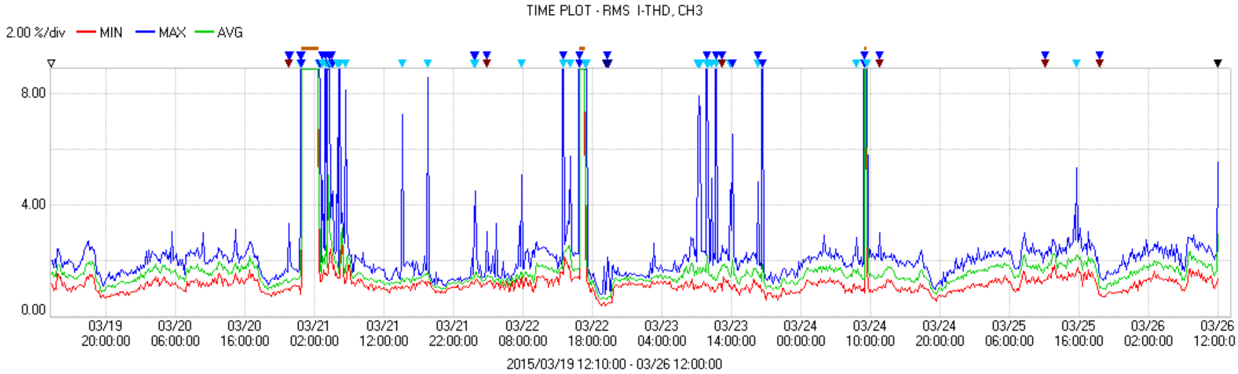


Long Term Measurement

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : T4
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

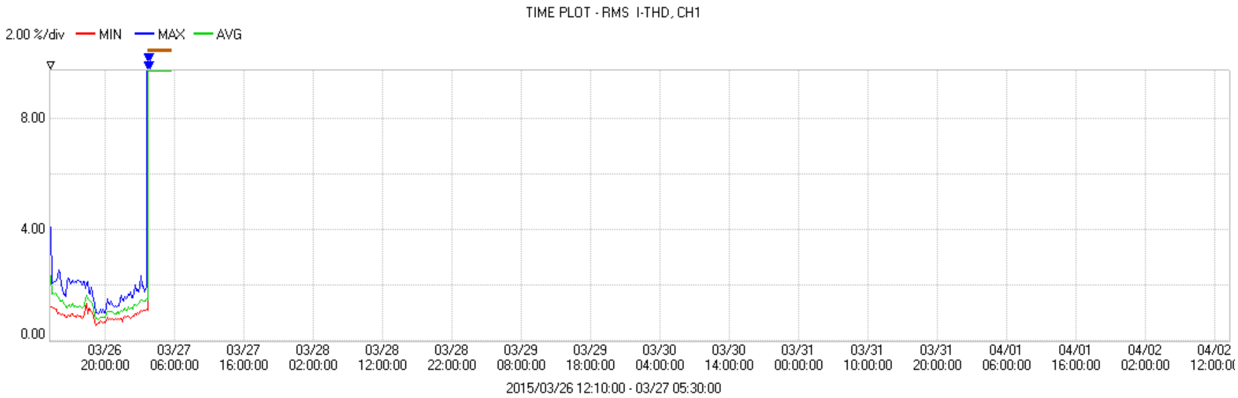


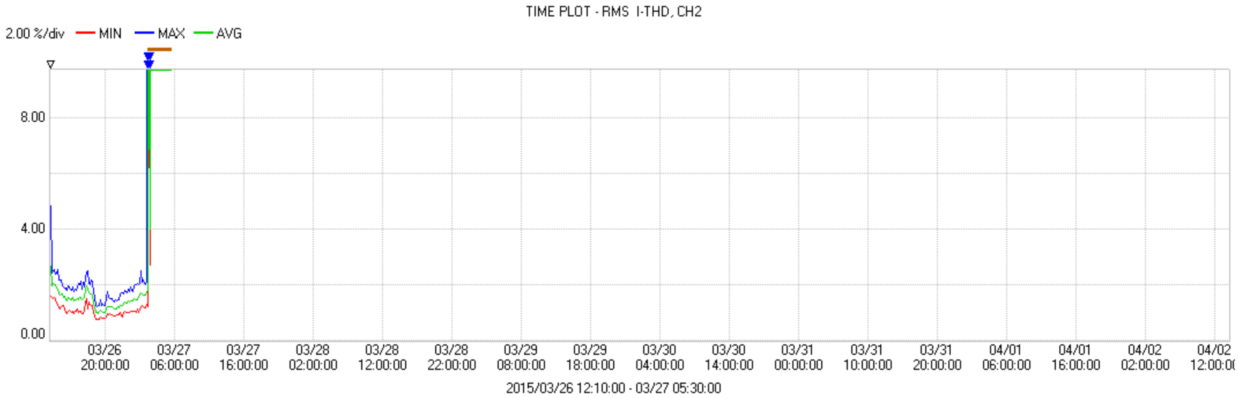


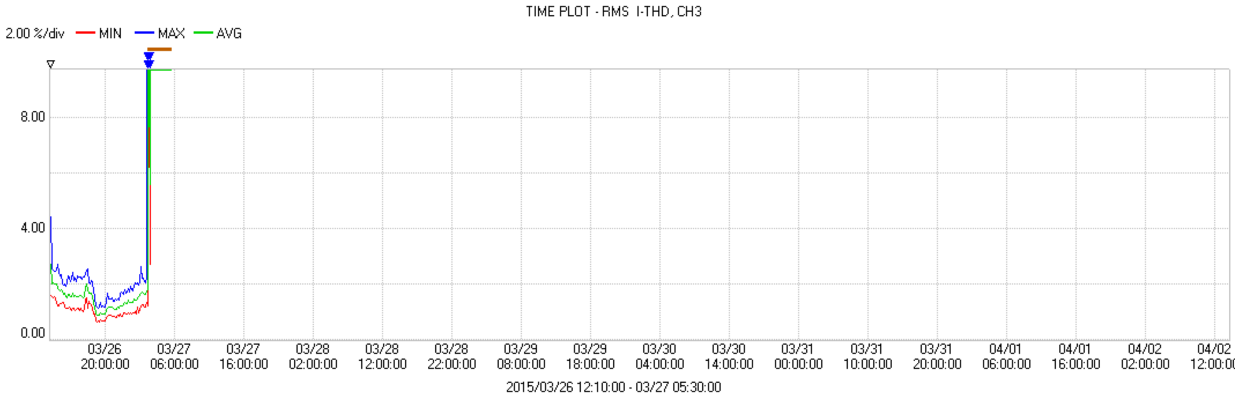


LONG TERM MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : T4
Duration : 26/March/2015 12:00 – 27/March/2015 05:30

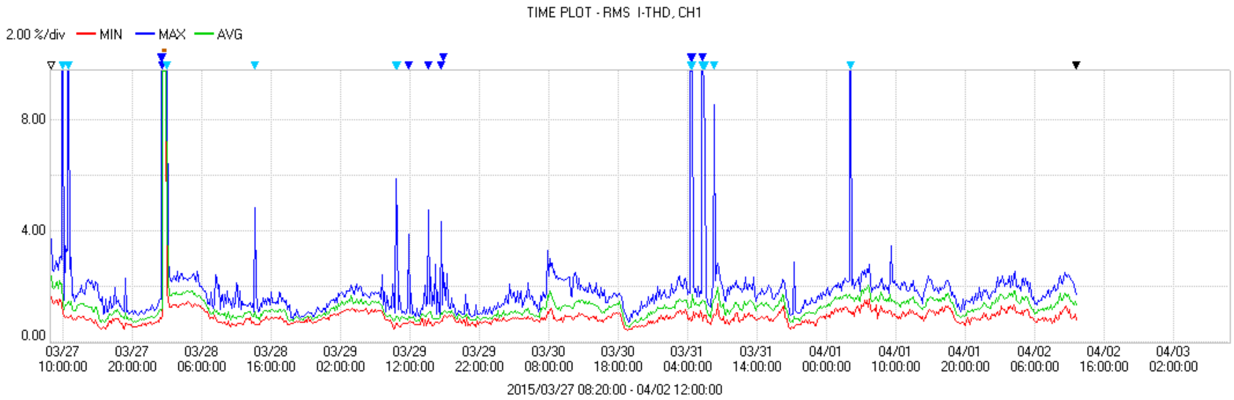


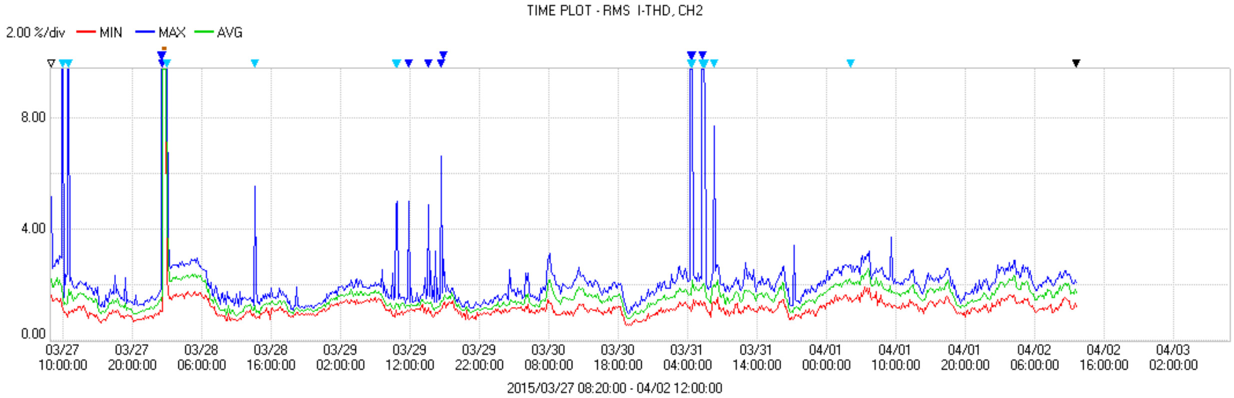


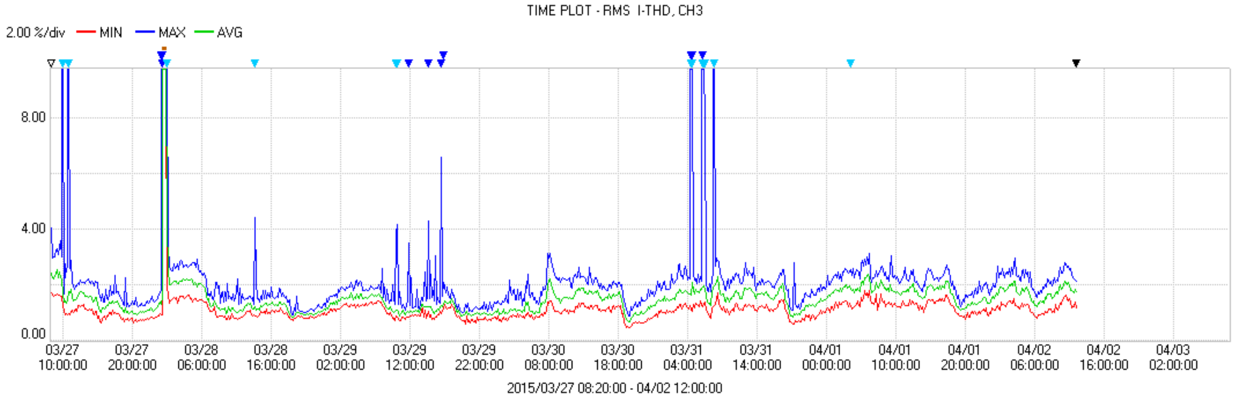


LONG TERM MEASUREMENT

Measurement Item : Ithd (CH1, CH2, CH3)
Measuring Point : T4
Duration : 27/March/2015 08:20 – 2/April/2015 12:00

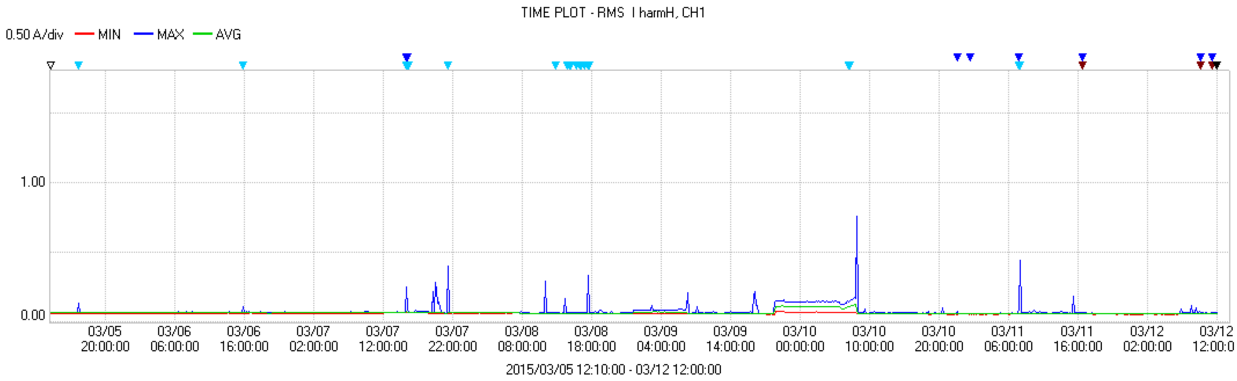


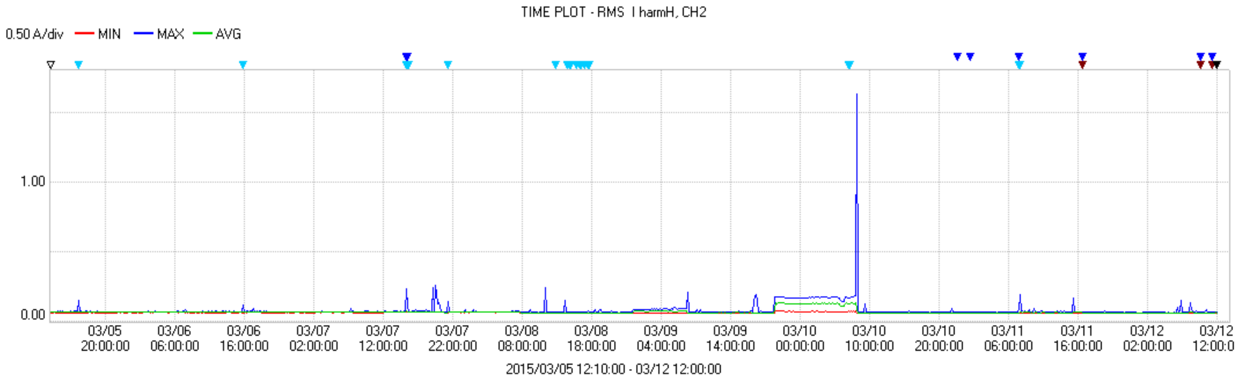


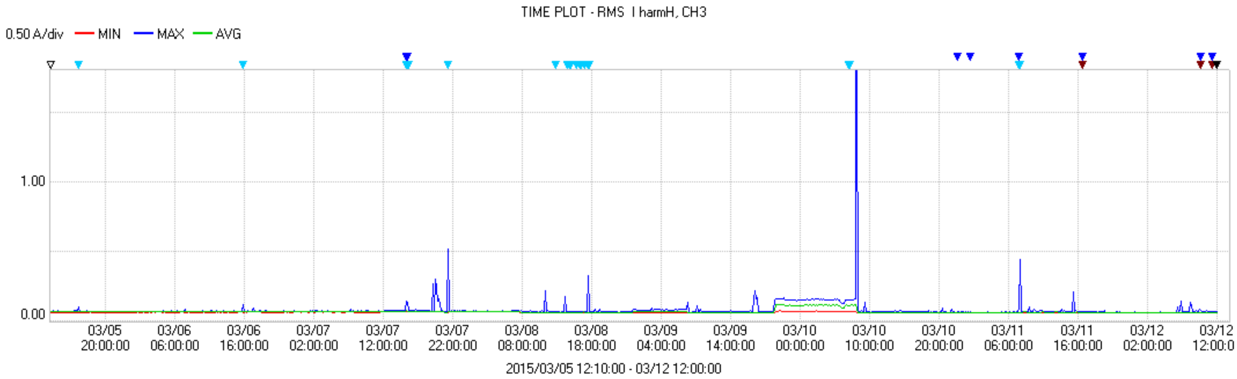


LONG TERM MEASUREMENT

Measurement Item : IharmH (CH1, CH2, CH3)
Measuring Point : M1
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

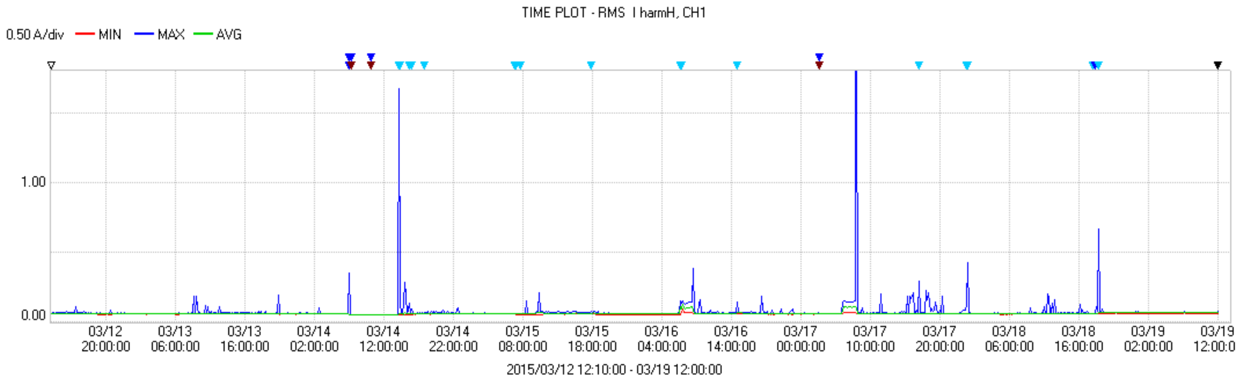


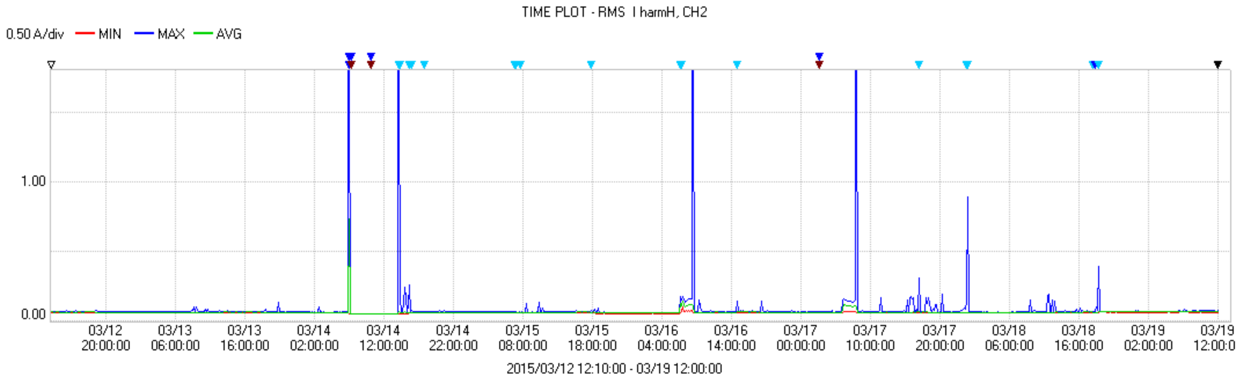


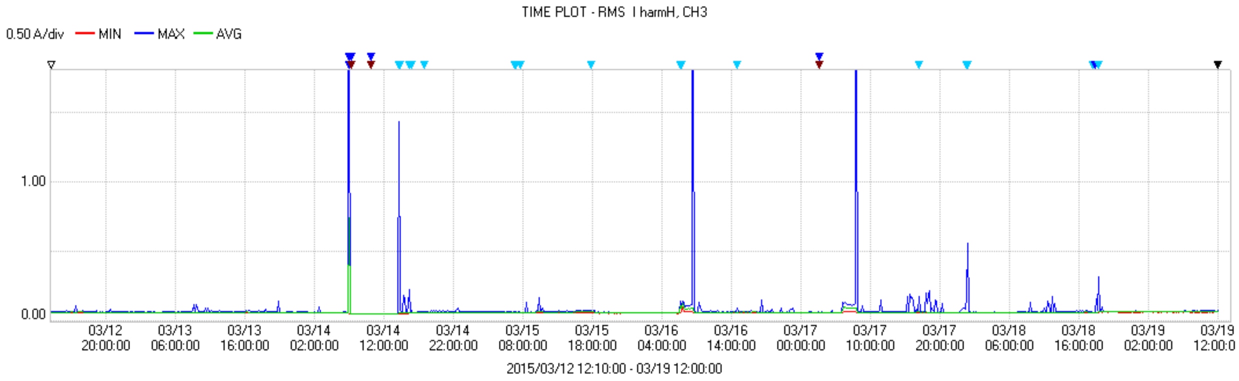


LONG TERM MEASUREMENT

Measurement Item : IharmH (CH1, CH2, CH3)
Measuring Point : M1
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

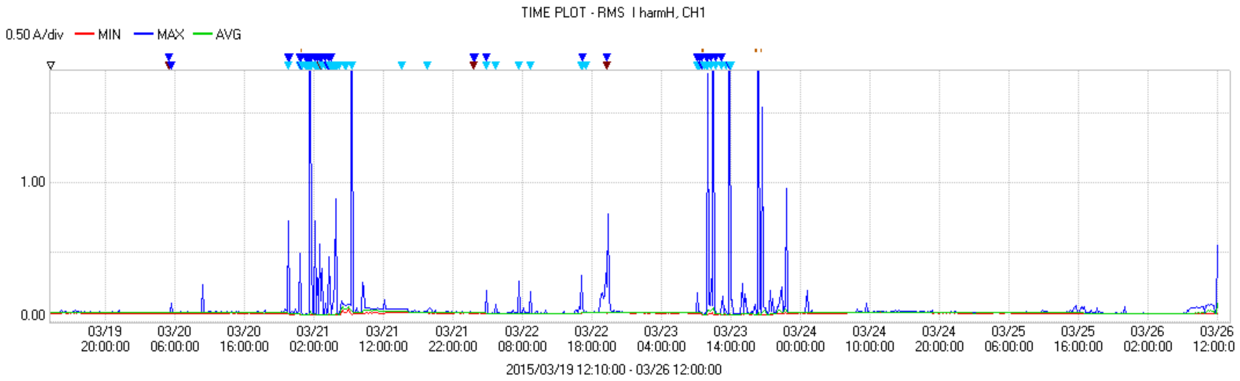


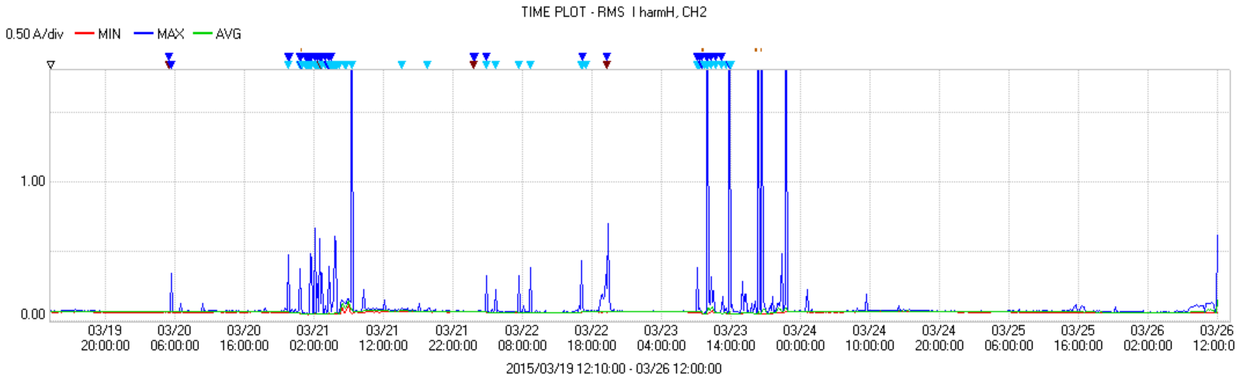


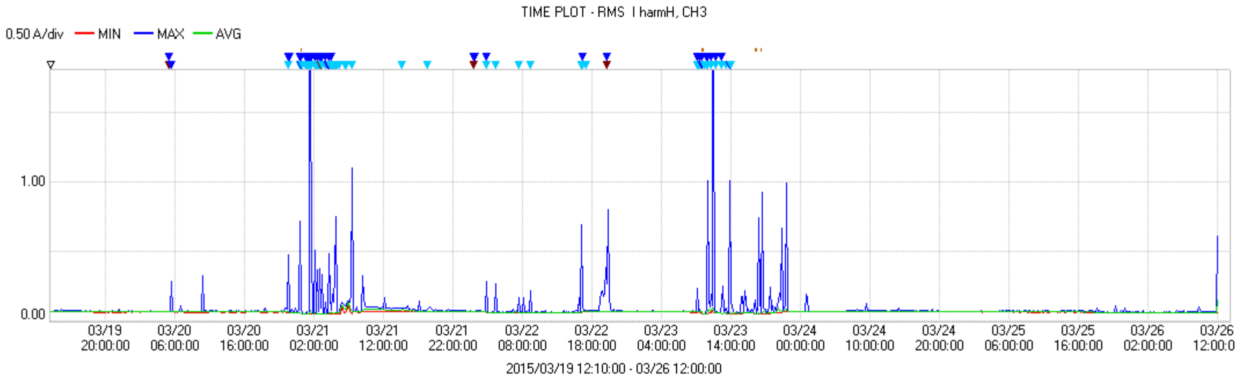


LONG TERM MEASUREMENT

Measurement Item : IharmH (CH1, CH2, CH3)
Measuring Point : M1
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

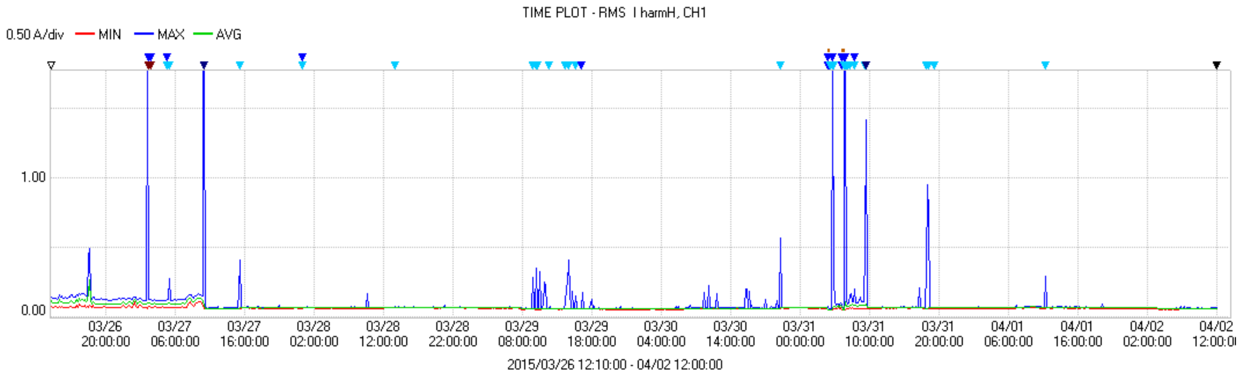


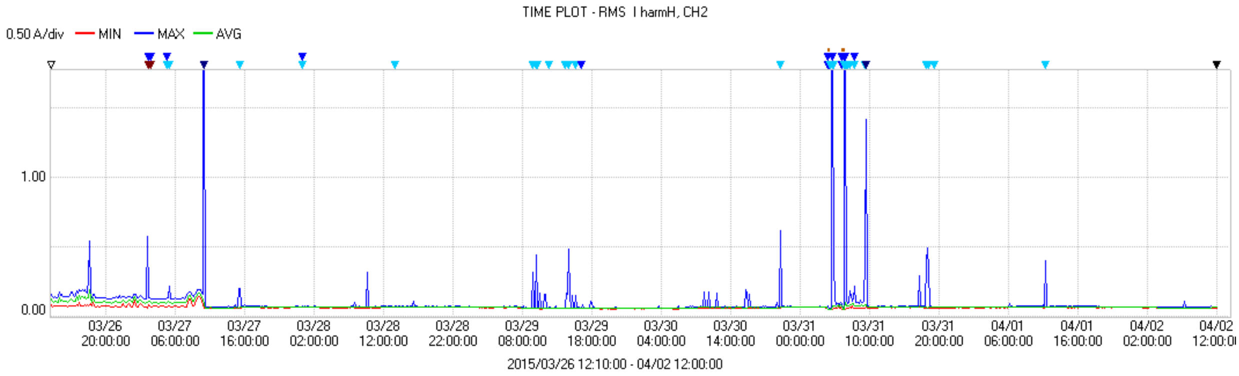


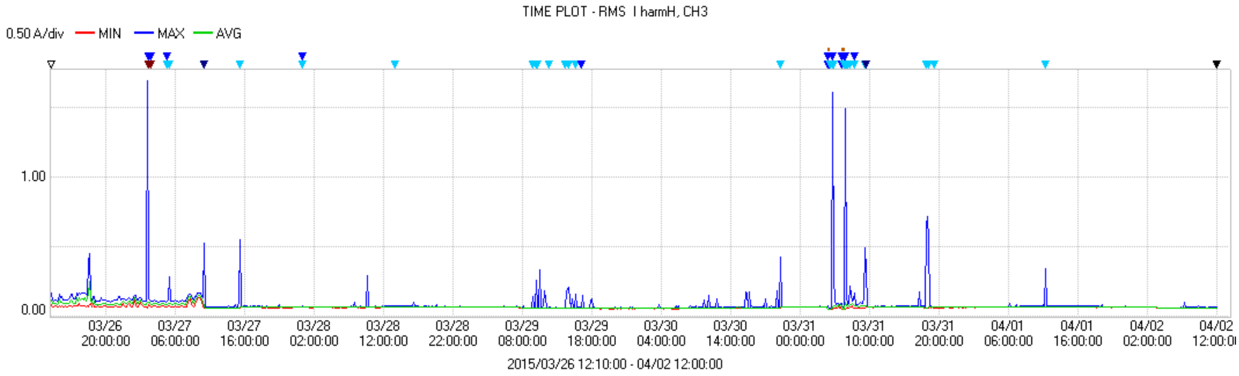


LONG TERM MEASUREMENT

Measurement Item : IharmH (CH1, CH2, CH3)
Measuring Point : M1
Duration : 26/March/2015 12:00 – 2/April/2015 12:00

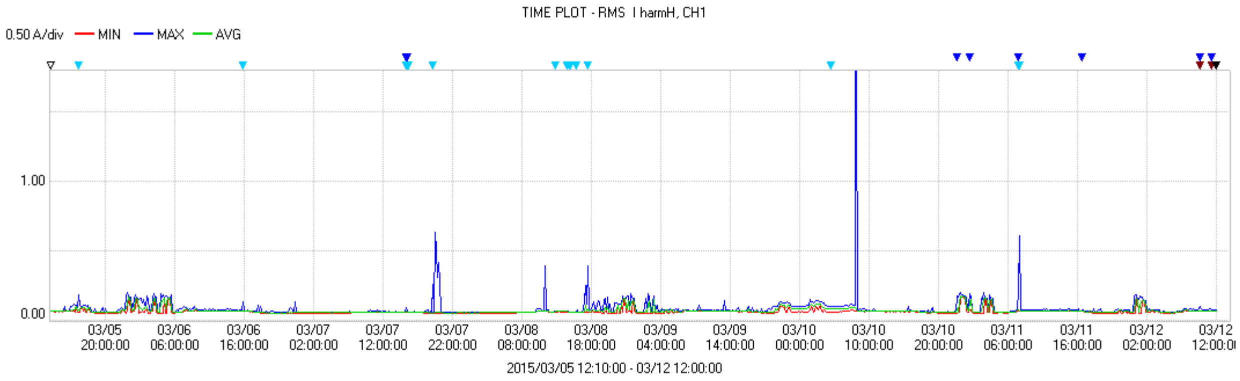


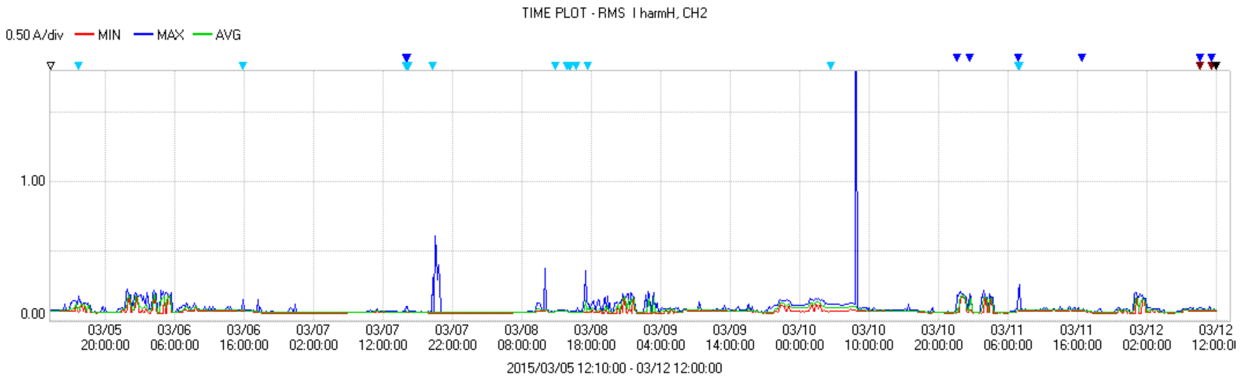


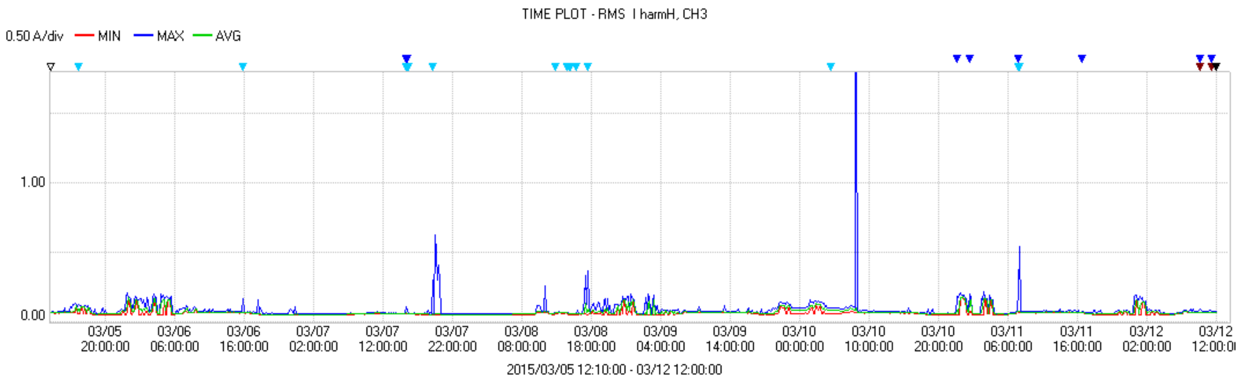


LONG TERM MEASUREMENT

Measurement Item : IharmH (CH1, CH2, CH3)
Measuring Point : M2
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

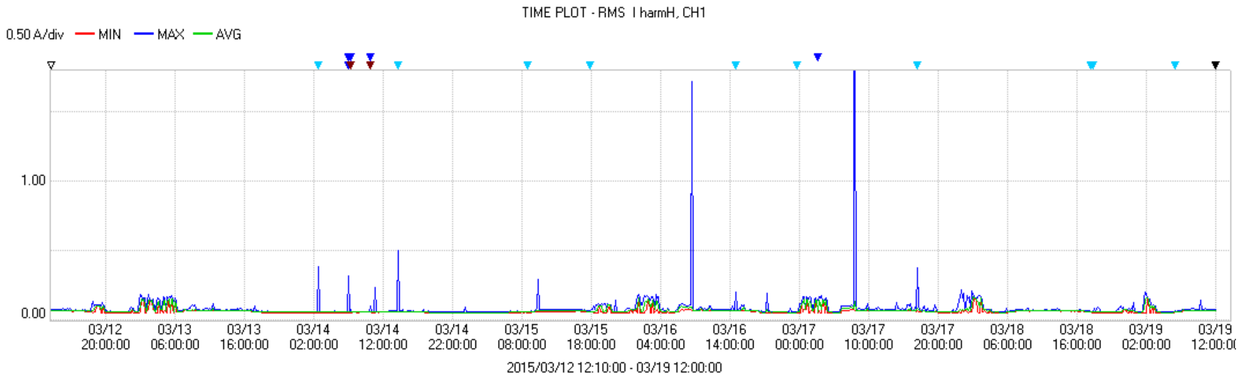


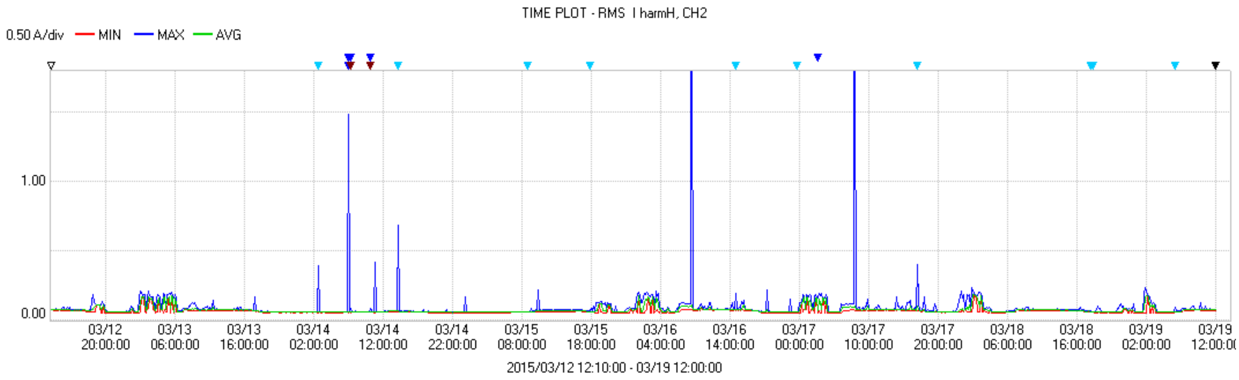


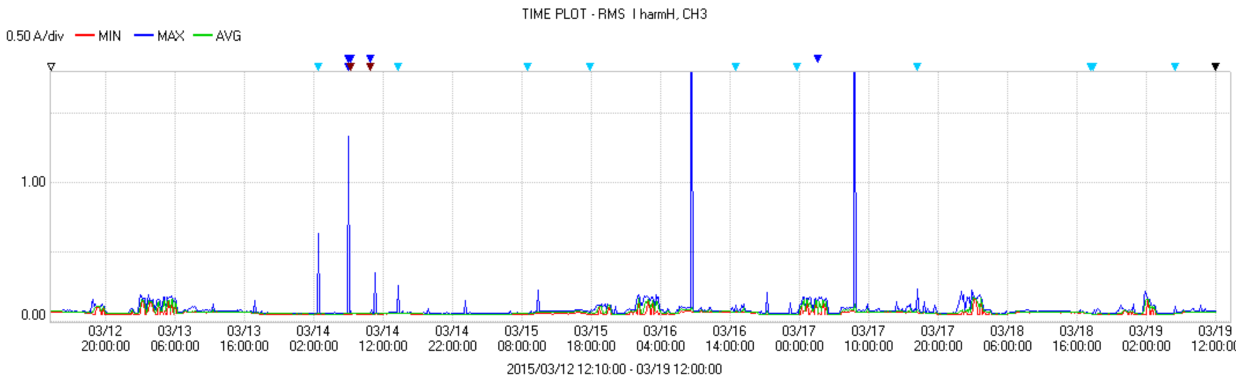


LONG TERM MEASUREMENT

Measurement Item : IharmH (CH1, CH2, CH3)
Measuring Point : M2
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

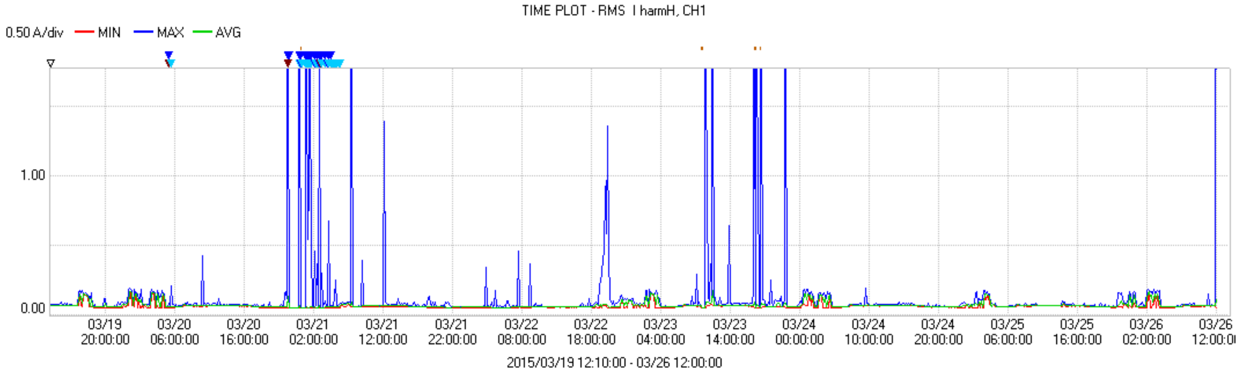


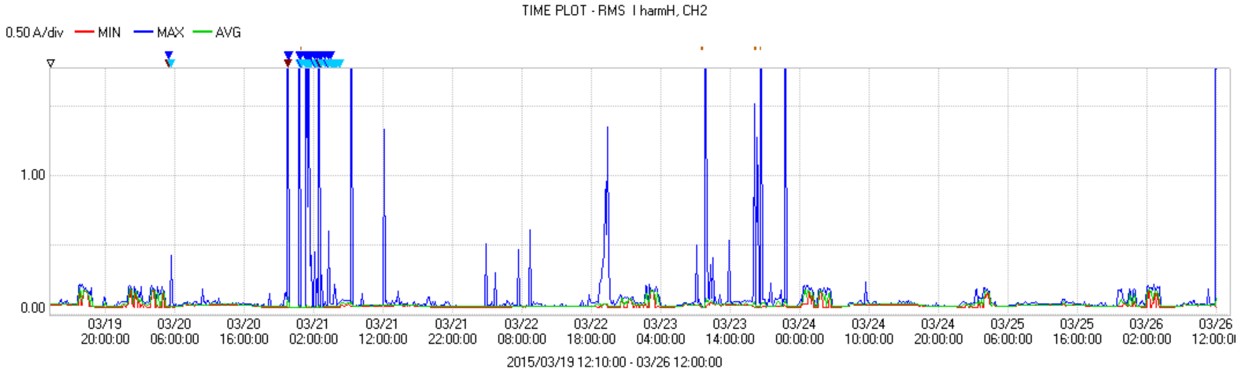


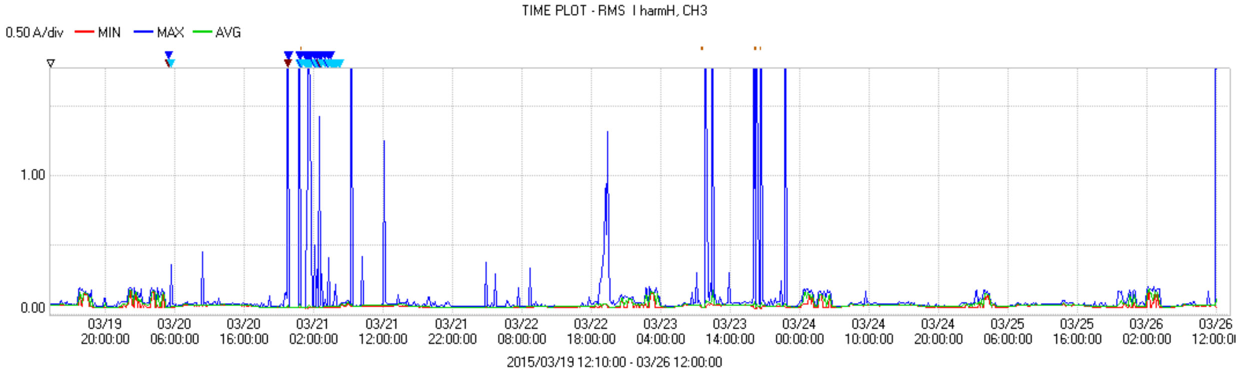


LONG TERM MEASUREMENT

Measurement Item : IharmH (CH1, CH2, CH3)
Measuring Point : M2
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

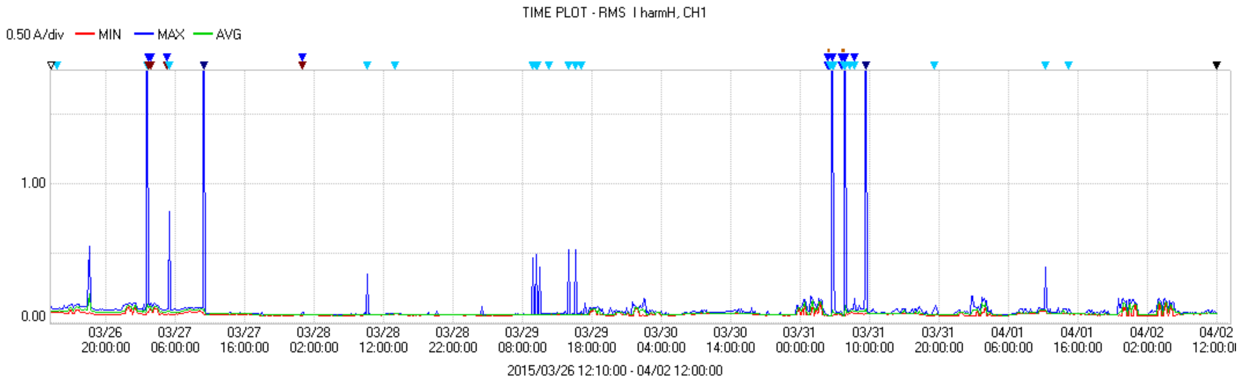


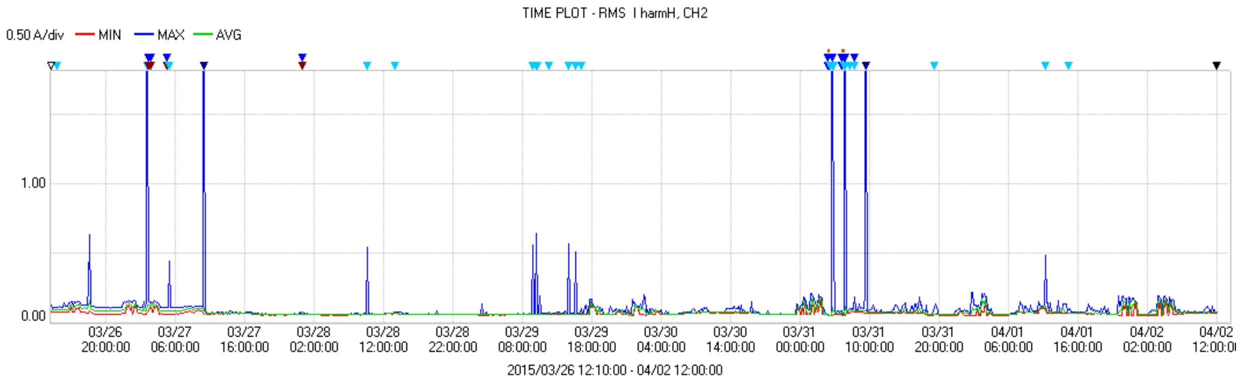


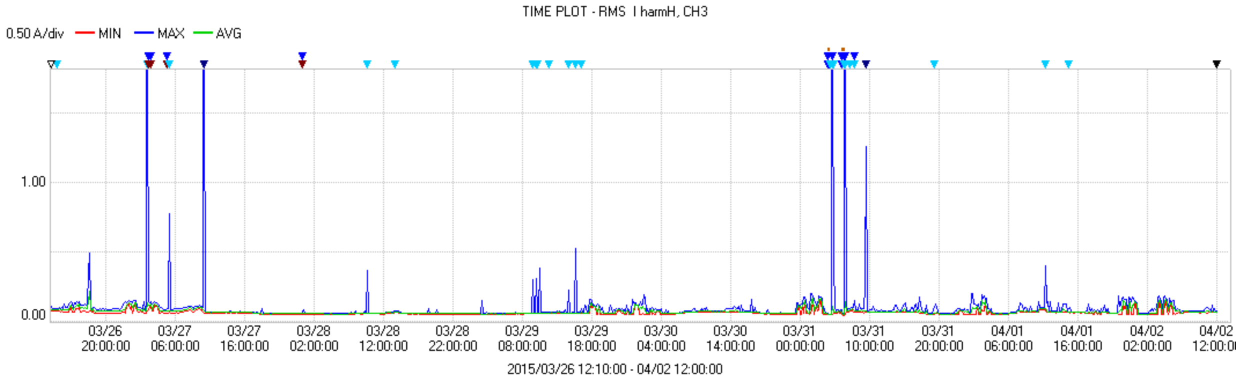


LONG TERM MEASUREMENT

Measurement Item : IharmH (CH1, CH2, CH3)
Measuring Point : M2
Duration : 26/March/2015 12:00 – 2/April/2015 12:00

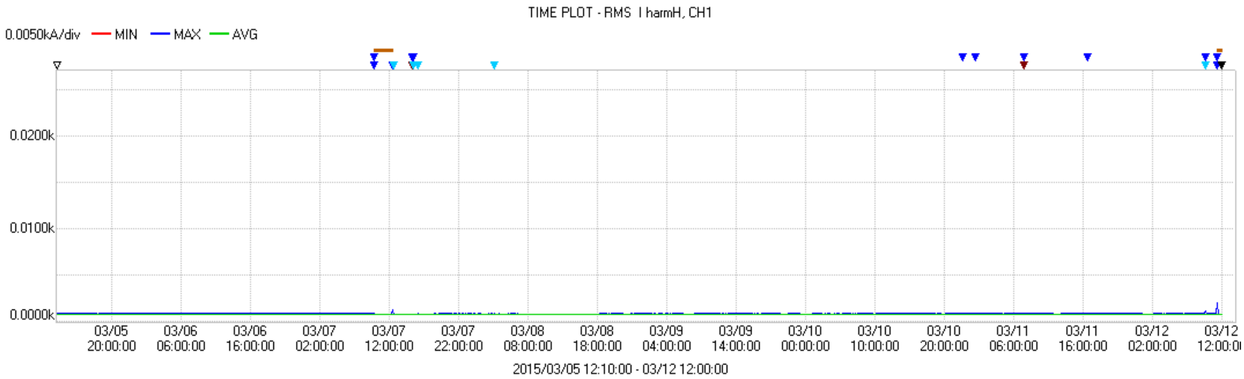


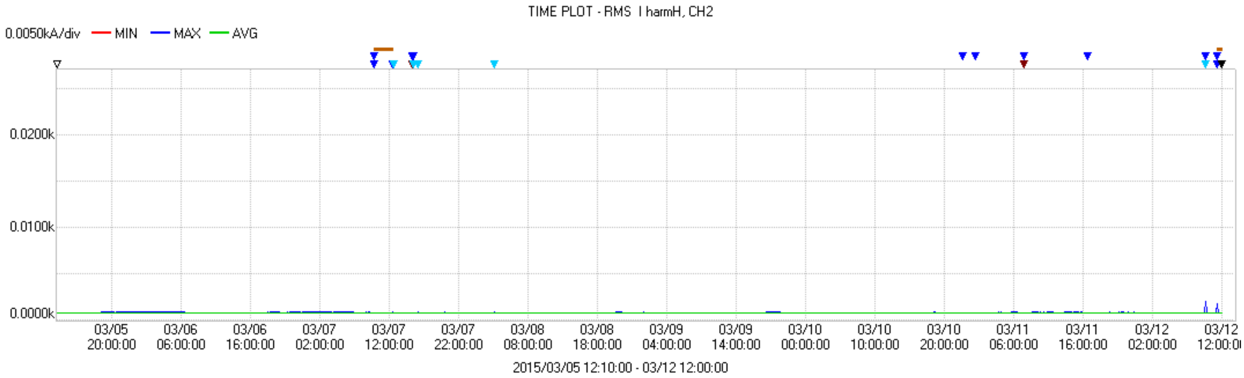


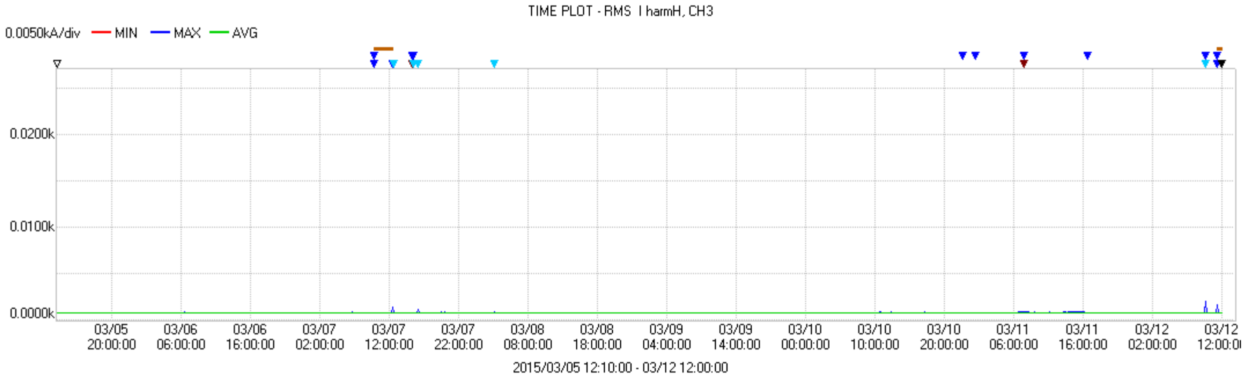


LONG TERM MEASUREMENT

Measurement Item : IharmH (CH1, CH2, CH3)
Measuring Point : T4
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

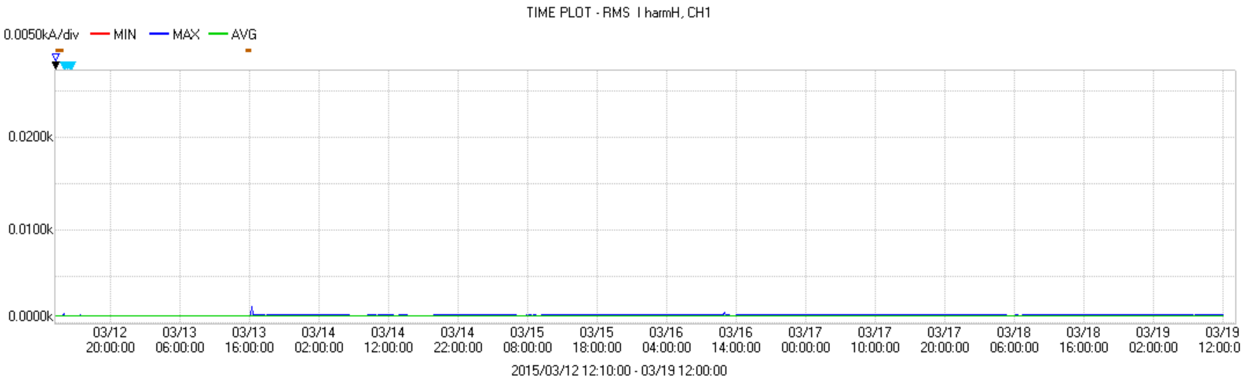


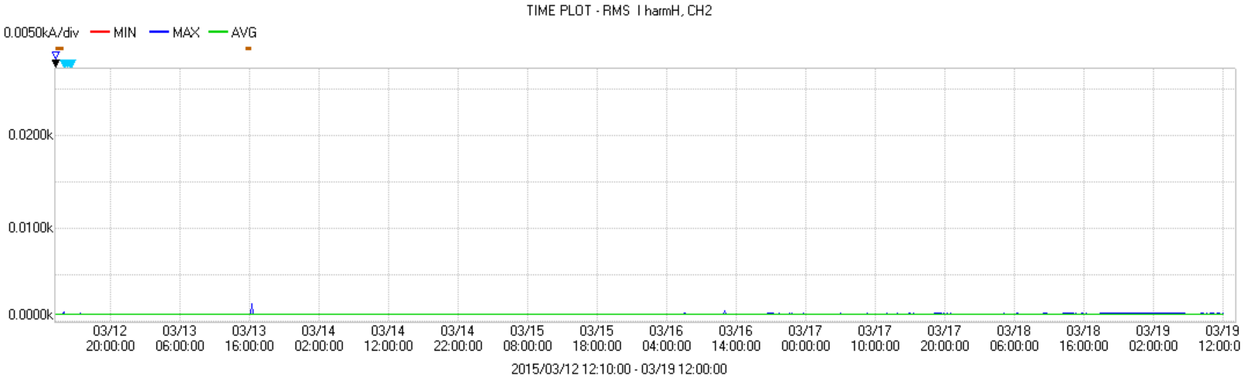


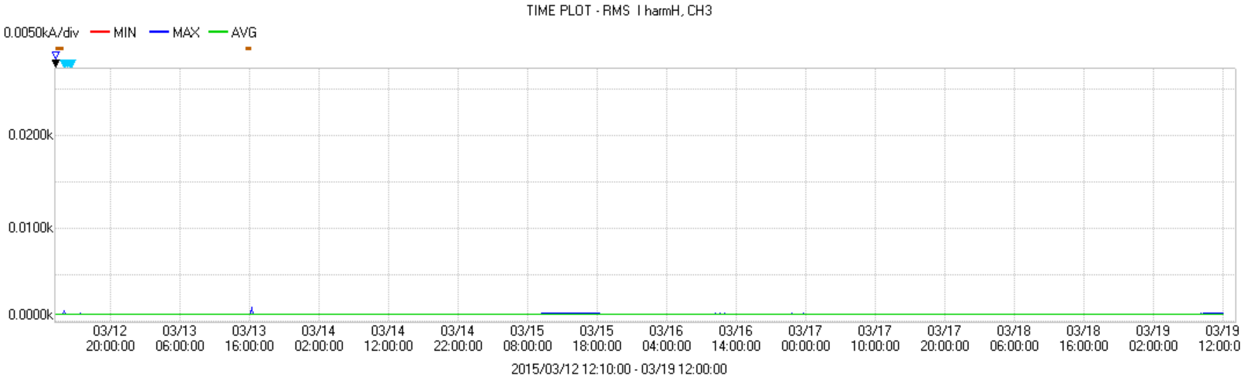


LONG TERM MEASUREMENT

Measurement Item : IharmH (CH1, CH2, CH3)
Measuring Point : T4
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

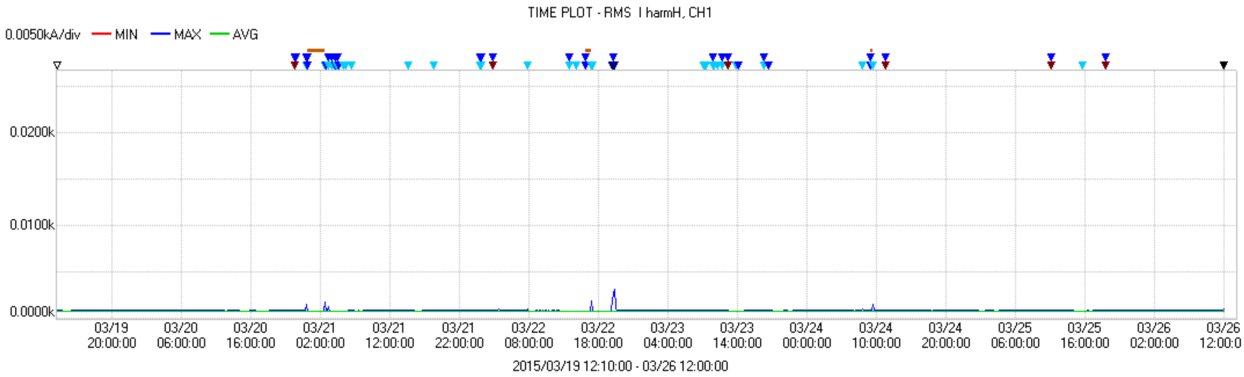


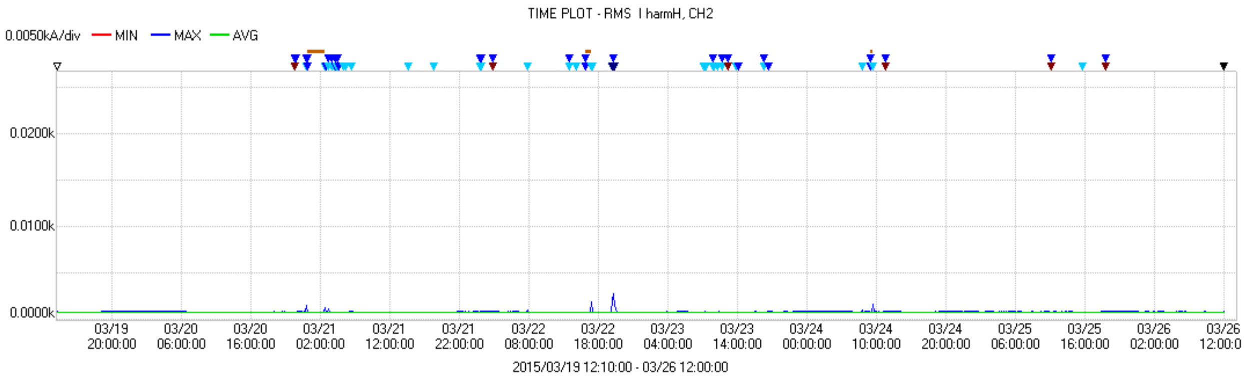


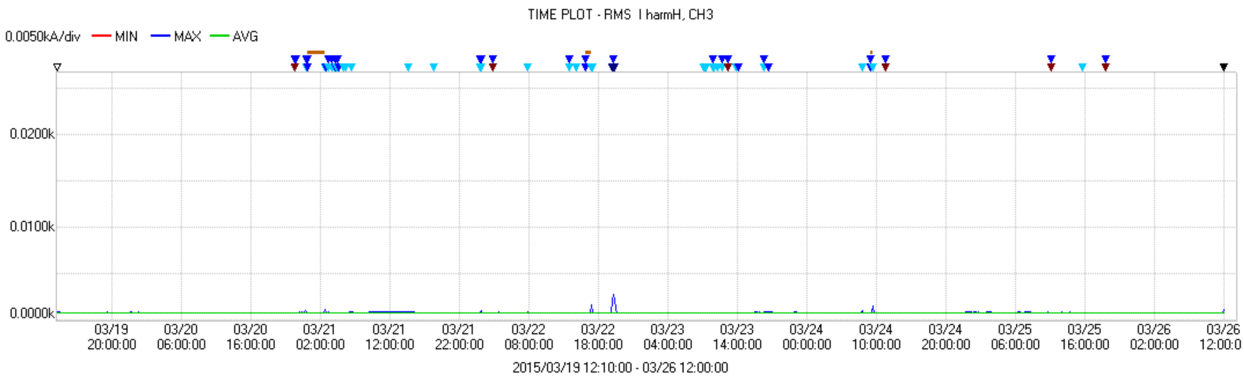


LONG TERM MEASUREMENT

Measurement Item : IharmH (CH1, CH2, CH3)
Measuring Point : T4
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

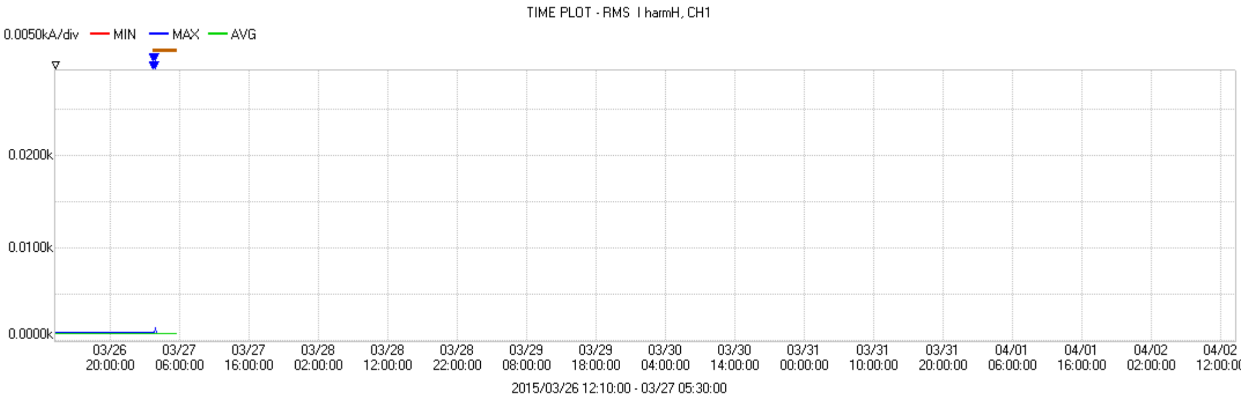


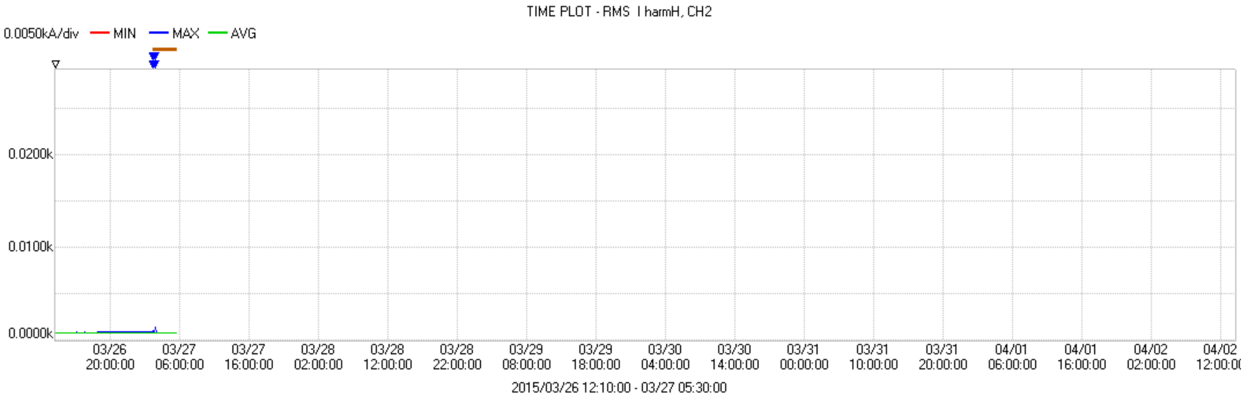


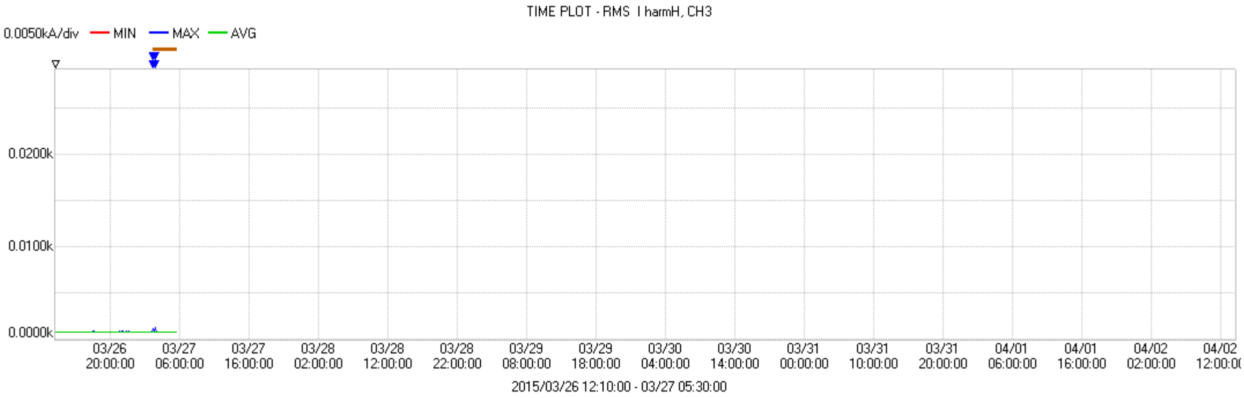


LONG TERM MEASUREMENT

Measurement Item : IharmH (CH1, CH2, CH3)
Measuring Point : T4
Duration : 26/March/2015 12:00 – 27/March/2015 05:30

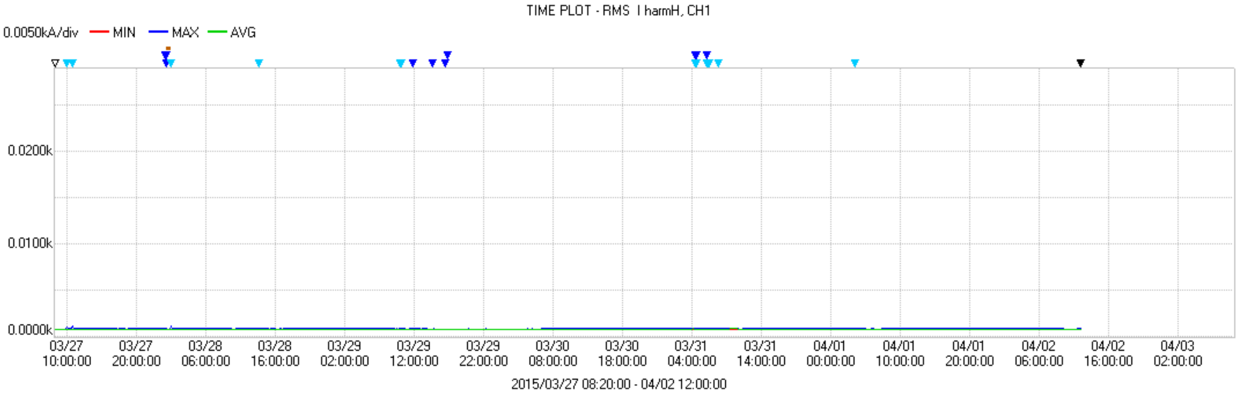


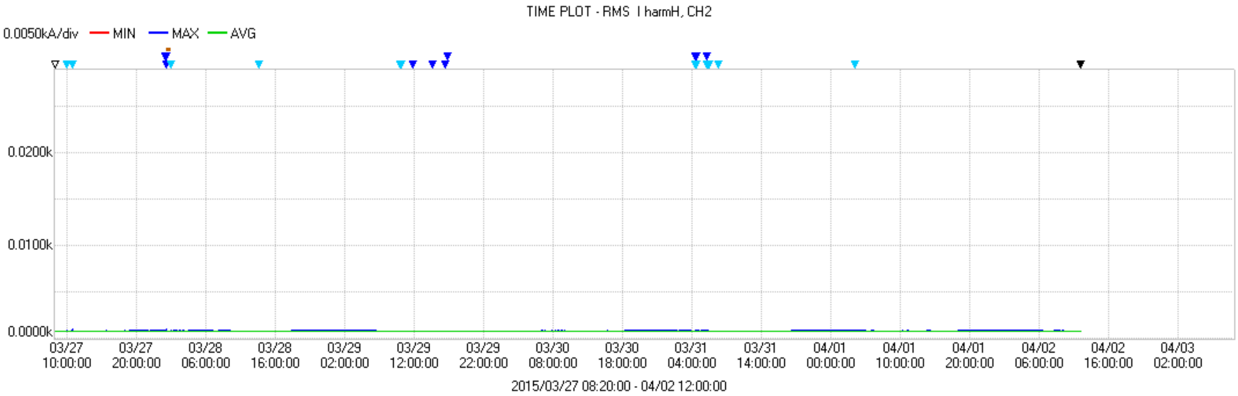


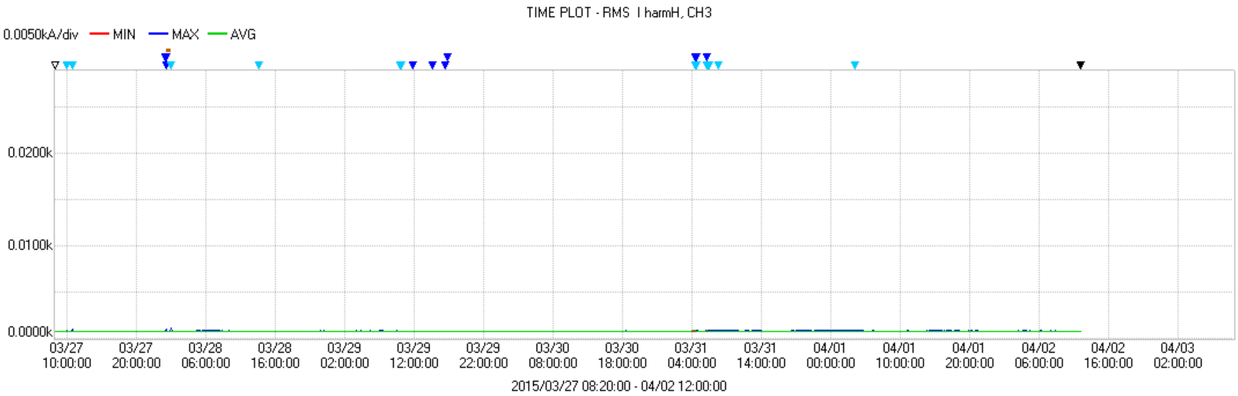


LONG TERM MEASUREMENT

Measurement Item : IharmH (CH1, CH2, CH3)
Measuring Point : T4
Duration : 27/March/2015 08:20 – 2/April/2015 12:00

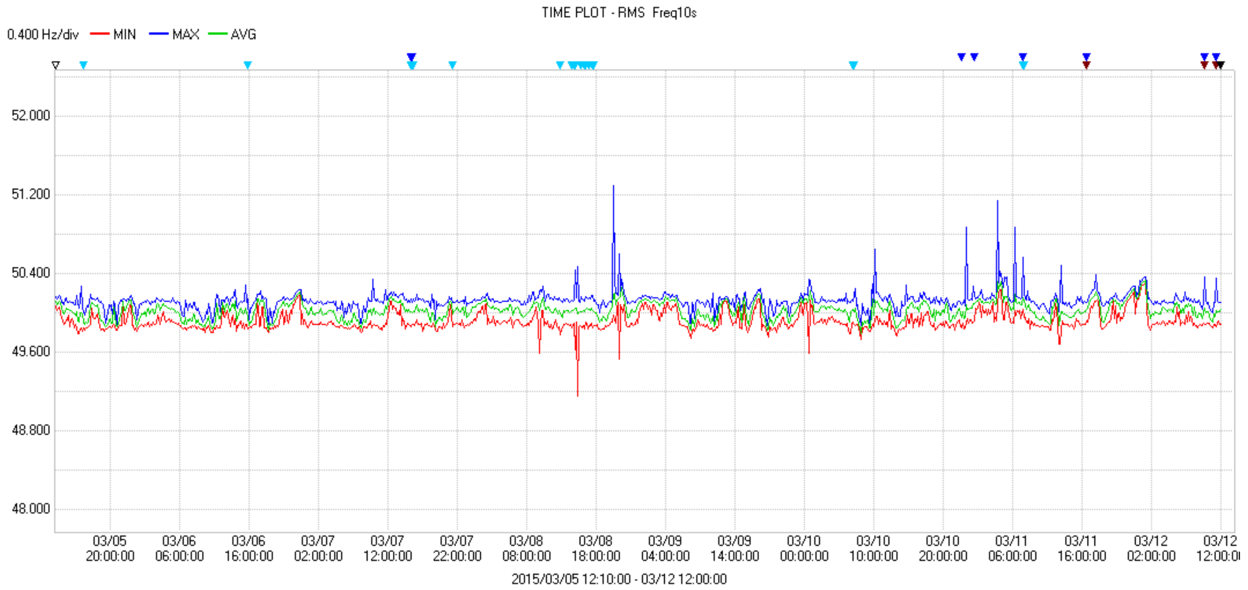




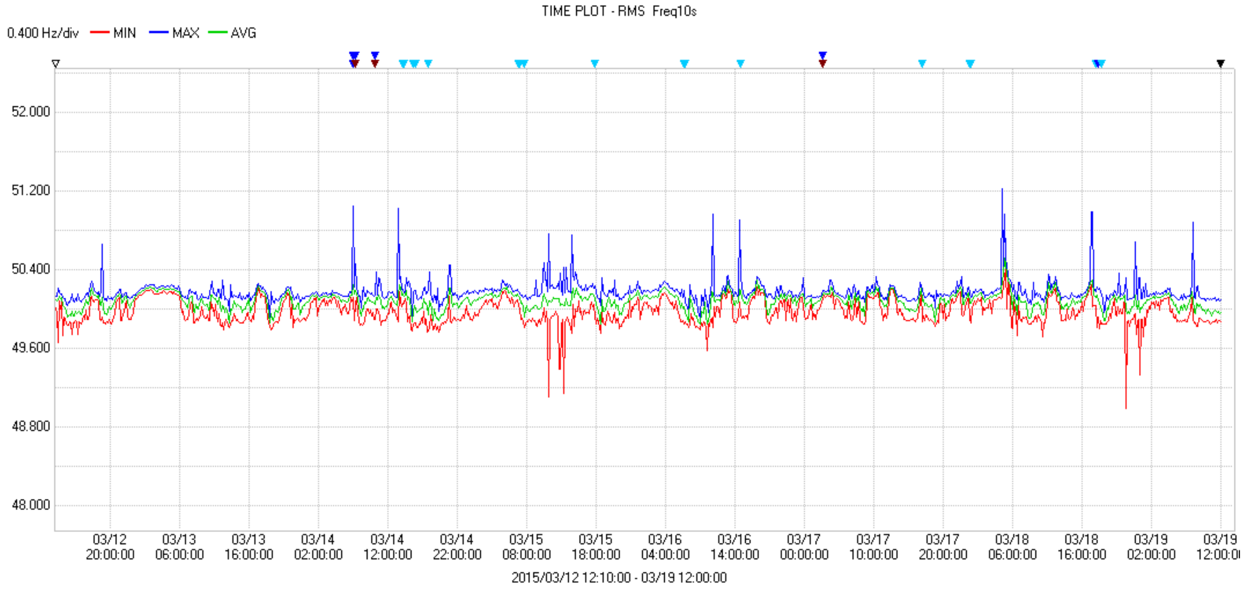


LONG TERM MEASUREMENT

Measurement Item : Frequency
Measuring Point : Milford substation 11kV bus
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

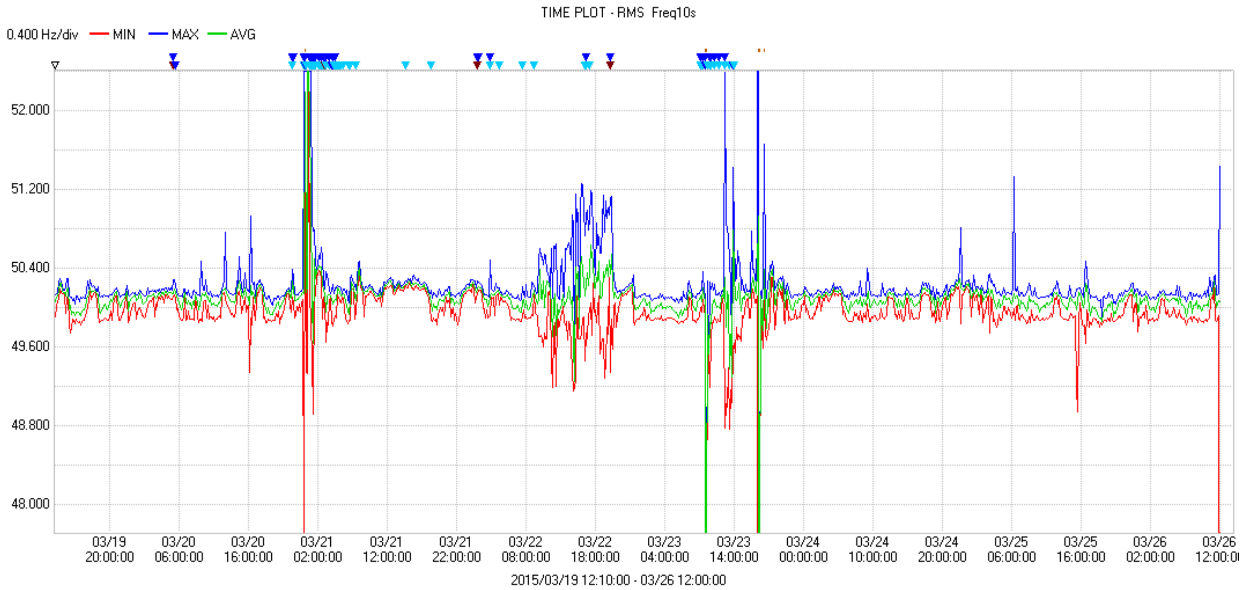


Measurement Item : Frequency
Measuring Point : Milford substation 11kV bus
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

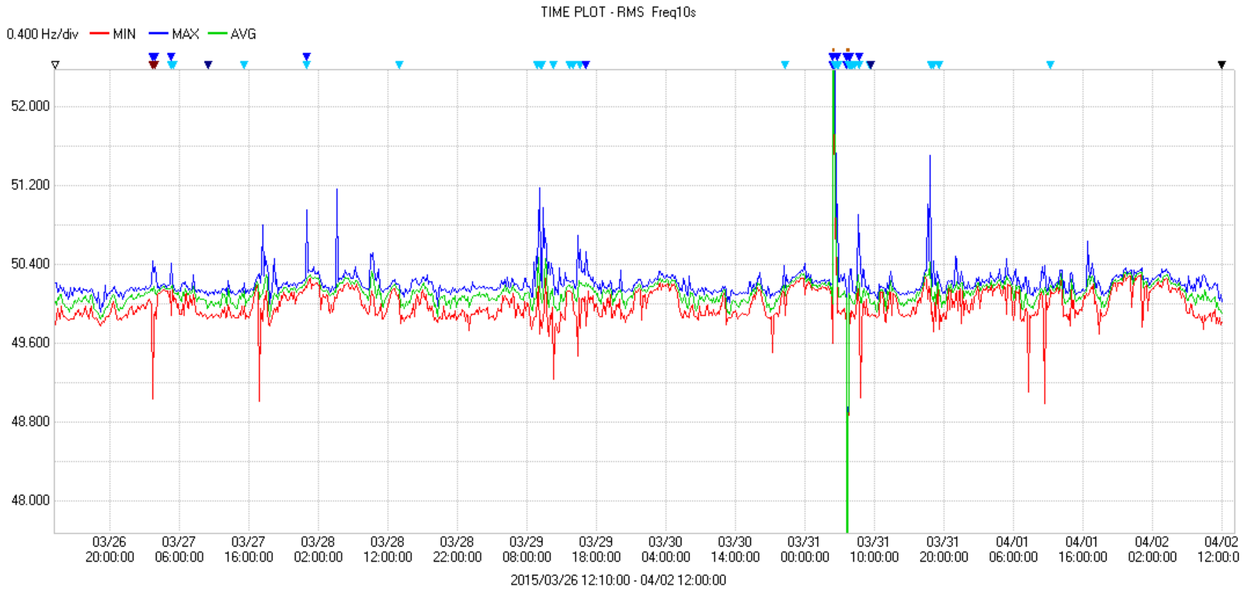


LONG TERM MEASUREMENT

Measurement Item : Frequency
Measuring Point : Milford substation 11kV bus
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

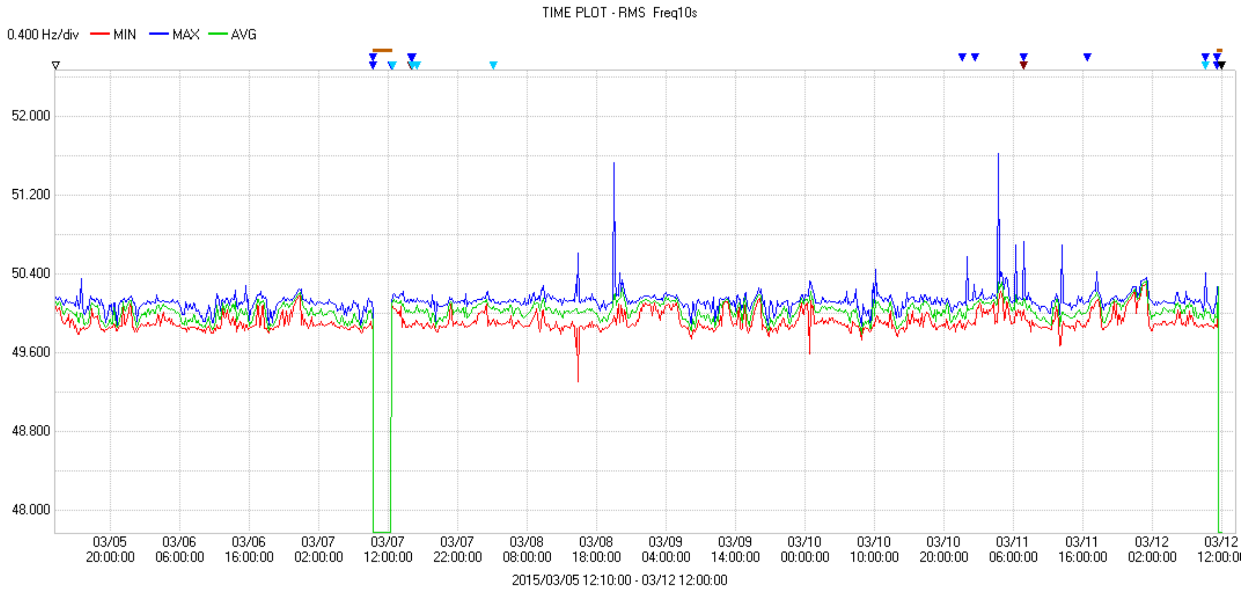


Measurement Item : Frequency
Measuring Point : Milford substation 11kV bus
Duration : 26/March/2015 12:00 – 2/April/2015 12:00

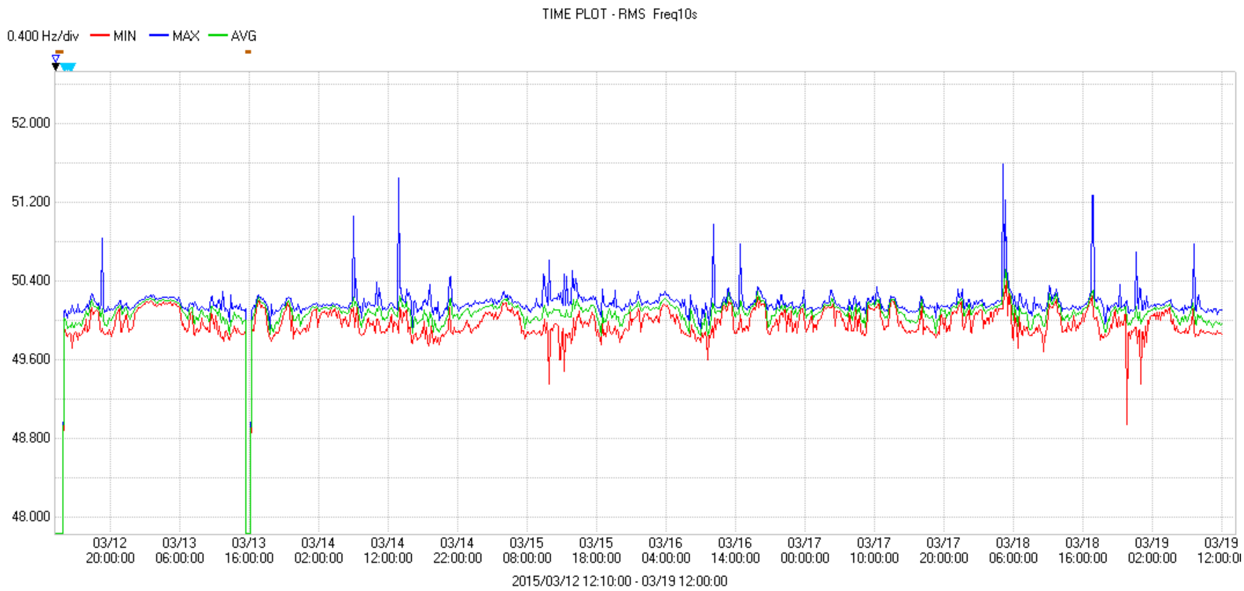


LONG TERM MEASUREMENT

Measurement Item : Frequency
Measuring point : Taraka substation 11kV bus
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

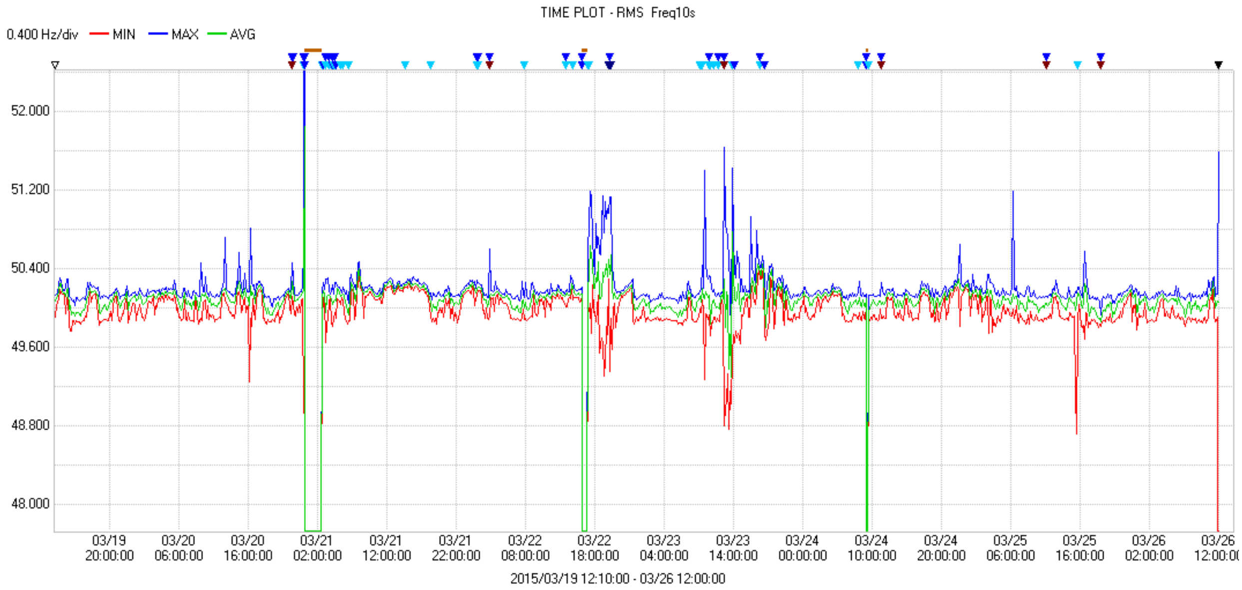


Measurement Item : Frequency
Measuring point : Taraka substation 11kV bus
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

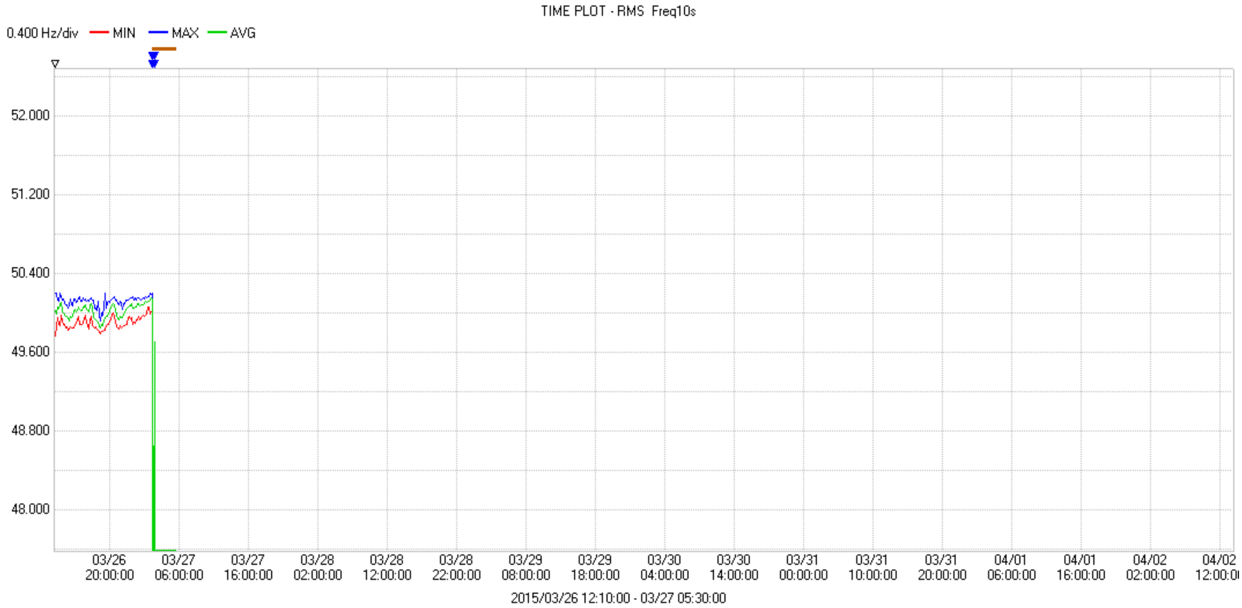


LONG TERM MEASUREMENT

Measurement Item : Frequency
Measuring point : Taraka substation 11kV bus
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

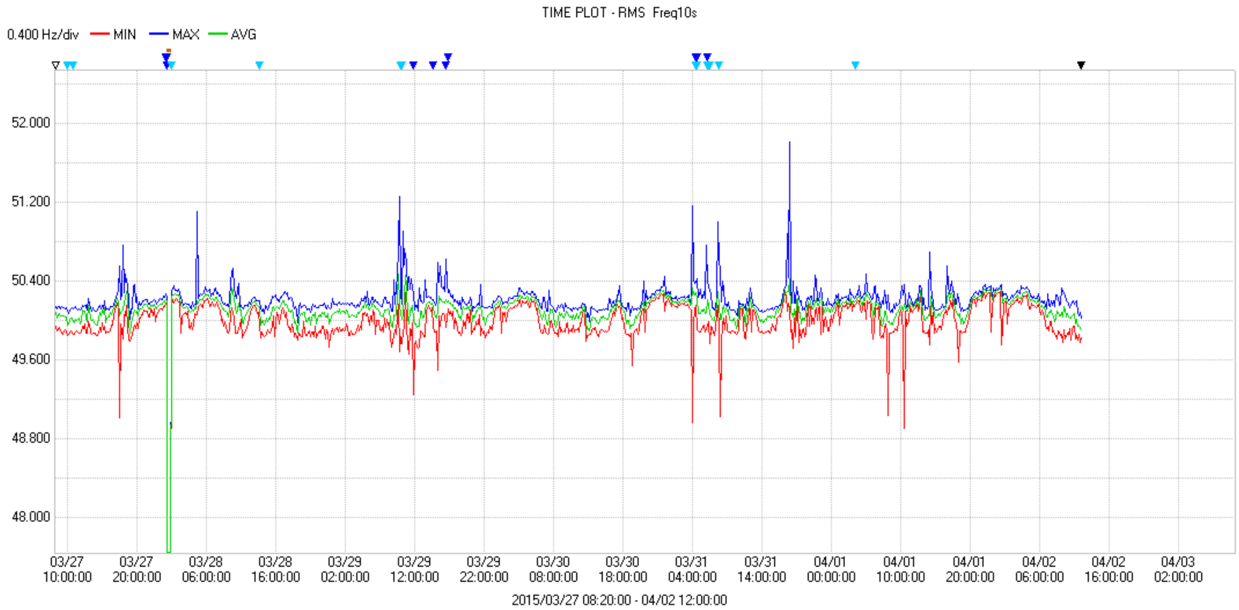


Measurement Item : Frequency
Measuring point : Taraka substation 11kV bus
Duration : 26/March/2015 12:00 – 27/March/2015 05:30



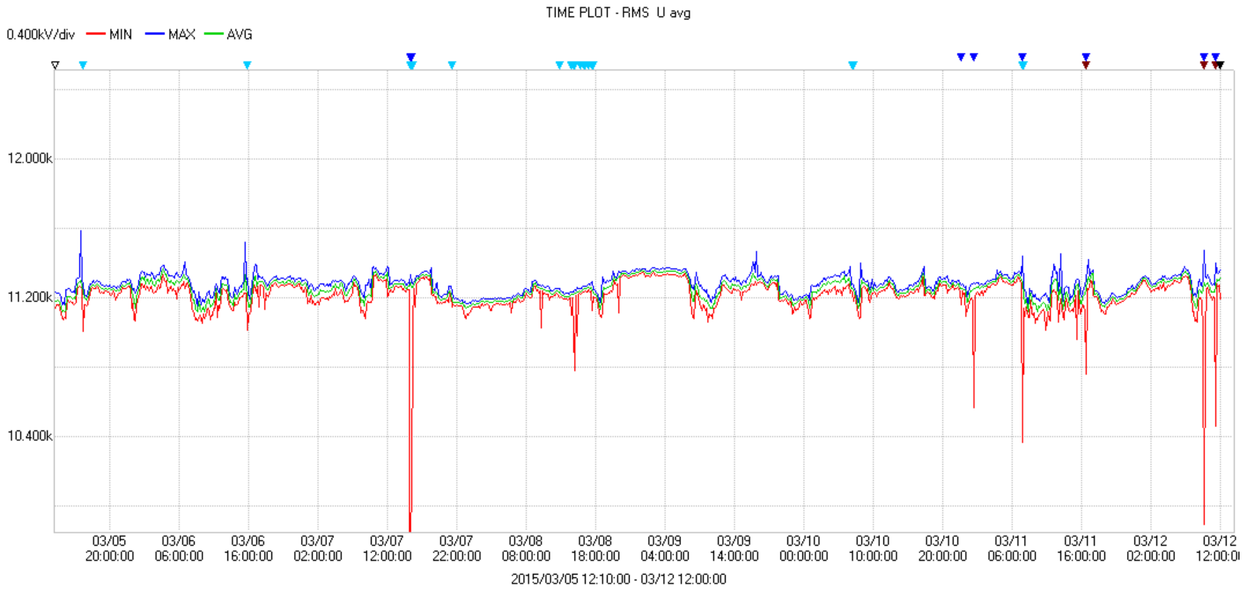
LONG TERM MEASUREMENT

Measurement Item : Frequency
Measuring point : Taraka substation 11kV bus
Duration : 27/March/2015 08:20 – 2/April/2015 12:00

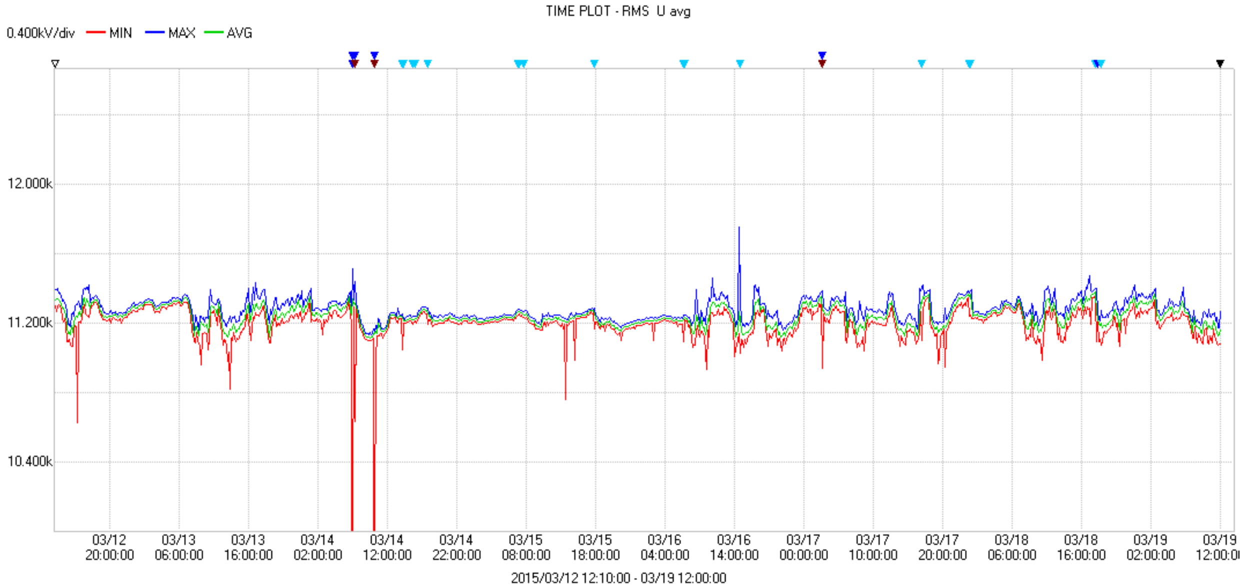


LONG TERM MEASUREMENT

Measurement Item : Voltage
Measuring Point : Milford substation 11kV bus
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

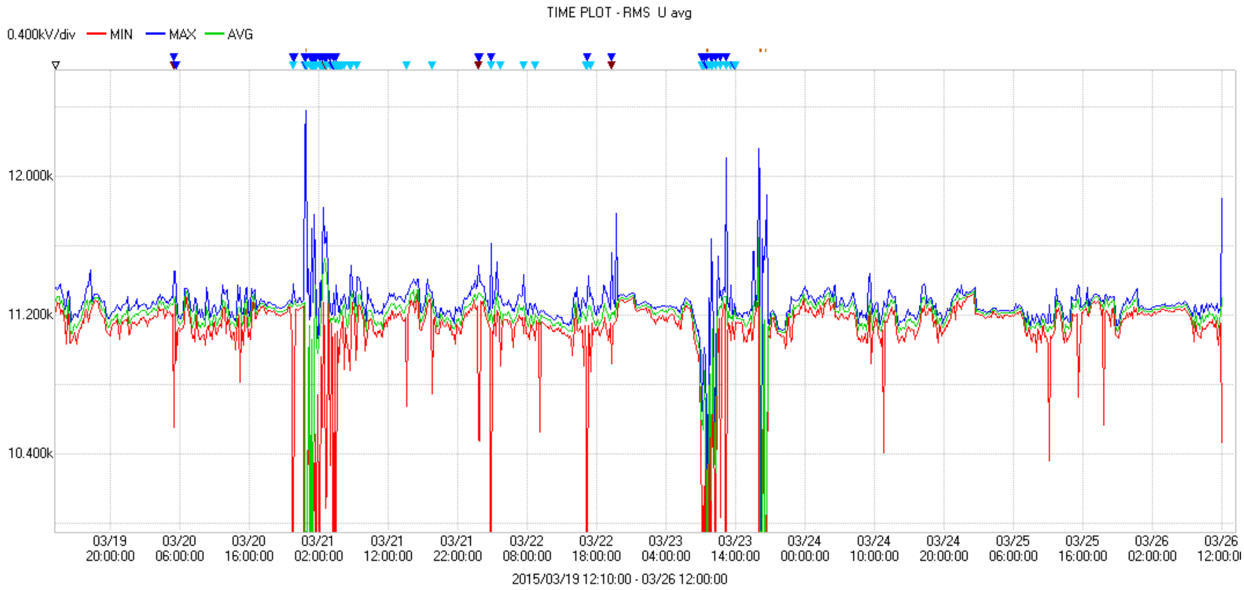


Measurement Item : Voltage
Measuring Point : Milford substation 11kV bus
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

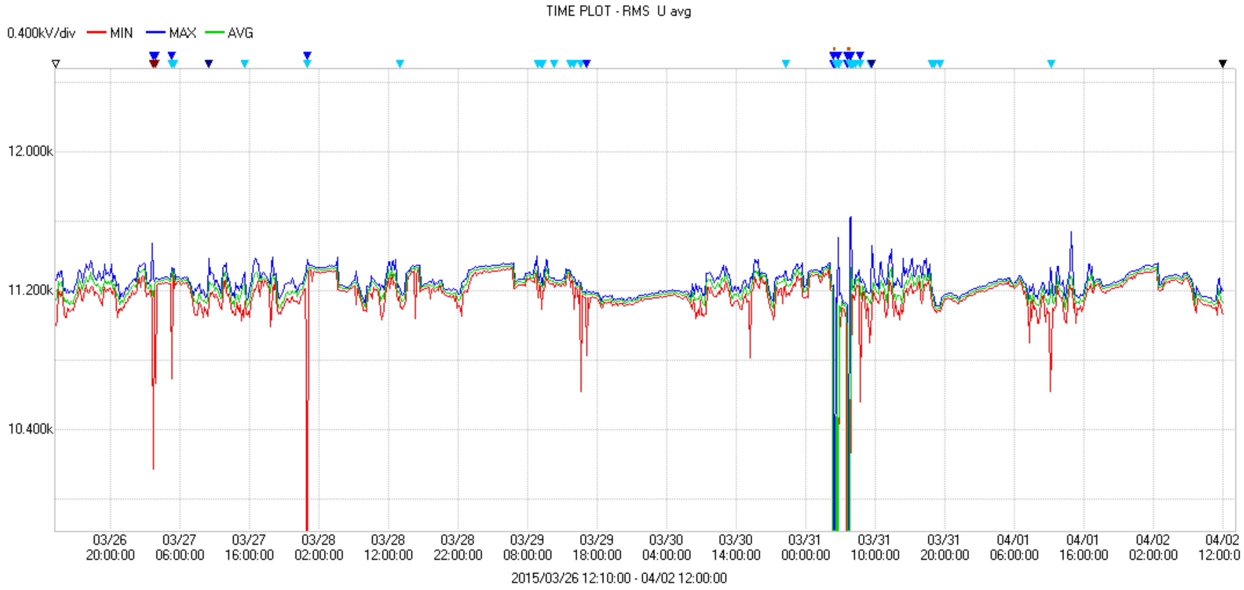


LONG TERM MEASUREMENT

Measurement Item : Voltage
Measuring Point : Milford substation 11kV bus
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

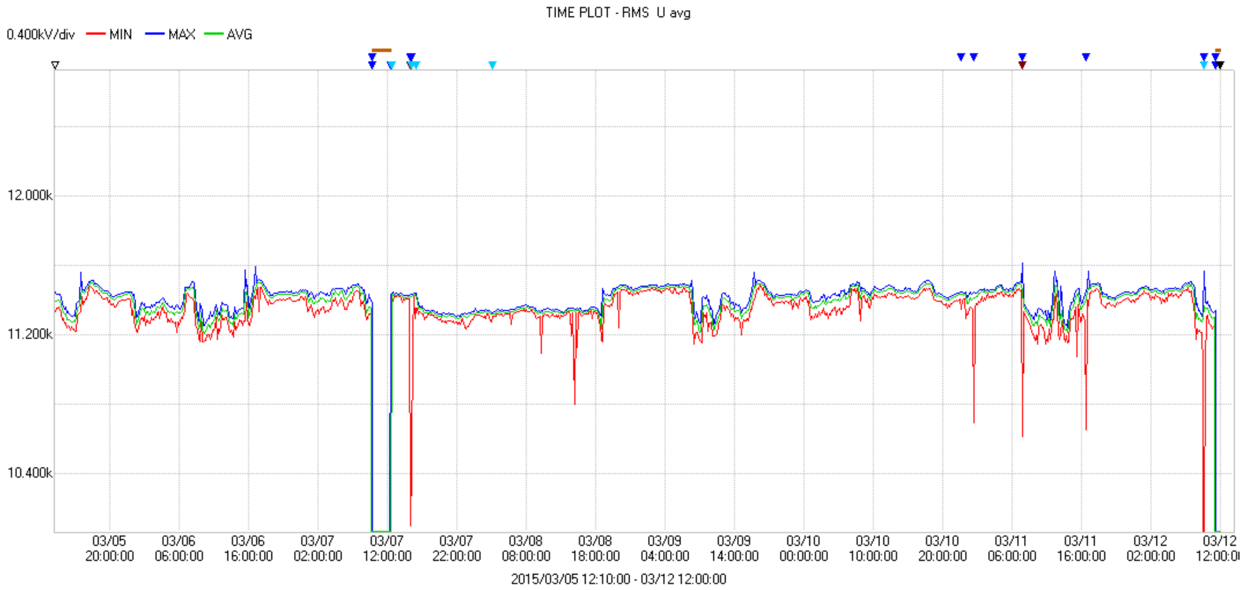


Measurement Item : Voltage
Measuring Point : Milford substation 11kV bus
Duration : 26/March/2015 12:00 – 2/April/2015 12:00

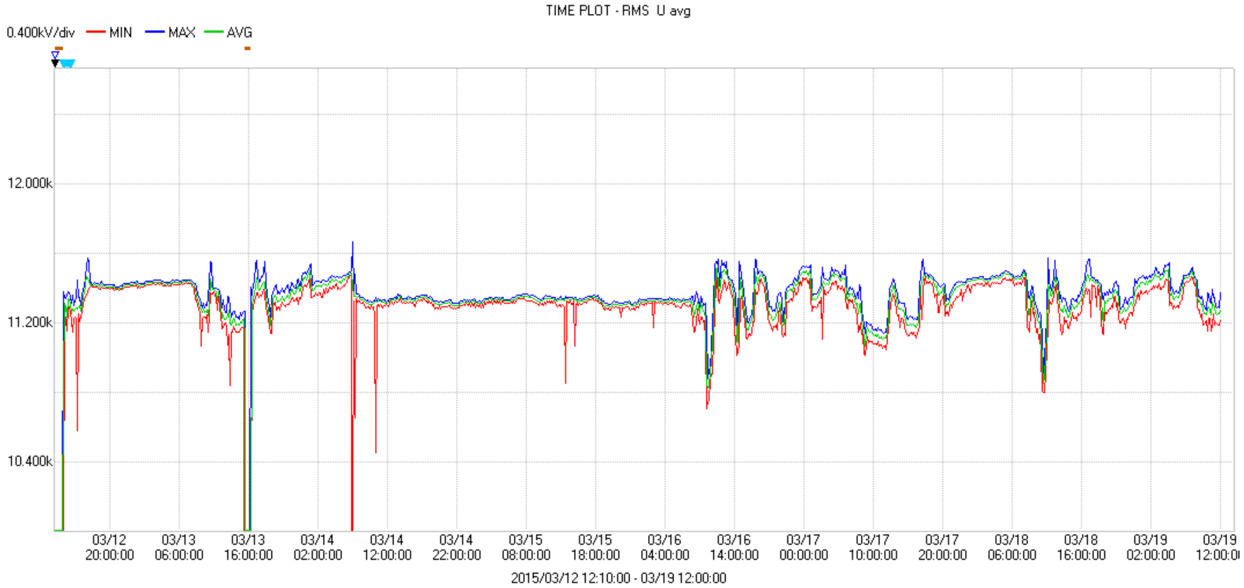


LONG TERM MEASUREMENT

Measurement Item : Voltage
Measuring point : Taraka substation 11kV bus
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

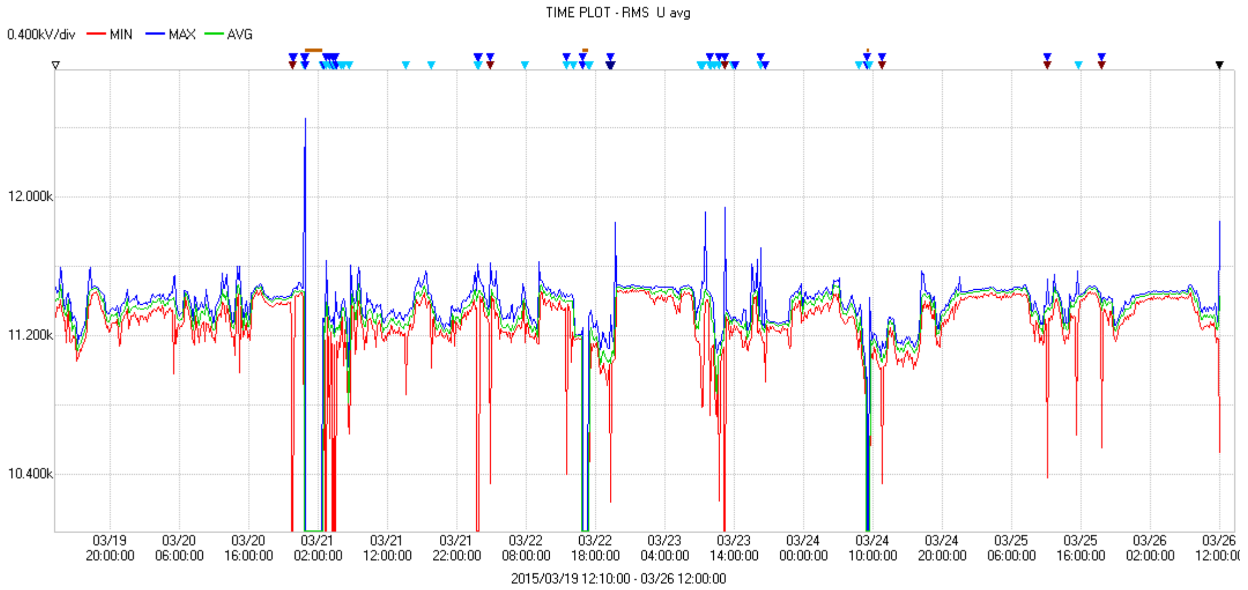


Measurement Item : Voltage
Measuring point : Taraka substation 11kV bus
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

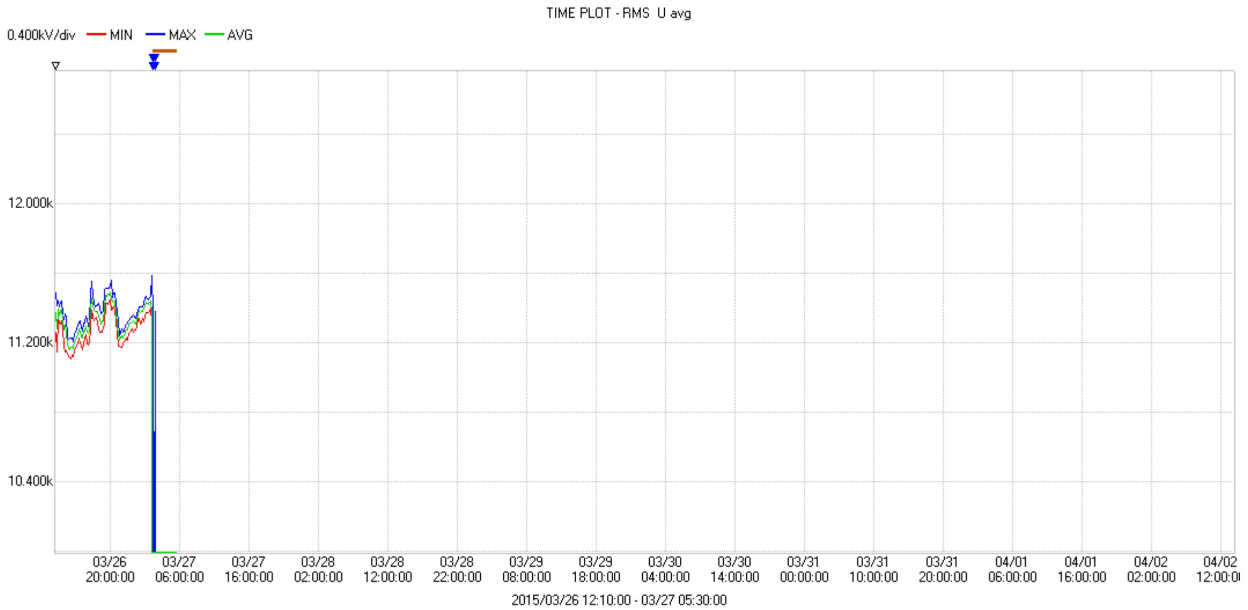


LONG TERM MEASUREMENT

Measurement Item : Voltage
Measuring point : Taraka substation 11kV bus
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

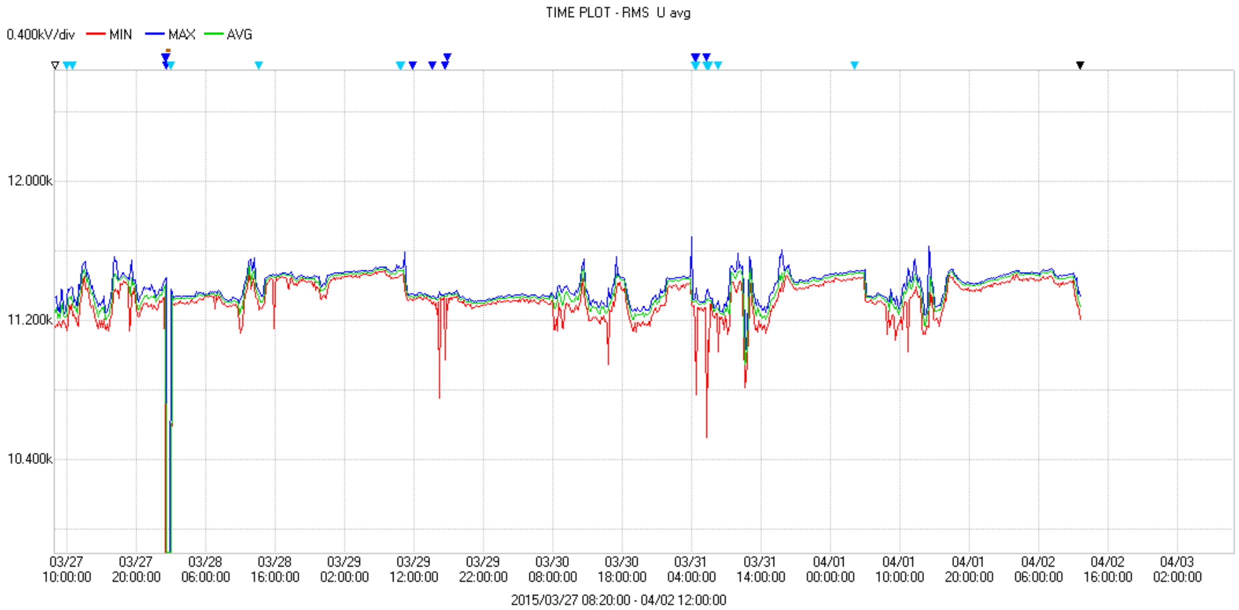


Measurement Item : Voltage
Measuring point : Taraka substation 11kV bus
Duration : 26/March/2015 12:00 – 27/March/2015 05:30



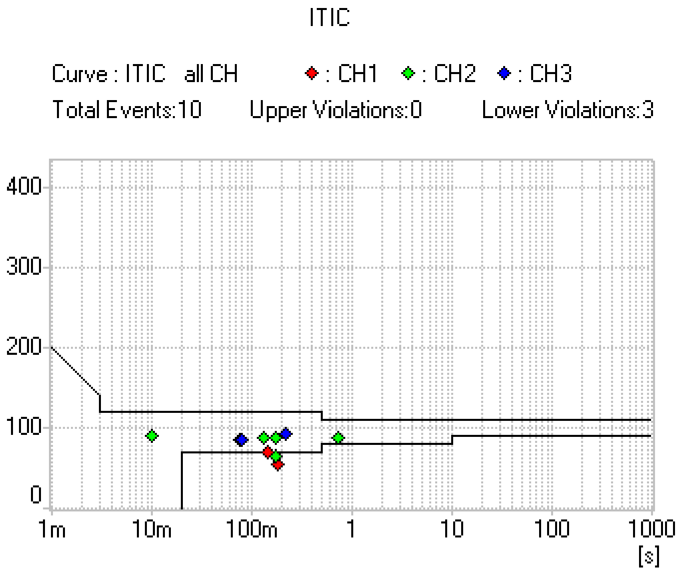
LONG TERM MEASUREMENT

Measurement Item : Voltage
Measuring point : Taraka substation 11kV bus
Duration : 27/March/2015 08:20 – 2/April/2015 12:00

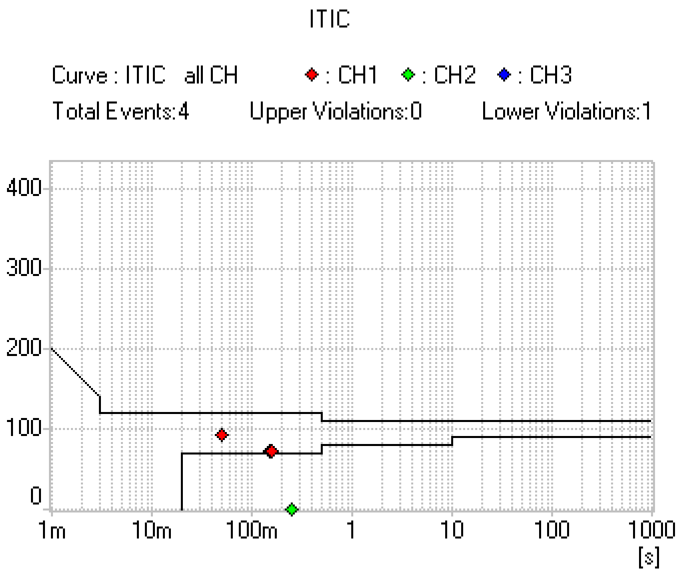


LONG TERM MEASUREMENT

Measurement Item : Swell, Dip
Measuring Point : Milford substation 11kV bus
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

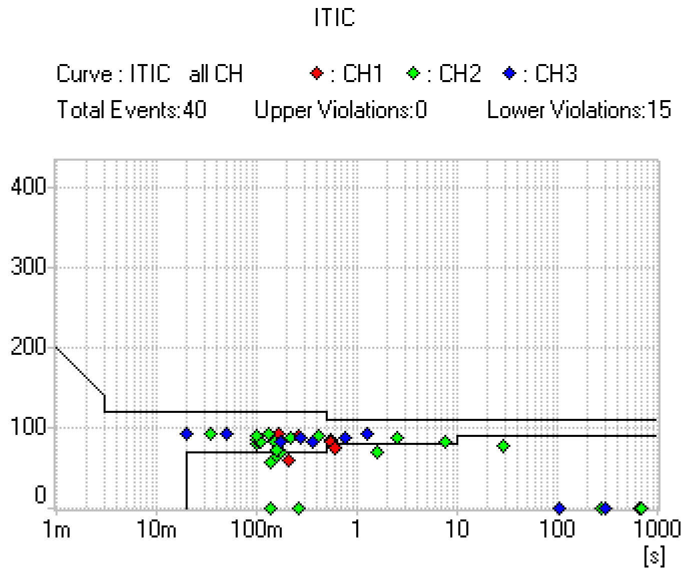


Measurement Item : Swell, Dip
Measuring Point : Milford substation 11kV bus
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

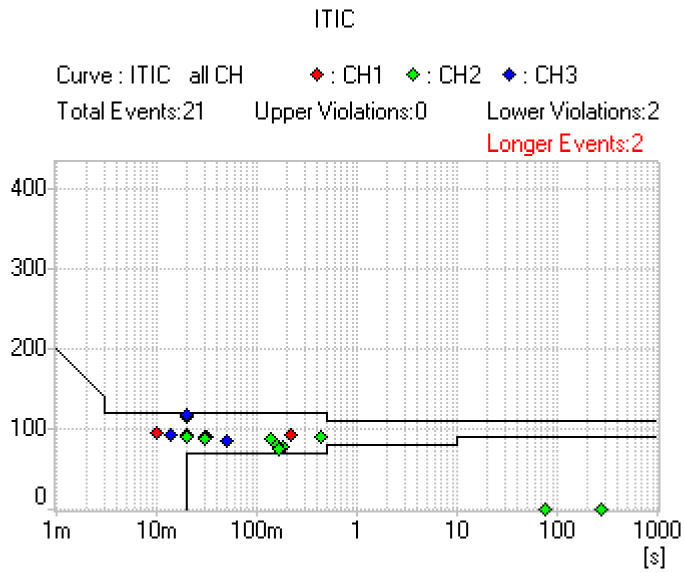


LONG TERM MEASUREMENT

Measurement Item : Swell, Dip
Measuring Point : Milford substation 11kV bus
Duration : 19/March/2015 12:00 – 26/March/2015 12:00

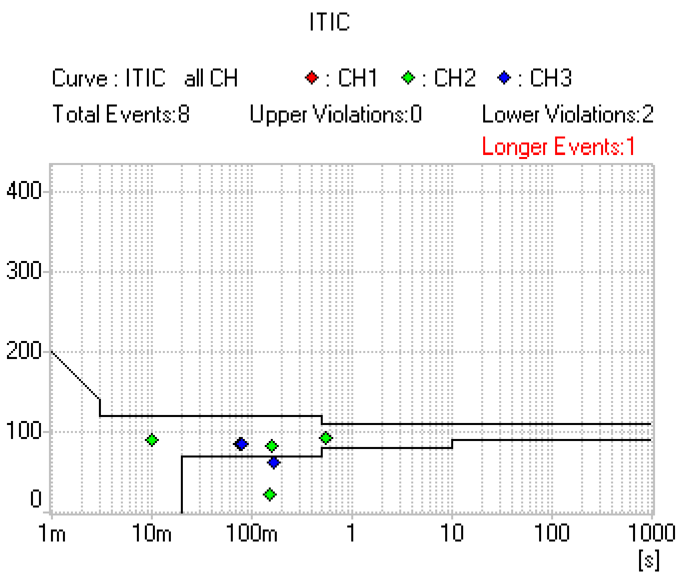


Measurement Item : Swell, Dip
Measuring Point : Milford substation 11kV bus
Duration : 26/March/2015 12:00 – 2/April/2015 12:00

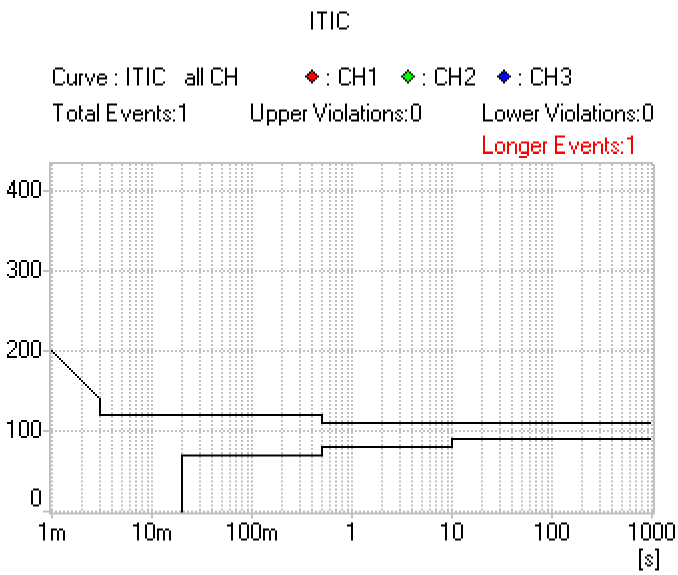


LONG TERM MEASUREMENT

Measurement Item : Swell, Dip
Measuring Point : Taraka substation 11kV bus
Duration : 5/March/2015 12:00 – 12/March/2015 12:00

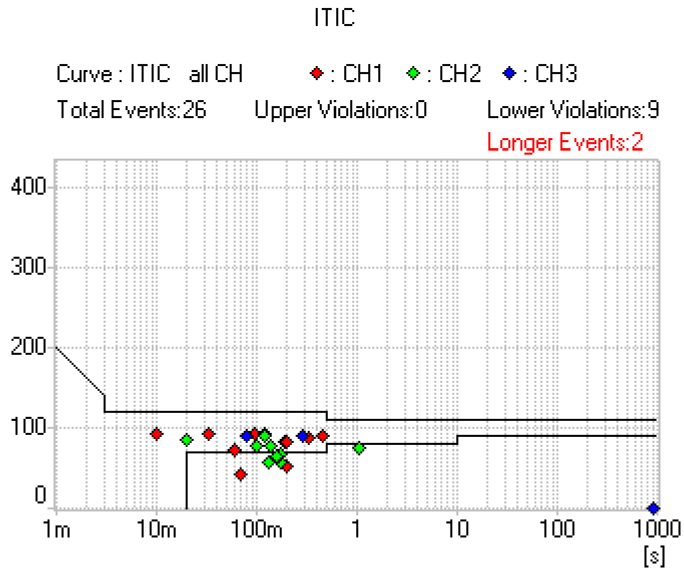


Measurement Item : Swell, Dip
Measuring Point : Taraka substation 11kV bus
Duration : 12/March/2015 12:00 – 19/March/2015 12:00

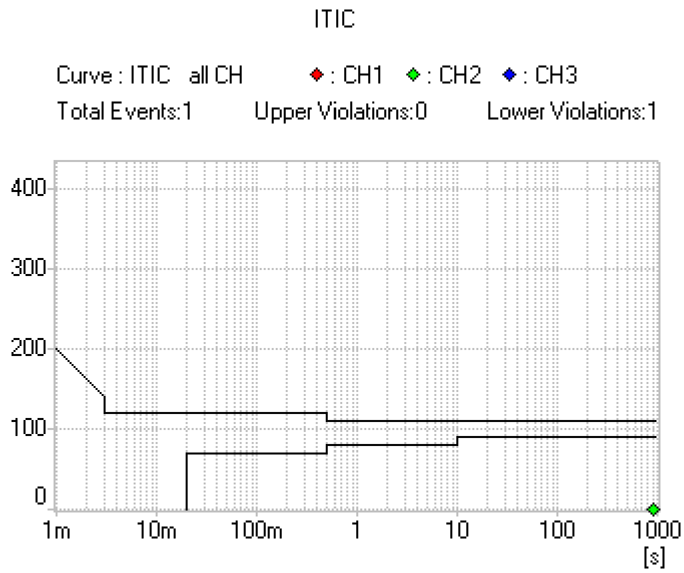


LONG TERM MEASUREMENT

Measurement Item : Swell, Dip
Measuring Point : Taraka substation 11kV bus
Duration : 19/March/2015 12:00 – 26/March/2015 12:00



Measurement Item : Swell, Dip
Measuring Point : Taraka substation 11kV bus
Duration : 26/March/2015 12:00 – 27/March/2015 05:20



LONG TERM MEASUREMENT

Measurement Item : Swell, Dip
Measuring Point : Taraka substation 11kV bus
Duration : 27/March/2015 08:30 – 2/April/2015 12:00