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Long Term Electricity Forecasting for Planning and Optimization at the Taninthayi Division Micro-Grid System Using LEAP

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Abstract:

The context in which many electricity systems find themselves is changing rapidly. Once viewed as an essential public service, many electricity systems are now facing the challenge of market liberalization, pressure to reduce greenhouse gas emissions and increasing fuel prices and fuel price volatility. In Myanmar, some regions are still electrifying micro-grid systems as they are far away from the national grid and geographical conditions. This study explored the long-term electricity forecasting for Taninthayi Region Micro-Grid System from 2021 to 2045. The Long-range Energy Alternating Pathways (LEAP) tool was utilized for the diverse scenarios analysis. Effective optimization and planning can be carried out for micro-grid systems based on accurate forecasting data. The lowest cost system developed by LEAP (optimum scenario) was used as a reference for examining future possible energy policy directions for micro-grid systems.

Keywords:

Long Term Electricity Forecasting, Different Scenarios, Microgrid, Energy Planning, Long-Range Energy Alternating Pathways (LEAP)

1. Introduction

One of the most critical areas in the research of power systems is power system planning. The planning problems can be categorized into short–term, mid–and long–term planning sub-problems. In contrast, in terms of planning objectives, the planning issues may also be classified into generation planning and transmission planning. Generally speaking, generation expansion aims to ensure a good enough generation capacity to meet the load demand. The principal task is to decide the most excellent time, location, size and generating units concerning operation constraints to gain minimum price, maximum stability, reliability and economic return. For effective planning, accurate forecasting data is critically important.

Microgrid solutions are presently playing an expanding part in providing access to power, particularly to remote populations whose electricity is not provided by the national grid. Microgrid builders need to manage their existing sites and extend to new regions. To control this expansion effectively and sustainably, they want to make data-driven decisions. The essential input in designing and managing of microgrid system is accurate forecasting of power demand in a specific area. Several forecasting mechanisms are proposed for such microgrid builders. Using day-by-day energy consumption data records from Taninthayi from 2011-to 2020, it was determined that exponential smoothing provides the best out-of-sample forecasting performance with estimate capabilities displayed for horizons up to twenty-five years ahead. This study uses the Long-range Energy Alternating Pathways (LEAP) device for long-term power demand forecasting.

2. Microgrid

Microgrid projects have been effectively completed, giving several innovative technical arrangements. The microgrid is a critical and necessary part of developing the smart grid. The microgrid is characterized as the "building block of the smart grid". The essential components of a microgrid system are distributed generation, storage devices, and power-consuming loads, mainly low and median-voltage systems. The D.E.R.s (distributed energy resources) such as micro-turbines such as fuel cells, wind generators, photovoltaic (P.V.) and storage devices such as flywheels, energy capacitors and batteries are placed on the microgrid. The microgrid can be effective for both the grid and the customer.

From the customer's view, microgrids answer both thermal and electricity desires and enhance local reliability, reduce emission, improve power quality by supporting the voltage and frequency and probably lower energy supply prices. From the utility's view: a microgrid will be seen as a controlled entity within the power system as one dispatchable unit (load or generator) or ancillary services provider. (Figure 1)

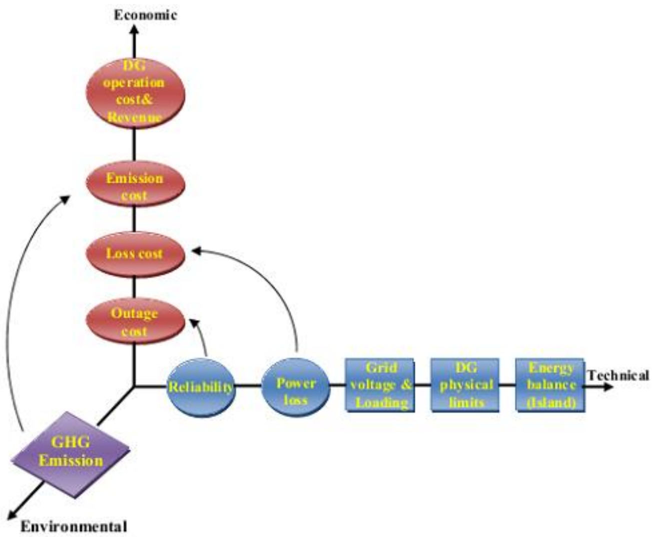

Figure 1. *Microgrid Operation Strategy.*

A microgrid typically operates in island mode and grid-connected mode. In the island model, production is needed to meet the load's demand. However, when the microgrid is connected to the grid, it can both receive and inject power into the primary grid. Furthermore, the gird-connected microgrid can provide energy to meet the demands of its local loads. When a disturbance occurs, the microgrid is disconnected from the distribution network as soon as possible to avoid further damage. In that case, the microgrid will function in an island model.

Furthermore, the operation mode is associated with the elasticity supply, natural loads demand and the power market. Thus, microgrids' optimum operation programming objectives concern the economic, technical and environmental aspects. Therefore, a microgrid can offer various financial, technical, ecological and social benefits to internal and external stakeholders relying on its operational strategy.

Microgrid control can be separated into coordinated control (supervisory control or energy management) and local control. First, the coordinated management optimizes to assign the ability output among distributed energy resources (D.E.R.), value} of energy production and emission. For example, the forecast values of hundreds of demand, the generation and the market electricity price every hour on a coming day are collected and calculated to search out the optimal output power of distributed energy resources, the consumption level of the utility grid and the cost and the emission. Second, the intelligent local controllers for D.E.R. can improve the efficiency of microgrid operation. Those controllers control the frequency and voltage in different operation modes of microgrid, such as islanded and grid-related modes.

3. Energy Planning and LEAP

LEAP interface is structured under seven views utilizing graphical icons: Analysis, Results, Energy balance, Summaries, Overviews, Technology database (T.E.D.) and the Notes views. Figure 2 shows a visual representation of the LEAP model.

The analysis read is that the style centre of the software. A section structured in the form of a tree provides the platform for creating, organizing and editing data. The data offers four main categories for the data organization in the model.

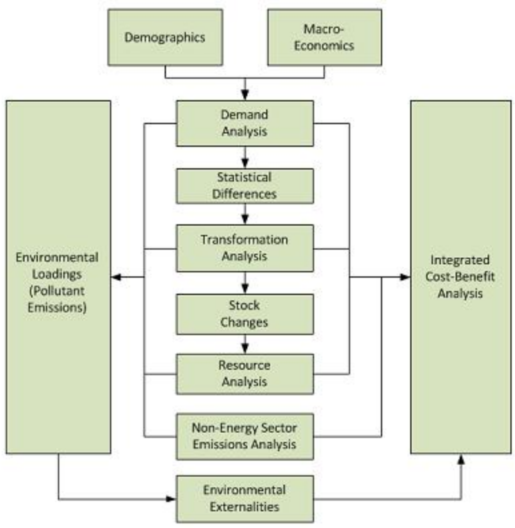

Figure 2. *Structure of LEAP model.*

These are user-defined variables which enable the creation of demographic (e.g., population, urbanization rates, household size), macroeconomic (e.g. G.D.P., interest rate) and other time-series variables (e.g., employment statistics, investment rate). Although critical assumptions are not directly determined in LEAP, they are used in intermediary calculations. For example, the population increase rate can project domestic demand.

Integrated energy analysis can ordinarily begin with demand analysis since all transformation and resource calculations deem the demand. However, LEAP provides flexibility in the organization of requests and three approaches for modelling demand, as illustrated in Figure 3.

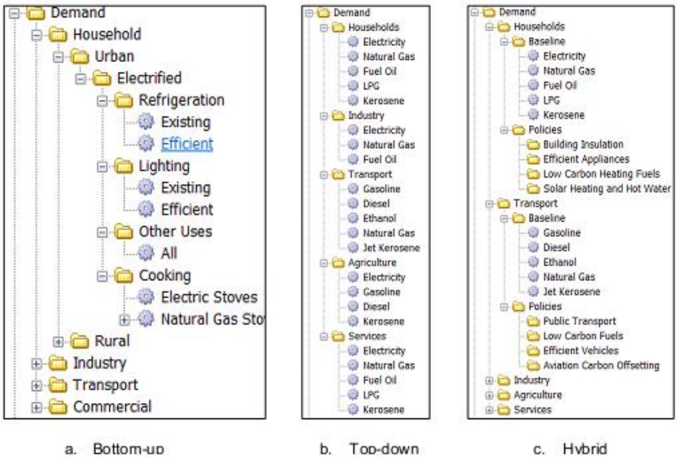

Figure 3. *Energy demand approaches in LEAP.*

The Bottom-Up or End-Use approach gives a detailed engineering-based modelling account for sectors, end-users, and energy consuming devices. The Top-down or Econometric approach is an aggregation approach in which consumption is then divided into sections and fuels only. Finally, the Hybrid system in LEAP uses the top-down approach for the reference eventualities. In contrast, the different eventualities square measure modelled as policy measures leading to reduced consumption over time. Table 1 summarises the pros and cons of the various approaches.

Table 1. *The Main Pros and Cons of the Leap Application.*

	Bottom-up	**Top-down**	**Hybrid**
No.	**Pros**		
i	Enables the assessment of impacts of changes due to policies.	Less data-intensive.	Less data-intensive than bottom-up.
ii	Gives a better understanding of energy usage.	Forecast using simple historical trends.	Can capture technology-based policies
iii		Able to capture fiscal policies such as carbon tax.	
	Cons		
i	Data-intensive.	Not well suited to examine technology-based policies.	Does not fice insight into system structure in the long term.
ii	Hard to capture the impacts of fiscal policies.		
iii	May require many trends and assumptions.		

The results display elaborated results for all system components together with demand, transformation, resources, price and environmental loading. The show also contains tools for constructing tables and charts, which might be simply exported to word, stand out or PowerPoint. Finally, favourites in the results view enable customized charts to be bookmarked for future reference.

The Energy Balance View displays energy summaries for any year of the model or calculated scenario as a standard energy balance table, chart or shanked diagram. The shanked diagram that has replaced the diagram view available in older versions of LEAP provides superior visualization as it shows the actual energy flow quantities.

This Summaries View can be used to build custom tables and graphical results summary reports. The outline additionally contains a piece of cost-benefits information that outlines the price, cost, and good things about the eventualities compared to the chosen reference.

4. Data Base For Taninthayi Region

Tanintharyi Region is the long narrow southern part of Myanmar. The Andaman Sea is located in the west, and the Tenasserim Hills area is in the east. This region is far away from the existing national grid. As a result, the micro-grid system is employed to electrify this area. Thus, the long-term electricity demand forecasting for the Taninthayi region is carried out using LEAP software. The location and the primary data for electrification are shown in Figure 4.

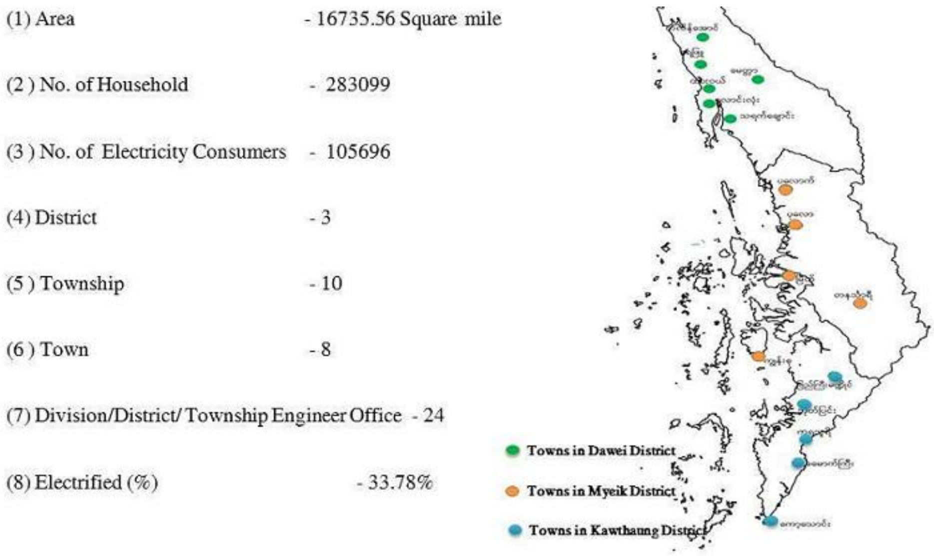

Figure 4. *Current electricity supply in Tanintharyi Region location map.*

Table 2 shows the list of electrified households in the Tanintharyi Region. Taninthayi is divided into three districts, as stated in the table. Therefore, the total numbers of families and numbers of electrified households are also shown in this table. Currently, electrification is accomplished through a micro-grid system powered by diesel generators. The current electrification rate is about 37.33 % and will be increased to 100 % in 2045.

Table 2. *List of Electrified Households in the Tanintharyi Region.*

NNo	Name of District	No.of Household	Electrified Household	Un-electrified Household	Electrification Rate (%)
1	Dawei	104092	55558	48534	3.3
2	Myeik	132919	36593	96326	7.5
3	Kawthaung	46088	13545	32543	9.3
Total		283099	105696	177403	7.33

Table 3. *Annually Increased Peak Load Condition in Recent Years.*

Sr. No.	Name of District	Supply Load (M.W.)									
		2017		2018		2019		2020		2021	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	Dawei	11.2	6.0	14.8	7.4	16.7	9.7	19.3	12.8	22.6	15.3
2	Myeik	7.95	4.1	7.99	5.1	11.4	6.3	14.1	7.2	16.8	8.5
3	Kawthaung	4.4	2.2	4.45	3.2	8.6	4.4	10.5	5.6	13.7	6.9
Total		23.55	12.3	27.25	15.7	36.7	20.4	43.9	25.6	53.1	30.7

Table 3 shows annually increased maximum and minimum load conditions in recent years. As shown in the table, both the maximum and minimum loads are increasing yearly. The load demand is double within these five years.

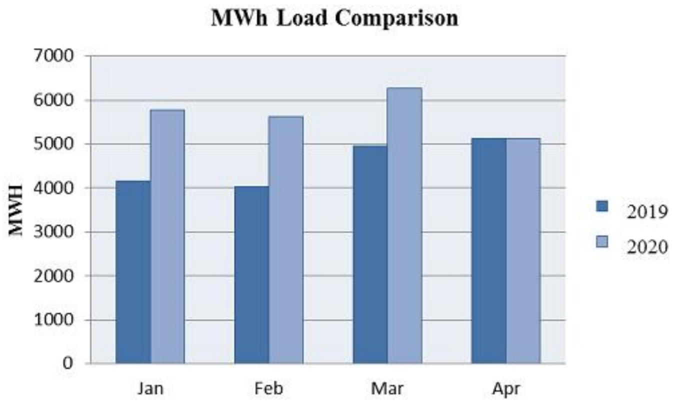

Figure 5. *Electric energy demand comparison for Tanintharyi Region in recent years.*

Figure 5 shows an electric energy demand comparison for the Tanintharyi region's first quarter in recent years. As shown in the figure, the electricity demand is significantly increased compared to the previous months of the same month. The hourly load demand each day is also observed for the electricity demand forecast.

Figure 6 shows hourly load demand data for a sample day in 2020. Since the main load in the selected region is domestic load, the electricity demand is maximum at 7:00 pm, and minimum at 3:00 am.

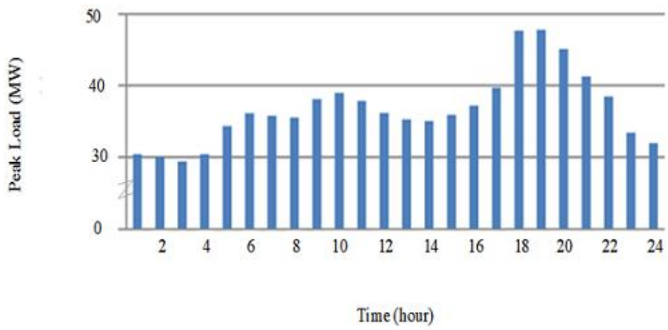

Figure 6. *Hourly load demand data for a sample day.*

The maximum demands in the previous ten years are recorded for the electricity demand forecast. Figure 7 shows annually increased peak load conditions in the Tanintharyi region. Year after year, the maximum demand rises. For example, the electricity demand gradually increased between 2011 and 2016. Afterwards, the electricity demand significantly increased between 2016 and 2021.

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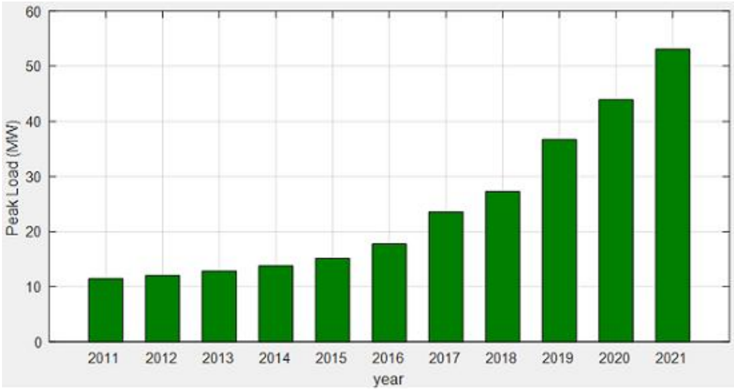

Figure 7. *Annually increased peak load condition in the Tanintharyi region.*

5. Application of LEAP Software for Long Term Electricity Demand Forecasting

LEAP is an integrated modelling tool that can be used to track power consumption, generation and resource extraction in altogether sectors of a country/region. It's a tool that can be used to create models of various energy systems, where each requires its own unique data structures. It supports a variety of different modelling methodologies. On the load side, it supports bottom-up/end-use accounting techniques and top-down/macroeconomic modelling. This study uses LEAP for long-term electricity demand forecasting for planning and optimizing the Taninthayi region.

Using the LEAP model, three alternative scenarios were elaborated for the long-term electricity demand forecasting for 2020–2045. The scenarios are taken as follows:

a. Reference scenario (REF): The Reference Scenario represents today's situation in the Taninthayi region's electricity sector. In the REF, the G.D.P. growth rate in the recent years.

b. Low-growth scenario (L.G.): This scenario assumes a low G.D.P. growth rate based on low-income and low population growth rates. All other parameters are similar to the REF scenario.

c. High-growth scenario (H.G.): This scenario assumes a high G.D.P. growth rate based on increased income and population growth rates. All other parameters are similar to the REF scenario.

For long-term electricity demand forecasting, the data set of the Taninthayi region is structured using LEAP's tree branch structure. The top-level branches within the tree are Key Assumptions. The critical assumption components inside the information sets store a selection of demographic, economic, and development indicators extracted from various information sources. During this research, key assumptions are as follows:

Income of Household = USD 3000.00 per household

Household size =5 person/household

Numbers of Households = 283099

End-year urbanization = 50 %

Population= Numbers of Households * Household size

GDP= Population * Income of Household

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Income growth rate= 0.5 %, 4.5 % and 7.0 % for Low, Average and High-level growth respectively.

Population growth rate= 0.3 %, 3.0 % and 4.0 % for Low, Average and High-level growth respectively.

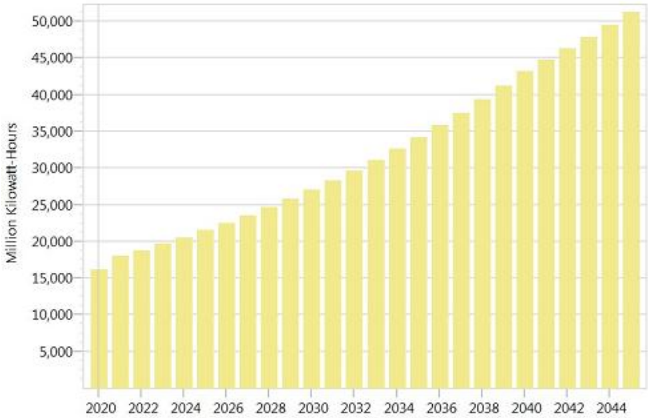

Figure 8. *Electricity demand with a low growth scenario.*

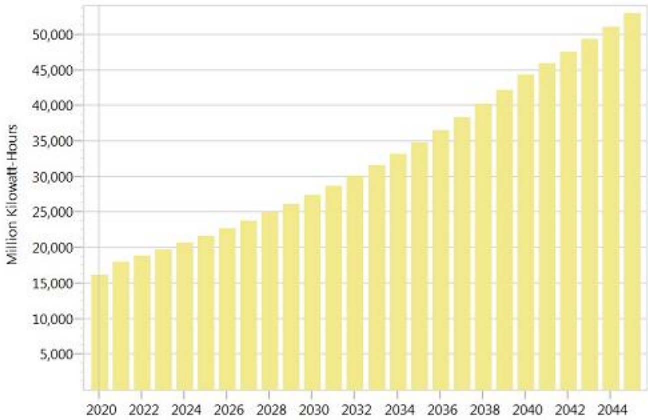

Figure 9. *Electricity demand with average growth scenario.*

The simulation results for electricity demand with three different scenarios are shown in Figure 8 through Figure 10. The comparison of electricity demand with three different strategies is shown in Figure 11. As shown in the figures, the electricity demand at the end of the forecast period will be 56044.74 million kWh, 53003.97 million kWh, and 51263.03 million kWh for high, average and low growth scenarios, respectively.

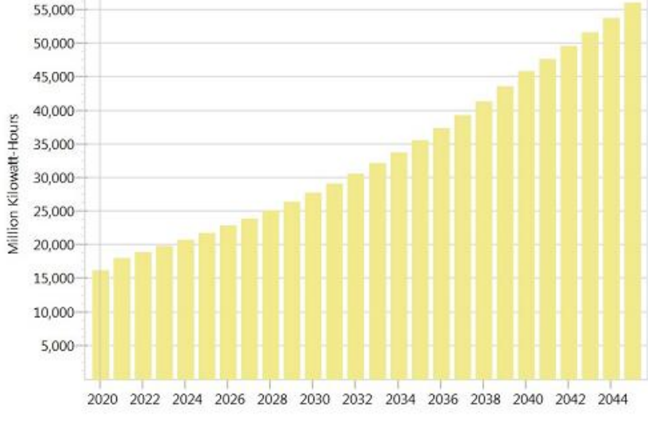

Figure 10. *Electricity demand with high growth scenario.*

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A comparative analysis of the electricity demand growth rate across all the scenarios is presented in Table 4 - the requirements under the demand category show 100 % electrification at the end of the projected period. In the average growth scenarios, the total energy demand increases annually by 4.87 % during the period 2021 - 2045, taking into account the economic growth projections of the region in these scenarios. It does, however, increase by 4.73% and 5.10% in the low and high growth scenarios, respectively.

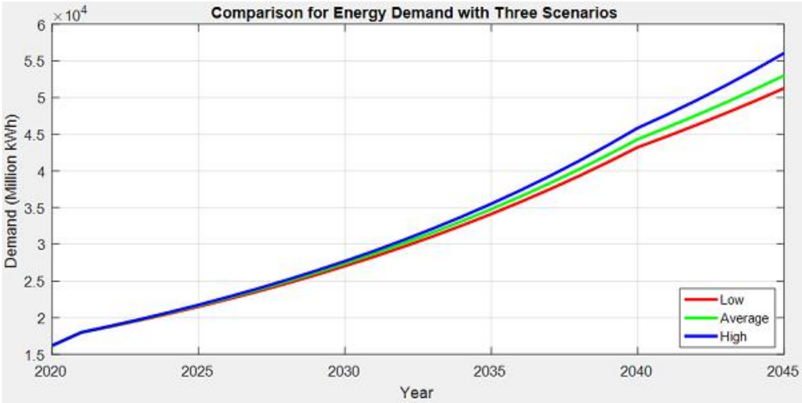

Figure 11. *Comparison of electricity demand with three different scenarios.*

Table 4. *Electricity Demand Growth Rate for 25 Years Periods.*

Period Scenario	**2021-2025**	**2026-2030**	**2031-2035**	**2036-2040**	**2041-2045**	**25 years Average**
High-Growth (%)	6.10	4.96	5.10	5.24	4.10	5.10
Average Growth (%)	6.00	4.82	4.90	4.96	3.64	4.87
Low-Growth (%)	5.86	4.69	4.77	4.84	3.47	4.73

6. Conclusions

This paper presents the result of testing the LEAP model's suitability for elaborating scenarios of the long-term electricity demand forecasting at the Taninthayi region microgrid. First, an overview of the previous and current electricity supply in the Taninthayi region is presented. Then, for long-term electricity demand forecasting, three different scenarios are considered based on the growth rate of this region in the period 2021 - 2045. Finally, a comparison of the actual results from all designs is presented. Based on these forecast data, the effective planning for the electricity supply of the Taninthayi region microgrid system can be developed.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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