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RESEARCH ARTICLE

Analysis of Additional Generation Planning in the Batam-Bintan Power System to Improve Reliability

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Abstract

The Batam-Bintan electrical system encounters operational challenges due to inadequate new power plants being commissioned to meet the increasing demand. Bintan Island's supply dependency on Batam Island through the undersea cables and 150 kV SUTT places operational stress systemically and adds vulnerability to disruption. The focus of the research is to optimize the system reliability through peak load forecasting up to 2030 and refining the strategic locations and sizes for the new power plants. The calculation forecast employs a second-order polynomial regression method, whereas the load flow analysis is performed with DIgSILENT PowerFactory 2022 software. Based on the research, the peak load is expected to grow from 675.2 MW in 2024 to 1322.1 MW by 2030. To attain reliability, 940 MW of additional generation capacity is required, which is made up of 580 MW of DG (distributed generation) and 360 MW of central generation. The placement of DG is focused on substations that are overloaded or approaching overload, while centralized generation is positioned where power loss is lowest. The evaluation results indicate the additional generation makes it possible to maintain voltage stability, reduce dependence on PLTU XYZ and meet the reserve power requirement of a 35% power margin.

Keywords: Batam-Bintan Power System, Reliability, Peak Load Projection, Load Flow Simulation

1. Introduction

The power system is a network consisting of various components, including generating units, transmission lines, substations, and distribution networks. All these components are integrated and work together to meet the electricity needs of customers according to the existing demand [1] [2]. The Batam-Bintan electrical system is an electrical system that connects two major islands in the Kepulauan Riau Province, namely Bintan Island and Batam Island. The Batam City located on Batam Island, is the largest city in the Kepulauan Riau Province, and Bintan Island has one municipality and one regency, namely Tanjungpinang City, which is also the capital of the Kepulauan Riau Province and Bintan Regency. The Batam-Bintan electrical system was interconnected in 2016, playing an important role in supporting the economic development and welfare of the communities on Batam and Bintan Islands. In fact, Batam and Bintan Islands have several Special Economic Zones. Currently, the load of the Bintan System is entirely supported by the Batam System through undersea cables and 150 kV high-voltage overhead transmission lines, making the Batam-Bintan system a single power system. The Batam-Bintan system has a generation capacity of 871 megawatts (MW) with a peak load of 675 MW, and its generation is dominated by thermal power plants.

The main problem of this system is multidimensional. First, the rapid growth in electrical load is not matched by the addition of new power plants, potentially triggering power deficits and network instability. The reserve capacity of the power generation system is prepared to ensure that energy supply remains sufficient during operational disruptions, such as generator unit failures or temporary disconnection of generators from the system due to maintenance [3]. Second, Bintan's dependence on undersea cables and the 150 kV high-voltage overhead transmission lines from Batam creates systemic weak points; disruptions to this infrastructure can include physical damage, corrosion, or natural disasters and can trigger widespread blackouts that impact economic activities and public services. Third, the current system is highly dependent on large power plants such as PLTU XYZ. If there is a disturbance or maintenance at that power plant, the limited operational reserves risk exacerbating the electricity supply crisis. The provision of reserve capacity aims to prevent load shedding due to electricity supply shortages while also enhancing the operational reliability of the power system [4].

The determination of optimal locations for power plant placement, especially distributed generation (DG), has been carried out using various methods, such as mixed-integer linear programming (MILP) [5], mixed-integer nonlinear programming (MINLP) [6], whale optimization algorithm (WOA) [7], grey wolf optimization [8], and hybrid approaches [9]. The research conducts power plant planning that combines centralized generation and distributed generation using load flow analysis methods, with the assistance of DIgSILENT PowerFactory 2022 software, which has not been done in previous studies. The DIgSILENT PowerFactory software was chosen as an aid in the simulation and analysis of power flow due to its superior capability in modeling complex electrical networks and supporting various operational scenarios of power systems [10].

The purpose of this research is to address the issue through the planned addition of new power plants. The main objective is to forecast the peak load of the Batam-Bintan system until 2030, then determine the optimal location and capacity of the power plants to increase the reserve margin and reduce Bintan's dependence on the Batam system by building centralized generation and distributed generation using load flow analysis methods, and evaluate the impact of the additional power plants on system quality.

With an analytical approach that combines historical data, load growth projections, and simulations using DigSILENT PowerFactory 2022, this research is expected to serve as a strategic foundation in strengthening the energy resilience of the Batam-Bintan system until 2030. Thus, this effort aligns with sustainable development goals, particularly in ensuring reliable energy access.

2. Power Generation Planning

Planning in the generation sector aims to determine the optimal strategy for providing electrical energy over a certain period, which is greatly influenced by projections of demand or electrical load. In this context, transmission planning plays a crucial role in ensuring the total load current from the generating units to the consumers is delivered with an adequate system reliability level, thereby maintaining a consistent continuity of electricity supply. Therefore, energy demand estimation becomes a crucial component in determining the required generation capacity and the amount of energy that must be provided to meet the system's needs efficiently [11].

2.1 The Polynomial Regression Method

Due to its capability to capture the nonlinear relationship between the variables, especially in capturing the complex load patterns influenced by season, time, social activities, and weather, second-order polynomial regression has become one of the most useful techniques for load forecasting. Frequent chaotic errors in systems can lead to periodic forecasting errors, but secondorder polynomial regression is known to boost accuracy during these times. Unlike traditional linear approaches, this method reconstructs the phase space of chaotic systems more optimally, yielding more accurate prediction results. Unlike the linear approach, this method also utilizes some degree of dependence on other factors, which, from practical application of this method in the outlined case study, might not reflect accurate observations [12].

2.2 Load Flow Analysis

In ideal case system models, energy sources are defined as either an ideal voltage or an ideal current power supply; in general, loads are referred to as impedances. An ideal voltage source is capable of keeping constant the voltage level supplied to the network, regardless of the network's current draw. Similarly, an ideal current source preserves constant current irrespective of the voltage level. Therefore, for linear circuits, it holds that voltage, current, and impedance exhibit a one-to-one relationship, thus permitting methods like nodal voltage analysis to produce linear equations.

Power systems have different operating boundaries. The generators have certain boundaries within which they can operate in terms of power and voltage. The loads are specified in terms of what power has to be supplied at which voltage level. If the load demand is set lower than the maximum limit of the source, only then power supply be fulfilled. Even though the elements in the network might still be considered to behave linearly, the relationship in focus, between power sources and loads, deviates from linearity. Therefore, if the set of equations defining the circuit in consideration is based on power parameters, the outcome will be a set of equations that are nonlinear and need particular methods to solve them [13].

2.3 Power System Reliability

How reliably a power system functions depends upon one of its components called reserve margin (RM). RM refers to the spare capacity set aside when the total generation capacity surpasses, even accounting for reserves, and peak load is reached. Also, how much load a system can handle is called load a system can have instead of describing the system by it.

There are various approaches to determining the criteria for reserve margin, but in general, it serves as an indicator of the adequacy of generation capacity to meet peak demand. Reserve margin estimation also takes into account the potential consequences that may arise in the event of a power supply shortage within the system [14].

3. Methods

This research involves the implementation of peak load forecasting, simulation with trialand-error experiments, and power system evaluation to plan additional power plants in the BatamBintan system. PowerFactory 2022 is used to conduct all simulations due to its capability for complex network modeling and scenario examination. The stages of the research are as follows:

3.1 Historical Data Collection

The annual peak load data for the Batam-Bintan system was collected from system reports, and it was found that the highest peak load in 2024 reached 675 MW out of a generating capacity of 871.9 MW. Additionally, peak load growth data from 2017 to 2024 was collected to support the load projection.

3.2 Peak Load Forecasting up to 2030

Future load projections are conducted by analyzing historical trends using a second-order polynomial regression method with the aid of Microsoft Excel software. In this study, polynomial regression was chosen due to the simplicity of the model, the limitations of historical data and its ability to represent non-linear trends commonly occurring in medium-term load growth. This method has proven effective in several studies, including when combined with predictor variable selection through sensitivity analysis to improve prediction accuracy [15][16][17].

3.3 Load Flow Simulation

DIgSILENT PowerFactory 2022 models the Batam-Bintan network, which includes undersea cables and 150 kV high-voltage overhead transmission lines that connect the islands. Load flow simulation is used to analyze voltage distribution on buses, current on lines, and system losses. The results identify buses with low voltage or substations with overloaded transformers. The load flow method in DIgSILENT PowerFactory 2022 has proven capable of handling complex systems, as well as supporting contingency analysis and comprehensive system operation evaluation [18][19].

3.4 Optimal Generator Placement

For distributed generation (DG), optimal locations were determined at 20 kV busbars associated with substation transformers operating near or above their rated limits under projected 2030 loads. In parallel, the planning of centralized generation (CG) units involved two largecapacity plants, one each on Batam and Bintan islands. These units were connected to existing 150 kV substation busbars, with siting decisions based on minimum system power losses. The objective function of the optimal DG placement (1) and with constraint (2) is as follows:

$$min\ F = \sum_{i=1}^{n} x_i \tag{1}$$

$$x_i = 1\ if\ Loading_i \geq 80\% \tag{2}$$

where:
x_i : 1 is the transformer i is selected as a DG placement,
x_i : 0 otherwise,
$Loading_i$: the actual loading percentage relative to the capacity of transformer i

The objective function of the optimal CG placement (3) is as follows:

$$minF = P_{loss}(x) \tag{3}$$

where:
P_{loss}: total active power loss in the system (MW)
x: variable representing the bus location where CG is installed

3.5 Optimal Generation Capacity Sizing

The iteratively determined generation capacity and the reserve margin requirement of 35% is in line with the planning standards. Each additional capacity proposal was checked with load flow simulations to ensure compliance with voltage, current, and capacity limitations. Centralized generators were modeled as big units, while distributed generators were added in increments of 20 MW based on portions of substation transformer load. The objective was to lower transformer loading to less than 80%, thus ensuring the transformer was not overloaded. The total installed capacity of centralized and distributed generators was adjusted to achieve the 35% reserve margin by 2030. The objective function of the optimal DG capacity (4) and with constraint (5) is as follows:

$$minF = \sum_{i=1}^{n} y_i \tag{4}$$

$$\begin{gathered} \frac{L_i - 20.y_i}{C_i} < 0.8\ \forall i \epsilon \left\{ i : \frac{L_i}{C_i \geq 0.8} \right\} \\ y_i \epsilon Z_{>0} \end{gathered} \tag{5}$$

where:
y_I: number of DG units installed at substation i
L_i: initial load at substation i (in MW)
C_i: rated capacity of the transformer at substation i (in MW)

The objective function of the optimal CG capacity (6) and with constraint (7) is as follows:

$$minF = \left| \frac{P_{CG} + P_{DG}}{P_{peak}} \times 100\% - 35\% \right| \quad (6)$$

$$\%loading \leq 50\% \quad (7)$$

where:
P_{peak}: system peak load (MW)
P_{DG}: total installed DG capacity (MW)
P_{CG}: planned CG capacity (MW)
$\%loading$: the percentage of line loading

3.6 System Performance Evaluation

In relation to the proposed generation units, a detailed system-wide load flow analysis was performed to evaluate the impacts on reliability and the operational integrity of the entire system. In the 2025–2027 scenario, only the existing generation fleet and distributed generators were utilized, with their sizes adjusted to maintain substation transformer loads below 80%. In the 2028–2030 scenario, projected additional demand was addressed with optimized distributed generation and additional centralized generators to meet the remaining demand and achieve the reserve margin target.

The study examined the integration impacts with respect to load flow and system losses which included monitoring voltage profiles at every bus, the line loading conditions, and total system losses after generator integration. Greater focus was placed on the operational efficiency of the system, identifying critical thresholds such as out-of-range voltages, line overloading, and other extreme values. The intention for this stage was to ascertain that the decisions made during planning will ensure that system reliability, operational compliance, and efficiency metrics are sustained during the planning years up to 2030.

Within this framework, optimal system is understood as the balance between all iterative planning steps performed provided all technical and legal stipulations are met. These include:

1. transformer loading being less than 80%,
2. achievement of a 35% reserve margin,
3. adherence to the line loading rule whereby CG injection must not exceed 50% of the conductor's loading capacity.
4. All voltage profiles across the system remain within standard acceptable limits as defined by SPLN standards,
5. No overloading occurs in all grid component.

The system is deemed optimal once these conditions have been satisfied, beyond which no additions of generation are made.

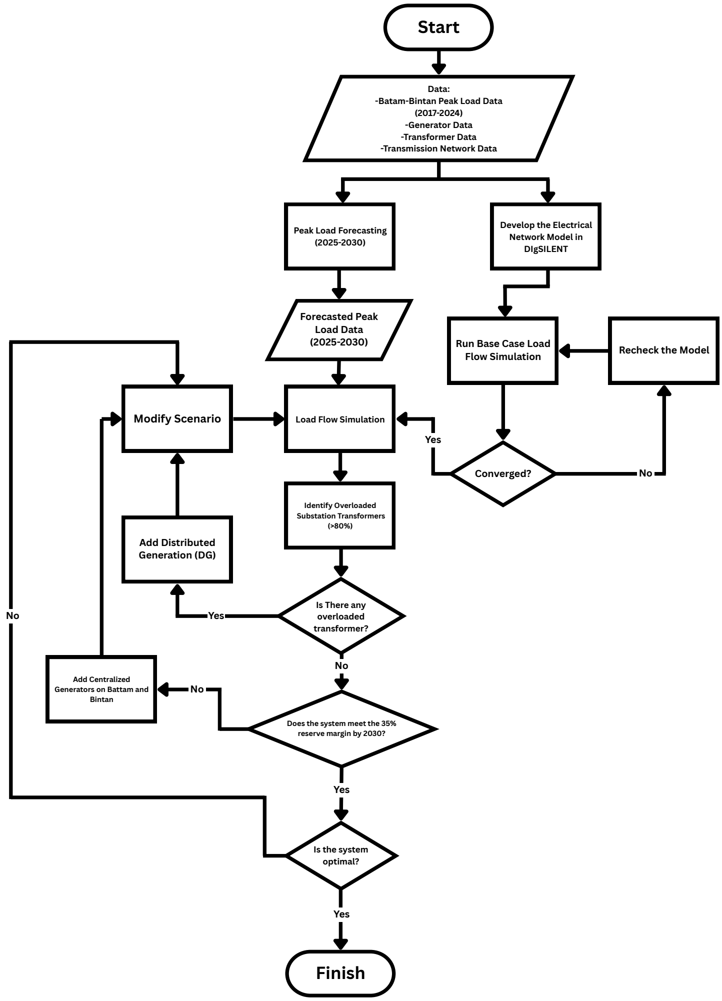

Figure 1. Research flowchart

4. Results & Discussion

4.1 Batam-Bintan Power System Condition

The Batam–Bintan power system consists of two separate electrical networks on Batam Island and Bintan Island, which are connected by a 150 kV overhead transmission line and a submarine cable. The transmission system data for Batam and Bintan are provided in Tables 1 and 2.

Table 1. Transmission system data – Batam

Description	Value	Remarks
Transformer Capacity	870	MVA
Number of Substations	11	Unit
Number of Substation Transformers	21	Unit
Transmission Line Length	200.9	km
Number of Transmission Towers	342	Unit

Table 2. Transmission system data – Bintan

Description	Value	Remarks
Transformer Capacity	310	MVA
Number of Substations (GI)	5	Unit
Number of Substation Transformers	9	Unit
Transmission Line Length	189.08	km
Number of Transmission Towers	273	Unit

Table 3. Transformer capacity data

Transformer Name	Capacity (MVA)
1 O	60
1 I	60
1 H	60
1 G	30
1 P	30
1 E	30
1 K	30
1 D	30
1 B	30
1 C	30
1 N	30
1 F	60
1 J	30
1 L	30
2 O	60
2 I	60
2 H	60
2 G	30
2 P	30
2 B	60

Transformer Name	Capacity (MVA)
2 C	30
2 N	30
2 J	60
2 A	30
3 I	60
3 J	30
4 I	60
L	10
1 M	30
2 M	30

Considering the system state in the year 2024 and before incorporating new generating units, a simulation was performed with DIgSILENT PowerFactory 2022. The results are summarized in Table 4.

Table 4. Existing power system simulation results (2024)

Description	Value	Remarks
Net Available Capacity	871.9 MW	
Total Load	675.03 MW	
Total Power Loss	7.63 MW	
Reserve Margin	29.1 %	
Highest Voltage (150 kV)	150 kV	Substation GI D
Lowest Voltage (150 kV)	146.9 kV	Substation GI P
Highest Power Loss on a Transmission line	0.6 MW	Transmission line N-O #1 & #2
Highest Transmission line Current Loading	774 A	Transmission line A-B #1 & #2

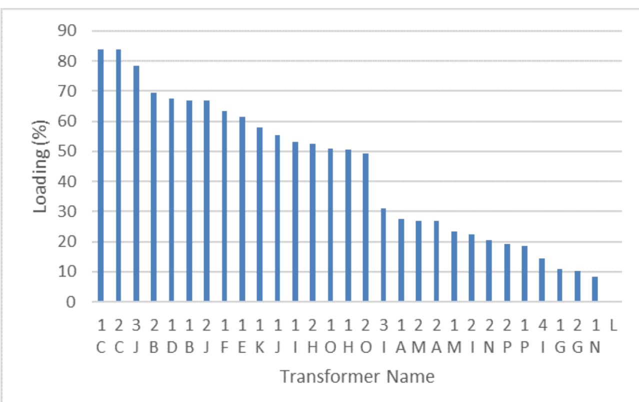

Figure 2. Percentage of transformer load at the substation in 2024

4.2 Peak Load Forecasting of The Batam-Bintan Power System

To estimate the peak load for the power system of Batam–Bintan, the historical annual peak demand data from 2017 to 2024 was utilized. To capture the non-linear trend of load growth, a second-order polynomial regression technique was applied. The calculations were performed in Microsoft Excel, which allows simple modeling of historical trends and graphing of future values.

The accuracy assessment of the forecasting model was carried out using the Mean Absolute Percentage Error (MAPE) approach. The evaluation yielded a MAPE value of 2%, significantly below the commonly accepted threshold of 10 percent. This indicates a highly accurate model that would, in fact, work well for medium to long-term planning of power systems.

Based on the forecasting results presented in Table 5, the projected peak load demand will grow remarkably from 675.2 MW in 2024 to 749.7 MW in 2025. The demand is expected to keep increasing and reach about 1322.1 MW by 2030. This profound increase is a consequence of the energy consumption patterns and requires a specific average annual growth rate. Additionally, industrial development, population increase, and expansion of economic areas in the BatamBintan region will also facilitate this growth.

Table 5. Forecasted peak load of the Batam–Bintan power system

Batam-Bintan Peak Load		
Year	**Peak Load (MW)**	**Forecast (MW)**
2017	416.4	
2018	444.4	
2019	458.8	
2020	465.4	
2021	481.2	
2022	538.1	
2023	603.3	
2024	675.2	
2025		749.7
2026		841.2
2027		944.2
2028		1058.7
2029		1184.7
2030		1322.1
MAPE		2%

4.3 Results of Load Flow Analysis for The Batam-Bintan Power System

4.3.1 Simulation of Existing Generation Capacity under 2025 Peak Load Condition

In this simulation, the existing generation capacity (2024) remains the same as the existing condition, while the load follows the peak load forecast for 2025.

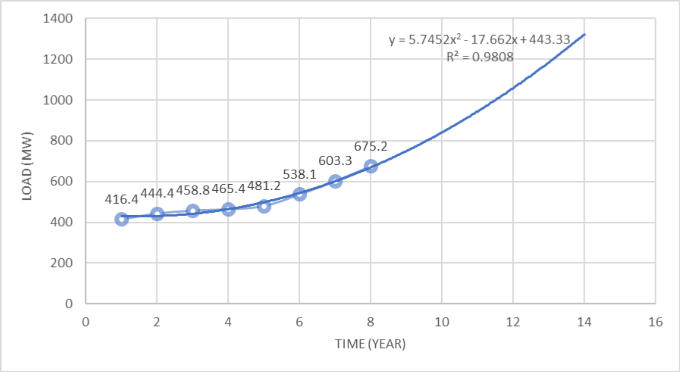

Figure 3. Forecasted peak load curve of the Batam–Bintan power system

The simulation results show that the available generation capacity is still sufficient to serve the peak load in 2025. As shown in Figure 4 and 5, if PLTU XYZ #1 is disconnected due to a fault or maintenance, then PLTU XYZ #2 internally becomes overloaded, and conversely, if PLTU XYZ #2 is not operational, then PLTU XYZ #1 internally becomes overloaded. A series of simulations will result in a transformer load of 93.78% for transformers #1 and #2 at Substation GI C and 87% for transformer #3 at Substation GI J. According to the Indonesian National Standard (SNI), the transformer load should not exceed 80%, thus violating the operational limits.

Table 6. Load flow results for the 2025 scenario with existing infrastructure

Description	Value	Remarks
Net Available Capacity	871.9 MW	
Total Load	749.73 MW	
Total Power Loss	8.22 MW	
Reserve Margin	16.3 %	
Highest Voltage (150 kV)	150 kV	Substation GI D
Lowest Voltage (150 kV)	146.5 kV	Substation GI P
Highest Power Loss on a Transmission Line	0.6 MW	Transmission line N-O #1 & #2
Highest Transmission line Current Loading	756 A	Transmission line A-B #1 & #2

4.3.2 Power Generation Expansion Plan for 2025-2030

Power plants are expanded considering the construction schedule and the goal of a 35% reserve margin by the year 2030. As shown in Table 7, capacity additions are implemented incrementally through both centralized generation units and distributed generation (DG). Distributed generation can be built more rapidly than centralized power plants. [20].

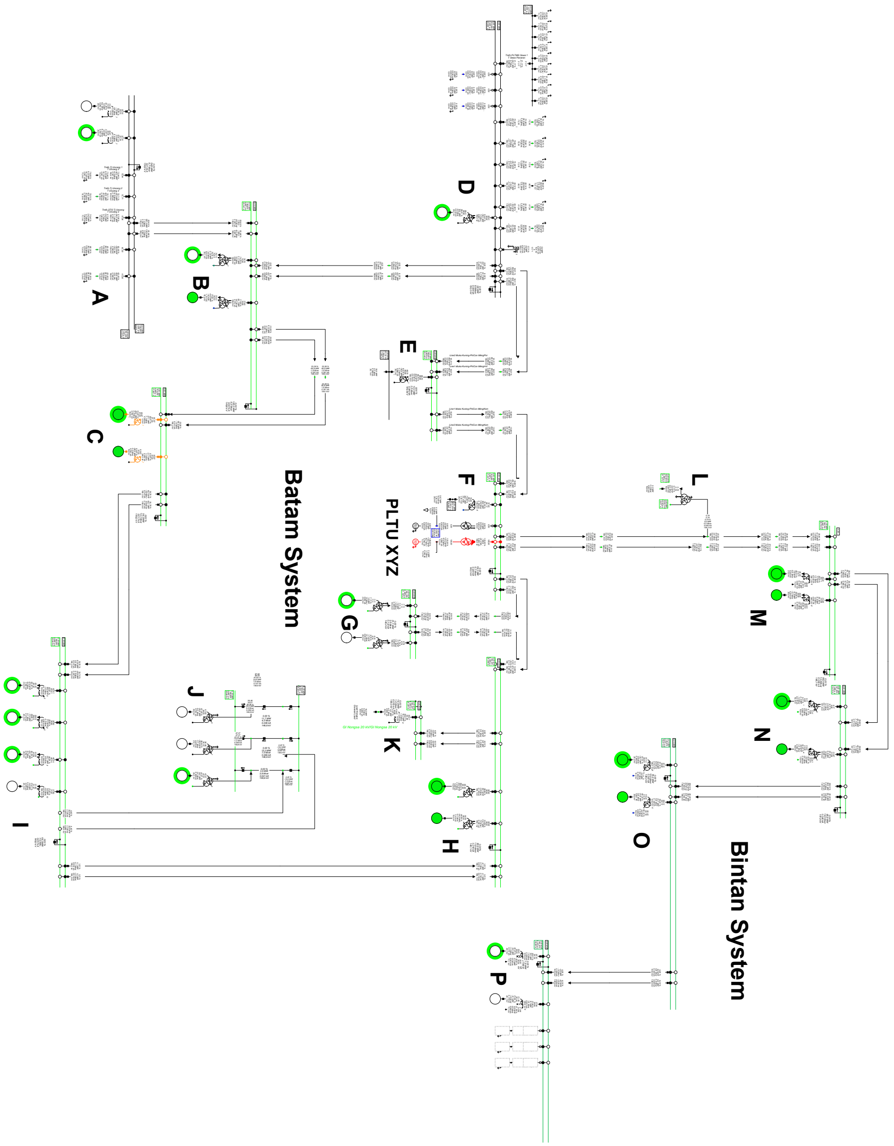

Figure 4. Load flow simulation with PLTU XYZ #1 out of service

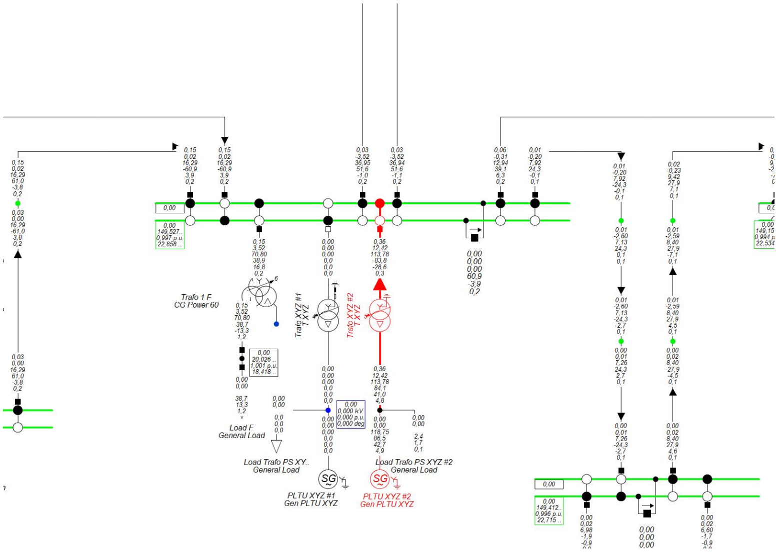

Figure 5. PLTU XYZ #2 overload if PLTU XYZ #1 out of service

Table 7. Power Plant Expansion Plan (2025–2030)

Year	Peak Load (MW)	Net Available Capacity (MW)	Additional Generation Capacity (MW)	Reserve Margin
2024	675.2	871.9		29.1 %
2025	769.7	1191.9	260	54.9 %
2026	861.2	1371.9	220	59.3 %
2027	964.2	1451.9	100	50.6 %
2028	1078.7	1651.9	200	53.1 %
2029	1204.7	1811.9	160	50.4 %
2030	1342.1	1811.9		35 %
TOTAL			940	

4.3.3 Optimization of DG Siting and Sizing Based on Transformer Loading Analysis

The location of distributed generation (DG) units is focused on areas with concern where the loading of the substation transformers reaches 80% or more, according to the power flow simulation for the year 2030. It is planned to add a total of 460 MW of DG capacity in the Batam system and 120 MW in the Bintan system. These additions will be implemented systematically during the years 2025–2027. The site for each DG unit is determined using the transformer loading parameters, which are near, at, or exceed the 80% mark.

Table 8. Siting and sizing of distributed generation units in the Batam system

Transformer Loading in Batam System by 2030			
Transformer Name	**Transformer Loading (%)**	**DG Addition (MW)**	**COD Year**
1 C	172.6		
2 C	172.6	40	2025
3 J	161.2	40	2025
2 B	141.5	40	2025
1 B	135.2	20	2025
1 F	129.1	40	2026
1 E	124.1	20	2026
1 K	115.6	20	2026
1 I	115.6	40	2026
1 J	161.2	40	2026
3 I	109.86	60	2026
2 H	114.6	40	2027
1 H	126.1	40	2027
2 I	**83.2**	**20**	2027
Total		**460**	

Table 9. Siting and sizing of distributed generation units in the Bintan system

Transformer Loading in Bintan System by 2030			
Transformer Name	**Transformer Loading (%)**	**DG Addition (MW)**	**COD Year**
1 O	98.4	60	2025
2 O	95.1	60	2025
Total		**120**	

4.3.4 Strategic Placement and Sizing of Centralized Generation Unit

Simulations conducted for both Batam and Bintan Islands determined the locations of the centralized power plants at each substation. The power flow simulations determined the final placements to be the ones with the least power losses. The model includes a centralized power plant of 200 MW capacity on Bintan Island since the island currently depends 100% on Batam's power system. Furthermore, Bintan has the Galang Batang Special Economic Zone (SEZ) which will substantially increase the demand for electricity in the future. The proposal also includes a 160 MW centralized plant on Batam Island to meet the increasing energy demand. As illustrated in Table 10, substation GI P was selected for Bintan system as the lowest power loss was 7.32 MW, while for the Batam system with loss of 10.05 MW, substation GI B was chosen.

Table 10. Power loss analysis for candidate centralized generation locations

Location	System Name	Losses (MW)	Proposed Generation Capacity (MW)
GI M	Bintan	8.38	200
GI P		7.32	
GI D	Batam	10.65	160
GI B		10.05	
GI A		10.68	

4.3.5 Pre-Expansion Voltage Profile of the 150 kV Busbars in the Batam-Bintan System

As of the year 2024, the Batam–Bintan interconnection system's 150 kV busbar voltages across the main substations are shown in Figure 6. All measured voltage values remained within the acceptable limits specified by SPLN standards, which allow a deviation of +5% to −10% from nominal voltage. The operation of the system, in general, exhibited balanced, stable operating conditions, as all the measured values were within tolerable limits.

Nevertheless, there was significant high voltage inconsistency at the Bintan region's four substations, GI M, GI N, GI O, and GI P, which showed lower voltage compared to the Batam system.

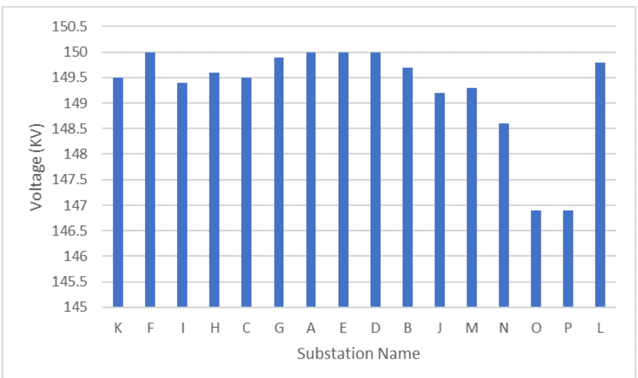

Figure 6. Voltage profile of 150 kV busbars in 2024

4.3.6 Expansion Voltage Profile of the 150 kV Busbars in the Batam-Bintan System

After the addition of generators, the voltage values of the 150 kV busbars in the BatamBintan system are shown in Figure 6. The busbars were analyzed using the power flow analysis conducted in DIgSILENT PowerFactory 2022.

As the figure shows, the values are in compliance with SPLN standards with small deviations yearly. Substations (GI) like GI F, GI G, GI A, GI E, and GI D maintained a nominal voltage level of 150 kV throughout the period of the observation, which indicates a stable supply of electricity to the system. This, moreover, shows the performance of the system at these key points in the grid. Within the Bintan system, substations like GI O, GI P, and GI N also showed marked improvement in the voltage profile, which indicates better voltage performance as a result of the new generation units commissioned in those substations, but the load on the Bintan system is not as high as the load on the Batam system, which causes this increase in voltage. In the 2028–2030 timeframe, the contour of the voltage curve changed slightly for the lower profile voltages for substations GI K, GI I, and GI C. The voltages still stayed within the required tolerance range, so this could be due to the increased system load over time. In general, the 150 kV Batam–Bintan interconnected system exhibits strong power system voltage quality throughout the entire projection period.

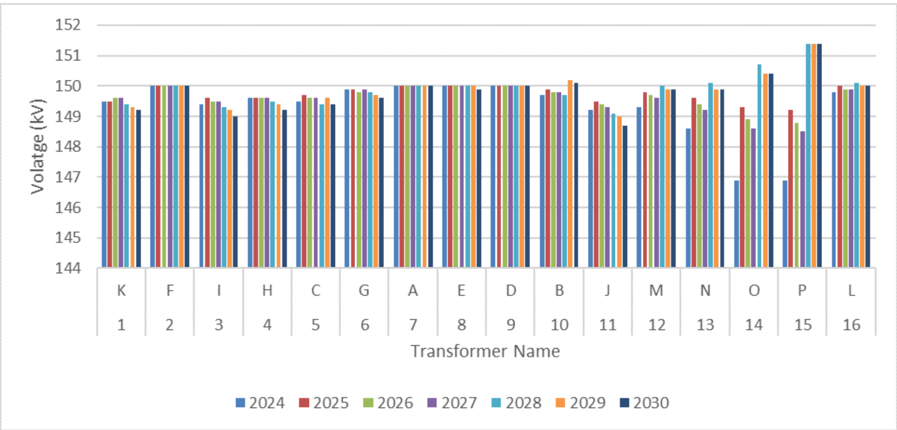

Figure 7. Voltage profile of 150 kV busbars in 2024-2030

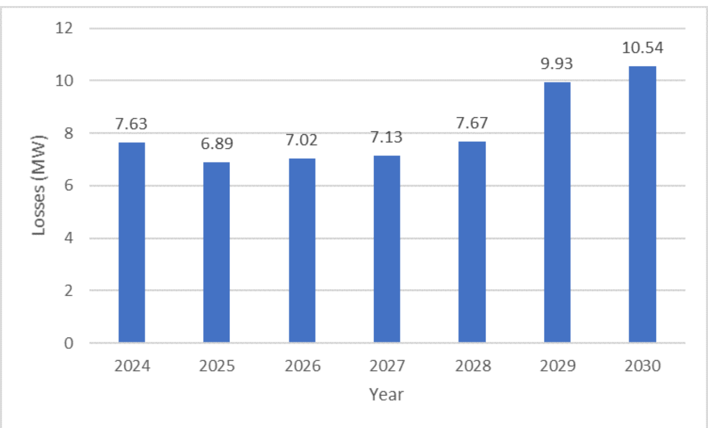

Figure 8. Losses trend from 2024 to 2030

Figure 8 illustrates the interconnection system losses of the Batam–Bintan power interconnection for the years 2024 and 2030 in megawatts (MW). The figure indicates the losses in power as tending to rise with an increase in consumption. In 2024, the system's peak load is recorded at 675.2 MW with corresponding power losses of 7.63 MW. As the integration of distributed generation (DG) helped reduce losses within the system, power losses fell below the 7 MW mark in 2025 to 6.89 MW, then increased gradually until 2027 alongside the growing peak load. From 2028 to 2030, however, power loss dramatically escalated due to the addition of large centralized power plants compounded by the yearly increase in peak demand.

5. Conclusion

The evaluation performed in this study indicates that the Batam-Bintan power system suffers from problems such as high load growth, unreliable dependence of the Bintan system on the Batam system, and scanty reserve capacity. Demand power estimation indicates that by the year 2030, with peak load growth projections using polynomial regression and power flow simulations with DIgSILENT PowerFactory 2022, power demand is bound to hit 1,322.1 MW. Furthermore, to maintain a minimum reserve margin of 35%, additional generation capacity of 940 MW is required, 580 MW from DG and 360 MW from centralized power plants. The strategic siting of power plants relative to transformer substation loads mostly reduces the overload on PLTU XYZ and improves the voltage quality of the system. The additional power plant scenario evaluation results indicate that system performance can be sustained within the accepted technical standards while lowering fault or maintenance outage risk.

References

[1] M. A. Syarief. "Sistem Informasi Laboratorium Teknik Elektro UMY Berbasis Web dengan Framework Laravel Crudbooster". Skripsi. Universitas Muhammadiyah Yogyakarta, 2017.

[2] H. Eteruddin, D. Setiawan, and P. P. P. Hutagalung. "Evaluasi Jaringan Tegangan Menengah 20 kV pada Feeder 7 Peranap PT. PLN Persero Rayon Taluk Kuantan". In: *Seminar Nasional Pakar*. 2020, pp. 1.4.1–1.4.6.

[3] R. Billinton and R. N. Allan. "Power System Reliability in Perspective". In: *IEEE Journal of Electronics Power* 30 (1984), pp. 231–236.

[4] R. Gianto and H. Priyatman. "Optimalisasi Peralatan Kontrol Sistem Tenaga Listrik untuk Meningkatkan Kestabilan Sistem Berukuran Besar". In: *Transmisi* 17 (Oct. 2015), pp. 218–225.

[5] Y. Gupta et al. "Optimal DG Allocation and Volt-Var Dispatch for a Droop-Based Microgrid". In: *IEEE Transactions on Smart Grid* 12.1 (2021). DOI: 10.1109/TSG.2020.3017952.

[6] S. Kaur, G. Kumbhar, and J. Sharma. "A MINLP Technique for Optimal Placement of Multiple DG Units in Distribution Systems". In: *International Journal of Electrical Power & Energy Systems* 63 (2014). DOI: 10.1016/j.ijepes.2014.06.023.

[7] E. Mahdavi et al. "Reconfiguration of Distribution Networks with Simultaneous Allocation of Distributed Generation Using the Whale Optimization Algorithm". In: *Energies* 16.12 (2023), p. 4560. DOI: 10.3390/en16124560.

[8] K. S. El-Bidairi et al. "Optimal Sizing of Battery Energy Storage Systems for Dynamic Frequency Control in an Islanded Microgrid: A Case Study of Flinders Island, Australia". In: *Energy* 195 (2020), p. 117059. DOI: 10.1016/j.energy.2020.117059.

[9] A. K. ALAhmad. "Voltage Regulation and Power Loss Mitigation by Optimal Allocation of Energy Storage Systems in Distribution Systems Considering Wind Power Uncertainty". In: *Journal of Energy Storage* 59 (2023), p. 106467. DOI: 10.1016/j.est.2022.106467.

[10] Q. Li et al. “Simulation and Modeling for Active Distribution Network BESS System in DIgSILENT”. In: *Energy Reports* 8 (2022). DOI: 10.1016/j.egyr.2022.01.113.

[11] R. P. Wijayanto. “Optimasi Perencanaan Pengembangan Pembangkit Listrik Jawa Bali Tahun 2015–2030 dengan Algoritma Genetika”. Tesis Magister. Fakultas Teknik, Universitas Indonesia, 2013.

[12] N. Amral, D. King, and C. S. Özveren. “Application of Artificial Neural Network for Short Term Load Forecasting”. In: *Proc. Universities Power Engineering Conf. (UPEC)*. 2008. DOI: 10.1109/UPEC.2008.4651477.

[13] S. Sunardiyo. “Studi Analisis Aliran Beban (Load Flow) Sistem Tenaga Listrik Implementasi pada Jaringan Kelistrikan di UNNES”. In: *Teknik-UNISFAT* 4.2 (2009), pp. 117–128.

[14] Arash Shabani et al. “Optimal generation expansion planning in IPP presence with HCGA”. In: *2008 IEEE 2nd International Power and Energy Conference*. IEEE. 2008, pp. 143–147.

[15] K. Dab et al. “Sensitivity Analysis of Exogenous Variables for Load Forecasting Using Polynomial Regression”. In: *Proc. IECON*. 2019, pp. 2560–2565. DOI: 10.1109/IECON.2019.8927167.

[16] G. De Nicolao et al. “Short-Term Load Forecasting: A Power-Regression Approach”. In: *Proc. PMAPS*. 2014, pp. 1–6. DOI: 10.1109/PMAPS.2014.6960648.

[17] N. Abu-Shikhah et al. “Medium-Term Electric Load Forecasting Using Multivariable Linear and Non-Linear Regression”. In: *Smart Grid and Renewable Energy* 2 (2011), pp. 126–135. DOI: 10.4236/SGRE.2011.22015.

[18] J. Roldan-Fernandez et al. “Modelling of Transmission Systems Under Unsymmetrical Conditions and Contingency Analysis Using DIgSILENT PowerFactory”. In: *PowerFactory Applications for Power System Analysis*. 2014, pp. 27–59. DOI: 10.1007/978-3-319-12958-7_2.

[19] R. Villena-Ruiz et al. “Learning Load Flow Analysis in Electric Power Systems: A Case Study in PowerFactory”. In: *Proc. 45th MIPRO Conference*. 2022, pp. 1357–1362. DOI: 10.23919/MIPRO55190.2022.9803465.

[20] Y. U. Farihah. “Optimasi Penempatan dan Kapasitas Distributed Generation Menggunakan Metode Differential Evolution untuk Meminimalkan Rugi Daya”. Tugas Akhir. Surabaya: Institut Teknologi Sepuluh Nopember, 2015.