International Journal of Advances in Engineering and Management (IJAEM)
Volume 8, Issue 1 Jan. 2026, pp: 401-410 www.ijaem.net ISSN: 2395-5252

Operating Condition Analysis of the 110kv Power Grid In The Tra Vinh Area Using Power world Simulator

Thanh Hien Nguyen[1], Thi Thu Thuy Bui[2]
[1,2] *Faculty of Electrical and Electronic Engineering, School of Engineering and Technology, Tra Vinh University, Vietnam*

Date of Submission: 12-01-2026 Date of Acceptance: 28-01-2026

ABSTRACT

This paper presents the results of an operating condition analysis of the 110kV power grid in the Tra Vinh area using PowerWorld Simulator in order to evaluate the current operating status and identify potential risks such as overloading, voltage drop, and power losses. The power network model is developed based on actual system data, allowing detailed investigation of normal operating conditions and various contingency scenarios.Simulation results indicate that the existing network generally maintains acceptable voltage stability and loading levels under normal operating conditions. However, in contingency scenarios involving transformer outages at TV2(T8) or HT(T11), the transformers TV2(T7) and HT(T12) experience severe overloading. In particular, the simultaneous outage of transmission lines HT(172)–DT(172) and HQ(172)–DT(174), together with the outage of transformer TV2(T8), represents the most critical scenario, causing local overloads, significant voltage drops, and a substantial reduction in supply reliability, which necessitates the shedding of important loads. Based on these findings, the paper proposes operational reconfiguration, reactive power compensation, and controlled load shedding solutions to optimize system operation, reduce losses, and enhance the reliability and efficiency of the 110kV Tra Vinh power grid.

Keywords: Tra Vinh 110kV power grid, operating condition simulation, voltage stability, overloading, power losses, reactive power compensation, PowerWorld Simulator.

I. INTRODUCTION

In recent years, electricity demand in Tra Vinh Province has increased rapidly due to the strong development of industry, commerce, and residential areas. The 110kV power grid plays a crucial role in transmitting and distributing electrical energy to 22kV substations throughout the region. However, uneven load growth among different areas has caused several transmission lines and transformers to operate close to or beyond their permissible limits, especially under transformer outage conditions. This situation places increasingly stringent requirements on the safe, efficient, and reliable operation of the 110kV power grid.

Practical operating experience shows that the Tra Vinh 110kV network has exhibited local overloading on several transformers and transmission lines, voltage drops at remote buses, and significant power losses during peak load periods. These problems become more severe when contingencies occur, reducing supply reliability and directly affecting critical local loads. Therefore, a comprehensive assessment of the operating conditions under both normal operation and contingency scenarios is essential for system operation, planning, and future network development.

Currently, power system simulation software such as PowerWorld Simulator enables detailed network modeling and performs power flow analysis to evaluate voltage profiles, power losses, and loading capability under various scenarios. However, in-depth studies on the 110kV power grid in Tra Vinh Province remain limited and do not fully reflect typical contingency situations. Therefore, this paper focuses on analyzing representative contingency scenarios and proposes operational solutions for the Tra Vinh 110kV power grid using PowerWorld Simulator to evaluate the current operating status, identify technical bottlenecks, and propose optimal solutions to reduce losses and enhance supply reliability, thereby improving overall system performance.

II. LITERATURE REVIEW

Many domestic and international studies have applied PowerWorld Simulator to analyze the operating conditions of high-voltage power networks. Schavemaker, P., & Van der Sluis, L. [1] presented the theoretical foundations of power system analysis and control, providing an important basis for studies related to power flow, line and transformer losses, and voltage behavior at system buses. Tran, H. T. et al. [2] applied the Artificial Bee Colony (ABC) algorithm to solve the Optimal

International Journal of Advances in Engineering and Management (IJAEM)
Volume 8, Issue 1 Jan. 2026, pp: 401-410 www.ijaem.net ISSN: 2395-5252

Power Flow (OPF) problem for the Ben Tre power system, aiming to minimize the total fuel cost of generation units. The results demonstrated that the ABC method is effective and suitable for medium-scale power systems. Ali, Y. [3] conducted a comparative analysis of load flow simulation results for a 10-bus test system using PowerWorld Simulator, ETAP, and PSS. The study highlighted the importance of power flow simulation tools in managing and operating complex power systems, ensuring safe, reliable, and efficient system performance. Wen, H. [4] investigated power flow analysis for a 110kV network model using PowerWorld Simulator combined with the Newton–Raphson method. The simulation results enabled intuitive visualization of power distribution and supported improved power allocation and operational optimization. Truong, T. T. U.et al. [5] analyzed the impact of wind power plant operation on voltage stability of the 110kV grid in Quang Tri Province using PV (Power–Voltage) and QV (Reactive Power–Voltage) curves with DIgSILENT software. The study identified critical voltage stability buses and proposed technical solutions to enhance voltage stability. In addition, Nguyen. T. H. [6] applied PowerWorld Simulator for power flow analysis and showed that the system parameters displayed in the software were consistent with theoretical calculations, confirming the accuracy and reliability of this simulation tool for practical power system studies.

According to the operational report of EVNSPC *(Vietnam Electricity Southern Power Corporation)*, the load of the 110kV power grid in Tra Vinh Province is forecast to increase significantly in 2025, especially during peak hours due to the growing electricity demand. Therefore, analyzing and evaluating the operating conditions of the Tra Vinh 110kV power grid is essential to optimize system operation, improve management efficiency, reduce power losses, and enhance supply reliability. This forms the scientific and practical basis for the research model presented in this paper.

III. RESEARCH METHODS

A. Theoretical Background

Line resistance is calculated as:

$$R = r_0.L = \frac{\rho}{F}.L \quad (\Omega) \quad (1)$$

Where $r_0$is theunit line resistance (Ω/km), L is theline length (km), ρ is the resistivity of conductor material(Ω.mm^2/km), and F is the conductor cross-sectional area (mm^2)

The line reactance is calculated as:

$$X = x_0.L = (0{,}144 \cdot \lg(D_{tb}/r) + 0{,}016).L \quad (\Omega) \quad (2)$$

Where x_0 is the line reactance per unit length (Ω/km), D_{tb} is the average distance between phase conductors (mm), and r is the conductor radius (mm).

The geometric mean distance between phases for horizontal configuration is calculated as:

$$D_{tb} = \sqrt[3]{D.D.2D} = 1{,}26.D \quad (mm) \quad (3)$$

Total line susceptanceis calculated as:

$$B = b_0.L = L.(2.\pi.f.C_0) = L.\left(\frac{7{,}54}{\lg(D_{tb}/r)} \cdot 10^{-6}\right) (S) \quad (4)$$

Where b_0 is the line susceptance per unit length (S/km) and C_0 is the line capacitance per unit length at the system frequency of 50 Hz.

The resistance of a three-phase two-winding transformer is calculated as:

$$R_T = \frac{P_k.10^{-3}.U_1^2}{S_T^2} (\Omega) \quad (5)$$

Where P_k is the short-circuit active power loss (kW), U_1 is the transformer primary voltage (kV), and S_T is the rated transformer capacity (MVA).

The transformer impedance (RT<<ZT) is calculated as:

$$X_T \approx Z_T \approx \frac{U_k\%.U_1^2}{100.S_T^2} (\Omega) \quad (6)$$

WhereU_k% is the short-circuit voltage percentage.

The transformer conductance is calculated as:

$$G_T = \frac{P_0.10^{-3}}{U_1^2} (S) \quad (7)$$

WhereP_0 is the transformer no-load power loss (kW)

The transformer susceptance is calculated as:

$$B_T = \frac{I_0\%.S_T}{100.U_1^2} (S) \quad (8)$$

WhereI_0% is the transformer no-load current percentage.

The line impedance in per-unit (pu) is calculated as:

$$Z^* = (R + jX).\frac{S_{cb}}{U_{cb}^2} = R^* + jX^* \quad (9)$$

Where R and Xare the actual line resistance and reactance (Ω), $R^*$and X^* are the per-unit line resistance and reactance (pu), S_{cb} is the system base power (100 MVA), and U_{cb} is the base voltage at bus i (kV).

The line admittance in per-unit (pu) is calculated as:

$$Y^* = (G + jB).\frac{U_{cb}^2}{S_{cb}} \quad (10)$$

International Journal of Advances in Engineering and Management (IJAEM)
Volume 8, Issue 1 Jan. 2026, pp: 401-410 www.ijaem.net ISSN: 2395-5252

Where G and B are the line conductance and line susceptance (S), and G* and B* are the per-unit line conductance and susceptance (pu).
The transformer impedance in per-unit (pu) is calculated as:

$$\overset{*}{Z}_T = (R_T + jX_T).\frac{S_{cb}}{U_{cb}^2} = \overset{*}{R}_T + j\overset{*}{X}_T \quad (11)$$

Where R_T and X_T are the actual transformer resistance and reactance (Ω), and R^*_T and X^*_T are the per-unit transformer resistance and reactance (pu)
Transformer admittance in the per-unit system is calculated as:

$$Y_T^* = (G_T + jB_T).\frac{U_{cb}^2}{S_{cb}} = G_T^* + jB_T^* \quad (12)$$

Where G_T and B_T are the active conductance and reactive susceptance of the transformer (S), and G^*_T and B^*_T are the per-unit active conductance and reactive susceptance of the transformer (pu).
Voltage drop of the transmission line is calculated as:

$$\Delta\dot{U} = \frac{\hat{S}.Z}{\dot{U}} = \frac{(P-jQ).(R+jX)}{\dot{U}} = |\Delta U|\angle\varphi \quad (kV) \quad (13)$$

The sending-end voltage of the transmission line is calculated as:

$$\dot{U}_1 = \dot{U}_2 + \Delta\dot{U} = |U_1|\angle\varphi_1 \ (kV) \quad (14)$$

Power loss of the transmission line is calculated as:

$$\Delta\dot{S} = \frac{(P^2+Q^2).Z}{U_i^2} - jQ_c - jQ_{cc} (MVA) \quad (15)$$

The sending-end power of the transmission line is calculated as:

$$\dot{S}_1 = \dot{S}_2 + \Delta\dot{S} = P_1 + jQ_1 \quad (MVA) \quad (16)$$

The power loss of the transformer, including no-load loss and load loss, is calculated as:

$$\Delta\dot{S}_T = \Delta P_0 + j\Delta Q_0 + \Delta P_{cu} + j\Delta Q_{cu} \ (MVA) \quad (17)$$

The voltage drop of a power transformer is calculated as:

$$\Delta\dot{U}_T = \dot{U}_1 - \frac{U_{1n}}{U_{2n}}.\dot{U}_2 = |U_T|\angle\varphi \ (kV) \quad (18)$$

Where $U_1$is the bus voltage at the transformer primary side(kV), $U_2$is the bus voltage at the transformer secondary side (kV),$U_{1n}$is the rated primary voltage of the transformer (kV), U_{2n} is the rated secondary voltage of the transformer (kV), and $k_T$is the transformer ratio.
The percentage voltage drop of a power transformer is calculated as:

$$\Delta U\% = \frac{U_1^{'} - U_2}{U_{2n}} x100\% \quad (19)$$

Where $U_1^{'} = \frac{U_1}{k_T}$ is he primary-side voltage referred to the secondary side, $U_{2n}$is the rated secondary voltage of the transformer, $U_1$is the actual voltage at the transformer primary bus, and $U_2$is the actual voltage at the transformer secondary bus.
The percentage instantaneous power loss is calculated as:

$$\Delta P\% = \frac{\Delta P}{P_{truyen}}.100\% \quad (20)$$

The required capacitor reactive power is calculated as:

$$Q_C = P.(tg\varphi_1 - tg\varphi_2) \quad (MVAr) \quad (21)$$

Where $Q_C$is the capacitor reactive power (MVAr),P is the load active power (MW), $\varphi_1$is the power factor angle before compensation, and$\varphi_2$is the power factor angle after compensation.The Newton–Raphson (NR) method is applied to solve the load flow problem in order to determine bus voltages, power flows, and system losses.
The current injected at bus iii is calculated as:

$$\overset{*}{I}_i = \sum_{j=1}^{n} |Y_{ij}|.|U_j|\angle\theta_{ij} + \delta_j \quad (22)$$

The complex power at bus iii is calculated as:

$$\overset{*}{P}_i - j\overset{*}{Q}_i = \overset{*}{U}_i.\overset{*}{I}_i = |U_i|\angle -\delta_i.\sum_{j=1}^{n}|Y_{ij}|.|U_j|\angle\theta_{ij} + \delta_j \quad (23)$$

Where$Y_{ij}$is the bus admittance between buses i and j in per-unit (pu),$U_j$is the voltage at bus jin per-unit (pu),U_i and U_j are the voltage magnitudes at buses i and j in per-unit (pu), andθ_{ij}= θ_i.$\delta_j$is the phase angle difference.
The Newton–Raphson (NR) method linearizes the nonlinear power flow equations by a first-order Taylor series expansion around the current approximate solution. The power mismatches at iteration kkk are defined as:

$$\begin{bmatrix}\Delta P \\ \Delta Q\end{bmatrix} = \begin{bmatrix}J_1 & J_2 \\ J_3 & J_4\end{bmatrix}.\begin{bmatrix}\Delta\delta \\ \Delta|U|^*\end{bmatrix} \quad (24)$$

Where ΔP and ΔQ are the active and reactive power mismatches, and$\Delta\theta$ andΔU are thecorrections of voltage angles and voltage magnitudes, respectively.J_1, J_2, J_3 and $J_4$are the submatrices of the Jacobian matrix.
In power system operation and planning, the N-1 and N-2 criteria are used to assess system security and reliability. The N-1 criterion requires the system to remain within allowable limits after the outage of any single component, while the N-2 criterion requires acceptable operation following the

International Journal of Advances in Engineering and Management (IJAEM)
Volume 8, Issue 1 Jan. 2026, pp: 401-410 www.ijaem.net ISSN: 2395-5252

simultaneous outage of two components, allowing emergency control actions if necessary. These criteria help identify technical bottlenecks and provide a basis for improving reliability, optimizing operation, and supporting long-term power system planning.

B. Data Collection and Processing

The single-line diagram and parameters of the 110kV power network in Tra Vinh area consist of six 115/23kV substations (from T1 to T6) with a total installed capacity of 440MVA.

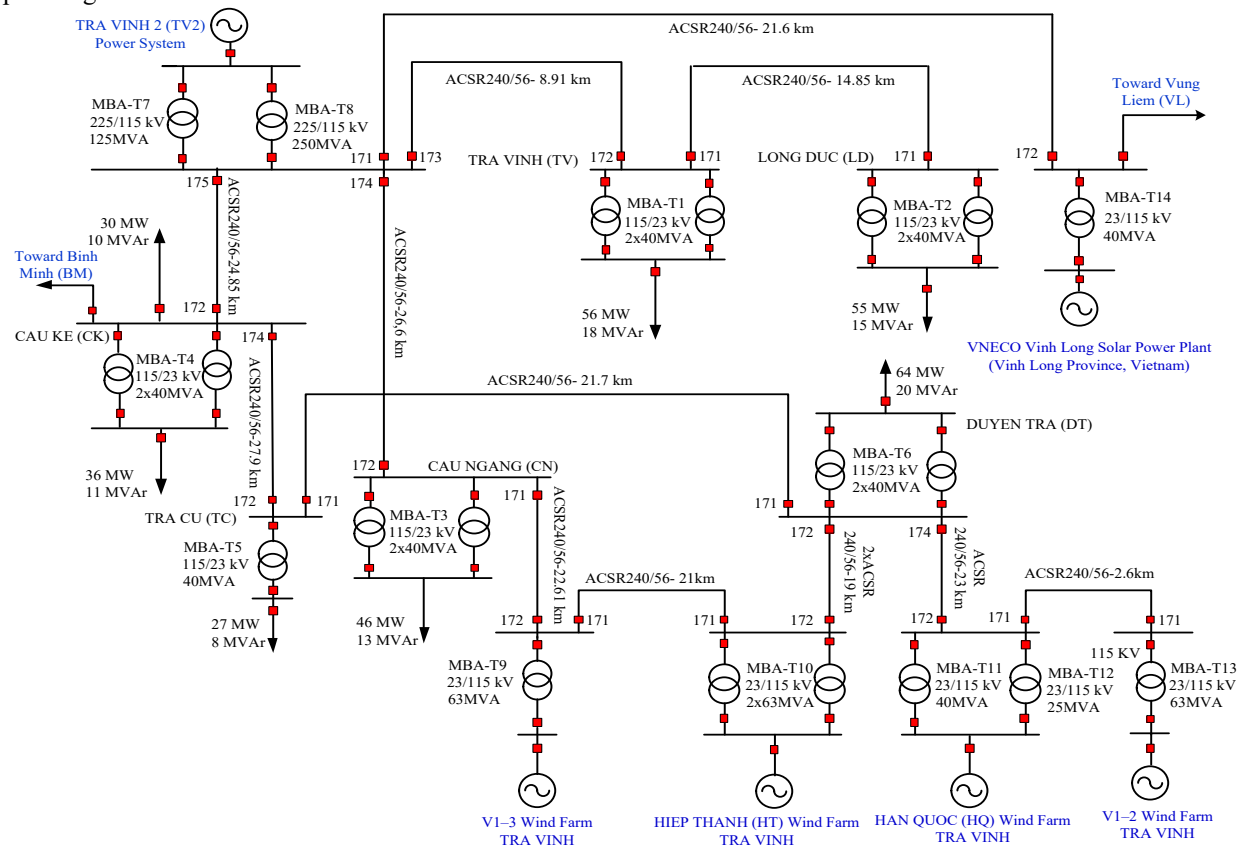

Fig. 1. Single-line diagram and parameters of the 110 kV power network in Tra Vinh area.

The parameters of the ACSR240/56 conductor used in the 110kV power grid in Tra Vinh area are presented in **Table 1**. The unit resistance r_0(Ω/km) is obtained from page 211 of reference [8], while the unit reactance x_0(Ω/km) and the unit susceptance b_0(S/km) are calculated using (2) and (4), respectively.

Table 1. Parameters of the ACSR240/56 conductor for the 110kV power grid in Tra Vinh area

Transmission line(**T/L**)	Length (km)	I_n (A)	r_0 (Ω/km)	x_0 (Ω/km)	$b_0.10^{-6}$ (S/km)
TV2(174) →CN(172)	26.6	664	0.1197	0.3114	3.6761
TV2(175) →CK(172)	24.85				
TC(172) →CK(174)	27.9				
DT(171)	21.7				
→TC(171)					
TV2(173) → TV(172)	8.91				
TV(171) →LĐ(171)	14.85				
VNECO(172) →TV2(171)	21.6				
V1-3(172) →CN(171)	22.61				
V1-3(171)→HT (171)	21				
V1-2(171)→HQ (171)	2.6				
HQ(172)	23				

International Journal of Advances in Engineering and Management (IJAEM)
Volume 8, Issue 1 Jan. 2026, pp: 401-410 www.ijaem.net ISSN: 2395-5252

Transmission line(T/L)	Length (km)	I_n (A)	r_0 (Ω/km)	x_0 (Ω/km)	$b_0.10^{-6}$ (S/km)
→ DT(174)					
HT(172)→DT(172)	19	1328	0.06	0.16	13.70

Transformer **(T/F)**Parameters in the Per-Unit (pu) system connected to the 110kV Power grid in the Tra Vinh area.

Table 2. Transformerparameters in per-unit (pu)

T/F	U_{1n}/U_{2n} (kV)	S_T (MVA)	R_T (pu)	X_T (pu)	G_T (pu)	B_T (pu)
TV2(T7)	225/115	125	0.0016	0.084	0.0004	0.0009
TV2(T8)	225/115	250	0.0006	0.042	0.0005	0.0013
TV(T1)	115/23	2x40	0.01	0.44	0.0003	0.0005
LĐ(T2)	115/23	2x40	0.01	0.44	0.0003	0.0005
CN(T3)	115/23	2x40	0.01	0.44	0.0003	0.0005
CK(T4)	115/23	2x40	0.01	0.44	0.0003	0.0005
TC(T5)	115/23	40	0.01	0.44	0.0003	0.0005
DT(T6)	115/23	40	0.01	0.44	0.0003	0.0005
V1-3(T9)	23/115	63	0.006	0.28	0.0003	0.0006
HT(T10)	23/115	2x63	0.006	0.28	0.0003	0.0006
HQ(T11)	23/115	40	0.009	0.44	0.0003	0.0005
HQ(T12)	23/115	25	0.02	0.7	0.0002	0.0004
V1-2(T13)	23/115	63	0.006	0.28	0.0003	0.0006
VNECO (T14)	23/115	40	0.009	0.44	0.0003	0.0005

The load power data at the 115/23kV substations at the annual peak load time in 2025, provided by the dispatching department of Tra Vinh Power Company (EVNSPC), are presented in **Table 3.**

Table 3. Peak load power of the electrical system in 2025

No.	T/F	S_T (MVA)	U_1/U_2 (kV)	P_{max} (MW)	Q_{max} (MVAr)
1.	TV(T1)	2x40	115/23	56	18
2.	LĐ(T2)	2x40	115/23	55	15
3.	CN(T3)	2x40	115/23	46	13
4.	CK(T4)	2x40	115/23	36	11
5.	TC(T5)	2x40	115/23	28	8
6.	DT(T6)	2x40	115/23	64	20

Based on the single-line diagram of the 110kV power grid in the Tra Vinh area, with conductor parameters presented in **Table 1**, transformer calculation data in **Table 2**, and peak load characteristics in **Table 3**, a system model is developed and simulated using PowerWorld Simulator. The simulation results are used to analyze power losses, evaluate voltage distribution at buses, and identify critical operating locations in the network. On that basis, appropriate operational solutions for transmission lines and substations are proposed to enhance system reliability and mitigate the risk of wide-area cascading failures.

C. Simulation Operating Scenarios

1. Normal operating condition under the peak load of 2025. The simulation results of the normal operating condition under the peak load in 2025 of the EVN power system are presented andanalyzed.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 8, Issue 1 Jan. 2026, pp: 401-410 www.ijaem.net ISSN: 2395-5252

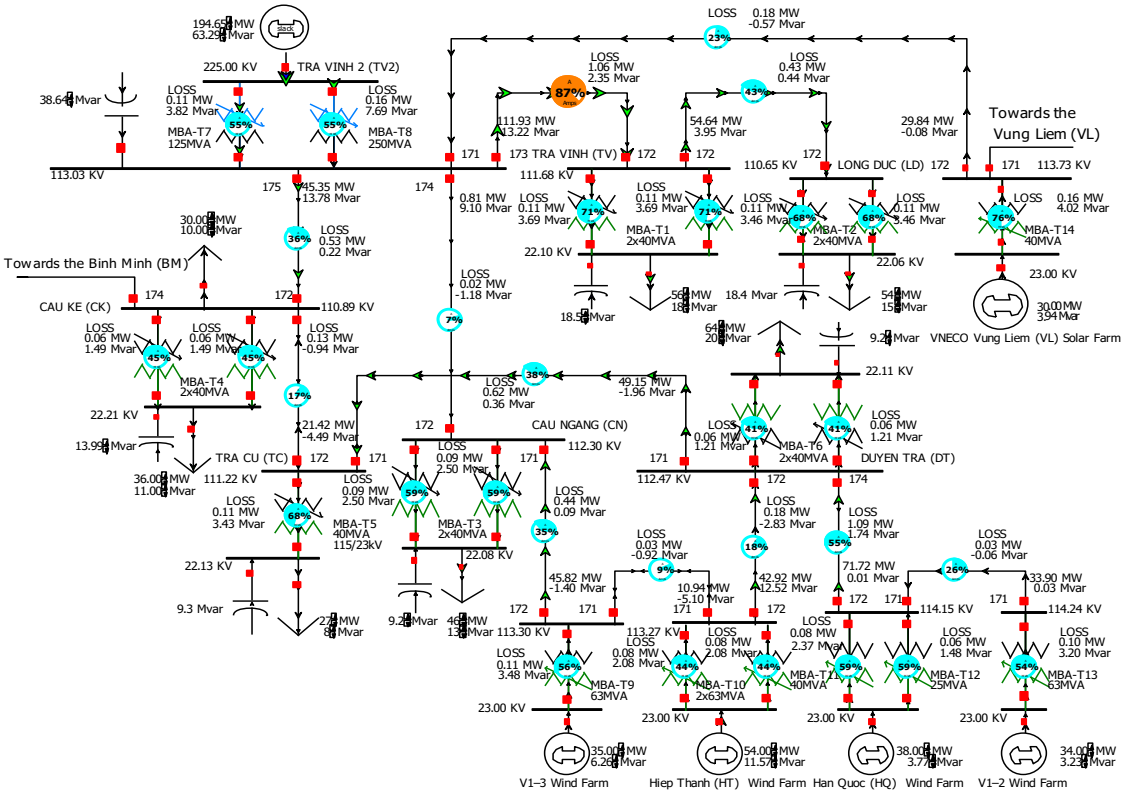

Fig. 2. Normal operating condition simulation of the 110kV Tra Vinh power grid.

Based on the simulation results, a table is compiled to analyze power losses and voltage levels at substations and transmission lines.

Table 4. Power loss and voltage levels of substations and transmission lines under normal operating conditions

No.	T/F and T/L	Loading (%)	$\Delta \dot{S}$ (MVA)	ΔU%	Voltage (kV)
1.	TV2(T7)	55	0.11+j3.86	1.72	225/113
2.	TV2(T8)	55	0.16+j7.78		
3.	TV(T1)	71	2x(0.11+j3.7)	1.04	111.7/22.9
4.	LĐ(T2)	68	2x(0.11+j3.36)	0.34	110.6/22
5.	CN(T3)	59	2x(0.09+j2.5)	1.68	112.3/22
6.	CK(T4)	45	2x(0.06+j1.5)	0.72	110.9/22.2
7.	TC(T5)	68	2x(0.11+ j3.43)	0.48	111.2/22.1
8.	DT(T6)	41	2x(0.06+j1.21)	1.1	112.522.1
9.	V1-3(T9)	56	0.1+j3.43	1.5	23/113.3
10.	HT(T10)	44	2x(0.08+j2.07)	1.5	23/113.3
11.	HQ(T11)	59	0.08 j2.37	0.8	23/114.1
12.	HQ(T12)	59	0.06+j1.48		
13.	V1-2(T13)	54	0.1+j3.2	0.7	23/114.2
14.	VNECO (T14)	76	0.16+j4.02	1.1	23/113.7
15.	TV2(174) →CN(172)	7	0.02 – j1.18	0.7	113→112.3
16.	TV2(175) →CK(172)	36	0.53 + j0.22	1.9	113→110.9
17.	TC(172) →CK(174)	17	0.13 – j0.94	0.3	111.2→110.9
18.	DT(171) →TC(171)	38	0.62 + j0.36	1.1	112.5→111.2
19.	TV2(173) →TV(172)	78	1.06 + j2.35	1.2	113.03→111.8
20.	TV(171) →LĐ(171)	43	0.43 + j0.44	0.9	111.7→110.7
21.	VNECO(172) →TV2(171)	23	0.18 – j0.57	0.6	113.7→113
22.	V1-3(172) →CN(171)	35	0.44 + j0,09	0.9	113.3→112.3
23.	V1-3(171) →HT(171)	9	0.03 – j0.92	0.03	113.3→113.3
24.	V1-2(171) →HQ(171)	26	0.03 - j0.06	0.1	114.2→114.2
25.	HT(172) →DT(172)	18	0.18 – j2.83	0.7	113.3→112.5
26.	HQ(172) →DT(174)	55	1.09 + j1.74	0.8	114.2→112.5

When Pis negative, the source absorbs active power, and when P is positive, the source delivers active power.Similarly, when Qis negative, the source absorbs reactive power, and when Q is positive, the source supplies reactive power.

1. Contingency simulation scenarios for transmission lines and substations.

- Contingency at transformer TV2(T8)

International Journal of Advances in Engineering and Management (IJAEM)
Volume 8, Issue 1 Jan. 2026, pp: 401-410 www.ijaem.net ISSN: 2395-5252

- Contingency at transformer TV(T1)
- Contingency at transformer LD(T2)
- Contingency at transformer CN(T3)
- Contingency at transformer HQ(T11)
- Simultaneous contingency of transmission lines HT(172)–DT(172) and HQ(172)–DT(174)
- Simultaneous contingency of transmission lines HT(172)–DT(172) and HQ(172)–DT(174), and transformer TV2(T7)
- Simultaneous contingency of transmission lines HT(172)–DT(172) and HQ(172)–DT(174), and transformer TV2(T8)

Table 5. Power loss and voltage levels of substations and transmission lines under the considered contingency scenarios

No.	T/F and T/L	Loading(%)	$\Delta\dot{S}$ (MVA)	ΔU%	Voltage (kV)
1.	TV2(T7)	165	0.72+j35.76	4.57	225/109.8
2.	TV(T1)	148	0.4+j16.4	4.95	111.2/21.2
3.	LĐ(T2)	140	0.38+j15.7	3.10	109.8/21.2
4.	CN(T3)	122	0.28 + j11.03	5.15	111.9/21.2
5.	HQ(T12)	154	0.32+j10.30	1.15	113.7/23
6.	TV2(175)→CK(172)	147	8.52+j21.14	8.5	110.8→101.4
7.	Simultaneous contingency of transmission lines HT(172)–DT(172) and HQ(172)–DT(174), and transformer TV2 (T7)				
	TV2(T8)	128	0.67+j43.19	5.8	225/108.3
	TV2(175)→CK(172)	154	9.41+j23.50	9.5	108.3→98
8.	Simultaneous contingency of transmission lines HT(172)–DT(172) and HQ(172)–DT(174), and transformer TV2 (T8)				
	TV2(T7)	387	3.77+j196.55	33.9	225/ 76
	TV2(175)→CK(172)	184	13.31+j34.19	19.7	76.2→61
	TV2(171)→TV(172)	137	2.63+j6.67	8.57	76.2→69.6
	CK(172)→TC(172)	103	4.7+j11.89	23.96	68.5→52.1

2. Local Load Increase Scenario by 20% in the Tra Vinh and Long Duc Areas.

Tra Vinh and Long Duc are the two main load centers supplying the city area and the industrial zone. Therefore, when a 20% load increase is simulated in the Tra Vinh area, the load power is
S_{TV}= 67.2+j21.6 (MVA) and S_{LD}= 64.8+j18 (MVA)

Table 6. Voltage drop and power loss under the 20% load increase in the Tra Vinh and Long Duc areas

No.	T/F	Loading (%)	$\Delta\dot{S}$ (MVA)	ΔU %	Voltage (kV)
1.	TV2(T7)	62	0.13+ j4.9	2.1	225/112.6
2.	TV2(T8)	62	0.19 + j9.85		
3.	TV(T1)	87	2x(0.16 + j5.66)	4.4	112.6/21.5
4.	LĐ(T2)	83	2x(0.15+j5.29)	1.8	109/21.4
5.	TV2(173)→TV(172)	107	1.61+j3.8	1.8	112.6 →110.6

IV. RESULTS AND DISCUSSION

A. Results of the Normal Operating Condition Simulation

According to the technical standards applied in the management and operation of the Vietnamese power grid, the allowable voltage deviation on the high-voltage network must not exceed ±5% of the rated voltage, and the power factor at substation buses must be at least 0.95.

Based on the simulation results presented in Table 4, the normal operating condition of the 110 kV power grid in the Tra Vinh area is analyzed, and the proposed operating solutions for substations and 110 kV transmission lines are summarized in Table 7.

Table 7. Analysis of the normal operating condition of the 110 kV Tra Vinh power grid

Evaluation item	Simulation results	Proposed operating strategy
Substation loading level	41% - 76%	All substations operate below rated capacity; no overload is observed, and sufficient capacity margin is available.
Highest loaded substation VNECO (T14)	76%	High loading level but still within allowable limits, ensuring safe operation.
Transformer power loss mainly affected by reactive component (MVAr)	Minimum 0.06 and maximum 7.78	Losses are consistent with loading levels; no abnormal behavior is observed.
Voltage drop at substations (ΔU%)	Minimum 0.34% and maximum 1.72%	Lower than the allowable limit (±5%), ensuring voltage quality.
110 kV bus voltage	114-110kV	Stable voltage within the permissible range of the 110 kV network.
Transmission line loading level	7% – 78%	Most lines operate at low to medium loading; no overloaded lines are detected.
Transmission line voltage drop	0.03% – 1.9%	All values are below 2%, satisfying technical requirements.
Transmission line power loss	Acceptable	Reactive power generation is observed, consistent with the characteristics of 110 kV transmission lines.
Overall operating condition	Stable	No overload, overvoltage, or severe undervoltage occurs.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 8, Issue 1 Jan. 2026, pp: 401-410 www.ijaem.net ISSN: 2395-5252

Evaluation item	Simulation results	Proposed operating strategy
Overall assessment	Meets requirements	The power grid operates safely and reliably, satisfying techno-economic criteria.

B. Results of Contingency Operating Condition Simulation for Transmission Lines and Substations

Based on the simulation results and recorded data presented in **Table 5**, appropriate instantaneous operating strategiesfor 110kV substations and transmission lines in the Tra Vinh area can be proposed to ensure safe, reliable, and efficient system operation under contingency conditions. The key operational concerns and corresponding solutions are summarized in **Table 8**.

Table 8: Analysis of Contingencies on Transmission Lines or Substations

No.	Substation / Line contingency	Simulation results	Proposed operating strategy
1.	TV2(T7)	Transformer overload reaches 65%, with very high reactive power losses of 35.76 MVAr. All secondary bus voltages at 115/23kV substations drop below the allowable limit of 22kV.	-*Option 1:* 100% load shedding at CK(T4) and TC(T5) substations. -*Option 2:* 100% load shedding at TV(T1) and TC(T5) substations. -*Option 3:* 100% load shedding at DT(T6) and CK(T4) substations. - Two transformers must be maintained in parallel operation.
2.	TV(T1)	Transformer overload of 48%, reactive power losses of 16.4MVAr.Secondary voltage at the substation drops below 22 kV.	- Load shedding of 35% of the total load at TV(T1)substation. - Two transformers must be maintained in parallel operation.
3.	LĐ(T2)	Transformer overload of 40%, reactive power losses of 15.7MVAr.Secondary voltage at the substation drops below 22kV.	- Load shedding of 30% of the total load at LĐ(T2) substation. - Two transformers must be maintained in parallel operation.
4.	CN(T3)	Transformer overload of 22%, reactive power losses of 11.03MVAr. Secondary voltage at the substation drops below 22kV.	- Load shedding of 20% of the total load at CN (T3) substation. - Twotransformers must be maintained in parallel operation.
5.	HQ(T12)	Transformer overload of 54%, reactive power losses of 10.30MVAr	- Reduce the output power of wind turbines connected to HQ(T12) substation to not exceed 25MVA. - Two transformers must be maintained in parallel operation.
6.	TV2(175)-CK(172)	Simultaneous outages of HT(172)–DT(172) and HQ(172)–DT(174) result in a 47% overload on the TV2(175)–CK(172) transmission line, with significant power losses.	- Load shedding at CK(T4) substation. - Restore either HT(172)–DT(172) or HQ(172)–DT(174) transmission line as soon as possible.
7.	TV2(T8) TV2(175) →CK(172)	The simultaneous outages of the HT(172)–DT(172) and HQ(172)–DT(174) transmission lines, together with a contingency at the TV(T7) substation, result in a 54% overload on the TV2(175)–CK(172) transmission line and a 28% overload on the TV2(T8) transformer, accompanied by significant power losses.	- Load shedding at the CK(T4) and TC(T5) substations, followed by the earliest possible restoration of the contingencies."
8.	TV2(T7) TV2(175) →CK(172) TV2(171) →TV(172) CK(172) →TC(172)	Simultaneous outages of the HT(172)–DT(172) and HQ(172)–DT(174) transmission lines combined with a contingency at the TV2 (T8) substation cause a severe voltage drop to 76–52 kV, far below the nominal 110 kV level, indicating a critical and most dangerous system-wide voltage instability condition.	Proposed strategy: Load shedding at the TV(T1), CK(T4), and TC(T5) substations, followed by immediate restoration of the contingencies. This represents the most critical and unacceptable contingency scenario; if it occurs, extensive load shedding at major substations is unavoidable

C. Simulation Results for a 20% Local Load Increase in the Tra Vinh and Long Duc Areas

Based on the simulation results, the power losses and voltage drops at substation buses were analyzed under a 20% local load increase scenario in the Tra Vinh and Long Duc areas. The assessment focused on the Tra Vinh–Long Duc transmission corridor, specifically the TV2(173) → TV(172) transmission line. The corresponding results are presented in **Table 6.**

Based on these results, the proposed instantaneous operating strategies for the relevant substations and transmission lines are summarized in **Table 9.**

International Journal of Advances in Engineering and Management (IJAEM)
Volume 8, Issue 1 Jan. 2026, pp: 401-410 www.ijaem.net ISSN: 2395-5252

Table 9: Analysis of Transmission Line and Substation Contingencies

No.	Substation / Line contingency	Simulation results	Proposed operating strategy
1.	TV2(T7)	Voltage drop ΔU= 2.1%, with minor losses. Stable operation with a large operating margin.	Maintain current operating conditions; continue monitoring as the load increases.
2.	TV2(T8)	Voltage drop ΔU = 2.1%, with minor losses. Reactive power losses Q(MVAr) increase, but the system remains stable without overload.	Proper allocation of reactive power compensation to reduce reactive power losses Q (MVAr).
3.	TV(T1)	Voltage drop ΔU = 4.4%. Reactive power losses Q(MVAr) increase, while operation remains stable without overload.	Apply appropriate reactive power compensation to reduce reactive power losses; maintain current operating conditions and monitor load growth; adjust transformer tap settings and prepare load balancing schemes.
4.	LĐ(T2)	Voltage drop ΔU = 1.8%, with minor losses. Stable operation with a large operating margin.	Maintain current operating conditions; continue monitoring as the load increases.
5.	TV2(173) →TV(172)	Line loading exceeds the allowable limit by 0.7% relative to the conductor ampacity, indicating a slight overload and increased loss risk.	Optimize operating conditions; transfer part of the load to adjacent lines and enhance network interconnections.

V. CONCLUSION

This paper developed a detailed model of the 110kV power grid in the Tra Vinh area using PowerWorld Simulator, based on actual system data, and conducted operating condition analyses under normal operation, typical contingency scenarios, and load increase conditions. The simulation results indicate that, under normal operating conditions, the power grid generally satisfies technical requirements in terms of voltage levels and thermal loading limits.

However, under contingencies at the TV2(T8) or HT(T11) transformers, severe overloads occur at the TV2(T7) and HT(T12) transformers, accompanied by significant voltage drops at buses far from the power sources and a substantial increase in power losses, which markedly degrades supply reliability. In particular, the simultaneous outages of the HT(172)–DT(172) and HQ(172)–DT(174) transmission lines combined with a contingency at the TV2(T8) substation are identified as the most critical scenario, resulting in local overloads, deep voltage sags, and the forced shedding of multiple critical loads.

These findings highlight the urgent necessity of evaluating the power grid under N-1 and N-2 contingency criteria for both operation and planning of the 110kV Tra Vinh power network. Based on the analytical results, this study proposes several groups of technical solutions, including reconfiguration of operating schemes, appropriate allocation of reactive power compensation, redistribution of load, and controlled load shedding under contingency conditions. These measures aim to mitigate overloads, limit voltage drops, reduce power losses, and enhance the overall reliability of power supply. The proposed solutions are of high practical relevance, supporting safe and efficient system operation and providing a scientific basis for planning and investment in the future development of the 110kV power grid in the Tra Vinh area.

REFERENCES

[1]. Schavemaker, P., & Van der Sluis, L. (2025). *Electrical power system essentials*. John Wiley & Sons.

[2]. Tran, H. T., Dang, N. T. L. N., Vo, P. G., Tran, T. K., & Pham, T. H. (2024). *Artificial bee colony algorithm to solve the optimal power flow problem on Ben Tre power system*. TNU Journal of Science and Technology, *229(04), 183–190.*https://doi.org/10.34238/tnu-jst.9569

[3]. Ali, Y. (2024). *Comparative analysis of power flow simulations in the test 10-bus power system using PowerWorld Simulator, ETAP, and PSS software*.In Proceedings of the 7th International Pak–Turk Conference on Emerging Technologies in the Field of Sciences and Engineering.

[4]. Wen, H. (2023). *Power flow analysis of 110kV power supply system based on PowerWorld.*Journal of Physics: Conference Series, 2495(1), 012025.https://doi.org/10.1088/1742-6596/2495/1/012025

[5]. Truong, T. T. U., Le, V. P., Mai, Q. T., Pham, V. K., & Tran, Q. T. (2023). *Impacts of wind power plant operation on voltage stability of the Quang Tri 110 kV power grid*. Journal of Science and Technology, The University of Danang, 21(9.1).

[6]. Nguyen, T. H. (2021*). Application of PowerWorld Simulator in analyzing power flow problems on computers*. Vietnam Journal of Industry and Trade: Scientific Research and Technology Application Results, (26), 314–321.

[7]. Doan, T. N., Nguyen, T. T., Hoang, D. N., Vo, V. P., & Le, T. D. (2020). *Research on improving the safety and operational efficiency of automatic voltage regulation systems in unmanned 110 kV substations*. Journal of Science and Technology – The University of Danang, 18(3).

[8]. Ministry of Industry and Trade of Vietnam. (2015). *National technical regulation on electrical engineering (Part 1: Power grid systems)*. Hanoi: Department of Science and Technology.