International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 05 May 2025, pp: 379-382 www.ijaem.net ISSN: 2395-5252

Simulation and Power Flow Analysis of the Duyen Hai – Phu Lam Transmission Line Using Power world Simulator

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Date of Submission: 15-05-2025 Date of Acceptance: 25-05-2025

ABSTRACT: The artical presents the simulation and analysis of power flow on the 500kV Duyen Hai – Phu Lam transmission line using PowerWorld Simulator software. This is one of the most important transmission lines in the Southern Vietnam power grid. The objective of the study is to evaluate the transmission capacity, voltage stability, and power loss in the system. Thereby, recommendations for operation and suggestions for improvement are made. The simulation results show that the system operates stably under baseline conditions, but there is a risk of a slight voltage drop at the Phu Lam load node when the load increases.

KEYWORDS: Power flow, PowerWorld Simulator, Southern power system, 500kV line, Duyen Hai – Phu Lam.

I. INTRODUCTION

In the context of Vietnam's increasingly developing economy, especially in the Southern region with large industrial and urban centers such as Ho Chi Minh City, the demand for electricity consumption is constantly increasing. This poses an urgent requirement to ensure a stable, continuous and efficient power supply for the entire region. To meet that goal, the National Power Transmission Corporation (EVNNPT) has invested and put into operation many high-voltage transmission lines, of which the 500kV Duyen Hai - Phu Lam line plays a strategic role. The 500kV Duyen Hai - Phu Lam line is responsible for transmitting large amounts of power from thermal power plants in the Duyen Hai area (Tra Vinh) - where many large-capacity coal-fired power sources are concentrated - to the load center of Ho Chi Minh city and neighboring provinces. With a length of about 240 km, this is one of the most important transmission lines in the Southern power system. Therefore, assessing the transmission capacity, power loss, as well as voltage stability on this line is a necessary requirement in the planning and operation of the national power system.

Power flow is a basic problem but plays an important role in power system analysis. Simulating power flow not only helps determine the distribution of real and reactive power in the system but also supports the detection of nodes with abnormal voltage, from which appropriate adjustment options can be proposed.

In this case study, PowerWorld Simulator software is used to build a simulation model of the 500kV Duyen Hai - Phu Lam transmission line. With an intuitive interface, fast processing ability and support for many solution methods, PowerWorld is an effective tool in analyzing and evaluating power systems. The article focuses on presenting the process of model establishment, power flow simulation, analyzing results and providing technical recommendations of practical value in the operation of power transmission systems.[1]

II. THEORETICAL BACKGROUND

2.1 Power flow in power system

Power Flow (or Load Flow) is the problem of calculating the distribution of active power (P), reactive power (Q), voltage (magnitude and phase angle) at nodes in an AC power system in a steady state. The main objectives of the flow problem are: determining the power flow in each transmission line, calculating the voltage at the buses in the system, calculating power losses and analyzing transmission efficiency.

Factors to consider in the flow problem include: Power generation at power plants, load at consumption nodes, line parameters (inductance, inductance, resistance), grid connection structure.

In the power system, buses are often classified into 3 groups: Slack Bus: Reference bus, with known voltage and phase angle, used to balance power in the system. PV Bus: Bus at power plants, with power generation P and voltage V kept stable, while Q and phase angle are unknowns. PQ Bus: Load bus, with P and Q given, V and phase angle need to be calculated.[1]

2.2 Method of calculating power flow
Two popular methods to solve the power flow problem include:

Gauss-Seidel method: The advantage is that it is simple and easy to implement, but the convergence speed is slow, not suitable for large power systems.

Newton-Raphson method: This is a nonlinear method, using Taylor expansion and solving the linear equation system iteratively. The advantage is that the convergence speed is fast, suitable for large-scale power systems. In this paper, PowerWorld Simulator uses the Newton-Raphson method to calculate the flow.
The basic equation system of the power flow is written as follows for each node i[2]:

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} + \delta_j - \delta_i)$$

$$Q_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\theta_{ij} + \delta_j - \delta_i)$$

In Which:
P_i,Q_i: Active and reactive power at node i
V_i,V_j: Voltage amplitude at nodes i and j
δ_i,δ_j: Voltage phase angle
Y_{ij}: Admission matrix element
θ_{ij}: Admission angle between two nodes i, j

2.3 Power loss and transmission efficiency

Power loss in transmission is an important factor affecting the efficiency of the power system. The total power generated from the plant is often larger than the actual power consumed due to losses in the lines and transformers. The power loss in the line is calculated as follows[3]:

$$P_{loss} = I^2 \cdot R = \frac{(P^2 + Q^2)}{V^2} \cdot R$$

In which:
P,Q: load capacity
V: voltage at the generator
R: line resistance
Reducing transmission losses is a goal in grid design, which can be achieved through measures such as: increasing voltage, shortening transmission distance, or optimizing generation capacity allocation.

III. POWERWORLD SIMULATION ANALYTICAL MODEL

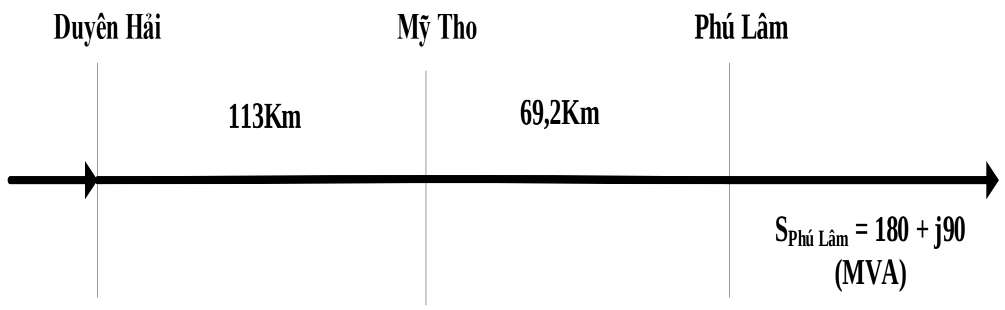

Figure1: Diagram of the 500kV Duyen Hai - Phu Lam power system[1].

Figure 1 shows the simulation results of the power flow of the 500 kV Duyen Hai – My Tho – Phu Lam transmission line using PowerWorld Simulator software. The transmission line includes three main nodes: Duyen Hai (generation node), My Tho (intermediate node), and Phu Lam (consumption node).

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3.1 Power distribution in the system

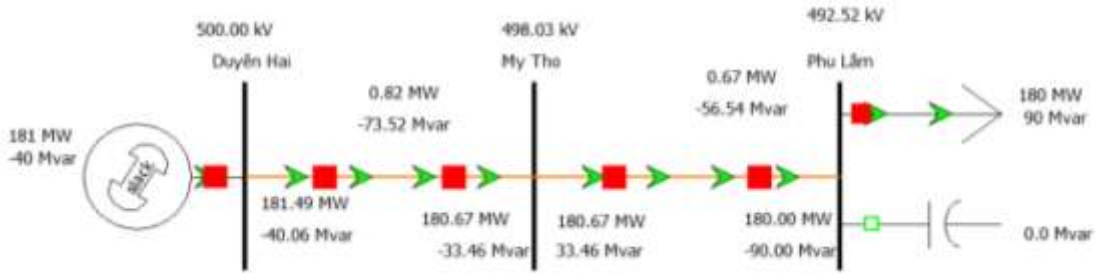

Figure 2: Power system diagram of Duyen Hai - Phu Lam using Powerworld Simulation [4,5,6]

Figure 2 shows the results that at the time of operation, Duyen Hai plant generates P = 181 MVA active power and Q = −40 MVar reactive power. The transmission power to My Tho node reaches P = 181.49 MW, the loss ΔP = 0.82 MW and Q = −73.52 MVar reactive power. At My Tho – Phu Lam section, the power continues to decrease to P = 180.00 MW, exactly equal to the load value at Phu Lam. The total active power loss on the entire line is about 1.49 MW, showing high transmission efficiency.

Regarding reactive power, the total Q generated from Duyen Hai is Q = −40 MVar, while the load at Phu Lam consumes −90 MVar, leading to a serious shortage of reactive power at the end of the line. Linear Q-flow analysis shows that the cumulative reactive loss from Duyen Hai to Phu Lam is up to 50 MVar.

3.2 Voltage analysis at nodes

The voltages at the nodes are:

- 500.00 kV at Duyen Hai (standard),
- 498.03 kV at My Tho (down 0.4%),
- 492.52 kV at Phu Lam (down 1.5%).

IV. DISCUSSION

Deploy a static shunt compensation system at Phu Lam station with a total rated capacity of 90 MVar to provide on-site reactive power, reduce the need for Q transmission from the generating source and limit line losses. In addition, combine modern voltage control devices such as OLTC (On-load Tap Changer), SVC (Static VAR Compensator) or STATCOM (Static Synchronous Compensator) in case of rapidly changing loads or needing flexible voltage adjustment in real time. In addition, simulate the power flow after installing the compensation device to evaluate the effectiveness of voltage improvement, power loss reduction and verify the voltage stability at the load nodes in different operating scenarios.

Although the voltage level at Phu Lam is still within the allowable limit (±5%), this significant voltage drop reflects the phenomenon of voltage reduction along the line, common in long-distance transmission systems when reactive compensation is not fully implemented.

With a total power loss of only 1.49 MW across the entire line, the system is considered to have high transmission efficiency. However, the amount of reactive power loss and voltage drop at Phu Lam shows that the system lacks reactive compensation at the load side. This can lead to voltage instability if the load increases or there is a grid failure.

To improve system operation, the following solutions are proposed:

- Add static capacitors at Phu Lam to reduce the need for remote transmission Q.
- Adjust reactive power at Duyen Hai generator to support voltage stability.
- Analyze load surge and fault scenarios (N-1) to assess system robustness under adverse condition

Proposal for reactive power compensation at Phu Lam station

The power flow simulation results showed that the load at Phu Lam station consumed Q = 90 MVar reactive power, while the entire amount of this reactive power was transmitted from Duyen Hai plant through the 500 kV line. This phenomenon caused significant losses on the line and reduced the voltage at the end of the system (voltage at Phu Lam was only 492.52 kV, down 1.5% compared to the standard). To improve the voltage quality and reduce the load on the transmission system, the article proposed to install shunt static compensation capacitors at Phu Lam station.

A. Reactive power compensation **objectives**

The objectives of the static compensation scheme are:

• Reduce the reactive power that must be transmitted from Duyen Hai.
• Reduce reactive losses on the line.
• Maintain the voltage at Phu Lam near the nominal level of 500 kV.
• Increase the stability of local voltage at the load.

B. Calculate the required compensation capacity

Suppose that the total reactive power consumed at Phu Lam needs to be compensated at Q_C = 90 Mvar. The capacitance C of the required compensation capacitor is calculated according to the formula:

$$Q_C = V^2 \cdot \omega C \quad \Rightarrow \quad C = \frac{Q_C}{V^2 \cdot \omega}$$

In which
$V = 500 \times 10^3$ V
$\boldsymbol{\omega = 2\pi f}$ = 314.16 rad/s with f = 50 Hz
$Q_C = 90 \times 10^6$ Var

$$C = \frac{90 \times 10^6}{(500 \times 10^3)^2 \cdot 314.16} \approx 1.15\,\mu F$$

Compensation scheme	Compensation capacity (MVar)	Required capacitance($\boldsymbol{\mu}$F)
Full load	90	1.15
2/3 load	60	0.77
1/3load	30	0.38

To ensure flexibility in operation, the capacitor system can be divided into many levels (For example: 3 30Mvar compensation groups) and controlled to switch on and off according to load demand.

V. CONCLUSION

The artical presents the process of simulating and analyzing the power flow of the 500 kV Duyen Hai - Phu Lam transmission line using PowerWorld Simulator software. Through modeling the system consisting of three main stations: Duyen Hai, My Tho and Phu Lam, the simulation results show that the system operates stably with low active power loss (~1.49 MW). However, the voltage at Phu Lam station tends to decrease (~1.5%) due to the large consumption of reactive power (90 MVar) while there is no on-site compensation equipment.

The analysis shows that the entire reactive power transmitted from Duyen Hai source causes significant losses and reduces the voltage quality at the end of the line. To overcome this, the article proposes a solution to install static capacitor banks with a total capacity of 90 MVar at Phu Lam station. Preliminary calculations show that this solution can significantly improve the voltage and reduce the pressure of transmitting reactive power from a distance.

In the following studies, the author proposes to deploy scenarios to apply to the remaining nodes of the transmission system in Vietnam to improve the reliability and economic efficiency of the entire transmission system in the Southern region of VietNam.

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