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# Enhancing the Algerian Power System for Long-Distance Transmission: A Comprehensive Study on HVDC Technology

Authors: DJILANI KOBIBI Youcef Islam1, DJEHAF Mohammed Abdeldjalil2, KHATIR Mohamed2 and SHERIF S. M. Ghoneim3
1. Mustapha Stambouli University, Mascara, Algeria
2. Djillali Liabes University, Sidi Bel-Abbes, Algeria
3- Taif University,Taif, Saudi Arabia

## INTRODUCTION & AIM

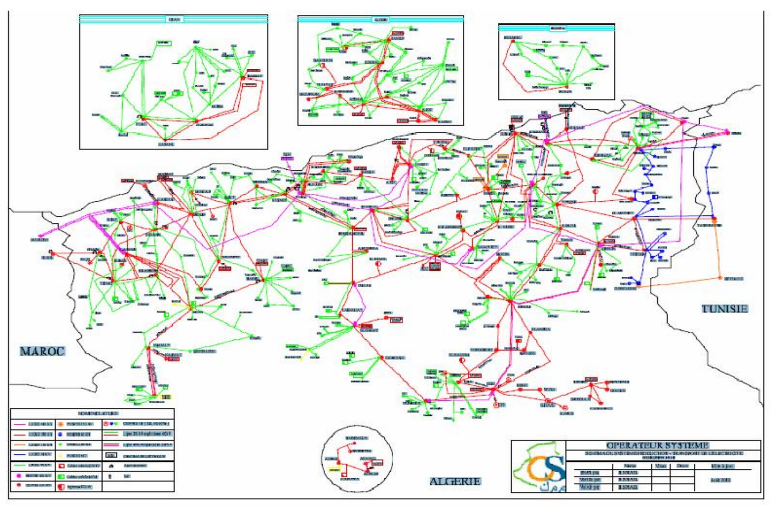
Efficient and reliable long-distance energy transmission is a critical challenge for geographically expansive nations like Algeria. With a growing demand for renewable energy integration, the Algerian power grid faces significant transmission losses and voltage stability issues.
High Voltage Direct Current (HVDC) technology offers a transformative solution, addressing the limitations of traditional Alternating Current (AC) systems by:
Reducing transmission losses over long distances.
Enhancing grid stability and flexibility.
Enabling efficient integration of renewable energy sources.
This study explores the implementation of HVDC technology within the Algerian power system using the **Power System Analysis Toolbox (PSAT)** to evaluate its potential benefits in improving power flow and voltage profiles.

## METHOD

To evaluate the integration of High Voltage Direct Current (HVDC) technology into the Algerian power system, the study employs a systematic approach involving simulation, modeling, and analysis using the Power System Analysis Toolbox (PSAT). The methodology focuses on both technical modeling and performance assessment of HVDC technology in addressing key challenges in long-distance energy transmission.

1. **Modeling the Existing Algerian Power System:**

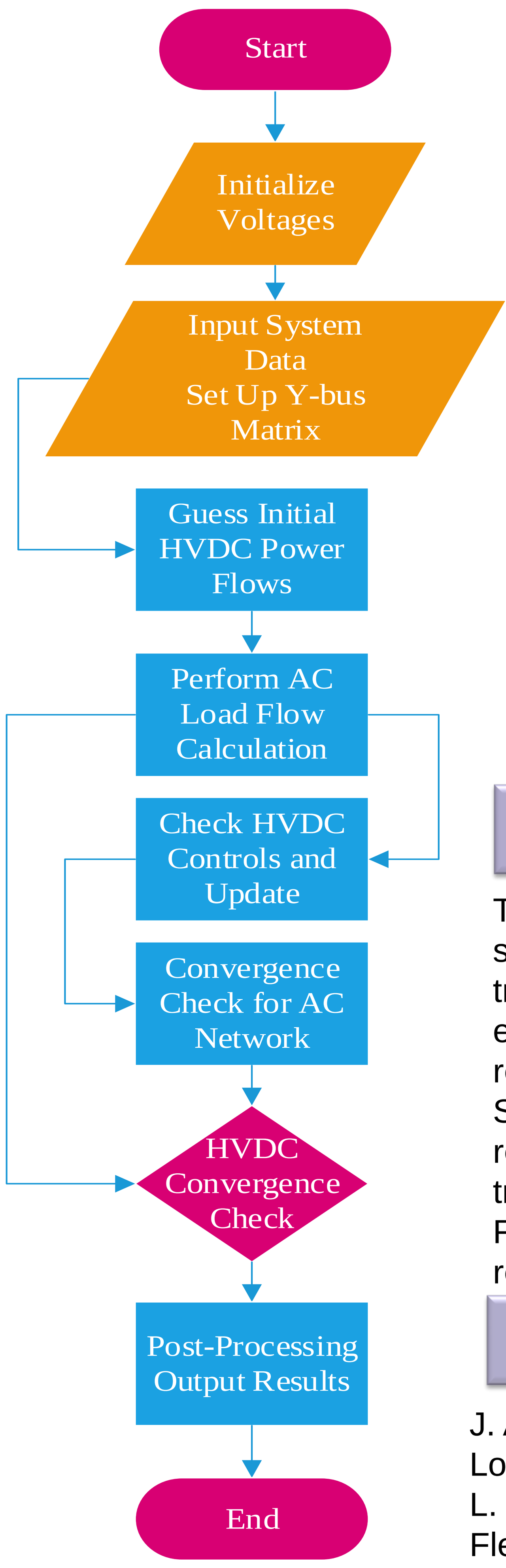
The Algerian grid is modeled in PSAT, comprising:
•114 bus bars representing nodes in the network.
•175 transmission lines connecting the nodes.91 loads distributed across six geographic regions.



•Voltage levels ranging from 60 kV to 220 kV.
This baseline model includes system data for generators, transformers, and load centers, capturing the operational characteristics of the current AC system.

2. **HVDC System Representation**

•Converter Stations: Modeled as controlled voltage sources at both ends of the HVDC link.
•DC Transmission Line: Represented as a simple resistive network with power injection points integrated into the AC system.
•Control Strategies: Implemented for:
•Constant Current Control: Maintaining consistent DC current flow.
•Constant Power Control: Optimizing voltage to ensure stable power transfer.




3. **Sequential Load Flow Analysis**

•The Newton-Raphson method is applied for solving nonlinear equations of both AC and DC systems.
•Sequential Method: AC and DC equations are solved iteratively, updating power injections at converter stations to reflect HVDC operation.

4. **Simulation Scenarios**

•Without HVDC: Power flow analysis is conducted on the baseline AC system, identifying:
▪Voltage limit violations at critical nodes (e.g., nodes 12 and 13).
▪Overcurrent issues in key transmission lines (e.g., lines 5, 6, 8, 28, and 169).
•With HVDC: HVDC links are introduced strategically at problem points to address:
▪Voltage stability issues.
▪Overcurrent violations.
▪Reduction in active and reactive power losses.

## RESULTS & DISCUSSION

**Without HVDC**
A power flow analysis was conducted on the Algerian electrical power system, yielding the following results:

| Global Production | |
|---|---|
| P [p.u.] | 38,0825404 |
| Q [p.u.] | 25,8225935 |
| Global Load | |
| P [p.u.] | 37,27 |
| Q [p.u.] | 21,58 |
| Losses | |
| P [p.u.] | 0,81254037 |
| Q [p.u.] | 4,24259355 |

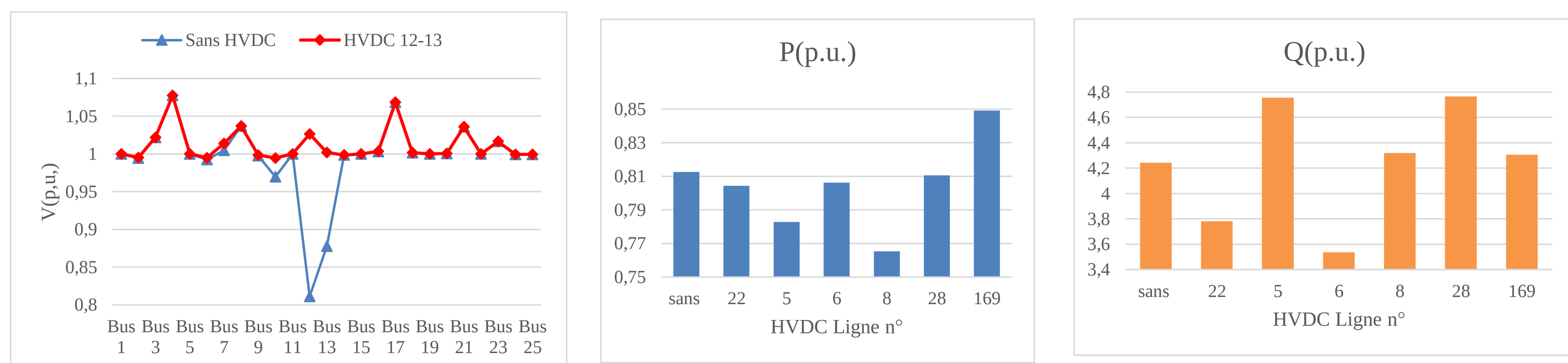
The analysis identified several violations of minimum voltage limits and maximum current limits:

| |
|---|
| Minimum voltage limit violation at bus <Bus 12> [V_min = 0.9] |
| Minimum voltage limit violation at bus <Bus 13> [V_min = 0.9] |
| Maximum current limit violation on line 5 [I = 2.10496 > I_max = 1] |
| Maximum current limit violation on line 6 [I = 3.77014 > I_max = 1] |
| Maximum current limit violation on line 8 [I = 6.08316 > I_max = 1] |
| Maximum current limit violation on line 28 [I = 2.21547 > I_max = 1] |
| Maximum current limit violation on line 169 [I = 1.84905 > I_max = 1] |

These results highlight issues of voltage drops and overcurrents at critical points within the network, particularly in Bechar and Ain Sefra (nodes 12 and 13), suggesting the need for infrastructure enhancements.

**With HVDC (Under-voltages)**
To address the under-voltage issues, line 22 connecting nodes 12 and 13 (Bechar and Ain Sefra) was replaced with an HVDC link. The results post-implementation are as follows:
The replacement with an HVDC link led to a reduction in both active and reactive power losses. Voltage profiles for nodes 12 and 13, as well as 7 and 10, showed significant improvement, demonstrating the efficacy of HVDC in enhancing voltage stability (Fig 3) and reducing losses in the network.

| Global Production | |
|---|---|
| P [p.u.] | 38,07438346 |
| Q [p.u.] | 25,36094702 |
| Global Load | |
| P [p.u.] | 37,27 |
| Q [p.u.] | 21,58 |
| Losses | |
| P [p.u.] | 0,804383462 |
| Q [p.u.] | 3,780947022 |




## CONCLUSION

The integration of High Voltage Direct Current (HVDC) technology into the Algerian power system demonstrates significant potential to address the challenges of long-distance energy transmission. By reducing transmission losses, improving voltage stability, and ensuring efficient power flow, HVDC can enhance the grid's reliability and support the integration of renewable energy sources.
Simulation results show: Improved voltage profiles across critical nodes. Significant reductions in active and reactive power losses. Resolution of overcurrent issues in key transmission lines.
Future work will focus on expanding the scope of HVDC applications and integrating dynamic renewable energy sources into the system.

## REFERENCES

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