

# Electrical Assessment of 10 MVA, 69 kV/ 13.2 kV Mabiga Substation Upgrading to 20 MVA, 69 kV/ 13.2 kV at Mabiga, Mabalacat City, Philippines

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**Abstract:** This technical report documents the electrical assessment and upgrading of the Mabiga Substation from 10 MVA to 20 MVA, 69 kV/ 13.2 kV, in Mabalacat City, Philippines. The study focuses on ensuring safety, reliability, and cost-effectiveness while addressing the increasing power demand of the area. Significant electrical calculations, including load forecasting, power system modeling, voltage drop, short circuit analysis, and protection coordination, are presented. Results indicate that a 20 MVA transformer is the optimal expansion plan considering a 30-year lifespan. The proposed project addresses overloading issues and improves power quality for the member-consumers of Pampanga II Electric Cooperative (PELCO II).

**Keywords:** Substation Upgrading, Load Forecasting, Short Circuit Analysis, Protection Coordination, Arc Flash Analysis, Distribution System.

## 1. Introduction

Pampanga II Electric Cooperative (PELCO II) is one of the Mega Large Electric Cooperatives in the Philippines under the supervision of the National Electrification Administration (NEA). PELCO II serves 7 towns in Pampanga, extending power through eight substations with a total capacity of 230 MVA.

The Mabalacat area is the most dominant load supplied via the Mabiga Substation. To address overloading conditions, this report documents the development and technical validation for upgrading the 10 MVA unit. The system is supplied from the 69 kV NGCP Mexico Transmission line (3-phase, 60 Hz, 3-wire).

## 2. Design Criteria

The design follows strict safety, reliability, and economic standards. Key codes and standards applicable include:

- Philippine Electrical Code (PEC) 2017
- Philippine Distribution Code (PDC)
- Electric Cooperative's Distribution Utility Planning

Manual

- (ECDUPM) 2009
- IEEE Std 80-2000 (Grounding Safety)

### A. ANSI Standard C37.010-1979

Environmental conditions considered for equipment selection include a maximum annual temperature of 36°C and an altitude of 106.3m above sea level.

## 3. Methodology

### A. Load Forecasting

Trend analysis using the Polynomial Curve Fitting method was employed using eight years of historical data. Model validity was verified through adjusted R<sup>2</sup> values (min 0.99), t-statistics, and P-values (max 0.1). The Mean Absolute Percentage Error (MAPE) was kept within ±3%.

### B. Power System Modeling

The system was modeled based on the Utility (NGCP) Thevenin equivalent circuit, including transformer and line modeling using Carlson's Line Modeling Method for higher accuracy.

Table 1

Historical and forecasted demand summary	
Actual Load (kW)	Forecasted (kW)
23,688	24,000
25,312	25,290
33,670	32,921
-	65,126

## 4. Results & Discussion

### A. Optimal Substation Expansion

Present Worth (PW) cost analysis over a 30-year study indicates that upgrading the 10 MVA transformer to 20 MVA is the most economical solution (PW = Php 191,827,689.16). This expansion satisfies the trigger requirement of 80% rated

capacity.

### *B. Short Circuit Analysis*

Calculated fault currents at the 13.2 kV Bus showed a maximum Three-Phase Fault (TPF) of 5,533 Amperes. To ensure a 10% safety margin, protective equipment with a minimum interrupting duty of 10,000 Amperes is recommended.

### *C. Grounding System*

Ground Potential Rise (GPR) was calculated at 6,597.9 V. Since GPR exceeds Etouch (1,254.48 V), Mesh and Step voltage methods were applied. Grid design using 2/0 copper wire satisfies touch/step limits under fault conditions.

### *D. Protection Coordination*

Coordination margins between the downstream 100k fuse, Recloser, and the Main VCB were maintained at 0.3s. Time Current Characteristics (TCC) curves were plotted using the IEC Very Inverse (VI) formula to ensure sequential isolation of faults.

## **5. Conclusion**

The assessment confirms that upgrading the Mabiga Substation to 20 MVA is necessary to accommodate the rapid load growth in Mabalacat City. The technical designs for the grounding grid, protection schemes, and transformer settings comply with national codes and international standards. Implementation of these upgrades will enhance system reliability, reduce outages, and optimize maintenance operations for PELCO II.

## **References**

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