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Electrical System Design for the Proposed Seed Bank Research Facility in Freedom Island at Metro Manila

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Abstract: **The purpose of this research is for the students of engineering, especially electrical to have them the knowledge regarding designing and analyzing an electrical system. This research conducted pure analysis of power system to assure the equipment in the electrical design work together for the delivery of the required power in each loads and to have them protected from any fault occurrences. Qualitative method was used in the study because the researchers conducted a systematic investigation regarding the architectural layout and location, the researchers gathered quantifiable data such as the symmetrical faults, load requirements and location condition, and the researchers performed mathematical and computational techniques for the power system analysis and have them verified and validated by professional electrical engineer. It is recommended to improve the protection coordination system, arc flash hazard protection, grounding system, and lightning protection analysis.**

Keywords: **Electrical System, Seed Bank, Symmetrical and Unsymmetrical faults, Analysis.**

I. INTRODUCTION

Electricity is one of the most important blessings that science has given to humankind. It has also become a part of modern life and one cannot think of a world without it. Electricity has many uses in our day-to-day life. It has used for lighting rooms, working fans and domestic appliances like using electric stoves, A/C and more. All these provide comfort to people. In factories, large machines work with the help of electricity. Essential items like food, cloth, paper and many other things are the product of electricity.

Generally, energy is the necessity for the economic development of a country. Many functions necessary to present day stop when the energy supply has interrupted. It is practically impossible to estimate the actual magnitude of energy played its part in the building of present-day development. The availability of huge amount of energy is due to the consumption of human effort and getting higher agricultural, industrial production. The greater the per capita consumption of energy in a country, the higher is the standard of living of its people.

A 5-hectare Research Facility is to be established in the Las Piñas–Parañaque Critical Habitat and Ecotourism Area (LPPCHEA), Freedom Island, where important bird habitats such as mangroves, beach forests, lagoons, and mudflats are found. The facility caters the endangered, critically endangered and endemic plant species nationwide where in its one of the priority beneficiary targets are natural conservation for the endangered and endemic plants found only in the Philippines.

II. LITERATURE REVIEW

From the Study of Troy Thrun, Sparling, May 01, 2004, "Electrical Design for Research Facilities" Engineers must consider a number of issues when designing a world-class research facility. Getting power to the right location is only the beginning. Flexibility in design is critical to limit downtime during renovation of lab space as research teams are switched out. Massive amounts of computing capability located within the facility can also be desirable to ensure the security of crunching billions of calculations. Specialized research lighting — as well as generator and uninterruptible power supplies — must all be considered.

There are plenty of factors to consider when it comes to electrical design analysis such as voltage drop, short circuit, load flow, arc flash, protection and coordination, and grounding system analysis. These are the factors that must be considered in building an electrical design specially for a research laboratory.

By thoroughly examining and documenting researchers' needs, design engineers can plan electrical systems that are both highly effective and rarely noticed. Limited or planned power outages, easy and quick lab renovations, capacity for future equipment, and shadow-free workbenches are the benchmark of quality electrical design.

III. METHODOLOGY

In this section, the researchers utilized a quantitative type of research design. According to USCLibraries, quantitative methods emphasize objective measurements and the statistical, mathematical, or numerical analysis of data collected through polls, questionnaires, and surveys, or by manipulating pre-existing statistical data using computational techniques. Quantitative research focuses on gathering numerical data and generalizing it across groups of people or to explain a particular phenomenon. It is conclusive in its purpose as it tries to quantify the problem and understand how prevalent it is by looking for projectable results to a larger population. In this study, the researchers collected the data such as the fault level provided by MERALCO and the architectural layout of research center, and proceeded to develop a design of electrical system in accordance with the gathered data.

The following are the Electrical System Analysis used in the design:

(1) Load Requirements (Lightings/Illumination, General Purpose Outlet, Water Pump and Fire Pump System, HVAC Requirements, Special Load Requirements, Summary of Loads),

(2) Electrical Layouts (Lighting, Power, Mechanical, Single Line Diagram),

(3) Schedule of Loads,

(4) Short Circuit (Fault) Level In Las Piñas Freedom Island,

(5) Voltage Drop Calculation,

(6) Transformer and Generator Sizing,

(7) Lumped Motor Diagram,

(8) Short Circuit Calculations,

(9) Protection Coordination Calculation,

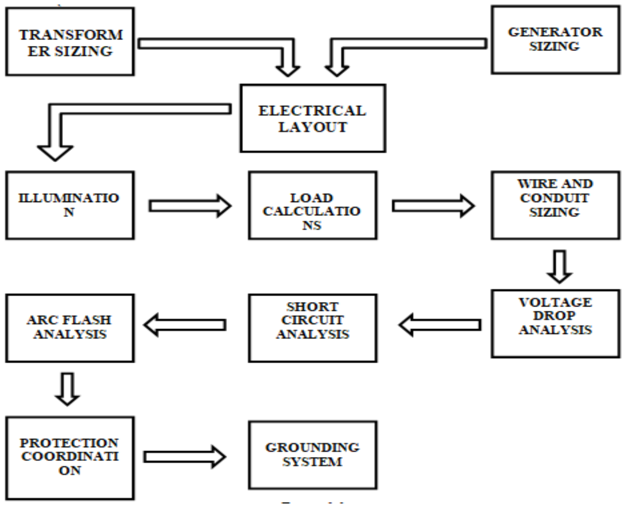
(10) Special Loads Protection,

(11) Arc Flash Calculation,

(12) Grounding Calculation, and

(13) Lightning Protection Calculation.

A. Design Presentation



After constructing the proposed electrical design, it will be evaluated in accordance to the Philippine Electrical Code. Once the electrical plan is finished it will be validated in terms of safety and other technical aspects by a Professional Electrical Engineer (PEE).

B. Single Line Diagram

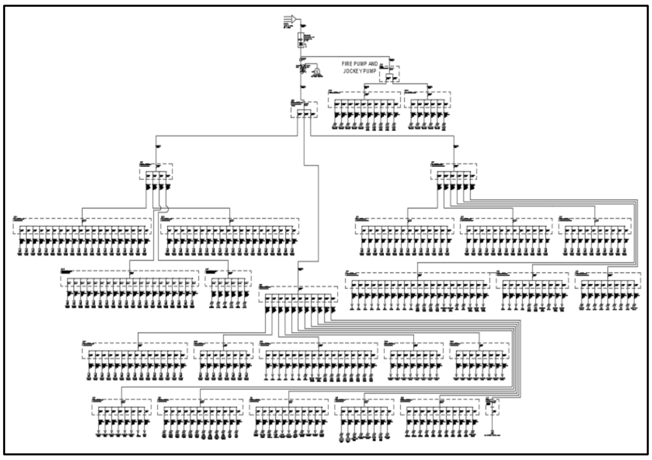


Fig. 1. Single line diagram of the Seed Bank Research Facility in Freedom Island at Metro Manila

C. Freedom Island Layout

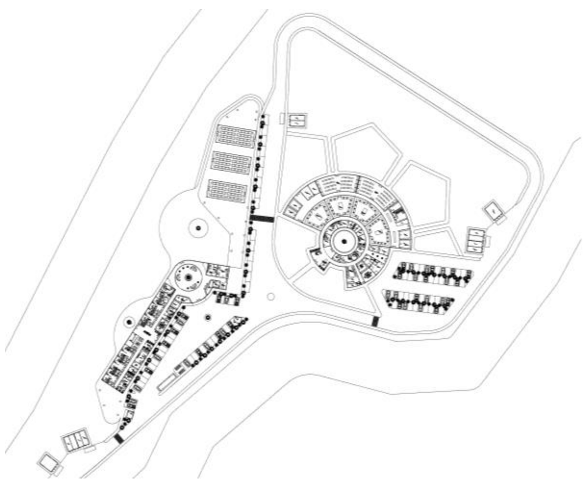


Fig. 2. Entire Freedom Island Layout

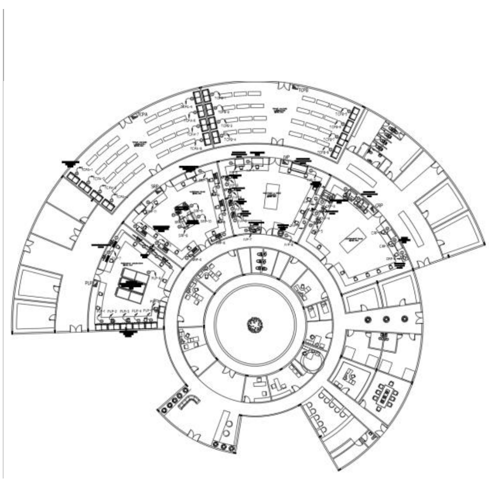


Fig. 3. Research Facility Layout

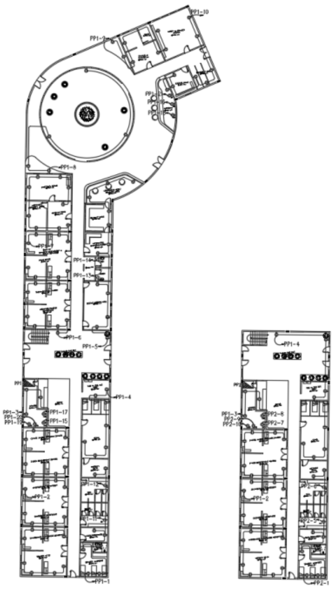


Fig. 4. Administration Building Layout

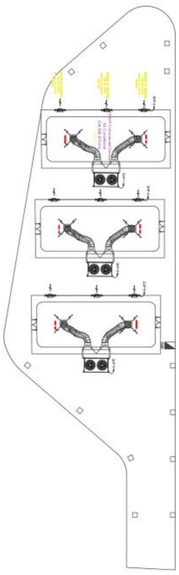


Fig. 5. Greenhouse and Seed Bank Layout

IV. ANALYSIS AND PRESENTATION OF DATA

A. *Summary of Loads*

TABLE I. SUMMARY OF LOADS

SUMMARY OF LIGHTING LOADS		
TOTAL LIGHTING LOADS IN RESEARCH FACILITY	29.7	KVA
TOTAL LIGHTING LOADS IN ADMINISTRATION BUILDING	27.2	KVA
TOTAL LIGHTING LOADS IN GREENHOUSES	31.008	KVA
TOTAL LIGHTING LOADS	**87.908**	**KVA**
SUMMARY OF POWER LOADS		
TOTAL POWER LOADS IN RESEARCH FACILITY	25..080	KVA
TOTAL SPECIAL LOADS IN RESEARCH FACILITY	86.383	KVA
TOTAL POWER LOADS IN ADMINISTRATION BUILDING	46.7	KVA
TOTAL POWER LOADS	**133.083**	**KVA**
SUMMARY OF HVAC LOADS		
TOTAL HVAC LOADS IN RESEARCH FACILITY	305.94005	KVA
TOTAL HVAC LOADS IN ADMINISTRATION BUILDING	214.3961	KVA
TOTAL HVAC LOADS IN GREENHOUSES	186.1017	KVA
TOTAL HVAC LOADS	**706.43785**	**KVA**
SUMMARY OF MECHANICAL LOADS		
TOTAL FIRE PUMP LOADS	1062.64	KVA
TOTAL JOCKEY PUMP LOADS	39.52	KVA
TOTAL WATER PUMP LOADS	6.32	KVA
TOTAL ELEVATOR LOAD IN ADMINISTRATION BUILDING	61.5279	KVA
TOTAL MECHANICAL LOADS	**1170.0079**	**KVA**

TABLE II. TOTAL LOADS

SUMMARY OF LOADS		
TOTAL LIGHTING LOADS	87.908	KVA
TOTAL POWER LOADS	133.083	KVA
TOTAL HVAC LOADS	706.4379	KVA
TOTAL MECHANICAL LOADS	1170.008	KVA
TOTAL LOADS	**2097.437**	**KVA**

B. *Voltage Drop Analysis*

TABLE III. PERCENT VOLTAGE DROP OF RESEARCH FACILITY

LINE	FARTHEST LOAD TO SUB PANEL BOARD %VDROP ≤ 3%	SUB PANEL BOARD TO SUB DISTRIBUTION PANEL %VDROP ≤ 3%	SUB DISTRIBUTION PANEL TO MAIN DISTRIBUTION PANEL %VDROP ≤ 3%	MAIN DISTRIBUTION PANEL TO TRANSFORMER (SOURCE) %VDROP ≤ 3%	TOTAL %VDROP	ALLOWABLE %VDROP ≤ 5%
LINE1	2.41	1.33	0.77	0.13	4.64	PASSED
LINE2	2.41	1.36	0.77	0.13	4.67	PASSED
LINE3	2.26	1.13	0.77	0.13	4.29	PASSED
LINE4	0.43	0.66	0.77	0.13	1.99	PASSED
LINE5	0.43	0.52	0.77	0.13	1.85	PASSED
LINE6	0.64	0.67	0.77	0.13	2.21	PASSED
LINE7	0.49	0.66	0.77	0.13	2.05	PASSED
LINE8	0.68	0.67	0.77	0.13	2.25	PASSED
LINE9	0.96	0.71	0.77	0.13	2.57	PASSED
LINE10	1.48	0.9	0.77	0.13	3.28	PASSED
LINE11	LOW CURRENT	1.41	0.77	0.13	2.31	PASSED

TABLE IV. PERCENT VOLTAGE DROP OF GREENHOUSE

LINE	FARTHEST LOAD TO SUB PANEL BOARD %VDROP ≤ 3%	SUB PANEL BOARD TO SUB DISTRIBUTION PANEL %VDROP ≤ 3%	SUB DISTRIBUTION PANEL TO MAIN DISTRIBUTION PANEL %VDROP ≤ 3%	MAIN DISTRIBUTION PANEL TO TRANSFORMER (SOURCE) %VDROP ≤ 3%	TOTAL %VDROP	ALLOWABLE %VDROP ≤ 5%
LINE1	0.4	1.47	0.67	0.13	2.67	PASSED
LINE2	0.4	1.2	0.67	0.13	2.4	PASSED
LINE3	0.4	0.92	0.67	0.13	2.12	PASSED
LINE4	0.65	0.19	0.67	0.13	1.64	PASSED

TABLE V. PERCENT VOLTAGE DROP OF ADMINISTRATION BUILDING

LINE	FARTHEST LOAD TO SUB PANEL BOARD %VDROP ≤ 3%	SUB PANEL BOARD TO SUB DISTRIBUTION PANEL %VDROP ≤ 3%	SUB DISTRIBUTION PANEL TO MAIN DISTRIBUTION PANEL %VDROP ≤ 3%	MAIN DISTRIBUTION PANEL TO TRANSFORMER (SOURCE) %VDROP ≤ 3%	TOTAL %VDROP	ALLOWABLE %VDROP ≤ 5%
LINE1	2.09	0.37	0.66	0.13	3.25	PASSED
LINE2	1.92	1.42	0.66	0.13	4.13	PASSED
LINE3	1.71	1.38	0.66	0.13	3.88	PASSED
LINE4	2.05	1.47	0.66	0.13	4.31	PASSED
LINE5	1.77	1.3	0.66	0.13	3.86	PASSED
LINE6	1.32	1.35	0.66	0.13	3.46	PASSED

C. Transformer Sizing

TABLE VI. TOTAL DEMAND LOAD

BUILDINGS	CONNECTED LOAD (KVA)	DEMAND LOAD (KVA)
RESEARCH FACILITY	751.29	751.29
GREENHOUSE	258.52	258.52
ADMIN BLDG	402.26	321.808
TOTAL	1412.07	1331.618

HML = 200 HP = 200 KVA , Diversity Factor(ks) = 1.46

$$\text{Transformer Size} = [\ 200\ \text{KVA} + \frac{1331.618\ \text{KVA}}{1.46} + \frac{1331.618\ \text{KVA}}{1.46} \times 50\%\ ] \times 1.25\ = 1960.13\ \text{KVA} \cong 2\text{MVA}$$

D. Short Circuit Analysis

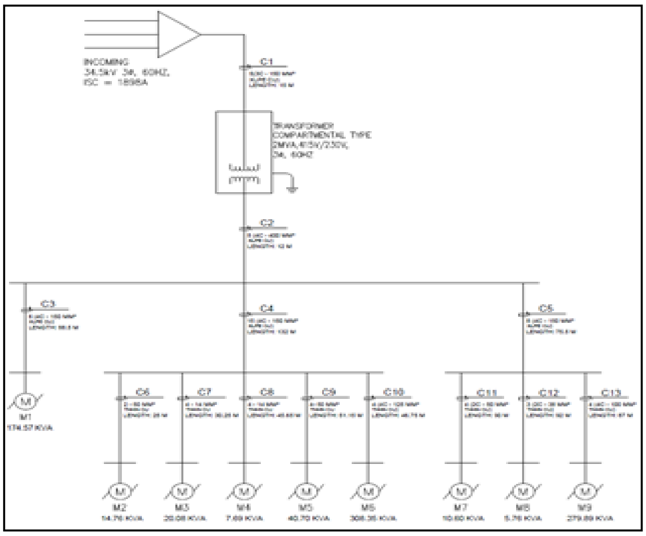


Fig. 6. Lumped Motor Diagram

TABLE VII. SUMMARY OF FAULT CURRENTS

SUMMARY OF FAULT CURRENTS								
FAULT LOCATION		3Ø (kA)	L-L (kA)	L-G (kA)	2L-G (kA)	HIGHEST FAULT (kA)	30% ALLOWANCE	KAIC
F1	UTILITY BUS	1.96	1.7	2.94	5.87	5.87	7.631	10
F2	MV BUS	1.96	1.7	1.94	1.92	1.96	2.548	10
F3	LV BUS	45.65	39.54	57.18	75.41	75.41	98.033	100
F4	MDP BUS	44.7	38.71	56.81	76.42	76.42	99.346	100
F5	GDP BUS	33.01	28.59	29.17	25.35	33.01	42.913	50
F6	RDP BUS	37.64	32.6	46.8	60	60	78	80
F7	ADP BUS	37	32.04	44	52.15	52.15	67.795	70

TABLE VIII. ETAP FAULT CURRENTS VERIFICATION

COMPUTED VALUE (A)	ETAP VALUE (A)	%ERROR	≤ 5%

FAULT LOCATION		3Ø FAULT (A)			
F1	UTILITY BUS	1958.045295	1949	0.461955	PASSED
F2	MV BUS	1957.976041	1949	0.458435	PASSED
F3	LV BUS	45653.883225	44744	1.993003	PASSED
F4	MDP BUS	44699.512268	43803	2.005642	PASSED
F5	GDP BUS	33011.956921	32785	0.687499	PASSED
F6	RDP BUS	37639.091075	37141	1.323334	PASSED
F7	ADP BUS	36993.593027	36525	1.266687	PASSED

FAULT LOCATION		LINE TO LINE FAULT (A)			
F1	UTILITY BUS	1695.667226	1688	0.452166	PASSED
F2	MV BUS	1695.607251	1688	0.448645	PASSED
F3	LV BUS	39536.262873	38749	1.991243	PASSED
F4	MDP BUS	38709.777624	37935	2.001504	PASSED
F5	GDP BUS	28588.354694	28393	0.683337	PASSED
F6	RDP BUS	32595.452871	32165	1.320592	PASSED
F7	ADP BUS	32036.451561	31631	1.265594	PASSED

FAULT LOCATION		LINE TO GROUND FAULT (A)			
F1	UTILITY BUS	2936.900700	2974	1.263213	PASSED
F2	MV BUS	1937.521445	1898	2.039794	PASSED
F3	LV BUS	57177.032507	57522	0.603332	PASSED
F4	MDP BUS	56807.617235	55310	2.636297	PASSED
F5	GDP BUS	29173.467873	29586	1.414066	PASSED
F6	RDP BUS	46795.652762	46617	0.381772	PASSED
F7	ADP BUS	43999.088521	43184	1.852512	PASSED

FAULT LOCATION		DOUBLE LINE TO GROUND FAULT (A)			
F1	UTILITY BUS	5872.798022	5652	3.759673	PASSED
F2	MV BUS	1917.487754	1940	1.174049	PASSED
F3	LV BUS	75408.562002	74759	0.86139	PASSED
F4	MDP BUS	76419.703546	74127	3.000147	PASSED
F5	GDP BUS	25350.194814	25933	2.299017	PASSED
F6	RDP BUS	59981.266110	59741	0.400569	PASSED
F7	ADP BUS	52151.245247	53594	2.766482	PASSED

As computed the results for the ratings, voltage drops, short circuit and arc flash. ETAP validated each manual computed results as close as <5% error.

These are the fault currents of every buses which are needed in the electrical system for the circuit breakers to have an accurate KAIC (Kilo Ampere Interrupting Capacity) rating. These KAIC ratings are the most important setting of the protection or the circuit breakers because it indicates the range when the highest possible fault current could occur.

For the Utility bus the highest fault current is 5.87 kA, 1.96 kA for MV bus, 75.41 kA for LV bus, 76.42 kA for MDP bus, 33.01 kA for GDP bus, 60 kA for RDP bus, 52.15 for ADP bus wherein the researchers, as designers, applied a 30% allowance.

E. Grounding Calculation

Summary of Resistances:

Earth Strip Size (S) = 240 mm2

Type of Earth Strip = 1 – 40 x 6 mm GI strip

Diameter of Pipe = 6.5 cm

Length of Pipe = 500 cm

Resistance of Earth Strip (Rs) = 2.49 ohm

Maximum Current Density (I) = 12982.44 Amps/m2

Surface Area of Earth Electrode = 1.0205 m2

Resistance of Earth Electrode (Re) = 1.82455 ohm

Quantity of Earth Electrode = 10

Resistance of Grid Connected Pits (Rearth) = 0.18246 ohm

Total Grid Resistance = 0.17 ohm

F. Interpretation of Data

The proposed seed bank research facility located in the Las Piñas–Parañaque Critical Habitat and Ecotourism Area (LPPCHEA) has an electrical system design that aims to safely control the distribution of electrical power throughout the facility and to provide reliable electrical needs for power, lighting, convenience, mechanical, and low current system with adequate expansion capacity for possible future loads. The design consists of Transformer with a total of 1.943 MVA, at a diversity factor of 1.46 allowing the entire system to have an approximately 2 MVA transformer size for each transformer at 34.5 kV primary voltages and a secondary voltage of 415 V.

For the safety and reliability, the design was validated and approved (signed and sealed) by a Professional Electrical Engineer in accordance with the Philippine Electrical Code.

V. SUMMARY, CONCLUSION AND RECOMMENDATIONS

A. Summary

The study was conducted to design and analyze the electrical system for the Seed Bank Research Facility located in Freedom Island, Las Piñas-Parañaque Critical Habitat and Eco Tourism Area.

Designing a building, especially commercial building is complicated that it requires time and complex analysis based on making this project and based on the experiences of Professional Electrical Engineer.

Designing is not just the layouts of the system such as lighting, power, mechanical and etc. but the analysis of the system in terms of the specific requirement of the system, the flow of the system, the protection needed by the system, and the danger that a system can cause to one another and to surroundings.

The researchers start to gather data, the architectural plan of Seed Bank Research Facility from the architecture students. The researchers collaborated with the Mechanical Engineering (ME) and Electronics and Communications Engineering (ECE) discipline to design the Heating, Ventilation and Air-Conditioning (HVAC) requirements of the system and Low Current System of the plan respectively. The Fault Level provided by MERALCO, which is considered as the main supply of the system.

B. Conclusion

The Simplified Single Line Diagram is used in the Short Circuit Analysis where the motors provided are lumped to produce Lumped Motor Diagram. The Lumped Motor Diagram is to be used in the whole short circuit calculations because motorized equipment are sensitive that requires intensive analysis for determining the per-unit impedance needed for the calculation of different fault currents in each bus which will make use of choosing the KAIC rating needed each bus. After knowing the KAIC rating needed for each bus the researchers precede to Protection and Coordination System this part will cover the Time-Current Characteristics of the Protection used by the electrical system.

From the Results and Discussion chapter, The Short Circuit fault currents are validated by the Electrical Transient & Analysis Program (ETAP) which produced value same as the computed value with less than five percent error.

C. Recommendation

For further improvement, the researchers highly recommend the future researchers to study more the following:

- Load flow Analysis, Harmonics, and Insulation Coordination that would make the electrical system efficient and effective.
- Improve or Enhance the Special Loads in the Research Facility that would fit the electrical system.
- The researchers recommend that the future researchers should study other ways to improve the efficiency and effectiveness of electrical system in the Research Facility.

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