# Evaluation of Power System Stability for Load Scheduling of Plaza A Building

FIDEL M. SEÑA
*Graduate School, Adamson University, Manila, Philippines*

***Abstract- The study mainly focused on the analysis of the as-built electrical system and as- found electrical system of Plaza A located at Northgate Ave, Alabang, Muntinlupa, Metro Manila. The evaluation of the electrical parameters, settings, and electrical protective devices was conducted. The building is supported by utility power and emergency power and with the addition of a new generator. The researcher verified the modification of the electrical system if it still complies with the standard set by the Philippine Electrical Code. He conducted simulations and study based on actual settings and rating using ETAP software. The analysis involved Load Flow Analysis, Arc Flash Analysis, and Short Circuit Analysis. The results of the simulations are within acceptable ranges. Thus, this study recommends synchronizing the three generators to ease burden of operation, conducting regular inspection and audit of the electrical system of the building, and regular training of workers.***

***Indexed Terms- Power system stability, Arc flash analysis, Load flow analysis, Short circuit analysis, Electrical load schedule.***

## I. INTRODUCTION

Continuous upgrade of its building components and provide better machination, automation, or modernization are tasks of a facility engineer. The continuous modification of the building components is necessary to ensure business is round the clock.

Updating the existing layout or plan of the building is often neglected, especially the load schedule of the building, most of the time resulting in an unbalanced load. Power system oscillations are a primary cause of unexpected power blackouts. A fault or a series of faults can disrupt the system, leading to oscillations in the power network [1]. Generators are connected by a network that functions similarly to weights linked by rubber bands. In this analogy, the weights represent the rotating inertia of the turbine generators, while the rubber bands symbolize the inductance of the transmission lines. When a person pulls on one weight and releases it, it creates an oscillation that affects several interconnected weights. Disturbing a single weight causes all the weights to oscillate. Over time, the system will settle down, depending on its damping characteristics [2]. Identifying unbalanced phase currents is crucial for control and fault alarm rates in power grids, especially in urban distribution networks. The zero-sequence current transformer, specifically designed for measuring unbalanced phase currents, offers advantages in measurement range, identity, and size, compared to using three separate current transformers [3]. Unbalanced load occurs when there is significantly more power drawn on one phase of a system which can lead to overheating of electrical components and overheating, and increase power losses and is insufficient in operation. Making the reliability of the electrical system decrease with respect to time. Equipment in these facilities is subject to fast wear and tear.

Thus, it is important to regularly evaluate and update the electrical system whenever there is modification to make sure ample power supply of the building and avoid equipment breakdown.

Decisions on maintenance policies encompass operational considerations related to machinery and facilities, including failure modes. They also involve strategic aspects concerning the organization's requirements for availability, safety, and quality, all aimed at optimizing the total life cycle cost [4].

## II. DESIGN OPTION

The evaluation of this project was verified and checked by a Professional Electrical Engineer. However, it depends on the management if it will be implemented or retain the current electrical system. Actual testing with the help of test device can verify and check the result of the study if the management intends to.

## III. DESIGN SPECIFICATIONS

The electrical system of the building served as basis of this study, including the one - line diagram and load schedule. The output or design plan was presented including the one-line diagram, riser diagram, and the simulated result of the load flow, arc flash, and short circuit analysis for comparison of its parameters.

## IV. ASSUMPTIONS FOR SIMULATIONS

The electrical design was based on the regulation of the latest edition of Philippine Electrical Code (PEC) 2017

Basic Design Codes:
Section 4.30.2.2 (A) PEC 2017, pg.347-348
Computation of branch circuit conductors in single motor
Section 4.30.2.4 PEC 2017, pg.349-350
Computation of branch circuit motors and other loads
Section 4.40.4.3 PEC 2017, pg.356-357
Computation of branch circuit conductors for air conditioning equipment
Section 4.30.4.2 PEC 2017, pg.354-356
Selection of branch circuit short circuit and ground fault protection for individual motor circuit
Section 4.30.4.3 (C) (4) PEC 2017, pg.356-357
Selection of branch circuit short circuit and ground fault protection for the group of motor

## V. BASIS OF THE ANALYSIS

The basis of the simulations is the Philippine Electrical Code (PEC) incorporated with the ETAP software and in line with other international standards, such as the International Electrotechnical Commission, American National Standard Institute, and Institute of Electrical and Electronics Engineering standards.

## VI. SUMMARY OF LOAD FLOW USING UTILITY SUPPLY

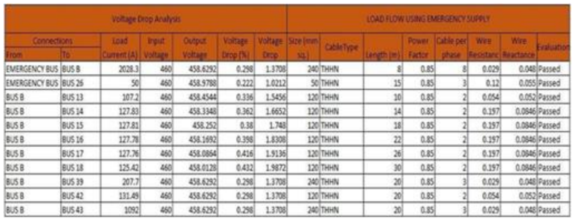
TABLE I. SUMMARY OF LOADS USING UTILITY SUPPLY

| Voltage Drop Analysis | | | | | | | LOAD FLOW USING UTILITY SUPPLY | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Connections | | Load Current (A) | Input Voltage | Output Voltage | Voltage Drop (%) | Voltage Drop | Size (mm sq.) | CableType | Length (m) | Power Factor | Cable per phase | Wire Resistanc | Wire Reactance | Evaluation |
| From | To | | | | | | | | | | | | | |
| UTILITY BUS | BUS A | 2028.3 | 460 | 454.1258 | 1.277 | 5.8742 | 240 | THHN | 8 | 0.85 | 8 | 0.029 | 0.048 | Passed |
| UTILITY BUS | BUS 64 | 516.79 | 460 | 455.1792 | 1.048 | 4.8208 | 150 | THHN | 10 | 0.85 | 4 | 0.16 | 0.085 | Passed |
| UTILITY BUS | BUS 26 | 50 | 460 | 459.4894 | 0.111 | 0.5106 | 50 | THHN | 15 | 0.85 | 3 | 0.12 | 0.055 | Passed |
| BUS A | BUS 19 | 107.2 | 460 | 453.9602 | 1.313 | 6.0398 | 120 | THHN | 10 | 0.85 | 2 | 0.054 | 0.052 | Passed |
| BUS A | BUS 20 | 127.83 | 460 | 453.56 | 1.4 | 6.44 | 120 | THHN | 14 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS A | BUS 21 | 127.81 | 460 | 453.7532 | 1.358 | 6.2468 | 120 | THHN | 18 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS A | BUS 22 | 127.78 | 460 | 453.6658 | 1.377 | 6.3342 | 120 | THHN | 22 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS A | BUS 23 | 127.76 | 460 | 453.583 | 1.395 | 6.417 | 120 | THHN | 26 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS A | BUS 24 | 125.42 | 460 | 453.514 | 1.41 | 6.486 | 120 | THHN | 30 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS A | BUS 39 | 207.7 | 460 | 454.1258 | 1.277 | 5.8742 | 240 | THHN | 20 | 0.85 | 3 | 0.029 | 0.048 | Passed |
| BUS A | BUS 42 | 131.49 | 460 | 454.1258 | 1.277 | 5.8742 | 120 | THHN | 20 | 0.85 | 2 | 0.054 | 0.052 | Passed |
| BUS A | BUS 43 | 1092 | 460 | 454.1258 | 1.277 | 5.8742 | 240 | THHN | 20 | 0.85 | 3 | 0.029 | 0.048 | Passed |

Shows the simulation for the load flow analysis of as built diagram using the utility or the normal supply of the building and, that the losses in the system are within acceptable limit of the standard indicated in the Philippine electrical code with a maximum loss of 5%. Above this, the system must be re-evaluated to comply with the standard. It also shows that the largest value of voltage drop is at 1.41% which is the bus for 6th floor. While the lowest voltage drop is at 0.11% which is for the fire pump equipment.

## VII. SUMMARY LOAD FLOW USING EMERGENCY SUPPLY

TABLE II. SUMMARY OF LOADS USING EMERGENCY SUPPLY



| Voltage Drop Analysis | | | | | | | LOAD FLOW USING EMERGENCY SUPPLY | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Connections | | Load Current (A) | Input Voltage | Output Voltage | Voltage Drop (%) | Voltage Drop | Size (mm sq.) | CableType | Length (m) | Power Factor | Cable per phase | Wire Resistanc | Wire Reactance | Evaluation |
| From | To | | | | | | | | | | | | | |
| EMERGENCY BUS | BUS B | 2028.3 | 460 | 458.6292 | 0.298 | 1.3708 | 240 | THHN | 8 | 0.85 | 8 | 0.029 | 0.048 | Passed |
| EMERGENCY BUS | BUS 26 | 50 | 460 | 458.9788 | 0.222 | 1.0212 | 50 | THHN | 15 | 0.85 | 3 | 0.12 | 0.055 | Passed |
| BUS B | BUS 13 | 107.2 | 460 | 458.4544 | 0.336 | 1.5456 | 120 | THHN | 10 | 0.85 | 2 | 0.054 | 0.052 | Passed |
| BUS B | BUS 14 | 127.83 | 460 | 458.3348 | 0.362 | 1.6652 | 120 | THHN | 14 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 15 | 127.81 | 460 | 458.252 | 0.38 | 1.748 | 120 | THHN | 18 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 16 | 127.78 | 460 | 458.1692 | 0.398 | 1.8308 | 120 | THHN | 22 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 17 | 127.76 | 460 | 458.0864 | 0.416 | 1.9136 | 120 | THHN | 26 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 18 | 125.42 | 460 | 458.0128 | 0.432 | 1.9872 | 120 | THHN | 30 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 39 | 207.7 | 460 | 458.6292 | 0.298 | 1.3708 | 240 | THHN | 20 | 0.85 | 3 | 0.029 | 0.048 | Passed |
| BUS B | BUS 42 | 131.49 | 460 | 458.6292 | 0.298 | 1.3708 | 120 | THHN | 20 | 0.85 | 2 | 0.054 | 0.052 | Passed |
| BUS B | BUS 43 | 1092 | 460 | 458.6292 | 0.298 | 1.3708 | 240 | THHN | 20 | 0.85 | 3 | 0.029 | 0.048 | Passed |

shows the simulation for the load flow analysis of as built diagram using the emergency or the generator one and generator two working together to supply the power of the building and, shows that the losses in the system is within acceptable limit of the standard indicated in the Philippine electrical code with a maximum loss of 5%. Above this the system must be re-evaluated to comply with the standard. It also shows that the largest value of voltage drop is at 0.432% which is the bus for 6th floor. While the lowest voltage drop is at 0.22% which is for the fire pump equipment.

## VIII. SUMMARY OF LOADS USING GENERATOR 3

TABLE III. SUMMARY OF LOADS USING GENERATOR 3

| Voltage Drop Analysis | | | | | | | LOAD FLOW USING GENSET 3 BUS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Connections | | Load Current | Input Voltage | Output Voltage | Voltage Drop (%) | Voltage Drop | Size (mm sq.) | CableType | Length (m) | Power Factor | Cable per phase | Wire Resistanc | Wire Reactanc | Evaluation |
| From | To | | | | | | | | | | | | | |
| GENSET 3 BUS | BUS B | 2028.3 | 460 | 458.4958 | 0.327 | 1.5042 | 240 | THHN | 10 | 0.85 | 6 | 0.0998 | 0.0843 | Passed |
| GENSET 3 BUS | BUS 26 | 50 | 460 | 459.3376 | 0.144 | 0.6624 | 50 | THHN | 15 | 0.85 | 3 | 0.12 | 0.055 | Passed |
| BUS B | BUS 13 | 107.2 | 460 | 458.321 | 0.365 | 1.679 | 120 | THHN | 10 | 0.85 | 2 | 0.054 | 0.052 | Passed |
| BUS B | BUS 14 | 127.83 | 460 | 458.2014 | 0.391 | 1.7986 | 120 | THHN | 14 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 15 | 127.81 | 460 | 458.1186 | 0.409 | 1.8814 | 120 | THHN | 18 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 16 | 127.78 | 460 | 458.0312 | 0.428 | 1.9688 | 120 | THHN | 22 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 17 | 127.76 | 460 | 457.9484 | 0.446 | 2.0516 | 120 | THHN | 26 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 18 | 125.42 | 460 | 457.8748 | 0.462 | 2.1252 | 120 | THHN | 30 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 39 | 207.7 | 460 | 458.4958 | 0.327 | 1.5042 | 240 | THHN | 20 | 0.85 | 3 | 0.029 | 0.048 | Passed |
| BUS B | BUS 42 | 131.49 | 460 | 458.4958 | 0.327 | 1.5042 | 120 | THHN | 20 | 0.85 | 2 | 0.054 | 0.052 | Passed |
| BUS B | BUS 43 | 1092 | 460 | 458.4958 | 0.327 | 1.5042 | 240 | THHN | 20 | 0.85 | 3 | 0.029 | 0.048 | Passed |

Shows the simulation for the load flow analysis of as built diagram using the generator three to supply the power of the building. The losses in the system are within acceptable limit of the standard indicated in the Philippine electrical code with a maximum loss of 5%. Above this the system must be re-evaluated to comply with the standard. It also shows that the largest value of voltage drop is at 0.462% which is the bus for 6th floor. While the lowest voltage drop is at 0.144% which is for the fire pump equipment.

## IX. ARC FLASH – ASBUILT

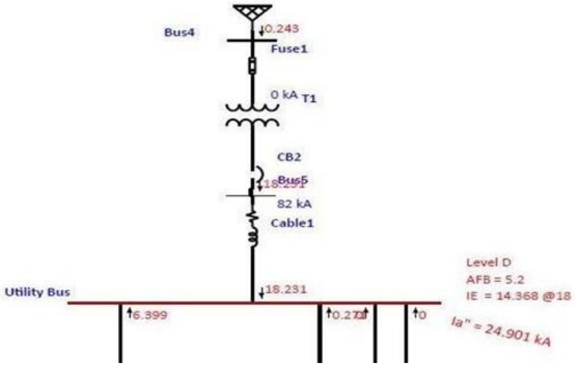


Fig. 1. Arc flash at utility bus using utility supply

shows the arc flash simulation of the utility bus using the utility supply or the normal supply. The arc flash boundary is 5.2ft. The incident energy at working distance is 14.368 Cal/cm2 at 18 inches of working distance.

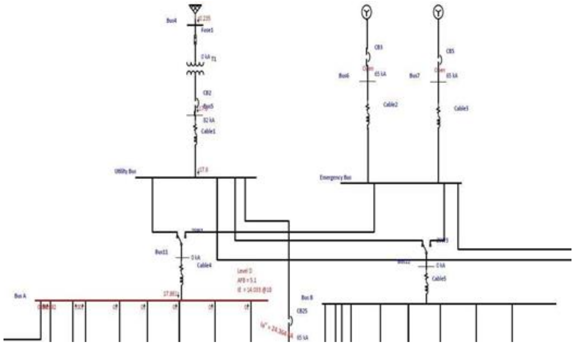


Fig. 2. Arc flash at bus A using utility supply

Shows the arc flash simulation of Bus A using the utility supply or the normal supply. The arc flash boundary is 5.1ft. The incident energy at working distance is 14.033 Cal/cm2 at 18 inches of working distance.

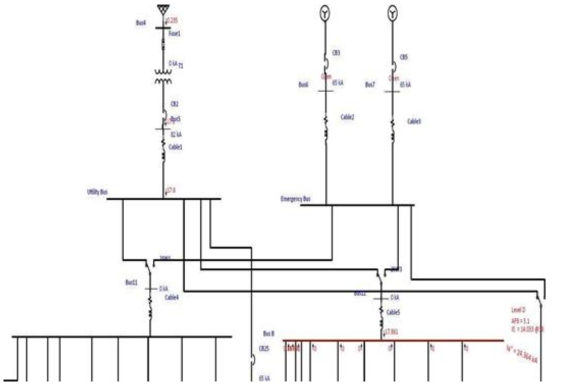


Fig. 3. Arc flash at bus B using utility supply

Shows the arc flash simulation of the emergency bus using the emergency power or generator 1 and generator 2 working together.

The arc flash boundary is 5.1ft. The incident energy at working distance is 14.033Cal/cm2 at 18 inches of working distance.

Shows the arc flash simulation of the emergency bus using the emergency power or the generator 1 and generator 2 working together to supply power. The arc flash boundary is 7.3ft. The incident energy at working distance is 28.513 Cal/cm2 at 18 inches of working distance.

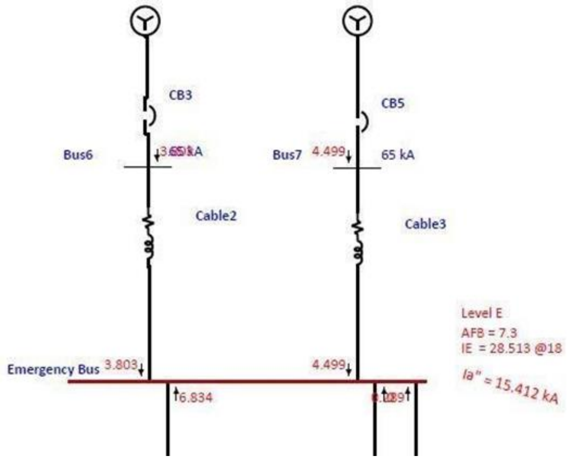


Fig. 5. Arc flash at bus A using emergency power

Shows the arc flash simulation of the bus A using the emergency power or the generator 1 and generator 2 working together to supply power. The arc flash boundary is 7.3ft the incident energy at working distance is 28.44 Cal/cm2 at 18 inches of working distance.

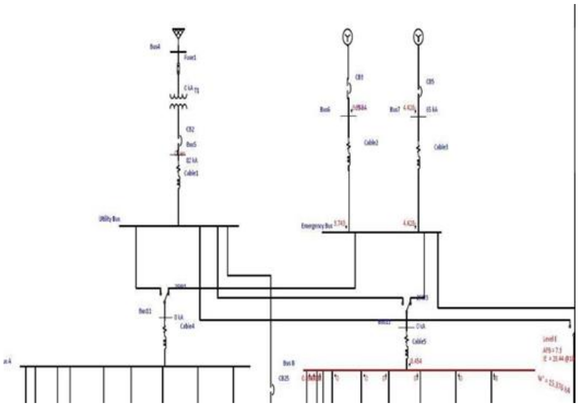
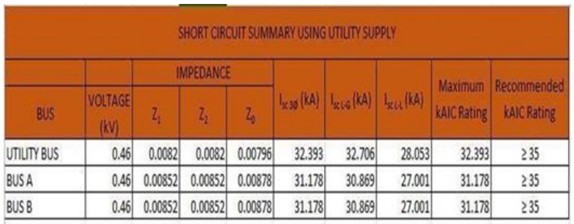


Fig. 6. Arc flash at bus B using emergency power

Shows the arc flash simulation of the bus B using the emergency power or the generator 1 and generator 2 working together to supply power. The arc flash boundary is 7.3ft. The incident energy at working distance is 28.44 Cal/cm2 at 18 inches of working distance.

## X. SHORT CIRCUIT ANALYSIS – ASBUILT

TABLE IV. SHORT CIRCUIT ANALYSIS USING UTILITY SUPPLY

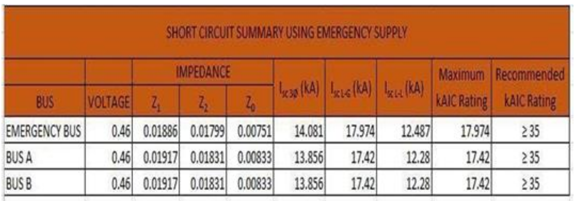


SHORT CIRCUIT SUMMARY USING UTILITY SUPPLY

| | | IMPEDANCE | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| BUS | VOLTAGE (kV) | $Z_1$ | $Z_2$ | $Z_0$ | $I_{sc3\Phi}$ (kA) | $I_{sc L-G}$ (kA) | $I_{sc L-L}$ (kA) | Maximum kAIC Rating | Recommended kAIC Rating |
| UTILITY BUS | 0.46 | 0.0082 | 0.0082 | 0.00796 | 32.393 | 32.706 | 28.053 | 32.393 | ≥ 35 |
| BUS A | 0.46 | 0.00852 | 0.00852 | 0.00878 | 31.178 | 30.869 | 27.001 | 31.178 | ≥ 35 |
| BUS B | 0.46 | 0.00852 | 0.00852 | 0.00878 | 31.178 | 30.869 | 27.001 | 31.178 | ≥ 35 |

Shows short circuit analysis of the as built electrical system using the utility power supply. Faults are simulated on different main buses. The maximum fault is 32.939 kAIC for utility bus; 31.178kAIC for Bus A which is same with Bus B, respectively. It also shows the total impedance per bus.

TABLE V. SHORT CIRCUIT ANALYSIS USING EMERGENCY SUPPLY



SHORT CIRCUIT SUMMARY USING EMERGENCY SUPPLY

| | | IMPEDANCE | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| BUS | VOLTAGE | $Z_1$ | $Z_2$ | $Z_0$ | $I_{sc3\Phi}$ (kA) | $I_{sc L-G}$ (kA) | $I_{sc L-L}$ (kA) | Maximum kAIC Rating | Recommended kAIC Rating |
| EMERGENCY BUS | 0.46 | 0.01886 | 0.01799 | 0.00751 | 14.081 | 17.974 | 12.487 | 17.974 | ≥ 35 |
| BUS A | 0.46 | 0.01917 | 0.01831 | 0.00833 | 13.856 | 17.42 | 12.28 | 17.42 | ≥ 35 |
| BUS B | 0.46 | 0.01917 | 0.01831 | 0.00833 | 13.856 | 17.42 | 12.28 | 17.42 | ≥ 35 |

Shows short circuit analysis of the as built electrical system using the utility power supply. Faults are simulated on different main buses. The maximum fault is 32.939 kAIC for utility bus; 31.178kAIC for for Bus A which is same with Bus B, respectively.

## XI. LOAD FLOW ANALYSIS – ASFOUND

TABLE VI. SHORT CIRCUIT ANALYSIS USING UTILITY SUPPLY

| Voltage Drop Analysis | | | | | | | LOAD FLOW USING UTILITY SUPPLY | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Connections | | Load Current | Input Voltage | Output Voltage | Voltage Drop (%) | Voltage Drop | Size (mm sq.) | CableType | Length (m) | Power Factor | Cable per phase | Wire Resistanc | Wire Reactanc | Evaluation |
| From | To | | | | | | | | | | | | | |
| UTILITY BUS | BUS A | 2028.3 | 460 | 454.9354 | 1.101 | 5.0646 | 240 | THHN | 8 | 0.85 | 8 | 0.029 | 0.048 | Passed |
| UTILITY BUS | BUS 64 | 516.79 | 460 | 455.9704 | 0.876 | 4.0296 | 150 | THHN | 10 | 0.85 | 4 | 0.16 | 0.085 | Passed |
| UTILITY BUS | BUS 26 | 50 | 460 | 455.7772 | 0.918 | 4.2228 | 50 | THHN | 15 | 0.85 | 3 | 0.12 | 0.055 | Passed |
| BUS A | BUS 19 | 107.2 | 460 | 454.7698 | 1.137 | 5.2302 | 120 | THHN | 10 | 0.85 | 2 | 0.054 | 0.052 | Passed |
| BUS A | BUS 20 | 127.83 | 460 | 454.6456 | 1.164 | 5.3544 | 120 | THHN | 14 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS A | BUS 21 | 127.81 | 460 | 454.5628 | 1.182 | 5.4372 | 120 | THHN | 18 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS A | BUS 22 | 127.78 | 460 | 454.4754 | 1.201 | 5.5246 | 120 | THHN | 22 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS A | BUS 23 | 127.76 | 460 | 454.3926 | 1.219 | 5.6074 | 120 | THHN | 26 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS A | BUS 24 | 125.42 | 460 | 454.3236 | 1.234 | 5.6764 | 120 | THHN | 30 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS A | BUS 39 | 207.7 | 460 | 454.9354 | 1.101 | 5.0646 | 240 | THHN | 20 | 0.85 | 3 | 0.029 | 0.048 | Passed |
| BUS A | BUS 42 | 131.49 | 460 | 454.9354 | 1.101 | 5.0646 | 120 | THHN | 20 | 0.85 | 2 | 0.054 | 0.052 | Passed |
| BUS A | BUS 43 | 1092 | 460 | 454.9354 | 1.101 | 5.0646 | 240 | THHN | 20 | 0.85 | 3 | 0.029 | 0.048 | Passed |

Shows the simulation for the load flow analysis of as built diagram using the generator three to supply the power of the building. The losses in the system are within acceptable limit of the standard indicated in the

Philippine electrical code with a maximum loss of 5%. Above this the system must be re-evaluated to comply with the standard. It also shows that the largest value of voltage drop is at 0.462% which is the bus for 6th floor. While the lowest voltage drop is at 0.144% which is for the fire pump equipment.

TABLE VII. SHORT CIRCUIT ANALYSIS USING GENERATOR 1 AND 2

| Voltage Drop Analysis | | | | | | | LOAD FLOW USING EMERGENCY SUPPLY | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Connections | | Load | Input | Output | Voltage | Voltage | Size (mm | CableTyp | Length | Power | Cable per | Wire | Wire | Evaluation |
| From | To | Current | Voltage | Voltage | Drop (%) | Drop | sq.) | e | (m) | Factor | phase | Resistanc | Reactanc | |
| EMERGENCY BUS | BUS B | 2028.3 | 460 | 458.6614 | 0.291 | 1.3386 | 240 | THHN | 8 | 0.85 | 8 | 0.029 | 0.048 | Passed |
| EMERGENCY BUS | BUS 26 | 50 | 460 | 459.5032 | 0.108 | 0.4968 | 50 | THHN | 15 | 0.85 | 3 | 0.12 | 0.055 | Passed |
| BUS B | BUS 13 | 107.2 | 460 | 458.4958 | 0.327 | 1.5042 | 120 | THHN | 10 | 0.85 | 2 | 0.054 | 0.052 | Passed |
| BUS B | BUS 14 | 127.83 | 460 | 458.367 | 0.355 | 1.633 | 120 | THHN | 14 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 15 | 127.81 | 460 | 458.2842 | 0.373 | 1.7158 | 120 | THHN | 18 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 16 | 127.78 | 460 | 458.1968 | 0.392 | 1.8032 | 120 | THHN | 22 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 17 | 127.76 | 460 | 458.114 | 0.41 | 1.886 | 120 | THHN | 26 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 18 | 125.42 | 460 | 458.0404 | 0.426 | 1.9596 | 120 | THHN | 30 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 39 | 207.7 | 460 | 458.6614 | 0.291 | 1.3386 | 240 | THHN | 20 | 0.85 | 3 | 0.029 | 0.048 | Passed |
| BUS B | BUS 42 | 131.49 | 460 | 458.6614 | 0.291 | 1.3386 | 120 | THHN | 20 | 0.85 | 2 | 0.054 | 0.052 | Passed |
| BUS B | BUS 43 | 1092 | 460 | 458.6614 | 0.291 | 1.3386 | 240 | THHN | 20 | 0.85 | 3 | 0.029 | 0.048 | Passed |

Shows the simulation for the load flow analysis of as built diagram using the emergency or the generator one and generator two working together to supply the power of the building. The losses in the system is within acceptable limit of the standard indicated in the Philippine electrical code with a maximum loss of 5%. Above this the system must be re-evaluated to comply with the standard. It also shows that the largest value of voltage drop is at 0.41% which is the bus for 6th floor. While the lowest voltage drop is at 0.108% which is for the fire pump equipment.

TABLE VIII. SHORT CIRCUIT ANALYSIS USING GENERATOR 3

| Voltage Drop Analysis | | | | | | | LOAD FLOW USING GENSET 3 BUS | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Connections | | Load | Input | Output | Voltage | Voltage | Size (mm | CableTyp | Length | Power | Cable per | Wire | Wire | Evaluation |
| From | To | Current | Voltage | Voltage | Drop (%) | Drop | sq.) | e | (m) | Factor | phase | Resistanc | Reactanc | |
| GENSET 3 BUS | BUS B | 2028.3 | 460 | 458.4958 | 0.327 | 1.5042 | 240 | THHN | 10 | 0.85 | 6 | 0.0998 | 0.0843 | Passed |
| GENSET 3 BUS | BUS 26 | 50 | 460 | 459.3376 | 0.144 | 0.6624 | 50 | THHN | 15 | 0.85 | 3 | 0.12 | 0.055 | Passed |
| BUS B | BUS 13 | 107.2 | 460 | 458.321 | 0.365 | 1.679 | 120 | THHN | 10 | 0.85 | 2 | 0.054 | 0.052 | Passed |
| BUS B | BUS 14 | 127.83 | 460 | 458.2014 | 0.391 | 1.7986 | 120 | THHN | 14 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 15 | 127.81 | 460 | 458.1186 | 0.409 | 1.8814 | 120 | THHN | 18 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 16 | 127.78 | 460 | 458.0312 | 0.428 | 1.9688 | 120 | THHN | 22 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 17 | 127.76 | 460 | 457.9484 | 0.446 | 2.0516 | 120 | THHN | 26 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 18 | 125.42 | 460 | 457.8748 | 0.462 | 2.1252 | 120 | THHN | 30 | 0.85 | 2 | 0.197 | 0.0846 | Passed |
| BUS B | BUS 39 | 207.7 | 460 | 458.4958 | 0.327 | 1.5042 | 240 | THHN | 20 | 0.85 | 3 | 0.029 | 0.048 | Passed |
| BUS B | BUS 42 | 131.49 | 460 | 458.4958 | 0.327 | 1.5042 | 120 | THHN | 20 | 0.85 | 2 | 0.054 | 0.052 | Passed |
| BUS B | BUS 43 | 1092 | 460 | 458.4958 | 0.327 | 1.5042 | 240 | THHN | 20 | 0.85 | 3 | 0.029 | 0.048 | Passed |

Shows the simulation for the load flow analysis of as built diagram using the generator three to supply the power of the building. The losses in the system are within acceptable limit of the standard indicated in the Philippine electrical code with a maximum loss of 5%. Above this the system must be re-evaluated to comply with the standard. It also shows that the largest value of voltage drop is at 0.462% which is the bus for 6th floor. While the lowest voltage drop is at 0.144% which is for the fire pump equipment.

## XII. ARC FLASH – ASFOUND

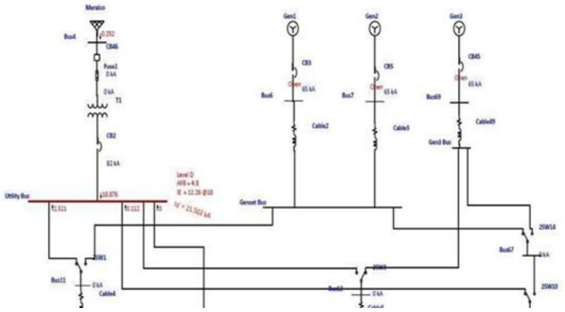


Fig. 7. Arc flash at utility bus using utility supply - asfound

Shows the arc flash simulation of the utility bus using the utility supply or the normal supply. The arc flash boundary is 4.8ft. The incident energy at working distance is 12.26 Cal/cm2 at 18 inches of working distance.

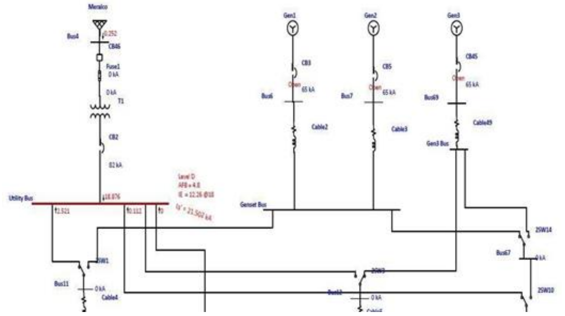


Fig. 8. Arc flash at bus A using utility supply - asfound

Shows the arc flash simulation of the utility bus using the utility supply or the normal supply. The arc flash boundary is 4.8ft. The incident energy at working distance is 12.26 Cal/cm2 at 18 inches of working distance

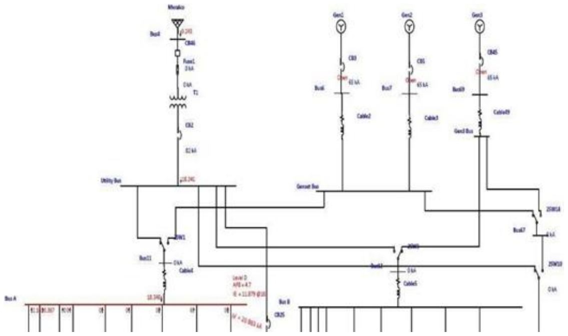


Fig. 9. Arc flash at bus B using utility supply - asfound

Shows the arc flash simulation of Bus A using the utility supply or the normal supply. The arc flash boundary is 4.7ft. The incident energy at working distance is 11.879 Cal/cm2 at 18 inches of working distance.

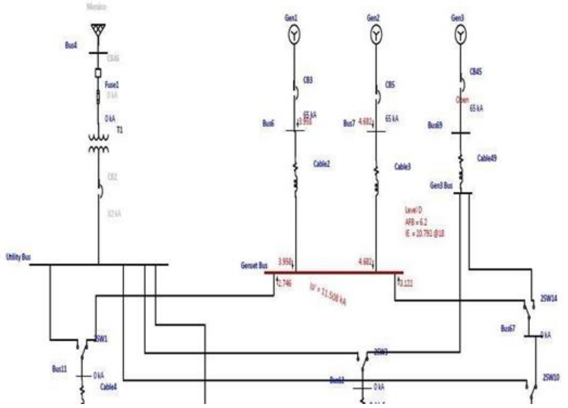


Fig. 10. Arc flash at emergency bus generator 1 and 2 -asfound

Shows the arc flash simulation of the emergency bus using the emergency power or generator 1 and generator 2 working together.

The arc flash boundary is 6.2ft. The incident energy at working distance is 20.792 Cal/cm2 at 18 inches of working distance.

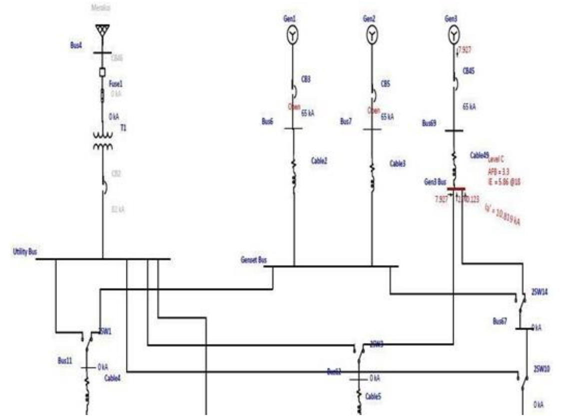


Fig. 11. Arc flash at bus B generator 3 -asfound

Shows the arc flash simulation of the generator 3 bus using generator 3 as power supply. The arc flash boundary is 3.3ft. The incident energy at working distance is 5.86 Cal/cm2 at 18 inches of working distance.

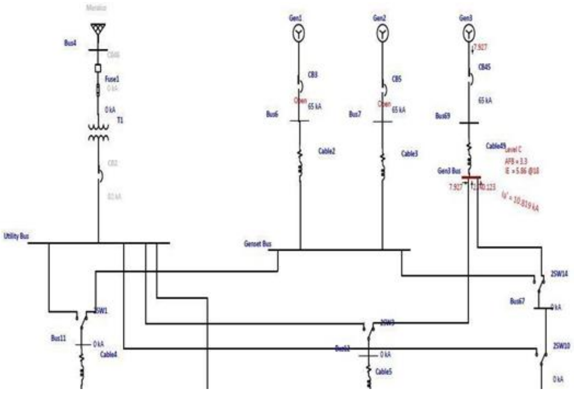
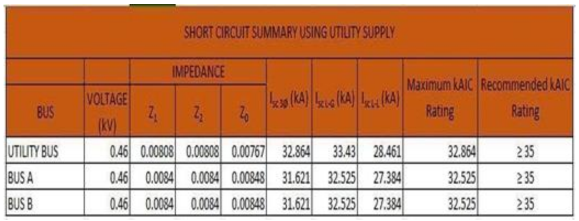


Fig. 12. Arc flash at genset 3 bus using generator 3 - asfound

Shows the arc flash simulation of the Bus B using generator 3 as power supply. The arc flash boundary is 3.3. The incident energy at working distance is 5.86 Cal/cm2 at 18 inches of working distance.

## XIII. SHORT CIRCUIT ANALYSIS – ASFOUND

TABLE IX. SHORT CIRCUIT ANALYSIS USING UTILITY SUPPLY

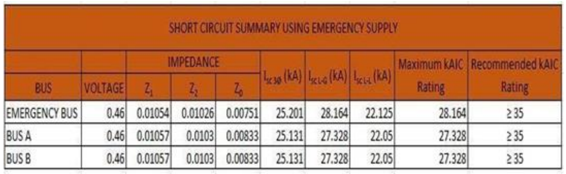


SHORT CIRCUIT SUMMARY USING UTILITY SUPPLY

|  |  | IMPEDANCE |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| BUS | VOLTAGE (kV) | $Z_1$ | $Z_2$ | $Z_0$ | $I_{sc\,3\phi}$ (kA) | $I_{sc\,L\text{-}G}$ (kA) | $I_{sc\,L\text{-}L}$ (kA) | Maximum kAIC Rating | Recommended kAIC Rating |
| UTILITY BUS | 0.46 | 0.00808 | 0.00808 | 0.00767 | 32.864 | 33.43 | 28.461 | 32.864 | ≥ 35 |
| BUS A | 0.46 | 0.0084 | 0.0084 | 0.00848 | 31.621 | 32.525 | 27.384 | 32.525 | ≥ 35 |
| BUS B | 0.46 | 0.0084 | 0.0084 | 0.00848 | 31.621 | 32.525 | 27.384 | 32.525 | ≥ 35 |

Shows the short circuit analysis of the as built electrical system using the utility power supply. Faults are simulated on different main busses. The maximum fault is 32.864 kAIC for utility bus; 32.525 kAIC for Bus A which is same with Bus B, respectively. It also shows the total impedance per bus.

TABLE X. SHORT CIRCUIT ANALYSIS USING GENERATOR 1 AND 2

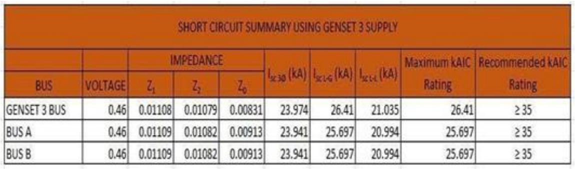


SHORT CIRCUIT SUMMARY USING EMERGENCY SUPPLY

|  |  | IMPEDANCE |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| BUS | VOLTAGE | $Z_1$ | $Z_2$ | $Z_0$ | $I_{sc\,3\phi}$ (kA) | $I_{sc\,L\text{-}G}$ (kA) | $I_{sc\,L\text{-}L}$ (kA) | Maximum kAIC Rating | Recommended kAIC Rating |
| EMERGENCY BUS | 0.46 | 0.01054 | 0.01026 | 0.00751 | 25.201 | 28.164 | 22.125 | 28.164 | ≥ 35 |
| BUS A | 0.46 | 0.01057 | 0.0103 | 0.00833 | 25.131 | 27.328 | 22.05 | 27.328 | ≥ 35 |
| BUS B | 0.46 | 0.01057 | 0.0103 | 0.00833 | 25.131 | 27.328 | 22.05 | 27.328 | ≥ 35 |

Shows the short circuit analysis of the as built electrical system using the utility power supply. Faults are simulated on different main busses. The maximum fault is 28.164 kAIC for utility bus; 27.328 kAIC for Bus A which is same with Bus B respectively.

TABLE XI. SHORT CIRCUIT ANALYSIS USING GENERATOR 3



SHORT CIRCUIT SUMMARY USING GENSET 3 SUPPLY

|  |  | IMPEDANCE |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| BUS | VOLTAGE | $Z_1$ | $Z_2$ | $Z_0$ | $I_{sc\,3\phi}$ (kA) | $I_{sc\,L\text{-}G}$ (kA) | $I_{sc\,L\text{-}L}$ (kA) | Maximum kAIC Rating | Recommended kAIC Rating |
| GENSET 3 BUS | 0.46 | 0.01108 | 0.01079 | 0.00831 | 23.974 | 26.41 | 21.035 | 26.41 | ≥ 35 |
| BUS A | 0.46 | 0.01109 | 0.01082 | 0.00913 | 23.941 | 25.697 | 20.994 | 25.697 | ≥ 35 |
| BUS B | 0.46 | 0.01109 | 0.01082 | 0.00913 | 23.941 | 25.697 | 20.994 | 25.697 | ≥ 35 |

Shows short circuit analysis of the as built electrical system using generator 3 as supply. Faults are simulated on different main busses. The maximum fault is 26.41 kAIC for utility bus; 25.697 kAIC for Bus A which is same with Bus B, respectively.

## XIV. SUMMARY

The electrical system of the building is within standard and within minimum requirement as required by the Philippine Electrical Code. Using E-tap software, simulations of load flow analysis, arc flash analysis, and short circuit analysis of the electrical system of the building, the electrical system is within standard and safe to operate. Update the single line diagram and load schedule of the building. The significant findings of the study guide the recommendations.

## XV. RECOMMENDATIONS

*A.* To improve an existing electrical system in compliance with the Philippine Electrical Code 2017, the proponent recommends the following:

*B.* Generator 3 is must also supply Bus A to further increase the reliability of the emergency power, while currently exclusively supplying the bus B.

*C.* The three generators must operate in load sharing condition to ease burden on the generator's operation, currently generators 1 and 2 only are on load sharing.

*D.* Regular and periodic reviews of the short circuit analysis, protection and coordination study, and arc flash analysis for an electrical distribution system must be conducted to ensure the continued safe and efficient operation of the system and allow for anticipation of retrofitting, load expansion, and electrical system modifications.

*E.* Regular training for workers in manufacturing operations must be considered essential to ensure safety, enhance productivity, and minimize electrical hazards. Training must cover a range of topics, including electrical safety, hazard identification, quality monitoring, and preventive and predictive maintenance procedures.

*F. below for more information on proofreading, spelling and grammar.*

Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads-the template will do that for you.

### *G. Abbreviations and Acronyms*

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

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