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Original Article

The Impact of Oversized Electrical Equipments on Energy Management of Thailand Department Stores

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Abstract - *Department stores are constantly adapting and modernizing to fit new lifestyles. Everyone is resting and working outside the home all day after COVID. The rate of electricity consumption increases according to the rate of service users. Most of the electricity is for air conditioning or kitchen appliances to cook. Electrical installation standards for The Engineering Institute of Thailand Under H.M., the King's Patronage must be followed when designing and choosing electrical equipment for shopping malls, large buildings, and extra-large buildings. The Provincial Electricity Authority, the Metropolitan Electricity Authority, the Department of Public Works and Town & Country Planning, faculty members, designers, supervisors, and contractors put together these standards. The results of the research, engineers can come to the conclusion that the size of electrical equipment can be reduced by up to 4 sizes, or 54% if a single transformer is used in a department store, and by 3 sizes, or 50% if an interchangeable transformer redundancy is used in department stores. The advantages are energy efficiency, cost-effectiveness for initial investment, and cost-effectiveness in managing and maintaining electrical systems to ensure their safety, stability, and economic viability.*

Keywords - *Electrical equipment, Cost-effectiveness, Energy efficiency, Maintaining electrical systems.*

1. Introduction

Since 2002, The Engineering Institute of Thailand, Under H.M. the King's Patronage (EIT), has collaborated with MEA, PEA, and Department of Public Works contractors to establish electrical installation standards for Thailand. The educational institutions, electrical system designers, and electrical installation contractors that use the item design requirements must be calculated in accordance with the relevant legal requirements in electrical engineering. As required by electrical installation standards [1-2], there is at least instruction in design and calculations. The electrical system design for the whole project of the shopping mall building for the project owner and requesting to use the electricity meter with the electricity authority, the equipment, and the amount of electricity must be ready for the use of electricity users. Therefore, the design with excessive overload allowance directly affects the project owner, who has to invest a lot to allow the use of electricity and cables for the shopping mall building and in the part of the electricity that must be reserved for the benefit of electricity in the future. It is a chain of investment that is too high for all sectors. If a design fits, a suitable investment is worth the investment [3-5]. Power management [6-7] is hard to do right, and a bad design can cause damage that will cost more money to fix. The situation in COVID and the conflict between Russia and Ukraine have resulted in a significant increase in the cost of electricity and related materials, with new tariffs taking effect in September 2022. The price and the cost of living have both increased significantly. The cost of doing business is extremely high.

This study can collect data on electricity usage. The selection of electrical equipment, maintenance, and management of electric power in various types of buildings [19–20]. A look at research on choosing electrical equipment that uses the least energy and costs the least money, primarily for residential condominium construction projects [10]. In 2020, N.N. Sadullaev and colleagues [11] studied increasing the energy efficiency and reliability of low-power consumer electricity distribution, creating a "hybrid" principle. It is an electric power source composed of wind power. The installation of mechanical outlets of power and solar panels with batteries works with conventional electricity [12–13]. An energy-efficient estimation method Md. Ashiquzzaman [22] looked into how modern high-rise buildings are wired and how they are designed by using the wiring system using the proposed Busbar Trucking and fault analysis system for Bangladesh. When Busbar Trucking (BBT) systems are used instead of traditional wiring systems for the main distribution lines, they offer much better protection and are easy to install. It saves time, space, and money on maintenance management.

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For the design of electrical systems in shopping malls or shopping centers [15–17], the design principles are the same for large or extra-large buildings. The relevant research by Bao Peng et al. [21] forecasts the energy consumption of shopping mall buildings. The measured energy value is less than 10%, indicating that the primary influencing factor can explain the mall's energy consumption and that the predictive model uses the energy obtained with high precision.

2. Experimental Method

2.1. Research Scope

The sample group, according to the Taro Yamane principle used in this research, is:

- Department store building in Thailand
- Buildings for shopping malls that use transformers with a capacity of more than 1,000 kVA or more than 12 kV, 3 Phase, as required by the Council of Engineers Act, Control Engineering, Electrical Engineering Branch, Council of Engineers.

➢ Research area: Thailand

➢ The length of time it takes to store, analyze, and evaluate

- The data collection period on Saturdays or Sundays is between 11:00 AM and 8:00 PM or during high electrical power usage.
- Data collection will take place between February 15, 2020, and July 31, 2022.
- Verification of data collection results To verify the accuracy of the information from June 16, 2022–June 30, 2022
- The research period runs between January 1, 2020, and August 31, 2022.

2.2. Research Tools

The study tool was a data model, which was a form that the building manager of the department store helped fill out with basic but essential technical information. The Request for Data Courtesy Form, which focuses on the research goals and conceptual framework, is made up of three parts:

Part 1: General information about shopping mall buildings with transformer sizes greater than 1000 kVA or greater than 12 kV at 3 Phases, distinguishing general information about shopping mall buildings such as name, age, location (near the main road, near the train station, etc.).

Part 2: Technical data and technical details are shown as follows.

1. Number of buildings, building type, size, and the number of transformers influence the overall power distribution capacity of transformers in shopping mall buildings.
2. Main circuit breaker size; circuit breaker setting to learn about the circuit breaker's technical details that have the ability to work to prevent overcurrent, short-circuit current, and leakage current to ensure safety for life and property within the shopping mall building.
3. Total Current Consumption or Total Electric Power or Mains Operating Current to view the total current consumption of the entire building from the measured meter or the circuit breaker's meter to provide the shopping mall building's total electricity consumption.
4. The proportion of capacitors used to the total number of uses A capacitor bank is a capacitor to power a power system, reducing the load on the transformer that supplies power to the load, thereby improving overall system efficiency and minimizing losses in an electrical system.

Part 3: The researcher seeks opinions to provide a level of suitability based on the technical information obtained in Part 2 regarding the overall electrification of shopping mall buildings in Bangkok to survey the building supervisors' knowledge and understanding. The product shows the capacity of the transformer breaker cable and compares it to the total amount of energy used by the department store building. It helps to figure out how much electricity is being used and how to set up the electrical equipment to keep people and property safe.

2.3. Calculation of the Power Loss of the Transformer

Calculation of the lost power of the transformer or the power loss in which the transformer has 2 parts of the power loss:

No-load loss is the amount of power lost in the iron core of a transformer when it is running at its rated voltage, but the secondary winding is open. Eddy's Current Loss and Hysteresis Loss cause the power loss. This no-load loss value is constant at the rated voltage and rated frequency.

The load loss is the power loss in the transformer's coil (copper loss) when the load is connected to the secondary winding. The resistance causes power loss in the winding. This load loss is variable in I2R or kVA. Currently, many transformer manufacturers have designed and produced low-loss transformers, both reducing no-load loss and load loss because the transformer is a device that must be connected to the electrical system all the time and used all the time. Therefore, if the loss of the transformer can be reduced, the cost of electricity can be greatly reduced. The list of calculations is as follows:

The percentage impedance of the load has different values (% Z at any load).

%Z at any Load

$$= \left[\frac{(\%LoadxCapacity)/100}{Fe+Cu.at.any\%Laod+(\%LoadxCapacity)/100}\right]x100 \qquad (1)$$

Cu at any percentage. The load is the loss of the copper winding at the rating. If it is underloaded or overloaded, a loss will affect the operating heat and increase the throughput.

$$\text{Cu at any}\%Load = \left[\frac{\%Load}{100}\right]^2 xLoadLoss \quad (2)$$

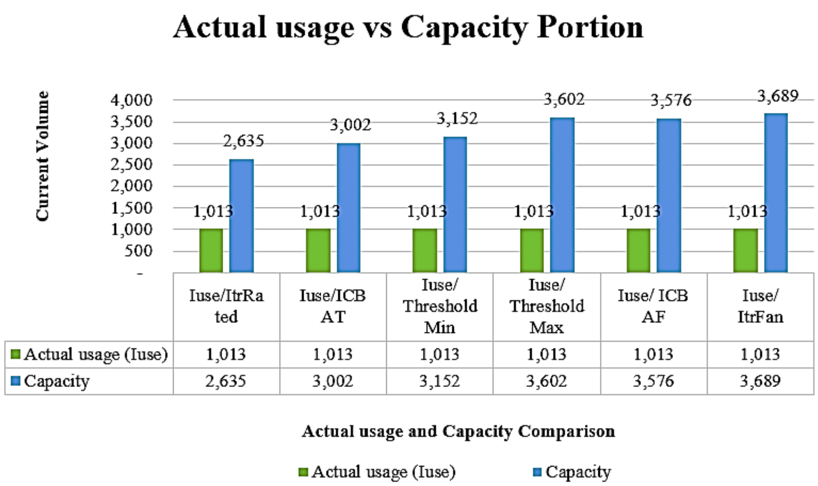
when, Fe = Steel core loss (relatively constant value)
Cu = The loss value of the copper coil

3. Results

For the data collection, 450 transformers that provide power to shopping malls in Thailand were chosen. The average transformer utilization is 1,826 kVA, which can be calculated as the transformer's current rating (Irated) at 2,635A and the actual current consumption (Iuse) of 1013A. The actual current consumption per transformer-rated current (Iuse/Irated) is 39%. Actual Current Consumption Per Ampere Trip: C.B's AT (Iuse/CB AT) at 36%, Actual Current Consumption per C.B's AF (Iuse/CB AF) at 28%, Actual Current Consumption per Ampere Trip. On average, the capacitor bank uses only 1.4 steps out of 11 steps (27%). The electric current of different parts will be shown in Fig. 1.

The average actual current consumption is 1013A. The setting of C.B AT averages 3,002A, where C.B can operate at 5%-120% of the average AT (Threshold) at 3,152–3,602A, according to the line graph in Fig. 2.

The results of electrical engineering analysis and statistical management analysis, the transformer can be reduced from a number of 2 to a number of 1. This minimizes the transformer's power supply and the overall loss of 5,566 W (steel core loss + copper loss), which occurs when the transformer is used for 24 hours. Total lost power consumption = 133,584 W/Day, a large amount of electricity that also reduces maintenance on the transformer and makes it last longer. Reducing the number of transformers does not affect the stability of the electrical system in shopping malls. This is because power distribution using a single transformer is still only considered 76% of the electricity consumption, which is more than enough for electricity use in shopping malls. The stability and reliability of the electrical system of a shopping mall building are shown in Fig. 3.



	Iuse/ItrRated	Iuse/ICB AT	Iuse/ Threshold Min	Iuse/ Threshold Max	Iuse/ ICB AF	Iuse/ ItrFan
Actual usage (Iuse)	1,013	1,013	1,013	1,013	1,013	1,013
Capacity	2,635	3,002	3,152	3,602	3,576	3,689

Fig. 1 The comparison of the actual amount of current used (green) with the different coordinates at the transformer and C.B (blue).

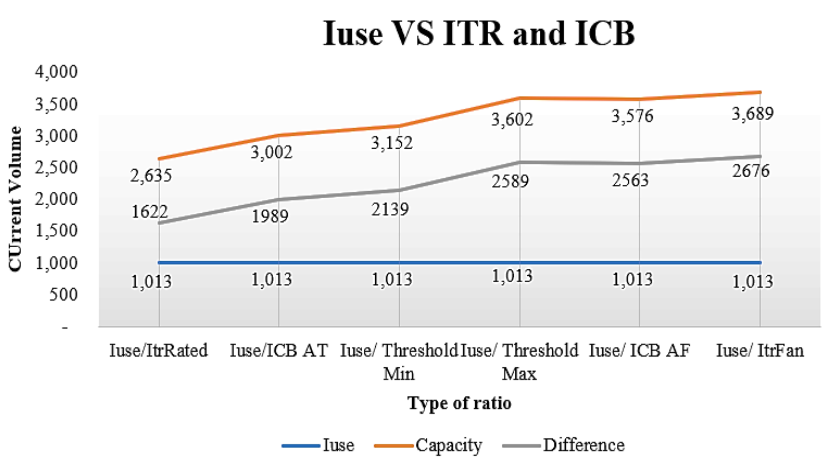


Fig. 2 The comparison of linear average actual current consumption

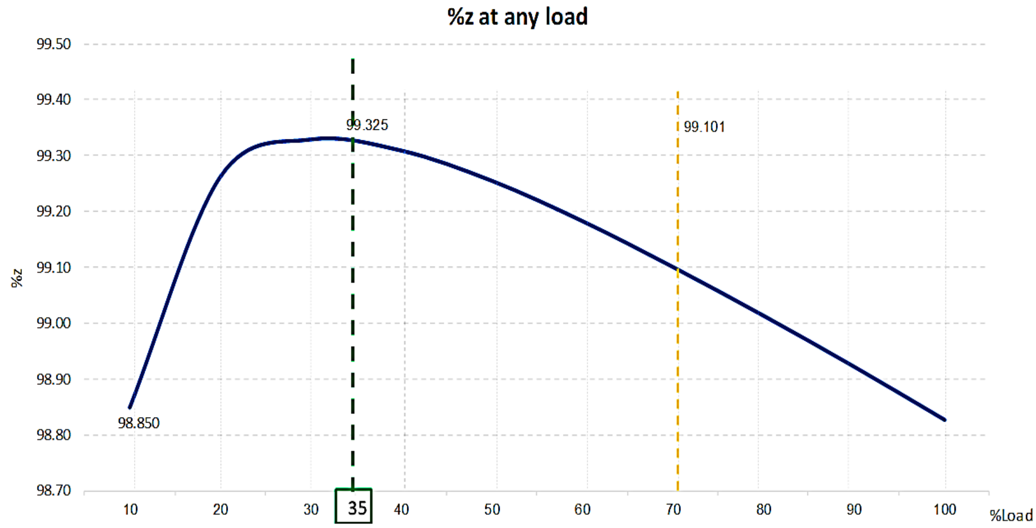


Fig. 3 Data collection on transformer selection of shopping mall buildings

The design and selection of new electrical equipment can be used as a guideline for cost management by reducing the size of the transformer by 1-4 sizes by referring to the average current consumption of 1,013A and comparing the size of used electrical power as a percentage of the transformer rating. The level of use of the transformer is as follows:

Tr.2000 kVA The rated current is 2,886A.
1,013A. = 1,013/2,886 = 35% Main C.B = 4000AF
(dry transformer capable of supplying AF up to 4,040A)

Tr.1600 kVA The rated current is 2,309A.
1,013A. = 1,013/2,309 = 43.8% Main C.B = 3200AF
(dry transformer capable of supplying AF up to 3,233A)

Tr.1250 kVA The rated current is 1,800A.
1,013A. = 1,013/1,800 = 56.3% Main C.B = 2500AF
(dry transformer capable of supplying AF up to 2,520A)

Tr.1000 kVA The rated current is 1,443A.
1,013A. = 1,013/1,443 = 70.2% Main C.B = 2000AF
(dry transformer capable of supplying AF up to 2,020A)

Tr.800 kVA The rated current is 1,154A.
1,013A. = 1,013/1,154 = 87.7% Main C.B = 1600AF
(dry transformer capable of supplying AF up to 1,616A)

Reducing the size of the transformer by 4 sizes impacts the overall investment cost by 54%, which from an economic point of view, will result in a 54% faster return on capital for a period of time. The return on investment is only 46%, which is a tremendous economic value. To reduce the risk of future service users, the researcher requests that 80% of the tycoons have the lowest average electricity consumption due to the fact that lowering the transformer's size will not affect the electrical reliability and stability of the power system when there are more users from 80% to 100% in the future. Load calculations must be reduced from lighting, air-conditioning, and coincidences, including branch circuits, feed lines, mains cables, and mains switchboards, in order to verify that the calculation is consistent with the summary of information management of electricity consumption of the department store building, which will affect the assembly equipment for transformers, cables, busways, and circuit breakers. At each level of the electrical system, there are electrical cabinets containing the capacitor bank, wiring ducts, cable ducts, tailpipes, labor cost, installation cost, lead time for ordering inventory (spare parts), installation area, maintenance cost, maintenance cost associated with the selection of electrical equipment design, including usage and maintenance of all electrical systems in shopping mall buildings. The researcher would like to find a way to reduce the size of the transformer. When there are more users to use up to 100% with the reduction principles as follows:

1. Calculated using the electricity consumption of 80–100% of service users and only 38% of the transformer's electricity consumption.
2. The researcher chose a user load threshold of 80% by multiplying the average actual Iuse of 1,013A by 1.25 to obtain a user Irate of 100%; 1,266A when multiplied by 1.25. The Iuse/Irated ratio of 1,266 to 2,635 is 48%, the amount of electricity the transformers can tie together without reducing the load calculation in other parts. The research has compiled data on the electricity usage of shopping center buildings that use electricity during peak periods of average electricity usage of around 80–100% of peak users. Due to the latter, users want to relax in the mall after the COVID. In the majority of shopping malls, the average electricity consumption is approximately 38% of the transformer rating.

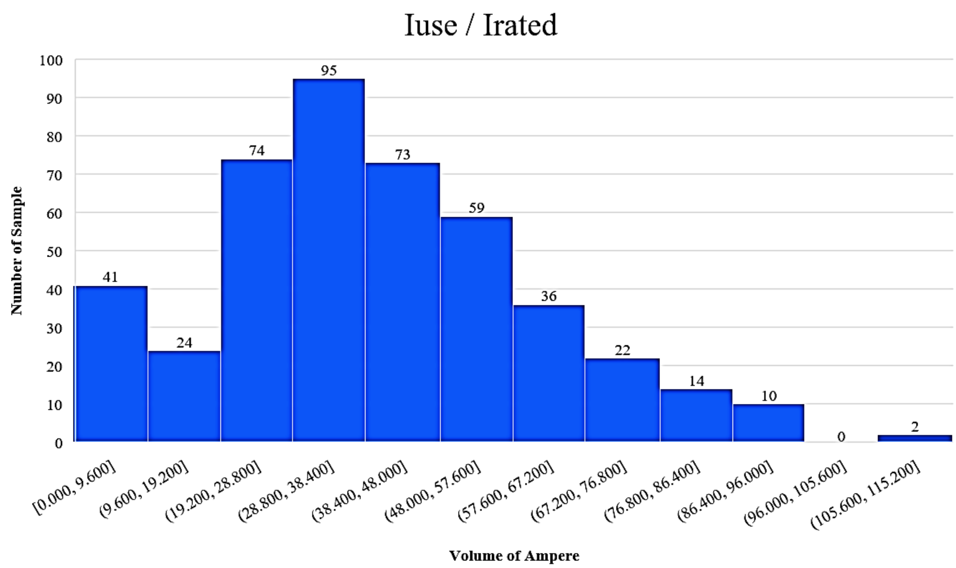


Fig. 4 The actual operating of the transformer, The current (Iuse) and the rated current (Irate)

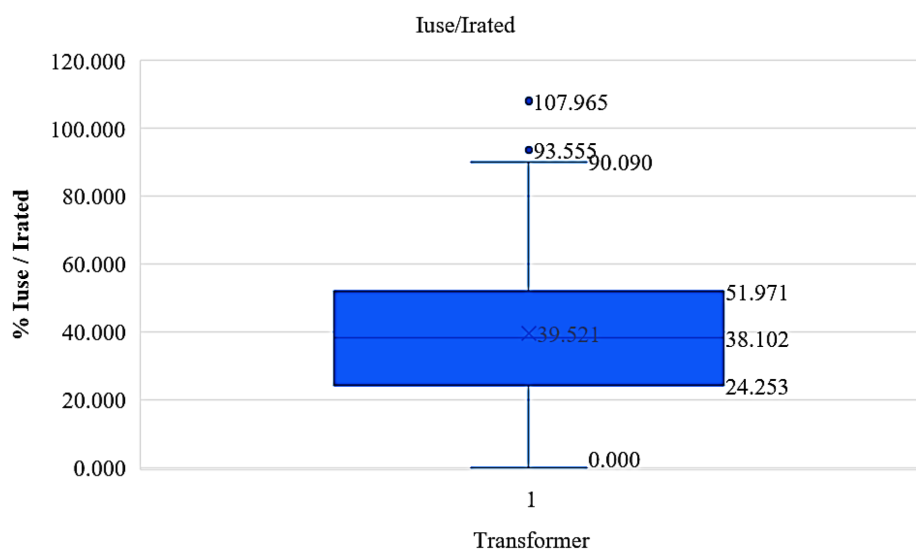


Fig. 5 The actual in quartile statistical, The current (Iuse) and the rated current (Irated)

3. Based on Taro Yamane's principle, the researchers figured out the trend of real electricity use by looking at 450 population samples. Visits to randomly selected test areas, including samples of hospitals and condominiums within the scope of large buildings, extra-large buildings, and high-rises, were used to validate the researcher's data.

The graph shown in Figure 4 shows the sample data that analyzes according to statistical principles. The relationship between the actual operating current and the rated current of the transformer by the total number of transformers. As the graph deflects to the left, it is clear that the ratio of Iuse to Irate is getting smaller, which supports the management's decision to cut costs by making the transformer smaller.

From Figure 5, the relationship between the actual operating current (Iuse) and the rated current (Irate) of the transformer shown is quartile statistical. In statistical science, a type of quartile divides the amount of data into four roughly equal parts. The data must be sorted in ascending order to find the quartile. The quartiles are a form of ranking statistics. There are three main quartiles:

The 1st quartile (Q1) is the middle between the data set's minimum and median. This quartile may be called the lower quartile or the empirical quantile at the 25th empirical quantile because 25% of the total data is below 24.523%.

The 2nd quartile (Q2) is the median of the dataset, so 50% of the data is below the point of 38.102%.

The 3rd quartile (Q3) is the middle between the median and the largest number in the dataset. This quartile may be called the upper quartile or the 75th empirical quartile because 75% of the total data is below the point of 51.917%.

4. Summary and Discussion

The results and engineering conclusions can be made to reduce the size of electrical equipment by up to 4 sizes, or 54% in the case of using a single transformer in a department store, and a reduction in electrical equipment size by up to 3 sizes, or 50%. In the case of using an interchangeable transformer, redundancy in department stores for safety reasons, energy use, and value for money in the initial investment.

However, using too large and improperly set up electrical equipment is highly unsafe for the electrical system. Because the circuit breaker has an improper Ampere Trip: AT setting, it cannot operate with an abnormal overcurrent. Therefore, the circuit breaker must be set up in a way that is suitable for actual use. The enormous power loss incurred by using large transformers and multiple large transformers simultaneously, with each transformer supplying only 39% of the rated power. The power distribution of the transformer will not have the opportunity to use the transformer at full capacity, and there will be no opportunity to use the cooling fan for instantaneous overcurrent as the transformer function can increase the power supply by another 40% for the Air Force function (AF) of the transformer.

Today's shopping mall buildings require transformer utilization and proper setup to be managed, and the construction of new shopping mall buildings requires consideration of load utilization. Future load limits, technological trends like solar or EV chargers, etc., and changes in how people live their lives, all affect how to choose the right and most effective electrical equipment.

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