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Maximum Demand Calculation System Analysis Using MATLAB

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Abstract: The project aims to develop a graphical user interface (GUI) tool for maximum demand calculation analysis. In today's energy landscape, effective management of maximum demand is crucial for ensuring the reliable and efficient operation of electrical systems. The GUI will provide a visually appealing and interactive interface, enabling users to input relevant data, analyze power consumption patterns, and obtain accurate maximum demand calculations, by automating the calculations and streamlining the workflow, the GUI tool will significantly reduce the time and effort required to perform maximum demand analysis. The challenge faced by electrical engineers and utility companies in precisely estimating the maximum power demand within a specific time frame is the focus of this project's issue statement. Maximum demand is important for capacity planning, load forecasting, and infrastructure design, among other power system management tasks. This project has successfully obtained the data from loads that are commonly used in an industry. The loads that have been used in this project were the contents of lighting, motors, pumps, compressors, and workshop equipment. Then, the graphical user interface (GUI) tool for maximum demand calculation analysis has been developed using MATLAB App Designer. Throughout the project, it has followed a systematic approach to achieve the objectives. It has begun by conducting a comprehensive literature review to understand the existing methods and techniques used in maximum demand calculation. Based on the research findings, the project designed and implemented an intuitive GUI that allowed users to input relevant data, such as load profiles, power consumption patterns, and timeframes. Then, it was developed by the necessary algorithms and mathematical models to process the input data and perform the maximum demand calculation. The implementation accurately considers peak loads, quantity of load, and various other factors that impact the maximum demand determination process. Moreover, to validate the accuracy and effectiveness of the system, the extensive testing and evaluation has been conducted. From the test, the maximum demand of the pumps for 10 days of usage is 12.95kW. In addition, the

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system conclusion from the load was Total cost of 10th June 2023 is RM468453.30 during peak time and RM464956.80 during off-peak time. The maximum demand cost is RM459725.00 for the total connected load in both conditions.

Keywords: Maximum Demand, GUI, MATLAB, Calculation System

1. Introduction

Maximum demand refers to the peak level of power consumption during a specific timeframe, typically measured in kilowatts (kW) or megawatts (MW). It plays a significant role in capacity planning, load forecasting, and infrastructure design, allowing utilities to allocate resources effectively and avoid potential power supply issues [1]. Traditionally, maximum demand calculations have relied on manual methods or complex software tools that require extensive technical knowledge. These approaches often involve time-consuming calculations, making the process cumbersome and prone to human error. Furthermore, the lack of user-friendly interfaces in existing tools can create barriers for engineers and utility professionals who may not have a strong background in advanced electrical analysis techniques [2].

Maximum demand (MD) is measured in Kilowatt (kW). It is the highest level of electrical demand monitored in a particular period, usually for a month period. Maximum Demand for any month shall be deemed to be twice the largest number of kilowatt-hours (kWh) supplied during any consecutive thirty minutes in that month. Maximum demand is the peak load imposed by the customer on the TNB system at any point in time [3]. TNB needs to cater to this peak load whenever required by the customer. Since electricity cannot be stored there must be sufficient available generation, transmission, and distribution capacity to meet the highest demand. MD tariffs are structured to reflect the time of day it is used. For these reasons, most tariffs for larger users are designed to encourage customers to control their electricity demand at daytime peaks [4].

The overarching thesis of this study is to monitor and control the maximum power consumption to control the monthly electricity bill as well. By employing the meter, the user may stop worrying about how much their power bill will increase and how much money they'll need to spend on bills. Every user can benefit from the maximum power demand calculation templates, especially manufacturing operations. This controller allows for the regulation of both necessary and unneeded loads during crest or off-crest periods [5].

In summary, the final year project focuses on the development of a GUI tool for maximum demand calculation analysis, aiming to simplify and streamline the process for electrical engineers and utility professionals. The GUI tool will provide an intuitive platform that empowers users to make informed decisions regarding maximum demand, contributing to the efficient operation of electrical systems and the overall sustainability of the energy sector.

2. Materials and Methods

In the materials and methods section, otherwise known as methodology, an outline has been created for this project's execution in order to ensure a smooth process. From the very beginning of this chapter, all the important information about this project will be illustrated. Then, to carry the perfect guidelines, the lab view software will be used, and an interfacing device and load will be discussed too.

A. Materials

- *Obtaining load data*

Certainly, the primary goal was to gather representative load data that accurately reflected the energy consumption and load profiles of commonly used load brands in the industry. This data served

as a foundation for analysis, optimization, and efficient utilization of energy resources. The complete list of loads that would be used in this project is given in Table 1.

Table 1: The load data in the industry

Load Category	Connected load, kW
Lighting	232.48
Motor	10500
Pumps	259
Compressor	9600
Workshop Equipment	120

The above data was collected through research from other researchers and from datasheets for every load category. The load category data sheets were taken from the load category's brand itself. The brands were chosen based on the common brand that is usually used in the industry. From the data, the calculation of maximum demand in App Designer MATLAB could be generated.

- *Developing GUI interface*

This began with an overview of the design objectives and requirements for the GUI maximum demand analysis templates. The specific functionalities and features to be incorporated into the app are defined, taking into consideration the needs of the industry and the analysis techniques employed. Additionally, relevant design considerations, involved the user experience, interface layout, and visual aesthetics, are discussed. Figure 1 shows a GUI system design tool of maximum demand calculation templates using MATLAB app designer.

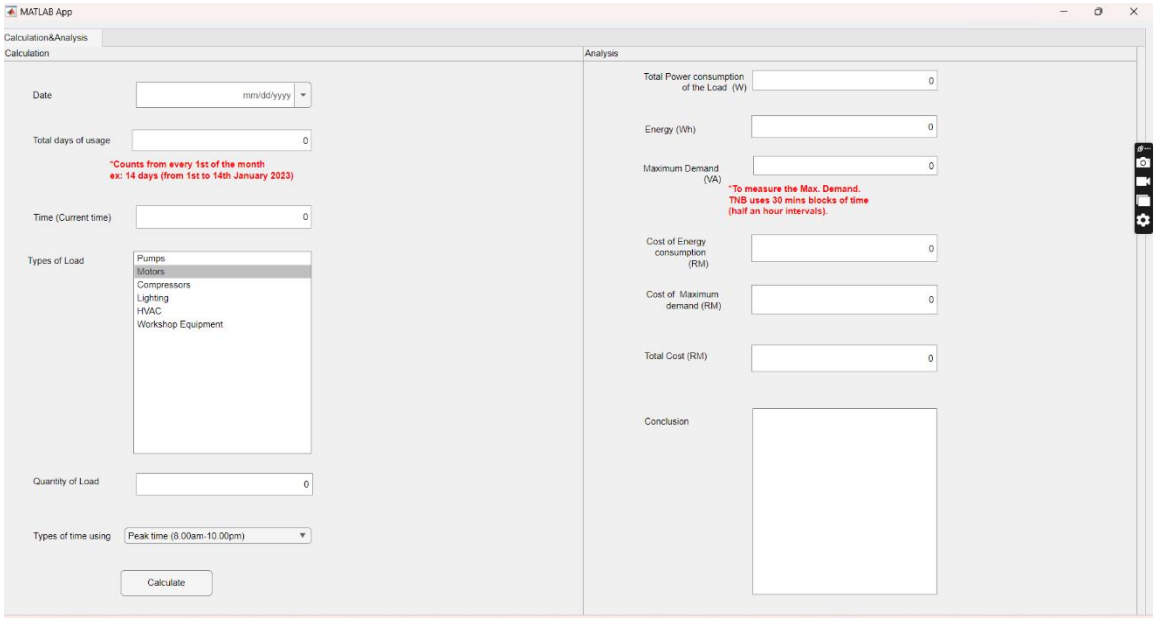

Figure 1: An overview of the project GUI interface

This maximum demand can be monitored by referring to the load power consumption and the amount of load that has been used in an industry. From this GUI system, the users can know and monitor the total power consumption, and cost of the electrical bill charged and most importantly, the users can know the maximum demand penalty that will be charged by the utility company for a specific month.

- *Analyzing the maximum demand*

For this process, the system should be determined by calculating the maximum demand charged based on the industry's requirements. It might involve finding the total power consumption, total energy, maximum demand, cost of energy consumption, and cost of maximum demand. Figure 2 shows an interface for the analysis part of this GUI maximum demand analysis template.

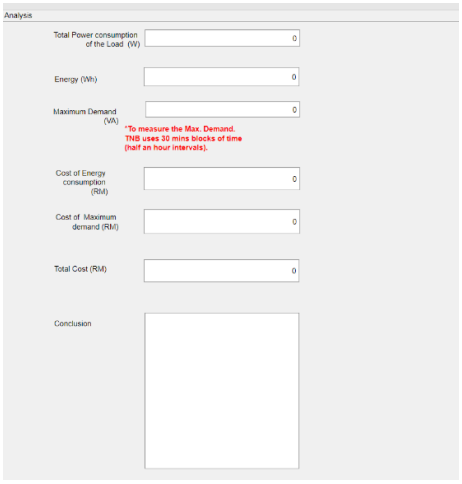

Figure 2: An overview of the analysis interface as the output data

B. Method

GUI development web-based using MATLAB software is such an important flow for the whole thesis. Figure 3 shows the flowchart of how the maximum demand templates have been developed by using the App Designer, which is the feature in MATLAB that is particularly form for designing apps.

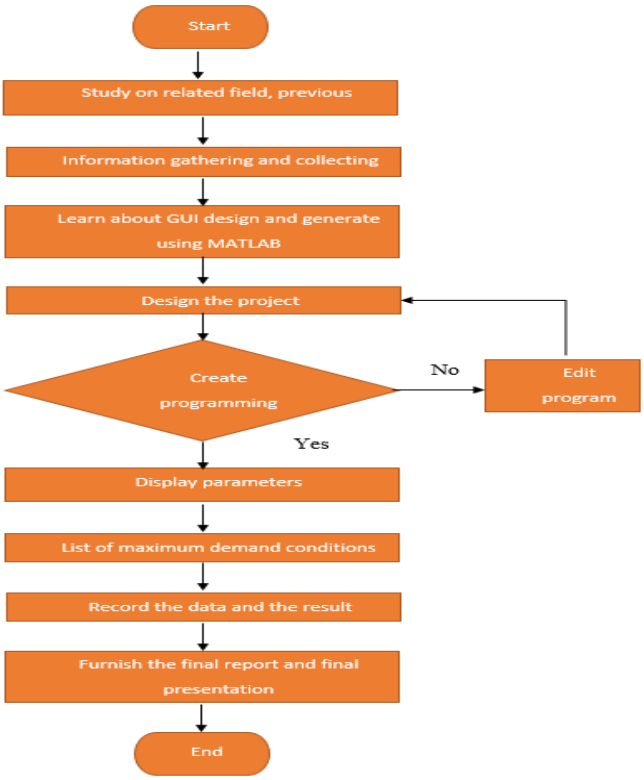

Figure 3: Flowchart of the GUI development

C. Equations

Maximum demand is the peak or maximum amount of electrical power that the consumer needs or wants. It is measured over a set time, typically at intervals of half an hour, for a whole month. Demand charges are levied by utilities around the world to entice customers to use more energy when it is more cost-effective for the utilities to produce it. Maximum demand can be calculated by using the equation 1 below:

$$Maximum\ demand = Diversity\ Factor\ (D.F) X\ Connected\ Load \quad Eq.\ 1$$

The time interval for measuring the Maximum Demand should be chosen. Moreover, TNB uses 30-minute blocks of time (half-hour intervals) as the time interval. Equation 2, which is another formula for calculating the maximum demand, has been discovered in the Electrical Supply Application Handbook (ESAH) from Tenaga Nasional Berhad (TNB), referred to [6].

Total power consumption × 0.5 (Block time- TNB uses 30 mins blocks of time

(Half an hour intervals). *Eq. 2*

The choice of time interval depends on the specific requirements of the electrical system 1 being analyzed. It is important to consider factors such as the nature of the load, the duration of peak demand, the response time of equipment, and any applicable industry standards or regulations. Based on Equation 3, the total connected load (or full load) is the sum of all electrical loads added together, [6]. While Equation 4 showed the equation of the total power consumption for the load.

Load 1 + Load 2 + Load 3 = Total Connected Load. *Eq. 3*

$$Total\ power\ consumption\ =\ Load\ power\ \times quantity\ of\ load \quad Eq.\ 4$$

Energy in electrical billing refers to the total power consumption by the load per hour, Equation 5 shows the formula to calculate the energy.

$$Total\ power\ \times (Total\ days\ of\ usage\ \times 24) \quad Eq.\ 5$$

The cost of maximum demand and energy can be calculated by using the below tariff in Table 2 by multiplying it by the total maximum demand and total power consumption for each day of usage. As referred to Equation 6 until Equation 8, there was a list of equations that would be used in this project.

$$Cost\ of\ energy = Total\ power\ \times 0.337\ (peak\ time) \quad Eq.\ 6$$

$$Cost\ of\ energy = Total\ power\ \times 0.202\ (off - peak\ time) \quad Eq.\ 7$$

$$Cost\ of\ maximum\ demand = maximum\ demand\ \times 35.50 \quad Eq.\ 8$$

$$Total\ cost = Cost\ of\ energy + cost\ of\ maximum\ demand \quad Eq.\ 9$$

Table 2: Tariff table for Industrial

TARIFF E3: HIGH VOLTAGE PEAK/OFF-PEAK INDUSTRIAL TARIFF	
For each kilowatt of maximum demand per month during the peak period	35.50 RM/kW
For all kWh during the peak period	33.70 sen/kWh
For all kWh during the off-peak period	20.20 sen/kWh

3. Results and Discussion

The results were obtained from the comprehensive study that was conducted as part of this project. The primary objective of this chapter was to analyze the maximum demand and the cost of the maximum demand itself. The calculation of maximum demand is a crucial aspect of energy management in industries. It involves analyzing the power consumption data and identifying the highest demand values within a specified period. Accurate determination of maximum demand allows industries to optimize their energy usage, plan capacity requirements, and efficiently manage their energy costs. Table 3 shows the list of calculation formulas to calculate the system requirement.

Table 3: Calculation formula of the parameters in GUI calculation templates

Total power consumption of the load (W)	Energy (Wh)	Maximum demand (Wh)	Cost of energy consumption (RM)	Cost of maximum demand (RM)	Total cost (RM)
Load power consumption × quantity of load	Total power consumption of the load (W)× (Total days of usage × 24)	Total power consumption of the load × 0.5 (TNB block time_30 mins)	If during peak time; = Total power consumption × 0.337 While during off-peak time; = Total power consumption × 0.202	Maximum demand × 35.50	Cost of energy consumption (RM) + Cost of maximum demand (RM)

A. Interface of the system

The analysis of maximum demand calculation for an industrial load has been developed in MATLAB App Designer. It would present the implementation of a user-friendly graphical interface and calculation algorithms for determining the maximum demand of the particular load systems in various applications. It has involved analyzing the power consumption and load profiles of the load equipment to determine the peak power demand within a specified period. The results and analysis section demonstrates the application of the developed GUI calculation templates to real-world calculation systems. It would be presented the case studies or examples illustrating the estimation of maximum demand for different types of loads and scenarios. In those cases, Figure 4 shows the example of the systems' interface and result calculation using the GUI maximum demand analysis systems in MATLAB. The conclusion box in the interface functions as the analysis summary of the whole system.

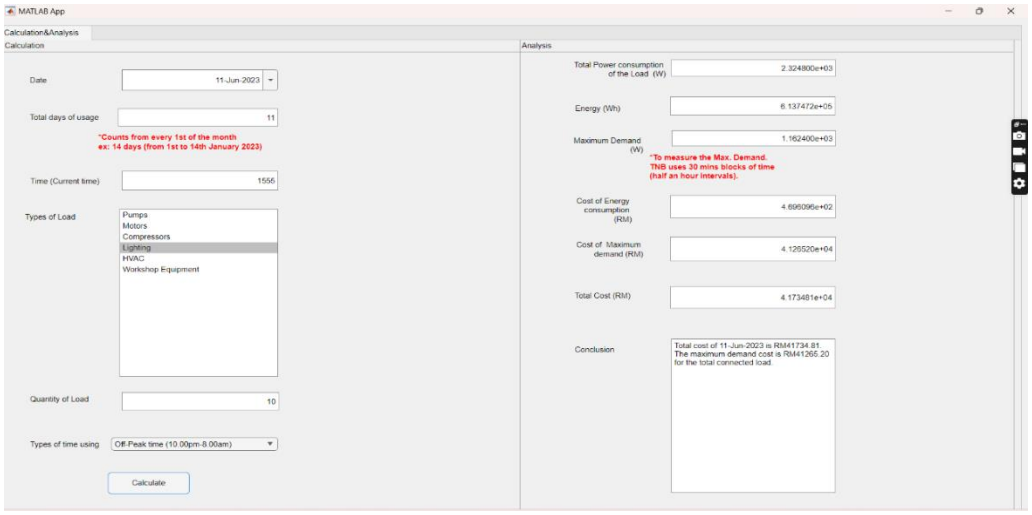

Figure 4: Example of systems' interface and result calculation

B. Discussions

- *Peak time*

For industrial sectors, such as factories or manufacturing plants, the peak time effects on electrical billing can be particularly significant due to their high energy requirements. Thus, the utility companies may charge higher rates per unit of electricity consumed during peak periods. By referring to Table 2, shows the result achieved from the maximum demand calculation templates using MATLAB. The result was being analysed on 10th June 2023. Hence, the results are based on the 10 days of usage from early month, 1st June 2023.

Table 2: Result during peak time

Quantity of load	Load	Systems calculation result	
10	Pumps	Total power of the load (W)	25900
		Energy (Wh)	6216000
		Maximum demand (W)	12950
		Cost of energy (RM)	8728.30
		Cost of maximum demand (RM)	459725
		Total cost (RM)	468453.3
	Motors	Total power of the load (W)	10500
		Energy (Wh)	25200000
		Maximum demand (W)	52500
		Cost of energy (RM)	35385
		Cost of maximum demand (RM)	1863750
		Total cost (RM)	1899135
	Lighting	Total power consumption of the load (W)	2324.8
		Energy (Wh)	557952
		Maximum demand (W)	1162.4
		Cost of energy (RM)	783.457
		Cost of maximum demand (RM)	41265.2
		Total cost (RM)	42048.66
	Workshop equipment	Total power consumption of the load (W)	1200
		Energy (Wh)	288000
		Maximum demand (W)	600
		Cost of energy (RM)	404.4
		Cost of maximum demand (RM)	21300

	Compressors	Total cost (RM)	21704.40
		Total power consumption of the load (W)	96000
		Energy (Wh)	23040000
		Maximum demand (W)	48000
		Cost of energy (RM)	32352
		Cost of maximum demand (RM)	170400
		Total cost (RM)	1736352

- *Off-peak time*

Next, for the time-of-use tariffs, an industrial sector might be placed on time-of-use tariffs, where the price of electricity varies depending on the time of day. Off-peak hours were typically associated with lower rates, while peak hours have higher rates. By strategically scheduling energy-intensive operations or processes during off-peak hours, businesses could take advantage of the lower rates to reduce their overall electricity costs. By referring to Table 3, the result achieved from the maximum demand calculation templates using MATLAB. The result was being analysed on 10th June 2023. Therefore, the results are based on the 10 days of usage from early month, 1st June 2023.

Table 3: Results in the system during off-peak time

Quantity of load	Load	Systems calculation result	
10	Pumps	Total power of the load (W)	25900
		Energy (Wh)	6216000
		Maximum demand (W)	12950
		Cost of energy (RM)	5231.8
		Cost of maximum demand (RM)	459725
		Total cost (RM)	464956.80
	Motors	Total power of the load (W)	105000
		Energy (Wh)	25200000
		Maximum demand (W)	52500
		Cost of energy (RM)	21210
		Cost of maximum demand (RM)	1863750
		Total cost (RM)	1884960
	Lighting	Total power consumption of the load (W)	2324.8
		Energy (Wh)	557952
		Maximum demand (W)	1162.4
		Cost of energy (RM)	469.60
		Cost of maximum demand (RM)	41265.20
		Total cost (RM)	41734.81
	Workshop equipment	Total power consumption of the load (W)	1200
		Energy (Wh)	288000
		Maximum demand (W)	600
		Cost of energy (RM)	242.4
		Cost of maximum demand (RM)	21300
		Total cost (RM)	21542.40
	Compressors	Total power consumption of the load (W)	96000
		Energy (Wh)	23040000
		Maximum demand (W)	48000
		Cost of energy (RM)	19392
		Cost of maximum demand (RM)	1704000
		Total cost (RM)	1723392

C. Results Comparison

Table 4 shows an example of loads in an industry comparison, which contains the value of maximum demand, the maximum demand cost and total cost billing for 10 days of usage.

Table 4: Loads Comparison

Load	Timing	Cost of maximum demand (RM)	Cost of energy (RM)	Total cost (RM)
Pumps	Peak time	459725	8728.30	468453.30
	Off-peak time	459725	5231.80	464956.80
Motors	Peak time	1863750	35385	1899135
	Off-peak time	1863750	21210	1884960
Compressors	Peak time	1704000	32352	1736352
	Off-peak time	1704000	19392	1723392
Lighting	Peak time	41265.20	783.457	42048.66
	Off-peak time	41265.20	469.60	41734.81
Workshop equipment	Peak time	21300	404.40	21704.40
	Off-peak time	21300	242.40	21542.40

Besides that, to compare the total cost of billing during peak time and off-peak time, it needed to consider the energy consumption pattern of your industrial sector during different periods. From Table 4, it has proved that the peak time and off-peak time were the major factors of the electrical billing for commercial and industrial. Other than that, the results, it has shown that the cost of maximum demand remained the same during peak time or off-peak time. It was important to note that the actual cost comparison would depend on the specific pricing structures, tariffs, and demand patterns applicable to the particular industrial sector.

4. Conclusion

In conclusion, the objectives of this project have been achieved. Firstly, this project has successfully obtained the data from loads that are commonly used in an industry. The loads that were used in this project were the contents of lighting, motors, pumps, compressors, and workshop equipment. Then, the graphical user interface (GUI) tool for maximum demand calculation analysis has been developed using MATLAB App Designer. This project aimed to provide a user-friendly platform for electrical engineers and utility companies to determine the maximum power demand in a given period. Based on the research findings, the project designed and implemented an intuitive GUI that allowed users to input relevant data, such as load profiles, power consumption patterns, and timeframes. The implementation accurately considers peak loads, quantity of load, and various other factors that impact the maximum demand determination process. Moreover, to validate the accuracy and effectiveness of the system, the extensive testing and evaluation has been conducted. From the test, the maximum demand of the pumps for 10 days of usage is 12.95kW. In addition, the system conclusion from the load was Total cost of 10th June 2023 is RM468453.30 during peak time and RM464956.80 during off-peak time. The maximum demand cost is RM459725.00 for the total connected load in both conditions.

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