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Article

Electricity Demand Forecasting of Hospital Buildings in Istanbul

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Abstract: Electricity demand forecasting is essential for utilities. For the consumer, predictability of demand is vital for efficient operation, installation, sizing and maintenance planning. Hospitals, which are among the institutions with high-energy consumption, provide uninterrupted service 24 h a day, 7 days a week. Every hospital building is unique, and many do not conform to a typical shape or floor plan. Depending on the services provided, each hospital can differ significantly in terms of energy demand. Therefore, demand forecasting is one of the most complex elements of hospital construction. Although there are many studies on energy optimization related to hospital buildings in the literature, there is a knowledge gap regarding the maximum power estimation of hospitals. In this study, the annual electrical energy use of 23 public hospitals with over 100 beds in Istanbul is measured, and after determining the monthly peak loads, two new forecasting models are generated using regression techniques for maximum demand forecasting. It is determined that the design criteria used in power calculations in hospitals was very high. A positive result was obtained from the linear regression technique, which is one of the basic regression techniques, and it was shown that the maximum power needs of the hospital can be estimated with great confidence by determining a new design factor in the light of the determined values. This study allows designers to set maximum demands and select transformer and generator sizes with a single formula.

Keywords: hospital power demand; demand forecasting; demand factor; installed power

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1. Introduction

Electricity demand forecasting is essential for utilities, and balancing energy production and consumption becomes more accessible with demand forecasting. For the consumer, it is vital that demand must be predictable for efficient operation, installation, sizing and maintenance planning. There is extensive literature on demand forecasting worldwide. Kasule and Ayan built a hybrid model based on particle swarm optimization and artificial bee colony algorithms for the electricity consumption prediction of Uganda [1]. Mohamed and Bödger researched New Zealand's electricity consumption and evaluated both residential and nonresidential users. Multiple linear regression was used in the estimation model, and it was considered to be efficacious when compared to the national estimates of the country [2]. Kavaklioglu et al., estimated Turkey's electricity consumption up to 2027 using the Neural Network model [3]. According to Tumbaz et al., the energy demand in Turkey uses time series and neural networks as well as regression techniques. They concluded that the ridge regression technique gave very good estimates [4]. Toksarı et al., Kankal et al., Oğcu et al., and Kıran et al., also use various estimates of Turkey's energy demand forecasting methodologies [5–8]. However, there are relatively few studies in the literature for hospital demand forecasting. Bertolini et al., used the data of two hospitals in Italy, created the Artificial Neural Network model and reached approximately 75% accurate predictions [9]. According to Cao et al., the accuracy of eight machine learning models was trained on daily and weekly datasets from a general hospital in Shanghai. It was concluded that RF, XGBoost and SVR are the most accurate learning models for hospital daily electrical load estimation [10]. Sotelo et al., Bagnasco et al., and Runge et al., built an Artificial Neural Network model for hospital electrical load estimation. [11–13]. The models have proven to be very efficient at forecasting demand.

Hospitals are areas that always play an indispensable role in human life. Hospitals provide 24/7 uninterrupted service [14]. According to the data of Istanbul Provincial Health Directorate as a cultural capital, financial and health center, there are 25 international training and research hospitals and 33 public hospitals in Istanbul [15]. Every hospital building is unique and does not conform to a typical shape or typical floor plan. Depending on the services provided and their designers, each hospital can differ significantly from one another [16]. There are special heating, cooling and ventilation systems used by thousands of patients, employees and visitors every day in hospitals. In addition, imaging (MRI, CT), operating room, intensive care unit, sterilization, laundry, laboratory, computer and server use, kitchen, etc. exist in hospitals. There are many energy-intensive activities [17,18]. For this reason, hospitals consume more energy compared to other building types [19]. According to a report by the US Energy Information Administration, large hospitals—200,000 square feet or more—accounted for 5.5 percent of the total energy used by the commercial sector in 2007, although they account for less than 1% of all commercial buildings and 2% of commercial floor area in the United States [20]. Another study by Neal concluded that the energy consumption of hospitals is more than 2.5 times that of commercial buildings [21].

However, despite all this technical infrastructure, installation optimization is overlooked because the system design is generally made according to regulations. The installed electricity capacity of the hospital is calculated according to the regulation without any demand forecasting. Thus, the entire infrastructure is designed in line with this value, which is often much more than demand. For this reason, in this study, annual electrical energy use and annual peak loads of 23 public hospitals with 100 beds or more are determined, and the values found are compared with the design criteria specified in the regulation. In the light of the determined values, a regression model is employed to determine a new design factor. In this model, after the completion of the application project for a new hospital, the total construction area and installed power, which are the known basic elements, and the maximum power estimation algorithm are generated. Then, a method similar to the empirical calculation of power per unit area (VA/m^2) for schools in the US National Electrical Code was designed as an option.

Demand forecasting is one of the most complex yet fundamental parts of hospital construction [22]. Although there are many studies on energy optimization in the literature [23–27], there is a lack of information about the maximum power estimation of hospitals.

This study aims to determine a new demand factor for maximum demand forecasting using a different approach from the previous literature. The novelty and scientific significance of this study lies in the methodology, which simply and systematically assesses the maximum demand effectiveness. The system capacity is the result of the sum of the electrical powers of each load. There is no estimation method for how much these devices will work or how many of them will work at the same time. Since the only constant value that is known is the system capacity, the maximum demand estimate with the system capacity has enabled effective results to be obtained.

2. Hospital Data and Analysis Methods

2.1. Hospital Data

The annual electrical energy usage of 23 public hospitals with more than 100 beds in Istanbul was measured, and monthly peak loads were determined. The hospitals subject to the study are shown on the map in Figure 1.

Figure 1. Hospitals in Istanbul.

The number of beds, total closed area, installed power and contract authorizations of 23 public hospitals with 100 beds or more in Istanbul are obtained from the records of the Istanbul Provincial Health Directorate. In addition, the peak power data for 2020 are determined from the electricity meters of the hospital. The data obtained are given in Table 1 [28,29].

Consumers often do not operate simultaneously and not all are at their full rated power. The actual power is therefore always less than the sum of the rated power of all individual users. The most important criterion in planning and projecting a distribution system is the calculation of the current load density and load characteristics and the determination of future changes in loads. To design systems economically, demand load, maximum demand, maximum overlap demand can be calculated from the system installed load. The measurement results need to be obtained to calculate data based on the overlap factor, diversity factor, load factor, and other load characteristics. Demand is the average load received from the grid in a given period. Active power can be reactive power, apparent power or current as expressed in A, kW, kVAr, or kVA. The time interval in which the load is averaged is called the "Demand Interval", which is selected as 15, 30, 60 min or more, taking into account factors such as the loading time and the thermal time constant of the system consuming the load. The demand range and the changes in demand for a given load are shown in Figure 2 [30].

Table 1. Hospital data.

Hospital Name	Bed	Area, m^2	System Capacity, kVA	Contract Power, kVA	Max. Demand, kVA
Haydarpaşa Numune R&T Hospital	709	49,000	4401	3281	1745
Göztepe R&T Hospital	682	75,000	4010	2406	1572
Bakırköy Dr. Sadi Konuk R&T Hospital	612	66,900	12,480	6690	3697
Zeynep Kamil Women's and Children's R&T Hospital	501	29,700	3200	1920	994
Kartal Koşuyolu Cardiovascular Surgery R&T Hospital	465	39,950	5000	5000	1656
Yedikule Pulmonary Diseases and Thoracic Surgery R&T Hospital	333	37,115	3710	1760	1412
Fatih Sultan Mehmet R&T Hospital	300	41,670	3457	2075	1450
Gaziosmanpaşa Taksim R&T Hospital	300	61,600	5750	3732	1821
Üsküdar Public Hospital	263	15,830	1666	1000	597
İstanbul Mehmet Akif Ersoy Cardiovascular Surgery R&T Hospital	260	33,950	5175	2100	1718
Kartal Public Hospital	256	33,330	1158	695	708
Erenköy Physical Therapy Hospital	250	12,160	383	230	205
Silivri Public Hospital	223	15,820	2070	960	894
Arnavutköy Public Hospital	201	30,350	2760	1200	1059
Eyüpsultan Public Hospital	140	14,990	2960	1200	850
Baltalimanı Bone Diseases R&T Hospital	133	11,160	1760	980	774
Bahçelievler Public Hospital	125	57,610	8625	6400	2863
Erenköy Mental Hospital	101	11,735	337	337	262
Avcılar Public Hospital	100	18,727	2070	960	753
Başakşehir Public Hospital	100	11,800	1380	463	701
Bayrampaşa Public Hospital	100	12,965	1380	819	529
Yakacık Women's and children's Hospital	100	6600	833	500	234
Sultanbeyli Public Hospital	100	8375	750	450	315

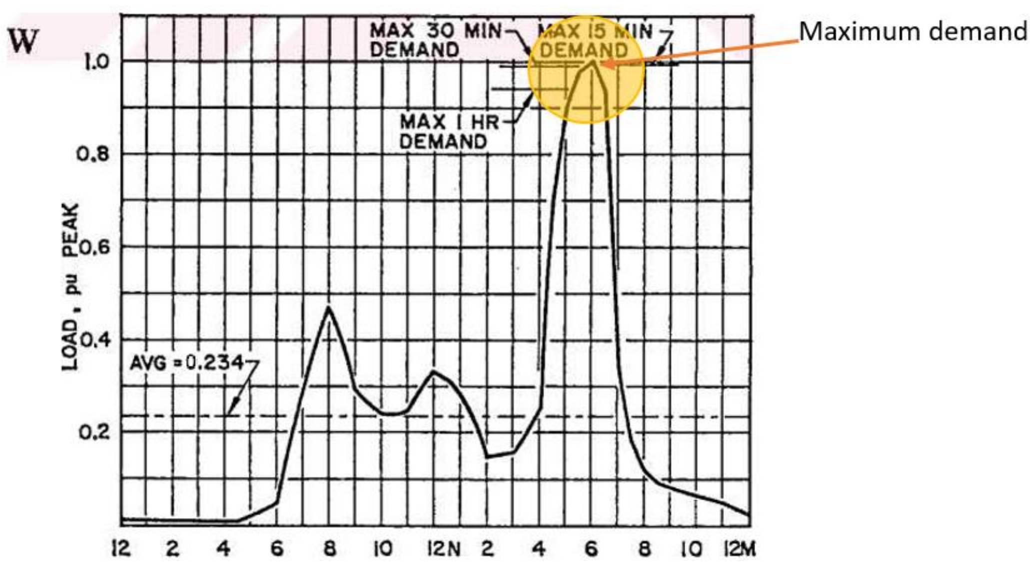

Figure 2. Demand interval and changes in demand.

2.1.1. Demand Factor

Demand Factor is the ratio of the *Maximum demand* of a system to the *Total Connected Load*. It is dimensionless and is expressed as a percentage. If all consumers in the network load at their own power values at the same time, it reaches "1". Sometimes the *Demand Factor* value can be greater than 1 and this is called an "overload". However, the *Demand Factor* is usually less than one [31].

$$Demand\ Factor = \frac{Maximum\ demand}{Total\ Connected\ Load} \tag{1}$$

2.1.2. Coincidence Factor

The coincidence factor (*CF*) is the ratio of the group maximum demand or maximum overlap demand to the sum of the individual maximum demands of the loads.

$$CF = \frac{Coincident\ Peak\ Demand}{T\sum_{n=1}^{N} MD_n} \tag{2}$$

Coincidence factor is the inverse of the diversity factor.

$$CF = \frac{1}{DF} \tag{3}$$

CF is always smaller than 1 ($CF < 1$) [32].

The 57th article of the Turkish Electricity Indoor Installations Regulation, the overlapping peak demand calculation, is made as follows.

In workplaces, administrative buildings, social buildings, health buildings and similar places, accidental loads, installed load, lighting load, socket load, mechanical installations excluding spares, winter-summer load, elevator load, and kitchen load whichever are more taken into consideration. The coincidence factor of the mechanical installation should be taken as 100%, and the coincidence factor of 70% for the kitchen load. Conflict factors for lighting, socket and elevator load should be taken from the list in Table 2 [33].

Table 2. Coincidence factor.

Building Type	Load	Coincidence Factor %
	Coincidence factor for lighting load:	
Hospitals	First 50 kVA	40
	After 50 kVA	20
Hotels	First 20 kVA	50
	20–100 kVA	40
Warehouse	First 12.5 kVA	100
Other buildings	All	100
	Coincidence factor for socket load:	
All buildings	First 10 kVA	100
	After 10 kVA	50
	Coincidence factor for elevators:	
Office, Otels		100
Schools, Hospitals		85
Apartments, others		55

The same values for the hospitals in Table 1 are also found in Table 3, which is numbered as 220.42 in NFPA70 (US National Electrical Code, National Fire Protection Association, MA, USA) [34].

Table 3. Lighting load demand factors.

Type of Occupancy	Portion of Lighting Load to Which Demand Factor Applies (Volt-Amperes)	Demand Factor (Percent)
Dwelling units	First 3000 or less at From 3001 to 120,000 at Remainder over 120,000 at	100 35 25
Hospitals *	First 50,000 or less at Remainder over 50,000 at	40 20
Hotels and motels, including apartment houses without provision for cooking by tenants *	First 20,000 or less at From 20,001 to 100,000 at Remainder over 100,000 at	50 40 30
Warehouses (storage)	First 12,500 or less at Remainder over 12,500 at	100 50
All others	Total volt-amperes	100

* The demand factors of this table shall not apply to the calculated load of feeders or services supplying areas in hospitals, hotels, and motels where the entire lighting is likely to be used at one time, as in operating rooms, ballrooms, or dining rooms.

Another method is to determine the volt-ampere level per unit area. This method is given in Table 4, only for lighting, which is numbered 220.12 in NFPA70 (US National Electrical Code, National Fire Protection Association, MA, USA) [34].

Table 4. General lighting load by occupancy.

Type of Occupancy	Unit Load	
	Volt-Amperes/m^2	Volt-Amperes/ft^2
Armories and auditoriums	11	1
Banks	39 [b]	3 1/2 [b]
Barber shops and beauty parlors	33	1
Churches	11	1
Clubs	22	2
Courtrooms	22	2
Dwelling units	33	2
Garages-commercial (storage)	6	1/2
Hospitals	22	2
Hotels and motels, including apartment houses without provision for cooking by tenants [a]	22	2
Industrial commercial (loft) buildings	22	2
Lodge rooms	17	11/2
Office	39 [b]	3 1/2 [b]
Restaurant	22	2
Schools	33	3
Stores	33	3
Warehouses (storage)	3	1/4
In any of the preceding occupancies except one-family dwellings and individual dwelling of two-family and multifamily dwellings:		
Assembly halls and auditoriums	11	1
Halls, corridors, closets, stairways,	6	1/2
Storage spaces	3	1/4

[a] See 220.14 (J); [b] See 220.14 (K).

Apart from all of these, it is stated in the NFPA70 (US National Electrical Code, National Fire Protection Association, MA, USA) 220.86 table that a method different from the standard calculations can be used for schools. Table 5 gives an empirical calculation method by determining the power per unit area [34].

Table 5. Optional method—Demand factors for feeders and service conductors for schools.

Connected Load		Demand Factor (Percent)
First 33 VA/m^2 Plus,	(3 VA/ft^2) at	100
Over 33 through 220 VA/m^2 Plus,	(3 through 20 VA/ft^2) at	75
Remainder over 220 VA/m^2	(20 VA/ft^2) at	25

2.2. Methods

Linear Regression: Linear regression is a statistical technique used for finding a relation between two or more variables. If the relation is found between two variables, it is called simple linear regression. Linear regression is a quite simple method to fit the curve and find the coefficients. The model takes the form y = mx + c, where m is the slope of the curve and c is the intercept. The parameter x is the independent variable. F(x) is the dependent variable. The aim is to find the coefficients m and c with the help of available data of x and y.

Performance Evaluation: There are different measures to evaluate the performance of the forecasted result.

Mean Squared Error (*MSE*): It is measured by finding the mean of squares of errors at every point.

$$MSE = \frac{\sum_{i=1}^{N}(Y_i - X_i)^2}{N} \quad (4)$$

where Y_i is the value of actual dependent variable at the *i*th instant of independent variable. X_i is the value of forecasted variable at the *i*th instant of. N is the number of independent variable instances.

Root Mean Squared Error (*RMSE*): It is measured by square root of mean of square of difference between forecasted variable value and actual output.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(Y_i - X_i)^2}{N}} \quad (5)$$

Mean Absolute Percentage Error (*MAPE*): It is also known as Mean Absolute Percentage Deviation (*MAPD*). It is one of the most accurate and most popular measures of finding the performance.

$$MAPE = \sqrt{\frac{\sum_{i=1}^{N}(Y_i - X_i)^2}{N}} \quad (6)$$

In this study, a linear regression model is created for maximum load estimation, and the relationship between maximum demand and installed power is determined. In addition, it is aimed to use a method similar to the elective method given for schools in Table 5 by normalizing the maximum demand per unit area.

3. Results

The basic elements that can be known in hospital design are the number of beds, the total closed area, and the system capacity. It has been determined that the only factor affecting the maximum demand among these factors is the system capacity. Accordingly, using the data in Table 1 of 23 public hospitals with over 100 beds, the relationship between system capacity and maximum demand is given in Figure 3. Regression models are used to estimate the maximum demand.

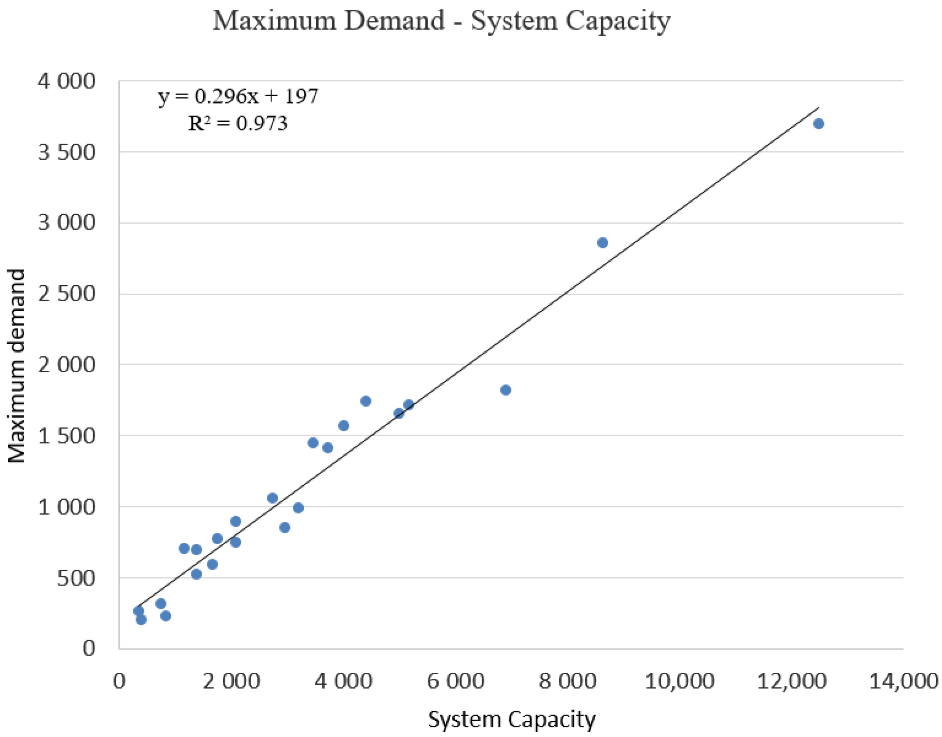

Figure 3. Maximum demand curve.

3.1. Formula 1

It is concluded that there is a linear relationship between the maximum demand and the system capacity. The formula of the curve obtained as a result of linear regression is y = 0.296x + 197. For maximum demand and system capacity, coefficients have been found as 0.296 (slope) and 197 (intercept). The error performances obtained are *MSE* = 49, 648.75, *RMSE* = 222.820, *MAPE* = 9.857.

As a result, it is found that the maximum demand in hospitals with over 100 beds can be determined by the following formula.

$$MD = 0.296\ (SC) + 197 \quad (7)$$

MD: Maximum demand (kVA)

SC: System capacity (kVA).

The values specified in the formula adapted to the regulation are given in Table 6.

Table 6. Demand factors for feeders and service conductors for hospitals.

Loads	Demand Factor (%)
First 197 kVA	100
over 197 kVA	30

This formula differs from the coefficients in the current regulations in that it does not have to calculate the loads (lighting, mechanical, etc.) one by one. If the system capacity is known, the maximum demand can be calculated with a single formula. The actual and forecasted maximum demands are given in Figure 4.

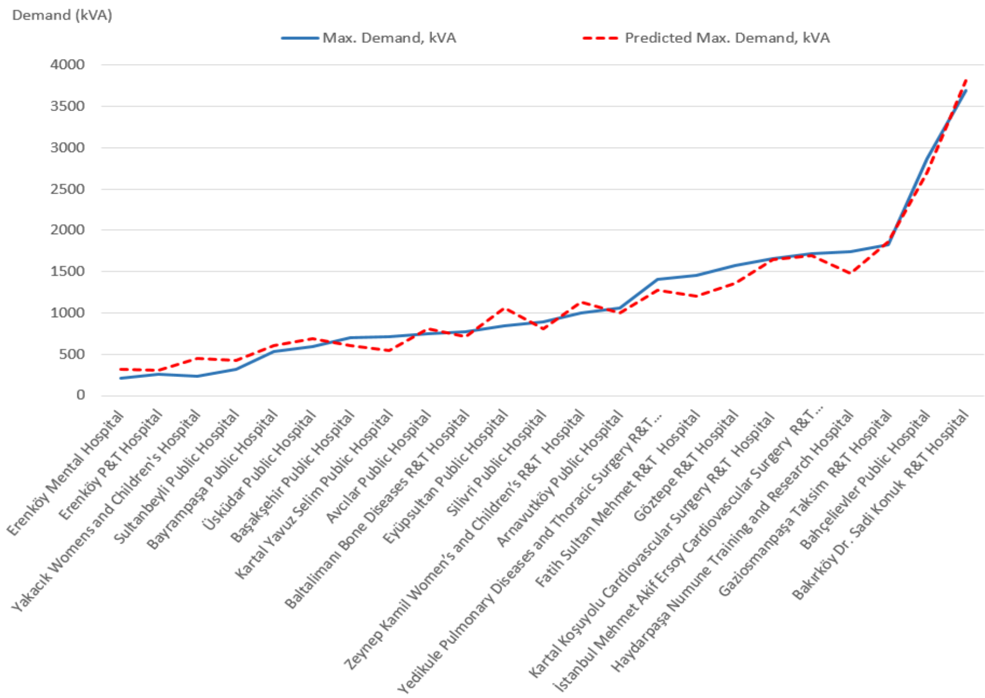

Figure 4. Actual and predicted max demand.

The relationship between system capacity, actual maximum demand, and predicted maximum demand is given in Figure 5.

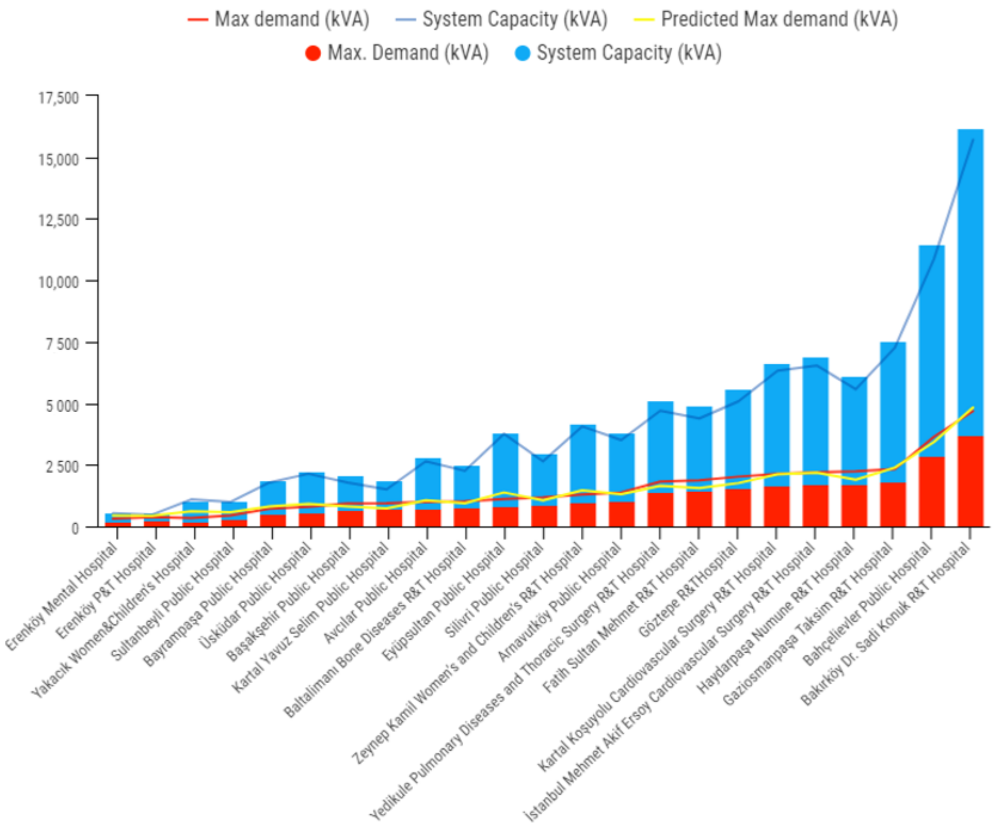

Figure 5. System capacity, actual and predicted max demand.

It is concluded that hospitals use about one-third of their system capacity. While preparing the hospital electrical projects according to the values in the regulation, transformer and generator capacities are selected almost three times more than the need, and idle capacity is created.

3.2. Formula 2

Another method is used to determine the volt-ampere level per unit area, such as the 220.86 table in NFPA70 (US National Electrical Code, National Fire Protection Association, MA, USA). According to the data in Table 1, the maximum demand per unit area is determined by the curve fitting method given in Figure 6.

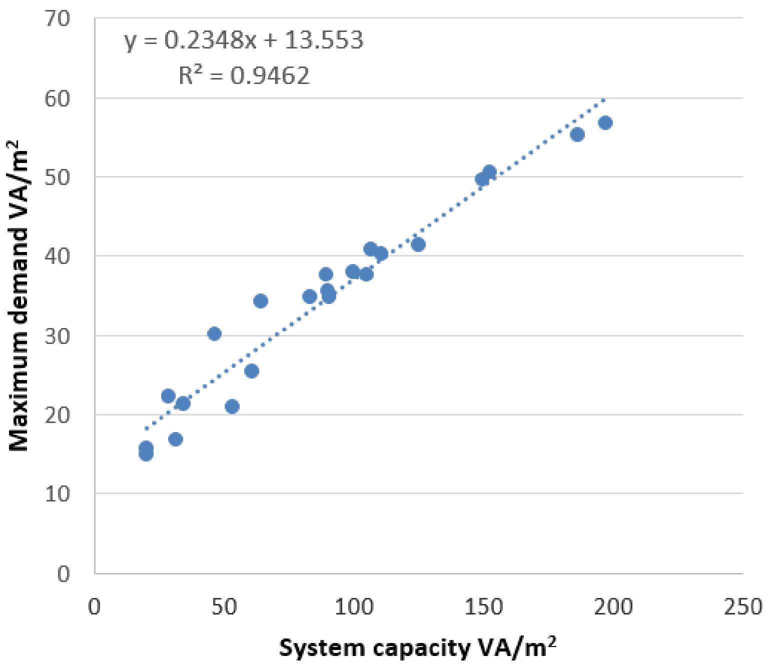

Figure 6. Maximum VA/m^2 curve.

It is concluded that there is a linear relationship between the maximum demand per area and the system capacity per area. The formula of the curve obtained as a result of linear regression is y = 0.2348x + 13.553. For maximum demand, system capacity coefficients have been found as 0.2348 (slope) and 13.553 (intercept). The error performances obtained are *MSE* = 0.0049, *RMSE* = 0.07, *MAPE* = 10.77.

As a result, it is found that the maximum demand per area in hospitals with over 100 beds can be determined by the following formula.

$$\frac{MD}{Total\ Area} = 0.2348\ \frac{SC}{Total\ Area} + 13.553 \quad (8)$$

MD: Maximum demand (VA)
SC: System Capacity (VA)
The values specified in the formula adapted to the regulation are presented in Table 7.

Table 7. Optional method-Demand factors for feeders and service conductors for hospitals.

Loads	Demand Factor (%)
First 13.5 VA/m^2 plus,	100
Over 13.5 VA/m^2	24

This formula differs from the coefficients in the current regulations in that it does not have to calculate the loads (lighting, mechanical, etc.) one by one. If the system capacity is known, the maximum demand can be calculated with a single formula. The actual and predicted maximum demand per area is given in Figure 7.

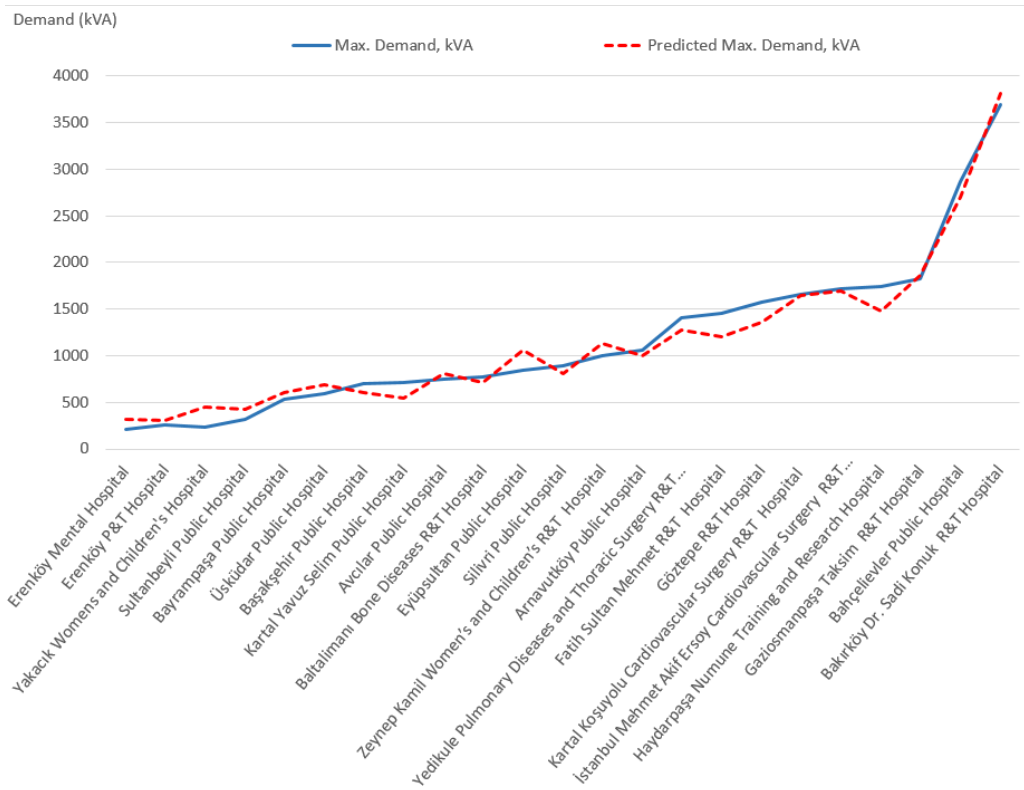

Figure 7. Actual and predicted max demand per area.

3.3. Cost-Saving Implications

This analysis is a new technique that can be used for both new hospitals and existing hospitals. This technique aids in overcoming the difficulties that arise in determining the installed power calculation. The power system has been designed excessively, which results in unnecessary initial costs and lifecycle costs. The proposed idea is to optimize the quantity of the transformer and generator to be the most appropriate to the actual situation.

For example, in the reconstructed Kartal Training and Research Hospital Project shown in Figure 8, the installed load of the hospital is 43 MVA; according to the result of the calculations made according to the Turkish Electricity Indoor Facilities Regulation, it is seen that the maximum demand should be 30 MVA.

Figure 8. Kartal Dr. Lütfü Kırdar R&T Hospital.

However, when the formula obtained from this study is applied, the maximum demand becomes as

$$MD = 0.296(SC) + 197 \tag{9}$$

$$MD = 0.296(43000) + 197 \tag{10}$$

$$MD = 12.925 \text{ MVA} \tag{11}$$

Similarly, when the volt-ampere level per unit area formula obtained from this study is applied, the maximum demand results as follows.

$$\frac{MD}{Total\ Area} = 0.2348\ \frac{SC}{Total\ Area} + 13.553 \tag{12}$$

$$\frac{MD}{250000} = 0.2348 \left(\frac{43000000}{250000} \right) + 13.553 \tag{13}$$

$$MD = 13.471 \text{ MVA} \tag{14}$$

While the system is designed with 30 MVA, 13 MVA needs to be designed for overlapping peak demand. As a result, transformers and generators are installed almost three times the amount actually needed. If the economic analysis is made for the Kartal Training and Research Hospital Project, which is being reconstructed, the initial cost saving result is shown in Table 8.

Table 8. Potential savings.

Product	Quantity	Unit Price ($) *	Total ($)
1600 kVA Transformer 36 kV 2 Circuit Breaker + 1 Switchgear + Transformer + LV Panel	11	30,000	330,000
4 × 240 mm^2, 0.6/1 kV YXV (N2XY) XLPE Cable	1100	71	78,100
1750 kVA Diesel Generator	10	220,500	2,200,000
Automatic switching system 1500–2000 kVA.	10	2130	21,300
Synchronization Unit 1250–2000 kVA	10	1170	11,700
Sound insulation cabinet 1750 kVA	10	5000	50,000
TOTAL			2,696,100

* Unit Prices were taken from Unit Price Book [35].

It has been calculated that a total of $2,696,100 will be spent. However, the idle operation losses of the extra transformers and the maintenance and operating costs of the extra transformers and generators are bound to cause increase in the operating costs of the hospital. While this work continues, the construction of Kartal Training and Research Hospital was completed, and it was put into service at full capacity in July 2020. Its highest power to date has been recorded as 9.9 MVA. The results proved the effectiveness of this study.

4. Discussion

4.1. The Effect of Hospital Typology

Hospital typology can exist in very different ways depending on the designer. The age, enclosed space, and form of each hospital building are unique. The exterior of some of them is covered with glass, some with aluminum, and some with plaster. The thermal insulation ratios of each of them are also different from each other. It is expected that the heating and cooling systems will affect the maximum power account. In addition, the medical service offered in hospitals also varies depending on the type of hospital. Considering that the types of devices used will differ, it is thought that the type of hospital will also affect the maximum demand. Therefore, is it possible to apply a singular formula as a standard to all hospitals? Having considered the following examples empirically, we have confirmed that the answer is yes. In the found method, a calculation method is used over the installed power. The calculation of the installed power is carried out by collecting each individual load in the system. Hence, it has been concluded that the age of the hospital, its structure, form, type, etc. are factors that do not affect the method found, and the method can be used for all hospitals in Turkey.

First, the Gaziosmanpasa Taksim Public Hospital in Figure 9 is considered.

Figure 9. Gaziosmanpaşa Taksim Public Hospital.

The installed power of Gaziosmanpaşa Taksim Public Hospital is 5750 kVA, and the maximum power was calculated at 1899 kVA when the linear model was applied. The actual maximum power is 1821 kVA.

Secondly, the Bahçelievler Public Hospital in Figure 10 is considered.

Figure 10. Bahçelievler Public Hospital.

The installed power of Bahçelievler Public Hospital is 8625 kVA, and the maximum power was calculated at 2750 kVA when the linear model is applied. The actual maximum power is 2863 kVA.

Thirdly the Mehmet Akif Ersoy Cardiovascular Surgery Training and Research Hospital in Figure 11 is considered.

The installed power of Mehmet Akif Ersoy Cardiovascular Surgery Training and Research Hospital is 5175 kVA, and the maximum power was calculated at 1728 kVA when the linear model is applied. The actual maximum power is 1718 kVA.

Lastly the Arnavutköy Public Hospital in Figure 12 is considered.

Figure 11. Mehmet Akif Ersoy Cardiovascular Surgery Training and Research Hospital.

Figure 12. Arnavutköy Public Hospital.

The installed power of Arnavutköy Public Hospital is 2760 kVA, and the maximum power was calculated at 1014 kVA when the linear model is applied. The actual maximum power is 1059 kVA.

Therefore, hospital typology is not a factor for maximum demand estimation.

4.2. The Effect of Considering a Limited Number of Hospitals

Although the number of hospitals is limited, the variety of selected hospitals is very large. Hospitals with more than 100 beds include new and old, glass-fronted and plastered-fronted, roofed and terrace, and with and without HVAC systems.

The 23 selected hospitals are a core that encompasses almost all hospitals. Therefore, as can be seen from the examples above, the method found can be applied to all types of hospitals in Turkey.

In the literature, there is information about the annual energy use intensity (EUI, kWh/m^2) of hospitals in various countries. However, there is no information about the maximum demand of hospitals. When hospitals in developed countries are evaluated in terms of medical devices and electromechanical equipment, they are generally similar to each other. Because the formula calculates the system capacity, it is predicted that the method can be used in countries such as America, Germany, and England when it is evaluated that the devices using the system capacity and the health system are similar. However, data and further studies are needed to apply the results of the study all over the world.

5. Conclusions

In this study, the annual electrical energy consumption of 23 public hospitals with over 100 beds in Istanbul is measured, and after determining the monthly peak loads, two new forecasting models are proposed using regression techniques for maximum demand forecasting. The actual maximum power is about one third of the installed power. The maximum demand can be calculated easily and with high accuracy by the formula "Maximum Demand = 0.296 (System Capacity) + 197" or by summing 100% of the 13.5 kva per square meter and 24% of the remaining load per square meter. The findings of this study have improved the understanding of hospital power design.

The results obtained from the study show that the maximum demand of a hospital at the design stage can be estimated with high accuracy using a simple formula. This method, which can also be applied to active hospitals, allows you to identify hospitals that need energy optimization in a short time.

The results of this study can be used as a reference for the design of hospital power systems. The findings in this article have practical benefits for the world. Design engineers and hospital managers can estimate the maximum power of hospitals with a single formula and evaluate hospital power systems.

The conceptual system developed in this research contributes to the scope of the field of sustainable engineering. The results of this study contribute to the energy policy design goals, as they demonstrate a new methodological approach to reducing installation and operating costs.

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Abbreviations

CF	Coincidence factor
DF	Demand Factor
MD	Maximum demand
MSE	Mean Squared Error
MAPE	Mean Absolute Percentage Error
MAPD	Mean Absolute Percentage Deviation
R&T	Training and research
RMSE	Root Mean Squared Error
SC	System Capacity

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