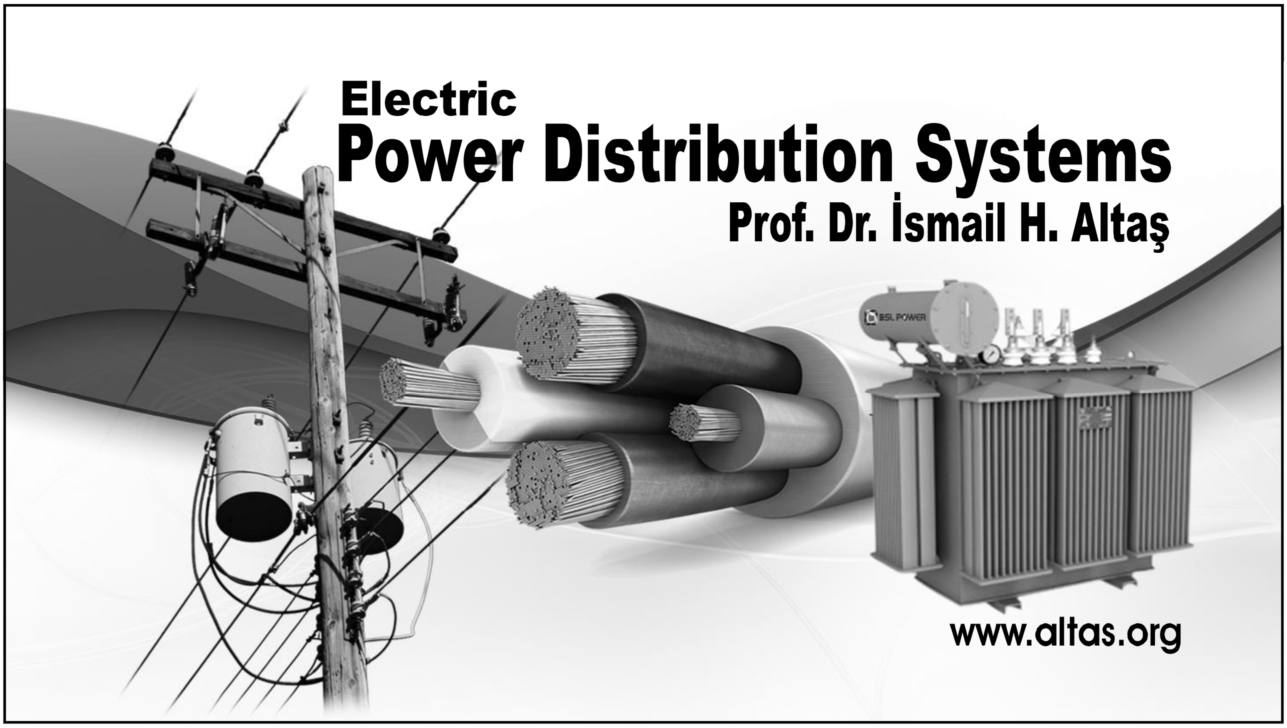


Electric Power Distribution Systems
Chapter 2 – Load Power Definitions

Publication of this lecture presentation notes on any platform by others is subject to permission.
Remember, Stealing is not sharing.

URBAN ELECTRICAL NETWORKS

SOURCE:
Yetkin SANER
ŞEHİR
ELEKTRİK ŞEBEKELERİ
PROJE UYGULAMALARI

1. REGULATIONS,

- Elektrik Kuvvetli Akım Tesisleri (EKAT) Yönetmeliği. Resmi Gazete tarihi: 30.11.2000, sayısı: 24246.
- Elektrik İç Tesisleri (EİT) Yönetmeliği. Resmi Gazete tarihi: 04.11.1984, sayısı: 18565.
- Elektrik Tesislerinde Topraklamalar (ETT) Yönetmeliği. Resmi Gazete tarihi: 21.08.2001, sayısı: 24500.
- Elektrik Tesisleri Proje (ETP) Yönetmeliği. Resmi Gazete tarihi: 30.12.2014, sayısı: 29221 (Mükerrer).
- Elektrik Tesisleri Proje Yönetmeliği' nde değişiklik yapılmasına dair Yönetmelik. Resmi Gazete tarihi: 25.01.2019, sayısı: 30666.
- Elektrik Tesisleri Kabul (ETK) Yönetmeliği. Resmi Gazete tarihi: 07.05.1995, sayısı: 22280.
- Elektrik Tesisleri Kabul Yönetmeliği' nde değişiklik yapılmasına dair Yönetmelik. Resmi Gazete tarihi: 11.12.2019, sayısı: 30975.

URBAN ELECTRICAL NETWORKS

2. Teknik Şartnameler (*) (Technical Specifications)

- Elektrik Dağıtım Tesisi Genel Teknik Şartnamesi Enerji ve Tabii Kaynaklar Bakanlığı' nın17.05.1984 tarih ve 162-620-7414/65993 sayılı yazısı ile onaylanmıştır.
- TEDAŞ Birim Fiyat Kitabı. Bu kitap her yıl güncelleştirilerek yayımlanmaktadır.

(*) Enerji ve Tabii Kaynaklar Bakanlığı' nın onayladığı Genel Teknik Şartname geneldir, tüm elektrik projelerinde bu şartnameye uyulmak zorunluluğu vardır. TEDAŞ da MYD adı ile Teknik Şartnameler yayımlamaktadır. TEDAŞ' a ait bu şartnamelere uyulmasının yasal bir dayanağı olmadığından, TEDAŞ ın dışındaki kurumların bu şartnamelere uymaları zorunluluğu yoktur. Fakat, güzel düzenlenmiş olan MYD şartnamelerinden yararlanılması gerekir. (https://www.tedas.gov.tr/#!tedas_şartnameler)

URBAN ELECTRICAL NETWORKS

LV and MV+LV COMMON NETWORKS

Overhead Line Distribution Networks

Undergraund Cable Network

- LV networks
- MV networks
- MV+LV common networks

Buildings and residences lined up along streets and roads in residential areas such as cities, towns and villages, as well as small industry(*) consumers, are fed from LV urban networks.

(*) Large industrial consumers are fed from MV.

URBAN ELECTRICAL NETWORKS

In order for a consumption unit to be fed from the LV mains, it is recommended that the demand power be at most 30 kW, and the distance from the TM to be 600 m for cables and 400 m for overhead lines. If these conditions cannot be met, it is necessary to establish a new TM.

In general applications, the residential area is divided into TM zones. TMs are installed in these regions. Consumers in the region are fed from the TM of that region by radial, ring or mesh LV network.

When a TM fails, all buildings in that TM area are de-energized. In order to overcome this negativity, it is necessary to feed a TM from other TM’s. In this application, the transformers in the TMs make instant backups to each other.

In order for the transformers in their TMs to provide instant backups, they must be loaded with approximately 70% of their power in normal operation and kept 30% of the power ready.

URBAN ELECTRICAL NETWORKS

In Figure 1,
the layout plan of the MV and LV distribution network is shown as an example.
In this example, 4 outputs in MV are made from the main TM, branch outputs Q1 and Q2 and branch outputs Q3 and Q4 feed the TR-1 ... TR-6 and TR-7 ... TR-13 distribution transformers connected to the MV mesh network with in-out connections.

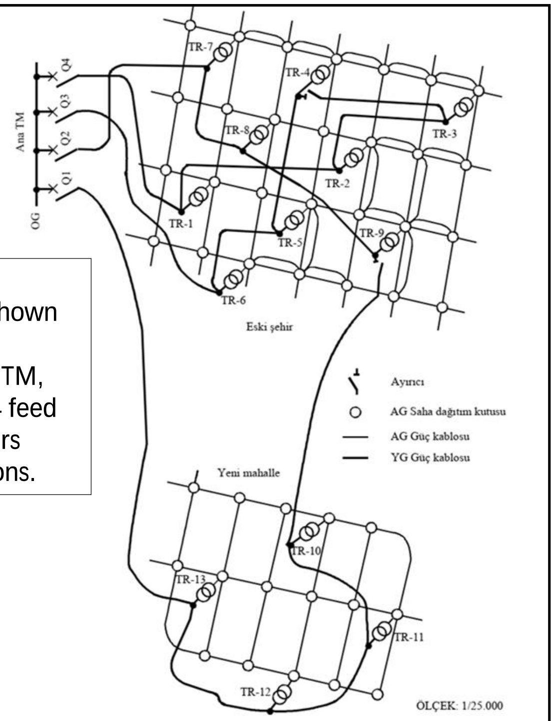
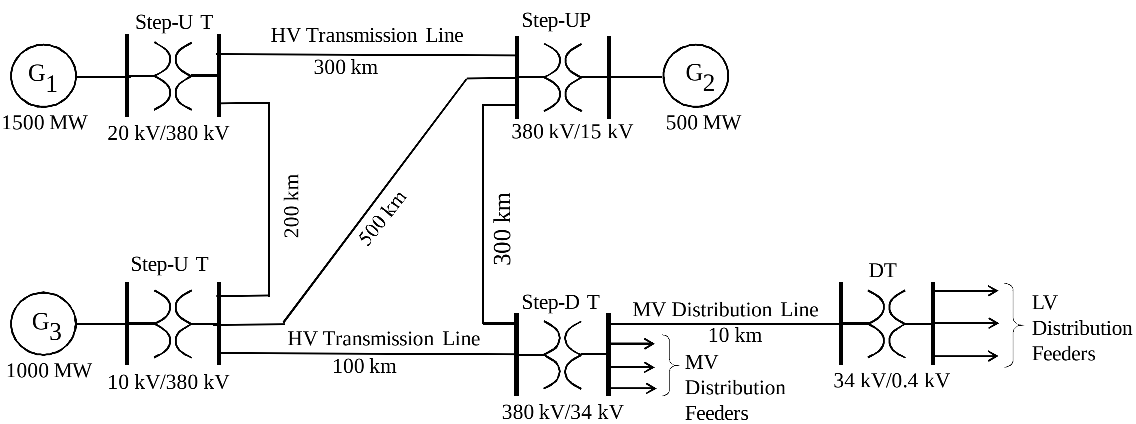
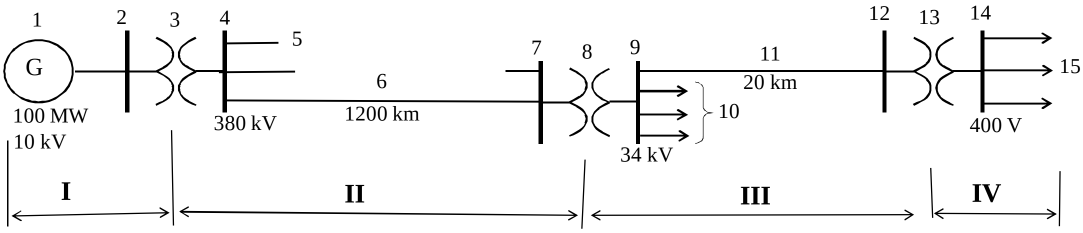


Figure 1.
MV loop and LV network distribution network site plan.
Only the Disconnectors on the OG loop are shown.

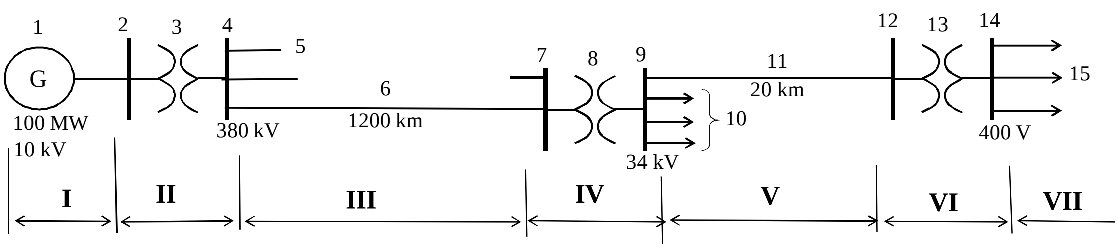
URBAN ELECTRICAL NETWORKS



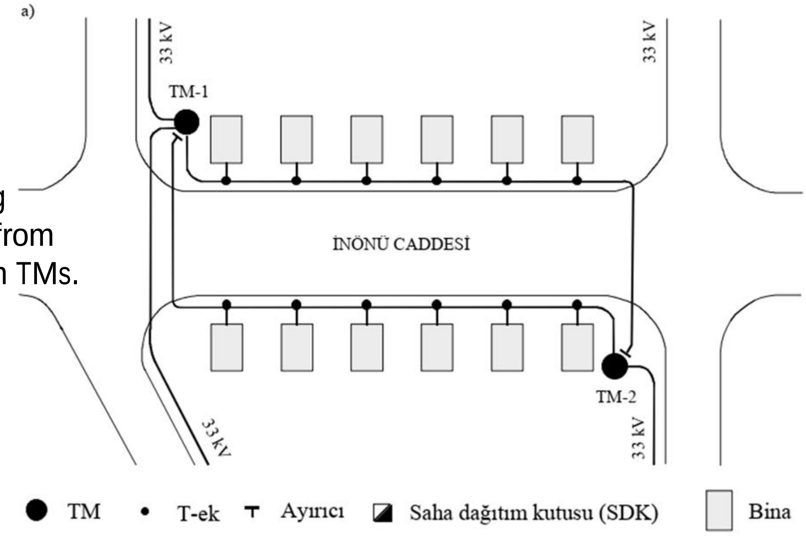
Introduction to Distribution Networks



Introduction to Distribution Networks

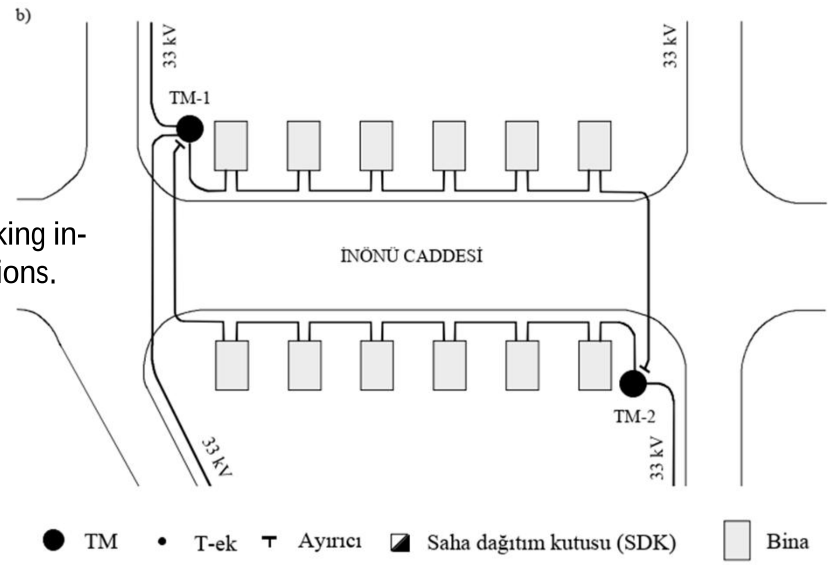


Introduction to Distribution Networks



Buildings are fed by taking separations with T-joints from the cable coming out from TMs.

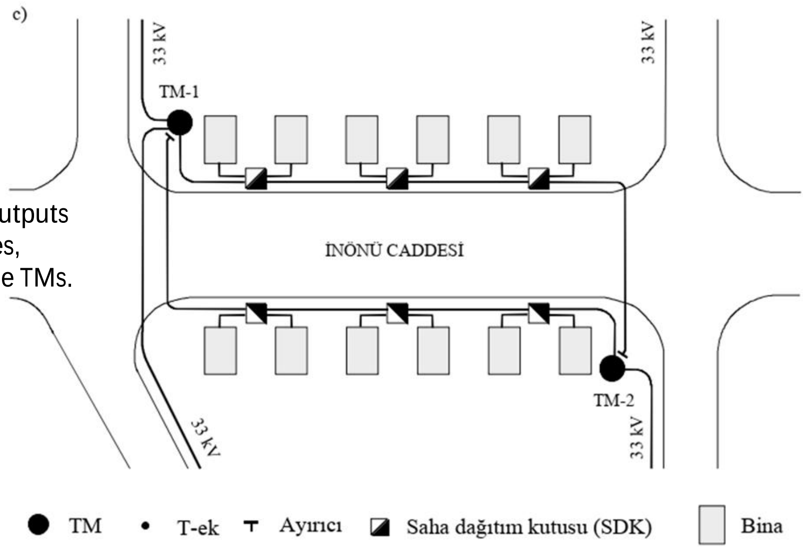
Introduction to Distribution Networks



Buildings were fed by making in-outs instead of T-connections.

Introduction to Distribution Networks

Buildings were fed from the fused outputs in each of the field distribution boxes, which were fed with in-outs from the TMs.



Introduction to Distribution Networks

It can be concluded that figure 2c is the most appropriate solution, since in Figure 2a and 2b, TMs are protected against faults from buildings, whereas in Figure 2c, building exits in field distribution boxes are protected by fuses before TMs. In this solution, although it is not complete, the (n-1) condition is provided in the building groups that are the sections of the network.

"N-1" means that the grid shall be capable of experiencing outage of a single transmission line, cable, transformer or generator without causing losses in electricity supply.

Similar to the N-1 operating logic, it can go up to N-2, N-3 and N-X.

Here, the larger the number X, the more advanced the system and the lower the probability of a power outage in case of failure.

To give an example of this, in a single-cable transmission line, if there is a fault in the cable, there is a power outage. With the N-1 Rule, the number of cables is increased to two and in case of a fault in one cable, the remaining cable does the work of the two cables alone.

ADDING NEW TMs TO DISTRIBUTION NETWORK

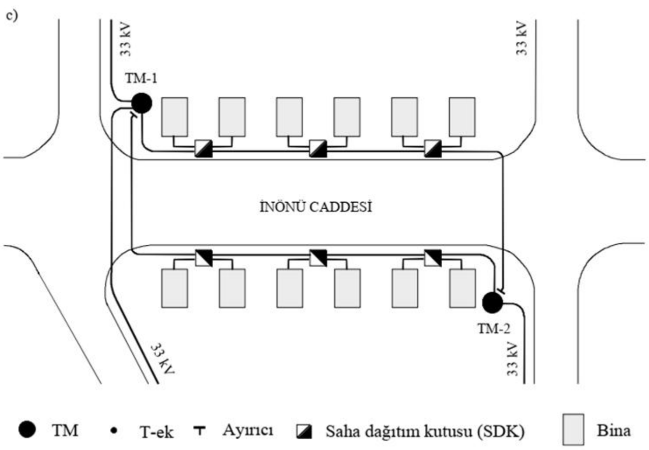
The need for electrical energy increases exponentially every 10 years due to the increase in population, the expansion of residential areas, the opening of new residential areas, the increase in consumption tools and consumption habits.

Although it is aimed to meet today's power requirement in the design of LV networks, the possible power increase of 20 years should also be taken into account in determining the power.

Investing today for the power increase that will spread over 20 years may not be economically viable, and the maintenance/repairs of additional devices will unnecessarily increase the cost, and their lifespan will be shortened due to aging.

Therefore, the solution for future power increases in distribution grids should be considered in grid projects today, but additional investments should be left until the power requirement arises.

ADDING NEW TMs TO DISTRIBUTION NETWORK



Şekil 2c

The arrangement in figure 2c is taken as an example of adding new TMs to LV distribution networks.

In the first stage, equivalent TMs with 630 kVA power, which is standard for city networks, were placed at both ends of the branch.

6 field distribution boxes from TMs were fed by making input-output.

With the power drawn from the field distribution boxes, the power flows on the arm are shown in figure 3a.

ADDING NEW TMs TO DISTRIBUTION NETWORK

For the sake of simplicity, it is assumed that the transformer loads are equal and constant, and the TMs are equal and the intermediate lengths are equal.

The power of the transformers is 630 kVA, with 630 kVA as a reserve in Figure 3a. Since this power will be doubled at the end of 10 years, the transformer power will be 2x630 kVA, with 630 kVA as spare as in figure 3b,

Since the power will double again at the end of the second 10 years, it will be 4x630 kVA with 630 kVA remaining as a reserve as in figure 3c.

ADDING NEW TMs TO DISTRIBUTION NETWORK

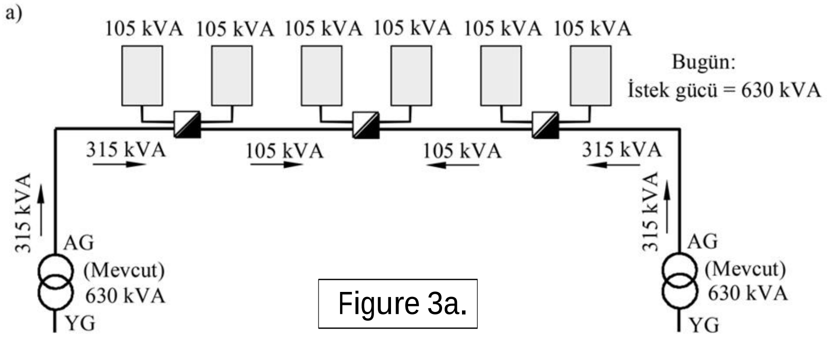
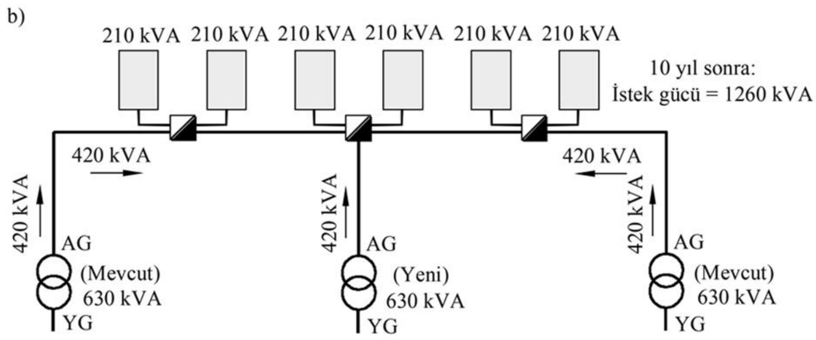


Figure 3a.

The current power requirement of each building is 105 kVA, and the current power requirement of two branches is 6x105 = 630 kVA. Although this power can normally be obtained from 1 transformer with 630 kVA power, 2 transformers with 630 kVA power have been installed since this power will not be enough to feed both branches in case of a fault in one branch. Under normal conditions, 315 kVA power is drawn from each of the transformers, which is half power. Figure 3a.

ADDING NEW TMs TO DISTRIBUTION NETWORK



Şekil 3b

Since the power requirement will double after 10 years, the power requirement of each building is 210 kVA, and the power requirement after 10 years in two-branch supply is 6x210 = 1260 kVA. In order to meet this power, 3 transformers with a power of 630 kVA, 1 of which will be hot spares, have been installed.

ADDING NEW TMs TO DISTRIBUTION NETWORK

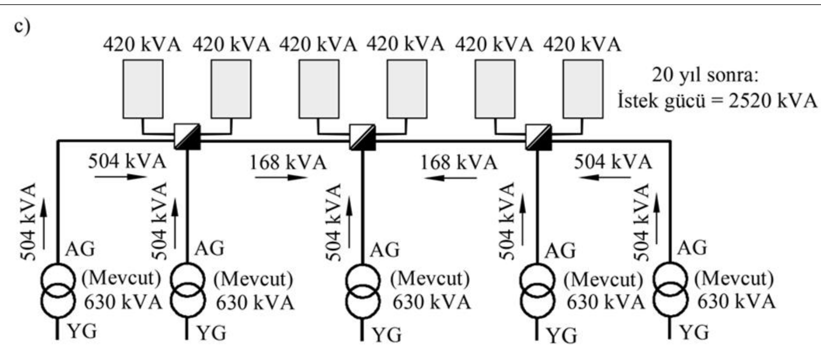
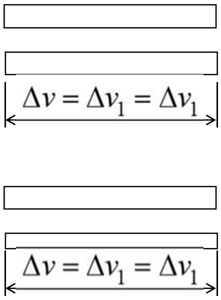


Figure 3c.

Since the power requirement will quadruple after 20 years, the power requirement of each building is 420 kVA, and the power requirement after 20 years in two-branch supply is 6x420 = 2520 kVA. In order to meet this power, 5 transformers with a power of 630 kVA, 1 of which will be hot spares, have been installed. Figure 3c.

ADDING NEW TMs TO DISTRIBUTION NETWORK



$$\Delta v = I_1 R_1 = I_2 R_2$$

$$\frac{I_1}{I_2} = \frac{R_2}{R_1}$$

Power increases and related investments need to be made in the half-decades, that is, in the 5th and 15th years.

In LV city networks, it should be preferred that LV power cables are of the same type and cross-section. Failure to comply will have to keep a wide variety of LV power cables in stock.It is appropriate that the cross section of the LV power cable to be decided is 95 mm^2 Cu (150 mm^2 Al).

If this cross-section is insufficient according to the load current, a second power cable of the same cross-section is connected in parallel.

If this is also insufficient, more LV power cables with the same cross section (*) are connected in parallel. The requirement that the LV power cables to be connected in parallel must be of the same cross-section confirms the preference of LV power cables in a uniform and cross-section.

(*): Paralel kablolar aynı kesitte olmazlarsa dirençleri farklı olacağından, kabloların yüklenme akımları da farklı olur. Bunu kanıtlamak için paralel kablolarda gerilim düşümlerinin eşit olması koşulu yazılır:

EXPANSION OF LV DISTRIBUTION NETWORKS

The insufficiency of the existing LV distribution grid or the increase in the power requirement due to the expansion of residential areas requires the expansion of the LV grid. Extending the LV grid is easier than installing a new one.

Because, the data and experiences obtained during the operation of the existing LV grid will be useful in the expansion process and will also contribute to the correct estimation of the consumption power.

In Figure 4, two options are given to shed light on the application to be made for this purpose.

EXPANSION OF LV DISTRIBUTION NETWORKS

In the first option in Figure 4a, a transformer (TR-2, Yellow colored) is added to the TM to meet the increased power requirement.

For the distribution of this power, new Q5 and Q6 outputs were added to the LV panel, and new residential areas 5 and 6 were fed from the new branches connected to these outputs.

Since the cable lengths will increase with the expansion of the feeding areas, there is a limit to the addition of a transformer to the TM at every power increase. In this case, it is necessary to switch to the second option, which envisages the distribution of TMs to the residential area.

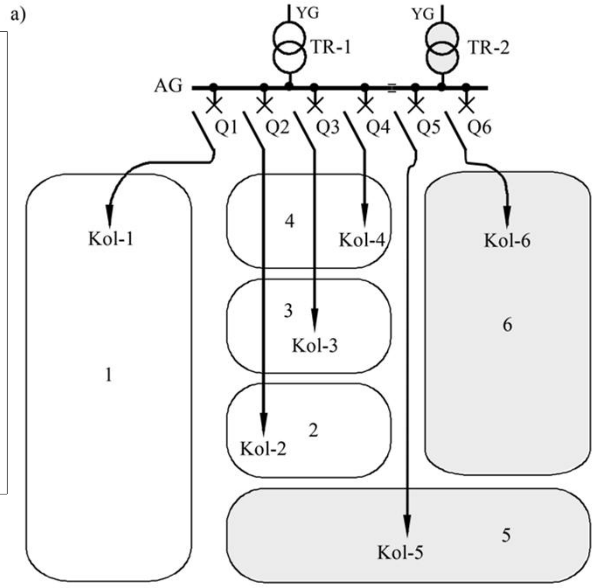


Figure 4a

EXPANSION OF LV DISTRIBUTION NETWORKS

In the second option in Figure 4b, apart from the insufficiency of the existing grid, since new residential areas were opened, a separate substation was installed close to the load center in the new residential area no. 6 for the required power.

In this option, since the TMs are not collected at one point but distributed to the distribution area, the supply reliability has increased compared to the first option. An LV panel with 1 transformer and 3 outputs fed from this transformer has been placed in the new TM.

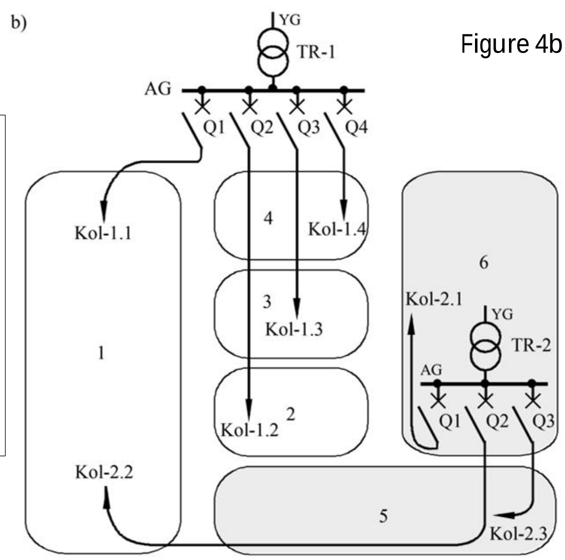


Figure 4b

EXPANSION OF LV DISTRIBUTION NETWORKS

New residential areas 6 and 5 were fed from the laterals connected to the Q1 and Q3 outputs of the LV panel.

Since the number of residences has increased with the change in the zoning plan in the settlement no. 1, and the power has increased, this settlement area has been fed from the branch connected to the Q2 exit in TR-2, apart from the Q1 in TR-1.

Although it may be thought that this option will be more expensive than the first option, on the contrary, this option may be more economical as the distribution area expands and the consumption power increases.

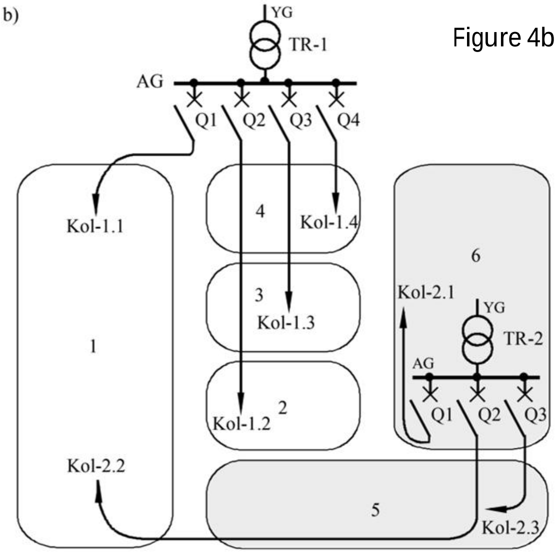
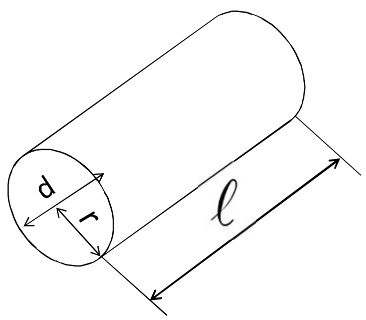
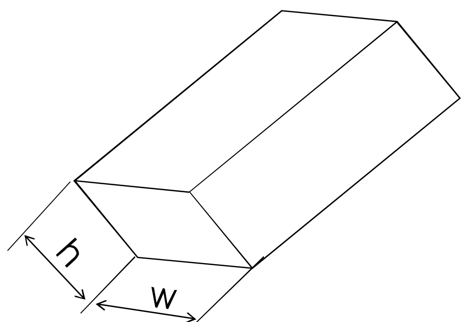


Figure 4b

LOAD (POWER) DEFINITIONS

Determination of conductor cross section (S)





$$S = \pi r^2$$

d: diameter
r: Radius
l: length

$$S = hw$$

h:hight
w: width

LOAD (POWER) DEFINITIONS

Determination of conductor cross section

Conductor size (mm2)	Current rating (Amperage)	Maximum power (Wattage)
0.50	3	720
0.75	6	1400
1	10	2400
1.5	15	3600
2.5	24	4800

- ❖ In Low Voltage (LV), conductor cross-sections are generally determined according to the load current and voltage drop.
- ❖ Since the loading current in overhead lines is small, the heating limits are not exceeded and the cross-section is determined according to the voltage drop.
- ❖ In underground cables, it is necessary to determine the cross-sections according to the loading current. Because the sections selected according to the load current are often larger than the sections calculated according to the voltage drop.
- ❖ In HV, the conductor cross-section should also be determined according to the short-circuit strength.
- ❖ Before starting the cross-section calculation according to the loading current and voltage drop, the smallest conductor cross-section is determined according to the mechanical and short-circuit strengths.

LOAD (POWER) DEFINITIONS

Döşenme biçimi ve yeri		En küçük iletken kesiti [mm²] Bakır	Alüminyum
Sabit ve korunmuş olarak döşenen kablolar		1,5	2,5
Bağlama döşemlerinde ve dağıtım tablolarında kullanılan kablolar:			
- 2,5 A e kadar		0,5	-
- 2,5 A ile 16 A arasında		0,75	-
- 16 A in üzerinde		1	-
İzolatörler üzerinde açıkta döşenen kablolar, mesnet noktaları arasındaki açıklık:			
- 20 m ye kadar		4	16
- 20 m ile 45 m arasında		6	16 (Çok telli)
Lamba duyu bağlantı kabloları		0,75	-
Yapı içindeki donanma kablolarında:			
- Donanma duyu ile fiş arasındaki kablolar		0,75	-
- Lambalar arasındaki kablolar		0,75	-
		AG	YG
Kuvvetli akım hava hatlarında kullanılan çıplak örgülü iletkenler	Bakır	10 mm²	16 mm²
	Tam alüminyum	21 mm²	-
	Çelik-alüminyum	-	21/4 mm²
	Çelik	16 mm²	16 mm²
	Bronz	16 mm²	16 mm²

Table 5.1.
The smallest conductor cross-sections used in electrical interior installations and overhead lines.

LOAD (POWER) DEFINITIONS

The sequence followed in determining the conductor cross section:

Table 5.1.

Döşenme biçimi ve yeri		En küçük iletken kesiti [mm²]	
		Bakır	Alüminyum
Sabit ve korunmuş olarak döşenen kablolar		1,5	2,5
Bağlama döşemlerinde ve dağıtım tablolarında kullanılan kablolar:			
- 2,5 A e kadar		0,5	-
- 2,5 A ile 16 A arasında		0,75	-
- 16 A in üzerinde		1	-
İzolatörler üzerinde açıkta döşenen kablolar, mesnet noktaları arasındaki açıklık:			
- 20 m ye kadar		4	16
- 20 m ile 45 m arasında		6	16 (Çok telli)
Lamba duyu bağlantı kabloları		0,75	-
Yapı içindeki donanma kablolarında:			
- Donanma duyu ile fiş arasındaki kablolar		0,75	-
- Lambalar arasındaki kablolar		0,75	-
		AG	YG
Kuvvetli akım hava hatlarında kullanılan çıplak örgülü iletkenler	Bakır	10 mm²	16 mm²
	Tam alüminyum	21 mm²	-
	Çelik-alüminyum	-	21/4 mm²
	Çelik	16 mm²	16 mm²
	Bronz	16 mm²	16 mm²

1. In order for the cables and overhead line conductors to withstand mechanical stresses during and after pulling, they should not be selected with a cross section smaller than a certain cross section.

   According to the mechanical strength, the smallest conductor cross-sections given in Table 5.1 are taken into account.

For interior installations:

1.5 mm^2 for lighting outlets,

2.5 mm^2 for socket outlets,

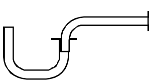
2.5 mm^2 for lighting and socket lines,

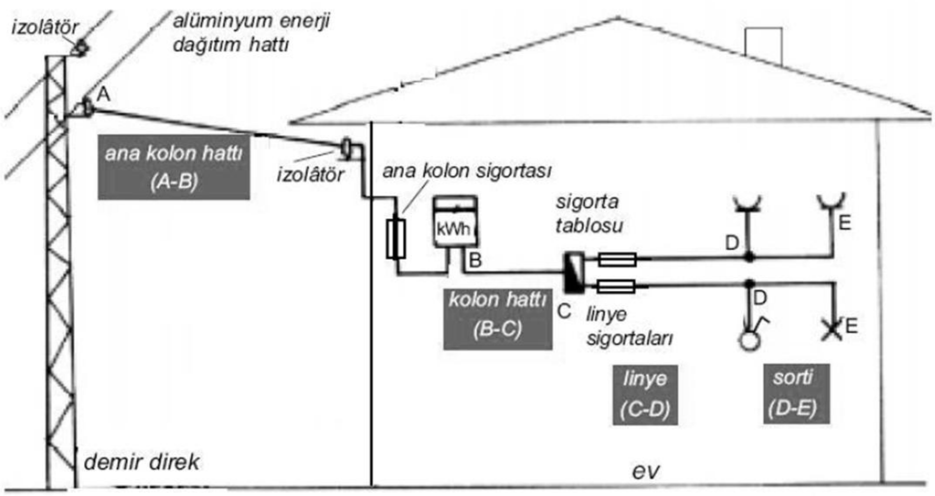
4 mm^2 for column lines,

A cross section less than 6 mm^2 (10 mm^2 for aluminum) is not used for the construction connection lines. [4]

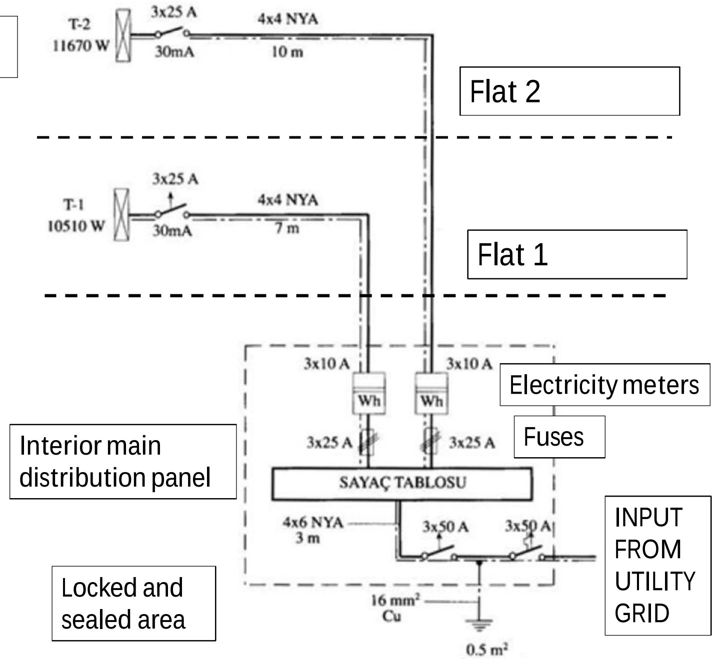
[4] Elektrik İç Tesisleri Yönetmeliği. Bak: Madde 52.d.vii-vii-ix-x.

LOAD (POWER) DEFINITIONS

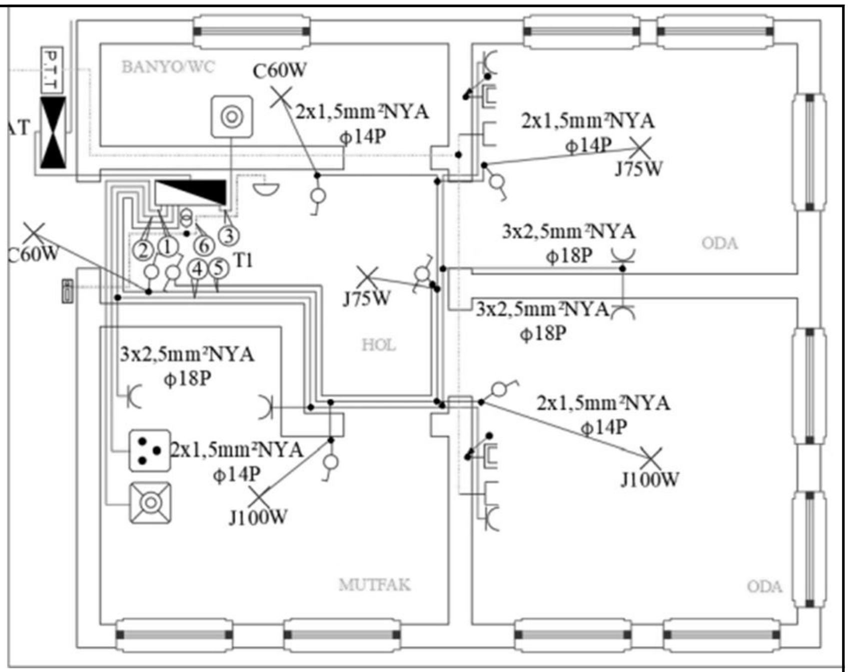




LOAD (POWER) DEFINITIONS



LOAD (POWER) DEFINITIONS



LOAD (POWER) DEFINITIONS

The sequence followed in determining the conductor cross section:

2. According to the short-circuit current, the smallest possible conductor cross-section is determined. See: Book 4.

   Regardless of the power drawn, the smallest conductor cross-section is determined according to the short-circuit current. This is the smallest acceptable conductor cross section. The conductor cross-sections to be obtained by the following methods cannot be smaller than this one:

3. The cross section is determined according to the loading current. See: Section 3.33.
4. Voltage drop calculation is made for the cross section determined according to the loading current.

   If the voltage drop does not meet the amount given by the regulations, the calculation is repeated by increasing the conductor-section, and that the voltage drop will kept in acceptable limits.

LOAD (POWER) DEFINITIONS

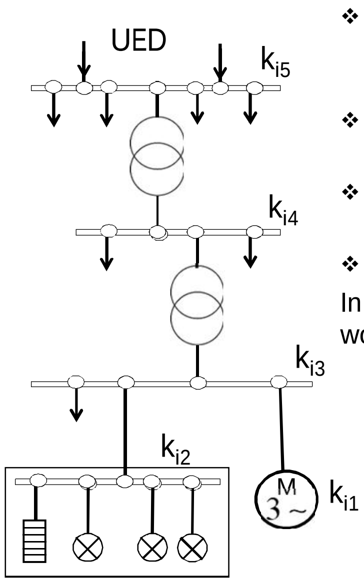
The sequence followed in determining the conductor cross section:

After determining the necessary and sufficient conductor cross-section, the following operations can be performed for this cross-section if desired.

5. The I^2R power loss is calculated. If this calculated power loss is greater than the predicted value, the cross section is increased and the power loss is reduced to the predicted value.
6. An economic calculation is made for energy loss in cables.
   - For this, energy loss is calculated by multiplying the I^2R power loss by the usage time of the cable.
   - For this energy loss, the conductor cross-section is compared with the energy cost to be paid within the economic life of the cable.
   - According to the economic result reached, it is decided whether to increase the cross section of the cable. See: Section 5.7.

LOAD (POWER) DEFINITIONS

POWER DEFINITIONS



- The validity of the results of the calculations for the conductor cross-sections depends, first of all, on the correct estimation of the electrical power to be drawn.
- The increase in power requirement day by day also requires future power estimations.
- Overestimating the distribution power will cause unnecessary investments, and underestimating it will cause insufficient conductor cross-sections.
- Therefore, it is very important to estimate the distribution power very closely.

In the simple network model where many consumption units (residence, site, workshop, commercial buildings, industry, etc.) are fed:

- The main transformer, fed from the transmission line, separated from the National Electricity System (UED),
- Distribution transformers fed from medium voltage (MV) distribution lines separated from this main transformer and
- There are many small loads (Motor, illuminator, heater, etc.) fed from low voltage (LV) lines separated from each distribution transformer. Figure 5.1.

LOAD (POWER) DEFINITIONS

POWER DEFINITIONS

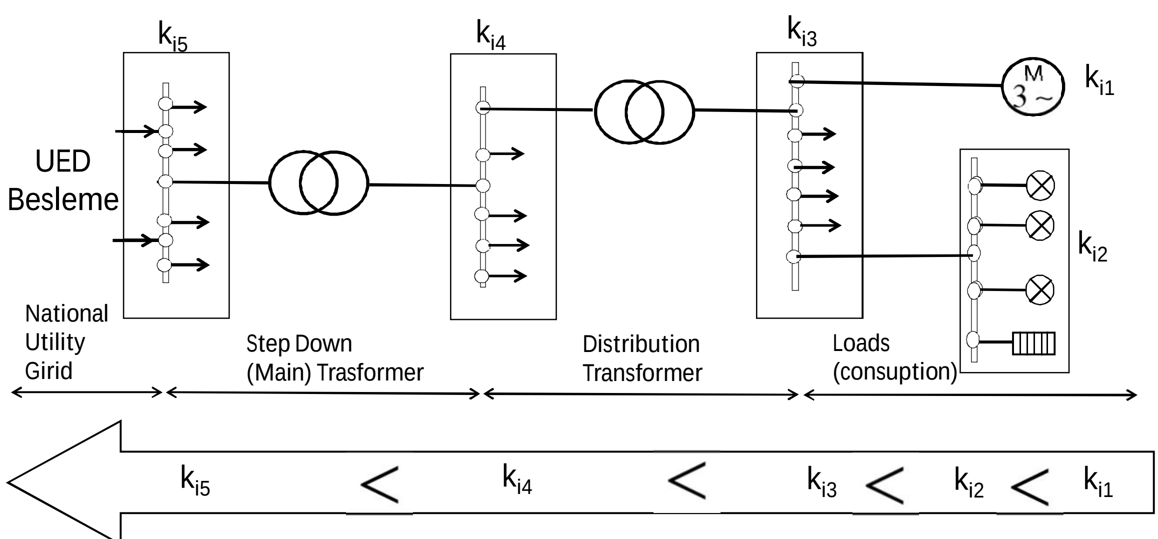


Figure 5.1. Distribution of loads and demand coefficients in simple network model.

LOAD (POWER) DEFINITIONS

POWER DEFINITIONS

INSTALLED POWER

1. Installed Power: Engine, heater, illuminator etc. installed and running in a consumption unit. The sum of the label powers of all electrical devices is called the Installed Power (KG).

❖ in determining the installed power. It is recommended to arrange separate power tables for the Powers of motor, lighting, heating etc.

Note: The installed power definition, made for consumption units, is also valid for generators and transformers. In this case, the installed power of the generator or transformer should be written in front of the installed power.

EXAMPLE: : in a factory

Motor power	: 683.2 kW
Lighting power	: 36.7 kW
Heating power	: 33.0 kW
Housing power	: 67.1 kW

+

Installed power of the factory : 820.0 kW

Transformer installed power : 630 kVA

LOAD (POWER) DEFINITIONS

POWER DEFINITIONS

INSTALLED POWER

DEMAND POWER

❖ Installed power is mostly static power, which has no practical meaning other than the determination of demand power.

❖ This power is not used in the determination of the transformer power and conductor cross section calculations, the demand power is taken into accpunt instead.

2. Demand Power: It is rare to encounter the situation in which all electrical devices that make up the installed power in a consumption unit are switched on at the same time and the ones in the circuit are working at full load.

The load curves of the consumption units within the duty cycle (Day, week, month, year) vary widely.

EXAMPLE: In the daily load curves of the urban networks,

the peak power is 2 times the power drawn at night; In annual power curves, on the other hand, the peak powers drawn according to the seasons can be 3 times the smallest power.

LOAD (POWER) DEFINITIONS

POWER DEFINITIONS

INSTALLED POWER

DEMAND POWER

PEAK POWER

DEMAND FACTOR

- The largest power in the load curve is called Peak Power.
- The area under the load curve gives the energy consumed in the duty cycle. Figure 5.2.

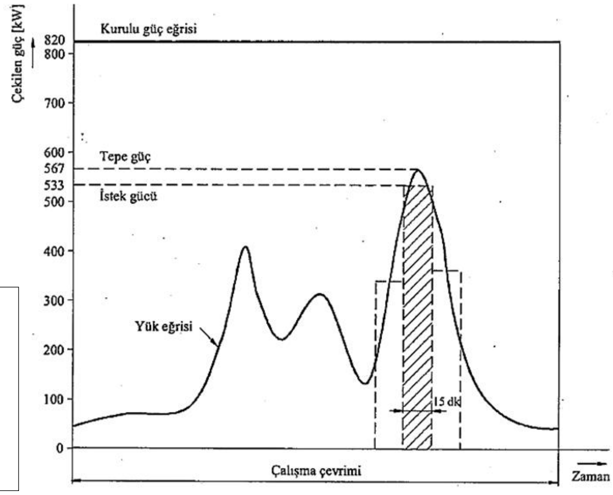
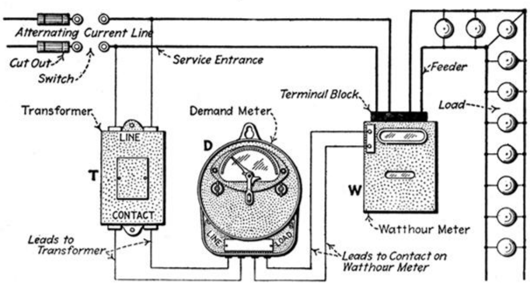


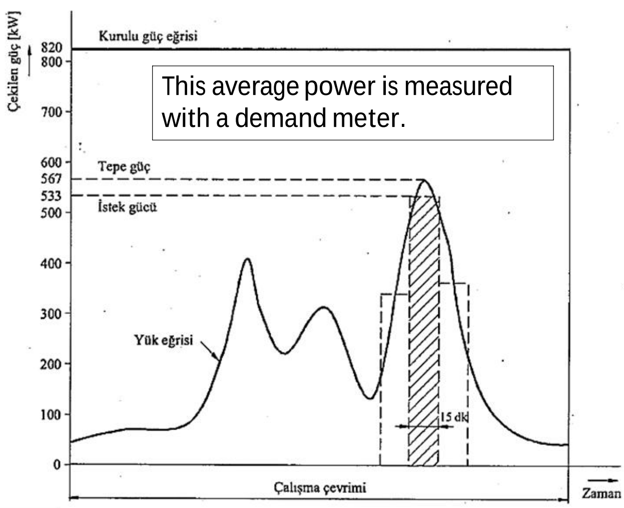
Figure 5.2.
Load Curve.
Installed power: 820 kW,
Peak power: 567 kW,
Demand power: 533 kW,
DF=533/820=0.65.

LOAD (POWER) DEFINITIONS

POWER DEFINITIONS

- The height of the rectangle showing the average of the energy consumed in a time interval (15 min, 30 min, 1 hour or more) determined in the load curve is the basis for the definition of demand power.





This average power is measured with a demand meter.

Figure 5.2.
Load Curve.
installed power: 820 kW,
Peak power: 567 kW,
Deman powe: 533 kW,
DF=533/820=0.65.

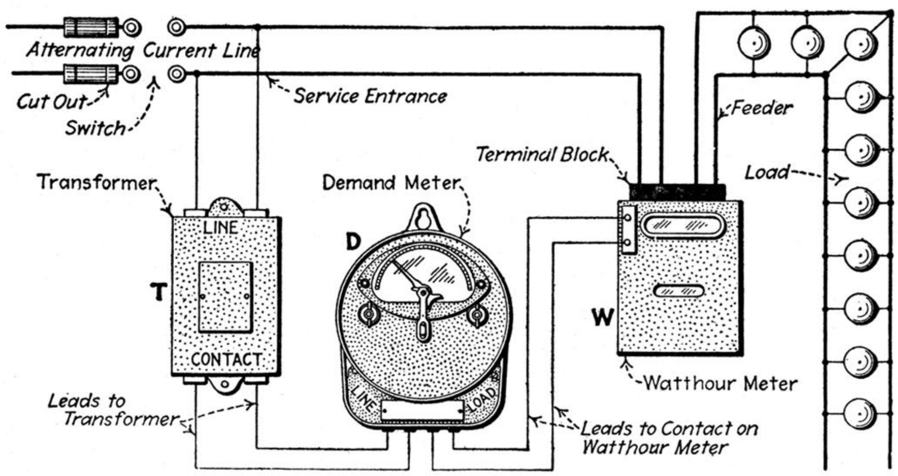
LOAD (POWER) DEFINITIONS

- ❖ This average power is measured with a demand meter.
- ❖ The demand meter, for example, shows 4 times the energy consumed at 15-minute intervals (15 minutes=1/4 hours) every 15 minutes.
- ❖ If the energy consumed in 15 minutes is 120kWh, the value shown by the demand meter is (120 kWh)/(1/4h)= 480 kW.
- ❖ The Turkish Electricity Distribution Corporation (TEDAŞ) wants the time interval to be 15 minutes in the calculation of the demand power.

The Peak Demand mode represents the highest 15 or 30 minutes of power used since your last 30-day billing period. Peak demand helps your electricity provider determine the size of equipment needed to supply energy to your business. The numbers in the example below indicate the maximum power load of 109 watts (0.109 kW) at some time since the last billing.

https://www.ucahelps.alberta.ca/reading-your-power-demand-meter.aspx

LOAD (POWER) DEFINITIONS



Methods of connecting an alternate-current demand meter for 440 and 660-volt loads. For 110 and 220-volt loads (and direct-current loads), the transformer is omitted.

LOAD (POWER) DEFINITIONS

- The maximum average power consumed in a consumption unit within the specified operating cycle (1 month) and within the specified time interval (15 minutes) is called the demand power (DP).
- Demand/Demand power (DP): The power found by multiplying the installed power by the demand factor.

(Elektrik Tesisleri Proje Yönetmeliği)

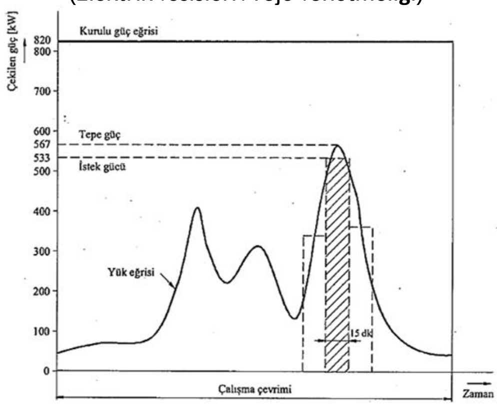


Figure 5.2.
Load Curve.
İnstalled power: 820 kW,
Peak power: 567 kW,
Deman powe: 533 kW, DF=533/820=0.65.

LOAD (POWER) DEFINITIONS

- Since the average power in a certain time interval is taken as the demand power, a small number of peak powers that jump for a very short time will not be very effective in the calculation of the demand power.

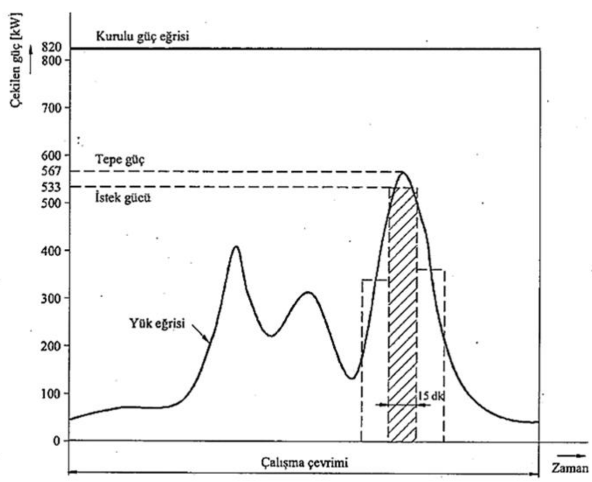


Figure 5.2.
Load Curve.
İnstalled power: 820 kW,
Peak power: 567 kW,
Deman powe: 533 kW, DF=533/820=0.65.

3. Demand Factor: The ratio of demand power to installed power is called demand factor (DF).

Demand factor/Demand coefficient: The ratio of the maximum power drawn by a network or facility section during the operating period to the total connected/installed power of the grid or grid section.

(Elektrik Tesisleri Proje Yönetmeliği)

Demand factor ➡ $k_i = \frac{\text{Demand Power}}{\text{Installed Power}} = \frac{P}{P_k} \quad k_i \leq 1$ [5.1]

- ❖ The demand coefficient is 1 or less than 1.
- ❖ The situation where the demand coefficient is 1 is rarely encountered, for example, in billboards and street lighting where all lamps are either on or off.

- ❖ In Figure 5.1, it is shown that the demand coefficient decreases as one moves from the loads to the UED.
- ❖ In a consumption unit, a request coefficient can be defined for all powers, as well as individual request coefficients for different loads such as lighting, outlets, heating, elevators, etc. within this consumption unit.

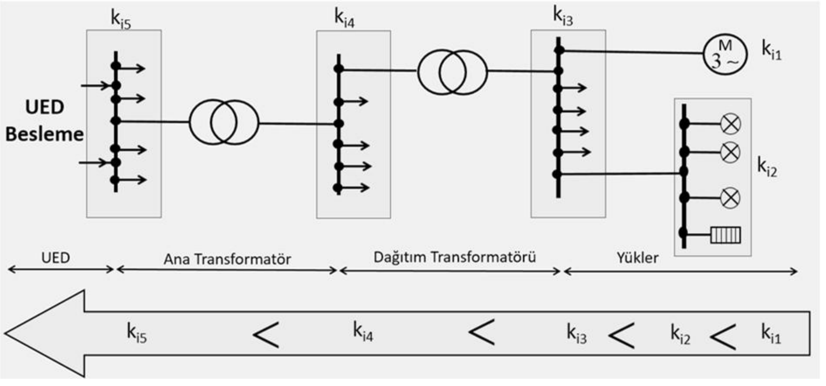


Figure 5.1. Distribution of loads and demand coefficients in a simple network.

- By measuring the demand power in the installed consumption units with a demand meter, these powers can be taken as an example for similar consumption units to be installed.

  For this purpose, the request coefficients given in the charts are also used. See: Table 5.2-5.4.
- Since the charts given for the determination of the demand coefficient become obsolete over time, they should only be used to get an idea, current values should be researched and should be be used.

Table 5.2. Demand coefficients for an apartment in residences[5].

Installed Power	Demand Coefficient k_i
Untill the first 8 kW	0.60
After 8 kW	0.40

[5] Elektrik İç Tesisleri Yönetmeliği. Bak: Madde 57.a.2

Table 5.3.
Demand coefficients for lighting, outlet and elevator power[5].

Bina cinsi	Kurulu güç	İstek katsayısı k_i
Aydınlatma gücü:		
Hastahaneler	İlk 50 kW a kadar 50 kW tan sonra	0,40 0,20
Oteller, moteller ve tatil köyleri	İlk 20 kW a kadar 20 ara 50 kW 50 kW tan sonra	0,50 0,40 0,30
Depolar	İlk 12,5 kW a kadar 12,5 kW tan sonra	1,00 0,50
Diğerleri	Tüm güç için	1,00
Priz gücü:		
Tüm binalar	İlk 10 kW a kadar 10 kW tan sonra	1,00 0,50
Asansör gücü:		
Büro binaları ve oteller	Tüm güç için	1,00
Okullar ve hastahaneler	Tüm güç için	0,85
Apartmanlar ve diğer binalar	Tüm güç için	0,55

[5] Elektrik İç Tesisleri Yönetmeliği. Bak: Madde 57.a.2

Table 5.4. Demand coefficients for offices and hospitals[6].

Power	Officies	Hospitals
Lights	0.95	0.7-0.9
Outlets	0.1	0.1-0.2
Heating and ventilation	1.0	0.9-1.0
Cooking	0.6-0.85	0.6-0.8
Elevator (Lift)	0.9-1.0	0.5-1.0
Others	0.3	0.6-0.8

[6] Siemens-Electrical Installations Handbook.

EXAMPLE

Find the demand coefficient in Figure 5.2.

Solution: From equation [5.1]:

$$k_i = \frac{\text{Demand power}}{\text{Installed power}} = \frac{P}{P_k} = \frac{533}{820} = 0.65$$

$$\boxed{k_i = 0.65}$$

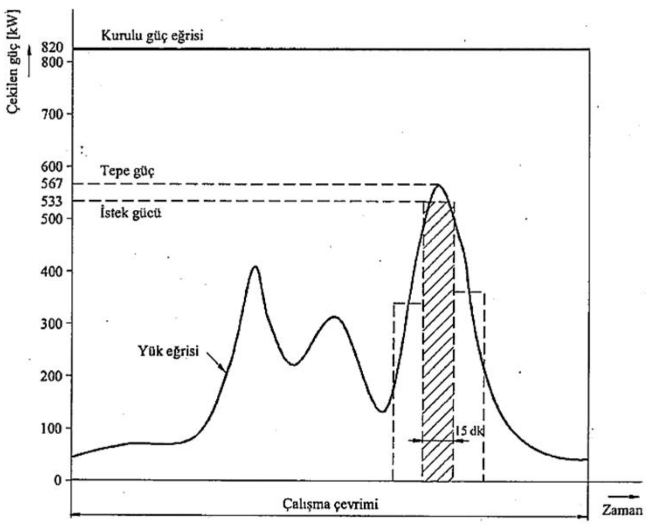


Figure 5.2. load curve.

EXAMPLE:

The powers of a factory are given as follows.
If the demand coefficient of this factory is k_i=0.65, what is the demand power?

Motor power: 683.2 kW,
Illumination power: 36.7 kW
Heating power: 33.0 kW,
Housing power: 67.1 kW

SOLUTION

Installed power of the factory
= Motor power + Lighting power + Heating power + Housing power
= 820.0 kW

[5.1] bağıntısından: İstek gücü = İstek katsayısı × Kurulu güç

$$P = P_k \times k_i = 820 \times 0.65 = 533 \text{ kW}$$

$$\boxed{P = 533 \text{ kW}}$$

EXAMPLE

The installed power of a flat is 9.5 kW. Calculate the will power of this circle.

Table 5.2. Demand coefficients for an apartment in residences[5].

Installed Power	Demand Coefficient k_i
Untill the first 8 kW	0.60
After 8 kW	0.40

[5] Elektrik İç Tesisleri Yönetmeliği. Bak: Madde 57.a.2

SOLUTION

With the coefficient values taken from Table 5.2:

$$k_i = \frac{\text{Demand power}}{\text{Installed power}} = \frac{P}{P_k}$$

$$P = (8.0 \text{ kW}) \times (0.60) + (1.5 \text{ kW}) \times (0.40) = 5.4 \text{ kW}$$

$$\boxed{P = 5.4 \text{ kW}}$$

- In order to determine the demand power of the houses, instead of taking the demand coefficient, depending on the number of houses, the demand power per house can also be taken.
- In Figure 5.3, the demand power curves, which have been prepared using the experience in practice, are given.
- As can be seen from the figure, the distribution power of more than 200 houses is taken as 1-2 kW per house.

- Unit demand powers taken from the application;

  Table 5.5 for residences,
  Table 5.6 for private buildings,
  Table 5.7 for industry and commercial establishments.

1. Akışları ısıtıcı kullanılan tam elektrik donanımlı konutlar.
2. Depolu ısıtıcı kullanılan tam elektrik donanımlı konutlar.
3. Elektrikli pişirme ve ev aygıtlarıyla donanımlı konutlar.
4. Aydınlatma ve elektrikli küçük ev aygıtlarıyla donanımlı konutlar.

1. Fully electrically equipped residences using streams heater.
2. Fully electrically equipped residences using a storage heater.
3. Houses equipped with electric cooking and household appliances.
4. Housing equipped with lighting and small electrical appliances.

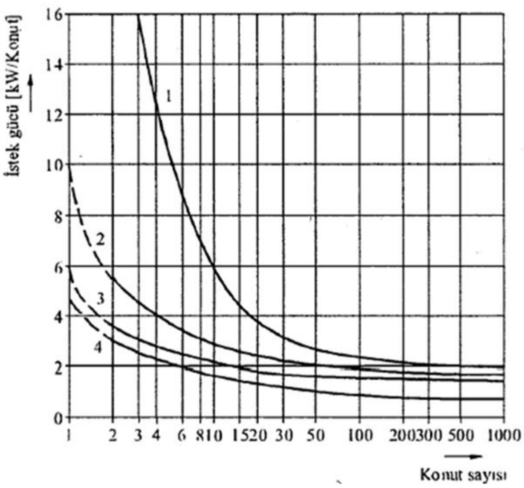


Figure 5.3. Demand coefficients per house depending on the number of houses[6].

Table 5.5. Demand powers per house for approximately 50 houses or more[6].

Residential Consumption	Demand power per residance (Average values for, approximately 50 or more residances)
No electrical cooking and water heating (Little electrical equipment)	1 kW/residance
There is electric cooking and water heating (Very electrically equipped)	2-3 kW/residance
There is electrical heating, with direct or overnight storage (Full electric equipped)	5-15 or higher kW/residance

Table 5.6. Unit demand powers for special buildings[6].

Consumption unit	Demand power per unit
Lights	10-25 W/m^2
Heating and ventilation	1-3 kW/per device
Office buildings	100 W/m^2 or 2 kW/office
Elevators	10-50 kW/Elevator
Hotels	3-4 kW/Room

Table 5.7. Demand powers per m^2 for industry and business[6].

Consumption	Demand power per m^2
Maintenance and repair workshops, lathe workshops, Weaving and spinning mills	50-100 kW/m^2
Machine tool factories, Mechanical workshops,and Melding workshops	70-300 kW/m^2
Press workshops, Steel smelting and rolling mills	200-500 kW/m^2

4. Diversified timing coefficient: While the demand coefficient is defined for a single consumption unit, the different timing coefficient is defined between more than one similar consumption units.

- ❖ For example, in Figure 5.4, since the demand Powers of the flats do not coincide with the same time in the building with 3 flats; The total demand power (Building power) is less than the sum of the demand power of the apartments.
- ❖ In more than one similar consumption unit, the ratio of the sum of the demand power of these consumption units to the common demand power of the entire consumption unit is called the diversified timing coefficient or Deversity factor (DF):

$$k_f = \frac{\text{Sum of individual demand powers}}{\text{Common demand power of entire consumption}} = \frac{\sum_{i=1}^{n} P_i}{P} \quad k_f \geq 1 \qquad [5.2]$$

- ❖ Diversity factor is either 1 or greater than 1.

- ❖ If Diversity Factor is
- ❖ taken between the flats, demand power of the building that includes these flats;
- ❖ taken between buildings, demand power of the TR region including these buildings;
- ❖ taken between TR regions, the demand power of the city that includes these TR regions is determined.
- ❖ The demand power of the city can be determined by taking Diversity coefficients starting from the flats, from the bottom, to the top. The demand power of the city can also be determined directly by taking a single demand coefficient for the city. See Example 7.
- ❖ The opposite of the diversity coefficient is called the coincidence factor:

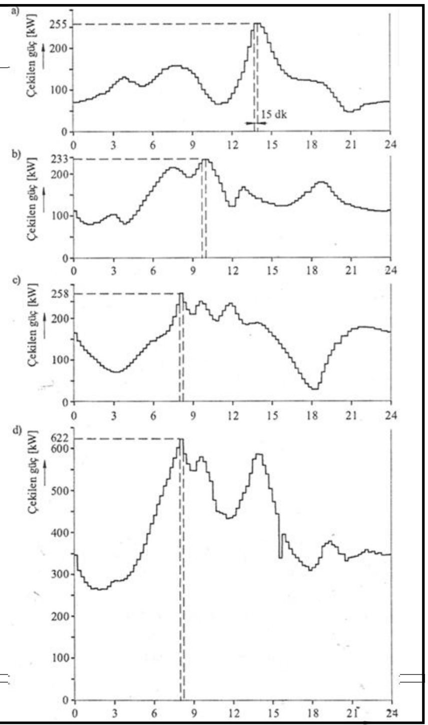
$$k_e = \frac{1}{k_f} \quad k_e \leq 1 \qquad [5.3]$$

LOAD (POWER) DEFINITIONS

Figure 5.4.
In the building with 3 flats
(a, b, c) Demand power of each flat.
d) Demand power of the building:

Demand Coefficient (Factor) of the building

$$k_i = DF = \frac{255+233+258}{622} = 1.20$$



LOAD (POWER) DEFINITIONS

POWER DEFINITIONS

- As seen in Figure 5.4, the request power of the circle in Figure 5.4c coincides with the common request power in Figure 5.4d at the same time.
- If the peak power can be shifted back and forth by taking the time when the will power of this circle appears, the common will power will be smaller.
- The coincidence factor is 1 or less than 1 as in the demand factor.
- Because of this similarity, it might be easily confused the coincidence factor with the demand factor, so the coincidence factor will not be used unless it is mandatory.
- Demand Factors are given in Tables 5.8 and 5.9.
- Since the charts given to determine the Demand Factors get old over time, as in the demand coefficient, they should be used only to get an idea, and current values should be researched and used.

Note:
Table 5.8 is taken from EİTY.
It is understood that the installed power is taken as the basis for the coincidence coefficient in the chart in the EITY. However, in order to comply with the definition of diversity and coincidence coefficient, the necessary correction has been made in Table 5.8 based on the demand power instead of the installed power. In this correction, DF=0.60 is accepted.

Table 5.8. Diversity and coincidence coefficients for houses[5].

The number of Flat or panel	Diversity factor k_f	Coincidence factor k_e
1	1.00	1.00
2	1.11	0.90
3-5	1.33	0.75
6-10	1.39	0.72
11-15	1.47	0.68
16-20	1.54	0.65
21-25	1.67	0.60
26-30	1.75	0.57
31-35	1.92	0.52
36-40	2.08	0.48
41-45	2.17	0.46
46-50	2.27	0.44
51-55	2.38	0.42
56-61	2.50	0.40
61 ve daha fazla	2.63	0.38

Table 5.9. General k_f diversity coefficients [7].

Units to apply diversity	Residences	Businesses	General Loads	Large consumers
Between residences	2.00	1.46	1.45	-----
Between distribution transformers	1.30	1.30	1.35	1.05
Between distribution center feeders	1.15	1.15	1.15	1.05
Between distribution centers	1.10	1.10	1.10	1.10
From consumers to power plants	3.29	2.40	2.46	1.45
From consumers to distribution centers	3.00	2.18	2.24	1.32
From consumers to feeders	2.60	1.90	1.95	1.15
From consumers to transformers	2.00	1.46	1.44	-----

LOAD (POWER) DEFINITIONS

Example:

Calculate the diversity factors between the 3 flats in Figure 5.4

SOLUTION

From equation [5.2:

$$k_f = \frac{\text{Sum of demand powers}}{\text{Common demand power}} = \frac{\sum_{i=1}^{n} P_i}{P} \quad k_f \geq 1$$

$$k_f = \frac{P_1 + P_2 + P_3}{P} = \frac{255 + 233 + 258}{622} = 1.20$$

$k_f = 1.20$

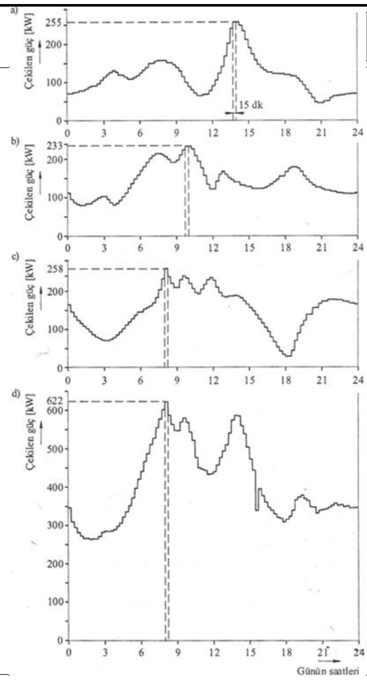


Figure 5.4

LOAD (POWER) DEFINITIONS

POWER DEFINITIONS

Example:

An apartment building is fed with three phase power input. However, the flats are fed with 1 phase. There are 10 flats with 5.4 kW demand power each, and the demand power of the concierge's flat is 5.2 kW. Calculate the demand power of the building.

Solution:

In this three-phase-fed apartment, the number of flats is 11 including the concierge's flat.

Number of flats per phase: $\frac{11}{3} \approx 4$ flats

Diversity coefficient for 4 flats (from Table 5.8): 1.33.

SOLUTION (continued…):

Diversity coefficient for 4 flats (from Table 5.8): 1.33.

The demand power of the apartment building, from [5.2]:

$$k_f = \frac{\text{Sum of demand power}}{\text{Common total power}} = \frac{\sum_{i=1}^{n} P_i}{P}$$

$$\rightarrow P = \frac{\sum_{i=1}^{n} P_i}{k_f} = \frac{10 \times (5.4\ \text{kW}) + 1 \times (5.2\ \text{kW})}{1.33} = 44.5\ \text{kW}$$

$P = 44.5$ kW

Table 5.8. Diversity and coincidence coefficients for houses[5].

Number of flats or tables	Diversity factor k_f	Coincidenece factor k_e
1	1.00	1.00
2	1.11	0.90
3-5	1.33	0.75
6-10	1.39	0.72
11-15	1.47	0.68
16-20	1.54	0.65
21-25	1.67	0.60
26-30	1.75	0.57
31-35	1.92	0.52
36-40	2.08	0.48
41-45	2.17	0.46
46-50	2.27	0.44
51-55	2.38	0.42
56-61	2.50	0.40
61 ve daha fazla	2.63	0.38

EXAMPLE

There are 60 apartment buildings in a housing site. Each apartment building has 10 flats with a demand power of 5.4.kW each. Two of the apartment buildings have the concierge's flat with 5.2 kW demand power. There are no concierge flats in others 58 apartment buildings. Calculate the followings.

a) Demand power of apartment buildings with concierge flats,
b) Demand power of apartment buildings without concierge flats,
c) Calculate the demand power per flat of the site.

SOLUTION

a) Demand power of apartment buildings with concierge flats,

In a three-phase-fed apartment, the number of flats is 11 including the concierge's flat.

Number of flats per phase : $\frac{11}{3} \approx 4$ flats

Demand factor for 4 flats from (Table 5.8): 1.33

Demand power of an Apartment building, from [5.2]:

$$P_1 = \frac{\sum_{i=1}^{n} P_i}{k_f} = \frac{10 \times (5.4\ \text{kW}) + 1 \times (5.2\ \text{kW})}{1.33} = 44.5\ \text{kW}$$

$P_1 = 44.5$ kW

In apartment buildings withot concierge flats, the number of flats is 10.

Number of flats per phase: $\frac{10}{3} \approx 4$ flats

Demand factor for 4 flats from (Table 5.8): 1.33

Demand power of an Apartment building without concierge flats, from [5.2]:

$$P_2 = \frac{\sum_{i=1}^{n} P_i}{k_f} = \frac{10 \times (5.4\ \text{kW})}{1.33} = 40.6\ \text{kW}$$

$P_2 = 40.6$ kW

c) Demandt power of per apartment in the housing site :

Demand factor for the site (from Table 5.9) is taken as : 2

Çizelge 5.9. General k_f Diversity factors].

Units to apply diversity	Residences	Bussiness buildings	General loads	Large consumers
Between residences	2.00	1.46	1.45	-----
Between distribution transformers	1.30	1.30	1.35	1.05
Between distribution center feeders	1.15	1.15	1.15	1.05
Between distribution centers	1.10	1.10	1.10	1.10
From consumers to power plants	3.29	2.40	2.46	1.45
From consumers to distribution centers	3.00	2.18	2.24	1.32
From consumers to feeders	2.60	1.90	1.95	1.15
From consumers to transformers	2.00	1.46	1.44	-----

Demand power of the site, from [5.2]:

$$P_3 = \frac{\sum_{i=1}^{n} P_i}{k_f} = \frac{58 \times (40.6\ \text{kW}) + 2 \times (44.5\ \text{kW})}{2} = 1222\ \text{kW}$$

$P_3 = 1222$ kW

Demand power per flat in a site with 602 flats:

$$P_{3(\text{flat})} = \frac{1222\ \text{kW}}{602} = 2\ \text{kW}$$

$P_{3(\text{flat})} = 2$ kW

WARNING:
Although the installed power of an apartment is 9.5 kW, the demand power is 2 kW. Considering to put a separate transformer for this site,

For the housing site

Installed Power
=5 528 kW

Demand Power
=1222 kW

Demand Power (TEDAŞ)
=1222 kW

Transformer rating:

$S_T = 1\ 250$ kVA

the installed power of the site
(9.5)(58)(10) + (2)(9)=5 528 kW

$$S_T = \frac{P}{\cos\varphi} = \frac{1222 \text{ kW}}{0.95} = 1\ 286 \text{ kVA}$$

Transformer rating:
$S_T = 1\ 250$ kVA

5.4 = (8 kW) × (0.60) + (X kW) × (0.40)
5.4=4.8 + 0.4 X
X=(5.4 - 4.8)/0.4
X=1.5
Kurulu güç (flats):
P_k=8+1.5=9.5

5.2=4.8 + 0.4 X
X=(5.2 - 4.8)/0.4
X=1.0
Kurulu güç (concierge flat):
P_k=8+1=9

The demand power of the site can also be determined directly by taking a single request coefficient for the site. If the request coefficient for the site is taken as 0.20 from the values obtained by TEDAŞ in practice, then the demand power of the site [5.1] would be:

$$P = k_i P_k = (0.20)(5\ 528) = 1105{,}6 \text{ kW}$$

Bulk Load, Uniformly Distributed Load

- Loads connected to the end of the line or to many points of the line determine the power drawn from the line.
- Each of the loads connected to the line is called a bulk load or nodal load.
- In the calculation of line sections, it is necessary to carry out long operations, since many bulk loads along the line will be taken into account separately.
- In order to shorten these processes, it is assumed that the bulk loads are evenly distributed along the line at very small and even intervals.
- Loads taken as uniformly distributed along the line are called uniformly distributed loads.
- The distributed load per unit length of the line is called the load density.
- According to this definition, the load density;

$$j = \frac{\text{Distributed load}}{\text{line length}} = \frac{P}{l} \quad [\text{W/m}], [\text{kW/km}] \qquad [5.4]$$

End of the Chapter: Load Power Definitions