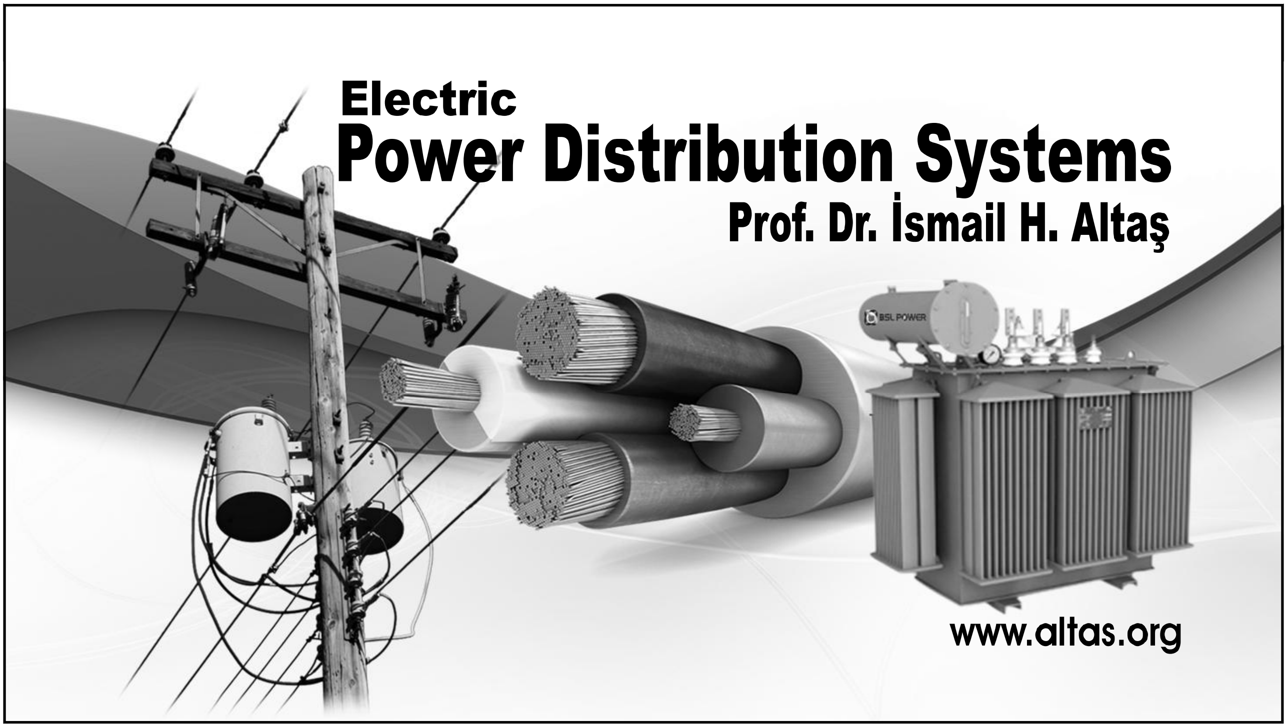

Electric Power Distribution Systems

CHAPTER 5 - RING NETWORKS

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DISTRIBUTION NETWORKS

The network formed by connecting the distribution lines fed from one or more points to each other in linear or different ways is called the distribution network.

Distribution network types

- Radial
- Branch
- Ring network
- Interconnected network

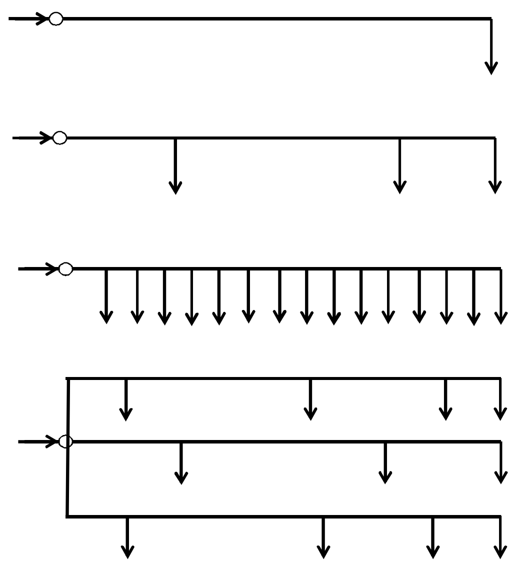
DISTRIBUTION NETWORKS

Single loaded Radial network

Multiple loaded Radial network

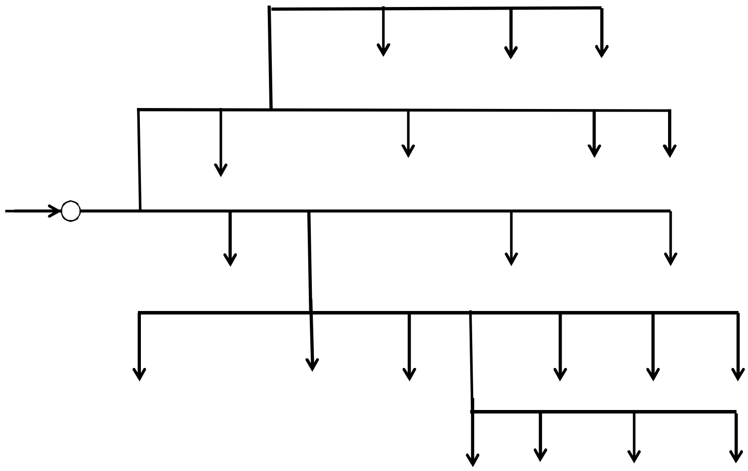
Uniformly loaded Radial network

Three branch Radial network



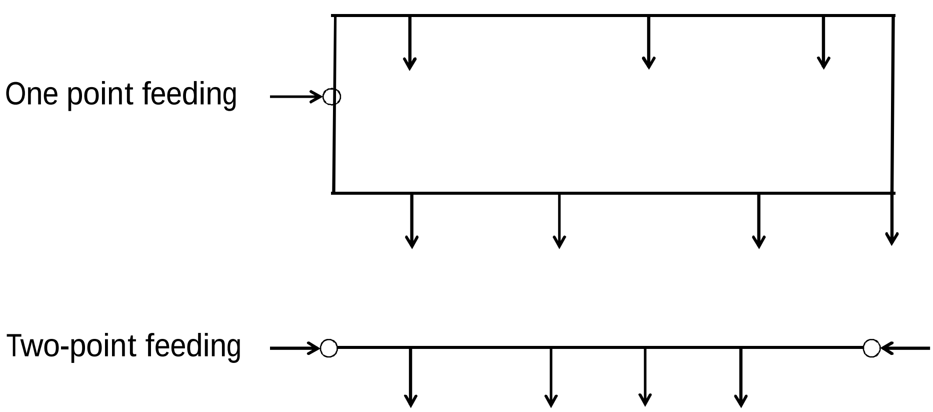
DISTRIBUTION NETWORKS

Multiple branch Radial network



DISTRIBUTION NETWORKS

RING NETWORK



RING NETWORK WITH ONE POINT FEEDING

Ring şebeke iki koldan beslendiğinden bu şebekede hat üzerindeki yüklerden biri vardır ki iki koldan beslenir. Bu yük r noktasındaki yük olsun. Ring şebeke bu r noktasından kesilirse, her iki koldaki gerilim düşümleri eşit olur. Şekil 5.38 de bu durum gösterilmiştir. Her iki koldaki gerilim düşümlerinin eşit olmaması, A’ ve A’’ noktalarında gerilimlerin eşit olmadığını gösterir ki, bu durumda yük akışı gerilimler eşit oluncaya dek sürer.

RING DISTRIBUTION NETWORKS

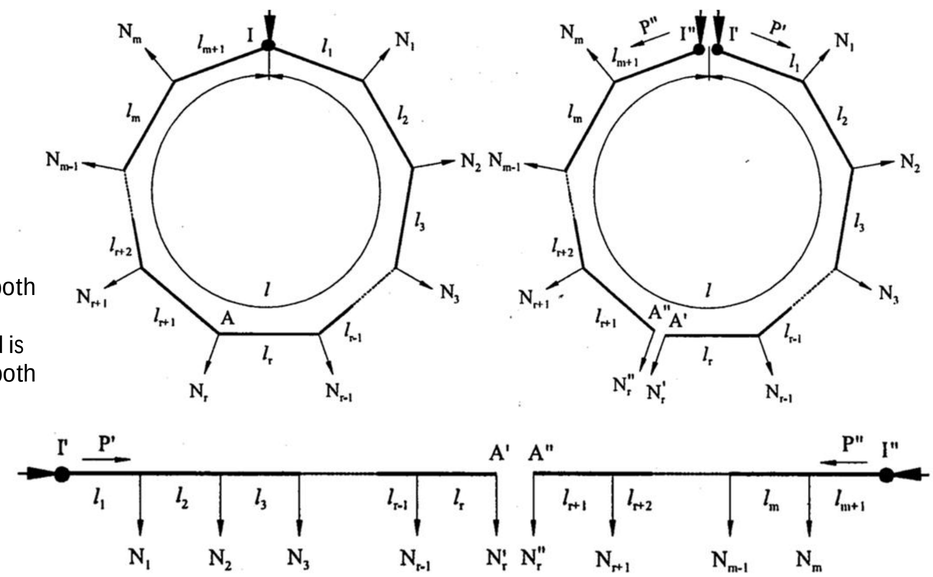


Figure 5.38.
The ring network is fed from both branches. If it is disconnected from the point where the load is divided, the voltage drops in both arms will be equal.

RING DISTRIBUTION NETWORKS

Since the conductor type and cross section are the same in the ring network, the voltage drop coefficients do not change. If it is written that the voltage drops in the arms are equal, from the relation u=kLN;

$$u = k_3^{''} \ell N \quad [\%]$$

$$u = k\left[\left(N_1 + N_2 + N_3 + \cdots + N_{r-1} + N_r^{'}\right)l_1 + \left(N_2 + N_3 + \cdots + N_{r-1} + N_r^{'}\right)l_2 + \left(N_3 + \cdots + N_{r-1} + N_r^{'}\right)l_3 + \cdots + \left(N_{r-1} + N_r^{'}\right)l_{r-1} + N_r^{'} l_r\right]$$

$$= k\left[\left(N_m + N_{m-1} + \cdots + N_{r+1} + N_r^{''}\right)l_{m+1} + \left(N_{m-1} + \cdots + N_{r+1} + N_r^{''}\right)l_m + \cdots + \left(N_{r+1} + N_r^{''}\right)l_{r+2} + N_r^{''} l_{r+1}\right]$$

RING DISTRIBUTION NETWORKS

Let's write Nr-Nr'' instead of Nr' and multiply Nr'' by distances to obtain the term

-Nr''(L1+L2+ .... + ... +Lr).

Let us move this term to the right side of the equation and multiply Nr'' by distances and then gather them into the same parenthesis.

$$\left(N_1 + N_2 + N_3 + \cdots + N_{r-1} + N_r\right)l_1 + \left(N_2 + N_3 + \cdots + N_{r-1} + N_r\right)l_2 + \left(N_3 + \cdots + N_{r-1} + N_r\right)l_3 + \cdots + \left(N_{r-1} + N_r\right)l_{r-1} + N_r l_r$$

$$= \left(N_m + N_{m-1} + \cdots + N_{r+1}\right)l_{m+1} + \left(N_{m-1} + \cdots + N_{r+1}\right)l_m + \cdots + N_{r+1} l_{r+2} + N_r^{''}\left(l_1 + l_2 + l_3 + \cdots + l_{r-1} + l_r + l_{r+1} + \cdots + l_m + l_{m+1}\right)$$

$N_r^{''} = P'' - N_{r+1} - \cdots - N_{m-1} - N_m$ olduğu yazılırsa:

RING DISTRIBUTION NETWORKS

$$
\begin{aligned}
&(N_1 + N_2 + N_3 + \cdots + N_{r-1} + N_r)l_1 + (N_2 + N_3 + \cdots + N_{r-1} + N_r)l_2 \\
&+(N_3 + \cdots + N_{r-1} + N_r)l_3 + \cdots + (N_{r-1} + N_r)l_{r-1} + N_r l_r \\
&-(N_m + N_{m-1} + \cdots + N_{r+1})l_{m+1} - (N_{m-1} + \cdots + N_{r+1})l_m - \cdots - N_{r+1} l_{r+2} \\
&+N_{r+1}(l_1 + l_2 + l_3 + \cdots + l_{r-1} + l_r + l_{r+1} + \cdots + l_m + l_{m+1}) \\
&+N_{m-1}(l_1 + l_2 + l_3 + \cdots + l_{r-1} + l_r + l_{r+1} + \cdots + l_m + l_{m+1}) \\
&+N_m(l_1 + l_2 + l_3 + \cdots + l_{r-1} + l_r + l_{r+1} + \cdots + l_m + l_{m+1}) \\
&= P''(l_1 + l_2 + l_3 + \cdots + l_{r-1} + l_r + l_{r+1} + \cdots + l_m + l_{m+1})
\end{aligned}
$$

If the term $(l_1 + l_2 + l_3 + \cdots + l_{r-1} + l_r + l_{r+1} + \cdots + l_m + l_{m+1})$

is written in open form and and the terms with factor L1 are written in the first paranthesis, the terms with factor L2 are written in the second paranthesis, and so on.... and if the term on the right side of the equation is written as equal to the length of the ring network:

RING DISTRIBUTION NETWORKS

$$
\begin{aligned}
&(N_1 + N_2 + N_3 + \cdots + N_{r-1} + N_r + N_{r+1} + \cdots + N_{m-1} + N_m)l_1 \\
&+(N_2 + N_3 + \cdots + N_{r-1} + N_r + N_{r+1} + \cdots + N_{m-1} + N_m)l_2 \\
&+(N_3 + \cdots + N_{r-1} + N_r + N_{r+1} + \cdots + N_{m-1} + N_m)l_3 \\
&+\cdots \\
&+(N_{r-1} + N_r + N_{r+1} + \cdots + N_{m-1} + N_m)l_{r-1} \\
&+(N_r + N_{r+1} + \cdots + N_{m-1} + N_m)l_r \\
&+(N_{r+1} + \cdots + N_{m-1} + N_m)l_{r+1} \\
&+\cdots \\
&+(N_{m-1} + N_m)l_{m-1} \\
&+N_m l_m \\
&= P'' l
\end{aligned}
$$

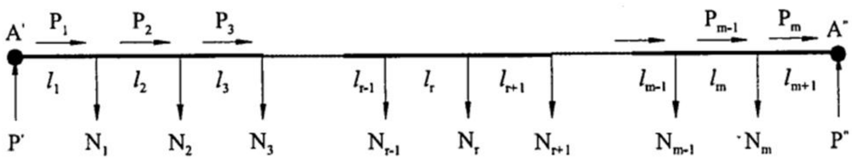
$$
P'' = \frac{(N_1 + \cdots + N_m)l_1 + (N_2 + \cdots + N_m)l_2 + \cdots + (N_{m-1} + N_m)l_{m-1} + N_m l_m}{l}
$$

RING DISTRIBUTION NETWORKS

This equation can be written as:

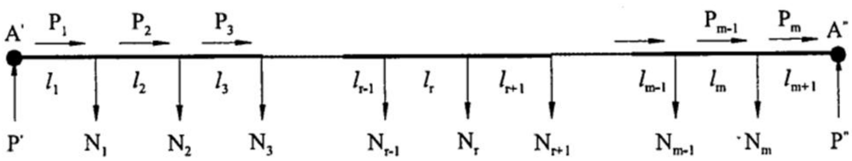
$$(N_1+\cdots+N_m-P'')l_1+(N_2+\cdots+N_m-P'')l_2+(N_3+\cdots+N_m-P'')l_3+\cdots$$
$$+(N_{m-1}+N_m-P'')l_{m-1}+(N_m-P'')l_m-P''l_{m+1}=0 \quad (1)$$

This last equation shows that, If the ring network is opened at point I and converted to a radial network that is being fed from two points, The powers P' and P'' drawn in opposite direction from point I can be used to calculate voltage drops as in radial networks.



RING DISTRIBUTION NETWORKS

Figure 5.39



Actualy, the powers drawn from the line that is fed from the point I' in Figure 5.39 will be

$$P_1=N_1+N_2+N_3+\cdots+N_{m-1}+N_m-P''$$
$$P_2=N_2+N_3+\cdots+N_{m-1}+N_m-P''$$
$$P_3=N_3+\cdots+N_{m-1}+N_m-P''$$
$$\vdots$$
$$P_{m-1}=N_m-P''$$
$$P_m=-P''$$

Since the voltage drop between points I' and I'' supposed to be zero, the following equation is written.

$$P''=\frac{\sum_{i=1}^{m}P_i l_i}{l} \quad (5.26)$$

RING DISTRIBUTION NETWORKS

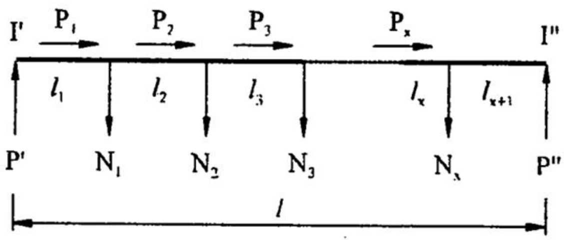
Since $$P'+P''=\sum_{i=1}^{m} P_i$$ Then, P' can be calculated, too.

After calculating P' and P'', in Figure 5.39, we proceed untill the shared load where the power driven from the beginining of the line becomes equal to P' or P''. Then at this point the network is cut and separated into two radial parts. The voltage drop in both radial parts will be equal. Therefore, it will be sufficient to make the calculations for one of them.

Equation (5.25) shows that, the loads in a radial network fed from two ends can be mowed to the feeding points. Therefore, The powers P' and P'' at both ends of the line can be used instead of powers N driven from various points along the line as shown in Figure 5.40.

RING DISTRIBUTION NETWORKS

Figure 5.40.
The powers P' and P'' at both ends of the line can be used instead of powers N driven from various points along the line.



$$P_1 = N_1 + N_2 + N_3 + \cdots + N_x$$

$$P_2 = N_2 + N_3 + \cdots + N_x$$

$$P_3 = N_3 + \cdots + N_x$$

$$\vdots$$

$$P_x = N_x$$

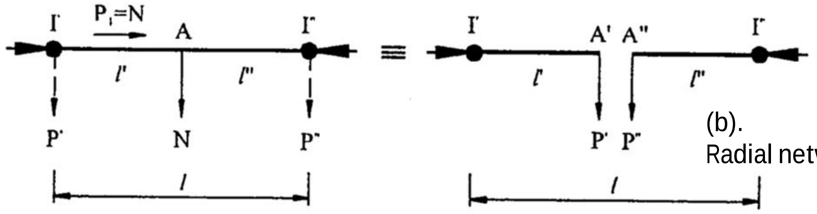
$$\boxed{P''=\frac{\sum_{i=1}^{m} P_i l_i}{l}}$$

$$P''=\frac{P_1 l_1 + P_2 l_2 + P_3 l_3 + \cdots + P_x l_x}{l}$$

RING DISTRIBUTION NETWORKS

If there is just one load N connected to the line;

(a).
Ring network



(b).
Radial network

Figure 5.41. P' and P'' components of tho load N.

$$\boxed{P'' = N\frac{l'}{l}} \quad (5.27.1)$$

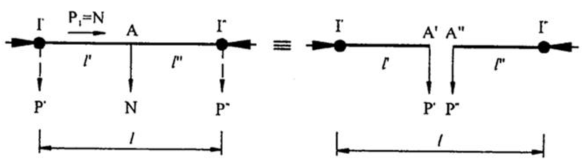
$$\boxed{P' = N\frac{l''}{l}} \quad (5.27.2)$$

These equations can also be obtained by getting the load torque with respect to points I' and I''.

RING DISTRIBUTION NETWORKS

If torque is applied in Figure 5.41 for (5.27.1)

$$\boxed{P'' = N\frac{l'}{l}}$$



$$Nl' - P''l = 0 \quad \rightarrow \quad P'' = N\frac{l'}{l}$$

$$Nl'' - P'l = 0 \quad \rightarrow \quad P' = N\frac{l''}{l}$$

The ring network has been converted to radial network in Figure 5.41b.

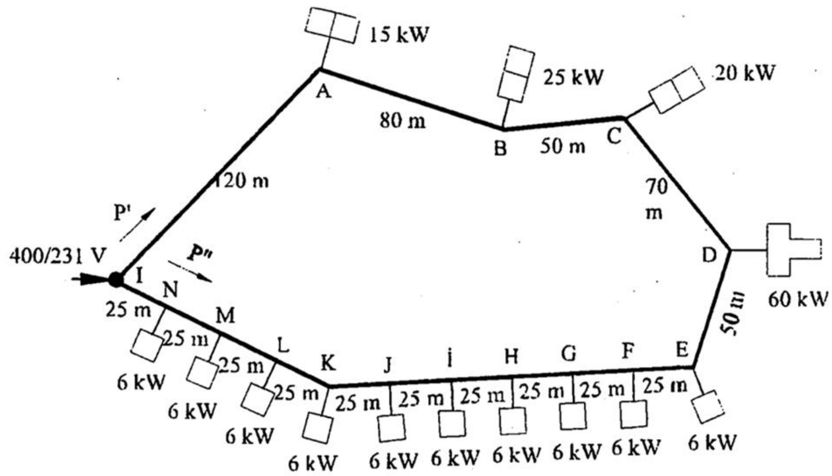
$u = kP'l'$ or $= kP''l''$

RING DISTRIBUTION NETWORKS

EXAMPLE

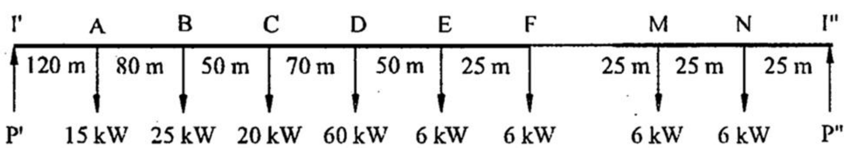
The cross-section of the undergraund cables used in the network shown in Figure is to be determined.

The highest allowable voltage drop limit is 5%.



RING DISTRIBUTION NETWORKS

Let us convert the ring network to a radial network first.



$$P'' = \frac{\sum_{i=1}^{m} P_i l_i}{l}$$

$$P'' = \frac{180.120+165.80+140.50+120.70+60.50+(54+48+42+30+24+18+12+6).25}{620}$$

$$= 96{,}694 \text{ kW}$$

$$P' = 180 - 96{,}694 = 83{,}306 \text{ kW}$$

In order to reach the power 83.306 kV drawn from the line, starting from the beginning of line we get 60 kW connected to the points A, B and C, and 23.306 kW of 60 kW connected to the shared point D.

RING DISTRIBUTION NETWORKS

Then, the % voltage drop: $u = k_3^{"} \ell N \quad [\%]$

$$k_3^{"} = \frac{u}{\sum P_i l_i} = \frac{\%5}{83{,}306.0{,}120 + 68{,}306.0{,}080 + 43{,}306.0{,}050 + 23{,}306.0{,}070} = \%0{,}260$$

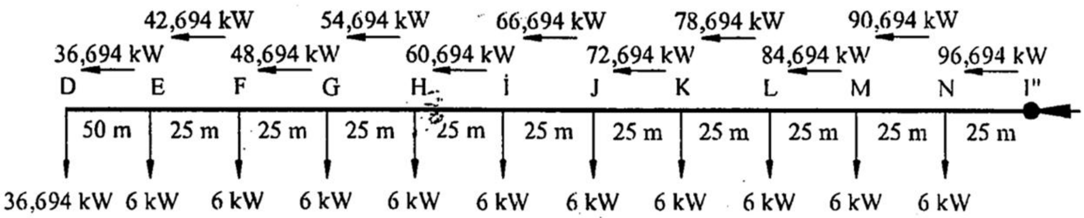
Therefore, From Tablae 5.11; For 3x70/35 mm^2 YVV $k_3^{"} = \%0{,}222$ İs chosen

Check the voltage drop for this cable:

$$u = k_3^{"} \sum P_i l_i = \%0{,}222.19{,}258 = \%4{,}275$$

RING DISTRIBUTION NETWORKS

If the voltage drop calculation is done for the other branch, the result would be obtained.



$$u = k_3^{"} \sum P_i l_i = \%0{,}222[36{,}694.0{,}050 + (42{,}694 + 48{,}694 + 54{,}694 + 60{,}694 + 66{,}694 + 72{,}694 + 78{,}694 + 84{,}694 + 90{,}694).0{,}025] = \%4{,}275$$

If the ring network is opened between DE, then voltage drop in the branches ID and IE will be

$$u_{\overline{ID}} = \%0{,}222(120.0{,}120 + 105.0{,}080 + 80.0{,}050 + 60.0{,}070) = \%6{,}882$$

The voltage drop is over 5%.

RING DISTRIBUTION NETWORKS

$$u_{\overline{IE}} = \%0{,}222(60+54+48+42+36+30+24+18+12+6)0{,}025 = \%1{,}832$$

If power loss equations are aplied.

$$\Delta P_{I'} = \sum m'_{3,i} P_i^2 l_i = 0{,}0022(23{,}306^2.0{,}070 + 43{,}306^2.0{,}050 + 68{,}306^2.0{,}080$$

$$+ 83{,}306^2.0{,}120) = 2{,}975 \text{ kW}$$

$$\Delta P_{I''} = 0{,}0022[36{,}694^2.0{,}050 + (42{,}694^2 + 48{,}694^2 + 54{,}694^2 + 60{,}694^2 + 66{,}694^2$$

$$+ 72{,}694^2 + 78{,}694^2 + 84{,}694^2 + 90{,}694^2 + 96{,}694^2)0{,}025] = 2{,}983$$

Total absolute power loss $\Delta P = 2{,}975 + 2{,}983 = 5{,}958 \text{ kW}$

Total percentage power loss $p = \frac{\Delta P}{P}.\%100 = \frac{5{,}958}{180}.\%100 = \%3{,}310$

RING DISTRIBUTION NETWORKS

Ring network fed from multiple points

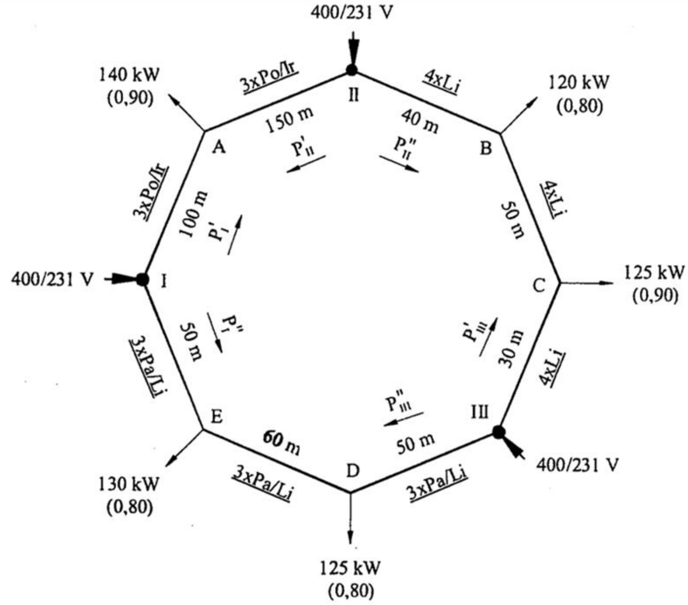
EXAMPLE

In the ring network fed from multiple points, the branches between the two feeding points are considered one by one and calculated as in the previous separation.

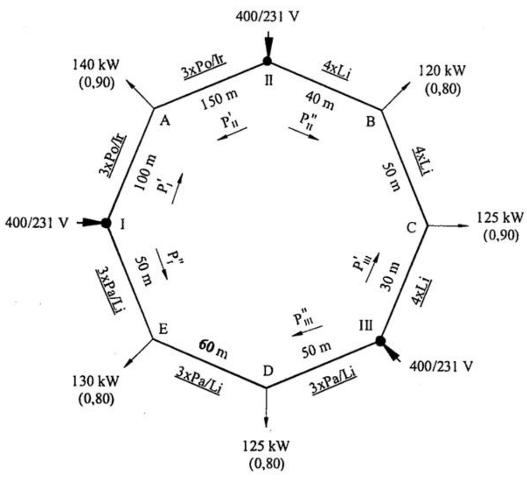
The cross-sections of the overhead aluminum line will be determined in the ring grid fed from three points as shown in the figure. The allowable voltage drop is 5%.

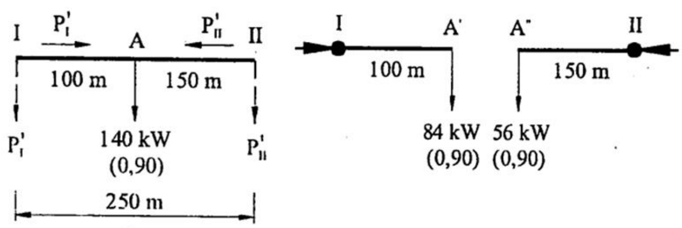
If the branches between the feeding points I-II, II-III and I-III in the ring network are considered separately, from the relation (5.26) and (5.27.1):

RING DISTRIBUTION NETWORKS



RING DISTRIBUTION NETWORKS



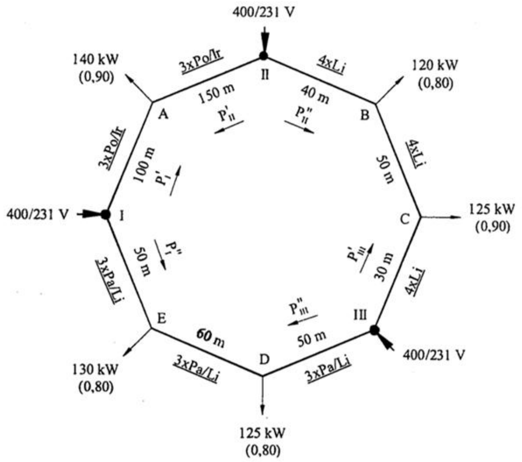


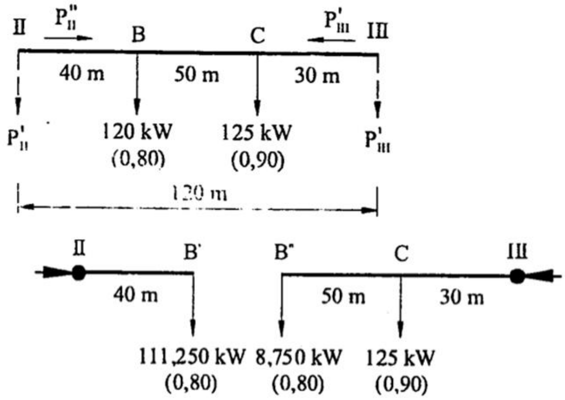
$$P'_{II} = N.\frac{l'}{l} = 140.\frac{100}{250} = 56 \text{ kW}$$

$$P'_{I} = N - P''_{I} = 140 - 56 = 84 \text{ kW}$$

$$P'_{III} = \frac{\sum P_i l_i}{l} = \frac{245.40 + 125.50}{120} = 133,750 \text{ kW}$$

RING DISTRIBUTION NETWORKS



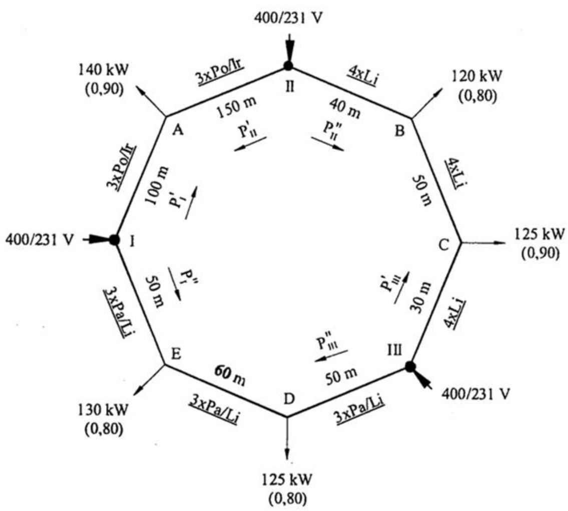


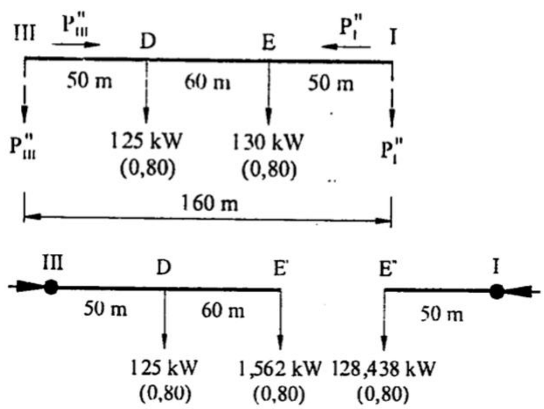
$$P_{II}'' = 245 - 133{,}750 = 111{,}250 \ \text{kW}$$

$$P_I''' = \frac{\sum P_i l_i}{l} = \frac{255.50 + 130.60}{160} = 128{,}438 \ \text{kW}$$

$$P_{III}'' = 255 - 128{,}438 = 126{,}562 \ \text{kW}$$

RING DISTRIBUTION NETWORKS





RING DISTRIBUTION NETWORKS

Voltage drop coefficients from (5.12)

$$k''_{3,I-II} = \frac{u}{\sum P_i l_i} = \frac{\%5}{84.0,100} = \%0,595$$

For k3''=0.595% (PF=0.90) from Table 5.18, the selected conductor will be Poppy.
For poppy:

$$u = k''_{3,I-II} \sum P_i l_i = \%0,568.84.0,100 = \%4,771$$

$$k''_{3,II-III} = \frac{u}{\sum P_i l_i} = \frac{\%5}{111,250.0,40} = \%1,124$$

For k3''=1.10% (PF=0.80) from Table 5.18, the selected conductor will be Lily.
For lily:

$$u = k''_{3,II-III} \sum P_i l_i = \%1,1.111,250.0,040 = \%4,895$$

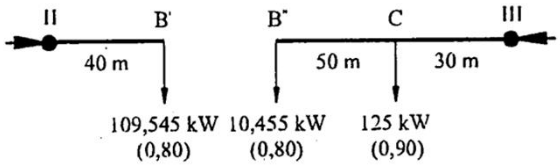
RING DISTRIBUTION NETWORKS

Although PF=0.80 was taken in the II-III arm, there is also a load with PF=0.90 in this arm. Therefore, the voltage drop in the branch III will be smaller and power DP will flow from the branch II to the branch III. According to this:

$$u_{II} = \%1,10(111,250 + \Delta P)0,040$$

$$u_{III} = \%1,10(8,750 - \Delta P)0,080 + \%1,04.125.0,030$$

Since $u_{II} = u_{III} \Rightarrow \Delta P = 1,705\ \text{kW}$



$$u = \%1,10.109,545.0,040 = \%4,820$$

RING DISTRIBUTION NETWORKS

If the voltage drop calculation is made for arm III, the same result is obtained.

$$u = \%1{,}10.10{,}455.0{,}080 + \%1{,}04.10{,}125.0{,}030 = \%4{,}820$$

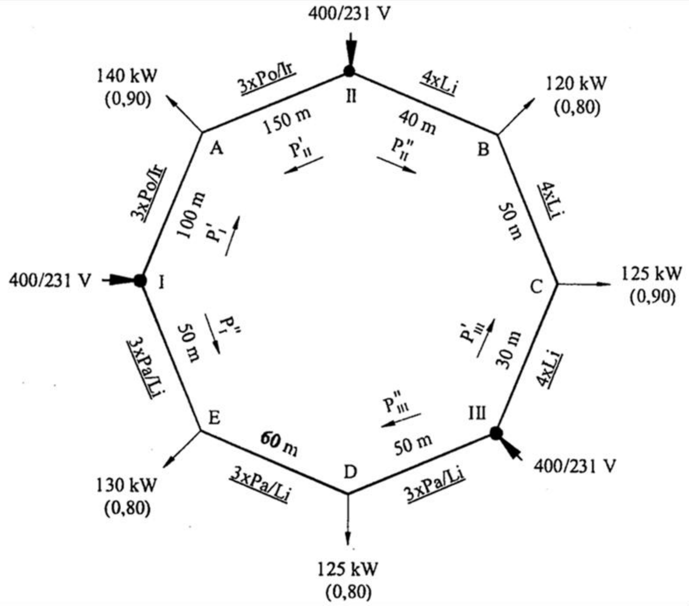
$$k''_{3,I-III} = \frac{u}{\sum P_i l_i} = \frac{\%5}{128{,}438.0{,}50} = \%0{,}779$$

Can a smaller conductor size be chosen for this recalculated and decreasing voltage drop?
If the calculation is made, it is seen that it cannot be selected.

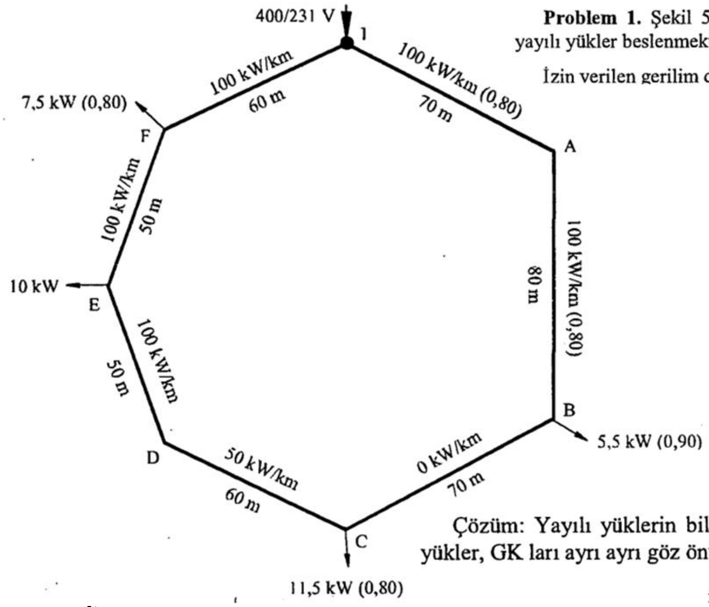
For k3''=0.750% (PF=0.80) from Table 5.18, the selected conductor will be Pansy.
For Pansy:

$$u = k''_{3,1-III} \sum P_i l_i = \%0{,}750.128{,}438.0{,}050 = \%4{,}816$$

RING DISTRIBUTION NETWORKS



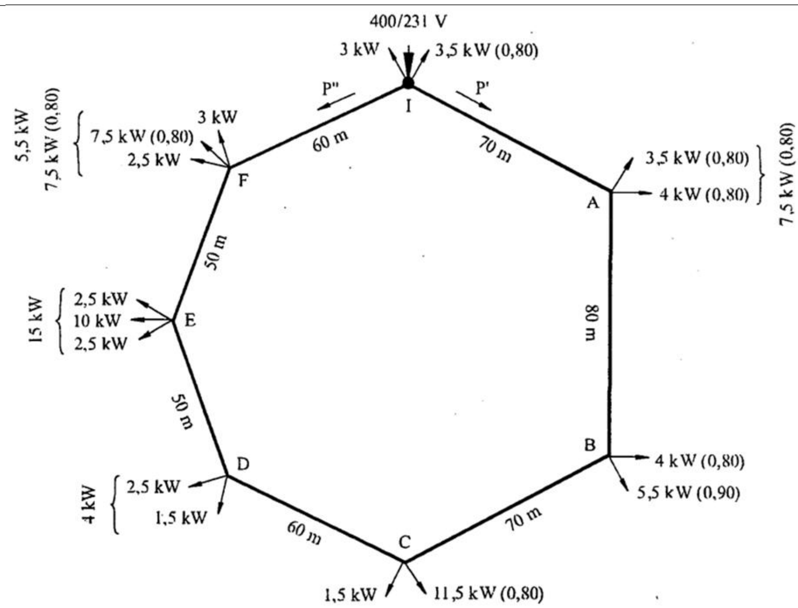
The selected conductor sizes are wrtten on the figure.



Problem 1. Şekil 5.50 deki yeraltı kablolarından kurulu göz şebekeden toplu ve yayılı yükler beslenmektedir. Yeraltı kablolarının kesitini saptayınız.

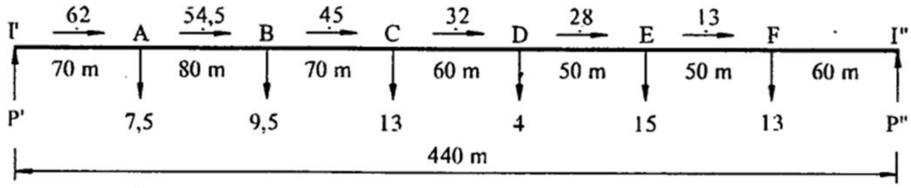
İzin verilen gerilim düşümü %5 dir.

Çözüm: Yayılı yüklerin bileşenleri alınmış ve toplu yüklerle toplanmıştır. Toplam yükler, GK ları ayrı ayrı göz önüne alınarak aşağıdaki şeklin üzerine yazılmıştır.



Önce, GK ları göz önüne alınmayacaktır.

Göz şebeke, besleme noktası olan I noktasından açılarak düz şebekeye dönüştürülürse, [5.26] dan:

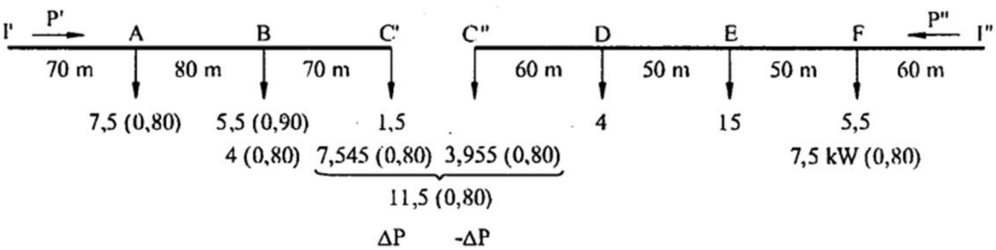


$$P" = \frac{62.70 + 54,5.80 + 45.70 + 32.60 + 28.50 + 13.50}{440} = 35,955 \text{ kW}$$

$$P' = 62 - 35,955 = 26,045 \text{ kW}$$

Bu sonuç, göz şebekenin C noktasından kesilmesi gerektiğini gösterir. C noktasının solundaki yükler 7,5+9,5=17 kW olduğundan, C noktasına bağlı olan yükler $26,045 - 17 = 9,045$ kW ve $13 - 9,045 = 3,955$ kW tır.

$$k_3" = \frac{\%5}{9,045.0,070 + 18,545.0,080 + 26,045.0,070} = \%1,269$$



Bu gerilim düşümü katsayısı için, çizelge 5.11 den, $k_3" = \%0,956$ ya karşılık olan 3x16/10 mm^2 kablo seçilir. Bu kablo için, GK ları göz önüne alınarak, [5.12] den:

$$u' = \%0,956[1,5(0,070 + 0,080 + 0,070)] + \%0,986.5,5(0,080 + 0,070)$$

$$+ \%1,00(7,545.0,070 + 11,545.0,080 + 19,045.0,070) = \%3,914$$

Göz şebeke GK ları göz önüne alınmadan kesildiğinden, GK larının farklı olması nedeniyle her iki koldaki gerilim düşümleri eşit olmayacaktır. Eşitliğin sağlanabilmesi için, kesilen yükün bir parçasından öbür parçasına ΔP gücü akacaktır.

Bu durumda, her iki kol için, [5.12] den:

$$(1)\ u' = \%0{,}956[1{,}5(0{,}070+0{,}080+0{,}070)] + \%0{,}986.5{,}5(0{,}080+0{,}070)$$

$$+\%1{,}00[(7{,}545+\Delta P).0{,}070+(11{,}545+\Delta P).0{,}080+(19{,}045+\Delta P).0{,}070]$$

$$= \%(3{,}91383+0{,}22\Delta P)$$

$$(2)\ u'' = \%0{,}956(4.0{,}050+19.0{,}050+24{,}5.0{,}060)$$

$$+\%1{,}00[(3{,}955-\Delta P).0{,}160+(11{,}455-\Delta P).0{,}060] = \%(3{,}82482-0{,}22\Delta P)$$

Gerilim düşümlerinin eşit olduğu yazılırsa: $3{,}91383+0{,}22\Delta P = 3{,}82482-0{,}22\Delta P$

$$\Delta P = -0{,}202\ \text{kW}$$

Sonuç gerilim düşümü, (1) den:

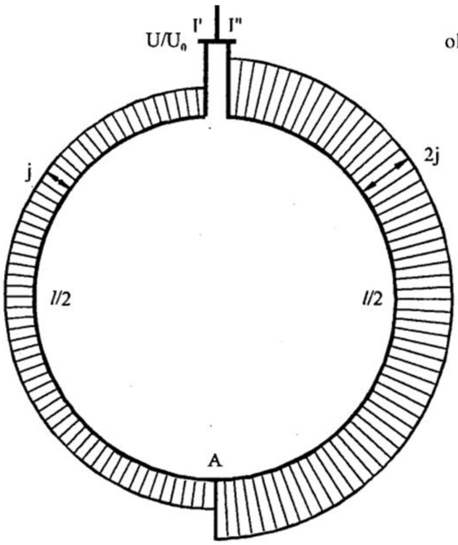
$$u' = \%[3{,}91383+0{,}22(-0{,}202)] = \%3{,}86939$$

Öbür kol için de aynı gerilim düşümü elde edilir. (2) den:

$$u'' = \%[3{,}82482-0{,}22(-0{,}202)] = \%3{,}86926$$

Sonuç: $u = \%3{,}869 < \%5$

olduğundan, seçilen **3x16/10 mm²** YVV kablo **uygundur**.



Problem 2. *l* uzunluğundaki göz şebekenin her bir yarısından yük yoğunluğu j ve 2j olan düzgün yayılı yükler çekilmektedir. Şekil 5.51. Hat boyunca kablo kesiti aynıdır.

a) Gerilim düşümünü hesaplayınız.

b) Aynı gerilim düşümünü veren, *l* boyunca aynı olan j_x yük yoğunluğunu bulunuz.

Uniformly distributed loads with densities j and 2j are drawn from each half of the ring network of length L.

The figure shows this situation.

The cable cross-section is the same throughout the line.

a) Calculate the voltage drop.
b) Find the charge density j_x that is the same across L, giving the same voltage drop.

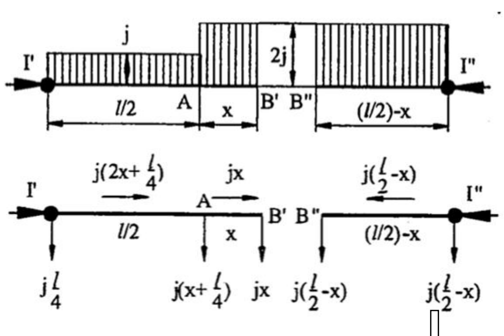
Answer:

$$j_x = 1{,}53125j$$

SOLUTION:

(a)

The ring network is cut from the section with the higher load density (up to point B) and the bulk loads are separated into its components.



The voltage drops in branches:

$$(1)\ u_{I'} = k\left[jx.x + j\left(2x + \frac{l}{4}\right)\frac{l}{2}\right]$$

$$(2)\ u_{I''} = kj\left(\frac{l}{2} - x\right)^2$$

Since the voltage drops will be equal

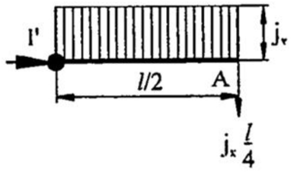
$$x^2 + \left(2x + \frac{l}{4}\right)\frac{l}{2} = \left(\frac{l}{2} - x\right)^2 \qquad \boxed{x = \frac{l}{16}}$$

Subtitute this results into (1) and (2);

$$u = kj\left(\frac{l}{2} - \frac{l}{16}\right)^2 \qquad u = \left(\frac{7}{16}\right)^2 kjl^2$$

SOLUTION:
(b)

Let's separate the ring network right in the middle.



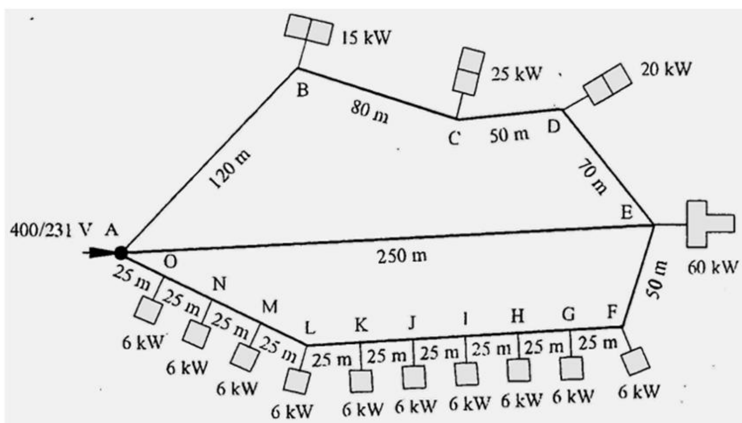
$$u_x = kj_x \frac{l}{4} \cdot \frac{l}{2} = kj_x \frac{l^2}{8}$$

In order for this voltage drop to be equal to the voltage drop in (a);

$$kj_x \frac{l^2}{8} = \left(\frac{7}{16}\right)^2 kjl^2 \quad \Rightarrow \quad \mathbf{j_x = 1{,}53125j}$$

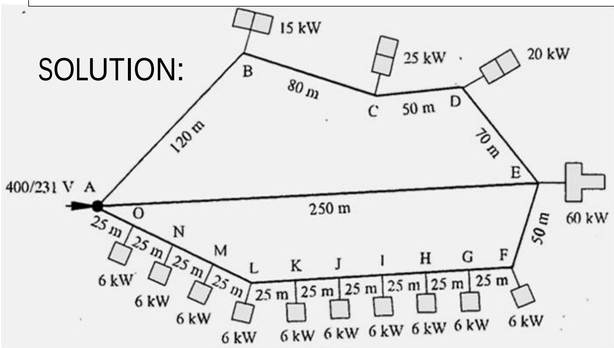
EXAMPLE:

Underground cable is uased to supply power to bulk loads in ring network shown in the figure. Determine the cross-sections of the cables. The allowable voltage drop is 5%.



RING DISTRIBUTION NETWORKS

SOLUTION:



E point is taken as the nodal point of the star and considering that the 60 kW load is fed from the AE=250 m line,

$$l_{A'} = 0{,}250 \text{ km} \rightarrow \sum_{A' \rightarrow E} Pl = 60.0{,}250 = 15 \text{ kWkm}$$

$$l_{A''} = 0{,}320 \text{ km} \rightarrow$$

$$\sum_{A'' \rightarrow E} Pl = 20.0{,}050 + 45.0{,}080 + 60.0{,}120 = 11{,}8 \text{ kWkm}$$

$$l_{A'''} = 0{,}300 \text{ km} \rightarrow \sum_{A''' \rightarrow E} Pl = (6+12+18+24+30+36+42+48+54+60).0{,}025 = 8{,}25 \text{ kWkm}$$

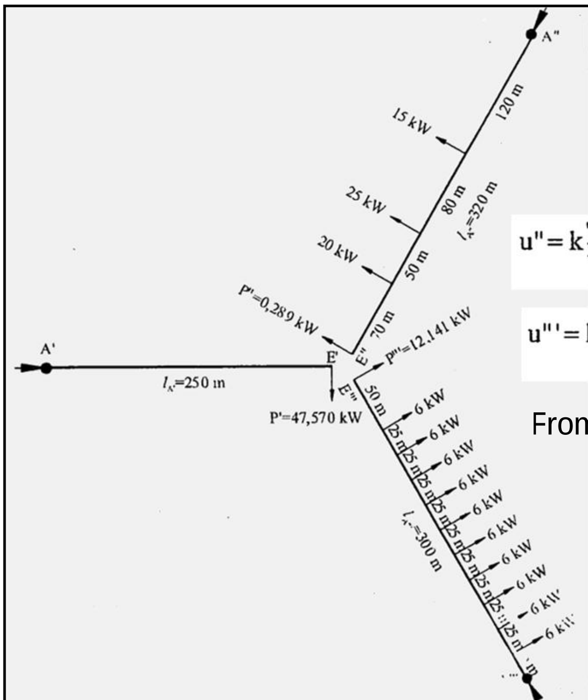
$$l_{A'} l_{A''} + l_{A''} l_{A'''} + l_{A'''} l_{A'} = 0{,}251$$

$$P_{A'A''} = \frac{0{,}250(11{,}8-8{,}25)+0{,}300(11{,}8-15)}{0{,}251} = -0{,}289 \text{ kW}$$

$$P_{A'A'''} = \frac{0{,}250(8{,}25-11{,}8)+0{,}320(8{,}25-15)}{0{,}251} = -12{,}141 \text{ kW}$$

$$P' = 60 - (0{,}289 + 12{,}141) = 47{,}570 \text{ kW}$$

BUTION NETWORKS



From the equality of voltage drops;

$$u' = k_3'' P' l_{A'} = k_3''.47{,}570.0{,}250 = 11{,}892 k_3''$$

$$u'' = k_3'' \sum_{A'' \rightarrow E} Pl + k_3''.0{,}289.0{,}320 = k_3''.11{,}8 + k_3''.0{,}09248 = 11{,}892 k_3''$$

$$u''' = k_3'' \sum_{A''' \rightarrow E} Pl + k_3''.12{,}141.0{,}300 = k_3''.8{,}25 + k_3''.3{,}6423 = 11{,}892 k_3''$$

From Table 5.11; $k_3'' = \frac{\%5}{11{,}892} = \%0{,}420$

3x50/25 mm² YVV is selected.

RING DISTRIBUTION NETWORKS

Gerilim düşümünü %5 sınırına yaklaştırmak için, $\overline{A'E}$ kolunun kesiti bir alt kesit olan 3x35/16 mm² seçilirse, $k''_{3,A'} = \%0{,}434$, $k''_{3,A''} = k''_{3,A'''} = \%0{,}321$ olduğundan, [5.29.2] den:

$$P_{A'A''} = \frac{\%0{,}434.0{,}250(\%0{,}321.11{,}8-\%0{,}321.8{,}25)+\%0{,}321.0{,}300(\%0{,}321.11{,}8-\%0{,}434.15)}{\%0{,}434.\%0{,}321.0{,}250.0{,}320+\%0{,}321^2.0{,}320.0{,}300+\%0{,}321.\%0{,}434.0{,}300.0{,}250}$$

$$= \frac{-0{,}1385}{0{,}031486} = -4{,}399 \text{ kW}$$

$$P_{A'A'''} = -16{,}525 \text{ kW}$$

$$P' = 60-(4{,}399+16{,}525) = 39{,}076 \text{ kW}$$

Gerilim düşümleri, [5.12] den

$$u' = \%0{,}434.39{,}076.0{,}250 = \%4{,}240 < \%5$$

$$u'' = \%0{,}321(11{,}8+4{,}399.0{,}320) = \%4{,}240 < \%5$$

$$u''' = \%0{,}321(8{,}25+16{,}525.0{,}300) = \%4{,}240 < \%5$$

olduğundan, seçilen kesitler **uygundur**.

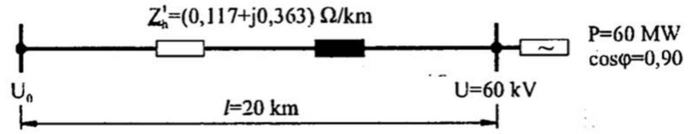
EXAMPLES ON DISTRIBUTION NETWORKS

EXAMPLES ON DISTRIBUTION NETWORKS

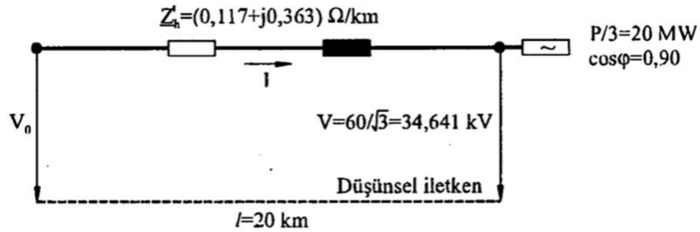
Örnek 1. Üç fazlı OG dağıtım hattından φ=0,90 geri GK ile P=60 MW etkin güç iletilecektir. Hat sonu gerilimi 60 kV, hattın uzunluğu 20 km, hattın empedansı $\underline{Z}_h^{'} = (0{,}117 + j0{,}363)\ \Omega/\text{km}$ dir.

Hat başı gerilimi, hat başındaki etkin ve tepkin güç, hattaki etkin ve tepkin güç kaybı, iletim verimi hesaplanacaktır.

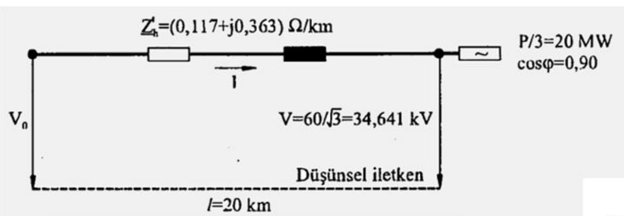
OG dağıtım hattının tek hat şeması:



Bir iletkenli şema:



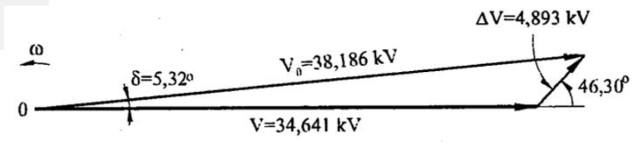
EXAMPLES ON DISTRIBUTION NETWORKS



Hat başı gerilimi:

$$\underline{V}_0 = \underline{V} + \underline{I}\underline{Z}_h$$

$$\underline{Z}_h = \underline{Z}_h^{'} l = 20(0{,}117 + j0{,}363) = 7{,}628\angle 72{,}14^\circ\ \Omega$$



Ö: 1 cm → 5 kV

$$I = \frac{P/3}{V\cos\varphi} = \frac{20}{(60/\sqrt{3})0{,}90} = 0{,}6415\ \text{kA}$$

$$\left(\text{Veya, } I = \frac{P}{\sqrt{3}U\cos\varphi} = \frac{60}{\sqrt{3}.60.0{,}90} = 0{,}6415\ \text{kA}\right)$$

$$\underline{V}_0 = \frac{60}{\sqrt{3}}\angle 0^\circ + 0{,}6415\angle -25{,}84^\circ . 7{,}628\angle 72{,}14^\circ = 34{,}641 + 4{,}893\angle 46{,}30^\circ$$

$$= 34{,}641 + 4{,}893(0{,}691 + j0{,}723) = 38{,}022 + j3{,}538 = 38{,}186\angle 5{,}32^\circ\ \text{kV}$$

$$U_0 = \sqrt{3}.38{,}186 = 66{,}140 \cong 66\ \text{kV}$$

EXAMPLES ON DISTRIBUTION NETWORKS

Hat başından verilen etkin ve tepkin güç: $\underline{S}_0 = 3\underline{V}_0 \overset{*}{\underline{I}}$

$$\underline{S}_0 = 3.38,186\angle 5,32°.0,6415\angle 25,84° = 73,489\angle 31,16° = 73,489(0,856 + j0,517) \text{ MVA}$$

$$P_0 = 73,489.0,856 = 62,9 \text{ MW}$$

$$Q_0 = 73,489.0,517 = 38 \text{ MVAr}$$

Hattaki etkin ve tepkin güç kaybı:

P=60 MW ve $Q = P tg\varphi = 60.0,484 = 29$ MVAr olduğundan:

$$\Delta P = P_0 - P = 62,9 - 60 = 2,9 \text{ MW}$$

$$\Delta Q = Q_0 - Q = 38 - 29 = 9 \text{ MVAr}$$

Bu sonuç aşağıdaki yoldan da elde edilir:

$$\Delta P = 3I^2 R_h = 3.0,6415^2.2,34 = 2,9 \text{ MW}$$

$$\Delta Q = 3I^2 X_h = 3.0,6415^2.7,26 = 9 \text{ MVAr}$$

İletim verimi:

$$\eta = \left(1 - \frac{\Delta P}{P}\right)\%100 = \left(1 - \frac{2,9}{60}\right)\%100 = \%95$$

EXAMPLES ON DISTRIBUTION NETWORKS

Bu problem, δ sapma açısının sıfır olduğu varsayılarak, boyuna gerilim düşümünden de yaklaşık olarak hesaplanabilir.

$$\Delta V = \Delta V_x = I(R_h \cos\varphi + X_h \sin\varphi)$$

$$\Delta V = 0,6415(2,34.0,90 + 7,26.0,436) = 3,382 \text{ kV}$$

$$V_0 = V + \Delta V = 34,641 + 3,382 = 38,023 \text{ kV}$$

$$U_0 = \sqrt{3}.38,023 = 65,858 \cong 66 \text{ kV}$$

Yalnız boyuna gerilim düşümünün alınması, V_0 yerine, bunun gerçel eksen üzerindeki izdüşümünün alınması demektir. Yapılan küçük hata bu basitleştirmeden kaynaklanmaktadır. $V_0 = 38,186$ kV olmasına karşın, $V_0 \cos\delta = 38,186.\cos 5,32°$ $=38,022$ kV olmaktadır.

Örnek 2. Üç fazlı OG dağıtım hattının uzunluğu 20 km, öz büyüklükleri $R'_h = 0{,}295\ \Omega/km$, $X'_h = 0{,}557\ \Omega/km$, hat sonu büyüklükleri U=30 kV, S=8 MVA ve cosφ=0,90 (Geri) dir.

Hat başı büyüklükleri ve iletim verimi bulunacaktır.

V hat sonu gerilimi gerçel eksen üzerinde alınırsa:

$$\underline{Z}_h = 20(0{,}295 + j0{,}557) = 12{,}606\angle 62{,}09°\ \Omega$$

$$I = \frac{S/3}{V} = \frac{8/3}{30/\sqrt{3}} = 0{,}154\ \text{kA} \qquad \underline{I} = 0{,}154\angle -25{,}84°\ \text{kA}$$

$$\underline{V}_0 = \frac{30}{\sqrt{3}}\angle 0° + 0{,}154\angle -25{,}84° . 12{,}606\angle 62{,}09° = 17{,}321 + 1{,}941\angle 36{,}25°$$

$$= 17{,}321 + 1{,}941(0{,}8064 + j0{,}5913) = 18{,}886 + j1{,}148 = 18{,}921\angle 3{,}48°\ \text{kV}$$

$$U_0 = \sqrt{3}.18{,}921 = 32{,}772 \cong 32{,}8\ \text{kV}$$

$$P = S\cos\varphi = 8.0{,}90 = 7{,}2\ \text{MW}$$

$$Q = S\sin\varphi = 8.0{,}4359 = 3{,}5\ \text{MVAr}$$

$$\underline{S}_0 = 3.18{,}921\angle 3{,}48° . 0{,}154\angle 25{,}84° = 8{,}742\angle 29{,}32° = 8{,}742(0{,}872 + j0{,}490)\ \text{MVA}$$

$$P_0 = 8{,}742.0{,}872 = 7{,}62\ \text{MW} \qquad \Delta P = 7{,}62 - 7{,}2 = 0{,}42\ \text{MW} = 420\ \text{kW}$$

$$Q_0 = 8{,}742.0{,}490 = 4{,}28\ \text{MVAr} \qquad \Delta Q = 4{,}28 - 3{,}5 = 0{,}78 = \ \text{MVAr} = 780\ \text{kVAr}$$

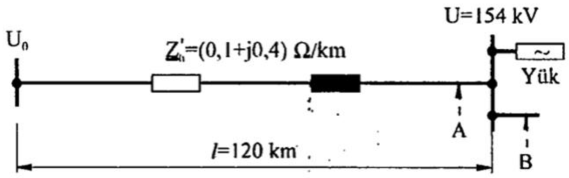
Gerilim regülasyonu:

$$\text{Gerilim regülasyonu} = \frac{I}{V}(R_h\cos\varphi + X_h\sin\varphi)\%100$$

$$= \frac{0{,}154}{17{,}321}(5{,}9.0{,}90 + 11{,}14.0{,}4359)\%100 = \%9$$

EXAMPLES ON DISTRIBUTION NETWORKS

Örnek 3. Üç fazlı kısa iletim hattının uzunluğu 120 km, empedansı $\underline{Z}_h' = (0{,}1 + j0{,}4)$ Ω/km, hat sonu gerilimi 154 kV, hattın A noktasından iletilen güç $\underline{S}_A = (50 + j40)$ MVA, kompanzasyon yapılan B noktasından iletilen güç $\underline{S}_B = (50 - j40)$ MVA dır.



a) Yük akımı ve faz açısı,

b) A noktasından çekilen akım ve faz açısı,

c) Hat başı gerilimi ve sapma açısı,

d) Hat başındaki etkin ve tepkin güçler,

e) Hattaki etkin ve tepkin güç kayıpları ile iletim verimi hesaplanacaktır.

EXAMPLES ON DISTRIBUTION NETWORKS

SOLUTION

a) U=154 kV barasından yükün çektiği güç, bu baraya A ve B noktalarından iletilen güçlerin karmaşık toplamına eşit olduğundan:

$$\underline{S} = \underline{S}_A + \underline{S}_B = 50 + j40 + 50 - j40 = 100 \text{ MVA}$$

$P = 100$ MW ve $Q = 0$ MVAr olduğundan, faz açısı sıfırdır.

Yük akımı:

$$I = \frac{P/3}{V\cos\varphi} = \frac{100/3}{(154/\sqrt{3}).1} = 0{,}375 \text{ kA} = 375 \text{ A}$$

V hat sonu gerilimi gerçel eksen üzerinde alınırsa:

$$\underline{I} = 0{,}375\underline{|0°} \text{ kA}$$

b) $$\overset{*}{\underline{I}}_A = \frac{\underline{S}_A/3}{V} = \frac{(50 + j40)/3}{154/\sqrt{3}} = (0{,}1875 + j0{,}1500) \text{ kA}$$

$$\overset{*}{\underline{I}}_A = 0{,}240\underline{|38{,}66°} \text{ kA}$$

A noktasından çekilen akım ve faz açısı:

$$I_A = 0{,}240 \text{ kA} = 240 \text{ A}$$

$$\varphi_A = 38{,}66°, \; \cos\varphi_A = 0{,}78$$

c) Hat başı gerilimi:

$\underline{V}_0 = \underline{V} + \underline{I}_A \underline{Z}_h$

$$\underline{Z}_h = 120(0,1 + j0,4) = 49,477\underline{|75,96^\circ}\ \Omega$$

$$\underline{V}_0 = \frac{154}{\sqrt{3}}\underline{|0^\circ} + 0,240\underline{|-38,66^\circ}.49,477\underline{|-75,96^\circ} = 88,912 + 11,874\underline{|37,30^\circ}$$

$$= 88,912 + 11,874(0,7955 + j0,6060) = (98,358 + j7,196)\ \text{kV}$$

$$\underline{V}_0 = 98,621\underline{|4,18^\circ}\ \text{kV}$$

$$U_0 = \sqrt{3}.98,621 = 170,8\ \text{kV}$$

Sapma açısı:

$$\delta = 4,18^\circ$$

d) Hat başındaki etkin ve tepkin güçler:

$$\underline{S}_0 = 3\underline{V}_0\overset{*}{\underline{I}}_A = 3.98,621\underline{|4,18^\circ}.0,240\underline{|38,66^\circ} = 71,007\underline{|42,84^\circ}$$

$$= 71,007(0,7333 + j0,6800) = (52,069 + j48,285)\ \text{MVA}$$

$P_0 = 52,1$ MW

$Q_0 = 48,3$ MVAr

e) Hattaki etkin ve tepkin güç kayıpları:

$$\Delta P = P_0 - P = 52,1 - 50 = 2,1\ \text{MW}$$

$$\Delta Q = Q_0 - Q = 48,3 - 40 = 8,3\ \text{MVAr}$$

İletim verimi:

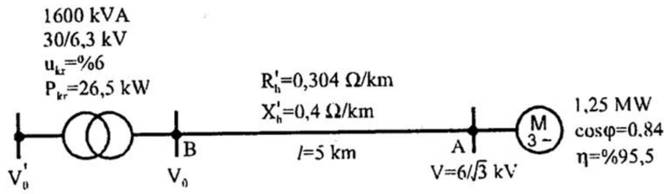
$$\eta = \left(1 - \frac{\Delta P}{P}\right)\%100 = \left(1 - \frac{2,1}{50}\right)\%100 = \%96$$

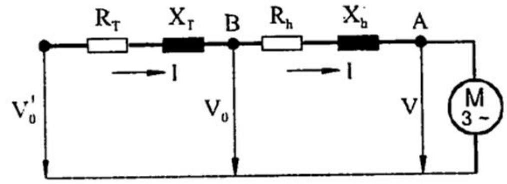
Örnek 5. Gerilimi 30/6,3 kV, gücü 1600 kVA olan transformatörden 5 km uzunluğundaki kablo ile gerilimi 6 kV, gücü 1,25 MW, cosφ=0,84, η=%95,5 olan motor beslenmektedir.

Transformatörün kısadevre gerilimi u_{kr}=%6, bakır kayıpları P_{kr}=26,5 kW tır.

Kablonun öz büyüklükleri: $R_h^{'}=0,304\ \Omega/km$, $X_h^{'}=0,4\ \Omega/km$ dir.

V_0 ve $V_0^{'}$ gerilimleri bulunacaktır.





V gerilimi gerçel eksen üzerinde alınmıştır.

Motorun çektiği akım:
$$I=\frac{P}{\sqrt{3}U\cos\varphi\eta}=\frac{1,25}{\sqrt{3}.6.0,84.0,955}=0,1499\ \text{kA}=149,9\ \text{A}$$

$$\underline{I}=0.1499\angle -32,86^\circ\ \text{kA}$$

$$\underline{Z}_h=5(0.304+j0,4)=2.512\angle 52.77^\circ\ \Omega$$

$$\Delta\underline{V}_h=\underline{I}\underline{Z}_h=0.1499\angle -32,86^\circ.2,512\angle 52,77^\circ=0,377\angle 19,91^\circ\ \text{kV}$$

V_0 gerilimi:

$$\underline{V}_0=\underline{V}+\Delta\underline{V}_h=\frac{6}{\sqrt{3}}\angle 0^\circ+0,377\angle 19,91^\circ=3,818568+j0,128385=3,821\angle 1,93^\circ\ \text{kV}$$

A barasının 6 kV bazında hesaplanan V_0 gerilimi B barasının 6,3 kV bazına indirgenir:

$$\underline{V}_{0t}=\underline{V}_0 t=3,821\angle 1,93^\circ.\left(\frac{6,3}{6}\right)=4,012\angle 1,93^\circ\ \text{kV}$$

Transformatörün alt gerilim devresine ilişkin empedansı, [2.5] ve [2.14] bağıntılarından:

$$Z_T = \frac{u_{kr}}{\%100} \cdot \frac{U_r}{S_r} = \frac{\%6}{\%100} \cdot \frac{6{,}3^2}{1{,}6} = 1{,}488\ \Omega$$

$$R_T = \frac{P_{kr} U_r^2}{S_r^2} = \frac{26{,}5.10^{-3}.6{,}3^2}{1{,}6^2} = 0{,}411\ \Omega$$

$$X_T = \sqrt{Z_T^2 - R_T^2} = \sqrt{1{,}488^2 - 0{,}411^2} = 1{,}430\ \Omega$$

$$\underline{Z}_T = 0{,}411 + j1{,}430 = 1{,}488\underline{|73{,}96°}\ \Omega$$

Transformatördeki gerilim düşümü:

$$\Delta\underline{V}_T = \underline{I}\underline{Z}_T = 0{,}1499\underline{|-32{,}86°}.1{,}488\underline{|73{,}96°} = 0{,}223\underline{|41{,}11°}\ \text{kV}$$

$$\underline{V}_0' = \underline{V}_{0t} + \Delta\underline{V}_T = 4{,}012\underline{|1{,}93°} + 0{,}223\underline{|41{,}11°} = 4{,}178 + j0{,}181 = 4{,}182\underline{|2{,}48°}\ \text{kV}$$

Üst gerilim devresine indirgeme yapılır:

$$\underline{V}_{ot}' = 4{,}182\underline{|2{,}48°}.\left(\frac{30}{6{,}3}\right) = 19{,}914\underline{|2{,}48°}\ \text{kV}$$

$$U_{0t}' = \sqrt{3}.19{,}914 = \mathbf{34{,}5\ kV}$$

End of the Chapter

Ring Networks