UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2004/2005

Mac 2005

# EEK 365 – SISTEM PENGAGIHAN ELEKTRIK KUASA

Masa : 3 Jam

**ARAHAN KEPADA CALON:-**

Sila pastikan kertas peperiksaan ini mengandungi **DUA PULUH ENAM (26)** beserta **(Lampiran 1 muka surat)** bercetak dan **ENAM (6)** soalan sebelum anda memulakan peperiksaan ini.

Jawab **LIMA (5)** soalan.

Agihan markah diberikan di sudut sebelah kanan soalan berkenaan.

Semua soalan hendaklah dijawab di dalam Bahasa Malaysia.

...2/-

1. (a) Anggap bahawa beban puncak tahunan suatu penyuap primer ialah *2000 kW*, pada tahap ini rugi kuasa iaitu jumlah rugi tembaga atau $\sum I^2R$, ialah *80 kW* per tiga fasa. Dengan menganggap faktor rugi tahunan 0.15, tentukan:

*Assume that annual peak load of a primary feeder is 2000 kW, at which the power loss, i.e., total copper, or $\sum I^2R$, loss is 80 kW per three-phases. Assuming an annual loss factor of 0.15, determine:*

[i] Purata rugi kuasa tahunan
*The average annual power loss*

(12.5%)

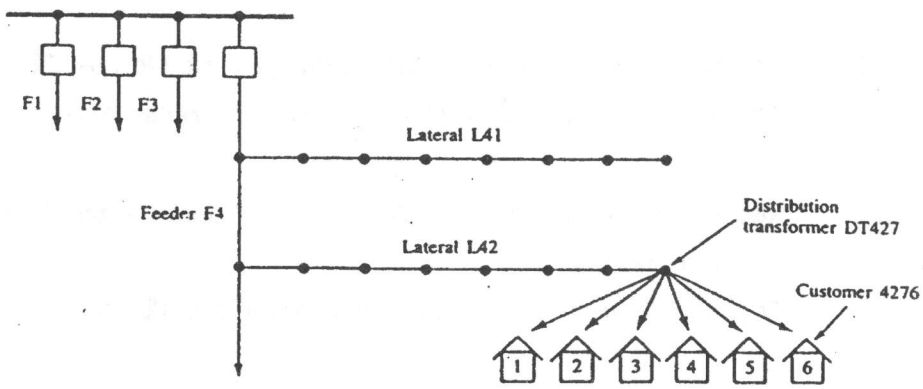
[ii] Jumlah rugi tenaga tahunan akibat rugi-rugi tembaga litar-litar penyuap.
*The total annual energy loss due to the copper losses of the feeder circuits.*

(12.5%)

(b) Anggap bahawa terdapat enam pengguna perumahan yang disambung ke suatu transformer distribusi seperti tertera dalam Rajah 1. Perhatikan kod dalam nombor akaun pengguna, contoh 4276. Angka pertama 4 mewakili untuk penyuap, angka kedua, menunjukkan nombor lateral yang disambung ke penyuap F4, angka ketiga 7 ialah untuk transformer distribusi atas lateral dan akhirnya angka keempat 6 ialah untuk nombor rumah yang disambung ke transformer distribusi tersebut. Anggap bahawa beban tersambung ialah 9 kW per rumah dan faktor permintaan dan faktor diversiti untuk sekumpulan 6 rumah, samada daripada rekod syarikat utiliti atau daripada buku data yang relevan telah memutuskan bahawa masing-masing sebagai 0.65 dan 1.10. Tentukan permintaan kepelbagaian sekumpulan enam rumah pada transformer distribusi DT 427.

...3/-

*Assume that there are six residential customers connected to a distribution transformer as shown in Figure 1. Notice the code in the customer account number, e.g., 4276. The first figure 4 stands for feeder; the second figure 2, indicates the lateral number connected to the F4 feeder; the third figure 7 is for the distribution transformer on that lateral and finally the last figure 6 is for the house number connected to that distribution transformer. Assume that the connected load is 9 kW per house and that the demand factor and diversity factor for the group of six houses, either from the utility company's records or from the relevant handbooks have been decided as 0.65 and 1.10 respectively. Determine the diversified demand of the group of six houses on the distribution transformer DT 427.*




Rajah 1
*Figure 1*

(25%)

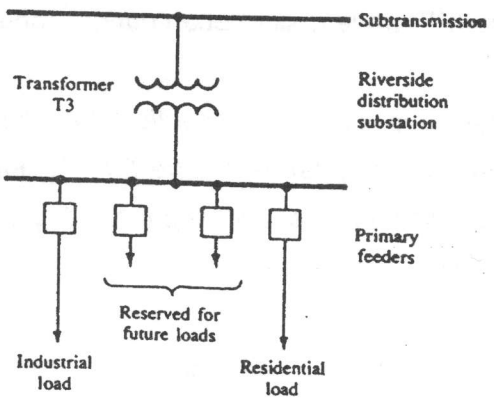
(c) Anggap bahawa terdapat dua penyuap primer yang dibekalkan oleh salah satu daripada tiga transformer yang terletak pada sub-stasyen utiliti seperti tertera dalam Rajah 2. Satu daripada penyuap membekalkan beban industri yang berlaku terutamanya pada 8 A.M. dan 11 P.M., dengan suatu puncak 2000 kW pada 5 P.M. Satu transformer lagi menyuapkan beban-beban perumahan yang terjadi terutamanya antara 6 A.M. dan 12 P.M. dengan suatu puncak 2000 kW pada 9 P.M. seperti tertera dalam Rajah 3. Tentukan yang berikut:

*Assume that there are two primary feeders supplied by one of the three transformers located at the utility distribution sub station as shown in Figure 2. One of the feeders supplies an industrial load which occurs primarily between 8 A.M. and 11 P.M., with a peak of 2000 kW at 5 P.M. The other one feeds residential loads which occur mainly between 6 A.M. and 12 P.M. with a peak of 2000 kW at 9 P.M. as shown in Figure 3. Determine the following:*

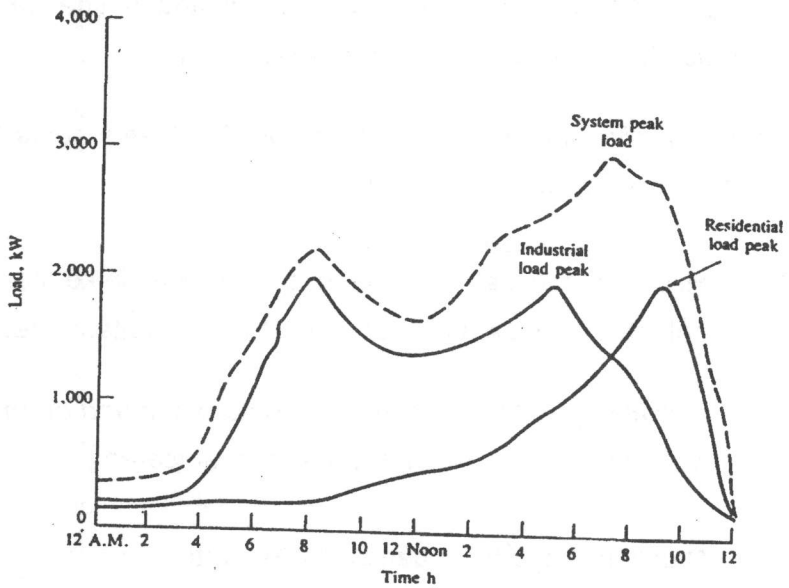
[i] Faktor kepelbagaian beban tersambung ke transformer T3.
*The diversity factor of the load connected to transformer T3.*
(8%)

[ii] Kepelbagaian beban untuk beban yang tersambung ke transformer T3.
*The load diversity of the load connected to transformer T3.*
(8%)

[iii] Faktor kesekenaan beban yang tersambung ke transformer T3.
*The coincidence factor of the load connected to transformer T3.*
(9%)




Rajah 2
*Figure 2*




Rajah 3
*Figure 3*

...6/-

(d) Anggap bahawa salah satu transformer distribusi suatu sub-stasyen membekalkan tiga penyuap primer. Permintaan maksimum tahunan 30-min penyuap disenaraikan dalam jadual berikut, bersama dengan faktor kuasa (PF) pada masa beban puncak tahunan.

*Assume that one of the distribution transformers of the substation supplies three primary feeders. The 30-min annual maximum demands per feeder are listed in the following table, together with the power factor (PF) at the time of annual peak load.*

| *Penyuap Feeder* | *Permintaan Demannd kW* | *PF* |
|---|---|---|
| 1 | 1800 | 0.95 |
| 2 | 2000 | 0.85 |
| 3 | 2000 | 0.90 |

Anggap suatu faktor kepelbagaian 1.15 di antara tiga penyuap untuk kedua-dua kuasa nyata (P) dan kuasa reaktif (Q).

*Assume a diversity factor of 1.15 among the three feeders for both real power (P) and reactive power (Q).*

[i] Hitung permintaan maksimum tahunan 30-min ke atas transformer sub-stesyen dalam kilowatt dan dalam kilovoltampere.

*Calculate the 30-min annual maximum demand on the substation transformer in kilowatts and in kilovoltamperes.*

(7%)

[ii] Cari kepelbagaian beban dalam kilowatt.
*Find the load diversity in kilowatts.*

(6%)

...7/-

[iii] Pilih suatu saiz transformer sub-stesyen yang sesuai jika pertumbuhan beban sifar dijangkakan dan jika polisi syarikat membenarkan sebanyak 25 peratus lebihan beban jangka pendek ke atas transformer distribusi sub-stasyen. Di antara saiz transformer tiga fasa *(3$\phi$)* piawai yang ada ialah

*Select a suitable substation transformer size if zero load growth is expected and if company policy permits as much as 25 percent short-time overloads on the distribution substation transformers. Among the standard three-phase (3$\phi$) transformer sizes available are*

2500/3125 kVA dingin diri/dingin paksa udara
*self-cooled/ forced-air-cooled*

3750/4687 kVA dingin diri/dingin paksa udara
*self-cooled/forced-air-cooled*

5000/6250 kVA dingin diri/dingin paksa udara
*self-cooled/forced-air-cooled*

7500/9375 kVA dingin diri/dingin paksa udara
*self-cooled/forced-air-cooled*

(6%)

[iv] Sekarang anggap bahawa beban sub-stasyen akan bertambah pada suatu kadar peratus tetap per tahun dan akan dua kali ganda dalam masa 10 tahun. Jika transformer dengan kadaran *7599/9375-kVA* dipasang dalam berapa tahunkah transformer tersebut dapat dibebankan kepada kadaran kipas berfungsi?.

*Now assume that the substation load will increase at a constant percentage rate per year and will double in 10 years. If the 7599/9375-kVA-rated transformer is installed in how many years will it be loaded to its fans-on rating?* (6%)

...8/-

2. (a) Rajah 4 menunjukkan suatu litar setara transformer satu fasa dengan sekunder tiga wayar untuk distribusi satu fasa tiga wayar. Transformer distribusi tipikal dikadarkan sebagai 25 kVA, 7200-120/240 V, 60 Hz, dan mempunyai impedans per unit berikut berdasarkan ke atas kadaran transformer dan berdasarkan ke atas penggunaan keseluruhan belitan voltan rendah (LV) dan arus neutral sifar:

*Figure 4 shows an equivalent circuit of a single-phase transformer with three-wire secondary for three-wire single-phase distribution. The typical distribution transformer is rated as 25 kVA, 7200-120/240 V, 60 Hz, and has the following per unit impedance based on the transformer ratings and based on use of the entire low-voltage (LV) winding with zero neutral current:*

$$R_T = 0.014 pu$$

dan *and*

$$X_T = 0.012 pu$$

Disini dua setengah voltan rendah boleh dibebankan terpisah dan secara umum beban sekunder tiga wayar tidak akan seimbang. Oleh itu secara umum litar setara yang diperlukan ialah transformer satu fasa tiga belitan seperti yang tertera dalam Rajah 4 bila kejatuhan voltan dan atau arus gagal yang akan dihitung. Maka dengan hanya menggunakan data yang ada (semua ini lazimnya disediakan) dan nilaikan secara berangka semua impedans yang ditunjukkan dalam Rajah 4.

*Here the two halves of the low voltage may be independently loaded and in general the three-wire secondary load will not be balanced. Therefore in general the equivalent circuit needed is that of a three-winding single-phase transformer as shown in Figure 4 when voltages drops and or fault currents are to be computed. Thus use the meager amount of data (it is all that is usually available) and evaluate numerically all the impedances shown in Figure 4.*

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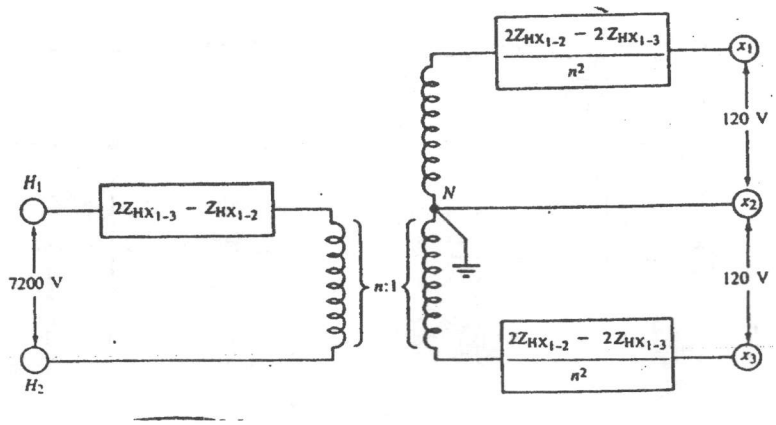
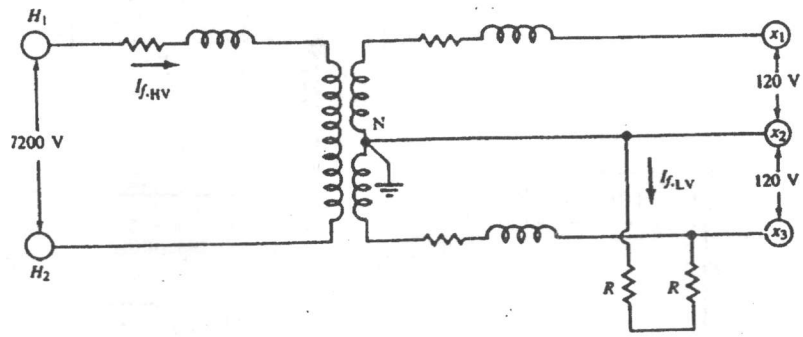



Rajah 4
*Figure 4*

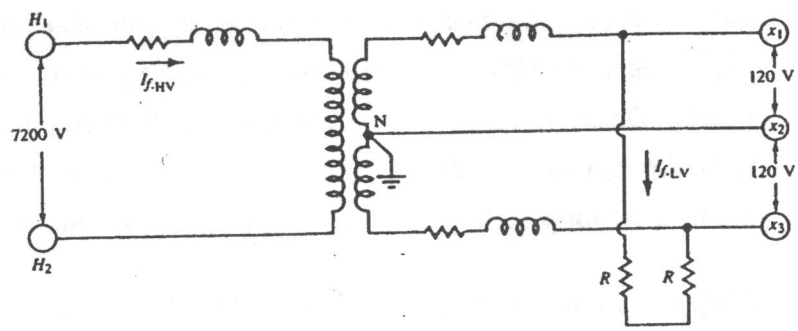
(20%)

(b) Dengan menggunakan litar setara yang didapatkan dalam Soalan 2(a), tentukan arus gagal talian ke neutral (120 V) dan talian ke talian (240 V) dalam sekunder 120/240-V satu fasa tiga wayar yang tertera dalam Rajah 5 dan 6. Dalam rajah-rajah tersebut R mewakili rintangan kabel kejatuhan perkhidmatan per konduktor. Lazimnya R jauh lebih besar daripada X untuk kabel yang sedemikian dan oleh itu X boleh diabaikan.

*Using the transformer equivalent circuit found in Question 2(a), determine the line to neutral (120 V) and line-to-line (240 V) fault currents in three wire single phase 120/240-V secondaries shown in Figure 5 and 6 respectively. In the Figures, R represents the resistance of service-drop cable per conductor. Usually R is much larger than X for such cable and therefore X may be neglected.*




Rajah 5
*Figure 5*




Rajah 6
*Figure 6*

Menggunakan data yang diberikan, tentukan yang berikut:
*Using the given data, determine the following:*

(20%)

[i] Cari nilai rms arus gagal simetri fasa litar voltan tinggi (HV) dan litar voltan rendah (LV) untuk kegagalan 120-V jika R bagi kabel kejatuhan perkhidmatan ialah sifar.

*Find the symmetrical rms fault currents in the high-voltage (HV) and low-voltage (LV) circuits for a 120-V fault if the R of the service-drop cable is zero.*

(20%)

[ii] Cari nilai rms arus gagal simetri dalam litar voltan tinggi dan voltan rendah untuk kegagalan 240-V jika R bagi kabel kejatuhan perkhidmatan ialah sifar.

*Find the symmetrical rms fault currents in the high-voltage and low-voltage circuits for a 240-V fault if the R of the service-drop cable is zero.* (20%)

[iii] Jika transformer ialah suatu jenis CSPB, cari kapasiti gangguan minimum yang dibenarkan (dalam ampere rms simetri) untuk suatu litar pemutus yang disambungkan kepada terminal-terminal voltan rendah transformer.

*If the transformer is a CSPB type, find the minimum allowable interrupting capacity (in symmetrical rms amperes) for a circuit breaker connected to the transformer's low-voltage terminals.*

(20%)

3. Pertimbangkan tatasusun luas kawasan dan permintaan puncak tahunan yang ditunjukkan dalam Rajah 7. Catatan bahawa permintaan puncak per lateral didapatkan sebagai

*Consider the layout of the area and the annual peak demands shown in Figure 7. Note that the peak demand per lateral is found as*

144 customers x 3.6 kVA/customer $\cong$ 518 kVA

Anggap bahawa suatu faktor kuasa 0.90 beban menyusul pada semua lokasi dalam semua litar-litar primer pada masa beban puncak tahunan. Untuk tujuan menghitung kejatuhan voltan pada main dan lateral tiga fasa, anggap bahawa beban fasa tunggal adalah seimbang di antara ketiga-tiga fasa. Unggulkan perhitungan kejatuhan voltan selanjutnya dengan menganggap beban diagihkan secara seragam sepanjang semua lateral. Anggap voltan operasi nominal bila menghitung arus daripada beban kilovoltampere. Untuk talian atas kepala wayar terbuka, hitung peratus kejatuhan voltan, menggunakan kuasa peratus kejatuhan voltan yang sudah dihitung per kilovoltampere-mile yang diberikan. Catatan bahawa $D_m = 37$ ini ditetapkan.

*Assume a lagging-load power factor of 0.90 at all locations in all primary circuits at the time of the annual peak load. For purpose of computing voltage drop in mains and in three-phase laterals, assume that the single-phase load is perfectly balanced among the three phase. Idealize the voltage-drop calculations further by assuming uniformly distributed load along all laterals. Assume nominal operating voltage when computing current from the kilovoltampere load. For the open-wire overhead copper lines, compute the percent voltage drops, using the precalculated percent voltage drop per kilovoltampere-mile curves given. Note that $D_m = 37$ in is assumed.*

Laporan bersama EEI-NEMA mentakrifkan voltan wayar pada titik penggunaan dalam bangunan ialah daripada 110 ke 125V. Disini untuk tujuan ilustratif had bawah ialah dinaikkan secara beberapa ke 116V pada meter, iaitu pada hujung kabel kejatuhan perkhidmatan. Kebenaran ini boleh memampas untuk kejatuhanvoltan tambahan yang tidak dihitung kerana:

*The joint EEI-NEMA report defines favorable voltages at the point of utilization, inside the buildings, to be from 110 to 125V. Here, for illustrative purposes, the lower limit is arbitrarily raised to 116V at the meter, i.e., at the end of the service-drop cable. This allowance may compensate for additional voltage drops not calculated due to:*

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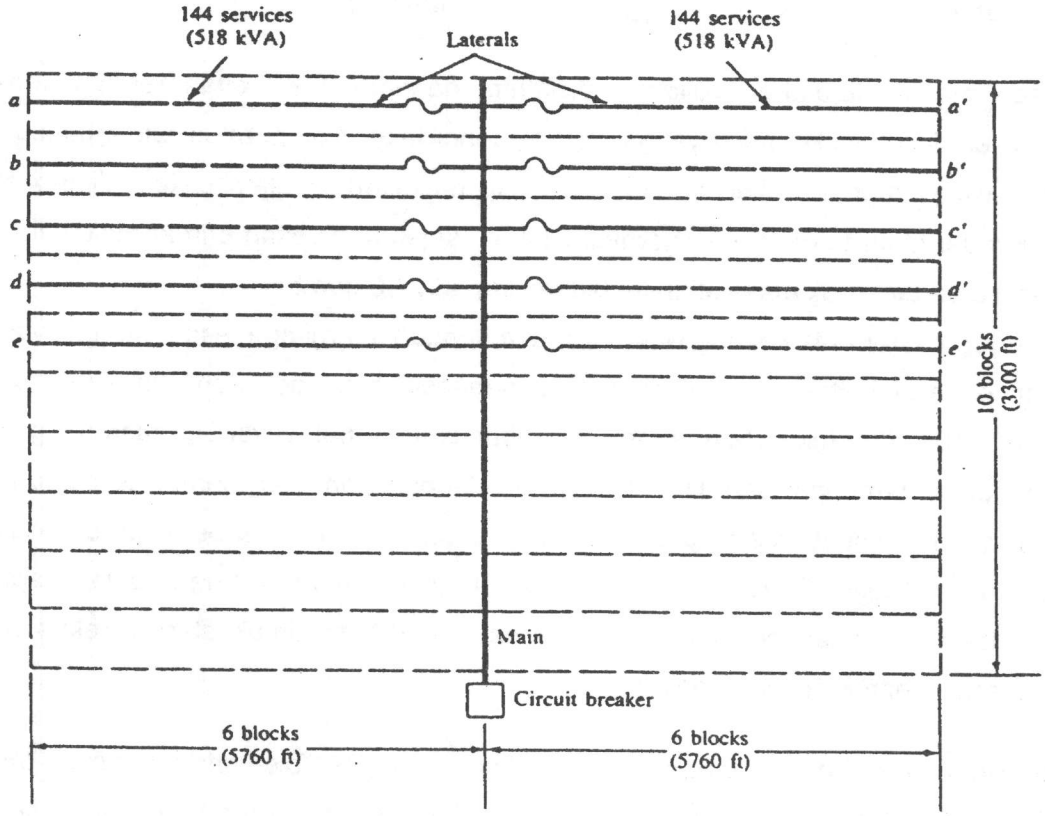



Rajah 7 Sistem distribusi jejari atas kepada
*Figure 7 An overhead radial distribution system*

1. Bebanan tak seimbang dalam sekunder fasa tunggal tiga wayar.
   *Unbalanced loading in three-wire single-phase secondaries.*
2. Bebanan tak seimbang dalam primer tiga fasa empat wayar.
   *Unbalanced loading in four-wire three-phase primaries.*
3. Penambah beban.
   *Load growth.*
4. Kejatuhan voltan dalam pendawaian bangunan.
   *Voltage drops in building wiring.*

Oleh itu kriteria voltan yang akan digunakan dalam masalah ini adalah
*Therefore the voltage criteria that are to be used in this problem are*

...14/-

$V_{max}$ = 125 V = 1.0417 pu

dan *and* $V_{min}$ = 116 V = 0.9667 pu

pada meter. Kejatuhan voltan maksimum, daripada bus voltan rendah sub-stesyen distribusi ke meter yang paling terpencil ialah 7.50 peratus. Dianggapkan bahawa kejatuhan voltan keadaan mantap maksimum dalam sistem distribusi sekunder akan tercapai sewajarnya. Oleh itu kejatuhan voltan primer maksimum yang dibenar untuk masalah ini dihadkan kepada 4.0 peratus.

Anggap primer atas kepada wayar terbuka dengan lateral tiga fasa empat wayar, dan bahawa voltan nominal digunakan sebagai voltan bes dan sama dengan 2400/4160 V untuk sistem primer wye-dibumikan empat wayar tiga fasa dengan konduktor tembaga dan Dm = 37in. Pertimbangkan litar primer terpanjang mengandungi suatu main 3300-kaki dan dua lateral terpencil seperti lateral a dan a' dalam Rajah 7. Gunakan konduktor bersaiz-*ampacity* tetapi dalam apa keadaan pun tidak boleh melebihi daripada AWG #6 untuk alasan kekuatan mekanik. Tentukan yang berikut:

*at the meter. The maximum voltage drop, from the low-voltage bus of the distribution substation to the most remote meter, is 7.50 percent. It is assumed that a 3.5 percent maximum steady-state voltage drop in the secondary distribution system is reasonably achievable. Therefore the maximum allowable primary voltage drop for this problem is limited t o 4.0 percent.*

*Assume open-wire overhead primaries with three-phase four-wire laterals, and that the nominal voltage is used as the base voltage and is equal to 2400/4160 V for the three-phase four-wire grounded-wye primary system with copper conductors and Dm = 37in. Consider the "longest" primary circuit consisting of a 3300-ft main and the two most remote laterals, like the laterals a and a' of Figure 7. Use ampacity-sized conductors but in no case smaller than AWG #6 for reasons of mechanical strength. Determine the following:*

[i] Peratus kejatuhan voltan pada hujung lateral dan main.
*The percent voltage drops at the ends of the laterals and the main*
(50%)

[ii] Jika criteria kejatuhan maksimum 4 peratus, cari suatu gabungan yang wajar konduktor yang lebih besar untuk main dan untuk lateral yang akan memenuhi criteria kejatuhan voltan. [lihat Lampiran I ].
If the 4 percent maximum voltage-drop criterion is exceeded, find a reasonable combination of larger conductors for main and for lateral that will meet the voltage drop criterion. [see Appendix I ].

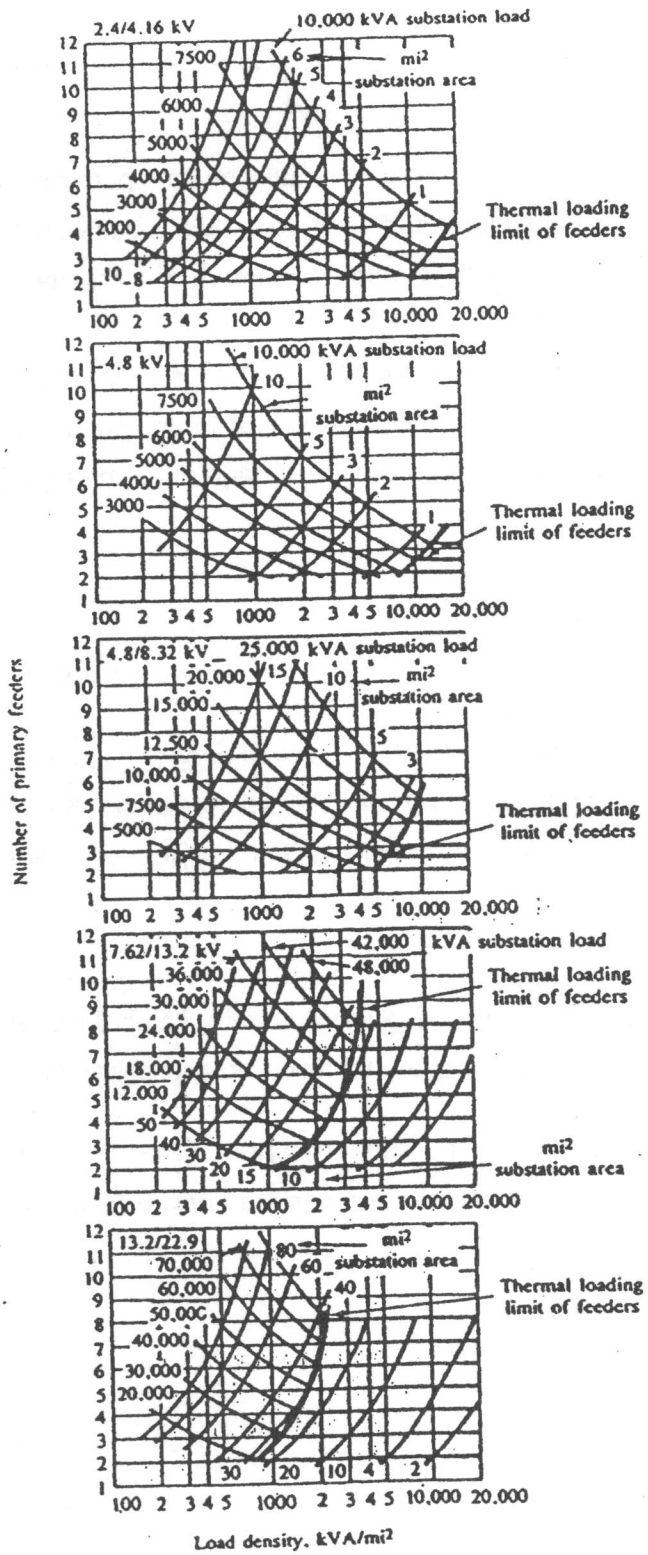
Catatan:
*Note:*
Daripada Jadual A-1
*From Table A-1, ampasiti dan konduktor koper*

*ampacity and K of AWG #4 copper conductor = 180 AR 0010*
*ampacity and K of AWG #5 copper conductor = 150 AR 0013*
*ampacity and K of AWG #6 copper conductor = 130 AR 0015*
(50%)

4. Kurva applikasi substesyen pengagihan dalam Rajah 8 dan 9 adalah sah hanya untuk saiz konduktor, peruangan dan faktor kuasa beban tertentu.

*The distribution substation application curves, given in Figure 8 and 9 are valid only for the conductor sizes, spacing and load power factor stated.*

...16/-




Rajah 8
*Figure 8*

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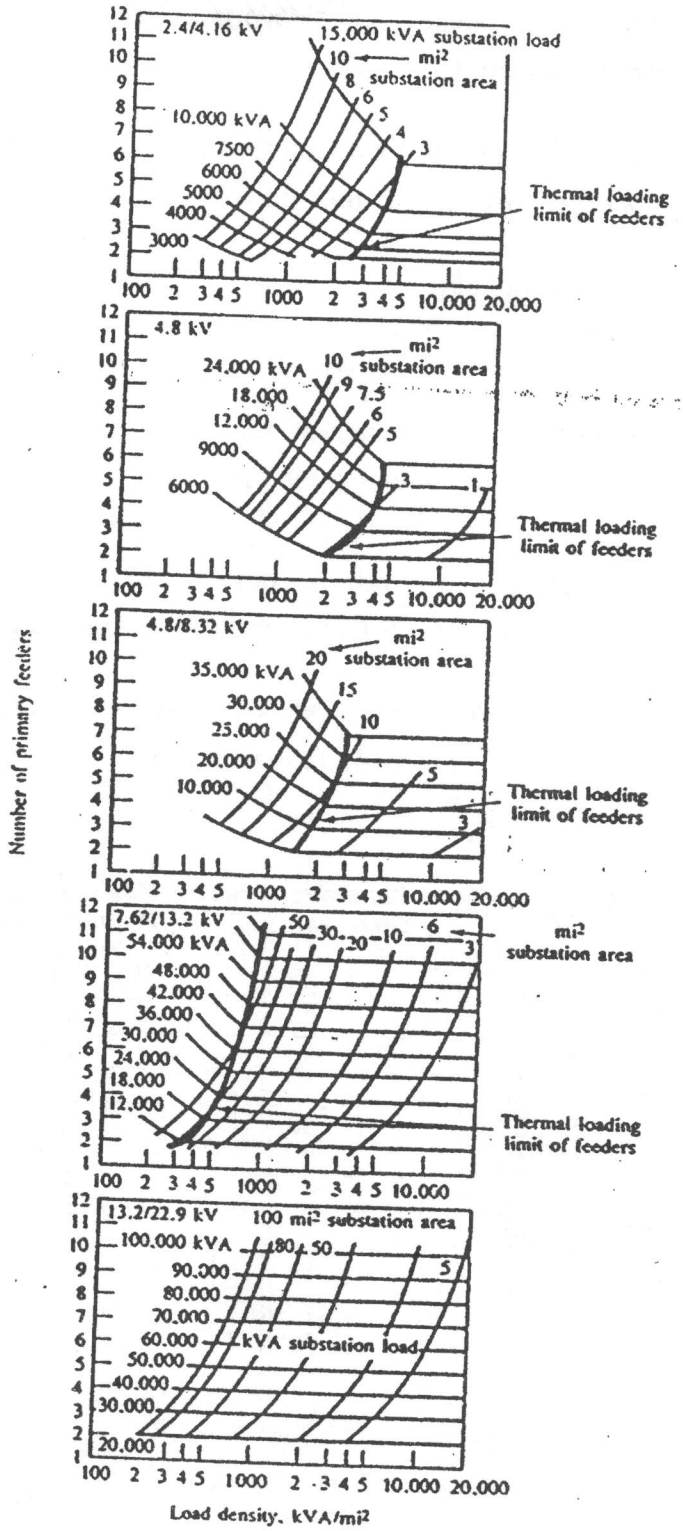


Rajah 9
*Figure 9*

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(a) Gunakan kurva applikasi sub-stasyen dan data dalam Jadual 1 untuk 8 kes yang berlainan dan tentukan:

*Use the substation application curves and the data given in table 1 for eight different cases and determine:*

[i] Saiz sub-stasyen
*the substation sizes*

(20%)

[ii] bilangan feeder yang diperlukan
*the required number of feeders and*

(20%)

[iii] tentukan sama ada feeder terhad termal (TL) atau terhad kejatuhan voltan (VDL). Jadualkan jawapan anda.

*Whether the feeders are thermally limited (TL) or voltage-drop-limited (VDL). Tabulate the results.*

(20%)

| ***Case no.*** | ***Load density D KVA/mi$^2$*** | ***Substation area Coverage Ta$_n$, mi$^2$*** | ***Maximum total Primary feeder % VD*** | ***Base feeder voltage kV$_{L-L}$*** |
|---|---|---|---|---|
| 1 | 500 | 6.0 | 3.0 | 4.16 |
| 2 | 500 | 6.0 | 6.0 | 4.16 |
| 3 | 2,000 | 3.0 | 3.0 | 4.16 |
| 4 | 2,000 | 3.0 | 6.0 | 4.16 |
| 5 | 10,000 | 1.0 | 3.0 | 4.16 |
| 6 | 10,000 | 1.0 | 6.0 | 4.16 |
| 7 | 2,000 | 15.0 | 3.0 | 13.2 |
| 8 | 2,000 | 15.0 | 6.0 | 13.2 |

Jadual 1
*Table 1*

(b) Dalam hal feeder TL ditemui, cuba tafsir-kaitkan sama ada ianya #4/0 AWG copper main atau #4 AWG copper lateral yang dibataskan secara termal (TL). Tunjukkan dan terangkan alasan dan perhitungan anda

*In case thermally loaded or thermally limited (TL) feeders are encountered, attempt to deduce if it is the #4/0 AWG copper main or the #4 AWG copper lateral that is thermally limited. Show and explain your reasoning and calculations.*

Catatan : Ampasiti konduktor #4/0 AWG copper main = 480A
Ampasiti konduktor #4 AWG copper lateral = 180A

*Note : Ampacity conductor #4/0 AWG copper main = 480A*
*Ampacity conductor #4 AWG copper lateral = 180A*

(40%)

5. (a) Pertimbangkan suatu kawasan perkhidmatan sub-stasyen distribusi benbentuk segi empat seperti di dalam Rajah 10. Luas segi empat ialah $4mi^2$ dan mempunyai berbagai lateral tiga fasa. Jurutera rekabentuk distribusi mempunyai data rekabentuk berikut yang dianggap merupakan anggaran yang memuaskan. Beban diagihkan seragam dan disambungkan ke ketumpatan beban 2000 $kVA/mi^2$. Faktor permintaan yang merupakan purata nilai untuk semua beban ialah 0.60. Faktor kepelbagaian antara semua beban dalam kawasan ialah 1.20. Faktor kuasa beban ialah 0.90 menyusul yang merupakan nilai purata yang boleh digunakan kepada semua beban.

*Assume a square shaped distribution substation service area as shown in Figure 10. The square area is 4 $mi^2$ and has numerous three-phase laterals. The designing distribution engineer has the following design data which are assumed to be satisfactory estimates. The load is uniformly distributed and the connected load density is 2000 $kVA/mi^2$. The demand factor which is an average value for all loads is 0.60. The diversity factor among all loads in the area is 1.20. The load power factor is 0.90 lagging which is an average value applicable for all loads.*

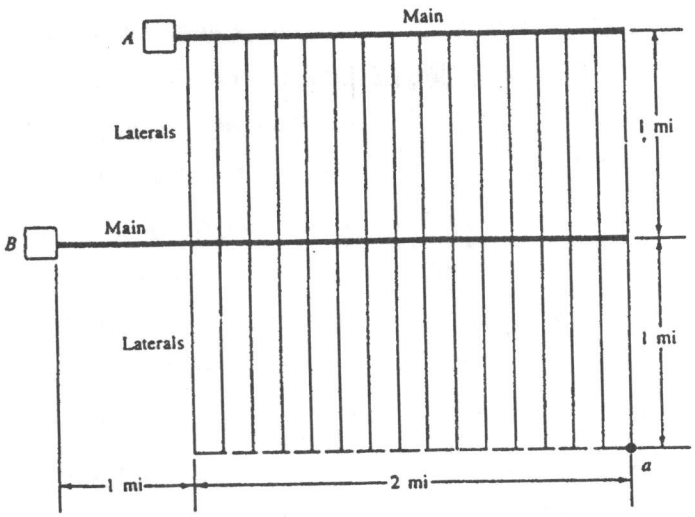
Untuk sebab-sebab tak diketahui (barangkali kerana jarak berlebihan daripada pusat beban atau batasan talian transmisi atau lain-lain, seperti perolehan tanah, harganya dan ordinans dan peraturan penggunaan tanah), tempat sub-stasyen yang ada ialah pada lokasi A dan B. Jika perekabentuk memilih tempat A sebagai lokasi sub-stasyen, maka akan terdapat feeder utama sejarak 2 batu dan 16 lateral tiga fasa 2–bt–panjang. Sebaliknya, jika perekabentuk memilih tempat B sebagai lokasi sub-stasyen, maka akan terdapat feeder utama 3-bt-panjang (termasuk express-feeder main 1-bt-panjang) dan 32 lateral tiga fasa 1-bt-panjang.

*For some unknown reasons (perhaps due to the excessive distance from load centers or transmission lines or other limitations, such as availability of land, its cost and land use ordinances and regulations), the only available substation sites are at locations A and B. If the designer selects site A as the substation location, there will be a 2-mi-long feeder main and 16 three-phase 2-mi-long laterals. On the other hand, if the designer selects site B as the substation location, there will be a 3-mi-long feeder main (including a 1-mi-long express feeder main) and 32 three-phase 1-mi-long laterals.*

Perekabentuk berkeinginan memilih satu yang lebih baik di antara dua tempat dengan menyelidik kejatuhan voltan beban puncak total pada hujung lateral yang paling terpencil iaitu pada titik a. Anggap primer feeder utama dibumikan-wye tiga fasa empat wayar 7.62/13.2kV dibuat daripada #2/0 konduktor tembaga atas kepala. Lateral adalah #4 konduktor tembaga dan adalah semuanya tiga fasa empat wayar dan dibumikan-wye. Menggunakan kurva peratus kejatuhan voltan per kilovoltampere-mile yang sudah dihitung, kita dapati bahawa K untuk konduktor #2/0 dan #4 ialah masing-masing 0.0004 dan 0.00095, tentukan tempat sub-stasyen yang lebih baik dengan menghitung peratus kejatuhan voltan pada titik a yang bersepadan dengan setiap tempat sub-stasyen dan pilih tempat yang lebih baik.

*The designer wishes to select the better one of the given two sites by investigating the total peak-load voltage drop at the end of the most remote lateral i.e., at point a. Assume 7.62/13.2kV three-phase four-wire grounded-wye primary feeder mains which are made of #2/0 copper overhead conductors. The laterals are of #4 copper conductors and they are all three-phase four-wire and grounded-wye.*
*Using the precalculated percent voltage drop per kilovoltampere-mile curves we found that the K for #2/0 and #4 conductors are 0.0004 and 0.00095 respectively, determine the better substation site by calculating the percent voltage drops at point a that correspond to each substation site and select the better one.*

(50%)




Rajah 10
*Figure 10*

(b) Anggap suatu kawasan perkhidmatan distribusi berbentuk segiempat seperti tertera dalam Rajah 11. Empat penyuap sub-stesyen melayani kawasan segi empat $2a \times 2a\ mi^2$. Ketumpatan beban distribusi ialah $D\ kVA/mi^2$ dan teragih seragam. Setiap penyuap utama ialah tiga fasa empat wayar dibumikan-wye dengan '*multigrounded common neutral open-wire line*'.

Kerana dimensi d terlalu kecil daripada dimensi a, anggap bahawa panjang setiap feeder main mendekati a mi, dan luas yang dilayani oleh lateral terakhir yang ditandai dalam rajah sebagai luas berlorek yang mendekati $a \times d\ mi^2$. Faktor kuasa semua beban ialah cos $\theta$ menyusul. Impedans talian feeder utama per fasa ialah

*Assume a square-shaped distribution service area as shown in Figure 11. The four-feeder substation serves a square area of $2a \times 2a\ mi^2$. The load density distribution is $D\ kVA/mi^2$ and is uniformly distributed. Each feeder main is three-phase four-wire grounded-wye with multigrounded common neutral open-wire line.*

...23/-

*Since dimension d is much smaller than dimension a, assume that the length of each feeder main is approximately a mi, and the area served by the last lateral, which is indicated in the figure as the cross-hatched area, is approximately a x d mi². The power factor of all loads is cos θ lagging. The impedance of the feeder main line per phase is*

$$Z_m = r_m + jx_m \quad \Omega/mi$$

Impedans talian lateral per fasa.

*The impedance of the lateral line per phase is*

$$Z_l = r_l + jx_l \quad \Omega/mi$$

$V_{L\text{-}L}$ ialah bes voltan talian-ke-talian dalam kilovolt, dan juga merupakan voltan operasi nominal.

*The $V_{L\text{-}L}$ is the base line-to-line voltage in kilovolts, which is also the nominal operating voltage.*

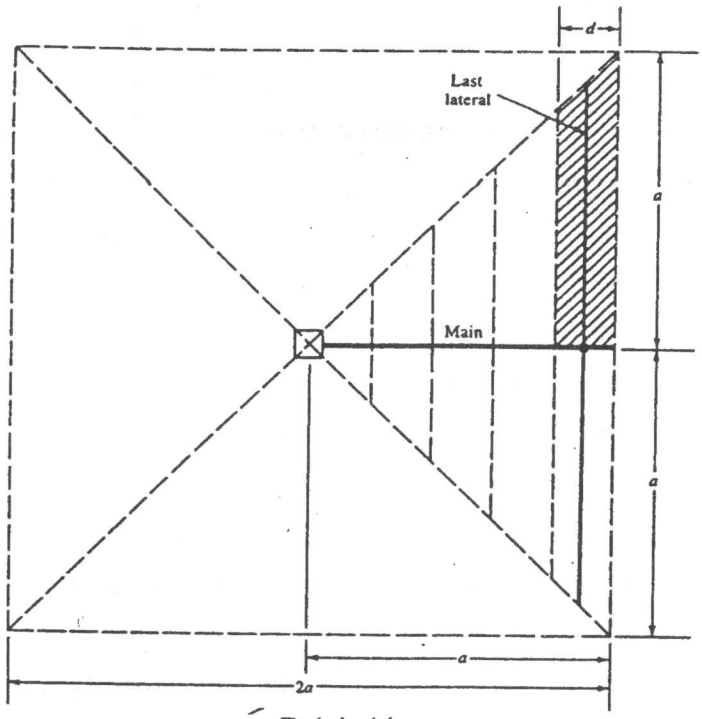
[i] Anggap bahawa lateral juga tiga fasa empat wayar dibumikan-wye dengan '*multigrounded common neutral open-wire line*'. Tunjukkan bahawa peratus kejatuhan voltan pada hujung lateral terakhir ialah

*Assume that laterals are also three-phase four-wire grounded-wye with multigrounded common neutral open-wire line. Show that the percent voltage drop at the end of the last lateral is*

$$\%\,VD = \frac{2D \times a^3 \left(r_m \cos\theta + x_m \sin\theta\right)}{30 \times V^2{}_{L-L}} + \frac{D \times a^2 \times d \left(r_l \cos\theta + x_l \sin\theta\right)}{20 \times V^2{}_{L-L}}$$

(25%)

...24/-




Rajah 11
*Figure 11*

[ii] Anggap bahawa lateral ialah satu fasa dua wayar dengan talian '*multigrounded common neutral open-wire line*'. Gunakan pendekatan Morrison's dan sesuaikan persamaan yang diberikan dalam bahagian [i]. Mengikut Morrison's peratus kejatuhan voltan dalam main suatu litar satu fasa ialah kira-kira 4 kali litar tiga fasa dengan menganggap penggunaan saiz konduktor-konduktor yang sama.

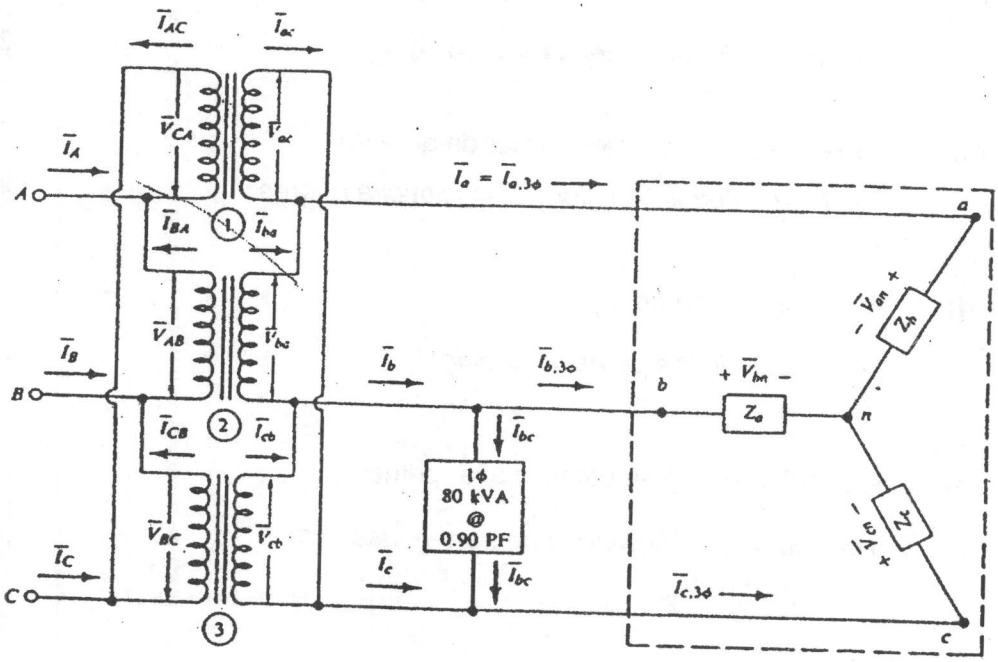
*Assume that the laterals are single-phase two-wire with multigrounded common neutral open-wire line. Apply Morrison's approximation and modify the equation given in part [i]. According to Morrison, the percent voltage drop in the main of a single phase circuit is approximately 4 times that for a three-phase circuit, assuming the usage of the same size conductors.*

(25%)

...25/-

6. Tiga transformer satu fasa disambung delta-delta untuk membekalkan kuasa kepada beban 200 kVA, tiga fasa sambungan-wye yang mempunyai faktor kuasa 0.8 menyusul dan suatu beban ringan 180 kVA satu fasa dengan faktor kuasa 0.90 menyusul seperti dalam Rajah 12.

*Three single-phase transformers are connected delta-delta to provide power for a three-phase wye-connected 200 kVA load with a 0.80 lagging power factor and a 80 kVA single-phase light load with a 0.90 lagging power factor, as shown in Figure 12.*




Rajah 12
*Figure 12*

Dengan menganggap bahawa tiga transformer satu fasa mempunyai peratus impedans yang sama dan nisbah peratus reaktans ke peratus rintangan yang sama. Voltan sebelah-perima bank ialah 7620/13,200 V dan voltan sebelah sekunder ialah 240 V. Anggap bahawa transformer satu fasa yang disambung antara fasa b dan c dikadarkan pada 100 kVA dan dua yang lain dikadarkan pada 75 kVA. Tentukan yang berikut:

...26/-

*Assume that the three single-phase transformers have equal percent impedance and equal ratios of percent reactance to percent resistance. The primary-side voltage of the bank is 7620/13,200 V and the secondary-side voltage is 240 V. Assume that the single-phase transformer connected between phases b and c is rated at 100 kVA and the other two are rated at 75 kVA. Determine the following:*

(a) Arus talian $\bar{I}_a$

*The line current* $\bar{I}_a$ (20%)

(b) Arus belitan sekunder $I_{ba}$

*The current in the secondary winding* $I_{ba}$ (20%)

(c) Beban pada setiap transformer dalam kVA

*The load on each transformer in kilovoltamperes* (20%)

(d) Arus belitan primer $I_{CB}$

*The current in the primary winding* $I_{CB}$ (20%)

(e) Arus talian mengalir dalam wayar primer $I_C$

*The line current flowing in primary-phase wire* $I_C$ (20%)

- oooOooo -

# Table A-1 Characteristics of copper conductors, hard-drawn, 97.3 percent conductivity

| Size of Conductor | | Number of stands | Diameter of Individual stands inches | Outside diameter Inches | Breaking strength pounds | Weight pounds per mile | Approx current carring capacity Amps | Geometrix main Radius at 60 cycles feat | $r_a$ Resistance Ohms per conductor per mile | | | | | | | | $x_a$ Inductive Reactance Megohms per conductor per mile at 1 Ft spacing | | | $x_a$ Shunt capacitive Reactance Megaohms per conductor per mile at 1 Ft spacing | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 25°C(77°F) | | | | 50°C(122°F) | | | | | | | | | |
| Circular mile | A.W.G B.A.S | | | | | | | | d-c | 25 cycles | 50 cycles | 60 cycles | d-c | 25 cycles | 50 cycles | 60 cycles | 25 cycles | 50 cycles | 60 cycles | 25 cycles | 50 cycles | 60 cycles |
| 1 000 000 | ... | 37 | 0.1644 | 1.151 | 43 830 | 16 300 | 1 300 | 0.0368 | 0.0645 | 0.0664 | 0.0670 | 0.0674 | 0.0840 | 0.0848 | 0.0872 | 0.0875 | 0.1666 | 0.333 | 0.400 | 0.216 | 0.1081 | 0.0901 |
| 900 000 | ... | 37 | 0.1560 | 1.092 | 39 810 | 14 670 | 1 220 | 0.0349 | 0.0660 | 0.0666 | 0.0672 | 0.0675 | 0.0711 | 0.0718 | 0.0740 | 0.0743 | 0.1603 | 0.330 | 0.396 | 0.220 | 0.1100 | 0.0916 |
| 800 000 | ... | 37 | 0.1470 | 1.029 | 35 120 | 13 040 | 1 130 | 0.0329 | 0.0731 | 0.0736 | 0.0760 | 0.0772 | 0.0800 | 0.0806 | 0.0826 | 0.0837 | 0.1722 | 0.344 | 0.413 | 0.224 | 0.1121 | 0.0934 |
| 760 000 | ... | 37 | 0.1424 | 0.997 | 33 400 | 12 230 | 1 090 | 0.0319 | 0.0780 | 0.0787 | 0.0807 | 0.0818 | 0.0863 | 0.0850 | 0.0870 | 0.0880 | 0.1730 | 0.346 | 0.417 | 0.226 | 0.1132 | 0.0943 |
| 700 000 | ... | 37 | 0.1376 | 0.963 | 31 170 | 11 410 | 1 040 | 0.0308 | 0.0836 | 0.0842 | 0.0861 | 0.0871 | 0.0916 | 0.0920 | 0.0937 | 0.0947 | 0.1760 | 0.352 | 0.422 | 0.230 | 0.1146 | 0.0964 |
| 600 000 | ... | 37 | 0.1273 | 0.891 | 27 020 | 9 781 | 940 | 0.0285 | 0.0975 | 0.0981 | 0.0997 | 0.1006 | 0.1066 | 0.1071 | 0.1086 | 0.1095 | 0.1700 | 0.340 | 0.432 | 0.236 | 0.1178 | 0.0977 |
| 500 000 | ... | 37 | 0.1162 | 0.814 | 22 510 | 8 151 | 840 | 0.0260 | 0.1170 | 0.1178 | 0.1188 | 0.1196 | 0.1280 | 0.1283 | 0.1296 | 0.1303 | 0.1646 | 0.329 | 0.443 | 0.241 | 0.1206 | 0.1004 |
| 500 000 | ... | 19 | 0.1622 | 0.811 | 21 690 | 8 161 | 840 | 0.0266 | 0.1170 | 0.1178 | 0.1188 | 0.1196 | 0.1280 | 0.1283 | 0.1296 | 0.1303 | 0.1663 | 0.371 | 0.446 | .241 | 0.1206 | 0.1006 |
| 460 000 | ... | 19 | 0.1539 | 0.770 | 19 780 | 7 336 | 790 | 0.0243 | 0.1300 | 0.1304 | 0.1316 | 0.1323 | 0.1422 | 0.1426 | 0.1437 | 0.1443 | 0.1679 | 0.376 | 0.461 | 0.246 | 0.1224 | 0.1020 |
| 400 000 | ... | 19 | 0.1451 | 0.726 | 17 860 | 6 521 | 730 | 0.0229 | 0.1462 | 0.1466 | 0.1477 | 0.1484 | 0.1600 | 0.1603 | 0.1613 | 0.1619 | 0.1900 | 0.382 | 0.466 | 0.249 | 0.1245 | 0.1038 |
| 350 000 | ... | 19 | 0.1357 | 0.679 | 15 560 | 5 706 | 670 | 0.0214 | 0.1671 | 0.1675 | 0.1684 | 0.1690 | 0.1828 | 0.1831 | 0.1840 | 0.1846 | 0.1943 | 0.389 | 0.466 | 0.254 | 0.1269 | 0.1064 |
| 350 000 | ... | 12 | 0.1706 | 0.710 | 15 140 | 5 706 | 670 | 0.0228 | 0.1671 | 0.1675 | 0.1684 | 0.1690 | 0.1828 | 0.1831 | 0.1840 | 0.1846 | 0.1916 | 0.384 | 0.460 | 0.251 | 0.1263 | 0.1044 |
| 300 000 | ... | 19 | 0.1257 | 0.629 | 13 810 | 4 891 | 610 | 0.01987 | 0.1950 | 0.1953 | 0.1961 | 0.1966 | 0.213 | 0.214 | 0.214 | 0.215 | 0.1982 | 0.396 | 0.476 | 0.259 | 0.1296 | 0.1080 |
| 300 000 | ... | 12 | 0.1381 | 0.657 | 13 170 | 4 891 | 610 | 0.0208 | 0.1950 | 0.1953 | 0.1961 | 0.1966 | 0.213 | 0.214 | 0.214 | 0.215 | 0.1957 | 0.392 | 0.470 | 0.256 | 0.1281 | 0.1068 |
| 250 000 | ... | 19 | 0.1147 | 0.574 | 11 340 | 4 076 | 540 | 0.01813 | 0.234 | 0.234 | 0.236 | 0.236 | 0.266 | 0.266 | 0.267 | 0.267 | 0.203 | 0.406 | 0.487 | 0.266 | 0.1329 | 0.1108 |
| 250 000 | ... | 12 | 0.1443 | 0.600 | 11 130 | 4 076 | 540 | 0.01902 | 0.234 | 0.234 | 0.236 | 0.236 | 0.266 | 0.266 | 0.267 | 0.267 | 0.200 | 0.401 | 0.481 | 0.263 | 0.1313 | 0.1094 |
| 211 600 | 4/0 | 19 | 0.1055 | 0.528 | 9 617 | 3 450 | 480 | 0.01666 | 0.276 | 0.277 | 0.277 | 0.278 | 0.302 | 0.303 | 0.303 | 0.303 | 0.207 | 0.414 | 0.497 | 0.272 | 0.1359 | 0.1133 |
| 211 600 | 4/0 | 12 | 0.1328 | 0.552 | 9 483 | 3 450 | 490 | 0.01750 | 0.276 | 0.277 | 0.277 | 0.278 | 0.302 | 0.303 | 0.303 | 0.303 | 0.206 | 0.409 | 0.491 | 0.269 | 0.1343 | 0.1118 |
| 211 600 | 4/0 | 7 | 0.1739 | 0.522 | 9 164 | 3 450 | 480 | 0.01579 | 0.276 | 0.277 | 0.277 | 0.278 | 0.302 | 0.303 | 0.303 | 0.303 | 0.210 | 0.420 | 0.503 | 0.273 | 0.1363 | 0.1136 |
| 167 800 | 3/0 | 12 | 0.1183 | 0.492 | 7 656 | 3 736 | 420 | 0.01560 | 0.349 | 0.349 | 0.349 | 0.350 | 0.381 | 0.381 | 0.382 | 0.382 | 0.210 | 0.421 | 0.506 | 0.277 | 0.1384 | 0.1148 |
| 167 800 | 3/0 | 7 | 0.1548 | 0.464 | 7 346 | 2 736 | 420 | 0.01404 | 0.349 | 0.349 | 0.349 | 0.350 | 0.381 | 0.381 | 0.382 | 0.382 | 0.216 | 0.431 | 0.518 | 0.281 | 0.1406 | 0.1171 |
| 133 100 | 2/0 | 7 | 0.1379 | 0.414 | 5 826 | 2 170 | 360 | 0.01252 | 0.440 | 0.440 | 0.440 | 0.440 | 0.481 | 0.481 | 0.481 | 0.481 | 0.222 | 0.443 | 0.532 | 0.289 | 0.1445 | 0.1205 |
| 106 500 | 1/0 | 7 | 0.1228 | 0.368 | 4 732 | 1 720 | 310 | 0.01113 | 0.555 | 0.555 | 0.555 | 0.555 | 0.606 | 0.607 | 0.607 | 0.607 | 0.227 | 0.455 | 0.546 | 0.296 | 0.1468 | 0.1240 |
| 83 690 | 1 | 7 | 0.1093 | 0.328 | 3 804 | 1 364 | 270 | 0.00992 | 0.699 | 0.699 | 0.699 | 0.699 | 0.766 | | | | 0.233 | 0.467 | 0.560 | 0.306 | 0.1528 | 0.1274 |
| 83 690 | 1 | 3 | 0.1670 | 0.360 | 3 420 | 1 351 | 270 | 0.01016 | 0.662 | 0.662 | 0.662 | 0.662 | 0.787 | | | | 0.232 | 0.464 | 0.557 | 0.299 | 0.1495 | 0.1246 |
| 66 370 | 2 | 7 | 0.0974 | 0.292 | 3 045 | 1 082 | 230 | 0.00883 | 0.881 | 0.882 | 0.882 | 0.882 | 0.964 | | | | 0.239 | 0.478 | 0.574 | 0.314 | 0.1570 | 0.1309 |
| 66 370 | 2 | 3 | 0.1487 | 0.320 | 2 913 | 1 071 | 240 | 0.00903 | 0.873 | | | | 0.956 | | | | 0.238 | 0.476 | 0.571 | 0.307 | 0.1537 | 0.1281 |
| 66 370 | 2 | 1 | .. | 0.256 | 3 003 | 1 067 | 230 | 0.00836 | 0.864 | | | | 0.946 | | | | 0.242 | 0.484 | 0.581 | 0.323 | 0.1614 | 0.1345 |
| 52 630 | 3 | 7 | 0.0867 | 0.260 | 2 433 | 856 | 200 | 0.00787 | 1.112 | | | | 1.216 | | | | 0.245 | 0.490 | 0.588 | 0.322 | 0.1611 | 0.1343 |
| 52 630 | 3 | 3 | 0.1325 | 0.265 | 2 350 | 850 | 200 | 0.00806 | 1.101 | | | | 1.204 | | | | 0.244 | 0.488 | 0.585 | 0.316 | 0.1578 | 0.1315 |
| 52 630 | 3 | 1 | | 0.229 | 2 439 | 841 | 190 | 0.00745 | 1.090 | Same as d-c | | | 1.192 | Same as d-c | | | 0.248 | 0.496 | 0.595 | 0.331 | 0.1656 | 0.1380 |
| 41 740 | 4 | 3 | 0.1180 | 0.254 | 1 870 | 674 | 180 | 0.00717 | 1.388 | | | | 1.516 | | | | 0.250 | 0.499 | 0.599 | 0.324 | 0.1619 | 0.1349 |
| 41 740 | 4 | 1 | | 0.204 | 1 970 | 667 | 170 | 0.00663 | 1.374 | | | | 1.503 | | | | 0.254 | 0.507 | 0.609 | 0.339 | 0.1697 | 0.1415 |
| 33 100 | 5 | 3 | 0.1060 | 0.226 | 1 606 | 534 | 150 | 0.00636 | 1.750 | | | | 1.914 | | | | 0.256 | 0.511 | 0.613 | 0.332 | 0.1661 | 0.1384 |
| 33 100 | 5 | 1 | | 0.1810 | 1 561 | 529 | 140 | 0.00580 | 1.733 | | | | 1.896 | | | | 0.260 | 0.519 | 0.623 | 0.348 | 0.1738 | 0.1448 |
| 26 250 | 6 | 3 | 0.0936 | 0.201 | 1 206 | 424 | 130 | 0.00568 | 2.21 | | | | 2.41 | | | | 0.262 | 0.523 | 0.628 | 0.341 | 0.1703 | 0.1419 |
| 26 250 | 6 | 1 | ..... | 0.1620 | 1 280 | 420 | 120 | 0.00526 | 2.18 | | | | 2.39 | | | | 0.266 | 0.531 | 0.637 | 0.356 | 0.1779 | 0.1483 |
| 20 820 | 7 | 1 | ..... | 0.1443 | 1 030 | 333 | 110 | 0.00466 | 2.76 | | | | 3.01 | | | | 0.271 | 0.542 | 0.651 | 0.364 | 0.1821 | 0.1517 |
| 16 510 | 8 | 1 | ..... | 0.1285 | 826 | 264 | 90 | 0.00417 | 3.47 | | | | 3.80 | | | | 0.277 | 0.554 | 0.666 | 0.372 | 0.1862 | 0.1552 |

* For conductor at 75°C, air at 25°C, wind 1.4 mi/h (2 ft/s), frequency = 60 cycles.

*Source*: [1, 21].