UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Pertama
Sidang Akademik 1995/96

Oktober - November 1995

EEE 367 - Sistem Penghantaran & Pengagihan Kuasa

Masa : [3 jam]

ARAHAN KEPADA CALON :

Sila pastikan bahawa kertas peperiksaan ini mengandungi 11 muka surat bercetak dan **ENAM (6)** soalan sebelum anda memulakan peperiksaan ini.

Jawab **LIMA (5)** soalan sahaja.

Agihan markah bagi soalan diberikan di sut sebelah kanan soalan berkenaan.

Jawab semua soalan di dalam Bahasa Malaysia.

...2/-

1. **Suatu punca voltan seimbang, sambungan Y, jujukan positif membekalkan voltan talian $V_{ab} = 480\angle 0^{\circ}$ V kepada beban Δ seimbang dengan $Z_{\Delta} = 30\angle 40^{\circ}$ Ω/fasa. Impedan talian antara punca dan beban ialah $Z_T = 1\angle 85^{\circ}$ Ω/fasa.**

Kira:

A balanced, positive-sequence, Y - connected voltage source with line voltage $V_{ab} = 480\angle 0^{\circ}$ volts is applied to a balanced Δ- connected load with $Z_{\Delta} = 30\angle 40^{\circ}$ Ω/phase. The line impedance between the source and load is $Z_T = 1\angle 85^{\circ}$ Ω/phase.

Calculate:

(a) **semua arus talian,**
the line currents, (40%)

(b) **semua arus fasa beban Δ, dan**
the Δ-load currents, and (35%)

(c) **semua voltan pada terminal beban.**
the voltages at the load terminals. (25%)

2. (a) **Nyatakan TIGA pendekatan yang sering digunakan untuk memudahkan analisis sistem kuasa tiga fasa seimbang.**

State three approaches commonly used to simplify the analysis of a balanced three-phase power system.

(25%)

...3/-

(b) **Rajah S2 menunjukkan gambarajah talian tunggal sistem kuasa tiga fasa mudah dengan empat (4) bas. Penjana tiga fasa berkadar 4160 kVA, 2.4 kV, X''_d = 20%. Transformer tiga fasa T_1 mempunyai kadaran 5000 kVA, 2.4/24 kV, X = 5% manakala bank transformer T_2 terdiri dari tiga transformer satu fasa serbasama, dengan kadar setiap satu bersamaan 1500 kVA, 13.8/12 kV, X = 5%. Beban dianggapkan terdiri dari impedan tetap Z_L = 10 + j30 Ω. Panjang talian penghantaran ialah 200 km dengan impedan siri 0.5Ω/km. Pilih kadaran penjana sebagai nilai asas rujukan. Lakarkan gambarajah reaktan dengan semua reaktan ditandakan dalam per unit.**

Figure S2 shows a single-line diagram of a simple four-bus three-phase power system. The three-phase generator is rated 4160 kVA, 2.4 kV, X''_d = 20%. The three-phase transformer T1 is rated 5000 kVA, 2.4/24 kV, X = 5% and the transformer bank T2 is made up of three identical single-phase transformers each rated 1500 kVA, 13.8/12 kV, X = 5%. The load is ussumed to be consisting of a constant impedance of Z_L = 10 + j30 Ω. The transmission line length is 200 km with series impedance of 0.5Ω/km. Select the generator rating as reference base value. Draw the reactance diagram with all reactances marked in per unit.

(75%)

Nota: Pertukaran asas Impedan

Note: Change of base of impedance

$$\text{Per unit } Z_{\text{baru}} = \text{per unit } Z_{\text{lama}} \left(\frac{\text{asas kV}_{\text{lama}}}{\text{asas kV}_{\text{baru}}}\right)^2 \left(\frac{\text{asas kVA}_{\text{baru}}}{\text{asas kVA}_{\text{lama}}}\right)$$

$$\text{Per unit } Z_{\text{new}} = \text{per unit } Z_{\text{old}} \left(\frac{\text{base kV}_{\text{old}}}{\text{base kV}_{\text{new}}}\right)^2 \left(\frac{\text{base kVA}_{\text{new}}}{\text{base kVA}_{\text{old}}}\right)$$

...4/-

Figure S2 **(Rajah S2)**

3. **Talian tiga fasa teralih, 60 Hz, 25°C dijarakkan secara mendatar antara pengalir fasa. Talian penghantaran dengan panjang 200 km terdiri dari dua berkas pengalir per fasa dan pengalir adalah 795,000 cmil ACSR 26/2 pintalan. Ruang berkas d ialah 40 cm dengan jarak 10 m antara titik tengah pengalir terberkas, seperti ditunjukkan dalam Rajah S3. Ciri-ciri pengalir ACSR boleh didapati dalam Jadual 1.**
Kira:

A completely transposed 60 - Hz, 25°C three-phase line has flat horizontal phase spacing. The transmission line has a length of 200 km consisting of two bundled conductors per phase and the conductors are 795,000 cmil ACSR 26/2 stranding. Bundle spacing is 40 cm with 10 m between adjucent bundle center, as shown in Figure S3. Characteristics of ACSR conductors are attached in Table 1.
Calculate:

(a) **Reaktan induktif dalam Ω/m per fasa.**
Inductive reactance in Ω/m per phase. (25%)

(b) **Reaktan kapasitif dalam Ω-m per fasa.**
Capacitive reactance in Ω-m per phase. (25%)

...5/-

(c) Jumlah rintangan talian per fasa.
Total line resistance per phase. (10%)

(d) Jumlah reaktan induktif talian per fasa.
Total line inductive reactance per phase. (20%)

(e) Jumlah reaktan kapasitif talian per fasa.
Total line capacitive reactance per phase. (20%)

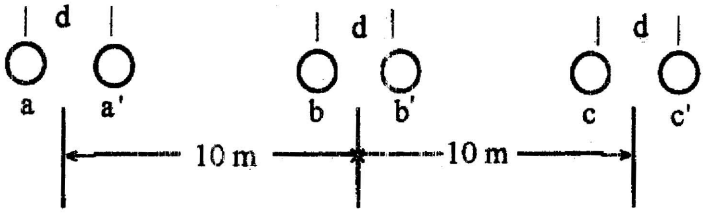

Figure S3 **(Rajah S3)**

...6/-

J a d u a l   I

Table A.4 Characteristics of aluminum cable, steel, reinforced (Aluminum Company of America)—ACSR

Code Word	Circular Mils Aluminum	Aluminum		Aluminum Strand Diameter (Inches)	Steel	Steel Strand Diameter (Inches)	Outside Diameter (Inches)	Copper Equivalent* Circular Mils or A.W.G.	Ultimate Strength (Pounds)	Weight (Pounds per Mile)	Geometric Mean Radius at 60 Hz (Feet)	Approx. Current Carrying Capacity† (Amps)	r_a Resistance (Ohms per Conductor per Mile) 25°C (77°F) Small Currents dc	25 Hz	50 Hz	60 Hz	50°C (122°F) Current Approx. 75% Capacity‡ dc	25 Hz	50 Hz	60 Hz	x_a Inductive Reactance (Ohms per Conductor per Mile at 1 Ft Spacing All Currents) 60 Hz	x'_a Shunt Capacitive Reactance (Megohms per Conductor per Mile at 1 Ft Spacing) 60 Hz
Joree	2 515 000	76	...	0.1819	19	0.0849	1.880		61 700		0.0621									0.0450	0.337	0.0755
Thrasher	2 312 000	76	...	0.1744	19	0.0814	1.802		57 300		0.0595									0.0482	0.342	0.0767
Kiwi	2 167 000	72	4	0.1735	7	0.1157	1.735		49 800		0.0570									0.0511	0.348	0.0778
Bluebird	2 156 000	84	4	0.1602	19	0.0961	1.762		60 300		0.0588									0.0505	0.344	0.0774
Chukar	1 781 000	84	4	0.1456	19	0.0874	1.602		51 000		0.0534									0.0598	0.355	0.0802
Falcon	1 590 000	54	3	0.1716	19	0.1030	1.545	1 000 000	56 000	10 777	0.0520	1 380	0.0587	0.0588	0.0590	0.0591	0.0646	0.0656	0.0675	0.0684	0.359	0.0814
Parrot	1 510 500	54	3	0.1673	19	0.1004	1.506	950 000	53 200	10 237	0.0507	1 340	0.0618	0.0619	0.0621	0.0622	0.0680	0.0690	0.0710	0.0720	0.362	0.0821
Plover	1 431 000	54	3	0.1628	19	0.0977	1.465	900 000	50 400	9 699	0.0493	1 300	0.0652	0.0653	0.0655	0.0656	0.0718	0.0729	0.0749	0.0760	0.365	0.0830
Martin	1 351 000	54	3	0.1582	19	0.0949	1.424	850 000	47 600	9 160	0.0479	1 250	0.0691	0.0692	0.0694	0.0695	0.0761	0.0771	0.0792	0.0803	0.369	0.0838
Pheasant	1 272 000	54	3	0.1535	19	0.0921	1.382	800 000	44 800	8 621	0.0466	1 200	0.0734	0.0735	0.0737	0.0738	0.0808	0.0819	0.0840	0.0851	0.372	0.0847
Grackle	1 192 500	54	3	0.1486	19	0.0892	1.338	750 000	43 100	8 082	0.0450	1 160	0.0783	0.0784	0.0786	0.0788	0.0862	0.0872	0.0894	0.0906	0.376	0.0857
Finch	1 113 000	54	3	0.1436	19	0.0862	1.293	700 000	40 200	7 544	0.0436	1 110	0.0839	0.0840	0.0842	0.0844	0.0924	0.0935	0.0957	0.0969	0.380	0.0867
Curlew	1 033 500	54	3	0.1384	7	0.1384	1.246	650 000	37 100	7 019	0.0420	1 060	0.0903	0.0905	0.0907	0.0909	0.0994	0.1005	0.1025	0.1036	0.385	0.0878
Cardinal	954 000	54	3	0.1329	7	0.1329	1.196	600 000	34 200	6 479	0.0403	1 010	0.0979	0.0980	0.0981	0.0982	0.1078	0.1088	0.1118	0.1128	0.390	0.0890
Canary	900 000	54	3	0.1291	7	0.1291	1.162	566 000	32 300	6 112	0.0391	970	0.104	0.104	0.104	0.104	0.1145	0.1155	0.1175	0.1185	0.393	0.0898
Crane	874 500	54	3	0.1273	7	0.1273	1.146	550 000	31 400	5 940	0.0386	950	0.107	0.107	0.107	0.108	0.1178	0.1188	0.1218	0.1228	0.395	0.0903
Condor	795 000	54	3	0.1214	7	0.1214	1.093	500 000	28 500	5 399	0.0368	900	0.117	0.118	0.118	0.119	0.1288	0.1308	0.1358	0.1378	0.401	0.0917
Drake	795 000	26	2	0.1749	7	0.1360	1.108	500 000	31 200	5 770	0.0375	900	0.117	0.117	0.117	0.117	0.1288	0.1288	0.1288	0.1288	0.399	0.0912
Mallard	795 000	30	2	0.1628	19	0.0977	1.140	500 000	38 400	6 517	0.0393	910	0.117	0.117	0.117	0.117	0.1288	0.1288	0.1288	0.1288	0.393	0.0904
Crow	715 500	54	3	0.1151	7	0.1151	1.036	450 000	26 300	4 859	0.0349	830	0.131	0.131	0.131	0.132	0.1442	0.1452	0.1472	0.1482	0.407	0.0932
Starling	715 500	26	2	0.1659	7	0.1290	1.051	450 000	28 100	5 193	0.0355	840	0.131	0.131	0.131	0.131	0.1442	0.1442	0.1442	0.1442	0.405	0.0928
Redwing	715 500	30	2	0.1544	19	0.0926	1.081	450 000	34 600	5 865	0.0372	840	0.131	0.131	0.131	0.131	0.1442	0.1442	0.1442	0.1442	0.399	0.0920
Flamingo	666 600	54	3	0.1111	7	0.1111	1.000	419 000	24 500	4 527	0.0337	800	0.140	0.140	0.141	0.141	0.1541	0.1571	0.1591	0.1601	0.412	0.0943
Rook	636 000	54	3	0.1085	7	0.1085	0.977	400 000	23 600	4 319	0.0329	770	0.147	0.147	0.148	0.148	0.1618	0.1638	0.1678	0.1688	0.414	0.0950
Grosbeak	636 000	26	2	0.1564	7	0.1216	0.990	400 000	25 000	4 616	0.0335	780	0.147	0.147	0.147	0.147	0.1618	0.1618	0.1618	0.1618	0.412	0.0946
Egret	636 000	30	2	0.1456	19	0.0874	1.019	400 000	31 500	5 213	0.0351	780	0.147	0.147	0.147	0.147	0.1618	0.1618	0.1618	0.1618	0.406	0.0937
Peacock	605 000	54	3	0.1059	7	0.1059	0.953	380 500	22 500	4 109	0.0321	750	0.154	0.155	0.155	0.155	0.1695	0.1715	0.1755	0.1775	0.417	0.0957
Squab	605 000	26	2	0.1525	7	0.1186	0.966	380 500	24 100	4 391	0.0327	760	0.154	0.154	0.154	0.154	0.1700	0.1720	0.1720	0.1720	0.416	0.0953
Dove	556 500	26	2	0.1463	7	0.1138	0.927	350 000	22 400	4 039	0.0313	730	0.168	0.168	0.168	0.168	0.1849	0.1859	0.1859	0.1859	0.420	0.0965
Eagle	556 500	30	2	0.1362	7	0.1362	0.953	350 000	27 200	4 588	0.0328	730	0.168	0.168	0.168	0.168	0.1849	0.1859	0.1859	0.1859	0.415	0.0957
Hawk	477 000	26	2	0.1355	7	0.1054	0.858	300 000	19 430	3 462	0.0290	670	0.196	0.196	0.196	0.196	0.216				0.430	0.0988
Hen	477 000	30	2	0.1261	7	0.1261	0.883	300 000	23 300	3 933	0.0304	670	0.196	0.196	0.196	0.196	0.216				0.424	0.0980
Ibis	397 500	26	2	0.1236	7	0.0961	0.783	250 000	16 190	2 885	0.0265	590	0.235	Same as dc			0.259	Same as dc			0.441	0.1015
Lark	397 500	30	2	0.1151	7	0.1151	0.806	250 000	19 980	3 277	0.0278	600	0.235				0.259				0.435	0.1006
Linnet	336 400	26	2	0.1138	7	0.0855	0.721	4/0	14 050	2 442	0.0244	530	0.278				0.306				0.451	0.1039
Oriole	336 400	30	2	0.1059	7	0.1059	0.741	4/0	17 040	2 774	0.0255	530	0.278				0.306				0.445	0.1032
Ostrich	300 000	26	2	0.1074	7	0.0835	0.680	188 700	12 650	2 178	0.0230	490	0.311				0.342				0.459	0.1057
Piper	300 000	30	2	0.1000	7	0.1000	0.700	188 700	15 430	2 473	0.0241	500	0.311				0.342				0.462	0.1049
Partridge	266 800	26	2	0.1013	7	0.0788	0.642	3/0	11 250	1 936	0.0217	460	0.350				0.385				0.465	0.1074

*Based on copper 97%, aluminum 61% conductivity.

†For conductor at 75°C, air at 25°C, wind 1.4 miles per hour (2 ft/sec), frequency = 60 Hz.

‡"Current Approx. 75% Capacity" is 75% of the "Approx. Current Carrying Capacity in Amps" and is approximately the current which will produce 50°C conductor temp. (25°C rise) with 25°C air temp., wind 1.4 miles per hour.

...7/-

420

4. (a) (i) **Dalam memodelkan talian penghantaran, talian boleh dimodelkan bergantung kepada jaraknya. Nyatakan TIGA kategori talian penghantaran dan jarak masing-masing dalam kilometer.**

In modeling the transmission lines, lines can be modeled in terms of length. State THREE categories of transmission lines and their corresponding length in kilometer.

(ii) **Jelaskan secara ringkas konsep beban impedan pusuan (SIL) yang digunakan dalam sistem kuasa.**

Explain briefly the concept of surge impedance loading (SIL) used in power systems.

(20%)

(b) **Parameter ABCD suatu talian tiga fasa teralih jarak sederhana, 50 -Hz 345-kV, diberikan seperti berikut:**

The ABCD parameters of a completely transposed, three-phase 50-Hz, 345-kV medium length line are as follows:

$A = 0.9706 \angle 0.159^{\circ}$ per unit

$B = 70.29 \angle 84.78^{\circ}\ \Omega$

$C = 8.277 \times 10^{-4} \angle 90.08^{\circ}$ S

$D = 0.9706 \angle 0.159^{\circ}$ per unit

...8/-

Talian ini membekalkan suatu beban penuh 700 MW beroperasi dengan faktor kuasa 0.99 mendahulu pada voltan talian 95% dari voltan terkadar. Hitungkan:

This line is supplying a full load of 700 MW at 0.99 leading power factor at 95% of rated voltage. Calculate the following:

(i) **Voltan talian V_s, arus talian I_s, dan kuasa nyata P_s hujung hantaran.**
Sending-end line voltage, V_s, line current I_s, and real power P_s.

(ii) **Peratusan regulasi voltan.**
Percent voltage regulation.

(iii) **Efisiensi talian penghantaran pada beban penuh.**
Transmission-line efficiency at full load.

(70%)

(c) (i) **Dalam konfigurasi sistem kuasa umum, konsep fundamental ialah pembahagian sistem kepada zon perlindungan. Terangkan secara ringkas konsep zon perlindungan ini.**

In a more general power system configuration, a fundamental concept is the division of a system into protective zones or zones of protection. State this concept in short.

(ii) **Takrifkan phrasa sistem perlindungan utama dan sistem perlindungan kedua.**

Define the terms primary and backup protection systems.

(10%)

...9/-

5. (a) **Talian penghantaran atas satu fasa, tanpa hilang mempunyai impedan ciri Z_A = 400 Ω, kelajuan gelombang υ_A = 3 x 10^8 m/s, dan panjang ℓ_A = 30 km disambungkan kepada kabel satu fasa, tanpa hilang dengan impedan ciri Z_B = 100 Ω, kelajuan gelombang υ_B = 2 x 10^8 m/s, dan panjang ℓ_B = 20 km. Pada hujung hantaran talian A, satu voltan unit langkah dengan magnitud E volt dikenakan dari punca dc dengan rintangan diri dalaman $Z_s = Z_A$. Hujung terimaan talian B ditamatkan dengan $Z_R = 2\ Z_B$ = 200 Ω. Lakarkan gambarajah kekisi (pantulan) untuk $0 \le t \le 6T$.**

A single-phase lossless overhead line with characteristic impedance of Z_A = 400 Ω, velocity of wave $\upsilon_A = 3 \times 10^8$ m/s, and length ℓ_A = 30 km is connected to a single phase lossless cable with characteristic impedance Z_B = 100 Ω, wave velocity $\upsilon_B = 2 \times 10^8$ m/s, and length ℓ_B = 20 km. At the sending end of line A, a step voltage of magnitude E volts is applied and $Z_S = Z_A$. At the receiving end of line B, $Z_R = 2\ Z_B$ = 200 Ω. Draw the lattice diagram for $0 \le t \le 6T$.

(50%)

(b) **Andai kata sebuah motor induksi tiga fasa, sambungan Y, 500 hp, 50-Hz, 4.16-kV mempunyai efisiensi beban penuh 88%, faktor kuasa 0.75 menyusul. Motor ini disambungkan kepada bas penyuap. Anda dikehendaki membetulkan faktor kuasa beban motor ini menjadi 0.90 menyusul menggunakan bank kapasitor disambungkan pada terminal beban. Hitungkan:**

Assume that a three-phase 500-hp, 50-Hz, 4.16-kV Y-connected induction motor has a full-load efficiency of 88%, a lagging power factor of 0.75, and is connected to a feeder. If is desired to correct the power factor of the load to a lagging power factor of 0.9 by connecting three capacitors at the load. Calculate:

...10/-

(i) **Kadaran bank kapasitor dalam kVARS.**

The rating of the capacitor bank in kVARS.

(ii) **Kapasitan dalam mikrofarad setiap unit (fasa) jika bank kapasitor disambungkan dalam delta (Δ).**

The capacitance in microfarads of each unit if the capacitors are connected in delta (Δ).

(50%)

6. **Tiga transformer satu fasa membentuk suatu bank transformer pengagihan Y - Δ untuk membekalkan kuasa kepada beban tiga fasa seimbang sambungan Y yang menyerap 200 kVA kuasa kompleks pada faktor kuasa 0.8 menyusul dan beroperasi pada voltan talian terkadar sisi keluaran (sekunder) transformer. Anggapkan ketiga-tiga transformer satu fasa mempunyai kadaran serbasama dan setiap satu berkadar 75 kVA, 12,470/415 V.**

Three single-phase transformers are connected in Y - Δ to supply power to a balanced three-phase Y-connected 200-kVA load with a 0.8 lagging power factor operating at rated line voltage of output side transformer. Assume that the three single-phase transformers have equal ratings and each is rated at 75 kVA, 12,470/415 V.

...11/-

(a) Lakarkan gambarajah skematik menunjukkan sambungan bank transformer.

Draw the schematic diagram showing the connection.

(25%)

(b) Tentukan nilai-nilai voltan dan arus fasa dan talian dalam kedua-dua belitan bank transformer (sisi utama dan sisi sekunder).

Determine the values of phase and line voltage and current in both primary and secondary-side of the transformer bank.

(75%)

- oooOooo -