

Расчёт сети в минимальном режиме  
Подстанция № 1

$$P_{\min} = 35 \% \cdot P_{\max} = 0,35$$

$$(P_1 + jQ_1) \cdot 0,2 = (20 + j10,2) \cdot 0,35 = 7 + j3,58$$

$$\Delta P = \frac{P^2 + Q^2}{U_n^2} \cdot r_{mp} = \frac{7^2 + 3,58^2}{115^2} \cdot 7,7 = 0,0098 \text{ MBm}$$

$$\Delta Q = \frac{P^2 + Q^2}{U_n^2} \cdot x_{mp} = \frac{7^2 + 3,58^2}{115^2} \cdot 190 = 0,24 \text{ Mвар}$$

$$P^i + jQ^i = (P + \Delta P) + j(Q + \Delta Q) = (7 + 0,0098) + j(3,58 + 0,24) = 7,0098 + j3,82$$

$$\Delta P_0 = 0,09 \text{ MBm} \quad Q_\mu = 0,32 \text{ Mвар}$$

$$P^{II} + jQ^{II} = (P^i + \Delta P_0) + j(Q^i + \Delta Q_\mu) = (7,0098 + 0,09) + j(3,82 + 0,32) = 7,0998 + j4,14$$

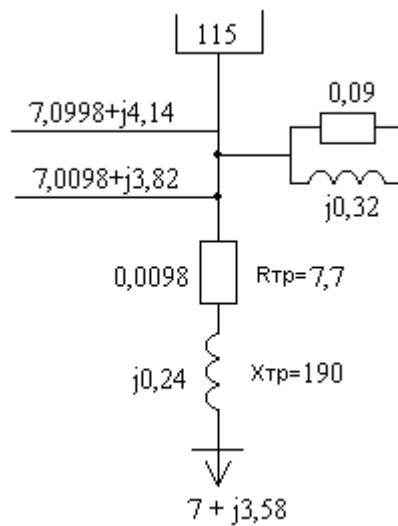


рис.16

Подстанция №2

$$P_{\min} = 35\% \cdot P_{\max} = 0,35$$

$$(P_2 + jQ_2) \cdot 0,15 = (38 + j17,9) \cdot 0,35 = 12,25 + j6,27$$

$$\Delta P_2 = \frac{P^2 + Q^2}{U_n^2} \cdot \frac{r_{mp}}{2} = \frac{12,25^2 + 6,27^2}{115^2} \cdot \frac{3,33}{2} = 0,0059 \text{ MBm}$$

$$\Delta Q_2 \approx 0 \text{ Mвар}$$

$$P_2^i + jQ_2^i = (P_2 + \Delta P_2) + j(Q_2 + \Delta Q_2) = (12,25 + 0,0059) + j(6,27 + 0) = 12,2559 + j6,27$$

$$(P_3 + jQ_3) \cdot 0,35 = (25 + j12,6) \cdot 0,35 = 8,75 + j4,479$$

$$\Delta P_3 = \frac{P^2 + Q^2}{U_n^2} \cdot \frac{r_{mp}}{2} = \frac{8,75^2 + 4,479^2}{115^2} \cdot \frac{3,33}{2} = 0,003 \text{ MBm}$$

$$\Delta Q_3 = \frac{P^2 + Q^2}{U_n^2} \cdot \frac{x_{mp}}{2} = \frac{8,75^2 + 4,479^2}{115^2} \cdot \frac{193}{2} = 0,175 \text{ Mвар}$$

$$P_3^i + jQ_3^i = (P_3 + \Delta P_3) + j(Q_3 + \Delta Q_3) = (8,75 + 0,003) + j(4,479 + 0,175) = 8,753 + j4,654$$

$$P_1 + Q_1 = (P_2^i + P_3^i) + j(Q_2^i + Q_3^i) = (8,753 + 12,2559) + j(4,654 + 6,27) = 21,0089 + j10,924$$

$$\Delta P_1 = \frac{P^2 + Q^2}{U_n^2} \cdot \frac{r_{mp}}{2} = \frac{21,0089^2 + 10,924^2}{115^2} \cdot \frac{3,33}{2} = 0,0176 \text{ MBm}$$

$$\Delta Q_1 = \frac{P^2 + Q^2}{U_n^2} \cdot \frac{x_{mp}}{2} = \frac{21,0089^2 + 10,924^2}{115^2} \cdot \frac{100,7}{2} = 0,53 \text{ Mвар}$$

$$P_1^i + jQ_1^i = (P_1 + \Delta P_1) + j(Q_1 + \Delta Q_1) = (21,0089 + 0,0176) + j(10,924 + 0,53) = 21,0278 + j10,2973$$

$$\Delta P_0 = 0,074 \text{ MBm} \quad Q_\mu = 0,63 \text{ Mвар}$$

$$P^{II} + jQ^{II} = (P_1^i + \Delta P_0) + j(Q_1^i + \Delta Q_\mu) = (21,0278 + 0,074) + j(10,2973 + 0,063) = 21,1018 + j10,3603$$

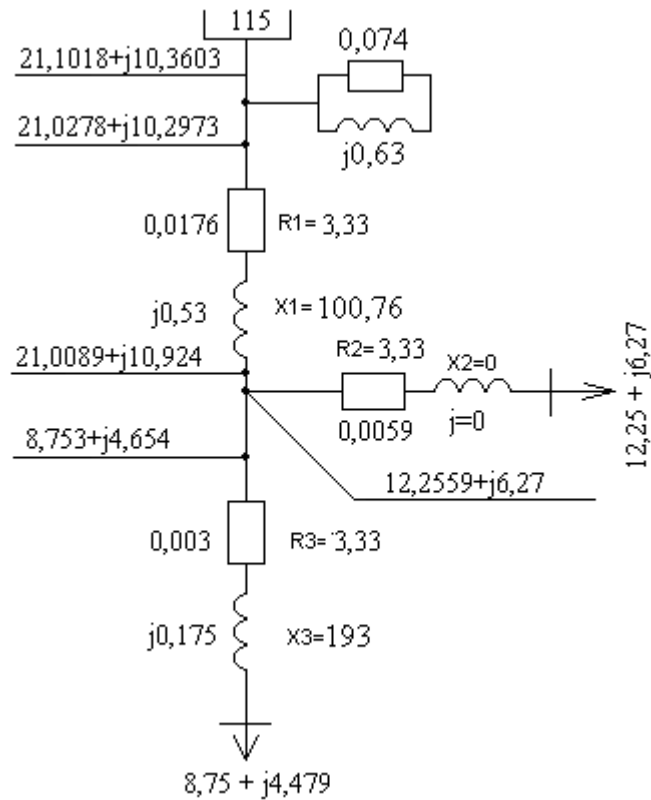


рис.17

Подстанция №3

$$P_{\min} = 35 \% \cdot P_{\max} = 0,35$$

$$(P_1 + jQ_1) \cdot 0,35 = (40 + j20,39) \cdot 0,35 = 14 + j15,73$$

$$\Delta P = \frac{P^2 + Q^2}{U_n^2} \cdot \frac{r_{mp}}{2} = \frac{14^2 + 15,73^2}{115^2} \cdot \frac{7,7}{2} = 0,0179 \text{ МВт}$$

$$\Delta Q = \frac{P^2 + Q^2}{U_n^2} \cdot \frac{x_{mp}}{2} = \frac{14^2 + 15,73^2}{115^2} \cdot \frac{190}{2} = 0,44 \text{ Мвар}$$

$$P^i + jQ^i = (P + \Delta P) + j(Q + \Delta Q) = (14 + 0,0179) + j(15,73 + 0,44) = 14,0179 + j7,61$$

$$\Delta P_0 = 0,09 \text{ МВт} \quad Q_\mu = 0,256 \text{ Мвар}$$

$$P^{II} + jQ^{II} = (P^i + \Delta P_0) + j(Q^i + \Delta Q_\mu) = (14,0179 + 0,09) + j(7,61 + 0,256) = 14,1079 + j7,866$$

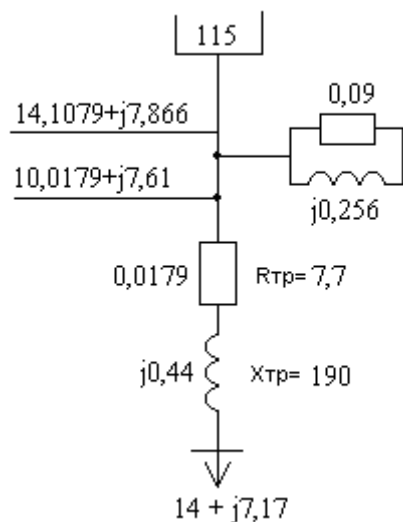


рис.18

Определяем параметры линии

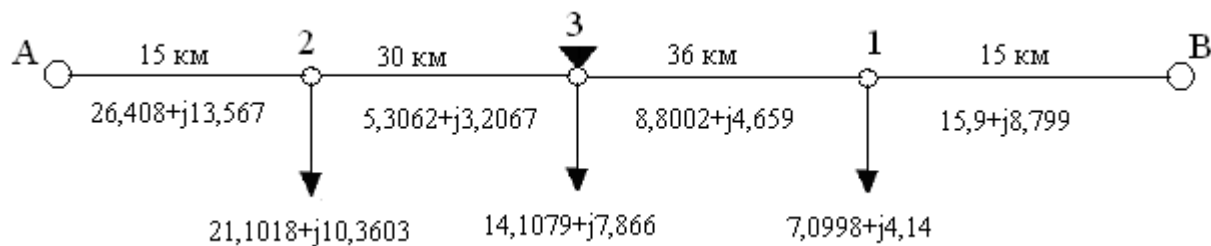


рис.19

$$P_A = \frac{\sum P_i l_i}{L_A} = \frac{7,0998 \cdot 15 + 14,1079 \cdot 51 + 21,1018 \cdot 81}{96} = 26,408 \text{ MВт}$$

$$Q_A = \frac{\sum Q_i l_i}{L_A} = \frac{4,14 \cdot 15 + 7,866 \cdot 51 + 10,3603 \cdot 81}{96} = 13,567 \text{ Мвар}$$

$$P_B = \frac{\sum P_i l_i}{L_A} = \frac{621,1018 \cdot 15 + 14,1079 \cdot 45 + 7,0998 \cdot 81}{96} = 15,9 \text{ MВт}$$

$$Q_B = \frac{\sum Q_i l_i}{L_A} = \frac{10,3603 \cdot 15 + 7,866 \cdot 45 + 4,14 \cdot 81}{96} = 8,799 \text{ Мвар}$$

Проверка

$$P_A + P_B = P_1 + P_2 + P_3$$

$$21,1018 + 14,1079 + 7,0998 = 42,3085$$

$$Q_A + Q_B = Q_1 + Q_2$$

$$10,3603 + 7,866 + 4,14 = 22,3663$$

Производим расчёт мощностей в режиме минимальных нагрузок

Участок 3-2

$$S_{3-2} = P_I + j(Q_I - Q_B) = 5,3062 + j(3,2067 - 4,036) = 5,3062 - j0,8293$$

$$\Delta P_{3-2} = \frac{P^2 + Q^2}{U_H^2} \cdot r_{3-2} = \frac{5,3062^2 + 0,8293^2}{110^2} \cdot 3,66 = 0,0019 \text{ МВт}$$

$$\Delta Q_{3-2} = \frac{P^2 + Q^2}{U_H^2} \cdot x_{3-2} = \frac{5,3062^2 + 0,8293^2}{110^2} \cdot 12,24 = 0,0066 \text{ Мвар}$$

$$S = S_{3-2} + \Delta S = (P_I + \Delta P) + j(Q_I + \Delta Q) = (5,3062 + 0,0019) + j(0,8293 - 0,0066) = 5,3081 - j0,8197$$

$$S_{3-2} = P_{II} + j(Q_{II} - Q_B) = 5,3081 + j(0,8197 + 4,036) = 5,3081 + j4,8557$$

Участок 2-А

$$S = (P_{3-2} + P_{2-A}) + j(Q_{3-2} + Q_{2-A}) = (5,3081 + 21,1018) + j(10,3603 - 4,8557) = 26,4099 + j5,5046$$

$$S_{2-A} = P_I + j(Q_I - Q_B) = 26,4099 + j(5,5046 - 2,018) = 26,4099 + j3,4866$$

$$\Delta P_{2-A} = \frac{P^2 + Q^2}{U_H^2} \cdot r_{2-A} = \frac{26,4099^2 + 3,4866^2}{110^2} \cdot 1,83 = 0,024 \text{ МВт}$$

$$\Delta Q_{2-A} = \frac{P^2 + Q^2}{U_H^2} \cdot x_{2-A} = \frac{26,4099^2 + 3,4866^2}{110^2} \cdot 6,12 = 0,085 \text{ Мвар}$$

$$S = S_{2-A} + \Delta S = (P_I + \Delta P) + j(Q_I + \Delta Q) = (26,4099 + 0,024) + j(3,4866 + 0,085) = 26,4339 + j3,5686$$

$$S_{2-A} = P_{II} + j(Q_{II} - Q_B) = 26,4339 + j(3,5686 + 2,018) = 26,4339 + j4,659$$

Участок 3-1

$$S_{3-1} = P_I + j(Q_I - Q_B) = 8,8002 + j(4,659 - 4,84) = 8,8002 - j0,181$$

$$\Delta P_{3-1} = \frac{P^2 + Q^2}{U_H^2} \cdot r_{3-1} = \frac{8,8002^2 + 0,181^2}{110^2} \cdot 4,392 = 0,0064 \text{ МВт}$$

$$\Delta Q_{3-1} = \frac{P^2 + Q^2}{U_H^2} \cdot x_{3-1} = \frac{8,8002^2 + 0,181^2}{110^2} \cdot 17,28 = 0,025 \text{ Мвар}$$

$$S = S_{3-1} + \Delta S = (P_I + \Delta P) + j(Q_I + \Delta Q) = (8,8002 + 0,0064) + j(0,181 + 0,025) = 8,8066 - j0,156$$

$$S_{3-1} = P_{II} + j(Q_{II} - Q_B) = 8,8066 + j(0,156 + 4,84) = 8,8066 + j4,996$$

Участок 1-В

$$S=(P_{3-1}+P_{1-B})+j(Q_{3-1}+Q_{1-B})=(8,8066+7,0998)+j(4,966-4,14)=15,9064-j0,856$$

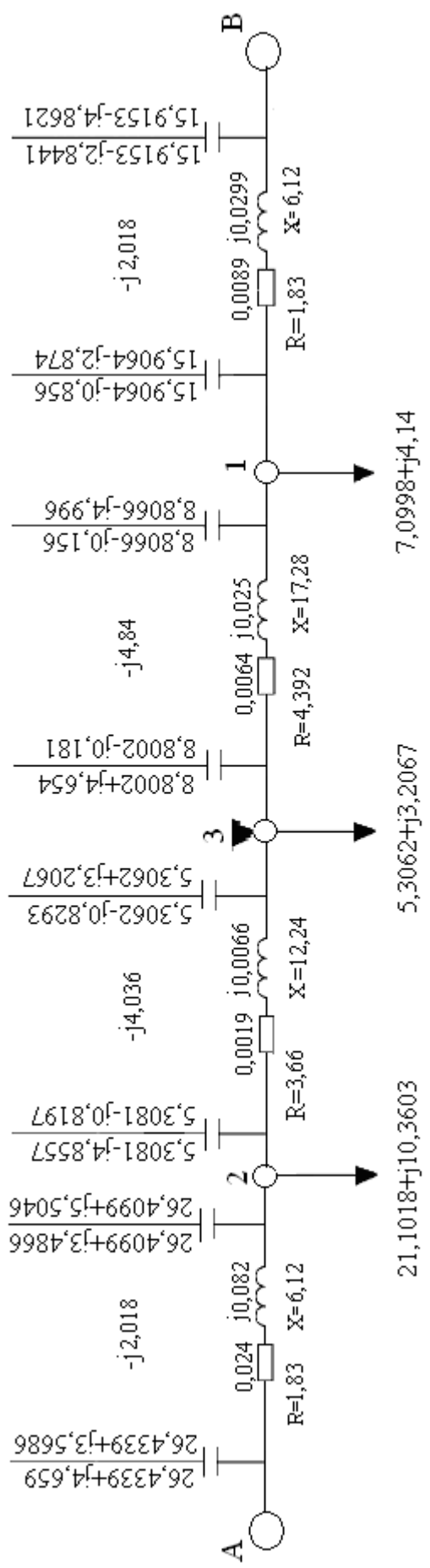
$$S_{1-B}=P_I+j(Q_I-Q_B)=15,9064+j(-0,856-2,018)=15,9064-j2,874$$

$$\Delta P_{1-B}=\frac{P^2+Q^2}{U_H^2}\cdot r_{1-B}=\frac{15,9064^2+2,874^2}{110^2}\cdot 1,83=0,0089 \text{ MBm}$$

$$\Delta Q_{1-B}=\frac{P^2+Q^2}{U_H^2}\cdot x_{1-B}=\frac{15,9064^2+2,874^2}{110^2}\cdot 6,12=0,0299 \text{ Mvar}$$

$$S=S_{1-B}+\Delta S=(P_I+\Delta P)+j(Q_I+\Delta Q)=(15,9064+0,0089)+j(2,874-0,0299)=15,9153+j2,8441$$

$$S_{1-B}=P_{II}+j(Q_{II}-Q_B)=15,9153+j(-2,8441-2,018)=15,9153+j4,8621$$



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## Аварийный режим

### Участок 3-2

$$S_{3-2} = P_I + j(Q_I - Q_B) = 60,2922 + j(36371 - 4,036) = 60,2922 - j32,335$$

$$\Delta P_{3-2} = \frac{P^2 + Q^2}{U_H^2} \cdot r_{3-2} = \frac{60,2922^2 + 32,335^2}{110^2} \cdot 3,66 = 0,322 \text{ МВт}$$

$$\Delta Q_{3-2} = \frac{P^2 + Q^2}{U_H^2} \cdot x_{3-2} = \frac{60,2922^2 + 32,335^2}{110^2} \cdot 12,24 = 1,077 \text{ Мвар}$$

$$S = S_{3-2} + \Delta S = (P_I + \Delta P) + j(Q_I + \Delta Q) = (60,2922 + 0,322) + j(32,335 + 1,077) = 60,6142 + j33,412$$

$$S_{3-2} = P_{II} + j(Q_{II} - Q_B) = 60,6142 + j(33,412 - 4,036) = 60,6142 + j29,376$$

### Участок 3-1

$$S = (P_{2-3} + P_{3-1}) + j(Q_{3-1} + Q_{2-3}) = (60,6142 + 40,236) + j(29,376 + 24,256) = 100,8502 - j53,632$$

$$S_{3-1} = P_I + j(Q_I - Q_B) = 100,8502 + j(53,632 - 4,84) = 100,8502 + j48,792$$

$$\Delta P_{3-1} = \frac{P^2 + Q^2}{U_H^2} \cdot r_{3-1} = \frac{100,8502^2 + 48,792^2}{110^2} \cdot 4,392 = 1,04 \text{ МВт}$$

$$\Delta Q_{3-1} = \frac{P^2 + Q^2}{U_H^2} \cdot x_{3-1} = \frac{100,8502^2 + 48,792^2}{110^2} \cdot 17,28 = 4,09 \text{ Мвар}$$

$$S = S_{3-1} + \Delta S = (P_I + \Delta P) + j(Q_I + \Delta Q) = (100,8502 + 1,04) + j(48,792 + 4,09) = 101,8902 + j53,632$$

$$S_{3-1} = P_{II} + j(Q_{II} - Q_B) = 101,8902 + j(53,632 - 4,84) = 101,8902 + j48,042$$

### Участок 1-В

$$S = (P_{3-1} + P_{1-B}) + j(Q_{3-1} + Q_{1-B}) = (101,8902 + 20,163) + j(48,042 + 12,32) = 122,0532 + j60,362$$

$$S_{1-B} = P_I + j(Q_I - Q_B) = 122,0532 + j(60,362 - 2,018) = 122,0532 - j58,344$$

$$\Delta P_{1-B} = \frac{P^2 + Q^2}{U_H^2} \cdot r_{1-B} = \frac{122,0532^2 + 58,344^2}{110^2} \cdot 1,83 = 0,63 \text{ МВт}$$

$$\Delta Q_{1-B} = \frac{P^2 + Q^2}{U_H^2} \cdot x_{1-B} = \frac{122,0532^2 + 58,344^2}{110^2} \cdot 6,12 = 2,11 \text{ Мвар}$$

$$S = S_{1-B} + \Delta S = (P_I + \Delta P) + j(Q_I + \Delta Q) = (122,0532 + 0,63) + j(58,344 + 2,11) = 122,6832 + j60,454$$

$$S_{1-B} = P_{II} + j(Q_{II} - Q_B) = 122,6832 + j(60,454 - 2,018) = 122,6832 + j58,436$$



