Ministry of Energy of the Russian Federation
Ministry of Education and Science of the Russian Federation
Ivanovo State Power Engineering University (ISPEU)
Open joint stock company "System Operator of United Power System" (SO UPS)
“Russian National Committee of International Council on Large Electric Systems” (CIGRE RNC)
Charitable foundation «Reliable Rising Generation» JSC "Schneider Electric"

ELECTRICAL POWER ENGINEERING-2014

INTERNATIONAL STUDENT COMPETITION ON ELECTRICAL POWER ENGINEERING, IVANOVO, RUSSIA, NOVEMBER 18-22, 2014

TASK FOR SELF-EDUCATION FROM POWER ENGINEERING 2013

CHIPER:	
Task 1	***15 points***

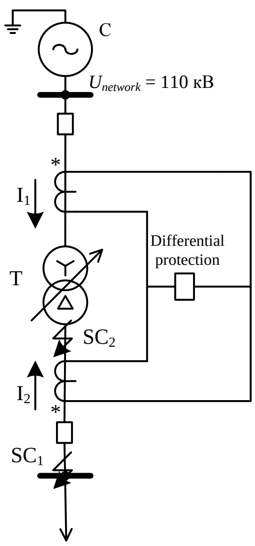


Fig. 1

A restrained differential current protection is installed on a transformer (Fig.1). The operating characteristic is shown in Fig.2.

Calculate the operating characteristic restraining coefficient and assess the sensitivity of protection.

Source data:

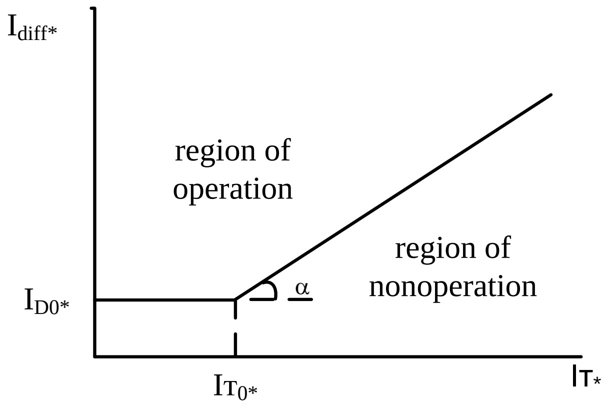


Fig.2

$$I_{диф} = \left|\dot{I}_1 + \dot{I}_2\right|, \quad I_T = 0{,}5 \cdot \left(\left|\dot{I}_1\right| + \left|\dot{I}_2\right|\right)$$

Minimum operating current I_{D0*} = 0,3 pu
Restraining start current I_{T0*} = 1 pu
Maximum external through fault current $I_{ext.max*}$ = 3,5 pu
Minimum internal through fault current $I_{int.min*}$ = 2,5 pu
Depredation factor K_{depr} = 1,3, coefficient taking into account the transient K_{trans} = 2, current transformers error ε=0,1, current transformers uniformity coefficient K_{uni}=1, under voltage control error ΔU_*=0,16 pu, error of fitting Δf_{fit}=0,02. $K_{ч.мин.доп}$ = 2.

Solution

CHIPER:	
Task 2	***35 points***

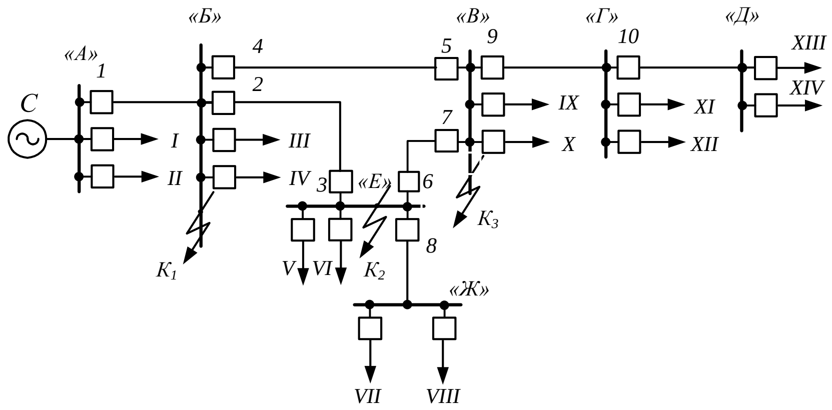


Fig. 2.

Directed and undirected definite time stepped current protections are installed on 35 kV lines (Fig.2).

1. Determine which protections should be directed.

2. Select the time settings for *1, 2, 3, 4, 5, 6, 7, 8, 9, 10* overcurrent protections.

3. Select $I_{cuttoff1}$ и $I_{overcurrent1}$. Write an approach for setting choice

4. Assess the sensitivity of overcurrent protection 1.

Source data: $I^{(3)}_{K1max}$ = 2,8 kA; $I^{(2)}_{protection\ K1min}$ = 1,8 kA; $I^{(2)}_{protection\ K2min}$ = 1,2 kA; $I^{(2)}_{protection\ K3min}$ = 0,63 kA; $I_{dynamic\ current\ max}$ = 0,2 kA.

For protection: Δt=0,5 s; K = 1,5; K_{reset} = 0,95; K_{omcMT3} = 1,2; K_{omcTO} = 1,3.

Time settings for outgoing lines I -XIV:

t_I	t_{II}	t_{III}	t_{IV}	t_V	t_{VI}	t_{VII}	t_{VIII}	t_{IX}	t_X	t_{XI}	t_{XII}	t_{XIII}	t_{XIV}
1	1.1	0.9	2.7	0.5	2.1	0	0.5	2.2	1.5	1.8	0.8	1.5	1

Solution

CHIPER:	
Task 3	***15 points***

The substation is supplied by 10 kV power transmission line 5 km in length. The line wire is AC-50/8 (r_0 = 0,603 Ohm/km; x_0 = 0,388 Ohm/km). Transmitted over the transmission line power is 1200 + j·1050 kVA.

Goal: to determine the capacity of the capacitor bank, which must be installed on the substation 10 kV side to decrease the voltage loss to a value of 5% of the rated voltage.

Solution

CHIPER:	
Task 4	***35 points***

Two transformers ТДН-16000/110 ($\Delta P_{s/c}$ = 85 kW, ΔP_{noload} = 19 kW), operating in parallel are installed on a substation. Graph of load changes during the year is shown in Fig. 1. The maximum load of the substation is P_1 = 20 MW. During the year, the lowest load is $P_2 = \alpha \cdot P_1$, value α varies in the range 0,3 ÷ 0,6. Power factor is not changed during the year and is equal to 0.9.

Goal:

1. Determine at what values of α it is economically feasible to off one of the transformers at the lowest load.

2. Determine the active power and electricity losses in transformers for the year if you disable one of the transformers at the lowest load (α = 0,3).

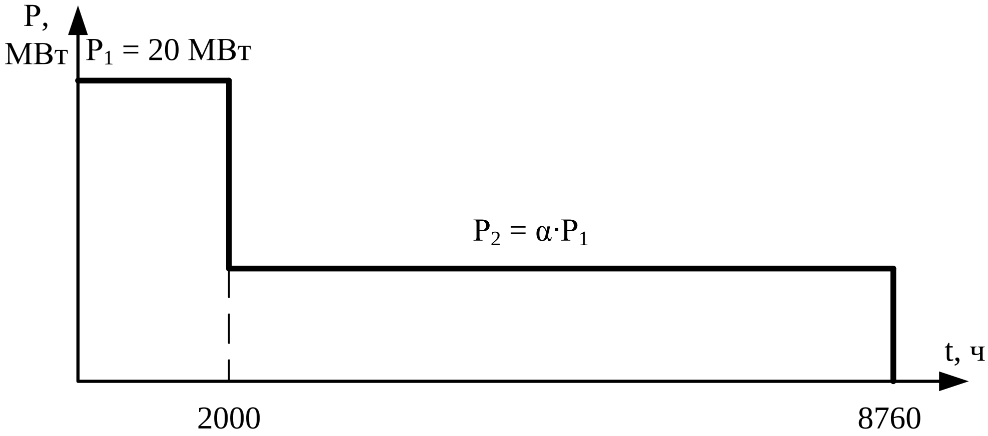


Fig. 1 Graph of active load behavior

Solution

CHIPER:	
Task 5	***15 points***

Total load of enterprise workshops ($\dot{S}p = 12365 + j8084\,\kappa B \cdot A$) is connected to main step-down substation 10 kV buses (Fig.1). Two synchronous motors STD type are connected to the same buses. Capacity of each motor is P_{nom} = 800 kW, leading power factor is equal to 0,9 and active power capacity factor β = 0,85.

Determine the type and the required capacity of 10 kV capacitor bank, if the value of $tg\ \varphi$ on 10 kV buses should not exceed 0.3.

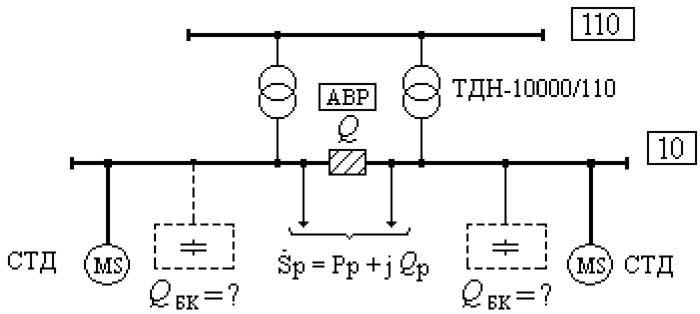


Fig. 1.

Solution

CHIPER:	
Task 6	***35 points***

A new electric arc furnace DSP-5 is connected to main step-down substation 10 kV buses (Fig.1).

Goal:

- determine the range of voltage variation at DSP-5 connection point (10 kW bus section) for operating mode of transformers T_1 and T_2, shown in Figure 1;
- draw a conclusion on the admissibility of voltage fluctuations if the length of the melt period is 10 min and the rate of occurrence of voltage changes is 0.3 s^{-1}.

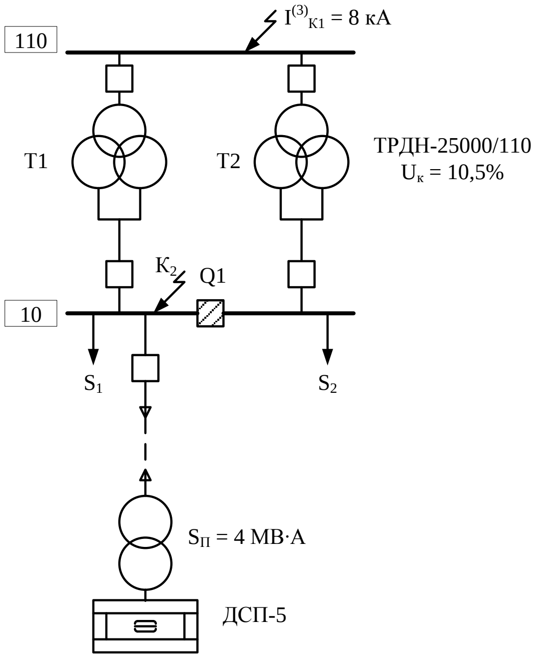


Fig. 1.

Solution

CHIPER:	
Task 7	***15 points***

High-voltage inputs of three-phase 35 kV electrical installation have form of a coaxial cylindrical system with two-layer insulation. The first layer - Bakelite (ε=3,5), the second layer - silicone rubber (ε=7). Calculate the value of the electric field at the boundaries of the insulating layers and in the middle of insulation layers of high voltage inputs when exposed to the rated voltage of industrial frequency.

Source data:

- the radius of the current-carrying rod - 4 mm;
- the outer radius of the first layer - 14 mm;
- the outer radius of the second layer - 20 mm.

Solution

CHIPER:	
Task 8	35 points

The voltage wave with an amplitude of 600 kV spreads on overhead line after a lightning strike. At a distance of 1 km from the point of impact the overhead line is connected to the cable line. At the connection point a high-frequency choke with an inductance of 2 mH is installed. Calculate and plot refracted $U_{refr}(t)$ and reflected $U_{refl}(t)$ waves. Plot potential distribution along the length of the lines in 5 ms after a lightning strike.

In calculations assume that the overvoltage wave has infinite length and rectangular front. Line parameters per unit length $L_{0OVHLine}$=1,33 μH/m, $C_{0OVHLine}=8,33\times10^{-12}$ F/m, $L_{0CableLine}$=0,67 μH/m, $C_{0CableLine}=67\times10^{-12}$ F/m.

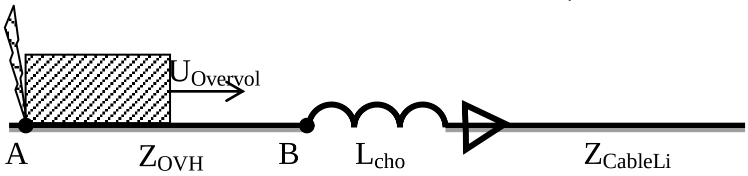


Fig. 1. Network layout with the choke

Solution

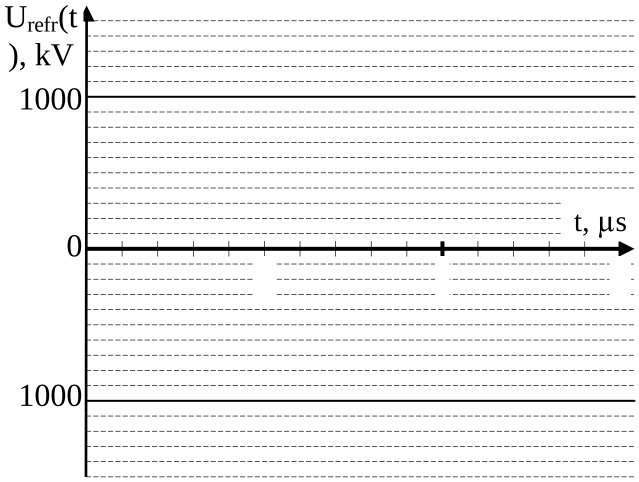


Fig. 2. The refracted wave $U_{refr}(t)$

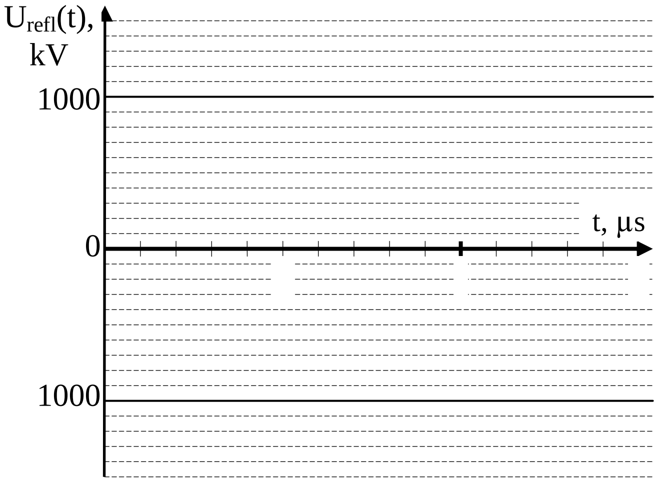


Fig. 3. The reflected wave $U_{refr}(t)$

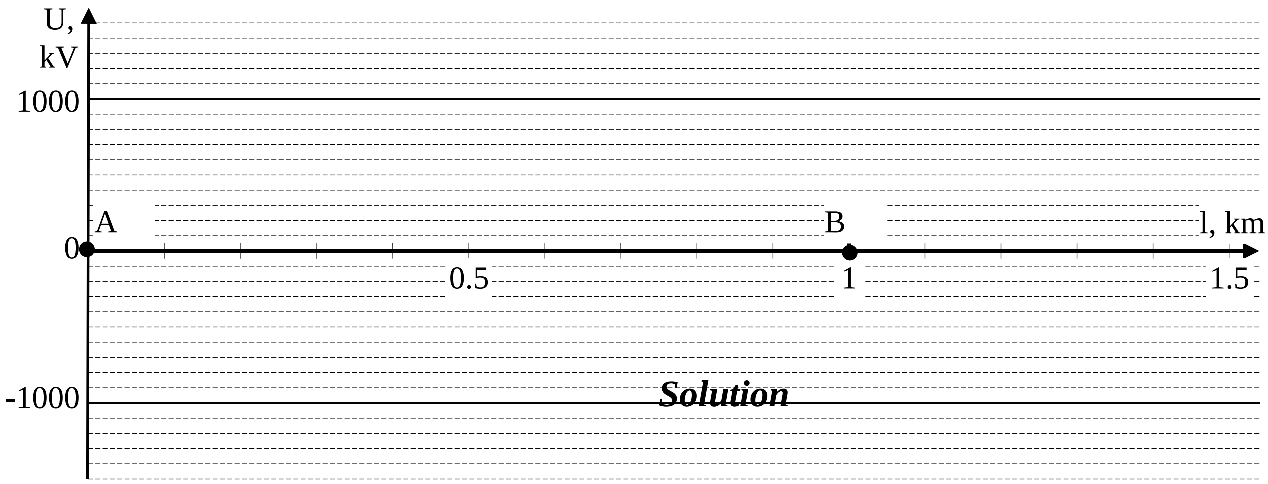
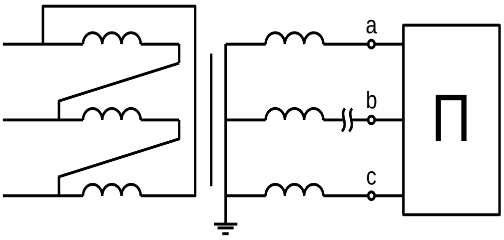


Fig. 4. Potential distribution along the power transmission line at t=5 μs

CHIPER:	
Task 9	***15 points***



A symmetrical three-phase resistive receiver which phases are connected in a "triangle" is connected to the secondary winding of the transformer (Δ/Y) 6,0/0,38 kV. $P_{receiver}$=6 kW.

Determine the values of a, b and c potentials relative to the ground if line conductor from the transformer to point b is broken.

Solution

CHIPER:	
Task 10	*35 points*

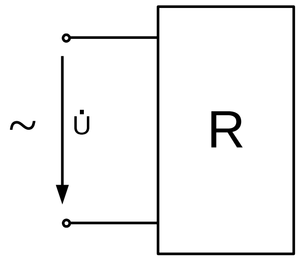


Рис. 1.

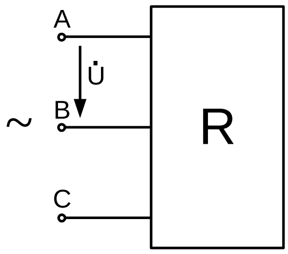


Рис. 2.

A resistive receiver, which is connected to the single-phase circuit with a voltage U is shown on Fig. 1. A symmetrical three-phase resistive receiver, which is connected to the three-phase circuit, the line voltage in it is equal to the voltage in the single-phase circuit. Wire length, material, and the current density in the wires of single-phase and three-phase circuits are the same. Determine the ratio between the masses of the single-phase and three-phase power supply circuits wires if the single-phase receiver power and three-phase receiver power are equal.

Solution

CHIPER:	
Task 11	***15 points***

Select the conductive part between the generator and the main transformer of the unit. The unit diagram is shown on Fig. 1.

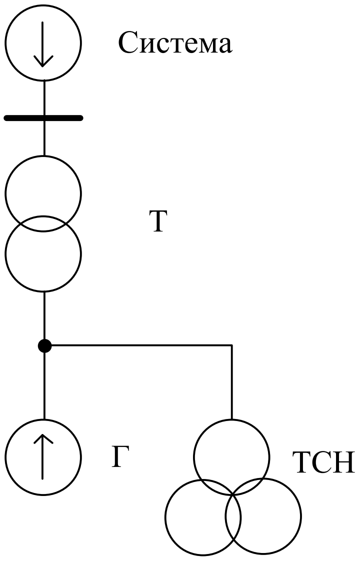


Fig. 1. The unit diagram

Note: 1) the unit power is 300 MW; 2) short-circuit power of the system is 6,500 MVA; 3) auxiliary transformer power is 25 MVA.

Solution

CHIPER:	
Task 12	***35 points***

Figure 1 shows the power circuit of the motor M.

Source data:

1. The initial RMS value of the periodic component of the three-phase short-circuit current at the point $I_{п,0}^{(3)} = 15$ kA.
2. The time constant of the aperiodic component of the three-phase short-circuit current at the point $T_a = 0,06$ s.
3. A cable with aluminum conductors with paper-oil impregnated insulation without armor with $q = 95$ mm^2 section is selected under the terms of the continuous mode.
4. Tripping time of the primary relay protection is equal to 0.1 s, the backup protection - 0.8 s.

The circuit-breaker total break time $t_{OB} = 0,07$ s.

Additional data:

1. The reciprocal of the temperature coefficient of resistance, $a = 228$ ^{0}C.
2. Constant characterizing the thermal properties of aluminum $b = 45,25\ (\frac{мм^4}{кА^2 \cdot c})$.
3. The initial temperature of the cable (pre-load) $\Theta_н = 65$^{0}C.

Goal: check out the pre-selected cable on thermal stability and noncombustibility condition.

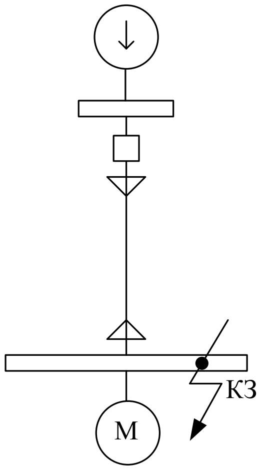


Fig. 1. The scheme of power plant power distribution

Solution: