MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
"ZAPORIZHZHIA POLYTECHNIC" NATIONAL UNIVERSITY

Methodical instructions for the course project on the subject:

"HIGH VOLTAGE APPARATUS"
for the students of the specialty
141 – "Power, Electrical and Electromechanical Engineering"
(educational program "Electric and Electronic Apparatus")

2020

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CONTENT

1 REGUEST FOR PROPOSAL AND CONTENTS OF THE COURSE PROJECT

The course project of the “High voltage apparatuses” course is made in accordance with the task.

The work purpose is to study the engineering methods of the electrical apparatuses calculation and designing. The quantity of pages of explanatory note may be 30 or 40, including necessary graphs, figures and tables. The graphic part of the project contains 2 A1 drawings. The first including necessary sectional views, which are necessary. Second draught is detail drawing. The graphic part and explanatory note must meet the demands of “ДСТУ 3008:2015”

The explanatory report content is the following

- the request for proposal;
- the introduction;
- the feasibility study of the designing construction;
- the general arrange of the apparatus construction;
- the electrical insulation calculation;
- the electrical, mechanical and heat calculation of single parts of apparatus;
- the apparatus construction description;
- the conclusions;
- the list of references.

The general information about this parts performance is adduced at the [1].

2 THE COMMUTATION AND PROTECTION APPARATUSSES OF THE SWITCH – GEAR.

Some types of this apparatuses have the following general parameters:

- disposition type (internal or external);
- climatic construction;
- accessories – fixing type (internal or external);
- insulation category (normal or intensified);
- nominal current;
- nominal voltage;

- the thermal stability current;
- the dynamic stability current.

Some apparatuses have specific parameters:

- for switches – construction type, Nominal interruption current (power), drive type;
- for current transformers – construction type, nominal secondary current, the secondary winding type (for measurement or for relay protection), the accuracy class, secondary power;
- for voltage transformers – construction type, the accurate class, secondary power, the connection circuit;
- for arresters – construction type, time – voltage characteristic, (discharge voltage);
- for fuses - construction type, the peak current (power), the speed of operation.

2.1 Factory – assembled switch – gear

The factory – assembled switch – gear consists of many apparatus. Their parameters (disposition type, the nominal parameters, condition of work under the short circuit regime, the admissible values of over voltage) must be coordinated. The initial data is represented at the table 2.1.

The recommended literature is [1,2-6].

Table 2.1 – Initial data for “Factory – assembled switch – gear” theme

Version	Nominal voltage Un, kV	Switch type	Nominal Current In, A	Nominal switch current Is.n., kA	Thermal stability current It, kA	Short circuit current time S	Dynamic Stability Current Id, kA
1	10	ВВ	400	31.5	20	4	51
2	10	ВВ	630	20	31.5	3	83
3	10	ВВ	1250	31.5	22	2	72
4	10	ВВ	2000	22	24	1	54
5	10	ВВ	3150	24	21	2	76
6	10	ВМП	1000	26	23	3	58
7	10	ВМП	800	28	26	4	60

Continues of table2.1.

8	10	ВВ	1600	30	28	3	62
9	10	ВК	1800	27	25	2	64
10	10	ВК	2400	23	27	1	76
11	10	ВЭ	1450	31.5	21	3	55
12	10	ВЭ	2500	20	30	2	57
13	10	ВЭ	3600	29	22	4	59
14	10	ВК	1500	27	29	3	68
15	10	ВК	3000	28	23	2	52
16	35	ВВ	2000	31.5	20	2	80

2.2 SF_6 gas factory – assembled switch – gear

The SF_6 gas factory – assembled switch – gear is the aggregate of the apparatuses which are disposed at the sealed metallic jacket with SF_6. Some apparatuses may be connected together by the flanges and condensation devices.

The initial data is represented at the table 2.2.

The recommended literature [1,2,3,4,5,6].

Table 2.2 – Initial data for "SF_6 factory assembled switch – gear" theme

Version	Nominal voltagUn, kV	Nominal Current In, A	Dynamic Stability Current Id, kA	Thermal stability current It, kA	Unit type	Collecting buses	
						System quantity	Poles quantity
1	220	1250	60	25	Transmission line	2	1
2	330	----	130	63	With voltage transformer	1	1
3	220	2500	110	50	Bus connection	2	1
4	110	2000	95	40	Sectionalizing switch	2	3
5	110	1600	80	31	Air entrance	1	3

2.3 Disconnector

T he disconnector has some peculiarities:

- there is visible air interval between the contacts during manual – off position;
- it may have one two grounded contact systems;
- it must have block – system of the load – carrying and grounded contacts.

The initial data is represented at the table 2.3
The recommended literature [1-5].

Table 2.3 – Initial data for the “Disconnector” theme

Version	Nominal voltage Un, kV	Nominal Current In, A	Dynamic Stability Current Id, kA	Thermal stability current It, kA	Grounded con-tacts	Poles quantity and insulator type	Contact movement	Altitude above sea level
1	10	400	41	16	---	1 Bushing	Vertical	2500
2	10	1000	100	40	1	3 Pedestal	Vertical	3000
3	10	630	35.5	12.5	---	3 Pedestal	Horizontal	1500
4	35	2000	80	31.5	1	3 Pedestal	Horizontal	1000
5	110	2500	125	50	1	3 Pedestal	Horizontal	1800

Continues of table2.3

6	220	1500	110	45	1	3 Pedestal	Horizontal	400
7	330	3000	140	60	2	1 Pedestal	Horizontal	2200
8	500	3500	160	80	1	1 Pedestal	Suspension	2800
9	1150	4000	100	40	1	1 Pedestal Suspension	Suspension	800
10	500	3200	160	63	---	3 Pedestal Suspension	Suspension	1600

2.4 Insulating switch and grounding switch

The insulating switches have the same peculiarities as disconnections. Besides it is necessary to take into account higher speed of operation, which is about 0.3 – 0.25s and higher dynamic and thermal stability.

The initial data is represented at the table 2.4.

The recommended literature [1 – 5]

Table 2.4 – Initial data for the “Insulating switch and grounding switch” theme

Version	Nominal voltage Un, kV	Nominal Current In, A	Dynamic Stability Current Id, kA	Thermal stability current It, kA	Grounded contacts quantity	Poles quantity	Altitude above sealevel H, m
J-1	35	630	80	12.5	3	3	2500

Continues of table2.4

J-2	110	1000	81	31.5	1	1	2800
J-3	220	1000	100	31.5	1	1	3100
J-4	150	1250	90	25	1	1	800
G-5	24	---	235	90/1	---	3	3200
G-6	110	---	16	63/3	---	1	2300
G-7	330	---	160	63/1	---	1	300
G-8	500	---	120	40/1	---	1	2100

2.5 Shorting device

The shorting device has some peculiarities:

- higher speed of operation in comparison with insulating switch (0,15 - 0,25 s).
- high thermal and electrodynamic stability.

The initial data is represented at the table 2.5

The recommended literature [1–5].

Table 2.5 – Initial data for “Short – circuiting” theme

Ver - sion	Altitude above sealevel H, m	Dynamic Stability Current Id, kA	Thermal stability current It, kA	Short circuit current time S	Grounded contacts	Poles quantity	Climatic construction
1	1800	42	12.5	4	1	2	Т
2	2200	32	15	3	1	1	У
3	2700	51	22	4	1	1	ХЛ
4	3100	51	18	3	---	1	УХЛ

2.6 High – voltage bushing and bushing insulator

This apparatuses has the following peculiarities.

- the disposition type vary.

- the insulation materials combination must be optimal.
- The best external insulation is china.
- if the nominal voltage is 36 kV, the higher, then, the construction may have one or two china elements.
- the peak electromagnetic intensity is near the middle grounded flange.
- the electrical insulation strength increase is achieved by external diameter increase or paper - oil capacitor insulation use.
- the current density must be from 0.5 to 2 A/mm^2.

The insulation data is represented at the table 2.6.

The recommended literature [1-5,7,8]..

Table 2.6 - Initial data for "High voltage bushing and bushing insulator" theme

Version	Nominal voltage Un, kV	Nominal current In. A	Insulation type	Inside medium	Sealing type	Apparatus type	Mechanical load p,kN	Altitude above sealevel H, m
1	10	1250	External	Air	---	B	4	2400
2	66	400	Inside-external	Air-oil	Scaling	B	5	600
3	20	1800	External	Air-vacuum	Sealing	B	7	2100
4	35	2500	Inside-external	Air-oil	Non-sealing	B	6	800
5	110	1600	Inside-external	Air-oil	Sealing	B	4	1700
6	220	2800	Inside-external	Air-SF_6	Scaling	B	2	1000
7	330	1000	Inside-external	Air-oil	Non-sealing	B	1	1500

Continues of table2.6

8	150	630	Inside-extern al	Air-oil	Scaling	B	3	1200
9	20	2000	External	Air	Non-sealing	I	9	2700
10	35	800	External with pollution	Air	Non-sealing	I	7	3000
11	10	3150	External-external	Air	Non-sealing	1	8	3400

2.7 Factory - assembled shield current lead

This apparatus has the following peculiarity.

- the permissible temperature for buses is 120 °C, for shield is 110 °C, for elements with build-in apparatus is 80 °C.
- the economy current density for aluminum buses must be from 0.5 to 0.75 A/mm^2.
- the excess of the air temperature inside the jacket may not be higher then 15…30 °C.

The initial data is represented at the table 2.7.

The recommended literature [1... 5,7,10]

Table 2.7 - Initial data for "Factory - assembled shield current lead" theme

Version	Nominal voltage Un, kV	Nominal current In. A	Dynamic stability current Id, kA	Thermal stability current It, kA	Altitude above sea-level H, m	Building apparatusses	Current lead type
1	6	1600	81	20	3200	Bushing insulator triangle	Shield
2	10	2000	100	31.5	2400	Linear	Shield

Continues of table2.7

3	15	3200	128	50	1600	Bushing insulator ,triangle	Shield
4	10	4000	250	90	1800	Flexible bushing	On-phase shield
5	15	5000	270	110	2000	Current transformer	On-phase shield
6	20	16200	560	220	2200	Arrester	On-phase shield
7	35	10000	300	120	1400	Voltage transformer	On-phase shield

3 ON LOAD TAP CHANGER OF THE POWER TRANSFORMER

On load tap change has the following stages:

a) the arrangement and purpose of the units and elements.

b) design and calculation of electrical insulation.

c) design and calculation of dimensions of the current carrying contour elements .

d) calculation of the heat temperature of the current carrying contour elements under the steady – state regime.

e) design and calculation of contact system.

f) design and calculation of the thyristor module (for hybride apparatuses).

g) the mechanical calculations.

h) the reliability calculation.

The hybrid system design and calculation has the following general stages:

- choosing of the principal shame of the power train and of the thyristor control system.
- the thyristor module construction.

The initial data is represented at the table 3.1.
The recommended literature [1,5,7,11,12].

Table 3.1 – Initial data for “On load tap change of the power transformer” theme

Ver-sion	Nominal voltage Un, kV	Control step voltage Us, V	Nominal current In, A	Control range voltage Ur, V	Phase quantity	Contactor type
1	10	200	400	8	3	Contact
2	35	1000	1000	10	1	Hybride
3	35	600	104	9	3	Contact
4	35	500	125	5	3	Contact
5	110	1400	1600	6	1	Hybride
6	35	400	630	9	3	Hybride
7	220	1200	2000	7	1	Contact

4 CURRENT - LIMITING REACTOR

General request of the reactor design and calculation are adduced in the [1,13]. The design sequence has the following stages:

- the current lead calculation.
- calculation of inductance and dimensions of the reactor.
- calculation of the losses and temperature.
- design and calculation of the terminals.
- the reliability calculation.
- the construction elaboration.

The initial data is represented at the table 4.1
The recommended literature [1,8,13]

Table 4.1 - Initial data for "Current - limiting reactor" theme

Version	Nominal voltage Un, kV	Nominal current In. A	Inductance resistance Xp, Om	Short-circuit current time T, s	Installation method	Construction type
1	3	2200	0.56	5	Vertical	Concrete
2	6	800	0.24	3	Horizontal leadge	Assembly
3	10	500	0.11	4	Vertical	Concrete
4	10	2*1000	0.28	6	Horizontal line	Assembly double
5	15	2700	0.48	3	Vertical	Concrete
6	15	2*1500	0.41	5	Horizontal leadge	Assembly double
7	20	2*1800	0.46	2	Horizontal leadge	Assembly double
8	20	3500	0.52	3	Vertical	Concrete
9	27	2*400	0.21	4	Horizontal line	Concrete double
10	27	3000	0.48	5	Horizontal leadge	Assembly
11	24	1250	0.22	4	Vertical	Concrete
12	24	2*2500	0.37	2	Horizontal line	Assembly double
13	35	2*2000	0.32	4	Horizontal line	Concrete Double
14	35	4000	0.56	3	Horizontal leadge	Assembly
15	6	2*1800	0.3	7	Vertical	Concrete double

5 CURRENT TRANSFORMER

The general questions of the current transfprmer design and calculation are represented in the [1,13]. The design sequence has the following stages:

- the primary and secondary winding calculation.
- the magnetic circuit dimensions calculation.
- the error calculation.
- calculation of the emf of secondary winding.
- the heating temperature calculation.
- the thermal stability and dynamics stability calculation.
- the construction in elaboration.

The initial data is represented in the table 5.1.

The recommended literature [1,5,8,13,14]

Table 5.1 - Initial data for "Current transformer" theme

Version	Nominal voltage Un, kV	Nominal current In, A	Secondary load		Dynamic Stability Current Id, kA	Thermal stability current It, kA	Accuracy class	Primary winding type
			Measurement winding Z2n, om	Relay protection winding Z2, om				
1	6	800	0.1	10	125	25	0.5/10r	builtin
2	6	2000	0.12	12	---	40	0.5/10r	---
3	10	1000	0.15	14	100	31	1/5r	builtin
4	10	3000	0.18	16	---	35	1/5r	---
5	15	600	0.2	18	115	16	0.5/5r	builtin
6	15	6000	0.23	20	---	20	0.5/5r	---
7	20	400	0.26	19	105	16	0.2/5r	builtin

Continues of table 5.1

8	20	4000	0.29	17	---	23	0.2/5 r	---
9	24	5000	0.27	15	---	35	1/10r	---
10	24	6000	---	23	---	18	10/10r	---
11	27	900	0.22	11	115	32	1/10r	builtin
12	27	8000	0.17	29	---	20	3/5r	---
13	35	1200	0.14	8	100	24	0.5/10r	builtin
14	35	10000	0.25	---	---	16	0.2	---

6 VOLTAGE TRANSFORMER

The general questions of the voltage transformer design and calculation are represented in the [1, 13]. The design sequence has the following stages:

- the magnetic circuit dimensions calculation.
- the primary and secondary winding calculation.
- the insulation electrical strength calculation.
- the error calculation.
- the permissible load calculation.
- the construction elaboration.

The initial data is represented in table 6.1.

The recommended literature [1,5,8,13,15]

Table 6.1 – Initial data for " Voltage transformers" theme

Ver-sion	Nominal voltage Un, kV	Accuracy class	Nominal power S2n, VA	Major insulation type	Installation type
1	3	0.5	30	Natural air cooling (dry)	Inside
2	6	1	50	Dry	Inside
3	6	3	130	Casting	External
4	10	0.5	80	Casting	Inside

Continues of table 6.1

5	10	1	120	Natural oil cooling (dry)	External
6	15	1	110	Casting	Inside
7	20	3	150	Oil	External
8	20	0.5	60	Casting	Inside
9	24	0.5	25	Casting	Inside
10	24	3	40	Oil	External
11	27	1	90	Oil	Inside
12	35	3	70	Oil	External
13	35	0.5	100	Oil	Inside

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