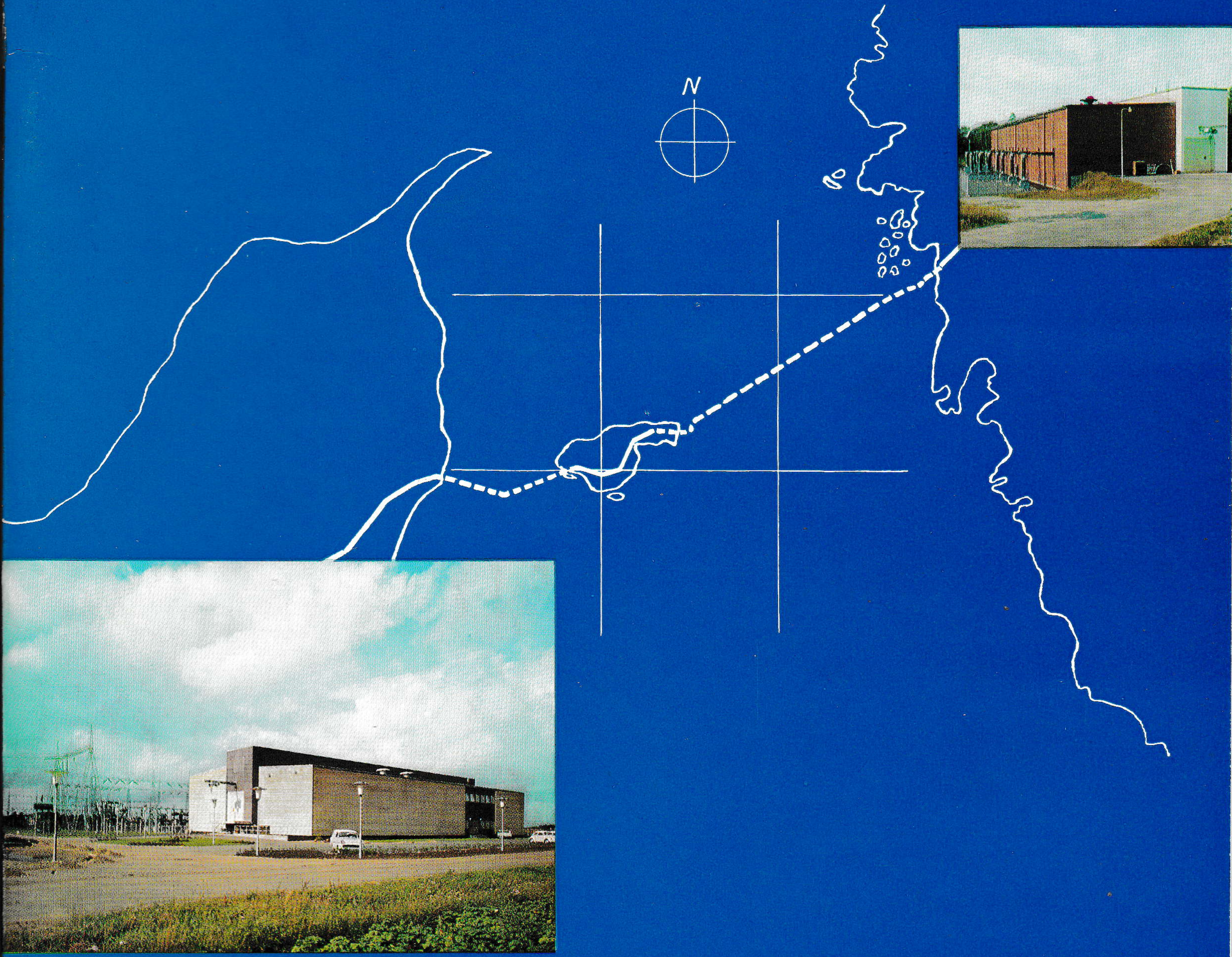
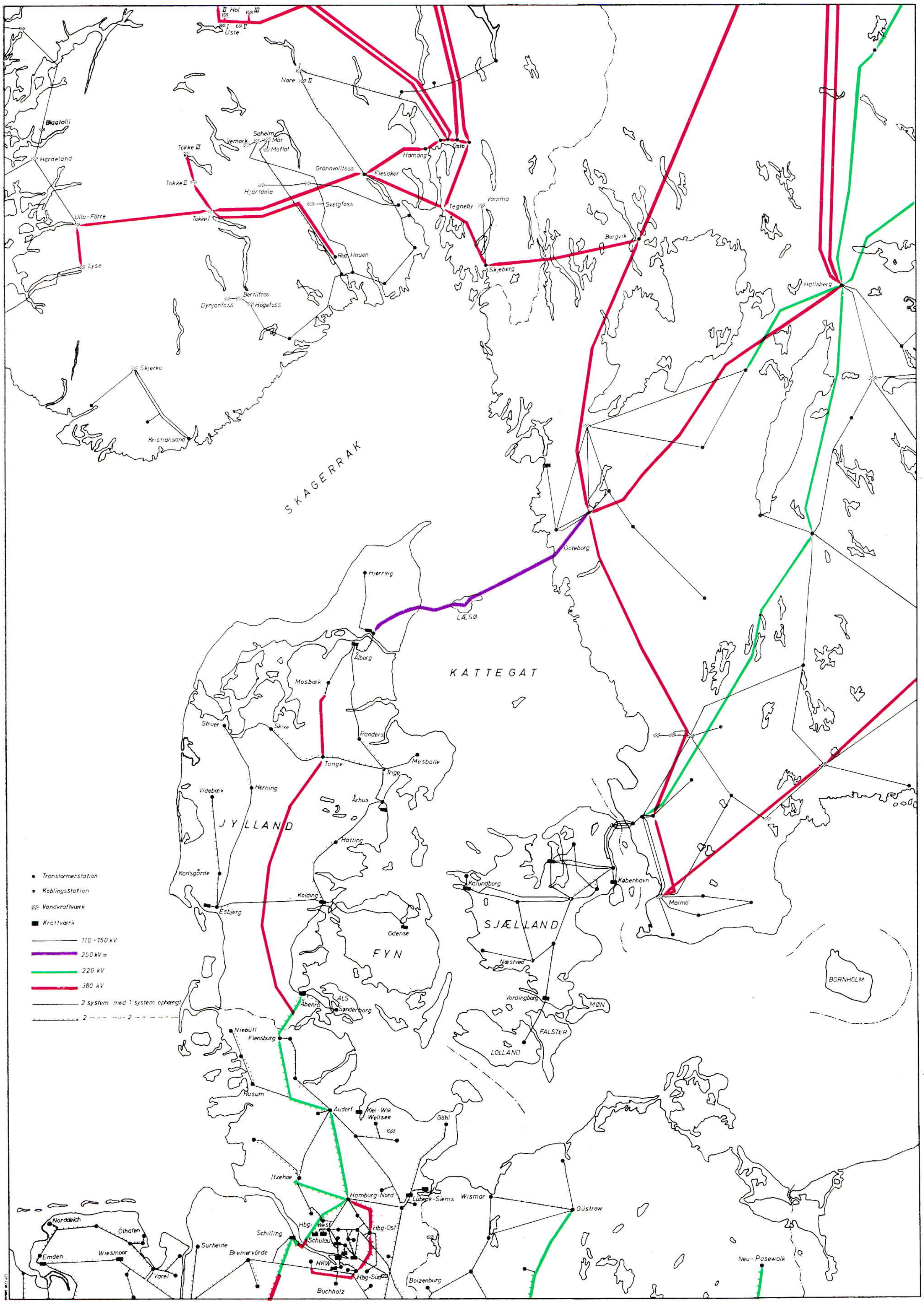


Konti-Skan

Elsam 1965

The KONTI-SKAN LINK

Map showing the principal transmission lines on the KONTInental and SKAN-dinavian side of the link.



SKAGERRAK
KATTEGAT
JYLLAND
FYN
SJÆLLAND
LOLLAND
FALSTER
MØN
BORNHOLM
LÆSØ
Oslo
Hamang
Flesaker
Tegneby
Varnma
Skjeberg
Borgvik
Hallsberg
Göteborg
Grønnvollfoss
Hjartdøla
Svelgfoss
Rød Hauen
Nore II
Tokke I
Tokke II
Tokke III
Vemork
Moflat
Ulla-Førre
Lyse
Hardeland
Bertilfoss
Dynjanfoss
Högefoss
Skjerka
Kristiansand
Hjørring
Ålborg
Mosbæk
Struer
Skive
Randers
Tange
Trige
Mesballe
Videbæk
Herning
Århus
Hatting
Karlsgårde
Esbjerg
Kolding
Odense
Åbenrå
Sønderborg
Kalundborg
København
Malmö
Næstved
Vordingborg
Niebüll
Flensburg
Husum
Audorf
Kiel-Wik
Wellsee
Göhl
Itzehoe
Hamburg-Nord
Lübeck-Siems
Wismar
Güstrow
Neu-Pasewalk
Schilling
Hbg-West
Schulau
Hbg-Ost
HKW
Hbg-Süd
Boizenburg
Buchholz
Norddeich
Ölhafen
Emden
Wiesmoor
Varel
Surheide
Bremervörde
Transformerstation
Koblingsstation
Vandkraftværk
Kraftværk
110 - 150 kV
250 kV =
220 kV
380 kV
2 system med 1 system ophængt
2 — " — — " — 2 — " — — " —

In April 1963 ELSAM, the Danish organization for coordinating the power supplies in Jutland and Funen, and the Swedish State Power Board signed contracts of building and utilizing a high voltage direct current transmission link between the region of Aalborg in Jutland and Gothenburg on the Swedish west coast. The link should have a nominal power of 250 MW at 250 kV single pole transmission using the sea as return.

The link is to be used for interchange of energy between the system in Jutland, which is connected to the European network through the Nordwestdeutsche Kraftwerke's system, and that in Sweden, which is connected to the other Scandinavian countries. The installed capacity (thermal) in Elsam's area as per 1965 is over 1200 MW and in the Hamburg area over 3000 MW. The installed capacity of the inter-connected Scandinavian system is 25000 MW, 20000 MW in hydro units and 5000 MW in thermal units.

Prolonged as well as short occasional power exchanges are foreseen on the link. During a period of 6 years from 1965 a fixed delivery of 250 MW supplied at the Danish-German border for at least 6 hours per weekday has been agreed upon. In average years thermal power in the order of 100 GWh is expected to be delivered to Sweden from Jutland. — Generally the link will reduce power requirements in the systems on either side and will enable a more rational use to be made of all the production resources.

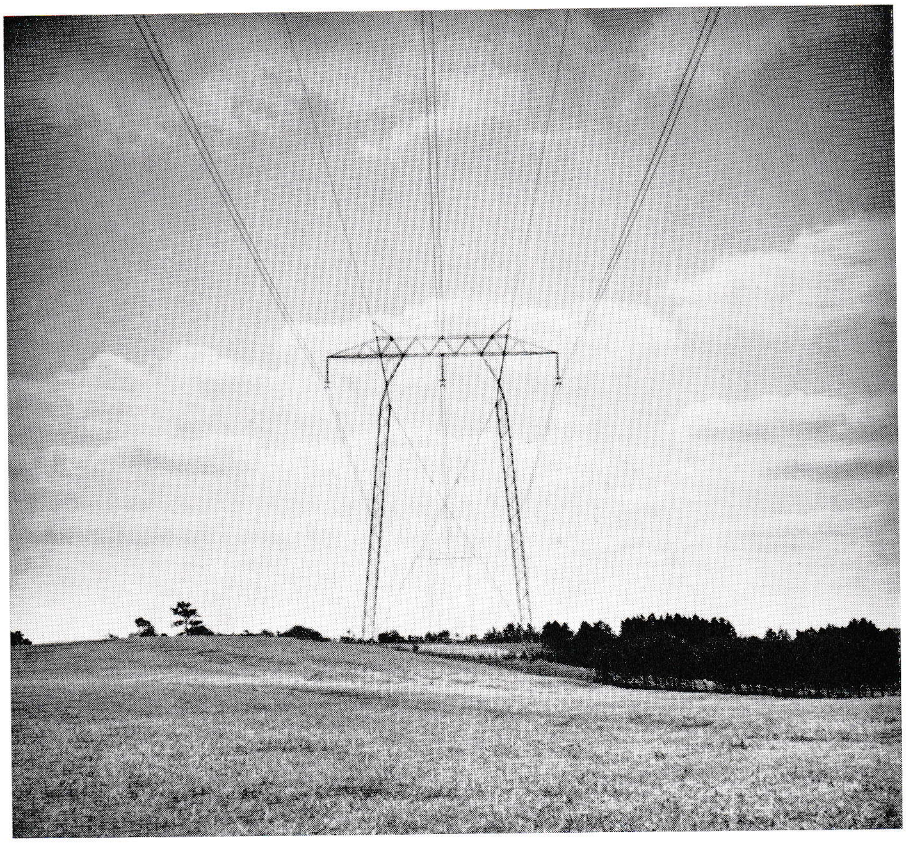
Before the d. c. scheme was agreed upon, several a. c. alternatives were investigated and found to be technically feasible. A d. c. scheme, however, would offer better stability and operating conditions in the networks of the two power blocks. D. c. would also eliminate the technical problems involved in synchronous operation of two large a. c. networks. Another advantage of the d. c. scheme is that it lends itself better to being built out in steps. This was an important and decisive factor in view of the magnitude of the investment and the uncertainties in the economics for the scheme, one being the random character of the ability to deliver surplus hydro power.

The d. c. link is connected to a new 150 kV station in Vester Hassing near Aalborg on the Danish side an to an existing 400 kV station in the Gothenburg region on the Swedish side. Each converter station contains two 6 pulse converter units for 125 kV, 1000 A, the rating of the complete link in 12 pulse operation being 250 MW at 250 kV.

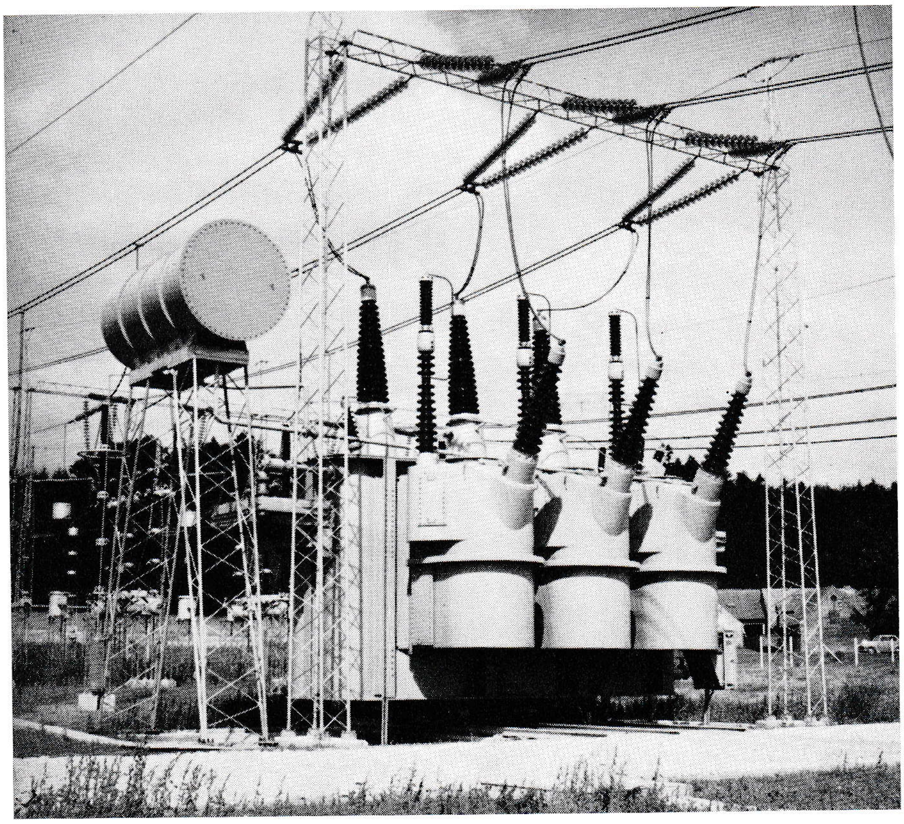
The d. c. transmission is regulated on constant power in either direction. Constant current regulation can be used as standby. A telecommunication link between the stations consisting of seven two-way channels including two spares is provided for setting the power, for tapchanging operation and for certain remote indications. One of the channels is used for teleprinter communication.

The d. c. link, 183 km long, comprises 6 km underground and 83,5 km submarine cable and 93,5 km overhead line.
From the converter station in Vester Hassing an overhead line runs to the east coast of Jutland, south of Sæby on steel towers, with 2-A. C. S. R. conductors of 910 sq mm (527 sq mm equivalent copper area), one of them serving as the electrode line to a point about 10 km south of the line termination. From this point a separate line leads to the electrode station on the coast. The insulation level for the d. c. line is 1500 kV. The insulators are of the antifog type, a string being made op of 16 discs each with a leakage path of 525 mm.
The submarine cable between Jutland and the island of Læsø is of a flat type, with two parallel conductors each having a copper section of 310 sq mm.
The overhead line across Læsø is similar to the one in Jutland but has 19 discs instead of 16 to a string. The two conductors are parallelled in the first stage of the project.
Between Læsø and the Swedish coast an oilimpregnated solid type of cable with 625 sq mm has been used. The insulation level for the cables is 700 kV.
Between the landing point at Billdal and Gothenburg on the Swedish side the overhead line is erected on guyed aluminium towers.
From the station in Vester Hassing a double circuit 150 kV overhead line with two submarine cables over the Limfjord runs down into Himmerland where it is connected to a new 400 kV line. This line runs down through the middle of Jutland to a point just north of the German border where it is tied in to the existing 220 kV double circuit line to the Nordwestdeutsche Kraftwerke's network. In a preliminary stage the 400 kV line is operated at 150 kV down to the station at Tange and at 220 kV southward from there with a 300 MVA transformer in Tange.
The electrode station on the Danish coast (anode) consists of 25 graphite rods placed in 5 meter deep vertical ducts.
The electrode station on the Swedish side (cathode) which is not subject to any corrosion consists of bare copper wires laid on the sea bottom and connected to the electrode line on land by means of plastic-insulated cable.
The d. c. transmission requires the contribution of reactive power which at each converter station amounts to half the rated power i. e. 125 MVar. To limit the harmonics, part of this power is generated by filters comprising 70 MVar in Vester Hassing and 80 MVar in Gothenburg. In addition separate shunt capacitor banks are installed at Gothenburg and a 80 MVar synchronous condenser in Vester Hassing.

ELSAM, 1965.



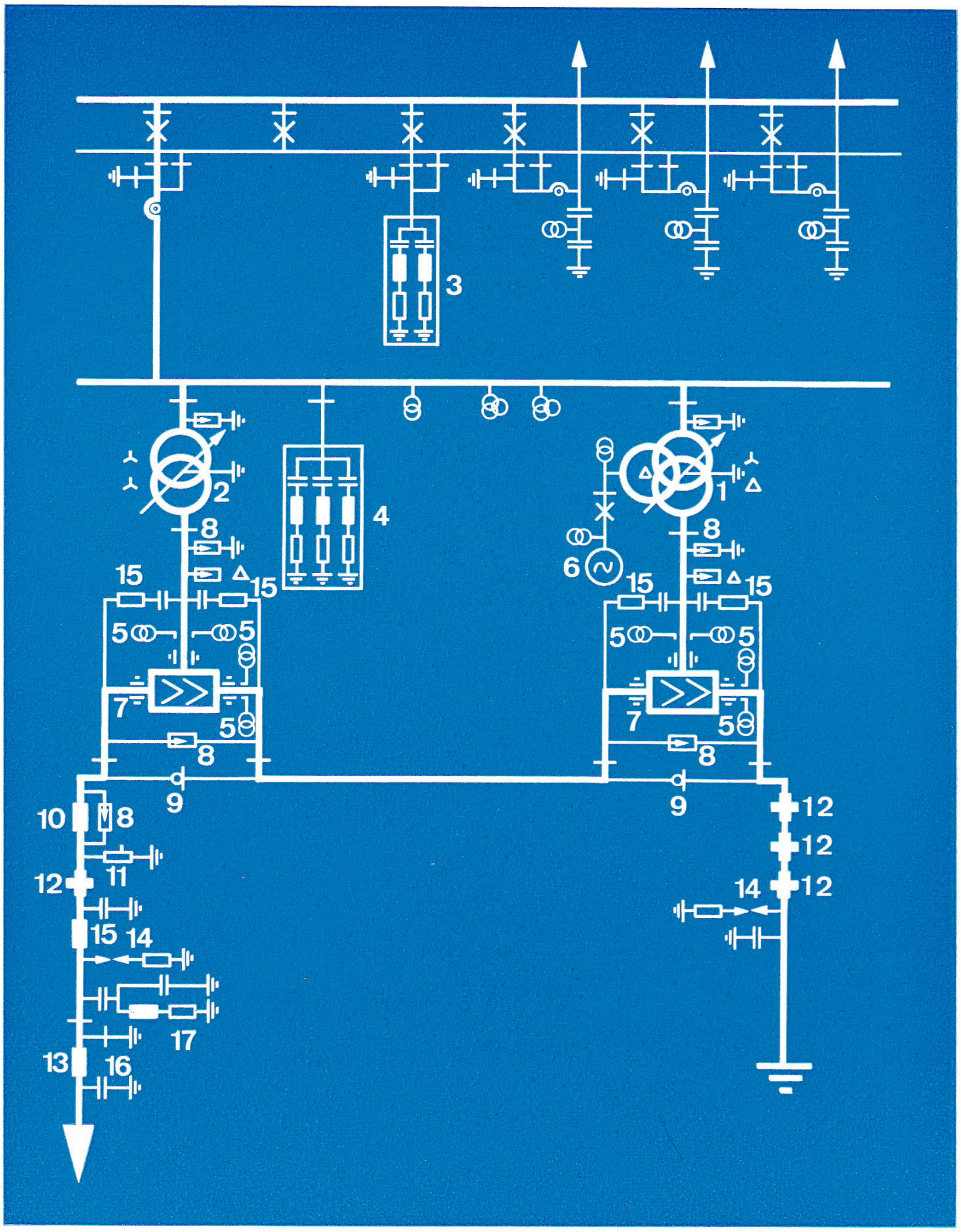
400 kV towers with 2 × 635,5 sq mm ACSR (2 × 355 sq mm equivalent copper area). 9 solid-core porcelain insulators per string. Insulation level 1600 kV.



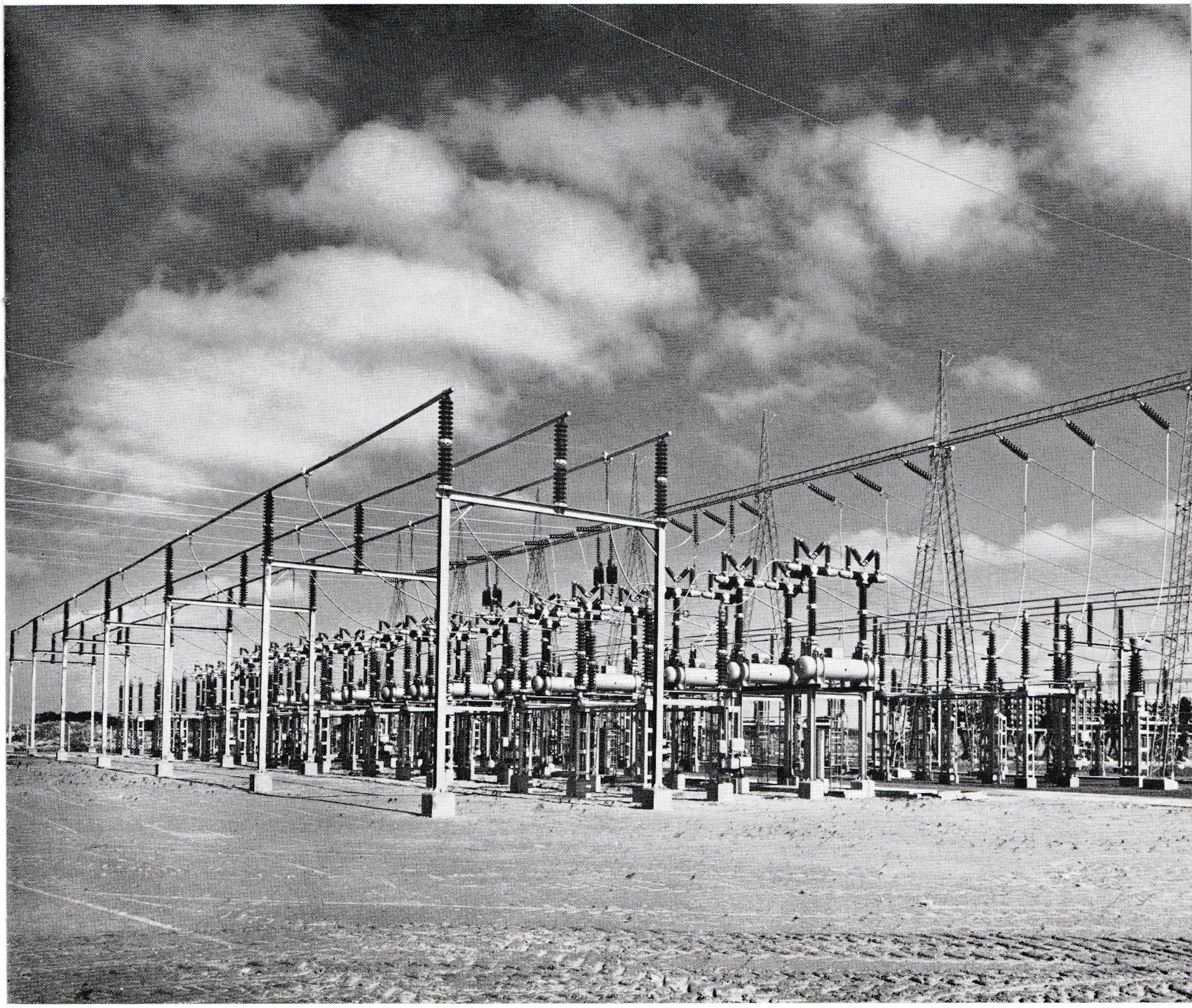
300/300/100 MVA, 220/164 ± 17,1 %/20 kV auto-transformer. Y/Y/△ connected. Insulation level 900/650 kV.

The photographs show a section of the 400 kV line and 220/150 kV transformer at Tange which are part of the primary ELSAM network connecting the d. c. station in Vester Hassing with the network of the Nordwestdeutsche Kraftwerke and thereby the interconnected European system.

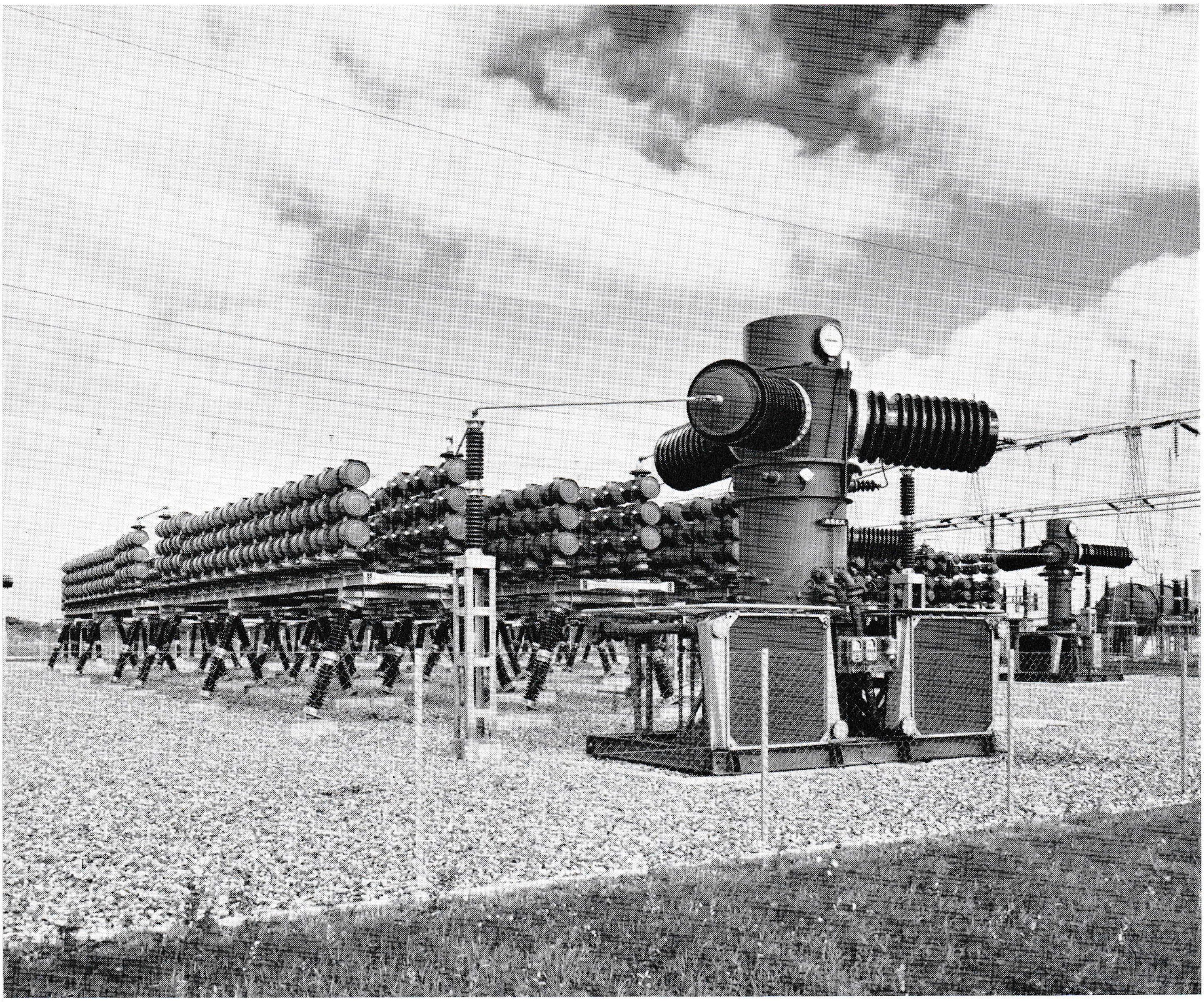
The d. c. station in Vester Hassing viewed from north-east. The outdoor station (in the background of the picture) covers 30.000 m² and the building has a total floor area of 2850 m². The nearest wing of the building contains erection bays, forming room, workshop, apparatus- and relayroom and in the windowed section, offices and controlroom. In the centre section is the transport passage and ventilator-gallery and in the wing farthest away the valve halls. The building is provided with a metallic screen to prevent radio-frequency interference from disturbing radio communications. — Extensive ventilating installations are provided to keep the valve hall and workrooms dustfree and at a constant temperature.



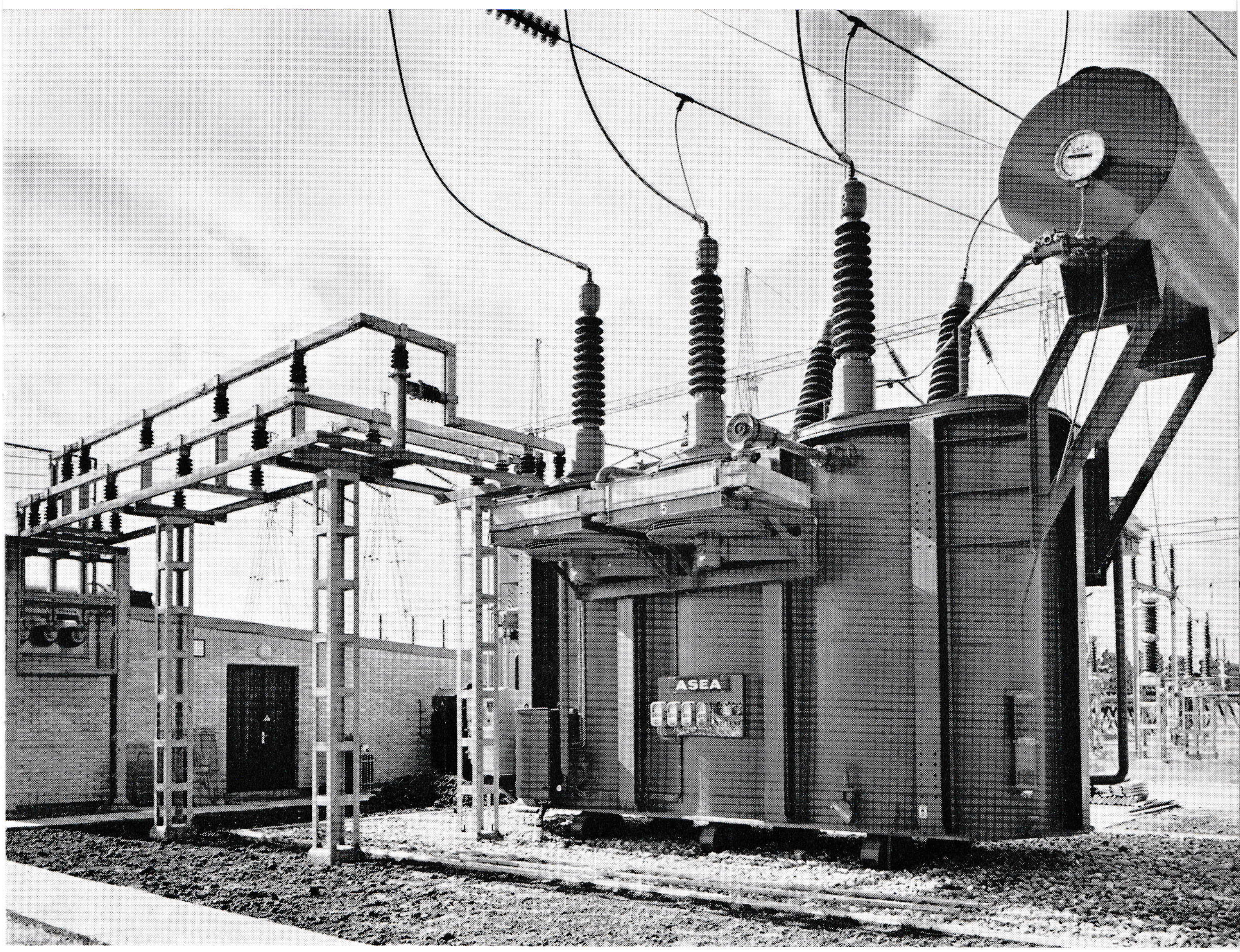
1: converter transformer
2: converter transformer
3: filter capacitor bank
(13. and higher-frequency harmonics)
4: filter capacitor bank
(5., 7. and 11. harmonics)
5: insulating transformers
6: synchronous condenser
7: valves
8: lightning arresters
9: by-pass isolators
10: ripple choke
11: potential divider
12: current measuring transductors
13: carrier frequency line trap
14: specially designed lightning arrester
15: high-frequency damping circuit
16: coupling capacitor for the power line carrier equipment
17: capacitor for lightning surge protection combined with a 600 Hz damping circuit



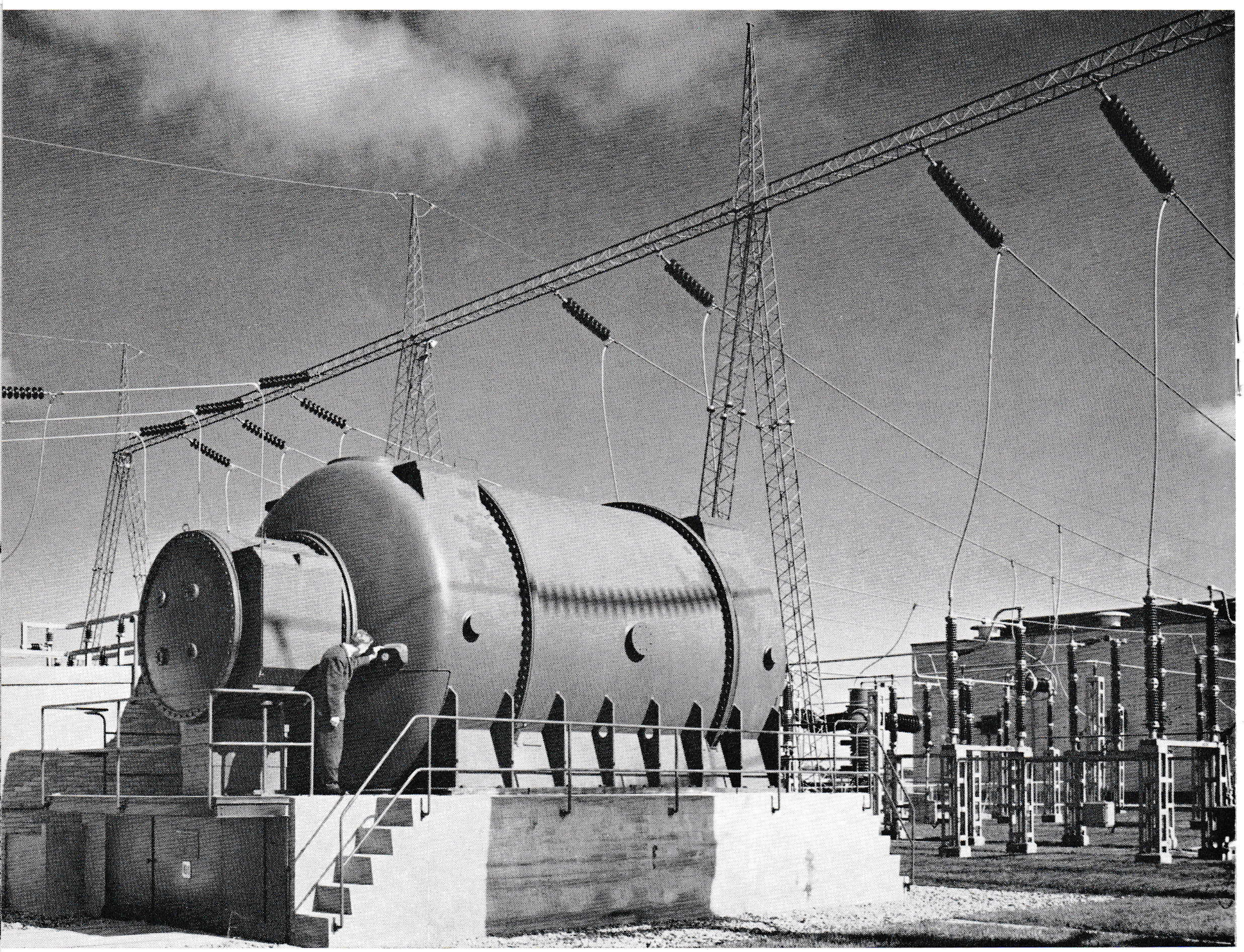
The 150 kV switchyard with 6 bays, 3 for outgoing lines, 1 for the converter transformers, 1 for a separate capacitor bank and 1 for the coupling breaker. The circuit breakers are re-strike free, airblast breakers with a short circuit rating of 5000 MVA.



The photograph shows part of the filter capacitor bank which is installed to limit harmonic generation and to produce reactive power. The capacitor bank consists of five star connected three-phase resonant circuits. Four of the circuits are series resonant circuits for the 5., 7., 11. and 13. harmonics, the fifth is a high-pass filter for higher-frequency harmonics. The reactive power required by the converters, about half of the active power transmitted, is partly generated in the filter capacitor bank, the rating at fundamental frequency being 70 MVar. — The »three-armed« installation in the foreground of the photograph is one af the reactors for the serie resonant circuits.

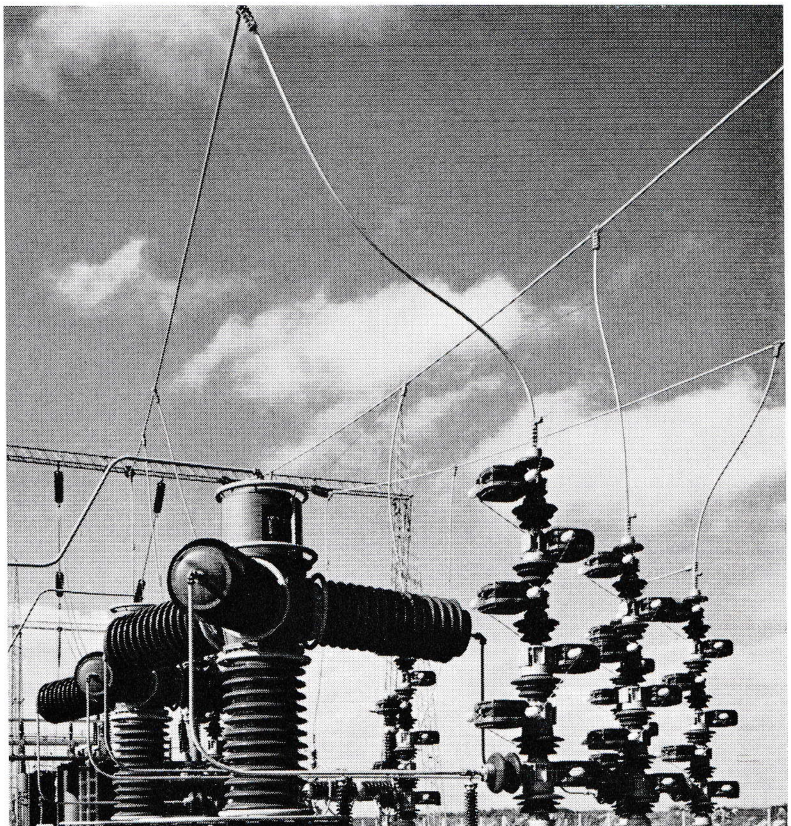


One of the two 149 MVA, 165 ± 15 %/111 kV converter transformers. Each transformer supplies its own valve group in two-way 6-pulse connection. The transformers are connected in Y/Y and Y/D respectively, giving a 30° phase displacement between the voltages of the valve windings; connected in series the converters thus work on a 12-pulse basis. The transformers are of normal design but with the valve windings being at d. c. potential the use of graded insulation has not been possible. The insulation level is 650 kV/1050 kV for the Y/Y connected transformer and 650 kV/775 kV for the Y/D connected. The transformer shown in the photograph is provided with a 13 kV, 100 MVA tertiary winding to which a synchronous condenser is connected.



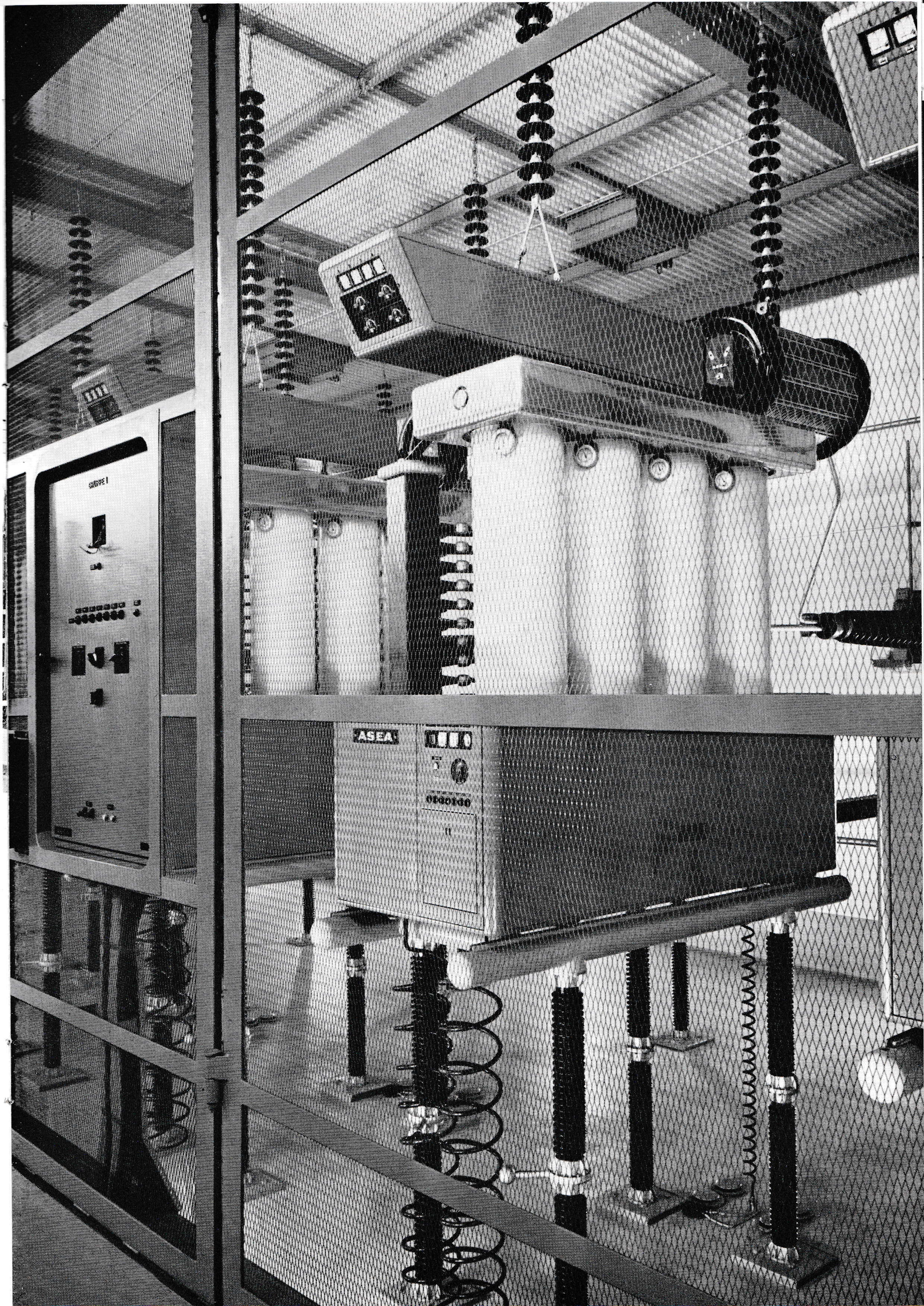
The synchronous condenser rated at 80 MVar (65 MVar under exited), 12 kV nominal voltage. The condenser is hydrogen-cooled and is, as can be seen, erected out-of-doors. A synchronous condenser rather than additional static capacitors have been chosen in order to increase the available short circuit power af the network thus reducing the momentary voltage variations on the a. c. network on load dropping and during valve disturbances. The regulator of the machine also helps to restore the voltage after certain types of valve disturbances.

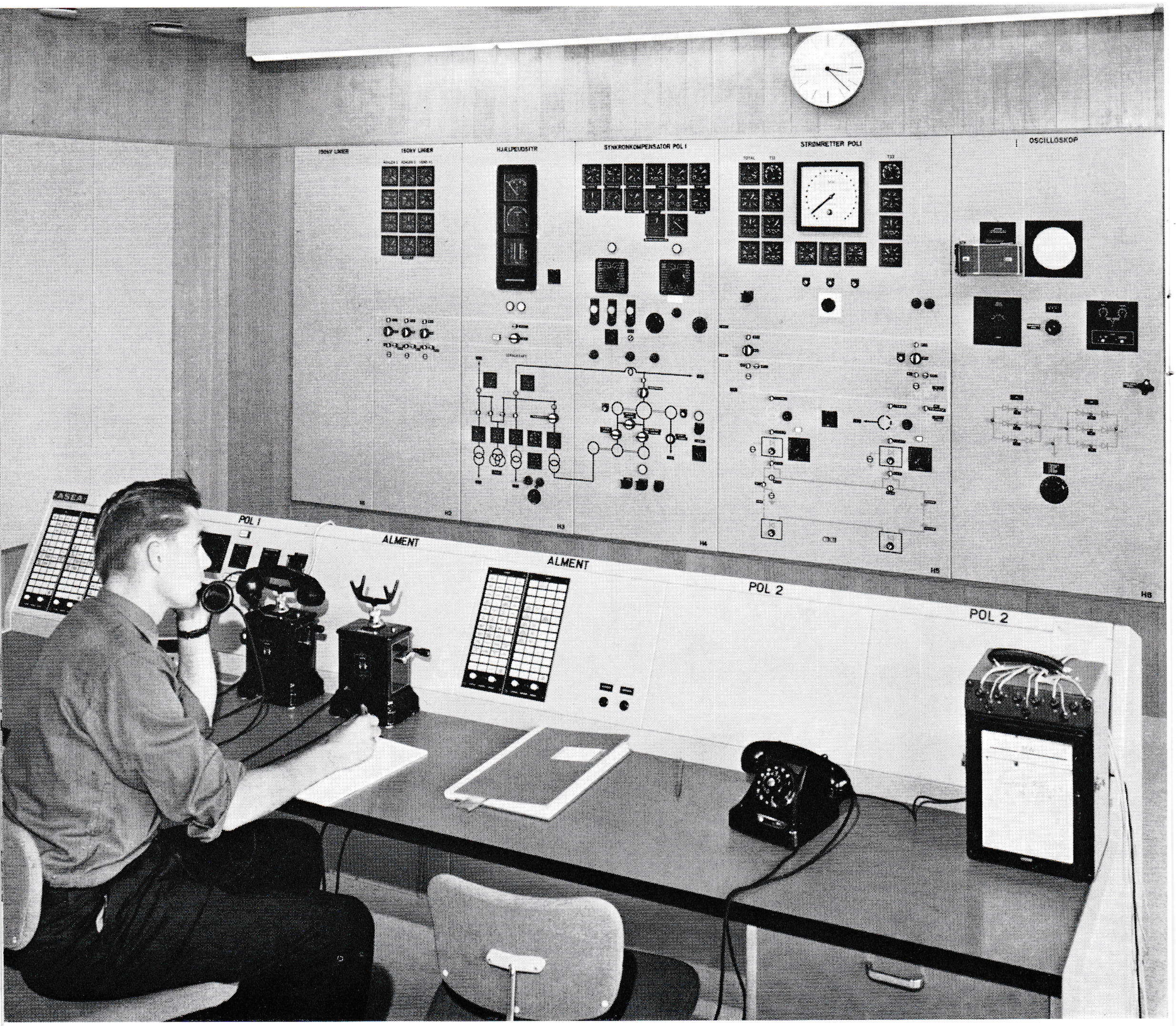
One of the valve damping circuits fitted across each valve group from the d. c. to the a. c. side. The circuit, which consists of a series connected capacitor and resistor, damps high-frequency oscillations on the recovery voltage across a valve when it stops conducting current.



The photograph shows the condensor type wall bushings, with built-in current transformers, for the connections from the valve hall to the outdoor station. Also seen are the insulating transformers for transferring auxiliary power and control pulses from earth potential to the high potential on the valves. The insulation level of the apparatus corresponds to the level of the respective valves, i. e. up to 1050 kV.

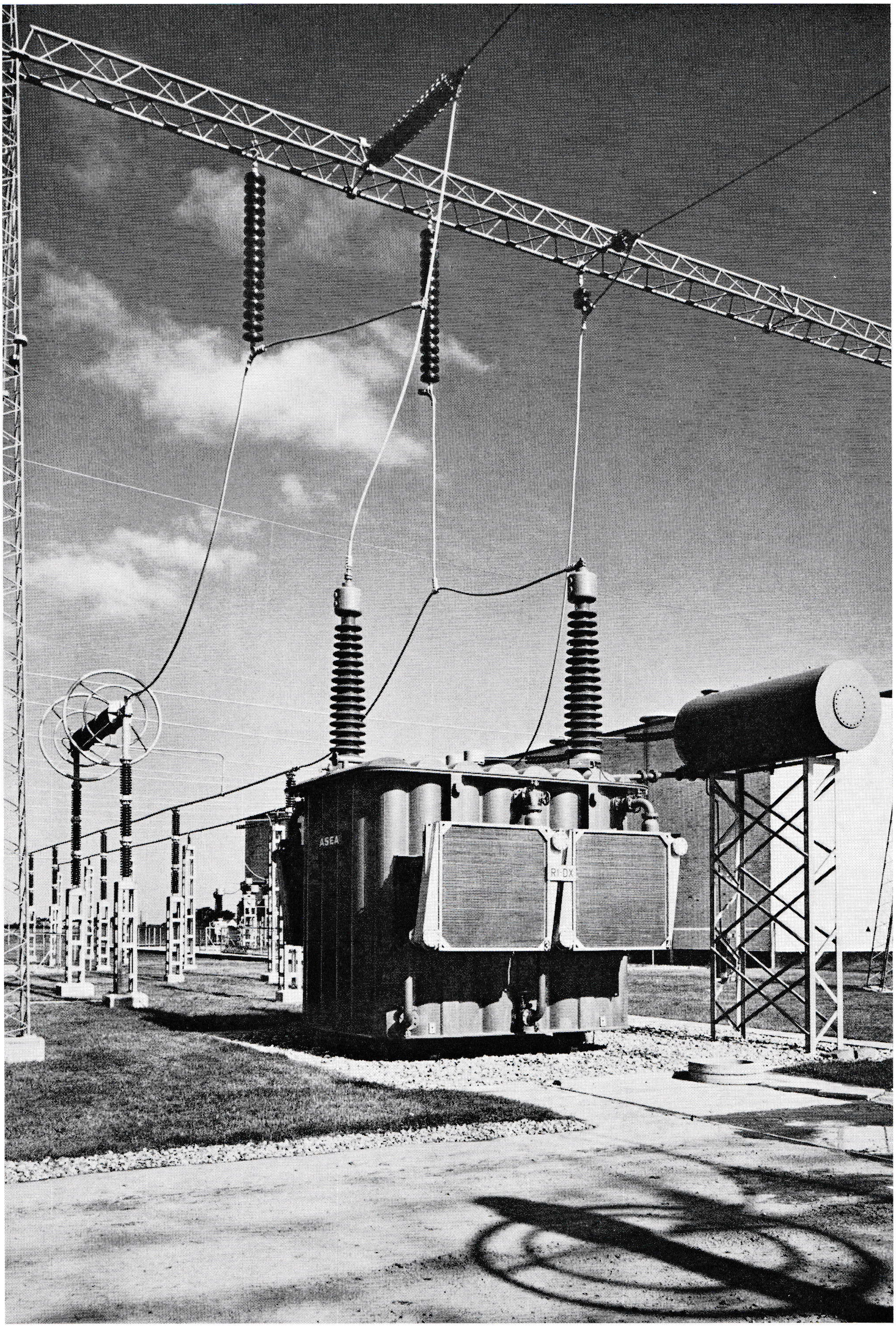
The heart of the converter installations, the valves. They can conduct about 1000 A and block and insulate against a recovery voltage with a peak value of 150 kV. The insulation level to earth of the two series connected valve groups are 750 kV and 1050 kV respectively attained by placing the valves on insulator-supported platforms. The horizontal steel cabinet contains the mercury cathode (in a steel cylinder) and its auxiliary equipment (ignition and arc maintenance electrodes etc.). The four porcelain tubes have intermediate electrodes connected to external voltage dividers, the lower electrode serving as control grid. The four parallel anodes are at the top. The tank and cathode are cooled with completely desalted water brought to the platform through the coiled plastic tubes seen in the foreground. The anodes are aircooled. In the background (top) is seen the anode reactor with a built-in parallel resistance, which is provided to attenuate the high frequency oscillations generated when a valve ignites.


GRUPPE I
ASEA

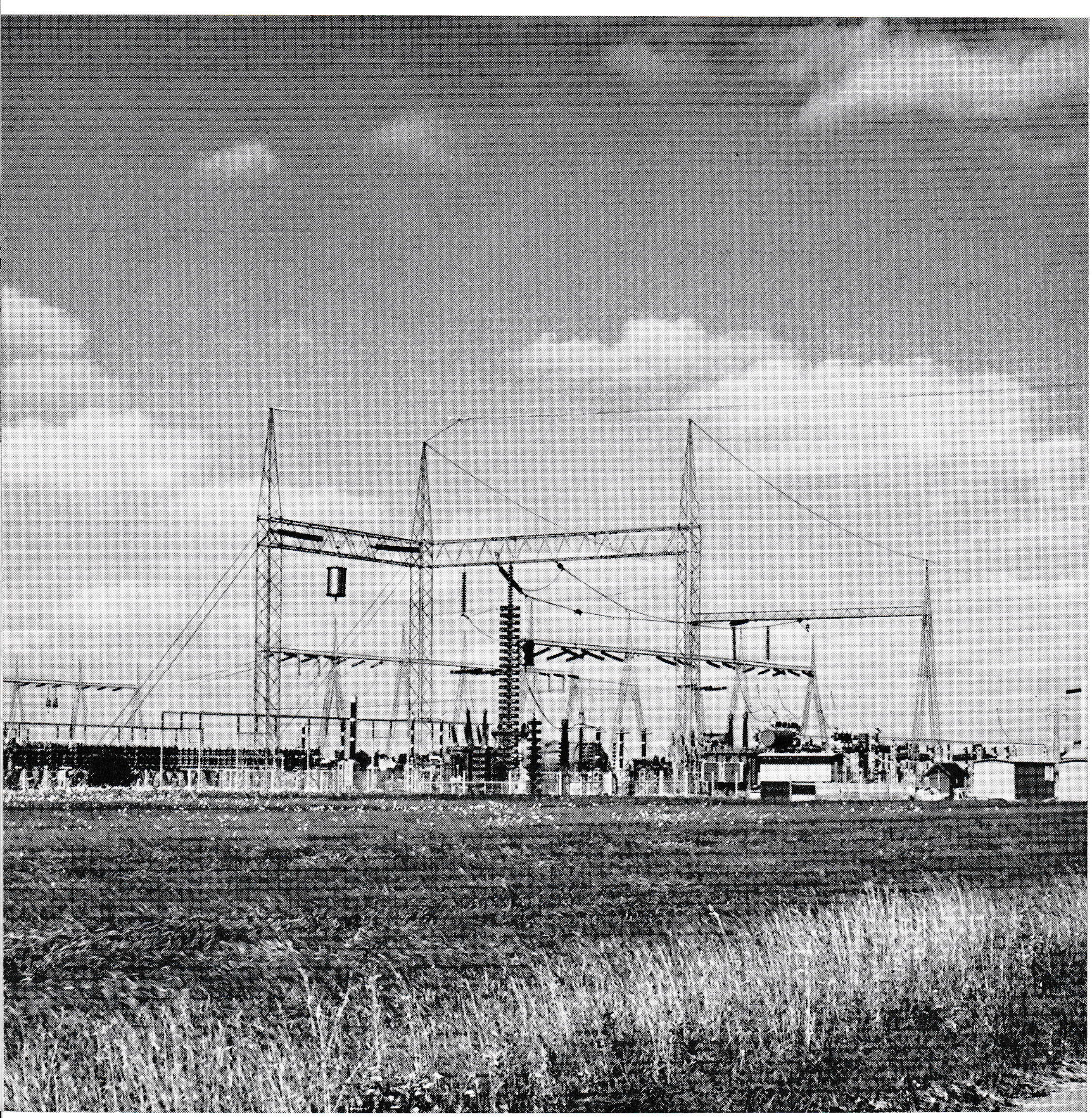


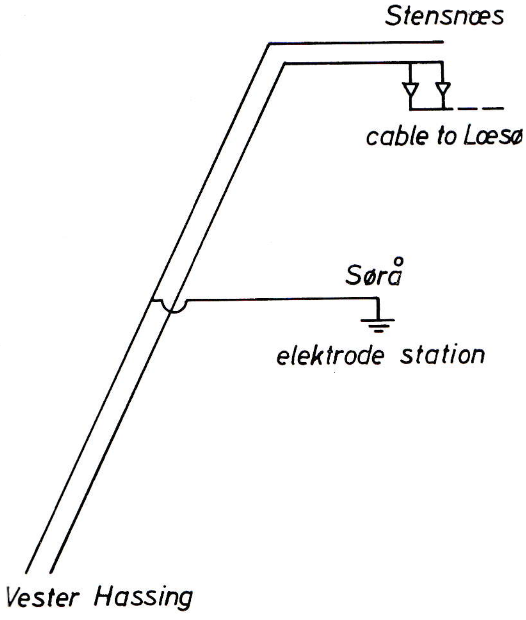
View of the control room with remote control switches, indicators and instruments for the a. c. equipment on the panels to the left and for the d. c. on the panels to the right. The indicator for the power-setting step-devise is seen in the centre under the clock. On the panel to the right is an oscillograph for displaying the voltage wave-shape at various points in the converter installation.

The d. c. reactor in the outgoing d. c. line. The reactor reduces the ripple in the d. c. current and limits the rate of change of the current. In the background (left) the lightning arrester connected across the reactor.


ASEA

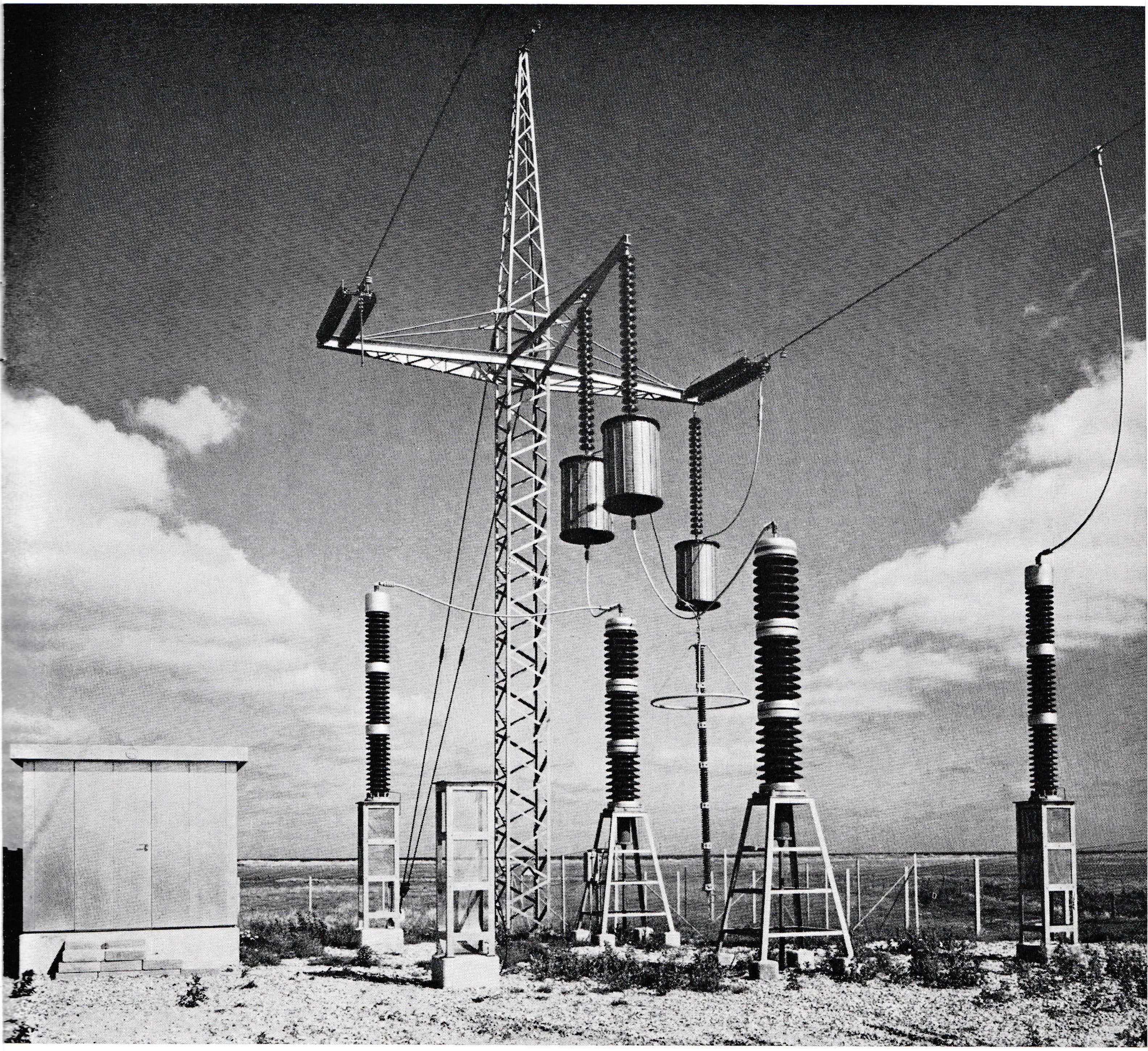
View of the bay for the outgoing d. c. line. In the centre is the capacitor for lightning surge protection and to the left of it, the carrier line trap. In the bay is also a coupling capacitor for the powerline carrier equipment, a high-resistance type protential divider in oilfilled porcelain insulators, current measuring transductors, damping circuits and a specially designed lightning arrester.



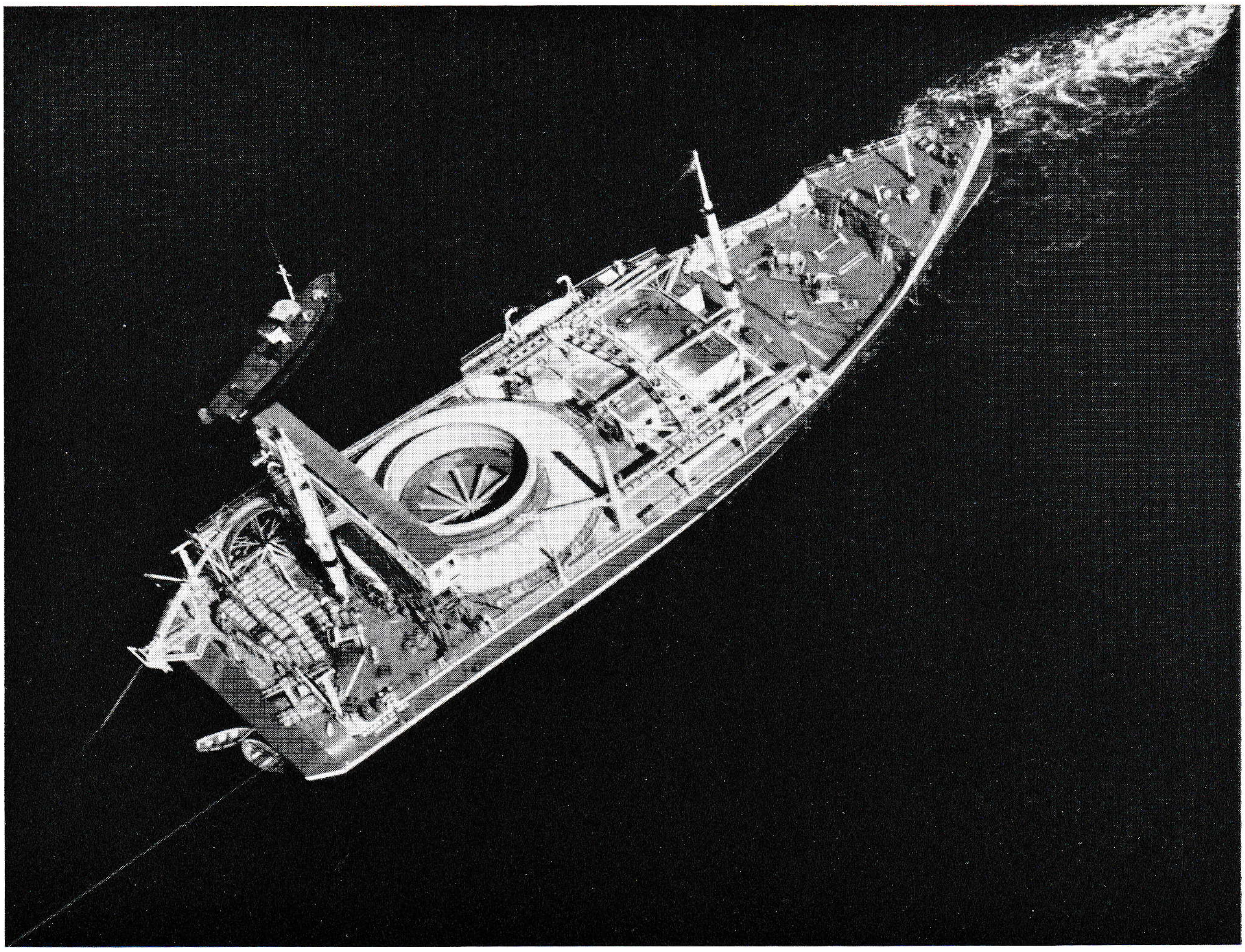


The d. c. line running northward from Vester Hassing. The selfsupporting towers' weight about 2,8 tons. The conductors are 910 mm² ACSR (equivalent copper area: 527 mm²), the spacing is 9 m. A disc-type glass insulator with a leakage path of 525 mm is used. In Jutland there are 16 discs to a string, with 19 discs near the terminals, at Læsø 19 discs have been used throughout. Near the terminals in Jutland the line is equipped with one earth conductor. The insulation level with 16 discs is about 1500 kV, where more discs are used the insulation level has, for reasons of insulation coordinations, been reduced to 1500 kV by means of arcing horns. — One pole serves initially as electrode line to a point some kilometres south of the sea terminal.

The photograph shows the electrode station at Sørå on the Danish east coast. From the main d. c. line the electrode line is strung on steel towers to the coast. The electrode station has been placed at some distance from the main cable terminal to reduce the return current in the cable sheath to a minimum. — To minimize the magnetic compass errors the current in the cable is kept flowing from Sweden towards Denmark, the direction of power flow being changed by changing the polarity. The Danish electrode station is therefore always anode and due to the corrosion problems special attention was given to the choice of anode material. The electrode consists of 25 graphite rods each placed in a 5 m deep well. Pumping equipment for salt water circulation is provided.

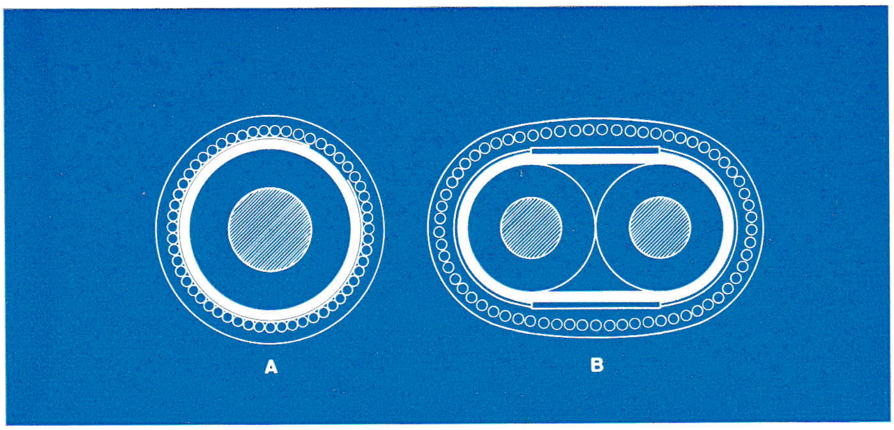


The termination of the d. c. line from Vester Hassing at Stensnæs on the Danish east coast. In the centre the two cable terminal joints for the two conductors of the flat type cable; between them in the background the specially designed lightning arrester. On either side of the cable terminal joints is seen coupling capacitors for the carrier equipment. Also to be seen are three carrier line traps and an aluminium cabinet housing the carrier equipment.



Cable-laying under way with Henry P. Lading.

Cross sections of A: the solid type, oilimpregnated cable (625 sq mm Cu) laid between Læsø and Sweden and B: the oil-filled flat type cable (2 × 310 sq mm Cu) between Jutland and Læsø.

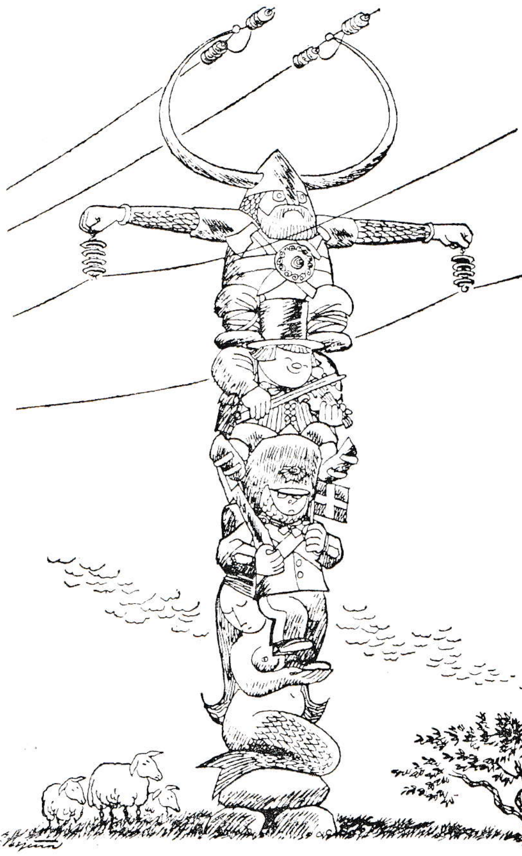


Approach to Vesterø harbour on Læsø.

Idyllic Læsø scene.

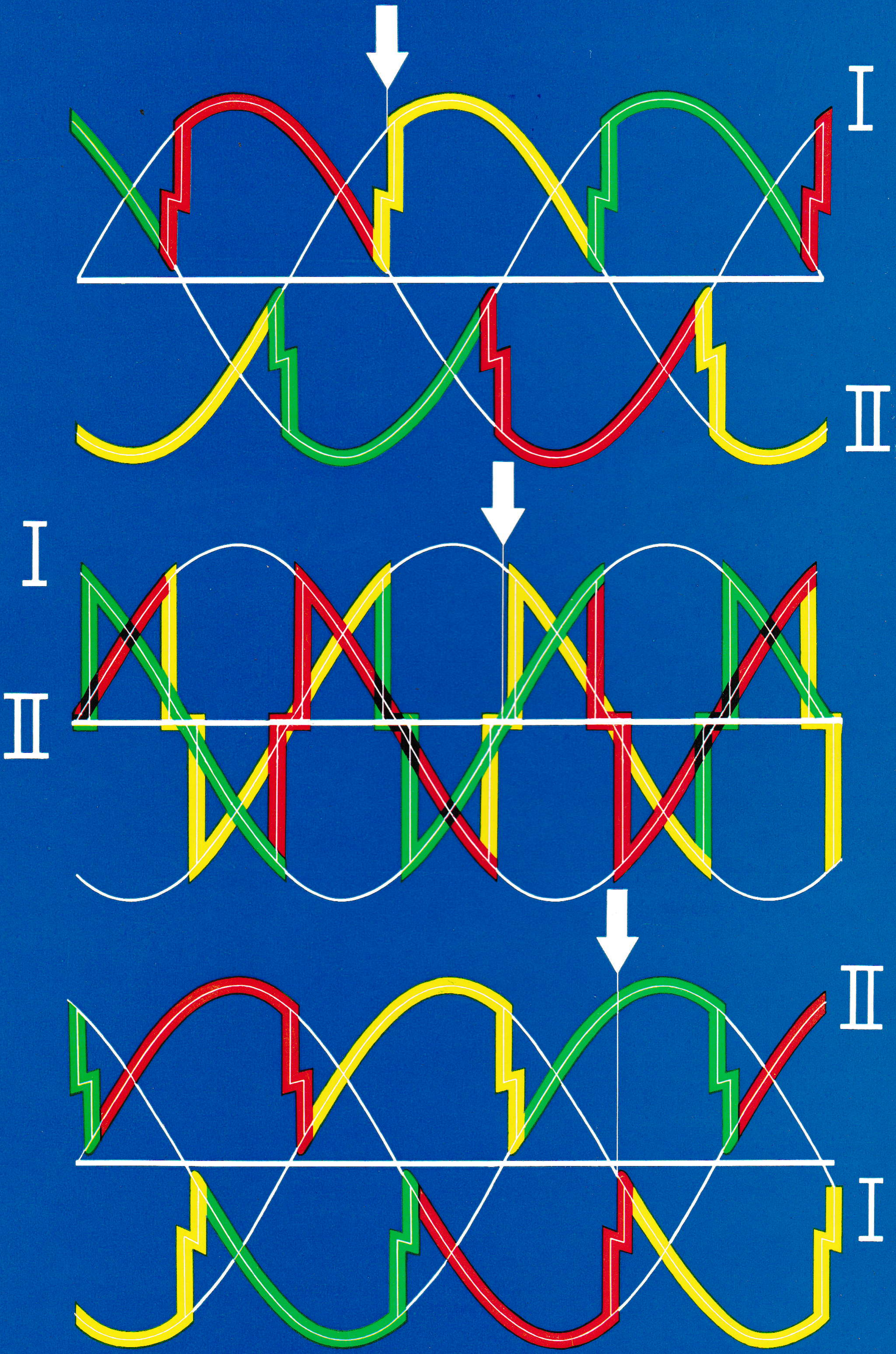
The end —

— of the link on the Danish side.



Artist's proposal for tower design with national character.

KONRAD JØRGENSENS
BOGTRYKKERI-KOLDING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II
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