PATENT SPECIFICATION

(11) 1 595 362

(21) Application No. 11350/78 (22) Filed 22 Mar. 1978 (19)
(31) Convention Application No. 7703490 (32) Filed 28 Mar. 1977 in
(33) Sweden (SE)
(44) Complete Specification Published 12 Aug. 1981
(51) INT. CL.[3] H02M 1/00
(52) Index at Acceptance
H2F 9G6 9J4 9K1 9K4 9R14B 9R14C
9R27C 9R39C 9R46C 9R5C 9T1 9T2
9T3 HVD

1 595 362

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(54) METHOD FOR CONTROLLING THE ALTERNATING VOLTAGE OF A CONVERTER AND MEANS FOR VOLTAGE CONTROL IN ACCORDANCE WITH THE METHOD

(71) We, ASEA AKTIEBOLAG, a Swedish Company of Västerås, Sweden, do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to a method for controlling the alternating voltage of a static converter connecting a d.c. network and an a.c. network, reactance elements being connectible in steps with the a.c. network, and the converter comprising means for providing angle control. The invention also includes a converter provided with voltage control by this method.

To compensate for the consumption of reactive power by a converter, it is common to connect reactance elements to the a.c. side of the converter. Such reactance elements, which may be capacitors or reactors or a combination thereof, are then provided with some form of step switch device for gradual connection of reactance into the a.c. network.

British Patent Specification No. 1,174,166 discloses how to supplement this reactive power control by utilising angle control of the converter. According to said Specification, this is done by temporarily increasing the margin of commutation of an inverter, but the same result is obtained in a rectifier by increasing the lower limit for the control angle.

A disadvantage of the known methods is that the stepwise connection and disconnection of the reactance elements, particularly in weak a.c. networks, gives rise to inconvenient voltage transients. This can be avoided by continuously controlling the reactive power through angle control of the converter, which, however, means that the converter will normally work with unnecessarily great reactive power.

The present invention aims to compensate for said voltage transients by interfering with the angle control of the converter.

According to the invention, a method for controlling the alternating voltage of a converter connecting a d.c. network and an a.c. network, reactance elements being connectible in steps with the a.c. network, and the converter comprising means for providing angle control, is characterised in that upon connection to, or disconnection from, the a.c. network of a step of the reactance elements the resultant voltage change is simultaneously compensated by a rapid change of the control angle of the converter, said rapid control angle change itself being accompanied by a more gradual change of the control angle in the direction opposite to said rapid change.

No voltage control occurs in the a.c. network at the very moment when the connection or disconnection of a reactance step takes place, but the voltage control takes place during the gradual transition between the rapid control angle change and the more gradual control angle change. It is then clear that, in the case of connection of a capacitor step, the control angle should be changed rapidly, almost instantaneously, somewhat in a direction towards 90°, whereafter this temporary change is written off more gradually in a few seconds. Upon disconnection of a capacitor step, on the other hand, the control angle should first be changed gradually towards 90°, whereafter it is returned rapidly to its previous or normal range simultaneously with the disconnection. If the reactance elements are control reactors, disconnection or connection of a reactor step will correspond to connection or disconnection, respectively, of a capacitor step.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which

Figure 1 is a circuit diagram of a converter plant,

Figure 2 is a circuit diagram of means for the voltage control of such a plant, and

Figures 3 and *4* are diagrams illustrating the principles of control of the method according to the invention.

Figure 1 shows a converter 1 which is connected to an a.c. network 3 by way of a converter transformer 2. The converter is further connected to a d.c. network in the form of a d.c. line 4 and controlled by a control system 5, for example according to British Patent Specification No. 1,238,720.

Reactance elements are connected to the network 3 in the form of a capacitor bank consisting of a number of units 6*a*, 6*b*, 6*c* which can be connected to, or disconnected from, the network in steps by means of connection members controlled from a control system 7. Instead of a capacitor bank, it is possible to have a reactor with step switches, or possibly a combination of reactors and capacitors. The capacitor bank 6*a*, 6*b*, 6*c* can be intended only for reactive power control, or may be included in filter or damping circuits for the network. The control system 7, in its turn, may be controlled from a transducer 8 which measures the reactive power in the network 3 at the time by means of voltage and current transformers 9, 10. The transducer 8 is suitably designed as a discriminator which emits a signal about connection or disconnection of the capacitor units in dependence on the deviations of the reactive power Q from a reference value Q*o*.

Further, a synchronous machine 11 is connected to the network 3, for example a generator or a synchronous condenser provided with a voltage regulator 12, which is connected to the network 3 by way of a voltage transformer 13.

The control system 7 for the capacitor bank and its connnection to the control system 5 of the converter are shown in more detail in Figure 2.

According to Figure 1, the transducer 8 emits a positive or negative signal in dependence on whether capacitor units are to be connected or disconnected. In Figure 2 this has been indicated by opposed diodes 81 and 82 on the output of transducer 8, a signal being emitted to the corresponding connection members 71*a* and 71*b*.

The signal for connection of a capacitor unit travels via the output 75*a* to the connection members of the capacitor bank, which are suitably arranged as a step switch. The signal is also passed via an Or gate 72*a* and a delay means 73*a* to a signal transducer 74*a* which supplies a rapidly growing signal which thereafter decays for a certain period of time. The delay in the means 73*a* corresponds to the reaction time for the corresponding connection members in the bank so that the signal from the transducer 74*a* comes at the same time as the capacitor unit is connected. The signal from the transducer 74*a* should not grow instantaneously, but should be allowed to grow for a few milliseconds in order to avoid disturbances in the converter.

By way of a summator 70 and a member 76, the signal from the transducer 74*a* is connected to a summator 50 on the input of the control system 5 of the converter.

Also the reference value for the upper or lower limit of the control angle of the converter is connected to the summator 50. If the converter operates as a rectifier, the summator 50 is in that case located on the input of α_{min}, that is, of the reference value for the lower limit of the control angle according to the above-mentioned British Patent Specification No. 1,238,720. If the converter operates as an inverter, on the other hand, the summator is located on the input of the smallest possible margin of commutation γ_o, which in turn determines the upper limit α_{max} of the control angle.

In both cases, an addition over the summator 50 means that the control angle is forced somewhat in a direction towards 90°. which means that the internal voltage of the converter drops, thus compensating for the voltage addition caused by the connection of a capacitor unit.

The absolute magnitude of the addition to the summator 50 can be computed in the member 76 in dependence on the working parameters in question, such as the magnitude Δ Q of the signal from the transducer 8, the power P of the converter at the time, the direct current I and the control angle α. In this way, the alteration of the control angle is adapted so that the voltage change in the network is held within reasonable limits.

The relations between the above-mentioned parameters will be clear from Figure 4, which illustrates the relation between the active power P of the converter and its reactive power Q. The circular curves then correspond to the relations in the case of a constant current I, whereas the bent radial curves correspond to the relations for a constant control angle α.

At a certain active power P_1, the control angle must be changed from α_1 to α_2 in case of an addition ΔQ in the reactive power from the reactance elements.

Upon disconnection of capacitor units, a signal is emitted by way of the connection member 71*b* to a delay means 73*b*. A signal is emitted by way of an Or gate 72*b* to a transducer 74*b*, from which a signal, for example a ramp signal, gradually grows and is supplied to the members 70, 76 and 50. When this signal has grown, the member 73*b* may supply a signal to an output 75*b* of the step switch of the capacitor bank, while at the same time the signal from the transducer 74*b* is disconnected over an Or gate 72*c*.

The characteristics of the different parameters are shown in Figure 3, in which Figure 3*a* indicates the addition in reactive power Q_C in case of connection of a part of the capacitor bank 6*a* - 6*c* at the time t_1 and disconnection at the time t_2.

Figure 3*b* shows how the margin of commutation γ at t_1 receives an addition almost instantaneously, which addition then gradually disappears. The corresponding change of the reactive power of the converter is clear from Figure 3*c*.

Disconnection at time t_2 is prepared by gradually increasing γ to the desired value, and thereafter rapidly reducing γ to the original value at t_2.

Any voltage changes in the network during these processes will influence the voltage control of the synchronous machine 11 as indicated in Figure 3*d*. To ensure a safe voltage control of the synchronous machine, the signal ramps in the transducers 74*a* and 74*b* should therefore be made correspondingly long.

The Or gates 72*a*, 72*b* and 72*c* shown in Figure 2 and having several inputs are designed for the control system 7 to be able to be used for connection and disconnection of different reactance elements from, for example, filters, damping circuits and compensating capacitors.

The above description of Figure 3 is mainly a discussion of an addition to the margin of commutation γ in the case of an inverter. As mentioned earlier, the same result can be obtained by increasing the lower limit α of the control angle during rectifying. A third possibility is transmitting the signal from the member 76 from one of the converters to the other in a d.c. transmission system. Such a transmission system, for example by means of a telelink, results in the desired voltage change taking place through the d.c. line. In this way the control play is avoided which may otherwise occur by the current control changing from a rectifier to an inverter.

Connection and disconnection of reactance elements can take place automatically, as shown, in dependence on some working parameters in the plant, but it can also be performed manually through direct influence of the connection members 71*a* and 71*b* in Figure 2. The system according to Figures 1 and 2 operates in parallel with and without disturbing the normal power control of the transmission system, thus maintaining the transmitted active power.

WHAT WE CLAIM IS:-

1. A method of controlling the alternating voltage of a converter connecting a d.c. network and an a.c. network reactance elements being connectible in steps, with the a.c. network, and the converter comprising means for providing angle control, characterised in that upon connection to, or disconnection from, the a.c. network of a step of the reactance elements the resultant voltage change is simultaneously compensated by a rapid change of the control angle of the converter, said rapid control angle change itself being accompanied by a more gradual change of the control angle in the direction opposite to said rapid change.

2. A method according to claim 1, in which a synchronous machine provided with means for voltage control is connected to said a.c. network, and said more gradual change of the control angle takes place so slowly that the voltage control of the synchronous machine is able to keep the alternating voltage within specified limits.

3. A method according to claim 1, in which the magnitude of the control angle change is adapted to the current working parameters of the converter so that any voltage changes in the a.c. network are held within the desired limits.

4. A converter provided with means for voltage control according to the method of claim 1, in which said means for providing angle control comprises ramp signal transducers involving a rapid change of the control angle of the converter during switching of reactance elements and a more gradual change of the control angle in the direction opposite to said rapid change.

5. A converter constructed and arranged substantially as herein described with reference to, and as illustrated in, the accompanying drawings.

6. A transmission system comprising an a.c. network connected to a d.c. network via a converter according to claim 4 or 5.

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Printed for Her Majesty's Stationery Office.
by Croydon Printing Company Limited. Croydon. Surrey. 1981.
Published by The Patent Office. 25 Southampton Buildings.
London. WC2A 1AY. from which copies may be obtained.

1595362 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

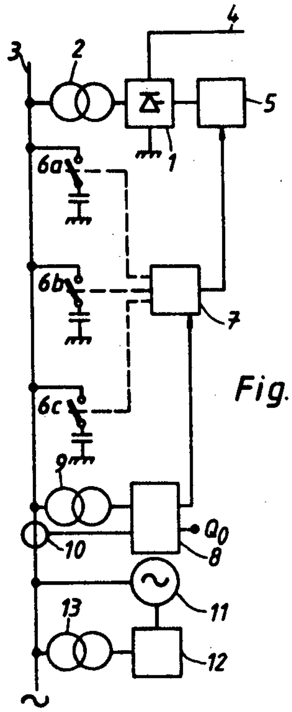

Fig.1

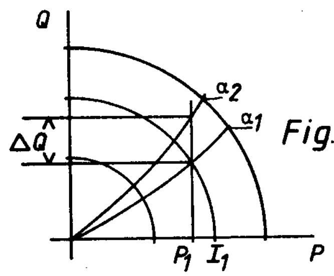

Fig. 4

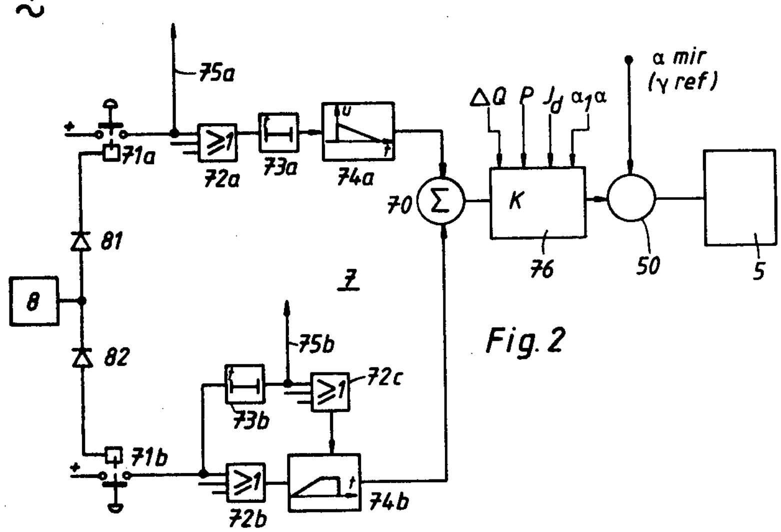

Fig. 2

Fig. 3