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(54) **Device for controlling the opening/closing of electrical switchgear and related procedure**

Vorrichtung zur Regelung der Öffnung und Schliessung eines elektrisches Schaltgerätes und verwandtes Verfahren

Dispositif pour la commande d'un appareil de commutation électrique et procédé associé

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Description

[0001] The present invention relates to a control device for the opening/closing of electrical switchgear such as circuit-breakers, isolators, reclosers and the like, in an electricity distribution and/or transmission network, and related method.

[0002] More specifically, the present invention relates to a control device that makes it possible to adjust the control parameters in input to an actuator in real time, thus allowing to obtain a desired law of motion for the moving parts of the switchgear moved by it.

[0003] As it is known, the switchgear operation is executed in relation to a control signal sent, for example, by a control panel or by a protection logic; in particular, this signal is sent to an actuator that causes the switchgear associated with it to perform a corresponding opening or closing operation.

[0004] In the prior art the actuators used for this purpose, generally of mechanical type, operate according to a law of motion that is not adjustable, not allowing the force they apply to the switchgear to be controlled. The behaviour of the actuator can therefore be defined as "binary", which is to say the force applied is either none or the maximum. This generally leads to oversize both the actuator and the energy storage system required to feed it in order to cope with every possible condition of use of the switchgear during its operating life; in this way the switchgear is in most cases supplied with more energy than it actually requires for the operation, which has a detrimental effect on the energy efficiency of the system and increases the energy dissipated in the impact at the end of the operation with consequent high mechanical stresses on the switchgear and lower overall reliability of the system. In addition, with these actuators it is impossible to stop an operation once it has started, which prevents one from improving the co-ordination of the circuit breakers in an electrical network; for example, it is not possible for a circuit-breaker to cancel its operation once it has started if it detects that a circuit-breaker downstream that eliminates the fault has been tripped, which would prevent it from opening and cutting off the power to fault-free parts of the electrical system and interrupting the service of the loads connected to it without reason.

[0005] One aspect that is essential to note consists in the fact that, using such actuators with a non-adjustable law of motion, the opening or closing operation obtained (simultaneously for all three phases) is generally asynchronous in relation to the phases of the electrical parameters, which is to say they do not have any temporal relationship with the electrical network; this in most cases leads to the generation of transients in the electrical network due to prestrike phenomena during closing and restrike phenomena during opening. In particular, depending on the type of load present in the electrical network, an operation performed at a non-optimal moment could cause high frequency oscillation phenomena with high amplitudes compared to the rated values of the electrical parameters of the electrical network; the current values can, for example, even rise several orders of magnitude higher than the rated current value. These transients clearly subject the electrical network to anomalous stress and have the potential to reduce the expected life of the equipment connected to the electrical network; moreover they lead in any case to a greater wear of the contacts of the switchgear itself and consequently reduce its useful life.

[0006] In the prior art, some solutions have been proposed with the aim of making the operation of the switchgear synchronous with the electrical network in which it is used to thereby limit the problems explained above. It should be emphasised that the opening and/or closing operation may be considered synchronous when, having set an ideal tripping moment in relation to the type of load and the mode in which it is connected to the electrical network, such as the zero voltage for a capacitor or the peak voltage for a reactive load, for example, the end-of-operation moment falls within a synchronism time window around the ideal moment in which the transients obtained are sufficiently low.

[0007] One of the solutions proposed is illustrated in United States patent No. 5119260 which faces the problem regarding only the synchronised opening of an inductive load at a predetermined time in relation to the natural passage of the current through zero in such a way as to avoid overvoltages. In this patent, the time for the operation is provided, measured during one or more previous operations, in order to keep the opening operation within the synchronisation time window. In order to take account of the fact that the operating time is not constant but varies in relation to the ambient temperature and the opening coil temperature, these temperatures are supplied to the controller using an appropriate sensor. In particular, the controller is equipped with a system that is able to evaluate the characteristics of the variation in the operating time in relation to the temperature measured values; moreover, in order to take into account possible variations in the operating time in relation to the period of time that has elapsed between two successive operations, the controller also receives a measurement of this period of time and uses it to correct the operating time envisaged using a special predetermined function. The control time in relation to the envisaged zero is then calculated in relation to the behaviour observed during the previous operations and the influencing factors considered, namely the temperature and the time that has elapsed between two consecutive operations.

[0008] This solution therefore assumes a precise knowledge of the electrical and mechanical behaviour of the device in relation to the aforesaid variables; this knowledge derives from characterisation measurements performed in a test phase regarding a sample of devices that is considered to be significant regarding the behaviour of every possible similar switchgear product

manufactured.

[0009] The main limitation of the solution resides in the accuracy with which one is able to represent the behaviour of a specific circuit-breaker, in particular taking into account the different stresses to which it may be subjected during its operating life and, therefore, the mechanical and electrical wear that influences the operating time.

[0010] Furthermore, the use of a processor that calculates the actual operating time taken in real time makes it possible to evaluate the error committed, in relation to the predetermined operating time, only at the end of the operation itself and thus precludes any form of corrective action during its execution; since the correction to be applied is therefore evaluated in relation to the previous operation it is not possible to guarantee that the synchronism condition will be respected in the next operation.

[0011] Finally, it is to underline the fact that the inventors of the device illustrated did not equip it for opening operation in the event of a fault and thus during the transient of short circuit currents.

[0012] Another solution is illustrated in US patent 5,361,184 which faces the problem concerning the control of the circuit breakers or isolating equipment both in the opening and closing phases, taking the optimal moment of operation to be the zero voltage for closing and the zero current for opening. In particular, in the illustrated device, the actual operating time taken is recorded during every operation; in addition, the device is equipped with means for detecting transients in order to evaluate whether the operation has been performed synchronously. If this is not the case, the device produces a signal for correcting the predetermined operating time for subsequent operations and obtaining synchronous operation; in addition a suitable ambient compensation system makes it possible to perform further corrections that take into account the influence of the temperature and of the atmospheric pressure on the predetermined operating time.

[0013] The main limit of the solution therefore resides in the fact that the device relies on prior knowledge of the behaviour of the circuit breakers and/or isolators in relation to the ambient factors. In addition, the adaptive correction of the operating time following the result of a previous operation can lead to oscillations and does not ensure that synchronisation is achieved. Finally, taking the zero voltage in closing and the zero current in opening to be the optimum time for performing the operation limits the possible cases for application of the device; it is for example entirely unsuited to closing upon inductive loads.

[0014] In this solution, further errors can be caused by the chosen modes of synchronisation with the electrical network signals that either employ the use of a voltage reference and the determination of a current reference from a phase angle measurement that is subsequently considered to be constant, or determine the moments of passing through the zero voltage from a single measurement, assuming the electrical network to be symmetrical and therefore operating with delays of 120° electrical degrees. This method of detecting the reference moments (zeros) makes the system ineffective with distorted voltages, in the presence of transient components and, more generally, with network parameters that have harmonic or non-symmetrical components and is therefore not applicable for synchronous opening upon faults.

[0015] In conclusion therefore, although the aforementioned solutions enable the said problems to be partially resolved in specific cases they are not, however, able to guarantee that synchronism is achieved in the actual time since even in those cases where adaptive control methods are adopted they do not act on the operation in progress but only introduce estimated corrections that have an effect, which cannot be totally controlled, on the next operation. They are, therefore, basically open loop control systems in which the implementation of feedback closes the control loop with a temporal dynamic that is significantly longer than the individual operation, such that it could be entirely ineffective.

[0016] Another example of solutions of known type is disclosed in WO96/36982 which discloses a control device with a single closed loop control device.

[0017] The main task of the present invention is to provide a control device for the opening/closing of electrical switchgear that is able to adjust the parameters in input to the actuator in real time in order to control the force it applies at every moment in the operating time, thus allowing a desired law of motion to be imposed on the moving parts of the switchgear actuated by it.

[0018] As part of this task, an object of the present invention is to provide a control device for the opening/closing of electrical switchgear that makes it possible to act on the individual poles of a three-phase system to perform the operation in an optimal manner for the electrical system as a whole, enabling one, in the event of a fault, to operate only on the phase affected and to continue operation of the fault-free phases, thus ensuring greater availability and continuity of service.

[0019] Another object of the present invention is to provide a control device for the opening/closing of electrical switchgear that guarantees the repeatability of the operation to be performed as well as its optimisation in relation to the different types of breaking techniques chosen.

[0020] A further object of the present invention is to provide a control device for the opening/closing of electrical switchgear that makes it possible to decrease the energy used in the operation, thus making it possible to optimise the sizing of the actuator and of the energy storage system, with a consequent economic benefit.

[0021] Yet another object of the present invention is to provide a control device for the opening/closing of electrical switchgear that makes it possible to control the motion of the actuator both in the initial and final phases,

making it possible, for example, to brake the switchgear decreasing the kinetic energy dissipated in the impact, or to coordinate the operation of one circuit-breaker with others downstream, cancelling an operation that has been started if it is no longer necessary to ensure greater continuity of service.

[0022] A further object of the present invention is to provide a control device for the opening/closing of electrical switchgear that makes it possible to control the operating time of the moving parts of the said switchgear and to perform the operation synchronously, for each individual phase, in relation to the phases of the electrical parameters of the network, irrespective of the command moment sent from a control panel or a protection logic.

[0023] Yet another object of the present invention is to provide a control device for the opening/closing of electrical switchgear that simple modifications can enable to obtain synchronism of the operation with the waveform of the electrical network with different types of networks and loads present, thus distinguishing itself by considerable flexibility in use and enabling in particular to realise the synchronisation during opening upon a fault, significantly limiting electrical wear.

[0024] A further object of the present invention is to provide a control device for the opening/closing of electrical switchgear which by controlling the law of motion of the actuator-switchgear assembly in real time makes it possible to eliminate the voltage and current transients of the electrical network, or at least limit them as much as possible, thus reducing any anomalous stresses on the insulation systems of the components present, as well as electrodynamic and thermal stresses.

[0025] Yet another object of the present invention is to provide a control device for the opening/closing of electrical switchgear that allowing to obtain operations that are synchronous with the waveform of the electrical network makes it possible to increase its reliability while also increasing the electrical and mechanical life of the switchgear present in it.

[0026] An additional though not the last object of the present invention is to provide a control device for the opening/closing of electrical switchgear that is highly reliable and relatively easy to manufacture at competitive costs.

[0027] This task, together with the above-mentioned and other objects that shall emerge more clearly hereinafter, are achieved by Control device for the opening/closing of electrical switchgear such as circuit-breakers, isolators, reclosers and the like, in an electricity distribution and/or transmission networkcharacterised by the fact that it comprises:

- an actuator with adjustable law of motion;
- a processing and control unit that receives an operating command and sends a control signal to the actuator that is processed in relation to:
- a predetermined nominal behaviour;
- information, direct or indirect, on the position, velocity, acceleration of the mobile part of the said switchgear;
- information regarding the variation, in relation to the nominal behaviour, of the entire actuator-kinematic chain-switchgear controlled system;

in order to realise the desired law of motion of said mobile part.

[0028] The above-mentioned task, together with the aforementioned and other objects are also achieved by a control method for the opening/closing of electrical switchgear such as circuit breakers, isolators, reclosers and the like, in an electricity distribution and/or transmission network characterised by the fact that it comprises the following phases:

a) sending a control signal to an actuator with adjustable law of motion;
b) directly or indirectly acquiring information on the movement or velocity or acceleration of the mobile part of said switchgear operated by the adjustable actuator and processing a control signal;
c) modulating the flow of energy supplied to the actuator in relation to said control signal in such a way as to adjust the force it exerts on the kinematic chain-switchgear system and obtain the desired law of motion of said mobile part.

[0029] This is accomplished by the present invention which provides a control device for electric switchgear and a control method for electric switchgear according to the appended claims.

[0030] Further characteristics and advantages of the invention shall emerge more clearly from the description of preferred but not exclusive embodiments of the device as in the invention, illustrated purely by way of example and without limitation with the aid of the attached drawings, in which:

Figure 1 is a general block diagram of the control device as in the invention;
Figure 2 is a detailed block diagram of an embodiment of the control device as in the invention;
Figure 3 is a detailed block diagram of control means and converter means used in the device as in the invention;
Figure 4 is a detailed block diagram of a preferred embodiment of the device as in the invention;
Figure 5 is a diagram illustrating the voltage phase in relation to time in normal operating conditions;
Figure 6 is a diagram illustrating the current phase in relation to time in the presence of a transient.

[0031] With reference to Figures 1 and 2, the device according to the invention comprises a processing and control unit, indicated overall by reference number 100, which receives an operating command 1 in input from a

control panel or protection logic and sends a first control signal 3 in output to an actuator 2. In the embodiment of the device as in the invention, the actuator used advantageously operates with an adjustable law of motion; in this way the force applied by the actuator to the switchgear 4, through a kinematic chain 5 connecting them, can be adjusted and makes it possible to have an actuator-kinematic chain-switchgear system 200 that is perfectly controlled in relation to the different application requirements using the procedures that will be illustrated in detail hereinafter.

[0032] In particular, the actuator concerned is an electromagnetic actuator, the subject of European patent application number EP 97203501.8-2302, the description of which is to be understood as included herein for reference; the specific reference to said actuator is clearly to be considered solely for the purposes of explanation in that any actuator with adjustable law of motion, such as a pneumatic actuator for example, could be used in equivalent way in the device as in the invention.

[0033] As illustrated in the said figures, the control device suitably comprises feedback means 6 for evaluating, by direct or indirect measurement, the position of the mobile part of the switchgear connected to the actuator; in particular, these means 6 may comprise a position sensor that detects a movement of any point of the controlled system 200 and sends a corresponding signal 7 indicating in real time the position of the mobile contacts of the switchgear to control means 10 of the processing and control unit 100; alternatively, velocity or acceleration sensors could be used that detect the velocity or the acceleration of any point of the system 200 and send the corresponding information 7 on the velocity or acceleration of the mobile parts to means 10. This sensor, irrespective of whether it is a position, velocity or acceleration sensor, may be positioned in any point of the kinematic chain 5 or of the switchgear 4 to suit specific applications and/or needs.

[0034] In another embodiment, the information regarding the position of the mobile parts may be supplied to the control means 10 namely without the use of sensors ("sensorless system") using a mathematical model of the controlled system 200; this model, forming part of the unit 100, receives a signal in input that is a function of the actuator's control parameters, in this case the voltage and current of the power supply to the coil, and supplies a signal indicating the estimated position of the mobile contacts of the switchgear to the control means 10 in real time. If the actuator used is, for example, a pneumatic type, the control parameters could be the pressure and the volume of the compressible fluid used.

[0035] The control means 10, which receive in input the operating command 1 and the direct or indirect signal 7 indicating the position or velocity or acceleration in real time of the mobile contacts of the switchgear, send a corresponding second control signal 19 to converter means 20 in output.

[0036] In particular, in the device as in the invention and as illustrated in greater detail in figure 3, the control means 10 comprise calculating means 11 that receive the signal 7 in input and by means of suitable integrations/derivations send a signal 14 indicating the law of motion of the mobile contacts at that moment in output to first closed loop control means 12 and second closed loop control means 13; this signal 14 thus constitutes information of the mode in which the mobile part of the switchgear moves from the initial time of motion to the time of measurement.

[0037] The first closed loop control means 12 compare the signal 14 indicating the actual law of motion of the mobile contacts with a predetermined law of motion and send a corresponding reference signal 16 in output to the second closed loop control means 13 and to comparator means 15. In particular, this predetermined law of motion corresponds to a predetermined nominal behaviour of the entire actuator-kinematic chain-switchgear system.

[0038] The second closed loop control means 13 compare the signal indicating the actual law of motion 14 with the reference signal 16 sending a corresponding correction signal 18 in output to comparison means 15; the comparison means 15 in their turn send the second control signal 19 in output to converter means 20 in relation to the correction signal 18 and to the reference signal 16 received in input.

[0039] In the embodiment illustrated, the converter means 20 comprise power supply means 21 for the actuator that can be provided using, for example, batteries or capacitors; alternatively, in the case of an actuator that is not electromagnetic but can nevertheless be controlled, such as a pneumatic actuator, this storage unit could be provided using a compressible fluid plenum chamber.

[0040] In addition, the converter means 20 advantageously comprise means for modulating 22 the flow of energy supplied to the actuator by the power supply means 21; these modulation means adjust the flow of energy supplied by the means 21 to the actuator by modulating the power supply current and/or voltage of the actuator itself in relation to the second control signal 19. The actuator, which converts the modulated electrical energy into mechanical energy, thus applies a continually adjusted force to the kinematic loop connected to it that makes it possible to move the mobile parts of the switchgear with the desired law of motion.

[0041] The control device proposed thus comprises an open loop control based on the nominal behaviour of the system to realise the opening and/or closing operation in the modes desired; this open loop control system is juxtaposed with a closed loop control system that corrects any possible changes in relation to the nominal behaviour to ensure implementation of the desired law of motion. In particular, given that the control is carried out in real time during the operation itself, the device as in the invention makes it possible to accurately take into

account all the disturbance acting on the controlled system able to influence its response by varying the behaviour in relation to the predetermined nominal behaviour, namely the effect of environmentalparameters, the electrical and mechanical wear of the switchgear, the time elapsed between operations, the ageing of the control equipment, the number and type of operations performed etc..

[0042] The possibility of controlling the force applied by the actuator and therefore of adjusting the law of motion of the mobile parts of the switchgear makes it possible to perform operations that are currently impossible for the devices of known type; for example, in the case of three-phase circuit breakers, the control device as in the invention makes it possible to obtain optimal operation on a single pole while leaving the other two phases, which are not affected by faults, in operation; furthermore, by adjusting the force applied by the actuator it is possible to stop an operation that has been started whenever it is no longer essential, or even to reverse the direction of the operation itself at least within a certain time window. This makes it possible to implement a new protection logic with improved co-ordination for example between circuit-breakers that, once an operation has already been started, are able to detect the operation of a circuit-breaker downstream that eliminates the fault and cancel the operation, preventing the circuit-breakers from opening and cutting off the power to fault-free parts of the electrical network without reason, also doing so without having to insert any intentional delays, useful for the purposes of selectivity. In the same way, the circuit-breaker that is controlled can, when required to operate on a transient, cancel the operation when the transient is over and not interrupt the service of the loads that it powers.

[0043] A further advantage that should under no circumstances be overlooked resides in the fact that the device as in the invention ensures repeatability of the operation by adjusting the force applied by the actuator and makes it possible to optimise the law of motion of the mobile parts moment by moment following a preferred trajectory and in relation to the different types of breaking systems used; in this way, moreover, the energy transmitted to the actuator, and therefore to the switchgear, is adjusted perfectly and this makes it possible not just to optimise the sizing of the actuator and its power supply system, but also to decrease the energy dissipated in the end-of-operation impact, with lower stresses on the switchgear, lower contact wear and therefore, in short, higher reliability of the entire electrical network.

[0044] As illustrated in Figure 4, in a preferred embodiment of the device according to the invention, the processing and control unit 100 also comprises synchronisation means 33 capable of providing information for the opening or closing of the switchgear synchronously with the electrical network. These synchronisation means, through the use of means for detecting the voltage and current phases of the electrical network, such as, for example, a current transformer 30 and a voltage transformer 31, receive information 32 tracking the electrical parameters of the network; in relation to this information, the synchronisation means, through suitable calculations, predict the succession of the zeros and maximums of the phases of the current and voltage following those detected, also taking account of frequency variations, harmonic components and single-phase transient components. In addition, they calculate the time between the zeros and maximums detected and those predicted.

[0045] In addition, the synchronisation means advantageously also comprise table means 34 that contain predetermined information regarding the state of the neutral, the type of load and of the electrical network, and send a signal 35 indicating the ideal end-of-operation times in relation to said predetermined information to a timer unit 36. In this embodiment and as illustrated in Figures 5 and 6, the operating command 1 is sent to the timer unit 36 and is a command that is generally asynchronous in relation to the electrical system. The timer unit 36 sends a corresponding synchronous start operation command 37 to the control means 10 in relation to this command 1, as well as to the signal 35 indicating the ideal end-of-operation times; this synchronous command 37 is delayed in relation to the asynchronous command 1 by a period of time 50 that is a function of the predetermined nominal operating time 51 and of the said signals 35 indicating the ideal end-of-operation times and the subsequent zeros or maximums predicted, in order to identify the first subsequent ideal moment useful for implementing the synchronous operation. The desired ideal moment 35 is clearly the optimal time for eliminating operation transients in relation to the type of operation, load and electrical network; as illustrated in Figure 6, this moment in time does not necessarily coincide with a zero or with a maximum but nevertheless ensures that the operation is performed within the synchronism window. The control means 10 thus receive the signal 37 indicating the co-ordinated control strategy for the three phases to perform the synchronous operation for each individual phase and operate analogously to that which has been described above.

[0046] A further advantage of the invention resides in the fact that, both in the synchronous operation situation and in the case only of adjustment of the law of motion of the mobile parts previously described, the control means 10 ensure execution of the operation in the nominal time envisaged thanks to the corrective action of the means 13 previously described; if, however, the deviation from the nominal behaviour at any point become accentuated during the operation, requiring a significant demand on the closed loop control, the device is able to correct the nominal characteristic of the system in a self-organising mode. In this case, the nominal operation time that is suitably monitored during the operations is redefined in relation to a new reference value; in the

case of synchronous operation, this new reference time is obviously made available by the means 10 to the timer unit 36. This self-organising procedure is also used in the device's testing phase so that the control system corrects the nominal characteristic in relation to the real behaviour of the specific switchgear unit, making it possible to define the actual initial nominal characteristic.

[0047] It has in practice been noted how the device as in the invention makes it possible to achieve the task in full as well as the objects set in that it makes it possible to adjust the force applied by the actuator in real time moving the mobile parts following a desired law of motion and making it possible to obtain all the advantages previously described.

[0048] In addition, in the preferred embodiment illustrated, the device makes it possible to obtain operation synchronous with the electrical network, with the widest different types of electrical systems and loads present in them and even in the presence of faults. This therefore results in further and significant advantages in terms of the flexibility of application of the device, and in terms of the elimination or at least significant reduction of voltage and current transients in the network, as well as in terms of limiting electrodynamic and thermal stresses, with significant consequent benefits both for the insulation systems of the components present in the electrical system and of the switchgear used, considerably increasing its useful life and reliability.

[0049] It should, finally, be emphasised that the device as in the invention, while offering all the benefits stated, is obtained using a manufacturing solution that is extremely attractive from an economic standpoint, the costs of which are comparable with those of a conventional circuit-breaker and decidedly lower than the conventional synchronous solutions. The device conceived in this way is capable of many modifications and variants, all within the inventive concept, as defined in the appended claims.

Claims

1. Control device for an electric switchgear (4) comprising:

   - an actuator (2) with adjustable law of motion;
   - a kinematic chain (5) connecting said actuator (2) with said switchgear (4);
   - a processing and control unit (100) that receives an operating command (1) and sends a first control signal (3) to the actuator (2), said processing and control unit (100) comprising control means (10), **characterized in that** said control means (10) comprises:

   - calculating means (11) that receive a direct or indirect signal (7) indicating the position, or velocity, or acceleration in real time of the mobile contacts of the switchgear and send a signal (14) indicating the law of motion of said mobile contacts;
   - first closed loop control means (12), that receive said signal (14) indicating the law of motion of said mobile contacts, compare said signal (14) indicating the law of motion of said mobile contacts with a predetermined nominal behaviour of the entire system actuator-kinematic chain-switchgear (200), and send a corresponding reference signal (16);
   - second closed loop control means (13), that receive said signal (14) indicating the law of motion of said mobile contacts and said reference signal (16), and send a correction signal (18);
   - comparator means (15), that receive said reference signal (16) indicating the law of motion of said mobile contacts and said correction signal (18), and send a second control signal (19), in order to realize a desired law of motion of said mobile contacts.

2. Control device as in claim 1, **characterised in that** said actuator (2) with adjustable law of motion is an electromagnetic actuator.

3. Control device as in claim 1 or 2, **characterised in that** it comprises feedback means (6) for evaluating, by direct on indirect measurement the position of the mobile part of the system (200).

4. Control device as in claim 3, **characterised in that** said feed back means (6) comprise a position or velocity or acceleration sensor that detects the position or velocity or acceleration of any point of the system (200) and sends said signal (7) indicating the position, or velocity, or acceleration in real time of the mobile contacts of the switchgear (4).

5. Control device as in claim 3, **characterised in that** said feed back means (6) comprise a mathematical model of the system (200) that receives a signal in input that is a function of measurements of control parameters of the actuator and sends a signal (7) indicating the estimated position of the mobile contacts of the switchgear (4) to the processing and control unit (100) in real time.

6. Control device as in one or more of the previous claims, **characterised in that** it comprises converter means (20) that receive in input said second control signal (19), said converter means (20) comprising:

   - power supply means (21) for the actuator (2); and
   - means (22) for modulating the flow of energy supplied to the actuator (2) by the power supply

means (21) in relation to said second control signal (19) received in input.

7. Control device as in one or more of the previous claims, **characterised in that** it comprises synchronisation means (33) suitable for providing the processing and control unit (100) with information for opening or closing the switchgear (4) in a mode that is synchronous with the electrical network.

8. Control device as in claim 7, **characterised in that** said synchronisation means (33) comprise:

- means (30, 31) for detecting the current and voltage phases of the electrical network;
- means for predicting the zeroes and maximums of the current and voltage phases, subsequent to those detected;
- means for calculating the period of time between the zeroes and maximums detected and those predicted.

9. Control device as in claim 7 or 8, **characterised in that** said synchronisation means (33) comprise:

- table means (34) containing predetermined information regarding the state of the neutral, the type of load and the type of the electrical network, said table means (34) being suitable of sending a signal (35) indicating the ideal end-of-operation times in relation to said predetermined information to a timer unit (36).

10. Control device as in claim 9, **characterised in that** said timer unit (36) receives in input:

- said operating command (1) that is asynchronous in relation to the electrical system;
- said signal (35) indicating the ideal end-of-operation times;
- a signal indicating the subsequent predicted zeroes or maximum;

and send to the control means (10) a corresponding synchronous start operation command (37) that is delayed in relation to the asynchronous command (1) by a period of time (50) that is a function of a predetermined nominal operation time (51) and of said signal (35) indicating the ideal end-of-operation times and of said signal indicating the subsequent predicted zeroes or maximum.

11. Electricity distribution and /or transmission network comprising a plurality of circuit breakers installed in a cascade arrangement, **characterised in that** at least one circuit breaker of said plurality of comprises a control device as in one or more of the previous claims and **in that** the opening/closing of said at least one circuit breaker occurs in a manner that is coordinated with other circuit breakers upstream or downstream of it so as to interrupt or reverse the opening or closing operation.

12. Electrical switchgear for electricity distribution and/or transmission networks, **characterised in that** it comprises a control device as in one or more of claims 1 to 10 and **in that** the amount of power delivered during an opening/closing operation is a function, moment by moment, of the residual travel of the mobile contacts.

13. Electrical switchgear as in claim 12, **characterised by** the fact that said adjustable actuator applies on the mobile part force adjustable moment by moment and is . capable of minimising the amount of energy dissipated in the impact in a closing operation.

14. Control method for the opening/closing of electrical switchgear (4), such as circuit breaker, isolators, reclosers and the like, in an electricity distribution and/or transmission network **characterised by** the fact that it comprises the following phases:

a) sending an operating command (1) to a processing and control unit (100) of said switchgear (4);
b) directly or indirectly acquiring information (7) on the movement or velocity or acceleration in real time of the mobile contacts of the switchgear (4) and sending a signal (14) indicating the law of motion of said mobile contacts;
c) comparing said signal (14) indicating the law of motion of said mobile contacts with a signal indicating a predetermined law of motion and sending a corresponding reference signal (16);
d) comparing said reference signal (16) with said signal (14) indicating the law of motion of said mobile contacts and, in relation to this comparison, sending a correction signal (18);
e) comparing said correction signal (18) with said reference signal (16) and, in relation to this comparison, sending a second control signal (19);
f) modulating the flow of energy supplied to an actuator (2) with adjustable law of motion in relation to said second control signal (19) so as to adjust the force it exerts on the kinematic chain-switchgear system in order to obtain a desired law of motion of said mobile contacts;
g) sending a first control signal (3) to said actuator.

15. Control method as in claim 14, **characterised in that** said phase a) comprises:

- detecting the current (30) and voltage (31)

phases of the electrical network;
- predicting the zeroes and maximums of the current and voltage phases, subsequent to those detected;
- calculating the period of time between the zeroes and maximums detected and those predicted;
- processing and sending an operating command (37) so as to make the operation synchronous with the electrical network.

16. Control method as in claim 15, **characterised in that** said phase of processing and sending an operating command (37) so as to make the operation synchronous with the electrical network comprises:

- acquiring a signal (35) indicating the ideal end-of-operation times in relation to predetermined information regarding the state of the neutral, the type of load and the type of the electrical network;
- sending said operating command (37), delayed in relation to an asynchronous command (1) by a period of time (50) that is a function of a predetermined nominal operation time (51), of said signal (35) indicating the ideal end-of-operation times and of said subsequent predicted zeroes or maximum.

Patentansprüche

1. Steuervorrichtung für eine elektrische Schalteinrichtung (4) umfassend:

- einen Aktuator (2) mit einstellbarem Bewegungsgesetz;
- eine kinematische Kette (5), welche den Aktuator (2) mit der Schalteinrichtung (4) verbindet;
- eine Verarbeitungs- und Steuereinheit (100), welche einen Operationsbefehl (1) empfängt und ein erstes Steuersignal (3) an den Aktuator (2) sendet, wobei die Verarbeitungs- und Steuereinheit (100) Steuermittel (10) umfasst, **dadurch gekennzeichnet, dass** das Steuermittel (10) umfasst:
  - Berechnungsmittel (11), welche ein direktes oder indirektes Signal (7) empfangen, welches anzeigend für die Position, oder Geschwindigkeit, oder Beschleunigung in Echtzeit der beweglichen Kontakte der Schalteinrichtung ist und ein Signal (14) senden, welches anzeigend für das Bewegungsgesetz der beweglichen Kontakte ist;
  - erste geschlossene Regelkreissteuermittel (12), welche das Signal (14) empfangen, welches anzeigend für das Bewegungsgesetz der beweglichen Kontakte ist, das Signal (14), welches anzeigend für das Bewegungsgesetz der beweglichen Kontakte ist, mit einem vorherbestimmten nominellen Verhalten des gesamten Systems Aktuator-kinematische Kette-Schalteinrichtung (200) vergleichen, und ein entsprechendes Referenzsignal (16) senden;
  - zweite geschlossene Regelkreissteuermittel (13), welche das Signal (14), das anzeigend für das Bewegungsgesetz der beweglichen Kontakte ist, und das Referenzsignal (16) empfangen, und ein Korrektursignal (18) senden;
  - Vergleichsmittel (15), welche das Referenzsignal (16), das anzeigend für das Bewegungsgesetz der beweglichen Kontakte ist, und das Korrektursignal (18) empfangen, und ein zweites Steuersignal (19) senden, um ein gewünschtes Bewegungsgesetz der beweglichen Kontakte zu verwirklichen.

2. Steuervorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** der Aktuator (2) mit einstellbarem Bewegungsgesetz ein elektromagnetischer Aktuator ist.

3. Steuervorrichtung nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** es Feedback-Mittel (6) umfasst zum Bewerten durch direkte oder indirekte Messung der Position des beweglichen Teils des Systems (200).

4. Steuervorrichtung nach Anspruch 3, **dadurch gekennzeichnet, dass** die Feed-back-Mittel (6) einen Positions- oder Geschwindigkeits- oder Beschleunigungssensor umfassen, welcher die Position oder Geschwindigkeit oder Beschleunigung irgendeines Punktes des Systems (200) erkennt und das Signal (7), das anzeigend für die Position, oder Geschwindigkeit, oder Beschleunigung in Echtzeit der beweglichen Kontakte der Schalteinrichtung (4) ist, sendet.

5. Steuervorrichtung nach Anspruch 3, **dadurch gekennzeichnet, dass** die Feed-back-Mittel (6) ein mathematisches Modell des Systems (200) umfassen, welches ein Signal in Eingang empfängt, das eine Funktion der Messungen von Steuerparametern des Aktuators ist und ein Signal (7) sendet, welches anzeigend für die geschätzte Position der beweglichen Kontakte der Schalteinrichtung (4) ist, an die Verarbeitungs- und Steuereinheit (100) in Echtzeit.

6. Steuervorrichtung nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** es Konvertermittel (20) umfasst, welche in Eingang das zweite Steuersignal (19) empfangen, wobei die Konvertermittel (20) umfassen:

   - Stromversorgungsmittel (21) für den Aktuator (2); und
   - Mittel (22) zum Modulieren des Flusses von Energie, welche dem Aktuator (2) durch die Stromversorgungsmittel (21) bereitgestellt wird, in Beziehung auf das zweite Steuersignal (19), welches in Eingang empfangen wurde.

7. Steuervorrichtung nach einem oder mehreren der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** es Synchronisationsmittel (33) umfasst, die dazu geeignet sind, die Verarbeitungs- und Steuereinheit (100) mit Information zu versehen zum Öffnen oder Schließen der Schalteinrichtung (4) in einem Modus, der synchron mit dem elektrischen Netzwerk ist.

8. Steuervorrichtung nach Anspruch 7, **dadurch gekennzeichnet, dass** die Synchronisationsmittel (33) umfassen:

   - Mittel (30, 31) zum Erkennen der Strom- und Spannungsphasen des elektrischen Netzwerks;
   - Mittel zum Vorhersagen der Nulldurchgänge und Maxima der Strom- und Spannungsphasen, nachfolgend zu den erkannten;
   - Mittel zum Berechnen der Zeitperiode zwischen den erkannten und den vorhergesagten Nulldurchgängen und Maxima.

9. Steuervorrichtung nach Anspruch 7 oder 8, **dadurch gekennzeichnet, dass** die Synchronisationsmittel (33) umfassen:

   - Tabellenmittel (34), welche vorherbestimmte Information enthalten bzgl. des Zustands des Neutralleiters, der Art der Last und der Art des elektrischen Netzwerks, wobei die Tabellenmittel (34) geeignet sind zum Senden eines Signals (35), das anzeigend für die ideale Ende-der-Operationszeit in Beziehung zu der vorherbestimmten Information ist, an eine Timereinheit (36) zu senden.

10. Steuervorrichtung nach Anspruch 9, **dadurch gekennzeichnet, dass** die Timereinheit (36) in Eingang empfängt:

    - den Operationsbefehl (1), der asynchron in Beziehung zu dem elektrischen System ist;
    - das Signal (35), welches anzeigend für die ideale Ende-der-Operationszeiten ist;
    - ein Signal anzeigend für die nachfolgend vorhergesagten Nulldurchgänge oder Maxima;

    und an die Steuermittel (10) einen entsprechenden synchronen Startoperationsbefehl (37) senden, der verzögert ist in Beziehung auf den asynchronen Befehl (1) um eine Zeitperiode (50), die eine Funktion einer vorherbestimmten nominellen Operationszeit (51) und des Signals (35), das anzeigend für die ideale Ende-der-Operationszeiten ist, und des Signals, welches anzeigend für die nachfolgend vorhergesagten Nulldurchgänge oder Maxima ist, ist.

11. Elektrisches Verteilungs- und/oder Übertragungsnetzwerk, umfassend eine Vielzahl von Trennschaltern, welche in einer Kaskadenanordnung installiert sind, **dadurch gekennzeichnet, dass** wenigstens ein Trennschalter aus der Vielzahl eine Steuervorrichtung nach einem oder mehreren der vorhergehenden Ansprüche umfasst, und dass das Öffnen/Schließen des wenigstens einen Trennschalters in einer Weise erfolgt, die koordiniert mit anderen übergeordneten oder nachfolgenden Trennschaltern ist, um die Öffnungs- oder Schließoperation zu unterbrechen oder umzukehren.

12. Elektrische Schalteinrichtung für elektrische Verteilungs- und/oder Übertragungsnetzwerke, **dadurch gekennzeichnet, dass** es eine Steuervorrichtung nach einem oder mehreren der Ansprüche 1 bis 10 umfasst, und darin, dass der Betrag der abgegebenen Leistung während einer Öffnungs-/Schließoperation eine Funktion, Augenblick um Augenblick, des Restwegs der beweglichen Kontakte ist.

13. Elektrische Schalteinrichtung nach Anspruch 12, **dadurch gekennzeichnet, dass** der einstellbare Aktuator auf den beweglichen Teil Kraft anwendet, welche Augenblick um Augenblick einstellbar ist, und in der Lage ist, den Betrag der Energie zu minimieren, welche in dem Anschlag in einer Schließoperation umgesetzt wird.

14. Steuerverfahren für das Öffnen/Schließen von elektrischen Schalteinrichtungen (4), wie Trennschalter, Isolatoren, Kurzunterbrechern und ähnlichem, in einem elektrischen Versorgungs- und/oder Übertragungsnetzwerk, **dadurch gekennzeichnet, dass** es die folgenden Phasen umfasst:

    a) Senden eines Operationsbefehls (1) an eine Verarbeitungs- und Steuereinheit (100) der Schalteinrichtung (4);
    b) direktes oder indirektes Erfassen von Information (7) der Bewegung oder Geschwindigkeit oder Beschleunigung in Echtzeit der be-

weglichen Kontakte der Schalteinrichtung (4) und Senden eines Signals (14), welches anzeigend für das Bewegungsgesetz der beweglichen Kontakte ist;

c) Vergleichen des Signals (14), das anzeigend für das Bewegungsgesetz der beweglichen Kontakte ist, mit einem Signal, welches anzeigend für ein vorherbestimmtes Bewegungsgesetz ist, und Senden eines entsprechenden Referenzsignals (16);

d) Vergleichen des Referenzsignals (16) mit dem Signal (14), welches anzeigend für das Bewegungsgesetz der beweglichen Kontakte ist, und, in Beziehung auf diesen Vergleich, Senden eines Korrektursignals (18);

e) Vergleichen des Korrektursignals (18) mit dem Referenzsignal (16) und, in Beziehung auf dieses Vergleichen, Senden eines zweiten Steuersignals (19);

f) Modulieren des Flusses von Energie, welche an den Aktuator (2) mit einstellbarem Bewegungsgesetz bereitgestellt wird, in Beziehung auf das zweite Steuersignal (19), um die Kraft, die er auf das kinematische Kette-Schalteinrichtungssystem ausübt, anzupassen, um ein gewünschtes Bewegungsgesetz der beweglichen Kontakte zu erhalten;

g) Senden eines ersten Steuersignals (3) an den Aktuator.

15. Steuerverfahren nach Anspruch 14, **dadurch gekennzeichnet, dass**, die Phase a) umfasst:

- Erkennen der Strom- (30) und Spannungsphasen (31) des elektrischen Netzwerks;
- Vorhersagen der Nulldurchgänge und Maxima der Strom- und Spannungsphasen, nachfolgend zu den erkannten;
- Berechnen der Zeitperiode zwischen den erkannten und den vorhergesagten Nulldurchgängen und Maxima;
- Verarbeiten und Senden eines Operationsbefehls (37), um die Operation synchron mit dem elektrischen Netzwerk zu machen.

16. Steuerverfahren nach Anspruch 15, **dadurch gekennzeichnet, dass** die Phase des Verarbeitens und Sendens eines Operationsbefehls (37) um die Oparation synchron mit dem elektrischen Netzwerk zu machen umfasst:

- Erfassen eines Signals (35), welches anzeigend für die idealen Ende-der-Operationszeiten in Beziehung auf vorherbestimmte Information bzgl. des Zustands des Neutralleiters, der Art der Last und der Art des elektrischen Netzwerks ist;
- Senden des Operationsbefehls (37), verzögert in Beziehung auf einen asynchronen Befehl (1) um eine Zeitperiode (50), welche eine Funktion einer vorherbestimmten nominalen Operationszeit (51) ist, des Signals (35) anzeigend für die ideale Ende-der-Operationszeiten und von nachfolgenden vorhergesagten Nulldurchgängen oder Maxima.

Revendications

1. Dispositif de commande pour appareillage de commutation électrique (4) comprenant :

- un actionneur (2) avec loi de mouvement réglable ;
- une chaîne cinématique (5) connectant ledit actionneur (2) avec ledit appareillage de commutation (4) ;
- une unité de traitement et de commande (100) qui reçoit une instruction d'exploitation (1) et envoie un premier signal de commande (3) à l'actionneur (2), ladite unité de traitement et de commande (100) comprenant des moyens de commande (10), **caractérisée en ce que** lesdits moyens de commande (10) comprennent :

  - des moyens de calcul (11) qui reçoivent un signal direct ou indirect (7) indiquant la position ou la vitesse ou l'accélération en temps réel des contacts mobiles de l'appareillage de commutation et envoient un signal (14) indiquant la loi de mouvement desdits contacts mobiles ;
  - des premiers moyens de commande à boucle fermée (12), qui reçoivent ledit signal (14) indiquant la loi de mouvement desdits contacts mobiles, comparent ledit signal (14) indiquant la loi de mouvement desdits contacts mobiles à un comportement nominal prédéterminé du système tout entier actionneur/chaîne cinématique/appareillage de commutation (200), et envoient un signal de référence correspondant (16) ;
  - des second moyens de commande à boucle fermée (13), qui reçoivent ledit signal (14) indiquant la loi de mouvement desdits contacts mobiles et ledit signal de référence (16), et envoient un signal de correction (18) ;
  - des moyens de comparaison (15), qui reçoivent ledit signal de référence (16) indiquant la loi de mouvement desdits contacts mobiles et dudit signal de correction (18), et envoient un second signal de commande (19) pour réaliser une loi de mouvement désirée desdits contacts mobiles.

2. Dispositif de commande conforme à la revendication 1, **caractérisé en ce que** ledit actionneur (2)

avec loi de mouvement réglable est un actionneur électromagnétique.

3. Dispositif de commande conforme à la revendication 1 ou 2, **caractérisé en ce qu'**il comprend des moyens de rétroaction (6) pour évaluer, par mesure directe ou indirecte, la position de la pièce mobile du système (200).

4. Dispositif de commande conforme à la revendication 3, **caractérisé en ce que** lesdits moyens de rétroaction (6) comprennent un capteur de position ou de vitesse ou d'accélération qui détecte la positon ou la vitesse ou l'accélération de tout point du système (200) et envoie ledit signal (7) indiquant la position ou la vitesse ou l'accélération en temps réel des contacts mobiles de l'appareillage de commutation (4).

5. Dispositif de commande conforme à la revendication 3, **caractérisé en ce que** lesdits moyens de rétroaction (6) comprennent un modèle mathématique du système (200) qui reçoit un signal en entrée qui est fonction de mesures de paramètres de commande de l'actionneur et envoie un signal (7) indiquant la position estimée des contacts mobiles de l'appareillage de commutation (4) à l'unité de traitement et de commande (100) en temps réel.

6. Dispositif de commande conforme à une ou plusieurs des revendications précédentes, **caractérisé en ce qu'**il comprend des moyens convertisseurs (20) qui reçoivent en entrée ledit second signal de commande (19), lesdits moyens convertisseurs (20) comprenant :

- des moyens d'alimentation (21) pour l'actionneur (2) ; et
- des moyens (22) pour moduler le flux d'énergie injecté dans l'actionneur (2) par les moyens d'alimentation (21) par rapport audit second signal de commande (19) reçu en entrée.

7. Dispositif de commande conforme à une ou plusieurs des revendications précédentes, **caractérisé en ce qu'**il comprend des moyens de synchronisation (33) convenant pour injecter dans l'unité de traitement et de commande (100) des informations d'ouverture ou de fermeture de l'appareillage de commutation (4) dans un mode synchrone du réseau électrique.

8. Dispositif de commande conforme à la revendication 7, **caractérisé en ce que** lesdits moyens de synchronisation (33) comprennent :

- des moyens (30, 31) pour détecter les phases d'intensité et de tension du réseau électrique ;
- des moyens pour prédire les zéros et les maxima des phases d'intensité et de tension, postérieurs aux valeurs détectées ;
- des moyens pour calculer la période écoulée entre les zéros et les maxima, détectés et prédis.

9. Dispositif de commande conforme à la revendication 7 ou 8, **caractérisé en ce que**

- des moyens de tabulation (34) contenant des informations prédéterminées concernant l'état du neutre, le type de charge et du réseau électrique, lesdits moyens de tabulation (34) étant susceptibles d'envoyer un signal (35) indiquant les temps idéaux de fin d'opération par rapport auxdites informations prédéterminées à une unité de minuterie (36).

10. Dispositif de commande conforme à la revendication 9, **caractérisé en ce que** ladite unité de minuterie (36) reçoit en entrée :

- ladite instruction d'exploitation (1) qui est asynchrone par rapport au circuit électrique ;
- ledit signal (35) indiquant les temps idéaux de fin d'opération ;
- un signal indiquant les zéros ou maxima prédis ultérieurs ;

et envoie aux moyens de commande (10) une instruction d'opération de démarrage synchrone correspondante (37) qui est temporisée par rapport à l'instruction asynchrone (1) d'une période (50) qui est fonction du temps de fonctionnement nominal prédéterminé (51) et desdits signaux (35) indiquant les temps idéaux de fin d'opération et les zéros ou maxima suivants prévus.

11. Réseau de distribution et/ou de transmission d'électricité comprenant une pluralité de disjoncteurs installés en cascade, **caractérisé en ce qu'**au moins un disjoncteur de ladite pluralité de disjoncteurs comporte un dispositif de commande comme dans une ou plusieurs des revendications précédentes et **en ce que** l'ouverture et la fermeture dudit au moins un disjoncteur se produit pour le coordonner avec d'autres disjoncteurs en amont ou en aval de celui-ci pour interrompre ou inverser l'opération d'ouverture ou de fermeture.

12. Appareillage de commutation électrique pour réseaux de distribution et/ou de transmission d'électricité, **caractérisé en ce qu'**il comprend un dispositif de commande conforme à une ou plusieurs des revendications 1 à 10 et **en ce que** la quantité de puissance délivrée pendant une opération d'ouverture ou de fermeture est fonction, pas à pas, de la

course résiduelle des contacts mobiles.

13. Appareillage de commutation électrique conforme à la revendication 12, **caractérisé par le fait que** ledit actionneur réglable applique sur la pièce mobile une force réglable pas à pas et est capable de minimiser la quantité d'énergie dissipée dans l'impact dans une opération de fermeture.

14. Procédé de commande pour l'ouverture/la fermeture de l'appareillage de commutation électrique (4), comme les disjoncteurs, les sectionneurs, les réenclencheurs et autres, dans un réseau de distribution et/ou de transmission d'électricité, **caractérisé par le fait qu'**il comprend les phases suivantes :

a) envoi d'une instruction d'exploitation (1) à une unité de traitement et de commande (100) dudit appareillage de commutation (4) ;
b) acquisition directe ou indirecte d'informations (7) concernant le mouvement ou la vitesse ou l'accélération des contacts mobiles de l'appareillage de commutation (4) et envoi d'un signal (14) indiquant la loi de mouvement desdits contacts mobiles ;
c) comparaison dudit signal (14) indiquant la loi de mouvement desdits contacts mobiles avec un signal indiquant une loi de mouvement prédéterminée et envoi d'un signal de référence correspondant (16) ;
d) comparaison dudit signal de référence (16) avec ledit signal (14) indiquant la loi de mouvement desdits contacts mobiles et, à la suite de cette comparaison, envoi d'un signal de correction (18) ;
e) comparaison dudit signal de correction (18) avec ledit signal de référence (16) et, à la suite de cette comparaison, envoi d'un second signal de commande (19) ;
f) modulation du flux d'énergie injecté dans un actionneur (2) avec une loi de mouvement réglable par rapport audit second signal de commande (19) pour ajuster la force qu'il exerce sur le système chaîne cinématique/appareillage de commutation et obtenir une loi de mouvement désirée desdits contacts mobiles ;
g) envoi d'un premier signal de commande (3) audit actionneur.

15. Procédé de commande conforme à la revendication 14, **caractérisé en ce que** ladite phase a) comprend les étapes consistant :

- à détecter les phases d'intensité (30) et de tension (31) du réseau électrique ;
- à prévoir les zéros et les maxima des phases d'intensité et de tension, postérieurs aux valeurs détectées ;
- à calculer la période entre les zéros et les maxima détectés et les valeurs prédites ;
- à traiter et à envoyer une instruction d'exploitation (37) pour synchroniser l'exploitation avec le réseau électrique.

16. Procédé de commande conforme à la revendication 15, **caractérisé en ce que** ladite phase de traitement et d'envoi d'une instruction d'exploitation (37) pour synchroniser l'exploitation avec le réseau électrique consiste :

- à acquérir un signal (35) indiquant les temps id »aux de fin d'opération par rapport à des informations prédéterminées concernant l'état du neutre, le type de charge et le type du réseau électrique ;
- à envoyer ladite instruction d'exploitation (37), temporisée par rapport à une instruction asynchrone (1) d'une période (50) qui est fonction d'un temps de fonctionnement nominal prédéterminé (51), dudit signal (35) indiquant les temps idéaux de fin d'opération et les zéros ou maxima suivants prévus.

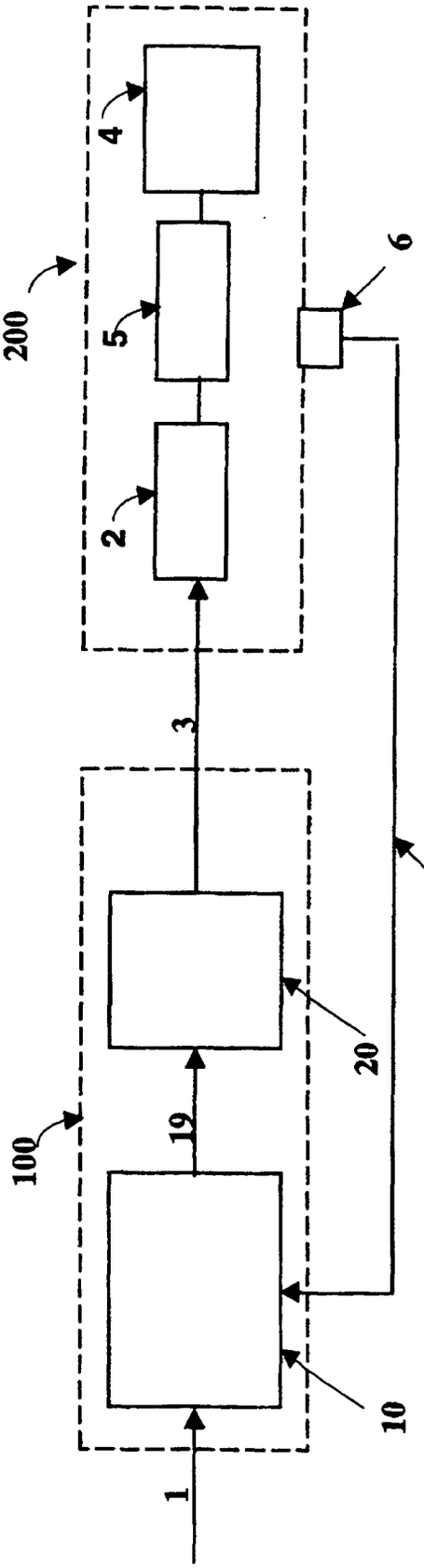

Fig. 2

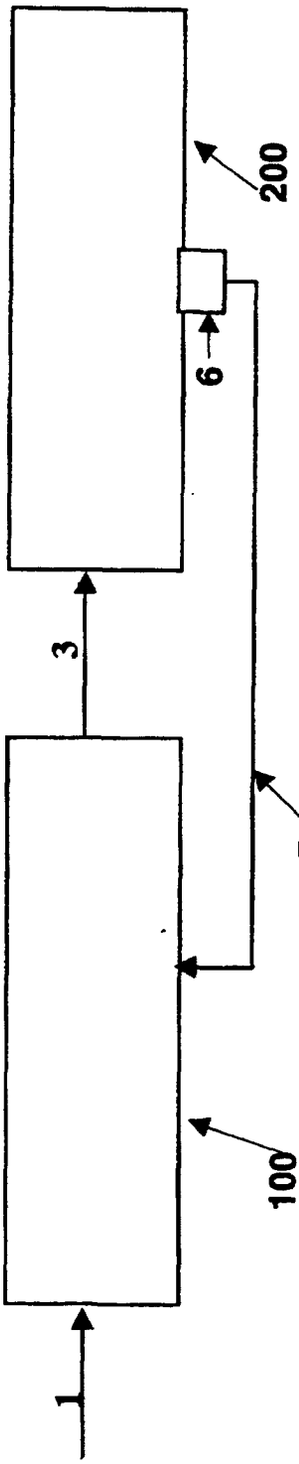

Fig. 1

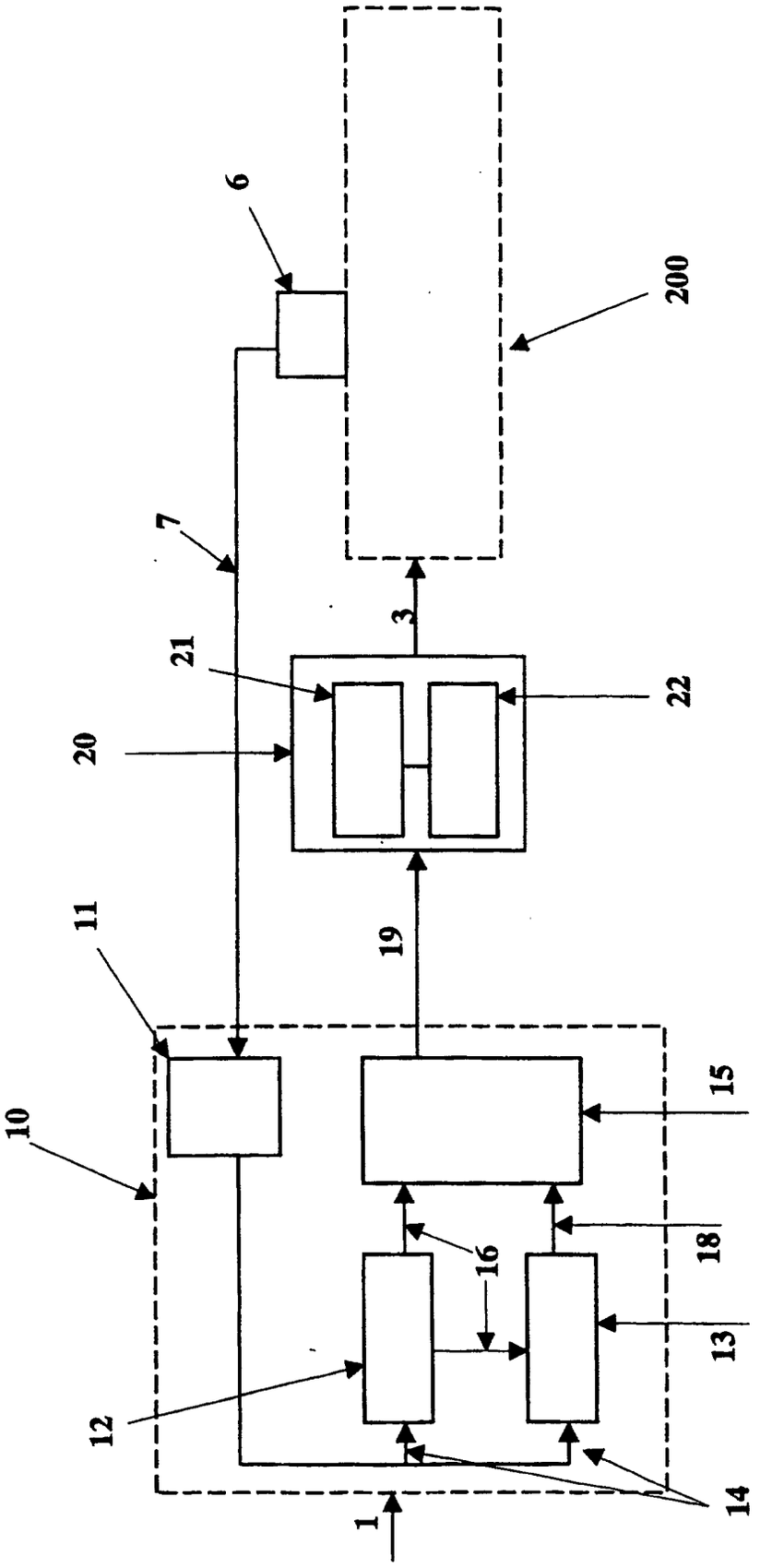

Fig. 3

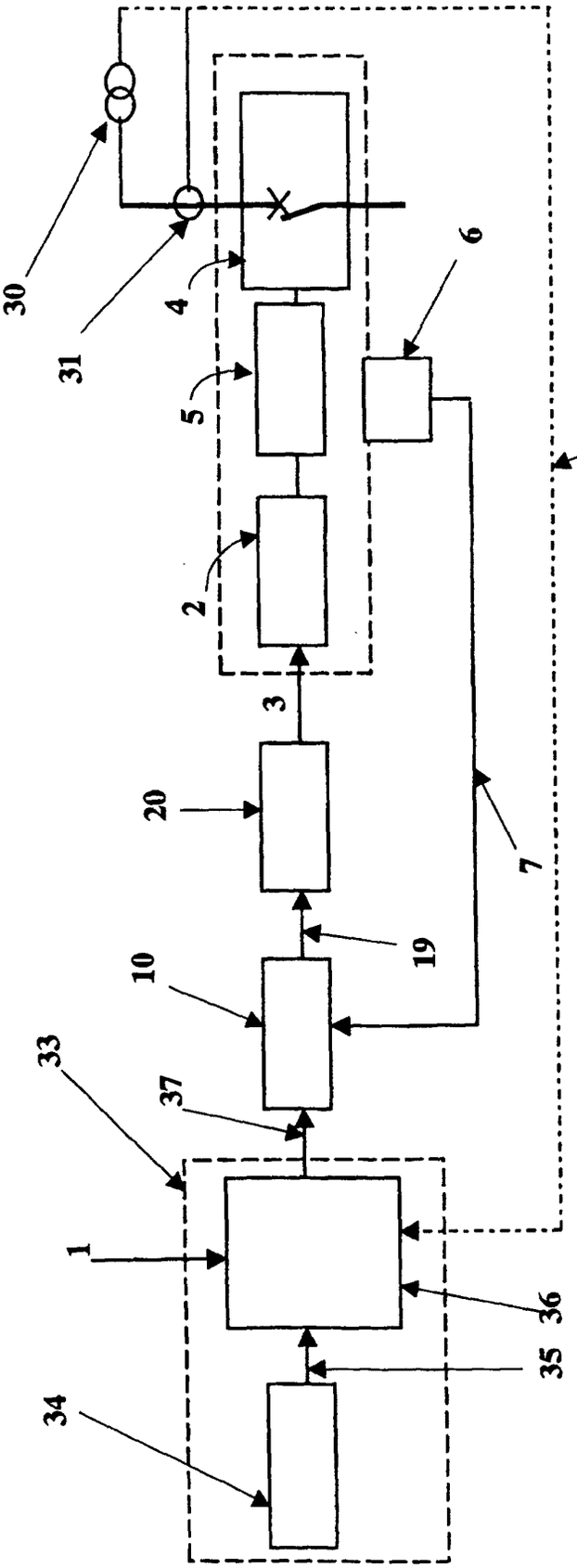

Fig. 4

Fig. 5

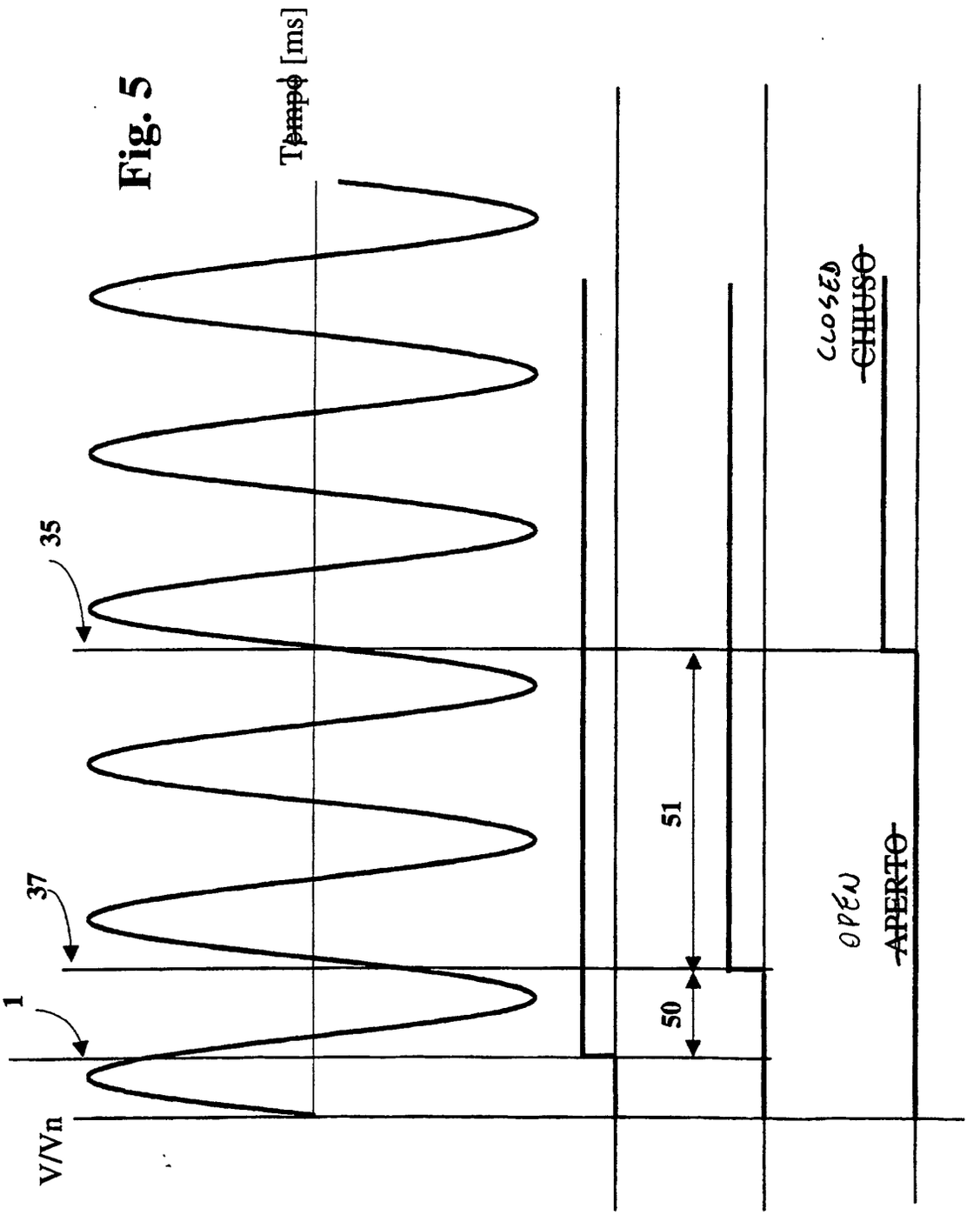

Fig. 6