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(54) **Method of protecting a thyristor switch of a pulse generator for an electrostatic precipitator.**

(57) To protect a thyristor switch in a pulse generator for an electrostatic precipitator it is desirable to control the spark-over rate in the precipitator. A first spark-over starts a measurement of the difference between the number of spark-overs and the number of times a pre-selected cooling period (p_k) has passed after the first spark-over and the measurement is stopped when the difference becomes 0. The measurement is started again the next time a spark-over occurs and one or more relevant running parameters of the precipitator are influenced in such a way as to diminish the probability of a further spark-over when the difference exceeds a given value.

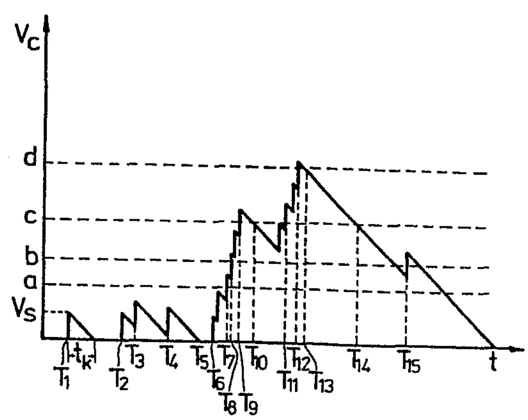

Fig. 1

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METHOD OF PROTECTING A THYRISTOR SWITCH OF A PULSE GENERATOR.

The invention relates to a method of protecting the switch element of a pulse generator for an electrostatic precipitator against overload due to spark-overs in the precipitator.

It is a documented fact that the performance of conventional two-electrode precipitators can be improved by pulse energization where high voltage pulses of suitable duration and repetition rate are superimposed on an operating DC-voltage. Earlier pulse energization work was hampered by the lack of reliable high-power switch elements capable of transferrring the considerable charge, necessary to charge the precipitator capacitance to the required high pulse voltage level, a large number of times per second. The use of thyristors in the switch elements has overcome this problem.

However, at a spark-over when the thyristor is in its "on" state, the thyristor is exposed to a spark-over current, the peak value of which might exceed the normal peak on-state current by a factor 5 to 10. Normally, a thyristor can withstand such an occasional overload of short duration, but as the overload gives rise to a temperature increase the thyristor might be destroyed if such short duration overloads occur at too small intervals.

According to the invention and in order to protect the thyristor switch by controlling the spark-over rate in the precipitator, a first spark-over starts a measurement of the difference between the number of spark-overs and the number of times a preselected cooling period has passed after the first spark-over, the measurement being stopped when the difference becomes 0 and being started again the next time a spark-over occurs, one or more relevant running parameters of the precipitator being influenced in such a way as to diminish the probability of a further spark-over when the difference exceeds a given number.

A series of figures for the difference value can be stipulated, each figure corresponding to a different or modified influence on the running parameters. The influence on the running parameters of the precipitator can be dependant on the figure exceeded such that a higher figure corresponds to an influence making a spark-over more improbable.

The invention may utilize a spark-over rate control device having a pulse detector and a spark-over detector which may be of any known kind, detecting the occurence of pulses and spark-overs by measuring variations in the precipitator voltage or in the pulse current.

The spark-over rate control may be achieved by means of a control voltage which is increased by a step voltage each time a spark-over occurs and which is decreased linearly with time at a rate corresponding to the necessary or desired cooling period, a signal triggering an influence on the running parameters of the precipitator being given when the control voltage exceeds a preset level or one of a number of preset levels

The influence performed when exceeding a first level may for example be a transient reduction of the pulse height (by say 10%). After this reduction the pulse height may increase either of itself to its previous size within a preset time or be governed by a pulse height control as described in EP-A-0054378.

When a second level is exceeded, the pulse height reduction may be made twice the reduction at the first level (say 20%) and thereafter the pulses may be brought back to their original or their regulated size.

The exceeding of a third level may result in blocking of the trigger signals for the thyristor of the pulse circuit until the control voltage has decreased below this third level.

Finally, exceeding a fourth level may cause not only the pulses but also the circuit feeding the underlying DC-voltage to be blocked until the control voltage has decreased below the fourth level, the trigger signals for the thyristor remaining blocked until the control voltage has decreased below the third level.

A spark-rate control of the kind described may also be used for controlling the spark-rate in a conventional electrostatic precipitator energized with a simple DC-voltage. In such a precipitator the DC-voltage is raised slowly until a spark-over occurs at which time the voltage is immediately lowered by a certain amount and then raised slowly again. The rate of rise and the amount by which the voltage is lowered can, through the use of a spark-rate control of the kind described, be made dependent on the numbers of spark-overs and the time between such spark-overs.

One example of a method according to the invention will now be described with reference to the accompanying drawings in which:-

Figure 1 shows the spark-over control voltage as a function of time; and,

Figure 2 shows a block diagram of a corresponding control system.

Normally, the spark-over control voltage V_c is 0, but at the time T_1, a spark-over occurs during a pulse in the precipitator. This starts an observation of the difference between the number of spark-overs, the starting spark-over included, and the number of times a fixed cooling period elapses. This is done by increasing the control voltage by a step voltage V_s and let it decrease linearly with the step $-V_s/t_k$ where t_k is a predetermined cooling period. When no further spark-over occurs before the cooling period has lapsed the control voltage becomes 0, which indicates that the above-mentioned difference has become 0 and the observation of the differences will start from the beginning when a new spark-over occurs.

Another course of observation is shown starting at the moment T_2. Before the cooling period has lapsed a new spark-over occurs at the moment T_3, and causes the control voltage to be increased by the step voltage V_s. A still further spark-over occurs after the cooling period has lapsed after the last spark-over (T_3), but before the difference between the number of spark-overs and the number of times the cooling period has passed during the observation has become zero and a new step voltage V_s is added to the control voltage and the observation is not ended until the control voltage becomes 0 at the moment T_5, which indicates that the difference has become 0.

At the moment T_6 a spark-over during a pulse starts a new observation sequence. As shown, a series of spark-overs causes a stepwise increase of the control voltage so that this voltage at the moment T_7 exceeds a level "a". This is taken as a signal that precautions must be taken to reduce the probability of further spark-overs during pulses. Such a precaution may be to lower the pulse voltage by, say 10%. Regulated down, the pulse voltage will increase to its preset value or to a value governed by an automatic pulse height control.

In the example shown a new spark-over occurs at the moment T_8 in spite of the above precaution. This new spark-over makes the control voltage exceed the level "b". This will call for a precaution having a greater effect than the one taken when level "a" was exceeded. This could, for example, be a 20% lowering of the pulse voltage. Again the pulse height is brought back to its preset or governed value.

In the present example not even this second precaution stops the spark-overs and whenever such a spark-over takes place, the control voltage is increased by V_s, and although its actual value constantly decreases with the slope defined by the preselected cooling period, the control voltage exceeds the level "c" at the moment T_9. This may give rise to a still more severe precaution, for example blocking the pulses by blocking the trigger signal to the thyristor which controls the pulses.

This is shown to stop the spark-overs, and at the moment T_{10} the control voltage has fallen below the level "c", which is taken as an indication that the block on trigger pulses to the thyristor may be released again.

However, at the moment T_{11} a new blocking of the trigger signals is made necessary, and even when the trigger signal is blocked, spark-overs, during pulses which may be triggered by noise signals or for other reasons, make it necessary to take a very radical precaution which is indicated by the control voltage exceeding the level "d" at T_{12}. Such a last emergency precaution may, for example, be to block the regulator for the underlying DC voltage, or a similar precaution which inevitably stops the spark-overs.

As soon as the control voltage has again fallen below the level "d" at T_{13} such an emergency precaution can be cancelled, but the blocking of the trigger pulses to the thyristor may be maintained until the level "c" is passed at T_{14} by the falling control voltage.

As shown in the diagram the control voltage continues to fall after passage of the level "c". Nothing happens when the control voltage passes the level "b" from above, but when a spark-over at the moment T_{15} brings it to pass level "b" from below, the level "b" precaution (designed in this example as a 20% decrease of the pulse voltage) is taken. Thereafter the control voltage is shown to drop to 0, and after that a further spark-over will start a new observation sequence.

The block diagram of Figure 2 is described as used for the method mentioned above in connection with an electrostatic precipitator energized by pulses superimposed on a high DC-voltage. The power supply for the precipitator has controllable units for providing the high DC-voltage and the pulse voltage and a thyristor for operating the pulse switching. Further, a spark-over detector is provided.

On line 9 the spark-rate control receives a signal from the spark over detector whenever a spark over occurs. This signal is transformed at 1 into a pulse of predetermined duration on the line 10. This signal is carried to element 2 wherein an output voltage is produced through integration of the signal producing step voltages and through built-in fixed integrations causing the output voltage to decrease at the rate $- V_s/t_k$. When the output signal on line 11 reaches 0 the integration is stopped.

In the elements 3-6 the voltage on the output line 11 is compared with set voltages corresponding to the aforementioned levels a, b, c and d. The respective outut signals from the elements 3-6 are used for controlling the power supply units of the precipitator as described above. E.g. the DC-supply of the precipitator may be blocked for as long as a signal is present on line d. Similarly the trigger signals to the thyristor may be blocked when a signal occurs on line c.

Whereas the precautions taken when the levels c and d are exceeded are maintained as long as the level is exceeded the precautions adopted when levels a or b are exceeded are taken one for each time the level is passed from below. Such signals for controlling the pulse voltage unit to cause a momentary lowering of the pulse voltage can be obtained by letting the output signals on a and b trigger a respective one shot multivibrator giving a signal pulse when a signal starts on the line a or b. Such one shot multivibrators are indicated by the elements 7 and 8.

As can be seen, the precautions taken may be of two kinds, namely a temporary kind where the precaution is temporary and is cancelled as soon as the control voltage falls below the level initiating that precaution, and a long-term kind having the character of a precaution taken when the control voltage exceeds the triggering level, but not cancelled when the control voltage drops below the triggering level.

The number of levels and the kinds of precautions described should not be taken as any limitation to the invention. Of course more levels or fewer levels could be chosen just as the kinds of precaution taken at the different levels may be chosen freely to suit particular circumstances.

CLAIMS

1. A method of protecting a thyristor switch of a pulse generator for an electrostatic precipitator against overload due to spark-overs in the precipitator, characterized in that a first spark-over starts a measurement of the difference between the number of spark-overs and the number of times a preselected cooling period has passed after the first spark-over, the measurement being stopped when the difference becomes 0 and being started again the next time a spark-over occurs, one or more relevant running parameters of the precipitator being influenced in such a way as to diminish the probability of a further spark-over when the difference exceeds a given reference value.

2. A method acccording to claim 1, wherein a series of figures for the reference value are set, each figure corresponding to a different or modified influence on the running parameters, the influence on the running parameters of the precipitator being dependant on the figure exceeded such that a higher figure corresponds to an influence making spark-over more improbable.

3. A method according to claim 1 or claim 2, in which one of the parameters influenced is the pulse height.

4. A method according to any of claims 1 to 3, in which one of the parameters which is influenced is the pulse superposition.

5. A method according to any of claims 1 to 4, in which one of the parameters influenced is the DC-voltage.

6. A spark-rate control for protecting a thyristor switch of a pulse generator for an electrostatic precipitator against overload due to spark-overs in the precipitator, which comprises a pulse detector and a spark-over detector providing a control voltage

which is increased by a step voltage each time a spark-over occurs and which is decreased linearly with time at a rate corresponding to a desired cooling period, a signal triggering an influence on one or more of the running parameters of the precipitator being given when the control voltage exceeds a preset level or one of the number of preset levels.

7. A spark rate control according to claim 6, in which the pulse height is transiently reduced by a predetermined amount or percentage when the control voltage exceeds a first level.

8. A spark-rate control according to claim 7, in which the pulse height is transiently reduced by a further predetermined amount or percentage when the control voltage exceeds a second level.

9. A spark-rate control according to any of claims 6 to 8, in which the trigger signals for the thyristor of the pulse-circuit are blocked as long as the control voltage is higher than a third level.

10. A spark rate control according to any of claims 6 to 9, characterized in that the DC-voltage feeding circuit is blocked as long as the control voltage is higher than a fourth level.

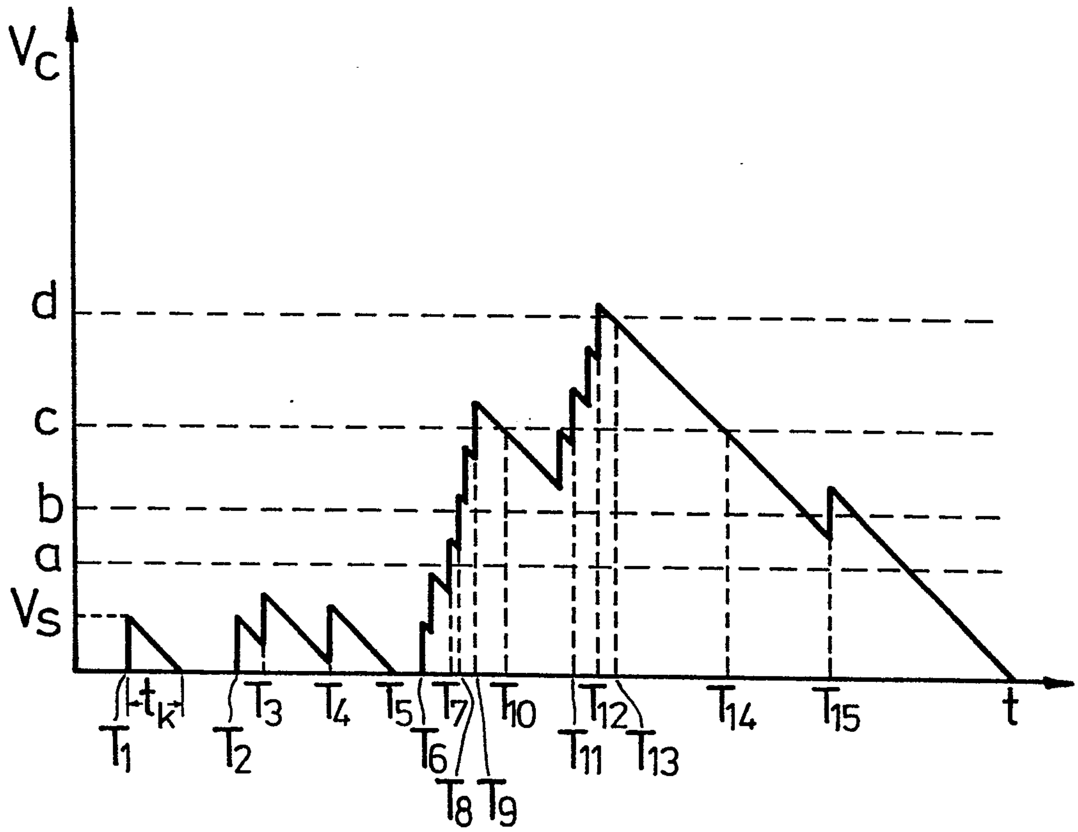

Fig. 1

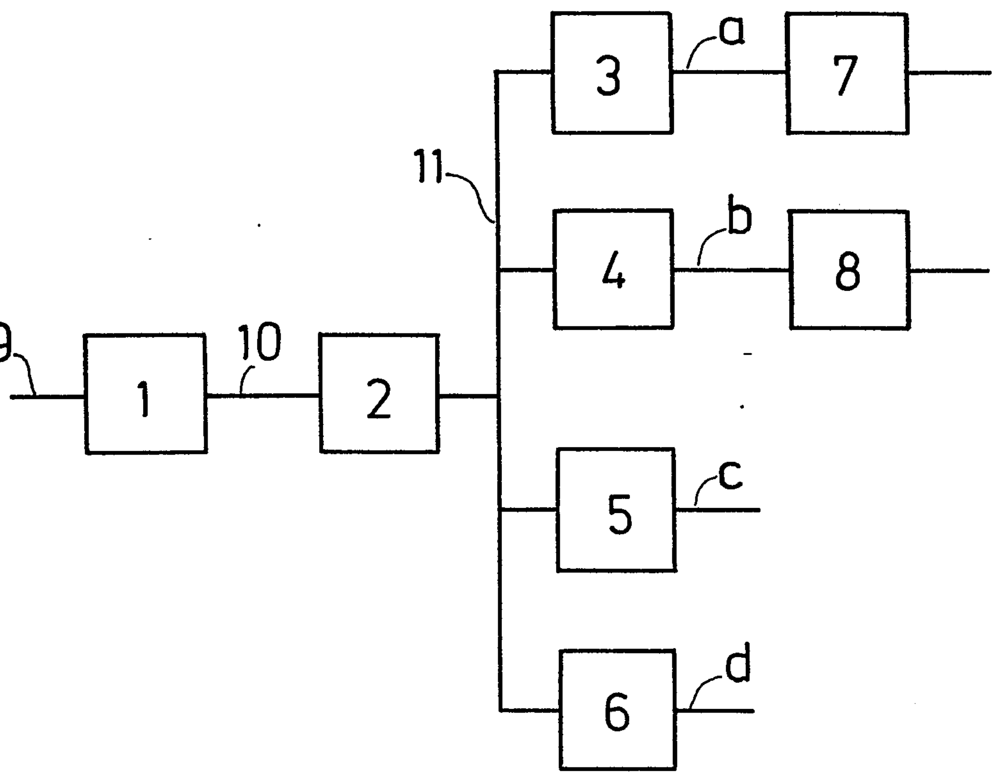

Fig. 2