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Downs et al.

[11] **3,735,243**

[45] **May 22, 1973**

[54] **CONTROL SYSTEM FOR TAP CHANGER WITH VACUUM INTERRUPTER**

[75] Inventors: **Clifford L. Downs**, Lenox; **Richard D. Blackburn**, Dalton, both of Mass.

[73] Assignee: **General Electric Company**

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[52] **U.S. Cl.** .....**323/43.5 R**, 307/136

[51] **Int. Cl.** **G05f 1/14**

[58] **Field of Search** .....307/136; 323/43.5 R, 323/43.5 S; 317/11 R, 11 A, 11 C, 11 E, 22

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Primary Examiner—Robert K. Schaefer
Assistant Examiner—William J. Smith
Attorney—Francis X. Doyle and Vale P. Myles

[57] **ABSTRACT**

A control system for a tap changer using a vacuum interrupter. The control system has provisions for monitoring the vacuum interrupter to detect any failure of such interrupter and thus prevent further operation of the tap changer. Should the interrupter fail to open on a tap change, the tap changer motor is reversed returning the changer to the starting position and locking the changer. Should the interrupter be open at the start of a tap change, the tap changer is reversed returning the tap changer to the starting position and then locking the tap changer. In another embodiment, should the interrupter fail to close after a tap change has been initiated, the tap change is completed and the changer locked in that position.

6 Claims, 4 Drawing Figures

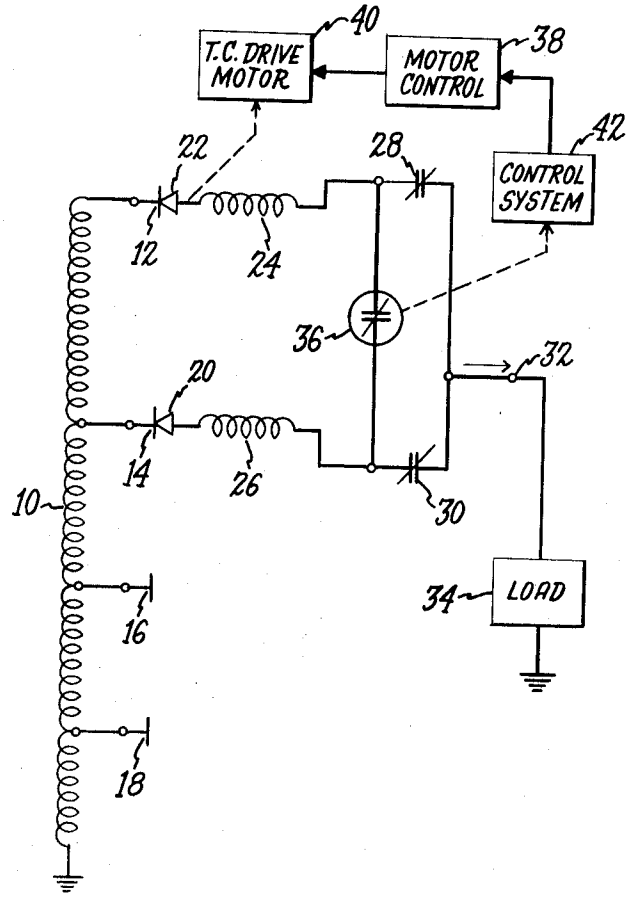


Fig. 1.

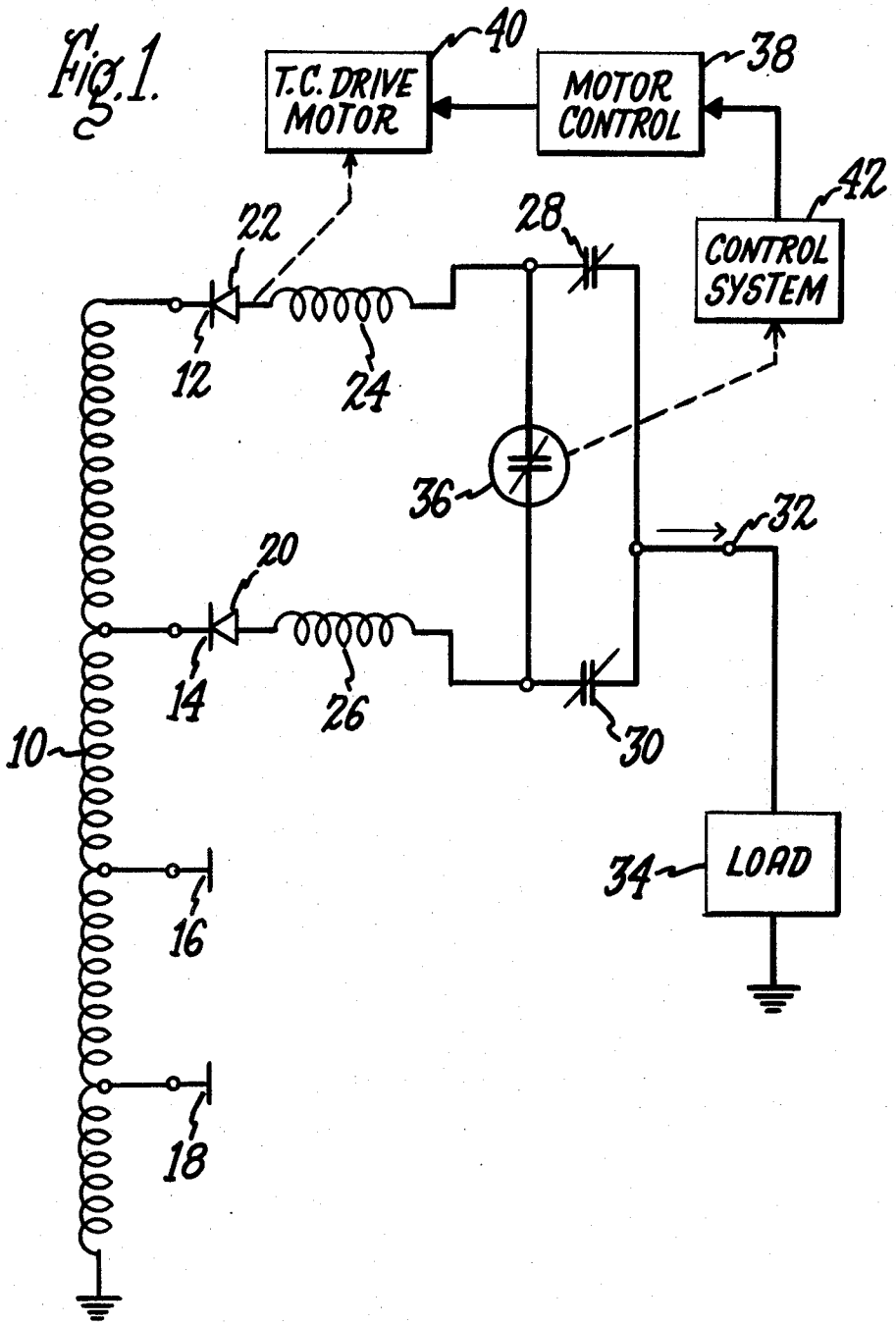

T.C. DRIVE MOTOR
40
MOTOR CONTROL
38
CONTROL SYSTEM
42
22
28
12
24
36
32
20
14
26
30
10
16
18
34
LOAD

Fig. 2.

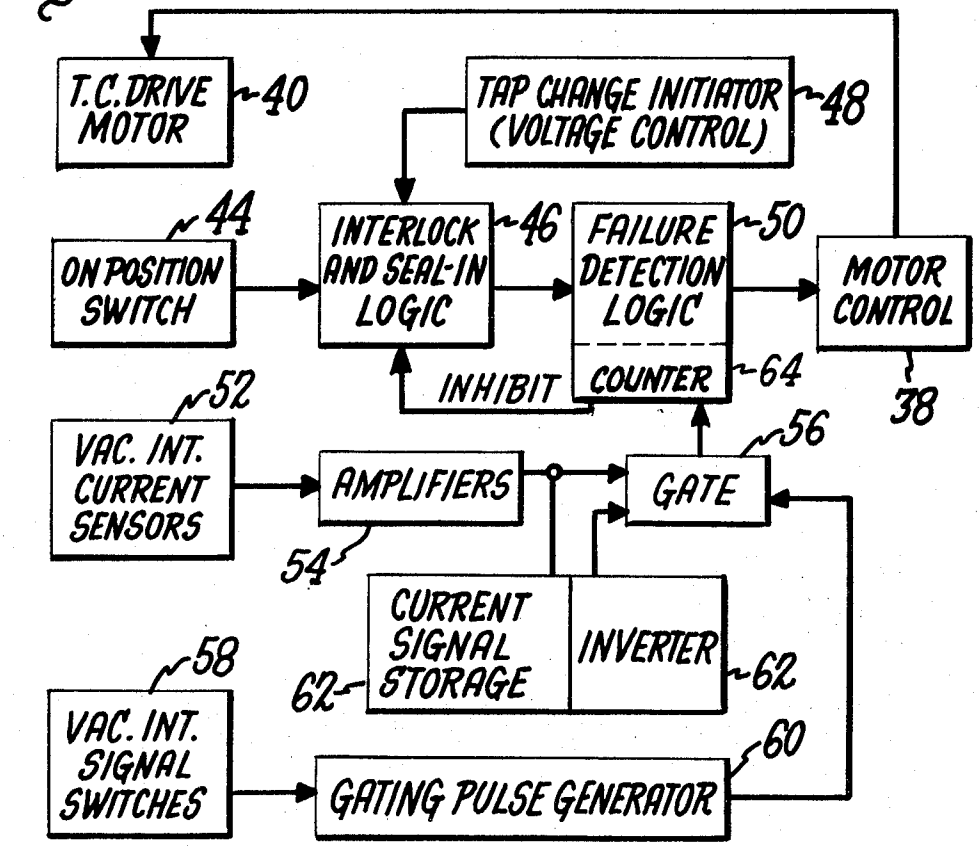

T.C. DRIVE MOTOR
40
TAP CHANGE INITIATOR (VOLTAGE CONTROL)
48
44
ON POSITION SWITCH
INTERLOCK AND SEAL-IN LOGIC
46
FAILURE DETECTION LOGIC
50
MOTOR CONTROL
38
INHIBIT
COUNTER
64
52
VAC. INT. CURRENT SENSORS
AMPLIFIERS
54
GATE
56
CURRENT SIGNAL STORAGE
INVERTER
62
62
58
VAC. INT. SIGNAL SWITCHES
GATING PULSE GENERATOR
60

Fig. 3.

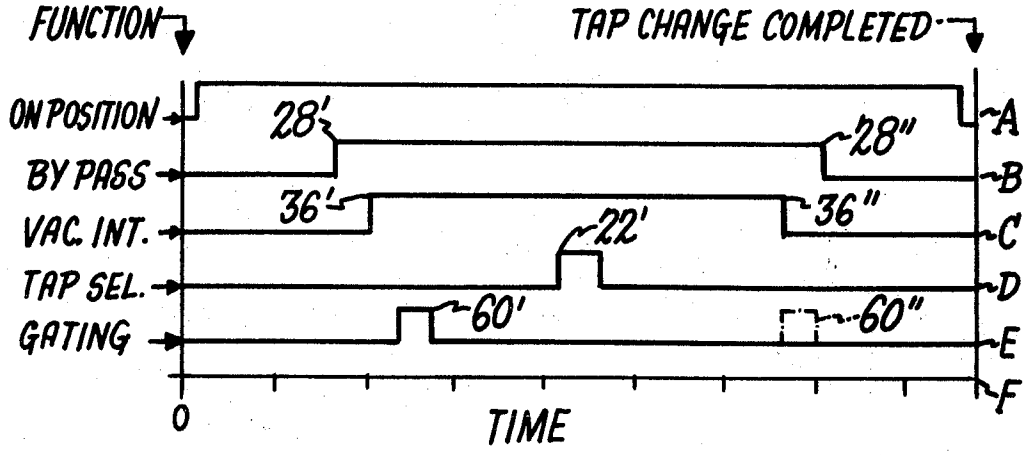
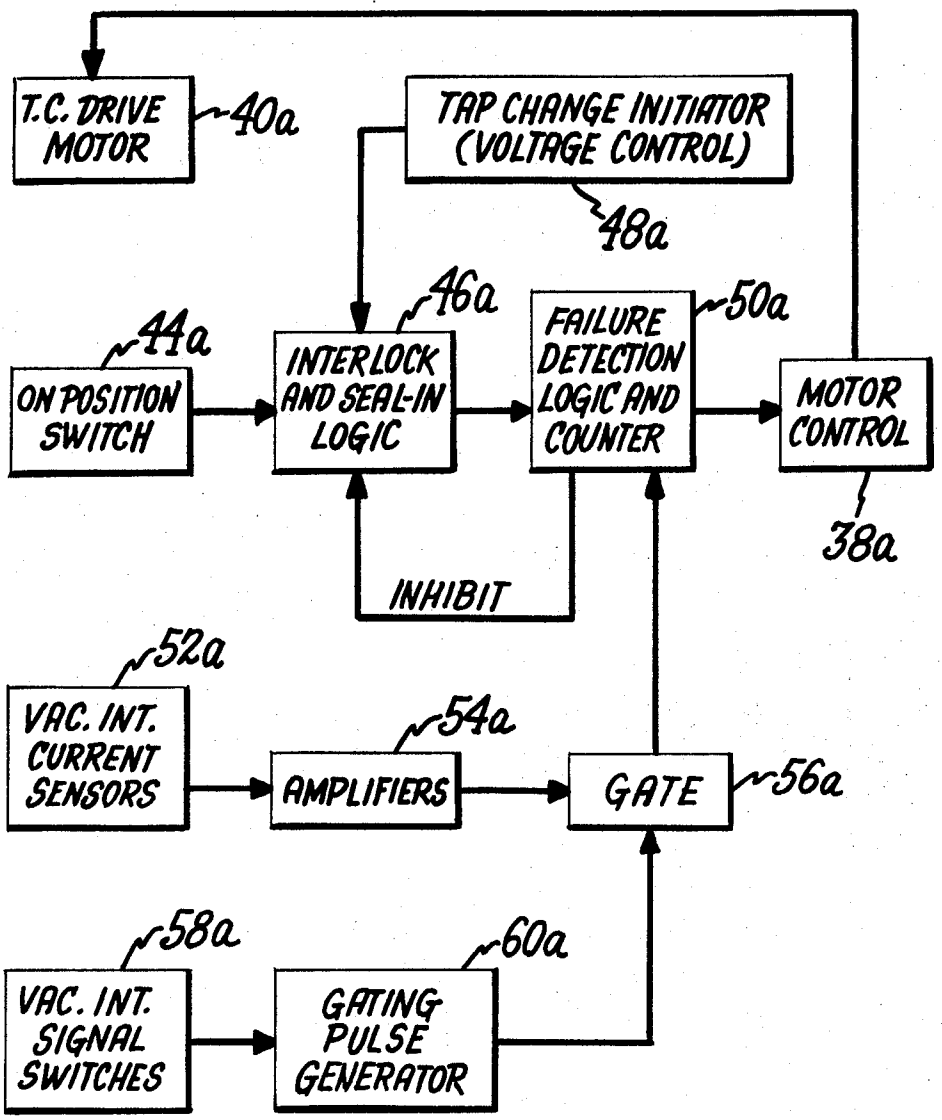

FUNCTION
TAP CHANGE COMPLETED
ON POSITION
BY PASS
VAC. INT.
TAP SEL.
GATING
28'
28"
36'
36"
22'
60'
60"
A
B
C
D
E
F
0
TIME

Fig. 4.


T.C. DRIVE MOTOR
40a
TAP CHANGE INITIATOR (VOLTAGE CONTROL)
48a
46a
44a
ON POSITION SWITCH
INTERLOCK AND SEAL-IN LOGIC
FAILURE DETECTION LOGIC AND COUNTER
50a
MOTOR CONTROL
38a
INHIBIT
52a
VAC. INT. CURRENT SENSORS
54a
AMPLIFIERS
GATE
56a
58a
VAC. INT. SIGNAL SWITCHES
60a
GATING PULSE GENERATOR

CONTROL SYSTEM FOR TAP CHANGER WITH VACUUM INTERRUPTER

BACKGROUND OF THE INVENTION

This invention relates to tap changers and more particularly to a control system for a tap changer to monitor the vacuum interrupter of such tap changer and prevent further operation of the tap changer upon failure of the vacuum interrupter.

As is well known to those skilled in the art, tap changers are used on various types of electromagnetic induction apparatus to change the voltage level at which such apparatus operates. For example, in voltage regulators, it is common to provide a tap changer that raises or lowers the level of voltage provided by the voltage regulator as is required to regulate a desired electrical power line.

Many types of tap changers are known, but generally a drive mechanism is provided which drives the tap selector contacts from one contact to another contact of a tap winding. Often means are provided usually in the form of mechanical or electrical switches to open the circuit from the moving tap contact to the load so as to prevent arcing between the moving tap contact and the stationary contact of the winding. One such device is described in U.S. Pat. No. 3,524,033 which discloses one form of bypass switch and vacuum interrupter.

In the tap changing devices such as, for example, those shown in U.S. Pat. No. 3,524,033, a vacuum interrupter is used to interrupt the circuit from the movable contact to the load before such movable contact moves away from the stationary contact on the tap winding. Obviously, if the vacuum interrupter should fail to open, arcing will occur between the contacts causing deterioration of such contacts, and possibly short circuiting of the tap changing mechanism. In order to prevent opening of the current carrying contacts of the tap changer in the event the vacuum interrupter should fail, a control system has been devised to detect such failure and prevent the further operation of the tap changer.

It is, therefore, a principal object of this invention to provide a control system for a tap changer which will monitor the vacuum interrupter and prevent tap changing in the event of failure of such vacuum interrupter.

A further object of this invention is to provide a monitor circuit for the vacuum interrupter of a tap changer which includes provision for permitting a second attempt at tap changing in the event of a failure indication of the vacuum interrupter.

BRIEF SUMMARY OF THE INVENTION

Briefly, in one form, this invention comprises a control system for a tap changer using a vacuum interrupter. The control system includes a monitoring device which monitors the current flow in the vacuum interrupter. When failure of the interrupter is indicated, by current flow or lack of current flow, the control system prevents further operation of the tap changer. A failure counter may be provided which allows a second attempt at operation of the tap changer after a failure indication to assure that such failure indication was not the result of a random electrical transient.

The invention which is sought to be protected will be particularly pointed out and distinctly claimed in the claims appended hereto. However, it is believed that this invention and the manner in which its various objects and advantages are obtained as well as other objects and advantages thereof will be better understood by reference to the following detailed description of a preferred embodiment particularly when considered in the light of the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a schematic diagram of a tap changing circuit having a vacuum interrupter and shown utilizing the control system of this invention;

FIG. 2 is a block diagram of one form of control system of this invention;

FIG. 3 is a timing diagram showing the timing relationship of the control signals of the control system of FIGS. 1 and 2, and

FIG. 4 is a block diagram showing a modified form of the invention.

DESCRIPTION OF PREFERRED EMBODIMENT

This invention relates to a control system for the tap changer of an electromagnetic induction apparatus and it is particularly shown in the various figures of the drawing in which like numerals will be used to indicate like parts throughout the various views. Particularly, the invention relates to a control system having a means for monitoring the operation of the vacuum interrupter of such tap changer and has provision for preventing further operation of the tap changer when the vacuum interrupter fails.

FIG. 1 shows one form of tap changer using a vacuum interrupter and showing the control system of this invention connected thereto. Considering FIG. 1, a tapped transformer winding **10** is shown having a plurality of stationary tap contacts **12, 14, 16** and **18.** A pair of movable tap selector contacts **20** and **22** are shown which cooperate with the fixed contacts **12, 14, 16** and **18.** As is shown, the tap selector contacts **20** and **22** are connected through reactor coils **24** and **26** and bypass switches **28** and **30,** respectively, to a contact **32** which is connected to a load **34.** A vacuum interrupter switch **36** is shunted across the parallel circuit which includes the bypass switches **28** and **30.** As is well understood by those skilled in the art, when it is desired to change from taps in the tap changer, for example, from tap **12** to tap **14,** the bypass switch **28** will be opened thus shunting the current from contacts **12, 22** through the vacuum interrupter **36** to the load **34.** The vacuum interrupter **36** must then be opened prior to the movement of movable contact **22** to prevent current flow through contacts **12, 22** and thus preventing arcing therebetween. After the contact **22** reaches fixed contact **14** then the vacuum interrupter **36** closes to divide the current through the movable contacts **22** and **24.** Bypass switch **28** will then be closed relieving the vacuum interrupter **36** of the current carrying duty. The above description is well known, is found in U.S. Pat. No. 3,524,033, and is also clearly shown in the timing diagram of FIG. **3.**

Referring now to the timing diagram of FIG. **3,** a tap change is initiated at time zero, and the motor starts to operate to make the required tap change. Then, as shown at curve A, the "on position switch" changes state shortly after time zero as is indicated by the time scale F. The "on position switch" locks the control system to make the indicated tap change regardless of change in the voltage level which initiated the tap change. Shortly after initiation of the tap change and

the change of state of the "on position switch", the bypass switch (such as **28**) is opened as is shown at **28'** on curve B. Shortly thereafter the vacuum interrupter opens as is shown at **36'** on curve C. Curve D shows the tap selector operation at **22'** which indicates the movement of movable contact **22** from fixed contact **12** to fixed contact **14.**

As will be understood, after contact **22** reaches fixed contact **14,** then, as indicated in curve C, vacuum interrupter **36** will close as shown at **36''**. Shortly thereafter, as shown in curve B, bypass switch **28** will close as shown at **28''**. Then, of course, as indicated in curve A, the tap change is completed and the tap changer drive motor is deenergized.

As will be understood, if the vacuum interrupter **36** fails to open, then movable contact **22** will be carrying one-half the load current and when it leaves fixed contact **12** severe arcing will occur between such contacts and, as is well known, such arcing could causing a short circuit condition within the tap changing mechanism. In order to prevent the operation of the tap changer should vacuum interrupter **36** fail to properly function, the control system of this invention has been provided. The control system is shown in a preferred form in block diagram in FIG. **2** where the motor control **38** is shown connected to the tap changer drive motor **40** in the same manner as shown in FIG. **1.** The essential control system of this invention is shown in FIG. **1** as block **42** and the block diagram of that control system is shown in FIG. **2.** As is shown in FIG. **2** an "on position switch" **44** is provided indicating that the tap changer is at rest in a given tap position. This switch initiates a signal into the interlock and seal-in logic circuit **46** thereby committing the control to continue. The tap change signal is provided from the tap change initiator block **48** to the interlock block **46** as shown. The signal from initiator **48** is fed to motor control circuit **38** energizing motor **40** to drive the contacts in the desired direction.

Current sensors are provided for the vacuum interrupter **36** as indicated by the block **52.** These current sensors provide a signal if current is flowing in the vacuum interrupter the signal passing through the amplifiers **54** to the gate circuit **56.** When the vacuum interrupter **36** opens or is operated, the signal switch shown by block **58** generates a signal which operates the gating pulse generator **60.** The gating pulse generator **60** initiates a pulse signal which is shown by curve E at **60'** which thereby provides a signal to gate **56** which by means of failure detection logic **50** may provide a signal to reverse motor control **38.** As will be understood, when the vacuum interrupter opens as indicated at **36'** in curve C, no current should be detected by the current sensors **52.** Thus no signal will be apparent in the amplifier **54.** However, should current be flowing in the vacuum interrupter after the interrupter is supposed to open as shown at **36'** in curve C, then a signal will appear through amplifiers **54** and through gate **56** when the gating signal is applied from generator **60.** This signal from amplifiers **54** through gate **56** will be applied to the failure detection logic block **50** to thereby reverse motor control **38,** thus preventing any movement of the tap changer movable contact **22.**

As will be understood, a plurality of gears and cams are provided in the tap changer motor drive system. Thus even though the motor **40** has operated since time zero, at the time of gating pulse **60'**, tap **22** has not moved from tap **12.** When the failure signal is applied to reverse motor **40,** it returns the cams and gears back to the original position.

A second failure could occur where the interrupter is open at the beginning of the tap change and this would be sensed when the bypass switch was open as at **28'**. Obviously, between the time of the opening of **28** and the opening of the vacuum interrupter **36,** current should be flowing in the vacuum interrupter. If no current is flowing, then the current sensor will cause a failure signal to be generated causing the motor to be reversed driving the tap changer back to the starting position. This may be obtained, for example, by a current signal storage generator and inverter as indicated at **62** in FIG. **2.** When current through the interrupter is detected by current sensors **52** after the bypass switch has opened, then a signal will be stored in the current signal storage **62.** After the interrupter **36** opens, the gating signal from generator **60** is provided to gate **56.** If no current signal was stored in **62** then a signal is passed through gate **56** to the failure detection block **50.** Thus, if there is no current in the vacuum interrupter during the period from **28'** to **36'** of FIG. **3,** then no signal is stored in the current signal storage **62.** As will be understood, by use of the storage and inverter **62,** if no signal is stored, then the inverter portion will provide a failure signal thru gate **56** when the gating pulse from generator **60** opens gate **56.** This failure signal will cause motor control **38** to reverse, then the tap changer will shut down. However, if a signal is stored in the storage and inverter **62,** then no signal will be provided when gate **56** is opened.

In order to prevent a random electrical transient from shutting down the tap changer, should it occur at the moment gate **56** is open, a failure counter may be provided in the failure detection logic block **50.** This is indicated by counter **64.** Counter **64** provides a time delay after the failure detection logic **50** has reversed motor control **38** and the inhibit signal has locked out the interlock logic block **46.** After the time delay, the inhibit signal is removed allowing initiator **48** and interlock logic **46** to initiate a second attempt to change the tap. If the attempt is successful, the error was caused by a transient and the tap changer resumes normal operation. If the second attempt is unsuccessful, then a failure of the vacuum interrupter **36** has occurred and the inhibit signal is permanently applied to prevent further operation of the tap changer.

Referring now to FIG. **4,** a modified version of the control system is shown. In this version, the failure detection if vacuum interrupter fails to open is exactly the same as in FIG. **2.** That is, a current signal from the sensors **52*a*** is fed through amplifier **54*a*** to gate **56*a***. When the gate signal, generated by switches **58*a*** and generator **60*a***, opens gate **56*a*** the error signal is fed to the failure detection logic **50*a*** which reverses motor control **38*a*** and through the inhibit shuts down the tap changer. Obviously, if desired, a failure counter may be provided in logic **50*a*** to prevent transients from shutting down the tap changer as previously described. However, should the vacuum interrupter **36** fail to close, as at **36''** in FIG. **3,** then an open failure has occurred. The signal switches **58*a*** provide a signal to the pulse generator **60*a*** on both the opening and closing of vacuum interrupter **36.** The second pulse from generator **60*a***, on the closing of vacuum interrupter **36** is indicated by the phantom pulse **60''** in FIG. **3.** If no current

is present in the vacuum interrupter **36** and thus no signal to gate **56***a* when the second pulse **60''** opens the gate **56***a* then failure detection logic **50***a* allows the tap change to be completed and then prohibits further operation of the tap changer.

Of course, it will be apparent to those skilled in the art that many types of electronic circuitry may be utilized in the different blocks of the block diagram of FIGS. **2** and **4**. In accordance with the basic features of this invention, it is necessary that a sensing means be provided for the vacuum interrupter, the preferred sensor being a current sensor, to determine whether or not current is flowing in the vacuum interrupter during the periods when the interrupter is required to be open for purpose of the tap changing and during those periods when the vacuum interrupter is required to be closed during tap changing. If such current is not found in the vacuum interrupter, then signals are required to be generated which will prevent the operation of the tap changer thereby preventing the movement of a movable tap from a fixed tap while such taps are still carrying a portion of the load current. Obviously, various changes may be made in the specific features of the device of FIG. **1** or in the various types of elements of FIGS. **2** and **4** and all such changes are considered as fall within the scope of the invention as is set forth in the following claims.

What is claimed as new and which is desired to secure by Letters Patent of the United States is:

1. A control system for a tap changer, said tap changer including a tapped winding with a plurality of fixed tap contacts, a pair of movable contacts movable to contact said plurality of fixed contacts, a vacuum interrupter shunting said movable contacts, and a bypass switch between each movable contact and a load, said control system comprising means actuated by an external source, a logic circuit for operating said tap changer, said means electrically connected to activate said logic circuit, sensing means sensing the operating condition of said vacuum interrupter, said sensing means providing electrical signals to said logic circuit to prevent operation of said tap changer when said vacuum interrupter is inoperative.

2. A control system for a tap changer as set forth in claim **1** in which said sensing means senses failure of said vacuum interrupter to open and provides a signal to said logic circuit to prevent operation of said tap changer.

3. A control system for a tap changer as set forth in claim **1** in which a signal storage and inverter circuit is provided, said sensing means electrically connected to said signal storage and inverter circuit, said sensing means providing no signal if said vacuum interrupter fails to close and said signal storage and inverter circuit providing a signal to said logic circuit to reverse said tap changer and prevent further operation of said tap changer.

4. A control system for a tap changer, said tap changer including a tapped winding with a plurality of fixed tap contacts, a pair of movable contacts movable to contact said plurality of fixed contacts, a vacuum interrupter shunting said movable contacts, and a bypass switch between each movable contact and a load, said control system comprising a logic circuit actuated by an external source to cause operation of said tap changer, sensing means sensing the operating condition of said vacuum interrupter, said sensing means providing electrical signals to actuate said logic circuit to prevent operation of said tap changer when said vacuum interrupter is inoperative.

5. A control system as set forth in claim **4** in which said sensing means is connected electrically to a gate, a switch operated by said vacuum interrupter, said switch operating a pulse generator to provide a gating pulse to said gate, said gate providing a failure signal to said logic circuit if said sensing means senses failure of operation of said vacuum interrupter.

6. A control system for a tap changer, said tap changer including a tapped winding with fixed tap contacts, and a pair of movable contacts, a vacuum interrupter shunting said movable contacts and a bypass switch between each movable contact and a load, said control system comprising means to sense the operation of said vacuum interrupter, a logic circuit to operate said tap changer, and means cooperating with said logic circuit to prevent operation of said tap changer when said vacuum interrupter fails, and a counter provided in said logic circuit, said counter providing a time delay and then allowing further operation of said tap changer after said logic circuit prevents such operation.

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