United States Patent

[11] **3,558,986**

[72] Inventors **Ferber R. Schleif**
Denver, Colo.;
Glenn E. Martin, Edgewater, Colo.

[21] Appl. No. **806,760**
[22] Filed **Dec. 2, 1968**
[45] Patented **Jan. 26, 1971**
[73] Assignee **the United States of America as represented by the Secretary of the Interior**

[54] **TIELINE SWING RELAY**
8 Claims, 3 Drawing Figs.

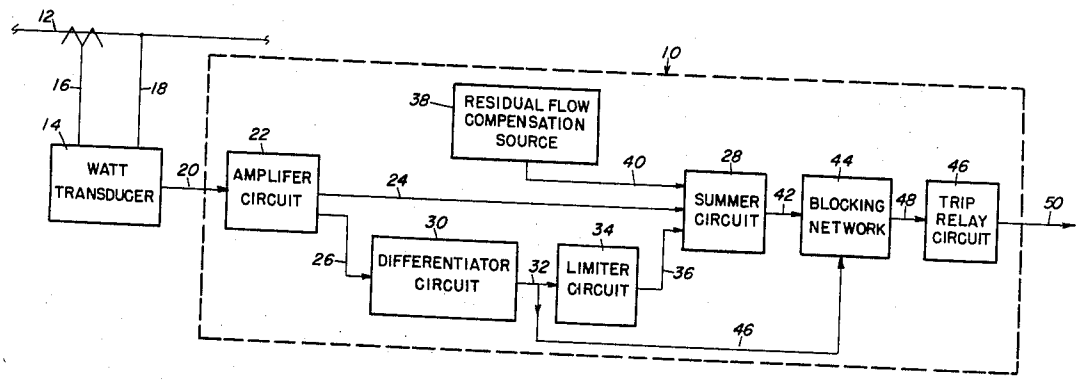
[52] **U.S. Cl.** **317/27**
[51] **Int. Cl.** **H02h 3/28**
[50] **Field of Search** ..... 317/27, 33, 36(TD), 36(D); 328/150; 307/126

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Primary Examiner—Harold Broome
Attorneys—Ernest S. Cohen and Gersten Sadowsky

ABSTRACT: Power and rate of change of power transmitted in an electrical network are used to detect network instability. A power signal, a rate of power change signal, and a residual flow compensating signal are summed to indicate network condition. When a design maximum is exceeded a trip relay initiates sectionalization of the network. Selective response of the relay, to preclude operation by transients, is provided by limiting the rate signal, and by blocking the summation signal where design incorporated maxima are exceeded.



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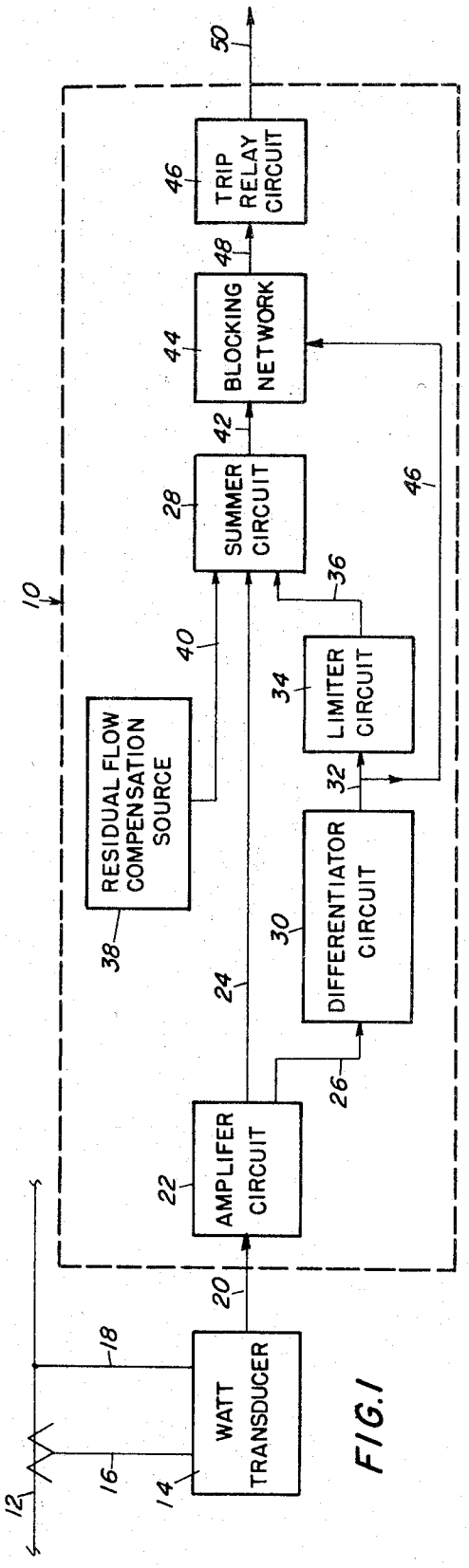


FIG. 1

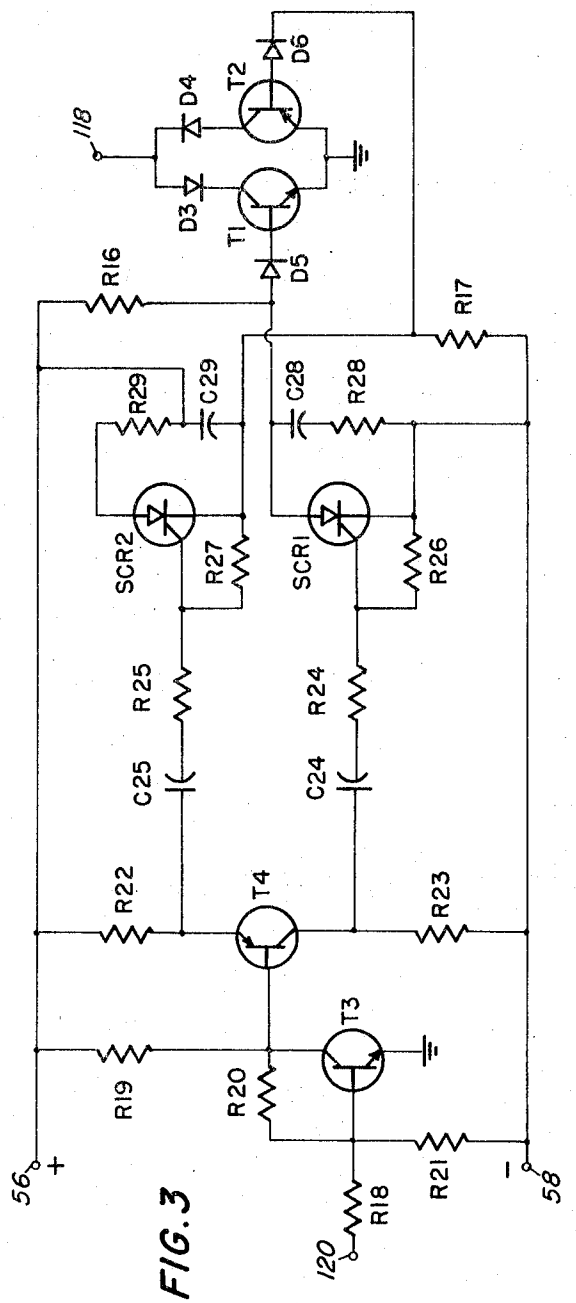
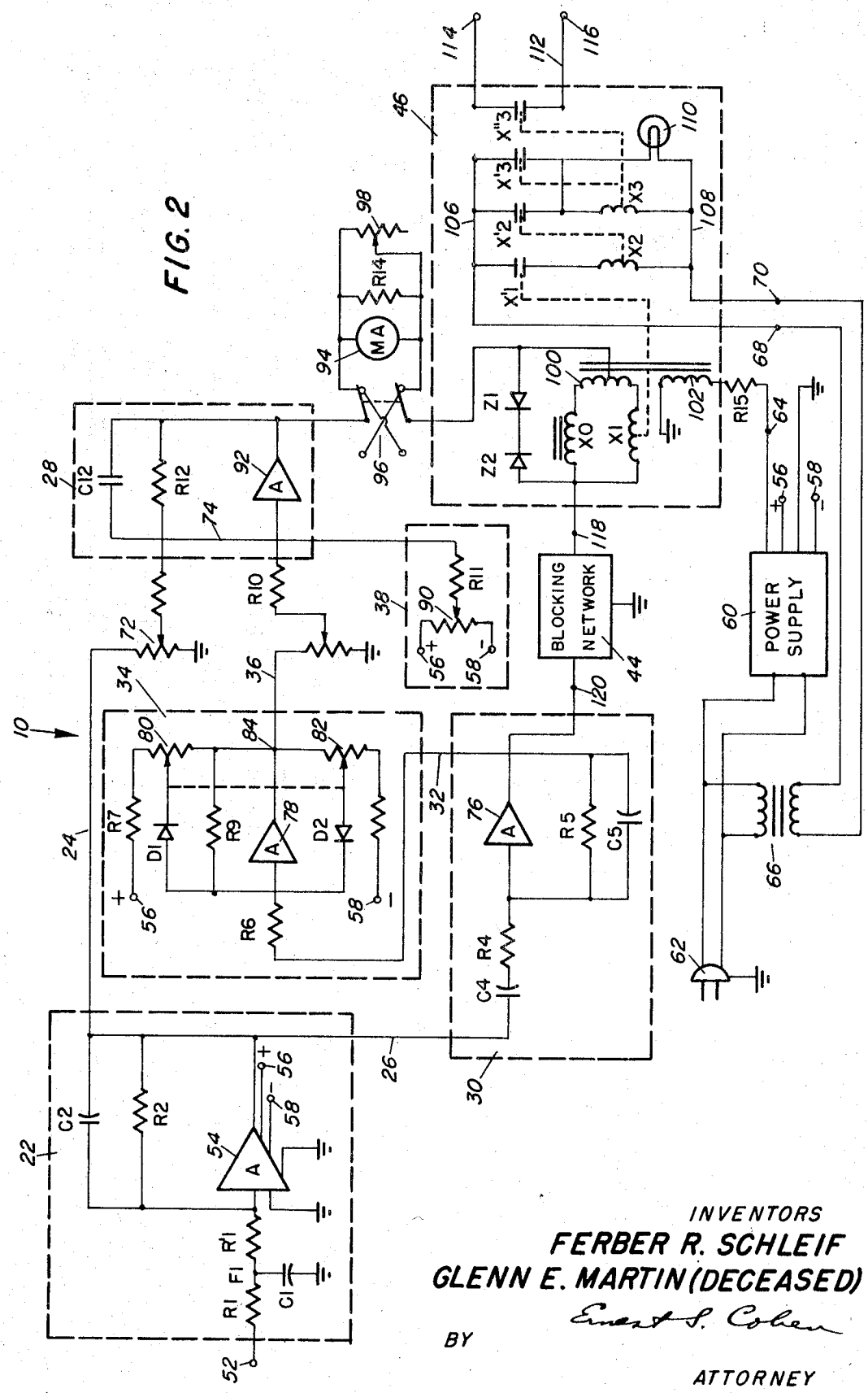


FIG. 3

INVENTORS
FERBER R. SCHLEIF
GLENN E. MARTIN (DECEASED)
Ernest S. Cohen
BY
ATTORNEY

FIG. 2



INVENTORS
FERBER R. SCHLEIF
GLENN E. MARTIN (DECEASED)
Ernest S. Cohen
BY
ATTORNEY

TIELINE SWING RELAY

BACKGROUND OF THE INVENTION

This invention relates to electrical relays and more particularly to a relay system which is sensitive to the power characteristics of interarea electrical transmission system ties.

Interconnection of large power systems with long transmission lines requires close surveillance of the interconnected system to detect the approach of unsatisfactory performance. Oscillations, excessive interchange, inadvertent interchange, or out-of-step conditions harmful to the power system must be discovered in ample time for corrective action to be taken. The relay of the present invention is designed to detect the approach of these harm harmful conditions and bring about sectionalization before the conditions exceed tolerable limits in the associated system.

Prior devices employed in the monitoring and control of power systems have included relays sensitive to the impedance, voltage, current or power of the system to detect harmful conditions. These devices were sensitive only to fault conditions in the system and not to the development of dynamic instability.

The relay of the present invention overcomes the limitations of the prior art by operation in response to functions of tieline power. Along a single interarea system tie, power variations of an oscillatory nature are mainly confined to a natural frequency which is characteristic of that tie and of the inertia of the interconnected system. Power variations at a much slower and irregular rate are also present due to the variation of system loads and the action of area generation control. The tolerable limits of these interchanges are best identified at the critical tie, rather than elsewhere in the system. Therefore, tieline power is employed as the quantity upon which this relay operates.

The relay employs power and rate of change of power in determining its operating point. The sensitivity of the relay to each of these quantities is adjustable to suit desired limits or characteristics of the tie. Either power or rate may be used alone if conditions require, but it is most advantageous to use the combination for greatest sensitivity in the early detection of undesirable conditions.

The relay of the present invention is connected to a transmission system tieline through a power transducer. The transducer measures the system power and provides a voltage output representative of the magnitude and direction of power transmission in the system. The output of the transducer is fed to an amplifier, the output of which is characteristic of the system power. The amplifier output is simultaneously fed into a differentiating network and into a summer. The differentiating network measures the rate of change of power and provides a corresponding rate signal which is fed into a limiter. The limiter controls the rate signal and blocks passage of current for high rate changes. The output of the limiter is fed into the summer simultaneously with the power signal from the amplifier. An adjustable bias signal, for offsetting residual flow characteristics of the system is also fed into the summer. The output of the summer, which provides an indication of power development in the tieline, is fed to a trip relay through an intermediate blocking network. The blocking network selectively blocks the connection between the summer and trip relay for signals indicating excessive rates of change of system power. An output from the differentiator is fed into the blocking network, activating the network when excessive rates of change are sensed by the differentiating circuit to prevent activation of the trip relay by spurious transients.

The relay is bidirectionally sensitive to disturbances in the transmission system. Since tielines are used to transmit power in either direction as system needs change, provision is made for power disturbances occurring in either direction of transmission to activate the relay. Overload power alone, independent of the rate of change of power, is sufficient to produce relay tripping for power flow in either direction.

Sensitivity to oscillatory conditions and anticipation of pullout in the present invention are provided by the rate of change of power feature. Overall selectivity is improved by combining the power and rate of change of power features. Thus, if the increase of power is slow and aperiodic, interchange up to the chosen steady limit is tolerated. However, at an appreciably lower value of power interchange, if the power increases rapidly, the rate-of-change signal in combination with the power signal produces tripping at a lower level of power in anticipation of the power limit that will be reached. The power and rate signals are both bipolar and add vectorially. If the power is high but decreasing, the rate signal subtracts from it and the trip point is made more remote. Even though the relay may be swinging through zero interchange, if the swing is great enough tripping may be produced by the rate of change alone.

Under ideal conditions on a single tie between well-integrated areas the power and rate sensitivity are selected to approximate the stability limits of the tie. Where the interconnected areas themselves have other critical ties, unsatisfactory conditions such as fluctuating voltage during oscillations may precede the stability limit. In these instances sensitivity permitting reasonable continuity of the tieline is the most practical choice.

Where the tieline from which power for the relay is measured is paralleled by another line or combination of lines, coordination becomes more difficult as a result of both steady state and transient conditions. The steady state power flow on the metered line is no longer necessarily proportional to the net interchange. There may be a residual flow on the tie when the net interchange is zero. This residual flow may vary in magnitude and direction as the distribution of generation is changed on or near the parallel lines. If the residual flow for any distribution of generation is subtracted from that seen by the relay, the remainder is again reasonably representative of the net tie. A residual flow compensator is therefore provided in the relay to subtract out this quantity.

Transient conditions which must be discriminated are greatly complicated by parallel tieline paths. The increased complication results from the increase in the rate of change for an oscillation of given amplitude as the frequency increases. Moreover, the natural frequency for a transient disturbance on one of the parallel or adjacent line sections is normally higher than that for the net interarea tie. Hence, without special precautions these minor local disturbances can produce higher rate-of-change signals than the net tie. Special precautions employed to prevent tripping from these undesirable causes include limiting of the rate signal, filtering, and selective blocking.

It is therefore an object of the present invention to provide a relay sensitive to power transmission in an electrical system.

It is a further object of this invention to provide a relay sensitive to the the rate of change of power transmission in an electrical system.

It is a further object of this invention to provide a relay sensitive to the combined effects of power and the rate of change of power transmission in an electrical system.

It is a still further object of this invention to provide a power sensitive relay in which residual power flow effects are eliminated.

It is a still further object of the present invention to provide a relay which is selectively sensitive to power and rate of change of power transmission in an electrical system, incorporating limiting and blocking functions to preclude relay activation by spurious signals.

These and other objects of the present invention will become more fully apparent with reference to the following specification and drawing which describe the preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a block diagram showing the tieline swing relay connected to a transmission line fragment through an intermediate watt transducer.

FIG. 2 is a schematic representation of the tieline swing relay enclosed by dotted lines in FIG. 1.

FIG. 3 is a schematic representation of a blocking network indicated in block form in FIGS. 1 and 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The tieline swing relay **10** of the present invention is schematically shown in FIG. 1 connected to a transmission line fragment **12** through a power transducer **14**. Power transducer **14** measures the power transferred by line **12** and is connected to the line by a current tap **16**, and a voltage tap **18**. Both taps **16** and **18** are schematic single phase representations of three phase connections well known to the prior art. Power transducer **14** measures the magnitude and direction of the power transferred in line **12** and provides a representative output voltage signal at line **20**.

The output signal of transducer **14** is fed through line **20** to an amplifier circuit **22**, which provides an amplified output signal, the magnitude and sign of which are representative of the power transfer detected by the transducer. The output of amplifier circuit **22** is fed through lines **24** and **26** respectively, to a summer circuit **28** and a differentiator circuit **30**.

Differentiator circuit **30** measures the rate of change of the amplified power signal from amplifier circuit **22** and provides an output signal at line **32** representative of this rate of change. The rate signal from the differentiator **30** is fed into a limiter circuit **34** which controls the range of the rate signal and compensates for high rate changes induced by transients and spurious signals of little immediate change to the transmission line **12**.

The output of limiter circuit **34** is fed through a line **36** to summer circuit **28** where it is added to the output of amplifier circuit **22** to form a signal representative of the combined amount and rate of change of power transferred in line **12**. The output of a residual flow compensation source **38** is s similarly fed through a line **40** to summer **28** and combined with the amount and rate of change of power signals to form a representative power signal in output line **42** of the summer. The output of the residual flow compensation source **38** is set at a level to neutralize the residual power flow on the transmission line **12** when the net system interchange of power through the line **12** is zero. The output from the summer in line **42**, therefore, represents those power transfer parameters of line **12** which are significant for protection of the line.

The output of summer circuit **28** is fed through a blocking network **44** to a trip relay by intermediate lines **42** and **48**. When the combined input signals to summer circuit **28** exceed a critical design maximum, characteristic of line **12** and the network it interconnects, the summer output signal activates trip relay **46**. The output of trip relay **46** then activates conventional circuit interruption equipment (not shown) through an interconnecting line **50**.

The relay circuit **10** will now be described in particular detail with reference to FIG. 2. The output of a power (watt) transducer **14**, as shown in FIG. 1, is connected to the positive and ground input terminals **52** and **54**, respectively, of the relay **10**. The power transducer provides a DC voltage output, characteristic of power transfer on the transmission line. The polarity of the power transducer output signal is positive for one direction of power flow and negative for the other direction. The power transducer, itself, is well known and forms no part of the present invention. Terminals **52** and **24** of relay circuit **10** connect the power transducer **14** with amplifier circuit **22** of the relay. The amplifier circuit includes filters F_1 and F_2, respectively, in series with and parallel to an amplifier **54**, which may comprise a vacuum tube or suitable solid state element. Filters F_1 and F_2 include resistors and capacitors R_1, R'_1 and C_1, and R_2 and C_2, respectively. The filter time constants are chosen to eliminate 120Hz ripple and signal hash above the relay operating range. Amplifier **54** is provided with suitable grounding at terminals G and with suitable voltage input from positive terminal **56** and negative terminal **58** of a power supply **60**. The voltage at terminals **56** and **58** is of equal magnitude and opposite sign with respect to ground. Since the implementation of suitable amplifiers in the present invention will be apparent to those of ordinary skill in the art, the internal function of the amplifier will b not be described in further detail.

Power supply **60** is connected to a suitable AC source of electrical power (not shown) at grounded input terminal **62**. Low voltage AC output is provided at terminal **64**, and equal DC voltages of opposite sign are provided at positive terminals **56** and negative terminal **58**, as described above. A stepdown transformer **66** is connected in parallel with power supply **60** and provides low voltage AC at transformer output terminals **68** and **70**.

The output of amplifier circuit **22** is fed to summer circuit **28**, which serves as the relay driver, via a conductor **24**, and to differentiator circuit **30** via a conductor **26**. Conductor **24** is connected in series with a potentiometer **72**, one terminal of which is connected to ground. The tap of potentiometer **72** is connected to a common input lead **74** of summer circuit **28** through a resistor R_3. Potentiometer **72** facilitates adjustment of the sensitivity of relay **10** relative to the amount of power transferred by line **12**, enabling selective proportioning of the amount and rate of change of power signals which are combined to determine relay tripping.

Differentiator circuit **30** includes a capacitor C_4 and resistor R_4 in series with an amplifier **76**, and a resistor R_5 and a capacitor C_5, each in parallel with the amplifier. The operational connections of amplifier **76** are similar to those described for amplifier **54**, as are those of the other amplifiers in the relay **10**, and will not be described in detail. The values chosen for R_5 and C_5 determine the threshold at which blocking network **44** is activated. Increasing the value of resistor R_5, while correspondingly decreasing the value of capacitor C_5 to preserve the filter time constant of the differentiator, increases the sensitivity of the blocking function.

The rate representative output of differentiator **30** is fed through conductor **32** and series resistor R_6 to an amplifier **78** in limiter circuit **34** of the relay. A resistor R_7, potentiometers **80** and **82**, and a resistor R_8 are connected in series between positive and negative terminals **56** and **58** of power supply **60**. The low voltage terminal of potentiometer **80** and the high voltage terminal of potentiometer **82** are joined to the output of amplifier **78** at a terminal **84**. A diode D_1 is joined between the voltage tap of potentiometer **80** and the input to amplifier **78** with the cathode of the diode joined to the potentiometer tap. Another diode D_2 is joined between the input of amplifier **78** and the voltage tap of potentiometer **82** with the anode of diode D_2 joined to the potentiometer tap. A feedback resistor R_9 is joined in parallel between the input and output terminals of amplifier **78** to provide amplifier gain feedback. Simultaneous adjustment of potentiometers **80** and **82** is achieved by linkage **86**, to provide positive and negative rate sensitivity limits adjustment. The adjustable limiter circuit **34** precludes excessive sensitivity at higher rates of swing than those characteristic of the tieline by adding appropriate positive or negative neutralization voltages through diodes D_1 and D_2 when the magnitude of the rate input to amplifier **78** exceeds a positive or negative design maximum, variable by adjustment of potentiometers **80** and **82**.

The output of limiter circuit **34** is connected to a terminal of a potentiometer **88**, the other terminal of which is connected to ground. The voltage tap of potentiometer **88** is connected to common input lead **74** of summer circuit **28** through a series resistor R_{10}. Potentiometer **88** facilitates adjustment of the sensitivity of relay **10** relative to the rate of power transferred by line **12**.

Still more ideal combination of the power and rate terms is obtained if these terms are squared before combination by substitution of squaring networks for resistors R_3 R_{10}.

A potentiometer **90** is joined between positive and negative terminals **56** and **58** of power supply **60** to provide a voltage output for residual flow compensation source **38**. The voltage tap of potentiometer **90** is joined to common input lead **74** of summer circuit **28** through a series resistor R_{11}. **11**. Adjustment of the potentiometer tap between the positive and negative voltage limits provides residual flow compensation for power transfer in either direction in transmission line **12**.

The combined power, rate, and compensation signals at common lead **74** are fed to an amplifier **92** in the summer circuit **28**. A resistor R_{12} and a capacitor C_{12} are each connected in parallel across the input and output terminals of amplifier **92**. Resistor R_{12} and capacitor C_{12} provide a filter time constant determinative of the summation value for relay pickup. The time constant at which relay pickup would be produced for a step signal may be adjusted by the relative size of capacitor C_{12}, while maintaining the value of R_{12} constant.

The output of summer circuit **28** is fed to an ammeter **94** through a reversing switch **96**. As current flow may be either in the positive or negative direction in the circuit, depending upon the direction and rate of change of power transfer in line **12**, the reversing switch is provided to enable use of a directional meter. Since optimum adjustments of the relay **10** are expected to compromise between operating conditions and since setting procedures will differ from those for more conventional relays, the relay **10** is designed to provide a continuous indication of its output signal as a per unit of trip setting. The ammeter **94** is a conventional meter calibrated from zero to 1.0. The tripping point corresponds with the full scale reading of 1.0. The full scale reading is adjustable for the range of power, rate, and compensation values by means of a shunting potentiometer **98** in parallel with a resistor R_{14}. Under steady state power transfer conditions the meter indication is proportional to power flow on line **12**. When the power transfer is increasing, the reading is higher than the steady state reading by the rate of increase. Conversely, when the flow is decreasing, the indication is less than that for steady state conditions by the rate of decrease.

The output of ammeter **94** is fed to the center tap of a biasing coil **100**. Sensitive operating relay X_0 and X_1 are each joined to an end of coil **100**. The other ends of relays X_0 and X_1 are joined to ground through blocking network **44**. Opposed Zener diodes Z_1 and Z_2 are joined in parallel with coil **100** and relays X_0 and X_1, represented in FIG. **2** as relay coils, to protect the relay coils from overloads. Coil **100** is magnetically coupled to a coil **102** through a common core **104**. Coil **102** is joined at one end in series with a resistor R_{15} and the low voltage AC output **64** of power supply **60**, and at the other end is joined to ground. Low voltage AC induced in coil **100** is effective to neutralize residual magnetism in the coils of relays X_0 and X_1.

When blocking network **44** is open, the output of amplifier **92** will pass to ground through the coils of relays X_0 and X_1. Relay X_0 energizes a system monitoring recorder (not shown) when the input voltage from summer circuit **28** reaches a predetermined percentage of the trip setting of relay X_1.

Common leads **106** and **108** are connected to the low voltage AC output terminals **68** and **70** of stepdown transformer **66**. A relay contact X_1' of relay X_1 and the coil of a relay X_2 are connected in series between common leads **106** and **108**. The relay contact X_2' of relay X_2, and a relay coil of a multicontact relay X_3 are similarly connected in series between common leads **106** and **108**. The low voltage contact X_3' of relay X_3 and a target lamp **110** are also connected in series between terminals **106** and **108**. A lead **112** is connected between relay contact X_2' and X_3' on the side of the contacts removed from common lead **106**.

When the output of summer circuit **28** reaches the trip setting of relay X_1 the relay is activated, closing contacts X_1' which energize relay coil X_2. Activation of relay X_2 closes contacts X_2' which energize relay coil X_3, closing contacts X_3' and X_3'', while simultaneously energizing target lamp **110** to indicate that the relay circuit has been tripped. High voltage contacts X_3'' of relay X_3 close the circuit **50** between relay **10** output terminals **114** and **116**. The output circuit **50** energized by contacts X_3'' is electrically isolated from the remainder of relay **10** and activates a high voltage circuit breaker (not shown) to interrupt power flow in transmission line **12**.

Relay X_1 is sensitive to the output magnitude of summer circuit **28** and trips for both positive and negative signals. When the output of the summer decreases below the relay trip setting, contacts X_1' open, deenergizing relay coil X_2 and opening contacts X_2'. Relay X_3 remains closed, however, since a seal in current is shunted from relay contact X_3'' to relay coil X_3 across conductor **112**. Relay X_3 must be reset to clear the main trip contact X_3'' and the lamp **110**.

A blocking network **44** for preventing activation of relay **10** by spurious rate signals is shown in FIG. **3**. Input to the blocking network from the summer circuit **28** is provided at terminal **118** of the blocking network. Input of the rate signal from the differentiator **30** is provided to the blocking network at input terminal **120**. Positive and negative biasing voltages are provided from power supply **60** at terminals **56** and **58** of the blocking network.

Positive signals from summer **28** pass to ground through the blocking network via terminal **118** in series with a diode D_3 and an NPN transistor T_1. The anode of diode D_3 is connected to terminal **118** and the cathode to the collector of transistor T_1. The emitter of transistor T_1 is connected to ground. The base of transistor T_1 is connected to positive terminal **56** through a diode D_5 and a biasing resistor R_{16}, providing a positive bias which holds the transistor conductive as long as rate signals in the normal operating range of relay **10** are received at input terminal **120**. Since the operation of relay **10** is bidirectional, parallel provision is made for negative signals from summer **28**. This parallel provision includes a diode D_4 in series with a PNP transistor T_2 connected between terminal **118** and ground. A diode D_6, and a resistor R_{17} cooperate to negatively bias transistor T_2 in a conductive mode for negative power flow when normal rate signals are received at terminal **120**.

The rate signal from differentiator circuit **30** is fed to the blocking network at input terminal **120**. The base of an NPN transistor T_3 is connected to terminal **120** through an input resistor R_{18}. Resistors R_19 and R_{20} are connected in series between positive terminal **56** and the base of transistor T_3. A resistor R_{21} is connected between the base of transistor T_3 and negative terminal **58**. The collector of transistor T_3 is connected between resistors R_{19} and R_{20} and the emitter is connected to ground. The relative values of resistors R_{19}, R_{20} and R_{21} are chosen with the resistance of R_{21} much larger than the sum of the resistances of R_{19} and R_{20}. Resistor R_{19} serves as a biasing resistor for transistor T_3, biasing the transistor into the conductive mode.

The base of a PNP transistor T_4 is connected to the collector of transistor T_4. Resistor R_{20}, which is also connected to the collector of transistor T_3, serves as a biasing resistor to establish the operating point of transistor T_4. The emitter and collector of transistor T_4 are connected to the positive and negative terminals **56** and **58** of power supply **60**, respectively, through equal value resistors R_{22} and R_{23}.

A positive rate signal received at terminal **120** of the blocking network causes transistor T_3 to become more conductive, increasing the negative bias on transistor T_4. As the negative bias increases to and beyond the abnormal range, transistor T_4 becomes more conductive and the emitter of the transistor becomes more negative, while the collector becomes more positive. The gate of a silicon controlled rectifier SCR_1 is connected to the collector of transistor T_4 through series resistors R_{24} and a capacitor C_{24}. The gate of SCR_1 is also connected to the negative terminal **58** through a biasing resistor R_{26}. As the collector of transistor T_4 swings to the positive a transient current, conducted through resistor R_{24} and capacitor C_{24}, fires SCR_1.

The anode of SCR_1 is connected to positive terminal **56** through a series resistor R_{16}, and the cathode is connected to negative terminal **58**. A capacitor C_{28} in series with a resistor

R_{28} is shunted between terminal **58** and the anode of SCR_1. A resistor R_{26} is connected between the gate of SCR_1 and terminal **58**, putting a negative bias on the SCR gate to prevent gating by noise pulses, and to provide gating pulse limiting to protect the SCR.

When a gating pulse fires SCR_1, capacitor C_{28} discharges rapidly through resistor R_{28} and SCR_1. The base of NPN transistor T_1 is simultaneously driven to the negative, causing the transistor to stop conducting, and preventing activation of the tripping relay. Capacitor C_{28} then recharges according to a time constant determined by the values of R_{16} and R_{29}. Capacitor C_{24} then blocks tripping for steady state conduction through transistor T_4, as T_1 again becomes conductive.

Similar provision is made for turning off transistor T_2 when a negative rate signal is received at input **120**. A negative rate input drives the emitter of transistor T_4 more positive causing a gating pulse to flow through a capacitor C_{25} in series with a resistor R_{25} to the gate of a silicon controlled rectifier SCR_2. Resistor R_{27} serves a function analogous to that of resistor R_{26}, while resistor R_{29} and capacitor C_{29} are analogous to R_{28} and C_{28}, respectively. Thus, when an abnormal negative rate pulse is received at terminal **120**, indicating that the rate of power flow is decreasing, the relay **10** is deactivated for power flow in the negative direction. Since positive rates of change associated with negative power flow, and negative rates of change associated with positive power flow have neutralizing effects when the power and rate signals are added at the summer circuit, the blocking network is not responsive to these combinations of signals. The values of the circuit elements in the blocking network are chosen to prevent blocking for rate signals in the range harmful to transmission line **12**, while blocking those rate signals which are of a spurious nature.

In one exemplary form of the invention the circuit parameters were as follows: Amplifiers **54**, **76**, and **78** were P65AU Philbrick operational amplifiers, while amplifier **92** was a P45AU Philbrick operational amplifier. D_1 and D_2 were IN646 diodes, while D_3—D_6 were IN464 diodes. Z_1 and Z_2 were IN3060B Zener diodes. T_1 and T_3 were 2N708 transistors, while T_2 and T_4 were 2N2187 transistors. SCR_1 and SCR_2 were 2N2322A silicon controlled rectifiers. Relays X_0 and X_1 were 2MA DC 2500 ohm, SPST Sigma 48RO 2500G—STL relays. Relays X_2 and X_3 were 6.3 volt AC DPDT Allied control B06–A relays. The power supply **60** was a PR30C Philbrick regulated power supply providing positive 15 volt DC output at terminal **56** and negative 15 volt DC output at terminal **58**, with a 6.3 volt AC output at terminal **64** for a 115 volt AC input. The stepdown transformer **66** provided 6.3 volt AC output at terminals **68** and **70** for a 115 volt AC input. A Hall watt transducer delivering an output of 0 to 100 millivolts DC was used as the input to the relay **10**. The values of the resistors used in the circuit were, in ohms: R_1 – 5.1K; R_1', R_{19}, R_{22}, R_{23} – 4.7K; R_2 – 390K; R_3, R_4, R_{10} – 10K; R_5 – 160K; R_6, R_9, R_{16}, R_{17}, R_{21} – 120K; R_7, R_8 – 25K; R_{11} – 250K; R_{12} – 100K; R_{14} – 28; R_{15} – 2.5K; R_{18} – 10K; R_{20} – 30K; R_{24} – 1.5K; R_{25} – 5.6K; R_{26}, R_{27} – 18K; R_{28}; R_{29} – 33K. Potentiometers **72** and **88** were 5K ohms, potentiometers **80** and **82** were 10K ohms, and potentiometer **98** was 0.5K ohms. The values of capacitors uses were, in microfarads: C_1 – 5; C_2 – 0.33; C_4 – 10; C_{12} – 6; C_{24} – 1.2; C_{25} – 1.3; C_{28}; C_{29} – 20.

It can thus be seen that a useful device for monitoring the power transfer characteristics of an electrical transmission network has been provided.

In adapting the present exemplary disclosure to a particular power transfer environment, numerous modifications of the invention will become apparent to those skilled in the art in the light of the above teachings and within the scope of the appended claims.

It is claimed:

1. Apparatus for monitoring and controlling power transfer in an electrical circuit comprising:
means for measuring the amount of power transfer in the electrical circuit and providing a first output signal representative of that amount;
means for measuring the rate of change of power transfer in the electrical circuit and providing a second output signal representative of that rate of change;
means for combining the first and second output signals to provide a combined signal; and
means selectively responsive to the combined signal for providing a control signal for controlling the power transfer in the electrical circuit.

2. An apparatus as described in claim **1**, further comprising:
means for providing a third output signal representative of residual power transfer in the electrical circuit; and
the means for combining further including means for incorporating the third output signal into the combined signal.

3. An apparatus as described in claim **1** in which:
the means for measuring the amount of power transfer includes a power transducer;
the means for measuring the rate of change of power transfer includes a differentiator circuit with an input from the power transducer; and
the means selectively responsive to the combined signal includes a trip relay which activates a control circuit.

4. An apparatus as described in claim **2** in which:
the means for measuring the amount of power transfer includes a power transducer;
the means for measuring the rate of change of power transfer includes a differentiator circuit with an input from the power transducer; and
the means selectively responsive to the combined signal includes a trip relay which activates a control circuit.

5. An apparatus as described in claim **1**, further comprising:
means for limiting the magnitude of the second output signal; and
means for blocking the control signal when the magnitude of the rate of change of power transfer in the electrical circuit exceeds a design limit.

6. An apparatus as described in claim **2**, further comprising:
means for limiting the magnitude of the second output signal; and
means for blocking the control signal when the magnitude of the rate of change of power transfer in the electrical circuit exceeds a design limit.

7. An apparatus as described in claim **3**, further comprising:
means for limiting the magnitude of the second output signal; and
means for blocking the control signal when the magnitude of the rate of change of power transfer in the electrical circuit exceeds a design limit.

8. An apparatus as described in claim **4**, further comprising:
means for limiting the magnitude of the second output signal; and
means for blocking the control signal when the magnitude of the rate of change of power transfer in the electrical circuit exceeds a design limit.