United States Patent [19]

Cohn

[11] **3,740,572**

[45] **June 19, 1973**

[54] **CONTROL OF POWER SYSTEM FOR OPTIMUM ECONOMY**

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[22] Filed: **July 3, 1972**

[21] Appl. No.: **268,234**

[52] **U.S. Cl.** **307/57**, 307/87, 235/151.21

[51] **Int. Cl.** **H02j 3/00**

[58] **Field of Search** 307/57, 87; 235/151.21

[56] **References Cited**

UNITED STATES PATENTS

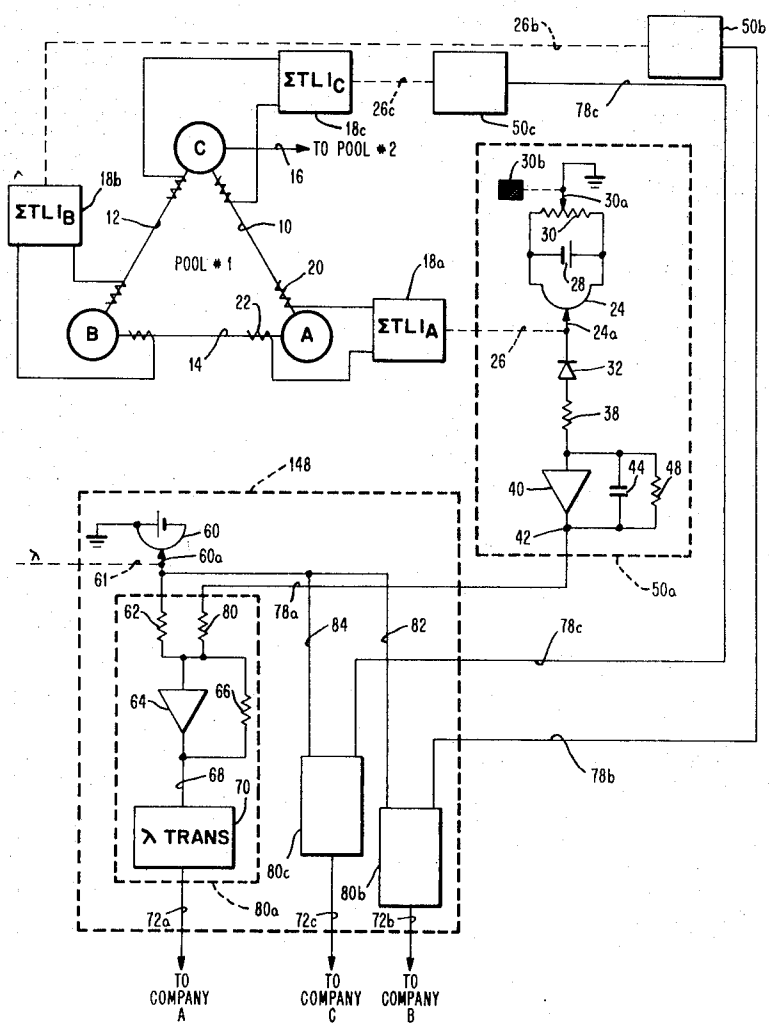
3,270,209 8/1966 Cohn 307/57

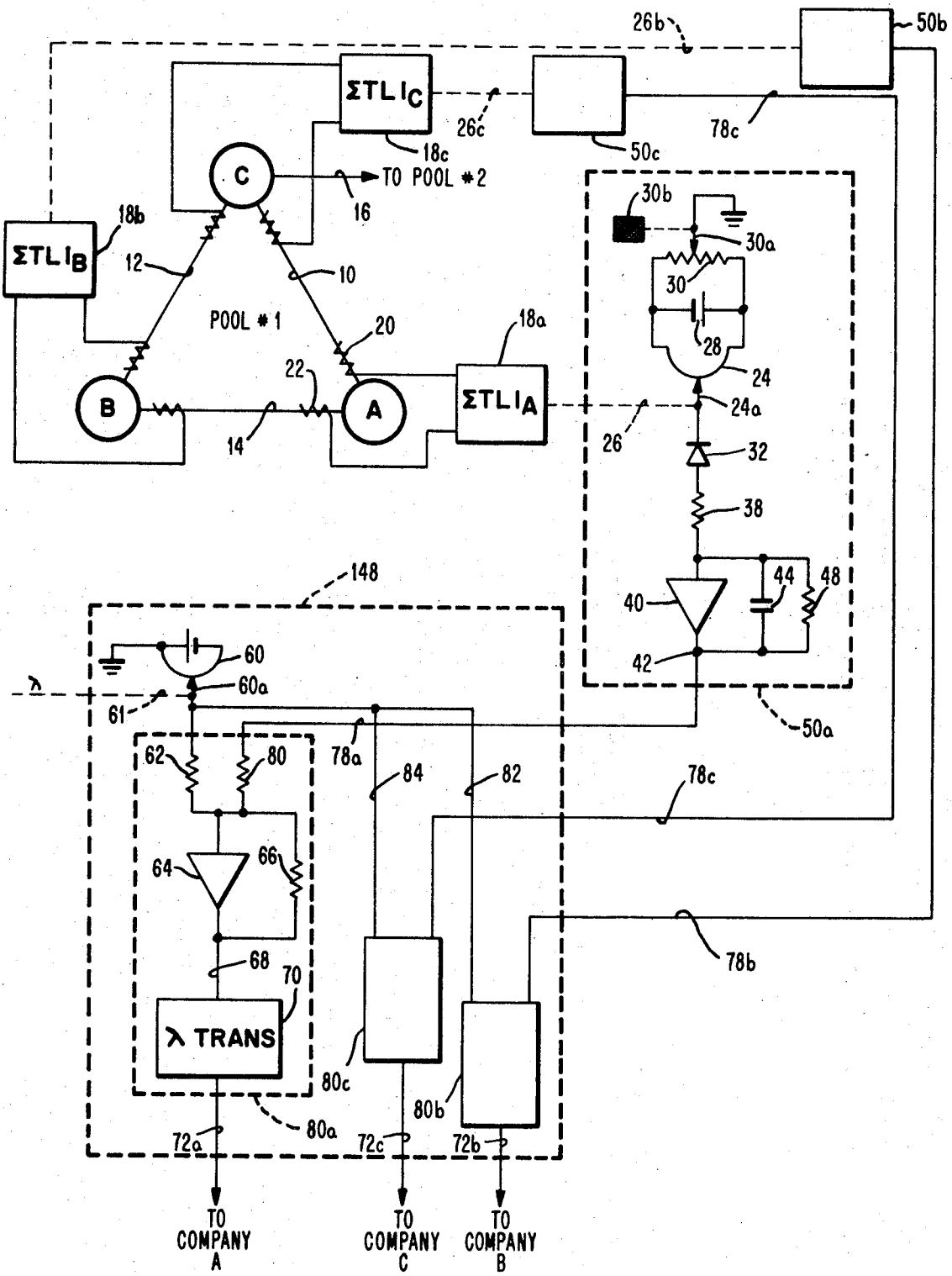
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[57] **ABSTRACT**

Economic loading of generators in the interconnected companies of a power pool may be normally carried out by producing and broadcasting to the participating companies a common λ signal of value sufficient to provide through control the desired total generation. Such control is modified by biasing the common λ signal to a particular company whose net tie-line interchange has exceeded a predetermined limit. The modification is such that the net interchange is not allowed to exceed the limit. Similar modification may be made when it is desired to prevent a particular tie from exceeding a limit.

7 Claims, 1 Drawing Figure




ΣTLI C
ΣTLI B
ΣTLI A
TO POOL #2
POOL #1
TRANS
TO COMPANY A
TO COMPANY C
TO COMPANY B

CONTROL OF POWER SYSTEM FOR OPTIMUM ECONOMY

BACKGROUND OF THE INVENTION

This invention relates to the control of the loading of generators of the individual interconnected power companies of a power pool for the maintenance of adequate generation in the pool. More particularly, the invention relates to the control of the generators of the interconnected power companies to provide an economic distribution of the load among those generators with the provision of means for altering the economic distribution as may be required, by limitations in the operation of a particular company.

In the operation of a plurality of interconnected power companies participating in the maintenance of the load in the power pool formed by the interconnection there may be utilized a control system of the type fully described in my U.S. Pat. No. 3,270,209, issued Aug. 30, 1966, wherein FIGS. 9, 10 and 11 illustrate a control arrangement applicable to a power pool having participating and interconnected operating companies each with their own dispatching offices and each with their own regulating sources. In that patent, FIG. 9 represents equipment that may be installed at the Pool Load Dispatching Office, FIG. 10 illustrates apparatus at a participating company's load dispatching office, and FIG. 11 shows equipment for a source at a station of one of the participating companies. As indicated in FIGS. 9–11 of said patent, suitable telemetering channels link control apparatus at the pool office to control apparatus at each of the participating company's dispatching offices, and suitable telemetering channels link control equipment at a participating company's dispatching office to control equipment at it respective stations. Thus, in the system described in FIGS. 9, 10 and 11 there is computed at the Pool Load Dispatching Office a common signal, λ, which is transmitted to each of the participating company's load dispatchers offices where it is used as a basis for calculating the incremental cost of generation for each of the generating stations. The generators of the station are then controlled so that their output is at a level corresponding with that incremental cost value.

In the operation of the individual participating companies it may be found desirable to limit the value of the net interchange of power between that company and the other participating companies or in some cases the interchange over a particular tie line between that company and another participating company. Such a limitation may be dictated, for example, by the necessity of limiting the generation of the company as a whole for the proper maintenance of reserve capability. Thus, a participating company may desire to fully participate in the maintenance of optimum economic distribution of the pool load up to the point where that company's reserve capability is endangered. That point may be detected by measuring the net interchange between that company and the other participating companies, and it may be found desirable to avoid a continued increase in generation output. For example, as the pool load increases with a corresponding increase in the signal representing the value of the incremental cost of delivered power, established at the Pool Load Dispatchers Office and transmitted to the participating companies, the desirable mode of operation may be

that which maintains the net tie-line interchange at its limit value.

SUMMARY OF THE INVENTION

In accordance with the present invention there is provided an improvement in the system for controlling the economic distribution of electrical load among generators of participating power companies which are interconnected to form a power pool wherein the output of the generation of each of the companies is controlled to a level such that the incremental cost of delivered power associated with those outputs corresponds to the value represented by a common cost signal for the pool with said incremental cost signal being modified to bring the total actual generation in the pool into equality with the total desired generation. The improvement comprises means which are operable when the tie-line interchange of one of the companies with respect to another exceeds a predetermined limit for modifying the value of the common incremental cost signal so as to produce an incremental cost signal for that particular company for establishing an associated value for the output of its generators such that the output will tend to maintain the tie-line interchange so that it will not exceed the limit value.

BRIEF DESCRIPTION OF THE DRAWING

The FIGURE is a circuit diagram partially in block form showing the improvement as it would be applied to the control system of FIGS. 9–11 of my U. S. Pat. No. 3,270,209.

DESCRIPTION OF THE PREFERRED EMBODIMENT

For a complete description of this invention, reference should be made to U. S. Pat. No. 3,270,209, and more specifically to that portion of the specification starting at Column 11, line 30, in conjunction with the present FIGURE, showing the improvement which will now be described.

In the FIGURE, the power pool being controlled is shown as pool No. **1** having three participating companies, namely, companies A, B and C which are interconnected as by tie-lines **10, 12** and **14,** and which may be interconnected to another pool such as pool No. **2** as by tie-line **16.** Alternatively, A, B and C may be considered individual power pools each having its own group of interconnected companies with the tie-lines **10, 12** and **14** interconnecting the pools into a group whose load is to be economically maintained.

Since the apparatus associated with each of the companies is the same in many respects, it will be described only as it relates to company A. Thus, the net tie-line interchange between company A and the other participating companies ΣTLI_A may be measured by recorder **18***a* which receives as inputs signals from thermal converter **20** in tie-line **10** and thermal converter **22** in tie-line **14.** The recorder **18**a then operates to produce by way of its retransmitting slidewire **24** the signal ΣTLI_A, representing the net tie-line interchange for company A. This signal is produced at slidewire contact **24***a* which is shown as being operated by the retransmitting coupling connection **26.** The slidewire **24** is shown as having a power source consisting of battery **28** across its terminals as well as potentiometer **30** whose adjustable contact **30**a is positioned by way of the hand adjusted knob **30***b* so that the position of the contact **30***a*

is established for the magnitude of the limit for the "power out" measured as the net tie-line interchange for participating company A.

It will be evident that when the contact **24***a* is positioned along slidewire **24** in that region of slidewire **24** at which the potential is positive, then there will be no current flow through the diode **32** which has its cathode connected to contact **24***a*. On the other hand, when the contact **24***a* has moved to the left far enough to be beyond the potential point corresponding with the position of contact **30***a*, there will then be a negative potential of contact **24***a* which will allow current to flow through diode **32** producing by way of the input resistor **38** a negative potential on the input to the high gain amplifier **40** which will in turn produce a positive potential at its output point **42.** The input resistor **38** in conjunction with the high gain amplifier **40** and the feedback capacitor **44** with its shunting high impedance resistor **48** form an operational amplifier which is effective to integrate the input from contact **24***a* so as to provide an ever increasing value for the potential at the output **42.** Thus, the circuit elements incorporated in block **50** *a* may be considered as an integrating circuit or a reset control circuit responding to the net tie-line interchange deviation from its preset limit value when the deviation is such that the net power out of company A exceeds the limit.

Block **148** of the FIGURE may be substituted for block 148 of FIG. 9 in U. S. Pat. No. 3,270,209 in order to provide for the incorporation of the improvement of this invention in the system of FIGS. 9–11 of said patent. Thus, as shown in the FIGURE, block **148** has an input signal in the form of a mechanical connection which is operable to position the contact **60***a* or slidewire **60** so that it represents a value for λ, which in FIG. 9 of U. S. Pat. No. 3,270,209 is representative of the common incremental cost of delivered power which is, in the system of that patent, intended to be the incremental cost of delivered power associated with the levels of generation of each of the participating companies. In the present system that value for λ as represented by the signal on contact **60***a* is supplied as one input through input resistor **62** to high gain amplifier **64** which has a feedback resistor **66** serving to form an operational amplifier which in the absence of any input would produce on it output line **68** a signal corresponding with the λ signal on contact **60***a* as transmitted by the mechanical coupling **61.** That signal would then be telemetered by the λ transmitter **70** over the telemetering channel **72***a* to company A where it would be received in accordance with the invention of U. S. Pat. No. 3,270,209 by a λ receiver such as receiver **150** of FIG. 10 of that patent.

The present improvement provides for a modification of the λ signal transmitted to company A whenever the net tie-line interchange for company A indicates that the power out exceeds its predetermined limit value. That modification is carried out by the introduction of a second input to amplifier **64** over line **78***a* and through input resistor **80** to amplifier **64,** the effect being such that the signal on the telemetering channel **72***a* is modified by the signal on line **78***a* so that the value of λ for company A will not increase as the value of the common λ represented by the potential on contact **60***a* continues to increase, but instead will be maintained at a value such that the output of the generators of company A will maintain the net tie-line interchange such that it will not exceed its limit value. Thus, the signal on line **78***a* is effectively subtracted from the signal derived from contact **60***a*.

It may be desirable to also limit the power flowing into company A by adding another circuit similar to that of block **50***a*. It would only be necessary to reverse the polarity of diode **32** in the added circuit to so limit the net interchange. When limiting the "power in" the λ is not allowed to decrease as much as the common λ.

It will be evident that as long as the net tie-line interchange as measured by recorder **18***a* exceeds the limit value set by the positioning of contact **30***a* the signal on line **78***a* will continue to increase in a positive polarity so as to cause the signal on line **68** to continue to increase in a negative polarity, the appropriate polarity for effecting a change in the generation at company A in a direction to decrease the generation as a result of the λ signal telemetered over channel **72***a*.

The control of participating company B may be effected in a similar manner as that described for company A whenever the net tie-line interchange exceeds a predetermined limit. Thus, there is associated with company B a net tie-line interchange recorder **18***b* which is connected through mechanical coupling **26**b to block **50***b* where block **50***b* corresponds to block **50***a* for area A. The output of **50***b* over line **78***b* to block **80**b of block **148** serves to modify the λ signal sent to company B over the telemetering channel **72***b* in that it modifies the signal received from contact **60***a* over line **82.** The block **80***b* is similar to block **80***a* for company A.

Similarly, the participating company C has associated net tie-line interchange recorder **18***c* connected by mechanical coupling **26***c* to block **50***c*. The net interchange ΣTLI_C for company C, however, does not include the flow over tie **16** to pool No. 2 for the flow over the remaining ties may adequately indicate the limit condition which is to be detected. Block **50***c* is, of course, similar to block **50***a* for company A, and the output of **50**c is transmitted over line **78***c* to block **80***c* so as to modify the λ signal supplied to block **80***c* on line **84** from contact **60***a*. The signal thus provided over the telemetering channel **72***c* is a λ signal for determining the generation desired from company C.

The system disclosed may, of course, be used to control the distribution of load in a pool in which the companies A and B may be connected with another pool as is shown for company C in the FIGURE. Also, the system is applicable to the control of a plurality of pools interconnected into a group. Thus, for the purposes of this description and the appended claims the word "company" may be interpreted as a number of interconnected power suppliers having separate economic interests or as one supplier representing a single economic interest.

It will be evident to those skilled in the art that the net tie-line interchange recorders may be replaced with recorders measuring the flow over a particular tie instead of the net flow. Thus, the modification of the common λ signal may be to prevent a particular tie from exceeding a present limit. It will also be evident to those skilled in the art that the control described may be carried out by digital computer control systems as well as a combination of digital and analog control circuitry.

What is claimed is:

1. In a system for controlling the economic distribution of electrical load among the generators of participating power companies interconnected to form a power pool wherein the output of the generators of each of the companies is controlled to a level such that the incremental cost of delivered power associated with those outputs corresponds to the value represented by a common incremental cost signal for the pool and said incremental cost signal is modified to bring the total actual generation in said pool into equality with the total desired generation for the pool, the improvement which comprises:

means operable when the tie-line interchange of one of said companies with respect to another exceeds a predetermined limit for modifying the value of the common incremental cost signal to produce an incremental cost signal for said one of said companies for establishing an associated value for the output of its generators such that said output value tends to maintain said tie-line interchange at a value which does not exceed said limit.

2. In a system for controlling the economic distribution of electrical load among the generators of participating power companies interconnected to form a power pool wherein the output of the generators of each of the companies is controlled to a level such that the incremental cost of delivered power associated with those outputs corresponds to the value represented by a common incremental cost signal for the pool and said incremental cost signal is modified to bring the total actual generation in said pool into equality with the total desired generation for the pool, the improvement which comprises:

means operable when the net tie-line interchange of one of said companies with respect to the others exceeds a predetermined limit for modifying the value of the common incremental cost signal to produce an incremental cost signal for said one of said companies for establishing an associated value for the output of its generators such that said output value tends to maintain said net tie-line interchange at a value which does not exceed said limit.

3. A system for controlling the output of the generators in a plurality of power companies interconnected to form a power pool comprising:

means responsive to the magnitude of the total generation required to meet the load on said pool for establishing in accordance with a predetermined function a common value for the incremental cost of delivered power associated with each of the companies,

means responsive to the change required in the generation in the pool to meet the pool load for continually modifying said common value until said load is met,

means associated with each company for controlling the output of each of the companies generators so that the company is operating at a generation level corresponding with said common value, and

means responsive to the net interchange of each of said companies with the others exceeding a predetermined limit for modifying the level of incremental cost of delivered power at which the companies are operating so that said level will be modifed from said common value as required to maintain said net interchange at a value not exceeding said limit.

4. A system as set forth in claim 3 in which each company includes in its computation of values of output for each generator the incremental transmission losses in the company's distribution system.

5. A system as set forth in claim 3 in which said predetermined function is established by a function generator relating the common value for the incremental cost of delivered power to a value of generation.

6. A system as set forth in claim 5 in which the value of generation for said function generator is established by summing the total load on the pool and a value representing the change in generation required to meet that load.

7. The method for controlling the output of the generators in a plurality of power companies interconnected to form a power pool comprising the steps of:

automatically producing a signal representing a common value for the interchange of delivered power for each of the companies in response to the magnitude of the total generation required to meet the load on said pool, said signal having a predetermined functional relationship to said total generation magnitude,

automatically modifying said signal as long as the generation in the pool is inadequate to meet the pool load,

automatically controlling the generation level of the generators in each of said companies so that the generation level corresponds with the common value for the interchange of delivered power represented by said signal, and

automatically modifying said signal as it is associated with a particular company whenever the net interchange of said company with the other companies exceeds a predetermined limit, said modification being effected in magnitude and direction so as to maintain the net interchange at a value not exceeding its limit value.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,740,572 Dated June 19, 1973

Inventor(s) Nathan Cohn

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, line 34, "or" should read --of--.

Column 3, line 46, "it" should read --its--.

Column 4, line 62, "present" should read --preset--.

Signed and sealed this 20th day of November 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents

PO-1050
(5/69)

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