Oct. 30, 1962 A. J. HAUCK 3,061,828

CIRCUIT MEANS

Filed March 11, 1958

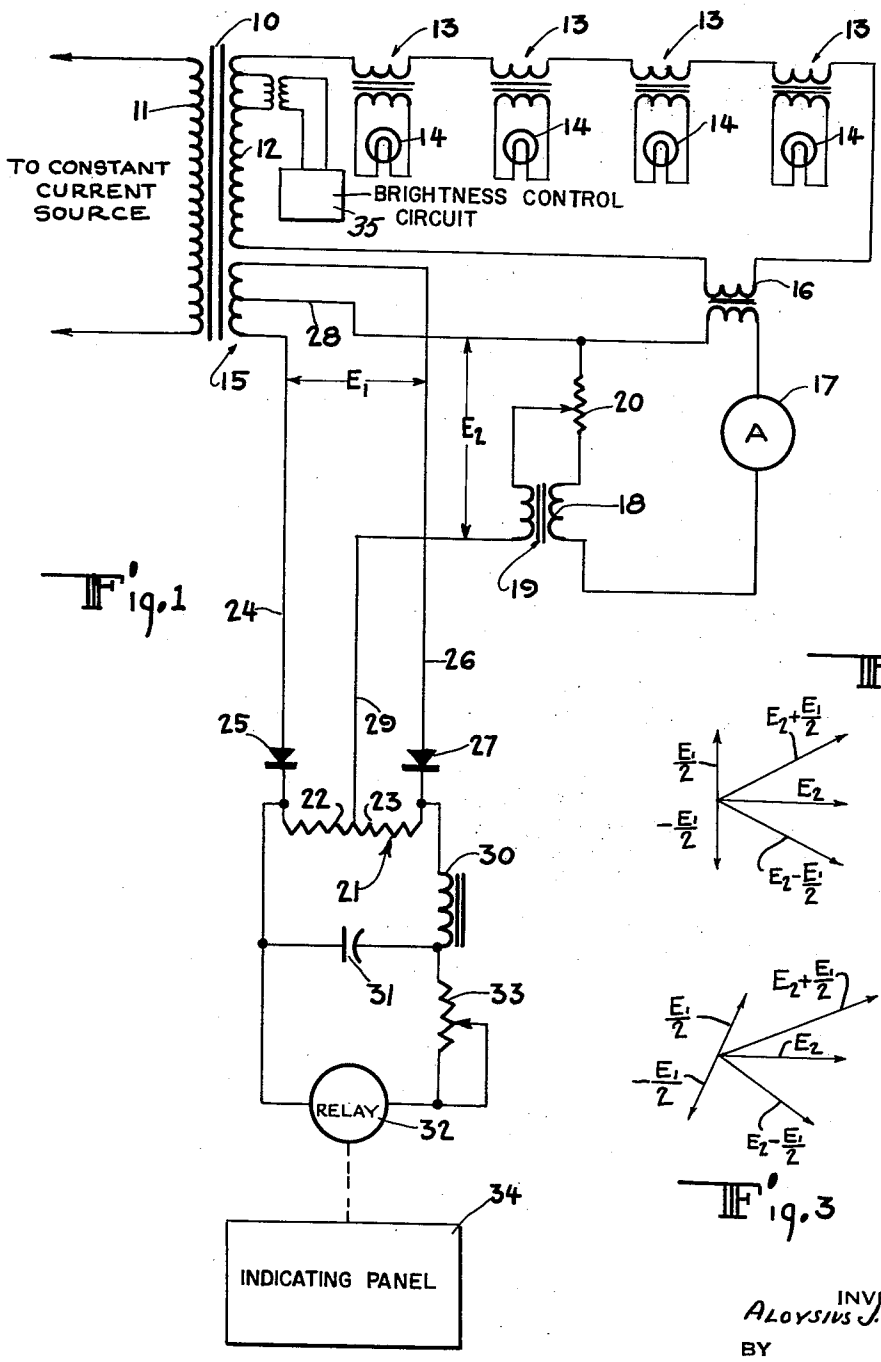

Fig. 1

Fig. 2

Fig. 3

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United States Patent Office

3,061,828

Patented Oct. 30, 1962

3,061,828

CIRCUIT MEANS

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Filed Mar. 11, 1958, Ser. No. 720,776
5 Claims. (Cl. 340—251)

This invention relates to a system for detecting changes in a load circuit and especially one for indicating failure of lamps in a lighting system.

Airport runway lights normally are at some distance from the control tower so that it is difficult to ascertain when any predetermined number have failed or burned out. Normally, the lamps in such an arrangement are fed from isolating transformers which are connected in series and it is desirable to be able to have an indication or warning at a remote point.

One of the objects of the invention is to provide a system which will detect and indicate failure of lamps in a lighting system.

Another of the objects of the invention is to provide an arrangement which will indicate at a remote location the condition or failure of parts of a lighting or similar system.

In one aspect of the invention, the detection means is arranged to respond to a change in a normally resistive load, such as is the case when a plurality of isolating transformers are connected in series, the secondaries of the transformers being connected to the lamps. When a lamp to which such a transformer is connected fails, the transformer primarily consumes load current as magnetizing current. The primaries of the isolating transformers may be fed from a constant current source of the resonant type, saturable type or high reactance type. Circuit means can be employed to provide a first signal, such as a voltage signal. The first signal can be obtained from a winding on an output transformer, if used, which feeds the load, or from a potential transformer connected across the load. The voltage of this signal will be in phase with the voltage across the series loop and proportional to the impedance of said loop. A second circuit means is provided for producing a second signal, such as voltage, displaced substantially 90 degrees from the load current. This signal can be obtained, for example, from a current transformer in the load circuit and an inductance in the secondary circuit of the current transformer. A combining circuit is employed combining the first and second signals or voltages in such a manner that when the load is normally resistive, or less than a predetermined number of lamps are out, the second signal plus one half of the first signal will be balanced by the second signal minus one half of the first signal. Then, if one of the lamps burns out, the load current and first signal will no longer be in phase because of the reactive impedance of the isolating transformer of the failed lamp and the combined signals will no longer be equal. A detecting means is provided to indicate a departure of the equal normal signal conditions as a result of a lamp burn out or to operate a relay for transmitting or using such departure information to a remote point.

These and other objects, advantages and features of the invention will become apparent from following description and drawings which are merely exemplary.

In the drawings:

FIG. 1 is a circuit diagram.

FIG. 2 is a showing of voltage relations when all lamps are burning.

FIG. 3 is similar to FIG. 2 but depicts voltage relation upon failure of lamp.

The invention will be described in conjunction with a lighting system but can be used in other similar ways.

Output transformer **10** may have its primary **11** connected to a constant current source of alternating current, such as a resonant type, saturable type, or high reactance type. The output transformer secondary **12** is connected to a load circuit including a plurality of isolating transformers **13** having their primaries connected in series with secondary **12**. The secondaries of isolating transformers **13** are connected in the usual manner to lamps **14**.

Output transformer **10** may have a center-tapped winding **15** for providing a voltage or signal which will be in phase with the voltage across the series load loop and proportional to the impedance of said loop. As an alternative, the voltage or first signal also could be obtained by connecting a potential transformer across the series loop if it is desired to omit output transformer **10**. Current transformer **16** may have its primary connected in series with the series load circuit. Ammeter or indicator **17** can be connected to the secondary circuit of the current transformer through winding **18** of mutual inductance **19**. Resistance **20** also may be included but may be omitted if an exact quadrature relationship is not required.

Combining resistance **21** can be considered to be composed of two parts **22**, **23**. Resistance **22** can have one side connected to winding **15** through line **24** and rectifier **25**. Resistance **23** may have one side connected to winding **15** through line **26** and rectifier **27**. Center tap **28** of winding **15** is connected to center tap **29** of resistance **21** through mutual inductance **19** or similar means.

Under normal operating conditions with all of the isolating transformers loaded, current in the load circuit and voltage induced in winding **15** will be substantially in phase. Under this condition, the voltage

$$E_2 \text{ plus } \frac{E_1}{2}$$

and

$$E_2 \text{ minus } \frac{E_1}{2}$$

will be substantially equal in magnitude and therefore there will be no direct current voltage appearing across resistance **22** plus resistance **23** as is shown in FIG. 2. If a lamp or a predetermined number of lamps burn out, the secondary of the respective isolating transformers will become unloaded and this will force the primary thereof to consume load current as magnetizing current. Such will result in the load current and voltage induced in winding **15** to be out of phase inasmuch as the magnetizing current is reactive. When this occurs, the condition

$$E_2 \text{ plus } \frac{E_1}{2}$$

and

$$E_2 \text{ minus } \frac{E_1}{2}$$

will become unequal in magnitude as illustrated in FIG. 3 and will cause a net direct current voltage to appear across resistor **22** plus resistor **23**. The magnitude of said voltage will be proportioned to the number of lamps that have failed.

Inasmuch as said direct current voltage will have a high ripple, it is desirable to use a filter including inductance **30** and capacitance **31** in the circuit feeding the sensitive relay or meter **32**.

There can be an adjustable resistor **33** included in the indicating circuit so as to cause or permit adjustment of meter contacts closure for various percentages of burned out lamps. If the voltage E_1 across winding **15** is made several times as large as voltage E_2 across in-

ductance **19**, the need for close adjustment of resistor **33** will be eliminated. Relay **32** may be connected, if desired, to an indicating panel **34** remotely located relative thereto such as in a control tower to operate a warning light or signal.

It has been found that the system is very sensitive and will detect satisfactorily failure of one light out of a hundred. As an example, the meter readings for varying percentages of open isolating transformers relative to full load were found to be:

Percent:	D.C. meter reading
0	.200
2¼	.500
4½	.600
6¾	.700
9	.800
11¼	.900

The arrangement also can be used in conjunction with a brightness control circuit indicated schematically at **35** such as illustrated in copending application Serial No. 720,777, filed March 11, 1958.

It should be apparent that variations can be made in details of the circuit and use thereof for detecting change in inductance in a load circuit without departing from the invention except as defined in the appended claims.

What is claimed is:

1. In a detection means for determining failure of lamps in a load connected to series connected isolating transformers, the combination including means for producing a first voltage in phase with the load voltage, means for producing a second voltage responsive to load current and displaced substantially 90° from the load current, means combining said first and second voltage so that during a normal condition when all of the lamps are burning, said second voltage plus one-half of said first voltage will be equal to said second voltage minus one-half of said first voltage, the combined voltage for said normal condition having no direct net value, and means indicating a departure of said combined voltage of said combining means from said normal condition because of lamp failure.

2. In a detection means for determining failure of lamps in a normally resistive load, said lamps being connected to series connected isolating transformers, the combination including means for producing a first voltage in phase with the load voltage, current transformer means connected in series with the series connected isolating transformers, reactive means connected to said current transformer means for producing a second voltage displaced substantially 90° from the load current, combining circuit means connected to said means for producing a first voltage and to said reactive means for producing said second voltage to combine said first and second voltages so that during a normal condition when said lamps are burning, said second voltage plus one-half of said first voltage will be equal to said second voltage minus one-half of said first voltage, the combined voltage for said normal condition having no direct net value, and condition responsive means responsive to a departure of said combined voltage of said combining circuit means from said normal condition because of failure of lamps in said load.

3. In a detection means for determining failure of lamps in a normally resistive load, said lamps being connected to series connected isolating transformers, the combination including means for producing a first voltage in phase with the load voltage, current transformer means

connected in series with the series connected isolating transformers, reactive means connected to said current transformer means for producing a second voltage displaced substantially 90° from the load current, combining circuit means connected to said means for producing a first voltage and to said reactive means for producing said second voltage to combine said first and second voltages so that during a normal condition when said lamps are burning, said second voltage plus one-half of said first voltage will be equal to said second voltage minus one-half of said first voltage, the combined voltage for said normal condition having no direct net value, filter circuit means connected to said combining circuit means, and condition responsive means connected to said filter circuit means, said condition responsive means being responsive to a departure of said combined voltage of said combining means from said normal condition as said filter circuit means when failure of lamps in said load occurs.

4. In a system for determining failure of lamps, the combination including a constant current source, a plurality of isolating transformers connected in series with said source to provide a load circuit, means for connecting lamps to said isolating transformers, a first voltage producing means connected to said sources for producing a first voltage in phase with the load voltage, a current transformer connected in said load circuit, circuit means connected to said current transformer for producing a voltage displaced substantially 90° from the load current, combining circuit means connected to said first voltage producing means and to said circuit means connected to said current transformer to combine said first voltage and said voltage displaced substantially 90° from the load current, said combining circuit means producing a resultant voltage upon predetermined changes of load circuit conditions, and resultant voltage responsive means connected to said combining circuit.

5. In a system for determining failure of lamps, the combination including a constant current source, an output transformer, a plurality of isolating transformers connected in series with said source to provide a load circuit, means for connecting lamps to said isolating transformers, a first voltage producing means connected with said output transformer for producing a first voltage in phase with the load voltage, a current transformer connected in said load circuit, circuit means connected to said current transformer for producing a voltage displaced substantially 90° from the load current, combining circuit means connected to said first voltage producing means and to said circuit means connected to said current transformer to combine said first voltage and said voltage displaced substantially 90° from the load current, said combining circuit means including a pair of resistance means and rectifiers for producing a resultant D.C. signal upon predetermined changes of load circuit conditions, and resultant signal responsive means connected to said combining circuit.

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