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(54) Title: LOAD REGULATION SYSTEM

(57) Abstract: A load control system is provided for an electrical distribution network having an electrical source and a plurality of loads supplied by the electrical source. The load control system comprises a controller associated with the electrical source, for monitoring the power supplied by the electrical source. The controller generates a distress factor signal corresponding to the power supplied by the electric source, and transmits this signal to the loads. The load control system also includes a plurality of load switching units associated with respective loads. Each load switching unit is responsive to the distress factor signal transmitted by the controller to interrupt the supply of power to its associated load if the distress factor signal exceeds a load factor value stored in the load switching unit.

AP 456

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EP 023254 A2	WO 92/05615	US 3721830 (H. Oi Shi et al)
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BACKGROUND OF THE INVENTION

This invention relates to a load control or regulation system for an electrical supply network which comprises at least one electrical source and a plurality of loads supplied by the source.

In an electricity distribution network, the maximum required supply capacity of the network is dependent on the peak load requirements of the consumers, and not on the average load. The occurrence of peak loads varies daily and seasonally. Thus distribution networks of this kind are generally overrated, with greater capacity than is usually required, increasing the capital expenditure involved in the network.

By regulating the load on the network to switch off non-critical loads as the total demand rises, the peak demand on the network can be reduced. This reduces the maximum required capacity of the network, with a consequent reduction in the capital expenditure involved, which in turn allows cheaper electricity.

At present, remote switching of loads in an electrical distribution network is carried out using so-called ripple control devices which are switched remotely, typically via transmission line signalling. In such systems, a load control unit switches an associated load on or off in accordance with a control signal emitted remotely at a central control system, the control signal identifying the load control units affected.

SUMMARY OF THE INVENTION

According to the invention there is provided a load control system for an electrical distribution network comprising at least one electrical source and a plurality of loads supplied by the at least one electrical source, the load control system comprising:

> a controller associated with at least one electrical source, the controller being adapted to monitor the power supplied by the electrical source, to generate a distress factor signal corresponding thereto and to transmit it to the loads; and
>
> a plurality of load switching units associated with respective loads, each load switching unit being responsive to the distress factor signal generated by the controller to interrupt the supply of power to its associated load if the distress factor signal exceeds a load factor value of the load switching unit.

Each load switching unit may be adapted to store a variable load factor value, the load factor value being variable in response to at least one predetermined criterion.

The load switching unit may be programmable with an initial load factor value which is reduced automatically by a first predetermined amount when the distress factor signal exceeds the initial load factor value, so that the reduced load factor value is substantially less than the distress factor signal.

In that event, the reduced load factor value may be increased incrementally over a predetermined time period until the load factor value exceeds the distress factor signal, whereupon the load switching unit restores the supply of power to its associated load.

The load factor value may then be increased by a second predetermined amount so that it substantially exceeds the distress factor signal.

The increased load factor value may then be reduced incrementally over a predetermined time period until it is equal to the initial load factor value.

At least one load supplied by the at least one electrical source may be an auxiliary electrical source such as a substation or a local transformer, adapted to supply electrical power to further loads.

The distress factor signal may comprise a tone with a frequency which varies according to the value of the distress factor.

Alternatively, the distress factor signal may comprise a code representing the value of the distress factor.

The load switching unit is preferably adapted to interrupt the supply of power to its associated load only if the distress factor signal exceeds the load factor value of the load switching unit for longer than a delay period generated by the load switching unit.

Preferably, the delay period is random or pseudo-random in length.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of an electrical distribution network incorporating a load control system according to the invention;

Figure 2 is a simplified block diagram of a controller of the load control system;

Figure 3 is a simplified block diagram of a load switching unit of the system;

Figures 4, 5 and 6 are flow diagrams illustrating the operation of the system; and

Figure 7 is a graph illustrating graphically the operation of the system.

DESCRIPTION OF AN EMBODIMENT

Referring first to Figure 1, an electrical distribution network is shown in a simplified schematic form and comprises a power station 10 which feeds one of several substations 12 via a transmission line 14. One of several local transformers 16 is fed by the substation 12 and supplies electricity to several loads 18 which can be, for example, domestic dwellings, factories, or other conventional electricity consumers. The electricity distribution network as such is conventional. At the power station 10 a controller 20 is installed, which monitors the total power demand on the transmission line, and compares the load to a predetermined maximum load to calculate a "distress factor" which is calculated as a percentage of the maximum desirable or permissible load. For example, the maximum permissible load can be set as, say, 95% of the maximum output capacity of the power station.

Similar controllers 20 to the one at the power station are provided at each substation and each local transformer, and monitor the loading of the substation or transformer relative to a respective maximum load.

The block diagram of Figure 2 shows a controller 20 schematically. The controller comprises a microprocessor 24 with an associated memory 26 in which a "maximum load" value or number is stored. This number is related to the installed infrastructure to which the controller is connected, and is used for the computation of a distress factor. The controller includes a distress factor receiver circuit 28, which receives distress factor signals from "upstream" controllers, if any, and a distress factor transmittor circuit 30, which transmits the distress factor generated by the controller to "downstream" controllers and load switching units. The controller further includes a load measurement circuit 32, which monitors the power being supplied by the power station, substation or transformer (as the case may be) associated with that controller. The microprocessor 24 calculates a distress factor from the magnitude of the load being supplied and the "maximum load" number stored in the memory 26. The microprocessor compares this distress factor with the external distress factor signal (if any) received from upstream controllers, and transmits the larger of the two distress factors via the transmitter 30.

Associated with each load 18, a load switching unit 22 is provided which is arranged to receive the distress factor signals from the controller at the power station (or from the relevant substation or local transformer) and is connected to a load which it can connect or disconnect from the mains supply. In the case of a domestic dwelling, the load will typically be a geyser or hot water cylinder. Generally, the load will be an item of equipment which consumes a significant amount of electricity, but which can be disconnected from its electrical supply without damage or undue inconvenience to users of the equipment.

As shown in Figure 3, the load switching unit 22 comprises a microprocessor 34 with an associated memory 36 and a timer circuit 38, and also includes a distress factor receiver 40 similar to that in the controller 20. The microprocessor 34 controls the operation of a switch 42 via which the relevant load 18 is supplied with power.

Each load switching unit 22 is initialled with a predetermined minimum load factor value. This load factor value is based on the type of load connected to the load switching unit, and is stored in the memory 36. This initial load factor is expressed as a proportion or a percentage value and is continually compared with the distress factor signal transmitted from the controller at the power station, the substation or the local transformer. The microprocessor 34 continually compares the stored minimum load factor value with the received distress factor signal from the distress factor receiver 40. As long as the received distress factor signal is less than the stored load factor value of the load switching unit, the load switching unit keeps the load connected to the electrical supply.

If the value of the received distress factor signal exceeds the stored load factor value, the timer circuit 38 in the load switching unit generates a random or pseudo random time delay of between, say, 0 and 15 seconds. At the end of the delay period, the stored load factor is again compared to the transmitted distress factor signal. If the distress factor signal has now reduced, so that it is less than the stored load factor value, operation of the load switching unit continues as normal, with on-going monitoring of the transmitted distress factor signal.

If, after the random delay, the transmitter distress factor signal is still greater than the stored load factor value, the microprocessor 34 operates the switch 42 to disconnect its associated load 18 from the mains supply.

This reduces the load on the distribution network as a whole, and contributes to reducing the distress factor of the relevant controller.

The use of a random delay in the load switching unit effectively ensures that a minimum number of loads are switched off, by gradually reducing the total load. Without the random delay feature, all load switching units with the same stored load factor value would switch off their loads simultaneously as soon as the received distress factor exceeded the load factor. However, with the random delay feature, those load switching units with the shortest delays switch off their loads before other load switching units with longer delay times. These latter load switching units may then not necessarily have to switch off their loads, since by the time their longer delays are completed, the received distress factor may have reduced to below the stored load factor, due to the switching off of the loads connected to those load swiching units with shorter delay times.

In this way, the system effectively removes the minimum load required to keep the distress factor below a predetermined maximum value.

At the same time as disconnecting the load, the load switching unit reduces the stored initial load factor value by 20 percentage points (for example, from 95 to 75%). The unit then increases the load factor value incrementally, maintaining the load disconnected, until the load factor value exceeds the value of the distress factor signal. For example, the load factor value can be increased by one percentage point per minute, so that, in the present example, the load will be disconnected for approximately twenty minutes. Obviously, the degree of reduction of the load factor value, and the rate at which the reduced load factor value is increased towards its initial value, can be selected according to the circumstances.

When the load factor value exceeds the current distress factor signal value, the load switching unit reconnects its load to the mains supply. At the same time, 10 percentage points are added to the load factor value, ensuring that it substantially exceeds the current distress factor signal value, and thus preventing the possibility of the load being switched off again immediately. The unit continues to monitor the value of the distress factor signal. While the load factor value remains greater than the initial predetermined load factor value, the load factor value is reduced incrementally (say, by one percentage point every five minutes) until the load factor value is again equal to the initial load factor value for that unit. Assuming that the distress factor signal does not fluctuate significantly in the meantime, this ensures that the load will remain on for approximately fifty minutes after being reconnected.

The graph of Figure 7 illustrates the above described operation of the load switching unit.

The above described process can be repeated indefinitely, every time the distress factor signal value exceeds the value of the load switching unit's load factor value.

The distress factor signal transmitted by the controllers can be, for example, a continuous tone, the frequency of which varies as the measured load varies, or a digital number representing the magnitude of the load. The signal can be transmitted at predetermined intervals, for example, once a minute.

It will be appreciated that the controllers 20 at the power station, the substation and the local transformer form a hierarchy. A number of loads are connected to a single local transformer, a number of local transformers are connected to a single substation, and a number of substations are connected to a single power station. Thus, the load switching units of individual loads can act to control the load on a particular local transformer, while the load switching units of respective local transformers operate to control the load on a given substation. In this context, the substations and local transformers operate as auxiliary electrical sources. Similarly, the load switching units of respective substations operate to control the load on the power station itself. Clearly, it will only be necessary for local transformers and substations to be disconnected if the disconnection of individual loads is not sufficient to maintain the power demand on the power station within the required limits.

Where there are several controllers in the hierarchy, "upstream" controllers will generally have a higher priority than "downstream" controllers. For example, if there is a controller at a local transformer and also at the substation feeding that local transformer, the controller at the substation sends its distress factor signal to the controller at the local transformer. The controller at the local transformer compares this distress factor signal with its own distress factor, and transmits the greater of the two factors to its respective loads. Thus, the controller at the substation can control the load switching units of the various loads via the controller at the local transformer. In some cases, the load requirements of the local transformer, for example, may not be critical. In such a case, there need be neither a controller nor a load switching unit at the local transformer itself, and the distress factor signals transmitted from the substation are sent via the transformer directly to the load switching units of the various loads.

The effect of the system is that the loads supplied by the electrical distribution network are switched off randomly, without it being necessary for individual load switching units to be identified and addressed individually with signals transmitted to them from a central control station. The load switching units (or at least the control circuitry thereof) are identical, and do not require a unique identity or serial number.

It will be appreciated that since the decision to switch the load on or off is taken by an individual load switching unit, rather than centrally, the controllers required for the system can be very simple. Nevertheless, multiple loads can effectively be switched on or off from a single monitoring or control point. The system does not require any communication cabling or other link between the controllers and the load switching units, apart from the existing cabling of the electrical distribution network.

The system is flexible, in that the priority of a load can be set by changing the initial minimum load factor value for a particular load switching unit. For example, an industrial load can be given a higher priority than a domestic load. The period for which loads are disconnected or connected can be adjusted by varying the arbitrary increases/decreases in the load factor value of the load switching units, or the rate at which the adjusted load factor values are incremented or decremented in use.

Figures 4, 5 and 6 are flow diagrams indicating the operation of the system graphically. The diagram of Figure 4 illustrates the operation of a controller. The controller monitors its electrical connections to determine whether or not a signal from an external controller of higher priority is present. Depending on whether or not such a signal is present, the controller either outputs its own distress factor signal, or the distress factor signal of the higher priority controller.

The diagram of Figure 5 illustrates the interaction of a controller and its associated load switching units, while the diagram of Figure 6 indicates the operation of an individual load switching unit.

CLAIMS

1. A load control system for an electrical distribution network comprising at least one electrical source and a plurality of loads supplied by the at least one electrical source, the load control system comprising a controller associated with at least one electrical source and a plurality of load switching units associated with respective loads, characterised in that the controller is adapted to monitor the power supplied by the electrical source, to generate a distress factor signal corresponding thereto and to transmit it to the loads; and in that each load switching unit is independently responsive to the distress factor signal generated by the controller to interrupt the supply of power to its associated load if the distress factor signal exceeds a load factor value of the load switching unit.

2. A load control system according to claim 1 wherein each load switching unit is adapted to store a variable load factor value, the load factor value being variable in response to at least one predetermined criterion.

3. A load control system according to claim 2 wherein the load switching unit is programmable with an initial load factor value which is reduced automatically by a first predetermined amount when the distress factor signal exceeds the initial load factor value, so that the reduced load factor value is substantially less than the distress factor signal.

4. A load control system according to claim 3 wherein the load switching unit is adapted to increase the reduced load factor value incrementally over a predetermined time period until the load factor value exceeds the distress factor signal, whereupon the load switching unit restores the supply of power to its associated load.

5. A load control system according to claim 4 wherein the load switching unit is adapted to increase the load factor value by a second predetermined amount, so that it substantially exceeds the distress factor signal, when the supply of power is restored to the load.

6. A load control system according to claim 5 wherein the increased load factor value is reduced incrementally over a predetermined time period until it is equal to the initial load factor value.

7. A load control system according to any one of claims 1 to 6 wherein at least one load supplied by the at least one electrical source is an auxiliary electrical source adapted to supply electrical power to further loads.

8. A load control system according to claim 7 wherein the distribution means is a substation or a transformer.

9. A load control system according to any one of claims 1 to 8 wherein the distress factor signal comprises a tone with a frequency which varies according to the value of the distress factor.

10. A load control system according to any one of claims 1 to 8

wherein the distress factor signal comprises a code representing the value of the distress factor.

11. A load control system according to any one claims 1 to 10 wherein the load switching unit is adapted to interrupt the supply of power to its associated load only if the distress factor signal exceeds the load factor value of the load switching unit for longer than a delay period generated by the load switching unit.

12. A load control system according to claim 11 wherein the delay period is random or pseudo-random in length.

DATED THIS 20th DAY OF July 1993

FISHER CORMACK & BOTHA
Patent Agents for the Applicants

ABSTRACT

A load control system is provided for an electrical distribution network having an electrical source and a plurality of loads supplied by the electrical source. The load control system comprises a controller associated with the electrical source, for monitoring the power supplied by the electrical source. The controller generates a distress factor signal corresponding to the power supplied by the electric source, and transmits this signal to the loads. The load control system also includes a plurality of load switching units associated with respective loads. Each load switching unit is responsive to the distress factor signal transmitted by the controller to interrupt the supply of power to its associated load if the distress factor signal exceeds a load factor value stored in the load switching unit.

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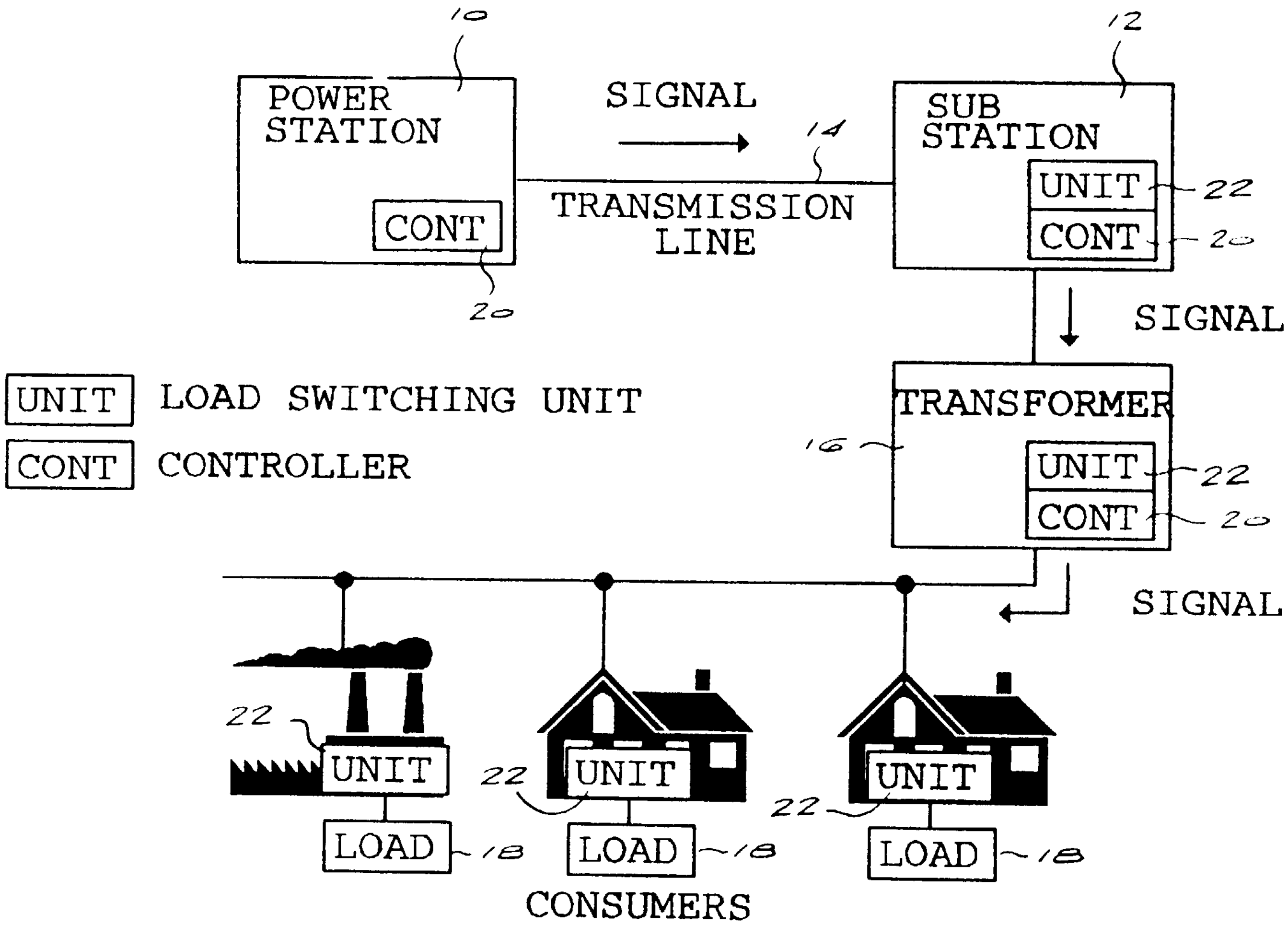
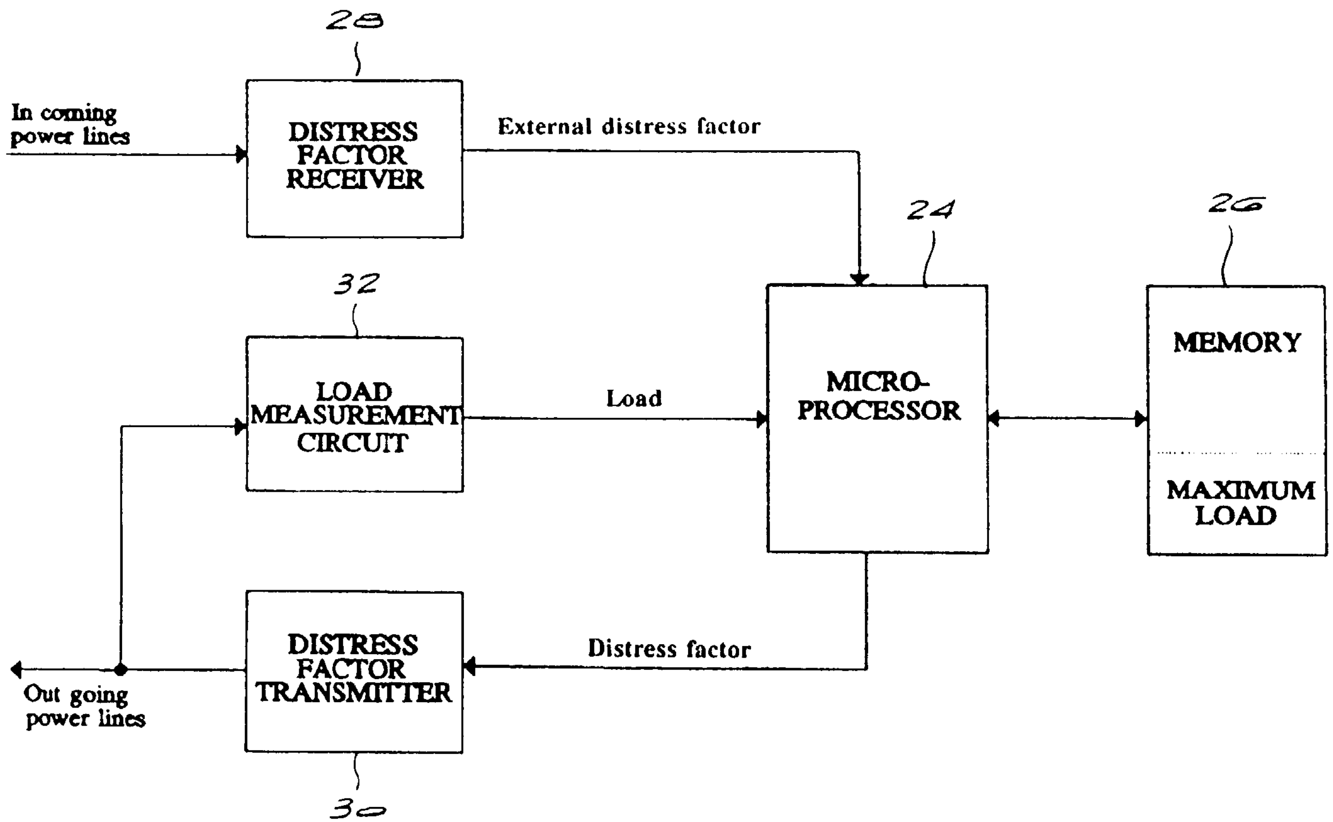


FIG 1

FIG 2



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2

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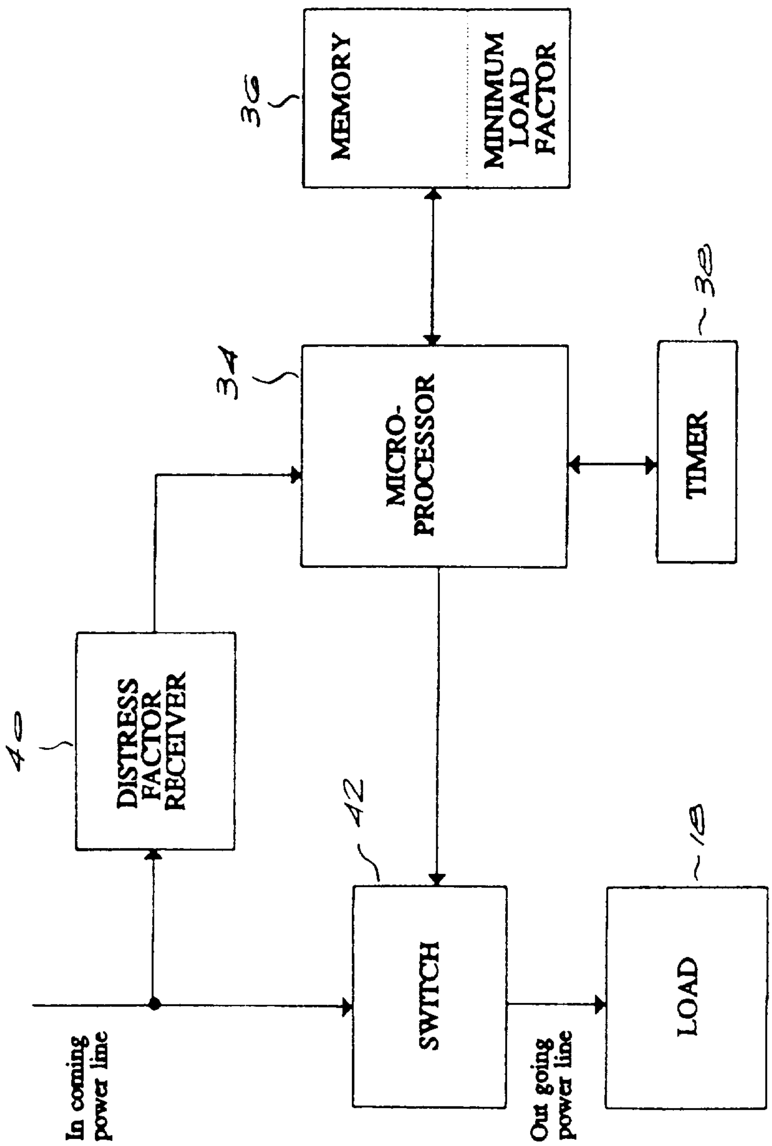
3

FIG 3



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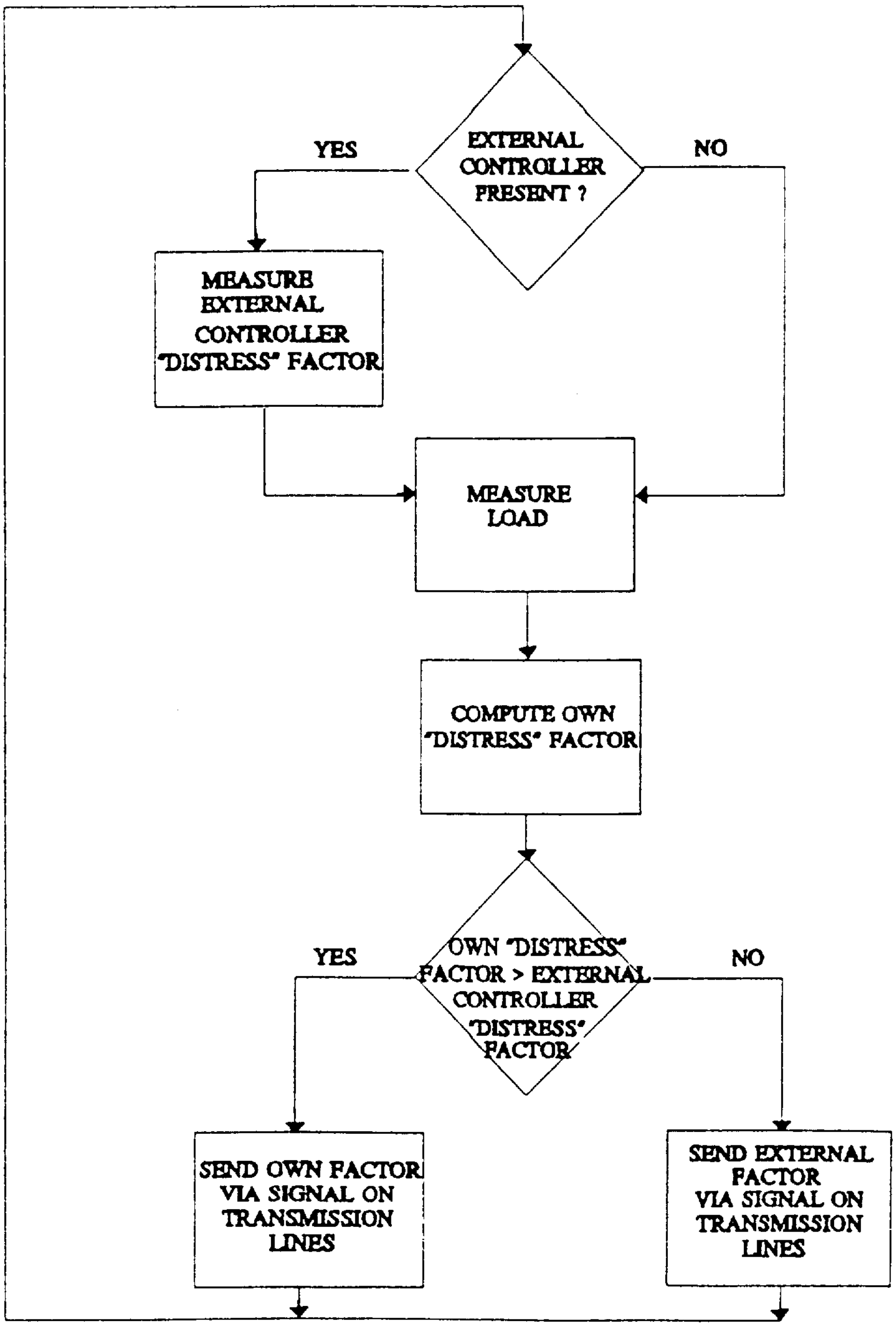
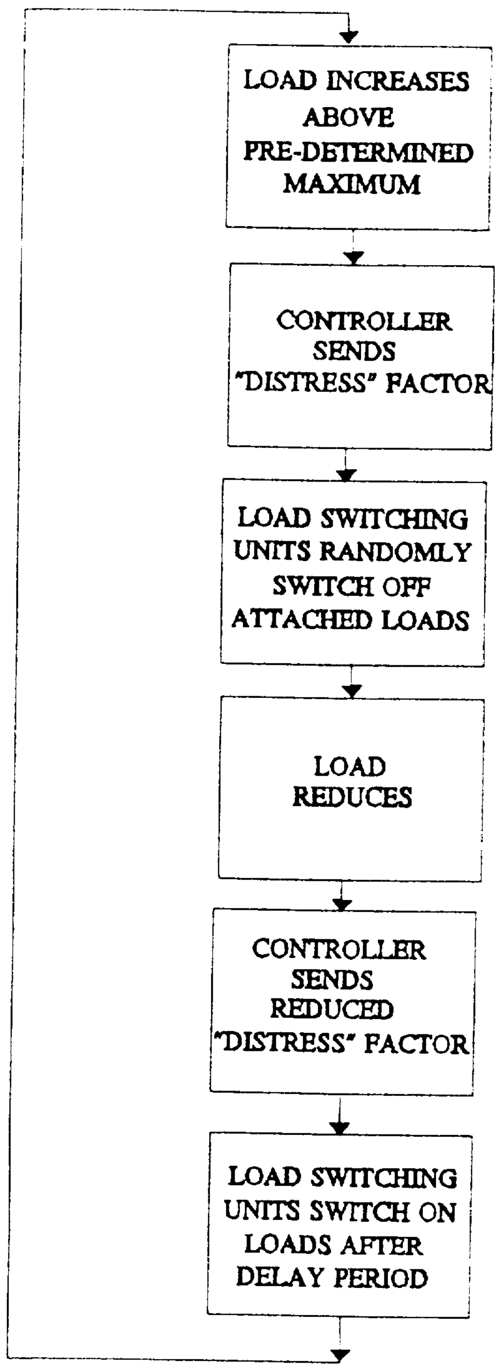

EXTERNAL CONTROLLER PRESENT ?
YES
NO
MEASURE EXTERNAL CONTROLLER "DISTRESS" FACTOR
MEASURE LOAD
COMPUTE OWN "DISTRESS" FACTOR
OWN "DISTRESS" FACTOR > EXTERNAL CONTROLLER "DISTRESS" FACTOR
YES
NO
SEND OWN FACTOR VIA SIGNAL ON TRANSMISSION LINES
SEND EXTERNAL FACTOR VIA SIGNAL ON TRANSMISSION LINES

FIG 4


LOAD INCREASES ABOVE PRE-DETERMINED MAXIMUM
CONTROLLER SENDS "DISTRESS" FACTOR
LOAD SWITCHING UNITS RANDOMLY SWITCH OFF ATTACHED LOADS
LOAD REDUCES
CONTROLLER SENDS REDUCED "DISTRESS" FACTOR
LOAD SWITCHING UNITS SWITCH ON LOADS AFTER DELAY PERIOD

5

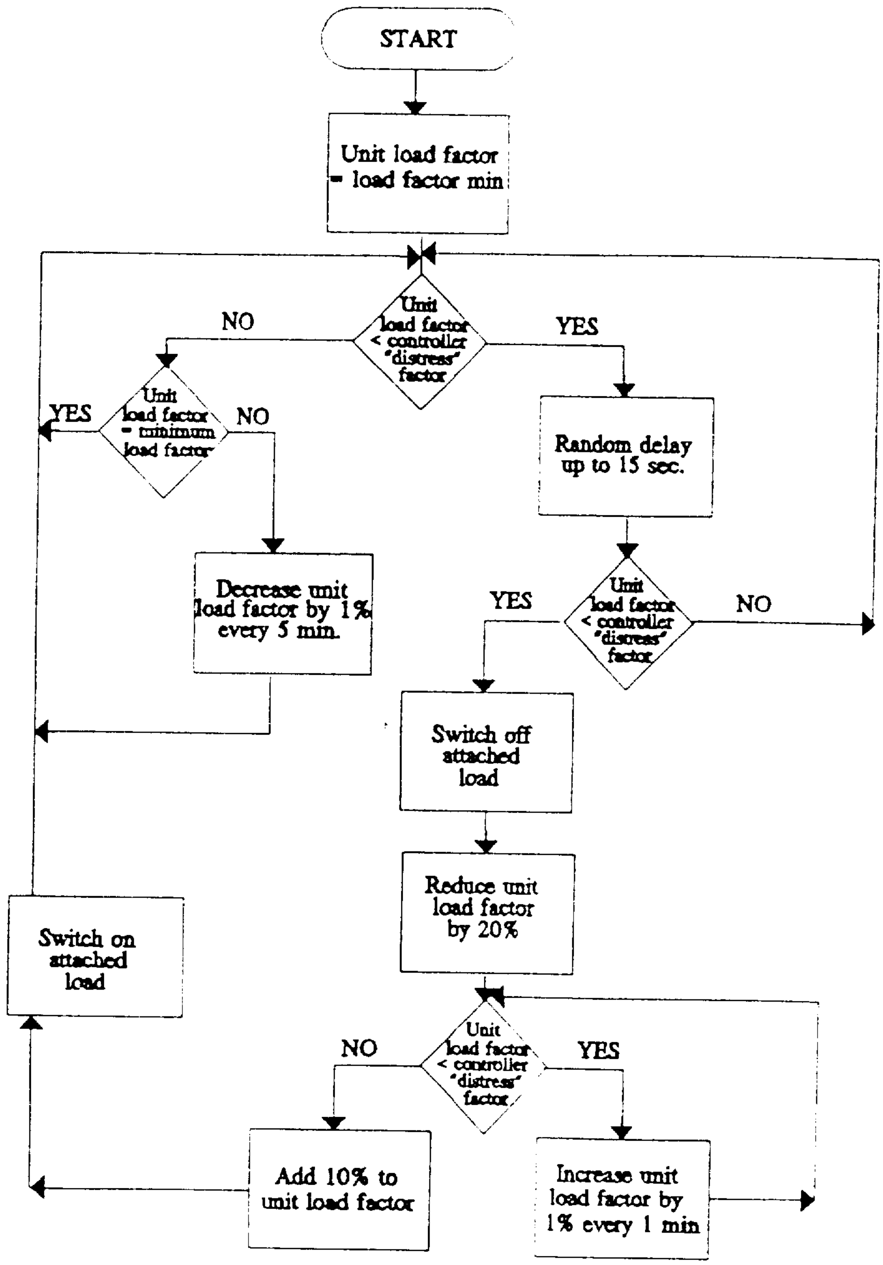

START
Unit load factor
= load factor min
Unit load factor < controller "distress" factor
NO
YES
Unit load factor = minimum load factor
YES
NO
Random delay up to 15 sec.
Decrease unit load factor by 1% every 5 min.
Unit load factor < controller "distress" factor
YES
NO
Switch off attached load
Reduce unit load factor by 20%
Switch on attached load
Unit load factor < controller "distress" factor
NO
YES
Add 10% to unit load factor
Increase unit load factor by 1% every 1 min

FIG 6

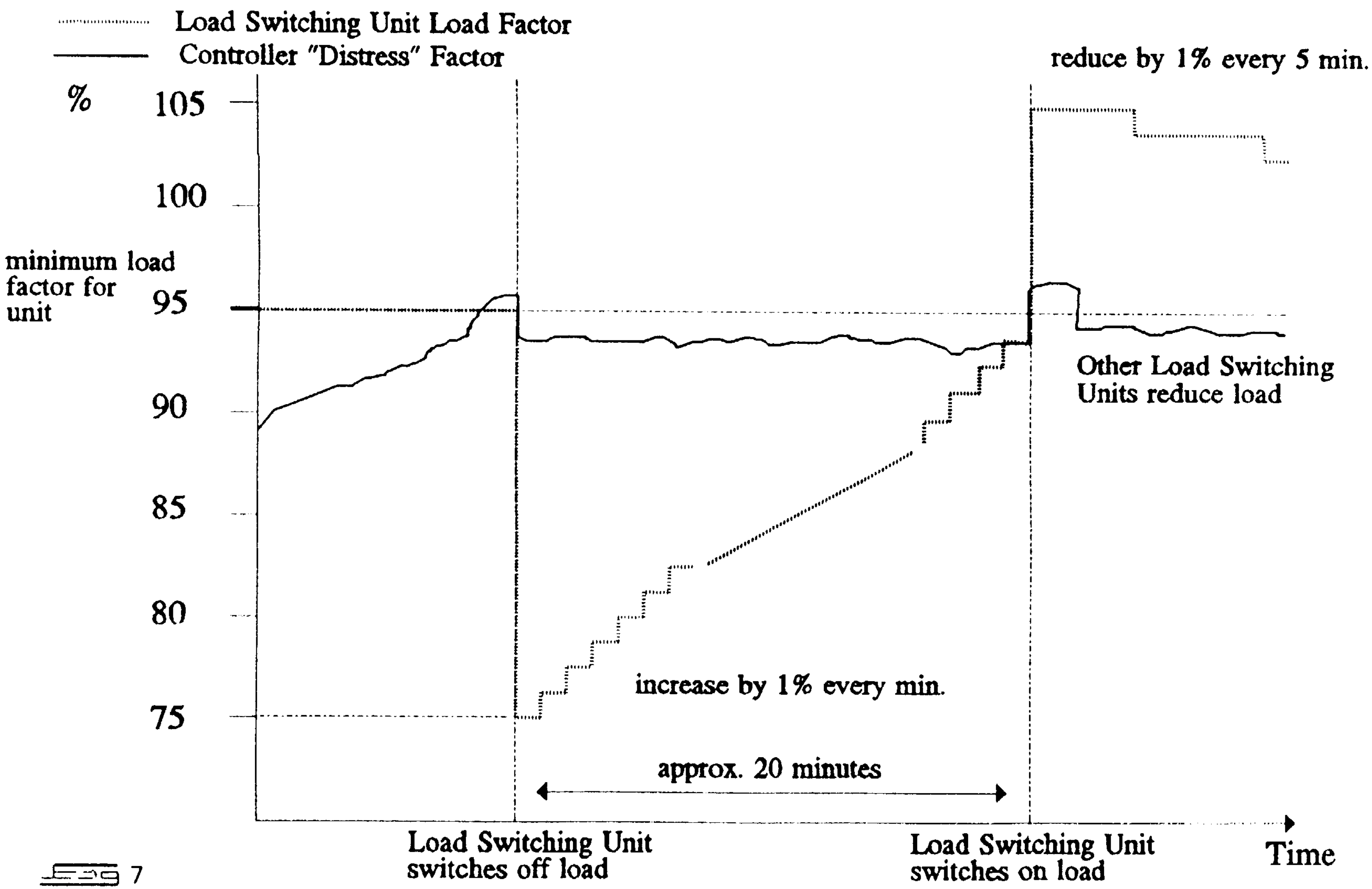

Load Switching Unit Load Factor
Controller "Distress" Factor
%
105
100
minimum load factor for unit
95
90
85
80
75
reduce by 1% every 5 min.
Other Load Switching Units reduce load
increase by 1% every min.
approx. 20 minutes
Load Switching Unit switches off load
Load Switching Unit switches on load
Time

Fig. 7