United States Patent

Huang

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[45] **Oct. 10, 1972**

[54] VOLTAGE REGULATING CIRCUIT

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[73] Assignee: **The United States of America as represented by the Secretary of the Navy**

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[21] Appl. No.: **97,861**

[52] **U.S. Cl.**.....**321/10,** 323/17, 323/DIG. 1

[51] **Int. Cl.**.....**H02m 1/14,** H02m 7/12

[58] **Field of Search**.....323/17, DIG. 1, 22 SC, 22 T, 323/93; 321/20, 27, 10, 18; 307/23, 45, 64

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Attorney—Richard S. Sciascia, Howard J. Murray, Jr. and Q. Baxter Warner

[57] **ABSTRACT**

An arrangement for desensitizing dc power supplies to momentary ac power interruptions by incorporating therein an energy-storage network which is charged rapidly to its peak capacity, and then remains on "-stand-by" status until an ac power loss occurs. It then supplements the output of the conventional capacitor to maintain steady dc power for a longer period of time than would be otherwise possible.

3 Claims, 13 Drawing Figures

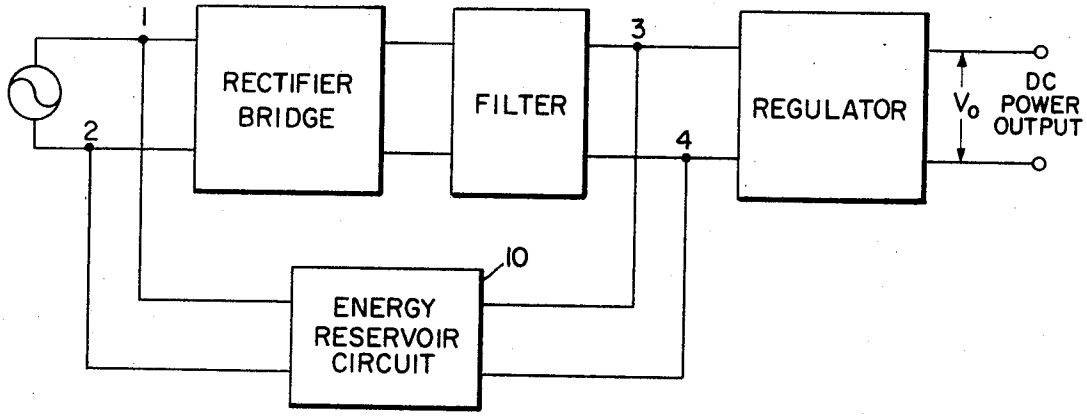


Fig. 1a

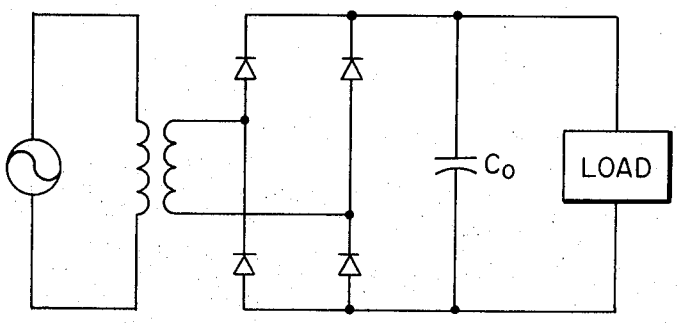


Fig. 1b

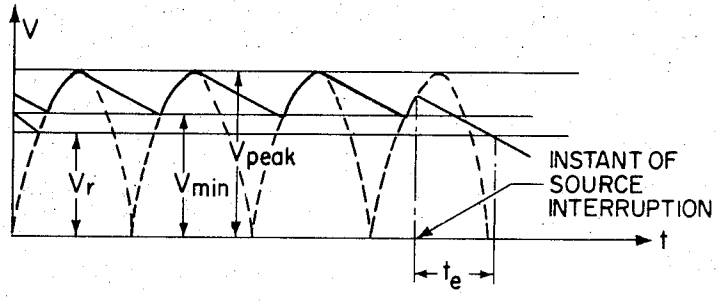


Fig. 1c

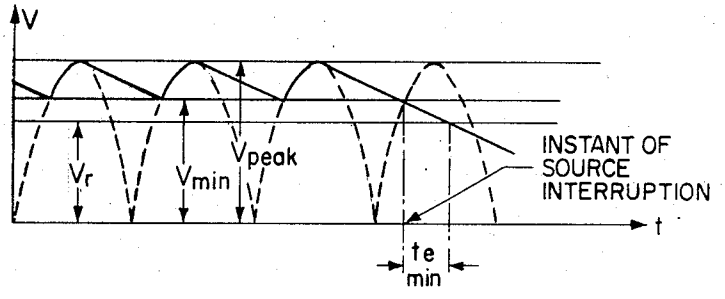
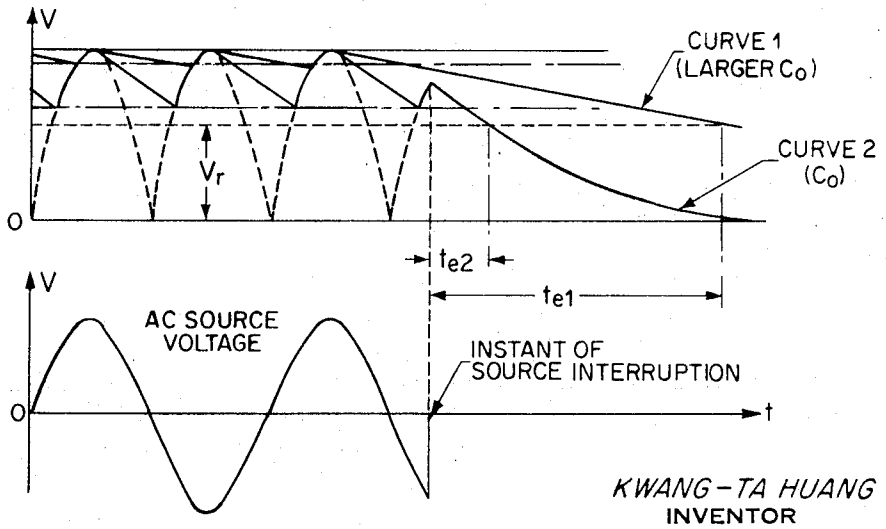
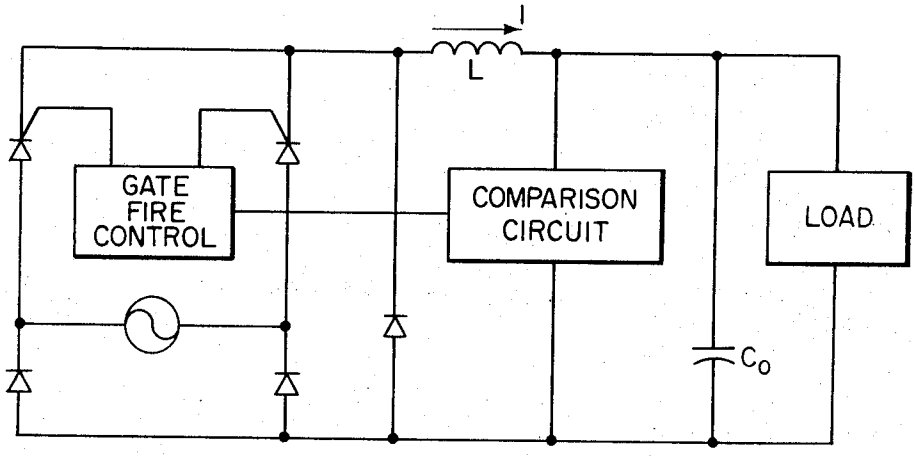


Fig. 2



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PRIOR ART

Fig. 3a

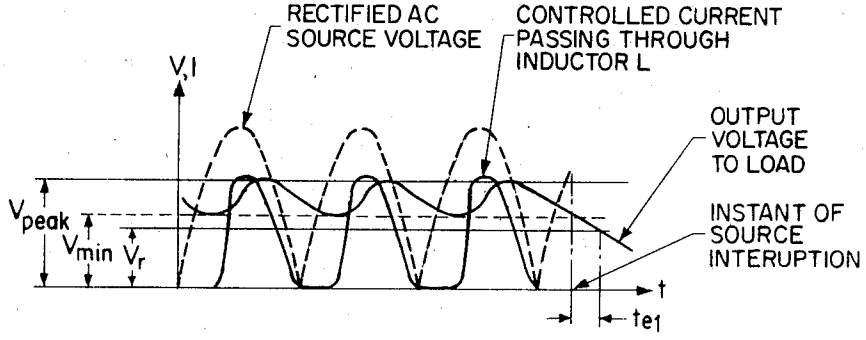


Fig. 3b

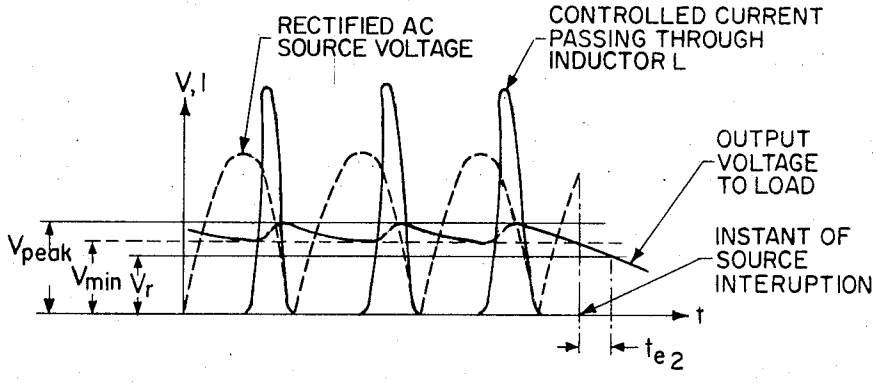


Fig. 3c

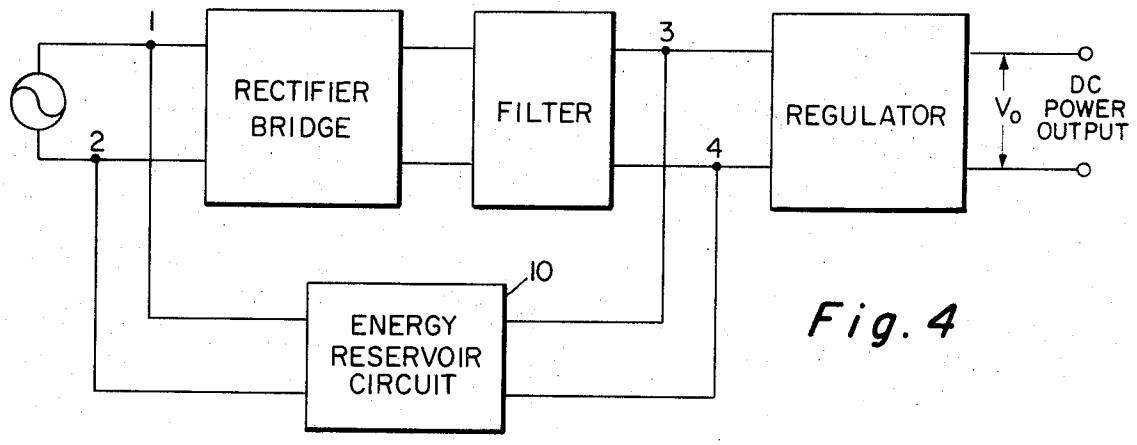

1
2
RECTIFIER BRIDGE
FILTER
3
4
REGULATOR
V_o
DC POWER OUTPUT
10
ENERGY RESERVOIR CIRCUIT

Fig. 4

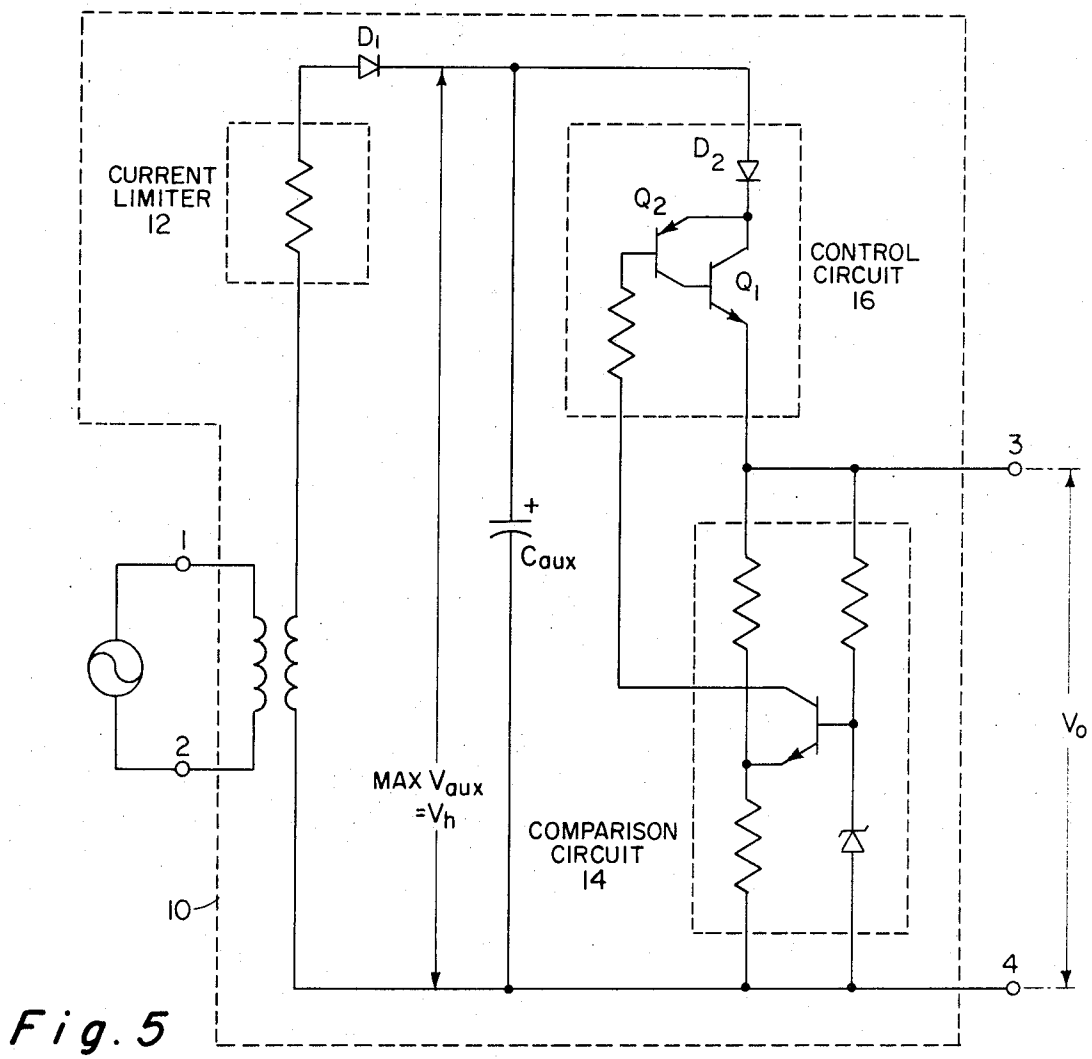

D_1
CURRENT LIMITER 12
D_2
Q_2
Q_1
CONTROL CIRCUIT 16
3
+
C_{aux}
1
2
MAX V_{aux} $=V_h$
COMPARISON CIRCUIT 14
V_o
10
4

Fig. 5

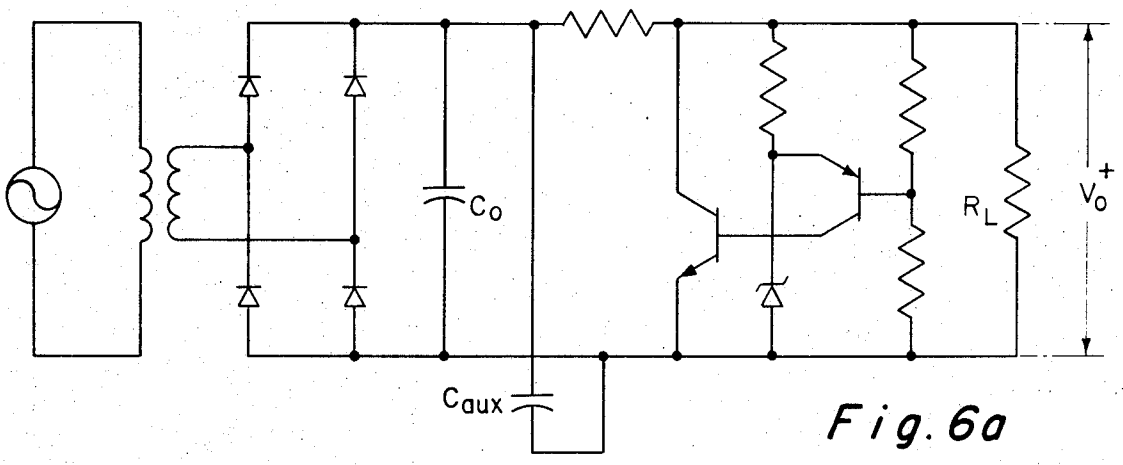


Fig. 6a

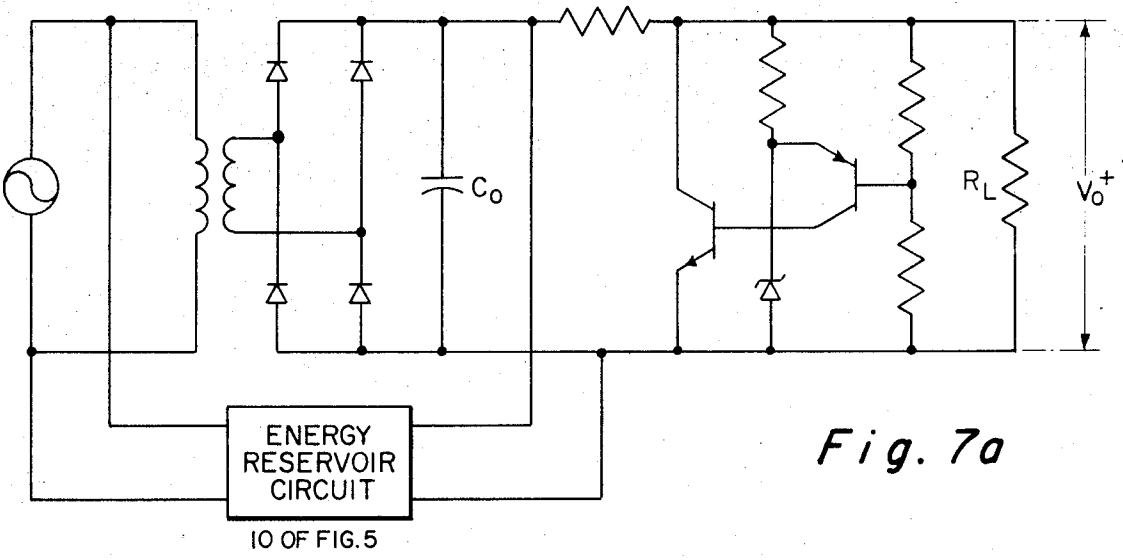


Fig. 7a

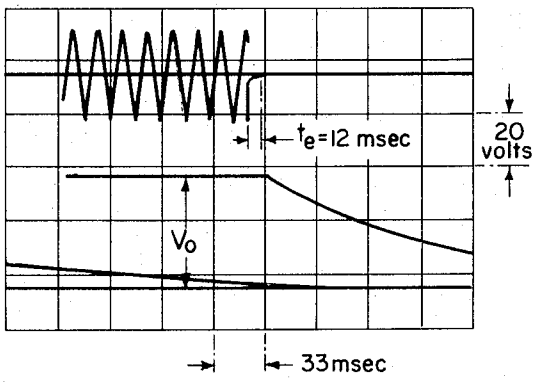


Fig. 6b

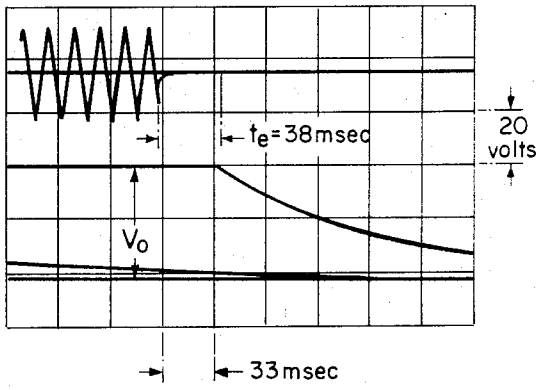


Fig. 7b

VOLTAGE REGULATING CIRCUIT

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

The rudimentary function of a dc power supply is to receive energy from an ac source, store that energy, and then release it as required by the load. If the ac source fails abruptly, the dc output will drop—not suddenly, but exponentially—as the quantity of stored energy is gradually siphoned by the load. The time that it takes for the energy to deplete obviously depends on the size of the capacitor storing the energy, the amount consumed by the load, and the minimum voltage required by the load.

It is not unusual for momentary ac power disruptions to occur—as they might during a lightning storm or during frequency adjustments at the power station. If the disruption is brief enough, the stored energy in the power supply may be ample to smooth over any effect on the dc voltage to the load. When the power supply incorporates a basic bridge rectifier-capacitor circuit, it is possible to improve dc output stability in the event of an ac disruption by increasing the size of the output capacitor. This expedient is not practicable, however, for more sophisticated dc power supplies, such as those that make use of variable-phase-angle-firing SCRs.

SUMMARY OF THE INVENTION

At the present time, dc power supplies generally are not designed to maintain continuous and steady voltages during momentary disturbances in their ac power-transmission-supply line. Yet, during lightning storms, or through some line fault, electrical disturbances can occur within transmission lines that tend to depress dc power-supply voltages. There are known methods for desensitizing the dc power supplies to these ac disturbances. One way—if the power supply does not make use of SCRs—is to use larger capacitors in the rectifier circuit. However, this is often unfeasible economically. The present concept makes use of an auxiliary energy-reservoir network for sustaining the output power for relatively long periods even when SCRs are employed.

STATEMENT OF THE OBJECTS OF THE INVENTION

One object of the present invention, therefore, is to provide a dc power supply network having decreased sensitivity to momentary interruptions in the ac source.

Another object of the invention is to provide a dc power supply having an auxiliary energy-reservoir network incorporated therein.

A further object of the invention is to provide means for sustaining output power from a dc supply circuit which includes SCRs therein.

An additional object of the invention is to eliminate the need for utilizing excessively large capacitors in order to maintain output power from a dc supply circuit in the face of momentary disturbances in the ac input thereto.

Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 (A) is a schematic circuit diagram of a basic dc power supply network as now known in the art;

FIGS. 1 (B) and (C) are graphs useful in explaining the operation of the network of FIGS. 1 (A);

FIG. 2 is a graph illustrating the effect of using a larger-valued capacitor in the network of FIG. 1 (A);

FIG. 3 (A) is a schematic circuit diagram of a conventional dc power supply network using SCRs;

FIGS. 3 (B) and (C) are graphs useful in explaining the operation of the network of FIG. 3 (A);

FIG. 4 is a block diagram of a dc power supply network designed in accordance with a preferred embodiment of the present invention;

FIG. 5 is a schematic diagram of the energy reservoir network of FIG. 4;

FIG. 6 (A) is a schematic circuit diagram of a conventional dc power supply network modified to add an auxiliary capacitor;

FIG. 7 (A) is similar to the circuit of FIG. 6 (A) but with the invention energy-reservoir network in place of the auxiliary capacitor; and

FIGS. 6 (B) and 7 (B) are graphs useful in explaining the operation of the networks of FIGS. 6 (A) and 7 (A), respectively.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A bridge rectifier and a capacitor connected as shown in FIG. 1 form the conventional configuration for converting ac voltage to dc voltage. The energy-storing capacitor, C_o, stores and supplies energy to the load. If the ac source is interrupted, the dc output voltage decays exponentially to zero. To illustrate, choose an arbitrary voltage, V_r, as the minimum value required to maintain load operation. The time, t_e [FIG. 1(B)], is the duration between the instant that ac power is lost and the instant that the dc output voltage reaches V_r. The useful charge, Q_u, on capacitor C_o that extends t_e is given by

$$Q_u = C_o (V_{inst} - V_r) \qquad 1.$$

where V_{inst} is the instantaneous voltage across capacitor C_o at the time the ac source is interrupted. The time duration, t_e, is given by

$$t_e = \frac{Q_u}{I_{dc}} = \frac{C_o (V_{inst} - V_r)}{I_{dc}} \qquad (2)$$

where I_{dc} is the dc load current. The shortest t_e results if the ac source is interrupted when the instantaneous voltage across capacitor C_o is V_{min} [FIG. 1(C)]; than Eq. (2) becomes

$$t_{emin} = \frac{C_o (V_{min} - V_r)}{I_{dc}} \qquad (3)$$

Equation (3) shows that when I_{dc} is fixed, t_{emin} is extended by increasing C_o. Although increasing C_o also raises V_{min} and, therefore, the quantity $V_{min} - V_r$, the increase in C_o is dominant in increasing Q_u, hence, t_{emin}.

FIG. 2 shows the increase in e obtained by using a larger C_o. Curve 1 is for the large-valued capacitor C_o.

Even though a simple method of extending t_e is to increase C_o there are factors that limit the size of the energy-storing capacitance.

When selecting a larger-valued capacitance, it becomes necessary to examine the rise in rectifier cost against the extension of t_e obtained. Also, with increasing capacitance, the ratio of initial turn-on current to rated load current increases. This necessitates operation of larger rectifiers at increasingly derated condition, which is inefficient. Also, a larger-valued capacitance increases the response time of the dc power supply thereby lengthening the flow duration of the turn-on current. Longer flow duration contributes to rectifier failure from heating.

FIG. 3 (A) is a circuit diagram of a basic silicon controlled rectifier (SCR) dc power supply. The dc output voltage level is controlled by the "variable-phase-angle-firing" technique, which provides a partial full-wave rectified waveform and requires a very large capacitance to obtain a "smoothed-out", limited-ripple waveform; therefore, unlike the transistor-regulated dc supply circuit, the SCR circuit is not amenable to significant increase in t_e by the mere increase of capacitance. This fact is displayed in FIG. 3 (B) which illustrates the limited-ripple voltage obtained by using a (large) capacitor, C_o. It also shows the extended duration t_{el} obtained with the loss of the ac power source. Increasing the capacitance reduces the ripple, as shown in FIG. 3 (C), but $V_{min} - V_r$ is essentially unchanged and duration t_{e2} increases slightly. The limitations on extending t_e in a basic dc power-supply circuit are therefore more severe in a power circuit using SCRs instead of transistors.

With either circuit, however, it is possible to supplement the Q_u available in the basic power-supply circuit—and thus t_e—with an energy-reservoir circuit, designed in accordance with the principles of the present invention. One preferred embodiment is illustrated in FIGS. 4 and 5 of the drawings.

The basic principle of this circuit is to charge an energy-storing capacitor at a high voltage and release this energy to the load during momentary ac power loss. The energy storing C_{aux} is charged rapidly to its peak capacity during normal operations of the ac power source. The reservoir circuit 10 of FIGS. 4 and 5 remains on standby status and consumes very little power. At the instant of ac power loss, the reservoir circuit 10 supplies Q_{aux} to supplement Q_u and maintain V_o throughout the outage. The capacitance C_{aux} can be calculated by modifying Eq. (3):

$$C_{aux} = \frac{I_{dc}(t_e - t_{mi})}{(V_h - V_r)} \quad (4)$$

where t_{mi} is the extended duration of dc voltage without insertion of the energy reservoir circuit; and V_h is the peak value to which C_{aux} can be charged.

The current limiter 12 in the auxiliary circuit is used to (1) prevent damage to the rectifier D_1 by the initial charging current and (2) protect the active elements in the control circuit from the high current from the rectifier transformer during a malfunction of dc power supply.

During the initial charging, the voltage of C_{aux} usually is lower than the output voltage, V_o. Rectifier D_2 is used to prevent damage to transistors Q_1 and Q_2 from the current flowing from point 3. The voltage difference, $(V_h - V_r)$, determines the selection of the maximum rating of V_{ce}, the voltage of the power transistor Q_1. The comparison circuit 14 is present to sense the voltage drop and to furnish the actual signal to operate the control circuit 16. The sensing voltage should be adjusted in such a position that the energy-reservoir circuit 10 remains on standby status in normal operation. The control circuit 16 adjusts the flow rate of Q_{aux} as required by the load to maintain the output voltage V_o.

The energy-reservoir circuit is connected to the basic power supply as shown in FIG. 4. The reservoir circuit 10 offers considerable latitude in the selection of the value of the energy-storing capacitance and the operating voltage. This flexibility is not offered in the basic dc power-supply circuit because the required output voltage fixes the voltage across the energy-storing capacitor, C_o; the method of obtaining the larger Q_u is limited to increasing C_o and a larger C_o is accompanied by undesirable effects, such as excessive inrushing of turn-on current.

The power ratings of the components in the reservoir circuit 16 can be modest because the average power is low, although the peak energy delivered momentarily may be appreciable. The auxiliary reservoir circuit, even with the use of a large energy-storing capacitor C_{aux}, does not reduce the response time of the basic power supply because the one is independent of the other.

FIGS. 6 and 7 illustrate the advantages obtainable by utilizing a network embodying the principles of the present invention. Simply adding a capacitor C_{aux} as in FIG. 6 (A) extends the dc output level by 12 msec (FIG. 6 (B)). However, utilizing the energy-reservoir network 10 of FIGS. 4 and 5 in the circuit of FIG. 7 (A) extends the dc output level to 38 msec (FIG. 7 (B)), using the same value of capacitor. This is an increase of over 200% as compared to the conventional technique of FIG. 6 (A).

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

I claim:

1. An energy reservoir circuit for desensitizing a d.c. power supply to momentary a.c. power interruptions comprising:

a charge storing network connected in parallel with the main rectifying and filtering network of a d.c. power supply, and storing network comprising;

a transformer;

a current limiter connected in series with the secondary of said transformer;

a rectifier connected in series with said current limiter;

a capacitor connected in parallel with the transformer secondary, current limiter and rectifier;

discharge rate controlling means connected in series with said capacitor; and

actuating means connected to said discharge rate controlling means.

2. A circuit as recited in claim 1 wherein said discharge rate controlling means comprises a power transistor in series with a protective diode.

3. A circuit as recited in claim 2 wherein said actuating means is comprised of a comparison circuit connected across the output of the energy reservoir for sensing a voltage drop in the output from the main rectifying and filtering network of a d.c. power supply.

* * * * *