ONTARIO HYDRO
RESEARCH DIVISION REPORT

To Mr. J.R. Leslie
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EVALUATION OF CIRCUIT FOR THE CONTROL OF CURRENT TRANSFORMER SATURATION

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Discussed in this report is an active electronic circuit which is designed to reduce or eliminate the saturation of relaying CTs during transient fault conditions.

Circuit Principles

The proposed circuit in its simplest configuration consists of an auxiliary burden R_2, switches S_1 and S_2 in series with diodes D_1 and D_2, and a control circuit as shown in Figure 1.

During normal operation switches S_1 and S_2 are closed, which effectively shorts out the auxiliary burden except for the diode drops (0.7 V) which add less than 5 VA at 5 A, or about 100 VA at 100 A secondary current. If the control circuit detects a dc transient component on the output of the current transformer it opens the appropriate relay, which inserts the auxiliary burden during the appropriate half cycle. The result is that a net dc voltage appears at the terminal of the secondary winding which has the effect of cancelling or neutralizing the effect of the dc transient component. The above operation is shown in Figure 2, where the flux in the CT core (b) is prevented from reaching saturation by the "demagnetizing action" of the auxiliary burden during the negative half cycles of the current.

Practical Circuit

A reported version of the control circuit appears in Figure 3. Here a thyristor (CR) is used in conjunction with a diode bridge (D_3-D_6) to perform the current switching operation. The thyristor is used to short out the additional burden, R_2, with the steering provided by means of switches (S_1, S_2) and diodes (D_1, D_2).

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Sensing of the dc component on the output of the CT is accomplished by means of an integrator (R_3, C_1). Electronic circuitry (E) performs level detection and supplies the necessary drive to relay coils (L_1, L_2) which actuate switches (S_1, S_2).

Power to the electronic circuitry is drawn from the secondary circuit of the CT by means of an isolating transformer (T) and suitable rectifiers and regulators (P).

Discussion

The circuitry described above can be used on new, or retro-fitted to existing current transformers. Since the circuitry senses an approximate integral of the output waveform, and not the actual flux in the core of the current transformer, it would be most effective when used in conjunction with low remanence core CTs. A remanence factor, of approximately four, should be applied when the circuit is used with closed core CTs to take account of remanence.

The circuit is not capable of preventing the saturation of CTs which occur during the first half-cycle of fault current. The CT must therefore be properly sized for fault current, burden, and system time constant so that it does not saturate during the first half-cycle of fault current.

The ratio of the auxiliary burden (R_2) to the normal burden (R_1) determines the demagnetizing action. For optimum performance, this ratio should be related to the system time constant (or X/R ratio). The longer the time constant, the larger the R_2/R_1 ratio is required for optimum performance.

The advantages of the circuit depend on the system time constant. The longer the system time constant the more effective and more useful the circuit becomes. The table below lists approximate over-dimensioning factors that are required for faithful reproduction of fault current with full offset.

System Time Constant (ms)	Approximate Overdimensioning Factor		
	Closed Core CT	Low Remanence CT	Low Remanence with Control
20	32	8	5 (7)
40	60	15	6 (10)
60	84	21	6 (11)
80	104	26	6 (12)
100	124	31	6 (12)

The values above assume a CT time constant of one second and an optimum R_2/R_1 value for the saturation control circuit. Since this optimum cannot be assured, the overdimensioning factor should be increased to the values shown in parenthésis, approximately.

The values in the above Table indicate that there is very little advantage of using the control circuitry if the system time constant is 20 ms or shorter, approximately. There appears to be a sizeable reduction in CT size for instances where the system time constant is 100 ms or longer. The control circuit is of great value where the CTs are not allowed to saturate and where a faithful reproduction of the primary current is required.

The reliability of the saturation control circuit is most important. It is also difficult to establish without a knowledge of the exact components used in its construction. It could be assumed that the circuit can fail in either the open or shorted mode. In the open mode the high auxiliary burden would be in the circuit continuously. This would severely detract from the performance of the CT under fault condition. In the shorted mode, the circuit is basically out of commission and the CT would therefore function as a normal unit.

It should be remembered that the addition of the control circuit to an existing installation increases the burden on the CT. This increase is not linear with current because of the diode and thyristor characteristics. At normal operating current of 5 A, the additional burden is expected to be about 1 ohm. At fault currents above ten times rated current the burden reduces to 0.1 ohm or even less.

Conclusion

The proposed circuit for controlling the saturation of current transformers is of value when accurate transformation of fault currents is important. Since such transformation is most difficult to obtain on systems with long time constants using conventional transformers, the use of the proposed circuit will probably result in savings under the above conditions.

There appears to be very little to be gained by the use of the proposed circuit for protection schemes that can accept CTs that will saturate after one or two cycles of good performance, or for use on systems with short time constants ($\leq$20 ms).

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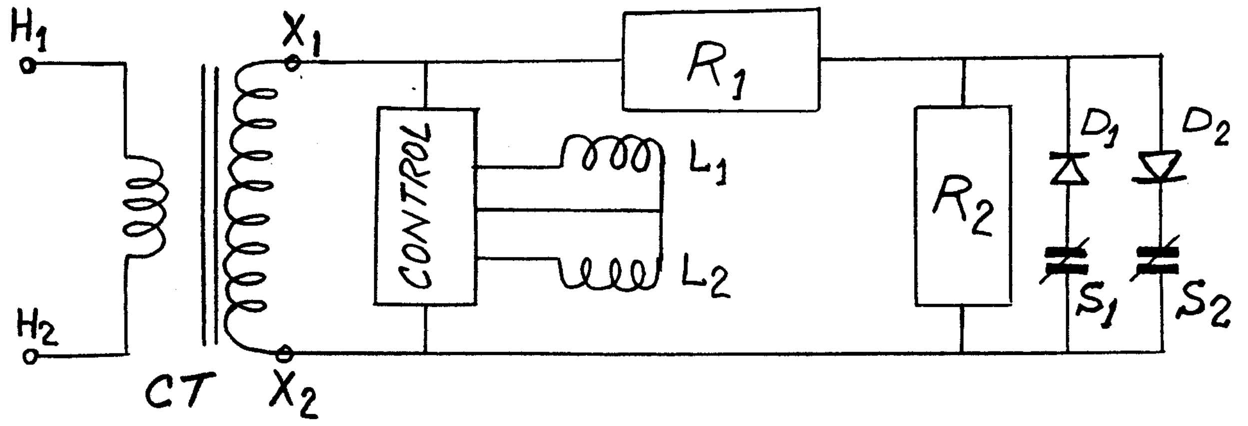

FIGURE 1

SIMPLIFIED CONFIGURATION OF
CONTROL CIRCUIT

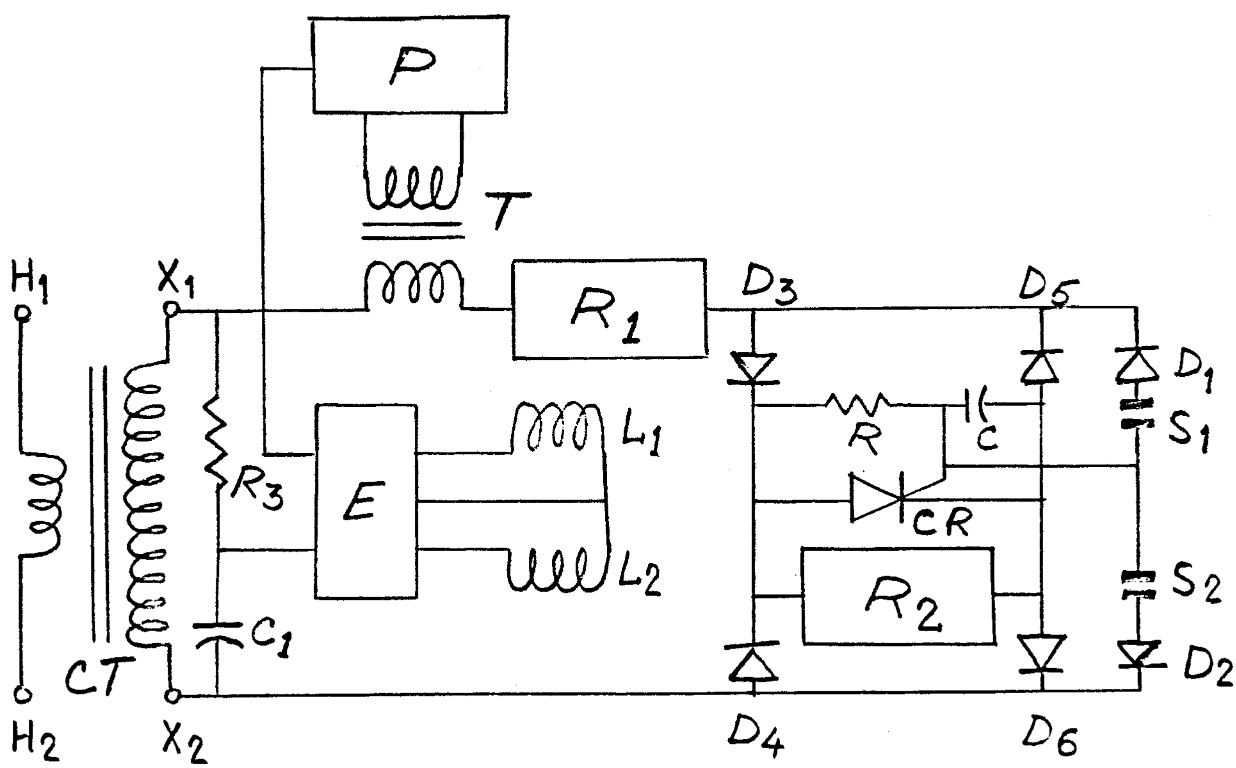

FIGURE 3

PRACTICAL CONFIGURATION OF
CONTROL CIRCUIT

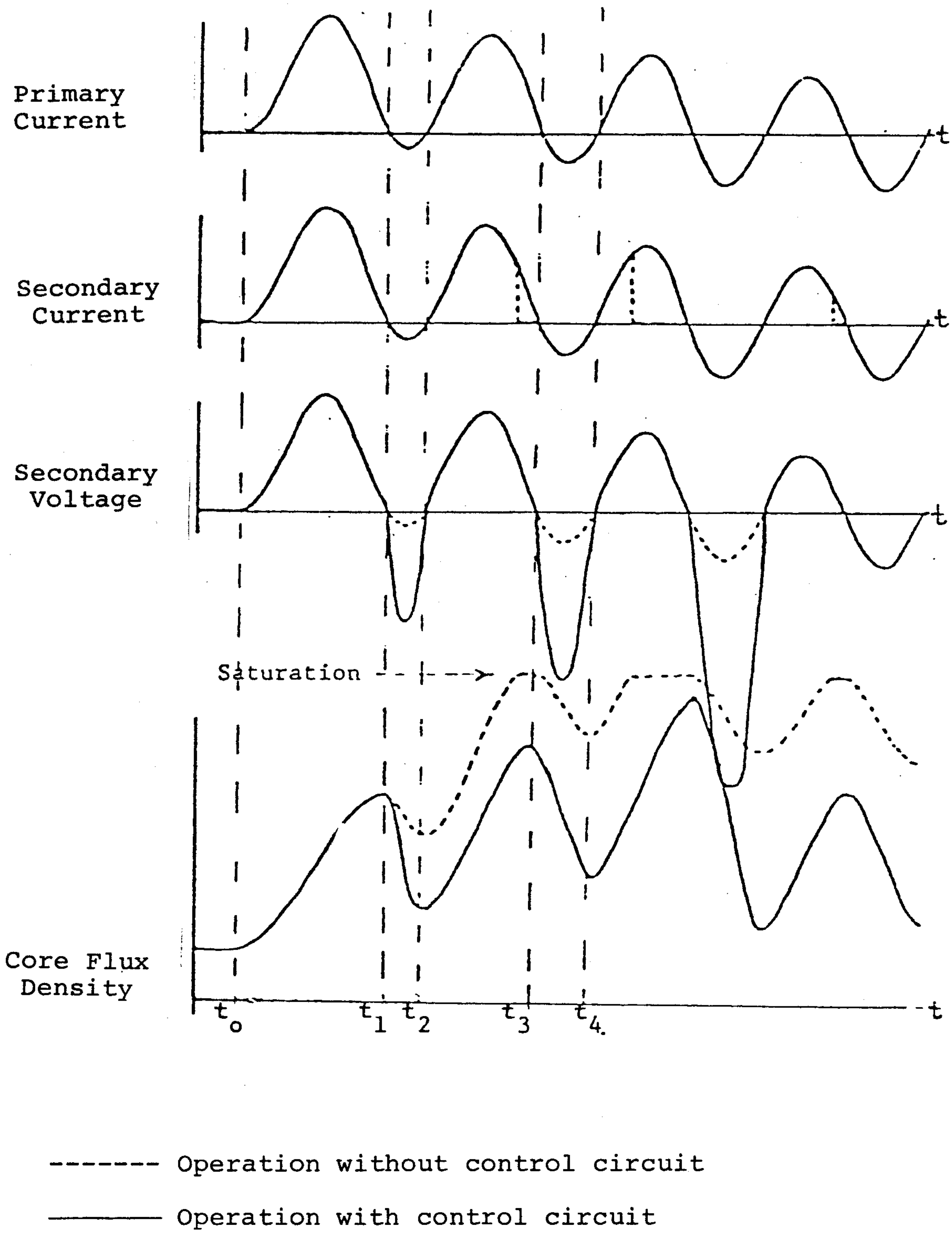

FIGURE 2

OPERATION OF SATURATION
CONTROL CIRCUIT