SATURATING REACTORS FOR CONTROL PURPOSES

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A universal complaint among users of automatic machinery is of the delays caused by maintenance work on switches. The trouble does not seem to be with particular switches but rather is inherent in the fundamental nature of the circuit breaking process. That is, opening a circuit must always produce more or less destructive arcing, and reclosing that circuit requires that foreign matter be absent from the contacting surfaces. True, many ingenuous ways have been found to mitigate these evils. Still, the machine builder wants something better for especially difficult applications. Our company decided to see if the essence of the switch could be replaced with something with more stamina.

We asked ourselves, how can we practically stop and start the flow of a current while leaving all connections intact. The physicist has some ready answers if we neglect the word "practical." He thinks immediately of electron tubes, resonant circuits, sliding iron core reactors, and reactors with variable D.C. saturating windings. We thought of all these but soon had to quit ignoring the catchword "practical." This word is all-important to the machine builder. Much as it hurts some of us to snub a lovable friend, electron tubes must, at least for the present, be ruled out of the general machine control field. The maintenance problem there seems to be worse than for switches. At any rate our customers think so and, commercially speaking, that settles that until such time as the customer's mind is changed.

Resonant circuits, in the ordinary sense, require much too bulky equipment to be practical at commercial frequencies and the provision of high frequency control power does not appeal if some other answer can be found. The non-linear or ferroresonant circuits have definitely appealing characteristics for the present purpose. We have done some experimental work with these circuits and propose to do more.

However, it is with variable inductance circuits that we have had our greatest success to date and it is to those that we now turn our attention. As is well known to those present, an alternating current can readily be varied between wide limits if an iron cored coil is included in the circuit and if that iron core is either moved in and out of the coil or if a variable direct current is sent through another winding on the core partially to saturate it. However, this way of varying the main current yields a proportional variation. That is, the A.C. varies gradually with the displacement of the core or the change in the D.C. saturation. Clearly this is not strictly comparable to switching where the current changes almost instantly from zero to maximum or vice versa.

Early in our investigation, I became acquainted with some discoveries of Mr. Alan S. FitzGerald,[1] a consulting electrical research engineer with laboratories at Haverford College. In his experiments with saturable core reactors, Mr. FitzGerald found that remarkable results could be obtained by adding another D.C. coil to the usual saturable core reactor. This new coil is connected in series with the A.C. winding but with an intervening full-wave rectifier so that the full main current flowed through the A.C. winding as A.C. and through the auxiliary winding as D.C.

This circuit has many properties interesting to physicists but for our purpose we shall discuss only those pertinent to problems of machinery control. It is found that a gradual variation of the regular saturating direct current will leave the main alternating current almost entirely unchanged until a critical value of D.C. is reached whereupon an abrupt and a very substantial change occurs in the main current. This effect is illustrated in fig. 1 where the load of alternating current is plotted as ordinates where the control or direct current is plotted as abscissae. For our purpose it is better to

[1] FitzGerald, Alan S., U. S. Patent No. 2,027,312.

replace the regular D.C. winding by two windings. By putting a constant D.C. through one of these, a normal working point or bias is established. Then the on and off may be effected by relatively slight variations in the D.C. through the third D.C. coil. Obviously, polarity effects are possible depending upon the value of the bias. For example, if the bias has the value I_7, then an additive increase in the other control current will reduce the A.C.

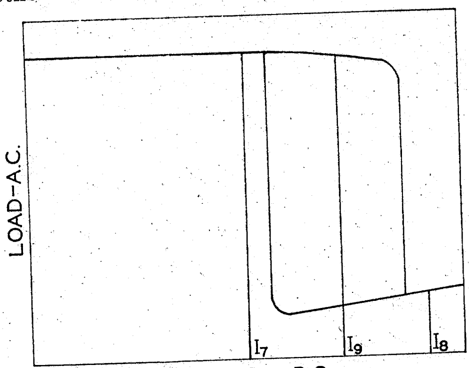

Fig. 1

If it is desired to have an increasing control current to increase the A.C., then the bias is set at I_8 and the control flux made to oppose the bias flux. Further the bias may be set at I_9 and the on and off function is accomplished by reversing polarity of the control current.

For specific application to machine operation, the D.C. is made to vary in response to motion of a machine member. Thus, the value of the D.C. is a function of that member's position and the A.C. will change abruptly when the pre-determined position is reached, just as though the machine member had mechanically tripped a snap switch. Someone will probably object at this time that D.C. is easily varied only by means of a wire wound rheostat so that the hated contact has reappeared as the slider on that rheostat. Thus we have chosen an elaborate path to get nowhere. This objection is met by using rectified A.C. as the control and varying this by means of an induction regulator or a simple sliding core reactor. The latter was not acceptable for direct control because of its proportional variation but it will do nicely in conjunction with the new circuit which has the discontinuous feature. Furthermore, the control reactor can be quite small because the circuit we have described is inherently an amplifier. That is, a given input power can be made to control a vastly greater output power as power amplification of 200 times is easily attained with one circuit while cascade connections can be made to develop amplification factors in the millions. Thus photocells can be made to control loads of several watts.

The apparatus is obviously extremely rugged and easy to build. We have only coils wound on iron cores and dry disk rectifiers. Such coils have proven themselves beyond all question as transformers and chokes. Dry disk rectifiers have given excellent accounts of themselves where they are applied with due regard for their potential and current limits. There are absolutely no moving parts beyond the original control inductor and that can be made rugged and free of all triggers and springs that give trouble in snap switches. The cost on a production basis has not been tried but careful estimates appear very satisfactory.

There is only one feature that we have found troublesome. While the load current changes abruptly and consistently when the critical control current is reached, it does not do so instantaneously. There is a definite time lag, which may be reduced by lowering the amplification but it cannot be eliminated. In some cases this is an objection although it is unimportant in many applications. The theory of this interesting circuit has not been fully explored. We have been too busy trying to put it to work. Essentially it seems to be something in the nature of a feedback effect. That is, the series D.C. flux conspires with the control flux to cause the action. The sudden change is related to the knee of the magnetization curve; that is, where the core begins to saturate.