

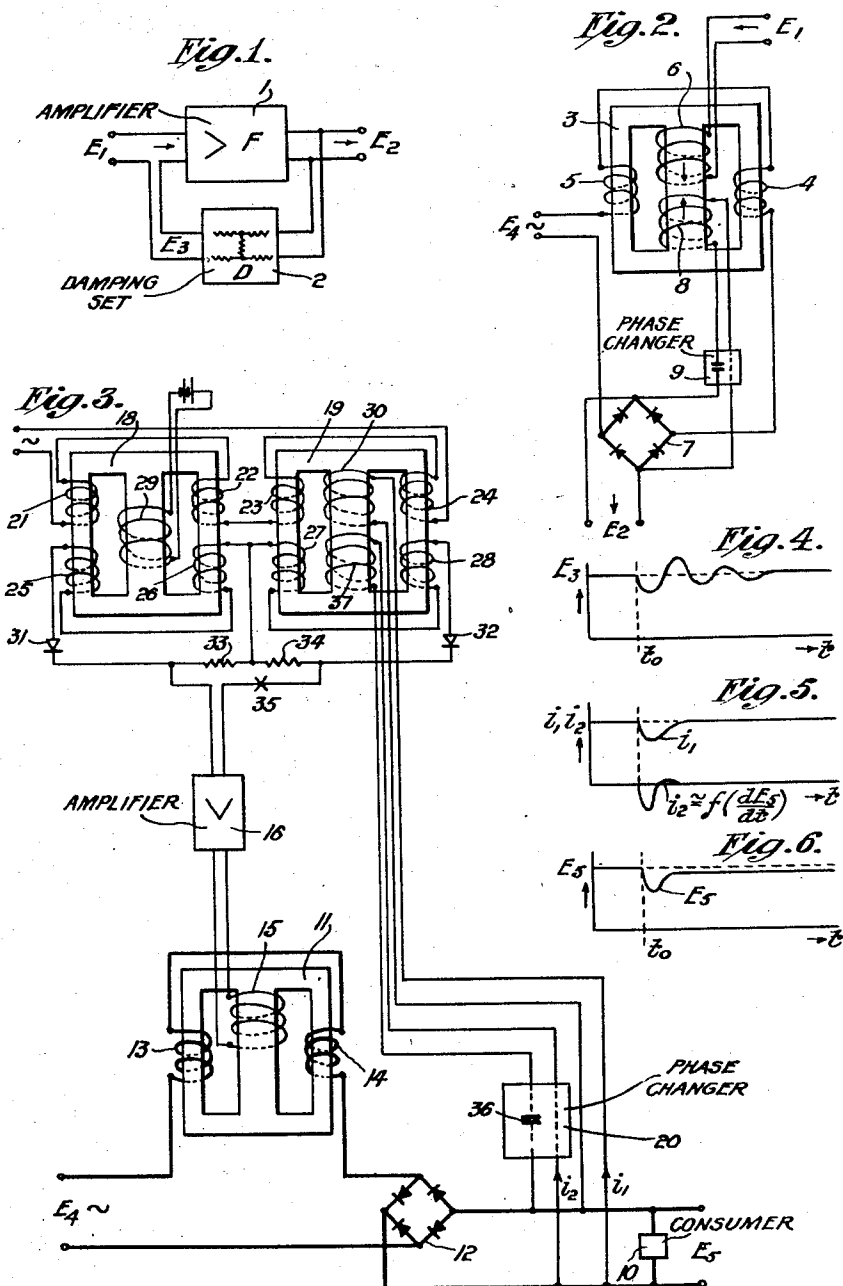
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ELECTRIC ENERGY CONTROL SYSTEM

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ELECTRIC ENERGY CONTROL SYSTEM

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The present invention relates to such coupling arrangements whose current or voltage regulation is effected at least partially by means of direct current magnetized reactors or transformers.

Coupling systems of this kind have found considerable use as amplifiers. In certain cases, use has been made of them to amplify a weak electrical impulse, e. g. from a photocell to a relatively high strength, so as to make it possible to set a relay in operation. In other cases, the amplification has been utilized in control devices in order to control and maintain a certain current or voltage within certain limits, e. g. for maintaining a network or battery voltage substantially constant.

However, arrangements of the indicated kind have thus far had certain drawbacks. On account of the known inertia in the operation of reactors, slight oscillations occur in the control devices for keeping the current or voltage constant. In magnetic amplifiers in general, further variations occur due to the sensitivity varying with different working fields or different loads. In other words, the working characteristics of the reactors are not quite linear. Some of the coupling elements which form part of a coupling arrangement according to this invention e. g. rectifiers, are subject to aging, to alterations and deteriorations in the course of prolonged operation.

One object of the invention is to eliminate these drawbacks.

A further object of the invention is to improve amplifiers and control devices which use reactors and in which a control effect in the form of a varying direct current is supplied to the reactors.

Another object of the invention, is to supply the reactors with an additional control effect that counteracts the normal control effect, at least within certain time periods. This may be achieved preferably by means of one or more phase changing elements.

Still another object of the invention is to provide a negative feed-back coupling to obtain quick-acting regulation and to improve the electrical properties of the amplifiers or control devices.

The invention is explained with reference to the appended drawings:

Fig. 1 is a block circuit diagram of an amplifier of the so-called four pole type and with negative feed-back coupling;

Fig. 2 shows a one stage amplifier with negative feed-back coupling;

Fig. 3 shows a voltage control arrangement with negative feed-back coupling and quick-acting regulation; and

Figs. 4 to 6 reproduce curves representing the

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course of the regulation in the control arrangement shown in Fig. 3.

The amplifier 1 in Fig. 1 is assumed to have an amplification F . The damping set 2 for negative feed-back coupling has a damping D . The voltage E_3 back coupled from E_2 via the damping set is assumed to be inverted, i. e. in 180° phase displacement with respect to E_1 . From this we get $(E_1 - E_3)F = E_2$ and $E_2.D = E_3$ or, if E_3 is eliminated,

$$E_2 = E_1 \frac{1}{1 - \frac{D}{F}}$$

If, for example, $F = 10^4$ and $D = 10^{-2}$, then

$$\frac{1}{DF} = 10^{-2}$$

so that the term

$$\frac{1}{DF}$$

may be neglected. The effective amplification is accordingly about

$$\frac{1}{D} = \frac{1}{10^{-2}} = 10^2$$

From this it can be seen that it is chiefly the damping set which determines the properties of the amplifier. In other words, by means of negative feed-back coupling, the amplification can be effected substantially independent of aging phenomena in the members that form part of the amplifier, and also of lack of linearity of the same, and finally of variations in the supply voltage (network voltage). Fig. 1 illustrates back coupling of the voltage. Of course the same circumstances apply to back coupling of the current or field.

Fig. 2 shows how the invention may be applied to obtain negative feed-back coupling in an amplifier stage with reactor 3. This reactor is magnetized from the alternating current voltage E_4 by means of the windings 4 and 5. The voltage E_1 which is to be amplified has changes occurring at a considerably lower frequency than E_4 and is fed to a winding on the input side of the amplifier. The amplified voltage (or effect) E_2 is tapped in the known manner on the amplifier's output side in series with the magnetizing windings 4, 5 and is rectified by the rectifier 7. A portion of the amplified and rectified energy is fed to a winding 8 which is coupled so as to counteract the winding 6, thus producing negative feed-back coupling. On account of a certain displacement in time between E_1 and E_2 , it is not possible to obtain exact counteraction between the currents in the windings 6 and 8. In the case of a single amplifier stage however, the time lag that occurs is so slight that good negative feed-back cou-

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pling can usually be obtained without employing extra measures for obtaining exact counteraction. If, on the other hand, several amplifiers are connected in cascade and negative feed-back coupling is to be provided jointly for several amplifiers, so-called phase compensation must be made use of for obtaining good or perfect negative feed-back coupling. Phase compensation can be effected in the known manner by means of capacities or coils or both of these. If phase compensation is used for a single amplifier stage, it may be obtained, for example as shown at 8 in Fig. 2, by a condenser coupled in series to the coil 8.

In Fig. 2 the effect for negative feed-back coupling to the winding 8 is tapped parallel to the output circuit at E2. The effect for the feed-back coupling winding may however be tapped just as well in series with the output circuit at E2. Furthermore, the reactor 3 may be provided with additional windings, e. g., direct current windings of the known kind.

Fig. 3 illustrates a voltage control arrangement in which the invention is adapted for maintaining the voltage as constant as possible over a consuming apparatus 10 fed from an alternating current network E4, when the output currents are of varying strength.

The feed voltage E4 is rectified by means of a rectifier 12, while the current to the output circuit is controlled by a main reactor 11. The main reactor is provided with magnetizing windings 13 and 14, a regulating winding 15, and eventually other windings in a known manner. Number 16 is an amplifier of any known type, preferably with reactors. The amplifier 16 which may be of the type shown in Fig. 2 obtains its input voltage from the reactors 18 and 19 which are magnetized with alternating current by means of the windings 21 to 24. A voltage corresponding to the voltage drop over reactor 18 is obtained from the windings 25 and 26, and this voltage is inverted in accordance with the voltage from windings 27 and 28 of reactor 19. The two inverted voltages are rectified by rectifiers 31 and 32 before being forwarded together and they are then tapped over resistances 33 and 34, the resultant from them being fed to the amplifier 16. The rectification may suitably consist of full wave rectification, but for the sake of simplicity it has been shown in Fig. 3 as half wave rectification. Reactor 18 is provided with a winding 29 which is magnetized by a substantially constant direct current. The actual control windings 30 and 37 on the input side of the control system belong to the reactor 10. According to the invention, the last-mentioned windings receive their magnetizing current from the charging circuit via a control arrangement, as will be described more in detail hereunder. Furthermore, the reactors 18, 19 may be provided with direct current windings and feed-back coupling windings (not shown), e. g. connected at point 35 to the amplifier 16, in the same manner as shown in Fig. 2.

The resulting ampere turns from the windings on the middle of reactor 18 should be of about the same magnitude as the resulting ampere turns from the windings on the middle of reactor 19. This means that the voltage drop over the two reactors is of approximately the same size, and accordingly the voltage to the amplifier 16 is nil when the voltage is normal over the load 10. Only variations of the voltage over 10 will upset the balance between the reactors 18 and 19 and produce a resulting voltage which is sup-

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plied to the amplifier and consequently to the main reactor 11 as well.

In the embodiment shown in Fig. 3, the control arrangement consists of a phase changer 20 which may include only a condenser 33 coupled in series with the winding 37. The winding 37 thus receives current oscillations resulting from variations of the voltage over the load 10, while the winding 30 receives direct current directly from the voltage over load 10.

First of all, it will be assumed that the winding 37 is disconnected and that the regulation is accordingly effected in the known manner, i. e. with the usual control effect supplied to the regulating winding 30. If an increased load occurs at a certain moment, there will be a drop in voltage over load 10 owing to the voltage drop in the rectifier 12, the reactor 13 and the network. This will cause the current through the coil 30 to decrease. In this way a regulating current is applied via the amplifier 16 to the main reactor 15. Before this regulating current reaches the reactor 11, a certain time will have elapsed, since the reactors have quite a considerable inertia. Due to this time lag, increased current from the network is not supplied directly to the output circuit, but the voltage drops to a relatively low value and thereby the regulating current assumes a relatively high value. This in its turn causes the output circuit to reach too high a voltage. This causes the voltage E5 to oscillate in a manner such as shown in Fig. 4, where the variations of load are assumed to take place in the time t_0 .

As shown in Fig. 3, the oscillation is counteracted and quick-acting regulation is obtained through a certain control effect being supplied from the output side to the input side of the control device by means of a condenser 36 and being impressed on the winding 37, which is now assumed to be connected in circuit. As is known, the current through the condenser 36 is a function of the derivatives of voltage E5 in dependence upon the time. If it is now similarly presumed that an increase of load occurs, then in the first moment, as shown in Fig. 5, the alterations of the currents i_1 and i_2 will be brought approximately into phase, thus furnishing a powerful regulation. At the next moment the current i_2 to the winding 37 through the condenser 36 becomes an inverted current through the winding 30, thus counteracting the oscillation and providing a course of regulation as shown in Fig. 6. For the course of the regulation to be correct, condenser 36 and winding 37 should have such dimensions that not only a somewhat powerful regulation is obtained but that also approximately the same time constant is obtained as in the entire control arrangement, thus causing the component that counteracts the oscillation to come into play at the right moment. Condenser 36 may suitably be of the electrolytic type.

Practical tests were made with a regulating arrangement substantially like that illustrated in Fig. 3. It showed a regulation free from oscillation when the winding 37 had about $\frac{1}{2}$ the number of turns of winding 30 and the condenser 36 was equal to about 200 μ f. Furthermore, for obtaining good sensitivity, the reactors 18 and 19 of the test apparatus were provided with positive back coupling.

When a certain weak oscillation, e. g. a pair of oscillations is allowed to pass the positive back coupling of the reactors, regulation is effected in the manner shown in Fig. 6, and thereafter is in-

creased still further to some extent when the oscillation again begins to become noticeable. In this way, an improved constancy of the voltage is obtained. Before the last-mentioned increase in the positive feed-back coupling occurred, it was found possible to maintain the voltage constant within a few per cent, and after the increase to less than 1 per cent. This improvement is made possible because, by means of the coupling arrangement, in addition to quick-acting regulation, negative feed-back coupling is obtained just at the critical frequency for self-oscillation.

The oscillogram in the drawings show the correctness of this state of affairs.

If the winding 37 is disconnected after a completed course of regulation, the self-oscillation will begin to occur again.

By means of the connection arrangement according to the invention in the embodiment shown in Fig. 3, there is obtained not only quick-acting regulation but also negative feed-back coupling, thus the regulating sensitivity of the arrangement is increased by 2 to 3 times.

It is evident that in practice the arrangement, which is the object of the invention, may be designed in many ways other than those illustrated, without departing from the scope of the invention. A few examples of possible modifications are given hereunder.

In the embodiment of Fig. 3, both control effects are fed to reactor 19. The normal control effect as well as the extra control effect may be divided and fed partially to reactor 18 and partially to reactor 19. Furthermore, it is not necessary to use two separate reactors in balanced connection on the input side. The control effects may be supplied to a reactor designed as a conventional amplifier stage or arranged in any other known manner. Furthermore, the extra control effect may be fed to a quite different reactor than that to which the ordinary control effect is supplied, e. g. to a reactor belonging to a subsequent amplifier stage. Besides, instead of in the manner shown in Fig. 3, the extra control effect may be tapped over the rectified voltage from one of the amplifier stages.

The negative feed-back coupling may be effected either in each stage separately or in two or more or all the stages jointly. By use of suitable coupling elements in the feed-back coupling circuits, the back coupling may be made dependent upon frequency, if so desired.

Strong negative feed-back coupling may be used in reactor amplifiers for instruments or the like where considerable magnetizing but no sensitivity losses may be allowed and where specially good amplifying properties are required.

In control arrangements similar to that illustrated in Fig. 3, where constant voltage or current is desired, in a charging circuit, such as a lighting network, over a battery or the like, the negative feed-back coupling should however not be used too long, because this leads to too many amplifier stages and poor efficiency. Instead, at least in one partial amplifier stage, use is made of positive feed-back coupling and the negative feed-back coupling is limited to counteract the system's tendency to oscillate at a certain frequency and in particular is designed, as mentioned above, in such a way as to cancel the oscillation, i. e. as to obtain the components counteracting the oscillation within a certain space of time.

Different methods may be employed for the purpose of having the counteracting components

occur in the right sequence and magnitude. In Fig. 3, such a component is obtained by means of a condenser and a winding. It is evident that a similar characteristic (or time function) may be obtained if the condenser is replaced by a transformer. Of course, use may also be made of both a transformer and a condenser.

What is claimed is:

1. In a magnetic amplifying system, a reactor carrying a number of winding means, an alternating current input circuit connected to a first one of said winding means, an output circuit connected with the second of said winding means in series with said first winding means, a source of current of a periodicity substantially below that of said alternating current input circuit, a third of said winding means connected with said source to control the output of said output circuit, circuit means for deriving part of said output and comprising rectifying means, and phase changing means, and a fourth of said winding means connected with said last circuit means to counteract said third winding means for at least a part of the time of control.

2. In a magnetic amplifying system, a reactor comprising a center core carrying a winding supplied with a relatively slow changing current and producing a magnetic field, and two side cores symmetrically arranged with respect to said center core, one core carrying a winding connected with an input circuit containing a relatively quick changing current and the second core carrying a winding connected in series with said input winding and connected with an output circuit and controlled by said field, means including a full wave rectifier for deriving from said output circuit a portion of its output and feeding back said portion through phase changing means to an additional winding arranged on said center core to counteract said field at least for the time following the first moment of control.

3. In a magnetic amplifying system, a reactor having a center core carrying a winding supplied with a relatively slow changing current and producing a magnetic field, a second reactor for supplying said current, and two side cores symmetrically arranged with respect to said center core, one core carrying a winding connected with an input circuit containing a relatively quick changing current and the second core carrying a winding connected in series with said input winding and connected with an output circuit, and controlled by said field, means including a full wave rectifier for deriving from said output circuit a portion of its output and feeding said portion, at least in part through phase changing means, to additional windings arranged on the center core of a third reactor having side core windings coupled to counteract said field at least for the time following the first moment of control.

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