Oct. 7, 1947. W. R. HARRIS ET AL 2,428,567

DRIVE SYSTEM

Filed Nov. 10, 1944 2 Sheets-Sheet 1

Fig. 1.

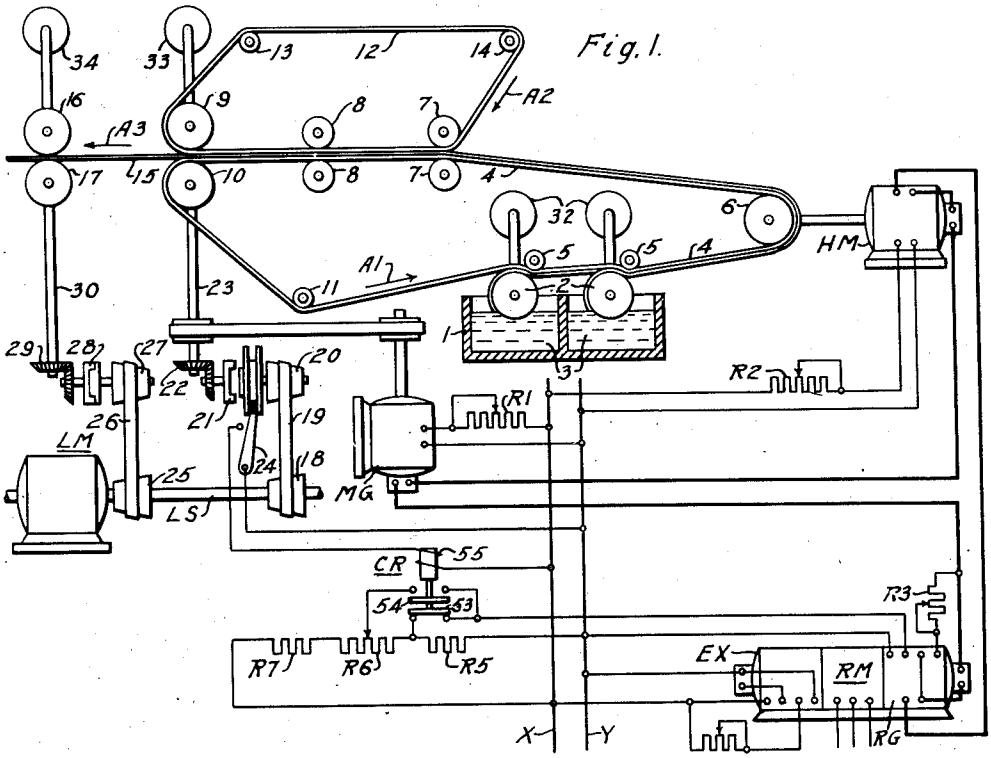
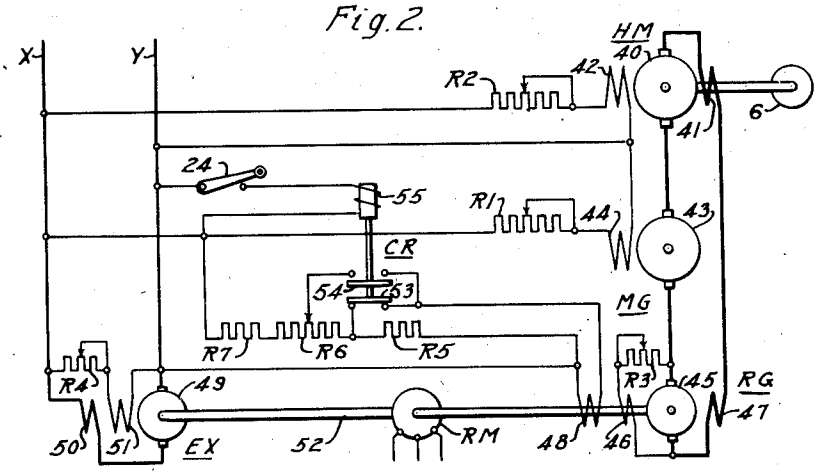


Fig. 2.



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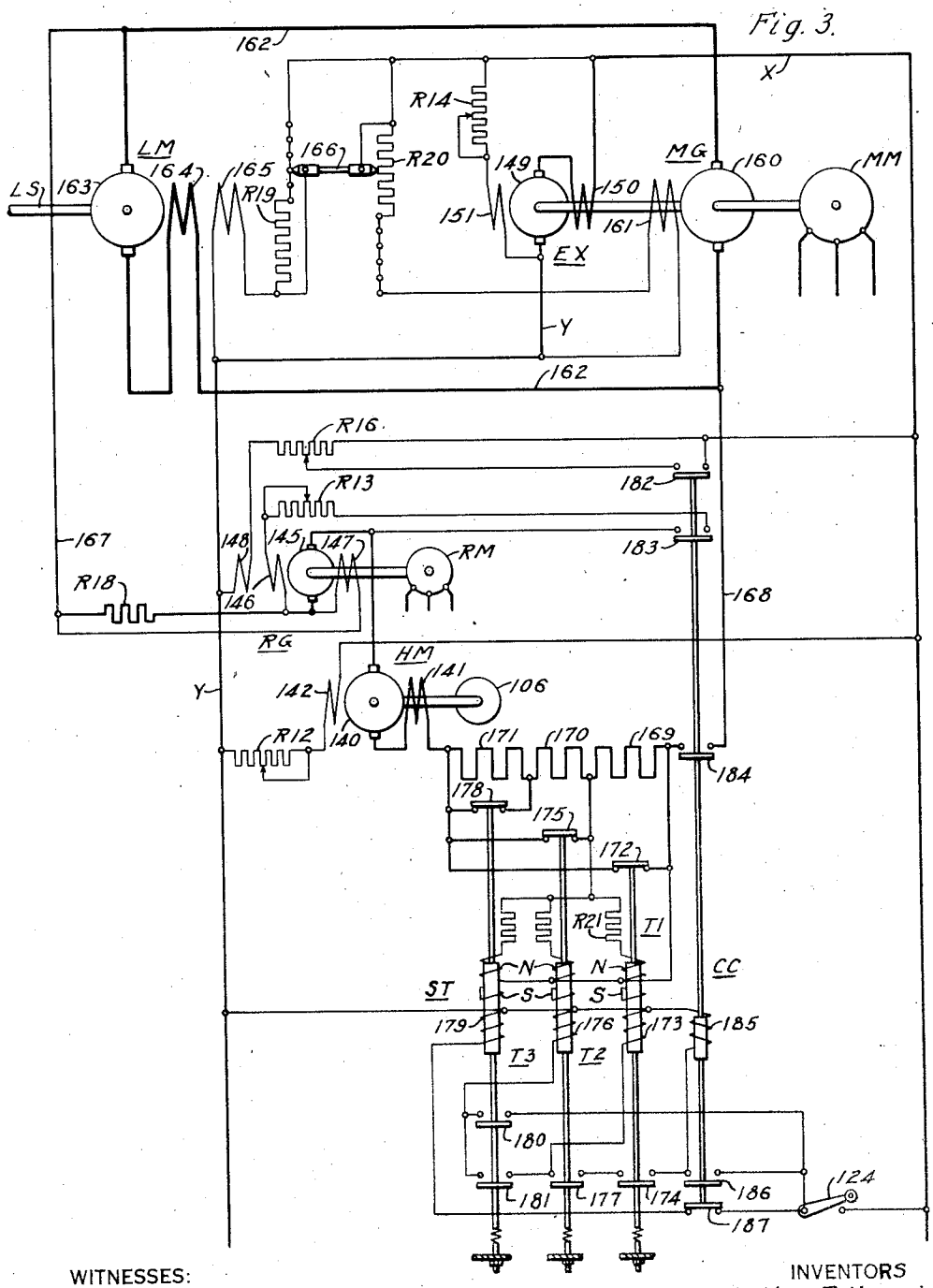
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Fig. 3.



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DRIVE SYSTEM

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Application November 10, 1944, Serial No. 562,864

9 Claims. (Cl. 172—239)

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Our invention relates to electric motor control systems for machine plants or units in which a machine part is to be driven in a given fixed or adjustable speed relation to another driven machine part. In a more specific aspect, the invention relates to systems of the just-mentioned type in which one of a group of correlated machine parts is driven by a main or master drive furnishing the predominant amount of driving energy, while another machine part is connected with an auxiliary or helper drive which provides a more or less auxiliary driving effort. Such helper drives, controlled in dependence upon the operation of a master drive, are used, for instance, in machine units of the type in which a web, sheet or strand element, or a material to be formed into such an element, is passed over rotating rolls, or between pairs of rolls while in contact or working engagement with the peripheral roll surfaces. Rolling mills, coating machines, waxing machines, printing presses and paper-making machines are examples of this type of machine. Hence, while the invention is hereinafter described with reference to and in terms of paper machines, it is similarly applicable to other machines of the above-mentioned type.

In paper machines, the wet pulp or paper stock is entrained by a traveling porous or foraminous member, such as a band of felt or a wire mesh (Fourdrinier wire), on which the stock forms a wet coating while the member is driven through one or several presses for removing water from the stock or otherwise working on the stock to convert it into a self-supporting web of paper. This web, still in the wet state, is then passed through further presses, driers and calenders to assume the desired final consistency and strength. Most of these machine sections contain rolls, some of which are actuated by a drive while others revolve merely by virtue of their frictional engagement with the traveling band or web. As a rule, the driven rolls are operated from a line shaft which in turn is driven by a steam engine, electric motor or other available source of motive power.

It has been known to apply electric helper drives to one or several rolls for various auxiliary or corrective purposes. For instance, in roll presses, having the lower roll power driven from the line shaft, a helper drive has been applied for actuating the top roll in a given speed relation to the power or master drive of the lower roll in order to eliminate slippage and irregularities or stresses in the strand or sheet material which are apt to

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occur if friction is exclusively relied upon for driving the top roll.

Some known helper drives include a generator coupled with the line shaft of the paper machine to generate a current whose voltage varies in proportion to the speed of the line shaft. An electric variable speed motor is fed from the generator and coupled with the roll to be controlled by the helper drive. As a result, the energization of the motor and its speed are dependent upon the speed of the master drive or line shaft, a separate booster generator and suitable control equipment being provided to make up for the IR drop in the helper drive system.

The helper drive is required to operate over a considerable speed range, and it is necessary that the booster voltage and the generator voltage be correctly proportioned at all speeds in order to maintain a proper operating adjustment over the entire speed range. Since the booster voltage should be proportional to the operating load, the drive is likely to get out of adjustment if the load is changed, since the machine operators often know little about the proper control of this type of electrical equipment.

An improvement over these known helper drive systems is disclosed in the copending patent application, Serial No. 496,747, filed July 20, 1943, of Walter R. Harris which is assigned to the assignee of the present application. The system according to the copending application contains a helper drive operating in a given relation to a separately or independently operating main drive and permits varying the speed of the main drive over a considerable range while maintaining the desired correlation of the two drives at all operating speeds and substantially independent of load variations of the master drive without necessity of action or supervision by the operator. The system also permits adjusting a desired torque or driving effort of the helper drive and maintains this torque substantially constant independently of speed or load variations of the master drive. In order to attain these advantages, the system is equipped with a regulating generator, driven at constant speed, which provides all excitation for the generator of the helper drive.

It is an object of the present invention to provide a control or drive system which, while securing the above-mentioned advantages of the systems according to the said copending application, affords the further advantage of eliminating some drawbacks and difficulties apt to occur in particular cases of application. More specifically, the present invention aims at devising an auto-

matic control system, of the type referred to, that lends itself readily to being used in connection with the drive motor and generator of already existing drive systems in such a manner that part of the already available installation is retained. In other words, one of the objects of this invention is to afford or facilitate the conversion of existing drive systems into automatically regulating systems so that a desired speed ratio of a main drive and a helper drive, and a constant driving effort of the helper drive is secured under utilization of electric machines already present in the system to be converted.

A still further object of the invention is to provide a helper drive system which permits operating the helper drive motor to a large extent by energy taken from the variable voltage system of a master drive to whose speed that of the helper drive motor is to be correlated, thus reducing the amount of rotary machines required for the control of the helper drive.

These and other objects of the invention, as well as its essential means for achieving these objects, will become apparent from the following description of the embodiments illustrated in the drawings, in which:

Figure 1 is a diagrammatic representation of the wet end sections of a paper-making machine having a master drive and a helper drive interlinked by a control system in accordance with the invention;

Fig. 2 is a separate circuit diagram of the same control system showing the essential electric elements more in detail and in straight-line representation; while

Fig. 3 is a straight-line circuit diagram showing another embodiment of a helper drive system according to the invention, this system being also exemplified by its application to a paper-making machine.

According to Fig. 1, the wet end section of the illustrated paper-making machine comprises a series of vats 1 each having a cylinder mould 2 partly immersed in liquid stock 3. Each mould consists of a roll whose surface is covered by a wire mesh to entrain part of the stock when revolving. An endless belt 4 of felt or other foraminous material is kept in engagement with the cylinder moulds by means of guide rolls 5. The felt 4 passes over a suction drum roll 6, between a set of baby presses 7 and 8, and between the rolls 9 and 10 of a first main press, thence returning to the cylinder moulds over a guide roll 11. A second endless belt of felt or the like material, denoted by 12, passes through the baby presses and the first main press together with felt 4 and is guided by guide rolls 13 and 14.

The lower roll 10 of the first main press is driven by a master drive and the suction drum roll 6 by a helper drive, as will be more fully described hereinafter. Due to these drives, felt 4 travels in the direction of the arrow A1 when in operation, and felt 12, entrained by friction, moves in the direction of the arrow A2.

During this operation, an amount of stock is transferred by the moulds 2 from vats 1 to the surface of felt 4, the total amount of stock thus applied to the felt depending upon the number and operating speed of the moulds. When passing over the suction drum 6, part of the excess water is removed from the stock. While passing further between the belts 4 and 12 and through the baby presses 7 and 8, the stock is freed of more water. When leaving the first main press 9—10, the stock is sufficiently condensed to form a web, denoted by 15, which, though still wet and of low strength, is sufficiently solidified and self-supporting to travel to the subsequent sections of the machine without assistance by felt supports. The web is passed between the rolls 16 and 17 of a second main press and thence through additional pressing, drying and calendering sections (not shown) in the direction of the arrow A3.

The drive of the main press roll 10 (master drive) will now be described in detail. The driving energy for the first main press, as well as for a number of other sections of the machine unit, is derived from a line shaft LS which is driven by a line shaft drive LM of adjustable speed, here represented diagrammatically by a motor. The line shaft drive may consist of any suitable source of motive power, such as a steam engine, internal combustion engine, turbine or electric motor. Speed change gears or the like may be provided between the drive and the line shaft, if necessary.

The line shaft LS is connected to the machine unit to be driven by means of belt drives. One of such drives is arranged between the line shaft and the bottom roll 10 of the first main press. A pulley 18 is mounted on the line shaft and connected by an endless driving belt 19 with a driven pulley 20 which is coupled with roll 10 through a coupling 21 and an intermediate transmission here represented by a bevel gear 22 and a connecting shaft 23. An electric switch 24 is associated with coupling 21 so that the switch contacts are open when the coupling is open, and closed when the coupling is closed.

Another belt drive comprises a line shaft pulley 25, an endless belt 26, a driven pulley 27, a coupling 28, a bevel gear 29 and a transmission 30 for actuating the bottom roll 17 of the second main press. Further belt drives are provided for connecting the line shaft with other units or sections (not illustrated) of the machine.

The machine section illustrated in Fig. 1 contains several helper drives in addition to the master or line shaft drive. As already mentioned, one of these helper drives serves to supply auxiliary driving power to the suction drum 6. This helper drive will maintain the torque of the suction drum 6 at a desired magnitude while the drum operates at a speed correlated to that of the first main press so as to prevent at any occurring operating speed an undue slippage or creeping apt to strain the traveling felt or the paper stock deposited thereon. The helper drive includes a direct-current motor HM connected to the suction drum 6. Before describing the other elements of the helper drive coacting with motor HM, some other helper drive motors shown in Fig. 1 may be mentioned.

Two helper drive motors, both denoted by 32, are provided for revolving the cylinder moulds 2. Another helper drive motor 33 serves to supply auxiliary driving power to the top roll 9 of the first main press, while a similar motor 34 is applied to the top roll 16 of the second main press. It will be understood that each of these other helper drives must be associated with a correlated motor drive. For instance, the proper helper drive motor 34 should be speed controlled in dependency upon the speed of press roll 17. Otherwise, however, the control system for motors 32, 33 and 34 may be similar to the helper drive system described hereinafter and hence are not illustrated in the drawings.

The helper drive and control system of the suc-

tion drum 6, as shown in Fig. 1, contains a main direct-current generator MG for feeding the helper motor HM with current of variable voltage. The armature of generator MG is driven from shaft 23 so that the generator speed is proportional to the speed of the master drive actuating roll 10 of the first main press. The excitation for generator MG and motor HM is supplied from direct-current buses X and Y through calibrating resistors R1 and R2, respectively. The buses X and Y obtain their energization from a suitable source of direct current of substantially constant voltage. Such a source is exemplified in the illustrated embodiment by an exciter EX. The exciter forms part of a motor generator set whose drive motor RM operates at substantially constant speed and drives also a regulating generator RG. These electric apparatus and circuits are interlinked electrically and electromagnetically in a manner apparent from Fig. 2.

The diagram of Fig. 2 represents the same electric drive and control system as is shown in Fig. 1 for controlling the helper drive motor HM of the suction drum 6 in dependence upon the master drive.

According to Fig. 2, the helper motor HM has its armature 40 acted upon by two field windings 41 and 42. Winding 41 is series-connected in the load circuit. Winding 42 is a shunt-type winding and separately energized from mains X and Y as described previously. The armature 43 of the main generator MG is energized by a generator field winding 44 which is also connected to mains X and Y.

The regulating generator RG has its armature 45 acted upon by three field windings 46, 47 and 48. Winding 46 is self-energizing, and the resistance of its circuit is adjusted by means of a resistor R3 so that the resistance line coincides with the no-load saturation curve of generator RG. As a result, the regulating generator tends to maintain its output voltage at the value determined by the other field windings. Field windings 47 and 48 are wound for counteracting each other as to their inductive effect on the regulator armature 45. That is, at a proper relative excitation of windings 47 and 48 their fields are balanced and, hence, inactive as regards the control of the output voltage of the regulator.

Field winding 47 is connected in the load circuit so that its excitation is proportional to the load current of motor HM. Winding 48 is connected to buses X and Y by circuit means described below, so as to be energized by an adjustable standard or pattern voltage which remains constant during the normal operation of the control system.

The exciter EX, feeding the buses X and Y, has its armature 49 connected in series with a field winding 50. A shunt field winding 51 is connected in parallel to the exciter armature, a calibrating rheostat R4 being arranged in the shunt circuit. The exciter armature 49 and the regulator armature 45 are mounted on the shaft 52 of motor RM. Due to the constant speed of this motor, the output voltage of exciter EX remains constant at a magnitude adjusted by means of rheostat R4.

Connected with the pattern field winding 48 is a series arrangement of a resistor R5, a potentiometer R6 and another resistor R7. This arrangement is tapped between R5 and R6 and at the slide contact of the potentiometer R6. The two taps are connected with the regulator winding 48 (pattern field winding) through contacts

53 and 54 of a control relay CR whose control coil 55 is connected to the exciter buses X and Y through switch 24. When exciter EX is in operation but switch 24 open, coil 55 is not energized, so that relay contacts 53 and 54 are in the illustrated position. In this position, the potentiometer tap at R6 is ineffective, while the tap point between R5 and R6 is connected through contact 53 with field winding 48. Consequently, the pattern field is now excited by the relatively low voltage drop across resistor R5. This resistor is calibrated for standstill conditions of the paper machine. That is ,this calibration and the corresponding control effect produced by the pattern field take care of preventing undue stretching or creeping of the belt 4 (Fig. 1) apt to occur during standstill conditions.

When closing the coupling 21 (Fig. 1) of the master drive, switch 24 is also closed so that relay coil 55 (Fig. 2) becomes energized. The coil opens contact 53 while closing contact 54. Now the tap between R6 and R5 is disconnected from the pattern field winding 48 and the latter switched over to the slide contact of potentiometer R6. As a result, the pattern voltage now effective across the field winding 48 is determined by the voltage drop between the potentiometer slider and and the remote end of resistor R7. This voltage drop is larger than the voltage previously applied and can be varied by adjusting the potentiometer contact down to a minimum determined by the magnitude of resistor R7.

Reviewing now the operation of the system as a whole, let us assume that the line shaft motor LM of the paper machine is in normal operation and the line shaft LS rotating at normal speed with coupling 21 open and the press rolls 9 and 10 at rest (Fig. 1). Let us further assume that the motor RM of the regulator set is running at full speed. Under these conditions, switch 24 is open and the pattern field of winding 48 energized by a low voltage in accordance with the calibration of the control system for standstill conditions. When now the coupling 21 (Fig. 1) is struck in, thus setting the main press in operation and thereby causing the belt 4 to begin its travel, switch 24 is closed and relay coil 55 energized so that the pattern voltage in field winding 48 assumes the higher value selected at R6 and places the control system in normal operating condition. At the same time, the main generator MG starts running and generates voltage for motor HM. This voltage is proportional to the speed of the master drive and, since generator MG is rated for supplying the full amount of driving energy, tends to maintain the helper motor HM at a speed corresponding to that of the master drive. However, as the motor circuit includes also the armature of the regulating generator RG, the speed torque characteristic of the motor depends also on the energy generated by the regulator RG, and this energy is so rated and controlled as to introduce a corrective current which prevents departures of the motor from the desired operating conditions. The corrective current is dependent on two control biases produced by the mutually differential pilot and pattern field windings 47 and 48 whose excitation, as explained before, responds to the magnitude of the load current measured by winding 47 and to the selected adjustment of the potentiometer R6, respectively.

The contact of potentiometer R6 is set for energizing the pattern field winding 48 so that a given current intensity, say 20 amperes, in the

motor circuit is necessary to energize the pilot winding 47 up to the same field strength. If the resultant voltage of generators MG and RG becomes too low to pass a current of this magnitude through the circuit, the pattern field becomes stronger than the pilot field and thus causes the regulator armature 45 to build up a corrective voltage. As a result, the resultant voltage impressed on the motor HM increases until the right current is obtained. Then the differential fields 47 and 48 of the regulator are again balanced so that the regulatory function ceases, and nothing further will happen as long as the datum current of 20 amperes is maintained.

Conversely, if the motor current is too high, the pilot field of winding 47 is stronger than the pattern field of winding 48 and the regulating generator produces a voltage of such adjustment that the resultant motor voltage is forced down by regulator action until the two regulator field windings 47 and 48 again balance each other.

By virtue of this regulating action, the helper drive system maintains the torque or driving effort of the helper drive motor at a constant value independent of load variations of the master drive over the entire range of operating speeds of the paper machine. That is, considerable speed variations are permissible with a system of this type without appreciable inaccuracy of control. All control functions are performed by stepless operation and without the use of control contacts or relays in the regulating network proper. All essential operating adjustments can be made by means of rheostats or the like impedance members. Since the regulating generator RG acts only as a corrective device while the main driving effort is provided by the generator MG, only a small regulator set is required.

The embodiment of the invention illustrated in Fig. 3 relates also to a driving system for a paper making machine which has a line shaft or master drive and is equipped with a helper drive motor to operate in a given speed relation to the speed of the master drive. In contrast to the above-described system, however, the driving energy of the master drive is provided by a variable voltage generator and the main portion of the driving energy supplied to the helper drive is taken from the same generator. According to Fig. 3, the helper drive motor HM serves for actuating a suction drum roll 106 corresponding to the roll denoted by 6 in Fig. 1. The armature of motor HM is denoted by 140, its series field winding by 141, and the shunt connected main field winding by 142. The shunt field winding 142 is energized through a calibrating resistor R12 from the mains X and Y of an exciter generator EX. Series connected with the motor armature 140 is the armature 145 of a regulating generator RG of the amplifying type. This generator has a self-exciting field winding 146 in series connection with an adjusting rheostat R13. The resistance of the circuit of winding 145 is so rated that it coincides with the no-load saturation curve of the regulating generator as explained in conjunction with the first-described example. That is, field winding 146 functions to sustain the regulator output voltage substantially at the value determined by the other field windings of this generator, and, since this generator operates on the straight portion of its magnetic characteristic, increases the sensitivity and magnitude of the amplifying effect involved in the operation of the regulating generator. The generator RG is further provided with a pilot

field winding 147 and a pattern field winding 148 both arranged for mutually differential action so that the magniture and polarity of the output voltage of armature 145 is dependent upon the differential excitation of these two windings. Winding 147 is excited by a component voltage which measures the current in the load circuit of the helper motor HM and to this end is connected across a measuring resistor R18 whose voltage drop varies in proportion to the load current. If desired, winding 147 may also be designed as a series field winding in the manner exemplified by the corresponding winding 47 in Fig. 1. The pattern field winding 148 is connected across the exciter mains X and Y through an adjusting rheostat R16. The differential field excitation of generator RG is zero when the ampere turns of pilot winding 147 are equal to the ampere turns of the pattern field winding 148 as adjusted at rheostat R16.

The exciter EX has its armature 149 acted upon by a series field winding 150 and a shunt field winding 151, the latter being connected across armature 149 and field winding 150 in series with a calibrating rheostat R14. The armature 149 is mounted on the shaft of a main generator MG which is driven by a constant speed motor MM. When in operation, the direct-current voltage generated by the exciter EX and imposed on the mains X and Y remains constant at the value adjusted by means of the rheostat R14.

The output voltage of the armature 160 of the main generator MG is controlled by a field winding 161 and imposed on the load circuit 162 of the line shaft motor LM. The armature 163 of this motor drives the line shaft LS of the paper machine. Motor LM has a series connected compensating or interpole winding 164 and a separately excited main field winding 165 which derives its excitation from the exciter mains X and Y through an adjusting rheostat R19. The excitation of the main generator field winding 161 is also taken from the mains XY and is controlled by a rheostat R20. The two rheostats R19 and R20 have a common slider assembly 166. When in operation, the speed of the line shaft motor LM is controlled by the adjustment of the slider assembly 166. Within the range of low operating speeds, a displacement of assembly 166 changes merely the exciting voltage of the generator field winding 161 while within the range of higher speeds this excitation remains constant while the exciting voltage of the motor field winding 165 is varied.

Connected across the main load circuit 162 of the variable voltage master drive is a second load circuit which includes the conductors denoted by 167 and 168. The armature 143 of the helper motor HM and the armature 145 of the regulating generator RG are series connected in this second circuit. The circuit is so rated that the main driving energy for motor HM is derived from the first load circuit 162 while the regulating generator provides merely a corrective boosting or bucking bias tending to maintain the helper motor at the proper load at any operating speed.

The load circuit of the helper motor includes a series of starting resistors denoted by 169, 170 and 171. Resistor 169 is provided with a short-circuiting path under control by the contact 172 of a timing relay T1 whose control coil 173 actuates also an interlock contact 174. Resistor 170 has a short-circuit path controlled by the main contact 175 of a timing relay T2. The control

coil 176 of this relay serves also for actuating an interlock contact 177. In a similar manner a short-circuiting path for resistor 171 is controlled by the contact 178 of a timing relay T3 with a control coil 179 and two interlock contacts 180 and 181. These timing relays form part of an automatic starting device denoted as a whole by ST. This device includes also a control contactor CC with three main contacts 182, 183 and 184 actuated by a coil 185 which operates also two interlock contacts 186 and 187. The starting device ST is energized from mains X and Y through a switch 124 which is automatically closed when the coupling between the line shaft LS and the machine unit driven thereby is struck in corresponding to the arrangement and function of switch 24 according to Figs. 1 and 2.

The operation of the drive system according to Fig. 2 as a whole is as follows.

Let us assume that the variable voltage master drive is in operation and causes the line shaft LS to revolve at a speed selected by the adjustment of the slider assembly 166. As long as the line shaft is disconnected from the machine unit to be driven by the master drive, the switch 124 is open so that the automatic starter is deenergized. Hence contacts 182, 183 and 184 are open so that field windings 146 and 148 of regulator RG are deenergized. The load circuit of helper motor HM is interrupted at contact 184. Consequently the pilot field winding 147 of the regulating generator is also without excitation. The constant speed motor RM of the regulating generator is assumed to be running at normal speed. When now the coupling of the master drive is closed thereby closing also switch 124, coil 179 of relay T3 is energized through contact 187 of contactor CC and opens the short circuit of resistor 171 at contact 178 while closing at contact 180 a circuit for coil 176 of relay T2. Relay T2 interrupts the short circuit of resistor 170 at contact 175 and, by closing the interlock contact 177, provides excitation for coil 173 of relay T1. As a result, the short circuit of resistor 169 is also opened at contact 172, and interlock contact 174 provides excitation for coil 185. The operation of relays T3, T2 and T1 as described so far is virtually instantaneous because these relays are not retarded during their pickup operation and act as timing devices only when dropping off. Consequently the contacts 182, 183 and 184 are closed very quickly so that the motor HM starts running immediately upon actuation of the master drive coupling. When closing, contactor CC establishes a self-holding circuit by the closure of its contact 187 and hence remains picked up as long as the switch 124 stays closed. At the same time contactor CC opens the energizing circuit of relay T3 at contact 187. Relay T3 drops off after the elapse of its timing period and then shorts the resistor 171. Relay T3 further opens its contact 180 and thereby disconnects coil 176 of relay T2. Upon elapse of its timing period, relay T2 shorts resistor 170 and disconnects, at contacts 177, the coil 173 of timing relay T1. Upon elapse of its timing period, relay T1 shorts the remaining resistor 169 so that now the helper motor HM is under full operating voltage. The timing operation of the starter ST is chosen in accordance with the accelerating characteristic of the machine unit driven by the master drive. Hence, when the machine unit is at full speed, the helper drive motor has substantially reached its correlated full speed. In order to obtain the desired timing periods, the relays T1, T2, and T3 are each provided with a short circuited winding S and a neutralizing winding N, the latter being energized from the circuit of motor HM through calibrating resistors R21 as soon as contact 184 of contactor CC is closed.

As mentioned above, the actuation of contactor CC immediately upon the closure of switch 124 has also the effect of connecting the field winding means of the helper motor HM to the appertaining energizing circuit. Hence, when the helper motor HM has reached full speed, the regulating generator RG is in operation to regulate the energization of the helper motor. When the load current of motor HM at the selected speed and voltage setting of the master drive system is too high, the ampere turns of winding 147 exceed the oppositely acting ampere turns of winding 148. Hence, a differential field effect is produced in the regulating generator RG which causes the armature 145 to generate a voltage in opposition to that derived from the main load circuit 162. Thus the resultant voltage in the load circuit of the helper motor is reduced with the effect of lowering the current of the helper motor. When the load current of the helper motor is too low, the ampere turns of the pattern field winding 148 exceed those of the pilot field winding 147 so that now the armature 145 produces a boosting voltage which increases the resultant energization of the helper motor to the correct current value. In either case, when the correct current is re-established, the differential field windings 147 and 148 are again in balance and, therefore, without further effect so that the condition then attained is stabilized by the self-energizing winding 146. The chosen adjustment of the rheostat R16 determines the current condition in the motor circuit of the helper drive and hence the torque of the helper drive at which the excitation of pilot field 147 is neutralized by the pattern field 148. In summary, the control system tends to maintain the torque of the helper drive motor at a selected magnitude while this motor is caused to run at a speed correlated to that of the master drive.

Helper drive systems of the type described may also be applied for controlling the operation of helper drive motors in other (not illustrated) sections of the paper machine. It will also be understood that systems according to the invention are also applicable with machines other than for making paper in which the operation of a drive is to be accurately controlled in dependence upon the operation of another drive, and especially in cases where the controlled drive performs an auxiliary or corrective function while the main driving effort is provided by a regulatable master drive. Hence, various modifications of our invention other than those exemplified in the foregoing are available to those skilled in the art without departure from the essential features of the invention and within the scope of the claims attached hereto.

We claim as our invention:

1. A system for controlling a helper drive in dependence upon the operation of a master drive, comprising a variable speed helper drive motor, circuit means for energizing said motor by voltage variable substantially in accordance with the speed of the master drive, a regulating generator having an armature connected with said motor and circuit means for producing a regulated armature voltage in order to control the load current of said motor, said regulating generator having field winding means for controlling the magnitude

and polarity of said armature voltage, drive means connected with said armature for driving it at substantially constant speed, means connecting said field winding means with said circuit means for providing for said field winding means a component excitation varying in accordance with said load current, and means connected with said field winding means for providing for the latter a constant component excitation in opposition to said first component excitation so that said armature voltage depends on the differential value of said two excitations.

2. A system for controlling a helper drive in dependence upon the operation of a master drive, comprising a variable speed helper motor, energizing means connected with said motor for supplying it with energization variable substantially in accordance with the speed of the master drive, a regulating generator having an armature connected with said motor and energizing means for producing a voltage in said armature in order to impose a corrective effect on said energization, said regulating generator having field winding means for controlling the polarity and magnitude of said voltage, circuit means connecting said field winding means with said motor and energizing means so as to provide a component variable voltage for controlling said field winding means in dependence upon said energization, circuit means connected to said field winding means for providing therefor a component constant control voltage in opposition to said variable control voltage so that the resultant control of said field winding means corresponds to the differential effect of said two control voltages.

3. A system for controlling a helper drive in dependence upon the operation of a master drive, comprising a variable speed helper motor, a main direct-current generator having an armature circuit connected with said motor for supplying said motor with energization variable substantially in accordance with the speed of the master drive, a regulating generator having an armature series connected in said armature circuit for producing a corrective voltage in order to regulate the resultant energization supplied to said motor, said regulating generator having field winding means for controlling the polarity and magnitude of said corrective voltage, circuit means connecting said field winding means with said armature circuit so as to provide a component variable voltage for controlling said field winding means in dependence upon said energization, circuit means connected to said field winding means for providing therefor a component constant control voltage in opposition to said variable control voltage so that the resultant control of said field winding means corresponds to the differential effect of said two control voltages.

4. A system for controlling a helper drive in dependence upon the operation of a master drive, comprising a direct-current helper drive motor, a main generator having a variable-voltage armature circuit connected with said motor, means for driving said main generator substantially in a given speed relation to the master drive, an amplifying generator having a regulating output circuit connected between said main generator and said motor, a constant-speed motor in driving connection with said regulating generator, said regulating generator having two oppositely acting and mutually balanceable field windings for effecting a voltage reversing control on said regulating output circuit, one of said field windings being connected with said output circuit of said main generator so as to be excited in dependence upon the current supplied to said helper drive motor, circuit means connected to said other winding for providing a constant exciting voltage therefor and having adjustable circuit means for selecting the value of said exciting voltage so as to balance the field of said first winding when said current has a magnitude corresponding to the selected adjustment of said circuit means.

5. In combination with a master drive and a helper drive, a control system for said helper drive which comprises a direct-current helper drive motor, a main generator having a variable-voltage output circuit connected with said motor, means for driving said main generator substantially in a given speed relation to said master drive, a separately driven regulating generator having a regulating output circuit connected between said main generator and said motor and at least three coacting field windings for controlling the voltage of said regulating output circuit, one of said field windings being connected with said regulating output circuit to provide self-excitation for said regulating generator, said output circuit of said main generator being connected with a second one of said windings to excite the latter in dependence upon an electric magnitude of the current supplied to said helper drive motor, and circuit means of substantially constant voltage connected with said third winding for causing said third winding to balance the field of said second winding when said magnitude has a given value.

6. A system for controlling a helper drive in dependence upon the operation of a master drive, comprising a helper drive motor of variable speed, a main generator having a variable-voltage load circuit connected with said motor, transmission means for connecting said main generator with said master drive in order to drive said generator in a given speed relation to said master drive, a separately driven regulating generator having an armature connected between said main generator and said motor and having field winding means for controlling the voltage of said armature, circuit means connecting said field winding means with said load circuit for providing a component exciting voltage variable in dependence upon an electric magnitude of the load current of said helper drive motor, and circuit means connected with said field winding means for providing a component constant exciting voltage so as to balance the effect of said first exciting voltage on said armature voltage when said magnitude corresponds to a predetermined value.

7. A system for controlling a helper drive in dependence upon the operation of a master drive, comprising a variable voltage motor drive having a speed controlling main load circuit of adjustable voltage, a helper drive motor, a second load circuit connecting said helper drive motor with said main load circuit so as to energize the latter by voltage variable in accordance with that of said main load circuit, an amplifying generator having an armature series connected in said second load circuit and field winding means for controlling the voltage generated by said armature, circuit means connecting said field winding means with said second load circuit so as to provide a component exciting voltage for controlling said field winding means in dependence upon the load current of said motor, and circuit means connected to said field winding means for providing therefor a component constant control voltage in

opposition to said variable control voltage so that the resultant control of said field winding means corresponds to the differential effect of said two control voltages.

8. A system for controlling a helper drive in dependence upon the operation of a master drive, comprising a variable voltage motor drive having a speed controlling main load circuit of adjustable voltage, a helper drive motor, a second load circuit connecting said helper drive motor with said main load circuit so as to energize the latter by voltage variable in accordance with that of said main load circuit, an amplifying generator having an armature series connected in said second load circuit, two oppositely acting and balanceable field windings, one of said windings being connected with said second load circuit so as to be excited in dependence upon the energization of said motor, and circuit means connected to said other winding for providing constant excitation therefor.

9. A system for controlling a helper drive in dependence upon the operation of a master drive, comprising a variable voltage motor drive having a speed controlling main load circuit of adjustable voltage, a helper drive motor, a second load circuit connecting said helper drive motor with said

main load circuit so as to energize the latter by voltage variable in accordance with that of said main load circuit, said second load circuit being rated for providing full energization for said motor, a regulating generator having an armature series connected in said second load circuit for imposing corrective energization thereon and being provided with a self-energizing voltage sustaining field winding and two oppositely acting and balanceable field windings, one of said windings being connected with said second load circuit so as to be excited in dependence upon the energization of said motor, and circuit means connected to said other winding for providing constant excitation therefor.

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REFERENCES CITED

The following references are of record in the file of this patent:

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Number	Name	Date
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