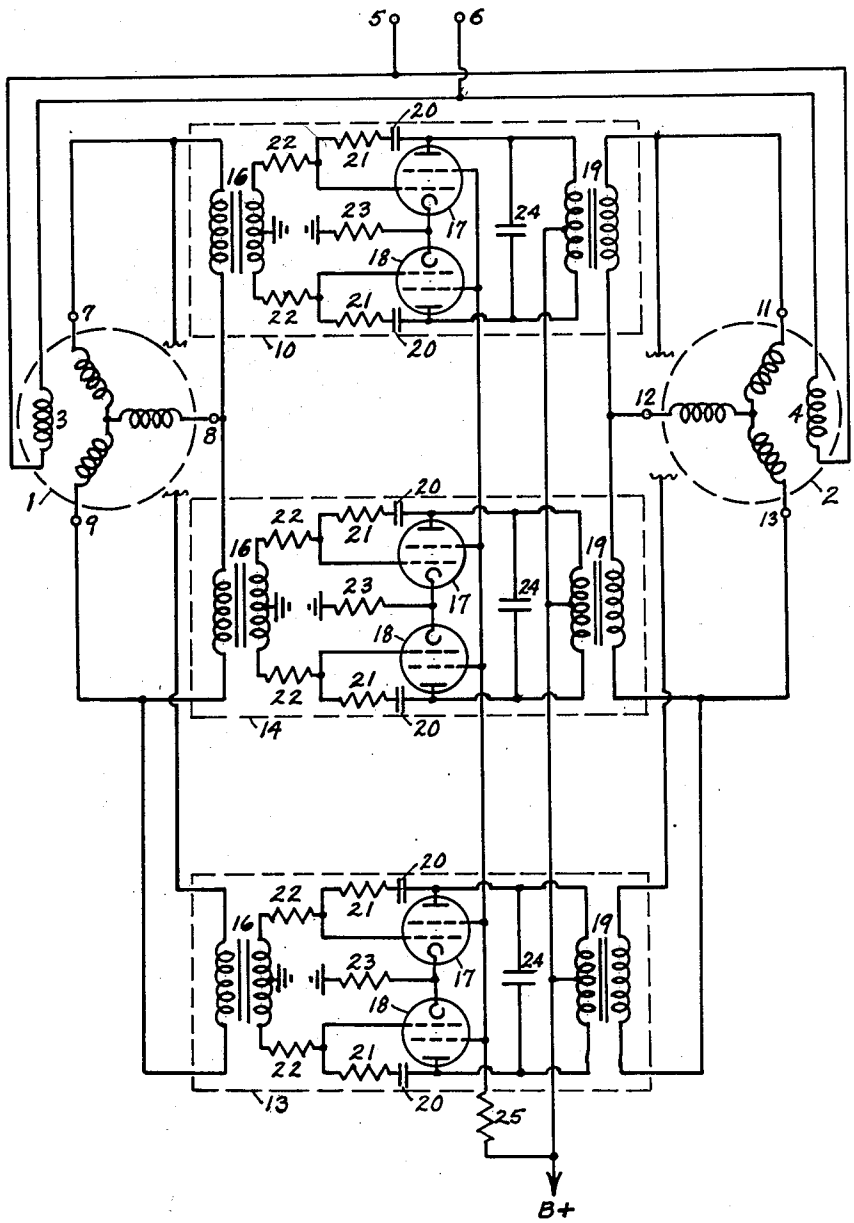
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TORQUE AMPLIFIER

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TORQUE AMPLIFIER

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This invention relates to an improved torque amplifier, and more particularly to an amplifier especially adapted for converting a rotational force into a similar force of substantially greater magnitude, which is characterized by a high degree of precision of following between the driven and the drive shafts.

Torque amplifiers in the past have generally consisted of relatively complicated mechanical and electromechanical systems which usually had severe limitations with respect to precision of following between the driven and the drive shafts, or with respect to the freedom from back torque.

These limitations were, at least in part, inherent in a mechanism employing mechanically linked or mechanically engaging elements. Furthermore, such torque amplifiers were relatively expensive to produce and difficult to maintain in satisfactory operating condition.

It is an object of the present invention, therefore, to provide a torque amplifier in which the amplification of torque is secured electronically rather than mechanically or electro-mechanically. Such an improved torque amplifier obviously is free from the limitations inherent in previously used arrangements. Its performance, particularly with respect to the precision of following between the driven and drive shafts, is substantially superior to that realizable with any previously proposed system of comparable cost and complexity.

In accordance with the present invention, there is provided a torque amplifier comprising a multi-phase "selsyn" generator, a vacuum-tube amplifier having input and output circuits for each phase, a multi-phase "selsyn" motor, connections between the generator and the input circuits of the amplifiers, and connections between the output circuits of the amplifiers and the motor.

While the improved torque amplifier of the present invention is adaptable for use in any application where one shaft must be driven at the same speed but with substantially greater torque than another shaft, its use is especially advantageous in applications requiring that the drive shaft be subjected to no appreciable back torque due to a load on the driven shaft. In view of the fact that the torque amplifier of the present invention operates electronically and hence employs valves which are essentially one-way in their operation, a load on the driven shaft has no appreciable effect upon the force required to rotate the drive shaft.

For a better understanding of the invention, together with other and further objects thereof,

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reference is made to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

In the accompanying drawing, the single figure is a circuit diagram of a torque amplifier in accordance with the present invention.

Referring now to the single figure of the drawing, there is shown a three-phase "selsyn" generator 1 and a three-phase "selsyn" motor 2. Field windings 3 and 4, respectively of generator 1 and motor 2, are both connected to terminals 5 and 6, which in turn are connected to a source of alternating current, not shown.

Phase 7—8 of the armature winding of "selsyn" generator 1 is connected to the input of amplifier 10, the output of which is connected to phase 11—12 of the armature winding of "selsyn" motor 2. Likewise, phase 8—9 of generator 1 is connected to the input of amplifier 14, the output of which is connected to phase 12—13 of motor 2. Similarly, phase 7—9 of generator 1 feeds amplifier 15, which in turn supplies phase 11—13 of motor 2.

Amplifiers 10, 14 and 15, which are identical, each comprise an input transformer 16, a pair of vacuum tubes 17 and 18, and an output transformer 19. Each amplifier includes dual feedback networks comprising in series capacitor 20, resistor 21 and resistor 22. The cathodes of vacuum tubes 17 and 18 in each amplifier are connected together and to ground through resistor 23. In each amplifier, capacitor 24 is connected between the plates of vacuum tubes 17 and 18. The capacitor 24 by-passes the alternating currents which are induced in phases 11, 12 and 13 of the motor 2 by the field winding 4 and which pass through the transformer windings 19 to the feedback circuits 20, 21. The feedback of the induced currents from the winding 4 to the amplifier tubes 17 and 18 is very undesirable when the generator 1 and the motor 2 are in balance as it produces unnecessary loading of the amplifier tubes and also causes a tendency of the motor 2 to hunt about the balance point.

Plate voltage for vacuum tubes 17 and 18 of amplifiers 10, 14 and 15 is supplied from a source indicated by B+. Screen-grid voltage for each of the vacuum tubes is supplied, through series resistor 25, from the source indicated by B+.

In operation, the relative amplitude of the voltages developed in each phase of "selsyn" generator 1 is a function of the angular displacement of the armature of this generator with respect to its field. Since amplifiers 10, 14 and 15 are identical, the relative amplitude of the volt-

ages impressed upon the three phases of "selsyn" motor 2 corresponds exactly with this relation in generator 1. These voltages, when applied to the armature of motor 2, have no effect when the armature of motor 2 is in the same position relative to its field as is the armature of generator 1 relative to its own field. If, however, the armature of motor 2 is displaced from this position, the output voltages from amplifiers 10, 14 and 15 produce a strong force tending to restore the armature to its synchronous position.

While the above explanation of operation covers the static case, that is, where neither armature is rotating, it will of course be obvious that synchronism is maintained in a similar manner even when the armature of generator 1 is rotated at high speed. Likewise, the direction of rotation of the armature of generator 1 is immaterial, in that a reversal of such direction immediately causes a corresponding reversal in the direction of rotation of the armature of motor 2.

The amount of torque amplification which may be secured is a function solely of the amount of power available in the output circuits of amplifiers 10, 14 and 15. These output circuits are of low impedance relative to the impedance of the amplifier input circuits. While the amplifiers have been shown as push-pull amplifiers utilizing voltage feedback, it will readily be understood that they may be replaced by single-ended amplifiers with or without feedback. It is also within the scope of the invention to substitute a multi-stage amplifier for each of amplifiers 10, 14 and 15, thereby permitting the use of vacuum tubes in the output stage having higher power handling capabilities without requiring higher driving voltages from synchronous generator 1.

In one successful embodiment of the invention, "selsyn" generator 1 and "selsyn" motor 2 had an armature impedance of 50 ohms per phase. Field windings 3 and 4, respectively of generator 1 and motor 2, were energized by a 115-volt, 60-cycle source of alternating current connected to terminals 5 and 6. Input transformers 16 each had an over-all step-up turns ratio of 1:4. Vacuum tubes 17 and 18 were type 6L6G. Output transformers 19 each had an over-all step-down turns ratio of 5:1. The source of positive potential B+ had a voltage of 360 volts at a current of 300 milliamperes. The following values of resistors and capacitors were employed:

Capacitors 20 and 24	microfarads	1.0
Resistors 21	ohms	25,000
Resistors 22	do	10,000
Resistors 23	do	250
Resistor 25	do	5,000

The above circuit constants are given merely by way of example, and it will be understood that they may be varied within wide limits without departing from the scope of the invention. For example, if "selsyn" generators or motors having different armature impedances are employed, the turns ratio of transformers 16 or 19 will of course be changed.

While there has been described what is at present considered the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A torque amplifier, wherein the power is supplied to each phase of a synchronous system by an electronic amplifier, comprising a multi-circuit synchronous generator, an input transformer connected to each phase thereof, a pair of vacuum tubes whose grids are connected in push-pull to each of said input transformers, feedback connections from the plates of said vacuum tubes to the grids thereof, an output transformer connected to the plates of each pair of vacuum tubes, a capacitor connected across the plates of each pair of vacuum tubes, and a multi-circuit synchronous motor having each phase connected to a separate one of said output transformers.

2. A torque amplifier, wherein the power is supplied to each phase of a synchronous system by an electronic amplifier, comprising a multi-circuit synchronous generator having each phase connected to the primary winding of an input transformer, a pair of amplifying vacuum tubes having their grids connected in push-pull to the secondary winding of each of said input transformers, feedback connections from the plates of said vacuum tubes to the grids thereof, connections from the plates of each pair of said vacuum tubes to the primary winding of an output transformer, a capacitor connected across the plates of each pair of said vacuum tubes, and a multi-circuit synchronous motor having each phase connected to the secondary winding of a separate one of said output transformers.

3. A torque amplifier, wherein the power is supplied to each phase of a synchronous system by an electronic amplifier, comprising a multi-circuit synchronous generator, a vacuum-tube amplifier having input and output circuits for each phase and a feedback circuit therein, a multi-circuit synchronous motor, connections between said generator and said input circuits, connections between said output circuits and said motor, and means associated with said feedback circuits to by-pass induced alternating currents from said motor.

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