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STATIC WARD LEONARD SYSTEM

Ward Leonard Method of speed control is achieved by varying the applied voltage to the armature. This method was introduced in 1891. The connection diagram of the Ward Leonard method of speed control of a DC shunt motor is shown in the figure below.

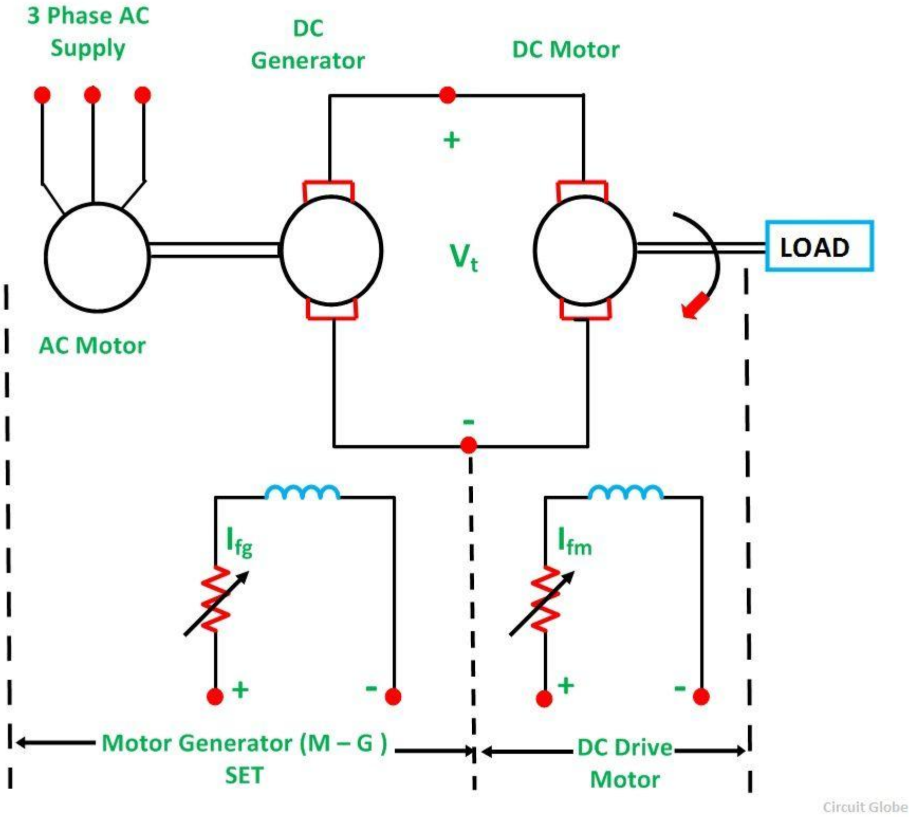

Fig. 1 Ward Leonard Control of Speed Control of DC Motor.

In the above system, M is the main DC motor whose speed is to be controlled, and G is a separately excited DC generator. The generator G is driven by a 3 phase driving motor which may be an induction motor or a synchronous motor. The combination of AC driving motor and the DC generator is called the Motor-Generator (M-G) set.

The voltage of the generator is changed by changing the generator field current. This voltage when directly applied to the armature of the main DC motor, the speed of the motor M changes. The motor field current I_{fm} is kept constant so that the motor field flux ϕ_m also remains constant. While the speed of the motor is controlled, the motor armature current Ia is kept equal to its rated value.

The generated field current I_{fg} is varied such that the armature voltage $V_t$changes from zero to its rated value. The speed will change from zero to the base speed. Since the speed control is carried out with the rated current Ia and with the constant motor field flux, a constant torque is directly proportional to the armature current, and field flux up to rated speed is obtained. The product of torque and speed is known as power, and it is proportional to speed. Thus, with the increase in power, speed increases automatically.

The **Torque and Power Characteristic** is shown in the figure below.

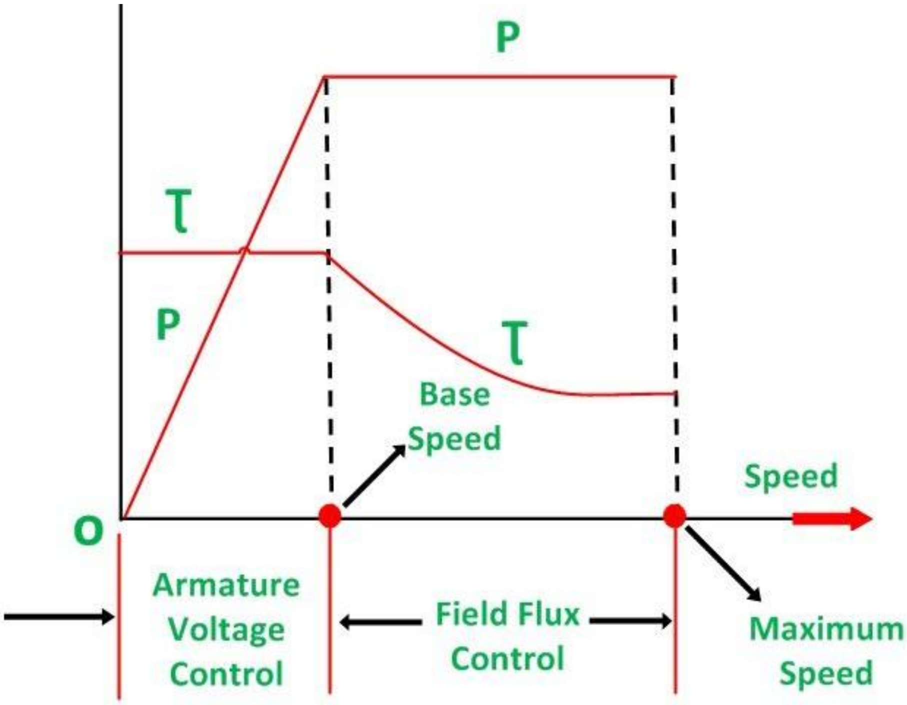

Fig. 2 Characteristics of Ward Leonard System

Hence, with the armature voltage control method, constant torque and variable power drive is obtained from speed below the base speed. The Field flux control method is used when the speed is above the base speed. In this mode of operation, the armature current is maintained constant at its rated value, and the generator voltage V_t is kept constant.

The motor field current is decreased and as a result, the motor field flux also decreases. This means that the field is weakened to obtain the higher speed. Since V_tI_a and EI_a remain constant, the electromagnetic torque is directly proportional to the field flux ϕ_m and the armature current I_a. Thus, if the field flux of the motor is decreased the torque decreases.

Therefore, the torque decreases, as the speed increases. Thus, in the field control mode, constant power and variable torque are obtained for speeds above the base speed. When the speed control over a wide range is required, a combination of armature voltage control and field flux control is used. This combination permits the ratio of maximum to minimum speed available speeds to be 20 to 40. For closed loop control, this range can be extended up to 200.

The driving motor can be an induction or synchronous motor. An induction motor operates at a lagging power factor. The synchronous motor may be operated at a leading power factor by over-excitation of its field. Leading reactive power is generated by over excited synchronous motor. It compensates for the lagging reactive power taken by other inductive loads. Thus, the power factor is improved.

A Slip ring induction motor is used as p prime mover when the load is heavy and intermittent. A flywheel is mounted on the shaft of the motor. This scheme is known as **Ward Leonard-Ilgener** scheme. It prevents heavy fluctuations in supply current.

When the Synchronous motor is acting as a driving motor, the fluctuations cannot be reduced by mounting a flywheel on its shaft, because the synchronous motor always operates at a constant speed. In another form of Ward Leonard drive, non-electrical prime movers can also be used to drive the DC generator.

For example – In DC electric locomotive, DC generator is driven by a diesel engine or a gas turbine and ship propulsion drives. In this system, Regenerative braking is not possible because energy cannot flow in the reverse direction in the prime mover.

Advantages of Ward Leonard Drives

The main advantages of the Ward Leonard drive are as follows:-

- Smooth speed control of DC motor over a wide range in both the direction is possible.
- It has an inherent braking capacity.
- The lagging reactive volt-amperes are compensated by using an overexcited synchronous motor as the drive and thus, the overall power factor improves.
- When the load is intermittent as in rolling mills, the drive motor is an induction motor with a flywheel mounted to smooth out the intermittent loading to a low value.

Drawbacks of Classical Ward Leonard System

The Ward Leonard system with rotating Motor Generator sets has following drawbacks.

- The Initial cost of the system is high as there is a motor generator set installed, of the same rating as that of the main DC motor.
- Larger size and weight.
- Requires large floor area
- Costly foundation
- Maintenance of the system is frequent.
- Higher losses.
- Lower efficiency.
- The drive produces more noise.

Applications of Ward Leonard Drives

The Ward Leonard drives are used where a smooth speed control of the DC motors over a wide range in both the directions is required. Some of the examples are as follows:-

- Rolling mills
- Elevators
- Cranes
- Paper mills
- Diesel-electric locomotives

- Mine hoists

Solid State Control or Static Ward Leonard System

Now a days Static Ward Leonard system is mostly used. In this system, the rotating motor-generator (M-G) set is replaced by a solid state converter to control the speed of the DC motor. Controlled Rectifiers and choppers are used as a converter.

In the case of an AC supply, controlled rectifiers are used to convert fixed AC supply voltage into a variable AC supply voltage. In the case of DC supply, choppers are used to obtain variable DC voltage from the fixed DC voltage.

A static Ward Leonard system is described which is fully capable of four-quadrant operation. Although both the forward and the reverse thyristor convertors are maintained in conduction simultaneously, the problems normally encountered with circulating currents do not arise.

At the moment, there are two main methods of achieving static Ward Leonard control. The first method utilizes two fully controlled thyristor convertors with their direct-current terminals connected inverse-parallel, with only one convertor allowed to conduct at any time; changeover between the convertors is achieved at load-current zeros. This technique requires current-zero detection circuits and logic circuitry to ensure that the convertors conduct in such a manner as to meet the demand of the operator. The control circuitry required to ensure correct operation of this system must be extremely reliable if serious maloperation is to be avoided. The second system is used mainly when extremely fast current-reversal times are required. Both convertors are permitted to conduct together, each one being transformer-isolated from the main supply. One convertor is operated in the rectifying mode, while the other is operated in the inverting mode. Although the mean voltages produced by the convertors can be arranged to be equal, a circulating current exists between them as a result of the instantaneous difference between the voltage waveforms, and this circulating current must be limited by the circuit impedance. It is sometimes necessary to include deliberately extra impedance or to use other means to reduce this current.

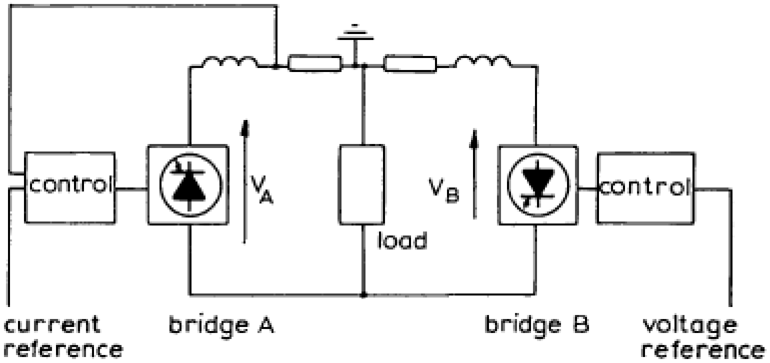

Fig. 3 Schematic Diagram of Static Ward Leonard System

One method is to ensure that the two convertors only conduct together for a small range of current around the reversal point. Other methods involve either arranging the thyristor firing angles so that a minimum potential difference exists between the convertors, or phase shifting the convertor supplies relative to each other. Although the problems of circulating current can be controlled, the control equipment must again be extremely reliable.

The new system avoids the use of current-zero detection techniques and permits a very rapid reversal by maintaining both bridges in conduction simultaneously. At the same time, the circulating current is rigidly controlled and is, in fact, used as a control function.

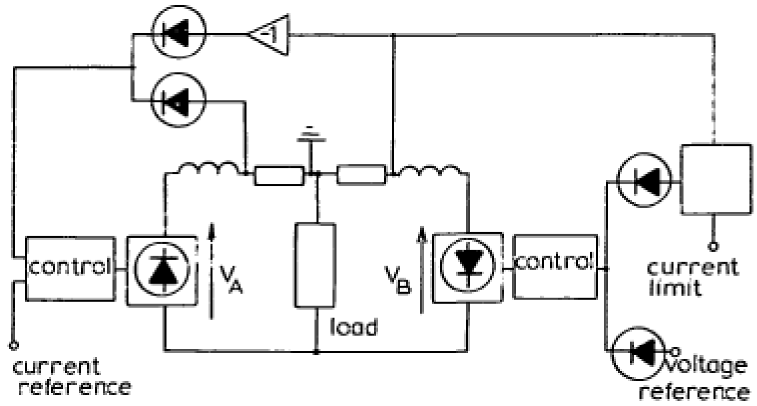

Fig. 4 Schematic Diagram of Static Ward Leonard System

The inductors in the d.c. power circuit are included for current smoothing. They would, of course, also limit the current in the event of a serious failure. Bridge A is kept under constant-current control with its feedback signal derived from a small resistance, in the output line, as shown. The level of constant current from bridge A is set by varying the current reference signal. The level of current in the load can then be varied by controlling the output voltage of bridge B. With bridge B producing full positive voltage (the positive direction defined by the arrows on the diagram), i.e. bridge B inverting, the current in the load will be equal to the constant current set by bridge A. As the voltage produced by bridge B is reduced, the current will be diverted from the load, the load current becoming zero when the whole of the current is circulating between the two bridges. If bridge B is made to produce negative voltage, i.e. operate in the rectification mode, the current in the load can be reversed. In order to reverse fully the current in the load, it is evident from Fig. 3 that bridge B must have twice the rating of bridge A. This basic disadvantage can, however, be overcome using the arrangement shown in Fig. 4, in which two feedback signals are taken to the control circuits, one representing the current in bridge A and one representing the current in bridge B. Bridge A is then controlled by use of a simple OR gate, whose action depends on which of the feedback signals is greater.

Thus, as the voltage produced by bridge B is changed from full positive to full negative (ignoring the current limit associated with bridge B for the moment), the system performs in precisely the same manner as the previous circuit until the current in the load becomes zero. When the load current passes through zero, the current through bridge B attempts to increase above its set constant value, and the feedback signal derived from this current then takes over control of bridge A, changing the voltage produced by bridge A in such a manner as to keep the current through bridge B constant. In other words, the current through bridge A reduces as the load current

reverses.
One further modification to the basic system of Fig.3 1 is required in order to prevent the current through bridge B increasing beyond its constant setting once the current in bridge A has become zero (load current fully reversed). This is shown on the right-hand side of Fig. 4. A feedback signal representing the current in bridge B is compared with a current-limit reference. If the feedback signal ever exceeds this reference signal, the control signal is rendered ineffective, and bridge B operates under constant-current control.

The system has been used to supply resistive and inductive loads, and has been shown to be fully capable of four-quadrant operation by applying it to a separately excited d.c. machine. Speed reversal of the d.c. machine was obtained by applying a low-frequency square wave as the voltage reference, and very rapid responses have been obtained. The system has also been successfully operated with a short circuit across the output.