

LOAD TAP CHANGING AC VOLTAGE REGULATOR

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

This invention relates to a load tap changing AC voltage regulator which can contribute to accomplishment of such purposes as energy saving.

PRIOR ART

Conventionally, as a load tap changing AC voltage regulator that can stabilize the output voltage to the load with it being kept connected, a load tap changing transformer 50 as shown in Fig. 9 has been used.

The load tap changing transformer 50 is provided with a primary winding P and a secondary winding S1, a transformer 51 having a tapped secondary winding S2, and a series transformer 52 whose primary winding P3 is connected to the secondary winding S2 in the main transformer 51 and whose secondary winding S3 is connected in series with the secondary winding S1 in the main transformer 51. In Fig. 9, the circuitry only for one phase is shown.

With the said conventional load tap changing transformer 50, a tap changeover for the said secondary winding S2 can change the output voltage to the load, however, because the secondary winding S1 in the main transformer 51 is connected in series with the secondary winding S3 in the series transformer 52, the load tap changing transformer 50 always functions only as an adding type (or subtracting type), which has presented a problem that the variation in output voltage that is caused by a variation in

input voltage or a change in load cannot closely be accommodated, resulting in impossibility of supplying steady power for the variety of loads.

SUMMARY OF THE INVENTION

This invention is provided in consideration of the above-stated situation, and intends to offer a load tap changing AC voltage regulator which can closely accommodate the variation in output voltage caused by a variation in input voltage or a change in load for steady supply of power and energy saving with a minimum of noise.

The load tap changing AC voltage regulator of the present invention is a load tap changing AC voltage regulator 1 that transforms the input voltage from the AC power supply 2 with the main transformer 3 to supply it for the load, and changes taps by means of the semiconductor contacts for the auxiliary winding installed in the said main transformer 3 to change the output voltage to the load, and that features having a tap changing control means 5 which detects the variation in output voltage to the load that is caused by a variation in input voltage from the AC power supply 2 and changes the taps of the auxiliary winding Sa for appropriate taps to compensate for the variation in output voltage without causing instantaneous disconnection ; a series transformer 4 adds to or subtracts from the output voltage a certain voltage for compensating for the variation in output voltage that results from the tap changeover for the auxiliary winding Sa provided by the tap changing control means 5 ; and a current limiting reactor 6 which suppresses the circulating current caused to flow through the auxiliary winding Sa by the tap changeover for the auxiliary winding Sa.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram illustrating a preferred embodiment of the load tap changing AC voltage regulator of the present invention.

Fig. 2 is a diagram illustrating the changeover with the tap changing contacts in the preferred embodiment of the present invention.

Fig. 3 is a diagram illustrating a type of operation of the current limiting reactor in the preferred embodiment of the present invention.

Fig. 4 is a diagram illustrating another type of operation of the current limiting reactor in the preferred embodiment of the present invention.

Fig. 5 is a block diagram illustrating another preferred embodiment of the load tap changing AC voltage regulator of the present invention.

Fig. 6 is a winding configuration diagram showing a three-phase transformer of three-phase input and three-phase output as an application of the preferred embodiment of the present invention.

Fig. 7 is a winding configuration diagram showing a Scott-connected transformer of three-phase input and single-phase two outputs as an application of the preferred embodiment of the present invention.

Fig. 8 is a winding configuration diagram showing a V-transformer of three-phase input and single-phase one output as an application of the preferred embodiment of the present invention.

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Fig. 9 is a winding configuration diagram for a conventional load tap changing AC voltage regulator.

Here is a description about each of the reference Nos.

- 1 : Load tap changing AC voltage regulator
- 2 : AC power supply
- 3 : Main transformer
- 4 : Series transformer
- 5 : Tap changing control means
- 6 : Current limiting reactor
- 7 : Voltage detector circuit
- 8 : Tap selector circuit
- 9 : Ignitor circuit
- 20 : Load tap changing AC voltage regulator
- Sa : Auxiliary winding
- L1 to L5 : Tap changing contacts
- R1 to R5 : Tap changing contacts

DETAILED DESCRIPTION OF THE INVENTION

The invention as stated in the claim 1 provides a load tap changing AC voltage regulator that transforms the input voltage from the AC power supply with the main transformer to supply it for the load, and changes taps by means of the semiconductor contacts for the auxiliary winding installed in the said main transformer to change the output voltage to the load, and that features having a tap changing control means which detects the variation in output voltage to the said load that is caused by a variation in input voltage from the said AC power supply and changes the taps of the said auxiliary winding for appropriate taps to compensate for the variation in output voltage without causing

instantaneous disconnection ; a series transformer which is connected to the output side of the said main transformer and adds to or subtracts from the said output voltage a certain voltage for compensating for the variation in output voltage that results from the tap changeover for the said auxiliary winding provided by the tap changing control means ; and a current limiting reactor which suppresses the circulating current caused to flow through the said auxiliary winding by the tap changeover for the auxiliary winding.

The invention as stated in the claim 2 provides a load tap changing AC voltage regulator as stated in the claim 1 with which the said tap changing control means is provided with a voltage detector circuit that detects the variation in output voltage to the said load that is caused by a variation in input voltage from the said power supply ; a tap selector circuit that selects appropriate taps to compensate for the variation in output voltage from the taps of the said auxiliary winding on the basis of the detection result by the voltage detection circuit ; and an ignitor circuit that changes the taps of the auxiliary winding without causing instantaneous disconnection and in a zero-crossing operation on the selection result by the tap selection circuit.

The function of the present invention will be described here.

With the load tap changing AC voltage regulator as stated in the claim 1, the tap changing control means detects the variation in output voltage to the said load that is caused by a variation in input voltage from the said AC power supply and changes the taps of the auxiliary winding installed in the said main transformer by means of the semiconductor contacts for appropriate taps to compensate for the variation in output voltage without causing instantaneous disconnection . The series transformer that is connected to the output side of the said main

transformer adds to or subtracts from the said output voltage a certain voltage for compensating for the variation in output voltage that results from the tap changeover for the said auxiliary winding provided by the tap changing control means. At this time, the current limiting reactor suppresses the circulating current caused to flow through the said auxiliary winding by the tap changeover for the auxiliary winding.

With the load tap changing AC voltage regulator thus operating, it is possible to closely accommodate the variation in output voltage caused by a variation in input voltage or a change in load for steady supply of power and energy saving through the tap changeover for the said auxiliary winding by the tap changing control means without instantaneous disconnection and the addition or subtraction of a certain voltage for compensating for the variation in output voltage by the series transformer. Tap changeover can be made with a minimum of noise, and because taps are changed by means of the semiconductor contacts for the auxiliary winding, unlike the main circuit tap changeover, the tap contact capacity can be decreased, which leads to the reduction in cost.

With the configuration of the load tap changing AC voltage regulator as stated in the claim 2, the said tap changing control means is composed of a voltage detector circuit that detects the variation in output voltage to the said load that is caused by a variation in input voltage from the said power supply ; a tap selector circuit that selects appropriate taps to compensate for the variation in output voltage from the taps of the said auxiliary winding on the basis of the detection result by the voltage detection circuit ; and an ignitor circuit that changes the taps of the auxiliary winding without causing instantaneous disconnection and in a zero-crossing operation on the selection result by the tap selection circuit, thus, the tap changing control means can be

- 7 -

made up of simple electronic circuits providing rapid operation.

Here is a detailed description of the preferred embodiments of the load tap changing AC voltage regulator related to this invention by referring to the diagrams attached.

The load tap changing AC voltage regulator 1 as shown in Fig. 1 is provided with an AC power supply 2 which delivers a given AC voltage ; a main transformer 3 equipped with a primary winding P and a secondary winding S which transform the input voltage from the AC power supply to feed it to the load ; a series transformer 4 equipped with a primary winding P4 and a secondary winding S4 that is connected in series with the output circuit of the main transformer 3 ; a tap changing control means 5 which detects the variation in output voltage to the said load that is caused by a variation in voltage input from the said AC power supply 2, and makes changeover with the tap changing contacts L1 to L5 and R1 to R5 (semiconductor contacts) for the auxiliary winding Sa installed in the said main transformer 3 without causing instantaneous disconnection ; a current limiting reactor 6 which is connected to the output sides of the said tap changing contacts L1 to L5 and the said tap changing contacts R1 to R5, and one of the terminals of the primary winding P4 in the series transformer 4.

The middle point of the said auxiliary winding Sa is connected to the other terminal of the primary winding P4 in the said series transformer 4, so that a voltage is supplied for the primary winding P4 in the said series transformer 4 from the auxiliary winding Sa through an appropriate one of the tap changing contacts L1 to L5, that of the tap changing contacts R1 to R5 and the current limiting reactor 6.

The said tap changing control means 5 is provided with a

voltage detector circuit 7 which detects the variation in output voltage to the said load that is caused by a variation in voltage input from the said AC power supply 2 ; a tap selector circuit 8 which selects an appropriate one of the tap changing contacts L1 to L5 and that of the R1 to R5 for the said auxiliary winding Sa to compensate for the variation in output voltage on the basis of the detection result by the voltage detector circuit 7 ; and an ignitor circuit 9 which makes changeover with the tap changing contacts L1 to L5 and R1 to R5 for the auxiliary winding Sa without causing instantaneous disconnection and in a zero-crossing operation on the selection result by the tap selection circuit 8.

The said series transformer 4 adds to or subtracts from the said output voltage a certain voltage for compensating for the variation in output voltage that results from the tap changeover for the auxiliary winding Sa provided by the tap changing control means 5.

As described later, the current limiting reactor 6 suppresses the circulating currents I_L and I_R caused to flow through the auxiliary winding Sa by the tap changeover for the auxiliary winding Sa.

Next, the operation of the load tap changing type AC voltage regulator 1 will be described by referring to Fig. 2 in addition to Fig. 1.

The following description is made on the assumption that, in the load tap changing AC voltage regulator 1 as shown in Fig. 1, the configuration of the tap changing contacts L1 to L5 and R1 to R5 for the auxiliary winding Sa is such that only the tap changing contacts L2 and R2 are closed and all the others are open, when the input voltage for the main transformer 3 is the proper one.

When the input voltage for the said transformer 3 is lowered, resulting in the decreased output voltage, the said voltage detector circuit 7 detects the variation in output voltage. On the detection result by the voltage detector circuit 7, the tap selector circuit 8 selects the tap changing contacts L1 and R1, which are the most appropriate to compensate for the decrease in output voltage, from the tap changing contacts L1 to L5 and R1 to R5 for the said auxiliary winding Sa, however, the ignitor circuit 9 makes the following zero crossing operation without causing instantaneous disconnection of the output voltage to the load in changing over to the tap changing contacts L1 and R1.

In other words, as shown in Fig. 2, starting from the state in which only the tap changing contacts L2 and R2 are closed, the tap changing contact L2 is opened with the tap changing contact R2 kept closed, then, the tap changing contact L1 is closed with the tap changing contact R2 kept closed, which is followed by the tap changing contact R2 opened with the tap changing contact L1 kept closed, and finally the tap changing contact R1 is closed with the tap changing contact L1 kept closed.

This results in that a voltage to compensate for the decrease in output voltage is applied to the primary winding P4 in the series transformer 4 from the auxiliary winding Sa through the tap changing contacts L1 and R1 and the current limiting reactor 6, and the voltage from the secondary winding S4 is also increased, and added to the output voltage for the main transformer 3, thus, a compensation for the decrease in output voltage is provided, and the proper output voltage is steadily supplied for the load.

On the other hand, when the input voltage for the said transformer 3 is increased, resulting in the raised output voltage,

the said voltage detector circuit 7 detects the variation in output voltage. On the detection result by the voltage detector circuit 7, the tap selector circuit 8 selects the tap changing contacts L3 and R3, which are the most appropriate to compensate for the rise in output voltage, from the tap changing contacts L1 to L5 and R1 to R5 for the said auxiliary winding Sa, however, the ignitor circuit 9 makes the following zero crossing operation without causing instantaneous disconnection of the output voltage to the load in changing over to the tap changing contacts L3 and R3.

In other words, starting from the state in which only the tap changing contacts L2 and R2 are closed, the tap changing contact L2 is opened with the tap changing contact R2 kept closed, then, the tap changing contact L3 is closed with the tap changing contact R2 kept closed, which is followed by the tap changing contact R2 opened with the tap changing contact L3 kept closed, and finally the tap changing contact R3 is closed with the tap changing contact L3 kept closed.

This results in that a voltage to compensate for the increase in output voltage is applied to the primary winding P4 in the series transformer 4 from the auxiliary winding Sa through the tap changing contacts L3 and R3 and the current limiting reactor 6, and the voltage from the secondary winding S4 is also decreased, and subtracted from the output voltage for the main transformer 3, thus, a compensation for the increase in output voltage is provided, and the proper output voltage is steadily supplied for the load.

With such operation, in the contact status of the tap changing contact L1 being closed and the R2 being closed as shown in Fig. 2, the circulating current I0 is caused to flow through the loop as shown in Fig. 3, but the circulating current I0 is suppressed to within the capacity of the tap changing contacts

L1 and R2 and the auxiliary winding Sa by the reactance of the said current limiting reactor 6.

In the contact status of the tap changing contact L1 being closed and the R1 being closed as shown in Fig. 2, the divided circulating currents I_L and I_R is caused to flow through the loop as shown in Fig. 4, when the magnetic fluxes B_L and B_R occurring on both sides of the current limiting reactor 6 cancel each other, resulting in that the current limiting reactor 6 will not act as a reactance, and no voltage drop is caused.

Fig. 5 shows a non-insulation type load tap changing AC voltage regulator 20, which is another preferred embodiment of the present invention. In the load tap changing AC voltage regulator 20, a particular element having the same function as the said load tap changing AC voltage regulator 1 is indicated, being provided with the same symbol.

This load tap changing AC voltage regulator 20 is configured in basically the same way as the load tap changing AC voltage regulator 1, however, it features that the primary winding P in the main transformer 3A is connected in parallel with the load with the auxiliary winding Sa being configured in the same way as the said load tap changing AC voltage regulator 1. With the non-insulation type load tap changing AC voltage regulator 20, the same function and effect as stated above can be provided.

Next, by referring to Figs. 6 to 8, application of the said load tap changing AC voltage regulator 1 to polyphase circuits will be described.

The example as shown in Fig. 6 gives the secondary winding 31 in a three-phase transformer 30 of three-phase input and three-phase output, and the primary winding 32 and the secondary

winding 33 in a series transformer, and in this case, by using a pair of windings 180-degree out of phase as a voltage regulation winding 34 for the secondary winding 31 in the three-phase transformer 30, addition and subtraction as by the said load tap changing AC voltage regulator 1 can be performed.

The example as shown in Fig. 7 gives the secondary winding 36 in a main transformer 35, and the primary winding 37 and the secondary winding 38 in a series transformer, as an adaptation of the Scott-connected transformer of three-phase input and single-phase two outputs. In this case, by making voltage regulation in the voltage regulation winding 39 for the secondary winding 36 in the main transformer 35 in phase with the said secondary winding 38 side, addition and subtraction as by the said load tap changing AC voltage regulator 1 can be performed as with the example as shown in Fig. 6. The N_1 and N_2 in Fig. 7 denote the number of windings for the said secondary winding 36, and the ratio of $N_1 : N_2 = 0.866 : 1$ is provided.

The example as shown in Fig. 8 gives the secondary winding 41 in a V-transformer 40 of three-phase input and single-phase one output, and the primary winding 42 and the secondary winding 43 in a series transformer. In this case, by making voltage regulation in the voltage regulation winding 44 for the secondary winding 41 in the V-transformer 40 in phase or opposite phase with the said secondary winding 43 side, addition and subtraction as by the said load tap changing AC voltage regulator 1 can be performed as with the example as shown in Fig. 6.

Next, the features of the load tap changing AC voltage regulator 1 (or 20) as a preferred embodiment of the present invention and the applications for it will be described.

With the load tap changing AC voltage regulator 1 (or 20),

providing the voltage detector circuit 7, the tap selector circuit 8, and the ignitor circuit 9 in the said tap changing control means 5 as electronic circuits, and the tap changing contacts L1 to L5 and R1 to R5 as semiconductor devices allows response within four to five cycles (40 to 50 msec).

The circuit configuration is based on the tap changing in the main transformer 3, resulting in practically no waveform distortion, and because a changeover with the tap changing contacts L1 to L5 and R1 to R5 is made in a zero-crossing operation, the output voltage can be changed over without instantaneous disconnection being caused and with no switching surge occurring.

In addition, the load tap changing AC voltage regulator 1 (or 20) is configured so that the capacity equivalent to the control width of the entire capacity is taken out with the auxiliary winding Sa for changeover, thus, compared to the system which changes over the main circuit current, the load tap changing AC voltage regulator 1 (or 20) can be designed with the contact capacity of the tap changing contacts L1 to L5 and R1 to R5 being substantially reduced. This leads to a substantial cost reduction when the tap changing contacts L1 to L5 and R1 to R5 are provided as semiconductor devices.

In addition, the main transformer 3 is of single winding construction, and the output of the auxiliary winding Sa is provided to serve either for addition or subtraction, thus, the capacity of the series transformer 4 can be reduced, which allows the main transformer 3 to be made compact.

With the load tap changing AC voltage regulator 1 (or 20) as a preferred embodiment of the present invention, the main circuit is configured with the use of the main transformer 3, thus, the overload capacity can be increased.

In addition, the tap changing contacts L1 to L5 and R1 to R5 are provided as semiconductor devices, resulting in that practically no noise is produced in changeover.

Unlike conventional voltage regulators, the load tap changing AC voltage regulator 1 (or 20) can be made to accommodate a different input voltage (380 V/100 V) by changing the specifications for the main transformer 3, thus, it features high adaptability to different voltages. Also, in polyphase input/output applications as shown in Figs. 6 to 8, a different voltage can be accommodated relatively easily.

The load tap changing AC voltage regulator 1 (or 20) as a preferred embodiment of the present invention can be used for reducing the power requirements of illuminators and other stationary systems (excluding inverter applied equipment), thus, it is useful for all users from large plants to general homes including overseas ones.

When this load tap changing AC voltage regulator 1 (or 20) is employed by a user who suffers from an unsteady power line as in some nations or districts, the supply voltage for various systems can be stabilized, which results in that the variety of systems are prevented from having a failure or malfunctioning, and can be satisfactorily operated, leading to power saving. An overseas different voltage (such as 415 V and 380 V) can be transformed to a domestically popular voltage (100 V, for example), being stabilized, thus, the load tap changing AC voltage regulator 1 (or 20) is well suited for a power supply device for exported equipment.

Also, with this voltage regulator, power can be supplied to a load facility, being stabilized at the minimum allowable input

voltage for it (90 to 95 V for a 100-V system), which allows reducing the power requirements of equipment for energy saving.

In addition, when a load facility is at a long distance from the power receiving facility, as is the case with golf links and a skiing ground, this voltage regulator can be used to compensate for voltage drop in the wiring system.

Improvement of the supply voltage in places of amusement such as a pinball house can also be made. A pinball house, etc. uses a number of small-sized transformers in the wiring system leading to the load equipment (such as pinball machines), thus, use of the load tap changing AC voltage regulator 1 (or 20) as a preferred embodiment of the present invention can improve the voltage variation rate for the small-sized transformers.

This invention is not limited to the above-stated embodiments, and permits various variants to be embodied within the scope of the claims.

This invention described above in detail provides the following effects :

With the invention as stated in the claim 1, it is possible to finely compensate for the variation in output voltage caused by a variation in input voltage or a change in load, and thus to steadily supply power and save energy. Tap changeover can be made with a minimum of noise, and because taps are changed by means of the semiconductor contacts for the auxiliary winding, unlike the main circuit tap changeover, the tap contact capacity can be decreased, which leads to the reduction in cost.

With the invention as stated in the claim 2, it is possible to configure the tap changing control means with simple electronic

circuits performing raid operation⁻¹⁶⁻ so that a tap changeover operation rapidly responding to the variation in output voltage caused by a variation in input voltage or a change in load can be provided.

What is claimed is :

1. A load tap changing AC voltage regulator that transforms the input voltage from the AC power supply with the main transformer to supply it for the load, and changes taps by means of the semiconductor contacts for the auxiliary winding installed in the said main transformer to change the output voltage to the load, and that features having a tap changing control means which detects the variation in output voltage to the said load that is caused by a variation in input voltage from the said AC power supply and changes the taps of the said auxiliary winding for appropriate taps to compensate for the variation in output voltage without causing instantaneous disconnection ; a series transformer which is connected to the output side of the said main transformer and adds to or subtracts from the said output voltage a certain voltage for compensating for the variation in output voltage that results from the tap changeover for the said auxiliary winding provided by the tap changing control means ; and a current limiting reactor which suppresses the circulating current caused to flow through the said auxiliary winding by the tap changeover for the auxiliary winding.

2. A load tap changing AC voltage regulator as stated in the claim 1 with which the said tap changing control means is provided with a voltage detector circuit that detects the variation in output voltage to the said load that is caused by a variation in input voltage from the said power supply ; a tap selector circuit that selects appropriate taps to compensate for the variation in output voltage from the taps for the said auxiliary winding on the basis of the detection result by the voltage detection circuit ; and an igniter circuit that changes the taps of the auxiliary winding without causing instantaneous disconnection and in a zero-crossing operation on the selection result by the tap selection circuit.

