Jan. 13, 1948. O. P. McCARTY 2,434,503

TAP CHANGING SYSTEM

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Fig. 1.

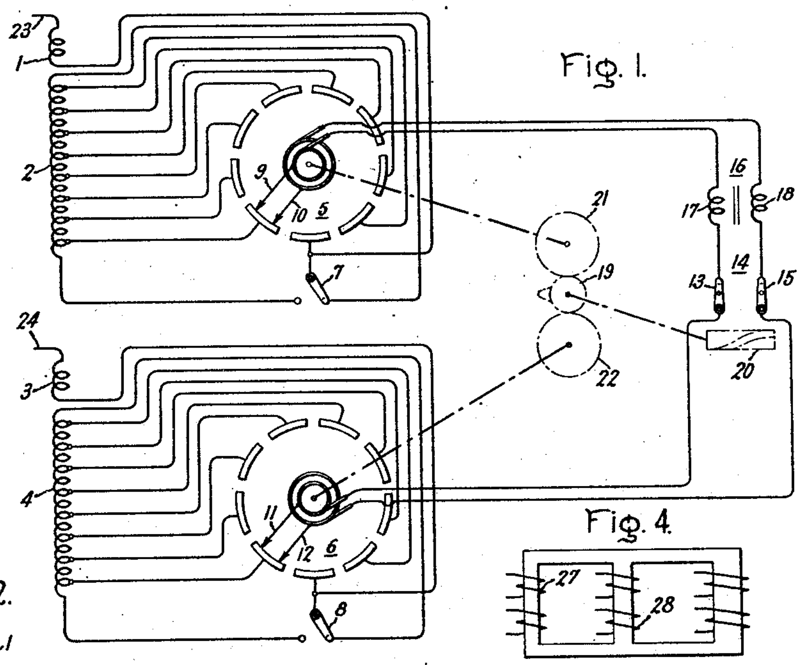


Fig. 4.

Fig. 2.

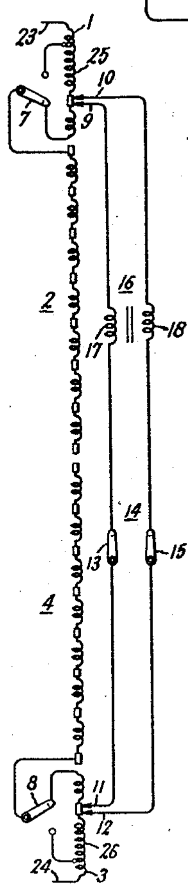
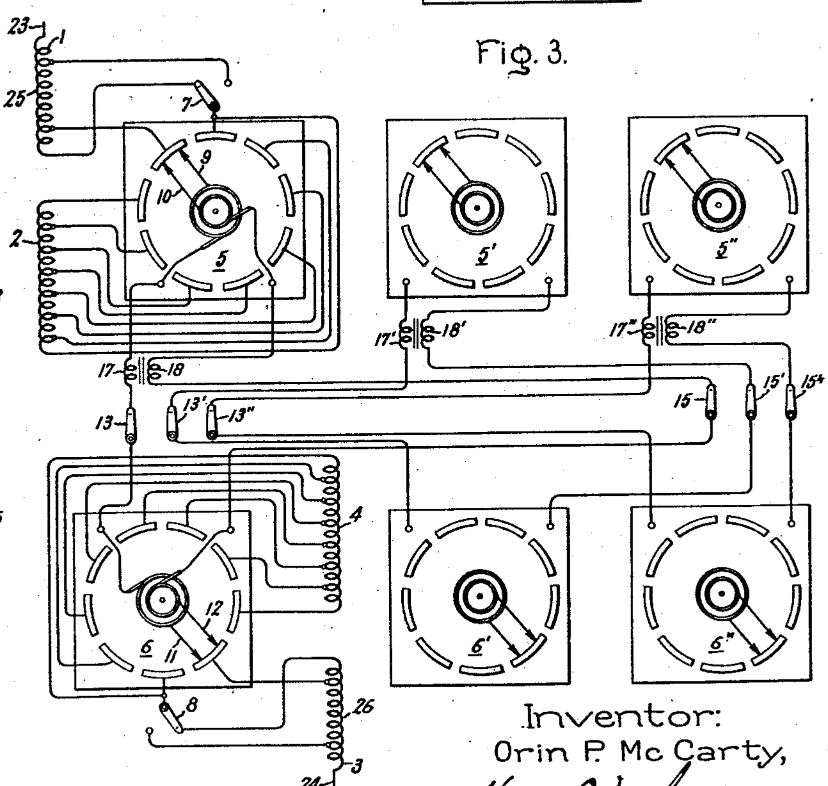


Fig. 3.



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2,434,503

TAP CHANGING SYSTEM

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11 Claims. (Cl. 323—55)

1

This invention relates to tap changing systems, and more particularly to improvements in wide range load ratio control circuits.

Changing circuit connections to taps on an electrical device when done under load in relation to taps on a transformer winding without interrupting the load current is called load ratio control, whether or not the voltage ratio of the transformer is actually changed. Originally, load ratio control circuits were used only to produce a change in transformer voltage ratio, but subsequently the same load ratio control systems and techniques were also used for changing the phase of the transformer voltage.

A well known load ratio control system employs a non-arcing duty ratio adjuster switch in combination with an arcing duty contactor. The ratio adjuster switch ordinarily has substantially the same number of contacts as there are taps and it performs the actual tap changing operation. The arcing duty contactor is connected in series with the ratio adjuster switch and it interrupts the current through the switch each time the switch moves from tap contact to tap contact. The ratio adjuster switch and the arcing duty contactor are dual circuit devices and they are so interconnected that the dual circuits are effectively in parallel so that the transformer load current is not interrupted by reason of the operation of the arcing duty contactor, this contactor merely operating alternately to open two effectively parallel circuits. The non-arcing duty ratio adjuster switch usually consists of a plurality of fixed contacts which are connected respectively to the winding taps and which fixed contacts are arranged in a circular path. These fixed contacts are engaged by a pair of contact fingers which move in an effectively circular path in going from tap contact to tap contact. The arcing contactor, on the other hand, may be a relatively simple device having only two sets of alternately operable contacts, but as this contactor performs the arcing duty of the circuit, it is relatively much more expensive than the ratio adjuster switch because in large power transformers the amount of energy which must be interrupted is quite large.

It is highly desirable that the ratio adjuster switches be standard'zed as to the number of tap contacts that they have and the spacings between these tap contacts, which spacings are determined by the voltage range of the multi-tap winding. Sometimes, however, it is necessary to provide a wider tap range and a greater number of taps or voltage steps that can adequately be

2

obtained from a standard ratio adjuster switch and under these conditions the ordinary solution of the problem is to design a special ratio adjuster switch having an extra large number of tap contacts and having extra wide contact spacings so as to be able to operate over the increased tap voltage range. That solution of the problem, however, is relatively expensive because of the special design and construction problems involved.

In accordance with this invention, I utilize a plurality of standard ratio adjuster switches for obtaining an extra wide range of voltage control of a single transformer, and furthermore, I interconnect these ratio adjusters in such a way that only one arcing duty contactor is used. In this manner the increased cost is relatively small and is nowhere near double the cost of a single load ratio control mechanism because, as has already been pointed out, the arcing duty contactor is the most expensive part of the system, and there is no increase in the number of arcing duty contactors.

An object of the invention is to provide a new and improved tap changing system.

Another object of the invention is to provide a new and improved wide range load ratio control circuit.

A further object of the invention is to provide a simple and inexpensive system for effectively doubling the tap range of a load ratio controlled transformer.

The invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing, Fig. 1 is a diagrammatic illustration of an embodiment of the invention, Fig. 2 is a somewhat schematic representation of a modification of the invention, Fig. 3 is a diagrammatic view of a three-phase arrangement embodying a further modification of the invention, and Fig. 4 illustrates a suitable arrangement of core and coils on a three-phase transformer with which my invention may be used.

Referring now to the drawing and in particular to Fig. 1, I show therein four windings **1**, **2**, **3** and **4** which collectively may be considered one of the principal windings of a transformer, that is to say, either the primary winding or the secondary winding. These windings are all shown in line so that they may be considered as being threaded by the same flux or they may be considered as being on the same leg of a transformer core. The windings **2** and **4** are the main windings and they are each provided with a plurality of taps which connect respectively to the tap contacts of separate ratio adjuster switches 5 and 6.

In order to double the effective tap range of each ratio adjuster switch, the ratio adjuster switch has associated with it a reversing switch 7 and the ratio adjuster switch 6 has associated with it a reversing switch 8. These reversing switches each have a pair of fixed contacts which are connected respectively to the terminals of their associated main windings, that is to say, the fixed contacts of the switch 7 are connected respectively to the terminals of the winding 2 and the fixed contacts of the reversing switch 8 are connected to the terminals of the main winding 4. The common or movable contacts of the reversing switches are connected respectively to tap contacts, of their associated ratio adjuster switches, which are between the tap contacts which are connected respectively to the outermost taps of their associated main windings. These common contacts are also connected respectively to their associated auxiliary windings. Thus, the common contact of reversing switch 7 is connected to a terminal of the winding 1 and the common contact of the reversing switch 8 is connected to a terminal of the winding 3.

Each ratio adjuster switch has a pair of contact fingers, those for ratio adjuster switch 5 being contact fingers 9 and 10 and those for ratio adjuster switch 6 being contact fingers 11 and 12. The contact fingers of each ratio adjuster switch are so arranged that one or the other of them is always in contact with one of the tap contacts.

The circuit through the illustrated windings is completed by interconnecting the contact fingers of the ratio adjuster switches. Thus, contact fingers 9 and 11 are interconnected through a set of arcing contacts 13 of an arcing duty switch 14 and the contact fingers 10 and 12 are interconnected through another set of contacts 15 on the arcing duty contactor 14.

In order to prevent excessive circulating currents from flowing in the ratio adjuster contact fingers and their interconnections, when the fingers of any ratio adjuster switch are in a bridging position where they make contact with adjacent tap contacts, a split reactor 16 is provided. This reactor has a pair of equal windings 17 and 18 on a common core, these windings being connected respectively in series with arcing contacts 13 and 15. They are so wound that circulating current will produce accumulative energization of the core of the reactor 16, thus introducing a high reactance in the path of any circulating current. However, load current which flows through the two halves of the reactor in the same direction has no appreciable effect upon the magnetization of the core and thus will introduce but negligible impedance in the load circuit, except during the momentary intervals when one contact finger is moving between tap contacts. During these momentary intervals all of the load current will flow through one or the other of the halves of the reactor 16.

The ratio adjuster switches 5 and 6 and the arcing duty contactor 14 are preferably mechanically interconnected by any suitable mechanism so that they will operate automatically in the proper sequence. Various mechanisms for accomplishing this result are well known in the art so that such mechanism is only illustrated schematically in the drawing. It may consist of a Geneva gear driver 19 which is directly connected to a cam 20 for operating the arcing contactor 14 and which driver operates Geneva gears 21 and 22 which are to operate the ratio adjuster switches 5 and 6 respectively. In practice, the reversing switches 7 and 8 will also be driven by this same mechanism as is customary in conventional load ratio control circuits which have only one ratio adjuster switch per phase of the transformer.

The windings 1 and 3 are not essential. They merely serve to increase the voltage or number of effective turns of the entire winding. The terminals of the entire winding, considered as the windings 1, 2, 3 and 4, in series, are indicated at 23 and 24.

The operation of Fig. 1 is as follows: The system is shown at one end or extreme position of its range of operation, and a circuit through it may be considered as starting at the terminal 23, going through the winding 1, through the reversing switch 7, then through the winding 2 to its lowermost tap, that is to say, to the tap which is closest to its lower terminal. The circuit then divides into two parallel branches, beginning at the ratio adjuster fingers 9 and 10, and these parallel branches continue through the halves 17 and 18 of the reactor 16, then through the arcing contacts 13 and 15 of the contactor 14, and then through the ratio adjuster fingers 11 and 12. The circuit then continues as a single circuit to the lowermost tap of the winding 4, thence through all of this winding and through the reversing switch 8 and through the winding 3 to the other terminal 24. It will be assumed that the polarities of the windings 1, 2, 3 and 4 are additive in the circuit which has just been traced between terminals 23 and 24.

Assume, now, that it is desired to reduce the effective number of turns between the terminals 23 and 24 and thus to reduce the voltage between these terminals. This is accomplished by rotating the Geneva gear driver 19 counter-clockwise as viewed in the drawing. The first thing that will happen will be that the arcing contacts 13 will open, thus causing all of the current to flow through the other parallel branch. Next, contact finger 11 will move clockwise out of engagement with the tap contact with which it is shown in engagement, and in a short time it will move into engagement with the next tap contact in the clockwise direction. Arcing contacts 13 will now close and arcing contacts 15 will open, thus transferring the current to the other of the two parallel branch circuits, and immediately thereafter contact finger 12 will move between tap contacts into engagement with the next tap contact in the clockwise direction. The arcing contacts 15 will then reclose. It will now be obvious that the section of the winding 4 between its two lowermost taps has been removed from the circuit.

Continued counterclockwise rotation of the Geneva gear driver 19 will next cause the cam 20 to reopen the arcing contacts 13. This will immediately be followed by the disengagement of the contact finger 9 with its tap contact and its movement clockwise to the next tap contact. Arcing contacts 13 then reclose and arcing contacts 15 open and this is followed by the disengagement of the contact finger 10 from its tap contact and its movement into engagement with the next tap contact in a clockwise direction, whereupon arcing contacts 15 reclose. It will now be observed that the section of the winding

2 between its two lowermost taps has been removed from the circuit. This completes two steps of operation of the system and one complete rotation of the Geneva gear driver 19. Continued rotation will repeat the cycle described above except that progressively more and more sections of the windings 4 and 2 are alternately removed from the circuit until the ratio adjuster switches 5 and 6 have been rotated clockwise until their contact fingers make engagement with the lowermost tap contact of each switch. This will correspond to having all of the windings 2 and 4 cut out of the circuit so that only the windings 1 and 3 are in series between the terminals 23 and 24.

Reversing switches 7 and 8 are now moved to their other position. This does not interrupt the main circuit as the main circuit is not through these switches at this time. If, now, counterclockwise rotation of the Geneva gear driver 19 is continued, the successive movement of the contact fingers 11 and 12 clockwise back into engagement with the top contact with which they are shown in engagement will insert the lower end section of the winding 4, that is to say, the section between its lowermost tap and its lower terminal, into the main circuit in the reverse direction. Similarly, when contact fingers 9 and 10 move clockwise back into engagement with the tap contact with which they are shown in engagement, the corresponding end section of winding 2 will be reversely inserted in the circuit. Continued clockwise rotation of gear 19 will then cause the sections of the windings 4 and 2 to be alternately inserted in the circuit with reverse polarity until finally substantially all of these windings are back in circuit with their polarities reversed, at which time the system will be at the other extreme end of its range of operation. Obviously, reversal of the direction of rotation of the driving gear 19 will reverse the operations described above.

In Fig. 2 the tap contacts of the ratio adjuster switch 5 have been arranged in a straight line instead of in a circle and all but one of them have been inserted directly between the sections of the winding 2, and the tap contacts of the ratio adjuster switch 6 have been rearranged in the same way relative to the winding 4. The remaining tap contact of each ratio adjuster switch, which corresponds in each case to the lowermost tap contact shown in Fig. 1, is inserted in or makes connection to an intermediate tap in an additional winding, this winding being a winding 25 for the tap contact which is engaged by the contact fingers 9 and 10 and a winding 26 for the tap contact which is engaged by the ratio adjuster contact fingers 11 and 12.

The voltage of the windings 25 and 26 bears a special relation to the voltage of the windings 2 and 4 respectively, and also the tap in the windings 25 and 26 is inserted in a particular place relative to the terminals of these windings. This relation is as follows: Assuming that the winding 2 has N taps, including its terminals, (and therefore has N tap contacts) which divide this winding into $(N-1)$ equal sections, each of voltage V, then the voltage of winding 25 is $(N+1)$ V and the tap in the winding 25 to which a tap contact is connected is so placed that the voltage between this tap contact and the lower end of the winding 25 is V and the voltage between this tap contact and the upper end of the winding 25 is NV. The same relationship exists between the windings 4 and 26.

The switches 7 and 8, while having the same general purpose as in Fig. 1 of effectively doubling the range of operation of the system by permitting substantially two revolutions of the ratio adjuster switches within the operating range, are no longer reversing switches. The fixed contacts of switch 7 are connected to the terminals of the winding 25, and the movable contact of the switch 7 is connected to one end of the winding 2. Similarly, the fixed contacts of the switch 8 are connected to the terminals of the winding 26, and its movable contact is connected to a terminal of the winding 4.

The operation of Fig. 2 is as follows: The system is shown in approximately the mid-position of its range, and the circuit from one terminal to the other may be traced from terminal 23 through winding 1 and the large section of winding 25 in series, and then the circuit divides into two parallel branches at the contact fingers 9 and 10 and continues through the reactor 16, the arcing contactor 14 to the ratio adjuster fingers 11 and 12, where the parallel branch circuits come together again, and the circuit continues through the high voltage section of the winding 26 and the winding 3 in series to the terminal 24. As in Fig. 1, the windings 1 and 3 are not essential and they may be omitted if desired.

If, now, it is desired to increase the voltage between terminals 23 and 24, arcing contacts 13 may first be opened and then contact finger 9 may be moved to the next lowermost tap contact which, as shown, is at the upper end of the winding 2. Arcing contacts 13 are then reclosed and arcing contacts 15 are opened, contact finger 10 makes a follow-up movement downward to the upper end tap contact for the winding 2, whereupon the arcing contacts 15 are reclosed. It will now be observed that the low voltage section of the winding 25 has been cut out of the circuit. The next step will be to cause the successive upward movement of the contact fingers 11 and 12 to the tap contact on the lower end of the winding 4, the movement of each contact finger being preceded by the opening of its serially connected arcing contacts and being followed by the reclosure of these contacts before the other contact finger is moved. Continued alternate operation of the contact fingers and arcing contacts in the above directed manner will cause successive sections of the windings 2 and 4 alternately to be inserted in the circuit, thus increasing the voltage of the circuit in equal increments of voltage V for each step.

If, instead of raising the voltage of the circuit, it is desired to lower the voltage of the circuit, then switches 7 and 8 would be moved to their other positions. This would not affect the circuit and no current would be interrupted because the windings 2 and 4 are open circuited for the condition of the system shown in Fig. 2 so that movement of the switches 7 and 8 to their other positions merely connects the windings 2 and 4 to the opposite ends of the windings 25 and 26 respectively. If, now, the arcing contacts 15 are opened and the contact finger 12 moved to the uppermost or upper end tap contact of the winding 4 and this is followed by the reclosure of the arcing contact 15 and a corresponding cyclic operation of the arcing contacts 13 and the contact finger 11, it will be seen that the voltage of the circuit has been decreased by the voltage between any successive pair of tap contacts. In other words, the net result has been the substitution of the winding 4 for the high voltage section of the winding 26, and as the winding 4 has V volts less than the high voltage section of the winding 26, the voltage of the circuit has been reduced by V volts.

It will be understood that the tap contacts of the windings 4 and 26 will in practice almost always be arranged in a circle, as is shown in Fig. 3 and will be described hereafter, so that reversing the direction of operation of the system merely means that the last described motion of the contact fingers 11 and 12 from the tap contact, with which they are shown in engagement to the tap contact at the upper end of the winding 4, is the same as their going from one tap contact to the next adjacent tap contact in the reverse or opposite direction. Similar movement of the contact fingers 9 and 10 to the lowermost tap contact of the winding 2, the current through them in each case being, of course, first interrupted and then reestablished by the operation of their respective serially connected arcing contacts, will again reduce the voltage of the circuit by V volts. Continued operation, step by step, will then progressively cut out sections of the windings 4 and 2, thus progressively decreasing the voltage until these windings are all cut out of the circuit and only the windings 1 and 3 are in series between the terminals 23 and 24.

In Fig. 3 a three-phase system is indicated in which corresponding elements in the three phases have the same reference numerals, and distinction between phases is made by primes and double primes. Only the complete circuit for one phase is shown, and it will be understood that the circuits for the other two phases are exactly the same. The circuit for the phase illustrated is the same as shown in Fig. 2 except that the tapped windings with which the respective ratio adjuster switches 5 and 6 are associated are not in line and are therefore indicated as being on different core legs or as having out-of-phase voltages. For example, windings 1, 2 and 25 may be considered collectively as a winding 27 on one leg of the three-legged core, shown in Fig. 4, and windings 3, 4 and 26 may be considered collectively as a winding 28 on another leg of the core. The interconnection of these collectively considered windings, which the circuit shown in Fig. 3 produces, may correspond to a zig-zag connection in that, for example, the terminal 24 may be a common neutral for the three-phase system.

The circuit of Fig. 3 may be operated in such a manner as to produce a phase shift in the voltage between the terminals 23 and 24 by operating the ratio adjusters so as to vary the relative proportions of the windings 2 and 4 in the circuit. Actually, the only physical difference between Fig. 2 and the completely illustrated phase in Fig. 3 is that the tap contacts for the windings 2, 4, 25 and 26 are brought out from between the sections of the winding and are arranged circularly.

In practice, the correspondingly numbered switches and arcing contacts will all operate in unison so that conditions will be the same at all times in the three different phases.

It will, of course, be understood that the three-phase system may also operate to produce merely magnitude voltage control without phase shift and that all that is necessary in such case is to have the windings between the terminals 23 and 24, and the corresponding terminals of the other phases (not shown), on the same core winding leg or, in other words, so that they all have voltages which are in phase. That is to say, all of the windings associated with each phase of the system will then have in-phase voltages.

While there have been shown and described particular embodiments of the invention, it will be obvious to those skilled in the art that various changes can be made 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 I claim as new and desire to secure by Letters Patent of the United States is:

1. A regulating system comprising, in combination, electric induction apparatus having at least two insulated windings, one of said windings having N taps which divide it into $N-1$ equal sections each of voltage V, the other winding having three taps with the voltages between the intermediate tap and the other two equal to V and NV, respectively, a ratio adjuster switch having $N+1$ contacts connected respectively to said N taps and said intermediate tap and having a common contact for selectively engaging said $N+1$ contacts, and a second switch for selectively connecting the remaining two taps of said other winding to an end tap of said one winding.

2. The combination recited in claim 1 in which said insulated windings are on a common core.

3. A dual regulating system comprising, in combination, electric induction apparatus having at least four insulated windings divided into two groups of two each, each group having one winding provided with N taps which divide it into $N-1$ equal sections, each of voltage V, the winding of each set having three taps with the voltages between the intermediate tap and the other two equal to V and NV respectively, separate ratio adjuster switches each having $N+1$ contacts connected respectively to the N taps and the intermediate tap of the windings of each group and having a common contact for selectively engaging its $N+1$ contacts, a second pair of switches each for selectively connecting the remaining two taps of said other winding of each group to an end tap of said one winding of each group, and means for interconnecting the common contacts of said ratio adjuster switches so as to connect said groups of windings in series.

4. The combination recited in claim 3 in which each ratio adjuster has two common contacts, separate interconnecting means for connecting each common contact of one ratio adjuster switch to a corresponding common contact of the other ratio adjuster switch, separate arcing contactors connected respectively in said interconnecting means, and a split reactor the two halves of which are connected respectively to said interconnecting means.

5. Electric induction apparatus comprising, a pair of multi-tapped windings on a common core, a first pair of contacts for selectively making connection with the taps of one of said windings, a second pair of contacts for selectively making connection with the taps of the other of said windings, a split reactor, a pair of arcing duty contactors, means including one half of said reactor and one of said contactors in series for interconnecting one contact of each of said pairs of contacts, and means including the other half of said reactor and the other of said contactors in series for interconnecting the remaining two of said contacts.

6. The combination as recited in claim 5 in which said windings are on the same core leg.

7. The combination as recited in claim 5 in which said windings are on different core legs.

8. The combination defined in claim 5 in which said windings have in-phase voltages.

9. The combination defined in claim 5 in which said windings have out-of-phase voltages.

10. The combination defined in claim 5 in which said windings are on the same core leg, and means for operating said pairs of contacts for voltage magnitude control.

11. The combination as in claim 5 in which said windings are on different core legs, and means

for operating said pairs of contacts for voltage phase angle control.

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