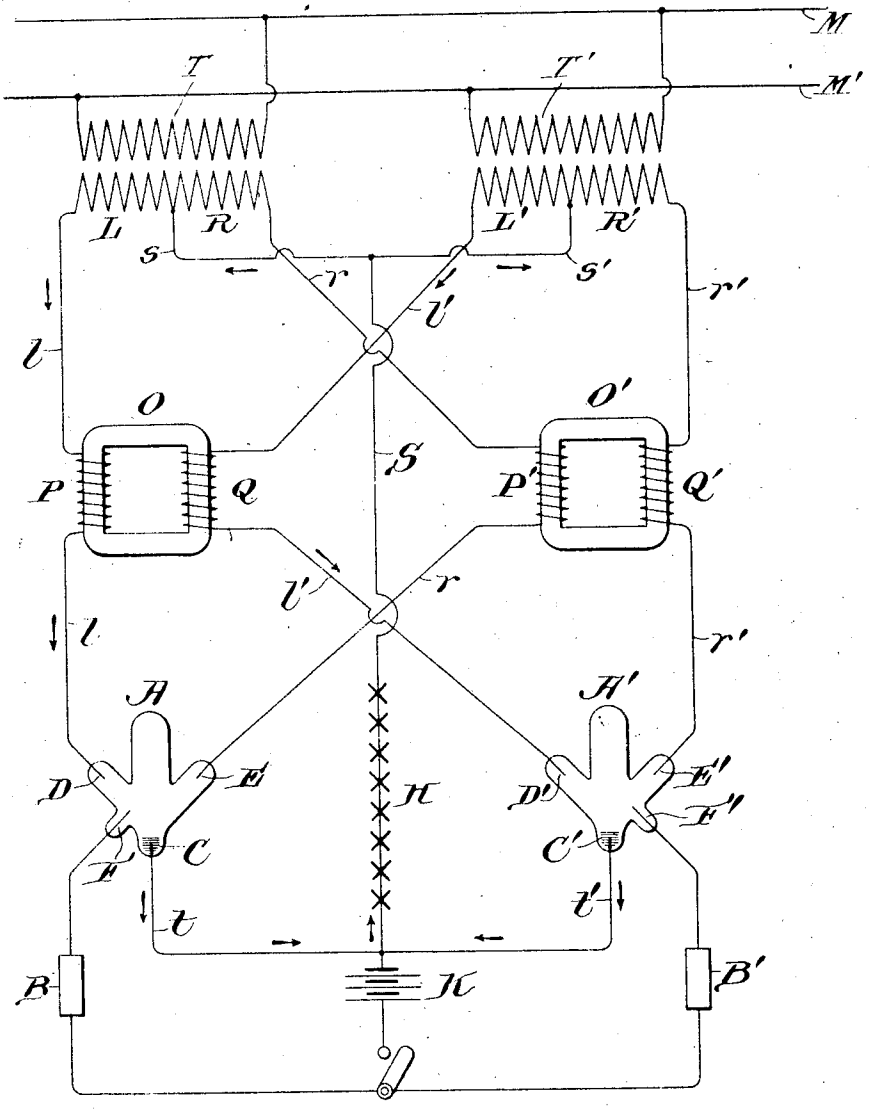
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RECTIFYING APPARATUS.

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1,086,300. Patented Feb. 3, 1914.



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RECTIFYING APPARATUS.

1,086,300. Specification of Letters Patent. Patented Feb. 3, 1914.

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To all whom it may concern:

Be it known that I, CHARLES A. KRAUS, a citizen of the United States, and resident of Newton Highlands, in the county of Middlesex and State of Massachusetts, have invented new and useful Improvements in Rectifying Apparatus, of which the following is a specification.

My invention relates to vapor electric apparatus and has for its object the provision of such circuit and distribution arrangements as will minimize and practically eliminate the difficulties and dangers due to short circuit arcing in the exhausted containers of such apparatus.

For illustration of my invention I take the mercury arc rectifier as a characteristic example of vapor electric apparatus in the operation of which short circuit arcing has heretofore proved a source of difficulty and of actual danger to the structure and integrity of the apparatus. As is well known, a mercury arc rectifier consists essentially of a highly exhausted envelop or container within which are provided two or more anodes and a mercury cathode, the anodes being constructed usually of solid conducting materials. The anodes being connected respectively to the outer terminals of a suitable exciting reactance and the mid- or neutral-point of the reactance being connected through a load circuit to the mercury cathode, the anodes allow the current to flow through the rarefied vapor in the container to the mercury cathode but refuse to allow current to flow in the reverse direction under normal proper working conditions. By this check valve action, only one-half wave of the impressed alternating current flows through either anode and the two half waves succeed each other by phase differences of 180° and combine in the load circuit to form a continuous, pulsating unidirectional current of which the wave form is dependent upon the reactance in the load circuit.

For reasons which are not yet well understood, it often happens that the check valve action of an anode fails to manifest itself, so that the current instead of flowing in the proper normal manner flows from one anode to the other. Since there is no considerable impedance in the circuit when the current passes between the anodes, the current reaches abnormally high values so that not only is the proper operation of the apparatus interrupted but, what is more serious, the integrity of the apparatus itself is endangered. This phenomenon is known as short circuit arcing. Although attempts have been made heretofore to prevent short circuit arcing by increasing the length of path between the anodes, this has not proved effective since the tendency to arc increases both with increase of potential and current, and short circuit arcs inevitably occur in rectifiers of comparatively large energy-capacity. For this reason the utilities of mercury arc rectifiers have been greatly restricted.

My invention is characterized by the introduction into rectifier circuits of suitably opposed, and, preferably, accurately balanced reactances in such manner that under the normal operating conditions these reactances do not affect the current to any practical degree but so that they may act as control reactances to keep the current below a predetermined safe value in case a short circuit arc should occur.

In the drawing hereto annexed there is illustrated in diagram an apparatus which exemplifies this invention in its application to the rectification of a single phase alternating current.

Referring to the diagram, A, A′ represent mercury arc rectifiers of the usual construction in which D, E and D′ E′ are the main or working anodes, C and C′ the mercury cathodes and F and F′ the auxiliary or starting anodes. The starting anodes may be put in circuit with a source of continuous unidirectional current as K which may be controlled by resistance indicated at B and B′. This portion of the apparatus is provided merely for starting it and my improvement is not concerned with it. The reactances which represent the sources of alternating current for the two rectifiers A and A′ are represented by L, R, and L′, R′. These reactances are substantially identical, and are so formed and associated with a source of alternating current that the terminal poles L, L′ and R, R′ respectively are

similar in respect to current-direction. The reactances L R and L′ R′ may thus be energized inductively by coils T and T′ from alternating current mains M M′. Between the source reactances and the rectifiers I provide mutually opposed, balanced, or neutralizing reactances P, Q, and P′, Q′, respectively, the members of each of these pairs being associated through a magnetic circuit O, O′, respectively. The cathodes C and C′ of the two rectifiers A and A′ are connected in parallel through lines t, t', to the line S in which the load H is interposed and from the line S to the mid points of the source-reactances in parallel through lines s, s'. The main or working anodes of each rectifier are connected respectively to the outer terminals of one of the source reactances, anodes D and E being connected respectively through lines l, r, to the outer terminals of the exciting reactance L, R, while the anodes D′ and E′ are connected respectively through the lines l', r', to the outer terminals of the exciting reactance L′, R′.

The line l includes the governing reactance P and the line l' includes the reactance Q which is opposed to or balanced by the reactance P. Likewise the line r includes the reactance P′ and the line r' the reactance Q′, so that the lines or connections from magnetically similar terminals of the two exciting reactances pass through governing reactances which are mutually opposed and preferably perfectly balanced.

Assume now that the entire apparatus is in operation to rectify a single phase alternating current converting it into a pulsating unidirectional current through the load H. During a one-half phase current will pass as indicated by the arrows from terminals of L and L′ through the lines l and l', reactances P and Q to anodes D and D′ respectively, thence to cathodes C and C′, respectively, thence through lines t, t', through load H and line S and lines s, s' to the neutral- or mid-points of the two exciting reactances, thus completing the circuit. During this half phase by reason of the check valve action of the anodes E and E′, no current flows from the opposite terminals of the exciting reactances through line r, r', that is, the magnetic circuit O, O′, are each alternatively working and idle, as they are energized in parallel from the two sources, or not. When, however, the next half phase is established, the check valve action of anodes D and D′ comes into play, lines l and l' become inactive and the current flows through r, r' to anodes E and E′, cathodes C and C′, and thence as before through t, t' through load H, line S and lines s, s' to the mid-points of the exciting reactances.

Under the above described normal working conditions, the governing reactances P, Q or P′, Q′ as the case may be, offset and neutralize each other so that the only energy loss due to their presence will be that represented by their simple ohmic resistance.

When current is flowing through anodes D, D′, the magnetic circuit O is energized, but the magnetic circuit O′ is not energized. The reactances P, Q, mutually balance each other up to the time of the occurrence of a short circuit. When a short circuit occurs, the current will flow, say from D to E, and through line r, which, of course, will energize one side of the magnetic circuit O′, and in so doing develop the full reactive power of the widing P′, and, since the increase of current in winding P, due to the short circuit supposed, is not accompanied by corresponding increase in the winding Q, feeding the winding D′, the difference in the current values in P and Q must furthermore overcome the unbalanced reactive power of the winding P, acting in series with P′ to limit the current flow. The dangerous and heretofore possibly destructive action of a short circuit arc is therefore suppressed and the apparatus preserved from injury. After such a short circuit arc in one of the rectifiers A, A′, the establishment of the next half cycle will cause the rectifier to resume its normal operation.

The only condition in such an apparatus as herein described under which short circuit arcing can cause undesirably or dangerous high currents to flow through the rectifiers is that of simultaneous short circuit arcing in the two rectifiers. Only in the case of the check valve action of, say, anodes D and D′ ceasing to function simultaneously can the current due to short circuit arcs reach abnormally high values.

The phenomenon of short circuit arcing occurs in a rectifier or analogous apparatus at intervals which depend on the construction of the rectifier, and also on the current and potential and when it occurs it endures at the most for half a cycle in a properly designed apparatus. Therefore, to enable short circuit arcing to produce abnormally or dangerously high currents in an apparatus arranged according to this invention, the short circuit arcing must coincide in the two rectifiers within a period of time considerably less than that occupied by a half cycle, since it is safe to assume that the short circuit arc is produced only when the potential wave during the half cycle is approaching its maximum value. But in order to demonstrate the practical immunity of an apparatus such as above described from the dangers of short circuit arcing, let us assume that this phenomenon may occur at any time during an entire half wave period; and let us assume also that the apparatus is working with a 60 cycle, single phase alternating current. Furthermore, in order to be as far as possible on the

safe side in this calculation, let us assume the rectifiers to be so constructed that either of the rectifiers will short circuit on the average of once in 15 minutes. Then the probability of a short circuit arc taking place in any one-half cycle in either of the rectifiers is represented by the fraction:

$$\frac{1}{1.08\times10^5}.$$

Then if two rectifiers of this kind are working under the conditions named, the probability that the short circuit arcs in the two rectifiers will coincide in any given half cycle is represented by the fraction:

$$\frac{1}{(1.08\times10^5)^2}.$$

Otherwise expressed, short circuit arcs may be expected to coincide on the average once in $1.08^2\times10^{10}$ cycles, or one coincidence in 1.62×10^6 minutes, or 1120 days of 24 hours each. In other words, the application of my invention lengthens the mean period of dangerous arcing from once in 15 minutes to something over once in three years. For commercial purposes this practically eliminates arcing as a factor of operation, because at the present time no rectifiers on the market have a life which approaches three years. So far as I am informed the life of present commercial rectifiers averages about 1200 working hours.

It should be noted that the introduction of the above described invention does not decrease the efficiency of a rectifying system because the capacity of the system is doubled while the governing reactances have no serious influence on the efficiency of the system, since only their ohmic resistance is normally operative.

What I claim and desire to secure by Letters Patent is:

1. In apparatus for rectifying alternating currents, two complete rectifying units, two sources of alternating current, two pairs of mutually opposed reactances, leads from similar terminals of the alternating current sources passing respectively through mutually opposed reactance members and thence, one to an anode of one rectifying unit, the other to an anode of the other rectifying unit, and a connection common to the cathodes of the two rectifying units to points neutral with respect to the alternating current sources.

2. In a vapor electric apparatus, two containers, each having a cathode and anodes, two sources of alternating current, two pairs of mutually opposed reactances, leads from similar terminals of the alternating current sources passing respectively through mutually opposed reactance members, and thence one to an anode of one container, the other to an anode of the other container, and a connection common to the two cathodes, and to points neutral with respect to the alternating current sources.

3. In a vapor electric apparatus, two containers, each having a cathode and anodes, two source reactances, two pairs of mutually opposed reactances, leads from similar terminals of the source reactances passing respectively each through one of a pair of mutually opposed reactance members, and thence one to an anode of one container, the other to an anode of the other container, and a connection common to the two cathodes, and to the mid-points of the source reactances.

4. The combination with transforming apparatus comprising two secondary windings, of two current rectifiers connected to said windings, and two impedance devices each comprising two windings that are respectively interposed in the connections between the rectifiers and the secondary windings of the transformers, the connections to each rectifier including a winding of each impedance device.

5. The combination with transforming apparatus comprising two secondary windings, of two current rectifiers connected to said windings, and two impedance devices each comprising two normally complementary windings that are respectively interposed in the connections between the rectifiers and the secondary windings of the transformers, the connections in each rectifier including a winding of each impedance device.

Signed by me at Boston, Massachusetts, this 3rd day of November, 1910.

CHARLES A. KRAUS.

Witnesses:
CHARLES D. WOODBERRY,
ODIN ROBERTS.