

COMPOUNDING DYNAMOS FOR ARMATURE REACTION.

BY ELIHU THOMSON.

Considerable attention has recently been drawn to the subject of means for counter-balancing or preventing armature reaction in dynamo-generators or motors. The valuable paper of Messrs. H. J. Ryan, and Milton F. Thompson, read before the INSTITUTE at its meeting on March 20th, called forth considerable discussion as to the actual utility or need of added devices, which undoubtedly render a machine more complex, but which can certainly be made to obliterate armature reaction or overcome its effects. The opinion which seems to prevail amongst engineers is, that by taking advantage of the best principles of design, the output of our machines is not limited by armature reaction, but rather by heating, or the capacity to diffuse that heat which is sure to be produced during operation.

The writer's views are in accord with the general sentiment indicated by the discussion of the paper in question, excepting that he conceives that it may on occasion become desirable to possess a structure, either generator or motor, in which a load which would inevitably overheat the machine if continuous, may be borne without destructive results for short periods only. The development of engineering work may in fact demand, occasionally, machines which would be regarded as emergency machines, to be operated with the highest possible loads for short periods. It is sometimes desirable that a dynamo be adapted to driving at different speeds while maintaining the same potential at the terminals, as in the case of direct driven dynamos coupled

with engines of different makes and speeds. Such an adaptation would require a change in the armature turns, or in the field excitation, the former demanding a reconstruction amounting to the production of a special type, while the latter, change of field strength, might involve such a weakened field at the higher speeds as would be incompatible with proper commutation. In such cases means and methods for securing proper commutation and neutralizing reaction may become quite useful. The subject itself has been worked upon by the writer as far back as 1879. At first a peculiar disposition of the field coils and pole pieces was selected, unfavorable to armature reactions, and later in a patent applied for by the writer in the year 1885, the series coil of a compound-wound machine was so disposed as to add, under load, a magneto-motive force to the field in the region of armature opposition, and as a consequence to diminish somewhat the magneto-motive force of the field where the reaction of the armature was positive, or assisting.

In the present paper, however the writer desires to bring to the attention of the INSTITUTE a different type of dynamo, worked upon by him some three or more years ago, in which there is no series winding whatever, though the machine is in effect compounded, or over-compounded at will.

It is expressly to be understood at the outset that the present paper is not intended to advocate the disposition described as a desirable commercial structure, or even as one which will be likely to come into practical use on any scale. On the contrary, it is believed to be open to objections which would take it out of competition with ordinary types in which the compounding effect is secured by the series coil or load circuit wound as usual as a part of the field energizing conductor.

The machine is, however, interesting as bringing out forcibly the capability of the armature current to neutralize its own effects in a proper structure and maintain, or even increase, the potential at the brushes under heavy loads. In fact the current in the armature in the type of machine herein treated, is made to react under load to magnetize a portion of the field structure which at no load is neutral or nearly so. The reaction may thus be made to give rise to a magnetic flux sufficient or more than sufficient to compensate for its effect in diminishing the flux of the other or excited portion. The result is accomplished by dividing each field pole into a portion which is left unwound and a portion

which is wound and excited in shunt or separately. At no load only, the wound polar portions act to generate the open circuit E. M. F. As the load is put on, the unwound or dead poles become active in consequence of a magnetic flux developed in them by the armature currents themselves, that is, in consequence of the M. M. F. generated by the current in the winding of the armature itself. The disposition of the poles in a bipolar structure would be represented by Fig. 1, where $\Delta \Delta$ are the excited poles, or wound field cores, under the fringe of which commutation is effected, while $D D$ are the "dead" poles or sections of polar surface unenergized at no load. A dotted line $a a$ may pass through the neutral or non-polar portion of the armature iron, threaded by all field lines on one side, while the lines $b b$ may indicate the diameter of commutation on which the brushes rest. In such

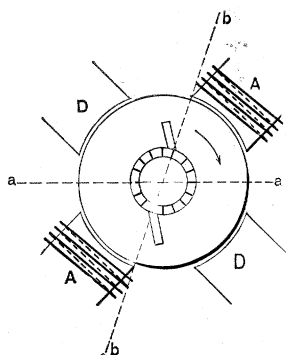


FIG. 1.

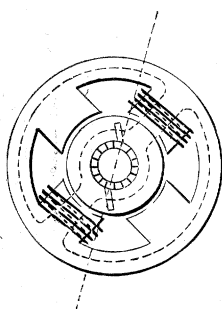


FIG. 2.

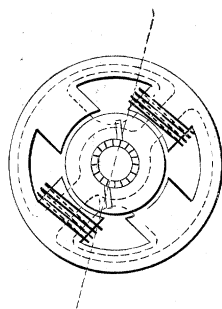


FIG. 3.

a structure by choosing the position and spread of the "dead" poles in relation to that of the wound or excited polar portions, and adjusting the M. M. F. of the initial field relatively to the turns on the armature and the speed of driving, the effect of compounding or over-compounding may easily be obtained. The "dead poles" may be made adjustable in position so as to vary the effective M. M. F. of the armature upon them and various changes in relations of the parts are conceivable.

In Figs. 2 and 3, an attempt has been made to represent the magnetic flux under no load and under load respectively. In Fig. 2 the flux in the air-gap between the excited poles $\Delta \Delta$ and the armature may be considered as of uniform density except at the edges, while in Fig. 3 it is, under the same poles, somewhat diminished towards the diameter of commutation. In Fig. 2

the dead poles are without flux across the air-gap, while in Fig. 3 the density increases from one edge to the other in the direction of rotation.

Fig. 4 is from a photograph of the dynamo constructed in accordance with the principle under discussion. It is multipolar, having four wound poles and four dead poles alternating in position around the armature. The latter is of standard iron projection type being in fact identical in construction and dimensions with the armatures used about three years ago in reg-

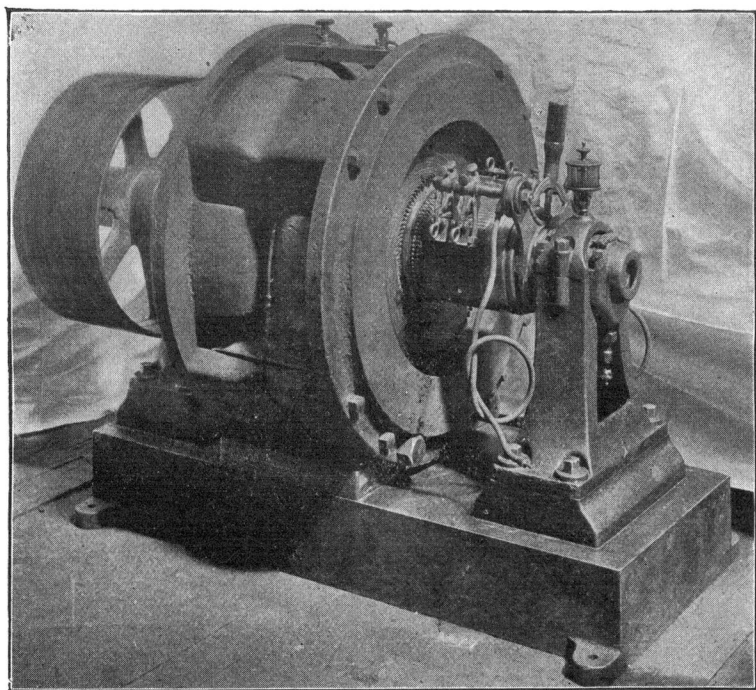


FIG. 4.

ular four-pole dynamos of the marine type of the Thomson-Houston Electric Co.

The principal data of the armature construction are as follows :

Diameter over all.....	17	inches.
Length (laminations).....	8	"
Radial depth of laminations....	4	"
No. of projections	87	
Width of slots.....	.34	inch.
Depth of slots.....	.75	"

The armature is series drum-wound and has two conductors in each slot. The commutator has 87 segments. The new field

system was constructed of two rings of cast open hearth steel having heavy lugs, four in number, projecting laterally from each ring on one side, and forming the dead poles when assembled in the machine. Separate castings for carrying the field coils and constituting the active poles were made, wound and bolted between the two ring castings of the field. The arrangement will be understood at a glance from an inspection of Figs. 5 and 6. Fig. 5 is a section of the field in a plane passing through the dead poles and the axis of the armature, and Fig. 6 is a similar section through the active or wound poles. The wound cores have a section of $3\frac{1}{2}$ in. \times 8 in. and are of steel. The field was bored to $17\frac{1}{4}$ in. thus giving a clearance of $\frac{1}{8}$ in. around the armature. The excited or wound poles covered each about 5 inches, the dead poles each $5\frac{1}{2}$ in., leaving spaces between wound and dead poles of about $1\frac{1}{2}$ in. The face of each dead pole is $5\frac{1}{2}$ by 8 in.

The coils on the active poles can be connected in shunt to the

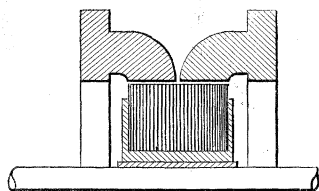


FIG. 5.

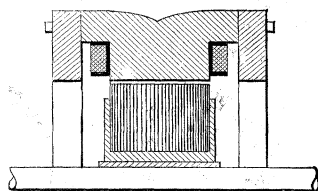


FIG. 6.

armature terminals with a variable rheostat in the branch, or separately excited as desired. It was found that for the purposes of test that the latter arrangement was most satisfactory as the exciting current could then be adjusted to any given value and would remain undisturbed by variations in the potential difference between the brushes or terminals of the machine.

Fig. 7 shows the relation of volts at the terminals to varying exciting current at no load (full line) and at 30 amperes load (dotted line) with a speed of 800 revolutions per minute. It will be noted that the load has caused an increase of voltage particularly at the relatively higher excitations. The normal current of full load for the armature as constructed and used in the regular multipolar field was 140 amperes, and it was found that as the load was increased steadily during a run, the potential was not only maintained but increased with each increment of load, thus showing an over-compounding effect. This effect was less marked

when the initial excitation was weak ; as when less than three amperes traversed the field coils. The over-compounding under load was, of course, still more increased when the field coils were connected in shunt to the armature. Thus, at a little over 750 revolutions per minute with an exciting current of four amperes, the open circuit volts were 84, rising to 104 when a load of 130 amperes was put on with an increase of the exciting current to 4.8 amperes.

It was noticed that on any considerable increase of load being made, the potential rose in some cases as much as 5 or 6 volts

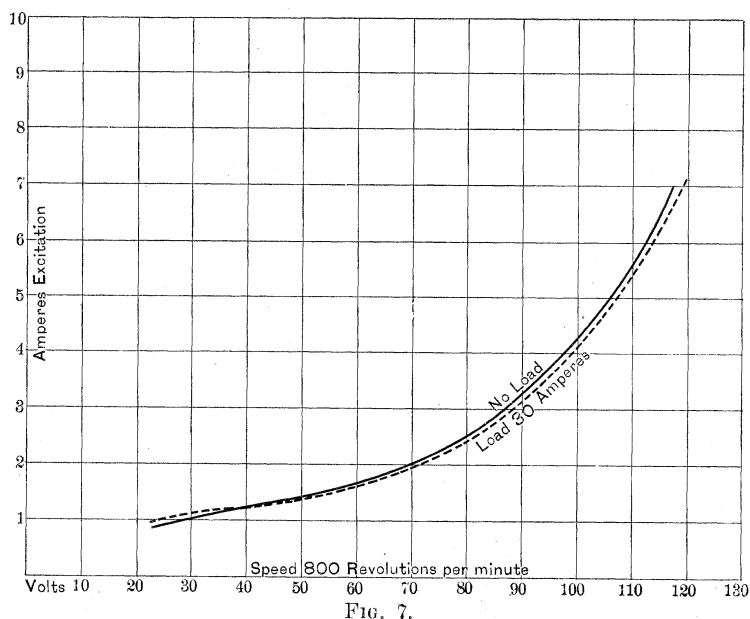


FIG. 7.

above the point at which it would remain; or which it would reach after a short interval. Similarly it was found that the sudden taking off of load caused a temporary fall below the stable voltage under the new or diminished load conditions. This curious effect was traced to the difference of time between that needed to build up or cut down the flux in the dead poles, as compared with that required to cut down or build up the excited poles, which, being wound with wire, were naturally more sluggish under the conditions of use. Currents would be induced in the coils under each change of flux, which change itself would

thereby be rendered more gradual. The dead poles being unwound could respond more rapidly. Any increase of load would of course tend to break down the wound poles and to increase the flux in the dead or unwound poles, and the taking off of load would have the opposite effect.

Fig. 8 shows a compounding curve obtained under a constant excitation of four amperes at a speed of 790 revolutions, the load being varied from 0 up to more than thrice the full load. It will be noticed that the potential at first increases, and only breaks down under extremes of load. The final breaking down

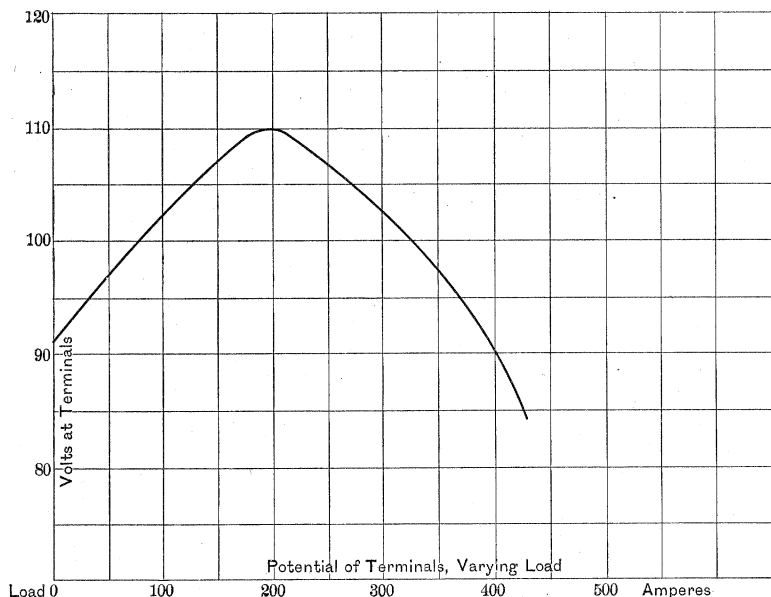


FIG. 8.

is doubtless due to saturation of the forward portions of the dead poles, together with the armature core projections. Part of the drop was undoubtedly due to resistance at the brushes which were of carbon, and by no means fitted to conduct off such heavy currents. Taking this drop and the drop over the armature conductor itself, it is not surprising that at the high loads the potential should fall off.

A horizontal plotting of the potentials generated in the armature coils under no load obtained by the two brush method of Dr. S. P. Thompson, is given in Fig. 9, the relative positions of

the wound and "dead poles" being marked in dotted lines, and the arrow indicating the direction of movement of the armature relatively thereto.

Fig. 10 gives the same plotting under a load of 100 amperes and accentuates the effect of the armature reaction in magnetizing the dead poles. The curves are only approximate indications

FIG. 9.

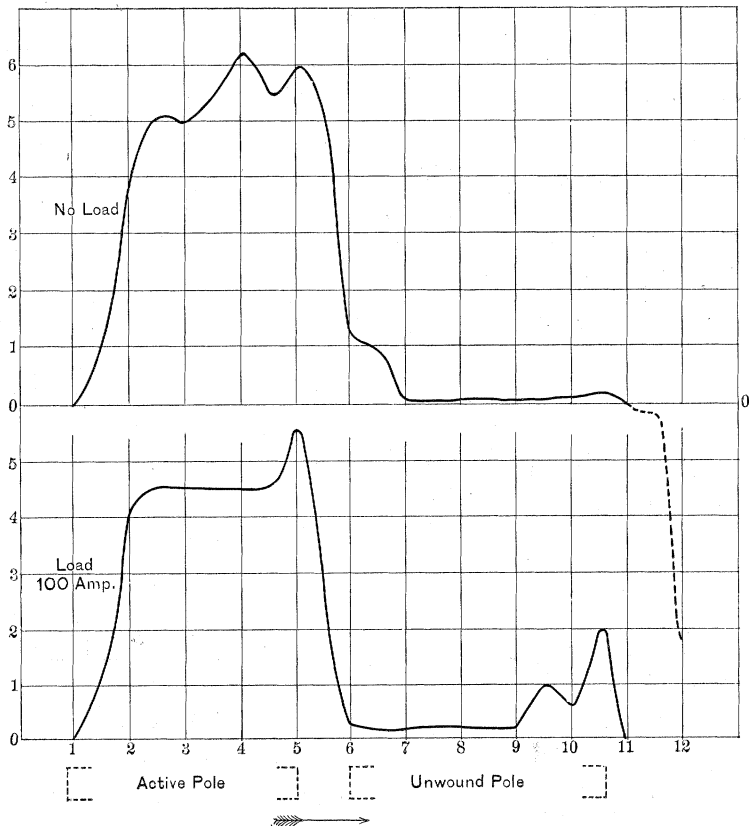


FIG. 10.

owing to the fact that the number of points at which readings were taken was less than was desirable, and because in some cases it was difficult to maintain all conditions unchanged, particularly with the very heavy loads.

Figs. 11 and 12 show a similar plotting for abnormal or extreme loads. The former shows how completely the wound pole has

been broken down by armature reaction, and how the unwound poles have now become the chief working field poles, or rather how the armature winding itself has furnished the field for its own cutting. A calculation of the flux density at the forward edge of the unwound pole shows that the magnetization has risen to saturation. The other parts of the pole are shown to be still

FIG. 11.

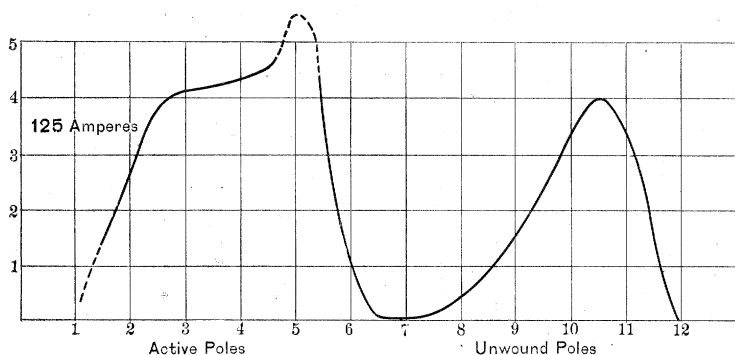
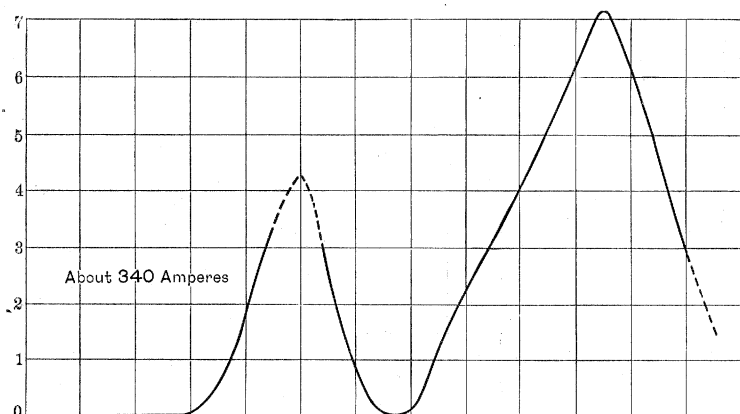


FIG. 12.

susceptible of increase of flux, but their relation to the armature is far less favorable for its generation.

The machine described is probably chiefly interesting from a theoretical aspect. Still it shows clearly that so far as the effect of the series field on compound wound machines is concerned, the electrical engineer has other resources at his command giving similar results. It cannot be doubted also that the design of armature and field might be considerably improved with special

regard for the particular feature of compounding. A feature of the machine which developed itself when carbon brushes were used, was that even at heavy loads the brushes could be set back from their maximum position, or true diameter of commutation in this case, and that the movement was attended with little, if any increase of spark, while the potential steadily went down. It was thus easily possible to adjust the potential by a backward movement of the brushes in the space between the unwound and wound poles, while the slight sparking under the carbon brushes was not increased thereby. The writer has never noticed this effect in so pronounced a degree in any other structures, but thinks that it may not be peculiar to this machine.

A further interesting consideration is the effect of dispensing with the wound poles altogether, and either neglecting to employ any reversing or commutating field while maintaining the brushes near the forward edge of the field poles which now remain, namely, the unwound poles, or employing commutating arrangements similar to those used by Mr. Sayers; that is, returning the leads through slots in the armature under the strong induction of the forward edge of the pole as the armature leaves it. In such a case it would appear from theoretical considerations that the machine should, if it possessed any permanent magnetism, excite itself as a series dynamo entirely without any winding on the field and solely by the action of the armature winding itself. This fact was, I believe, first pointed out by Drs. J. and E. Hopkinson.

In conclusion it may be stated that tests of the machine used to generate single phase and three phase alternating currents in its armature winding were made by dispensing with the commutator and substituting rings and connections common in such cases. The results indicated a substantially similar effect of compounding, but to a less degree, owing no doubt to the fact that the phase of the electro-motive-force generated by the wound pole flux would not coincide with that due to reaction on the dead poles, since the position of the poles with relation to any portion of the moving wire is different at the same instant.

The Secretary announced that the American Telephone and Telegraph Co. [long-distance] had extended to the members of the Institute the courtesy of their lines throughout the United States during the continuance of the meeting.

[Recess until 10 A.M.]