THESIS

THE CONSTRUCTION OF A
DOUBLE-CURRENT GENERATOR

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The Construction

of a

Double-current Generator

A Thesis

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The Faculty

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By

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Preface.

The object of this thesis was the reconstruction of a dynamo-electric machine from a direct current motor into a rotary converter, or double- current generator. Also the construction of three s_ngle phase transformers, suitable for changing the voltage of the alternating current obtained from the above machine, to a number of convenient voltages for laboratory use.

In working up the best methods to employ in the different steps of the construction, we are greatly indebted to Professor A.R. Sawyer and Professor M. M. Cory for their supervision and helpful suggestions. We are also very grateful to the men in charge of the pattern shop, the machine shop, and foundry for so generously aiding us in the matter of machinery tools and timely advice.

In the text which follows, we have endeavored to give a very careful discussion of the problems solved and the methods used, so that they may be readily understood by those having a general knowledge of mathematics and machine shop methods.

Signed,

The Authors.

Chapter I.

SLIP-RINGS AND END FRAME CONSTRUCTION.

The machine used in this work was a Westinghouse two horse power, direct current motor driven by another motor of the same size and type. Our object was to rebuild the machine so that it would deliver three phase alternating current in addition to direct current.

The first thing done was to build a new end frame for the pulley end of the motor, which would place the bearing far enough away from the armature to allow space for three slip-rings. Blue-print No.I shows the arrangement of slip-rings and brushes. Instead of building a pattern for the frame, we decided to remove the one from the commutator end and duplicate it for the slip-ring end. To do this, it was necessary to build a core-box, as shown in blue-print No.II. This core was turned out on a lathe and then the core-box was made by means of a plaster-of-Paris cast. In order to use the frame for a pattern, it was necessary to plug all openings. The plugs for the ends of the bearing were made in the form of core-prints. In places where finish was needed, we fastened heavy strips of paste-board to the pattern. This gave plenty of extra stock for machining.

The alternating current brushes were ordered from the General Electric Company and it was necessary to design a suitable yoke to support them. Blue-print No. III shows a full-size drawing of the yoke which we built for this purpose. It is secured to the collar on the inner end of the bearing, by means of a set-screw.

A pattern was made for a brass cylinder 4.75" outside, and 3.75" inside diameter. Three slip-rings were turned from this cylinder, each of them being 0.625" wide and 0.375" thick. These slip-rings were insulated from the shaft by a wooden cylinder whose outside diameter was equal to the inside diameter of the rings and whose inside diameter was the same as the diameter of the shaft. This wooden cylinder was secured to the shaft by a set-screw with a counter-sunk head, the head being covered with insulating wax. Short screws were used to fasten the slip-rings to the wooden cylinder. Holes were drilled laterally in the insulating cylinder to provide conduits for the connections to the armature windings.

It was found that the shaft of the machine was too short for the new arramgement, therefore a short piece of steel was welded on to the end by the oxy- acetylene process.

The studs which carried the brush-holders, were carefully insulated from the frame to prevent grounding.

ChapterII.

TRANSFORMERS.

The transformers constructed were of the low-voltage shell type, and were designed for 78 volts primary and 6, 18, 12, and 110 volts secondary. The most simple transformer to meet these requirements is the auto-transformer, three of which were constructed. We were somewhat handicapped in our design by the fact that it was necessary to use punchings which were originally designed for another transformer. As a result the core appears somewhat out of proportion to the coil.

All computations for size of wire, number of turns, volume of core, etc., were based on a design as given in "The Elements of Mechanical and Electrical Engineering", (Supplementary Volume), published by the International Text-book Company.

Design of a Single Phase, 0.5 K. W., Shell-type, Auto-transformer:

As we have a 2 H.P. machine, the total power will be approximately 1500 watts. Hence the watts per phase will be about 500. Therefore we shall design a 500 watt transformer for each phase.

D.C. voltage	= 220 volts.
A.C. voltage, (Y-connection)	= 78 volts.
Secondary volts	= 78.
Desired primary volts	= 110.
Assumed efficiency	= 93.5 %.

Input = 500/.935 =535 watts

Therefore the total loss at full load should not exceed 35 watts. This loss is divided approximately as follows:

Copper loss	= 20 watts
Hysteresis loss	= 12 watts
Eddy-current loss	= 3 watts
Total loss	= 35 watts

The loss per cubic inch of core, for 60 cycles, at a density of 30000, is about o.15 watts. Therefore the volume of the core is,

12/.15 = 80 cu.in.

The area of the punching is,

(5,53 x 8.92) - 2 (2.2 x 3.23) = 35 sq.in.

Use 34 sq. in. to make allowance for champfered corners. Then the thickness of the core becomes:

80/34 = 2.35".

Make the core 2½ inches thick.

The total amperes input at full load is,

Primary watts / Primary volts = 535/78 = 6.86 amps.

The maximum current which the wire must carry is,

110/78 = 6.86/X

X = 78 x 6.86/110

= 4.76 amperes.

Allowing 1200 circular mils per ampere to get the size of the conductor, we have,

$4.76 \times 1200 = 5712$ or approximately 6000 cir. mils.

From this we see that #12 or #13 will be close enough for our purpose.

Width of core	= 2.187"
Depth of core	= 2.500"
Length of core	= 3.230"

#12 wire is about 0.1" thick including insulation.

The primary coil has to be provided with a sufficient number of turns to generate a counter electromotive force equal and opposite to the impressed electromotive force. The number of turns required to set up this electromotive force will depend upon the magnetic flux ϕ which threads through the turns. The maximum magnetic flux through the coil will be;

$$\phi = B_{max} \times A.$$

Where B_{max} is the maximum value which the magnetic density reaches during a cycle, and A is the area of cross-section of the iron in the core.

In this case B_{max} is 30000 lines per square inch, and the area of cross-section of the iron is,

$2.5 \times 2.187 = 5.46$ sq.in. hence,

$\phi = 30000 \times 5.46 = 163800.$

Taking the electromotive force generated in the primary as the equal and opposite of the line voltage, we may write, $E_p = 4.44\ \phi\ T_p\ n / 10^8$ where,

ϕ = the maximum value of the magnetic flux thru the core;

T_p = the number of turns on the primary coil;

n = the frequency, (cycles per second).

E_p = the impressed primary voltage.

Applying the above formula to the case in hand, we have,

$$78 = \frac{4.44 \times 163800 \times T_p \times 60}{10^8}$$

$$T_p = \frac{78 \times 10^5}{4.44 \times 1638 \times 6}$$

$= 178.6$ turns.

Use 180 turns for the primary. the total number of turns for the 110 volts will be,

$T_t = 180 \times 110/78 = 254$ turns.

Knowing that the core is 3.23" long and that #12 wire is 0.1" in diameter, we find the number of turns per layer of wire to be,

$3.23/0.1 = 32.3$

Use 30 turns to allow for tapeing.

Now there are 254 turns in all; hence the number of layers required is,

$$254/30 = 8.5 \text{ layers.}$$

Allowing for wedging the coil and for clearance, we find the inside perimeter of the coil to be,

$$P_1 = 10.625''$$

Adding the thickness of 8.5 layers of wire, we find the outside perimeter of the coil to be,

$$P_2 = 17.42''$$

The average perimeter is then,

$$P_a = P_1 + P_2/2$$

$$= \frac{10.625 + 17.42}{2}$$

$$= 14.02''$$

The total length of wire, in feet, for all three transformers is found to be,

$$L_t = \frac{P_a \times N}{12} \times 3$$

$$= \frac{14.02 \times 254}{12} \times 3$$

$$= 890 \text{ feet.}$$

No. 12 wire weighs 19.8 pounds per 1000 ft. Therefore the total weight of the wire needed becomes,

$$19.8 \times 0.890 = 17.5 \text{ lbs.}$$

The number of turns of wire required to give one volt is,

254 / 110 = 2.31 turns.

Knowing this relation, it is easy to get any desired voltage from the transformer, by simply winding on the required number of turns or by taking off a tap at the proper turn.

After constructing one transformer, it was tested with the following results:

	No Load
E	78 volts
I	.345 amps
W	16 watts
P.F.	64 %

Chapter III.

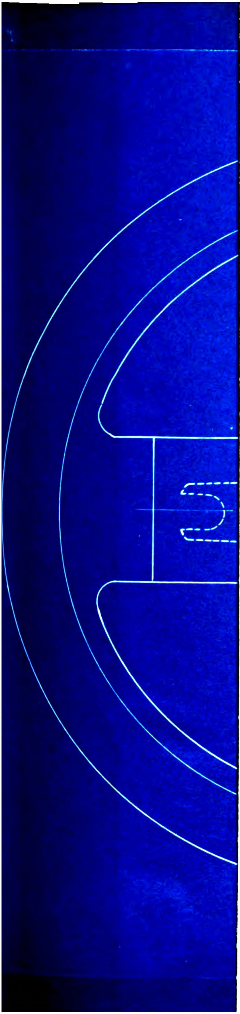
SWITCH BOARD.

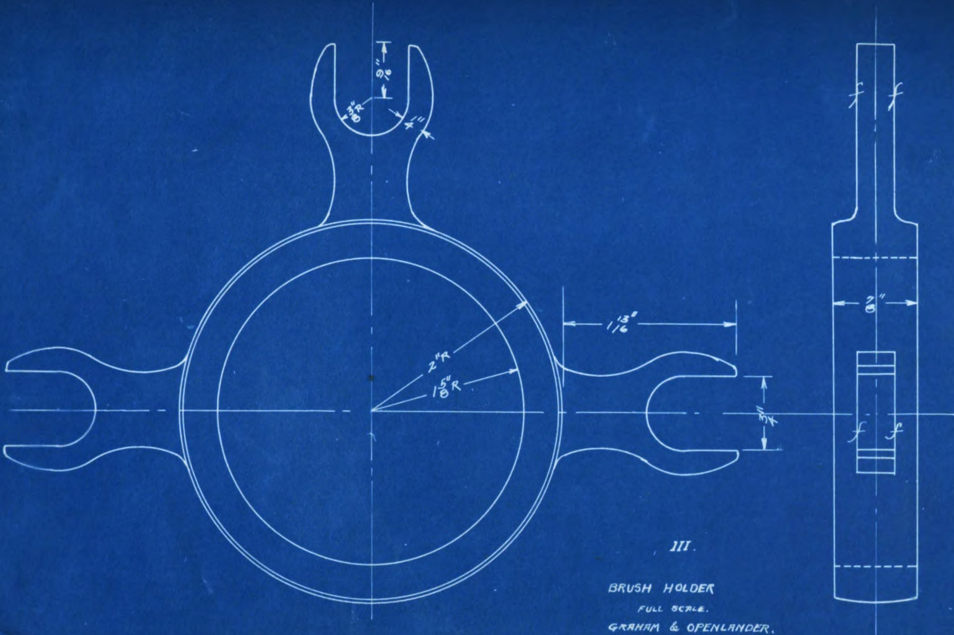
For convenience in laboratory use, we constructed a wooden switch-board three feet wide and four feet long. The idea, in the design of this board, was to have all wiring amd apparatus in plain sight for the benefit of the student, rather than concealed wiring as is done commercially. For example, our transformers were not cased, thus rendering them easy of access for inspection and study.

The direct-connected motor generator set was placed on the floor, directly below the switch-board which was elevated upon a standard two feet high. 220 volt leads to the motor were brought to the top of the board. Space was provided on the board for the starting box and also for a speed regulator, so that alternating current of a variable frequency could be obtained.

The rest of the apparatus on the board included the following generator auxiliaries; one alternating current voltmeter, one direct current voltmeter, and three transformers mounted along the lower portion of the board, one side of each being connected to one ring of the armature and the other to a common neutral.

The general arrangement of the switch-board and connections are shown on blue-print No. IV. The diagram shows the method of making connections in order to obtain alternating voltages ranging from 6 to 135 volts, also 110 or 220 volts of direct current.





III.

BRUSH HOLDER

FULL SCALE.

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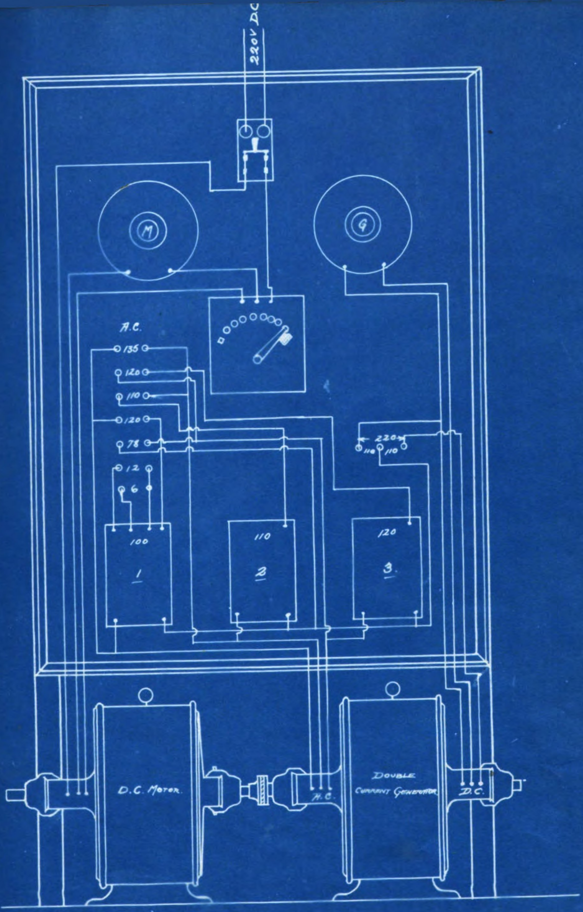

IV.
SWITCH-BOARD.

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