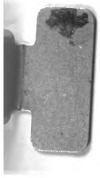
THESIS

DESIGN OF A NEW DYNAMO LABORATORY FOR M. A. C.

G. A. BARLOW

1916



The Design of a New Dynamo Laboratory for the Michigan Agricultural College

A Thesis Submitted to
The Faculty of

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By

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THESIS

INTRODUCTION

This thesis takes up the design of a new dynamo laboratory for the Michigan Agricultural College, which was destroyed on March 5, 1916 when the engineering building burned.

The old laboratory had the direct current and alternating current machinery all in one room, mounted on three concrete piers about 27 feet long, 18 inches high, and 28 inches wide. The wires were run from the switchboard which consisted of five panels, thro the bottom of the piers to the various outlets on the sides of the piers, where switches were mounted to supply current to the machines.

The switchboard was constructed, so as by the use of jumpers it was possible to plug from one circuit to the other, so that current from any source could be sent to any part of the room.

The design of the laboratory will be according to the good points of the old laboratory, and other laboratories around the country, combined with standard methods as used in power house design, but holding to certain conditions such as keeping within the walls, leaving out high tension experiments, keeping within a reasonable cost of construction, and not defacing the walls or the floor. Thus if the laboratory is moved at any time, it will not leave the room in bad condition.

The new laboratory is to be divided into two rooms, using the old laboratory room to perform alternating current experiments and the old physics laboratory for direct current experiments.

Taking up the design of the alternating laboratory first. It will depend on the experiments to be performed, which will be

taken from other schools and our own, as given in the laboratory manuals. Those were selected which were considered to be of the greatest value to the student of to-day.

From the experiments to be performed, the amount of apparatus can be figured on, assuming that there will be four squads which will represent a good sized class.

On pages following will be found the experiments that were selected, and the apparatus required to perform each. The order in which they are given does not necessarily mean that they are to be performed in that identical order, because they really should be performed in the same order as the work that is taken up in class.

ALTERNATING CURRENT EXPERIMENTS.

1. A Study of Impedance.

   1 A.C. Voltmeter. (125).

   1 A.C. Ammeter. (5).

   D.C. Combination Volt-Ammeter.

   Tachometer.

   Lamp Banks,

   Rotary Converter, or Meter-Generator Set.

   Inductance Coil.

2. A Study of Inductance and Capacity in Series.

   1 A.C. Voltmeter, (500).

   1 A.C. Ammeter, (2) or (5).

   Wattmeter, (150-2).

   D.C. Combination Volt-Ammeter.

   Tachometer.

   Inductance Coil.

   Condenser.

   Rotary Converter, or Motor-Generator(variable speed).

3. Power Measurements in A.C. Circuits.

   3 A.C. Wattmeters, (150-5).

   1 Voltmeter, (125).

   1 Ammeter, (5).

   "Y" Lamp Banks.

ALTERNATING CURRENT EXPERIMENTS.

4. Calibration of a Recording Watt-Hour Meter.

Recording Meter.

Portable Testing Watt-Hour Meter.

Voltmeter,(125).

Ammeter,(15).

Induction Wattmeter,(150-10).

Lamp Banks.

Inductance Coil(adjustable).

5. To Determine the Voltage Regulation of an A.C. Generator.

A.C. Voltmeter,(250).

2 A.C. Ammeters,(5).

3 Current Transformers,(50-5).

D.C. Wattmeter,(150).

Ammeter,(15).

Tachometer.

6. Brake Test on an Induction Motor.

2 A.C. Wattmeters,(300-10).

2 Ammeters,(5).

Voltmeter,(250).

2 Current Transformers,(25-5).

2 Current Transformers,(50-5).

2 Tachometers.

Prony Brake.

Scales.

ALTERNATING CURRENT EXPERIMENTS.

7. Circle Diagram of a Three Phase Induction Motor.

A.C. Voltmeter,(250).

2 Ammeters,(5).

2 Current Transformers,(50-5).

2 Wattmeters,(300-10).

D.C. Voltmeter,(150).

D.C. Ammeter,(15).

Tachometer.

8. Influence of the Excitation of a Synchronous Motor on the Power Factor.

2 A.C. Ammeters,(5).

Voltmeters,(250).

2 Wattmeters,(150-10).

2 Current Transformers,(50-5).

2 D.C. Ammeters,(15).

1 D.C. Voltmeter,(300).

Lamp Banks.

9. Determination of the Efficiency of a Transformer from its Losses.

1 K.W. Transformer.

1 A.C. Voltmeter,(125).

Ammeter,(5).

2 Wattmeters,(150-2)

Potential Transformers.

D.C. Voltmeter?(150).

D.C. Ammeter,(15).

Tachometer.

ALTERNATING CURRENT EXPERIMENTS.

10. Variation of Transformer Core Loss and Exciting Current with Change of Frequency.

10 K.W. Transformer.

A.C. Voltmeter,(125).

Ammeters,(5).

Wattmeters,(150-5).

Tachometer.

Regulator.

11. Study of Voltage Relations Resulting from Various Transformer Connections.

3(1-1) Transformers.

2 Voltmeters.

6 Lamp Banks.

12. A Study of A.C. Generator Regulation,etc.

A.C. Voltmeters,(250).

Tachometer.

Ammeters,(10).

Lamp Banks.

13. Study of an Induction Generator.

Motor-Generator Set.

Induction Motor(Generator).

Ammeter,(5).

Voltmeter,(250).

Lamp Banks.

ALTERNATING CURRENT EXPERIMENTS.

14. Study of the Characteristics of a Rotary Converter.

A.C. Voltmeter, (250).

A.C. Ammeter, (10).

D.C. Voltmeter, (300).

D.C. Ammeter, (15).

Lamp Banks.

Rheostat.

It would be of great value if we could have the laboratory equipped so that each squad could work the same experiment at the same time which is in connection with the class work for that week, instead of having equipment so that each squad has to work on a different experiment, so that the laboratory work comes before the class work at one time, and about three weeks after at another time. The first case would require too much apparatus to be installed, to be used only a few times a term. So it would be best to equip the laboratory so that the same experiment could be worked by two squads at the same time.

The apparatus required under these conditions would be:

Voltmeters, 4-125; 6-250.

Ammeters, 10-5 Amps., 4-10.

D.C. Combination, 2.

Tachometers, 6.

Inductance Coils, 4.

Wattmeters, 2(150-2); 6(150-5); 4(250-10).

Condensers, 2-10 micro-farads.

Recording Meters, 2.

Portable Wattmeters, 2.

Lamp Banks, 4 and 2 "Y".(ten lamps).

Current Transformers, 6(50-5); 6(25-5).

D.C. Wattmeters, 2-150.

D.C. Ammeters, 2-15.

Scales, 2.

Inductance Regulators, 2.

Starting Boxes for Rotary Converters, 2.

The machines in the laboratory will be chosen so as to have four sources of three phase alternating current, and other machines to carry on other experiments.

The four machines that will be used as a source of power consist of one rotary converter of 10 K.W., and three motor-generator sets, one of two phase 220 volts, 10 K.W.; one of three phase, 220 volts, 15 K.W.; and one three phase, 220 volts, 10 K.W.

The motors of the motor-generator sets should be differential compound so as to have a constant frequency at any change of load. It may be necessary to put a Tirril Regulator in connection with a booster set to keep the line voltage constant.

The rotary converter is to have connection on the switchboard directly, then thro a star-connected auto-transformer to step up the voltage from 135 volts to 220 volts so it can be connected with the other 220 volt, three phase machine, and the neutral can be taken off for the three wire system; so the transformer will serve to give 220 volts and 110, volts. when 135 volts is supplied to them, and will give 135 and 110 volts when 220 volts is supplied to them.

The two phase generators will have plugs in the switchboard and a set of Scott transformers so it can be run in parallel with the motor-generators.

The direct current motors and rotary converters will be provided with starting boxes which will be located on the wall along side of the machine. There will also be switches on the alternating side of the rotary converters and the two phase generators to make it possible to get the two phase without

running the machine, or to get the 138 volts without running the rotary onverters.

The machines that will be used for experiments are as follows:*

1 G.E., 5 H.P., 220 volt, Induction Motor, Three Phase.

1 " " 2 " " " " " " " "

1 " " 1 " " " " " " " "

1 G.E., R.I., 1 H.P., 110/220, commutating, single Phase.

1 West., 2 H.P., 220 volt, three phase induction motor.

1 " " single phase, series railway motor.

2 G.E., 1 H.P., 220 volt, A.C. Rotary converters.

These eight machines will be arranged so as to perform any experiment necessary. The two rotarys may be made to work as direct current generaters for loads on the motors, and also to perform a synchronous converter experiment.

The transformers should consist of:-

2-10 K.W., 220/2300.

2-1 K.W., 110/220.

3 door-bell transformers, 110 to 6, 1 to 1 transformers.

The switchboard consists of three panels; each panel is made up of two slabs, the top slab being 62"x24", and the bottom 16"x24". The top and bottom of the four machine boards are the same, so that there is only one shown in the drawing of the front view of the switchboard.

There is one board used for distribution only, in connection with the taps of the machine board. The other board is used for direct current only. It has the switch for the direct cur-

rent side of the four sources of alternating current, the 220 volts and the three wire system.

The switchboard is to be wired according to the standard used in power stations. It is so planned that with one voltmeter, the voltage can be read on any phase of the four machines and the synchronoscope is so wired that all machines can be operated in parallel.

The wiring to the motor-generators and to the rotary converters from the switchboard is run along the wall in conduit back of the machines to them, and to the outlets on the work-table by the rotary. The wiring from the rest of the switchboard will be run thro conduits across the center of the laboratory to two groups of outlets, as shown in the drawings, where taps can be made to supply current for experiments, and the rest of the wires run to taps on the work-table as shown in the lay-out.

The general lay-out as shown in the drawing, was to obtain the best arrangement of the equipment, so as to work the experiments with the least trouble.

Along the south wall are the motor-generator sets, and the rotary converters. The two phase machine is next to the switchboard; then the 10 K.W. set; the 15 K.W. set, and lastly the rotary converter over near the corner towards the table.

The transformers for the rotary, and the Scott transformers are located in the southeast corner back of the switchboard, so as to make the wires from the switchboard to the transformers as short as possible.

The work-table will be used to carry on experiments, and the space underneath it will be used to store transformers, regulators, etc., that are too large for the cupboard.

The north wall will be used for blackboard space.

DIRECT CURRENT LABORATORY.

The direct current laboratory which will be located in the old physics laboratory, will be similar to the alternating current laboratory in a great many ways. The direct current laboratory is somewhat smaller than the alternating current laboratory, but it will be of sufficient size to contain the present direct current equipment which will consist of enough to handle four squads at a time with sufficient apparatus, so that the same experiment can be worked by two squads at the same time, as in the alternating current laboratory.

The same kind of bases will be used in both laboratories for the machines, and the same side switchboard panels will be used, altho the D.C. will have only two panels.

The arrangement of the D.C. laboratory will be as shown in the lay-out, that is, the switchboard located along the south wall near the door, with a booster set along the side of it, and the rotary converter between the booster set and the table along the west wall.

The lamp banks are located in the northwest corner and in the rear of the booster set. The machines with which to carry on experiments will be located along the north wall and around the column as shown.

The east wall will be covered with a blackboard. It is advisable to cover the entire width of the wall, so that the instrument case that will set up against the wall can be placed anywhere along the wall, and the rest of the space used for blackboard.

The drawing shows the cupboard near the window. This will leave the space near the door for the blackboard, and also a place to post notices so they may be seen conveniently by a person entering the laboratory, and also will prevent the blurr of the board frequently caused by light from the window.

On the pages immediately following will be found a list of direct current experiments, including the apparatus with which they are to be performed.

DIRECT CURRENT EXPERIMENTS.

1. (a). Resistance measurements of the various electrical circuits of a dynamo-electric machine.

   (b). Connection and operation of a motor starting box.

   1 Voltmeter.

   1 Ammeter.

2. No-load characteristic of a shunt generator.

   (a). Speed-voltage Characteristics.

   (b). Field Ampere-voltage characteristics.

   Tachometer.

   2 Ammeters.

   Voltmeter.

   Rheostat.

3. No-load characteristics of a shunt motor.

   (a). Armature volt-speed characteristics.

   (b). Field ampere-speed characteristics.

   Ammeter.

   Rheostat.

   Water Barrel.

   Voltmeter.

4. Load-speed characteristics of:-

   (a). Shunt Motor.

   (b). Compound-wound motor.

   Lamp Banks or water barrel.

   Voltmeter.

   Ammeter.

DIRECT CURRENT EXPERIMENTS.

5. Characteristics of a series dynamo-electric machine.

   (a). As generator.

   (b). As motor.

   Field Rheostat.

   Voltmeter.

   Ammeter.

   Large Lamp Bank.

6. Load and voltage characteristics of a shunt and compound-wound generator.

   2 Ammeters,

   Field rheostat.

   Ammeter.

   Lamp Banks.

   Tachometer.

   Voltmeter.

7. Distributiom of the magnetic flux in the air gap of a dynamo-electric machine.

   2 Field rheostats.

   2 Voltages.

   Ammeters, (2).

8. Compounding a D.C. generator and motor.

   Ammeter.

   Voltmeter.

   Tachometer.

   Field rheostat.

DIRECT CURRENT EXPERIMENTS.

9. Determination of the core loss of a D.C. generator.

2 Voltmeters.

2 Ammeters.

Ammeter.

Field rheostat.

10. A study of the effect of shifting the brush position upon the operation of a motor.

Lamp bank or water barrel.

Ammeter.

Voltmeter.

11. A study of a three wire system.

3 Ammeters.

3 Voltmeters.

Lamp Banks,

12. Operation of shunt and compound generators in parallel.

3 Voltmeters.

3 Ammeters.

13. Determination of the efficiency of a motor-generator.

3 Ammeters.

3 Voltmeters.

CONSTRUCTION.

The wiring of the D.C. laboratory will be similar to the A.C. laboratory, that is, the wires to the various places will be run thro conduit as shown in the lay-out.

The rotary converter will be supplied with current from a switch on the switchboard, and a starting box near the rotary for controlling it.

From the neutral of the three transformers which will be set behind the rotary converter, a wire will be run to the switchboard for a 220/110 three wire system. The Edison storage battery will be made to give 125 volts, and wired so as to form a three wire system of 125 volts and 62.5 volts. The battery will be charged by means of a charging resistance so it may be charged directly from the 220 volt circuit.

The ammeters and the voltmeters for the D.C. laboratory will consist of milli-voltmeters with shunts of 1, 5, 10, 20, and 50 ampere capacity, and proper resistance so they can be used on any pressure circuit. Thus the milli-voltmeter may be used as any sized ammeter or voltmeter by using the proper shunt or resistance.

DIRECT CURRENT APPARATUS.

The apparatus required will be as follows:-

Milli-voltmeter, (15).

Shunts, (6-1); (6-5); (3-20); (3-50).

Series resistance to make milli-voltmeter into 10, 50, 100, and 250 volt voltmeter.

4 Tachometers.

6 Field rheostats.

6 Lamp banks.

4 Water barrels.

The machines will consist of one rotary converter for the three wire system, and the booster set, and sixteen machines with which to perform experiments. The machines are :-

1-6 H.P. Westinghouse, 220 volt motor.

1-1.37 K.W. Westinghouse, 125 volt generator.

2-2 H.P. Westinghouse, 125 volt generators.

2-5 H.P. " " " " "

2-2 H.P. F.Bissell Co., 220 volt motors.

2-1 H.P. Stow multi-speed, 220 volt motors.

2-1 H.P. Northern, 220 volt motors.

2-2 H.P. General Electric, shunt, 220 volt, motor-gen.

2-2 H.P. " " compound, 220 volt, " "

The sixteen machines, listed on the previous page, will be placed in pairs so as to use one machine as a motor and the other as a generator, or use one as a motor and then the generator will serve as a brake, and by varying the output of the generator, the load on the motor will be varied.

Each motor will be provided with its proper sized starting box, which will be mounted on the side of the base. Thus the flexible jumpers which will consist of 4, 6, and 8 feet lengths, can connect the motor to the outlet provided..The jumpers for the switchboard will be of flexible wire, six feet long with a plug on each end to plug in to the receivers.