Power analysis of the Montana State College 2300 volt power system
by David C Johns

A THESIS Submitted to the Graduate Committee in partial fulfillment of the requirements for the degree of Master of Science in Electrical Engineering
Montana State University

Abstract:
This paper- points out the method used, and the solutions formulated in attempting to solve the problem of the power and voltage unbalance on the Montana State College 2300 Volt system, After months of checking all the transformers, in the' various vaults on the campus, with Maxi-meters, the peak leads were determined. From this, the overloads could be found and corrected by substitution of the proper size transformers.

The three phase lines were also phased out and tagged in order that the total load on each phase could be determined. Knowing the loading on the different phases, the unbalance was located. Dhen after making individual analyses of all the transformer vaults, a general analysis prompted two solutions, The first solution is designed to take care of probable future needs, whereas the second solution is a measure to correct this unbalance immediately with a minimum of time and money, tabulated lists of high voltage equipment are to be found at the end of the thesis.

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Approved:

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ABSTRACT

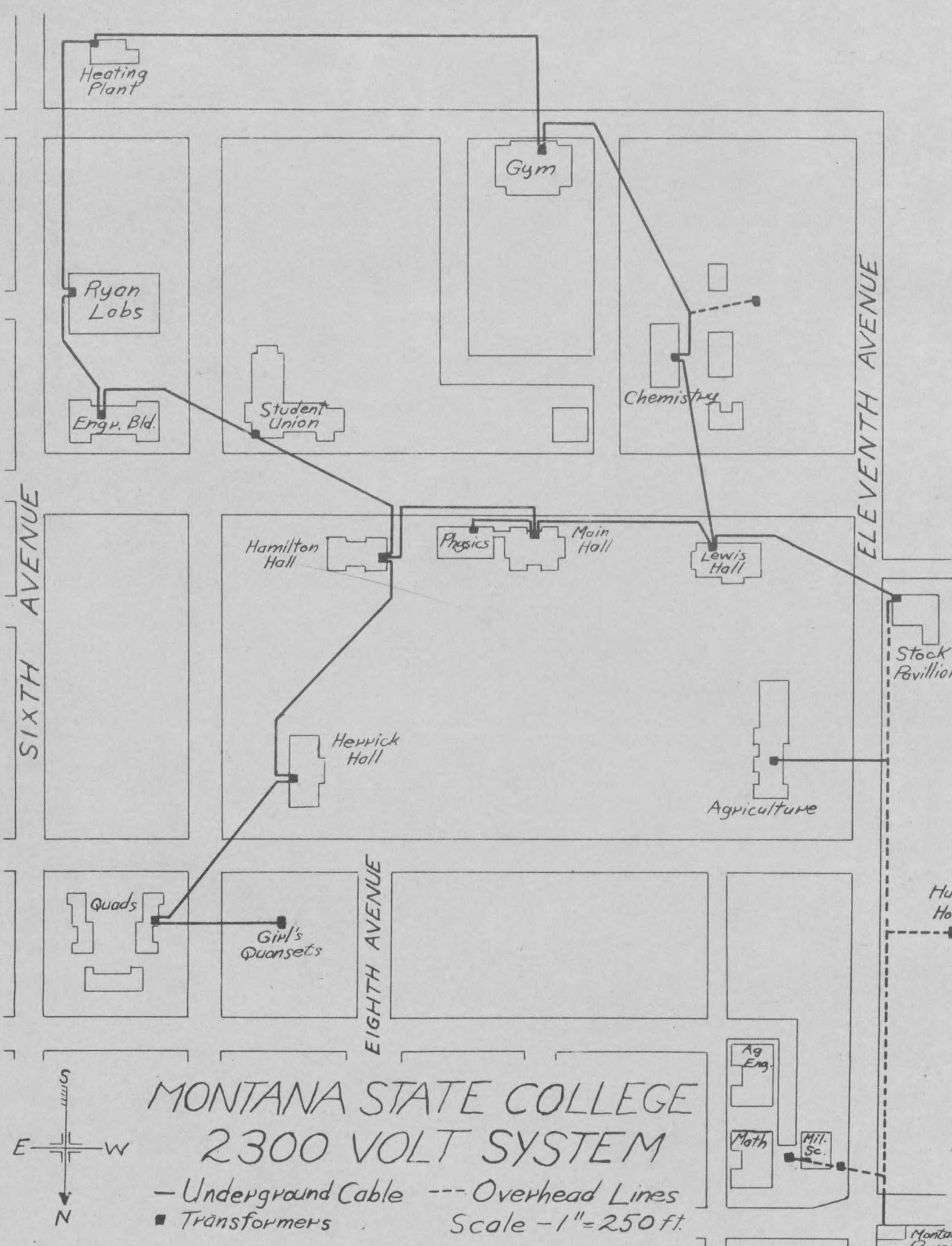
This paper points out the method used, and the solutions formulated in attempting to solve the problem of the power and voltage unbalance on the Montana State College 2300 volt system. After months of checking all the transformers, in the various vaults on the campus, with Maxi-meters, the peak loads were determined. From this, the overloads could be found and corrected by substitution of the proper size transformers. The three phase lines were also phased out and tagged in order that the total load on each phase could be determined. Knowing the loading on the different phases, the unbalance was located. Then after making individual analyses of all the transformer vaults, a general analysis prompted two solutions. The first solution is designed to take care of probable future needs, whereas the second solution is a measure to correct this unbalance immediately with a minimum of time and money. Tabulated lists of high voltage equipment are to be found at the end of the thesis.

INTRODUCTION

The last three years have shown a great change at Montana State College. Because of the G. I. Bill, the enrollment jumped by leaps and bounds, more than doubling the pre-war enrollment. However, the same buildings were in existance after the war as had been here before the war. They had not increased in size or number. To house and instruct this increased number of students, many temporary buildings were erected here and there on the campus, and some of the old buildings were remodeled to hold more students. This increased enrollment thus created an increased electrical load.

The new buildings were erected hastily, and the electrical loads of these new buildings were connected onto the phases, of the main distribution lines, at random. Additional transformers were placed in different buildings, but no attention was placed upon the loading on the different phases.

Now, after three years of expansion, the high voltage system on the campus is as shown in figure 1. Because of the unsystematic manner in which the additional loads have been placed on the phases, the voltages around the campus are greatly unbalanced. In the Ryan Laboratories, to cite an example, there has been as much as 20 volts difference in the three phase circuit. The Physics department has also commented on the unbalance of the voltage. They state that this



MONTANA STATE COLLEGE
2300 VOLT SYSTEM
— Underground Cable --- Overhead Lines
■ Transformers Scale – 1" = 250 ft.
S
E W
N
SIXTH AVENUE
EIGHTH AVENUE
ELEVENTH AVENUE
Heating Plant
Gym
Ryan Labs
Student Union
Engr. Bld.
Chemistry
Hamilton Hall
Physics
Main Hall
Lewis Hall
Stock Pavillion
Herrick Hall
Agriculture
Quads
Girl's Quansets
Hudson House
Ag Eng.
Math
Mil. Sc.
Montana Power

figure 1

changing unbalance of voltages makes it quite impossible to perform some electronic experiments which employ a Geiger Counter.

The problem is to check this system, determine just where the unbalance occurs, and to offer a solution.

In the figures to follow, both the peak current and the rated current is indicated. The primary voltage on the transformers is 2300 volts. The secondary voltages on the transformers is 230 volts, with 115 volts from either leg to the center tap.

Table III gives the names corresponding to the various symbols used in the diagrams of the transformer vaults. Table IV lists all high voltage equipment as to type and style, giving the location of each piece of equipment. Table V lists high voltage equipment according to the building in which it is now located. These tables are at the end of the thesis.

ANALYSIS OF THE HIGH VOLTAGE SYSTEM

PROCEDURE

The underground high voltage system on the Montana State College campus was designed for a closed loop feed, as is shown in figure 1. However, the underground lines have been broken several times, and when repaired, have not been phased out, but instead just reconnected. The oil circuit breakers could not be closed because the line was then out of phase. This has caused undue strain on the loop line, as the majority of the load has been carried by one circuit.

The first part of the analysis consisted of phasing the underground and above-ground lines on the entire campus. The lines were phased out, by means of Army field telephones, starting at Montana Hall and traveling East around the loop, coming back to Montana Hall. The reference point was located in Montana Hall because an oil circuit breaker on the loop system is to be replaced at Montana Hall, and the phase order can be corrected at that time. A diagram showing the changes to be made is located on the board panel in the transformer vault at Montana Hall. This first part was done for two reasons. First, the loop circuit should be closed, and to do this the phase sequence as well as the phase order must be the same all around the loop. Secondly, to locate an unbalance in the campus load, it is necessary to know which phases the various transformers are on.

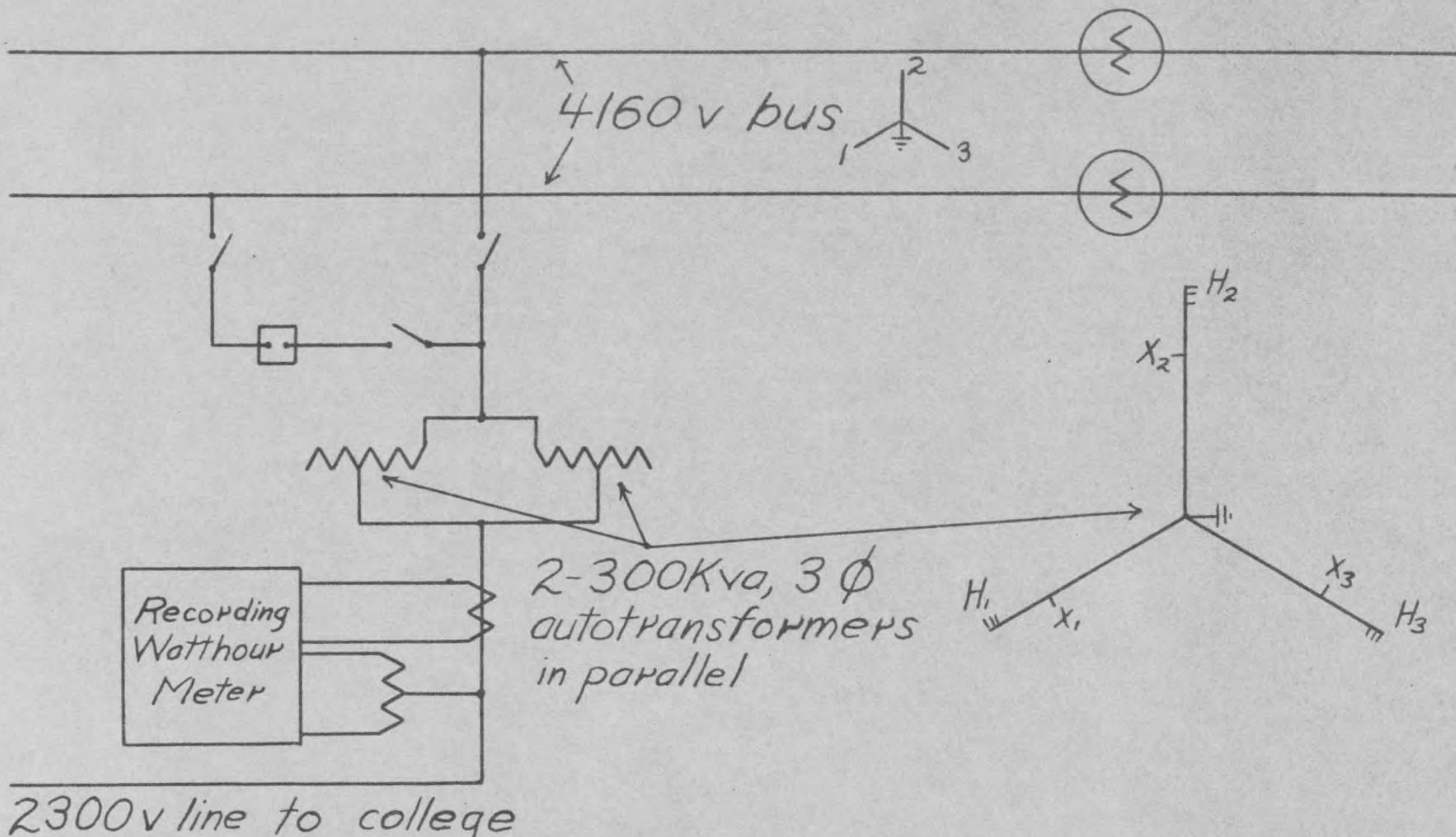
The peak currents in the various buildings were determined by putting Maxi-meters on the transformer secondaries and recording the peak currents averaged over thirty minute intervals. The peak currents are averaged over thirty minute intervals because the Maxi-meters operate on a thermal principle, and there is approximately a thirty minute lag in the meter.

From the individual building analyses, two possible solutions will be presented.

MONTANA POWER SUB-STATION

The 2300 volt line for the Montana State College system comes from the Montana Power Companies' sub-station. Figure 2 shows a single line diagram of the sub-station. The 4160 volt buses pass through induction voltage regulators which maintain the voltage approximately constant. There are two 4160 volt buses from which the college may take it's power. In case of a power failure in one of the incoming 50,000 volt lines, the college can be fed from a second 4160 volt bus, as shown in figure 2. The power is taken from the 4160 volt buses through a switching arrangement of knife switches, and is connected to two 300 Kva, three phase autotransformers connected in parallel.

The autotransformers have connections as shown in figure 2. Thus the campus line is a 2300 volt grounded star, 1328



SINGLE LINE DIAGRAM of the SUB-STATION CIRCUIT for the COLLEGE 2300 VOLT LINE

figure 2

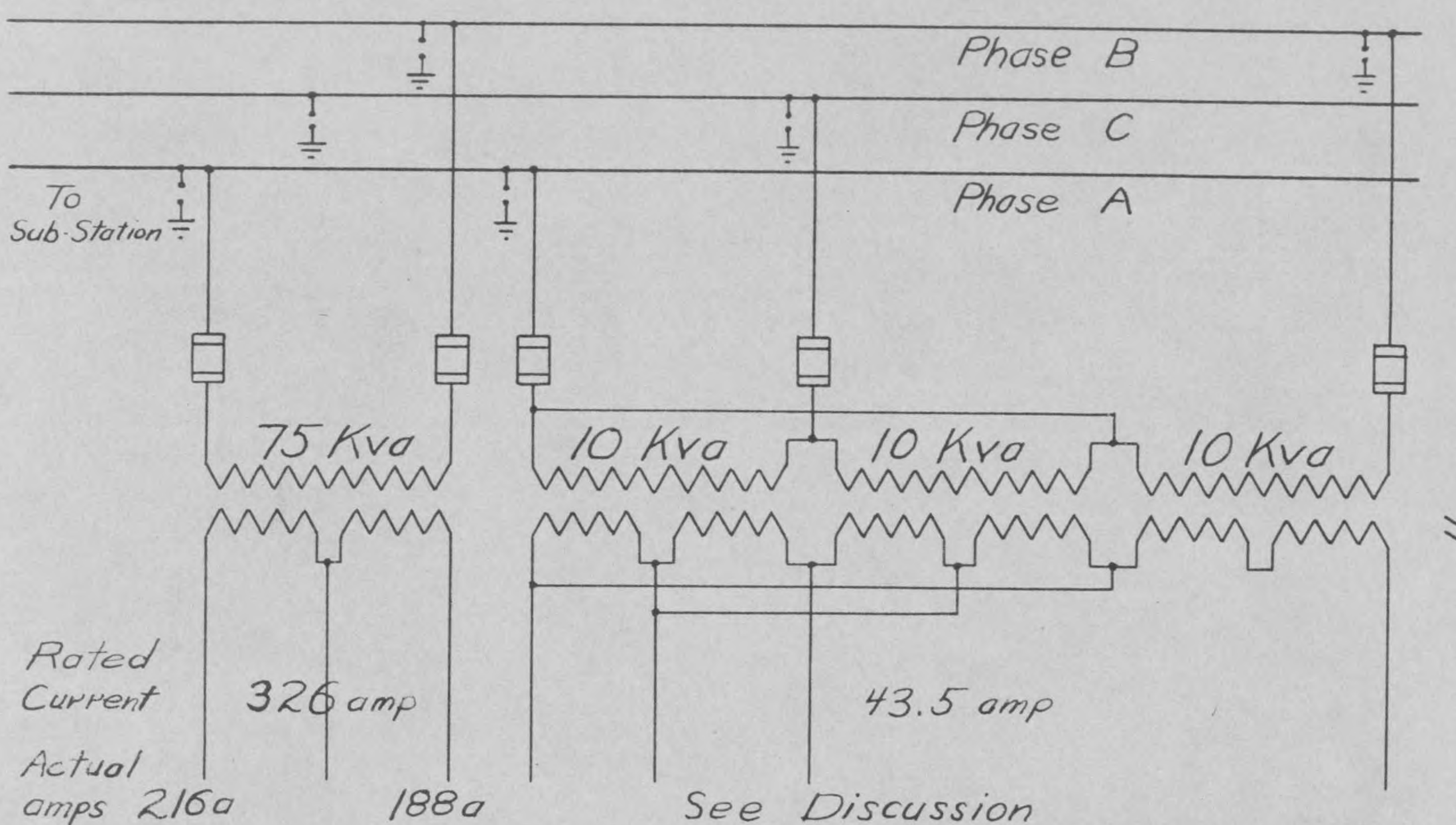
volts from ground to any one phase.

From the sub-station, the three phase line goes underground, to arise in the main switch vault, located just South of the sub-station. At this point the three phase 2300 volt line is taken to the campus on a mixture of #6 weather proofed, and rubber covered, hard drawn copper wires, mounted on the center crossarm of the 50,000 volt line to Livingston.

BARRACKS, WOOL LABORATORY, AND MILITARY BUILDING

The power for these buildings is supplied by two separate systems. Located near Eleventh Street on an elevated platform is a 75 Kva transformer. This transformer supplies the lighting and plug circuit loads for these buildings. Located on a pole between the Military Building and the North Barracks are three 10 Kva transformers. The connection is an open delta with two transformers in parallel on one leg. At one time the lighting load was taken from the parallel arrangement. However, it now serves only to provide three phase power to the Rural Engineering Shops. Figure 3 shows these transformers and their present connections.

The power required by these buildings is very great, much in excess of the Kva available at the present. The 220 volt and 110 volt single phase loads are almost at their maximum. There will be some additional loads on these lines after the start of the new fiscal year. These loads will



TRANSFORMERS for WOOL LABORATORY, BARRACKS, and the MILITARY BUILDING

figure 3