ELECTRICAL ENERGY MANAGEMENT IN BATTERY CHARGING SYSTEM CASE STUDY OF MATSUSHITA BATTERY (THAILAND) CO., LTD.

by

Ms. Sarinporn Promphut

A Final Report of the Six - Credit Course
CE 6998 - CE 6999 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
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Project Title	Electrical Energy Management in Battery Charging System Case Study of Matsushita Battery (Thailand) Co., Ltd.
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Academic Year	November 2001

The Graduate School of Assumption University has approved this final report of the six-credit course. CE 6998 – CE 6999 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

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ABSTRACT

This project explores the efficiency optimizations of transformer in battery charging process using the measurement method. In this process, most of the energy losses came from the transformer. Energy loss has been the important factor that affected product quality and company operation cost. Therefore, the factor, which was the most concerned with in the battery charging process, was the efficiency of the transformer. In this project, I select the measurement method to analyze data of the existing transformer.

The measurement reveals the result of the existing system that a transformer has 88.2% efficiency, generate energy losses of 20,000 kWh/year or 50,000 Bahts/year. With the new transformer efficiency of 97%, customers can reduce energy loss and save energy consumption at15,200 kWh/year or 38,000 Bahts/year.

ACKNOWLEDGEMENTS

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Special appreciation is due to my colleagues and my friends for their assistance and continuous cooperation. Above all, I am forever grateful to my parents whose willingness to invest in my future has enabled me to achieve my educational goal.

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I. INTRODUCTION

1.1 General Background

For battery manufacturing companies competition is very high and product changes too fast when compared with new technology development. The manufacturers need to improve their process capability for the high volume market demand. (As shown in Figure 1.1.)

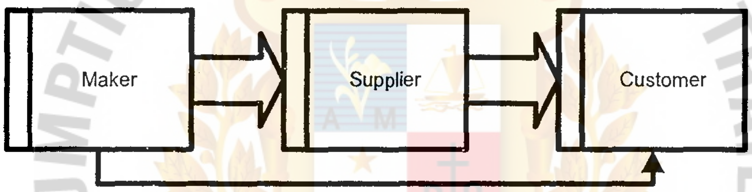


Figure 1.1. The Supply Chain of Battery Business.

The charging assembly manufacturing process is a part of battery assembly manufacturing process that includes many component parts, and has a long process for assembling in the production line. Therefore, the process included many raw materials and tools or equipment concerned with volume building of the production line and quality of the product.

In the process of charging assembly, one of the operations is charger machine. The charger machine has two main component parts: transformer and rectifier.

A transformer is an electrical device that, by electromagnetic induction, transforms electric energy from one or more circuits to one or more circuits at the same frequency. By varying magnetic relationships or values of the input versus the output, a transformer produces changed values of voltage and current. A transformer works by having the input windings made around a core of special steel that conveys the pulses of AC current to output windings around a core of special steel that conveys the pulses of AC Current to output windings around the same or connected portions of the steel core.

One component that contributes to a lot of energy loss is the transformer, which is concerned with many factors from the process and environment. Process engineer tries to segregate the problem such as shown in Figure 1.2. cause-effect diagram

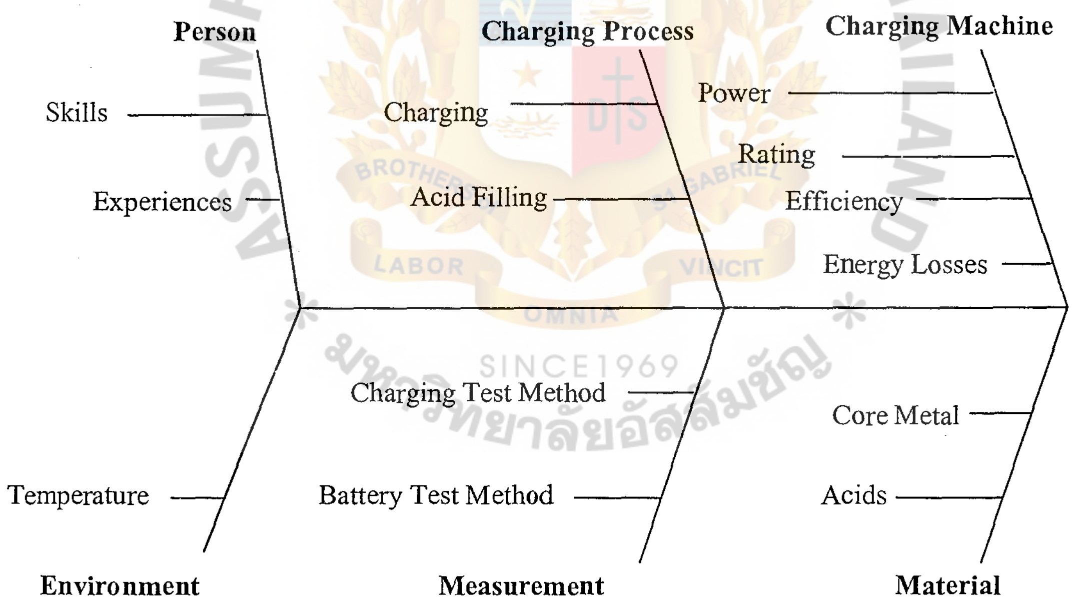


Figure 1.2. A Cause-Effect Diagram of Charger Machine.

(1) Increase insulation class

(2) Increase efficiency

(3) Reduce energy loss

(4) Reduce power consumption

(5) Improve machine capability

(6) Improve product quality in terms of performance.

1.4 Scope and Limitation

For the study, the focus is on the transformer, and then we narrow down the process parameters as follows:

(a) Find out the optimized parameter of charger machine conditions.

(b) Find out the parameter for controlling.

1.5 Deliverables

This study will provide the solution of transformer energy loss and the problem related to the charging performance. The output of the project will give the benefit as follows:

(a) To get the right way for solving the problem of transformer energy loss.

(b) To clarify and avoid the problem which may occur with charging assembly process.

(c) To increase capacity or unit hour (UPH) of the machine.

(d) To help process engineer as process tools for solving similar problems in charging assembly process.

1.6 Plan and Development of the Project

For understanding and clarifying the project information to be in the same direction, we go through the study of the process step. The framework of the project will be as follows:

(1) Literature Review

This chapter mentions most of the transformers that are being used in battery manufacturer.

(2) Research Methodology

We show the measurement method in this project. The method that we selected involves consideration of the response or output that we are focusing on including data analysis, economical methods used to analyze the data so that results and conclusion are objective to the decision making process in the future.

(3) Survey Result and Data Collection

By the measurement concept in selecting the design, we collect all raw data by using high technology instrument, which shows data in the form of numerical and graph.

(4) Conclusion and Recommendation

What we get from the measurement result and discussion, we can give the recommendation to guide the process engineer as to how to get improvement from the process. And this chapter has some suggestions for maintenance and warranty conditions.

II. LITERATURE REVIEW

2.1 What Is a Transformer?

A transformer is a device, having no moving parts, which transfers electric power from one circuit to another by electromagnetic means, usually with changes in values of both voltage and current. A step-up transformer receives electrical power at one voltage and delivers it at a higher voltage; conversely, a step-down transformer receives electrical power at one voltage and delivers it at a lower voltage. The transformer takes electrical current and decreases it to a lower voltage. Wires carrying current at a higher voltage come into a transformer and wrap around an iron core. Wires leading out of the other side of the transformer carry current at a lower voltage away. The amount of change in voltage depends on the ratio between the number of times the incoming wires are wrapped around the core to the number of times the outgoing wires are wrapped. The transformer is a highly efficient device so that practically the full electrical power received from one circuit is delivered to the other. Since electric power (P) may be considered by the product of voltage (V) and current (I) (that is, $P = V \times I$), it is evident that the values of current in a transformer change in opposite fashion to those of the voltage. That is, in a step-up transformer where the voltage delivered is higher than that received, the current delivered is lower than that received; in a step-down transformer, where the voltage delivered is lower than that received, the current delivered is higher than that received.

2.1.1 Impedance

Resistance, inductance, and capacitance or more generally, resistance and reactance may therefore, cause the total obstruction to the flow of current in an AC circuit. This total obstruction, which impedes the flow of electricity, is called "impedance" (usually denoted by the letter Z). In AC circuits, then, Ohm's Law becomes:

$$I = \frac{V}{Z}$$

Where I is the current, V the voltage, and Z the impedance.

2.2 Transformer Classification

Many different types of transformers are available on the market to day. Manufacturers' catalogs list them according to their ratings and construction features and they are often classified according to:

(1) service or application

(2) purpose

(3) method of cooling

(4) number of phases

(5) types of insulation

(6) method of mounting

In this project we mention only the method of cooling because we study the efficiency difference between oil type and dry type transformer.

2.2.1 Cooling Systems

Another way transformers are classified is according to the type of cooling system that is used. The two general classifications would be air or liquid cooled.

Air-cooled transformers are normally small and depend on the circulation of air over or through their enclosures. They may be either ventilated or non-ventilated. Forced air provided by fans may be used. The fan(s) may be part of the transformer itself, or installed in a structure to provide general circulation of air for a larger area which includes the transformer(s). The transformers may have smooth surfaces or may be equipped with fins to provide a greater surface area for removing heat from them.

Oil-cooled transformers have the transformer's coils and core submerged in the liquid. The liquid may be mineral oil, silicone fluid, or a synthetic material that has been registered by the particular manufacture. Natural circulation of the oil due to the heat is used in some of the transformers. Fins are normally provided to dissipate the heat to the surrounding air. Fans may be used to facilitate removing heat from the transformer. At other times, a water jacket with circulating cool water may be inserted inside the transformer housing to cool the oil. Another method would be to pump the oil through the fins or radiator and not to depend on the natural circulating currents. Any of these methods or combinations of them may be part of the design of any particular transformer.

An effective cooling system can increase transformer capacity by 25% to 50%. Under these transformer circumstances, a 1000-kVA transformer may be operated as high as 1500 kVA without causing damage to the device.

2.3 Transformer Losses

All that has been said refers to an ideal or perfect transformer. In any actual instrument, the output is less than the input because of the transformer losses (heat developed in the wires and in the core).

2.3.1 Copper Losses

The heat losses developed in the wires are those caused by the resistance to the flow of current, which has been likened to the friction of water in a pipe, or friction between electrons moving in the conductor. This loss is determined by multiplying the square of the value of the current by the resistance (IR^2). It must be emphasized that only the resistance, R, causes this effect. The inductance (usually denoted by the letter L) does not resist the flow of current, it prevents it from coming into being. Therefore, in determining the heat losses, only the resistance, R, is to be considered; the inductance, L, or inductive reactance, X_L) and the impedance, Z, are not to be considered. It is obvious, too, that the greater the current flowing in the transformer (whether primary or secondary), the greater will be the heat (I^2R) losses in the conductors of the coils. These losses are usually referred to as the "copper losses" in a transformer.

2.3.2 Hysteresis

If each molecule of the iron comprising the core of the transformer is considered as a minute magnet, then, as the magnetic field set up by an alternating current changes direction, these small magnets will reverse their position to accommodate the strong magnetic field. As these molecules change their position with each alternation of magnetic field, friction between them is produced and energy is used up in overcoming it. This loss of energy due to friction between the molecules is given off as heat, and is called 'hysteresis".

2.3.3 Eddy Currents

The alternating magnetic field set up in a transformer not only induces voltage and currents in the coils through which it passes, but does so also in the core of iron. The currents thus induced in the iron core swirl around like eddies in a pool of water, and are, therefore, appropriately named "eddy currents". These currents in the core also produce an I^2R heat loss.

2.3.4 Iron Losses

The sum of both the hystersis and eddy current losses is usually referred to as the "iron losses" in a transformer. Since there is only a relatively small difference in the magnetic field in the iron core at any time, as explained above, these losses will present little variation as the load and the transformer is increased or decreased.

2.3.5 No-Load Losses

It will be observed that when the secondary of a transformer is open, that is, it has no load connected to it, a small current will nevertheless flow in the primary. As mentioned previously, the large self-induced voltage in the primary practically counterbalances the original voltage in that coil. The current which the primary takes under these circumstances (sometime referred to as the "exciting" current) serves to supply the hystersis and eddy current (or iron) losses as well as a small I^2R loss in the primary coil itself. The sum of these losses is usually referred to as the 'no-load loss" in a transformer.

2.4 Transformer Ratings

The capacity of a transformer is limited by the permissible temperature rise. Both the current and the voltage contribute to determine the heat generated in a transformer. As has been shown above, because of reactance, the current and the voltage waves do not always act in concert, and the power supplied as expressed in watts) is not always a measure of the heat generating processes. Hence, the rating of a transformer is expressed as a product of the volts and amperes, or volt-amperes (for practical purposes, kVA is used). For a given power factor of load, these values often are used interchangeably.

The nameplate on a transformer giving all the pertinent information required for the proper operation and maintenance of the unit. The capacity of a transformer (or any other piece of electrical equipment) is limited by the permissible temperature rise during operation. Both the current and the voltage determine the heat generated in a transformer. Of more importance is the kilovolt-ampere rating of the transformer. This indicates the maximum power on which the transformer is designed to operate under normal conditions (when the current and voltage are "in phase"). Other information generally given is the phase (single-phase, three-phase, etc.), the primary and secondary voltages, frequency, the permitted temperature rise, the cooling requirements which include the number of gallons of fluid that the cooling tank may hold. Primary and secondary currents may be stated at full load.

Depending upon the type of transformer and its special applications, there may be other type indications for various gauges, temperature indication, pressure, drains, and various valves.

Thus, it can be seen that while the transformer consists primarily of a primary and secondary winding, there are many other factors to take into consideration when selecting a transformer for a particular use. Most power supply transformers are designed to operate at a frequency of 50 of 60 cycles per second. Aircraft and other special application transformers are designed for a frequency ranged from 400 to 4000 cycles per second. The higher frequencies permit a saving in size and weight of transformers and associated equipment; further, where separate circuits prove economical, fluorescent lighting at the higher frequencies has been found to be more efficient.

2.5 Oil Type Transformer Maintenance

A transformer maintenance program must be based on thorough routine inspections. These inspections must be in addition to normal daily/weekly data gathering trips to check oil levels and temperatures. Some monitoring may be done remotely using supervisory control and data acquisition (SCADA) systems, but this can never substitute for thorough inspections by competent maintenance or operations people.

2.5.1 Oil-Filled Transformers

After 1 month of service and once each year, make an indepth inspection of oil-filled transformers. Before beginning, look carefully at temperature and oil level data sheets. If temperature, pressure, or oil level gages never change, even with seasonal temperature and loading changes, something is wrong. The gage may be stuck or data sheets may have been filled in incorrectly. Examine the DGA's for evidence of leaks, etc.

(1) Transformer Tank.

Check for excessive corrosion and oil leaks. Pay special attention to flanges and gaskets (bushings, valves, and radiators) and lower section of the main tank. Report oil leaks to maintenance, and pay special attention to the oil level indicator if leaks are found. Severely corroded spots should be wire brushed and painted with a rust inhibitor.

(2) Top Oil Thermometers.

These are typically sealed spiral-bourdon-tube dial indicators with liquid-filled bulb sensors. The bulb is normally inside a thermometer well, which penetrates the tank wall into oil near the top of the tank. As oil temperature increases in the bulb, liquid expands, which expands the spiral tube. The tube is attached to a pointer that indicates temperature. These pointers may also have electrical contacts to trigger alarms and start cooling fans as temperature increases. An extra pointer, normally red, indicates maximum temperature since the last time the indicator was reset. This red pointer rises with the main pointer but will not decrease unless manually reset; thus, it always indicates the highest temperature reached since being set. See the instruction manual on your specific transformer for details.

(3) Winding Temperature Thermometers.

These devices are supposed to indicate the hottest spot in the winding based on the manufacturers heat run tests. At best, this device is only accurate at top nameplate rated load and then only if it is not out of calibration. They are not what their name implies and can be misleading. They are only winding hottest-spot simulators and not very accurate. There is no temperature sensor imbedded in the winding hot spot. At best, they provide only a rough approximation of hot spot winding temperature and should not be relied on for accuracy. They can be used to turn on additional cooling or activate alarms as the top oil thermometers do.

Winding temperature thermometers work the same as the top oil thermometer (2.6.1.2) above, except that the bulb is in a separate thermometer well near the top of the tank. A wire-type heater coil is either inserted into or wrapped around the thermometer well which surrounds the temperature sensitive bulb. In some transformers, a current transformer (CT) is around one of the three winding leads and provides current directly to the heater coil in proportion to winding current. In other transformers, the CT supplies current to an auto-transformer that supplies current to the heater coil. The heater warms the bulb and the dial indicates a temperature, but it is not the true hottest-spot temperature.

These devices are calibrated at the factory by changing taps either on the CT or on the autotransformer, or by adjusting the calibration resistors in the control cabinet. They normally cannot be field calibrated or tested, other than testing the thermometer, as mentioned. The calibration resistors can be adjusted in the field if the manufacturer provides calibration curves for the transformer. In practice, most winding temperature indicators are out of calibration, and their readings are meaningless. These temperature indications should not be relied upon for loading operations or maintenance decisions.

Fiber optic temperature sensors can be imbedded directly into the winding as the transformer is being built and are much more accurate. This system is available as an option on new transformers at an increased cost, which may be worth it since the true winding "hottest-spot" temperature is critical when higher loading is required.

Thermometers can be removed without lowering the transformer oil if they are in a thermometer well. Check your transformer instruction manual. Look carefully at the capillary tubing between the thermometer well and dial indicator. If the tubing has been pinched or accidently struck, it may be restricted. This is not an obvious defect, and it can cause the dial pointer to lock in one position. If this defect is found, the whole gage must be returned to the factory for repair or replacement; it cannot be repaired in the field. Look for a leak in the tubing system; the gage will be reading very low and must be replaced if a leak is discovered. Thermometers should be removed and tested every 3 to 5 years as described below.

Thermometer Testing. Every 3 to 5 years, and if trouble is suspected, do a thermometer testing. Suspend the indicator bulb and an accurate mercury thermometer in an oil bath. Do not allow either to touch the side or bottom of the container. Heat the oil on a hotplate while stirring and compare the two thermometers while the temperature increases. If a magnetic stirring/heating plate is available, it is more effective than hand stirring. Pay particular attention to the upper temperature range at which your transformers normally operate (50 °C to 80 °C). An ohmmeter should also be used to check switch operations. If either dial indicator is more than 5 °C different than the mercury thermometer, it should be replaced with a spare. A number of spares should be kept, based on the quantity of transformers at the plant. Oil bath test kits are available from the Qualitrol Company.

The alarms and other functions should also be tested to see if the correct annunciator points activate, pumps/fans operate, etc.

If it is not possible to replace the temperature gage or send it to the factory for repair, place a temperature correction factor on your data form to add to the dial reading so the correct temperature will be recorded. Also lower the alarm and pump-turn-on settings by this same correction factor. Since these are pressure-filled systems, the indicator will typically read low if it is out of calibration. Field testing has shown some of these gages reading 15°C to 20°C lower than actual temperature. This is hazardous for transformers because it will allow them to continuously run hotter than intended, due to delayed alarms and cooling activation. If thermometers are not tested and errors corrected, transformer service life may be shortened or premature failure may occur.

(4) Oil Level Indicators.

After 1 month of service, inspect and every 3 to 5 years check the tank oil level indicators. These are float operated, with the float mechanism magnetically coupled through the tank wall to the dial indicator. As level increases, the float rotates a magnet inside the tank. Outside the tank, another magnet follows (rotates), which moves the pointer. The center of the dial is normally marked with a temperature 25 °C (77 °F). High and low level points are also marked to follow level changes as the oil expands and contracts with temperature changes. The proper way to determine accurate oil level is to first look at the top oil temperature indicator. After determining the temperature, look at the level gage. The pointer should be at a reasonable level corresponding to the top oil temperature. If the transformer is fully loaded, the top oil temperature will be high, and the level indicator should be near the high mark. If the transformer is de-energized and the top oil temperature is near 25 °C, the oil level pointer should be at or near 25 °C.

To check the level indicator, you can remove the outside mechanism for testing without lowering transformer oil. After removing the gage, hold a magnet on the back of the dial and rotate the magnet; the dial indicator should also rotate. If it fails to respond or if it drags or sticks, replace it. As mentioned above, defective units can be sent to the factory for repair.

There may also be electrical switches for alarms and possibly tripping off the transformer on falling tank level. These should be checked with an ohmmeter for proper operation. The alarm/tripping circuits should also be tested to see if the correct annunciator points and relays respond. See the transformer instruction book for information on your specific indicator.

If oil has had to be lowered in the transformer or conservator for other reasons (e.g., inspections), check the oil level float mechanism. Rotate the float mechanism by hand to check for free movement. Check the float visually to make sure it is secure to the arm and that the arm is in the proper shape. Some arms are formed (not straight).

(5) Pressure Relief Devices.

These devices are the transformers' last line of defense against excessive internal pressure. In case of a fault or short circuit, the resultant arc instantly vaporizes surrounding oil, causing a rapid buildup of gaseous pressure. If the pressure relief device does not operate properly and pressure is not sufficiently relieved within a few milliseconds, a catastrophic tank rupture can result, spreading flaming oil over a wide area. Two types of these devices are discussed below. The instruction manual for your transformer must be consulted for specifics.

If they have been painted, they should be replaced. It is virtually impossible to remove all paint from the mechanism and be certain the device will work when needed.

Newer Pressure Relief Devices. Newer pressure relief devices are spring-loaded valves that automatically reclose following a pressure release. The springs are held in compression by the cover and press on a disc which seals an opening in the tank top. If pressure in the tank exceeds operating pressure, the disk moves upward and relieves pressure. As pressure decreases, the springs reclose the valve. After operating, this device leaves a brightly colored rod (bright yellow for oil, blue for silicone) exposed approximately 2 inches above the top. This rod is easily seen upon inspection, although it is not always visible from floor level. The rod may be reset by pressing on the top until it is again recessed into the device. The switch must also be manually reset.

Once each year, and as soon as possible after a known through-fault or internal fault, inspect pressure devices to see if they have operated. This must be done from a high-lift bucket if the transformer is energized. Look at each pressure relief device to see if the yellow (or blue) button is visible. If the device has operated, about 2 inches of the colored rod will be visible. Each year, test the alarm circuits by operating the switch by hand and making sure the correct annunciator point is activated. If the relief device operates during operation, do not re-energize the transformer; Doble and other testing may be required before re-energizing, and an oil sample should be sent for analysis

Every 3 to 5 years, when doing other maintenance or testing, if the transformer has a conservator, examine the top of the transformer tank around the pressure relief device. If oil is visible, the device is leaking, either around the tank gasket or relief diaphragm. If the device is 30 years old, replace the whole unit. A nitrogen blanketed transformer will use a lot more nitrogen if the relief device is leaking; they should be tested as described below.

A test stand with a pressure gage may be fabricated to test the pressure relief function. Current cost of a pressure relief device is about $600, so testing instead of replacement may be prudent. Have a spare on hand so that the tank will not have to be left open. If the tank top or pressure relief device has gasket limiting grooves, always use a nitrile replacement gasket; if there are no grooves, use a cork-nitrile gasket. Relief devices themselves do not leak often; the gasket usually leaks.

Older Pressure Relief Devices. Older pressure relief devices have a diaphragm and a relief pin that is destroyed each time the device operates and must be replaced.

The relief pin determines operating pressure; a number, which is the operating pressure, normally appears on top of the pin. Check your specific transformer instruction manual for proper catalog numbers. Do not assume you have the right parts, or that correct parts have been previously installed--look it up. If the operating pressure is too high, a catastrophic tank failure could result.

On older units, a shaft rotates, operates alarm/trip switches, and raises a small red flag when the unit releases pressure. If units have been painted or are more than 30 years old, they should be replaced with the new model as soon as it is possible to have a transformer outage.

Once each year and as soon as possible after a through-fault or internal fault, examine the indicator flag to see if the device has operated. They must be examined from a high-lift bucket if the transformer is energized. A clearance must be obtained to test, repair, or reset the device. See the instruction manual for your specific transformer. Test alarm/trip circuits by operating the switch by hand. Check to make sure the correct annunciator point activates.

Every 3 to 5 years, when doing other maintenance or testing, examine the top of the transformer tank around the pressure relief device. If the transformer has a conservator and oil is visible, the device is leaking, either around the tank gasket or relief diaphragm. The gasket and/or device must be replaced. Take care that the new device will fit the same tank opening prior to ordering. Most of them are made by the Qualitrol Company; contact the manufacturer to obtain a correct replacement.

(6) Sudden Pressure Relay.

Internal arcing in an oil-filled power transformer can instantly vaporize surrounding oil, generating gas pressures that can cause catastrophic failure, rupture the tank, and spread flaming oil over a large area. This can damage or destroy other equipment in addition to the transformer and presents extreme hazards to workers.

The relay is designed to detect a sudden pressure increase caused by arcing. It is set to operate before the pressure relief device. The control circuit should de-energize the transformer and provide an alarm. The relay will ignore normal pressure changes such as oil-pump surges, temperature changes, etc.

Modern sudden pressure relays consist of three bellows with silicone sealed inside. Changes in pressure in the transformer deflect the main sensing bellows. Silicone inside acts on two control bellows arranged like a balance beam, one on each side. One bellows senses pressure changes through a small orifice. The opening is automatically changed by a bimetallic strip to adjust for normal temperature changes of the oil. The orifice delays pressure changes in this bellows. The other bellows responds to immediate pressure changes and is affected much more quickly. Pressure difference tilts the balance beam and activates the switch. This type relay automatically resets when the two bellows again reach pressure equilibrium. If this relay operates, do not re-energize the transformer until you have determined the exact cause and corrected the problem.

Old style sudden pressure relays have only one bellow. A sudden excessive pressure within the transformer tank exerts pressure directly on the bellows, which moves a spring-loaded operating pin. The pin operates a switch which provides alarm and breaker trip. After the relay has operated, the cap must be removed and the switch reset to normal by depressing the reset button.

Once every 3 to 5 years, the sudden pressure relay should be tested according to manufacturer's instructions. Generally, only a squeeze-bulb and pressure gage (5 psi) are required. Disconnect the tripping circuit and use an ohmmeter to test for relay operation. Test the alarm circuit and verify that the correct alarm point is activated. Use an ohmmeter to verify the trip signal is activated or, if possible, apply only control voltage to the breaker and make sure the tripping function operates. Consult the manufacturer's manual for your specific transformer for detailed instructions.

(7) Buchholz Relay (found only on transformers with conservators).

The Buchholz relay has two oil-filled chambers with floats and relays arranged vertically one over the other. If high eddy currents, local overheating, or partial discharges occur within the tank, bubbles of resultant gas rise to the top of the tank. These rise through the pipe between the tank and the conservator. As gas bubbles migrate along the pipe, they enter the Buchholz relay and rise into the top chamber. As gas builds up inside the chamber, it displaces the oil, decreasing the level. The top float descends with oil level until it passes a magnetic switch which activates an alarm. The bottom float and relay cannot be activated by additional gas buildup.

The float is located slightly below the top of the pipe so that once the top chamber is filled, additional gas goes into the pipe and on up to the conservator. Typically, inspection windows are provided so that the amount of gas and relay operation may be viewed during testing. If the oil level falls low enough (conservator empty), switch contacts in the bottom chamber are activated by the bottom float. These contacts are typically connected to cause the transformer to trip. This relay also serves a third function, similar to the sudden pressure relay. A magnetically held paddle attached to the bottom float is positioned in the oil-flow stream between the conservator and transformer tank. Normal flows resulting from temperature changes are small and bypass below the paddle. If a fault occurs in the transformer, a pressure wave (surge) is created in the oil. This surge travels through the pipe and displaces the paddle. The paddle activates the same magnetic switch as the bottom float mentioned above, tripping the transformer. The flow rate at which the paddle activates the relay is normally adjustable. See your specific transformer instruction manual for details.

Once every 3 to 5 years while the transformer is de-energized, functionally test the Buchhholz relay by pumping a small amount of air into the top chamber with a squeeze bulb hand pump. Watch the float operation through the window. Check to make sure the correct alarm point has been activated. Open the bleed valve and vent air from the chamber. The bottom float and switching cannot be tested with air pressure. On some relays, a rod is provided so that you can test both bottom and top sections by pushing the floats down until the trip points are activated. If possible, verify that the breaker will trip with this operation. A volt-ohmmeter may also be used to check the switches. If these contacts activate during operation, it means that the oil level is very low, or a pressure wave has activated (bottom contacts), or the transformer is gassing (top contacts). If this relay operates, do not re-energize the transformer until you have determined the exact cause.

(8) Transformer Bushings: Testing and Maintenance of High-Voltage Bushings.

When bushings are new, they should be Doble tested as an acceptance test. Refer to the M4000 Doble test set instructions, the Doble Bushing Field Test Guide, and the manufacturer's data for guidance on acceptable results.

After 1 month of service and yearly, check the external porcelain for cracks and/or contamination (requires binoculars). There is no "perfect insulator"; a small amount of leakage current always exists. This current "leaks" through and along the bushing surface from the high-voltage conductor to ground. If the bushing is damaged or heavily contaminated, leakage current becomes excessive, and visible evidence may appear as carbon tracking (treeing) on the bushing surface. Flash overs may occur if the bushings are not cleaned periodically.

Look carefully for oil leaks. Check the bushing oil level by viewing the oil-sight glass or the oil level gage. When the bushing has a gage with a pointer, look carefully, because the oil level should vary a little with temperature changes. If the pointer never changes, even with wide ambient temperature and load changes, the gage should be checked at the next outage. A stuck gage pointer coupled with a small oil leak can cause explosive failure of a bushing, damaging the transformer and other switchyard equipment. A costly extended outage is the result.

If the oil level is low and there is an external oil leak, check the bolts for proper torque and the gasket for proper compression. If torque and compression are correct, the bushing must be replaced with a spare. Follow instructions in the transformer manual carefully. It is very important that the correct type gasket be installed and the correct compression be applied. A leaky gasket is probably also leaking water and air into the transformer, so check the most recent transformer DGA for high moisture and oxygen.

If the oil level is low and there is no visible external leak, there may be an internal leak around the lower seal into the transformer tank. If possible, re-fill the bushing with the same oil and carefully monitor the level and the volume it takes to fill the bushing to the proper level. If it takes more than one quart, make plans to replace the bushing. The bushing must be sent to the factory for repair or it must be junked; it cannot be repaired in the field.

About 90% of all preventable bushing failures are caused by moisture entering through leaky gaskets, cracks, or seals. Internal moisture can be detected by Doble testing. See FIST and Doble Bushing Field Test Guide for troubles and corrective actions. Internal moisture causes deterioration of the insulation of the bushing and can result in explosive failure, causing extensive transformer and other equipment damage, as well as hazards to workers.

After 1 month of service and yearly, examine the bushings with an IR camera; if one phase shows a markedly higher temperature, there is probably a bad connection. The connection at the top is usually the poor one; however, a bad connection inside the transformer tank will usually show a higher temperature at the top as well. In addition, a bad connection inside the transformer will usually show hot metal gases (ethane and ethylene) in the DGA.

Once every 3 to 5 years, a close physical inspection and cleaning should be done. Check carefully for leaks, cracks, and carbon tracking. This inspection will be required more often in atmospheres where salts and dust deposits appear on the bushings. In conditions that produce deposits, a light application of Dow Corning grease DC-5 or GE Insulgel will help reduce risk of external flashover. The downside of this treatment is that a grease buildup may occur. In high humidity and wet areas, a better choice may be a high quality silicone paste wax applied to the porcelain, which will reduce the risk of flashover. A spray-on wax containing silicone, such as Turtle Wax brand, has been found to be very useful for cleaning and waxing in one operation, providing the deposits are not too hard. Wax will cause water to form beads rather than a continuous sheet, which reduces flashover risk. Cleaning may involve just spraying with Turtle Wax and wiping with a soft cloth. A lime removal product, such as "Lime Away," also may be useful. More stubborn contaminates may require solvents, steel wool, and brushes. A high pressure water stream may be required to remove salt and other water soluble deposits. Limestone powder blasting with dry air will safely remove metallic oxides, chemicals, salt-cake, and almost any hard contaminate. Other materials, such as potters clay, walnut or pecan shells, or crushed coconut shells, are also used for hard contaminates. Carbon dioxide (CO_2) pellet blasting is more expensive but virtually eliminates cleanup because it evaporates. Ground up corn-cob blasting will remove soft pollutants such as old coatings of built-up grease. A competent experienced contractor should be employed and a thorough written job hazard analysis (JHA) performed when any of these treatments are used.

Corona (air ionization) may be visible at tops of bushings at twilight or night, especially during periods of rain, mist, fog, or high humidity. At the top, corona is considered normal; however, as a bushing becomes more and more contaminated, corona will creep lower and lower. If the bushing is not cleaned, flashover will occur when corona nears the grounded transformer top. If corona seems to be lower than the top of the bushing, inspect, Doble test, and clean the bushing as quickly as possible. If flashover occurs (phase to ground fault), it could destroy the bushing and cause an extended outage. Line-to-line faults also can occur if all the bushings are contaminated and flashover occurs. A corona scope may be used to view and photograph low levels of corona indoors under normal illumination and outdoors at twilight or night. High levels of corona may possibly be viewed outdoors in the daytime if a dark background is available, such as trees, canyon walls, buildings, etc. The corona scope design is primarily for indoor and night time use; it cannot be used with blue or cloudy sky background. This technology is available at the Technical Service Center (TSC), D-8450.

Once every 3 to 5 years, depending on the atmosphere and service conditions, the bushings should be Doble tested. Refer to Doble M-4000 test set instructions, Doble Bushing Field Test Guide, FIST 3-2, and the manufacturer's instructions for proper values and test procedures. Bushings should be cleaned prior to Doble testing. Contamination on the insulating surface will cause the results to be inaccurate. Testing may also be done before and after cleaning to check methods of cleaning. As the bushings age and begin to deteriorate, reduce the testing interval to 1 year. Keep accurate records of results so that replacements can be ordered in advance, before you have to remove bushings from service.

2.6 Basic Principal of Dry Type Transformer

Dry-type transformers are most commonly used where the incoming electric service is at 480 Volts. Service at 120 Volts is a common supply voltage for small appliances and business machines. If 120-Volt lighting is served by the same transformer, that must be considered in any comparison. Panel boards for 277 Volt lighting are more expensive per branch circuit but fewer branch circuits might be needed with the higher voltage. However, practical considerations of areas of control may reduce this advantage. Therefore, it is necessary to look at each situation carefully when considering the panel board and the dry-type transformer size.

Dry-type transformers, for a variety of reasons, have largely replaced oil filled units within industrial, commercial and institutional buildings in the USA. However, unlike oil-filled units in the utility grid, little attention is often paid to the energy efficiency of dry-type units. Unlike motors, they have no moving parts to wear out, and so are expected to last 20 years or more.

Efficiency is seldom specified when buying dry-type transformers. Values of 95% or higher are typical, and differences between high- and low-efficiency units are only 1% to 2%, with a significant first-cost premium for the more efficient units. But first cost is not the last cost of any transformer. Complete life-cycle costs must be carefully examined along with the economics of high-efficiency dry-type transformers.

2.7 Insulation

The National Electric Manufacturers Association (NEMA) has designed four classes of insulation with specifications and temperature limits for dry type transformers. In each case, the temperature base has been set at 40°C or 104°F. Equipment should not be installed in areas with ambient temperatures in excess of this value without having its output rating lowered. The NEMA classifications are:

(1) Class A. Allow for not more than 55°C rise on the coil. This is close to the boiling point of water, but combustible materials may be present in the area with the transformer.

(2) Class B. Temperature rise may not exceed 80°C rise in the coil. These transformers are smaller than Class A types and weigh about one-half as much. These transformers are becoming less popular than the Class F and H series for distribution systems.

(3) Class F. This classification allows a temperature rise on the coils up to 115°C. These transformers are smaller than Class B types and are available up to 25 kVA for single- or three-phase applications.

(4) Class H. A maximum temperature rise of 150°C is allowed on the windings. The insulating materials used with these transformers are high-temperature glass, silicone, and asbestos. These units come in rating of 30 kVA or greater.

Excessive temperature rise is the primary cause of transformer failure. Transformers are designed to have higher allowable temperature rises. Sorgel Transformers, for example, uses a barrel-type construction on their power transformers that allow for 220°C rise. These transformers are still operated within the NEMA classifications, but this method of construction allows a temperature margin to compensate for any host spots that may occur.

2.8 Economical Analysis

(a) Life-Cycle Costing

When a lower cost, 98% efficient unit and a higher cost unit at 99% are compared, that means that the losses are actually cut in half.

Conductor losses, also known as coil losses or load losses, should not be overlooked – for one reason because such losses vary by the square of the load. That means a fully loaded transformer has four times the load losses compared with one running at 50% of its design load. In many applications, transformers are heavily loaded. But even at lower load factors, if the units are not efficient (and many are not), losses mount rapidly.

Thus, the continuing costs of transformer losses should be balanced with the savings to be gained from efficient units – savings which go on year after year – quickly paying back the extra first cost.

Other benefits pile up as well. Efficient transformers run cooler, and thus more reliably, because of decreased stress on insulation materials. As a result, they will have a higher overload capacity, an important issue in dry-type transformers. The ultimate result can be units with a smaller kVA rating actually doing the same job, with attendant first-cost savings.

(b) Efficiency vs. Temperature Rise

Efficiency and temperature rise are related, but separate issues. Inefficiency is purely and simply the generation of waste heat- I^2R losses in the transformer windings. To the extent heat is *generated*, the unit is inefficient. The temperature rise, on the other hand, results not only from how much heat is generated, but also from how much is *removed*.

An inefficient dry-type transformer can, in fact, run cool by incorporating into its design larger air passages or fan-cooling. High-efficiency transformers eliminate the need for these extra cooling costs.

(c) The Economics of Efficiency

The examples below are of high-efficiency, copper-wound transformers designed to achieve an 80°C temperature rise and high efficiency. These are compared to standard, run-of-the-mill units using aluminum, the low-cost winding material, and designed to a 150°C rise.

The 1,500 kVA unit represents a typical, large dry-type transformer used for industrial and some larger commercial applications. In these applications, duty cycles can be quite high. Both 65% and 85% are used in the examples. Paybacks in high-electricity-cost areas can be as fast as one year for the design shown.

For light commercial applications, such as lighting circuits in office buildings, smaller units, such as the 75 kVA example shown, are used. Here, duty cycles would typically be lower. The sample calculations are for 50% and 75% duty cycles. In these applications, however, the customer is likely to pay a higher electricity rate than is the case in industrial applications. But here, again, paybacks can be short – as little as 1.1 years.

Once the unit's first cost premium is paid back, those energy savings continue to accumulate for the decades the transformer will be in service.

III. RESEARCH METHODOLOGY

When we start to set the measurement for study any factor concerning our response related to the process, it is necessary that everyone involved in the measurement has a clear idea in advance of exactly what is to be studied. We may proceed as follows:

3.1 Recognition and Statement of the Problem

In terms of Charging Assembly process, we always find energy losses problem. The problem will effect the efficiency of charging machine and process time.

3.2 Choice of Factors and Levels

We must select the factors following the cause-effect diagram, energy loss which effect charging machine as mentioned in Chapter 1, Introduction. The factors that are selected will be decided on a region of interest for each variable. The level of factors has to cover a range of current process specification.

3.3 Selection of Response Variable

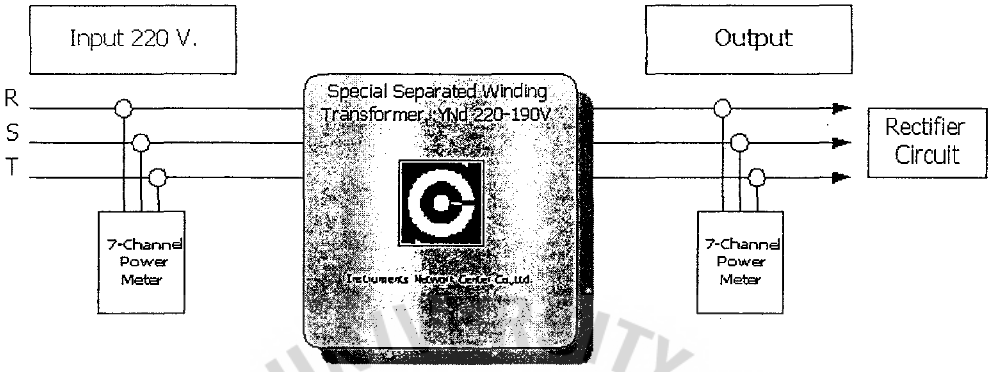
In selecting the response variable, we are certain that this variable really provides useful information about the process under study. So we set the output of charging operation as transformer efficiency because the transformer efficiency will figure exactly the charging machine performance.

3.4 Measurement Analysis

3.4.1 Measurement Details of the Existing System

At first we must evaluate the existing system by measuring energy consumption at both input and output of the existing transformer, and make sure that there is not any affect to the other related machine.

Take an example of one battery charger machine (oil type transformer), measure all power consumption by using high efficient three phase power analyzer which can analyze as True RMS and have low error not exceeding 1.5% of Real Power (kW) and Reactive Power (kVAr).



(7 channel = Voltage 4 channel, Current 3 channel)

Figure 3.1. Point of Measuring.

Parameters that we should consider are Voltage (V), Current (I), Power (kW), Power factors (ϕ) and Reactive Power (kVAr). Measurement all parameter as the following:

Table 3.1. Parameters and Point of Measurement.

Parameters	Measure Point	Measure Point
Power	Input	Output
Voltage	Input	Output
Current	Input	Output
Current harmonics	Input	Output

We record and update data every second and display average data of every 15 minute. The period of measurement is three day working hours (working not less than three batches per day) at normal running operation.

3.4.2 Measurement Detail after Improve the System

We start up the measurement seven days after replacing the new transformer and record power consumption parameter for three day working. (working not less than 3 batch per day) at normal running operation

Measurement result will display the average power consumption (kW) after system improvement. By comparing the difference of power consumption before and after improvement can be concluded as the following equation:

Power Saving = Power before improvement– Power after improvement........(3.1)

In case of having more than one machine supposed to be N machines it can be calculated as the following equation:

Total Power Saving = Real power saving per machine x N.......................(3.2)

From equation (3.2) we can calculate power saving per year as the following equation:

Energy Saving (kWH) = Power saving x Working hours per year..............(3.3)

Estimated working hours per year is 8,000 hours, thus

Energy saving per years = Total Power Saving x 8,000 hours.....................(3.4)

Estimated electricity cost per unit is 2.5 Bahts per unit (kWH) Thus can calculate saving cost as the following:

Energy Saving Cost per Year = Energy Saving per Year x 2.5 Bahts..........(3.5)

Calculate pay back period as the following equation:

Pay Back Period(Year) = Energy Cost ÷ Energy Saving per Year...............(3.6)

3.5 Measurement Instrument

In this project we use high technology digital power analyzer to collect and record all power consumption data. This instrument is AR.5 brand circutor from Spain. It has high accuracy and memory. Which the high accuracy in term of technical we divided measurement instrument into three class are class 0.5, class 1, and class 2. The first class 0.5 is very high accuracy instrument used for those who sell and buy electricity, which have small deviation of volt, current and power. The second class 1 is suitable for any organizations that want to recheck or record their electric consumption to compare with the MEA (Metropolitan Electricity Authorization) or PEA (Provincial Electricity Authorization). It has the deviation of kWh less than ± 1%. The last one class 2 is suitable for monitoring in control room or MDB Main Distribution Board) which has the deviation of kWh less than ± 2%. The AR.5 is class 1 instrument that we selected to use for measurement. We can trust and rely on the data and can use those raw data for our analysis.

AR.5 series networks analyzers are fully-programmable measuring instruments that measure and record in memory all the electrical parameters from any electric power system. These instruments are equipped with three voltage channels and other three current channels to carry out the measurement of any parameter from either balanced or unbalanced three-phase power systems.

Figure 3.2. AR.5 Digital Power Analyzer.

Instantaneous readouts are displayed by a 160 x 160 pixels graphic screen, and, simultaneously, these results can be saved in an internal memory according to preset file types. That way, records can include average, maximum and minimum values of voltages, currents and powers, but also wave form snapshots, values of accumulated energy, disturbances, etc.). The AR.5 is also a re-programmable instrument, so that, by means of an external cartridge connected to the built-in communication output, diverse operation programs can be loaded or updated in order to accomplish any analysis involving the control of electric power or the quality of distribution systems.

3.5.1 Operation Program

The AR.5 have many several operation programs, which can be indistinctly selected when the instrument is turn on. Each program permits a periodical record in memory of some parameters, just continuously along the time or by predefining trigger conditions. All the setting process is done by means of intuitive menus shown on the instrument screen.

3.5.2 Standard Operation Program, Energy:

Basic program permits to measure voltages, currents, powers and energies from any phase and to save in memory the results over regularly recording periods. Main actions delivered by the analyzer are following enumerated:

(1) Numerical displaying on screen of all the data of voltage, current, power and other electrical parameters by phase and three-phases in table format.

(2) Visualization of three instantaneous parameters of the user choice in a bigger-size mode for a clearer reading and a graphic representation on display of the three phases (L1, L2 and L3) of the user-selected parameter.

(3) Concurrently representation of the wave forms of voltage and current of each phase (L1, L2 and L3).

(4) Measurement of the neutral current by using any of line ammeter clamps.

(5) Periodical record in memory at user-defined time intervals of data files with .A5M extension, that contains average values, maximum and minimum values, etc. These files can be further managed in a PC by means of the AR.5 VISION software.

When the AR.5 is loaded with this program, the analyzer permits to effectuate detailed analysis on power factor correction, electric power consumption; and to obtain graphs of average, maximum and minimum values of 20 discrete basic electrical parameters.

The program for harmonic measurement includes all the functions that the standard program offers, but also these functions are related to the harmonic measurement according to the harmonized standards IEC 61000-4-7. Main actions delivered by the analyzer in terms of harmonic measurement are following enumerated:

(1) Analysis and record of harmonics up to the 30 th or 50 th order (user-selectable)

(2) Visualization in display of the voltage and current wave forms, zoom function also available

(3) Indication in display of the discrete harmonic content, either by bar-graph and numeric table

(4) Measuring of the neutral current harmonics by using any of line ammeters clamps.

(5) Periodical record in memory at user-defined time intervals of data files with .A5I extension, which contains data related to electrical parameters and harmonic distortion also. These files can be further managed in a PC by means of the AR.5VISION software.

Obtained results permits to effectuate a diagnostic on installations affected by harmonics, as well as calculated overload factors over capacitors and power transformers. Also, the over current through the neutral conductor in unbalanced systems can be measured; and basic and essential data to design harmonic filters can be obtained.

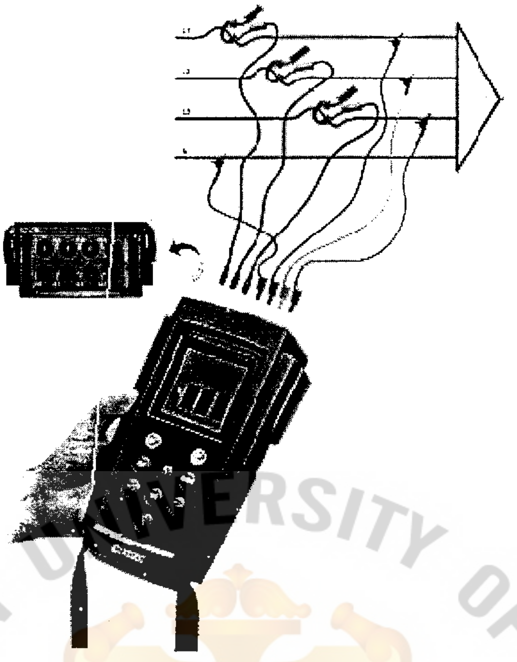


Figure 3.3. AR.5 Operation.

3.5.3 Software for the Aanalysis of Electric Network. AR.5 Vision

AR.5 VISION is a software package to be run under WINDOWS environment. This software delivers appropriate tools to retrieve, manage and obtain graphic and/or numeric representations from logs stored by diverse analyzers of the quality of electric power supply. Particularly, the software permits to set a RS 232 communication to any analyzer of the AR.5, QNA, CVM-BP and CVM-BQ range.

3.5.4 Basic functions of the AR.5-VISION

(a) Software

Actions delivered by the software can be divided into two function groups:

(1) INSTRUMENT <-> PC communication link. Data saved in memory of the analyzer can be retrieved and saved into the PC memory. (Figure 3.4.)

(2) Data virsualization, in graphic or numeric mode, for the analysis of power systems (Figure. 3.5.) The program provides a general display of results, by the combination of diverse parameters, that is useful to globally evaluate the quality of the electric power network. But besides "zoom" actions over graphical representation are available, together with graphical or numerical detailed information, which also permits the analysis of short-time disturbances.

(b) Files Management and Data Display

The matter of recording the quality of the power electric supply involves many discrete parameters, in order to particularize the detection of diverse problems on the quality of power supply. Concretely, following listed record types can be obtained and virsualized. From any record type the user can obtain numeric data table and graphic representations that offer following listed features:

(1) Numeric data can be exported to a standard spreadsheet for calculation purposes

(2) Graphic representations deliver cursors with numeric indications and possibility of "zoom" actions over the graph

Figure 3.4. PC Communication Link.

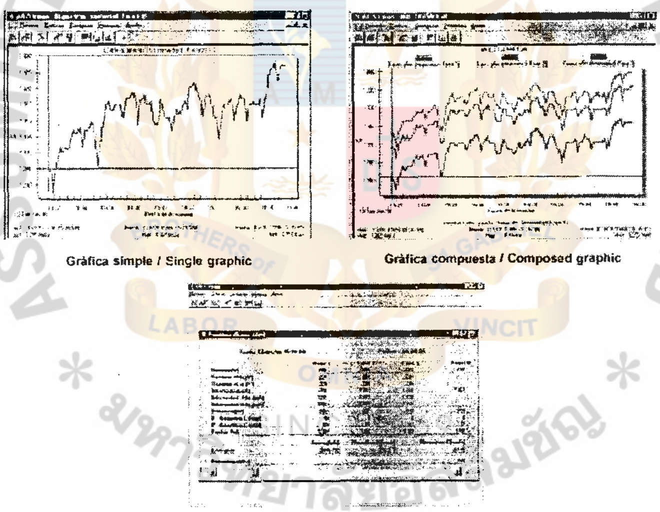


Figure 3.5. Data Virsualization.

IV. DATA COLLECTION AND ANALYSIS

From on site survey measurement we can collect the information of the existing system as the following:

4.1 General Data of the Existing System

Distributed Transformer for Battery Charger

Table 4.1. Technical Data of the Existing System.

Parameters	Technical Data
Transformer type	3-ϕ oil type transformer
Input Voltage	220 Volt
Output Voltage	220 Volt
Operating Frequency	50 Hz
Winding Connection	YNd
Current DC	103.5 Amp
Volt Dc	180 Volt
Temperature Rise	50/90 °C
Insulation Class	A/H
Insulation Resistance	3 MΩ

4.2 Measuring Result:

Loading data from the AR.5. We can see the consumption of voltage, current, real power and reactive power as the following details:

4.2.1 Input Side Numerical Data

Table 4.2. Measurement Data of the Input Side.

Date	Time	V-AB	A1	PF1
4/7/01	9:04:20	208	81	-0.9
4/7/01	9:04:25	208	81	-0.9
4/7/01	9:04:30	207	82	-0.9
4/7/01	9:04:35	208	81	-0.9
4/7/01	9:04:40	208	81	-0.9
4/7/01	9:04:45	207	81	-0.9
4/7/01	9:04:50	207	81	-0.9
4/7/01	9:04:55	208	81	-0.9
4/7/01	9:05:00	209	81	-0.9
4/7/01	9:05:05	210	81	-0.9

4.2.2 Input Side Graphical Data

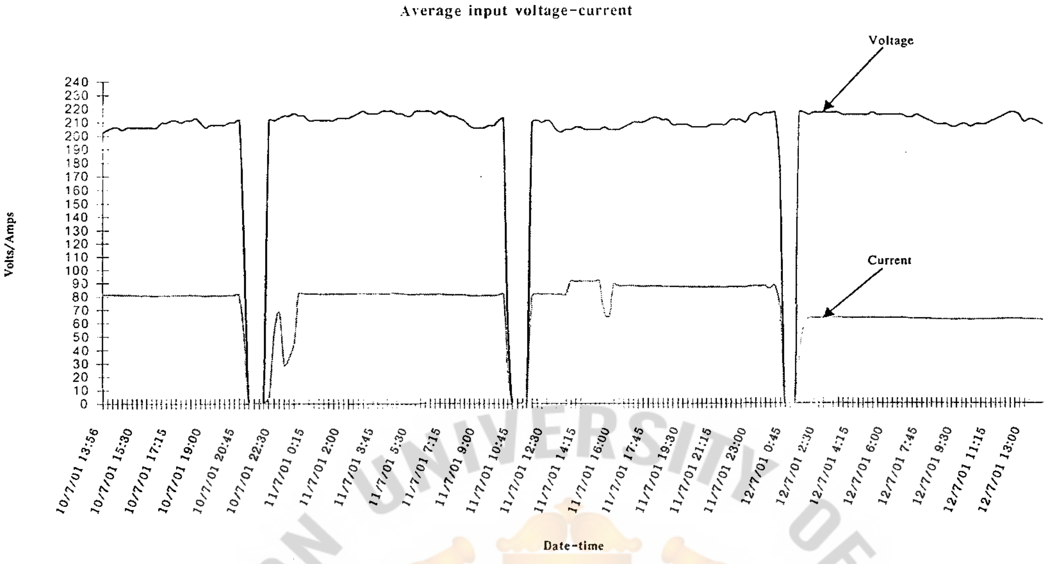


Figure 4.1. Illustrate Voltage and Current Profile at Input Side.

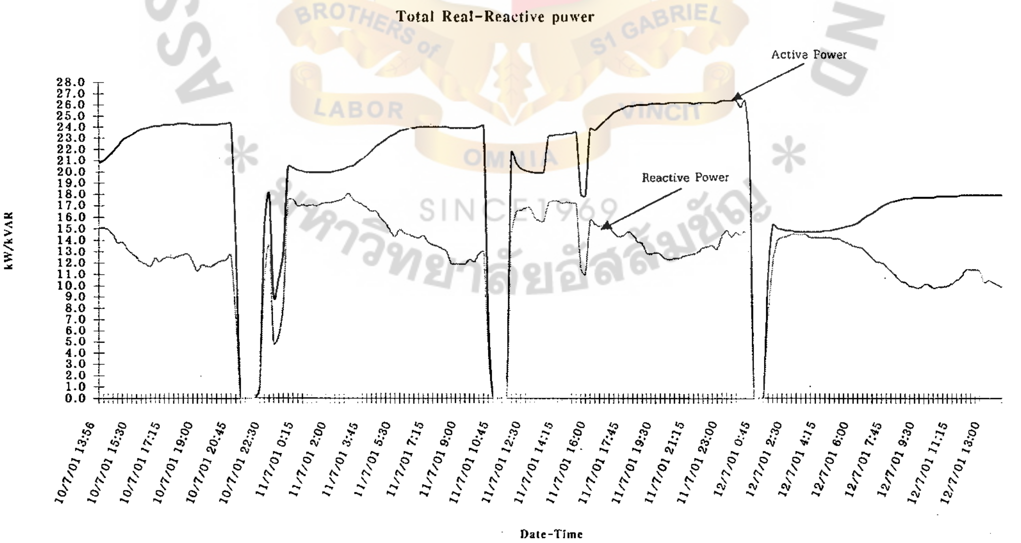


Figure 4.2. Illustrate Real and Reactive Power at Input Side.

4.2.3 Output Side Numerical Data

Table 4.3. Measurement data of the Output Side.

Date	Time	V-AB	A1	PF1
4/7/01	9:09:20	190	84	-0.9
4/7/01	9:09:25	190	84	-0.9
4/7/01	9:09:30	190	84	-0.9
4/7/01	9:09:35	190	84	-0.9
4/7/01	9:09:40	190	84	-0.9
4/7/01	9:09:45	190	84	-0.9
4/7/01	9:09:50	190	84	-0.9
4/7/01	9:09:55	190	84	-0.9
4/7/01	9:10:00	190	84	-0.9
4/7/01	9:10:05	190	84	-0.9
4/7/01	9:10:10	190	84	-0.9
4/7/01	9:10:15	190	84	-0.9
4/7/01	9:10:20	190	84	-0.9
4/7/01	9:10:25	190	84	-0.9
4/7/01	9:10:30	190	84	-0.9

4.2.4 Output Side Graphical Data

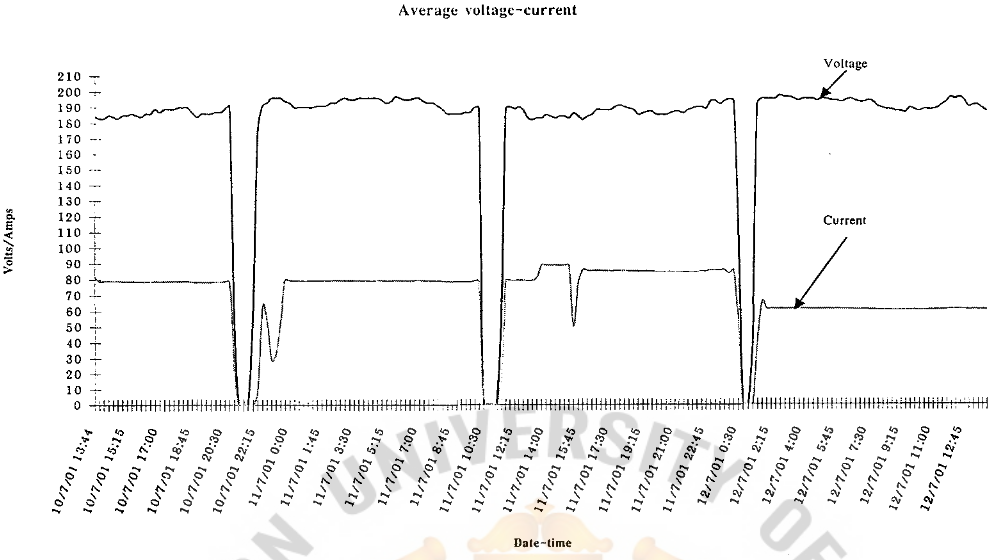


Figure 4.3. Illustrate Voltage and Current Profile at Output Side.

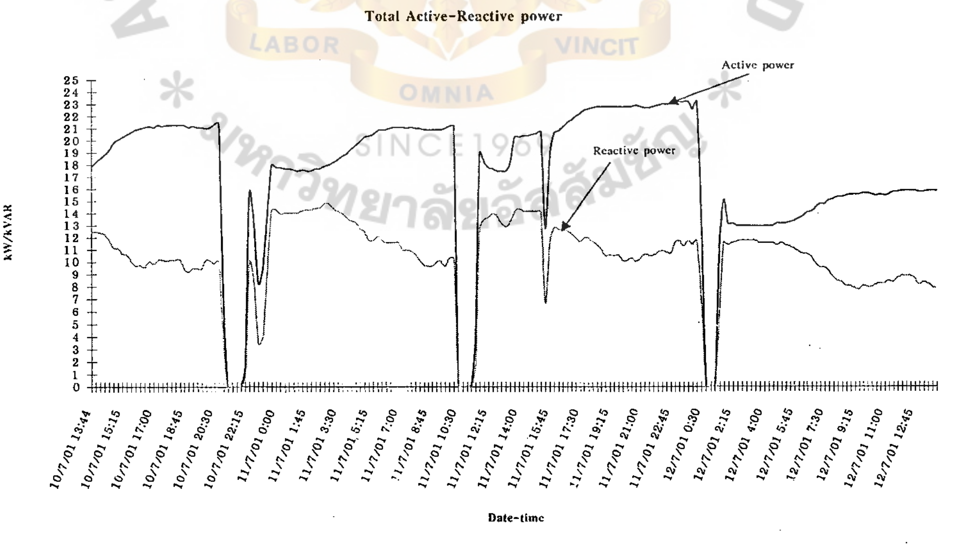


Figure 4.4. Illustrate Active and Reactive Power at Output Side.

4.3 Analysis of Measuring Result.

From the measuring data since July 10-12, 2001

Table 4.4. Concluded Data from Measuring the Energy Consumption of Oil Type Transformer.

	Input side				***Output side***			
Variable	*Volt*	*Amp*	*kW*	*PF.*	*Volt*	*Amp*	*kW*	*PF.*
Average	211	76.4	21.1	0.75	188	74.2	18.6	0.73
Maximum	218	91.4	26.4	0.83	197	88.9	23.2	0.81
Minimum	203	29.6	9.0	0.61	182	29.2	8.3	0.60

Refer to the result we can calculate the energy loss as the following details:

(1) Average energy losses of transformer equal

kW_{loss} = kW_{in} - kW_{out}

= 21.1-18.6

= 2.5 kW (where average kW_{in}= 21.1 kWatt)

The total energy losses of battery charger system are in range of 0.7-3.2 kW from which the difference between power input and power output can be seen as in Figure 4.5.

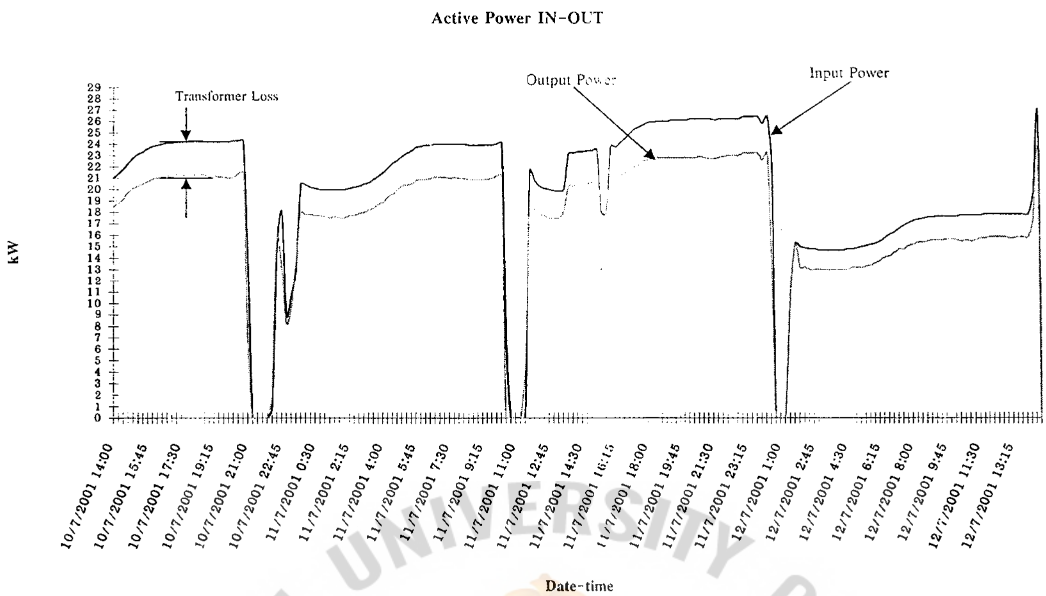


Figure 4.5. Illustrate the Power Differentiates Between Input and Output Side.

From Table 4.2. we can calculate efficiency of the existing transformer

$$\text{Transformer efficient } (\eta) = kW_{out} \div kW_{in}$$

$$= 18.6 \div 21.1$$

$$= 88.2\%$$

Before replacing the old transformer with the new one the important parameter that we should know is transformer rating. From collecting data of the existing system, maker does not specify the rating of the existing transformer. Thus, we can calculate the average size of the existing transformer from the raw data as the following:

(1) Average size of the existing transformer (kVA)

kVA = kW ÷ PF.

= 21.1÷ 0.73

= 28.9 kVA

The total apparent power of battery charger machine is in range of 13.8-28 kVA.

4.3.1 How to Improve the Efficiency of the Existing Transformer.

In case of replacing the existing system with the new transformer which has high efficiency of 97%; assume the power feed to Rectifier Circuit is constant (kW_{out} is constant) From the equation

Transformer efficiency (η) = $kW_{out} \div kW_{in}$

Thus kW_{in} = $kW_{out} \div \eta$

= 18.6 ÷ 0.97

= 19.2 kW

∴ Total energy saving in transformer equal 21.1-19.2 = 1.9 kW

Calculate power consumption (kWH) as the following:

Working hours per year 8,760 Hours

Working hours excluding holiday 8,000 Hours

The power saving per year equal 8,000 Hrs. x 1.9 kW = 15,200 kWH

Electricity charge per unit (kWH) = 2.5 Bahts

Power saving cost = 15,200 kWH x 2.5 Bahts

= 38,000 Bahts

∴Power saving cost per machine per years is 38,000 Bahts

4.3.2 Financial Analysis

Payback period:

Estimate Investment cost

(1) The higher efficient transformer cost for DC Rectifier circuit is 3-ϕ 220Vac./0-240Vdc.

(2) 240Vdc. 120Adc. 120,000 Baht per machine

(3) Installation cost per machine is 5,000 Bahts

(4) Use the existing wiring cable

Total Investment Cost 125,000 Bahts per machine

Payback period = 125,000 ÷38,000 = 3.3 years

$\therefore$ Payback period is 3.3 years Power saving cost which is 38,000 Bahts per year and the Investment cost per machine is 125,000 Bahts.

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Referring to the analysis of the result of the measurement that we consider energy losses and transformer efficiency, we found that the existing transformer has high-energy losses and low efficiency. Thus, we propose the new transformer to our customer. Generally transformer should have efficiency more than 95%.

We look at the whole result of measurement. Table 5.1 shows the parameter of the new transformer proposed to the customer.

Table 5.1. Parameters and Technical Data of New Transformer.

Parameters	Technical Data
Type of wiring	3m Phase, copper winding
Type of core	Silicon laminated steel core
Type of cooling	AN (Dry-type, air natural self cooled)
Varnish Method	Impregnated with insulating vanish By vacuum-pressure impregnation system and dried in oven chamber.
Input Voltage	220 Vac
Output Voltage	Design for DC Power Supply 3ph 220Vac/0-240 Vdc. 120Adc.
Operating Frequency	50Hz
Winding Connection	Ynd
Phase Shift	Winding configured to provide primary secondary Phase shift of "O" degree.

Table 5.1. Parameters and Technical Data of New Transformer. (Continued)

Parameters	Technical Data
Impedance Voltage	< 3%
Insulation Class	Class F (155°C)
Operating temperature rise	Not more than 100°C
Ambient temperature	40°C (maximum)
Efficiency	97% (25-100% Load)
Duty cycle	100% (Designed for continuous operation)
Complied standard	IEC 76 and VDE 0532-1966
Enclosure	-Made of galvanized steel sheet with grid ventilated -Finished by powder coated painting -protection class [P20for indoor use only]
Overload protection	Thermal relay (series in 3 coils winding with NC contact).
Warranty	3 years, against defective material, and workmanship, limited liability

5.2 Transformer lifetime Warranty Conditions.

We do hereby warranty the original Purchaser that its products shall be free from defects in material or workmanship under normal use and conditions for a period of four (4) years from the date of purchase by original Purchaser.

This warranty does NOT apply if damage is caused by fire, accident, misuse, neglect, incorrect adjustment or repair, damage by incorrect installation, adaptation, modification, fitting of non-approved parts or repair by unauthorized personnel.

5.3 Recommendation for Dry Type Transformer Maintenance.

Although the transformer is an equipment that needs no maintenance, it is better for a user to regularly monitor to extend the transformer lifetime. The following table is the simple regulation to monitor the dry type transformer.

Table 5.2. Maintenance Regulation for Dry Type Transformer.

Condition	Regulation
When new after energizing and allowing Temperature and loading to stabilize	Do an infrared scan and compare with temperature gage, if any. If transformer is gas filled (nitrogen [N_2]), check pressure gage against data sheets; never allow gas pressure to fall below 1 pound per square inch (psi). Check loading and compare with nameplate rating. Functionally test fans and controls for proper operation. Functionally test temperature alarms and annunciator points. Check area around transformer clear of debris and parts storage. Check transformer room for proper ventilation.
After 1 week of operation at normal Loading	Perform infrared scan and compare with temperature gage, if any. Check temperature gage, if any, and compare with nameplate rating. Check loading and compare with nameplate rating.

5.3.1 Maintenance Method for Different Insulation Class of Dry Type Transformers

Cooling classes of dry type transformers are covered by ANSI/IEEE standard C57.12.01 Section 5.1. A short explanation of each class is given below.

(1) Class AA are ventilated, self-cooled transformers. This means that there are ventilation ports located at the out walls of the transformer enclosure. There are no fans to force air into and out of the enclosure with typically no external fins or radiators. Cooler air enters the lower ports, is heated as it rises past windings, and exits the upper ventilation ports. (It will not be repeated below; but it is obvious that in every cooling class, some heat is also removed by natural circulation of air around the outside of the enclosure.)

(2) Class AFA transformers are self-cooled (A) and additionally cooled by forced circulation of air (FA). This means that there are ventilation ports for fan inlets and outlets only. (Inlets are usually filtered.) Normally, there are no additional ventilation ports for natural air circulation.

(3) Class AA/FA transformers are ventilated, self-cooled (same as Class AA in item 1). In addition, they have a fan or fans providing additional forced-air cooling. Fans may be wired to start automatically when the temperature reaches a pre-set value. These transformers generally have a dual load rating, one for AA (self-cooling natural air flow) and a larger load rating for FA (forced air flow).

(4) Class ANV transformers are self-cooled (A), non-ventilated (NV) units. The enclosure has no ventilation ports or fans and is not sealed to exclude migration of outside air, but there are no provisions to intentionally allow outside air to enter and exit. Cooling is by natural circulation of air around

the enclosure. This transformer may have some type of fins attached outside the enclosure to increase surface area for additional cooling.

(5) Class GA transformers are sealed with a gas inside (G) and are self-cooled (A). The enclosure is hermetically sealed to prevent leakage. These transformers typically have a gas, such as nitrogen or freon, to provide high dielectric and good heat removal. Cooling occurs by natural circulation of air around the outside of the enclosure. There are no fans to circulate cooling air; however, there may be fins attached to the outside to aid in cooling.

(a) Potential Problems and Remedial Actions for Dry Type Transformer Cooling Systems.

It is important to keep transformer enclosures reasonably clean. It is also important to keep the area around them clear. Any items near or against the transformer impede heat transfer to cooling air around the enclosure. As dirt accumulates on cooling surfaces, it becomes more and more difficult for air around the transformer to remove heat. As a result, over time, the transformer temperature slowly rises unnoticed, reducing service life.

Transformer rooms and vaults should be ventilated. Portable fans (never water) may be used for additional cooling if necessary. A fan rated at about 100 cubic feet per minute (cfm) per kilowatt (kW) of transformer loss, located near the top of the room to remove hot air, will suffice. These rooms/vaults should not be used as storage.

When the transformer is new, check the fans and all controls for proper operation. After it has been energized and the loading and temperature are stable, check the temperature with an infrared (IR) camera and compare loading with the nameplate. Repeat the temperature checks after 1 week of operation.

Once each year under normal load, check transformer temperatures with an IR camera . If the temperature rise (above ambient) is near or above nameplate rating, check for overloading. Check the temperature alarm for proper operation. Check enclosures and vaults/rooms for dirt accumulation on transformer surfaces and debris near or against enclosures. Remove all items near enough to affect air circulation. To avoid dust clouds, a vacuum should first be used to remove excess dirt. Low pressure (20 to 25 pounds per square inch [psi]) dry compressed air may be used for cleaning after most dirt has been removed by vacuum. The transformer must be de-energized before this procedure unless it is totally enclosed and there are no exposed energized conductors. Portable generators may be used for lighting.

After de-energizing the transformer, remove access panels and inspect windings for dirt- and heat-discolored insulation and structure problems. It is important that dirt not be allowed to accumulate on windings because it impedes heat removal and reduces winding life. A vacuum should be used for the initial winding cleaning, followed by compressed air. Care must be taken to ensure the compressed air is dry to avoid blowing moisture into windings. Air pressure should not be greater than 20 to 25 psi to avoid imbedding small particles into insulation. After cleaning, look for discolored copper and insulation, which indicates overheating. If discoloration is found, check for loose connections. If there are no loose connections, check the cooling paths very carefully and check for overloading after the transformer has been re-energized. Look for carbon tracking and cracked, chipped, or loose insulators. Look for and repair loose clamps, coil spacers, deteriorated barriers, and corroded or loose connections.

Check fans for proper operation including controls, temperature switches, and alarms. Clean fan blades and filters if needed. A dirty fan blade or filter reduces cooling air flow over the windings and reduces service life. If ventilation ports do not have filters, they may be fabricated from home-furnace filter material. Adding filters is only necessary if the windings are dirty upon yearly inspections.

Check pressure gages by looking at the weekly data sheets; if pressure never varies with temperature changes, the gage is defective. Never allow the pressure to go below about 1 psi during cold weather. Add nitrogen to bring the pressure up to 2½ to 3 psi to insure that moist air will not be pulled in.

APPENDIX A

THE MEASUREMENT DATA OF THE SYSTEM

Table A.1. Transformer Input Data.

Date	Unit V	Unit A	Unit W	V-AB	V-BC	V-CA	V-ll ave	A1	A2	A3	A ave	P1	P2	P3	P total	Q1	Q2	Q3	Q total	PF1	PF2	PF3	PF ave	kWH
10/7/01 13:56	V	A	kW	204	204	203	203	82.8	82.0	80.0	81.6	7.1	7.0	6.7	20.8	5.1	5.1	4.9	15.1	0.72	0.72	0.72	0.72	1.4
10/7/01 14:00	V	A	kW	206	206	203	204	83.0	82.1	79.8	81.6	7.2	7.0	6.8	21.0	5.0	5.1	4.9	15.1	0.72	0.72	0.72	0.72	6.6
10/7/01 14:15	V	A	kW	208	208	204	206	83.0	81.6	79.9	81.5	7.3	7.1	6.9	21.4	5.0	5.0	4.8	14.9	0.73	0.73	0.73	0.73	12.0
10/7/01 14:30	V	A	kW	206	208	204	206	83.0	81.6	79.6	81.4	7.4	7.3	7.0	21.8	4.8	4.9	4.6	14.5	0.75	0.74	0.74	0.75	17.5
10/7/01 14:45	V	A	kW	204	206	203	204	82.5	82.6	79.1	81.4	7.6	7.6	7.1	22.3	4.5	4.7	4.5	13.8	0.77	0.77	0.76	0.77	23.1
10/7/01 15:00	V	A	kW	208	208	204	206	82.6	82.5	79.1	81.4	7.7	7.7	7.2	22.8	4.5	4.7	4.5	13.8	0.78	0.77	0.77	0.78	28.8
10/7/01 15:15	V	A	kW	208	208	204	206	82.7	81.7	79.5	81.3	7.9	7.7	7.4	23.1	4.4	4.5	4.3	13.3	0.79	0.79	0.79	0.79	34.6
10/7/01 15:30	V	A	kW	208	208	206	206	82.6	81.4	79.4	81.1	7.9	7.8	7.5	23.3	4.3	4.4	4.2	12.9	0.80	0.79	0.79	0.80	40.5
10/7/01 15:45	V	A	kW	208	208	206	206	82.7	81.1	79.1	80.9	8.0	7.9	7.6	23.6	4.2	4.2	4.0	12.5	0.81	0.80	0.81	0.81	46.4
10/7/01 16:00	V	A	kW	206	208	204	206	82.3	81.5	79.1	81.0	8.1	8.0	7.6	23.8	4.0	4.1	3.9	12.1	0.82	0.81	0.81	0.82	52.4
10/7/01 16:15	V	A	kW	206	208	204	206	82.4	81.1	79.0	80.8	8.1	8.0	7.7	23.9	4.0	4.0	3.8	11.9	0.82	0.82	0.82	0.82	58.4
10/7/01 16:30	V	A	kW	206	208	204	206	82.4	80.7	79.1	80.7	8.2	8.0	7.7	24.0	3.9	3.9	3.7	11.7	0.83	0.82	0.82	0.83	64.4
10/7/01 16:45	V	A	kW	211	211	208	210	82.5	81.4	79.1	81.0	8.2	8.1	7.7	24.1	4.1	4.2	4.0	12.4	0.82	0.81	0.81	0.81	70.5
10/7/01 17:00	V	A	kW	210	211	208	210	82.5	81.1	79.2	80.9	8.2	8.1	7.7	24.1	4.0	4.1	3.9	12.1	0.82	0.82	0.81	0.82	76.5
10/7/01 17:15	V	A	kW	211	213	210	211	82.8	81.0	79.2	81.0	8.3	8.1	7.8	24.2	4.2	4.2	4.0	12.4	0.82	0.81	0.81	0.81	82 6
10/7/01 17:30	V	A	kW	211	213	210	211	82.7	81.2	79.4	81.1	8.3	8.1	7.8	24.2	4.2	4.2	4.0	12.5	0.81	0.81	0.81	0.81	88.7
10/7/01 17:45	V	A	kW	211	211	208	210	82.7	80.9	79.6	81.1	8.2	8.1	7.8	24.2	4.2	4.1	4.0	12.4	0.82	0.81	0.81	0.81	94.8
10/7/01 18:00	V	A	kW	211	213	210	211	82.7	81.2	79.5	81.1	8.3	8.1	7.8	24.3	4.2	4.2	4.1	12.6	0.81	0.81	0.81	0.81	100.9
10/7/01 18:15	V	A	kW	213	213	210	211	82.7	81.0	79.8	81.2	8.3	8.1	7.8	24.3	4.3	4.2	4.1	12.7	0.81	0.81	0.81	0.81	107.0
10/7/01 18:30	V	A	kW	213	215	211	213	82.9	80.8	79.9	81.2	8.3	8.1	7.9	24.3	4.3	4.2	4.1	12.8	0.81	0.80	0.81	0.81	113.1
10/7/01 18:45	V	A	kW	210	211	208	210	82.6	80.2	79.9	80.9	8.2	8.0	7.9	24.2	4.2	4.0	3.9	12.1	0.82	0.82	0.82	0.82	119.1
10/7/01 19:00	V	A	kW	206	208	204	206	82.2	80.2	79.3	80.6	8.2	8.0	7.8	24.2	3.8	3.7	3.6	11.3	0.84	0.83	0.83	0.83	125.2
10/7/01 19:15	V	A	kW	208	210	206	208	82.3	80.5	79.6	80.8	8.2	8.1	7.8	24.2	4.0	3.9	3.8	11.8	0.83	0.82	0.82	0.83	131.3
10/7/01 19:30	V	A	kW	208	210	206	208	82.3	80.5	79.5	80.8	8.2	8.1	7.8	24.2	4.0	3.9	3.8	11.7	0.83	0.83	0.83	0.83	137.4
10/7/01 19:45	V	A	kW	208	210	206	208	82.4	80.5	79.5	80.8	8.2	8.1	7.8	24.2	4.0	3.9	3.8	11.7	0.83	0.82	0.83	0.83	143.5
10/7/01 20:00	V	A	kW	210	210	206	208	82.4	80.7	79.5	80.8	8.2	8.1	7.8	24.2	4.0	4.0	3.9	12.0	0.83	0.82	0.82	0.82	149.5
10/7/01 20:15	V	A	kW	210	211	208	210	82.4	81.1	79.5	81.0	8.2	8.1	7.8	24.3	4.0	4.1	4.0	12.2	0.82	0.82	0.82	0.82	155.6
10/7/01 20:30	V	A	kW	211	211	208	210	82.5	81.1	79.7	81.1	8.2	8.1	7.8	24.3	4.1	4.1	4.0	12.3	0.82	0.82	0.81	0.82	161.7
10/7/01 20:45	V	A	kW	213	213	211	211	82.8	81.4	79.8	81.3	8.3	8.1	7.8	24.3	4.2	4.3	4.1	12.7	0.81	0.80	0.81	0.81	167.8
10/7/01 22:30	V	A	kW	213	213	211	211	55.1	53.9	52.4	53.8	5.1	4.9	4.8	14.8	3.3	3.3	3.1	9.8	0.75	0.74	0.75	0.74	175.3
10/7/01 22:45	V	A	kW	215	215	211	213	70.0	69.0	66.9	68.6	6.2	6.0	5.8	18.1	4.5	4.5	4.4	13.5	0.71	0.71	0.71	0.71	179.8
10/7/01 23:00	V	A	kW	217	217	215	215	30.1	29.8	28.8	29.6	3.0	3.0	2.9	9.0	1.6	1.6	1.6	4.9	0.81	0.80	0.81	0.81	182.1
10/7/01 23:15	V	A	kW	217	215	213	215	35.2	34.7	33.7	34.5	3.6	3.5	3.4	10.6	1.8	1.8	1.8	5.5	0.82	0.82	0.82	0.82	184.7
10/7/01 23:30	V	A	kW	218	217	217	217	47.1	46.6	44.8	46.2	4.5	4.3	4.2	13.0	2.8	2.9	2.8	8.5	0.75	0.74	0.75	0.75	188.0
10/7/01 23:45	V	A	kW	217	217	215	215	84.0	83.0	80.1	82.4	7.0	6.8	6.5	20.5	5.8	5.9	5.7	17.5	0.67	0.66	0.65	0.66	193.2
11/7/01 0:00	V	A	kW	217	217	215	215	83.9	82.8	80.2	82.3	7.0	6.8	6.5	20.4	5.9	5.9	5.7	17.6	0.66	0.65	0.65	0.66	198.3
11/7/01 0:15	V	A	kW	213	213	210	211	83.7	82.1	80.1	82.0	6.9	6.7	6.5	20.2	5.7	5.7	5.5	17.0	0.67	0.66	0.66	0 67	203.4
11/7/01 0:30	V	A	kW	213	213	210	211	84.0	81.9	80.1	82.0	6.9	6.6	6.5	20.1	5.8	5.7	5.5	17.1	0.67	0.66	0.66	0.66	208.4
11/7/01 0:45	V	A	kW	213	213	210	211	83.7	81.7	80.3	81.9	6.9	6.6	6.5	20.0	5.8	5.7	5.5	17.0	0.67	0.66	0.66	0.66	213.5
11/7/01 1:00	V	A	kW	213	213	210	211	83.7	81.7	80.4	81.9	6.9	6.6	6.5	20.0	5.8	5.7	5.5	17.1	0.66	0.66	0.66	0.66	218.5
11/7/01 1:15	V	A	kW	213	213	210	211	83.6	81.8	80.4	81.9	6.8	6.6	6.5	20.0	5.8	5.7	5.5	17.0	0.66	0.66	0.66	0.66	223.5
11/7/01 1:30	V	A	kW	213	213	211	211	83.6	81.8	80.4	82.0	6.8	6.6	6.5	20.0	5.8	5.8	5.6	17.2	0.66	0.65	0.66	0.66	228.6
11/7/01 1:45	V	A	kW	215	215	211	213	83.6	81.8	80.6	82.0	6.8	6.6	6.5	20.0	5.9	5.7	5.6	17.3	0.66	0.65	0.66	0.66	233.6
11/7/01 2:00	V	A	kW	215	215	211	213	83.6	81.8	80.5	82.0	6.8	6.6	6.5	20.0	5.9	5.7	5.6	17.3	0.66	0.65	0.66	0.66	238.6

Table A.1. Transformer Input Data. (Continued)

Date	Unit V	Unit A	Unit W	V-AB	V-BC	V-CA	V-ll ave	A1	A2	A3	A ave	P1	P2	P3	P total	Q1	Q2	Q3	Q total	PF1	PF2	PF3	PF ave	kWH
11/7/01 2:15	V	A	kW	215	215	211	213	83.7	82.1	80.4	82.1	6.9	6.7	6.5	[illegible]	5.9	5.8	5.6	17.4	0.66	0.65	0.66	0.66	243.7
11/7/01 2:30	V	A	kW	217	215	213	215	83.7	82.3	80.4	82.1	6.9	6.7	6.5	[illegible]	5.9	5.9	5.6	17.5	0.66	0.65	0.65	0.65	248.7
11/7/01 2:45	V	A	kW	218	218	215	217	83.8	82.8	80.4	82.3	6.9	6.8	6.5	20.3	5.9	6.0	5.7	17.7	0.66	0.65	0.65	0.65	253.8
11/7/01 3:00	V	A	kW	220	220	217	218	84.0	83.0	80.4	82.5	7.0	6.8	6.5	[illegible]	6.0	6.1	5.8	18.1	0.65	0.65	0.64	0.65	259.0
11/7/01 3:15	V	A	kW	218	218	217	217	83.8	82.6	80.3	82.2	7.1	6.9	6.6	[illegible]	5.9	5.9	5.6	17.5	0.67	0.66	0.66	0.66	264.2
11/7/01 3:30	V	A	kW	218	218	217	217	83.8	82.6	80.3	82.2	7.1	7.0	6.7	[illegible]	5.8	5.8	5.6	17.3	0.67	0.66	0.67	0.67	269.4
11/7/01 3:45	V	A	kW	218	218	217	217	83.7	82.4	80.3	82.2	7.2	7.0	6.8	[illegible]	5.7	5.7	5.5	17.1	0.68	0.67	0.67	0.68	274.7
11/7/01 4:00	V	A	kW	220	220	217	218	83.7	82.3	80.4	82.1	7.3	7.2	6.9	21.5	5.7	5.6	5.4	16.8	0.69	0.69	0.69	0.69	280.1
11/7/01 4:15	V	A	kW	220	220	217	218	83.7	82.2	80.4	82.1	7.5	7.3	7.0	21.9	5.6	5.5	5.3	16.5	0.70	0.70	0.70	0.70	285.6
11/7/01 4:30	V	A	kW	220	220	217	218	83.9	83.0	79.9	82.3	7.7	7.5	7.1	22.3	5.4	5.6	5.3	16.5	0.72	0.71	0.70	0.71	291.2
11/7/01 4:45	V	A	kW	218	218	217	217	83.7	82.6	79.8	82.0	7.8	7.6	7.2	22.6	5.3	5.4	5.1	15.9	0.73	0.72	0.72	0.72	296.9
11/7/01 5:00	V	A	kW	218	218	217	217	83.5	82.3	79.8	81.9	7.9	7.7	7.3	22.9	5.1	5.2	5.0	15.5	0.74	0.74	0.73	0.74	302.7
11/7/01 5:15	V	A	kW	217	217	213	215	83.2	81.3	80.3	81.6	7.9	7.7	7.5	23.2	5.0	4.9	4.8	14.8	0.76	0.75	0.76	0.76	308.5
11/7/01 5:30	V	A	kW	217	217	213	215	83.2	80.8	80.1	81.3	8.0	7.7	7.6	23.4	4.9	4.8	4.6	14.3	0.77	0.76	0.77	0.77	314.4
11/7/01 5:45	V	A	kW	220	220	217	218	83.3	81.1	80.4	81.6	8.0	7.8	7.7	23.7	5.1	4.9	4.8	14.9	0.76	0.75	0.76	0.76	320.3
11/7/01 6:00	V	A	kW	218	220	217	218	83.5	80.7	80.6	81.6	8.1	7.8	7.8	23.8	5.0	4.8	4.7	14.6	0.77	0.76	0.77	0.76	326.3
11/7/01 6:15	V	A	kW	218	220	217	218	83.5	80.7	80.4	81.5	8.2	7.8	7.8	23.9	5.0	4.8	4.6	14.5	0.77	0.76	0.77	0.77	332.3
11/7/01 6:30	V	A	kW	218	220	217	218	83.7	80.6	80.1	81.5	8.2	7.9	7.8	23.9	4.9	4.8	4.5	14.3	0.77	0.77	0.78	0.77	338.3
11/7/01 6:45	V	A	kW	218	218	217	217	83.8	80.7	80.3	81.6	8.2	7.9	7.8	24.0	4.9	4.8	4.5	14.2	0.78	0.77	0.78	0.77	344.3
11/7/01 7:00	V	A	kW	218	220	217	218	83.7	80.9	80.6	81.7	8.2	7.9	7.8	24.0	4.9	4.8	4.6	14.4	0.77	0.76	0.77	0.77	350.4
11/7/01 7:15	V	A	kW	217	218	215	217	83.7	80.7	80.1	81.5	8.2	7.9	7.8	24.0	4.8	4.7	4.4	13.9	0.78	0.77	0.78	0.78	356.4
11/7/01 7:30	V	A	kW	217	218	213	215	83.3	80.8	80.0	81.4	8.2	7.9	7.8	24.0	4.6	4.6	4.3	13.6	0.79	0.78	0.79	0.78	362.4
11/7/01 7:45	V	A	kW	217	217	213	215	83.1	81.0	79.8	81.3	8.2	8.0	7.7	24.0	4.6	4.5	4.3	13.5	0.79	0.78	0.79	0.79	368.4
11/7/01 8:00	V	A	kW	215	217	211	213	82.7	81.5	79.5	81.3	8.2	8.1	7.7	24.0	4.4	4.5	4.3	13.3	0.79	0.79	0.79	0.79	374.5
11/7/01 8:15	V	A	kW	213	215	210	211	82.4	82.0	79.1	81.2	8.2	8.1	7.6	24.0	4.3	4.4	4.2	13.0	0.80	0.80	0.79	0.80	380.5
11/7/01 8:30	V	A	kW	208	210	206	208	82.7	80.5	78.7	80.6	8.2	7.9	7.7	23.9	4.1	4.1	3.8	12.0	0.82	0.81	0.82	0.82	386.5
11/7/01 8:45	V	A	kW	208	210	204	206	82.6	80.5	78.6	80.5	8.2	8.0	7.6	23.9	4.0	4.0	3.7	11.9	0.82	0.81	0.82	0.82	392.5
11/7/01 9:00	V	A	kW	208	210	204	206	82.6	80.5	78.6	80.5	8.2	8.0	7.6	23.9	4.0	4.0	3.7	11.9	0.82	0.81	0.82	0.82	398.5
11/7/01 9:15	V	A	kW	208	210	204	206	82.7	80.5	78.6	80.6	8.2	8.0	7.7	23.9	4.0	4.0	3.7	11.9	0.82	0.81	0.82	0.82	404.5
11/7/01 9:30	V	A	kW	210	211	206	208	82.7	80.6	79.1	80.8	8.2	8.0	7.7	23.9	4.2	4.2	3.9	12.3	0.81	0.81	0.81	0.81	410.5
11/7/01 9:45	V	A	kW	210	211	206	208	82.7	80.5	78.7	80.7	8.2	8.0	7.7	23.9	4.1	4.1	3.8	12.1	0.82	0.81	0.82	0.82	416.5
11/7/01 10:00	V	A	kW	211	213	210	211	83.2	80.8	79.5	81.1	8.2	7.9	7.8	24.0	4.3	4.3	4.0	12.8	0.81	0.80	0.80	0.80	422.5
11/7/01 10:15	V	A	kW	213	215	211	213	83.3	80.9	79.6	81.3	8.2	8.0	7.8	24.1	4.3	4.4	4.1	13.0	0.80	0.79	0.80	0.80	428.6
11/7/01 11:45	V	A	kW	210	211	208	210	81.5	79.9	78.2	79.9	7.4	7.2	7.0	21.7	4.8	4.8	4.6	14.3	0.75	0.74	0.74	0.75	435.8
11/7/01 12:00	V	A	kW	213	213	210	211	83.7	82.5	79.5	81.9	7.2	7.0	6.6	20.8	5.4	5.6	5.3	16.4	0.70	0.68	0.68	0.69	441.1
11/7/01 12:15	V	A	kW	211	211	210	210	83.5	81.9	79.9	81.8	7.0	6.7	6.5	20.3	5.6	5.6	5.3	16.6	0.68	0.67	0.67	0.67	446.2
11/7/01 12:30	V	A	kW	213	213	210	211	83.5	81.8	80.2	81.8	6.9	6.6	6.5	20.1	5.7	5.6	5.4	16.8	0.67	0.66	0.66	0.66	451.2
11/7/01 12:45	V	A	kW	211	211	208	210	83.4	81.8	80.1	81.8	6.8	6.6	6.4	20.0	5.7	5.6	5.4	16.8	0.67	0.66	0.66	0.66	456.2
11/7/01 13:00	V	A	kW	206	206	203	204	83.1	81.5	80.3	81.6	6.7	6.6	6.4	19.9	5.4	5.3	5.2	16.0	0.68	0.68	0.68	0.68	461.2
11/7/01 13:15	V	A	kW	204	204	201	203	83.0	81.4	80.1	81.5	6.7	6.6	6.4	19.9	5.3	5.2	5.0	15.7	0.69	0.68	0.69	0.69	466.2
11/7/01 13:30	V	A	kW	204	206	203	204	83.0	81.4	80.2	81.5	6.8	6.6	6.5	20.0	5.4	5.2	5.1	15.7	0.69	0.68	0.69	0.69	471.3
11/7/01 13:45	V	A	kW	206	206	203	204	92.9	90.9	89.2	91.0	7.9	7.7	7.4	23.1	5.8	5.8	5.5	17.2	0.71	0.70	0.71	0.71	477.1
11/7/01 14:00	V	A	kW	208	208	204	206	93.2	91.2	89.6	91.3	7.9	7.7	7.5	23.2	5.9	5.8	5.6	17.4	0.71	0.70	0.71	0.71	482.9
11/7/01 14:15	V	A	kW	206	208	204	206	93.1	91.1	90.1	91.4	7.9	7.7	7.5	23.3	6.0	5.8	5.6	17.4	0.71	0.70	0.71	0.71	488.7

Table A.1. Transformer Input Data. (Continued)

Date	Unit V	Unit A	Unit W	V-AB	V-BC	V-CA	V-ll ave	A1	A2	A3	A ave	P1	P2	P3	P total	Q1	Q2	Q3	Q total	PF1	PF2	PF3	PF ave	kWH
11/7/01 14:30	V	A	kW	206	206	203	204	93.1	91.1	90.0	91.4	7.9	7.8	7.5	23.3	5.9	5.7	5.5	17.2	0.71	0.71	0.71	0.71	494.6
11/7/01 14:45	V	A	kW	206	208	203	204	93.0	91.1	89.9	91.3	7.9	7.8	7.6	23.4	5.9	5.7	5.6	17.3	0.71	0.71	0.71	0.71	500.4
11/7/01 15:00	V	A	kW	206	206	203	204	93.0	91.0	89.9	91.3	8.0	7.8	7.6	23.4	5.9	5.7	5.5	17.2	0.71	0.71	0.72	0.72	506.3
11/7/01 15:15	V	A	kW	206	206	203	204	93.0	90.9	89.9	91.3	8.0	7.8	7.6	23.5	5.8	5.7	5.5	17.1	0.72	0.72	0.72	0.72	512.2
11/7/01 15:30	V	A	kW	208	208	204	206	68.1	66.4	65.9	66.8	6.1	6.0	5.8	18.0	4.0	3.8	3.7	11.6	0.75	0.75	0.75	0.75	516.7
11/7/01 15:45	V	A	kW	206	206	203	204	66.7	65.6	63.6	65.3	6.1	6.0	5.7	17.9	3.7	3.7	3.5	11.0	0.77	0.76	0.76	0.76	521.2
11/7/01 16:00	V	A	kW	206	206	201	204	90.7	90.0	86.3	89.0	8.2	8.0	7.5	23.8	5.2	5.4	5.0	15.7	0.75	0.75	0.74	0.75	527.2
11/7/01 16:15	V	A	kW	206	206	203	204	89.5	89.1	85.1	87.9	8.2	8.0	7.4	23.7	5.1	5.3	5.0	15.4	0.76	0.75	0.74	0.75	533.1
11/7/01 16:30	V	A	kW	208	208	204	206	89.5	89.0	85.0	87.8	8.3	8.2	7.5	24.1	5.0	5.2	4.9	15.2	0.77	0.76	0.75	0.76	539.2
11/7/01 16:45	V	A	kW	211	210	206	208	89.7	89.1	85.2	88.0	8.4	8.3	7.7	24.5	5.0	5.3	5.0	15.4	0.77	0.76	0.75	0.76	545.3
11/7/01 17:00	V	A	kW	211	211	208	210	89.6	88.8	85.4	88.0	8.5	8.4	7.9	24.9	5.0	5.2	4.9	15.2	0.78	0.77	0.77	0.77	551.6
11/7/01 17:15	V	A	kW	211	211	208	210	89.4	87.9	85.5	87.6	8.6	8.5	8.1	25.3	4.9	4.9	4.7	14.6	0.79	0.78	0.78	0.78	557.9
11/7/01 17:30	V	A	kW	211	211	208	210	89.5	87.4	85.5	87.5	8.7	8.5	8.2	25.5	4.8	4.8	4.5	14.3	0.80	0.79	0.79	0.79	564.3
11/7/01 17:45	V	A	kW	213	213	210	211	89.6	87.3	85.8	87.6	8.8	8.5	8.3	25.7	4.9	4.8	4.6	14.4	0.79	0.79	0.80	0.79	570.8
11/7/01 18:00	V	A	kW	215	215	211	213	89.6	87.3	86.3	87.7	8.8	8.6	8.4	25.9	5.0	4.9	4.7	14.7	0.79	0.79	0.79	0.79	577.3
11/7/01 18:15	V	A	kW	215	215	211	213	89.3	87.1	86.3	87.6	8.8	8.6	8.4	25.9	5.0	4.8	4.6	14.5	0.80	0.79	0.80	0.80	583.8
11/7/01 18:30	V	A	kW	211	213	210	211	89.2	87.0	86.0	87.4	8.8	8.6	8.4	26.0	4.8	4.6	4.4	13.9	0.81	0.81	0.81	0.81	590.3
11/7/01 18:45	V	A	kW	211	213	210	211	89.2	87.2	85.7	87.4	8.9	8.7	8.4	26.0	4.6	4.6	4.4	13.7	0.81	0.81	0.81	0.81	596.8
11/7/01 19:00	V	A	kW	208	210	206	208	88.9	86.7	85.7	87.1	8.9	8.6	8.4	26.0	4.4	4.3	4.1	12.9	0.83	0.82	0.83	0.82	603.4
11/7/01 19:15	V	A	kW	208	210	206	208	88.8	86.8	85.7	87.1	8.9	8.7	8.4	26.1	4.3	4.2	4.1	12.8	0.83	0.82	0.83	0.83	609.9
11/7/01 19:30	V	A	kW	210	210	206	208	88.9	86.9	85.4	87.1	8.9	8.7	8.4	26.1	4.3	4.3	4.1	12.9	0.83	0.82	0.82	0.82	616.5
11/7/01 19:45	V	A	kW	210	210	208	208	88.9	87.0	85.3	87.1	8.9	8.7	8.4	26.1	4.3	4.3	4.1	12.8	0.83	0.82	0.82	0.82	623.0
11/7/01 20:00	V	A	kW	208	208	206	206	88.7	86.8	85.2	86.9	8.9	8.7	8.4	26.1	4.2	4.2	4.0	12.4	0.83	0.83	0.83	0.83	629.6
11/7/01 20:15	V	A	kW	208	208	204	206	88.6	86.7	85.2	86.9	8.9	8.7	8.4	26.2	4.2	4.1	4.0	12.3	0.84	0.83	0.83	0.83	636.1
11/7/01 20:30	V	A	kW	208	208	206	206	88.6	86.7	85.2	86.8	8.9	8.7	8.4	26.2	4.2	4.1	4.0	12.4	0.83	0.83	0.83	0.83	642.7
11/7/01 20:45	V	A	kW	208	208	204	206	88.5	86.7	85.2	86.8	8.9	8.7	8.4	26.2	4.2	4.1	4.0	12.4	0.84	0.83	0.83	0.83	649.3
11/7/01 21:00	V	A	kW	210	210	206	208	88.7	86.7	85.1	86.9	9.0	8.7	8.4	26.2	4.3	4.2	4.0	12.6	0.83	0.83	0.83	0.83	655.8
11/7/01 21:15	V	A	kW	210	210	206	208	88.9	86.7	85.0	86.9	9.0	8.7	8.4	26.2	4.3	4.3	4.0	12.7	0.83	0.82	0.83	0.83	662.4
11/7/01 21:30	V	A	kW	210	210	206	208	88.9	86.7	84.9	86.8	9.0	8.7	8.4	26.1	4.3	4.3	4.1	12.8	0.83	0.82	0.83	0.83	669.0
11/7/01 21:45	V	A	kW	210	210	206	208	89.0	86.7	84.8	86.8	9.0	8.7	8.4	26.2	4.4	4.3	4.1	12.9	0.83	0.82	0.83	0.83	675.5
11/7/01 22:00	V	A	kW	211	213	210	211	89.2	86.8	84.8	87.0	9.0	8.7	8.4	26.2	4.5	4.5	4.2	13.3	0.82	0.81	0.82	0.82	682.1
11/7/01 22:15	V	A	kW	213	213	210	211	89.2	86.8	84.9	87.0	9.0	8.7	8.4	26.2	4.5	4.5	4.3	13.4	0.82	0.81	0.82	0.82	688.7
11/7/01 22:30	V	A	kW	213	213	210	211	89.2	86.7	85.2	87.0	9.0	8.7	8.5	26.2	4.6	4.5	4.3	13.5	0.82	0.81	0.82	0.81	695.3
11/7/01 22:45	V	A	kW	211	211	210	210	89.2	86.8	84.8	87.0	9.0	8.7	8.4	26.2	4.5	4.5	4.2	13.2	0.82	0.81	0.82	0.82	701.9
11/7/01 23:00	V	A	kW	217	217	215	215	90.0	87.3	85.7	87.7	9.1	8.7	8.5	26.4	4.8	4.9	4.5	14.3	0.80	0.79	0.80	0.80	708.5
11/7/01 23:15	V	A	kW	218	218	217	217	90.2	87.5	86.0	87.9	9.1	8.7	8.6	26.4	5.0	5.0	4.7	14.8	0.80	0.78	0.79	0.79	715.1
11/7/01 23:30	V	A	kW	217	215	215	215	90.1	87.3	85.7	87.7	9.1	8.7	8.6	26.4	4.8	4.8	4.5	14.2	0.81	0.79	0.80	0.80	721.7
11/7/01 23:45	V	A	kW	217	217	217	217	90.3	87.3	86.0	87.8	9.1	8.6	8.6	26.4	5.0	4.9	4.6	14.6	0.80	0.79	0.80	0.80	728.4
12/7/01 0:00	V	A	kW	218	218	217	217	88.2	85.3	84.1	85.9	8.9	8.4	8.4	25.8	4.9	4.8	4.5	14.4	0.80	0.78	0.80	0.79	734.9
12/7/01 0:15	V	A	kW	218	217	217	217	90.3	87.3	86.0	87.9	9.1	8.7	8.6	26.4	5.0	5.0	4.7	14.7	0.80	0.79	0.80	0.79	741.5
12/7/01 1:30	V	A	kW	218	217	217	217	39.7	39.1	37.8	38.9	3.8	3.7	3.5	11.0	2.4	2.4	2.3	7.2	0.75	0.75	0.75	0.75	749.7
12/7/01 1:45	V	A	kW	218	217	215	217	60.0	59.2	57.2	58.8	5.2	5.1	4.9	15.3	4.0	4.0	3.9	12.0	0.69	0.68	0.69	0.69	753.6
12/7/01 2:00	V	A	kW	217	217	215	215	64.6	63.5	61.8	63.3	5.1	4.9	4.8	15.0	4.7	4.7	4.5	13.9	0.63	0.62	0.63	0.63	757.3
12/7/01 2:15	V	A	kW	218	217	215	217	64.8	63.9	62.1	63.6	5.1	4.9	4.8	14.9	4.8	4.8	4.6	14.2	0.62	0.62	0.62	0.62	761.1

Table A.1. Transformer Input Data. (Continued)

Date	Unit V	Unit A	Unit W	V-AB	V-BC	V-CA	V-ll ave	A1	A2	A3	A ave	P1	P2	P3	P total	Q1	Q2	Q3	Q total	PF1	PF2	PF3	PF ave	kWH
12/7/01 2:30	V	A	kW	218	217	215	217	64.8	63.9	62.1	63.6	5.1	4.9	4.8	14.8	4.8	4.8	4.6	14.3	0.62	0.61	0.62	0.62	764.8
12/7/01 2:45	V	A	kW	218	218	217	217	65.0	64.2	62.0	63.7	5.1	4.9	4.7	14.8	4.8	4.9	4.7	14.5	0.62	0.60	0.61	0.61	768.5
12/7/01 3:00	V	A	kW	218	218	217	217	65.0	64.2	62.0	63.7	5.1	4.9	4.7	14.7	4.8	4.9	4.7	14.5	0.62	0.60	0.61	0.61	772.2
12/7/01 3:15	V	A	kW	218	218	217	217	65.0	64.1	62.0	63.7	5.1	4.9	4.7	14.7	4.9	4.9	4.7	14.5	0.61	0.60	0.61	0.61	775.9
12/7/01 3:30	V	A	kW	218	218	217	217	64.9	64.1	62.0	63.7	5.0	4.9	4.7	14.7	4.8	4.9	4.7	14.5	0.61	0.60	0.61	0.61	779.6
12/7/01 3:45	V	A	kW	217	217	215	215	64.8	63.9	61.9	63.6	5.0	4.9	4.7	14.7	4.8	4.8	4.6	14.2	0.62	0.61	0.61	0.61	783.3
12/7/01 4:00	V	A	kW	217	217	215	215	64.9	63.9	61.9	63.6	5.1	4.9	4.7	14.7	4.8	4.8	4.6	14.2	0.62	0.61	0.61	0.61	787.0
12/7/01 4:15	V	A	kW	217	217	215	215	64.9	63.7	61.9	63.5	5.1	4.9	4.7	14.7	4.8	4.8	4.6	14.2	0.62	0.61	0.62	0.62	790.7
12/7/01 4:30	V	A	kW	217	217	215	215	64.9	63.8	62.0	63.6	5.1	4.9	4.7	14.8	4.8	4.8	4.6	14.2	0.62	0.61	0.62	0.62	794.5
12/7/01 4:45	V	A	kW	217	217	215	215	64.8	63.8	62.1	63.6	5.1	4.9	4.8	14.8	4.8	4.7	4.6	14.2	0.62	0.61	0.62	0.62	798.2
12/7/01 5:00	V	A	kW	217	217	215	215	64.8	63.7	62.1	63.6	5.1	4.9	4.8	14.9	4.8	4.7	4.5	14.1	0.63	0.62	0.62	0.62	801.9
12/7/01 5:15	V	A	kW	218	217	215	217	64.8	63.6	62.1	63.5	5.1	4.9	4.8	15.0	4.8	4.7	4.5	14.1	0.63	0.62	0.63	0.62	805.7
12/7/01 5:30	V	A	kW	217	217	215	215	64.7	63.5	62.3	63.5	5.1	5.0	4.9	15.1	4.7	4.6	4.5	13.9	0.63	0.62	0.63	0.63	809.5
12/7/01 5:45	V	A	kW	217	215	213	215	64.6	63.5	62.5	63.5	5.1	5.0	4.9	15.2	4.6	4.5	4.4	13.7	0.64	0.64	0.64	0.64	813.3
12/7/01 6:00	V	A	kW	217	215	213	215	64.5	63.5	62.5	63.5	5.2	5.1	5.0	15.3	4.6	4.4	4.4	13.5	0.64	0.64	0.65	0.65	817.2
12/7/01 6:15	V	A	kW	217	215	213	215	64.5	63.7	62.4	63.5	5.3	5.1	5.0	15.5	4.5	4.4	4.3	13.4	0.65	0.65	0.65	0.65	821.1
12/7/01 6:30	V	A	kW	217	217	213	215	64.5	63.7	62.3	63.5	5.3	5.2	5.1	15.8	4.5	4.4	4.3	13.3	0.66	0.66	0.66	0.66	825.1
12/7/01 6:45	V	A	kW	217	217	213	215	64.4	63.5	62.2	63.4	5.4	5.3	5.2	16.1	4.4	4.3	4.2	12.9	0.67	0.67	0.68	0.67	829.1
12/7/01 7:00	V	A	kW	215	215	213	213	64.3	63.3	61.9	63.2	5.6	5.4	5.3	16.3	4.2	4.1	4.0	12.4	0.69	0.69	0.69	0.69	833.2
12/7/01 7:15	V	A	kW	215	215	211	213	64.3	63.3	61.8	63.1	5.6	5.5	5.4	16.6	4.1	4.0	3.9	12.1	0.71	0.70	0.71	0.71	837.4
12/7/01 7:30	V	A	kW	217	215	213	215	64.1	63.3	61.7	63.0	5.7	5.6	5.4	16.9	4.0	4.0	3.9	12.0	0.72	0.71	0.71	0.71	841.6
12/7/01 7:45	V	A	kW	215	215	211	213	64.0	63.2	61.6	62.9	5.8	5.7	5.5	17.1	3.9	3.9	3.8	11.7	0.73	0.73	0.73	0.73	845.9
12/7/01 8:00	V	A	kW	213	213	210	211	63.8	63.6	61.1	62.8	5.9	5.8	5.5	17.3	3.7	3.8	3.7	11.3	0.75	0.74	0.74	0.74	850.3
12/7/01 8:15	V	A	kW	211	211	208	210	63.7	63.2	61.1	62.7	5.9	5.8	5.6	17.4	3.6	3.7	3.5	10.9	0.76	0.76	0.75	0.76	854.6
12/7/01 8:30	V	A	kW	210	210	206	208	63.6	62.6	61.0	62.4	5.9	5.8	5.6	17.5	3.5	3.5	3.3	10.4	0.77	0.77	0.77	0.77	859.0
12/7/01 8:45	V	A	kW	210	210	206	208	63.6	62.5	61.0	62.4	6.0	5.8	5.7	17.6	3.5	3.4	3.3	10.3	0.78	0.77	0.78	0.77	863.5
12/7/01 9:00	V	A	kW	208	210	206	208	63.5	62.4	60.8	62.3	6.0	5.9	5.7	17.6	3.4	3.4	3.2	10.0	0.78	0.78	0.78	0.78	867.9
12/7/01 9:15	V	A	kW	208	208	206	206	63.5	62.3	60.8	62.2	6.0	5.9	5.7	17.7	3.3	3.3	3.2	9.9	0.79	0.78	0.78	0.79	872.3
12/7/01 9:30	V	A	kW	208	208	204	206	63.4	62.6	60.6	62.2	6.0	5.9	5.7	17.7	3.2	3.3	3.1	9.8	0.79	0.79	0.79	0.79	876.8
12/7/01 9:45	V	A	kW	210	210	208	208	63.6	62.5	60.9	62.3	6.0	5.9	5.7	17.7	3.4	3.4	3.2	10.1	0.78	0.78	0.78	0.78	881.2
12/7/01 10:00	V	A	kW	210	210	206	208	63.6	62.5	60.9	62.3	6.0	5.9	5.7	17.7	3.4	3.4	3.2	10.1	0.78	0.78	0.78	0.78	885.7
12/7/01 10:15	V	A	kW	208	208	204	206	63.5	62.4	60.5	62.1	6.1	5.9	5.6	17.7	3.3	3.3	3.1	9.8	0.79	0.79	0.79	0.79	890.2
12/7/01 10:30	V	A	kW	210	210	206	208	63.5	62.8	60.5	62.3	6.1	6.0	5.6	17.8	3.3	3.4	3.2	9.9	0.79	0.79	0.78	0.79	894.6
12/7/01 10:45	V	A	kW	210	210	206	208	63.7	62.5	60.6	62.3	6.1	5.9	5.7	17.8	3.3	3.4	3.1	9.9	0.79	0.78	0.79	0.79	899.1
12/7/01 11:00	V	A	kW	210	210	206	208	64.1	62.0	61.0	62.4	6.1	5.9	5.7	17.8	3.4	3.4	3.1	10.0	0.79	0.78	0.79	0.78	903.6
12/7/01 11:15	V	A	kW	210	211	208	210	63.8	62.2	61.2	62.4	6.1	5.9	5.7	17.8	3.5	3.4	3.3	10.2	0.78	0.78	0.78	0.78	908.0
12/7/01 11:30	V	A	kW	211	213	210	211	63.8	62.5	61.5	62.6	6.1	5.9	5.8	17.8	3.5	3.5	3.4	10.5	0.77	0.77	0.77	0.77	912.5
12/7/01 11:45	V	A	kW	213	215	211	213	64.0	62.5	61.6	62.7	6.1	5.9	5.8	17.9	3.7	3.6	3.5	10.8	0.77	0.76	0.77	0.77	917.0
12/7/01 12:00	V	A	kW	217	217	215	215	64.1	62.7	62.3	63.0	6.0	5.9	5.9	17.9	3.9	3.7	3.7	11.4	0.75	0.75	0.76	0.75	921.5
12/7/01 12:15	V	A	kW	217	218	217	217	64.1	62.7	62.3	63.0	6.0	5.9	5.9	17.9	3.9	3.7	3.7	11.4	0.75	0.75	0.76	0.75	926.0
12/7/01 12:30	V	A	kW	217	218	217	217	64.1	62.8	62.3	63.0	6.0	5.9	5.9	17.9	3.9	3.7	3.7	11.4	0.75	0.75	0.75	0.75	930.5
12/7/01 12:45	V	A	kW	217	217	215	215	64.1	62.6	62.2	63.0	6.0	5.9	5.9	17.9	3.8	3.7	3.6	11.3	0.75	0.75	0.76	0.76	935.0
12/7/01 13:00	V	A	kW	211	211	210	210	64.0	62.2	61.3	62.5	6.1	5.9	5.8	17.9	3.5	3.5	3.3	10.3	0.78	0.77	0.78	0.78	939.5
12/7/01 13:15	V	A	kW	211	213	210	211	63.8	62.6	61.4	62.6	6.1	5.9	5.8	17.9	3.5	3.5	3.4	10.5	0.78	0.77	0.77	0.77	944.0

Table A.1. Transformer Input Data. (Continued)

Date	Unit V	Unit A	Unit W	V-AB	V-BC	V-CA	V-ll ave	A1	A2	A3	A ave	P1	P2	P3	P total	Q1	Q2	Q3	Q total	PF1	PF2	PF3	PF ave	kWH
12/7/01 13:30	V	A	kW	211	213	210	211	64.0	62.3	61.2	62.5	6.1	5.9	5.8	17.9	3.5	3.5	3.3	10.3	0.78	0.77	0.78	0.78	948.5
12/7/01 13:45	V	A	kW	211	211	208	210	63.9	62.1	61.1	62.4	6.1	5.9	5.8	17.9	3.4	3.4	3.2	10.1	0.79	0.78	0.79	0.78	953.0
12/7/01 14:00	V	A	kW	208	210	206	208	63.9	61.8	60.8	62.2	6.1	5.9	5.8	17.9	3.4	3.3	3.1	9.9	0.80	0.79	0.80	0.79	957.5
Average	V	A	kW	212	213	210	211	78.0	76.4	74.8	76.4	7.2	7.0	6.8	21.1	4.6	4.5	4.3	13.5	0.75	0.74	0.75	0.75	957.5
Maximum				220	220	217	218	93.2	91.2	90.1	91.4	9.1	8.7	8.6	26.4	6.0	6.1	5.8	18.1	0.84	0.83	0.83	0.83	957.5
Minimum				204	204	201	203	30.1	29.8	28.8	29.6	3.0	3.0	2.9	9.0	1.6	1.6	1.6	4.9	0.61	0.60	0.61	0.61	957.5

Table A.2. Transformer Output Data.

Date-Time	Unit V	Unit A	V-AB	V-BC	V-CA	V-ll ave	A1	A2	A3	A ave	P1	P2	P3	P total	Q1	Q2	Q3	Q total	PF1	PF2	PF3	PF ave	kWH
10/7/01 13:44	V	A	186	183	183	184	81.0	78.2	85.0	81.4	5.7	6.2	6.0	17.9	4.2	4.0	4.3	12.5	0.64	0.72	0.64	0.66	0.2
10/7/01 13:45	V	A	185	183	183	183	77.1	78.7	81.2	79	5.8	6.3	6.1	18.2	4.2	3.9	4.4	12.5	0.68	0.72	0.69	0.7	4.8
10/7/01 14:00	V	A	185	183	183	183	77.3	78.9	81.3	79.1	5.9	6.4	6.2	18.5	4.1	3.9	4.4	12.4	0.69	0.73	0.69	0.7	9.5
10/7/01 14:15	V	A	186	184	185	185	77.6	78.9	81.0	79.2	6	6.5	6.3	18.8	4.1	3.9	4.3	12.3	0.70	0.73	0.70	0.71	14.3
10/7/01 14:30	V	A	186	184	184	184	77.2	79.2	81.0	79.1	6.1	6.7	6.4	19.2	3.9	3.7	4.2	11.8	0.72	0.75	0.72	0.73	19.1
10/7/01 14:45	V	A	185	183	183	183	76.6	79.5	81.1	79.1	6.3	6.9	6.6	19.8	3.7	3.5	4.0	11.2	0.74	0.77	0.73	0.75	24.1
10/7/01 15:00	V	A	187	185	185	185	76.8	79.2	81.2	79	6.4	7	6.7	20.1	3.7	3.4	4.0	11.1	0.75	0.78	0.74	0.76	29.2
10/7/01 15:15	V	A	187	185	185	185	77.2	78.5	81.0	78.9	6.5	7	6.8	20.3	3.6	3.3	3.8	10.7	0.76	0.79	0.76	0.77	34.3
10/7/01 15:30	V	A	187	186	185	186	77.2	78.7	80.7	78.9	6.6	7	6.9	20.5	3.6	3.3	3.7	10.6	0.77	0.79	0.76	0.78	39.5
10/7/01 15:45	V	A	187	185	185	185	77.1	78.9	80.5	78.8	6.7	7.1	6.9	20.7	3.4	3.1	3.6	10.1	0.78	0.80	0.77	0.78	44.7
10/7/01 16:00	V	A	186	184	183	184	76.9	78.6	80.6	78.7	6.7	7.2	7	20.9	3.3	3.0	3.4	9.7	0.79	0.81	0.79	0.8	50.0
10/7/01 16:15	V	A	187	186	185	186	76.9	78.8	80.6	78.8	6.7	7.2	7.1	21	3.4	3.0	3.4	9.8	0.79	0.81	0.79	0.79	55.3
10/7/01 16:30	V	A	187	186	185	186	77.2	78.5	80.3	78.7	6.8	7.2	7.1	21.1	3.3	3.0	3.3	9.6	0.79	0.81	0.79	0.8	60.6
10/7/01 16:45	V	A	190	189	188	189	77.0	79.0	80.7	78.9	6.8	7.3	7.1	21.2	3.4	3.1	3.6	10.1	0.78	0.80	0.78	0.79	65.9
10/7/01 17:00	V	A	189	187	187	187	77.2	78.7	80.5	78.8	6.8	7.2	7.1	21.1	3.4	3.0	3.5	9.9	0.78	0.81	0.78	0.79	71.3
10/7/01 17:15	V	A	191	189	189	189	77.4	78.9	80.5	78.9	6.9	7.3	7.1	21.3	3.5	3.1	3.6	10.2	0.78	0.80	0.78	0.79	76.6
10/7/01 17:30	V	A	191	188	189	189	77.3	78.7	80.7	78.9	6.8	7.3	7.1	21.2	3.5	3.1	3.6	10.2	0.78	0.80	0.78	0.79	82.0
10/7/01 17:45	V	A	191	189	188	189	77.3	78.5	80.8	78.9	6.8	7.3	7.2	21.3	3.5	3.1	3.5	10.1	0.78	0.81	0.78	0.79	87.3
10/7/01 18:00	V	A	192	190	190	190	77.3	78.6	80.8	78.9	6.8	7.3	7.2	21.3	3.5	3.1	3.6	10.2	0.78	0.80	0.77	0.78	92.7
10/7/01 18:15	V	A	192	190	190	190	77.5	78.4	80.8	78.9	6.8	7.3	7.2	21.3	3.5	3.1	3.6	10.2	0.77	0.80	0.77	0.78	98.1
10/7/01 18:30	V	A	192	189	190	190	77.7	78.3	80.7	78.9	6.9	7.2	7.2	21.3	3.5	3.1	3.6	10.2	0.78	0.80	0.78	0.79	103.4
10/7/01 18:45	V	A	189	187	187	187	77.5	78.0	80.5	78.7	6.9	7.2	7.2	21.3	3.3	2.9	3.3	9.5	0.79	0.81	0.79	0.8	108.8
10/7/01 19:00	V	A	186	184	184	184	77.1	78.0	80.2	78.4	6.8	7.2	7.1	21.1	3.2	2.8	3.2	9.2	0.80	0.82	0.80	0.81	114.1
10/7/01 19:15	V	A	188	186	186	186	77.2	77.9	80.6	78.5	6.8	7.2	7.2	21.2	3.3	2.9	3.3	9.5	0.79	0.82	0.79	0.8	119.5
10/7/01 19:30	V	A	188	186	186	186	77.2	77.9	80.4	78.5	6.8	7.2	7.1	21.1	3.3	2.9	3.3	9.5	0.79	0.82	0.79	0.8	124.8
10/7/01 19:45	V	A	188	186	186	186	77.1	77.9	80.5	78.5	6.8	7.2	7.1	21.1	3.3	2.9	3.3	9.5	0.79	0.82	0.79	0.8	130.1
10/7/01 20:00	V	A	189	187	186	187	77.1	78.0	80.6	78.6	6.7	7.2	7.1	21	3.6	3.1	3.5	10.2	0.77	0.81	0.78	0.79	135.4
10/7/01 20:15	V	A	189	187	187	187	77.2	78.2	80.8	78.7	6.8	7.2	7.1	21.1	3.5	3.1	3.5	10.1	0.78	0.81	0.78	0.79	140.7
10/7/01 20:30	V	A	190	188	189	189	77.2	78.3	80.8	78.8	6.9	7.3	7.2	21.4	3.4	3.0	3.5	9.9	0.79	0.81	0.78	0.79	146.1
10/7/01 20:45	V	A	192	190	191	191	77.6	78.5	80.8	79	7	7.3	7.2	21.5	3.4	3.1	3.6	10.1	0.78	0.80	0.78	0.79	151.5
10/7/01 22:30	V	A	194	190	191	191	62.0	63.5	65.0	63.5	5	5.4	5.2	15.6	3.3	3.1	3.5	9.9	0.70	0.73	0.70	0.71	157.8
10/7/01 22:45	V	A	196	192	193	193	52.1	53.6	55.0	53.6	4.2	4.6	4.4	13.2	2.8	2.6	3.0	8.4	0.70	0.73	0.69	0.71	161.2
10/7/01 23:00	V	A	199	195	196	196	28.2	29.4	30.1	29.2	2.6	2.9	2.8	8.3	1.2	1.0	1.3	3.5	0.80	0.83	0.79	0.81	163.3
10/7/01 23:15	V	A	198	195	196	196	32.0	33.2	34.0	33.1	3	3.3	3.2	9.5	1.4	1.2	1.5	4.1	0.81	0.83	0.80	0.81	165.7
10/7/01 23:30	V	A	198	194	196	196	53.6	55.3	56.7	55.2	4.3	4.7	4.5	13.5	3.0	2.8	3.2	9.0	0.69	0.72	0.68	0.7	169.1
10/7/01 23:45	V	A	196	193	194	194	77.4	79.5	81.6	79.5	5.7	6.3	6	18	4.7	4.5	5.1	14.3	0.64	0.67	0.63	0.64	173.6
11/7/01 0:00	V	A	195	192	193	193	77.5	79.4	81.5	79.5	5.7	6.2	5.9	17.8	4.8	4.5	5.1	14.4	0.63	0.67	0.63	0.64	178.2
11/7/01 0:15	V	A	192	189	190	190	77.6	79.3	81.2	79.4	5.7	6.2	5.9	17.8	4.6	4.5	4.9	14.0	0.64	0.67	0.64	0.65	182.6
11/7/01 0:30	V	A	192	189	190	190	77.8	79.2	81.0	79.4	5.7	6.1	5.9	17.7	4.7	4.5	4.9	14.1	0.64	0.67	0.63	0.65	187.1
11/7/01 0:45	V	A	192	189	190	190	77.9	79.0	81.1	79.3	5.7	6.1	5.9	17.7	4.7	4.5	4.9	14.1	0.64	0.66	0.63	0.64	191.6
11/7/01 1:00	V	A	192	189	190	190	77.9	78.9	81.2	79.4	5.7	6	5.9	17.6	4.7	4.5	4.9	14.1	0.63	0.66	0.63	0.64	196.0
11/7/01 1:15	V	A	192	189	190	190	77.9	78.9	81.3	79.4	5.6	6	5.9	17.5	4.7	4.5	4.9	14.1	0.63	0.66	0.63	0.64	200.4
11/7/01 1:30	V	A	193	191	191	191	77.9	78.9	81.3	79.4	5.6	6.1	5.9	17.6	4.8	4.5	5.0	14.3	0.63	0.66	0.63	0.64	204.9
11/7/01 1:45	V	A	193	190	191	191	78.0	78.8	81.4	79.4	5.6	6	5.9	17.5	4.8	4.5	5.0	14.3	0.63	0.66	0.63	0.64	209.3
11/7/01 2:00	V	A	193	190	191	191	78.0	78.9	81.4	79.4	5.6	6	5.9	17.5	4.8	4.5	5.0	14.3	0.63	0.66	0.63	0.64	213.7

Table A.2. Transformer Output Data. (Continued)

Date-Time	Unit V	Unit A	V-AB	V-BC	V-CA	V-ll ave	A1	A2	A3	A ave	P1	P2	P3	P total	Q1	Q2	Q3	Q total	PF1	PF2	PF3	PF ave	kWH
11/7/01 2:15	V	A	195	192	192	193	77.8	79.1	81.4	79.4	5.7	6.1	5.9	17.7	4.8	4.6	5.0	14.4	0.63	0.66	0.63	0.64	218.2
11/7/01 2:30	V	A	195	192	193	193	77.6	79.2	81.5	79.5	5.7	6.1	5.9	17.7	4.8	4.6	5.1	14.5	0.63	0.66	0.63	0.64	222.7
11/7/01 2:45	V	A	197	194	195	195	77.5	79.4	81.7	79.5	5.7	6.2	6	17.9	4.9	4.7	5.2	14.8	0.62	0.66	0.62	0.63	227.2
11/7/01 3:00	V	A	198	195	196	196	77.6	79.4	81.6	79.5	5.7	6.3	6	18	4.9	4.7	5.2	14.8	0.62	0.66	0.62	0.64	231.7
11/7/01 3:15	V	A	197	194	195	195	77.6	79.2	81.5	79.5	5.8	6.3	6.1	18.2	4.8	4.5	5.1	14.4	0.63	0.67	0.64	0.65	236.3
11/7/01 3:30	V	A	197	194	195	195	77.6	79.2	81.6	79.4	5.8	6.4	6.2	18.4	4.7	4.5	5.0	14.2	0.64	0.68	0.64	0.65	240.9
11/7/01 3:45	V	A	198	195	196	196	77.6	79.1	81.6	79.4	5.9	6.5	6.3	18.7	4.7	4.4	4.9	14.0	0.65	0.69	0.65	0.66	245.6
11/7/01 4:00	V	A	198	195	196	196	77.6	78.9	81.5	79.3	6	6.5	6.4	18.9	4.6	4.3	4.8	13.7	0.66	0.70	0.67	0.67	250.4
11/7/01 4:15	V	A	198	195	196	196	77.5	79.0	81.4	79.3	6.1	6.7	6.5	19.3	4.4	4.2	4.8	13.4	0.67	0.71	0.67	0.69	255.3
11/7/01 4:30	V	A	198	195	196	196	77.3	79.3	81.3	79.3	6.3	6.8	6.5	19.6	4.4	4.2	4.7	13.3	0.68	0.72	0.68	0.7	260.2
11/7/01 4:45	V	A	197	195	196	196	77.2	79.3	81.2	79.2	6.4	6.9	6.6	19.9	4.2	4.0	4.6	12.8	0.70	0.74	0.70	0.71	265.3
11/7/01 5:00	V	A	197	194	195	195	77.4	78.9	81.1	79.1	6.5	7	6.8	20.3	4.2	3.9	4.4	12.5	0.71	0.75	0.71	0.72	270.4
11/7/01 5:15	V	A	195	192	193	193	77.6	78.3	81.0	79	6.5	7	6.9	20.4	4.0	3.7	4.1	11.8	0.72	0.76	0.73	0.74	275.5
11/7/01 5:30	V	A	196	193	194	194	77.8	78.4	80.6	78.9	6.6	7	6.9	20.5	4.0	3.7	4.1	11.8	0.73	0.76	0.74	0.74	280.7
11/7/01 5:45	V	A	198	196	197	197	78.0	78.4	81.0	79.1	6.7	7.1	7	20.8	4.1	3.8	4.2	12.1	0.73	0.76	0.73	0.74	285.9
11/7/01 6:00	V	A	198	195	196	196	78.3	78.4	80.4	79	6.8	7.1	7	20.9	4.0	3.7	4.1	11.8	0.74	0.76	0.74	0.75	291.2
11/7/01 6:15	V	A	197	195	195	195	78.1	78.4	80.3	78.9	6.8	7.1	7	20.9	3.9	3.7	4.0	11.6	0.74	0.76	0.75	0.75	296.5
11/7/01 6:30	V	A	197	195	195	195	78.2	78.5	80.2	78.9	6.9	7.1	7	21	3.9	3.7	4.0	11.6	0.75	0.76	0.75	0.75	301.8
11/7/01 6:45	V	A	197	195	196	196	78.4	78.5	80.3	79.1	6.9	7.1	7.1	21.1	3.9	3.7	4.0	11.6	0.75	0.76	0.75	0.75	307.1
11/7/01 7:00	V	A	198	196	196	196	78.5	78.5	80.5	79.2	6.9	7.1	7.1	21.1	3.9	3.7	4.0	11.6	0.75	0.76	0.75	0.75	312.4
11/7/01 7:15	V	A	195	194	194	194	78.2	78.5	80.1	79	6.9	7.1	7.1	21.1	3.7	3.5	3.8	11.0	0.76	0.77	0.76	0.76	317.7
11/7/01 7:30	V	A	195	193	193	193	77.9	78.5	80.4	78.9	6.8	7.1	7.1	21	3.7	3.5	3.8	11.0	0.76	0.77	0.76	0.76	323.0
11/7/01 7:45	V	A	195	193	193	193	77.5	78.5	80.7	78.9	6.8	7.2	7.1	21.1	3.7	3.4	3.8	10.9	0.76	0.78	0.76	0.77	328.3
11/7/01 8:00	V	A	193	191	191	191	76.8	78.7	80.9	78.8	6.7	7.2	7.1	21	3.6	3.3	3.7	10.6	0.76	0.79	0.76	0.77	333.7
11/7/01 8:15	V	A	191	189	188	189	76.7	78.7	80.6	78.7	6.7	7.2	7.1	21	3.5	3.1	3.6	10.2	0.77	0.80	0.77	0.78	339.0
11/7/01 8:30	V	A	188	186	185	186	77.0	78.4	79.7	78.4	6.7	7.2	7	20.9	3.4	3.0	3.4	9.8	0.78	0.81	0.78	0.79	344.2
11/7/01 8:45	V	A	187	186	185	186	76.8	78.4	79.7	78.3	6.7	7.2	7	20.9	3.3	3.0	3.4	9.7	0.78	0.81	0.78	0.79	349.5
11/7/01 9:00	V	A	188	186	185	186	77.0	78.4	79.7	78.4	6.7	7.2	7	20.9	3.3	3.0	3.4	9.7	0.78	0.81	0.78	0.79	354.7
11/7/01 9:15	V	A	188	187	185	186	77.0	78.4	79.9	78.4	6.7	7.2	7	20.9	3.4	3.1	3.5	10.0	0.78	0.80	0.78	0.79	360.0
11/7/01 9:30	V	A	189	188	186	187	77.0	78.4	80.1	78.5	6.7	7.2	7	20.9	3.5	3.1	3.5	10.1	0.77	0.80	0.78	0.78	365.3
11/7/01 9:45	V	A	188	187	186	187	77.0	78.6	79.8	78.4	6.8	7.2	7	21	3.3	3.0	3.4	9.7	0.79	0.81	0.78	0.79	370.6
11/7/01 10:00	V	A	191	190	191	190	77.7	78.7	80.3	78.9	6.9	7.2	7.1	21.2	3.4	3.3	3.6	10.3	0.78	0.79	0.77	0.78	375.9
11/7/01 10:15	V	A	191	190	191	190	77.6	78.7	80.4	78.9	6.9	7.2	7.1	21.2	3.4	3.3	3.6	10.3	0.78	0.79	0.77	0.78	381.2
11/7/01 11:45	V	A	190	189	189	189	77.3	79.0	81.1	79.1	6.1	6.6	6.3	19	4.2	4.0	4.5	12.7	0.70	0.72	0.69	0.7	387.5
11/7/01 12:00	V	A	191	189	190	190	77.2	79.5	81.2	79.3	5.8	6.4	6	18.2	4.4	4.3	4.8	13.5	0.66	0.69	0.65	0.67	392.1
11/7/01 12:15	V	A	191	189	189	189	77.6	79.2	81.2	79.3	5.7	6.2	5.9	17.8	4.5	4.4	4.8	13.7	0.65	0.68	0.64	0.66	396.6
11/7/01 12:30	V	A	192	189	190	190	77.8	79.0	81.3	79.4	5.7	6.1	5.9	17.7	4.7	4.4	4.9	14.0	0.64	0.67	0.64	0.65	401.1
11/7/01 12:45	V	A	190	187	188	188	77.7	79.0	81.3	79.3	5.6	6	5.9	17.5	4.6	4.4	4.8	13.8	0.64	0.67	0.64	0.65	405.5
11/7/01 13:00	V	A	185	183	183	183	77.7	78.6	81.3	79.2	5.6	6	5.9	17.5	4.4	4.2	4.6	13.2	0.65	0.68	0.66	0.66	409.9
11/7/01 13:15	V	A	184	182	182	182	77.7	78.7	81.1	79.2	5.6	6	5.9	17.5	4.3	4.1	4.5	12.9	0.66	0.69	0.67	0.67	414.3
11/7/01 13:30	V	A	185	183	183	183	79.7	80.7	83.3	81.2	5.8	6.2	6.1	18.1	4.5	4.2	4.6	13.3	0.66	0.69	0.67	0.67	418.9
11/7/01 13:45	V	A	185	183	183	183	87.2	88.6	90.8	88.9	6.5	7	6.8	20.3	4.7	4.5	4.9	14.1	0.68	0.71	0.68	0.69	424.1
11/7/01 14:00	V	A	186	185	184	185	87.3	88.5	90.9	88.9	6.5	7	6.8	20.3	4.8	4.6	5.0	14.4	0.67	0.70	0.68	0.68	429.2
11/7/01 14:15	V	A	185	184	183	184	87.4	88.4	91.0	88.9	6.5	7	6.9	20.4	4.8	4.5	4.9	14.2	0.68	0.71	0.68	0.69	434.3
11/7/01 14:30	V	A	185	183	183	183	87.5	88.2	91.1	88.9	6.5	7	6.9	20.4	4.8	4.5	4.9	14.2	0.68	0.71	0.69	0.69	439.5

Table A.2. Transformer Output Data. (Continued)

Date-Time	Unit V	Unit A	V-AB	V-BC	V-CA	V-ll ave	A1	A2	A3	A ave	P1	P2	P3	P total	Q1	Q2	Q3	Q total	PF1	PF2	PF3	PF ave	kWH
11/7/01 14:45	V	A	186	184	183	184	87.4	88.2	91.0	88.9	6.6	7	6.9	20.5	4.8	4.5	4.9	14.2	0.68	0.71	0.69	0.69	444.7
11/7/01 15:00	V	A	186	184	183	184	87.4	88.3	91.0	88.9	6.6	7	7	20.6	4.8	4.5	4.9	14.2	0.68	0.71	0.69	0.69	449.8
11/7/01 15:15	V	A	185	183	182	183	87.2	88.1	91.1	88.8	6.6	7.1	7	20.7	4.8	4.4	4.9	14.1	0.68	0.72	0.70	0.7	455.0
11/7/01 15:30	V	A	189	186	185	186	49.6	50.2	51.8	50.5	4.1	4.4	4.3	12.8	2.3	2.1	2.3	6.7	0.74	0.77	0.75	0.75	458.3
11/7/01 15:45	V	A	186	184	183	184	75.5	77.6	79.3	77.5	5.9	6.5	6.3	18.7	3.9	3.6	4.1	11.6	0.71	0.75	0.72	0.73	463.0
11/7/01 16:00	V	A	185	182	181	182	83.1	86.0	88.0	85.7	6.5	7.2	6.9	20.6	4.3	4.0	4.5	12.8	0.71	0.75	0.71	0.73	468.2
11/7/01 16:15	V	A	186	184	183	184	82.8	85.8	87.5	85.3	6.6	7.3	6.9	20.8	4.2	4.0	4.5	12.7	0.72	0.75	0.72	0.73	473.4
11/7/01 16:30	V	A	187	185	184	185	82.8	85.8	87.3	85.3	6.7	7.4	7	21.1	4.2	3.9	4.5	12.6	0.72	0.76	0.73	0.74	478.7
11/7/01 16:45	V	A	190	187	187	188	82.9	85.6	87.6	85.4	6.8	7.5	7.2	21.5	4.2	3.9	4.5	12.6	0.73	0.77	0.73	0.74	484.2
11/7/01 17:00	V	A	190	188	187	188	83.1	85.1	87.5	85.2	6.9	7.5	7.3	21.7	4.2	3.8	4.3	12.3	0.74	0.77	0.74	0.75	489.7
11/7/01 17:15	V	A	191	188	187	188	83.4	85.2	87.0	85.2	7	7.6	7.4	22	4.1	3.7	4.2	12.0	0.74	0.78	0.75	0.76	495.2
11/7/01 17:30	V	A	190	188	187	188	83.5	85.1	86.7	85.1	7.1	7.6	7.5	22.2	4.0	3.6	4.1	11.7	0.75	0.79	0.76	0.77	500.8
11/7/01 17:45	V	A	192	190	189	190	83.8	85.1	86.8	85.2	7.2	7.7	7.6	22.5	4.1	3.7	4.2	12.0	0.75	0.78	0.76	0.77	506.5
11/7/01 18:00	V	A	193	191	190	191	83.9	84.9	87.1	85.3	7.3	7.7	7.6	22.6	4.1	3.7	4.2	12.0	0.75	0.78	0.76	0.76	512.2
11/7/01 18:15	V	A	192	190	190	190	83.7	84.7	87.1	85.2	7.3	7.7	7.7	22.7	4.0	3.6	4.1	11.7	0.76	0.79	0.77	0.77	517.9
11/7/01 18:30	V	A	191	189	188	189	83.4	84.7	86.9	85	7.3	7.8	7.7	22.8	3.9	3.5	4.0	11.4	0.77	0.80	0.77	0.78	523.6
11/7/01 18:45	V	A	190	188	187	188	83.4	84.7	86.8	85	7.3	7.8	7.7	22.8	3.8	3.4	3.9	11.1	0.77	0.80	0.78	0.78	529.3
11/7/01 19:00	V	A	187	185	185	185	83.2	84.3	86.8	84.8	7.3	7.8	7.7	22.8	3.6	3.2	3.7	10.5	0.79	0.81	0.79	0.8	535.1
11/7/01 19:15	V	A	188	186	185	186	83.2	84.4	86.8	84.8	7.3	7.8	7.7	22.8	3.7	3.2	3.7	10.6	0.78	0.81	0.79	0.8	540.8
11/7/01 19:30	V	A	188	187	186	187	83.2	84.6	86.6	84.8	7.3	7.8	7.7	22.8	3.6	3.2	3.7	10.5	0.79	0.81	0.79	0.79	546.5
11/7/01 19:45	V	A	189	187	186	187	83.1	84.6	86.6	84.8	7.3	7.8	7.7	22.8	3.7	3.2	3.7	10.6	0.78	0.81	0.78	0.79	552.3
11/7/01 20:00	V	A	187	184	184	185	83.0	84.3	86.6	84.6	7.3	7.8	7.7	22.8	3.5	3.1	3.5	10.1	0.79	0.82	0.80	0.8	558.0
11/7/01 20:15	V	A	187	185	184	185	83.0	84.3	86.5	84.6	7.3	7.8	7.7	22.8	3.5	3.1	3.5	10.1	0.79	0.82	0.80	0.8	563.8
11/7/01 20:30	V	A	187	185	184	185	82.9	84.3	86.6	84.6	7.3	7.8	7.7	22.8	3.6	3.1	3.6	10.3	0.79	0.82	0.80	0.8	569.5
11/7/01 20:45	V	A	188	185	185	186	82.9	84.3	86.5	84.6	7.4	7.8	7.7	22.9	3.5	3.0	3.5	10.0	0.79	0.82	0.80	0.8	575.3
11/7/01 21:00	V	A	189	186	186	187	83.0	84.4	86.4	84.6	7.3	7.8	7.7	22.8	3.6	3.1	3.6	10.3	0.79	0.82	0.79	0.8	581.0
11/7/01 21:15	V	A	189	186	186	187	83.1	84.5	86.1	84.6	7.3	7.8	7.6	22.7	3.7	3.2	3.7	10.6	0.78	0.81	0.79	0.79	586.8
11/7/01 21:30	V	A	188	186	185	186	82.8	84.3	86.1	84.4	7.3	7.8	7.6	22.7	3.6	3.2	3.7	10.5	0.79	0.82	0.79	0.8	592.5
11/7/01 21:45	V	A	190	187	187	188	82.9	84.6	85.8	84.4	7.4	7.8	7.6	22.8	3.6	3.2	3.7	10.5	0.79	0.81	0.78	0.8	598.3
11/7/01 22:00	V	A	191	189	189	189	82.9	84.6	85.8	84.5	7.4	7.9	7.6	22.9	3.7	3.3	3.8	10.8	0.79	0.81	0.78	0.79	604.0
11/7/01 22:15	V	A	192	189	190	190	83.0	84.5	86.0	84.5	7.4	7.9	7.7	23	3.7	3.3	3.9	10.9	0.78	0.81	0.78	0.79	609.8
11/7/01 22:30	V	A	192	189	189	190	83.0	84.5	86.0	84.5	7.4	7.9	7.7	23	3.7	3.3	3.8	10.8	0.79	0.81	0.78	0.79	615.6
11/7/01 22:45	V	A	191	189	189	189	83.1	84.7	85.8	84.5	7.4	7.9	7.7	23	3.6	3.3	3.8	10.7	0.79	0.81	0.78	0.79	621.4
11/7/01 23:00	V	A	195	193	195	194	83.9	85.1	86.5	85.2	7.6	7.9	7.7	23.2	3.9	3.6	4.1	11.6	0.78	0.79	0.77	0.78	627.2
11/7/01 23:15	V	A	195	193	195	194	83.9	85.1	86.5	85.2	7.6	7.9	7.7	23.2	3.9	3.7	4.1	11.7	0.78	0.79	0.77	0.78	633.1
11/7/01 23:30	V	A	194	191	193	192	83.9	85.0	86.5	85.1	7.6	7.9	7.7	23.2	3.8	3.5	4.0	11.3	0.79	0.80	0.77	0.79	638.9
11/7/01 23:45	V	A	196	193	195	194	84.2	85.1	86.5	85.2	7.6	7.9	7.7	23.2	3.9	3.7	4.1	11.7	0.78	0.79	0.77	0.78	644.8
12/7/01 0:00	V	A	196	194	195	195	82.2	83.1	84.6	83.3	7.4	7.7	7.5	22.6	3.8	3.6	4.0	11.4	0.77	0.79	0.76	0.77	650.5
12/7/01 0:15	V	A	195	193	194	194	84.1	85.1	86.3	85.2	7.6	7.9	7.7	23.2	3.9	3.7	4.1	11.7	0.78	0.79	0.77	0.78	656.3
12/7/01 1:30	V	A	191	194	188	191	40.0	41.5	42.4	41.3	3.5	3.8	3.7	11	2.0	1.8	2.1	5.9	0.78	0.80	0.75	0.77	662.5
12/7/01 1:45	V	A	196	194	195	195	63.8	65.5	67.3	65.5	4.8	5.3	5	15.1	3.8	3.7	4.1	11.6	0.65	0.68	0.64	0.66	666.4
12/7/01 2:00	V	A	197	194	195	195	59.5	60.9	62.7	61.1	4.2	4.6	4.4	13.2	3.8	3.6	4.0	11.4	0.61	0.64	0.60	0.62	669.7
12/7/01 2:15	V	A	197	194	196	195	59.3	60.9	62.8	61	4.2	4.6	4.4	13.2	3.8	3.7	4.1	11.6	0.60	0.64	0.59	0.61	673.0
12/7/01 2:30	V	A	197	194	196	195	59.3	60.9	62.8	61	4.1	4.6	4.3	13	3.9	3.7	4.1	11.7	0.59	0.63	0.59	0.61	676.3
12/7/01 2:45	V	A	199	195	197	197	59.2	61.0	62.8	61	4.1	4.6	4.3	13	3.9	3.7	4.2	11.8	0.59	0.63	0.58	0.6	679.6

Table A.2. Transformer Output Data. (Continued)

Date-Time	Unit V	Unit A	V-AB	V-BC	V-CA	V-ll ave	A1	A2	A3	A ave	P1	P2	P3	P total	Q1	Q2	Q3	Q total	PF1	PF2	PF3	PF ave	kWH
12/7/01 3:00	V	A	198	195	196	196	59.2	60.9	62.8	61	4.1	4.6	4.3	13	3.9	3.7	4.2	11.8	0.59	0.63	0.58	0.6	682.9
12/7/01 3:15	V	A	198	195	197	196	59.2	60.9	62.8	61	4.1	4.6	4.3	13	3.9	3.7	4.2	11.8	0.58	0.63	0.58	0.6	686.2
12/7/01 3:30	V	A	197	194	196	195	59.2	60.9	62.7	61	4.1	4.6	4.3	13	3.9	3.7	4.2	11.8	0.59	0.63	0.58	0.6	689.5
12/7/01 3:45	V	A	196	193	195	194	59.3	61.0	62.7	61	4.1	4.6	4.3	13	3.8	3.7	4.1	11.6	0.59	0.63	0.59	0.6	692.8
12/7/01 4:00	V	A	197	194	195	195	59.3	61.0	62.6	61	4.1	4.6	4.3	13	3.8	3.7	4.1	11.6	0.59	0.63	0.59	0.61	696.1
12/7/01 4:15	V	A	197	194	195	195	59.4	60.9	62.5	61	4.1	4.6	4.3	13	3.8	3.7	4.1	11.6	0.60	0.63	0.59	0.61	699.3
12/7/01 4:30	V	A	197	194	195	195	59.4	60.9	62.7	61	4.1	4.6	4.3	13	3.8	3.7	4.1	11.6	0.60	0.63	0.59	0.61	702.7
12/7/01 4:45	V	A	196	193	194	194	59.5	60.8	62.7	61	4.2	4.6	4.4	13.2	3.8	3.6	4.0	11.4	0.60	0.64	0.60	0.61	706.0
12/7/01 5:00	V	A	197	194	195	195	59.5	60.8	62.7	61	4.2	4.6	4.4	13.2	3.8	3.7	4.1	11.6	0.60	0.64	0.60	0.61	709.3
12/7/01 5:15	V	A	197	194	196	195	59.5	60.8	62.6	61	4.2	4.6	4.4	13.2	3.8	3.6	4.0	11.4	0.60	0.64	0.60	0.62	712.7
12/7/01 5:30	V	A	196	193	194	194	59.6	60.6	62.7	61	4.2	4.6	4.5	13.3	3.8	3.6	3.9	11.3	0.61	0.64	0.61	0.62	716.0
12/7/01 5:45	V	A	196	193	194	194	59.5	60.6	62.8	61	4.3	4.6	4.5	13.4	3.7	3.5	3.9	11.1	0.62	0.65	0.62	0.63	719.4
12/7/01 6:00	V	A	195	192	193	193	59.4	60.5	62.9	60.9	4.3	4.7	4.6	13.6	3.7	3.4	3.8	10.9	0.62	0.66	0.63	0.64	722.9
12/7/01 6:15	V	A	196	193	194	194	59.2	60.6	63.0	60.9	4.3	4.8	4.7	13.8	3.6	3.3	3.8	10.7	0.63	0.67	0.64	0.65	726.4
12/7/01 6:30	V	A	196	194	195	195	59.2	60.5	63.0	60.9	4.4	4.9	4.8	14.1	3.6	3.3	3.8	10.7	0.64	0.68	0.65	0.66	729.9
12/7/01 6:45	V	A	196	193	194	194	59.2	60.5	62.8	60.8	4.5	4.9	4.8	14.2	3.5	3.2	3.7	10.4	0.65	0.70	0.66	0.67	733.5
12/7/01 7:00	V	A	195	192	193	193	59.2	60.5	62.5	60.7	4.6	5	4.9	14.5	3.3	3.1	3.5	9.9	0.67	0.71	0.68	0.69	737.2
12/7/01 7:15	V	A	194	192	193	193	59.1	60.6	62.5	60.7	4.7	5.1	5	14.8	3.2	3.0	3.4	9.6	0.69	0.72	0.69	0.7	740.9
12/7/01 7:30	V	A	195	193	194	194	59.0	60.5	62.5	60.6	4.7	5.1	5	14.8	3.2	3.0	3.4	9.6	0.69	0.73	0.70	0.71	744.7
12/7/01 7:45	V	A	195	192	193	193	58.8	60.4	62.5	60.6	4.8	5.2	5.1	15.1	3.1	2.9	3.3	9.3	0.71	0.74	0.71	0.72	748.5
12/7/01 8:00	V	A	192	190	190	190	58.3	60.6	62.3	60.4	4.8	5.3	5.1	15.2	2.9	2.7	3.2	8.8	0.73	0.76	0.73	0.74	752.4
12/7/01 8:15	V	A	191	189	189	189	58.6	60.2	62.2	60.3	4.9	5.3	5.2	15.4	2.9	2.6	3.0	8.5	0.73	0.77	0.74	0.75	756.2
12/7/01 8:30	V	A	190	188	188	188	58.8	60.1	61.8	60.3	4.9	5.3	5.2	15.4	2.8	2.6	3.0	8.4	0.74	0.78	0.75	0.76	760.1
12/7/01 8:45	V	A	189	188	187	188	58.7	60.1	61.8	60.2	5	5.3	5.2	15.5	2.7	2.5	2.9	8.1	0.75	0.78	0.75	0.76	764.1
12/7/01 9:00	V	A	189	187	187	187	58.7	60.2	61.7	60.2	5	5.4	5.2	15.6	2.7	2.5	2.9	8.1	0.76	0.79	0.76	0.77	768.0
12/7/01 9:15	V	A	189	187	187	187	58.7	60.2	61.7	60.2	5	5.4	5.2	15.6	2.7	2.4	2.8	7.9	0.76	0.79	0.76	0.77	771.9
12/7/01 9:30	V	A	188	186	186	186	58.5	60.3	61.8	60.2	5	5.4	5.2	15.6	2.6	2.4	2.8	7.8	0.76	0.79	0.76	0.77	775.9
12/7/01 9:45	V	A	191	189	189	189	58.8	60.3	61.9	60.3	5	5.4	5.3	15.7	2.7	2.5	2.9	8.1	0.75	0.78	0.75	0.76	779.8
12/7/01 10:00	V	A	190	188	188	188	58.7	60.3	61.9	60.3	5	5.4	5.3	15.7	2.7	2.5	2.8	8.0	0.76	0.79	0.76	0.77	783.8
12/7/01 10:15	V	A	189	187	186	187	58.6	60.5	61.6	60.2	5	5.4	5.2	15.6	2.7	2.5	2.8	8.0	0.76	0.79	0.76	0.77	787.7
12/7/01 10:30	V	A	190	188	186	188	58.5	60.6	61.8	60.3	4.9	5.4	5.2	15.5	2.8	2.5	2.9	8.2	0.75	0.79	0.75	0.76	791.7
12/7/01 10:45	V	A	190	188	187	188	59.0	60.5	61.6	60.4	5	5.4	5.2	15.6	2.8	2.6	2.9	8.3	0.75	0.78	0.75	0.76	795.6
12/7/01 11:00	V	A	190	188	187	188	59.3	60.3	61.5	60.4	5	5.3	5.2	15.5	2.8	2.6	2.9	8.3	0.75	0.78	0.75	0.76	799.5
12/7/01 11:15	V	A	191	189	189	189	59.3	60.3	61.9	60.5	5	5.3	5.3	15.6	2.9	2.6	3.0	8.5	0.75	0.77	0.75	0.76	803.5
12/7/01 11:30	V	A	193	191	191	191	59.3	60.4	62.2	60.6	5.1	5.4	5.3	15.8	2.8	2.6	3.0	8.4	0.75	0.78	0.75	0.76	807.5
12/7/01 11:45	V	A	194	192	193	193	59.5	60.3	62.4	60.7	5.1	5.4	5.3	15.8	2.9	2.7	3.1	8.7	0.74	0.77	0.74	0.75	811.5
12/7/01 12:00	V	A	197	195	196	196	59.5	60.3	62.8	60.9	5.1	5.4	5.4	15.9	3.0	2.7	3.2	8.9	0.74	0.77	0.74	0.75	815.5
12/7/01 12:15	V	A	196	195	196	195	59.5	60.3	62.9	60.9	5.1	5.4	5.4	15.9	3.0	2.7	3.2	8.9	0.73	0.77	0.74	0.75	819.5
12/7/01 12:30	V	A	197	195	196	196	59.5	60.3	62.9	60.9	5.1	5.4	5.4	15.9	3.0	2.7	3.2	8.9	0.73	0.76	0.74	0.74	823.6
12/7/01 12:45	V	A	195	193	194	194	59.5	60.3	62.6	60.8	5.1	5.4	5.4	15.9	2.9	2.7	3.1	8.7	0.74	0.77	0.74	0.75	827.6
12/7/01 13:00	V	A	191	189	190	190	59.5	60.4	61.9	60.6	5.1	5.4	5.3	15.8	2.7	2.6	2.9	8.2	0.76	0.78	0.76	0.77	831.6
12/7/01 13:15	V	A	192	190	191	191	59.3	60.5	62.2	60.7	5.1	5.4	5.3	15.8	2.8	2.6	3.0	8.4	0.76	0.78	0.75	0.76	835.6
12/7/01 13:30	V	A	192	190	191	191	59.4	60.5	61.9	60.6	5.2	5.4	5.3	15.9	2.8	2.6	2.9	8.3	0.76	0.78	0.76	0.77	839.6
12/7/01 13:45	V	A	190	188	189	189	59.4	60.4	61.6	60.5	5.2	5.4	5.3	15.9	2.7	2.5	2.8	8.0	0.77	0.79	0.76	0.77	843.6
12/7/01 14:00	V	A	189	187	187	187	59.4	60.3	61.3	60.3	5.2	5.4	5.3	15.9	2.6	2.5	2.8	7.9	0.78	0.79	0.77	0.78	847.6

Table A.2. Transformer Output Data. (Continued)

Date-Time	Unit V	Unit A	V-AB	V-BC	V-CA	V-ll ave	A1	A2	A3	A ave	P1	P2	P3	P total	Q1	Q2	Q3	Q total	PF1	PF2	PF3	PF ave	kWH
Average	V	A	191.8	189.5	189.7	190	72.7	74.0	76.0	74.2	6.0	6.4	6.2	18.59	3.71	3.44	3.87	11.0	0.72	0.75	0.72	0.73	847.6
Maimum			199	196	197	197	87.5	88.6	91.1	88.9	7.6	7.9	7.7	23.2	4.9	4.7	5.2	14.8	0.81	0.83	0.80	0.81	847.6
Minimum			184	182	181	182	28.2	29.4	30.1	29.2	2.6	2.9	2.8	8.3	1.2	1.0	1.3	3.5	0.58	0.63	0.58	0.60	0.2

APPENDIX B

TRANSFORMER LOSS CALCULATION

Table B.1. Transformer Loss Calculation.

Date-Time	Total Power Input (kW)	Total Power Output (kW)	Transformer Losses (kW)
10/7/01 14:00	21.0	18.5	2.5
10/7/01 14:15	21.4	18.8	2.6
10/7/01 14:30	21.8	19.2	2.6
10/7/01 14:45	22.3	19.8	2.5
10/7/01 15:00	22.8	20.1	2.7
10/7/01 15:15	23.1	20.3	2.8
10/7/01 15:30	23.3	20.5	2.8
10/7/01 15:45	23.6	20.7	2.9
10/7/01 16:00	23.8	20.9	2.9
10/7/01 16:15	23.9	21.0	2.9
10/7/01 16:30	24.0	21.1	2.9
10/7/01 16:45	24.1	21.2	2.9
10/7/01 17:00	24.1	21.1	3.0
10/7/01 17:15	24.2	21.3	2.9
10/7/01 17:30	24.2	21.2	3.0
10/7/01 17:45	24.2	21.3	2.9
10/7/01 18:00	24.3	21.3	3.0
10/7/01 18:15	24.3	21.3	3.0
10/7/01 18:30	24.3	21.3	3.0
10/7/01 18:45	24.2	21.3	2.9
10/7/01 19:00	24.2	21.1	3.1
10/7/01 19:15	24.2	21.2	3.0
10/7/01 19:30	24.2	21.1	3.1
10/7/01 19:45	24.2	21.1	3.1
10/7/01 20:00	24.2	21.0	3.2
10/7/01 20:15	24.3	21.1	3.2
10/7/01 20:30	24.3	21.4	2.9
10/7/01 20:45	24.3	21.5	2.8
10/7/01 21:00	13.8	6.8	7.0

Table B.1. Transformer Loss Calculation. (Continued)

Date-Time	Total Power Input (kW)	Total Power Output (kW)	Transformer Losses (kW)
10/7/01 21:15	0.0	0.0	0.0
10/7/01 21:30	0.0	0.0	0.0
10/7/01 21:45	0.0	0.0	0.0
10/7/01 22:00	0.0	0.0	0.0
10/7/01 22:15	0.8	2.0	-1.2
10/7/01 22:30	14.8	15.6	-0.8
10/7/01 22:45	18.1	13.2	4.9
10/7/01 23:00	9.0	8.3	0.7
10/7/01 23:15	10.6	9.5	1.1
10/7/01 23:30	13.0	13.5	-0.5
10/7/01 23:45	20.5	18.0	2.5
11/7/01 0:00	20.4	17.8	2.6
11/7/01 0:15	20.2	17.8	2.4
11/7/01 0:30	20.1	17.7	2.4
11/7/01 0:45	20.0	17.7	2.3
11/7/01 1:00	20.0	17.6	2.4
11/7/01 1:15	20.0	17.5	2.5
11/7/01 1:30	20.0	17.6	2.4
11/7/01 1:45	20.0	17.5	2.5
11/7/01 2:00	20.0	17.5	2.5
11/7/01 2:15	20.1	17.7	2.4
11/7/01 2:30	20.2	17.7	2.5
11/7/01 2:45	20.3	17.9	2.4
11/7/01 3:00	20.5	18.0	2.5
11/7/01 3:15	20.6	18.2	2.4
11/7/01 3:30	20.9	18.4	2.5
11/7/01 3:45	21.2	18.7	2.5
11/7/01 4:00	21.5	18.9	2.6
11/7/01 4:15	21.9	19.3	2.6

Table B.1. Transformer Loss Calculation. (Continued)

Date-Time	Total Power Input (kW)	Total Power Output (kW)	Transformer Losses (kW)
11/7/01 4:30	22.3	19.6	2.7
11/7/01 4:45	22.6	19.9	2.7
11/7/01 5:00	22.9	20.3	2.6
11/7/01 5:15	23.2	20.4	2.8
11/7/01 5:30	23.4	20.5	2.9
11/7/01 5:45	23.7	20.8	2.9
11/7/01 6:00	23.8	20.9	2.9
11/7/01 6:15	23.9	20.9	3.0
11/7/01 6:30	23.9	21.0	2.9
11/7/01 6:45	24.0	21.1	2.9
11/7/01 7:00	24.0	21.1	2.9
11/7/01 7:15	24.0	21.1	2.9
11/7/01 7:30	24.0	21.0	3.0
11/7/01 7:45	24.0	21.1	2.9
11/7/01 8:00	24.0	21.0	3.0
11/7/01 8:15	24.0	21.0	3.0
11/7/01 8:30	23.9	20.9	3.0
11/7/01 8:45	23.9	20.9	3.0
11/7/01 9:00	23.9	20.9	3.0
11/7/01 9:15	23.9	20.9	3.0
11/7/01 9:30	23.9	20.9	3.0
11/7/01 9:45	23.9	21.0	2.9
11/7/01 10:00	24.0	21.2	2.8
11/7/01 10:15	24.1	21.2	2.9
11/7/01 10:30	7.1	0.0	7.1
11/7/01 10:45	0.0	0.0	0.0
11/7/01 11:00	0.0	0.0	0.0
11/7/01 11:15	0.0	0.0	0.0
11/7/01 11:30	0.0	4.6	-4.6

Table B.1. Transformer Loss Calculation. (Continued)

Date-Time	Total Power Input (kW)	Total Power Output (kW)	Transformer Losses (kW)
11/7/01 11:45	21.7	19.0	2.7
11/7/01 12:00	20.8	18.2	2.6
11/7/01 12:15	20.3	17.8	2.5
11/7/01 12:30	20.1	17.7	2.4
11/7/01 12:45	20.0	17.5	2.5
11/7/01 13:00	19.9	17.5	2.4
11/7/01 13:15	19.9	17.5	2.4
11/7/01 13:30	20.0	18.1	1.9
11/7/01 13:45	23.1	20.3	2.8
11/7/01 14:00	23.2	20.3	2.9
11/7/01 14:15	23.3	20.4	2.9
11/7/01 14:30	23.3	20.4	2.9
11/7/01 14:45	23.4	20.5	2.9
11/7/01 15:00	23.4	20.6	2.8
11/7/01 15:15	23.5	20.7	2.8
11/7/01 15:30	18.0	12.8	5.2
11/7/01 15:45	17.9	18.7	-0.8
11/7/01 16:00	23.8	20.6	3.2
11/7/01 16:15	23.7	20.8	2.9
11/7/01 16:30	24.1	21.1	3.0
11/7/01 16:45	24.5	21.5	3.0
11/7/01 17:00	24.9	21.7	3.2
11/7/01 17:15	25.3	22.0	3.3
11/7/01 17:30	25.5	22.2	3.3
11/7/01 17:45	25.7	22.5	3.2
11/7/01 18:00	25.9	22.6	3.3
11/7/01 18:15	25.9	22.7	3.2
11/7/01 18:30	26.0	22.8	3.2
11/7/01 18:45	26.0	22.8	3.2

Table B.1. Transformer Loss Calculation. (Continued)

Date-Time	Total Power Input (kW)	Total Power Output (kW)	Transformer Losses (kW)
11/7/01 19:00	26.0	22.8	3.2
11/7/01 19:15	26.1	22.8	3.3
11/7/01 19:30	26.1	22.8	3.3
11/7/01 19:45	26.1	22.8	3.3
11/7/01 20:00	26.1	22.8	3.3
11/7/01 20:15	26.2	22.8	3.4
11/7/01 20:30	26.2	22.8	3.4
11/7/01 20:45	26.2	22.9	3.3
11/7/01 21:00	26.2	22.8	3.4
11/7/01 21:15	26.2	22.7	3.5
11/7/01 21:30	26.1	22.7	3.4
11/7/01 21:45	26.2	22.8	3.4
11/7/01 22:00	26.2	22.9	3.3
11/7/01 22:15	26.2	23.0	3.2
11/7/01 22:30	26.2	23.0	3.2
11/7/01 22:45	26.2	23.0	3.2
11/7/01 23:00	26.4	23.2	3.2
11/7/01 23:15	26.4	23.2	3.2
11/7/01 23:30	26.4	23.2	3.2
11/7/01 23:45	26.4	23.2	3.2
12/7/01 0:00	25.8	22.6	3.2
12/7/01 0:15	26.4	23.2	3.2
12/7/01 0:30	21.7	13.4	8.3
12/7/01 0:45	0.0	0.0	0.0
12/7/01 1:00	0.0	0.0	0.0
12/7/01 1:15	0.0	0.0	0.0
12/7/01 1:30	11.0	11.0	0.0
12/7/01 1:45	15.3	15.1	0.2
12/7/01 2:00	15.0	13.2	1.8

Table B.1. Transformer Loss Calculation. (Continued)

Date-Time	Total Power Input (kW)	Total Power Output (kW)	Transformer Losses (kW)
12/7/01 2:15	14.9	13.2	1.7
12/7/01 2:30	14.8	13.0	1.8
12/7/01 2:45	14.8	13.0	1.8
12/7/01 3:00	14.7	13.0	1.7
12/7/01 3:15	14.7	13.0	1.7
12/7/01 3:30	14.7	13.0	1.7
12/7/01 3:45	14.7	13.0	1.7
12/7/01 4:00	14.7	13.0	1.7
12/7/01 4:15	14.7	13.0	1.7
12/7/01 4:30	14.8	13.0	1.8
12/7/01 4:45	14.8	13.2	1.6
12/7/01 5:00	14.9	13.2	1.7
12/7/01 5:15	15.0	13.2	1.8
12/7/01 5:30	15.1	13.3	1.8
12/7/01 5:45	15.2	13.4	1.8
12/7/01 6:00	15.3	13.6	1.7
12/7/01 6:15	15.5	13.8	1.7
12/7/01 6:30	15.8	14.1	1.7
12/7/01 6:45	16.1	14.2	1.9
12/7/01 7:00	16.3	14.5	1.8
12/7/01 7:15	16.6	14.8	1.8
12/7/01 7:30	16.9	14.8	2.1
12/7/01 7:45	17.1	15.1	2.0
12/7/01 8:00	17.3	15.2	2.1
12/7/01 8:15	17.4	15.4	2.0
12/7/01 8:30	17.5	15.4	2.1
12/7/01 8:45	17.6	15.5	2.1
12/7/01 9:00	17.6	15.6	2.0
12/7/01 9:15	17.7	15.6	2.1

Table B.1. Transformer Loss Calculation. (Continued)

Date-Time	Total Power Input (kW)	Total Power Output (kW)	Transformer Losses (kW)
12/7/01 9:30	17.7	15.6	2.1
12/7/01 9:45	17.7	15.7	2.0
12/7/01 10:00	17.7	15.7	2.0
12/7/01 10:15	17.7	15.6	2.1
12/7/01 10:30	17.8	15.5	2.3
12/7/01 10:45	17.8	15.6	2.2
12/7/01 11:00	17.8	15.5	2.3
12/7/01 11:15	17.8	15.6	2.2
12/7/01 11:30	17.8	15.8	2.0
12/7/01 11:45	17.9	15.8	2.1
12/7/01 12:00	17.9	15.9	2.0
12/7/01 12:15	17.9	15.9	2.0
12/7/01 12:30	17.9	15.9	2.0
12/7/01 12:45	17.9	15.9	2.0
12/7/01 13:00	17.9	15.8	2.1
12/7/01 13:15	17.9	15.8	2.1
12/7/01 13:30	17.9	15.9	2.0
12/7/01 13:45	17.9	15.9	2.0
12/7/01 14:00	17.9	15.9	2.0
Average (kW)	19.7	17.3	2.4
Max (kW)	26.4	23.2	8.3
Min (kW)	0.0	0.0	-4.6

APPENDIX C

SINGLE LINE DIAGRAM OF EXISTING SYSTEM

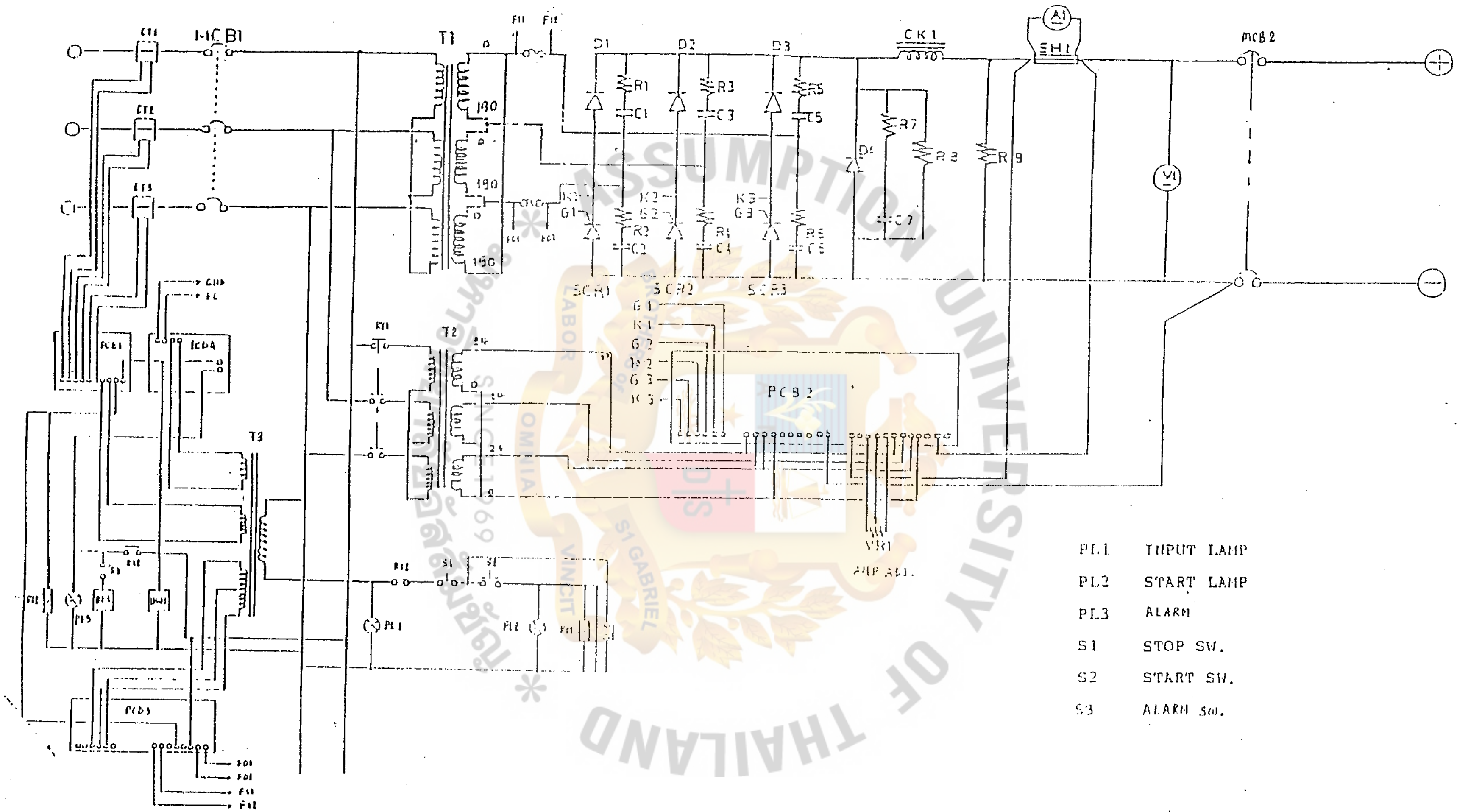


Figure C.1. Single Line Diagram of the Existing System.

APPENDIX D

NEW DESIGN TRANSFORMER

SEPARATED WINDING TRANSFORMER

TECHNICAL SPECIFICATION

A). TYPE OF WINDING	3 Phase, copper winding
B). TYPE OF CORE	Silicon laminated steel core
C). TYPE OF COOLING	AN (Dry type, air natural self cooled)
D). VARNISH METHOD	Impregnated with insulating varnish By vacuum pressure impregnation system And dried in oven chamber
E). INPUT VOLTAGE	220Vac.
F). OUTPUT VOLTAGE	Design for DC Power Supply 3ph 220Vac /0-240Vdc. 120Adc.
G). OPERATING FREQUENCY	50Hz
H). WINDING CONNECTION	Yyd
I). PHASE SHIFT	Windings configured to provide primary secondary Phase shift of "0" degree
J). IMPEDANCE VOLTAGE	≤ 3%
K). INSULATION CLASS	Class F (155 C)
L). OPERATING TEMPERATURE RISE	Not more than 100 C
M). AMBIENT TEMPERATURE	40 C (maximum)
N). EFFICIENCY	≥ 97% (25-100%) Load)
O). DUTY CYCLE	100% (Designed for continuous operation)
P). COMPLIED STANDARD	IEC 76 and VDE 0532-1966
Q). ENCLOSURE	
Made of galvanized steel sheet with grid ventilated	
-Finished by powder coated painting	
-Protection class IP20 (for indoor use only)	
R). OVERLOAD PROTECTION	Thermal relay (serie in 3 coils winding with NC contact)
S). WARRANTY	3 years, against defective material, and Workmanship, limited liability

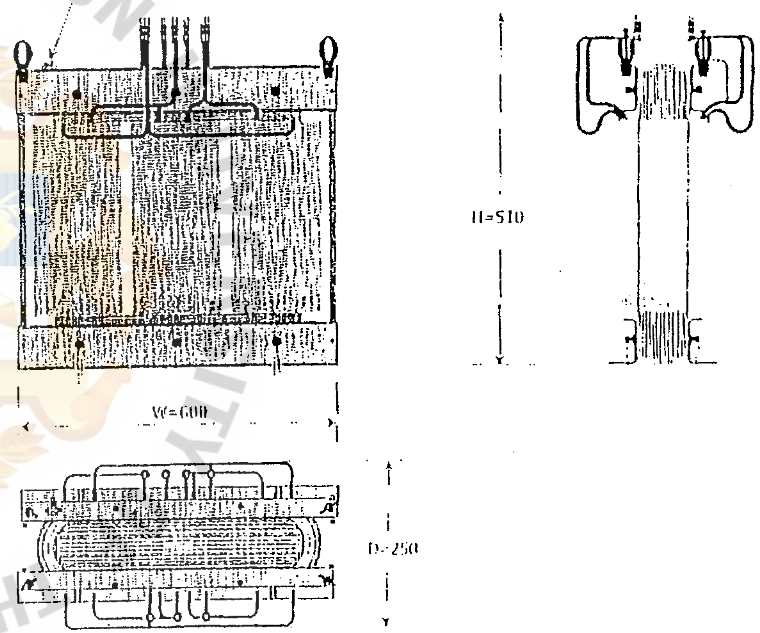


Figure D.1. New Design Transformer.

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