APARTMENT DIGITAL ELECTRIC SUBMETERING SYSTEM

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Abstract-**Presently, most apartments utilize a master metering system, wherein only one electric meter accumulates all the consumption within the entire apartment building. A conventional transaction in terms of payment is in a post-paid basis in which the lessee or the apartment occupant consumes electricity before paying for the said consumption.**

The system will work on this paradigm: using submetering system (hybrid of direct and master-metered), the consumers comprising of the lessee of a commercial unit or the person renting apartment will be availing the electricity service by means of paying the owner or lessor a certain amount (i.e Php 1,000.00) in advance. The electricity will be available as long as the prepaid load is not equal to the base rate provided by the electricity supplier. The transaction for the electric consumption will be in a prepayment format. Thus, this project is practical and has long term sustainability.

The digital electric meter displays kilowatt hour electricity consumption, remaining prepaid balance and cost per kilowatt hour on its liquid crystal display. Thus, allowing the lessees to observe the given information on the device. All the data generated by the device are stored in an EEPROM in case of any electricity interruptions, permitting the data to be accessed once the electricity has returned. The microcontroller utilized for the system is PIC16F877 and the programming language used for coding is Assembly Language. A circuit breaker is attached to the system in order to avoid overloading and a short circuit incidence. Contactor is used to switch on and off the power source of the project.

Separate tests conducted by the group and by CASURECO II resulted to an average of 95% accuracy or a 5% error of the device in terms of the electricity reading and billing. The result was attained by comparing the observed value and the computed value of the kilowatt hour electricity consumption. Although the main purposes of the project were achieved, improvements are still necessary. Apartment Digital Submetering System will be more efficient by acquiring an accuracy of almost a hundred percent and handling greater household consumption.

I. INTRODUCTION

Being considered a prime commodity, electricity is almost universally available. Electric metering system has been implemented in various ways and in various circumstances although in today's times improvement of such has just started to be established especially on highly urbanized zones where high rise buildings are constructed. Apartment Digital Electric Submetering System has mutually exclusive benefits to the consumer, leaser of commercial buildings and apartment owner, and the Utility Companies as well.

Background of the Study

For many years traditional electromechanical meters have been the instrument used by electric utility companies for residential and commercial power consumption. As the deregulation of the generation and distribution of power progress, the price of electricity becomes increasingly competitive. Consumers also demand for better customer service, higher power quality, highly energy measurement accuracy and more timely data. Electric utility companies are forced to find solutions that will result to a more sophisticated energy measurement method that give greater information on the population's power consumption. Recently, one of the technological barriers faced by electronic energy meters is producing highly accurate, low-cost electronic meters.

Significance of the Study

The Apartment Digital Electric Submetering System provides one solution for the enhancement of the current system of all electric utility companies. Apartment Digital Electric Submetering System addresses the needs of suburban living in apartments and residential types of habitats. Fortunately, semiconductor companies are on the rise giving solutions such as providing low cost CMOS processes and circuit technology to energy measurement Integrated Circuits, answering problems on accuracy.

ADESMS makes use of this technology at hand. A microcontroller is programmed to enliven the system, wherein, it becomes the brain of the system giving highly accurate energy measurements and a room for prepayment.

II. STATEMENT OF THE PROBLEM

A number of apartments nowadays are still implementing a master-metered form of billing in which the allocation of the payment is divided by the number of apartment units. With this kind of setup, all consumers pay an exactly the same amount regardless of the consumer's income, capability to pay and level of consumption. In master metering, individual consumption per apartment unit is not addressed but rather billings are averaged according to total amount of spending.

Conventional electric meters that are integrated with present apartments consist of dials, wherein the clockwise and counter clockwise movement of the pointer should still be considered before obtaining the actual value of electricity consumption. And not everyone has the knowledge of reading such meters. Thus, consumers are not aware of their daily consumption regarding the amount of electricity usage and its associated equivalent monetary cost. This may probably result to over consumption of electricity leading to unpaid bills and debts. An added burden is the cost of disconnections and reconnections which, basically, is high.

The increasing number of highly urbanized zones already affects the way people live. Accounting to the fact that in this urbanized areas, most of the people availing apartment units and commercial units such as condominiums are either students or single, independent employees. These people do not have the luxury of time to go to the different Utility Companies to pay for their electric consumption which, primarily, becomes another reason why these people dealt with penalties and disconnections for not paying their bills on time.

III. METHODOLOGY

The implementation of the whole project is composed of both hardware and software. The hardware consists of a PIC16F877 microcontroller, circuit breaker, voltage and current transformers, contactor relay, keypad, and a liquid crystal display (LCD). The software includes the source code that drives the PIC microcontroller to perform its task.

Hardware

There are two types of getting the power consumption of the appliances, one is to measure the power input and the other one is to measure the power output. In this project, the power input is measured by means of multiplying the input current and voltage.

The voltage transformer was used to step down the sensed input AC (Alternating Current) signals from a standard 220 Vac outlet into the approximate value of 9Vac. The signals from the transformer were converted into DC (Direct Current) by means of the AC to DC converter circuit. The AC to DC converter converted the AC coupled current and voltage into DC current and voltage in order for the microcontroller to calculate and store kilowatt-hour consumption over a specified period of time.

The current transformer with the ratio of 1:500 was used to sense the current utilized by the appliances. A burden resistor with the value of 60 ohms, was placed parallel into the secondary winding in order to get the desired value of the signal. The signal was converted into DC signal as it passed to the AC to DC circuit. The circuit of the AC to DC converter is shown below.

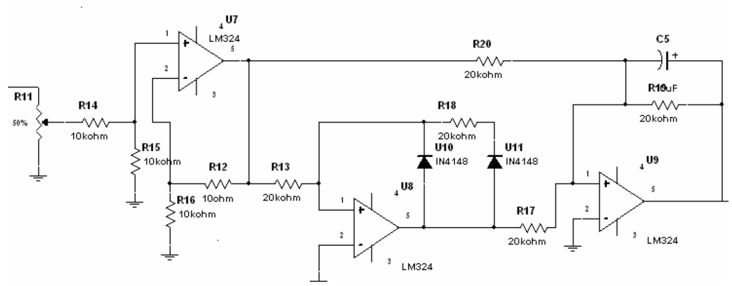

Figure 5-1: AC to DC converter

After going through the AC to DC converter, the given two parameters were fed into the PIC16F877 microcontroller to calculate, update and store the kilowatt-hour consumption over the period of time. The input voltage and current, with its computed power reading, were then projected to the LCD.

The 20 characters x 4 lines LCD was utilized for two purposes: reloading of the prepaid amount, and reading for the kilowatt per hour consumption.

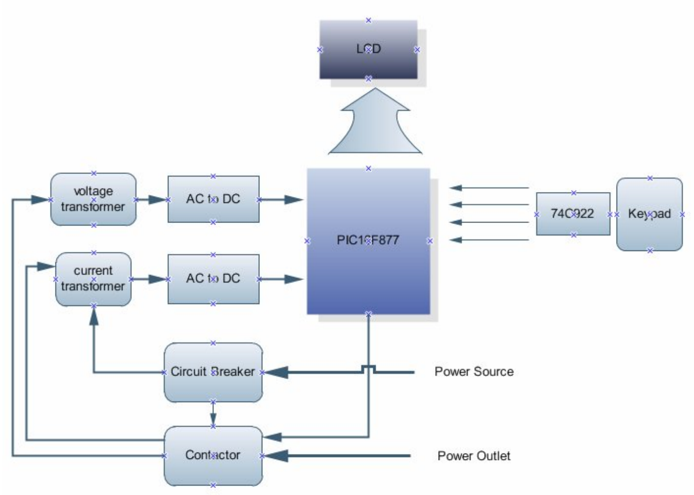

Figure 5-2: Block Diagram of the System

Figure 5-2 shows the block diagram of the whole flow of the system. The power source represents the input signal from a standard 220 Vac outlet and the power outlet in the figure above corresponds to the outlet to be connected with the appliances. The circuit breaker connected to the power source and current transformer functions to prevent the occurrence of a short circuit or overload.

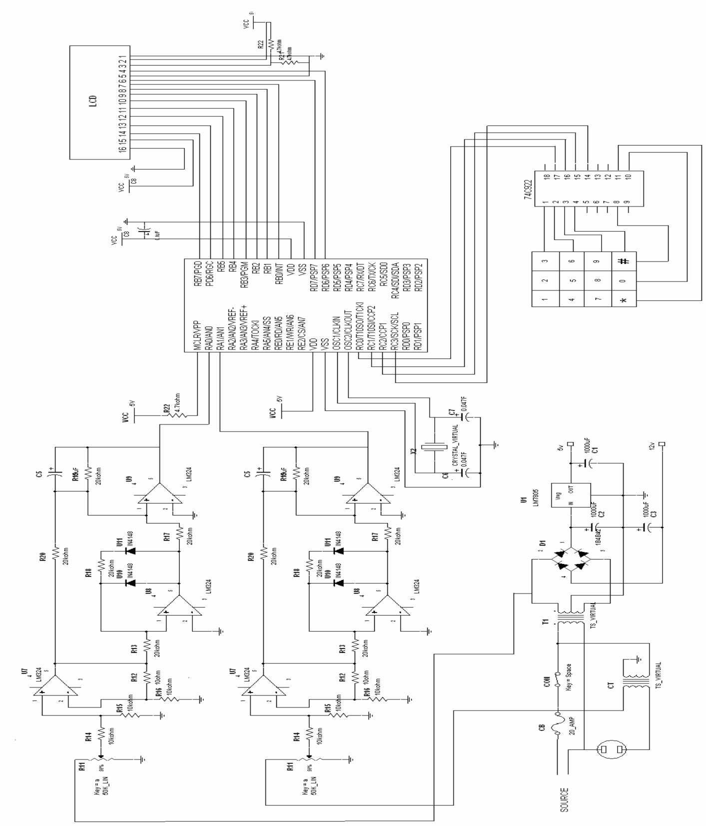

Figure 5-3: Schematic Diagram

Figure 5-3 shows the more detailed diagram of the whole system. It illustrates the specific IC's used to drive every part of the system and the corresponding connection of every pin. The Liquid Crystal Display module used the built-in PIC16F877 microcontroller LCD driver. The keypad controller driven by 74C922 served as a control or gateway to the flow of electricity. The keypad controller reloaded electricity in an apartment unit. An LED located at the left side of the LCD blinked when the amount was below Php250, indicating a warning that the current balance should be reloaded. The amount in peso that was reloaded to the utilities will be decremented according to electricity usage As long as the amount is greater than the base rate or the charge per kilowatt hour, the supply will be activated in the unit. The contactor relay automatically stopped the supply the moment the amount was less than the given base rate. The base rate of the utilities can also be altered using the keypad controller since its value is constantly changing in certain periods of time.

The PIC16F877 was the main controller of the project. Integrating the LCD with the microcontroller's built-in LCD driver, controlling the switching device or the contactor relay of the project, converting the input signal from the AC/DC converter with its built-in Analog-to-Digital converter, computing for the kilowatt hour and operating the keypad controller are among the tasks of PIC16F877.

Software

The project was programmed with the use of Assembly language based on its own PIC microcontroller instruction set. The system's interface is password-protected in order to secure unauthorized usage of the controller. Once the password is correctly entered, the user can already assign the charge per kilowatt hour and input the prepaid amount to be consumed by the lessee. The flow of the program starts from displaying the message 0 in the LCD as the power turned on. The message 0 can be seen in figure 13.

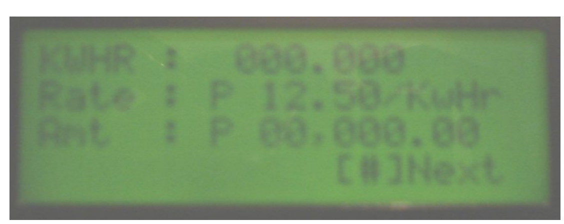

Figure 5-4: Message 0

The program recognizes if the number sign [#] was pressed, if yes, the program directed the next instruction, which is to display the message 1. Message 1 in figure 5-5 accepts the default four digit pin and another four digit pin after the slash {/} if the user wish to change the default password. If the asterisk [*] was pressed, the LCD will display the former LCD message but if the number sign [#] was pressed, the program will analyse if the default pin matched the user entered pin. If yes, the program will display the next LCD message shown in figure 5-6 and the last four digit pin will now be the default pin. The first part of the flow chart is shown in figure 5-5, the process of detecting if the user entered pin matched the default pin.

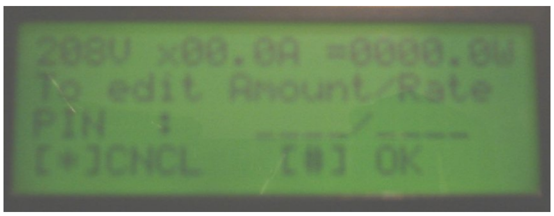

Figure 5-5: Message 1

The figure 5-6 below shows the next LCD message after the program detected the correct pin. The LCD will prompt the user to enter the present base rate and the amount to be reloaded. If the cancel [*] was pressed, the LCD will display the previous message. Once the ok [#] was pressed, the Digital Electric Meter will be activated and ready to use if the microcontroller detected the amount to be greater than the base rate. The detected value of the current and voltage utilized by the appliances will be displayed in the first line of message 1.

Figure 5-6: Message 2

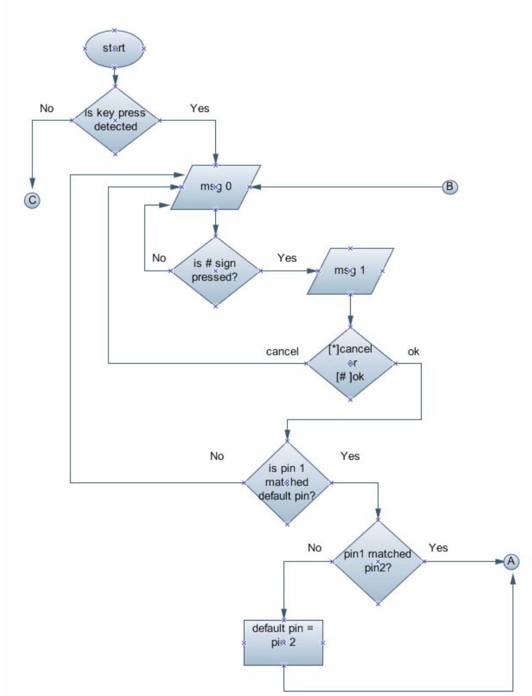

Figure 5-7: Flow Chart 1

The flowchart given above shows that the program starts by displaying a message display (msg 0) once a key press is detected. If the # sign was pressed, the system will display the next message (msg 1). A selection in the display shows * for cancel and # for ok. By selecting, cancel (*), the system will return to msg 0. Otherwise, the PIN for the system will be asked from the user when ok (#) is chosen. Once the PIN matched, msg 2 will be displayed.

Every time the one kilowatt-hour is accumulated, the amount will decrease according to the value of the base rate. The power consumption of the appliances connected to the project is displayed on first line of message 0 of the LCD. LCD displays 6 digits for the watt hour reading, wherein the leftmost digit corresponds to ones place value and the rightmost digit is the hundred thousands watt hour.

The microcontroller processes the data and computes for the energy or kilowatt per hour consumption through the input current and voltage multiplied by the time an appliance or device is in use.

The process of calculating the power, kilowatt-hours and amount in peso of consumption is shown below:

1. Multiply the value of current and voltage to obtain the power.

$$\text{Power (watts)} = I*V$$

2. Divide the power by 1000 to convert the Watts to kW.

$$kW = watts/1000$$

3. Multiply kW by the number of hours.

$$kWh = kW \times h$$

4. Multiply the kWh to the present cost per kWh.

$$Consumption = kWh \times cost\ per\ kWh$$

The EEPROM will update and save the power consumption reading in a specific period of time. The contactor relay will tripped off when the program detected that the amount is less than the rate and will also send signal to for the LED to blink if the amount is less than 250.

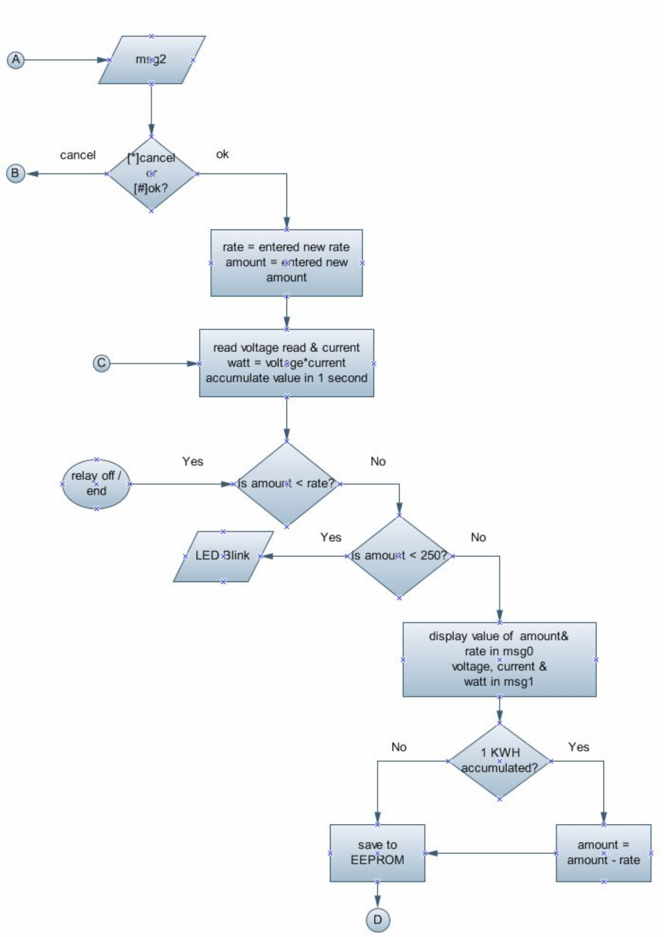

Figure 5-8: Flow Chart 2

Figure 5-8 shows the continuation of the flowchart in Figure 5-7, which is the flow of the program after the PIN entered by the user matches the default PIN. In msg 2 display, option for cancel (*) and ok (#) is shown. Pressing ok (#) will ask the user to input amount for the rate per kilowatt hour and the prepaid amount paid by the apartment occupant. Pressing cancel (*) will revert to msg 0. Then, accumulation of the electricity consumption will be made. The system checks whether the prepaid amount is lesser than the rate per kilowatt hour. If it is less than the amount, the relay will automatically switch off the source. But as long as the amount is more than the kilowatt hour rate, electricity is still supplied. Although, when the prepaid amount is lesser than 250 pesos, an LED blinker warning will be given. The electricity consumption is displayed in msg 0. Once every 1 kilowatt hour is consumed, the rate per kilowatt hour will be subtracted from the prepaid amount. Data produced by the system are automatically saved to the EEPROM of the PIC microcontroller.

IV. RESULTS AND ANALYSIS

The actual physical design of the Apartment Digital Submetering System is shown below. Visible components of the design are the liquid crystal display (LCD), light-emitting diode (LED), keypad, female socket and the circuit breaker.

Figure 7-1: Actual Physical Design

Several trials were done in order to test the efficiency and accuracy of the reading of the digital electric meter. For every trial, different appliances were connected to the device. These appliances include: mosquito killer, oven toaster, electric fan, emergency light, and a personal computer. The result for the observation is shown in the table below:

Table 7-1: Results of the Tests

TRIALS	AVERAGE POWER READING (in watts)	TIME (in hour)	COMPUTED ENERGY (in kWhr)	ACTUAL ENERGY READING (in kWhr)	PERCENTAGE ACCURACY
1st Trial	655.5	0.25	163.875	165	99.31%
2nd Trial	81.5	0.25	20.375	19	93.25%
3rd Trial	104	0.25	26	24	92.31%
4th Trial	236	0.25	59	58	98.31%

The total power reading of the appliances that were used during testing was computed by averaging. The highest reading of the digital electric meter was obtained, as well as the lowest power reading to obtain the values that were substituted to the average formula. Every trial lasted for fifteen minutes to compute for the energy in kilowatt hour.

For the first trial, the appliances that were utilized for the testing consist of a mosquito killer, oven toaster and a stand fan. The computed energy, given the power and the time duration, is 163.875 watt hour or 0.1639 kilowatt hour. After the fifteen-minute test, the reading of the digital electric meter was 165 watts. Computing for the percentage accuracy, the percentage resulted to 99.31%. The percentage error was 0.69%.

The appliances used for the second trial were mosquito killer, electric stand fan and an emergency light. 20.375 watt hour was the computed energy, obtained by multiplying the power reading with the time duration which was 0.25 hour. However, the test resulted with an output of 19 watt hour or 0.019 kilowatt hour. The percentage accuracy of the project during the second trial was 93.25% with a percentage error of 6.75%.

The third trial's average power reading was 104 watts, using only two appliances: mosquito killer and electric stand fan. Comparing the actual kilowatt hour reading, which was 24 watt hour to that of the computed energy of 26 watt hour, the percentage error obtained during the third trial was 7.69% and the accuracy was 92.31%. During the last trial of the testing, the percentage accuracy was 98.31% with an error of 1.69%. This was obtained by having values for the computed kilowatt hour of 59 Whr or 0.059 kWhr and the actual reading of the kilowatt hour which was 58 Whr or 0.0598 kWhr. The appliances used during the last trial were voltage regulator connected to a personal computer, electric fan and mosquito killer.

The device is more than 90 percent efficient and accurate. Based from the results obtained from testing the device four times, the average percentage is 95.795%. Also, the test done at the Calibration Section of CASURECO II resulted to 95.16% with an error of 4.84%.

There were discrepancies as to the results of the percentage accuracy during the four trials conducted for a span of fifteen minutes each trial. The discrepancies were affected by several factors associated with the concept of the project. The input signal is an alternating current, which results to a varying input to the system. Input voltage and input current change abruptly with respect to the time. Therefore, power and kilowatt hour reading varies, making it hard for the observer to monitor the exact value of the two given parameters. Also, the process of obtaining the average power reading was done by just observing the reading of the power and energy in the LCD. Thus, human error is likely to occur.

Another factor is that for every trial made, different appliances were connected to the device that is why there were differences in the kilowatt hour reading.

V. CONCLUSION

In conclusion, the project was accomplished successfully. The additional requirements which are data storage for the net credit, base rate and kilowatt hour reading, as well as the certification of calibration and accuracy from Casureco II, were achieved.

The objectives enumerated during the preliminary and pre-final defense were met. The device has resolved the issues on practicability on the part of the electric company provider, apartment owner and the tenant. With centralized billing, the electric company will only be responsible of reading the kilowatt hour consumption of the main meter reading instead of the individual unit. Also, the leasee and leasor are spared from debts because of prepaid consumption of electricity. The tenants will also be aware of their electric consumption in monetary equivalent. Thus, this leads to avoidance of electricity disconnection from the service provider due to unpaid bills.

Energy consumption can be summarized as the power input or the power output multiplied by the time duration an appliance or appliances were used. The energy consumption for an apartment household can be associated with monetary value, thus, management of the electricity may be considered. In order to get the power consumption of the loads, multiplication of the voltage and current should be made. The power input should always be equal to the power output; therefore, it will not matter if the input parameters (voltage and current) or that of the output is considered. The input voltage and current were stepped down into smaller value by means of the transformer and the AC signal was converted to DC to cut off its negative values before feeding it up to the analog to digital converter of the microcontroller.

However, during the development of the project, several difficulties were experienced. The project was only 50% accurate with an error of 50%. The kilowatt hour reading is twice the appropriate amount. With this, the payment for every kilowatt hour consumption is twice the supposed payment. Also, there was no data storage for the device. The data on the digital meter resets every time a power interruption occurs. The data storage was addressed by utilizing the built-in EEPROM of the PIC16F877. The EEPROM was used to store the data from the device so that even if there is an occurrence of a power interruption, data can still be recovered.

Even though the primary goals for the projects were realized, future enhancements can still be added. These include smaller casing for the device, improvement of its accuracy and efficiency by attaining at least a percentage accuracy of 99%, and the device can handle larger household consumption of more than 20 amperes.