Tribhuvan University

Institute of Engineering

Department of Electrical Engineering

Pulchowk Campus

A Project Report

On

PC Based Maximum Demand Controller

(As a partial fulfillment for B.E. In Electrical Engineering)

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November, 2003

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TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

DEPARTMENT OF ELECTRICAL ENGINEERING

PULCHOWK CAMPUS

The undersigned certify that they have read and recommended to the Department of Electrical Engineering, a final year project work entitled, **"PC Based Maximum Demand Controller"** submitted by **Mr. Sudarshan Dahal, Mr. Sumit Paudyal, Mr. Shushil Kumar Singh** and **Mr. Yam Lal Tharu** in partial fulfillment of the requirement for the degree of Bachelor of Engineering.

Date: November 7, 2003

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Mr. Indra Man Tamrakar

Project Supervisor

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External Examiners:

Acknowledgement

The project entitled **PC Based Maximum Demand Controller** is our attempt towards implementing the engineering concepts gained during our institutional life. This report has been prepared as the exposition of the fundamental works performed during the project period. This report illustrates only the required explanations of the work at the various topics.

We cannot stay away from acknowledging the helps, suggestions, and inspirations of our respected teachers and friends. We are grateful to our respected sir **Mr. Indra Man Tamrakar,** the Head of the Department, for kindly supervising us and conducting us with many lab facilities including testing and measuring equipments, computers, printers etc. We are also thankful to him for his kindness in reading and correcting this report manual.

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Abstract

Energy Management system is becoming a widely accepted concept, with rise in energy costs, non-availability of quality power and increased awareness about energy management among consumers. Creating awareness regarding need for energy management, incentives for best energy managed companies and Power tariff structure suited to encourage energy saving can improve the existing power situation and will help in formulating a better planned power supply system.

An integral energy management system for a building for controlling and monitoring of data, requires considerable investment. And neither monitoring nor controlling, is an end in itself, there have to be reasons and ultimate objectives in investing considerable amount of sum, in this regard. The investment varies depending on the type of building, Range of parameters to be monitored, utilities to be connected to the system and level of sophistication. Hence in opting for an energy management system, care shall be taken to arrive at an appropriate system, with desired level and range of operation. The monitored parameters are to be recorded and studied carefully, to evolve necessary steps and maintenance schedules for optimum use of energy.

The advances in microprocessor technology and applications are continuing to change the definition of Energy Management System (EMS). Basically, an EMS combines the function of programmable controller, demand controller, and any number of individual equipment, lighting, and temperature controls. In addition, it also includes a monitoring capability, handling sensor inputs from throughout the building or facility. Most importantly, the EMS can use the input from these sensors to make optimum energy-related decisions about equipment operation, especially in the ventilation and heating cooling systems. Depending on its computer power, EMS can currently control thousands of points in many different buildings. The system can include building safety and security monitoring, as well as fire alarm systems. The wide variety of system types, software sizes, and interfaces and distribution equipment make the study of EMS a very vast.

The project titled PC Based Maximum Demand Controller is supposed to be a foundation towards employing a digital computer or a microprocessor for the purpose of managing industrial loads to control peak demand at least to our institution level. Here we have interfaced general PC for the purpose. It is desired to achieve general automatic switching characteristics through the general interfacing circuitry by a programmable approach. A high degree of flexibility that can be obtained from a digital controller is the main attraction that derived us to select this work. Programmable controllers are primarily used in automatic stepwise control of batch systems to replace electromechanical relays. They are also very commonly used for ON/OFF and time of day control of individual equipments (points). The programmable approach equipped with memory makes a controller a highly reliable, they offer a display for monitoring purposes, and they can often cost-effectively replace an interlock system of relays. Prices are depending on capacity and sophistication.

The conventional methods of demand control are the 'load scheduling' and 'visual monitoring'. They are less reliable and associated with errors caused by human factors such as negligence. While every plant should be practicing manual demand control, only larger plants may find it attractive to install automatic controls.

The whole work is basically divided into two parts. 1) Interfacing and 2) Programming. Interfacing is aimed at feeding voltage and current signals coming from the instrument transformers to the microcomputer and the programming is mainly aimed at achieving the desired relaying characteristics and generating the control and handshake signal to the interfacing circuitry as well. In the interfacing circuitry the National Semiconductor ADC0809 has been used as our data acquisition system. The digital signal from the data acquisition system is fed to the PC through Programmable Peripheral Interface (PPI), Intel 8255. PPI is programmed in input/output mode (I/O) as well as Bit Set Reset mode (BSR) to input and output data as well as control signals to ADC and trip signals to power Circuit Breakers. Turbo C has been used as the programming tool.

Digital algorithm, Discrete Fourier Transform is employed to extract the fundamental frequency components from digitized samples of one cycle of the input current or voltage. Then the values of the fundamental frequency components are used to calculate the power factor and power demand. Based on the preset value of the demand, the actual demand is compared with the preset demand to generate the switching pulses. The program outputs the digital word to switch of the desired point.

The running of the program gives the current value of power factor, voltage, current drawn and the instantaneous demand of the load. Incorporating the database, the values can be stored to suit for further analysis. The package is being equipped with graphical user interface, is very much user friendly. The package can be extended to automate control the various other aspects of the power consumption.

Nomenclature

EMS	Energy Management System
ADC	Analog to Digital Converter
SAR	Successive Approximation Register
PPI	Programmable Peripheral Interface
DFT	Discrete Fourier Transform
I/O	Input Output
BSR	Bit Set Reset
PC	Personal Computer
CT	Current Transformer
PT	Potential Transformer
IN1	Input Channel 1
SC	Start of Conversion
EOC	End of Conversion
ALE	Address Latch Enable
OE	Output Enable
Add	Address
PA	Port A
MUX	Multiplexer
CB	Circuit Breaker
IC	Integrated Circuit
SCADA	Supervisory Control and Data Acquisition

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Chapter 1

Concepts of Energy Management

1.1 General Introduction

Energy Management system is becoming a widely accepted concept, with rise in energy costs, non-availability of quality power and increased awareness about energy management among consumers. Creating awareness regarding need for energy management, incentives for best energy managed companies and Power tariff structure suited to encourage energy saving can improve the existing power situation and will help in formulating a better planned power supply system.

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1.2 Definition

The Major costs involved for the building includes Construction / Financing costs, Energy Costs, Operating Costs and Retrofit Costs. And the average life expectancy of a modern building is 40-50 years.

Of the above, the energy costs are found to be significant, and this varies according to the Total Area of the building, Type of building, Type of Electrical loads and etc. The energy costs, operating costs are recurring costs, which are found to increase with time.

The Electrical loads of various utilities, for a modern multistoried building as expressed on percentage basis gives the following data:

i) HVAC: 60 %
ii) Lighting: 23 %
iii) Lifts: 6 %
iv) Others: 11 %

The energy costs shall depend on this and period of use of these utilities. The energy and operating costs of the buildings can be reduced by methods involving energy conservation. From mechanical engineering aspect, improved thermal insulation, alignment of building, use of double glazed windows, air-conditioning controls etc. provide scope for energy conservation.

From electrical aspect, electronic building controls and energy efficient lighting system design & operation, energy efficient pumping systems provide scope for energy conservation.

The scope for energy conservation exists for all aspects of building services including Heating, Ventilation & Air-conditioning, Electrical systems, lighting systems, Water supply and Sewerage systems, Centralized Gas Supply, Heating etc.

1.3 Energy Management System for buildings

Energy management system suited for operating for a building can be termed as building management system. This system can be used to monitor and control all or some aspects of building services including heating, ventilation and air-conditioning (HVAC), electrical systems, lighting systems, fire alarm and detection system, security systems including CCTV, public addressing, sensors, access control etc.

1.3.1 Heating, Ventilation & Air-conditioning Systems:

The simplest form of energy management system for HVAC system is the thermostat, which minimizes energy consumption on a time temperature basis. Another simple energy management system is achieved with load-cycling controllers, which make use of (on-off operations) to reduce consumption.

A higher level of control is achieved with demand controller (which effectively monitors the electrical demand and on a predictive basis disconnects and reconnects major loads. The most sophisticated control, which is practical even in moderate-size building with the HVAC energy management system, usually incorporated into the building control system.

1.3.2 Lighting:

The objective of Energy Management in lighting is to use more efficient lighting equipment and practices to achieve same or better lighting result for lower electrical energy consumption and lower cost.

The important aspects of providing better energy efficient and effective lighting are:

i) Selection of light source:

Compact fluorescent lamps are found to be more energy efficient and effective, when compared to GLS lamps. The CFL lamps available at 7/9/11 W are comparable to GLS lamps of 40, 60 & 100 W. Use of CFL lamp instead of GLS lamp will thus produce an energy saving up to 60%.

Similarly, switching to lower rated HPSV lamps instead of HPMV lamps can bring down energy costs substantially for large areas and major roads.

ii) Selection of light fixture and accessories:

Selection of light fixture plays an important role in proper distribution of light output and the lighting effect created. A well-designed optical system based light fixtures generates the optimum light output with maximum visual comfort.

For office areas, antiglare mirror optic light fixture suited for use with twin fluorescent lamps is advisable as it generates the light output, suited for continuous working hours.

Use of High Frequency Electronic Ballasts can improve performance of the lamps and has a high power factor with minimum interference for communication / data signals.

1.3.3 Electrical Power Systems:

Design stage itself care shall be taken, in selection of cables, all equipment and accessories. A considerable quantity of energy is wasted in distribution of Power, mainly by use of lower rated cables, faulty connections & terminations. This aspect is to be studied and rectified at the design /construction stage itself. Proper maintenance of all HV/LV equipment including HV panel, transformer, DG sets are absolutely necessary for preventing wastage of energy.

For all multistoried buildings, it should be a practice to maintain records of periodic maintenance and defects rectification.

1.3.4 Water Supply and Sewerage Systems:

Conservation of energy for the above systems mainly lies in selection of motors and pumps, fire fighting pumps etc. Regular maintenance of supply lines, overhauling of equipment are necessary for preventing wastage of energy.

1.3.5 Elevators:

Apart from interfacing with Building Automation system, elevators have independent microprocessor based control for efficient operation. Variable voltage, variable frequency drives, lift bank control (Duplex / triplex) & Automatic Rescue Device are advancements in elevators that help in optimum usage of elevators and safety of passengers. Variable frequency variable frequency drives used for elevators are considered the most energy efficient.

The controls from the elevator panel can be interfaced with the building automation system for monitoring and control as per Client's needs.

1.4 Methods for Effective Energy Management

1. Efficient utilization of available energy resources.

2. Conservation of energy.

3. Technology development for recovery of waste energy.

4. Use of renewable energy systems.

5. Energy Auditing & prevention of leakage of energy.

An energy cost is generally major factor in the manufacturing industry. Energy management in the industry can be achieved by use of energy efficient equipments, audit of energy flow in the system, creating awareness among end users. By detailed energy audit, it is possible to reduce energy cost by 10- 20 %. Even in the best managed industrial concerns, 6-8 % energy saving is possible without major investment.

The required capacity as estimated above can be reduced by 20-25 % by adopting energy conservation measures and through demand side management. This can reduce the capital investment required by 25 %. A unit of energy saved is equivalent to a unit of energy generated becomes relevant in this context.

1.4.1 Energy Management - Power supply Sector:

The Energy management aspects to be adopted by power supply companies should cover all possibilities in generation, transmission and distribution. The major fronts in which energy management can be achieved include:

- System power factor management & improvement.
- Planned growth of distribution system in major cities & distribution centers.
- Load balancing of distribution transformers.

- Providing electronic meters for accurate measurement of energy.
- Restructuring tariff structure. (TOD metering).

Power factor reduction from 0.8 to 0.6 derates the system installed capacity by 25 %. This shall include capacities of generator, transmission line, distribution transformer and subsequent low / medium voltage feeders.

Low power factor results in drawing higher currents, thus further escalating energy costs. Low power factor causes excessive voltage drops in the system, thus affecting the life of all low voltage equipments.

Power capacitors shall be used, which enables reduction of KVA demand for given KW load thus reducing energy costs. Higher power factor shall improve performance, capacity and expected life of all system equipments including transformer, generator, switchgear and cables.

Power management systems are primarily used for control and monitoring of electrical distribution system for effective and efficient management.

A typical PLC based power management system shall include Programmable Logic Controller, connected to I/O racks, interfacing systems with power monitors & various third party devices. The PLC can interface with plant process control systems to gather data and control signals through data networks. The PLC can be integrated with overall plant control scheme.

The PLC hardware system along with the software are equipped to perform reading of all power data and giving information in standardized data tables and giving alarm signals. The system provides display, logging and analysis of collected power data. The system can allocate power costs to various departments and utilities. Other system functions shall include providing demand management and load shedding.

1.5 Energy Audit

Each industry / major company should have an energy cell for control & management of energy. The cell shall study the existing system parameters and should identify areas, where energy can be saved. The cell shall line up implementations for energy conservation and create awareness among end users.

Methodology shall be to document various proposals for energy saving compiled along with technical details for their implementation, expected annual saving against estimated costs of implementation, simple pay back period etc.

An energy audit shall involve collection of detailed information on the process, equipment used, illumination systems, heating, ventilation and air-conditioning systems, boilers, pumps etc. Based on the information, the energy costs of specific areas/processes can be worked out, which enables formulation of an energy consumption chart. The energy consumption chart can be verified for finding surplus use of energy compared to similar systems, leakage of energy in the system, and help us in suggesting energy efficient schemes/equipments for specific areas.

Each of the energy saving measures and systems are further studied in detail for savings in energy return of investment, system performance, integration with existing system etc.

The energy saving measures to be followed by an industry shall include periodic measurement of all energy resources i.e. electrical energy, coal, gas, boiler, mechanical systems etc.

The energy costs shall be done area wise and should be related to production costs. Energy indices are to be prepared for analysis of data. Energy indices can be developed for various industries - textile, cement, chemical, hotel, transportation etc. The indices can be expressed as unit of energy consumed for a specific output of end product. This specific energy costs are found to remain within a certain range for industries working under similar conditions.

In the prevailing situation of severe competition in the market, cost reduction has become very important for improving profit margin as well as for survival and specific energy consumption has to be made optimum to achieve better performance.

The requirement to achieve energy efficiency is increasing, as now the energy agenda has shifted from strictly economic concerns to more global environmental ones. A ban is imposed on the use of chlorofluorocarbons which depletes the ozone layer is going to be enforced by 2010. Now environmental parameters do also necessitate conservation of energy and utilization of renewable energy systems.

1.6 Methods for Energy Conservation

Energy efficient lighting systems

- Use of compact fluorescent lighting systems for energy efficient lighting design.
- Use of electronic ballasts for efficient operation and energy saving.
- Use of high pressure sodium vapor Lamps for yard lighting applications instead of mercury vapor lamps

Energy saving systems - Measurement methods

- Use of trivector meters.
- Providing maximum demand controllers.
- Digital indication systems for overload.
- Microprocessor based control systems and advanced type screw chillers for HVAC.
- Microprocessor based control systems & variable voltage variable frequency drives for elevators.

Building automation systems

- Control of lighting system according to seasonal day light variations & no. of users.
- Control of chiller plant & AHU's in accordance with outside temp. & no. of users.
- Automatic control of water pumping systems.

Renewable energy systems

- Solar photovoltaic house lighting systems
- Solar water heaters
- Solar water pumping systems
- Solar yard lighting systems.

Solar Photovoltaic systems are the most important among the renewable energy system finding its application in household and industrial systems. Solar photovoltaic primarily uses sun's light energy and converts it into electricity through solar cells.

The solar systems can be as simple as an individual system as solar water heater where solar energy directly powers the functioning of the system. The system can function only when sunshine is available.

A more complex system is the home lighting system, which includes a battery backup for operating at night, and powering both AC and DC loads.

The above systems work independently, but solar system can also be used in conjunction with other complementary power sources to provide complete energy solutions.

The solar energy's unique attributes of needing no fuel, high durability and reliability and being able to operate for prolonged periods without maintenance make it economical for all types of remote applications. These unique attributes permit solar energy to be used in places and for purposes where no other power source is feasible.

A typical solar photovoltaic system shall include sunlight as the fuel, solar modules, charge regulators, batteries, inverters, mounting structure, internal wiring, back up generators etc.

Solar modules generate DC electricity directly form sunlight, charge regulators link the modules, battery and load. Also, charge regulators protect battery from overcharge or excessive discharge. Batteries store the energy generated by solar modules and inverter converts DC electricity into AC for powering equipments.

The mounting structures are used to hold the solar modules securely in place either at ground /roof or at poles. Back up generators are required for excessive power demands or during unanticipated sunless periods.

Solar systems are considered as one of the easiest and most reliable way to generate electricity. Regular maintenance to check wiring, connections, batteries and overall system condition will help assure long-term trouble free operation.

Grid connected solar power systems powering loads up to 2 MW are being used at present for peak handling of loads, powering day loads of agricultural pumping in remote areas and for telecommunication applications.

1.7 Non-Conventional source of energy for Buildings

Among the various sources of non-conventional energy, solar energy is most suited to be utilized as an alternate power source for buildings.

Solar photovoltaic power systems basically include solar module, battery system and electronic circuitry. The main application for this system is in lighting, water pumps, remote telephone exchanges etc.

Based on application, solar photovoltaic system can be stand-alone type PV power system or grid connected PV power system.

In buildings, standalone type shall include independent solar modules, batteries, electronic circuitry and the lighting loads connected to it. Standalone systems are applicable for outdoors lighting, streetlights and for remote telephone exchanges.

A larger type stand-alone system is suited for community housing, large buildings, where a central system shall feed power to all loads. The central system shall include bank of solar modules, battery system, electronic circuitry etc. This system is adapted for buildings, where a part of the lighting load is taken care of by the solar photovoltaic system.

Higher initial investment and occasional low performance of electronic circuitry in the SPV system may be deterrents in opting for a total SPV system.

Solar photovoltaic system is suited for low power applications, where mostly lighting loads are to be connected. It would be most appropriate to opt for a combination of normal power and SPV power, as it would prove to be economical and reliable system.

The hybrid systems are found to be most suited for applications involving continuous operation and reliable system. In remote telephone exchanges and army posts hybrid of solar photovoltaic system with diesel generating sets are widely used and appreciated for the reliability of operation.

Chapter 3
Digital switching Algorithm

In a digital power system switching scheme, the processor executes different functions like data acquisition and processing under an elaborate program control. At the core of this program is a signal-processing algorithm that processes the incoming digitized relaying data to detect the fault. Numerous algorithms for a digital relaying/switching have been derived during the past two decades and a comparative evaluation of different algorithms for load switching has also been reported.

Most of these algorithms are aimed at extracting the fundamental frequency components from the complex distorted voltage and current signals containing a dc offset component and harmonic frequency components in addition to the power frequency fundamental component. The algorithms should be computationally simple and fast in order to perform the switching function. Some of them are explained below:

3.1 Discrete Fourier Transform Technique

In this technique, the algorithm for extracting the fundamental frequency components from the contaminated input signal is based on the Discrete Fourier Transform. The Discrete Fourier Transform (DFT) of the data sequence is used to evaluate the Fourier coefficients. In this approach, the fundamental Fourier sine and cosine coefficients are obtained correlating the incoming data samples with stored samples of reference fundamental sine and cosine waves, respectively. The fundamental Fourier sine and cosine coefficients are respectively equal to real and imaginary parts of the fundamental frequency component. Using DFT, the real and imaginary parts of the fundamental frequency components of the input voltage and current is calculated to calculate the current power demand.

Discrete Fourier Transform (DFT)

The discrete Fourier Transform (DFT) is used to evaluate the Fourier is used to evaluate the Fourier coefficient from N samples of x (t) taken at times t=0, T_s, $2T_s$, …… (N-1) T_s, where Ts=T/N is the sampling interval. Therefore, the input to the DFT is a sequence of samples (numbers) rather than a continuous function of time x (t). The sequence of samples (i.e. data sequence) which results from periodically sampling the continuous signal x (t) at intervals of Ts is referred to as a discrete time signal. A system with both continuous and discrete-time signal is called a discrete-time system.

The DFT may be regarded as a discrete-time signal processing technique for the evaluation of the Fourier coefficients. The DFT equation is obtained from Eq. (1) by

$$C_{fk} = 1/T \int_0^T x(t)\exp(-jk\omega t)dt \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

replacing the continuous function by discrete-time values and the integration by a summation. If the periodic function x (t) is sampled N times per period at the sampling interval of T_s , the N samples represent the period T, so $T=NT_s$. These N samples of x (t) from the data sequence x_m , m = 0,1,2….(N-1).

Therefore, the DFT of a data sequence x_m , m = 0,1,2….(N-1) is defined as:

$$C_{fk} = 1/N \sum_{m=0}^{N-1} x_m \exp(-2\,\Pi\,km/N),\ k = 0,1,2 \ldots.(N-1)\ldots\ldots\ldots(2)$$

The DFT uses N data samples X_0, X_1, X_2, $X_{(N-1)}$, which allows us to solve for only N unknown coefficients. The transform coefficient number k determines the number of cycles in period T and identifies the frequency as k/T Hz.

The computation of Fourier coefficients by using Eq. (2) involves complex arithmetic, which makes the computation difficult with the microprocessor. Therefore, for microprocessor implementation of the DFT, separate equations for real and imaginary parts are used, instead of the DFT, equation in complex form.

Eq. (2) can be written as follows.

$$C_{fk} = 1/N \sum_{m=o}^{N-1} x_m (\cos (2 \prod km)/N)\text{-}j \sin (2 \prod km)/N) \ldots\ldots.. (3)$$

$$\text{Or } ½ (a_k\text{-}jb_k) = 1/N \sum_{m=o}^{N-1} x_m (\cos (2 \prod km)/N)\text{-}j \sin (2 \prod km)/N); k = 0,1,2 \ldots.(N\text{-}1)$$

Therefore

$$a_k = 2/N \sum_{m=1}^{N-1} x_m (\cos (2 \prod km)/N) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

And

$$b_k = 2/N \sum_{m=1}^{N-1} x_m (\sin (2 \prod km)/N) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$;k = 0,1,2,\ldots\ldots N\text{-}1$$

These equations can be easily implemented on the microprocessor in order to obtain the Fourier coefficients corresponding to any frequency component. The value of k determines the frequency.

Fast Fourier Transform (FFT)

The Fast Fourier Transform is a fast algorithm for efficient computation of DFT. This algorithm drastically reduces the number of arithmetic operations and memory required to compute the DFT. It is based on manipulation and factorization of the DFT matrix W^E if N is the number of samples per period (of fundamental cycle), the easiest case for this algorithm is when $N=2^{n,}$ where n is an integer. The FFT for this case is called power-of-2

FFT. The more general case is for N having n integral factors. The FFTs for this case are called mixed radix transforms.

The main advantage of this transform is that it reduces the computations involved. The numbers of complex operations for N×1 transform N $\log_2$ (N). The main disadvantage with this transform is that complex arithmetic is involved.

The FFT has accelerated the application of Fourier techniques in digital signal processing in many areas other than digital switching/relaying. In relaying applications, N is small (from 4 to 20 for most algorithms) and only a few of the C_{jk} are wanted. Generally, only the fundamental frequency components (K=1) is used in distance relaying while the fundamental and a few harmonics are, i.e. the second (K=5) are used in algorithms for transformer relaying. Hence the FFT has found little application in digital switching.

3.2 Walsh-Hadamard Transform Technique

In this technique, the algorithm for extracting the fundamental frequency components from the complex contaminated signals is based on Walsh-Hadamard Transform (WHT). The Walsh coefficients are obtained by using the Walsh-Hadamard transformation on the incoming data samples, i.e. voltage and current samples acquired over a full cycle or half cycle data window. These coefficients are obtained by mere addition and subtraction of data samples. A fast algorithm known as the Fast Walsh-Hadamard transform (FWHT) is available to compute the Walsh coefficients efficiently. Using Fourier-Walsh theory, the Fourier coefficients are expressed in terms of Walsh coefficients. The fundamental Fourier sine and cosine coefficients, which are equal to the real and imaginary components of the fundamental frequency phasor, respectively are computed by addition, subtraction and shift operation of Walsh coefficients. Using the real and imaginary components of the fundamental frequency voltage and current phasors, the real and imaginary components of the consumed power are calculated. The use of FWHT eliminates the time consuming operation of squaring and square rooting, and minimizes the dividing and multiplying operation, thus rendering this algorithm suitable for microprocessor (digital) implementations.

If a continuous function f (t) is specified by N samples ($X_1, X_2, X_3, \ldots\ldots X_N$) during a time period, f (t) can be defined by the discrete Walsh transform and its inverse as given below:

$$X_N = 1/N \sum_{K=0}^{N-1} W_k \text{ Wal } (n, k/N)$$

$$W_k = \sum_{K=0}^{N-1} X_n \text{ Wal } (n, k/N)$$

Where Wal (n, k/N) are the Walsh functions, for k, n = 0,1,2,…..N-1.

3.3 Rationalized Haar Transform Technique

In this case, the algorithm for extracting the fundamental frequency components from the distorted signals is based on what is known as the Rationalized Haar Transform (RHT) coefficients C_{rhk}, k = 0,1,2…N-1 are obtained by using the rationalized Haar transformation on the incoming data samples, i.e. voltage and current samples acquired over a full-cycle data window or a half-cycle data window at a sampling rate of 16 samples per cycle. These coefficients are obtained by mere addition and subtraction of data samples. A half cycle data window is based on the assumption that the relaying signals contain only odd harmonics and the transient dc offset component is filtered out from the incoming raw data samples before they are processed.

Relationship to express fundamental Fourier sine and cosine coefficients in terms of the RHT coefficients has been derived. The fundamental Fourier sine and cosine coefficients, which are respectively, equal to the real and imaginary components of the fundamental frequency phasor can be computed by addition, subtraction and shift operations of the RHT coefficients. Using real and imaginary components of the fundamental frequency voltage and current phasors, the real and reactive components the power demand can be calculated. This algorithm has been developed with the sampling rate of 16 samples per cycle, i.e. a sampling frequency of 800 Hz for the 50 Hz power frequency.

Using the discrete Fourier Transform, the phasor representation of voltage and current in rectangular form can also be obtained directly by correlating the incoming data samples with the stored samples of the reference fundamental sine and cosine waves. But this method involves time consuming multiplications. Therefore, instead of obtaining the real and imaginary components of voltage and current phasors directly, if the data samples are used to calculate the RHT coefficients first, and thereby the corresponding Fourier sine and cosine coefficients are calculated, over computational complexity will be drastically reduced.

For a continuous function f (t) specified by N samples (X_1, X_2… X_N) during the given period, f (t) can be defined by discrete Haar transform and its inverse as given below:

$$X_n = 1/N \sum_{i=1}^{N-1} C_i \text{ Haar } (n, i/N)$$

$$C_i = 1/N \sum_{i=1}^{N-1} X_n \text{ Haar } (n, i/N)$$

Where Haar (n, i /N) are the function which are given for $0 \leq t \leq 1$

Haar (0, t)	=	1	$0 \leq t \leq 1$
Haar (1, t)	=	1	$0 \leq t \leq ½$
		-1	$½ \leq t \leq 1$
Haar (2^p+n, t)	=	√2p	$n/2^p \leq t \leq (n+1/2)/2^p$
	=	-√2p	$(n+1/2)/2^p \leq t \leq (n+1)/2^p$

4.2 A/D converter specifications, Types and Interfacing

A/D specifications

The function of an A/D converter is to produce a digital word, which represents the magnitude of some analog voltage or current. The basic specifications for an A/D converter are resolution, accuracy, linearity and speed or conversion time.

The resolution of an A/D converter refers to the number of bits in the output binary word. An 8-bit converter, for instance, has a resolution of 1 part in 256.

An accuracy specification for an A/D converter is a comparison between the actual output and expected output.

Another important specification for an A/D converter is the linearity. Linearity is the measure of how much the output ramp deviates from the straight line as the converter is stepped from minimum to maximum volts.

Speed or conversion time is another equally important specification of an A/D converter. This is simply the time a converter takes to produce a valid output binary code from an applied input voltage. When we refer to a converter as high-speed, we mean that it has a short conversion time. There are many different ways to do an A/D conversion, however the most common are as follows:

- Successive approximation
- Parallel comparator A/D converter
- Dual-Slope A/D converter

An A/D converter with a multiplexer on its inputs is often called a data acquisition system or DAS. Since our data acquisition system National 0809 uses the successive approximation principle, here the priority is given in the principle of operation and interfacing of the Successive Approximation A/D converter.

Successive Approximation A/D converter

Figure shows a circuit for an 8-bit Successive-approximation A/D converter which uses the readily available parts. The heart of this converter is the Successive Approximation Register (SAR), which function as follows.

On the occurrence of the first clock pulse at the start of conversion cycle, SAR outputs a high on its most significant bit to the D/A converter. The D/A converter and the amplifier convert this to a voltage and apply it to one input of the comparator. If this voltage is higher than the input voltage on the other input of the comparator will go low and tell the SAR to turn OFF that bit because it is too large. If the voltage from the D/A converter is less than the input voltage, then the comparator output will be high which tells the SAR to keep that bit ON. At the occurrence of the next clock pulse, the SAR will turn on the next most significant bit to the D/A converter. Based on the answer produced by the comparator the SAR will reset or keep this bit. The SAR proceed in this way on down to the least most significant bit, adding each bit to the total in turn and using the signal from the comparator to decide whether to keep that bit in the result. Only nine clock pulses are needed to do the actual conversion here. When the conversion is complete, a binary result is on the parallel outputs of SAR, and the SAR sends out an End-Of-Conversion (EOC) signal to indicate this. In the figure the EOC signal is used to strobe the binary result into the latches, where it can be read by a microcomputer. If the EOC signal is connected to the Start-Conversion (SC) input. If the EOC signal is connected to Start-Conversion (SC) input, then the converter will do continuous conversions. The input analog signal will between the ground and the $+V_{CC.}$

Several commonly available successive- approximation A/D converters have analog multiplexers on their inputs. The national ADC 0809 for instance has 8-input multiplexers in front of the A/D converter. This allows the one converter to digitize any one of 8 input signals. The input channel to be digitized is determined by the three bit address applied to the address inputs of the device. Similarly, the National ADC0816 has 16-input multiplexer with a 4-bit address inputs to select a channel.

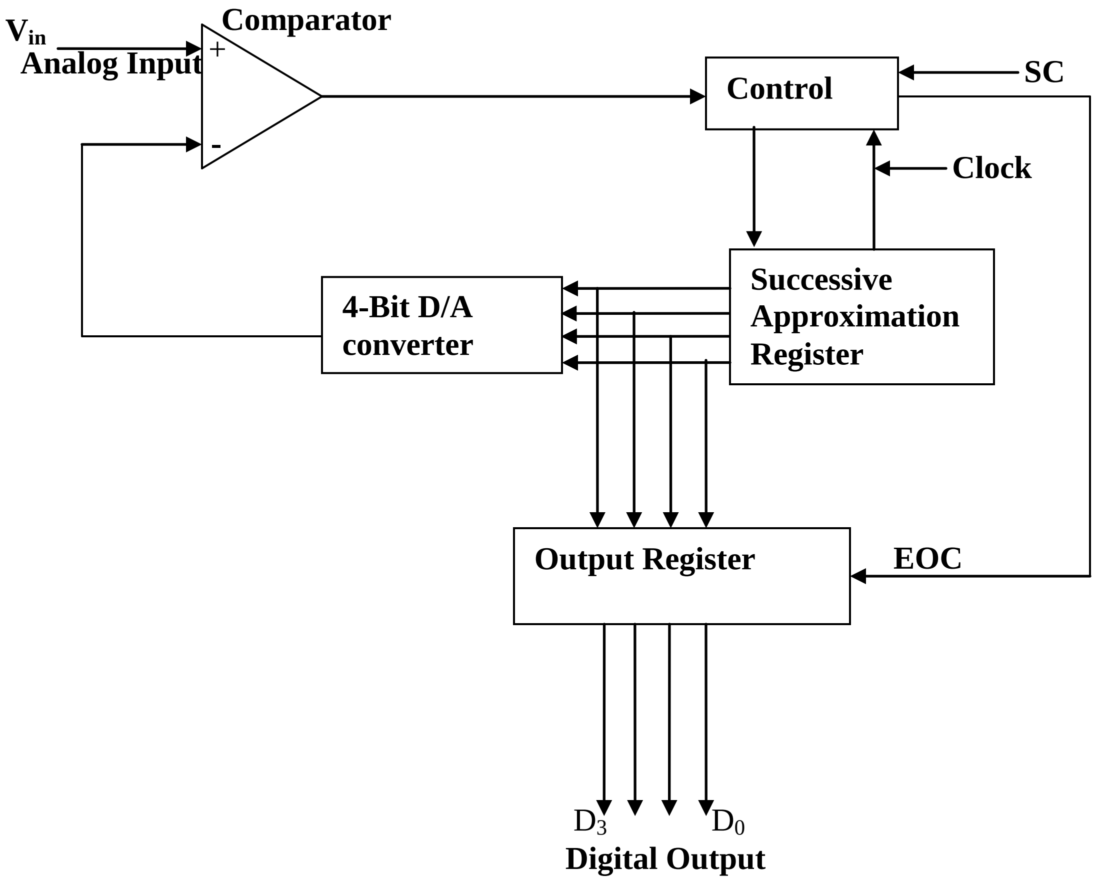


Fig. Schematic Block Diagram of Successive Approximation type ADC

Interfacing a successive-approximation A/D converter

Successive approximation A/D converters usually have outputs for each bit. The code output on these lines is usually straight binary or offset binary. We can simply connect the parallel outputs of the converter to the required number of input port pins and read in the converter output under program control. In addition to the data lines, there are two other successive-approximation A/D converter signals we need to interface to the microcomputer for the data transfer. The first of these is a START CONVERT signal that we output from the microcomputer to the A/D to tell it to do a conversion for us. The second signal is an END OF CONVERSION (EOC), which the A/D converter outputs that the conversion is complete and that the word on the outputs is valid.

The program steps or sequence of the control signal to get a data sample from this type of converter is like this. First the 3-bit address of the desired input channel is sent to the multiplexer inputs. After at least 50ns, the Address Latch Enable (ALE) is sent high. After another 2.5µs the start conversion input is sent high and then low. Then the ALE input is brought low again for a time required by the particular converter. Then we detect the EOC signal going high on a polled or interrupt basis. We then read in digitized value from parallel outputs of the converter, which represent the input analog signal of a particular channel.

ADC0808/ADC0809

The ADC0808 or ADC 0809 is a monolithic CMOS device from National Semiconductors which contains an 8-bit A/D converter and 8-channel multiplexer. It uses the successive approximation technique for conversion. It operates with a single +5 volt supply and its clock frequency range is 10 to 1280 kHz. The conversion time at clock frequency 640 kHz is 100µs. Its maximum analog voltage input is +5 volt. Figure 4.2.1 shows the schematic diagram of ADC0808/0809 and Table 4.2.1 shows the logic for multiplexer channel.

Fig 4.2.1 schematics of ADC 0809/0809

Table 4.2.1 Logic for MUX channel

4.3 Clock

Any A/D converter requires a suitable clock frequency to perform the conversion task. The clock frequency for 0808/0809 lies in the range of 10 kHz to 1280 kHz. For the clock frequency 640 kHz, the converter has conversion time of 100µs. The clock can be derived from the processor's clock frequency by using frequency divider. Here in our case we have used 555 timer in a stable mode to generate a rectangular wave of 460 kHz.

4.4 Half Wave Rectifier

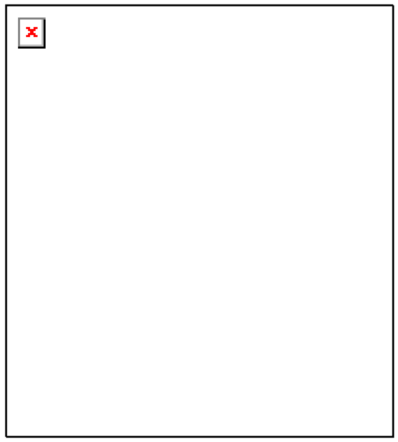
The interface we have designed is suitable for converting the instantaneous value of ac voltage into digital form. This will only give correct result only for positive ac voltage having maximum value of 5V. In order to consider the negative values of ac voltage, the interface circuit has to be modified. For this purpose we have used half wave rectifier.

The Half wave rectifier is a circuit, which converts an ac voltage to dc voltage. In the Half wave rectifier circuit the transformer serves two purposes.

1. It can be used to obtain the desired level of dc voltage (using step up or step down transformers).
2. It provides isolation from the power line.

The primary of the transformer is connected to ac supply. This induces an ac voltage across the secondary of the transformer.

During the positive half cycle of the input voltage the polarity of the voltage across the secondary forward biases the diode. As a result a current I_L flows through the load resistor, R_L. The forward biased diode offers a very low resistance and hence the voltage drop across it is very small. Thus the voltage appearing across the load is practically the same as the input voltage at every instant.



During the negative half cycle of the input voltage the polarity of the secondary voltage gets reversed. As a result, the diode is reverse biased. Practically no current flows through the circuit and almost no voltage is developed across the resistor. All input voltage appears across the diode itself.

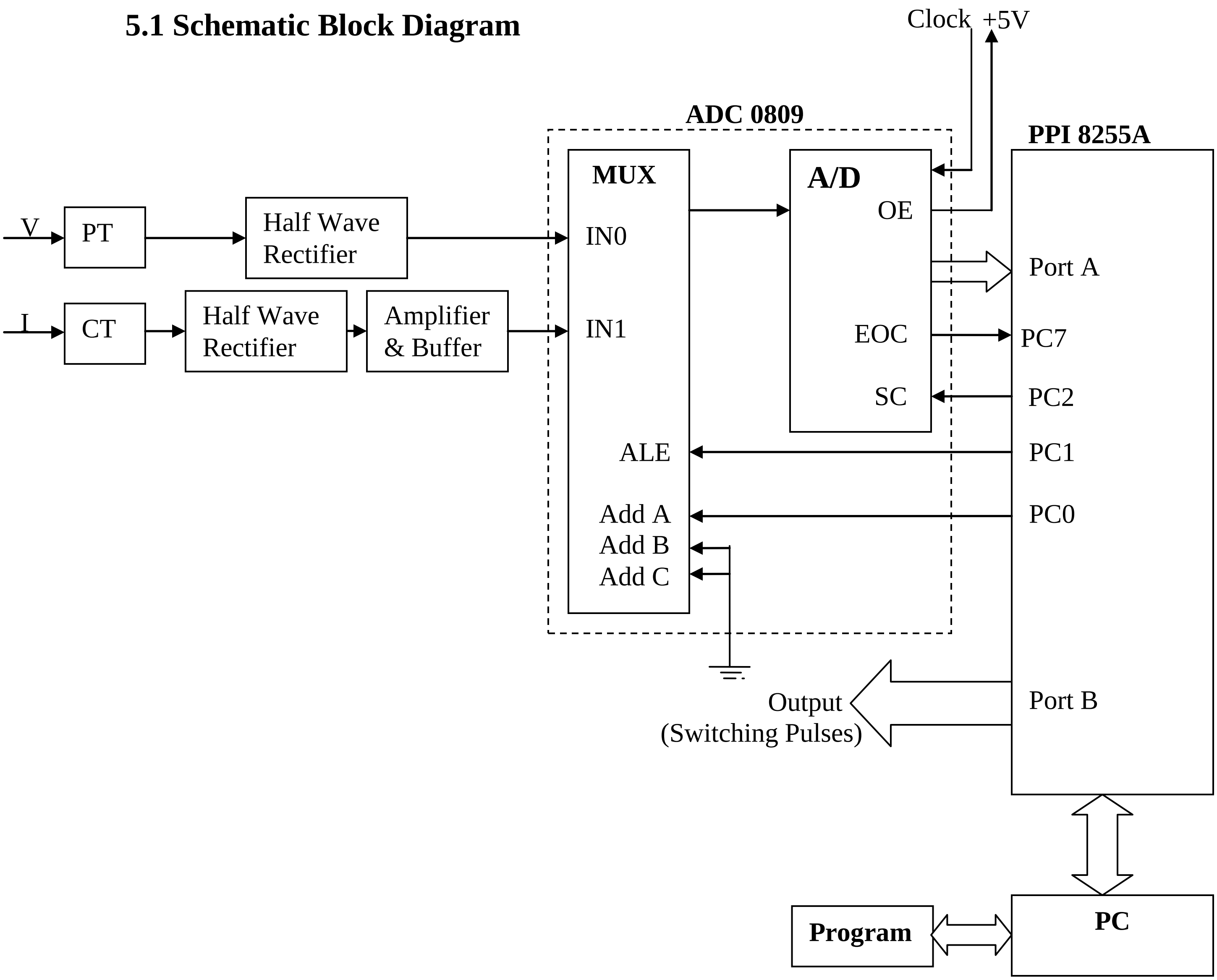
Hence we conclude that when the input voltage is going through its positive half cycle, output voltage is almost the same as the input voltage and during the negative half cycle no voltage is available across the load. This explains the unidirectional pulsating dc waveform obtained as output. The process of removing one half the input signals to establish a dc level is aptly called half wave rectification.

The RMS voltage at the load resistance can be calculated as

$$V_{rms} = \frac{V_m}{2}$$

Chapter 5
Project Realization

5.1 Schematic Block Diagram



5.3 Hardware Description

As the microprocessor accepts signals in voltage form, the current signal derived from the current transformer is converted into a proportional voltage signal using a current to voltage converter.

The interface we've designed can convert instantaneous value of ac voltage into digital form. This will give the correct result only for positive ac voltages having maximum value of 5V. In order to consider the negative values of ac voltage, the interface circuit employs the half wave rectifier. The half wave rms value multiplied by two gives the rms value of the full wave equivalent. The peak of the positive cycle is +5 volts.

For the input voltage we have used a voltage transformer whose secondary gives the 5 volt peak.

The signals are then fed to the inputs of ADC0809. The ADC0809 is a monolithic CMOS device from National Semiconductors which contains an 8-bit A/D converter and an 8-channel multiplexer. It uses the successive approximation technique for conversion. It operates with a single +5V supply and its clock frequency range is 10 to 1280 kHz. The conversion time at clock frequency 640 kHz is 100 µs. The maximum analog voltage input is +5V.

Since we have only two signals, we use only two of the 8-input channels of the device, namely IN0 and IN1. The microprocessor sends a command to switch on the desired channel of the multiplexer to obtain level shifted voltage proportional to the current a particular circuit.

The microprocessor issues:

C B A = 0 0 0 to select channel IN0, and

C B A = 0 0 1 to select channel IN1.

The address is latched into the address decoder on the low-to-high transition of the address latch enable (ALE) signal issued by the microprocessor.

The A/D is a successive approximation type. The successive approximation register (SAR) performs 8 iterations to approximate the input voltage. An A/D converter's SAR is reset on the positive edge of the start of conversion (SC) pulse. End of conversion (EOC) will go low between 0 to 8 clock pulses after the rising edge of start of conversion. The microprocessor reads the end of conversion signal to examine whether the conversion is over or not. As soon as the conversion is over, the microcomputer reads the current signal in digital form.

The clock frequency for ADC 0809 lies in the range of 10 kHz to 1280 kHz the clock is obtained by using 555 timer in the astable mode and the clock frequency is 600 kHz.

As a peripheral device we have used the Intel 8255A. It is a programmable peripheral interface available in a 40-pin DIP. The 8255A has 24 I/O pins that can be grouped in two 8-bit parallel ports: A and B, with the remaining eight bit as port C. The eight bits of port C can be used as individual bits or be grouped in two 4-bit ports: C_{UPPER} and $C_{LOWER.}$ The functions of these ports are defined by writing control words in the control register.

The 8255A has two modes: the Bit Set/Reset (BSR) mode and the I/O mode. The BSR mode is used to set or reset the bits in the bits in the port C. The I/O mode is further divided into three modes: Mode 0, Mode 1, and Mode 2. In Mode 0, all ports function as simple I/O ports. Mode 1 is a handshake mode whereby ports A and/or B use bits from port C as handshake signals. In Mode 2, port A can be set up for a bidirectional data transfer using handshake signals from port C, and port B can be set up either in Mode 0 or Mode 1.

We have used the BSR mode to generate control signals like start of conversion (SC), end of conversion (EOC), etc.

The format of control word in the BSR mode is as follows:

D_7	D_6	D_5	D_4	D_3 D_2 D_1	D_0
0	X	X	X	Bit Select	S/R

The configuration of the ports necessary to meet our requirement is as follows:

Port A: As an input port to read digital data from ADC.

Port B: As an output port because PB0,… PB7 are used to output pulse for load shedding.

Port C_L: As an output port because bits PC0, PC1, PC2 are used for channel select, address latch enable (ALE), and start of conversion (SC).

Port C_U: As an input port because bit PC7 is used to read the status of end of conversion (EOC).

The corresponding control word is as follows:

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
1	0	0	1	1	0	0	0

5.4 Software description

In this project we have used C as a programming tool.

The control signals for the ADC, namely address select, address latch enable (ALE), and start-of-conversion (SC) are generated through the program by using PPI in the BSR mode.

A sample code to generate a SC signal for ADC is given below, where we assume that the bit PC2 is tied up with the SC pin of ADC and the address of PPI control register is 'base+3' where base address is 0x3E8.

```
Outportb (control, 0x04); //reset start of conversion c2
Outportb (control, 0x05);   // set start of conversion c2
Delay (0.01);
Outportb (control, 0x04); //reset start of conversion c2
```

We have two input signals voltage and current and for power calculation we need rms values of these signals about the same instant. To achieve this we need two ADCs. However, we have achieved the same effect by taking samples of input signals alternatively. We didn't take the complete set of samples of one input and wait for the other. As such, we get the full cycle samples of the both the signals almost about the same instant.

With these full cycle samples of input signals, we determined the rms values of fundamental components by using a Digital Filter. We have used Discrete Fourier Transform as a digital filter.

From the full cycle samples available, the rms value of the fundamental component is calculated as follows:

$$a_1 = 2/N \sum_{m=0}^{N-1} x_m \sin (2\Pi m/N)$$

$$b_1 = 2/N \sum_{m=0}^{N-1} x_m \cos (2\Pi m/N)$$

$$Rms = \sqrt{a_1^2 + b_1^2}) / \sqrt{2}$$

The rms values of the fundamental components and the calculated power demand and power factor value are continuously displayed on the screen.

Using the extracted fundamental frequency components from the available full cycle data window, we perform the following functions.

- Calculate the rms values of the current and voltage
- Calculate the power factor of the load.
- Calculate the active power demand.
- Compare the demand with the preset demand.

When the current demand is greater than the preset demand, the program sends a tripping signal for the load of least priority. The tripping signals are outputted by port B of PPI. If the demand is again higher than the preset, the program again sends the tripping signal to next higher priority load and the controller operates so on until the demand is under the preset value.

The program gives the visual display on the screen indicating the values of power demand, power factor, voltage, and current. The output points are represented by LEDs. The switching OFF of the load is represented by turning ON of the corresponding LED.

Chapter 6

Project Simulation, Outputs and Conclusion

We have achieved the digital switching techniques by automatic logical decision through this work. We have fed the line voltage and current and we calculated the corresponding power factor and demand. Since ADC converts only positive cycle of input we have used the half wave rectifier to detect the peak value of input signals. The calculated rms value multiplied by two gives the rms value of the full wave equivalent. In fact full wave rectifier could be employed, but the circuit we designed didn't function properly. So the use of the half wave rectifier was chosen to get the desired output. It gave the additional advantage of reducing the hardware. The CT we used is the ring type because it gave the constant CT ratio for wide range of currents. The PT ratio we used is 220/6 volt. To achieve the 5 volt we dropped 1 volt in the resistance. After having conditioned signals from the hardware, it is fed to computer through PPI. The software does the function of Load Scheduling.

The solid achievement worth mentioning is the success in feeding an ac voltage signal to the microcomputer and obtaining the fundamental frequency component of the signal being fed, employing digital filtering technique. Actually it took great effort to employ the proper digital relaying algorithm in order to obtain the fundamental frequency component accurately. Later we succeeded by using Discrete Fourier Transform technique. The interfacing techniques and ideas and digital relaying algorithm that we learnt during this project has also been taken as the important achievements.

The running of the program displays the current demand value, line voltage and current, and the power factor. Since the computer is continuously reading the ports in parallel there is slight variations in the readings. The outputs have shown slight variations from the input parameters because errors are introduced during signal conditioning due to non-linear characteristics. We have incorporated some hardware factors to mitigate the error.
One will find the output screen very user-friendly.

The application of automatic switching for demand control is very advantageous for the industries and commercial buildings. The control is of the supervisory type. Here we have used only eight output points. But using MUX the system can be extended to 256 points by using eight output points. Using the software improvement, the package can be extended to perform various subsidiary functions such as storing the demand profile, time of day control etc. Also since we have two inputs voltage and current and ADC has eight channel input, we have remaining 6 channels for the additional inputs. This can be used to input other power system related parameters for the purpose of controlling and analysis. This will not impose the greater costs because of the extensive use of the same hardware.

Thus we achieved the automatic demand control trough a PC. This system is very advantageous to the industries because it tolls the labor cost and eliminates the human errors. This task is an initial footprint towards the automatic EMS through Load Management. This system can be expanded to achieve more supervisory control thus leading to the foundation of SCADA system.

The succeeders are supposed and in fact inspired to carry out this foundation work and turn it to a complete EMS package.

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Thank you Very much!