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DESIGN OF COST EFFECTIVE SINGLE CHIP POWER, PFAND VAF METER

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Abstract— *Energy management is became key thing current days. It is also most required for any sector weather it is industrial sector or non-industrial sector. Especially for an industrial sector the energy consumption details are much needed because the expense of the energy consumption is one of the most critical as it takes away more percentages of revenues. But because of more cost and bigger size of measuring devices it is hard to use such devices as per requirement. The Energy management process works better only if there is better measuring system otherwise energy management process cannot perform as per expectation. So, here in this paper multifunctional measuring device is explained. The device is useful for such applications like energy management, energy audit, distribution system, Process control, HVAC and building management system and different panels like Electrical panels, DG set panels, motor control and power control center panels, control and relay panels, switchgear panels etc. The meter explained here is works with single controller. So the size of the energy measuring IC can be saved and hence size of the device can be reduced.*

Keywords—*power meter; panel meter; microcontriller; energy; energy management; power; multifunction*

I. INTRODUCTION

The device is used for the process of the measurement of the electrical parameters. The line current and voltage data are converted in to the range of ADC present in the microcontroller by signal conditioning process. After the signal conditioning process the ADC present in the controller converts these analog signals in to the digital signals and the further process will be done in the microcontroller. After the necessary process the output from the controller is send to the display, memory and communication device.

The cost, size and accuracy are the main parameters which are taken in to the consideration while designing the system. Here we are planning to design the project in such way that it fulfills the criteria of class 1 accuracy as per IEC standards. IEC standards are the standards developed by International Electro technical commission. The components are selected in a way that the device can fulfill the criteria of International Electro technical commission. [14]

The Meter contains R5F521A microcontroller which is used to control the whole device. The controller belongs to Renesas microcontrollers. The R5F521A controller is a part of a Renesas RX21A group of microcontrollers. The Renesas RX21A is a group of controller with having high speed and high performance microcontrollers. Its variable length instruction format allocates more frequency used instructions.

The final data after measurement and other procedures are displayed on the seven segment LED displays. Here we are using 4 digit seven segment displays for better visibility. For storing the data we are using FRAM. It is the nonvolatile memory. It can store the data for long time period. Also with using this as a storage device the issues of write delays can be resolved. The detailed explanation of the device is given in further sections.

II. COMPONENT DETAILS

A. Microcontroller:

The microcontroller is the main part of this system and it is like brain of the whole system. For this Device, the Renesas R5F521A controller is used. The controller belongs to RX21A group of controllers of Renesas. The RX21A CPU has 73 basic and 9 DSP instructions. It has 10 addressing modes and it is compatible to perform register to register, register to memory, memory to memory transfer, immediate to register, immediate to memory and bitwise operations. The RX21A group is having internal divider and multiplier for high speed division and multiplication. [1]

The five stages which are used to processing the instructions of RX CPU are instruction fetching, decoding, execution, memory access and a write back. It is having 4GB linear Address space. Also it is having sixteen registers of 32 bits as General purpose registers, eight registers of 32 bits as controlling registers and one 64 bit register as Accumulator. It is having high instruction execution rate, i.e. one instruction in 1 clock cycle. [1]

Controller works better in 3phase as well as single phase. The controller fulfills better accuracy criteria as per IEC accuracy standards.

The Important Specification of the controller is given in Table 1.
Table 2 shows the details of analog to digital conversion section in the controller.

NO.	FUNCTIONS	DETAILS
1.	No. Of Pins	100 Pins
2.	Serial communications interface	5 channels
3.	I2C bus interface	2 channels
4.	Serial peripheral interface	2 channels
5.	A/D Converter	7 channels
6.	Temperature Sensor	Supported
7.	Operating Frequency	50 MHz
8.	Operating Temperature	-40 to +85°C

TABLE I. CONTROLLER SPECIFICATIONS

Here is the Specification detail of the Analog to digital conversion section of the microcontroller in the Table 2.

NO.	PARAMETER	SPECIFICATION
1.	Input channels	7 channels
2.	A/D conversion method	2nd order ΔΣ modulation
3.	Resolution	24 bits
4.	Min conversion time	81.92 μs
5.	Over sampling frequency	3.125 Hz

TABLE II. ADC SPECIFICATIONS

B. ***Storage IC Details[2]:***

NO.	FUNCTIONS	DETAILS
1.	Endurance	100 Trillion read/write
2.	Data Retention	151 Years
3.	Protocol Used	SPI Protocol
4.	Storage Temperature	-55 to +125°C
5.	Voltage	2.7 V to 3.6 V
6.	Operating Temperature	-40 to +85°C

TABLE III. FRAM SPECIFICATION DETAILS

C. ***Communication IC Details:***

NO.	FUNCTIONS	DETAILS
1.	Transient Immunity	50 kV/μs
2.	Input Voltage Supply	-0.3 V to +6 V
3.	Signaling Rates	up to 20 Mbps
4.	Size	10.30 mm × 7.50 mm
5.	Bus Capacitance	16 pF
6.	Temperature	-40 to +85°C

TABLE IV. ISO 308X SPECIFICATION DETAILS

III. HARDWARE DESIGN

The hardware part contains CPU PCB, Power supply PCB. The CPU PCB contains two sections like controller and Display section. The CPU section contains a microcontroller, Power Conversion section, Data communication section and Relay section. The necessary protection for the controller is provided on the CPU card.

In the display section the seven segment LEDs are placed in 3-line Display. The D type of flip flop is being used for displaying the data to the seven segment LEDs.

The power supply card contains current transformers, Voltage signal conditioning section, Current signal conditioning section and power conversion section. The entire explanation of the device with its different sections is explained in this paper.

The System Block Diagram is shown below in the figure.

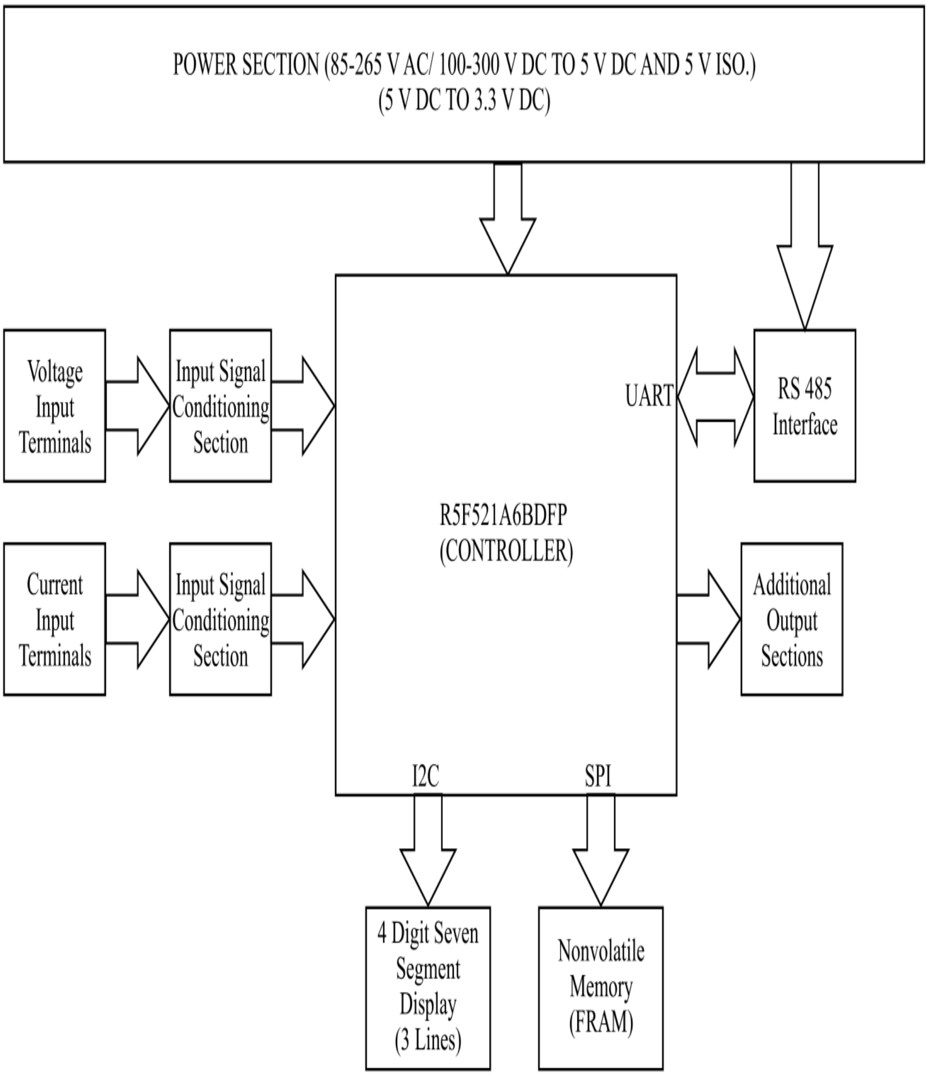

Fig. 1. System Block Diagram

As shown in the diagram the meter is having controller with inbuilt ADC and energy measuring unit. So the device can work only using single chip instead of more number of ICs.

The block diagram of the display section of the device is shown below.

As shown in the Fig, 2 the display section consists of three no. of display and three groups of LEDs for indication purpose. Each group of LEDs can consist up to eight LEDs as they are in connection with the seven segment display. So there are eight LEDs in one digit of seven segment display and we have 4 digit of seven segment display so we can connect up to 32 LEDs with this 4 digit seven segment display. There are two flip flops are used in the display section of the device. The flip flops used in the device are D flip flops and it is used to generate delay in the circuit.

Here total 8 pins of microcontroller are occupied for display and 2 extra pins of microcontroller are for flip flop. These two pins are used to send clock pulses and output data to the flip flops for display purpose. For controlling the displays the transistors are connected to all eight channels connected between controller and seven segment display. So this is the explanation of the display block diagram.

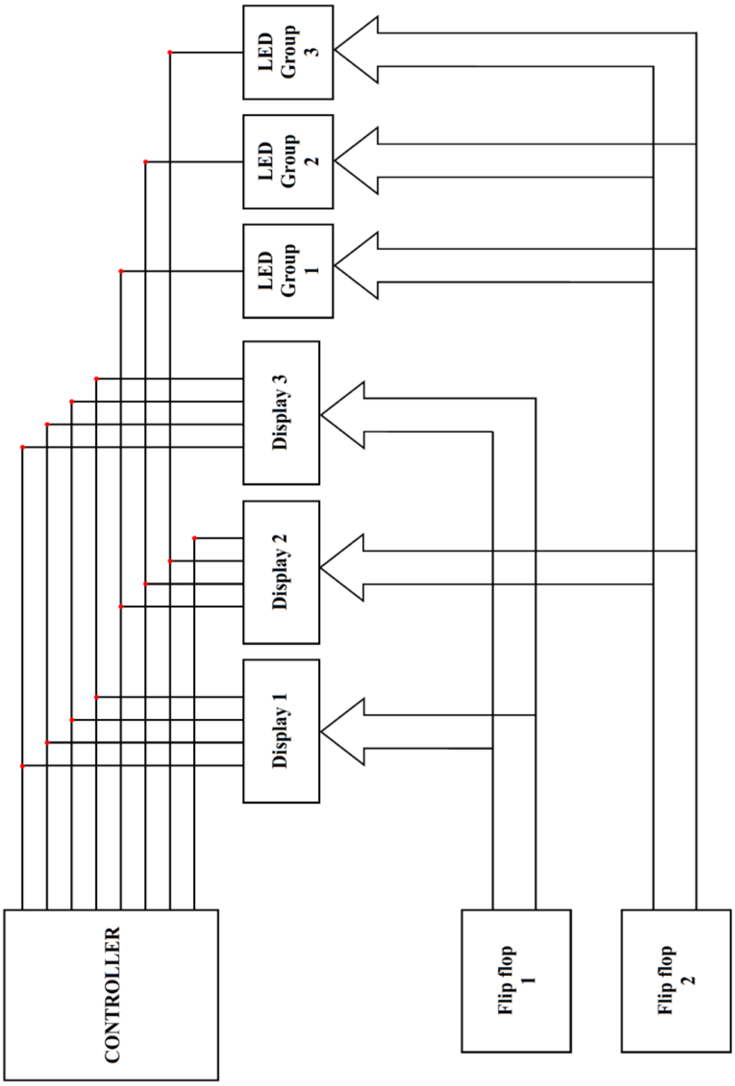

Fig. 2. Display Block Diagram

The Block Diagram of this device is designed in Corel Draw software. The Hardware design process is done by using the capture software and PCB editor software which is belongs to OrCad software tools. The OrCad tools are very useful tools for design automation purpose. The OrCad tools are developed by Cadence Design Systems. The Cadence Design Systems had owned this company since 16 July, 1999. The company originally founded in 1985 by John Durbetaki, Ken and Keith Seymour as "OrCad Systems Corporation". The company's first product was SDT (Schematic Design Tools).

IV. Software Implementation

The software flowchart of the device is shown in this section. The controller which is used in this device is having 512 KB flash memory for codes. The program is designed in the software named E2 studio. Full name of E2 studio is Eclipse Embedded Studio. It is developed based on a popular open-source Eclipse C/C++ development tooling project that covers and debug phase with an extended GDB interface support. The flowcharts of this project are shown in following sections.

A. ***Process Flow***

The process flow includes the process followed to design the codes in the microcontroller of this device. The process flow incudes the complete process flow of the metrology of the system in which the process of RMS values of voltages and current also shown in this section. The flowchart in figure 3 shows the complete process of the metrology. In this diagram the process from reading the input values to publish the final output is shown. [11]

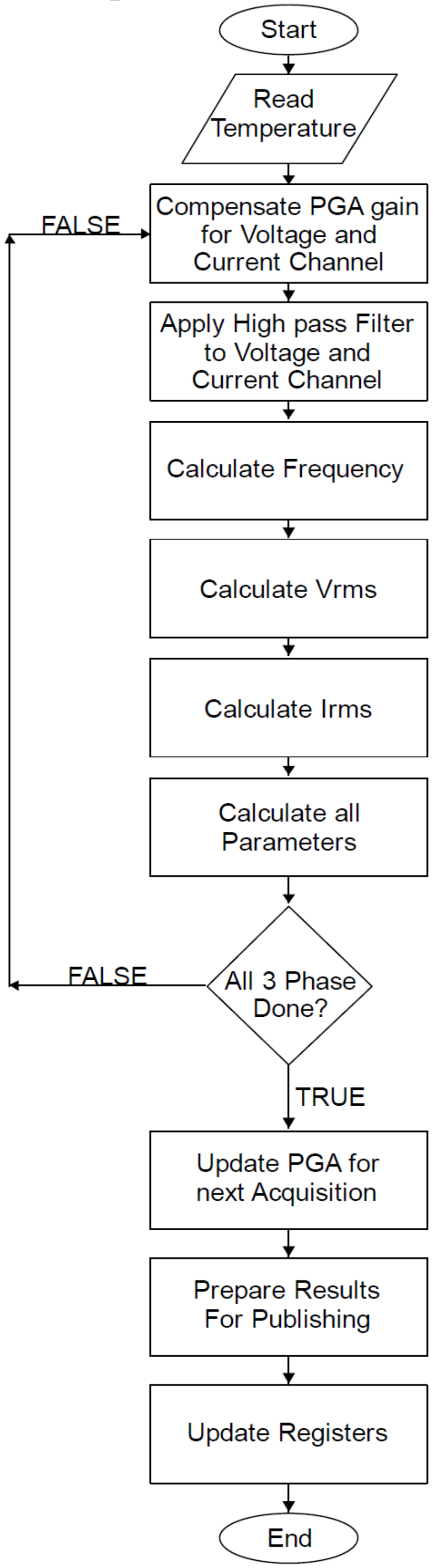

Fig. 3. Process Flow Diagram

B. ***Voltage Calculation***

The figure 4 shows the process of calculation of RMS voltage.

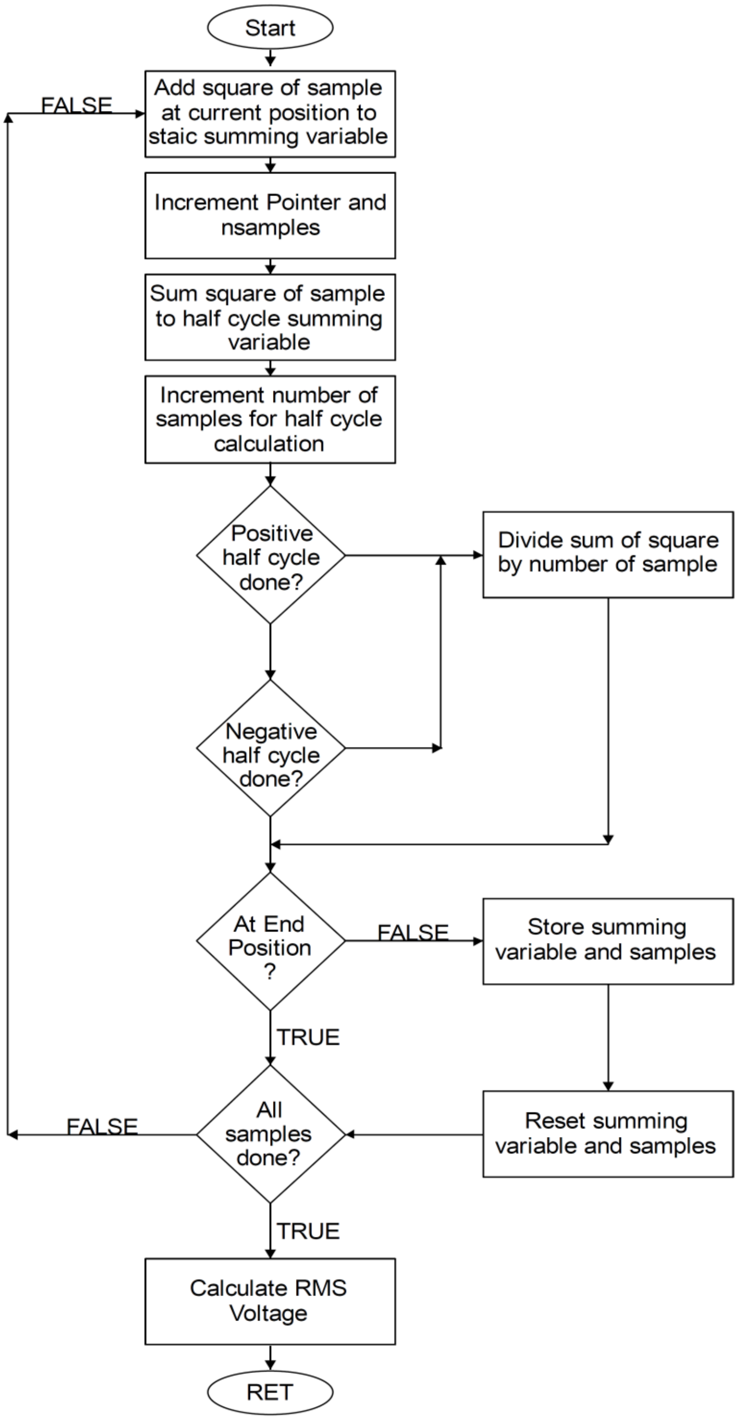

Fig. 4. RMS Voltage Flowchart

So, here is the flowchart for the calculation of the voltage calculation. The device measures the RMS values of the voltage calculations. The meter measures true RMS value of all basic parameters.

The figure 5 shows the process of the calculation of RMS current. The voltage and current signals are taken as input signals and then the signals are calculated and the output is shown in form of root mean square. The value of RMS voltage and RMS current are used for further calculation of the remaining parameters. By using this input signals the instantaneous parameters as well as the other parameters like energy can be calculated.

C. Current Calculation

The RMS current calculation is as per shown below in the figure 5.

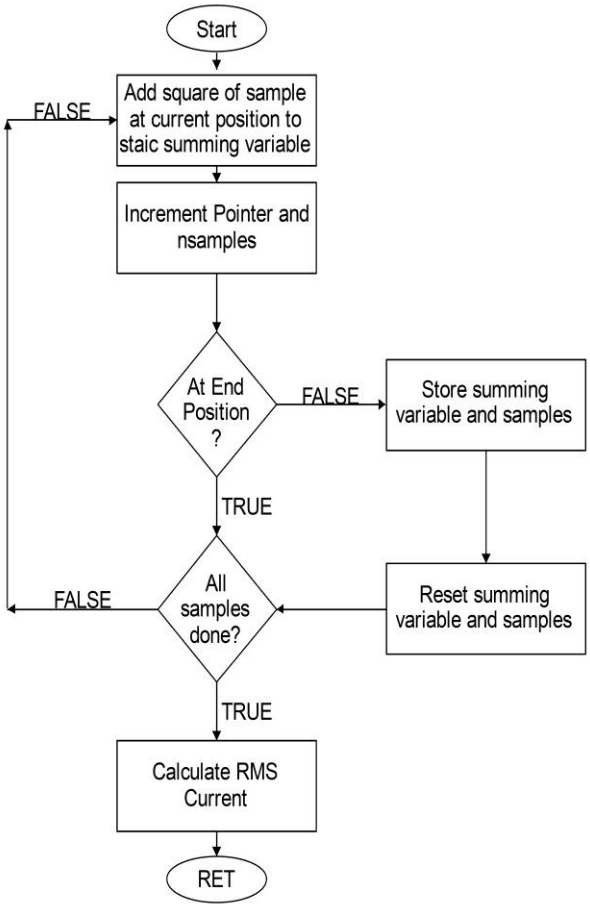

Fig. 5. RMS Current Flowchart

D. Other Parameter Calculation

By using the input signals the controller calculate the other instantaneous and quadratic parameters. The calculation of power is done by simply multiplying the input voltage and input current samples. Now the reactive power is calculated by phase shifting of the voltage and current samples. And by adding the active and reactive power values the value of the apparent power can be calculated. After all parameter calculation the PF and energy will be calculated. So this is the calculation explanation of the device [13].

E. Need of Calibration

Some results from the testing clear the fact that there is little time delay between voltage and current waveforms. The delay is slight and completely in phase. This time delay is captured simultaneously. The waveforms of current are appear to lead their matching waveforms of voltage by approximately 90µs. This is not a large number but it is sufficient to cause significant errors in the measurements of some parameters like active and reactive power, and power factor.

So to overcome this minor variation in output quantities and to increase the accuracy of the meter the calibration is must needed. In this meter the calibration can be done by using Modbus communication as well as by using the device itself. This double way calibration can help to increase reliability of the device.

V. TESTING SECTION

The testing section shows the output of the instantaneous parameters. The following testing results shows the output power reading at each phase and total when the input voltage and current were given to the meter. The output of the device can be taken by using Modbus communication also. By doing this testing the accuracy of the measuring device can be calculated and stated. The system proposed here is having the capacity to fulfill the accuracy criteria as per described in IEC standards for measuring devices.[14] Here for this testing the frequency is taken as 50 Hz.

The voltage and current inputs is applied on the meter by using the phantom load. The figure 6 and 7 shows the measurements for the output power on different current and voltage supply as input at unity power factor. The all phases are shown in x axis and Watt output range is shown in y axis in fig 6 to fig 10. In x-axis R, Y and B are the three phases and T is the total power. Hare the min and max means minimum and maximum values of measurements.

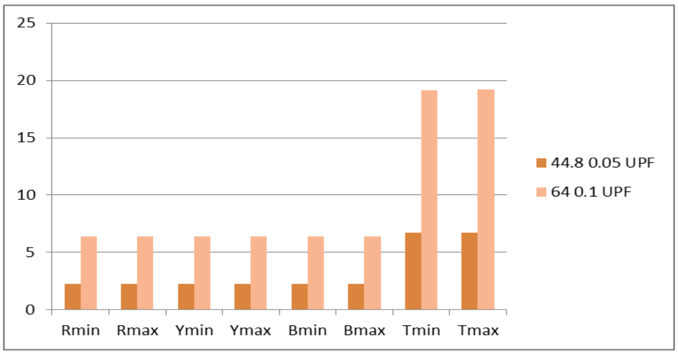

Fig. 6. Output Power at UPF-1

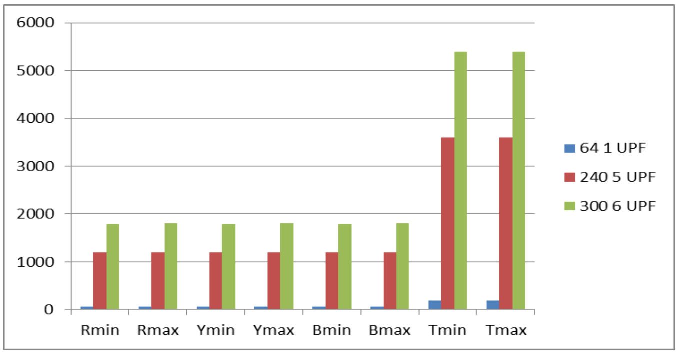

Fig.7. Output Power at UPF- 2

From above 2 Charts the value of error for this device reading can be measured. The error measured in the reading of this meter is useful to check the accuracy of the meter.

The figure 8 and 9 shows the measurements for the output power on different current and voltage supply as input at 0.5 lagging power factor.

The output value of power for this input values are shown in below figures.

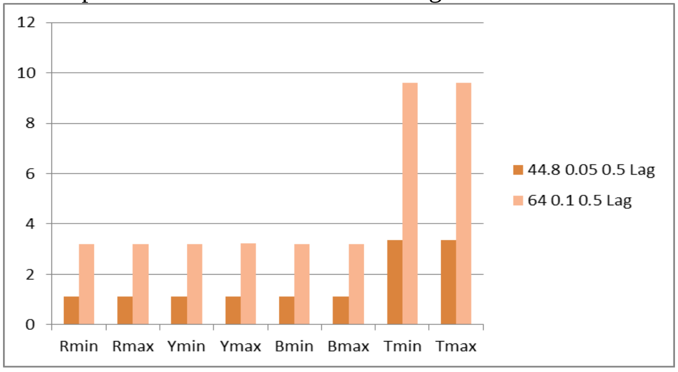

Fig. 7. Output Power at 0.5 Lag-1

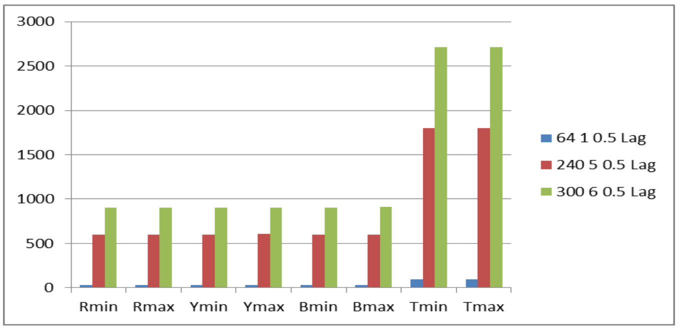

Fig. 8. Output Power at 0.5 Lag-2

The figure 9 and 10 shows the measurements for the output power on different current and voltage supply as input at 0.8 leading power factor.

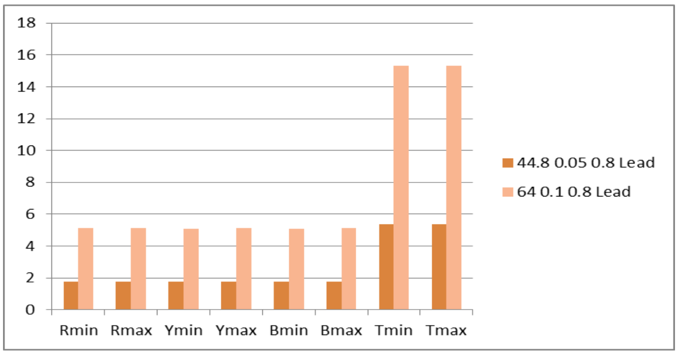

Fig. 9. Output Power at 0.8 Lead-1

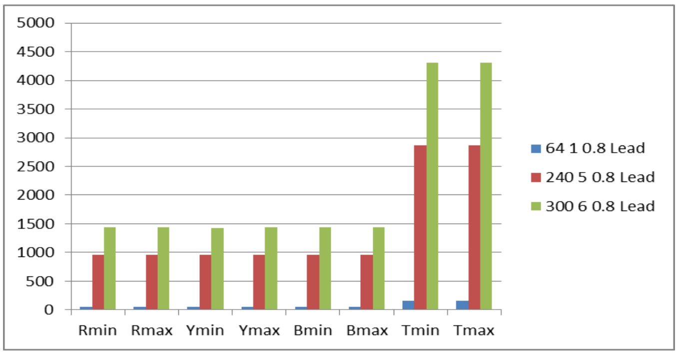

Fig. 10. Output Power at 0.8 Lead-2

Besides this the various basic testings like functionality testings and noise testings etc. were done on this device. So after all these testing the meter fulfils all the requirements mentioned in the Class 1 accuracy standards of IEC standards for measuring devices.

Conclusion

The device explained is a single chip measuring device so there is no need of need of energy measuring IC and ADC. The device proposed meets the accuracy criteria as per IC 13779/ IEC 62053-21. The meter is easy to use low cost product. More than basic metering it can optionally provide RS 485 port with Modbus Remote terminal unit protocol. For displaying the output values the meter uses 4 digit seven segment LED display. The meter described here is very useful for various applications in industries as well as for non-industrial applications. Also it can be very useful in Energy management field and energy audit field also. The device is having very compressed size and cost because of its hardware structure. The device enclosure is made by ABS material so that the meter is lighter in weight and still strong and possibility of damage to this meter is very less. By using this meter in the industrial field can be very useful in energy monitoring process. By using this meter the electricity bill can be maintain by managing the electricity usage properly.

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