TESTING A SMART METER SIMULATION IN MATLAB/SIMULINK FOR APPLICATION IN POWER SYSTEMS IN DEVELOPING COUNTRIES

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Abstract - In order to avoid energy theft, corruption in the billing procedures of electricity bills, excessive energy consumption and wastage, the metering system employed in most Indian households needs to change. The current system is extensive and relies on electromagnetic and digital (in some cases) systems to measure the units of electricity consumed by a household. This is time consuming and not always accurate. Smart metering uses automatic meter reading (AMR) systems which directly calculate the different parameters of electric consumption and thus eliminate the inaccuracy caused by manual readings. We have developed and observed a MATLAB/Simulink model for the same to be used in Indian power system applications.

Keywords - Smart Meters, Power Systems, Load Mapping, Energy Consumption Measurement

I. INTRODUCTION

Liberalization of the energy market has emphasized the necessity for brand spanking new investments into intelligent buildings. The goal of the liberalization of the energy market was to allow anyone to buy and sell energy or to offer other related services. Smart meters are powerful tools that fundamentally change the operation of power grids. They can also be used as sensors across the entire distribution grid. These meters also allow increased resolution of knowledge on various measurement parameters across the grid and these data are often employed by utilities for the subsequent applications:

a. For faster outage detection, response, and restoration by providing data to the field operations.
b. Keeping customers better informed about the status of the power grid. Utilities can communicate relevant information like cause of power outage, field-estimated restoration time, and public safety notices.

Electricity pricing usually peaks at certain predictable times of the day and the season. In particular, if generation is constrained, prices can rise if power from other jurisdictions or more costly generation is brought online. Proponents assert that billing customers at a higher rate for peak times encourages consumers to adjust their consumption habits to be more responsive to market prices and assert further, that regulatory and market design agencies hope these "price signals" could delay the construction of additional generation or at least the purchase of energy from higher priced sources, thereby controlling the steady and rapid increase of electricity prices.[citation needed] There are some concerns, however, that low income and vulnerable consumers may not benefit from intraday time-of-use tariffs. An academic study based on existing trials showed that homeowners' electricity consumption on average is reduced by approximately 3-5%.

The ability to connect/disconnect service and read meter consumption remotely are major labour savings for the utility and can cause large layoffs of meter readers.

II. FLOWCHART OF MODEL

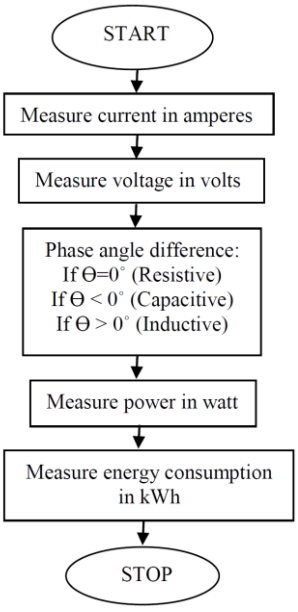


Fig 1. Flowchart of mathematical model used

Above figure shows the outline of the mathematical model we're going to build in this paper. We measure the voltage as well as current for different loads, resistive, capacitive (RC) and inductive (RL). We'll be using a three-phase modelled energy meter to measure our energy and the values for our load will vary according to the load we're applying in that particular

iteration. We need to then check if the phase angle is in the correct range with respect to the load applied. If this does not correspond to the load applied, we repeat the measuring process. After that we measure the power factor and use it to identify the type of load applied. The energy consumption will then be calculated automatically by our automated reader.

III. MATHEMATICAL MODELLING

The load that we've measured or the active power for our power system is given as:

$P = \sqrt{3} IV \cos\theta$ (1)

Where P is the load measured,
I=current
V=voltage across the load
$\cos\theta$ = power factor

The output current, by Ohm's law will then be:
I=V/R

where R= Resistance of the load connected

Using the below equation, we can calculate the energy consumption E during a time interval from t0 to t1:

$$E = \int_{t0}^{t1} v(t)i(t)dt$$

where v(t) = supply voltage

i(t) = load current

Load block: (below figure shows load subsystem for resistive load)

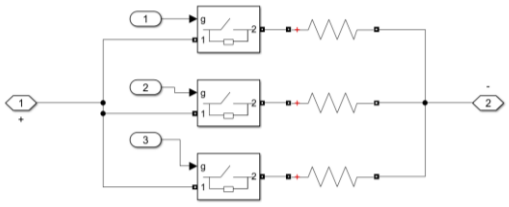


Fig 2. Load block for R load

The load block shown above uses and ideal switch and RLC branches which we shall vary in order to try different types of loads and observe the outputs for each. We use repeating sequences to close the ideal switch and control the circuit.

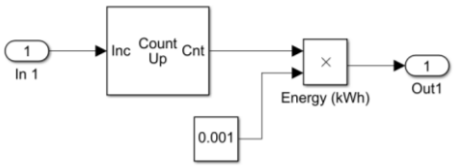
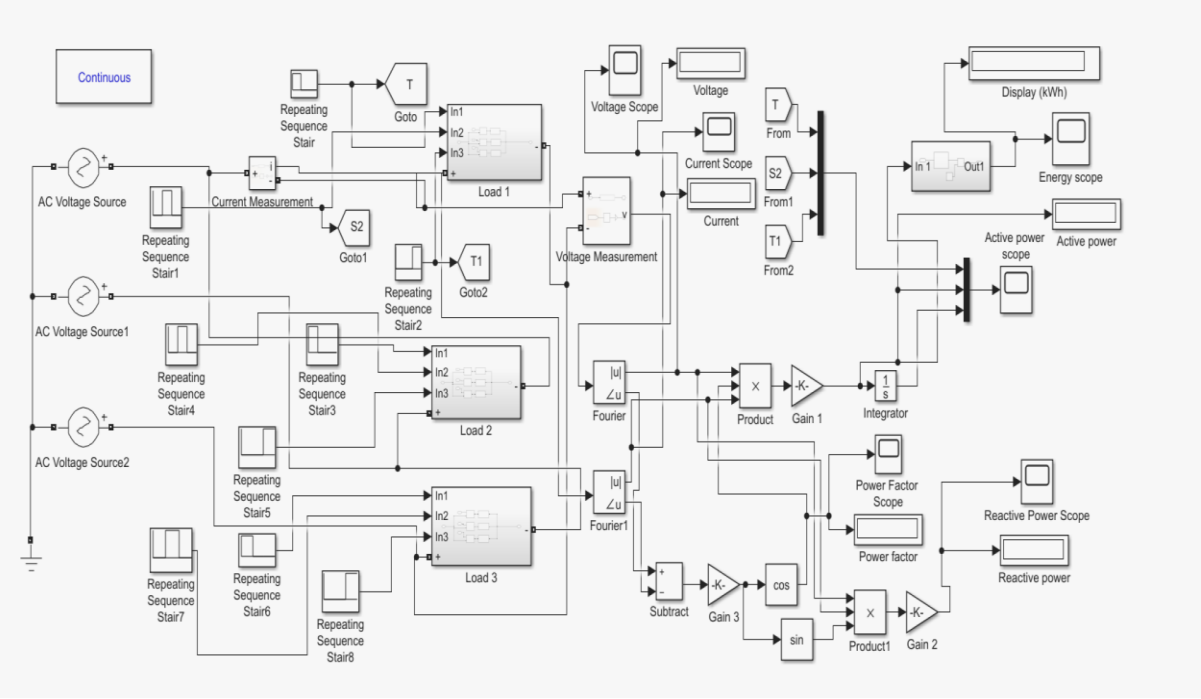


Fig 3. Energy measurement block

The energy measurement block takes in the active power as an input and gives the value of energy consumption in kWh. A counter is used for the clock and a product block helps us convert Wh into KWh.



IV. RESULT AND DISCUSSION

A. R Load

The above figure shows our model simulated for a 200ohm load. We observe 1 power factor as expected and valid values for our active power and energy consumption when simulated for 3600 seconds or one hour. We simulate it over one day as it gives us an accurate representation of the load requirement, in the case of a resistive load. It accurately depicts our load structures.

Resistive loads are the loads consisting of any heating element. We will vary the resistive load values from 50 ohm to 500 ohm and observe the outputs that it produces. If our calculated load and measured load give similar graphs, we can assume that our Simulink smart meter model is successful in detecting the load and energy consumption data. We have plotted and tabulated our results when our load is resistive, below:

We can observe the current graph for our resistive load and it is as expected.

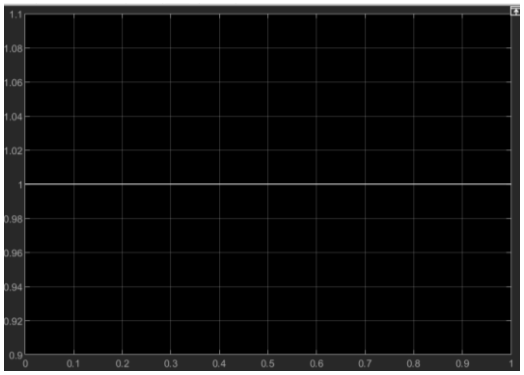


Fig 4. Power factor vs time for R load

Since the load on this model is purely resistive, we observe power factor=1. This is consistent with a resistive load.
Below is the plot of the energy consumption of our resistive load. We observe energy surges which might be due to an unbalanced system and system surges which are completely normal.

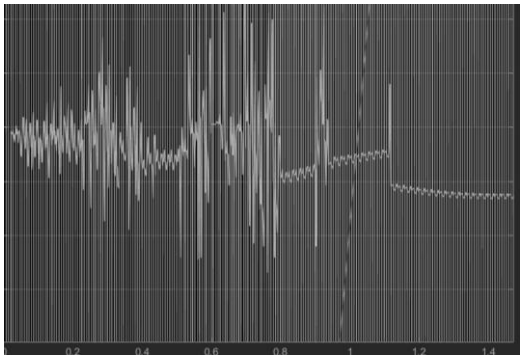


Fig 5. Active power graph for R load

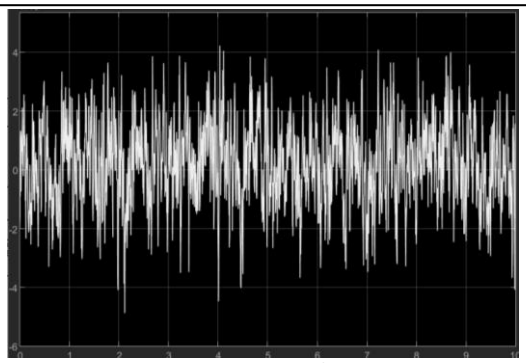


Fig 6. Reactive power for R load

Our reactive power graph shows ripples which is understandable as our model is unbalanced.

Calculated active power= 729.04 W
Observed active power= 728.90 W
% error= 0.0192

B. R-C Load

We now apply an RC load or a capacitive load with a constant R value and we vary the C value. Below, we display the graphs for when we simulated our meter for C= 1e-6:

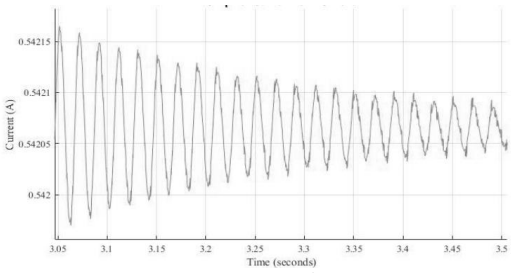


Fig 7. Current for RC load

The value of current gradually decreases as expected for a capacitive load that we have applied. The capacitor charges and then proceeds to discharge. Thus, the above graph is in accordance with our required output.

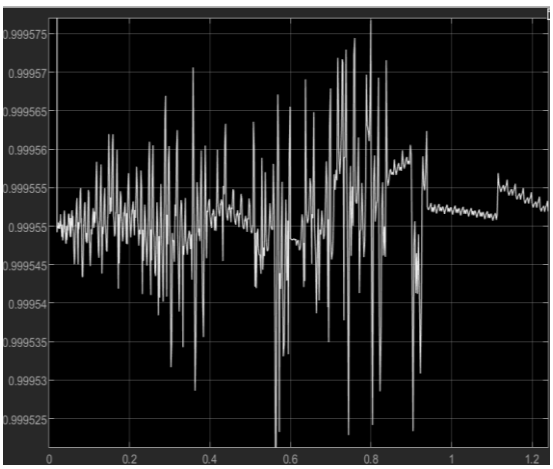


Fig 8. Power factor vs time for RC load

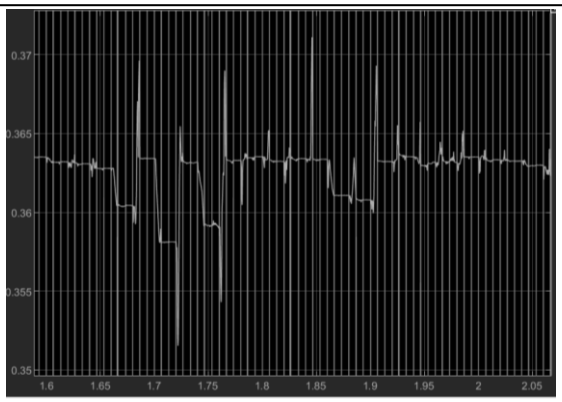


Fig 9. Active power for RC load

From the figure above, we can see that the value of power factor is less than 1. This is indicative of the presence of a capacitive element in our load. When the power factor decreases, the price per unit of electricity or electrical power increases. Companies are penalized by the authorities if they produce less power factor power as this decreases the overall, usable active power that is being produced.

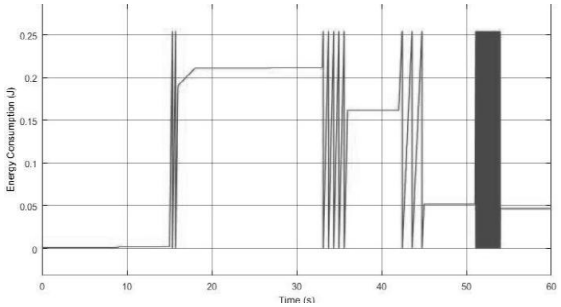


Fig 10. Active power for RC load

The above graph shows the energy consumption by our capacitive load or RC load. Shunt capacitor banks are used in electrical power systems to improve the efficiency of power supply.

Calculated active power= 733.828 W
Observed active power= 733.70 W
% error= 0.0174

C. R-L Load

Again, we change the load subsystem to represent an RL load. An inductive load is expected to have positive Θ and we try to observe the waveforms generated and calculated values via our Simulink model.

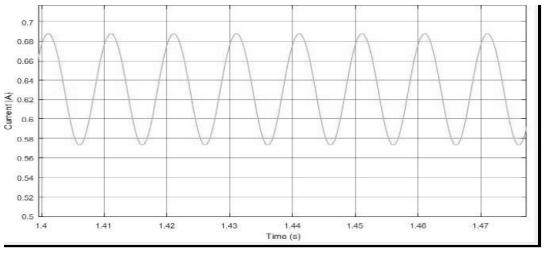


Fig 11. Current in RL load

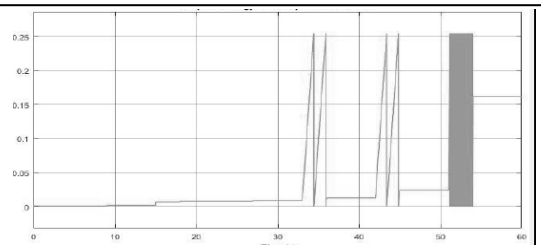


Fig 12. Energy consumption for RL Load

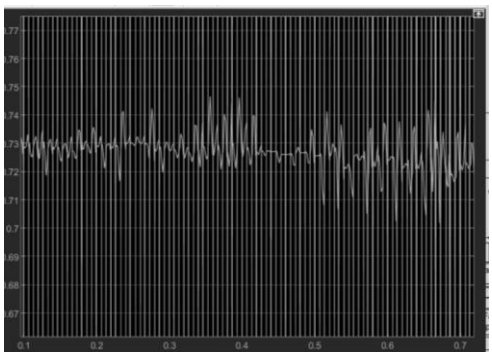


Fig 13. Active power for RL Load

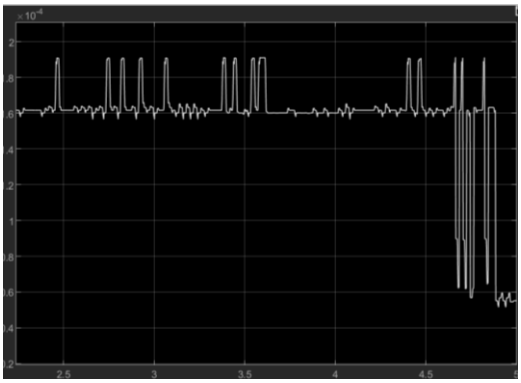


Fig 14. Reactive power for RL Load

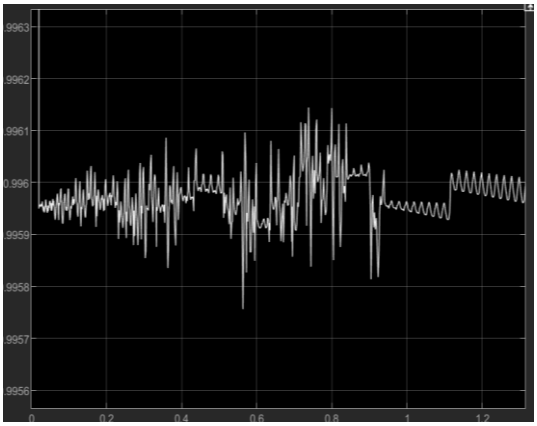


Fig 15. Power factor for RL Load

We can see the power factor graph which is in accordance with an RL load being applied and so is the current graph. Our energy consumption graph is pretty much like the other two.

Calculated active power= 1.3858 x 10^ (-6) W
Observed active power= 1.3860 x 10^ (-6) W
% error= 0.0144

V. CONCLUSION

It was proposed and implemented with success in a simulator, a model of an energy circuit for measurement of three-phase electric energy consumption from an electrification network connected to the installations of a customer of electric energy. With direct application in all Energy Smart Meters.
The capability and advantages of the proposed and implemented frequency measurement method were proved.

Smart meters made a revolution over conventional meters through its intelligent inbuilt technologies. It has gained momentum worldwide as it favors both utility and consumer with its smart abilities. Smart meters paved the way for smart grid realization through AMI.

As a conclusion, three phase energy meters have been modeled and designed. We observe expected output graphs and can thus say that our model is suitable for measuring energy consumption for resistive, capacitive and inductive loads.

FUTURE SCOPE

Energy meter is the device that can be used to measure and display the power reading of the consumer's house. This energy meter helps the consumer aware of the wasting of the energy by displaying the pattern of the energy of each load. This simulation design is therefore recommended for implementation by adding the hardware and monitoring the energy using Internet of Things (IoT).

We can combine the waveforms that we've acquired and use it to train a model to further predict the possible load requirements in real time. This can be used for predictive modeling and distribution companies can use these to predict demand and reduce wastage drastically.

Live tracking of this can also be done by using a GSM (Global System for Mobile Communications) based model, which directly communicates the energy consumption value to anyone connected on the mobile system. This helps in remote tracking of the energy consumption and an effective billing system can be built that does not require manual labour and thus reduces the manual error significantly.

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