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Science for the People:
Inventions and Innovations for Sustainable Development

Design & Development of an Electrical Energy Metering System with Forecasting Capability Based on Least Square Regression

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Abstract

Today, energy consumption has been a major issue. High kilowatt rate is now being charged by electric cooperatives due to inflation, increased in the price of fuel, foreign exchange rates and other factors. Excessive charges in electricity bill to other households sometimes make them not able to pay on time and get disconnected from electric service. These issues affects not only households but even electric cooperatives, causing them to have some financial challenges. Being able to predict future electric consumptions brings much advantage to both end-users and to power system operators. This paper presents an electric metering system that has the capability of forecasting future electrical energy consumption of a certain household. The electrical metering system was designed using a current sensor, a single board computer (SBC) and a LCD display. The results are displayed on a touch screen display. The method of forecasting was based on least square regression and then implemented in an SBC. Performance of the forecasting algorithm was validated using historical data of ten randomly sampled households. The results show that the algorithm was able to forecast with a minimum observable error of 1.4 kWh and 13% for MAE and MAPE respectively. With this kind of metering system, household will be able to gain an outlook of their possible energy consumption thus allowing them implement possible actions in order to avoid untoward incident.

Introduction

A large portion of the community fails to come up with an outlook of their energy consumption. With the rise of energy rate per consumption and addition of excessive charges as shown in fig. 1, consumers are now facing more adversity than before. For these reason, they are more likely to experience disconnections during their subscription. Disconnection puts both the consumers and the providers at a disadvantage. Forecasting the energy consumption becomes a key component in the management of electrical energy consumption of a certain household. This can help in raising the preparedness of the consumer. We propose a system that will provide real time monitoring of household energy consumption using a current sensor and forecasting using a linear least square regression. A Single Board Computer (SBC) will be used to process, store and display the data, particularly the Raspberry Pi.

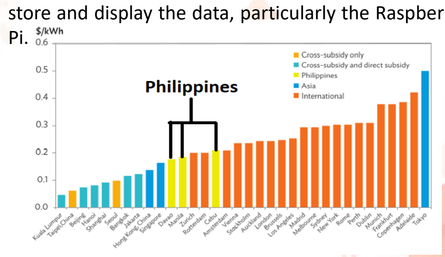
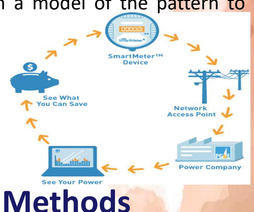


Fig. 1 Comparison of Electricity Tariffs per Major City 2017

Objectives

With the problem on energy awareness and preparedness, we propose a hardware that will provide monitoring and analysis of historical electric consumption and obtain a model of the pattern to provide an outlook.

Possible effect of proposed system



Materials and Methods

A non-invasive current sensor will be used to acquire real time current values and feed them to the raspberry pi. From there it will store the data and process them in kWh for modeling using least square regression. Then the recent and forecast consumption are displayed with the GUI on the LCD display. Fig. 2 shows the overview of the proposed electrical metering system with forecasting capability.

Fig. 2 Overview of the proposed system

The proposed system was yet to be implemented in real time, however the forecasting algorithm performance was evaluated through simulation using 30 months of historical data of 10 randomly selected households. It will be based on a linear model shown on eq. 1 and the coefficient a0 and a1 will be determined using LSR. For every month of testing, 4, 6 or 12 months of data prior to that month was used for training the LSR model. Fig. 3 shows the LSR model of one household forecasting the next month using a window of 4.

$$y = a_0 + a_1 x + e \quad (1)$$

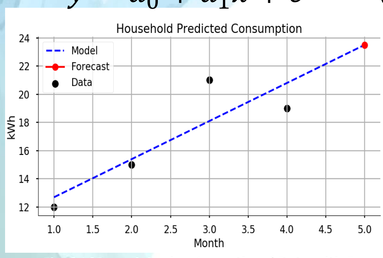


Fig. 3 LSR model using 4 months of Data with Forecast

Results & Discussions

Results of the simulation is shown on Fig. 4. It shows the forecasting on households 9 & 10 for 30 months. The window used to model each forecast was 4 months.

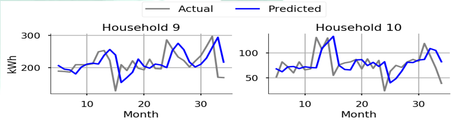


Fig. 4 Forecasting results

In order to quantify and evaluate the accuracy of the forecasting algorithm, the following metrics were used: Mean Absolute error (MAE) and mean absolute percentage error (MAPE). A comparison using different windows will also be included to see which window performed better. Fig. 5 shows that window 4 performed the best, having the lowest average absolute error in 6 out of the 10 houses and that household 4 contains the lowest average absolute error, due to it having the lowest variance.

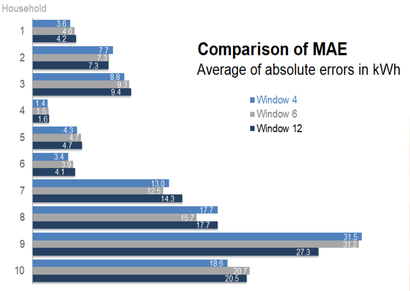


Fig. 5 MAE between households

In table 1 it shows the relative error for each household. It can also be seen that a window of 4 has the lowest sMAPE in 6 out of 10 houses. A minimal relative error was observed for data with larger range of values. Smaller values tend to perform worse on the algorithm, although this can be considered insignificant due to the fact its effect is negligible.

Table 1 sMAPE between households

Household	Window (Training) 4	6	12
1	23%	26%	26%
2	49%	44%	44%
3	36%	37%	37%
4	22%	23%	24%
5	27%	32%	35%
6	47%	51%	49%
7	16%	15%	17%
8	30%	27%	30%
9	15%	14%	13%
10	25%	27%	27%

Conclusion & Recommendation

With this proposed system, a consumer would be able to easily monitor and forecast their energy consumption. This can help raise energy awareness and preparedness in a household level and further improve its energy utilization. The results show that the algorithm performed well on select houses, especially on those with higher range of values and lower variance. However it is recommended that the LSR to be optimized and to be compared to other forecasting algorithms for further reliability.