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Village load profiling and forecasting model

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Abstract: *This paper describes building up of a model for computing the load forecasts as well as producing load profiles of a selected village and comparing it with national load profile. The main requirement before developing the models were ease of interphase (graphical user interphase) and accuracy of load profiles and forecast. The user-friendliness of the model is its ability to access, import and analyze historical data of the location whose load profile or load forecasting is to be determined. Selection and calibration of the model through the use of neural analysis tool has also been employed by the model parameters calibration and validation. The model has been built and successfully demonstrated. It produced load profiles and some forecasting performed, as shown in the result section, of selected village. The total load profile for villages does not necessarily follow a similar pattern to the national load profile due to socio economic activities, lifestyle patterns and extent of industrialization or commercialization of the village. This work is an extension of the work by the same authors who had worked on approximate mathematical model for load profiling and demand forecasting.*

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I. Introduction

Load profile is an important indicator of how demand for power varies with time. The profile is important to different stakeholders such as household tenants who may wish to use profile information readjust their pattern of energy usage to minimize energy costs. The profile could be important to planners and power authorities by knowing in advance when to provide extra power to a particular locality and also to avoid straining power system unexpectedly. It is not always easy to do accurate long term load demand forecasting and this could lead to overestimation which would in turn result in substantial investment, while on the other hand underestimating will result in customer dissatisfaction [1, 2].

While national load profile in Botswana generally show high peak demand around morning hours, 06h00 to around 10h00, the profiles for settlements, e.g., small villages which do not experience high industrial and commercial activity, were not readily available. This work was therefore intended to determine if the load demand profile of settlements individually follow a pattern of national load profile. The exercise was carried out by studying a small village of around 4500 inhabitants called Manyana located in Botswana in Southern African Region.

A data gathering in terms of power demand and energy usage for different activities was collected [3]. Information gathering also entailed types of electrical appliances available and their ratings, time of switching on and off of such appliances. Both household, industrial and commercial facilities were considered. The data collected was packaged and analysed using least square approximation method, after considering readily available techniques such as load forecasting which ranges from regression-based models, classical time series and regression methods, over time-series approaches, hybrid artificial intelligence and computational intelligence methods [3]. The information gathered was used to carry out the work further in this paper where a user-friendly graphical interface programme was developed. The programme allows the user to power demand at required time of any villages or settlement with similar socio-economic and lifestyle pattern to the village under consideration.

The rest of the paper is divided as follows: Section II deals with software program used on the work. Section III gives detailed followed on model development. Section IV deals with the results and analysis while Section V gives conclusion and future work.

II. Modelling With Matlab R2015 Software

Matlab R2015 software was used as a tool for programming, and the following series of steps were followed in developing the model for computing the load forecasts as well as producing load profiles for different villages.

Matlab R2015b was used as a tool for programming because it is able to provide programming environment for algorithm development, data analysis, visualization, and numeric computation. The software comprises of Simulink which is a graphical environment for simulation and Model-Based Design for multi domain dynamic and embedded systems [4]

III. building of model

The following steps as shown in Figure 1 were necessary on building the model:

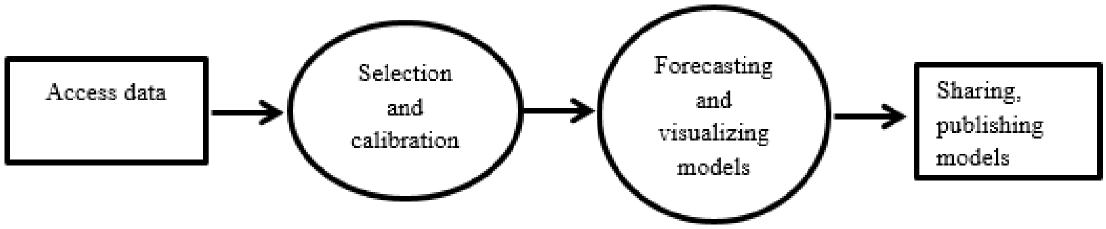

Figure 1. Converter Typical Hourly System Load

a. Access historical data

The data to use in modeling was collected, packed and stored in excel spreadsheet [3]. This data information deals with power demand by commercial sector, household sector, a combination of the two sectors. The data would be imported into the matlab software automatically by coding. Importing of data is used to create variables such as time in hours, summer and winter household energy consumption, summer and winter commercial energy consumption and lastly summer and winter total energy consumption (commercial plus household)

b. Selection and calibration of the model

Matlab Neural Analysis tool was selected for its ability to analyze data, fit in nonlinear regression time series data into a mathematical model and even for its visualization capability. Model based Calibration toolbox provided applications and design tools for optimally calibrating complex models. Calibration of model parameters and validation is necessary to ensure accuracy of results.

c. Pseudo code development used for importing data

The pseudo code was developed as shown below:

- ❖ Import data from Excel spreadsheet
- o Store data variables as arrays for logical indexing
- ❖ Visualize and analyze data
- o plot several load profile for:
- ▪ commercial against time for both summer and winter
- ▪ household against time for both seasons
- ▪ total load profile (household and commercial combined) for both seasons
- o compute standard deviation, range ,mean from all the graphs
- o basic polynomial curve fitting to validate derived mathematical models for the total load profiles[3]
- ❖ Developing load forecast models
- o input time and season and return the load prediction for villages.
- ❖ Graphical user interfacing
- o user friendly interface for running our models.
- ❖ Publication
- o share the findings to other formats for presentations

IV. Results And Analysis

(a) Importing survey results from excel spreadsheet

The program was developed, as in (b) below, and used to access Excel spreadsheet containing all results variables from the survey and imported the information from such source [3]. The user friendliness of the program is such that it can access and import data in different spreadsheet for any other village. The imported variables are stored as array columns as shown on Figure 2

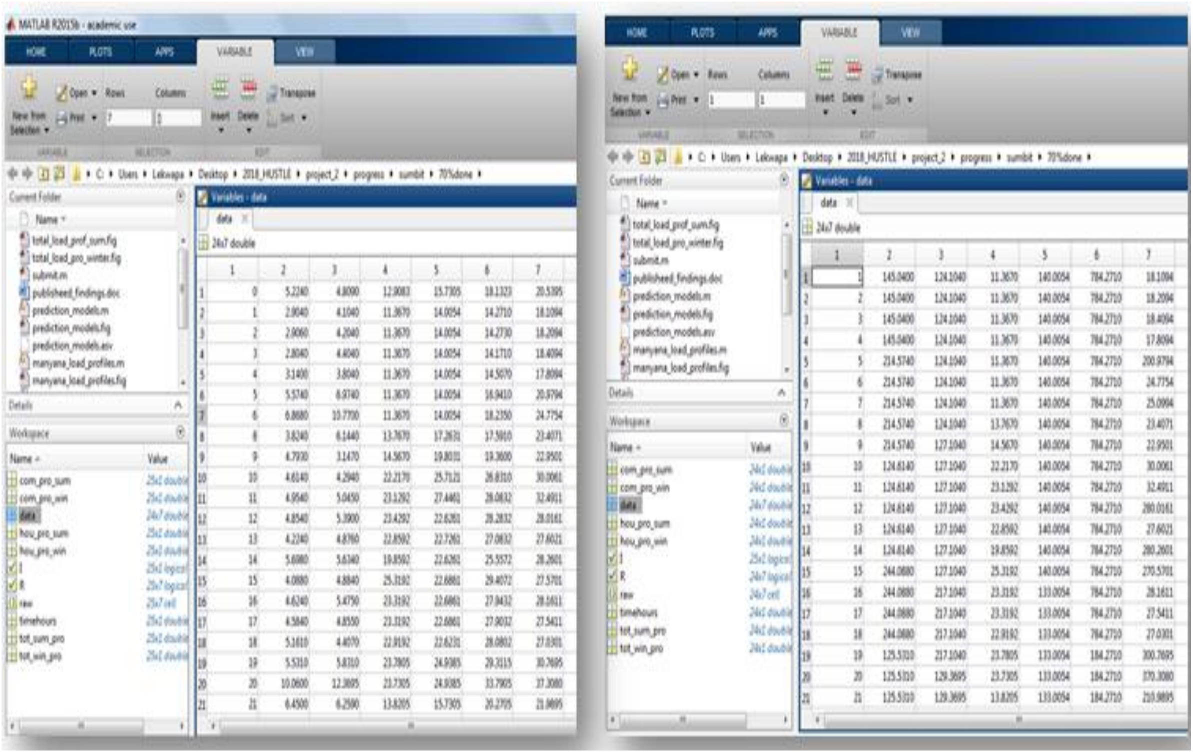

Figure 2 – Imported variables stored as array columns showing energy consumption for a village

(b) Developed program for importing survey results

❖ %Import data from spreadsheet
❖ %Workbook path:\ ……\load_forecast.xlsx
❖ %Worksheet: Sheet1
○ xlsread('\.........\load_forecast.xlsx','Sheet1','B1:H27');
❖ %Workbook path: \.........\load_forecast.xlsx
○ raw(cellfun(@(x) ~isempty(x) && isnumeric(x) && isnan(x),raw)) = {''}; %Exclude rows with blank cells
○ I = any(cellfun(@(x) isempty(x) || (ischar(x) && all(x==' ')),raw),2); % Find row with blank cells
○ raw(I,:) = [];
❖ % Replace non-numeric cells with NaN
○ R = cellfun(@(x) ~isnumeric(x) && ~islogical(x),raw);
❖ % Find non-numeric cells
○ raw(R) = {NaN};
❖ % Replace non-numeric cells
❖ % Create output variable
○ data = reshape([raw{:}],size(raw));
❖ % Allocate imported array to column variable names
○ timehours = data(:,1); % time of the day in hours
○ hou_pro_sum = data(:,2); % household energy consumption in summer
○ hou_pro_win = data(:,3); %household energy consumption in winter
○ com_pro_sum = data(:,4); %commercial energy consumption in summer
○ com_pro_win = data(:,5); %commercial energy consumption in winter
○ tot_sum_pro = data(:,6); %total energy consumption in summer (commercial plus household)
○ tot_win_pro = data(:,7); %total energy consumption in winter

(c) Visualization of data

The program was developed to create and visualize load profiles for power demand by different consumers being commercial and household during summer and winter. The profiles are as shown in figures 4, 5, 6, 7 and 8.

a. Summer commercial load profile

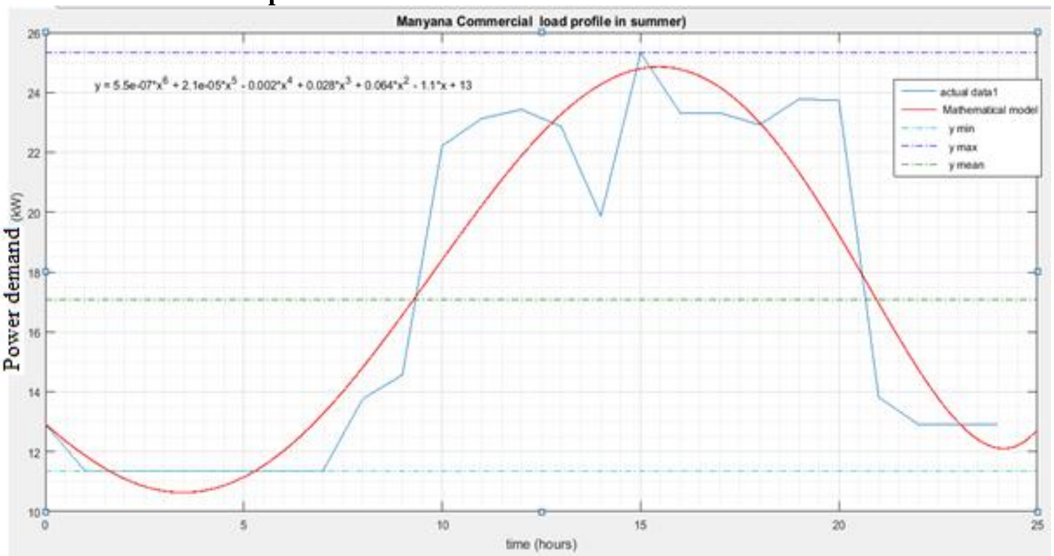

Figure 3 Manyana commercial load profile in summer

The graphical representation of power demand against time in hours is represented in Figure 3. The red graph shows a mathematical model which estimates the energy consumption pattern. From the graph statistical data has shown a power peak demand of 25.4kW from 1000hours to 1700hours. Similarly the minimum power demand was found to be 11.5kW after working hours (1700 to 0900 hours the following day). This profile can differ from one village to another because of the socio-economic activities of those villages.

b. Creating winter commercial load profile

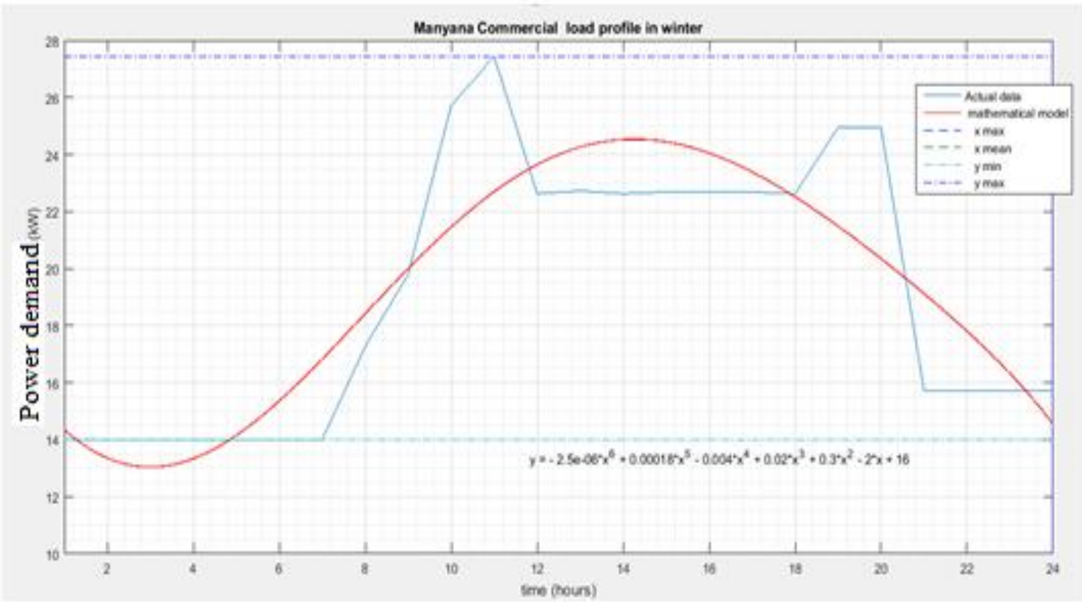

Figure 5 commercial load profile in winter

It was also found out that the commercial load profile in winter follows a similar pattern to the commercial load profile in summer as shown in Figure 4. The maximum power demand was found to be 27.5kW, occurring during working hours between 0800 and 2000 hours. Similarly other statistical information such as the mean, range and median could be obtained using statistical tool. Basic curve fitting tool could also validate our mathematical model for comparison.

c. Household load profile in summer

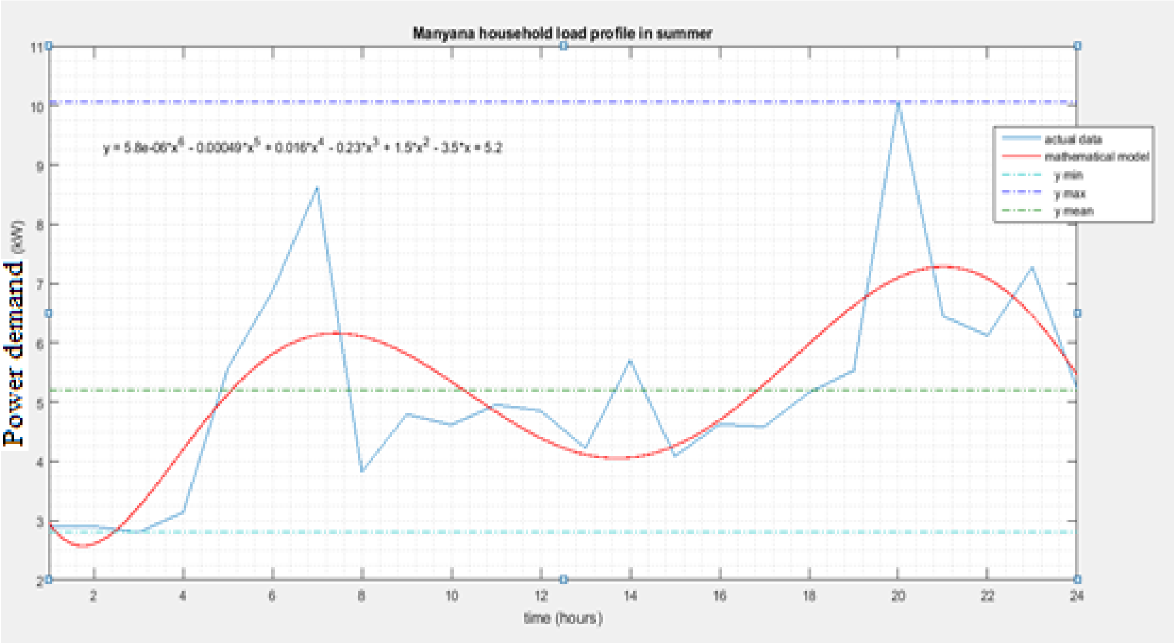

Figure 5 - Manayana household Load profile in summer

The trend for household summer energy consumption showed a morning peak demand of power between 0400 and 0600 hours at a maximum of 8.5kW. The other peak demand for power is shown from 1900 to 2000 hours with a maximum power demand of 10.0kW. Figure 5 gives a visualization of household load profiles for Manyana village.

d. Household load profile in winter

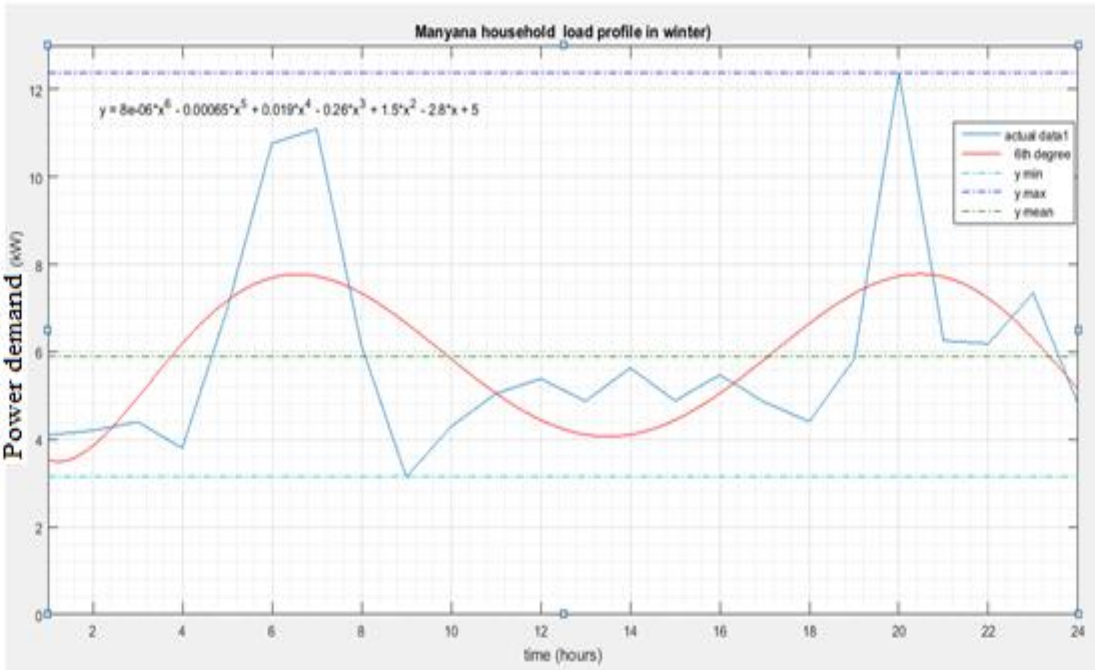

Figure 6 - Manayana household Load profile in winter

The trend for household load profile in winter from Figure 7 shows a morning maximum power demand between 0400 and 0800 am. It also displays an evening power demand peak between 1900 and 2100hours with a maximum of 12.37 kW a day.

e. Total load profile in summer

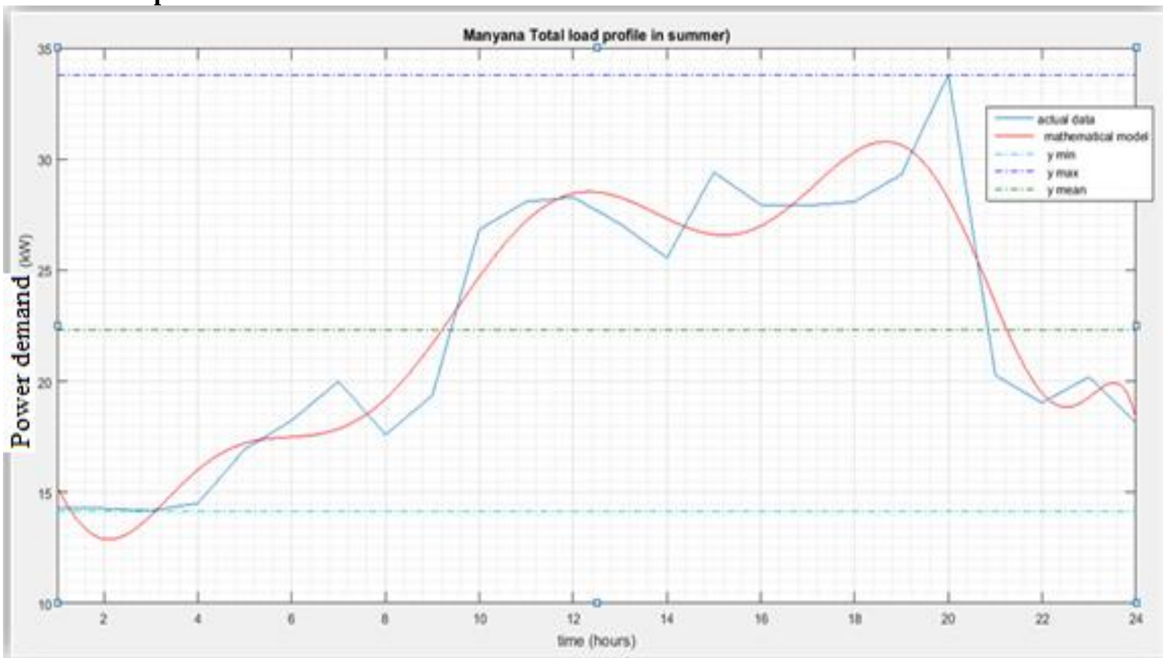

Figure 7- Manyana total load profile in summer

The combined load profiles (household plus commercial) in summer displays a maximum power demand from 1000 and 2000 hours with a maximum power demand of 33.79kW at 2000 hours. Other important statistical parameters needed for design such as mean, median and standard deviation could be obtained from the graph as indicated in Figure 8.

f. Total load profile in winter

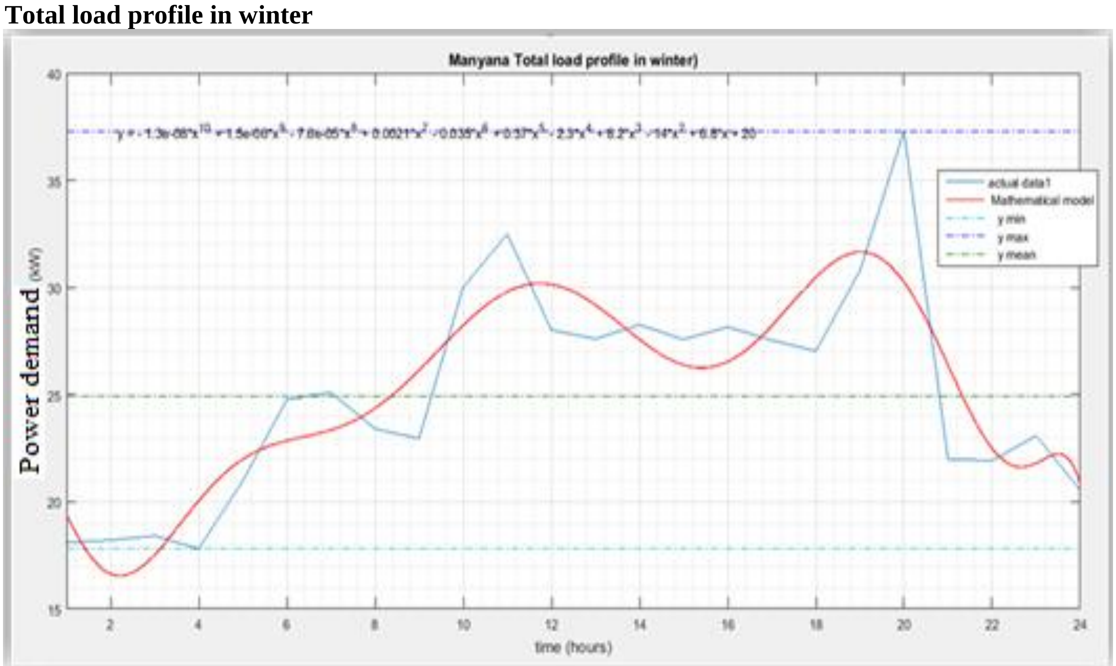

Figure 8 - Manyana total load profile in winter

The combined commercial and household load profiles on Figure 9 shows morning power peak demand of 33.5kW between 0900 and 1200, and also an evening peak demand with a maximum of 37.31kW between 1900 and 2100 hours.

g. Typical Hourly System Load (National Load Profile)

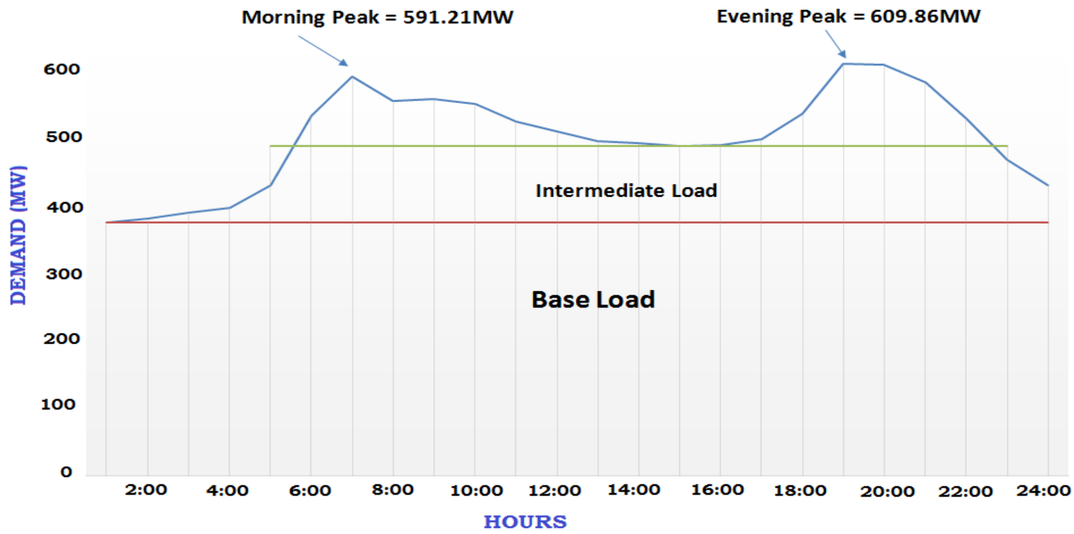

Figure 9. Typical Hourly System Load (National Load Profile) **[4]**

(d) Forecasting results

A code was developed and used with mathematical models to provide the Graphical user interphase [2, 5]. This allows the user to simply input time in hours and to select from the menu the type and season for the forecast, the type meaning either commercial, household or a combination of both, and season meaning either winter or summer.

a. Household load forecast in winter

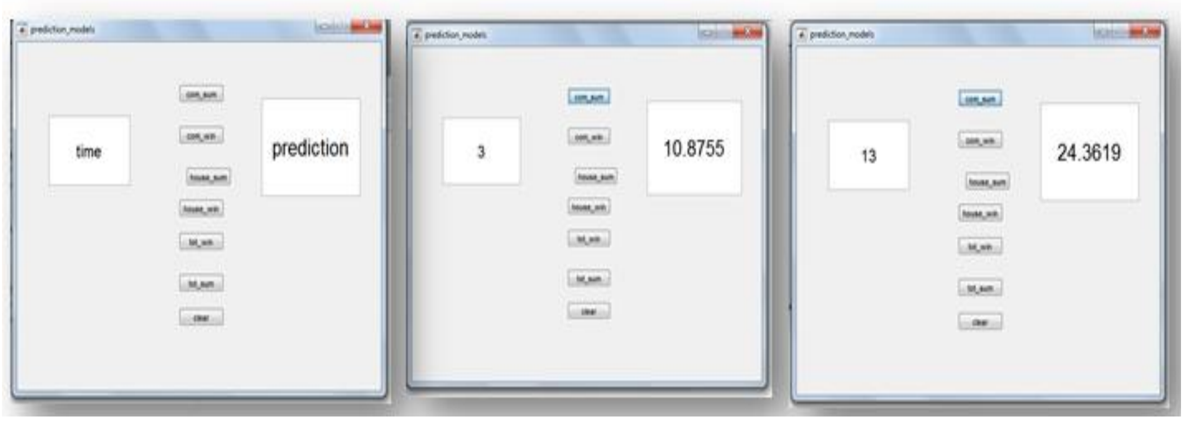

Figure 10 - Manyana total load profile in winter

V. Discussion, Conclusion And Future Work

Figures 8 and 9 show that the total load profile of the village under consideration did not follow the pattern of national load profile shown in Figure 9. Figures 10 shows that a user-friendly load profiling and forecasting was successfully developed. This was also highlighted by [7]. A similar forecasting can also be done for the commercial sector in Manyana village in summer or winter. The program enables the user to imply enter the time at which the forecasting is required and it immediately shows the results. The precision and accuracy of the results was achieved by taking the mean of the sample group at each discrete points (time in hours) for both the commercial and household sample groups. By comparing the mathematical models derived using the method of least square approximation to represent forecasting models for different load profiles, and the matlab r2015b basic curve fitting tool, it shows small deviations but approximate models were obtained. The project could be extended to provide medium and long term forecasts.

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