Multi-layer energy management software base VBA for multi microgrid operation planning and cost analysis

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Increasing the number of distributed generation resources in the form of microgrids, in addition to improving the technical conditions of these networks, causes many economic benefits to producers and consumers. Using a combination of several microgrids as a cluster of microgrids improves the mentioned advantages, however, the main problem is to find the best schedule for microgrids. In this paper, a software called MLEMS is proposed for the planning and cost analysis of multi-microgrid systems. This open-source software is based on the Visual Basic programming language, in the form of macro modules. By using GAMS and Matlab, in addition to the day-ahead scheduling of microgrid operation, the best solutions are also found to minimize the operation cost of multi-microgrid systems. Different parts of the software are provided in the form of modular layers to perform a better energy management system in which the user can enter the information for each microgrid separately. By designing the multi-microgrid system, modeling, optimization, and planning will be provided for any users in the software environment. A case study is performed to optimize the operating costs; using the proposed software for a multi-microgrid system and after several analyses, the best solution is given to the microgrid user. The Lindo solver has been presented the lowest solve time for the sample multi-microgrid system in the shortest solution time of 0.25 seconds. The cost of operating the sample system for a 24-hour has been calculated $ 520 by exposure to the operation plan in the MLEMS.

keywords: *Renewable energy, operation planning, cost analysis, energy management, multi-microgrid system.*

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1. INTRODUCTION

The Increasing energy demand and population growth in different areas of the world should be considered as determining factors that necessitate focusing on the implementation of proper energy management systems (EMSs). According to the International Energy Agency (IEA), in 2030, more than 960 million people in the world will not have access to any available electrical energy. Moreover, the average urban population growth is estimated to be 60% [1]. Using energy resources to meet this huge volume of potential demand is a vital issue in energy management planning. With the entrance of large volumes of distributed generation, renewable energy resources in the form of multi-microgrid sources will meet a large part of the required energy. Given this amount of resources, the tools required to plan resources and energy costs management are essential. Economic and environmental aspects are the main objective functions in EMS problems[2]. One of the key tools of microgrid design is using proper energy management in a way that provides the resources at the lowest possible cost for the load[3]. To improve energy management and energy planning, regional and environmental programs in small networks such as municipalities and city planners should be replaced by national and centralized programs[4**?**]. In the form of energy planning at the local scale, modeling energy consumption of four commercial models, including small, medium, and large office buildings and retail stores with EnergyPlus software has been simulated in different time periods for building energy planning [6]. With the increase of Distributed Energy Resources (DER) and the creation of microgrids, the management of this network as a local grid and its economic, social, and technical impact has been studied by researchers[**?**]. Having the communication and management software platform will be one of the fundamental components in DER aggregation. Software defined network, Energy harvesting IoT led to significant improvements in monitoring, communications, troubleshooting, control, automation, optimization, and management for a local network like as microgrid, smart grid, commercials building, and retail store[**?**]. However, the new achievements emphasize only the collection of online or offline data and multidimensional communication and use of raw information in energy management analysis. In [18] a co-optimization approach to the generation and transmission planning has been introduced to minimize the total planning cost and consider the microgrid reliability criteria throughout the planning horizon for a cluster of microgrids. In[19] theoretical and software approach has been provided for microgrid optimum long-term planning considering emission and lowest cost. One of the main challenges of microgrid planning is the presence of renewable resources with fluctuation generation. Stochastic optimal planning has been used to enhance this challenge in [20, 21] based on the chance-constrained and Monte Carlo method respectively. There is a lot of software designed in the field of energy management, some of which like pvsyst, Sam, Solar Design Tool, PV* Solpv, DesignPro, and SolarPro which focus on one type of energy source and others such as Homer, RETScreen, Insel, Hybrids, Somes, Solstor, Ipsys, Ares, and Hybrid Designer can contain different energy resources and some software like as IGrhyso, HySim has been allocated to special country in within limited time[22, 23]. By choosing resources properly, a significant reduction in operating costs has been achieved by Homer[12]. Some software programs are designed with one goal and some with different capabilities. Multi-layer arrangement in a multi-microgrid system will improve energy exchange and trade between microgrids. A multi-leader multi-follower (MLMF) Stackelberg game approach in[24] has been used to model the energy trading process, but resources forecasting as an important energy management tool is not well seen in it. Voper is one of the few programs that use geographic information to design microgrids. Additionally, Ecost has been designed for overhead distribution network planning [25]. In ref[26], Ugrid has been introduced by several features, which show the extension of an open-source holistic structure design. The most important feature of the above-mentioned programs is the study and application of one or a few important characteristics of energy management tools like optimization of generation equipment, optimized network planning, and implementing the optimizations during the generation in analysis and design. In this study, an innovative approach is presented to select multiple modules of EMS in the proposed software design for the users of multi-microgrid systems. In this way, some modules contribute a better analysis of the optimization results for the microgrid users. For better analysis of weather forecasts, additional software has been used behind the main software in the form of modules. By entering the grid information and adjacent microgrids by the user with technical and economic analysis of microgrids, a day ahead of schedule for load and resources is provided. The main contributions of this paper include:

- Providing different parts of the software for the users in the form of modular layers, and showing the capability of each layer for a better EMS in a microgrid cluster.
- Implementing a multi-microgrid system model & design and planning includes selecting distributed generation, data gathering and finding the best solution.
- Connecting to a background program & sending and receiving data & performing optimization.
- Presenting resource utilization plan in the day-ahead by graph/log considering economic goals.

2. STRUCTURE OF MLEMS

MLEMS is designed in a multi-layer form, and each layer acts as a module. As shown in Fig.1 each layer contains programming packages called Layer Programming Modules (LPMs). Layer information must be completed by microgrid users labeled user 1, 2, 3, N. In fact, data gathering is done by users for each layer separately. To improve EMS capabilities, background programs, such as Matlab, can be called. This is done by a package called Communication Programming Module (CPM). Any external software related to MLEMS is considered a programming module. The task of these modules is to exchange information between applications. LPM and CPM contain programming codes based on macros written in Visual Basic for Applications (VBA). By selecting the desired plan, determining generators, specifying the number of loads, entering sufficient information, and applying the necessary constraints, the program can be run. Optimization based on Mixed-Integer Linear Programming (MILP), provides the solutions in the first solver. The user can select the type of solver, and finally, the optimal microgrid solution will be provided to the user. The proposed software algorithm is described step by step in Algorithm1.

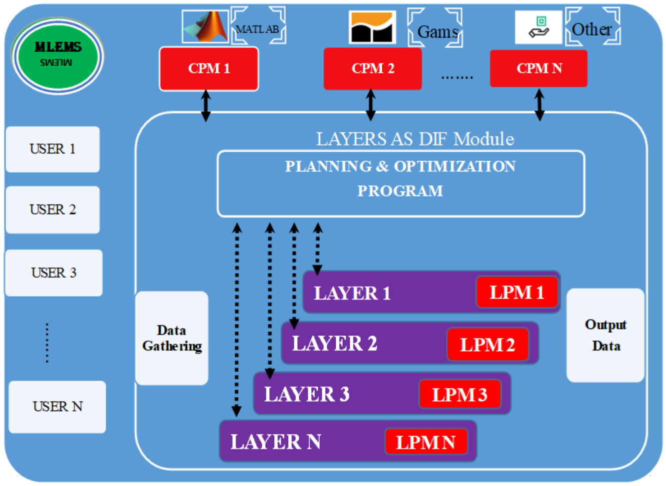


Fig. 1. Details of the structure of proposed MLEMS

3. DIFFERENT LAYERS AND GATHERING INFORMATION

A. MLEMS input & output element

In the input section, raw information specific to each microgrid must be entered by the user. According to Fig.2 weather data related to the region of each microgrid and its load and resource data should be entered. The price of energy in the exchange between the main network, adjacent microgrid and storage resources must be specified. The choice of optimization and forecasting methods can be selected by the user. Determining the allowable limit of storage resources and how to communicate with different microgrids can also be applied. Ancillary software that the user of each microgrid wants to be called for better analysis will also be selectable. Finally, all constraints, both in terms of generation and consumption and the requirements associated with each microgrid and main grid must be appointed. In the software output section, various facilities will be provided. Technical and economic analysis will be provided for each user according to the input information. The amount of power between the microgrids and the main

Table 1

Algorithm 1 : proposed software algorithm	
A: User Planning	C : Calling background software
1. Selection load and its type	1. Calling matlab for weather forecast
2. Selection number of microgrid	2. Calling matlab for load forecasting
3. Selection of resources and its type	3. Calling matlab for generation forecasting
B: Data Gathering	D: Run optimization program
1. Input weather data	1. Calling GAMS with first solver
2. Input constraints	2.First answer is saved as initial answer
3. Input load/generation forecast	3. Calling GAMS with N solver to find best answer
4. Input the purchase/sale price of energy	4. Show cost analysis for each microgrid

network and the cost of each microgrid as well as the amount of power that can be received from storage resources will provide for any microgrid user. The optimal answer with the lowest cost due to the unit commitment in the day ahead planning will be available for each user with a variety of solvers. Weather forecasting output, although considered as part of the data for optimal resource planning, can also be provided as raw information to the user. Finally, several goals can be imagined for the output of this software, which in this paper will focus only on cost minimization. The output results of the software are provided to the users in the form of various tables and graphs.

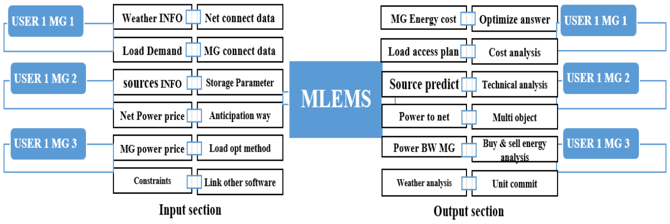


Fig. 2. Schematic of MLEMS input & output section

B. Method of operation

First, the software asks the user to make the desired multi-microgrid structure.The multi-microgrid system zoning is first selected; resources and loads are then added for each zone. The number of diesel generators (DGs), renewable sources (solar panels or wind turbines), and the number of controllable and uncontrollable loads can be selected in this section by the micro-grid user. The users have access to each layer to enter the input values separately in their own console. As shown in Table 2, in this section, the user is asked to enter information in the load layer, controller type in the control layer, connection type to the main grid in the operating mode layer, costs in the economic layer, and energy storage size and power data in the emergency layer, as well as generation and weather forecasting in each layer.

C. Calculation Method

To implement the model, a suitable mathematical modeling system has been used to have high flexibility and accuracy in obtaining results. To achieve this goal, the MILP method will be used to plan the operation of the microgrid in the day ahead of program to achieve economic optimization of the operating cost of the multi-microgrid system. In this method, the goal is to find a minimum or maximum of a linear function, which is implemented in this paper with the aim of minimizing operating costs. The two categories of independent and dependent variables must be defined. Variables that are defined as optimal variables will be in the group of independent variables. These variables will be the decision variables. Dependent variables will be calculated based on decision variables. After completing the input information, it is necessary to select the proper calculation method. The user has to enter information, such as start /shutdown cost and renewable energy curtailment cost per kW, in the economic layer. Moreover, the type of operation cost and optimization method, e.g., MILP, can be selected in this section. The type of control method for the multi-microgrid system can be selected in the control layer section. Additionally, the operating mode (grid-connected or islanded mode) of the network can be selected in the mode layer section. This layer allows the user to select the type of microgrid connection to the main network or adjacent microgrids. The objective function for multi microgrid system (the number of microgrids is indicated by m) will be obtained in accordance with Equation (1). Objective function minimizes multi microgrid operation cost including fuel cost, start and shutdown cost, storage cost, shedding load cost, up/down reserve cost and curtailed power cost. The $l(P^{(m,h)}_{(DE,i)})C^m_f$ expression in objective function will be used to linearize the cost of fuel consumption of diesel units per microgram. The parameter C^m_f will be the cost of fuel. Csu^m_i ,$Cshd^m_i$ are start and shutdown cost parameters which phrases $v_i(h)$, $z_i(h)$ express start and shutdown constraints for diesel generation $P^{m,h}_{DE,i}$ in each microgrid. The parameter C^m_{shed} will be the cost of load shed and the amount of power removed for balancing between load and generation will be $P^{h,m}_{i,shed}$. Also C^m_{dch},$P^{h,m}_{sb,ch}$ are the cost of discharge and amount of discharge power of storage system respectively. C^m_{cur},$P^{h,m}_{i,cur}$ are curtailed cost and curtailed power which belong the part of renewable energy is produced more than load demand respectively. Up and down power reserve and its parameter is defined by($P^{h,m}_{r,up,i}$,$P^{h,m}_{r,dwn,i}$,$C^m_{sh,r}$. respectively.

Table 2. Layers section and its essential data for proposed software

Layer Type	Gen	Emergency	Control	Storage	Load	Economic	Mode	Weather
User Input	GenW/M/Y	Gen Power	Main	Baat	W/M/Y	Start PRG	Island	W/M/Y
Method	Matlab-fuzzy	VBA-macro	GAMS -MILP	GAMS -MILP	Matlab-fuzzy	GAMS -MILP	VBA-macro	Matlab-fuzzy
Key : Gen (Generator)-Bat (Battery)-PRG (Program)-Y(Yearly)-M(Monthly) W(Weakly)-RES (Renewable Energy Sources)								

$$
\begin{aligned}
OF = Min \sum_{m=1}^{M}\sum_{h=1}^{H}\sum_{i=1}^{N} & [(l\left(P_{DE,i}^{m,h}\right)c_{f}^{m}) + (Csu_{i}^{m} * v_{i}(h)) + \\
& (Cshd_{i}^{m} * z_{i}(h))] \\
+ \sum_{m=1}^{M}\sum_{h=1}^{H}\sum_{i=1}^{N} & (c_{shed}^{m} * P_{i,shed}^{h,m}) + (c_{dch}^{m} * P_{sb,ch}^{h,m}) \\
+ \sum_{m=1}^{M}\sum_{h=1}^{H}\sum_{i=1}^{N} & (c_{cur}^{m} * P_{i,cur}^{h,m}) \\
+ \sum_{m=1}^{M}\sum_{h=1}^{H}\sum_{i=1}^{N} & c_{sh,r}^{m} + (c_{r,up,i}^{h,m} * P_{r,dwn,i}^{h,m})
\end{aligned} \tag{1}
$$

The fuel cost and curtailed power is calculated as Equation (2) and (3) respectively. The $A_{o}^{i,m}$, $B_{o}^{i,m}$in Eq. (2) can be extracted according to the manufacturer's specifications and in the diesel information sheet which used for linearization. $P_{pvt}^{h,m}$,$P_{wdt}^{h,m}$ Are photovoltaic and wind power generation which part of this power charge battery for essential situation($P_{ch,ren}^{h,m}$). The amount and status of charge as a battery bank ($SOC^{h,m}$) is shown in Equation(4). In this equation$P_{sb,ch}^{h,m}$,$P_{sb,dch}^{h,m}$ are the amount of charge and discharge power of the storage system. $P_{sb,Rup}^{h}$ is up reserve in the storage system in the time interval ($\Delta h = 1$). According to Equation (5), the charge and discharge efficiency values of the storage source will be considered equal. Equation (6,7) expresses the state of charge value and its maximum and minimum constraint. Finally, the maximum and minimum charge and discharge power constraint is obtained from Equation (8,9). When the energy produced from renewable energy exceeds its minimum value, this energy will be used to charge storage resources. If the microgrid breaker is closed and the power is received from the network $P_{net}^{h,m}$, the objective function (OFnet) for this power will be in accordance with Equation (10). If several breakers of microgrids are closed, the equation (11) will be established. Other constraints include: the constraint between the start and shutdown status of the units, the capacity limit of generation units per microgrid, the limitation of the status of units in the special case given in equation (12-15). To create a relationship between the statuses of the units, including the Moment of start and shutdown a logic must be defined so that it is not capable of starting when the unit is in the starting position. So a constraint as Equation (12) is defined. The capacity constraint of generation units in each microgrid indicates the limitation of generation in the range of minimum and maximum power generation capacity which is expressed by Equation (13). Constraint in Equation (14) indicates the status of the units remains constant in a particular state at a specified time U_{i}^{h}. A similar constraint is considered for the minimum time out of the generation unit, which is stated in Equation (15).

$$l\left(P_{DE,i}^{m,h}\right) = max[A_{o}^{i,m} * u_{h}^{i,m}] + max[B_{o}^{i,m} * P_{h}^{i,m}] \tag{2}$$

$$P_{cur}^{h,m} = P_{pvt}^{h,m} + P_{wdt}^{h,m} - P_{l}^{h,m} - P_{ch,ren}^{h,m} \tag{3}$$

$$soc^{h+1,m} = soc^{h,m} - \Delta h(\frac{P_{sb,dch}^{h,m}}{y_{sb,dch}^{h,m}}) + \Delta h(P_{sb,ch}^{h,m} * y_{sb,ch}^{h,m}) \tag{4}$$

$$y_{sb,dch}^{h,m} = y_{sb,dch}^{h,m} \ ,\Delta h = 1 \tag{5}$$

$$\Delta h(\frac{P_{sb,Rup}^{h}}{y_{sb,ch}^{h,m}}) + soc^{\min,m} < soc^{h,m} < soc^{\max,m} - \Delta h(P_{sb,Rup}^{h} * y_{sb,ch}^{h,m}) \tag{6}$$

$$soc_{bat}^{\min,m} \le soc_{bat}^{h,m} < soc_{bat}^{\max,m}, \quad , \tag{7}$$

$$P_{bat,dch}^{\min,m} \le P_{bat,dch}^{h,m} < P_{bat,dch}^{\max,m} \tag{8}$$

$$P_{bat,ch}^{h,m,\min} \le P_{bat,ch}^{h,m} < P_{bat,ch}^{h,m,\max} \tag{9}$$

$$OFnet = Minmize \sum_{h=1}^{H} P_{net}^{h,m} * C_{net}^{m} \tag{10}$$

$$OFnett = Minmize \sum_{h=1}^{H}\sum_{m=1}^{M} P_{net}^{h,m} * C_{net}^{m} \tag{11}$$

$$v_{i}(h) - z_{i}(h) \le u_{i}(h) - u_{i}(h-1) \tag{12}$$

$$P_{DE,i}^{\min,m} * u_{i}(h) \le P_{DE,i}^{h,m} \le P_{DE,i}^{\max,m} * u_{i}(h) \tag{13}$$

$$u_{i}^{h} - u_{i}^{h-1} \le u_{i}^{\tau} \tag{14}$$

$$u_{i}^{h} - u_{i}^{h-1} \ge u_{i}^{\tau} - 1 \tag{15}$$

If the communication breakers between different microgrids are closed, a power balance between generation and consumption ($P_{l,m}^{h}$) must be established. Therefore, in this regard, Equation (16) is considered to maintain a power balance in the receiving microgrid and Equation (17) to maintain a power balance in multi-microgrid system

$$
\begin{aligned}
& \sum_{i=1}^{N} P_{DE,i}^{h,m,n} + \sum_{k=1}^{K} P_{pv,k}^{h,m} + \sum_{w=1}^{W} P_{wd,w}^{h,m} + \\
& \sum_{m=1}^{M} P_{net}^{h,m} + P_{shed}^{h,m} + P_{bat,ch}^{h,m} = P_{lm}^{h} \ ,
\end{aligned} \tag{16}
$$

$$
\begin{aligned}
& \sum_{m=1}^{M}\sum_{i=1}^{N} P_{DE,i}^{h,m,n} + \sum_{m=1}^{M}\sum_{k=1}^{K} P_{pv,k}^{h,m} + \\
& \sum_{m=1}^{M}\sum_{w=1}^{W} P_{wd,w}^{h,m} + \sum_{m=1}^{M} P_{shed}^{h,m} + \\
& \sum_{m=1}^{M} P_{bat,ch}^{h,m} = \sum_{m=1}^{M} P_{lm}^{h}
\end{aligned} \tag{17}
$$

4. LINKING AND RELATION WITH OTHER PROGRAMS

A One of the advantages of this software is its capability to be quickly linked to other programs, such as GAMS and Matlab to implement estimation and optimization layers. In coding VBA, distinct modules should be used to call these programs. Due to the use of multiple layers that require estimating, Matlab is used to perform the estimation process based on fuzzy logic. A large part of the computations is related to the operation cost optimization of the multi-microgrid system, so economic analysis is accomplished by calling GAMS. The executive instructions in GAMS and the VBA code for loading the new model is shown in figure 3.

In the calling background software section, which is marked in purple in figure 3 first, the type of software to be called is announced. For this purpose, the directory path must be entered correctly. The software runs in the background of the main software and then that part of the background software (Matlab), which is a fuzzy interface system and a three-dimensional view, runs here. Finally, the output will be provided to the software in separate data. With considering VBA code in the green box (figure 3) GAMS runs in the background. We use the VBA version of the. To solve the proposed model we call the GAMS executable with considering different solvers. The path of the GAMS directory must be correctly announced by the user in this section. The GAMS software can be closed after the call. Also, the optimized data will be saved and accessed in a specific way by the software for better analysis. As last part in figure 3 , the yellow section is belong to VBA code to calling assigned model for new analysis. Therefore, a console is provided to the user in this section, so that he can see the assigned model. All details of the model will be visible to the user in this section. In fact, in this section, the user's desired model for use in multi-microgrid system analysis in energy management software will be determined.

5. CASE STUDY

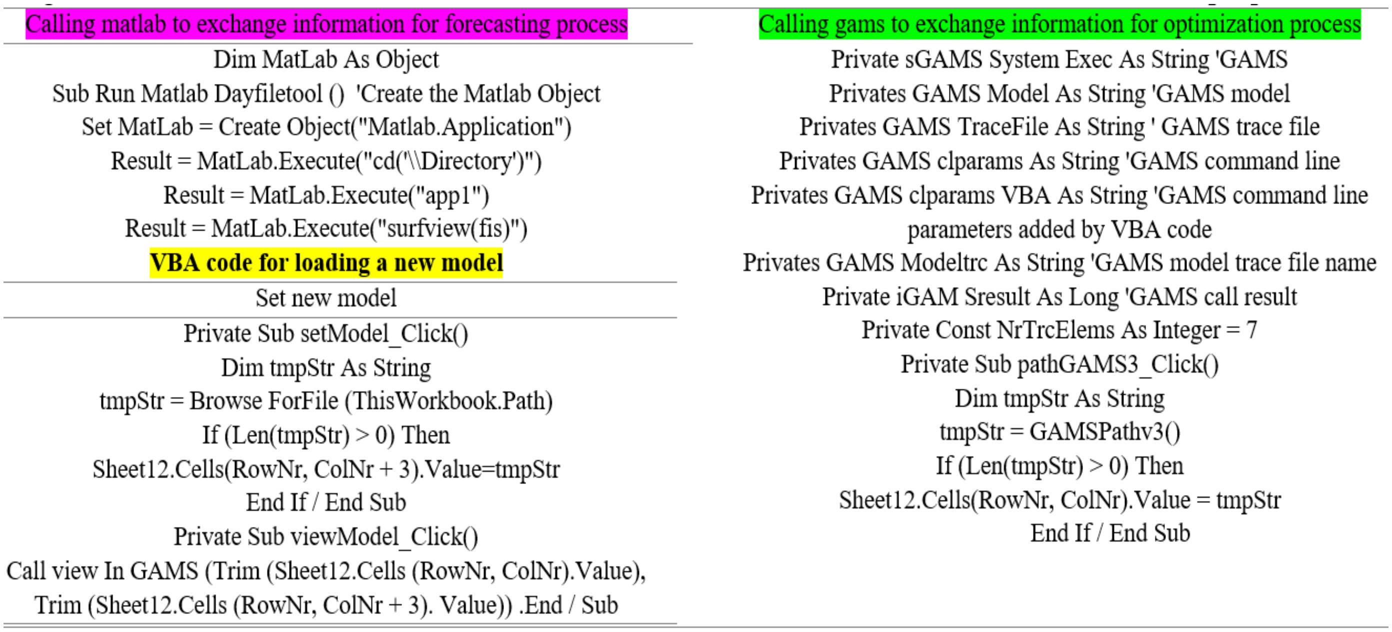
Seventeen macro modules including those related to layer section, software calling, and optimization model selection are used for implementing the case study. The load can be estimated by different methods including artificial neural networks and fuzzy systems[27]. In this study, the load estimation layer is based on a fuzzy system as shown in Fig. 4. Diesel generator information like linearization coefficient and other data in accordance with reference [28].

To evaluate the performance of MLEMS, a modified IEEE 9-bus test system as Fig. 5 with five zone is examined and analyzed for planning microgrids in three active zones. The user makes its own multi microgrid structure as shown in Fig. 6. Each zone includes a diesel generator, a PV system, a wind turbine, and a load. According to Fig. 7, the user is asked to enter specific information for each layer. To enter the information of each section, the user will go to the desired menu and enter the requested information. Selection of load type including controllable or uncontrollable, load size and any load information is provided for the user in the load layer menu. Connection type which includes island or ingrid with adjacent multi microgrid system or local network is defined in operation mode layer menu. Any information about load/generation and weather anticipation must be entered into this menu. Energy storage size and its power range in the emergency layer will be entered in the emergency and storage layer menu. The possibility of using different models for analysis, the possibility of viewing the type of model used, the possibility of using different models and solvers, the capability of different methods in forecasting and optimization will be other advantages of the proposed software. Appendix (1) shows only several of sub-menus that the user must complete in the software. The information that has to be given to the software in the diesel generator section includes min/max power, ramp up/down reserve, fuel price, and shutdown and start cost. Additionally, load data and storage input data, such as the state-of-charge of the battery and its constraint, are considered for the user in the energy storage section as a separate console. After filling input data, a model has to be selected on the run page. Then, as soon as the user presses the run button, the software starts running and calls the background software. The optimization and calculation process begins with the first solver to find the best solution. If no solution is found or there is no optimal solution, another solver should be employed. For the case study, the software output for each microgrid is displayed to the user as explained in the following. Wind power and PV estimations of microgrids (z1, z2, z3) are shown in Fig. 8. According to this figure, PV generation is estimated from 7:00 to 16:00 with maximum generation in the middle of the day ahead programming(about 1.6kw, 1kw, 0.65kw for each microgrid). Also, the wind turbine generation is estimated from 5:00 to 22:00 with a focus on maximum generation between 10:00 -12:00 AM (more than 2kw, 3.3kw, 2kw for each microgrid). Total wind power generation and total renewable generation are shown in Fig. 9. The total solar system and total wind power generation are calculated as 45 and 3.1 kW, respectively. Total renewable power output is 6.56 kW in 24 hours. Moreover, the maximum ramp up/down reserve of diesel generator for microgrid 1 is calculated as 1.1 and 2.4 kW respectively as shown in Fig.10. These values are obtained for microgrids 2 equal to 1.8 and 0.3kw, respectively. Finally this variable is calculated 2.7,2.7 kw for microgrids 3 in the day ahead programing. It can be seen that due to the presence of renewable sources in the middle of the day, a lower capacity of diesel sources has been used. Figure 6 shows the generator side of the biogas engine generator set at Nyongara slaughterhouse driven by the biogas powered engine to generate 10 kW electricity. Figure 7 shows the side view of the biogas engine set at Nyongara slaughterhouse.

State of charge and discharge and finally the best answer for the day ahead programming of each DG in multi microgrid system is provided as shown in Fig. 11. When not using diesel resources (8-11 o'clock) part of the storage source capacity is reduced. As shown in this figure, microgrid2 and microgrid3 have recorded totals of 42.1 and 199.5 kW as the lowest and highest power in the multi-microgrid system during 24 hours. It is observed that in some midday hours, due to the presence of renewable sources, the use of diesel sources has decreased. However, part of the demand at this time is met by storage sources and in some special cases by diesel sources in microgrid2 and 3. Due to the capacity of diesel resources and the larger generation range in Microgrid 3, a larger share of generation has been provided by this microgrid in the day ahead program. Table 3 shows a comparison between MLEMS and similar programs considering the cost analysis time, usable different type of resources, software cost for user, type of microgrid or multi microgrid structure, type of programming language, the best solver, and the optimal solution. Lindo solver provides the best solution with a daily cost of about 520$ in 0.25 Sec. Compared to other software, it does not cost the user. It will be possible to use different methods to run the model in diffrent layers, and it is also possible to use single and multiple microgrid structures. Other features of this method are detailed in Table 3.

6. CONCLUSION

For analyzing and planning day-ahead schedules, a planning and cost analysis software was created based on VBA for multi-microgrid users. The free software has several modules which present a completely user-friendly environment. This software call background external optimization programs for better results. The software uses different layers to complete the optimization process to meet users' requirements. The software will provide technical and economic analysis for planning a multi-microgrid system on the output side with various raw data that it receives from microgrid users in the input section. To evaluate the software, a case study was used. It was observed that the software provides the optimal solutions in the best possible time with the best solver. Linking to other programs improves the quality of the solution. Although the software will provide optimal answers with different solvers, the best solution for the case study was provided by the Lindo solver with a daily cost of about 520$ in 0.25 Sec.



Calling matlab to exchange information for forecasting process

```
Dim MatLab As Object
Sub Run Matlab Dayfiletool ()  'Create the Matlab Object
Set MatLab = Create Object("Matlab.Application")
Result = MatLab.Execute("cd('\\Directory')")
Result = MatLab.Execute("app1")
Result = MatLab.Execute("surfview(fis)")
```

VBA code for loading a new model

Set new model

```
Private Sub setModel_Click()
Dim tmpStr As String
tmpStr = Browse ForFile (ThisWorkbook.Path)
If (Len(tmpStr) > 0) Then
Sheet12.Cells(RowNr, ColNr + 3).Value=tmpStr
End If / End Sub
Private Sub viewModel_Click()
Call view In GAMS (Trim (Sheet12.Cells (RowNr, ColNr).Value),
Trim (Sheet12.Cells (RowNr, ColNr + 3). Value)) .End / Sub
```

Calling gams to exchange information for optimization process

```
Private sGAMS System Exec As String 'GAMS
Privates GAMS Model As String 'GAMS model
Privates GAMS TraceFile As String ' GAMS trace file
Privates GAMS clparams As String 'GAMS command line
Privates GAMS clparams VBA As String 'GAMS command line
parameters added by VBA code
Privates GAMS Modeltrc As String 'GAMS model trace file name
Private iGAM Sresult As Long 'GAMS call result
Private Const NrTrcElems As Integer = 7
Private Sub pathGAMS3_Click()
Dim tmpStr As String
tmpStr = GAMSPathv3()
If (Len(tmpStr) > 0) Then
Sheet12.Cells(RowNr, ColNr).Value = tmpStr
End If / End Sub
```

Fig. 3. Link and relation code with other software

Table 3. Comparison and software cost result for case study

REF	Software	Problem	Language	Optimization Method	Software Cost	Usable Resources	Using Other Software	Multi microgrid Structure
[12]	Homer	RA	C++	OFS/PDF	Part Cost	Pv+wind+dg+chp+bat	No	Yes
[26]	Ugrid	D & P	C++	GMC	No Cost	Pv+chp	No	No
[29]	CitySim	P & S	C++	SRA	Part Cost	Dg+wind+chp+bat+pv	No	No
[30]	Der-Cam	OPF	G-CODE	MILP	No Cost	Pv+wind+dg+bat	No	No
[31]	EnergyPro	M & A		MILP	Part Cost	Dg+wind+chp+bat+pv	No	No
[32]	EnergyPlan	P & S	Delphi	No Optimize	No Cost	Pv+wind+dg+chp+bat	No	No
Paper	MLEMS	D & P	VBA	MILP , other	No Cost	Dg+wind+pv+bat	Yes	Yes
Solver Name	Solver Status	Model Status	Objective Value($)	Solver Time (s)	Key : Design and Planning(D&P) -Recourse Arrangement (RA)- Gaussian mean Clustering (GMC)-OFS (original grid search)- P&C (planning and simulation) -OPF (optimal power flow)-PDF (proprietary derivative-free)- SRA (The Simplified Radiosity Algorithm)-M&A(Model)			
Lindo,other	Completion	Optimal	520	0.25				

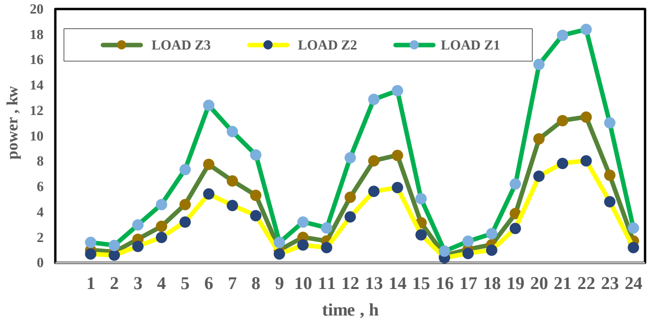


Fig. 4. Load estimation layer result in each microgrid

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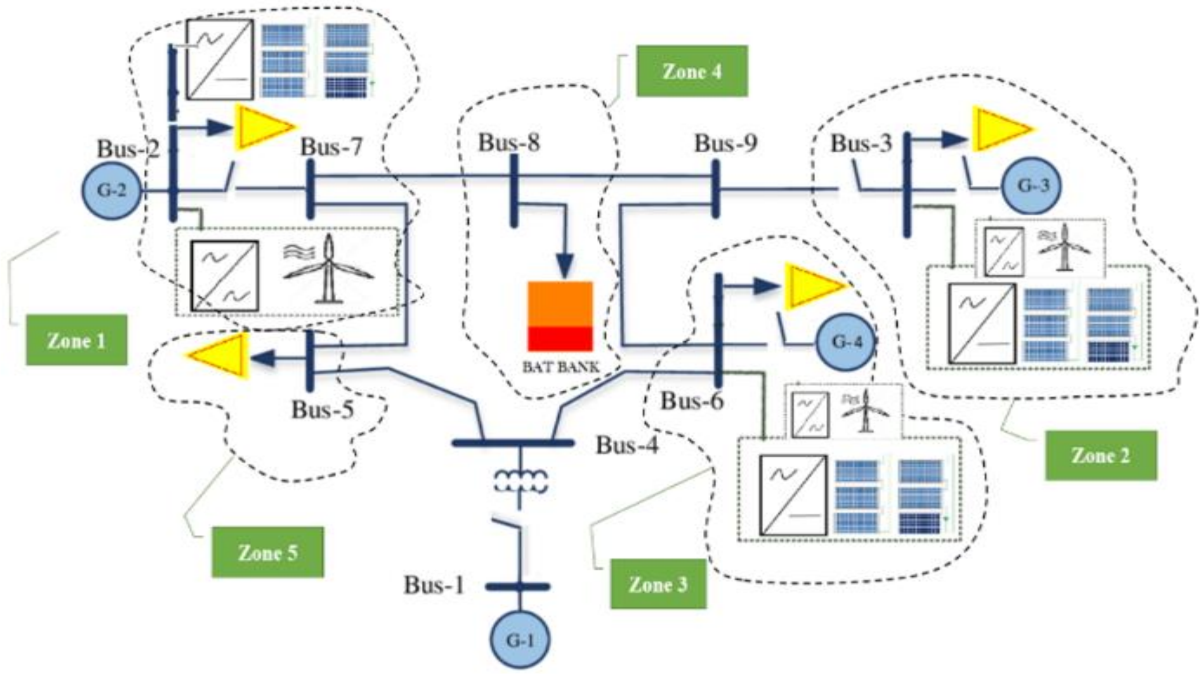

Fig. 5. Proposal microgrid system partition

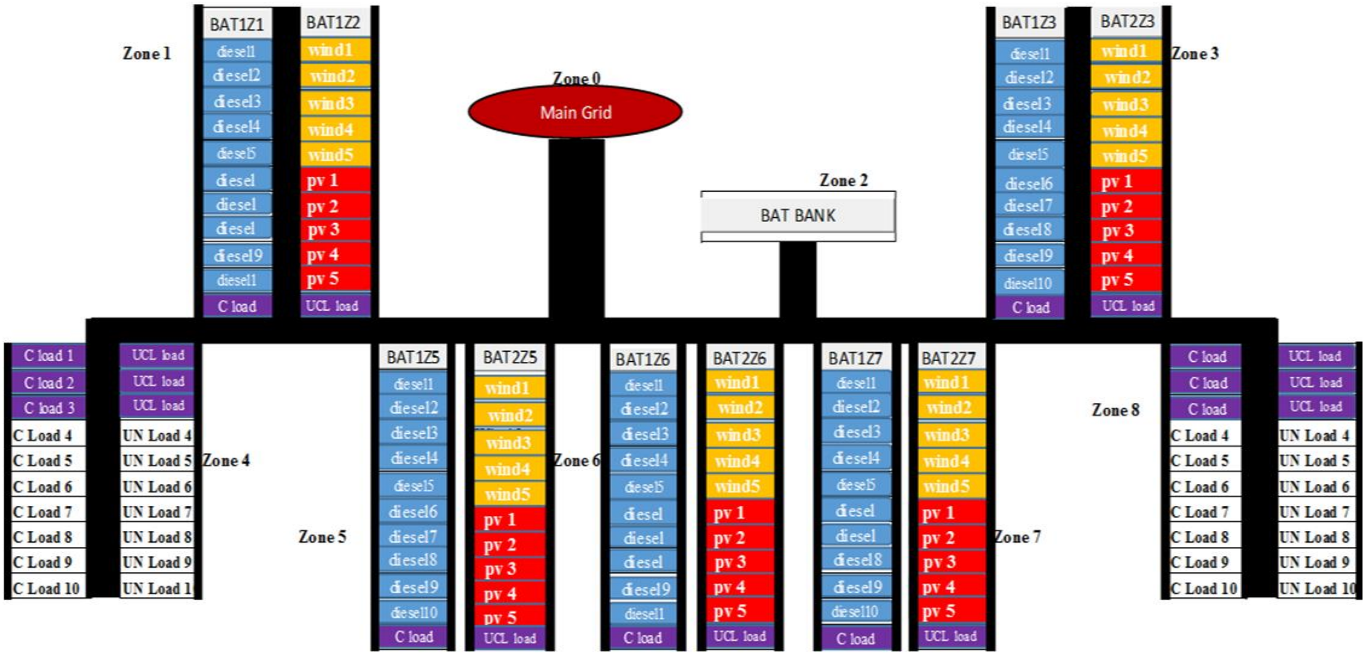

Fig. 6. Make new multi-microgrid structure in software

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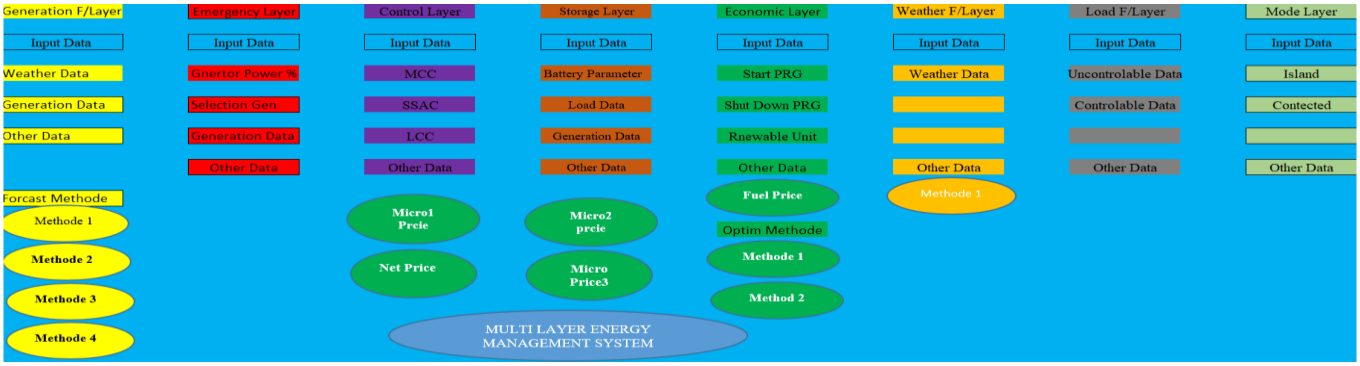
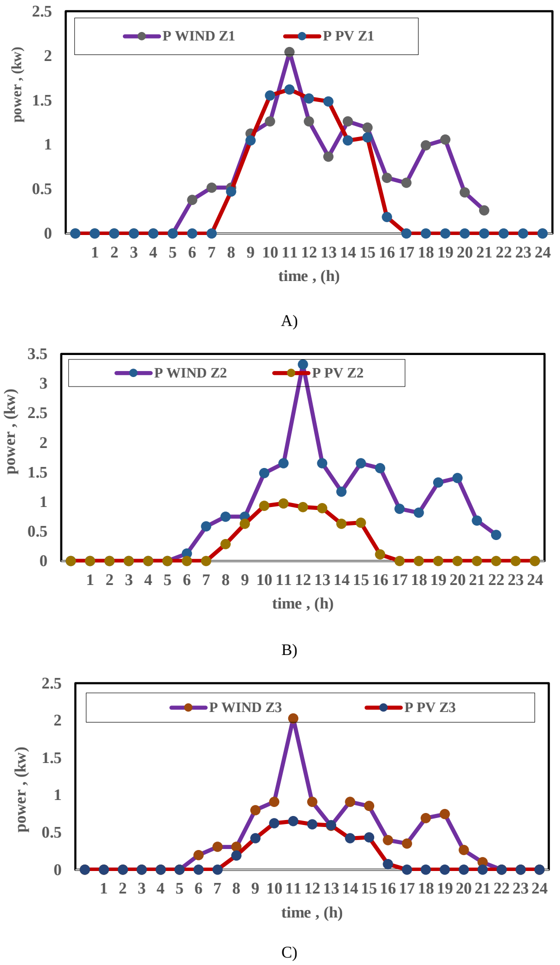


Fig. 7. Different Menu in MLEMS software



A)

B)

C)

Fig. 8. Output of generation estimation layer for each microgrid; A, B, and C show power estimation of microgrid1,2,3, resp

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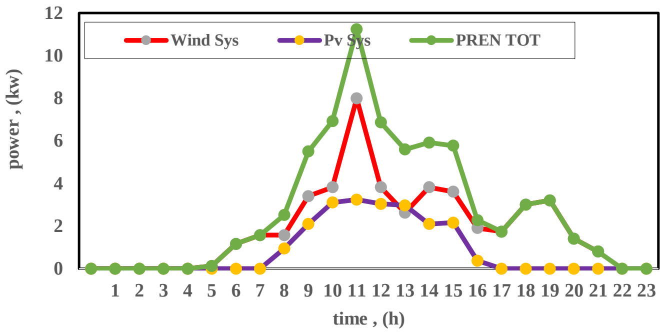

Fig. 9. Total wind, solar and renewable power estimation

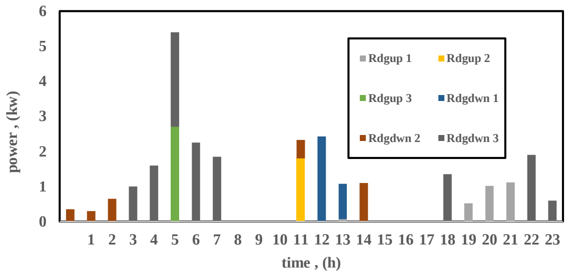

Fig. 10. DG ramp up/down reserve for each microgrid

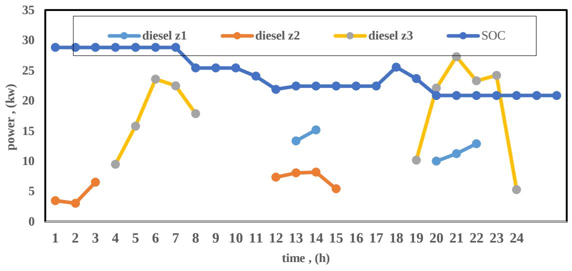

Fig. 11. Output of optimization layer for microgrid

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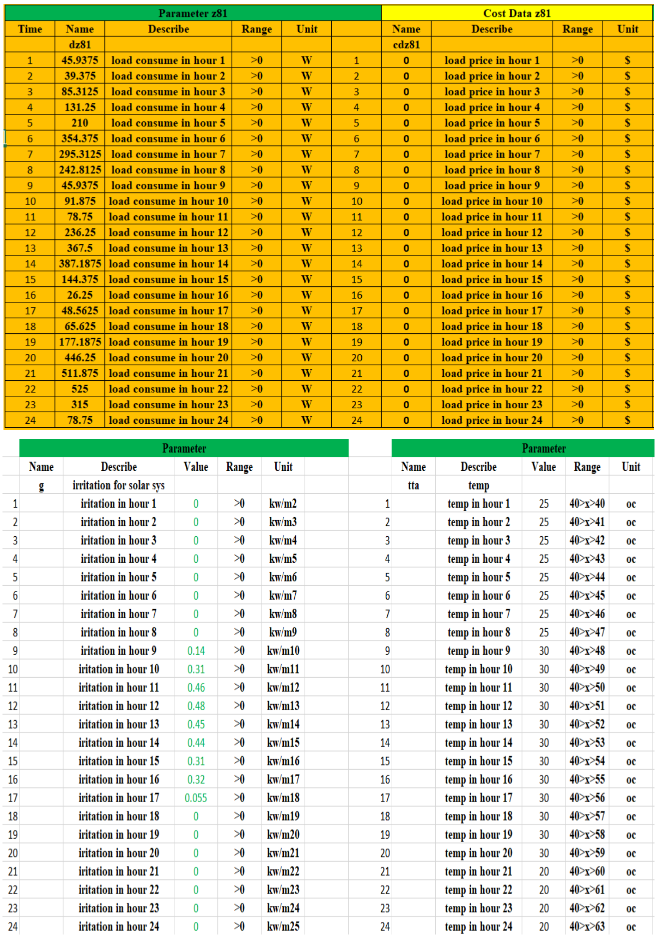

Parameter z81						Cost Data z81			
Time	Name	Describe	Range	Unit		Name	Describe	Range	Unit
	dz81					cdz81			
1	45.9375	load consume in hour 1	>0	W	1	0	load price in hour 1	>0	$
2	39.375	load consume in hour 2	>0	W	2	0	load price in hour 2	>0	$
3	85.3125	load consume in hour 3	>0	W	3	0	load price in hour 3	>0	$
4	131.25	load consume in hour 4	>0	W	4	0	load price in hour 4	>0	$
5	210	load consume in hour 5	>0	W	5	0	load price in hour 5	>0	$
6	354.375	load consume in hour 6	>0	W	6	0	load price in hour 6	>0	$
7	295.3125	load consume in hour 7	>0	W	7	0	load price in hour 7	>0	$
8	242.8125	load consume in hour 8	>0	W	8	0	load price in hour 8	>0	$
9	45.9375	load consume in hour 9	>0	W	9	0	load price in hour 9	>0	$
10	91.875	load consume in hour 10	>0	W	10	0	load price in hour 10	>0	$
11	78.75	load consume in hour 11	>0	W	11	0	load price in hour 11	>0	$
12	236.25	load consume in hour 12	>0	W	12	0	load price in hour 12	>0	$
13	367.5	load consume in hour 13	>0	W	13	0	load price in hour 13	>0	$
14	387.1875	load consume in hour 14	>0	W	14	0	load price in hour 14	>0	$
15	144.375	load consume in hour 15	>0	W	15	0	load price in hour 15	>0	$
16	26.25	load consume in hour 16	>0	W	16	0	load price in hour 16	>0	$
17	48.5625	load consume in hour 17	>0	W	17	0	load price in hour 17	>0	$
18	65.625	load consume in hour 18	>0	W	18	0	load price in hour 18	>0	$
19	177.1875	load consume in hour 19	>0	W	19	0	load price in hour 19	>0	$
20	446.25	load consume in hour 20	>0	W	20	0	load price in hour 20	>0	$
21	511.875	load consume in hour 21	>0	W	21	0	load price in hour 21	>0	$
22	525	load consume in hour 22	>0	W	22	0	load price in hour 22	>0	$
23	315	load consume in hour 23	>0	W	23	0	load price in hour 23	>0	$
24	78.75	load consume in hour 24	>0	W	24	0	load price in hour 24	>0	$

	Parameter				
	Name	Describe	Value	Range	Unit
	g	irritation for solar sys			
1		iritation in hour 1	0	>0	kw/m2
2		iritation in hour 2	0	>0	kw/m3
3		iritation in hour 3	0	>0	kw/m4
4		iritation in hour 4	0	>0	kw/m5
5		iritation in hour 5	0	>0	kw/m6
6		iritation in hour 6	0	>0	kw/m7
7		iritation in hour 7	0	>0	kw/m8
8		iritation in hour 8	0	>0	kw/m9
9		iritation in hour 9	0.14	>0	kw/m10
10		iritation in hour 10	0.31	>0	kw/m11
11		iritation in hour 11	0.46	>0	kw/m12
12		iritation in hour 12	0.48	>0	kw/m13
13		iritation in hour 13	0.45	>0	kw/m14
14		iritation in hour 14	0.44	>0	kw/m15
15		iritation in hour 15	0.31	>0	kw/m16
16		iritation in hour 16	0.32	>0	kw/m17
17		iritation in hour 17	0.055	>0	kw/m18
18		iritation in hour 18	0	>0	kw/m19
19		iritation in hour 19	0	>0	kw/m20
20		iritation in hour 20	0	>0	kw/m21
21		iritation in hour 21	0	>0	kw/m22
22		iritation in hour 22	0	>0	kw/m23
23		iritation in hour 23	0	>0	kw/m24
24		iritation in hour 24	0	>0	kw/m25

	Parameter				
	Name	Describe	Value	Range	Unit
	tta	temp			
1		temp in hour 1	25	40>x>40	oc
2		temp in hour 2	25	40>x>41	oc
3		temp in hour 3	25	40>x>42	oc
4		temp in hour 4	25	40>x>43	oc
5		temp in hour 5	25	40>x>44	oc
6		temp in hour 6	25	40>x>45	oc
7		temp in hour 7	25	40>x>46	oc
8		temp in hour 8	25	40>x>47	oc
9		temp in hour 9	30	40>x>48	oc
10		temp in hour 10	30	40>x>49	oc
11		temp in hour 11	30	40>x>50	oc
12		temp in hour 12	30	40>x>51	oc
13		temp in hour 13	30	40>x>52	oc
14		temp in hour 14	30	40>x>53	oc
15		temp in hour 15	30	40>x>54	oc
16		temp in hour 16	30	40>x>55	oc
17		temp in hour 17	30	40>x>56	oc
18		temp in hour 18	30	40>x>57	oc
19		temp in hour 19	30	40>x>58	oc
20		temp in hour 20	30	40>x>59	oc
21		temp in hour 21	20	40>x>60	oc
22		temp in hour 22	20	40>x>61	oc
23		temp in hour 23	20	40>x>62	oc
24		temp in hour 24	20	40>x>63	oc

Fig. 12. Appendix (1)- Part of the information in the software various menus