wjert, 2021, Vol. 7, Issue 6, 38-52. *Review Article* ISSN 2454-695X

World Journal of Engineering Research and Technology

WJERT

www.wjert.org Impact Factor Value: 5.924

WATER HEATER THERMAL MODELING FOR LOAD SIDE MANAGEMENT STRATEGY OF SOLAR PHOTOVOLTAIC ON GRID /OFF GRID SYSTEMS

[1]*M. Abouelela, [2]Mohammed Jawad Al-Nakhli and [3]Abdullah M. Al-Shaalan

[1]Professor, Electrical Engineering Dept., King Saud University, Saudi Arabia.

[2]Project Manager, RenewableEnergy Project Development Office, Ministry of Energy, Saudi Arabia.

[3]Professor, Electrical Engineering Dept., King Saud University, Saudi Arabia.

Article Received on 01/09/2021 **Article Revised on 21/09/2021** **Article Accepted on 12/10/2021**

***Corresponding Author**
Prof. M. Abouelela
Professor, Electrical Engineering Dept., King Saud University, Saudi Arabia.

ABSTRACT

This paper presents thermal modeling of water heaters for Load Side Management (LSM) strategy for household appliances energized through PV system. Our objective is to enhance the dependency on the solar power while reducing power consumption from the grid. The proposed thermal model of the water heaters helps the LSM control to manage the power available from the solar PV in order to optimize the function of grid connected PV systems. The concept of controlling power delivered to certain heavy loads while keeping their function has been recently introduced and applied. The inverter type air conditioning units use this concept to reduce its power consumption. In this work the concept is applied to the water heater where the power supplied to the heater is depending on the power availability from Solar PV. In the developed solution here, the power delivered to the heater is controlled according to the energy available from the PV source. The model uses PWM (Pulse Width Modulation) to control heating power. The model considers, the heating time of water to a certain temperature as an argument for the control algorithm. The developed algorithm continuously measures available solar power and uses the heater thermal model in order to generate the suitable PWM signal that controls the energy delivered from the grid when needed. The algorithm was tested using Matlab Simulink and the simulation results show the validity of the proposed technique for Load side

managements. The algorithm is suitable for both on grid and off grid connections.

KEYWORDS: LSM strategy, PV system, PWM, on grid, off grid, Water heaters.

I- INTRODUCTION

The residential sector is considered as one of the most electricity consuming sectors related to other sectors. In some countries it reaches up to 60% of its total consumption (Kallel et al..2015). In order to overcome the peak demand, despite the greenhouse-gas emissions governments get attention to the investment in constructing new traditional power plants with upgrading transmission and distribution network. In the last decade the growing demand for energypresents a serious financial problem to several governments. In their turn, the end users are charged by extra cost due to the high increase in the electricity bill. They are always in need of effective solution that optimizes their consumption in order to limit the raise in the electricity bill. Nowadays, Renewable energy has become attractive solutions of producing energy at low cost, including solar and wind sources (Zhou et al..2015). LSM helps consumers in reducing electricity cost by scheduling the power consumption. Among the renewable energy sources, PV conversion is an excellent solution and has been widely spread. It has several advantages on other sources like: the availability of the sun irradiance around the world, no pollution, its noiseless operation, and low maintenance cost (Ayodele et al..2017). In 2018 only, the total capacity has been grown by 24% with total capacity installed worldwide around 94 GW (IRENA 2019). Recently, the integration of solar PV sources into the distribution network in several countries highly helps in facing the problem of the high demand of electrical energy. Load Side Management (LSM) with PV Solar is very useful when utilizing the solar PV power in distributed generation (DG) for homes. LSM algorithms try to make the peak time of the residential sector identical to the peak solar energy which will contribute in reducing the peak load on the power network. For this purposes governments are planning to add more PV installation in the residential sectors.

I.1 Load Side Management (LSM) & Home Energy Management System (HEMS)

- LSM may be considered as one of the methodologies used for establishing global HEMS. HEMS are developed to improve energy efficiency in homes and buildings (Abouelela, M.abouelela 2015). Additional goals may include electric utility benefits, such as fair energy distribution (Abouelela, M.abouelela 2015), controlling energy usage to reduce peak demand and support load shifting (Bin-Halabi et al..2018). Another application of HEMS is to ensure effective strategy to prevent power transformer overloading (A. Bin-

Halabi et al. 2018). In (Bin-Halabi et al. 2019). HEMS is used for remote detection and identification of illegal consumption of grid Power. In HEMS the heavy loads are connected to the power source using controlled switches (Abouelela, M.abouelela 2015). The states of these switches may be remotely controlled in such a way to keep the home power consumption within a certain limit that meets user satisfaction and grid capabilities. LSM is addressing the user side without taking into consideration the electric utility benefits. So in LMS the switches are controlled according to an algorithm that considers only the rules imposed by the user side regard less the utility side precautions. For Solar PV household systems LSM is of great importance in order to enhance the money payback of a given installation. The related studies mainly include issues of developing, modeling, simulation and optimization of LSM at each level. Various LSM techniques have been developed and simulated in order to guide consumers towards an economic choice (Pina André et al. 2012). Several Comprehensives studies on LSM were conducted to manage power for rural area applications in order to maximize the benefit of the renewable energy resources due to technical issues associated with grid expansion to the remote areas and the high cost required (Zhou et al..2015; Bin-Halabi et al. 2019). On other hand, for the renewable energy grid connected applications, many studies were introduced in order to get the benefit from the grid in selling the surplus energy and to charge the battery from the grid if needed. In (Kallel et al. 2015) the author proposed to economically schedule the power consumption in small scale applications to reduce electricity cost. LSM PV solar energy or power supplied from the grid can be stored in case PV generates surplus power or when the grid electricity is inexpensive. The stored energy may be managed economically for usage if the electric authority decides to raise the tariff at peak load periods, or when the PV power is unavailable (André et al.. 2012). LSM control algorithm is developed in order to satisfy a costumer plan tasks in order to optimally utilize the generated power from the PV system (Stathopoulos et al.. 2014; Abedia et al..2012; Juan et al. 2012; Logenthiran et al.. 2012; Matallanas et al.. 2012).

In (Baldauf 2015) the LSM strategy introduced by the author for a PV roof top installed in residential household helps in reducing electricity costs for the consumer and also power losses of the grid. A novel LSM algorithm is proposed to manage solar PV intermittency in a building (Sivaneasana et al.. 2018). The proposed algorithm controls the building air conditioning and mechanical ventilation (ACMV) system, in such a way to force the load demand of the ACMV to be equal to the drop of solar generation by controlling the fan speed.

Three different scenarios were discussed and the results showed that the algorithm provides a cost effective solution compared to utilizing large energy storage system or complicated solar forecasting system.

In this paper, LSM control algorithm for household appliances is presented and discussed. The proposed model is based on defining a certain dynamic threshold level for the power difference between the available PV power and the load demand at a given instance .The algorithm starts by gradually reducing the power delivered to certain loads instead of a complete power cutoff The complete power cutoff may also be applied for other loads that do not accept low operative power level. Classifications of heavy loads that may work or not work at reduced power level will be given in the next section.

II-PROPOSED LSM STRATEGY

Fig.1 represents a simplified LMS configuration where the target of the controlling algorithm resident in the Program Management Control unit (PMC) is to find to an effective load profile to reduce the consumer bill electricity. This may be done by minimizing power supplied from the grid when there is PV intermittency. The proposed model of LSM control compensates the reduction of power generated by solar PV system from its rated capacity by reducing the power consumption of the variable heavy loads depending on the power availability from Solar PV.

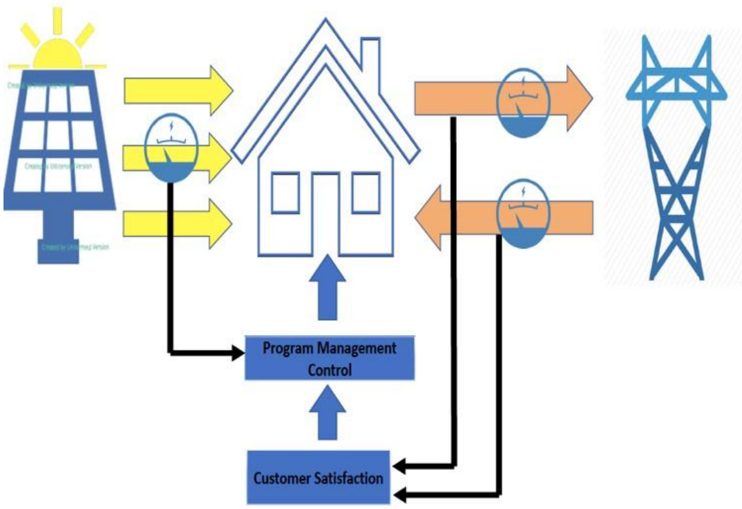

Fig. 1: a simplified LMS configuration (Al-Nakhli, Abouelela 2020).

Fig.2 gives the flow chart that summarizes the algorithm. In this work we will consider the water heater as the heavy load that can work at reduced power rate without stopping its function. Of course the heating time will be affected; a complete analysis for the water heater behavior will be given later. Thus, the developed solution depends on managing both delivered power and heating time while taking into consideration the available power from the PV supply. The following definitions are used for the parameters processed by the algorithm:

EWH: Electric Water Heater

P_{PV} is the power available from the installed PV array for the household at a given instant,

P_{Load} is the total power demand by the household at a given instant = P_{PV} + the grid power.

P_{hmin} = minimum operated power of EWH while keeping its function effectively.

P_H = the heater rated power,

$P_{diff} = P_{PV} - P_{load}$

P_{th} is a power threshold reference value which set previously by the consumer and defined as the maximum power allowed to be supplied from the grid in case P_{PV} is not sufficient to the load demand. Actually P_{th} determines and reflects how much money the consumer wants to save in a given time interval. It is a dynamic input to the algorithm and can be selected by the consumer based on his satisfaction and his budget.

(OFLi) is the ON/OFF loads reference. i = 1, 2,…n where n is the number of on/off loads Furthermore, we have three load situations to be considered. These situations are summarized in table 1.

In case P_{PV} is very small or equal to zero, the absolute value of P_{diff} will be highly greater than P_{th} so we can raise P_{th} to a certain level defined by the customer to avoid power disconnection of all loads. The decision of raising P_{th} or keeping it is left to the consumer who can select between constant energy saving option and his satisfaction of operated loads. This case is not considered in this work, only we considered the case when P_{PV} is not less than 60% of its rated value which corresponds to 1000W/m^2 irradiance and 25^{o}C temperature.

This strategy will ensure that the amount of power supplied by the grid to the household will remain almost constant and not affected by the decreasing of the solar power.

A simple control circuit based on using PWM (Pulse width Modulation) can be used to control the power delivered to the EWH. A single-phase full wave ac voltage controller circuit shown in Fig.3.The Thyristor switches T1 and T2 are turned on by applying appropriate gate trigger pulses during the time interval t_{on} and off during the time interval t_{off}.

P_{load} at a given instant = $P_{fulload}$ (ton /ton +toff) (1)

Where $P_{fulload} = V^2_S / R_{heater}$ (2)

R_{heater} is the heater equivalent resistance in Ω. Vs is the RMS value of the supply voltage.

In this LSM strategy, loads are classified as:

- Heavy controllable loads: defined as loads which have high rating power and their consumption may be reduced by using power control electronic circuits. These loads keep working but with less effective performance. For example, the fan speed of an air conditioner, the cooling rate of refrigerator, heating time of the water heater and electric Kettle etc.… . Table 2 shows some typical such loads with the measured factors that may be affected due to working under lower power rate.

- on/off loads: defined as loads which do not work correctly or stop working at all if lower power rate is used such as lights, TV etc…. It is to be noted here that any of the loads given in table 2 can also be classified as on/off load according to the customer satisfaction.

The dependence of the power supplied to a 3 KW EWH on the firing angle of thyristors T1 andT2 is given in Fig.4.

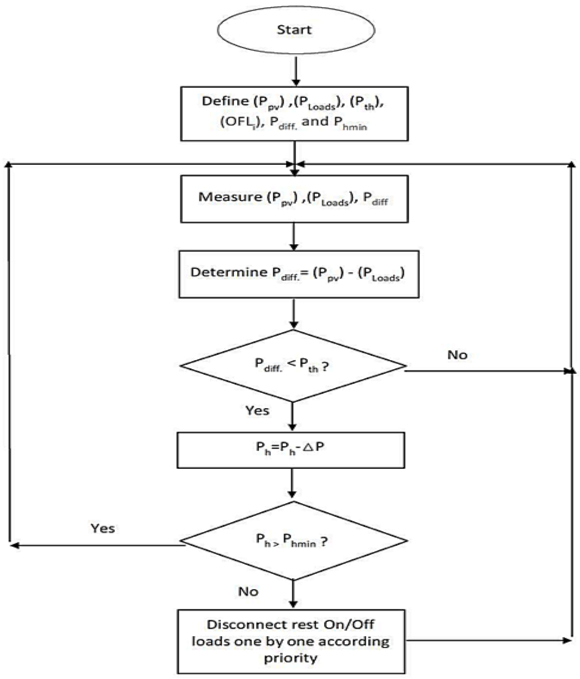

Fig. 2: Flow chart of the proposed algorithm.

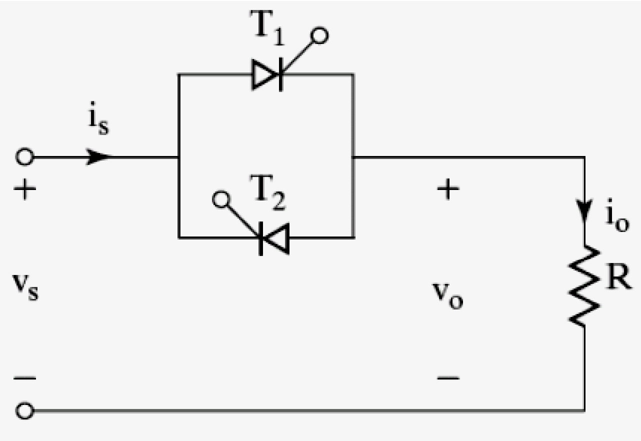

Fig. 3: Single phase full wave AC voltage controller circuit (Dos Santos, Krause 2017).

III- Analysis and Simulation Results

III.1 Off Grid Case Study

In a given off grid system connected in a residential home, the PV power available at a certain instant is 2000 W and the system employs a 3 kVA inverter with 0.8 power factor. The attached loads at that instant are 600 W which is within the PV power range, so the PV array supplies the all needs of the loads. Now if 1500 W kettle is turned on, the total needed power is 2100 W which exceeds the available power from the PV array. In this case the inverter will go into the bypass mode (supply all the 2100 W from the grid) in order to meet the load demand. Since the inverter supplies all the power from the grid the customer will lose the 2000 W available from the PV array during the working time of the kettle. If the LSM system described above is used, the kettle power can be reduced by using appropriate firing angle that makes the kettle consumes only 1400 W. In this case the overall loads (including the kettle) will consume 2000 W and the inverter keeps supplying the power from the PV source without going into the bypass mode. Also, if the PV power is reduced again or the load demand is increased above that available from the PV source the control algorithm will compensate for this action by reducing the kettle power again while keeping all other loads working normally.

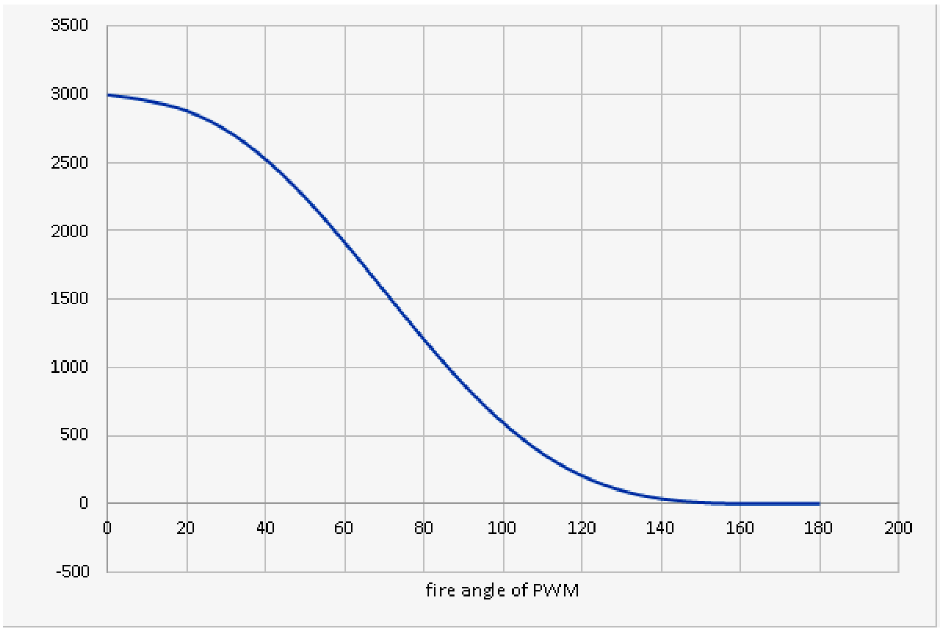

Fig. 4: Dependence of a 3KW EWH power on the firing angle of the PWM.

III.2 On Grid System Case Study

The on grid system case study is tested and analyzed using MATLAB Simulink. The LSM model has been developed for a household PV grid connected system of size 12 KW. The simulation considers several different on /off loads and one heavy controllable load which is the EWH that is presented in the simulation as a resistive load. Also, the model contains the PMC block and different meters to monitor the power, voltage and current measurements also screens to check the validity of the graphs obtained by each scenario, Fig.5 shows the MATLAB Model of the EWH that is used through the simulation.

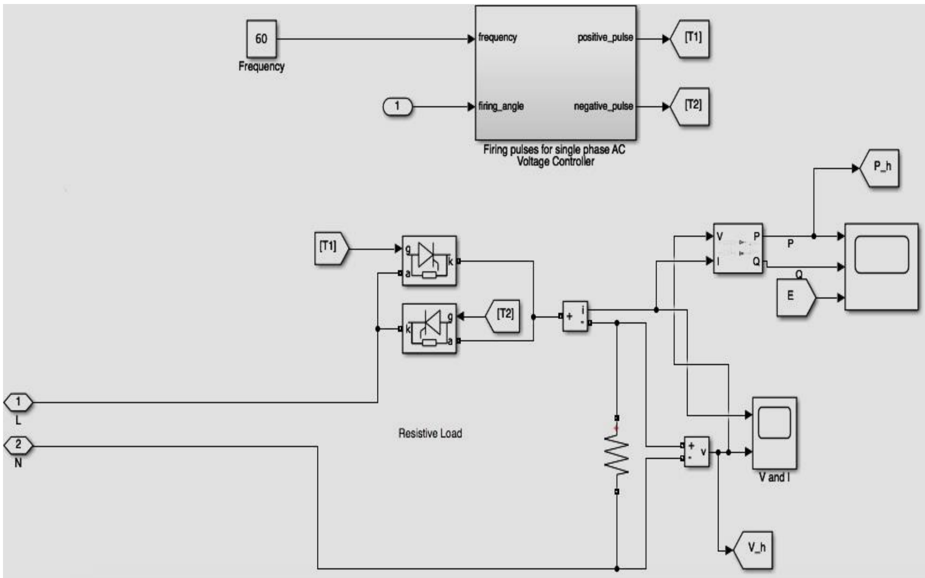

Fig. 5: The MATLAB Model of the EWH using PWM.

III.2.1 Thermal Model Results of EWH

In order to achieve more realistic control for the proposed LSM, the thermal behavior of the heater must be considered. If the thermal power dissipation approaches the input electrical heating power, there is no meaning of keeping the heater on. So, if we take this condition into consideration, we can define a certain heater power level at a certain firing angle at which we disconnect the heater completely. The heating time is also an affecting factor because even if the difference between the heater input electrical power (P_{inh}) and the thermal power loss is small, the heating time will be increased. The heating time is one of the parameters affecting the consumer satisfaction and priorities and must be considered in the LMS algorithm.

Table 3 gives a summary of the results that describes the dependence of the heating time and the standby losses of the water on the fire angle of the PWM. These results can be used to define the satisfaction level of the consumer and his preferences.

The formulas used in the thermal model is defined in equations 3 and 4

The energy required to heat water is given by the equation 3:

$E = (\Delta T * \text{Volume of water} * 4184)/3600$ (3)

Where E is the heating energy in joules, ΔT is the temperature difference in ^{O}C, water volume in liters.

Notice that $\Delta T *$ Volume of water gives the energy in calories and we use the relation:

1 calorie is equal to 4.184 joules.

Assuming that heater size is 50 Liters and we would like to raise temperature from 20 ^{O}C to 80 ^{O}C, then the energy required E to raise a 50 liter of water from $20^{O}C$ to $80^{O}C$ is:

E = (80 - 20)* 50*4184/3600= 3.48667 kj = 3.48667 kWh (4)

To calculate the heating time for a given rated power equation (5) is used:

Heating time = Energy require (Joule) / Rated heating power (W) (5)

For EWH working at 3kW rated power the heating time will be: 1.16222222 hrs.

Most of the commercial EWH has thermal losses factor ranged from 10% to 25 % of its rated power depending on its thermal isolation. This makes the real heating time longer than calculated in equation 5. In the data sheets of a given EWH a parameter called the Standby loss (H_{loss}), defined as is the amount of energy consumed by a tank-type water heater to maintain temperature of water when no hot water is being drawn from tank.

For the 3KW heater considered here if we take the worst case of thermal losses:
Standby loss (H_{loss}) = 25%* rated heater power = 3000*0.25= 750 W.

Of course if we consider the Standby loss in our model it is not worthy to still keeping power on to the EWH at rates slightly greater than H_{loss}. In such case the heating time will be too long. From table 3, as a conclusion of the simulation results, up to 60^o firing angle the heating time is fairly acceptable while from 60^o to 80^o it is relatively high and may be not accepted by the consumer due to nonsatisfaction. For fire angle above 80^o thermal deception will occur and we must stop using PWM and go to a complete disconnection of the EWH from the power source.

III.2.2 Simulation results

The model was simulated several times starting from fire angles 10^o to 180^o to evaluate the results and find the optimized solution which satisfies the consumer. Some selected results are given below to explain the behavior of the proposed algorithm using PWM control. Fig.6 gives an example where the threshold level (P_{PV} –P_{load}) is set to - 2500 W (at maximum only 2500 W is supplied from the grid). The simulation results displays the situations where P_{diff} exceeds 2500 W. These are the regions on the curve below the red horizontal line; the algorithm set the firing angle to 30^o to reduce the P_{inh} to 2700 W which makes the total power consumption reduced while keeping the condition of $P_{diff} <= P_{th}$. If the reduction of the heater power is not enough to compensate for the shortage in the PV power the on /off loads may be disconnected in sequence according to the priority set by the consumer as shown in fig.6 for loads 1 and 2.

The arrows refer to the regions on the PV power curve where $P_{diff} < P_{th}$, P_{inh} is reduced to 2700 and Load 1 and Load 2 is turned off. Note that there is a slight time delay for the action taken by the algorithm; this is due to its processing time on the Simulink. Fig.7 gives the same results but when the algorithm set the firing angle to 50^O. Comparing Fig.6 and Fig.7 we can notice that for the same power / time profile for P_{diff} the time intervals where load 2 and also load 1 are being off is generally reduced while keeping the EHH working at reduced P_{inh}. Of course this is the main objective of this work which is to keep most of the loads working most of the time while keeping minimum power supply from the grid.

Fig.8 gives the situation when the firing angle is set to 80^O, the heater power is about 1200 W but the heating time is increased to about 2.9 hours. Although P_{inh} is still greater than the standby loss; it is the customer decision to keep this condition or completely off the heater. Fig.9 shows the condition when the heater is completely off when P_{diff} become highly greater than P_{th} and its not accepted to keep the heater working at very low power rate.

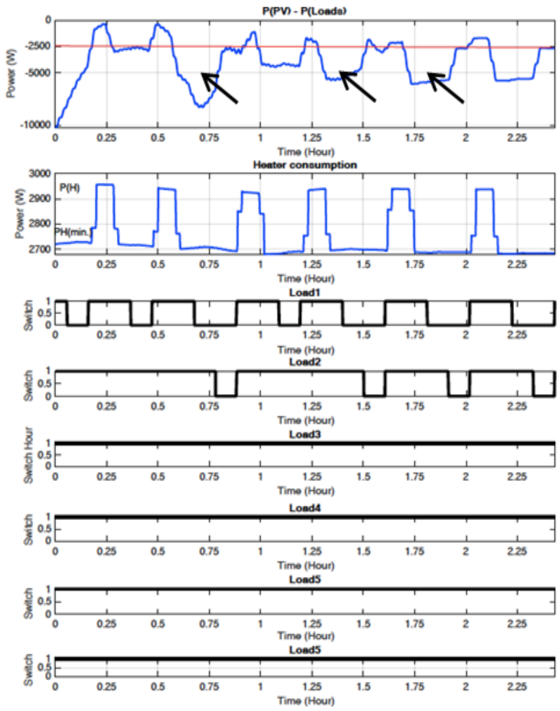

Fig.6 Simulation results at firing angle = 30^{O}

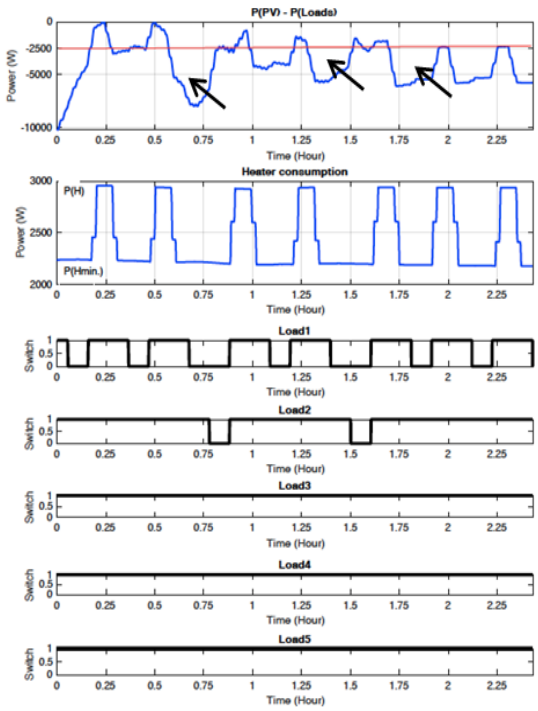

Fig.7 Simulation results at firing angle = 50^{O}

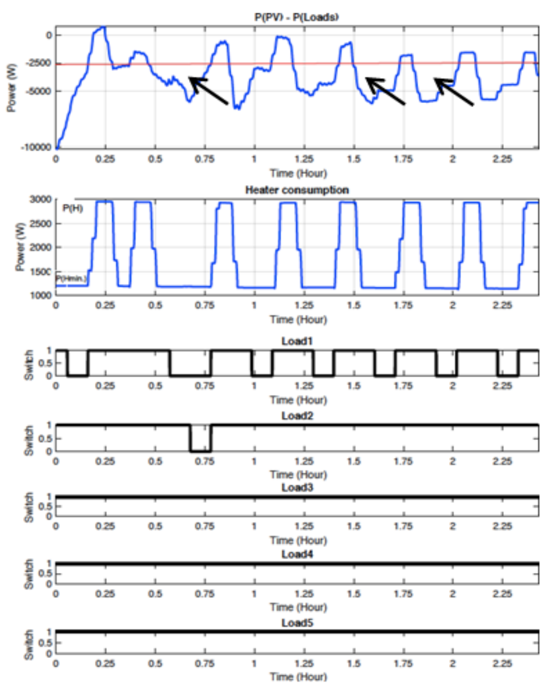

Fig.8 Simulation results at firing angle = 80^{O}

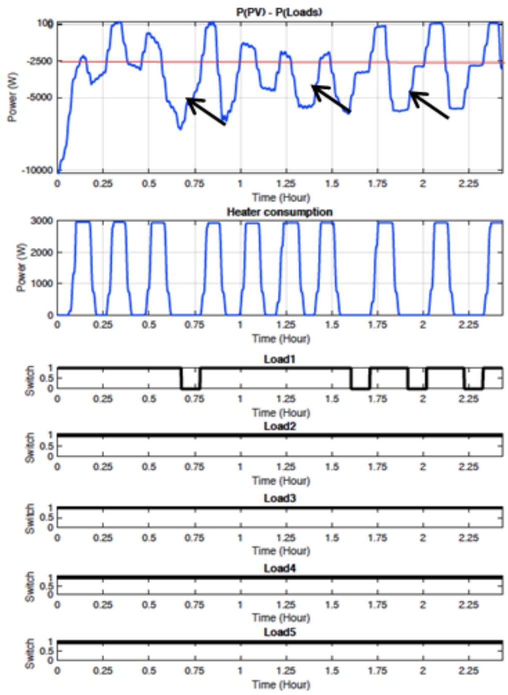

Fig.9 Simulation results at firing angle = 180^{O}

Table 1: **Different situations and action taken.**

S.No	Situation	Action Taken
1	$P_{load} < P_{PV}$	Keep all loads on
2	$P_{load} > P_{PV}$ & (absolute of P_{diff})< P_{th}	Keep all loads on
3	$P_{load} > P_{PV}$ & (absolute of P_{diff}) > P_{th}	Start reducing the power delivered to the water heater by □P_h and test again, if still $P_{diff} > P_{th}$ start disconnecting on/off loads according to the priority defined by the consumer until the situation $P_{diff} < P_{th}$ is fulfilled.

Table 2: Some typical loads that may be affected due to working under lower power rate.

S.No	Appliance	Measured factor 1	Measured factor 2
1	Water heater	Temperature	Heating time
2	Washing machine	Temperature	Spin revolutions
3	Dishwasher	Washing parameter	NA
4	Oven	Temperature	Cooking time
5	Refrigerator	Temperature	Cooling rate
6	Deep Freezer	Temperature	Cooling rate
7	Air conditioning	Temperature	Cooling time

Table 3: A summaries of the dependence of the heating time and thestandby losses of the water on the fire angle of the PWM.

S.No	Firing angle degrees	Heater power (P_{inh}) W	Heating time hours	Compared to standby loss
1	0	3000	1.16222222	Accepted
2	10	2956	1.17952188	Accepted
3	20	2882	1.209808	Accepted
4	30	2741	1.27204183	Accepted
5	40	2526	1.38031143	Accepted
6	50	2246	1.55238943	Accepted
7	60	1916	1.8197634	Accepted
8	70	1560	2.23504274	Strictly Accepted up to consumer
9	80	1206	2.89110006	Strictly Accepted up to consumer
10	90	700	3.97567465	$< H_{loss}$ not Accepted
11	100	595	5.85994398	$< H_{loss}$ not Accepted
12	110	369	9.44896116	$< H_{loss}$ not Accepted
13	120	205	17.0081301	$< H_{loss}$ not Accepted
14	130	98	35.5782313	$< H_{loss}$ not Accepted
15	140	37.55	92.8539725	$< H_{loss}$ not Accepted
16	150	10	348.666667	$< H_{loss}$ not Accepted
17	160	1.23	2834.68835	$< H_{loss}$ not Accepted
18	180	0	Not defined	$< H_{loss}$ not Accepted

IV CONCLUSION

Load side management is an effective solution to optimize the load demands in economic way in order to contribute in limiting the raise in the electricity bill. The proposed strategy of LSM helps the consumer in getting the payback in less time by reducing power supplied from the grid. The performance is applied on both off grid and on grid systems where the mathematical analysis and the simulation results confirm the validity of the proposed algorithm. Using PWM the load power can be controlled while keeping the function for some types of heavy loads. The results show different intermittency occurs on the loads due to the constraints requested by the consumer. The proposed strategy of LSM model aims at compensate the shortage of the solar PV power by first controlling the firing angle to a value that reduces the heater input power and keeping the supplied power from the grid below certain threshold value. The next action taken by the LMS algorithm is to go the on/off load control. The main objective of this work which is to keep most of the loads working all over the time while keeping minimum power supplied from the grid.

ACKNOWLEDGMENT

The results and analysis presented in this work is a part of the M.Sc thesis of the Eng. Mohamed Alnakhli (the second Author) under the supervision of Prof. M.A. Abouelela and Prof. A.Alshalan.

The authors would like to acknowledge the Researchers Supporting Project number (RSP-2021/337), King Saud University, Riyadh, Saudi Arabia.

REFERENCES

1. Abedia S, Alimardanib A, Gharehpetianb G B, Riahya GH, Hosseinian S H, "A comprehensive method for optimal power management and design of hybrid RES-based autonomous energy systems", Renewable and Sustainable Energy Reviews, 2012; 16: 1577– 1587.
2. Abouelela M A, Abouelela M M (2015) "Wireless communication role in Home Energy Management system (HEMS), 23rd Telecommunications Forum Telfor (TELFOR). Publisher: IEEE, https://ieeexplore.ieee.org/document/7377448.
3. Abouelela M A, Abouelela M M. "Home Energy Management System (HEMS) for Fair Power Distribution", Advanced Science Letters, 2015; 22(10): 2638-2641(4). **Publisher:** American Scientific Publishers.
4. Al-Nakhli M, Abouelela M, "Load Side Management (LSM) for Solar PV household

System", Test Engineering & Management, January-February, 2020. ISSN: 0193-4120. 5996–6002.

5. André P, Carlos S, Paulo F, "The impact of demand side management strategies in the penetration of renewable electricity," Energy, Elsevier, 2012; 41(1): 128-137.
6. Ayodele T R,. Ogunjuyigbe A S O, Akpeji K O, Akinola O O, "Prioritized rule based load management technique for residential building powered by PV/battery system", Engineering Science and Technology, Elsevier, 20(3): 859-873.
7. Baldauf A. "A smart home demand-side management system considering solar photovoltaic generation". 5th International Youth Conference on Energy (IYCE), 2015; 1-5. IEEE.
8. Bin-Halabi A, Nouh A, Abouelela M, "Interactive Energy Management System to Avoid Rolling Blackouts," 2018 5th International Conference on Electric Power and Energy Conversion Systems (EPECS), Kitakyushu, 2018; 1-7. http://www.epecs-conf.org/.
9. Bin-Halabi A, Nouh A, Abouelela M (2018), "A Simple and Effective Strategy to Prevent Power Transformer Overloading" American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS), 2018; 48(1): 201-214.
10. Bin-Halabi A, Nouh A, Abouelela M, "Remote Detection and Identification of Illegal Consumers in Power Grids" IEEE Access, 2019; 7: 71529–71540, https://ieeexplore.ieee.org/document/8726294.
11. International Renewable Energy Agency (IRENA), Renewable capacity highlights, 31 March 2019.
12. Kallel R, Boukettaya G, Krichen L, "Demand side management of household appliances in stand-alone hybrid photovoltaic system", Renewable Energy, Elsevier, 2015; 81(C): 123–135.
13. Juan M. Lujano-Rojas a, Cláudio Monteiro b,c, Rodolfo Dufo-López a, José L. Bernal-Agustín, "Optimum load management strategy for wind/diesel/battery hybrid power systems", Renewable Energy, 2012; 44: 288-295.
14. Logenthiran T, Srinivasan D, Shun TZ," Demand side management in smart grid using heuristic optimization", IEEE Trans Smart Grid, 2012; 3(3): 1244–1252.
15. Matallanas E, Castillo-Cagigal M, Gutierrez A, Monasterio-Huelin F, Caamano-Martín E, Masa D, et al, "Neural network controller for active demand-side management with PV energy in the residential sector". Applied Energy, Elsevier, 2012; 91: 91(1): 90-97.
16. Santos A D, Krause J, Science Education Research and New Technologies: Chapter 7, Software for Simulation of Static Switch Controllers, 2017; 120-123, eBook (PDF) ISBN:

978-953-51-4626-1, https://www.intechopen.com/books/5845.

17. Sivaneasana B, Kandasamyb N K, Lima M L, Goha K P, “A new demand response algorithm for solar PV intermittency management”, Applied Energy, Elsevier, 2018; 218: 36–45.
18. Stathopoulos M, Zafirakis D, Kavadias K, Kaldellis JK (2014), “The role of residential load-management in the support of RES based power generation in remote electricity grids”, Energy Procedia, 2014; 46: 281–286.
19. Zhou W, Henerica T, Xiaoxhua X, “Demand side management of photovoltaic -battery hybrid system”, Applied Energy Elsevier, 2015; 148: 294–304.