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HIGH EFFICIENCY INTEGRATED SOLAR HOME AUTOMATION SYSTEM BASED ON DC LOAD MATCHING TECHNIQUE

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ABSTRACT

This research proposes novel solutions for utilizing the unavoidable solar system losses by the hypothesis of dispensing the power converters in residential solar system application, which is based on the matching between the source and load. Since the energy source is a direct current DC supply, the matching process has achieved throughout studying the normal alternative current AC appliances and its compatibility to be switched on DC supply, either by direct coupling or simple modification. The work investigates eliminating more than one of the main costly components that is used in the traditional solar powered home system, such as DC-AC Inverter and AC-DC converters. Design and implement of a novel efficient solar charge controller as an alternative to that conventional MPPT one in the traditional solar system. The compatibility of the market loads with DC supply were classified the appliances according to power supply circuit categories. To upgrade the system towards optimum performance achievements, an energy management and monitoring system have been adopted on the system components via a very low power consumption automation technique which is based on a wireless network communication nodes, such as XBee adapted with the automation sensors. All the proposed system components were investigated in three stages; firstly, the proposed alternative solar-battery charge controller stage, secondly, the analysis and selection of the appliances power supply with respect to DC compatibility stage, finally, the wireless low power consumption automation system stage. These phases were evaluated by using Simulink Matlab2013 and verified with experimental data.

Keywords: photovoltaic, solar system's loads, inverters efficiency, power system, power supply, dc load matching.

INTRODUCTION

Although, the most well-known green technologies that include photovoltaic, wind turbines, fuel cells, and other forms of energy that are deemed more environmentally friendly are direct current (DC), Unfortunately, the prevailing power system infrastructures are based on alternating current (AC).

Currently, power system infrastructures of photovoltaic must first convert the DC power produced by these energy sources to AC. This adds complexity and reduces efficiency of the power system due to the need of a power converter. Furthermore, an ever increasing number of DC consuming devices such as computers, televisions, and monitors are being incorporated into our buildings, the power supplied to these devices must be converted again from AC back to DC adding further losses and complexity to the power system. One of the closest idea to this project is illustrated in (Tyson DenHerder, 2006), design and simulation of photovoltaic super system using Simulink , but in [1] the author searches the use of 12V dc load only to avoid using the DC-AC Inverter.

Instead of using multiple converters to convert DC to AC and then AC to DC, the power system could solely be based on DC. This would eliminate the need for two sets of converters for each DC load, reducing the cost, complexity, and substantially increasing for system efficiency.

In this paper, however, a definitive analysis on a DC domestic automated solar system is evaluated and simulated to determine the net benefits of eliminating the converters, such as the main DC-AC inverter and the solar charge controller which is a DC-DC converter, we have taken in to account what modifications should made to matching among the system components that contribute to enhance the system performance.

AC is still the fundamental power type of our power infrastructure, although many things have been changed since the invention of electricity, but, due to the development of power converters and environmentally friendly DC sources, the interest in DC has returned.

There were several studies in this field. A loss comparison between AC and DC distribution and presents a large steady state analysis of an existing AC grid which is constructed along with a DC counterpart. These models are compared in terms of efficiency (A.Baloukts, and Terma Magnesias, 2005). K. Y. Khouzam, in (K. Y. Khouzam , L. Khouzam, and P. Groumpos,1991), a small-localized DC distribution system for building loads is investigated. This power system is supplied by a DC distributed energy source for the DC loads and has a separate AC grid connection for the AC loads. The author relates that this methodology leads to a higher efficiency compared to a system solely based on AC through avoiding the use of the rectifier. The author notes that power rectifiers have a relatively low efficiency compared to inverters and DC-DC converters.

Kou,S.A.,and W.A.Beckman,(1998), investigate DC distribution for a small-scale residential system. The authors note that although conduction losses in a DC system appear to be lower, the efficiency of power converters during partial loading is a concern and can ultimately lead to higher losses in DC. In this study, the load and the supply are fully considered as a DC, and efficiencies of the AC and DC power systems are compared.

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It is worth mentioning that the process of switching to comprehensive DC system has some additional benefits in healthy perspective as mentioned in (R. and Henderson, A. (1987)) and (Department of Pathology Columbia University), because the electromagnetic waves (30-300)Hz surrounding us in our house, office, and closed places of the alternative current (AC) supply has a negative effects on human body as per the scientists studies in this field.

The objectives of this project will focus on developing a very high efficiency solar home automated system which achieves the following:

High efficiency, Low cost, less complexity, and more reliable system.

Enhances the ability and effectiveness of energy saving in Green Power application.

Eliminate more than one of the main costly components that is used in the traditional solar powered accommodation system.

Facilitates the system parameters analysis and energy data managements.

Incorporate the Green DC power supply, because photovoltaic solar cells are attached to DC consumed load throughout the Battery bank directly without additional adaptors.

Opens horizons toward a high efficiency Automated Solar Powered Building by using a very low power consumption communication nodes to access and monitoring sensors data.

Contribute to get rid the doubts of the negative effects of electromagnetic signals on human body via disposing of AC environment.

PROJECT METHODOLOGY

Block Diagram

There were a sequence of steps has been carried out to achieve the goal, it can be briefly described as seeing in figure 1, which represents the block diagram, it is clear that there is no AC inverter or even the normal solar charge controller.

The DC matching method has been implemented on the proposed solar system to investigate the gain that would be attained from this method, the investigation achieved in the following aspects:-

- Solar-Battery charge controller gain; new novel circuit has been used to minimize the conversion losses and complexity as well as contribute with improve the system performance. This would estimate to give about (10-20) % of the total attained energy.

- Eliminating of DC/AC inverter; as the hypothesis of the work is based on the DC matching, there is no need for the existence of the power inverter. This would estimate to give about (60-80) % of the total attained energy.

- Appliances classifications according to DC compatibility and dispensing some AC-DC adaptors. This would estimate to give about (10-20) % of the total attained energy.

Based on the research objectives, the Project Planning Steps were as follows:-

1. Studying the related projects partially or as a comprehensive system to conclude the weak and the strong points of the past work in the same application, utilizing this study to prepare a procedure to analyze the system components individually as a power source or as an appliances by using a Matlab simulation.

2. Investigate the compatibility of the market appliances with DC supply by classifying them according to either the power supply circuit categories, for electronics appliances, or the speed control technique for motorized loads. The modern Inverter technology has been taken in the account in this investigation because it fits more with the work idea as well as to attain more savings.

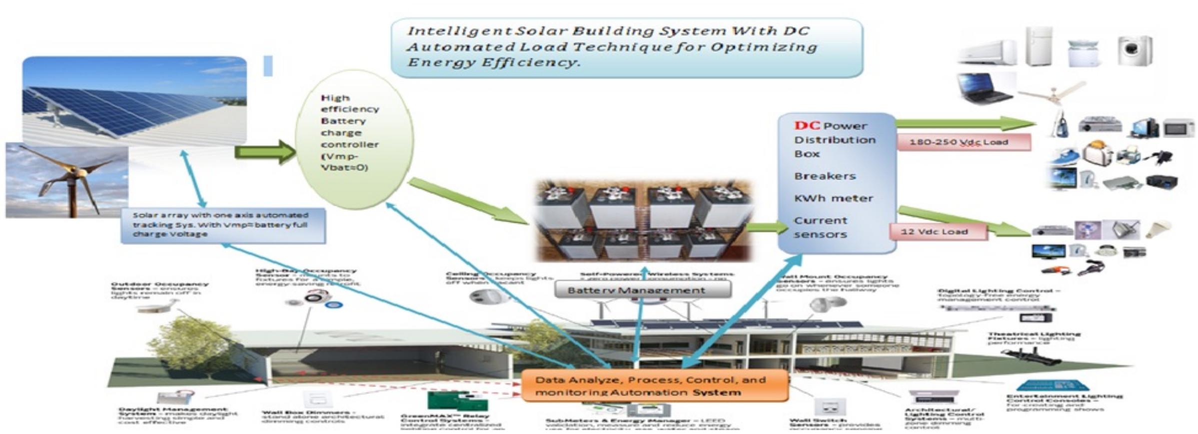

Figure-1. Block Diagram of Intelligent Solar System with DC load technique.

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3. Studying and analyzing of the well-known AC domestic loads, normal and Inverter Technology types, with respect to; operation voltage range, appliance performance, and efficiency improvement when they are switched on DC power source. Power consumption rate analysis would be performed on system components individually and comprehensively.

4. Classifying all the AC home appliances according to their direct DC matching, the appropriate voltage value, and the need or not for modification to be compatible with DC.

5. Data collection, efficiency, and energy analysis have been extracted for all appliances.

6. Comparison in terms of system efficiency and cost for both AC and DC.

7. As an intelligent smart home, a very low power consumption wireless communication sensors driven by XBee nodes are used to manage, control and monitoring the power consumption rate.

8. Building a home prototype that satisfies the objectives of this proposed project with all components to be a study model which is ready for Green Energy Project investment.

Block Diagram and Flow Chart

The block diagram of this proposed project is shown in chapter one with some details in Figure-2, which illustrate obviously the proposed photovoltaic automated solar home system which is recognized from other traditional one by the following points:-

1. Completely DC system, so there is no AC power Inverter used to drive a domestic normal load.
2. Lessening some of main power converters (DC-AC Inverter and some AC-DC converters) and improve the DC-DC converter of the solar battery charge controller by setting the supply voltage up or controlling of some parameters.

3. Low cost with high efficiency and reliability as compared with the traditional one especially if it is designed and established originally based on some parameters like; installation region, environment, material quality, and application.

Alternative Solar-Battery Charge Controller

The main difference between the method used in the proposed Solar-Battery controller and other procedures used in the past, is that solar PV array output power is used directly through a bypass MOSFET to charge the battery bank when the voltage of the battery bank at lower level from its maximum value, while switching on another path when the batteries reaches its full charge value through another MOSFET to transfer this surplus power to what is called as an Auxiliary load ,fans or auxiliary battery used for system ventilation or solar tracking to reduce the ambient temperature for the system components as shown in Figure-3. The two MOSFET's are controlled by the main microcontroller of the solar system with suitable addition of hysteresis to avoid the high frequency switching, so adding more improvements on system performance, this would reduce the complexity of the system on one hand and produce a competitive or alternative low cost circuit as compared with, the MPPT and converter controller.

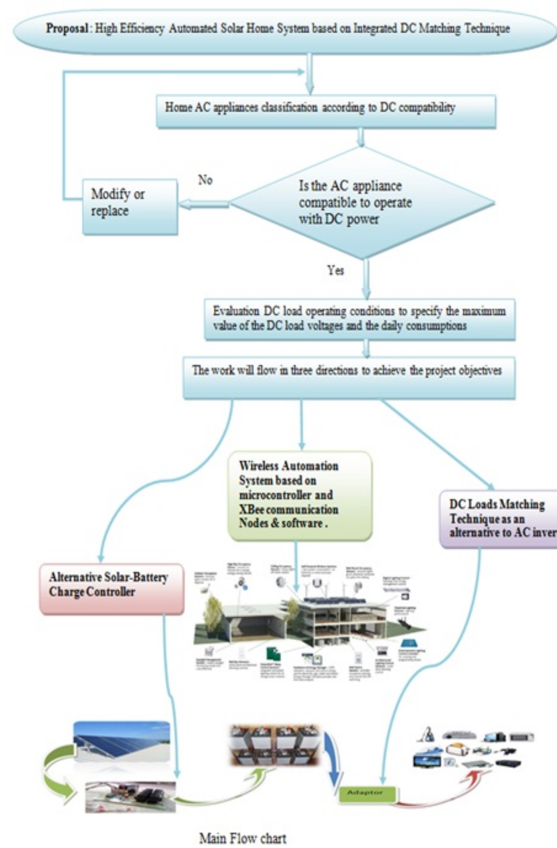

Figure-2. Main Flow chart.

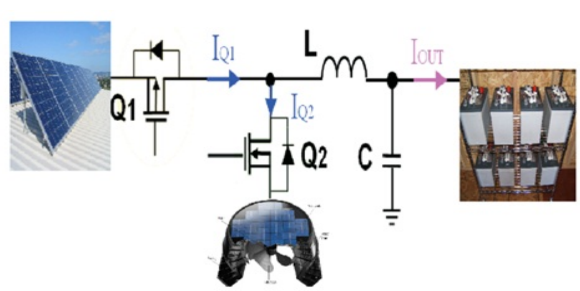

Figure-3. Solar-Battery controller circuit.

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The objective of this part of work is to design a new circuit to control the charging current of the photovoltaic panels to battery bank of the system. This circuit mainly based on this a specific domestic application, and geographical location or the environmental condition parameters that are irradiance and temperature.

A sequence of steps have been carried out in this part of the project to achieve the goal. It can be briefly described as a flowchart shown in Figure-4.

Since this work is a portion of an integrated project in which an automated solar system uses a completely DC load matching technique with efficiency optimization for system performance, so the assumptions of some parameters such as; V_load or V_bmax. Are based on previous components evaluation that would detailed in later subjects from this thesis when a classifications for the home appliances made.The proposed circuit can be shown as a part of a smart automated solar system in Figure-5.

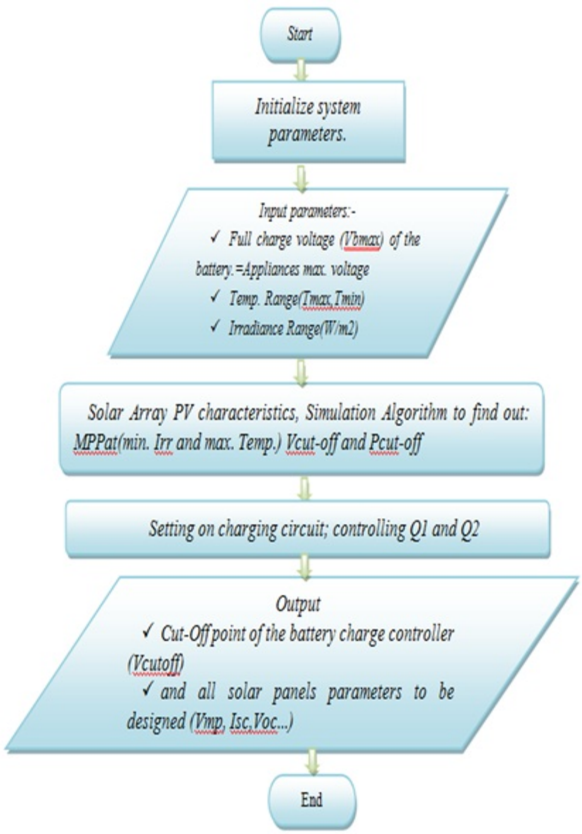

Figure-4. Solar-Battery controller Flowchart.

Figure-5. Showing the location of the proposed Solar-Battery charge controller.

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The full charge battery voltage taken to beV_(bmax.)=162V, which is equivalent to the maximum appliances DC operation voltage.

Based on the application, geographic location and system components operation conditions, specification of variation range has been implemented for the irradiance values and environment temperatures.

VP curves algorithm is curried out for the solar panel array of this particular load voltage which produced the required curves that shown in Figure-6. The algorithm process proposed in this paper and would be illustrated in the next paragraphs.

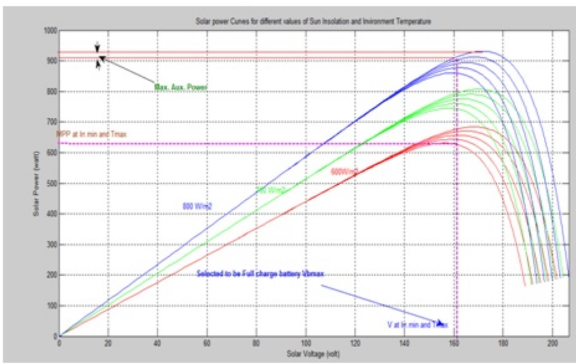

Figure-6: VP curves at different ranges of temp. and Irradiance.

Parameters Evaluation of Solar Array

Referring to Figure 4. After specifying the voltage range of the load (160-180)V, it is taken to be as a battery full charge voltage. The solar power cut-off point can be determined based on:

Vbmax= Vload for the conditions;

Paux=Pmpp-Pc.o @ Irrmin<Irr≤Irrmax & Tmax<T≤Tmin

Paux=0 @Irr=Irrmin & T=Tmax

Where Paux is the auxiliary load power which is appear in Figure-6, (936-913) W, while Pc.o is the power at maximum power point, Irr is the irradiance value, T is the temperature.

A fast and accurate PV system simulator based on the MATLAB-Simulink environment is implemented. An important contribution of this work is the incorporation of a two-diode model as the main engine of the simulator.

Solar Modelling

Figure-7, Shows the attempted representation category of solar cell modelling which is a single solar cell represented by a resistance Rs that is connected in series with a parallel combination of the following elements:

- Current source
- Two exponential diodes
- Parallel resistor Rp

This model is known to have better accuracy, especially at low irradiance levels. As a result, its application allows for a more accurate prediction of PV system performance especially during partial shading conditions.

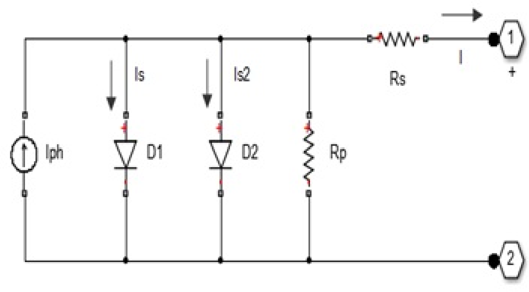

Figure-7. Solar Cell representation with Two Diode.

Simulation of the PV array and Cut-off point

As mentioned above, Vbmax = Vload, which is assigned here as (162)V, the power cut-off point for our system has been found as follows :

Region, point, to be attempted in the design of the cut-off circuit that illustrated in Figure-6.

Referring to Figure-3, together with the software algorithm, we can find out the value of the cut-off point which controls the charging current between the solar array and battery bank.

The algorithm analyses the parameter and gets the peak value of the VP curve at the maximum temperature and minimum irradiance, the voltage at that peak power point should be taken to be equal to battery voltage at full charge Referring to Figure-6, then:-

V_bmax=V_load=V_(cut_off)=V_mp

V_oc=1.25*Vmp

V_mp=162.7 ....at 0.6KW/m²

If Vmp=178.56......at 1KW/m²

Voc=216 ....at 1KW/m²

Where: V_bmax is the full charge battery voltage.

V_load: is the maximum load voltage.

V_(cut_off): is the voltage value at the peak of power curve.

Vmp; is the solar voltage at maximum power.

Voc; is the open circuit PV array voltage.

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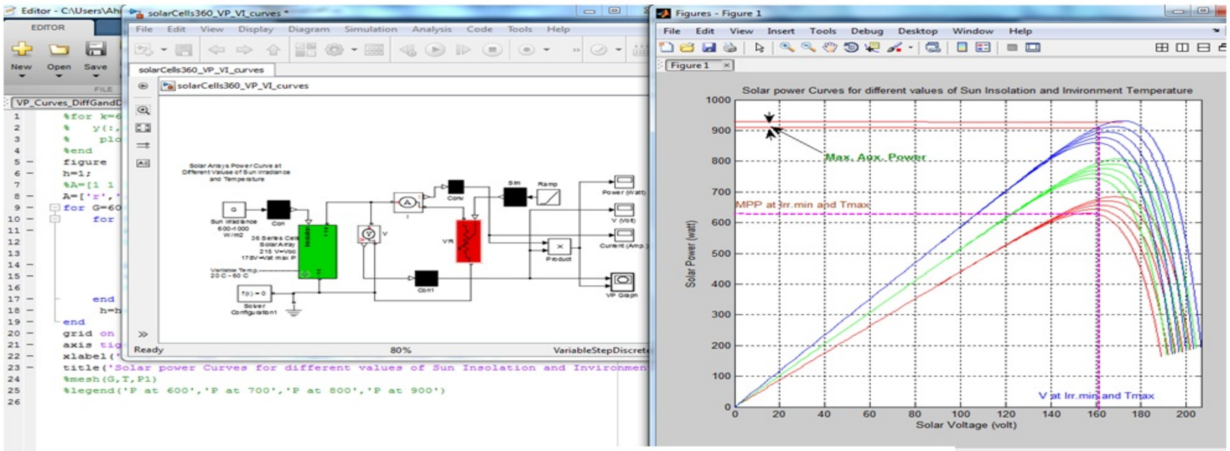

Figure-8. Shows the solar cells arrays evaluation algorithm to find the cut-off.

The power, which is at maximum environment temperature and less sun irradiance, is 162.7V which is apposite to 913 watt of power. Although that the peak value of the power is about 936 watt at 0.85KW/m² irradiance, the cut-off circuit is more efficient, because it utilizes the over power voltage, which is generated mostly at high temperature, to energize cooling fans of auxiliary load. It is consider being more reliable because the electronic switching component of the circuit is working only after this region to change the direction of the charging current towards the auxiliary system load. This work proposed a MOSFET transistor switching circuit that satisfy the use of all possible power of the solar panels without components complexity.

As mentioned earlier V_bmax has been taken to be the voltage at maximum power and to be at maximum mean temperature and minimum mean irradiance, in this case at 50 ^{0}C temp. and 600 W/m².

After the Cut-off region, the difference, like (936-913) is used to energize the auxiliary load of the system, hence; the auxiliary load voltage range between 0-Voc, as shown in the MATLAB Simulink simulation in Figure-9, while Figure-10, illustrates the curves of the main output voltages to charge the battery bank with Irradiance variation, and the auxiliary one to supply the system ventilation components or can be used for another purposes.

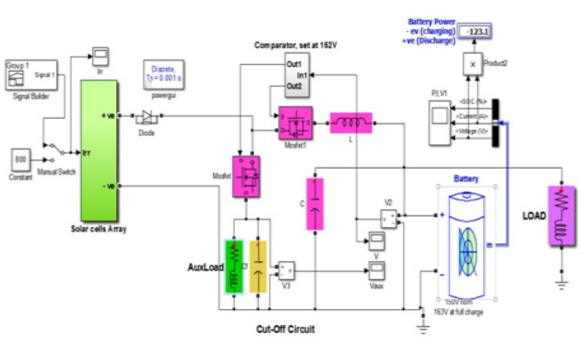

Figure-9. Simulation diagram of the Cut-Off circuit.

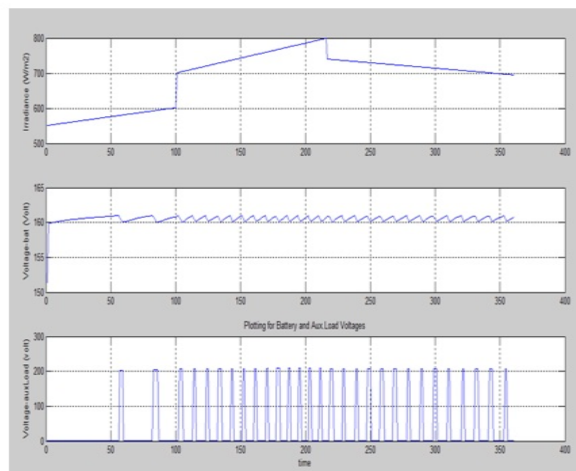

Figure-10. Battery and auxiliary outputs voltages of the cut-off circuit at different irradiance values.

DC Loads Matching Technique as an alternative to AC Inverter

The conversion efficiencies are lower for lower power devices, with efficiencies around 20% at the low end of the figure, and higher for high power devices, with efficiencies around 90% at the high end.

To switch from (Solar-Battery-Inverter-AC load) into (Solar-Battery-AC load), it needs to design an algorithm to manage the comprehensive solar system which is applied in a domestic appliances load to be compatible with DC source, so it is convenient to divide the simulation, which is implemented with Simulink-MATLAB2013a, and Experimental results into sub-subjects based on the procedure which is implemented to achieve the goal of this work.

Comparison of Solar System with and without AC Inverter

Figure-11, shows a simulation of traditional (Solar-Battery-Inverter-AC load) system, the Inverter

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actually is composed from a Boost DC-DC Converter and DC-AC Inverter, the output was supplied on a 100 Ω resistive load , the resistive load could be any type of the appliances that shown in Figure-12, it could be seen that under switching ON the value of RMS voltage ($Vrms = 173.2\ V$) at 100 Ω Resistive load, while the waveform was as shown in Figure-13, and the steady state power consumption was $Pbat = 2366$ Watt, which represents the power consumed from the system battery.

While Figure-14, shows the results of the same simulation conditions as a battery voltage and resistance values. In this case the output power consumed from the battery is only $Pbat = 320.4$ Watt.#

Thus, Inverter elimination had been attained a power of:

$$Pgain = Pbat\ with\ inv. - Pbat\ only\ load = 2367 - 320.4 = 2046\ Watt.$$

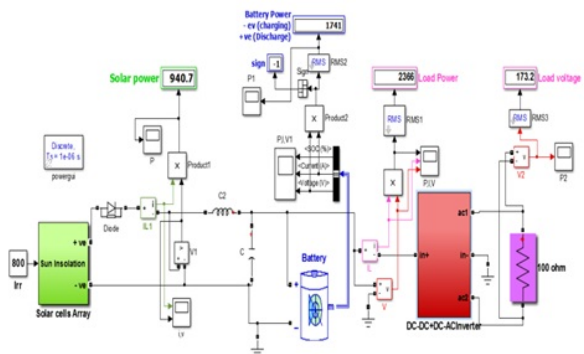

Figure-11. AC Inverter as a part of a residential solar system with its sub-circuits.

Figure-12. Load Classification according to DC matching compatibility.

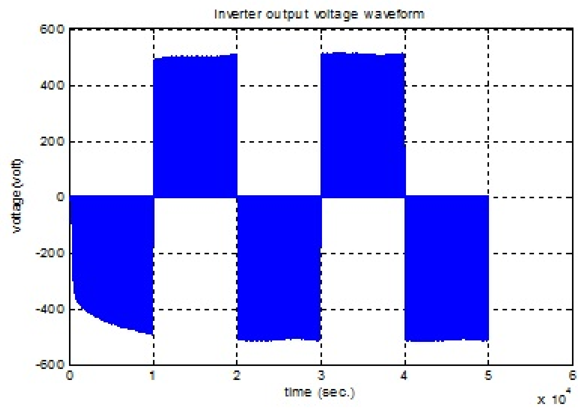

Figure-13. Inverter Voltage output waveform.

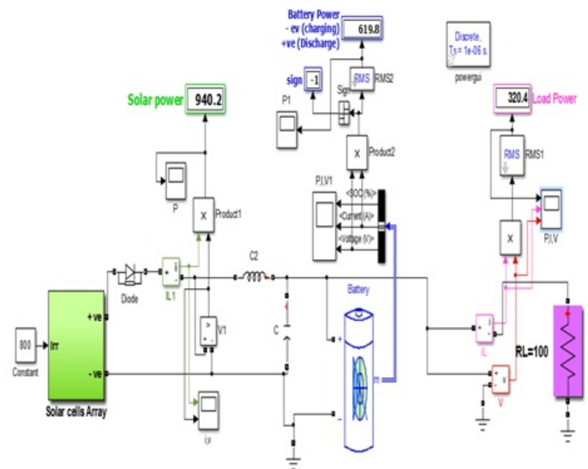

Figure-14. Inverter elimination effect and how many Watts of power would be attained.

Although, our Inverter design in the simulation had a very low efficiency, but even at efficiency of 90%, this procedure prove that at least 10% will be gained when the inverter is eliminated. The results of Figure-14, shows that the output load voltage is a pure DC from the battery. We conclude that if the home appliance compatible with both DC and AC supply, the elimination of the Inverter in (Solar-Battery-AC load) is better because this will attain a gain of that losses which dissipated in the conversion process of the inverter.

Resistive Load

As shown in Figure-15. It is clear that there is no effect for the resistive load if it is operated in DC or AC in same conditions accept the voltage value, because there is no power factor. So the result of the checking either the AC or DC has an different effect on a Resistive loads is appeared on the simulation, and it is simply same.

Electronic Devices and Resistive Loads:

Recently, vast majority of the electronic devices have a Switching Mode Power Supply (SMPS) either built in or outside as an AC adaptor, the SMPS block diagram

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can be drawn as in Figure-16, in both cases the following analyzing is verified, but for the device that has adaptor, the compatibility to DC more efficient because the process is just removing the adaptor and connect that device directly on the DC supply. Figure-17, shows the simulation when these types of appliances are supplied on AC power source one time and DC supply on the other time.

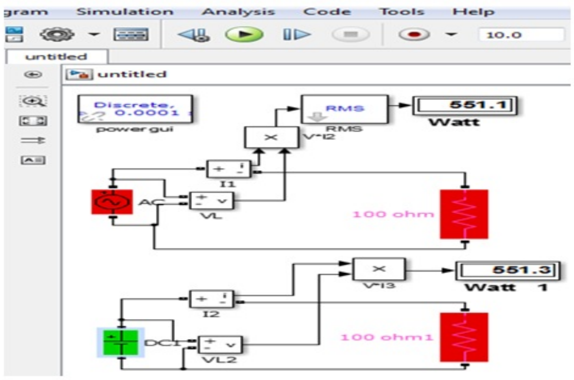

Figure-15. Resistive load if operated with DC or AC.

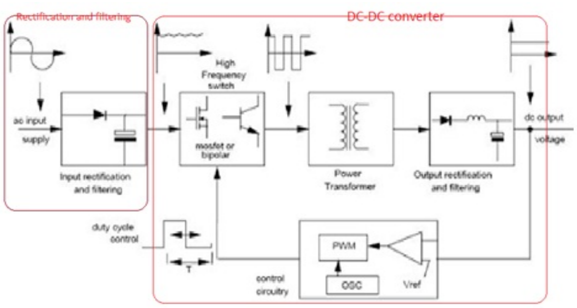

Figure-16. Standard SWPS block diagram illustrate the basic operation and the signal exchanging phases.

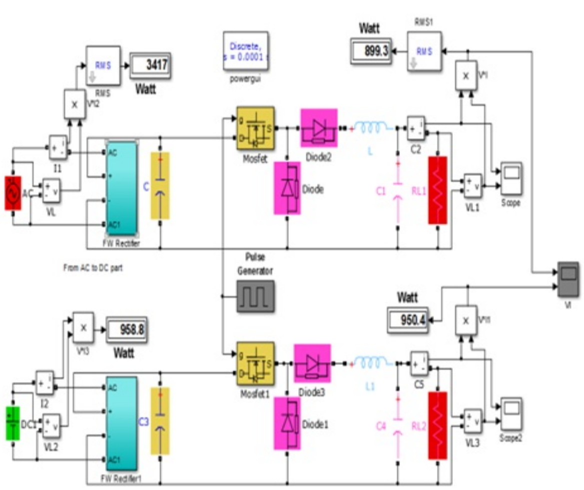

Figure-17.a). Electronic load comparison simulation when switched on, AC and DC.

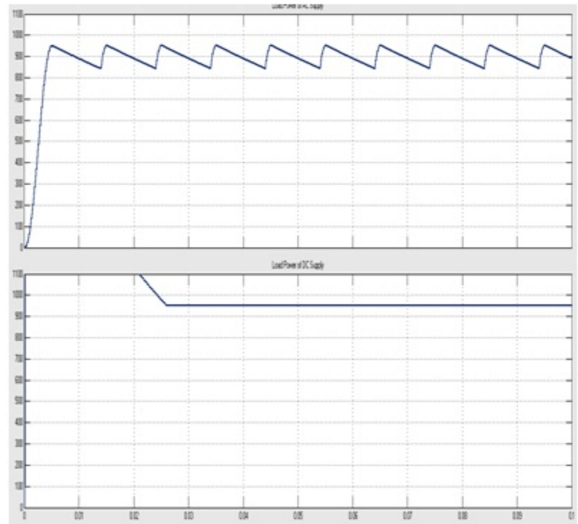

Figure-17.b). Electronic load comparison simulation when switched on, AC and DC.wave.

Obviously, shown in Figure-17,b, the load power signal of the DC supply circuit has a no ripple and it is smooth, while the same signals are distorted with ripples in AC case. It is worth mentioned that the two circuits are identical with all their components as shown in Figure-17.a, and the value of the output power for the AC power supply is 899.3 Watt, while it is 950.4 Watt for the DC power supply.

According to the classification of Figure-12, each type of appliances has been tested and evaluated in terms of efficiency to prove it's better performance when switching on DC source.

Universal Motor Loads

Referring to Figure-12, fortunately Universal Motor is a type of electric motor that can operate on both AC and DC power and are very useful for applications like Blenders, Vacuum Cleaners and Hair Dryers. They are also commonly used in power tools such as drills, saws and sanders, because they are generally run at high speeds. They are suitable for applications which demand large starting torque, frequent starting and high speed. They are able to run on either alternating current (AC) or direct current (DC) and with similar characteristics. The major electrical design areas are field and armature windings, commutator and brushes, insulation and cooling system.

Compressor Type Load

Refrigerator, air-conditioning, and freezer , all have a compressor as a main energy consumer, which is enrolled within the outdoor unit of the air conditioner system, while the fan of the evaporator inside the indoor one.

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Inverter rotary compressor

The Inverter technology (DC) is the latest evolution of technology concerning the electro motors of the compressors. An Inverter is used to control the speed of the compressor motor, so as to continuously regulate the temperature. The DC Inverter units have a variable-frequency drive that comprises an adjustable electrical inverter to control the speed of the electromotor, which means the compressor and the cooling / heating output. The drive converts the incoming AC current to DC and then through a modulation in an electrical inverter produces current of desired frequency. A microcontroller can sample each ambient air temperature and adjust accordingly the speed of the compressor. The inverter air conditioning units have increased efficiency in contraction to traditional air conditioners, extended life of their parts and the sharp fluctuations in the load are eliminated. This makes the inverter AC units quieter, with lower operating cost and with less broke downs. The inverter AC units might be more expensive than the constant speed air conditioners, but this is balanced by lower energy bills.

Upon these information, fortunately, this will serve and support out proposed research because this compressor could be fit our comprehensive DC system by suitable voltage range and connection.

Hence, the elimination of DC-AC Inverter is possible and this process has a feasibility that it could attain more efficiency for the system especially in the field of residential buildings. It is clear that removing any component from a system would remove its losses of energy and decreases the cost and the probability of faults, but if it could be removed with maintain the same or better performance. The idea of this proposed work is not only to reduce the cost or optimize the system efficiency, it's to find solutions for each class of load to be compatible to operate with DC supply.

Practical Verification Results and Discussion

Alternative Solar-Battery Charge Controller. To verify the results of simulation in the previous Chapter for the solar battery charge controller an experimental measurements have been done several times and the best results were recorded.

Data was collected for AL-Nahda2 in Dubai city for December, 2013 at cloudy day which similar to the usual days in Malaysia, as an acting environment temperature and irradiance. Load data was collected for a 1.28 KW max. solar power, this power was used to energize my own 2 bed room flat. The daily delivered solar power rate drawn with a sampling rate of 10per hour and total delivered daily energy was calculated by the area under the daily delivered solar power rate curve by using trapezoidal method. Figure-18, shows the daily solar-battery and solar-Aux. load power rate over the day time, It is clear that only small potion, which is in green color, the power separated by the red line (P_(cut_off)) ,only this portion was delivering the ventilation (Aux.) load to cool the system components to improve the performance, it's obviously that this portion of solar energy appears normally at noon time , which is considered a suitable time to cool the system from the sun rise temperature.

In this way, the control process of the solar panels power is, not only separate a part of the overcharge power and deliver it to cooling components of the system, but also contribute to add more attain solar energy results from performance improvement during this operation.

This part of energy which is used to improve the performance can be adjusted either automatically by the system management and automation, or manually at the first installation according to the location environment.

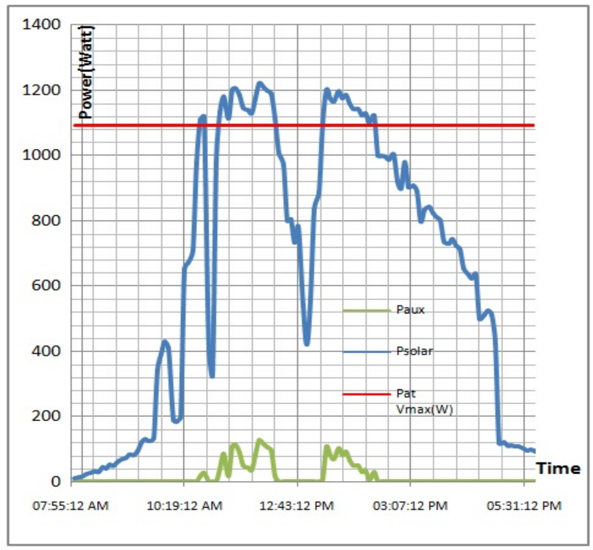

Figure-18. Daily Solar-Battery and Solar-Aux. load power rate.

DC Loads Matching Technique as an alternative to AC inverter

Practical Verifications

In this section, a practical experiment have been implemented for all appliances categories that had mentioned in figure 1, but detailed experimental results would be illustrated for only electronics devices and compressor based appliances, which is either air-condition or refrigerator sample had been taken.

Electronic Devices and Resistive Loads:

Figure-19,a and b show an experimental test of operating a 19" LCD monitor with 4 series DC power supplies to result a 101 Vdc one time and two 12 V parallel at another as shown clearly in Table-1.

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Table-1. DC and AC supply comparison results with same load Reading.

	Power supply voltage	Power supply current	Inverter	Load Volt-age	Load Current	LCD Consumption	Efficiency
DC	101	0.1	no	101	0.1	10.1	99.99 %
AC	12	2.21	yes	240	0.0424	10.18	10.18/(12*2.21)=38.38%

Figure-19. a,b: 19" LCD monitor with Direct DC&AC.

Compressor type loads:

The Inverter technology (DC) is the latest evolution of technology concerning the electro motors of the compressors. An Inverter is used to control the speed of the compressor motor, so as to continuously regulate the temperature as demonstrated in previous chapter.

Figure-20, shows the Experimental work of the Inverter type appliances, Air-conditioning and refrigerator, they were tested and evaluated on DC power supply, the results are briefly shown in Table-2 and Figure-21.

Figure-20. The Experimental work , DC operation, of an Inverter technique appliances A.C. and Refrigerator.

Table-2. Experimental Efficiency Comparison table between (DC power-AC refrigerator) and(DC power-Inverter-AC refrigerator).

Supply Type	Power supply voltage	Power supply current	Inverter	Load Volt-age	Load Current	Refrigerator Starting Consumption	Consumption Efficiency (Used Power/Supply Power)
DC	250	0.82	no	250	0.82	205	99.99 %
AC	24	11.04	yes	240	0.866	208	208/(24*11.04)=78.5%

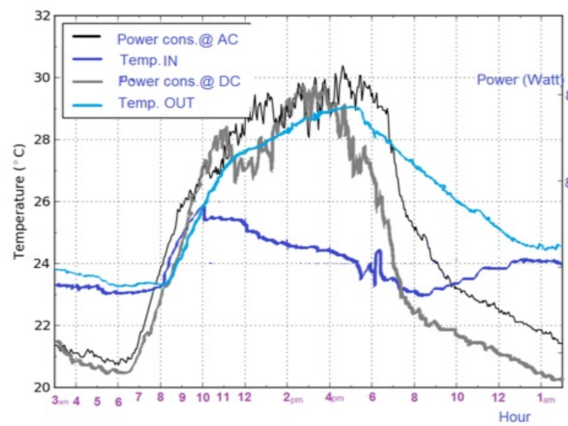

Figure-21. The power consumption rate comparison when the 1 HP Air-conditioner working on AC and DC supplies.

Very low power automation system.

Design, and now under implementation, of a very low power consumption wireless network automation system to upgrade the system towards optimum performance and intelligence as shown in primary results in Figure-22.

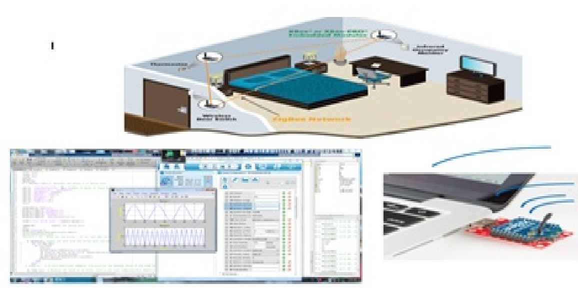

Figure-22. Low power automation system.

It is briefly based on using only the XBee processing and its low power capabilities together with suitable sensors for monitoring and control the consumption of the appliances.

CONCLUSIONS

The elimination of DC-AC Inverter is possible if it is taken in account the appliances classifications according to the power supply of that appliance or the technique that used to control its operation, for Resistive appliances loads, the DC operation instead of AC is simple and has same efficiency , while the electronic appliances has higher efficiency if it is operated with DC supply, the universal motor tools offers better performance with DC, finally the compressor based appliances which is based on Inverter technology has also better performance on DC as shown in the power consumption curve of Figure 21. So the disposal from the Inverter opens a horizon toward high efficiency Solar-Battery-Load system not only in the residential applications but also in general. More analysis and researches to optimize the performance this methods is required to enlarge this application and to dominate the technique of using the DC source to avoid the potential side effects that could come from using the alternative current environment. The idea of this proposed work is not only to reduce the cost or optimize the system efficiency, it is to find solutions for each class of load to be compatible to operate with DC supply. It's worth mentioning that modern domestic products tends to be more compatibility towards the DC supply either in electronics devices or the control circuits for the motorized or compressor based.

REFERENCES

[1] A. Baloukts and Terma Magnesias 2005. Load Matching in a Direct-Coupled Photovoltaic System- Application to Thevenin's Equivalent Loads. Department of Informatics & Communications, Technological Educational Institution of Serres, P.O.Box62124, Serres, Greece.

[2] POLAT , Dynamic Modeling of the Universal Motor used in Washer., Istanbul Technical University, 8 - 10 September 2011 İstanbul – Turkey, 2011 IEEE .

[3] Department of Pathology Columbia University Health. Sciences, and ~ Biological Sciences, Hunter College, the Graduate Division of the City Universityof New York, New York, NY (U.S.A.).

[4] General Motors Corporation, "High efficiency power system with plural parallel AC/DC converters," US Patent 6 166 934, Jun. 30, 1999.

[5] Gurol KANCA SENUR 2001, The Design Methodology to Develop New Generation Universal-Motors for Vacuum Cleaners, Electrical Machines Co. 34840 Avcilar-ISTANBUL. 2001 JEEE.

[6] K. Y. Khouzam, L. Khouzam and P. Groumpos. 1991, "Optimum matching of ohmic loads to the photovoltaic array," Solar Energy, Vol. 46, No. 2, pp.101–108.

[7] Kou S. A. Klein and W.A. Beckman 1998. "A method for estimating the long-term performance of direct-coupled PV pumping systems. "Solar Energy, Vol.64, No.1, pp.33–40, 1998.

[8] Kashif Ishaque, Zainal Salam† and Hamed Taheri. 2011. Accurate MATLAB Simulink PV System Simulator Based on a Two-Diode Model. Dept. of Energy Conversion, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, Johor, Malaysia.

[9] R. and Henderson A. 1987. Mechmistic Approaches to Interactions of Electric and Electromagn~tic fields with Living Systems, Reviewed in Refs.1-Bassett, C.A.L. (1989) CRC Rev., in press. 2- Goodman, (Blank, M. and Findl, E., eds.), pp. 217-230, Plenum, New York.

[10] Refrigeration-Technology/2014 http://worldmaritimenews.com/archives/38267/japan-daikin-unveiles-new-container-refrigeration-technology/ /..25-6-2014.Solar-Applications,2014,

[11] http://www.danfoss.com/Products/Categories/Literature/ra/Compressors/Direct-Current-Compressors/Direct-Current-Compressors-Solar-Applications-10-45V-DC/ee06f4a0-0649-4e60-901c-8ea54593a573.html,..25-6-2014

[12] Tyson DenHerder, California Polytechnic State University 2006. Design and simulation of photovoltaic super system using Simulink. California polytechnic state university - san luis Obispo.