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Battery Backup Power System for Electrical Appliances with Two Options of Primary Power Sources

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***Abstract*— Backup power system (BPS) compatible with two options of primary power sources; grid-connected power (AC) or solar PV-power (DC), to provide power to household appliances that comprises; a rechargeable battery bank, a charging-balancing circuit to keep the battery fully charged when power from the utility grid is available, a battery management circuit to optimize a voltage output of the system and protect individual batteries from overcharging thereby prolonging the operating lifetime of batteries, a relay switch circuit controlled by the main power source to change-over the load/appliances between direct link through bypassing the main power and the storage battery power when both options of main power are unavailable, three led indicators to display the battery status. Short circuit protection is provided to protect the backup power system from appliance short circuits, and to protect the batteries in the event of a short circuit within the system. The result shows the excellent utilization of the traditional BPS losses, wherein some appliances, the proposed topology can achieve about 99% power efficiency as compared with the traditional one.**

Keywords*— *Backup Power Supply; Energy Storage; Control Methods; Topologies

I. INTRODUCTION

To cope with the recent issues of global warming and greenhouse gas emission, the use of renewable energy resources is enormously increasing, in this context, there is a need exists for a reliable, quiet and efficient source of backup power for supplying power to appliances. Grid-connected or solar PV-power backup power system (BPS) provides clean, conditioned system to utilize the energy for a longer period of time. Commercially all the backup power systems need to satisfy the load requirements to maintain the required performance for the appliance. Although sometimes the BPS ignorantly dismiss as merely a (battery in a box), they are in fact complex devices that carry out various functions, at least of which is securing clean energy for electrical equipment. as long as the complexity of these backup devices increase, their maintenance requires more efforts and expense to minimize the risk of failure.

Currently, BPS must provide an output with regulated sinusoidal at low total harmonic distortion (THD), regardless the variations in the input voltage and rapid changes in the connected load to the system [1]. In addition, the low transient response for the online mode to the battery-powered mode and vice-versa, high reliability, unity power factor, high efficiency, low weight, small size, and low cost ..etc. that are further necessary considerations in the BPS.

Generally, the BPS can be divided into static systems and Rotary systems. The static systems use converter and inverter with power electronics to store, process, and deliver the power at grid-failure, in contrast, Rotary systems use generator and motor to perform same functions. Another type, that combines both static and rotary systems, called hybrid BPSs [2][3]. Most BPSs available in the markets according to their power ratings, starting from only 300VA to provide backup power to one computer, to the bigger units that may provide backup power to a complete building with a number of a megawatt. The BPSs can be classified depending on their topological design, the Offline BPS, Line-interactive BPS, and Online BPSs [4]–[8].

As mentioned above, all the invented and the proposed BPS systems included the DC/AC inverter as the main element to drive the appliances with the AC power, which is not the same in this work. This work relates to a backup power system to provide power to household appliances such as; all major residential and small commercial end-users, including electronic lighting (fluorescent or LED), cooling, space and water heating, clothes washing, and motors, water pumps or compressors (in particular in variable-speed operation where appropriate).

II. METHODOLOGY

To contribute in reducing the environmental pollution and the noisy apparatuses usage that are still used to maintain electric power in public markets or hawkers areas (e.g. PASAR-MALAM in Malaysia), where the utility grid power is not available, the rechargeable backup power system with the appropriate size and energy storied is a suitable solution. This size of apparatus can be generalized to cover the needs of electricity, as an emergency backup power, anywhere suffer from power outages problems or during the blackout due to storms, accidents, and countless other circumstances. Therefore, the work is the alternative green power supply for internal combustion generators and can be scalable according to load demands.

A. Comparison between the traditional and the proposed system

The main components of the current BPS can be listed as in Table 1, which also compare between the traditional and the proposed BPS in terms of the existence of these components.

TABLE I
BPS MAIN COMPONENTS AND THEIR EXISTENCE IN THE SYSTEM.

Component name	Function description	Traditional system	Proposed system
Battery	It is the energy storage element of the backup power system. Every battery system contains at least one string, and depending on the BPS configuration, multiple strings may be added to increase runtime and/or redundancy.	Generally (1-4) package lead-acid. (123Ah*12)-(35Ah*12*4) =(1.48-1.665) kWh	(80-90) Lithium-ion cells each of (5Ah*3.7V) to (1.48-1.665) kWh
Rectifier	It performs two very important roles: charging the batteries and converting incoming utility power from AC to DC.	Full bridge rectifier and filter, usually a set of passive components	Same as in the traditional system
Inverter	The inverter within a BPS accepts the DC from the DC bus (Battery or battery bank), which is supplied by the rectifier and the battery. During a power outage, the rectifier will no longer provide current to the D/C bus, leaving the battery to support the load. Its efficiency is (40-95)% depends upon the demand power and its brand.	Exist as a main component to supply the appliances with AC	Not exist. Therefore, saving between (60-5)% according to the load power.
Static bypass	it provides close the circuit automatically and allows the incoming power to divert around the rectifier, batteries, and inverter. Although the power supply is not conditioned, the static bypass lets critical systems continue functioning even if the BPSs components fail.	Usually, it is the relay switching circuit.	Same as in the traditional system

The main objective of this research is to build a BPS with more efficiency and flexibility to accept two types of input power; AC, from the utility grid, and DC, from the Solar PV array. This design adopts two concepts disclosed in the literature:

1- Its interconnection strategy is inspired by the concept of source-load Voltage Matching, which has described in our previous efforts in [9]–[11].

2. The prior art shows that the DC-distribution system has the best impact on the performance of the current household [12]–[17].

To clarify the hypothesis of the proposed work, Fig. 1 illustrates the BPS comparison between the traditional, as in the literature, and the presented in this work.

In this context, A BPS systems with hybrid power sources have been presented in [18][19][20]. In these systems, super-capacitor and the battery are combined as such to make sure sufficiently energy available to provide backup power to load. When the utility grid power is a blackout, the rechargeable battery will be connected together with the super-capacitor to respond quickly to the external load. The diagram of the hybrid BPS system is demonstrated in Fig. 2.

B. Linear and Switching DC/DC converter, and the proposed direct-link comparison

1) Linear DC/DC converter

The linear converter is a good choice for providing power with the very low amount to applications or devices. Although they are easy to employ, cheap and simple, the linear converters are in general inefficient. We can write the equation for dissipated power (P_{dis}) for this type of power converter as:

$$P_{dis} = (input\ voltage - output\ voltage) \times load\ current$$

The linear converter uses linear, non-switching technique to convert the power output of the power supply. The converter's resistance differs according to the power of load and results in a constant output voltage. Most linear converters require that the input voltage be a higher than the wanted output level voltage. This difference in voltage is called the dropout. Low dropout converter is a DC linear converter that can control the output power even when the input voltage at a level close to the output. Therefore, the linear converters are simple and cheap solutions but are in general inefficient because the input-output voltage difference is frequently dissipated as heat. The representation of the linear DC/DC converter can be shown in Fig. 3 (a).

2) Switching DC/DC converter

Switching converter is higher efficiency than the linear type and it is obtainable in a single chip, which is compact in size and reliable. This converter can be subdivided into isolated, and non-isolated. With this type of converter, several key requirements for the energy management nowadays solution which includes lower power consumptions under a variety of load environments, high reliability, less space, and large input voltage range. Those needs are driving the requirement for higher efficiency with a wider range of input voltage for converters in wide applications.

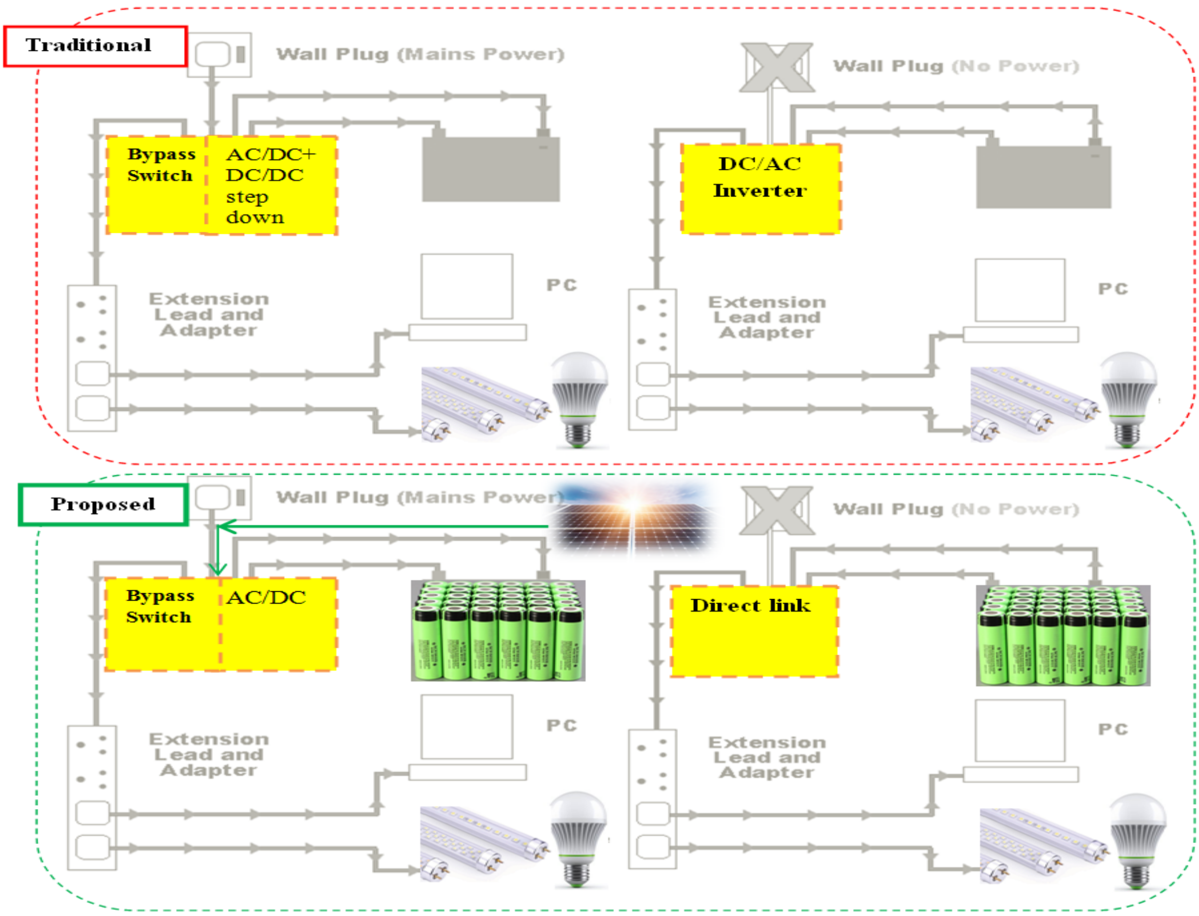

Fig. 1. illustrates the comparison between the traditional and the invented backup power system.

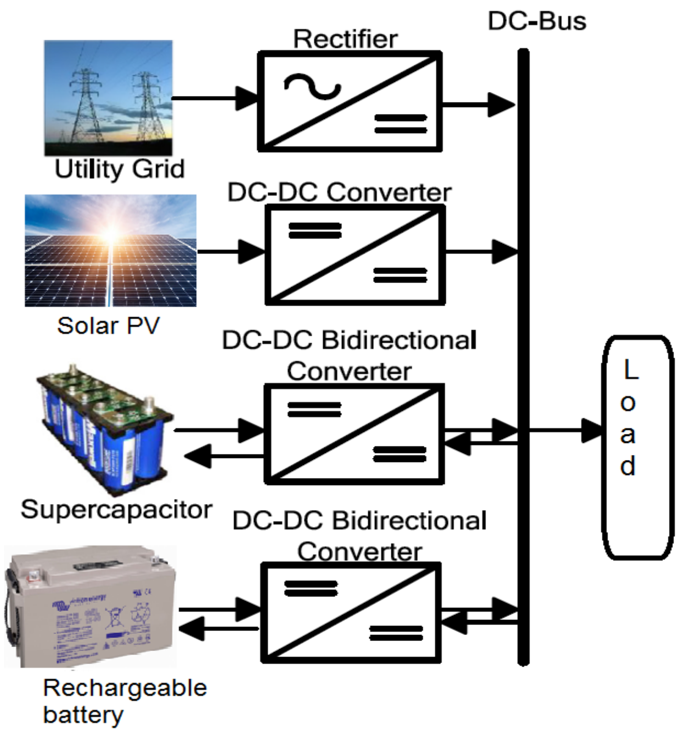

Fig. 2. The diagram of the hybrid BPS system.

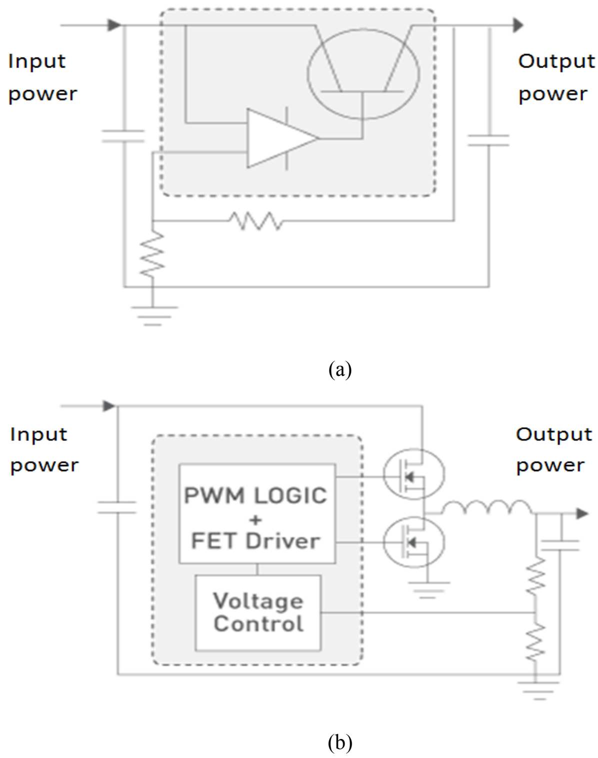

Fig. 3. (a) linear DC/DC converter, (b) Switching DC/DC converter

3) Proposed direct-link converter with the BPS

The direct-link BPS consists of a battery charger, a static switch, and a backup rechargeable battery shown in Fig. 4. A surge suppressor and filter are occasionally used at BPS output to avoid the noise of the input AC source and the disturbance before being delivered to load at the output. At normal operation mode, the charger charges the battery bank and simultaneously supplying power to the load the input AC source. There is no inverter in this topology therefore, no conversion losses were generated during this mode. At power failure or blackout, the static switch disconnects the load from the source leaving the connection with the battery bank.

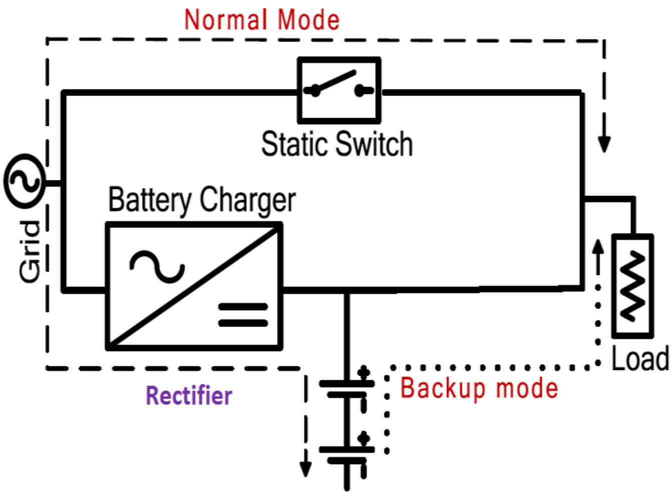

Fig. 4. Block diagram of the proposed direct-link converter with the BPS

III. RESULTS

A simulation with MATLAB has been designed to implement the three types of converters when handling the power from the source to the load in the BPSs. The basic designs, that have been described above in the methodology section of this report, were employed to perform the comparison among the three addressed converters. One ampere step-size division selected from 10 amperes as a maximum delivered current to the load. The Efficiency, which is the power output to the power input multiplied by 100%, of the converter, was calculated each time of 1Amp load current. It is observed that the linear converter has a constant efficiency value over the current variations, while a sharp growing up to about 89% efficiency is achieved when the switching DC/DC converter is performed, but it still has losses especially at lower load current. These losses are due to the switching of the semiconductor devices such as the MOSFETs or IGBTs. The proposed direct link perform better than both other converters because it links the source with load directly, only a few losses were dissipated due to the passive diodes and the fuse resistors. All those information are shown graphically in Fig. 5.

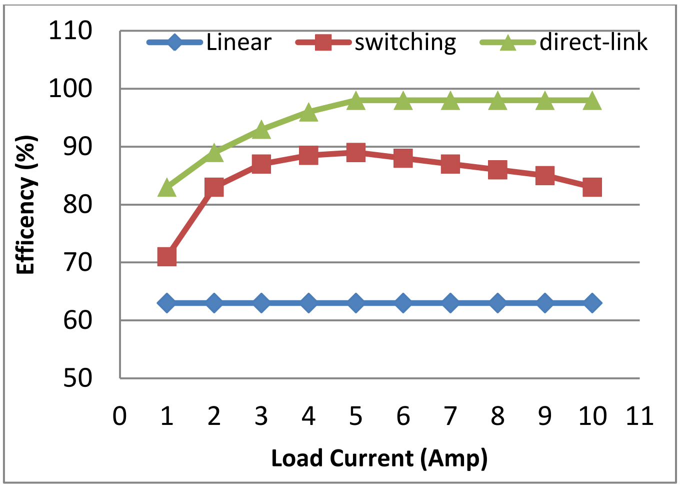

Fig. 5. Efficiency Curve for Linear, Switching and Direct-link Converters

IV. CONCLUSIONS

In this paper, a discussion of BPSs has been presented in order to clarify the variety of backup power topologies, and the basic concept of their control strategies. The classification of the BPSs has been discussed according to their main converter design, some advantages and disadvantages, and efficiency. The result presents the comparative analysis in terms of efficiency for the three different systems to offer helpful information in the selection of the control scheme for BPS applications. The proposed Direct-link DC/DC or AC/DC converter Model proves great performance in terms of lower power losses during the conversion process. The proposed system control scheme can also be implemented for solar charge controller in PV systems and in the hybrid energy power systems. This topology with DC-distribution enhancement expands their application to be used in smart grid and bring new trends for research and developments in this area. A future work is planned to conduct extensive experimental results to verify the simulation outcomes of this paper.

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