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Hybrid SMPS for PC Applications

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Abstract

Standby power refers to the electrical energy that is used by devices even when they appear to be turned off. Standby power allows electronics to turn on quickly, but means that they are constantly drawing some power from the electrical grid. Many electronic appliances consume standby power, which as per IEC definition is the equipment's' lowest level of power intake while in switched on but idle state. The users of these devices are often unaware of such continuous power drain. Computers, that enable better productivity and accuracy, are in common use today. Personal Computers (PC) need stable power inputs that can deliver rigidly regulated and isolated DC outputs of high power quality at different levels. However, the standby power associated with Personal Computers is substantial. Therefore, the primary objective of the project is to develop a Switch Mode Power Supply (SMPS) that integrates with a battery that is charged by solar energy. The battery provides standby power of the requisite quality to the Pc. Power factor is improved using buck-boost PFC converter in Discontinuous Conduction Mode at the front end. Simulation of the suggested model implemented in Matlab/Simulink Software has demonstrated improved performance for the proposed Hybrid SMPS.
Keyword- Switch Mode Power Supply (SMPS), IEC, Personal Computers (PC), Matlab/Simulink Software

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I. INTRODUCTION

Standby power is electrical power used by appliances and equipment while switched off or not performing their primary function, often waiting to be activated by a remote controller. That power is consumed by internal or external power supplies, remote control receivers, text or light displays, circuits energized when the device is plugged in even when switched off. While this definition is inadequate for technical purposes, there is as yet no formal definition; an international standards committee is developing a definition and test procedure.

The term is often used more loosely for any device that continuously must use a small amount of power even when not active; for example a telephone answering machine must be available at all times to receive calls, switching off to save power is not an option. Timers, powered thermostats, and the like are other examples. An uninterruptible power supply could be considered to be wasting standby power only when the computer it protects is off. Disconnecting standby power proper is at worst inconvenient; powering down completely, for example an answering machine not dealing with a call, renders it useless. All electronic equipments such as TV, computer etc. consume energy even when they are not in use so as to maintain a ready state for instant, on demand use, the power so used is called standby power. Standby power is not performing the primary functions of the equipments. From the standpoint of individual consumers, the energy utilization for standby power may not be substantial. But as a whole, the standby state power usage is a sizeable loss of electrical energy for the nation. While standby power does not perform the core functions of the equipments concerned, it is not always wasted power. It sometimes enables useful functions such as facilitating the use of remote control, providing clock displays etc. But in other instances like ignoring to switch off an electronic device or power adapter, standby power is a waste of precious power. Around 10% of total residential consumption is due to standby power [1].

From early 2000 onwards, International Energy Agency (lEA) has been putting emphasis on reducing standby power. In the year 2010, a regulation was introduced to restrict standby power consumption of equipments. Considering the case of personal computer, standby power can be around lOW. Although significant efforts have been taken to bring down the use of standby power, such efforts mostly revolve around manual mode of operation. It is possible to implement automated regulation in SMPS unit of PC to reduce standby power consumption without manual intervention. Lower power socket including microcontroller unit (MCU) and pyro electric infrared sensors (PIR) can be used to minimize standby power to less than 1 W by sensing user presence [2]-[3]. Another approach to reduce standby power is to implement accurate control of the apparatus by both software and microcontroller [4].To reduce the standby power of LCD monitor, SMPS unit is combined with the solar cell technology so that system consumes the standby power from the charged battery while SMPS is turned off [5]. So a Hybrid SMPS using solar cell can be used to eliminate the standby power in Pc. For controlling the DC output, a DCM operation of these converters is preferred in view of its advantages like single voltage sensor operation and inherent PFC with less control complexity.

A half-bridge converter has been used at the output for high frequency isolation and multiple DC output voltages in bridgeless converter based SMPS. It provides better core utilization than any other unipolar converter. It is also cost effective compared to push pull and full bridge converters [12-15]. It has been observed from the available literature that many researchers have not attempted the hybrid SMPS integrating solar panel for standby power reduction along with improved power quality. This system consumes the standby power from the charged battery while SMPS is turned off System will automatically change the power supply mode to electricity when battery status turns weak. The solar panel will continue to charge the battery even while the SMPS is operational. For power quality improvement, buck-boost converter in DCM is used along with half-bridge converter that provides multiple output DC voltages.

The half-bridge VSI is designed in CCM to reduce the component stress. The proposed system is designed, analyzed and simulated in MATLAB/Simulink software [16] and the performance is studied during constant and varying input voltages to demonstrate the improved performance in terms of low THD and high PF.

II. CONFIGURATION-OPERATION OF HYBRID SMPS UNIT

A. Buck Boost Converter

The uncontrolled DC voltage of diode bridge rectifier V d is used to power the buck boost converter. A high frequency switch Swl is used for energy transfer from the input side to the next stage. An inductor Lb is connected in parallel with the diode converter to store and release the energy in controlled manner.

When the switch Swl is turned off, making the diode Db forward biased, the input inductor Lb releases its stored energy through the output capacitor Cl2 and Cll. When the switch Swl turns on, inductor Lb stores energy through the output of diode bridge rectifier. A closed loop control is used for obtaining improved power quality at the utility interface.

B. Multi Output Half Bridge Converter

The regulated DC output voltage from buck-boost converter is fed to the half-bridge converter for achieving multiple output voltages. The half-bridge converter consists of two input capacitors CII and C12, multiple output High Frequency Transformer and two high frequency switches Sw2 and Sw3. The high frequency transformer used for obtaining multiple outputs is having one primary winding and four secondary windings and centre tapped configuration is used to reduce the losses. At the secondary side of transformer, filter inductors L1, L2, L3, L4 and capacitors Co2, Co3, C04 are connected to each winding to reduce the current and voltage ripples respectively.Circuit diagram of Hybrid SMPS The operation of the half-bridge converter in one switching cycle can be described in four modes, second and fourth modes are similar. In the first state, the upper switch Sw2 is turned on; the input current flows through the primary winding of the HFT to the lower input capacitor C12. Diodes D1, D3, Ds, and D7 start conducting and corresponding inductors store energy. So inductors currents iLl, iL2, iu, iL4 increase and output filter capacitors Co1,Co2, Co3, Co4 discharge through the loads. In the second mode both the switches are turned off, and diodes Dl-Ds freewheels the stored energy until the voltage across the transformer becomes zero and at the same time inductors currents iLl, Il2, iL4 decreases. In third mode, Sw3 is turned on and the input current flows through upper capacitor Cll to the primary winding. Diodes D2, D4, D6, and Ds in the secondary windings conduct and inductors L1, L2, L3, and L4 stores energy. When the energy stored in the inductors reach its maximum values, the switch is turned off. In the last mode, all the diodes start conducting which is similar to the second state and the same operating states repeat in each switching cycle. The output voltages are regulated by closed loop control of one of the output voltages.

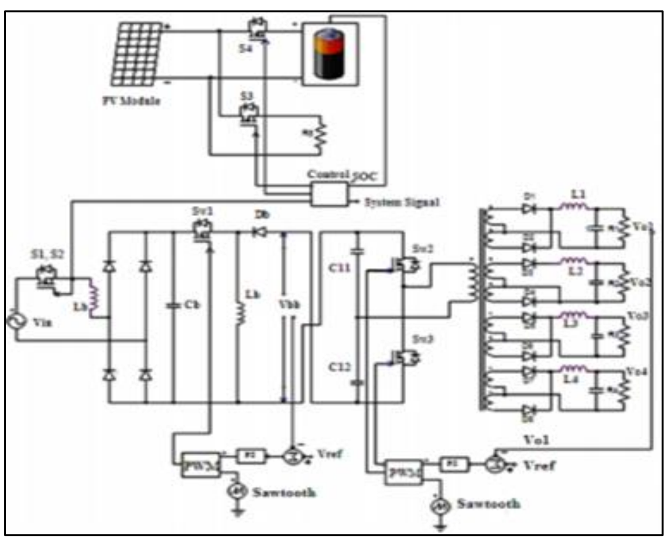

Fig. 1: Circuit diagram of Hybrid SMPS

C. Hybrid System

Standby power is the energy used PC when they are turned off but still plugged into a power socket. For personal computers the standby power can be provided by battery charged from solar cell. Fig.2 shows the basic schematic diagram of hybrid SMPS system. Computer systems have a blinking power LED during standby mode which can be used for detecting whether PC is in standby or nonnal working condition. Under standby condition system consumes the standby power from the battery while SMPS is turned off. System will automatically change the power supply method to normal supply when battery status becomes weak, and by the time battery will be charged by solar panel.

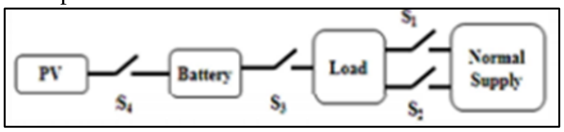

Fig. 2: Circuit diagram of Hybrid SMPS

Hybrid SMPS has four modes of operation:

- Mode 1: under normal working condition and battery is fully charged – S1 is ON and S2, S3, S4 OFF.
- Mode 2: under normal working condition and battery is not fully charged – S1 S4 is ON and S2, S3 OFF.
- Mode 3: Standby condition and battery status is strong - S3 is ON and S1 S2, S4 OFF.
- Mode 4: Standby condition and battery status is weak - S2, S4 is ON and S3, S1 OFF.

III. CONTROL SYSTEM

A. Control of Hybrid SMPS

The control of the Hybrid SMPS is carried out using three independent controllers. The front end buck boost converter utilizes voltage follower approach while the half bridge converter utilizes average current control. And another controller is used for switching between normal supply and battery which is charged from solar panel depending upon the standby condition. A. Control of Buck Boost Converter A closed loop control is used for obtaining power quality at the utility interface using buck boost converter. For this purpose, the dc output voltage of buck boost converter is sensed and compared with a reference voltage V cdc so as to generate the voltage error. This is given to the PI controller and output V p is compared with high frequency saw tooth wave to generate the pulse width modulated gating pulses. These PWM pulses are given to the switch of buck boost converter to maintain the dc output voltage constant.

B. Control of Multi Output Half Bridge Converter

An average current control scheme is used for controlling the output voltage of the half bridge converter. The highest rated winding output voltage Vol is sensed and compared with constant reference value Volref to generate voltage error signal (Vel). The error is fed to PI controller and its output is compared with the saw-tooth signal to generate PWM switching signals so as to maintain the output voltage constant. The control is able to maintain any individual output constant depending upon on the overall variation in the duty ratio. If the load on any windings is changed, the duty cycle undergoes a change according to the impact on the highest rated output and voltage regulation can be obtained. But the responses of the other windings are slightly slower as compared to the winding whose output is sensed.

C. Control of Hybrid SMPS System

A closed loop control of hybrid SMPS system is possible by using basic logic circuits as in fig.3. To reduce the standby power using hybrid SMPS mainly two inputs are needed, one is system signal which shows whether PC is in normal working condition or standby condition and other one showing state of charge (SOC) of battery. Table.l shows the switching strategies of three switches under different conditions.

System Signal	SOC	S_1	S_2	S_3	S_4
0	0	1	0	0	0
0	1	1	0	0	1
1	0	0	0	1	0
1	1	0	1	0	1

Table 1: Switching Strategy for Hybrid SMPS

IV. PERFORMANCE OF PROPOSED MULTI OUTPUT HYBRID SMPS

During standby condition supply will be provided from battery and threshold value of battery is set as 40%. Below this SOC, battery status becomes weak. So if SOC falls below 40%, even under standby condition power will be provided from normal supply until battery is fully charged. System is considered in normal working condition from 0 to 0.03sec and standby condition from 0.3

to 0.6 sec. Fig. 3 shows the input voltage V in and input current lin, it is clear that the input current follows the input voltage ensuring almost unity PF. Its PF at full load is 0.997. Fig. 3 shows the input current harmonic spectrum at full load.

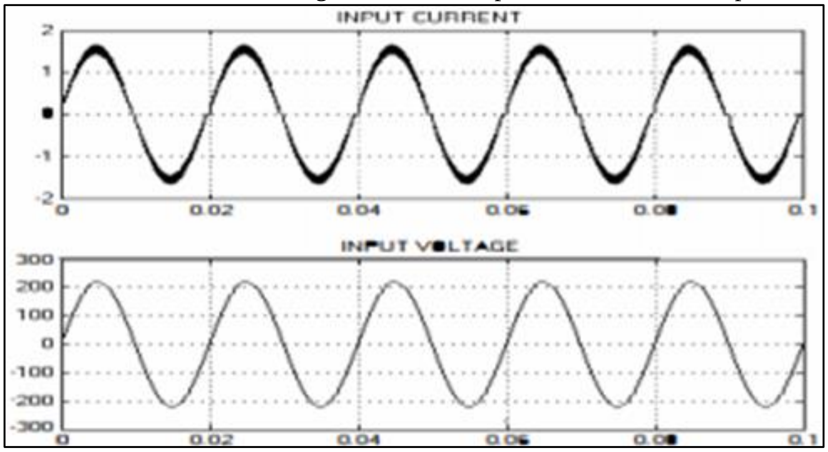

Fig. 3: Input current and input voltage at ac mains

V. CONCLUSION

A hybrid SMPS system with reduced standby power and improved power quality has been designed. Satisfactory performance has been achieved with power quality. Power factor is improved using buck-boost PFC converter in Discontinuous Conduction Mode at the front end. Under standby condition power is provided by battery (+5v) to reduce stand by power consumption from normal supply.

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