Interrupted DC as a Technical Solution for the Energy Transition

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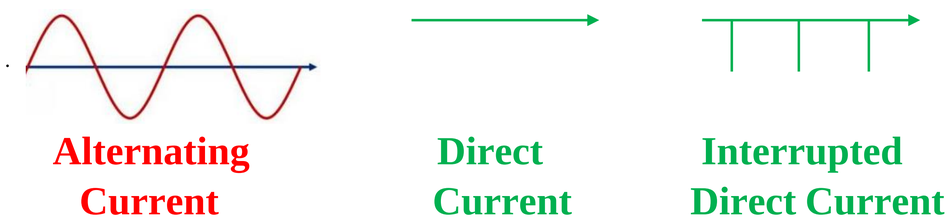
Introduction

This study evaluated a simple technique for powering common appliances with an all DC electric power grid. Our results show that interrupted DC of at least 100 Hz and 99% duty cycle may be superior to AC for powering computers and works well for most appliances.

Appliances and industrial equipment are already or becoming direct current ("DC") power compatible and the premier power source (solar electric) is DC. Tesla's alternating current ("AC") grid electricity, which allowed easy voltage conversion via transformers wastes energy, requires unnecessary expensive equipment and is no longer needed. The principal remaining reason for using AC at the end user, is that AC is more gentle on mechanical switches and thermostats. DC electricity makes giant sparks upon switch opening, which welds switch contacts and precludes use of direct current for existingequipment. We investigated how to overcame this limitation of DC by evaluating different types of interrupted DC on sparking in switches and by powering common appliances such as kitchen equipment, computers and electrical tools with interrupted DC.



Materials and Methods

Effect of frequency and pulse duration on spark size within switches:
We interrupted 105 volt direct current via a MOSFET driven by a pulse width modulation circuit between 50 and 20,000 hertz with off (interrupted) times between 5-500 microseconds. This interrupted DC power was connected to loads: 300 watt infrared heater, and 600 watt hair dryer, which were switched on and off with a Leviton 20 amp single throw wall switch having a drilled hole next to the switch contacts. A large surface area silicon photocell was inserted into the hole, fixed with epoxy and covered with black tape. The light sensor output was fed into an op amp integrator with a reset button to zero the integrator between switch turn on-turn off light measurements and the output voltage buffered and measured. Measured voltage output drifted less than 1 millivolt per second and measurements were carried out in a dimly lighted room.

Spark size was measured by integrating total light output produced as a function of pulse duration and frequency and compared with that from 60 Hz AC power. This experiment was repeated with a hand operated 20 amp circuit breaker in series with a 1000 watt frying pan. A hole was drilled into the circuit breaker next to the switch contacts and the same type photocell installed, and connected to the light integration circuit.

Appliances: compatibility with interrupted DC
A variety of appliances were powered by 60Hz interrupted DC with 99% duty cycle. During the 1% off time, back EMF voltage (voltage of reverse polarity caused by inductance) was detected, compared to a threshold value and used to select suitability of the appliance for interrupted DC power.

Computers: compatibility with interrupted DC
The quality and quantity of 60Hz AC vs pulsed DC power to a 15 inch Dell laptop was measured with an oscilloscope. Efficiency of power consumed in the laptop adapter was determined by measuring voltage and current into and out of the 19.5 volt adapter while driving a 7.5 ohm resistive load.

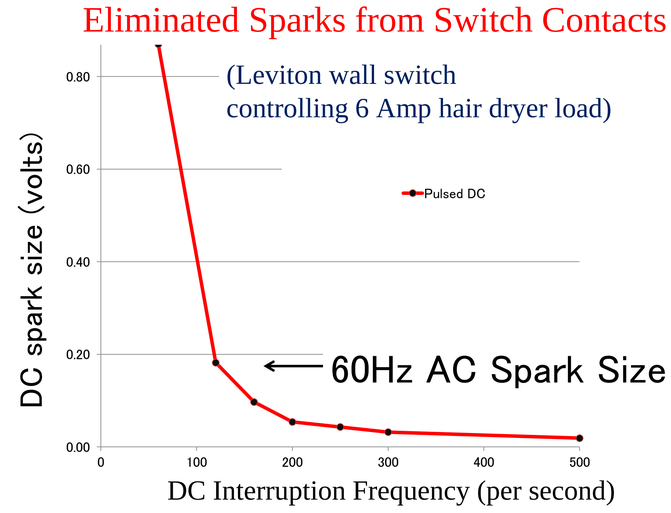
Results

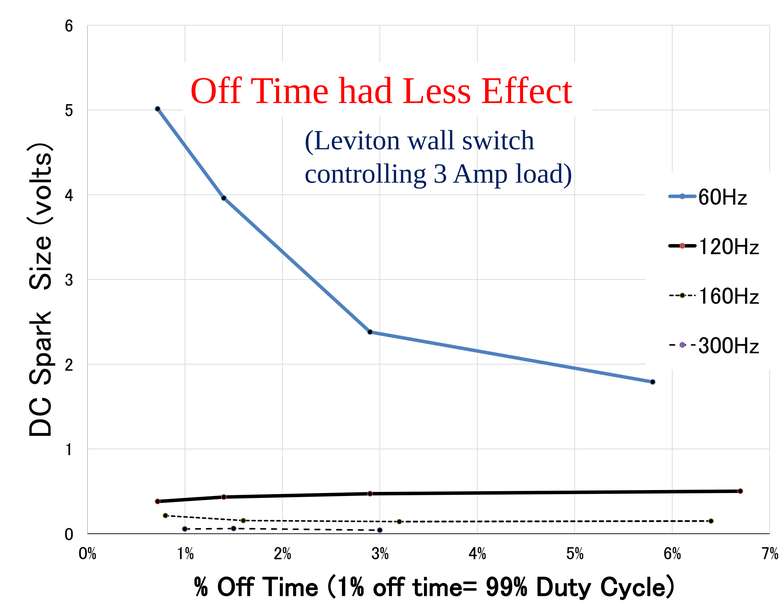
The following appliances were powered with 60Hz 99% duty cycle interrupted DC power. Back EMF detected above an arbitrary threshold was determined and used to terminate power upon detection via a circuit that detected and compared the back EMP pulse with a voltage reference.

APPLIANCE TESTED	BACK EMF
Coffee pot	not detected
hair dryer	very low, below limit
waffle maker (800 watt)	not detected
3 gallon water heater	not detected
40 gallon water heater	not detected
4 gallon water heater	not detected
infrared space heater (800 watt)	not detected
electric grill (600 watt)	not detected
electric grill (1400 watt)	not detected
kotatsu space heater (300 watt)	not detected
induction stove (800 watt)	not detected
computers wi power adapters (Dell, Apple)	not detected
computer printer via power adapter (HP)	not detected
5 volt USB power supply adapter	not detected
hand electric drill	not detected
vacuum cleaner (1000 watt)	moderate, below limit
small Dremel drill	very low, below limit
hand electric sander	very low, below limit
refrigerator	very high, above limit
aquarium pump	high, above limit
5 watt wall transformer	very high, above limit
20 watt wall transformer	very high, above limit

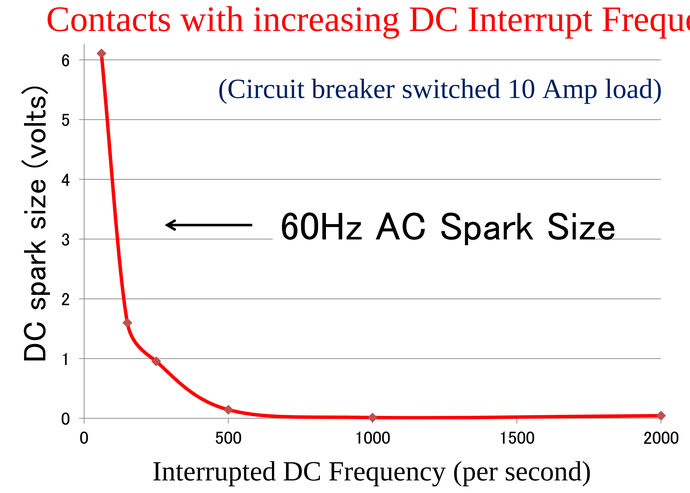
Of these appliances, only the legacy wall transformers and AC induction motor powered devices (water pump, vacuum pump) did not work with interrupted DC. These devices (in red) were successfully avoided by an automatic shut off switch that activated by detection of a high "kickback" EMF pulse during the off-time interval of interrupted DC.

Higher Frequency Interrupted DC Virtually Eliminated Sparks from Switch Contacts





Interrupted DC Decreases Sparks in Circuit Breaker Contacts with increasing DC Interrupt Frequency



Computer power adapter works better on Interrupted DC than AC

A variety of notebook computers were powered by interrupted DC with no adverse effects. Harmonics from the adapter to the connected computer were sensed with an oscilloscope. Virtually no harmonics were found (well below 1%) in both cases. Measured computer power adapter efficiency when powered by 60Hz AC supply was 64.6%. This was significantly lower than the measured computer power adapter efficiency of 69.4% when powered by 60Hz interrupted (99% duty cycle) DC for the same load.

Conclusion

Interrupted DC is superior to AC for powering most appliances for two reasons.
One, interrupted DC creates much less spark in switches, especially at interrupt rates of 120 or more per second. This means that large, robust/expensive DC power switch and breaker contacts may not be required for interrupted DC power. DC compatible switches and breakers presently are high cost and the use of interrupted DC should allow simpler, smaller and less expensive switches and breakers for solar infrastructure.
Two, energy robbing power factor corrections and frequency/phase shift monitoring and corrections carried out by expensive infrastructure can be avoided. Computer and cell phone power adapters presently require circuitry (and extra diodes with associated AC-DC conversion losses) to handle power factor issues caused by AC current and voltage phase shifts. Interrupted DC was more efficiently used than AC power by the computer power adapter, probably for this reason.

Abandonment of the legacy AC grid for DC, using interrupted DC at the end-user equipment level would provide competitive advantages of drastically lower infrastructure cost, less complexity, and significantly higher energy efficiency in a world where end use equipment is converting to all DC.