

Battery Chargers – Technology Overview

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Battery charging is a complex electrochemical process, in which the discharged electric energy must be replenished from the electric network. The quality of the charging process is critical to the health and longevity of batteries. As a result, battery chargers play a key role in the life and performance of today's industrial batteries.

A battery charger is an electrical/electronic device that converts the incoming AC line voltage into a regulated DC voltage to meet the charging needs of the respective battery (see Fig. 1). Although today's industrial battery charging market is dominated by ferroresonant and SCR type chargers, which have been in existence for many years, new switchmode technologies are making headways into the industrial battery charger markets. This is due to the higher efficiencies and smaller sizes and weights that a switchmode technology offers over ferroresonant and SCR types.

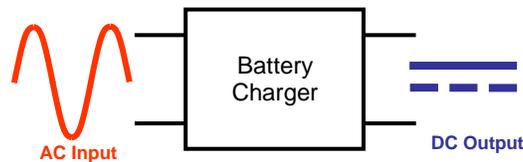


Fig. 1: Battery charger function

Ferroresonant Chargers:

A Ferroresonant charger is a class of chargers that employ a ferroresonant transformer to regulate the charger output. A ferroresonant transformer is a three-winding transformer, having one winding in parallel with a capacitor (see Fig. 2). As a result of this connection, the transformer core is driven into saturation by the resonant tank circuit. The charger output is derived from the saturated winding of the transformer and is relatively independent of supply voltage. The AC output is rectified to obtain a regulated DC voltage (see Fig. 3). The absence of electronic controls makes these chargers more durable and dependable in various applications.

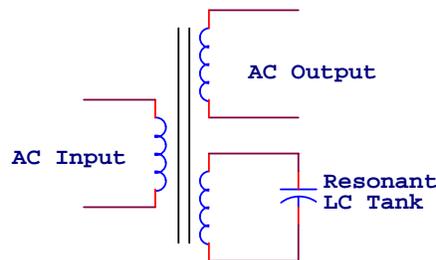


Fig. 2: Ferroresonant transformer

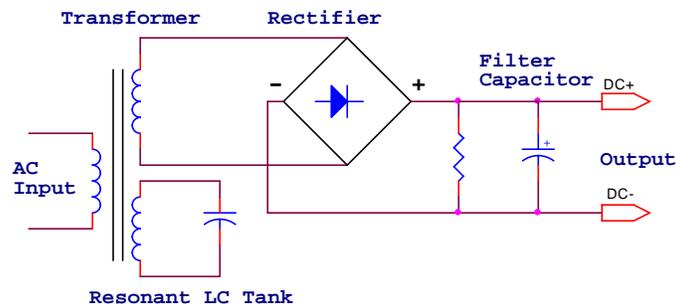


Fig. 3: Ferroresonant battery charger

Ferroresonant chargers have many limitations including lack the sophisticated control circuitry to give batteries what they need. As a result, these chargers may work well with flooded batteries, but can easily overcharge and damage more delicate modern sealed batteries. In addition, ferroresonant chargers are very sensitive to slight changes in line frequency and have low efficiencies since the ferroresonant transformers dissipate more heat than conventional transformers. These chargers are large and bulky, quite heavy, and they make an audible humming noise while charging.

SCR Chargers:

SCR battery chargers use SCRs (silicon controlled rectifiers) along with conventional transformers to regulate the charger output (see Fig. 4). Since the SCR switching action is controlled, SCRs provide more precise control of output voltage and can be easily interfaced with a microprocessor to implement various charging profiles. Unlike ferroresonant types, SCR chargers are less sensitive to line frequency variations and work well with all types of batteries including sealed types.

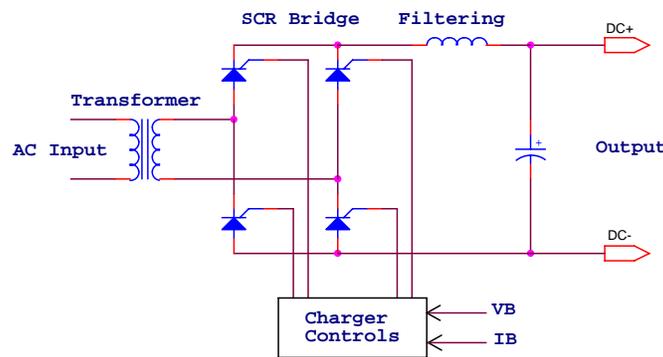


Fig. 4: SCR battery charger

One of the limitations of SCR controlled chargers is that they generate **un-smoothed** DC voltages resulting in higher ripple voltages and consequently higher ripple currents. These currents can cause additional battery heating especially at high charge rates (e.g. fast charging). Similar to ferroresonant chargers, SCR chargers operate at line frequencies (50/60Hz) and use a low frequency transformer for isolation and voltage step-down and thus are bulky and heavy. Unlike ferroresonant types, the power factor is poorer resulting in higher kVA power intake.

Switchmode Chargers:

A Switchmode battery charger / power supply is a class of converters that incorporates fully controllable switching power devices, e.g. MOSFETs and IGBTs, and can thus operate at frequencies much higher than line frequencies (few kHz to 100's of kHz). Unlike SCRs, which are half controlled devices with uncontrollable turn-off, MOSFETs and IGBTs can be fully turned on and off at any instant in time allowing for precise control of the charger output.

A typical switchmode power supply (SMPS) incorporates a front end AC-DC rectifier to generate an unregulated DC input voltage, a high frequency (HF) chopper that chops the input DC voltage, and an output filtering stage to generate a smooth, very low ripple output voltage (see Fig. 5). Pulse Width Modulation (PWM) is generally employed to regulate the charger output of a SMPS where the duty cycle of the switching power device (ratio of on-time to switching time) is controlled.

Switchmode power supplies are generally grouped into two basic categories: non-isolated, in which the output and the input source share a common ground, and isolated, in which a transformer is employed to provide output isolation. Since a charger output must be isolated from the AC line, a battery charger employing a non-isolated SMPS would require an input low frequency 60Hz isolation transformer to provide output isolation and voltage step-up/down function (see Fig. 6).

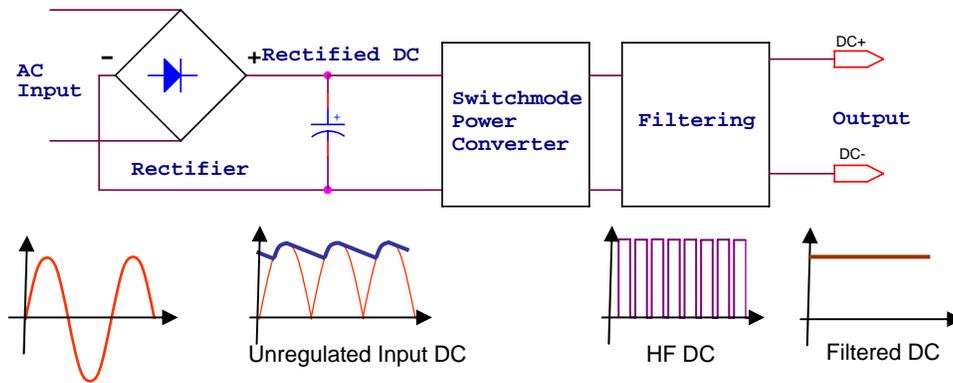


Fig. 5: Typical switchmode power supply

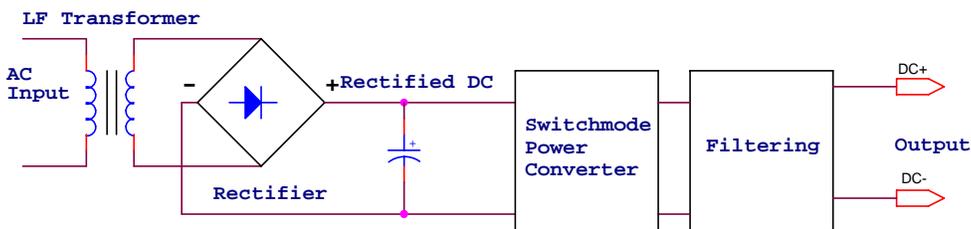


Fig. 6: Non-isolated SMPS battery charger employing a low frequency transformer front end

On the other hand, isolated SMPS incorporate a high frequency isolation transformer to provide output isolation as well as voltage step-up or step-down function. Unlike non-isolated types, the unregulated DC input voltage is chopped into a high frequency AC voltage which is then coupled to the output through a high frequency (HF) transformer. The HF transformer provides output isolation and voltage step-up/down function. A secondary side rectifier is used to rectify the high frequency AC voltage which is then filtered to generate a smooth, ripple free output voltage (see Fig. 7).

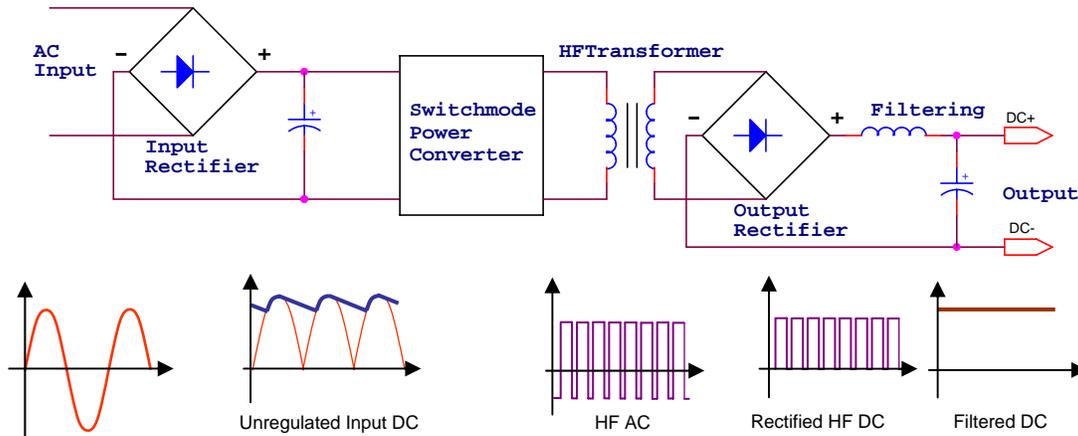


Fig. 7: Isolated SMPS battery charger employing a high frequency transformer

The main advantage of isolated SMPS over non-isolated types is the **significant size and weight reduction of the isolation transformer and the subsequent improvement in transformer efficiency.** Note that the size of an isolation transformer is inversely proportional to the operating frequency, i.e. the higher the operating frequency, the lower the transformer size. For example, a high frequency transformer operating at 60kHz is ideally 10,000 times smaller than a low frequency 60Hz transformer and is much more efficient. This is why isolated SMPS have dominated the power supply industry, and are poised to make similar improvements in battery charging applications.

Comparison

The selection of the appropriate charger technology depends mainly on the battery requirements and the applications needs. Although ferroresonant and SCR chargers have been in existence for many years and are quite durable and reliable, the performance benefits of switchmode batter chargers can outweigh those of ferroresonant and SCR types.

In summary, the table 1 summarizes the main features, benefits, and limitations of the three charger types.

Table 1: Charge Technology Comparison

COMPARISON CRITERIA	FERRORESONANT	SCR	SWITCHMODE
Efficiency	➤ Medium at full load ➤ Low at light load	Medium	High
Response	Very Slow	Medium	Very Fast
Control	Minimal	Medium	High
Size and Weight	Large / Heavy	Large / Heavy	Small / Light
Noise	Very Audible	Audible	Non Audible
Complexity	Low	Medium	High
Ruggedness	High	High	Medium
Power Quality	Medium to High	Poor	Medium to High