Battery Charging Technology Overview

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Advanced Charging Technologies

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 high frequency battery charging technologies is making headways into the industrial battery charger markets. This is due to the higher efficiencies and smaller sizes and weights that a high frequency charger offers over ferroresonant and SCR types.

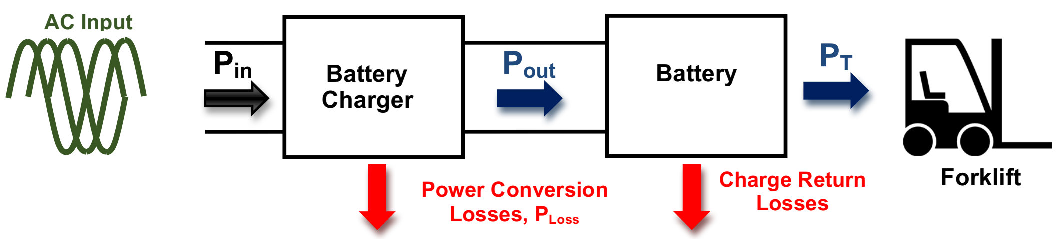

Fig. 1: Battery charger block diagram

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.

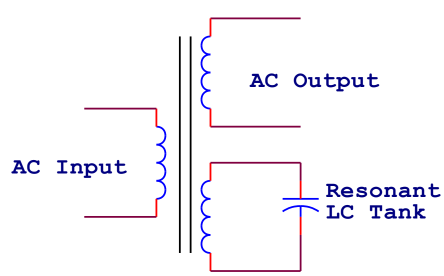

Fig. 2: Ferroresonant transformer

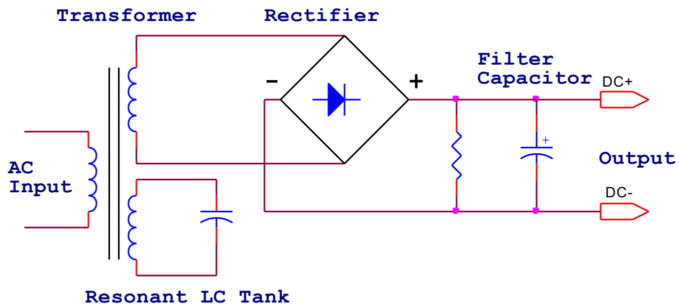

Fig. 3: Ferroresonant battery charger

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.

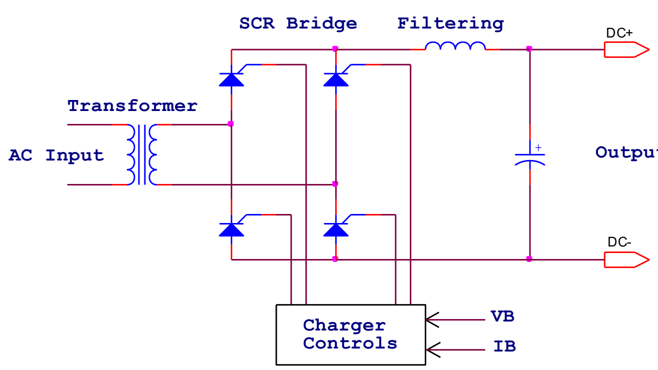

Fig. 4: SCR battery charger

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.

High Frequency Chargers:

A frequency battery charger is a class of power supplies 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 high frequency battery charger incorporates a front-end AC-DC rectifier to generate an unregulated DC input voltage, a high frequency (HF) power converter that converts input DC input a high frequency AC voltage, a high frequency isolation transformer to provide output isolation as well as voltage step-down function, and an output rectifier and filtering stage to generate a smooth, very low ripple output DC voltage (see Fig. 5). Pulse Width Modulation (PWM) is generally employed to regulate the charger output, where the duty cycle of the switching power device (ratio of on-time to switching time) is controlled to control the output current and/or output voltage of the charger.

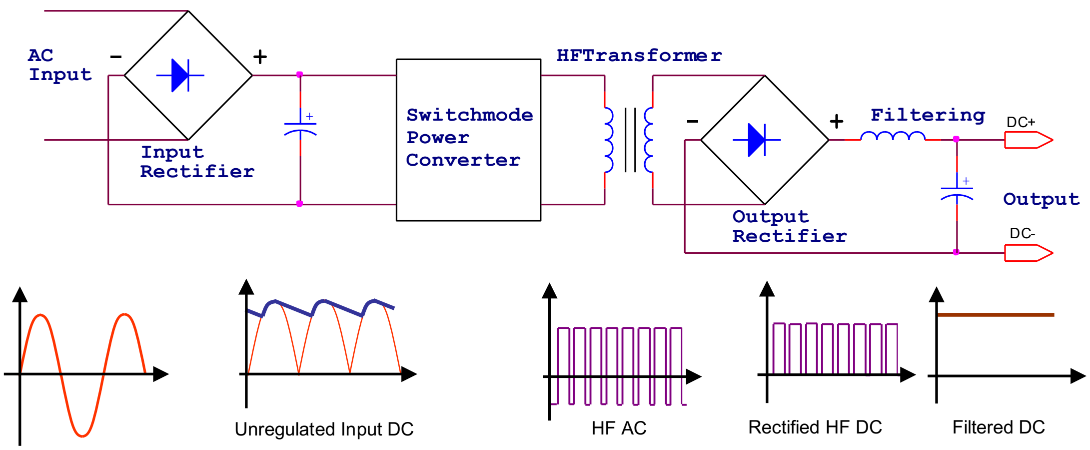

Fig.5: Typical isolated high frequency battery charger employing a high frequency transformer

The main advantage of high frequency battery chargers over Ferro and SCR chargers 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.

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 high frequency battery chargers can outweigh those of ferroresonant and SCR types.

Table 1 summarizes the main features, benefits, and limitations of the three charger types.

Table 1: Charge Technology Comparison

CRITERIA	FERRORESONANT	SCR	HIGH FREUQNECY
Efficiency	Medium	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

Typical Energy Costs and Savings

Consider a typical application utilizing a 36V, 1000Ahr battery operating for two shifts per day with daily EBU usage of 2.0 (two shifts with 80% DOD in each shift). The table below summarizes the energy costs of a ferro, SCR, typically HF, and ACT's Quantum chargers.

	FERRO	SCR	TYPICAL HF CHARGER	ACT QUANTUM
Charge Cycle Efficiency	**83%**	83%	89%	**93.5%**
Typical Power Factor	**85%**	70%	95%	**95%**
Charge Return Factor	**120%**	120%	115%	**110%**
kWhrs / Charge Cycle	**47.00**	45.04	42.00	**38.24**
kWhr Cost ($0.06/kWhrs) - Annual	**$1,466.38**	$1,405.29	$1,310.55	**$1,193.23**
Peak kW Demand	**9.79**	9.17	8.56	**8.14**
kW Demand Cost ($12 / kW)	**$1,424.79**	$1,355.00	$1,245.00	**$1,185.08**
Total Charging Cost / Year	**$2,891.18**	$2,740.28	$2,555.54	**$2,378.31**
Total Charging Cost over 5 Year	**$14,455.88**	$13,701.41	$12,777.72	**$11,891.56**

Note that the efficiency used in the calculation is the total charge cycle efficiency (from start to finish). Note also that the Quantum charger technology features extremely high charge cycle efficiency (~ 93.5%). As shown in the above table, using HF charging technology can realize more than $300 in annual energy savings over ferro charger, which adds up to $1678.00 over 5 years. The Quantum chargers further improve the savings resulting in more than $2,500 in savings over ferro chargers and more than $1,800 over SCR charger over a 5 year period.