Ample International Inc was founded in 2006, to develop and manufacture low-carbon pollution electric cars through advanced technology and innovation to protect the environment. An R&D center was set up in Changzhou, Jiangsu province where I led a team of over 40 engineering experts. Through four years of research, plus over US$ 8 million investment, an electric model car has been built, with the innovative technologies of 1 U.S. patent and 9 Chinese patents invented by our R&D team. The new electric model car features high electricity efficiency, low carbon pollution, light weight, relative low cost, concise appearance, and fluency curve. The cruise distance is 200 km with maximum speed of 70 kmh.

In September of 2011, Shanxi Ample Technology Co., Ltd. in Shanxi, China, was formed to move this project to the manufacturing stage. With the support of China's National Energy Bureau and the Shanxi provincial government, 500 acres of land in Shuozhou, Shanxi province was acquired. The production capacity will be 10,000 units car annually. The first new electric car will hit the market by the end of 2012.

The Shanxi province is the most polluted area of China. Our Shanxi Ample electric car project provides it an effective way to fight air pollution. Manufacturing energy efficient and low-polluting electric cars helps protect the global environment and benefiting mankind is always our mission.

The application of Resonant Soft Switch Technology on Electric Vehicle

1. Soft Switch Presentation

软开关介绍

1) Development History

发展历程

Now it comes electronic age. Where there is electronics, there must be power supply. The new age makes three basic requirements to Power supply: High Reliability, High Efficiency and Low electromagnetic interference.

Power Technology (also called power conversion technology academically) is developing for two decades, and entered high frequency age after taking the

place of old power frequency silicon rectifying technique, also experienced from first phase hard switching PWM period and change into the second phase soft switching PWM period.

社会进入了电子时代，有电子装置的地方就必须有电源。新时代对电源的三大基本要求是：高可靠性、高效率、低电磁干扰。

电源技术（学术上称之为功率变换技术）经历了二十余年的发展，逐步替代了落后的工频硅整流技术而进入了高频变换时代。在高频变换技术进程中又走过了它的初期阶段即硬开关PWM阶段，于近年进入了它的第二阶段，即软开关PWM阶段。

2) Hard Switch and Soft Switch

硬开关和软开关

So called hard switch PWM (Pulse Width Modulation) means it works by power conversion, when the switch changes from ON/OFF, it is on big current or high voltage conditions. Take the knife switch as a sample, when in connection of power, shut on or off the switch, there will be strong electric spark of arc, which make the switch being burnt through and get the big electromagnetic interference to power networks to space and caused big power consumption.
So the components working in such conditions with hard switching PWM technology, and being poor working reliability, low efficiency and serious electromagnetic interference. As a result, hard switching PWM technology is out of fashion of electronic ages.

In recent years, Power supply Technology was developed to the 2nd phase soft switch PWM period due to request of social development.
Regard to soft switch technology, we take the knife switch as a sample too, when take on/off the switch, what if we make current or voltage at both ends of knife be zero? Will we avoid the spark of arc being appeared? In actual power conversion technology, it is really take the technique to make both ends' voltage or current be zero while key switch shut on/off, also be so called ZVS and ZCS soft switch technique.

Soft switch PWM technology is a revolutionary progress compared to hard switch PWM technology; it indeed improved the electronics products three basic functions: Reliability, Efficiency and Electromagnetic interference (EMI). However, there are also many defects and regrets, such as its soft switch are not integrated; the loss of Duty ratio at heavy load switching decreases the output ability. Circular Current loss drop the efficiency; working current is pulse like hard switch PWM, which lead to EMI; Master control ring still be undeveloped single ring voltage control way, etc. All these limit the

enhancement of power supply's three basic functions.

Decades ago, several types resonant circuit were proposed in academics, especially the multi-resonant circuit. It features high efficiency, sine current, low electromagnetic interference, small and light. And its simple and innovative circuit and good function has attracted producers invest to manufacture.
However, due to its poor reliability, low producibility and it came to nothing finally.

In fact, the soft switch PWM technique mentioned above is developed on the basis of hard switch circuit with partial soft switching technology of resonant circuit mode. Therefore, it is called "boundary resonant technology" in academics. Actually, it was a compromise choice in the course of development.

所谓硬开关PWM（脉冲宽度调制），是指在功率变换过程中电子开关在开通和关断的瞬间处于大电流或高电压的工作条件。以日常生活中常见的闸刀开关为例说明，当您带负荷推合或拉开闸刀的瞬间，闸刀间会产生强烈的拉弧火花，正是这种强烈的火花造成了开关的烧蚀损坏，形成了对电网和空间极大的电磁干扰，而且导致开关工作损耗增高。在硬开关PWM技术中，承担功率变换的主开关器件其实正是处于这样的工作环境中。所以它的工作可靠性差、效率低、电磁干扰极为严重。因此，硬开关PWM技术已经显得不能适应电子时代的要求，它过时了。

社会发展的需求，迫使电源技术于近几年进入了它的第二阶段即相移控制式的软开关PWM阶段。

所谓软开关技术，我们还是以闸刀开关作形象比喻，如果能在闸刀推合和拉开的瞬间人为地令开关闸刀两端的电压或电流为零，岂不就可以避免拉弧火花的产生？在功率变换技术中，其实就是在主开关器件关断和导通的瞬间，实现其两端电压或电流为零的技术，也就是术语中常说的ZVS（零压开关）和ZCS（零流开关）软开关技术。

软开关PWM技术是相对于硬开关PWM技术的一次革命性进展，它确实在相当程度上改善了电源产品的可靠性、效率、电磁干扰（EMI）三大基本功能，但也存在诸多不足和遗憾，如：它的软开关可惜不是完整意义上的；重载占空比丢失降低输出能力，环流损坏降低效率；工作电流和硬开关PWM一样呈脉冲形态，导致电磁干扰；主控环依然是落后的单环电压控制方式等等，这都制约了电源三大基本性能的提高。

十多年前，学术界曾提出多种谐振电路模式，特别是多谐振电路模式，它转换效率很高，工作电流呈正弦形态，电磁干扰极低，体积小重量轻，电路简洁新颖，诱人的性能也曾吸引了众多的厂商付诸生产，可惜由于它的工作可靠性差，可生产性差，最终成了闪亮的流星。

其实前面提到的软开关PWM技术正是部分吸收谐振模式中的软开关特性，把它应用到了硬开关PWM电路而取得的进展。因而学术界也称之为“边缘谐振技术”，其实，这是电源技术发展过程中的一种折中和无奈。

3) Tonghe's Patent Technology

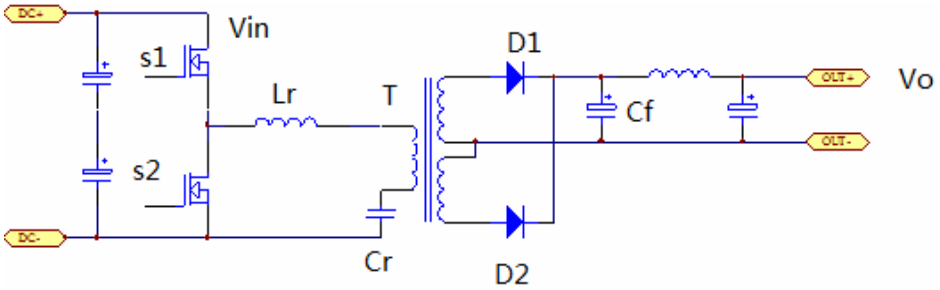
通合专利技术

To save the limited petroleum source and protect the environment are ecoming the global consensus. We Tonhe Electronics (hereinafter referred as “Tonhe”), as one of high tech enterprises should contribute to. With the rapidly growing and developing of E-vehicle industry, Tonhe put its energy on how to charge EV more efficiently and created the innovative soft switching technology. Tonhe's patent “resonant voltage type dual-loop control multi-resonant” DC-DC rectifier catered for the developing direction of new energy industry, with its high reliability, small volume, high power and efficiency.

珍惜有限的石油资源，保护自然环境已成为全球共识。通合作为中国的高新技术企业也要为这一目标贡献自己的力量。伴随着国内外如火如荼的电动汽车产业发展，通合公司将精力放在如何更有效的为电动汽车充电上,并发明出重要革新----软开关技术。

通合的专利“谐振电压型双环控制多谐振”DC-DC 变换器以其高可靠、体积小、功率大、效率高等优势顺应了新能源行业的发展趋势。

The main topology uses LLC structure, the basic circuit is as follows:



The working principle of soft switch can be briefly described as: S1 and S2 two switch tube breakover alternately, get resonant current among inductor (Lr), Transformer (T) and capacitor. The switch tube is controlled precisely and its

voltage drops to 0V by resonant current all the time, when breakover and shut off. Thus, no crisscross between voltage and current no matter under breakover or shut off.

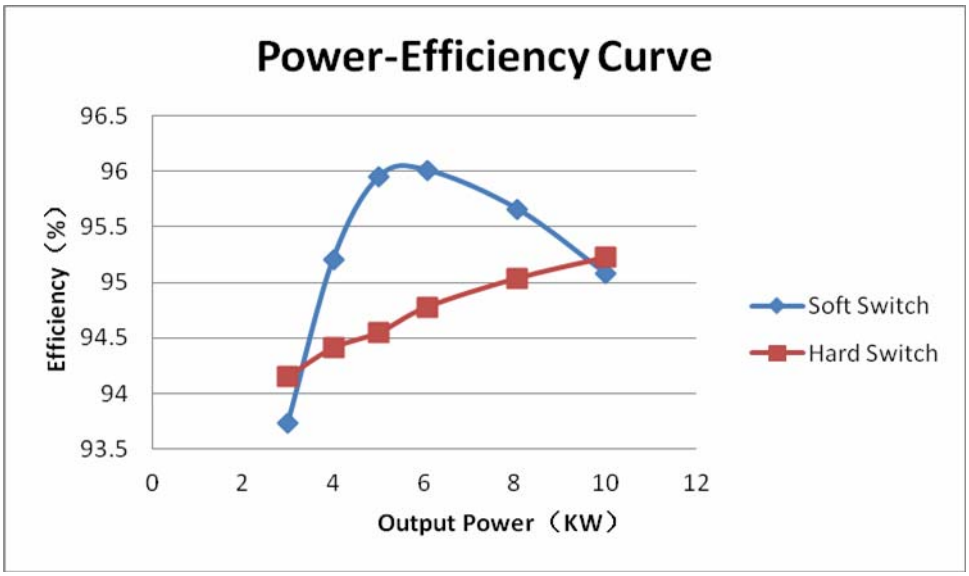
主拓扑采用 LLC 结构，大体电路如下：
软开关的实现原理可简易表述为：S1S2 两只开关管交替导通，在电感（Lr），变压器（T），电容（Cr）形成谐振电流。用精确地控制使开关管导通与关断前总能将自身电压被这一谐振电流拉到 0 伏。这样一来，无论是导通还是关断，都不会产生电压与电流的交错。

There are mainly four advantages by use of this technology

a. The circuit is extremely simple, minimizes induction consumption loss and electromagnetic interference (EMI)
b. Perfect output capability and the power of mono charger is up to tens of kilowatts.
c. Maximize conversion efficiency, 48V100A (3 ph input) telecom power supply's efficiency is up to 96% under full load conditions.
d. Power supply voltage clamp, semiconductor components don't need withstand high voltage.

使用这一技术带来了 4 个好处：
1 电路极端简洁，传导损耗最小，产生干扰最小
2 输出能力最强，单机输出功率可达数十千瓦以上。
3 转换效率最高,，三相输入 48V100A 通信电源满载效率可高于 96%
4 电源电压钳位，半导体器件不需承受高电压。

Especially on efficiency, soft switching technology has the incomparable advantages.
尤其是在效率方面，软开关技术有着它无与伦比的优势。



The power curve diagram above shows that soft switch is superior on efficiency than hard switch. Also during the course of charging the battery, generally when the battery voltage is low, charging current is high. After a period of time, required current will get less with the rise of battery voltage, which means the charger always stay with a 50-75% power output. This range is just the best efficiency range of soft switching charger, which make soft switch charging efficiency is at least 2% higher than hard switch.

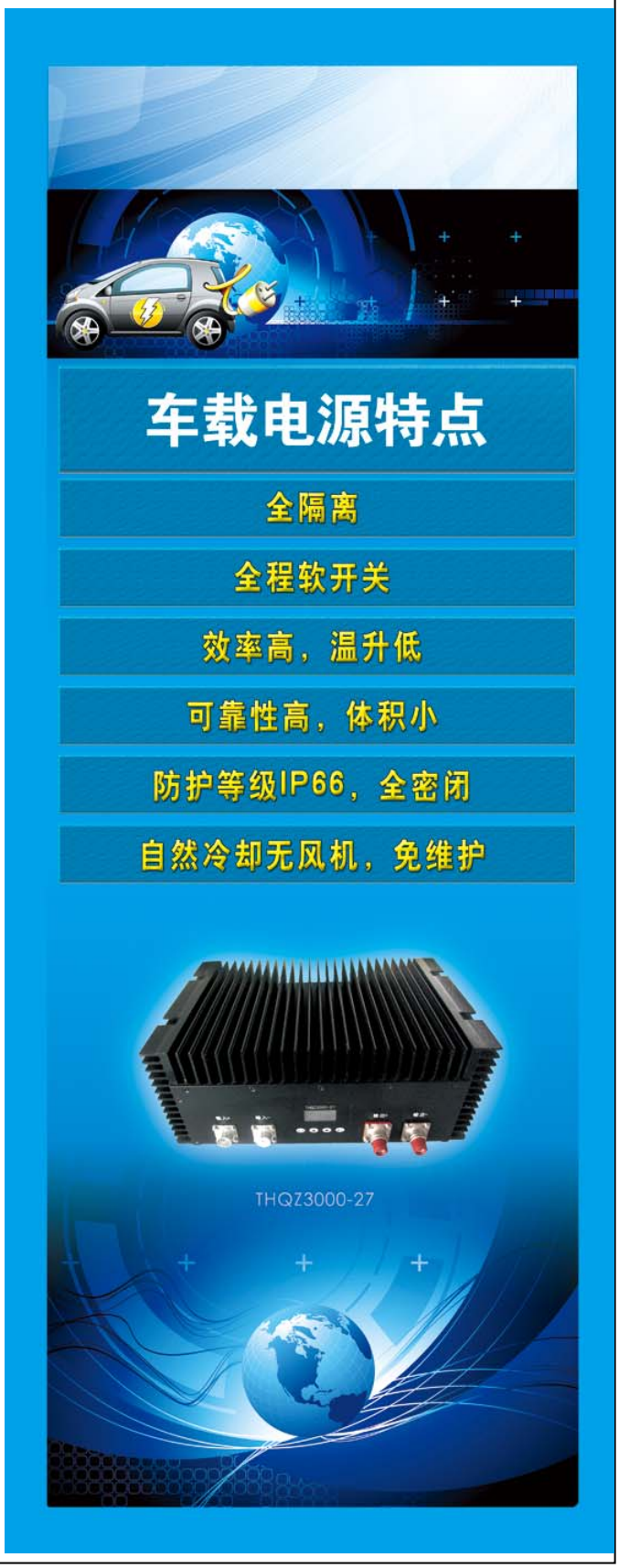
上图的功率曲线示意图体现了软开关在效率上对硬开关的全面胜出，并且在电池充电中，往往是电池电压低时充电电流大，经过一段时间后随着电池电压的升高，所需电流也会逐步减小。这意味着实际充电机总是维持在 50%-75%的功率输出。而这一范围恰恰是软开关充电机的最佳效率范围，这使得软开关充电效率可以比硬开关高出至少 2 个百分点。

2. Typical products

TH750Q20NZ

module / project	TH750Q20NZ	TH700Q17NZ
Output features		
rated output voltage (V)	450-750	450-700
Output current (A)	0-20	0-17
power（KW）	15	12
Efficiency	>92%	
The uneven flow under parallel work	≤ 5%	
stable voltage accuracy:	±0.5%	
stable current accuracy:	±1%	
Communication Protocol	CAN 2.0B/485	
Input features		
Input voltage range (DAC)	380V±15%	

Input Frequency (HZ)	45-65	
PF (full load)	APFC 0.99	PFC 0.997
THD	<5%	
Dimension (length*width*height) mm	680*600*133	482*450*88



module / project	THQZ3300-440S Charger	THQZ3000-27 DC-DC
Output features		
rated output voltage (V)	200-440	27
Output current (A)	0-11A	0-110A
power（W）	3300	3000 (max)
Efficiency	>94%	>93%
stable voltage accuracy:	±0.5%	
stable current accuracy:	±1%	
Communication Protocol	CAN 2.0B	
Input features		
Input voltage range (V)	220VAC±15%	300-440VDC
Input current range	0-16A	0-10A
Input Frequency (HZ)	45-65	
PF (full load)	≥0.995	
Dimension (length*width*height) mm	390*260*140	350*300*140
Weight	15kgs	13kgs
Multiple protections		
Protections	Multiple protections including over voltage, under voltage, over temperature, converse connection protection and short circuit protections	
Automatic current limiting	In case the output current is up to the limit, Constant Current Output and the current will not raise.	

Cooling type	Natural cooling	
IP level	IP66	
Start delay	3-8 s	
Ambient condition		
Storage temperature（℃）	-40—80	-40—90
working temperature（℃）	-20—65	-40—60
HM	≤90%, no condensation	
Battery type	lithium iron	lithium iron

3. Typical application
典型应用

The EV chargers developed elaborately on the basis of the patent technology “Resonance Voltage Control Power Conversion”. Now the off board chargers are widely used in large and medium size charging stations and the on-board chargers works in many electric vehicles created by several large car manufacturers in China. We accumulates rich experiences in the fields of EV charging station construction and on-board EV power and achieved good results. The performance of is in a leading position with the leading technical performance.
石家庄通合电子采用谐振电压控制型功率变换器技术平台，精心研制的电动汽车充电机，已成功应用到国内多个大中型充电站和充换电站，同时也应用在了在国内多家车企的纯电动汽车的车载充电机，各项性能指标居行业领先，在汽车充电站建设和车载电源领域积累了丰富的经验，取得了不俗的业绩 。

Live example:
a. Fast Battery Replacement Station in Qingdao, China, which is the largest scale station for electric buses, with the most complete function and providing the best service in China at the present.
应用实例：
采用软开关技术的充电机已成功应用在目前国内功能最全、规模最大、服务能力最强的纯电动公交车换电站-中国青岛市换电站（如下图）。


充电站
CB 电巴科技
CB 电巴科技

b. The chargers with soft switch technology are successfully used in the charging system for electric CBU vehicle. Now more than 200 charging stations with applying the technology. As shown below:
采用软开关技术的充电机已成功应用在纯电动汽车整车充电的系统中，目前在中国采用该技术的充电站已建设两百多座。（应用如下图）

3. The on-board chargers and DC-DC are successfully used in many electric vehicles developed by the leading car manufacturers and well evaluated.
Sample of one of EV chargers

采用软开关技术的充电机，已成功应用在中国多个知名车企，在纯电动汽车的车载充电机中进行了批量使用，各方面的性能指标获得了良好的评价。

车载充电机如下图：

Foton Electric Sanitation truck

Electric Car by Foton

Electric bus by Yutong

All the advantages and successful experience lead us to believe the soft switch technology represents green energy, which much works in Electric Vehicle industry wonderfully.

种种优势使我们相信，软开关技术代表着绿色能源，它一定会在未来电动汽车行业绽放奇葩