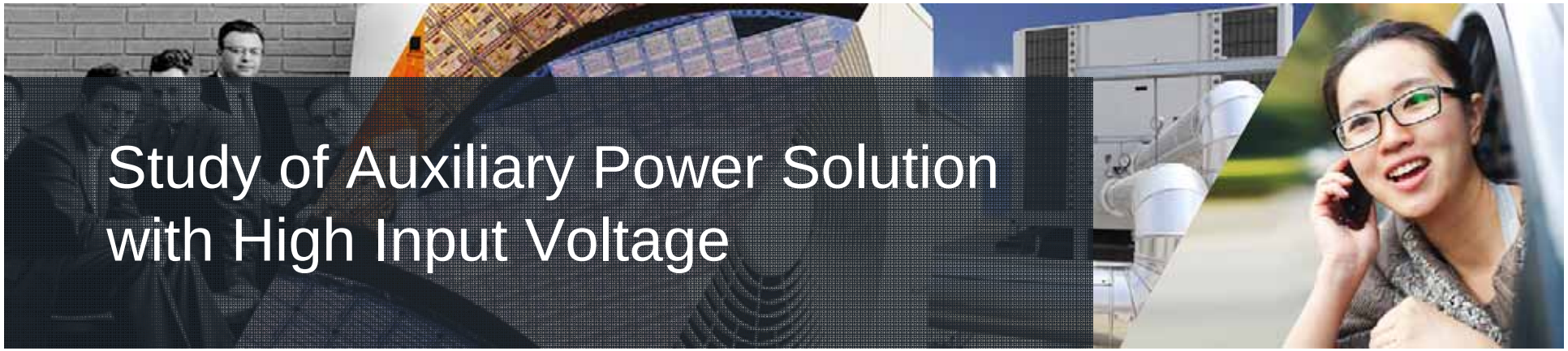


Study of Auxiliary Power Solution with High Input Voltage

Presenter : Steel Huang
Date: 6/18 2014

Agenda

- Background
- Two Traditional Solutions Introduction
- Phase Cut Regulator Introduction

Background
- Application Area

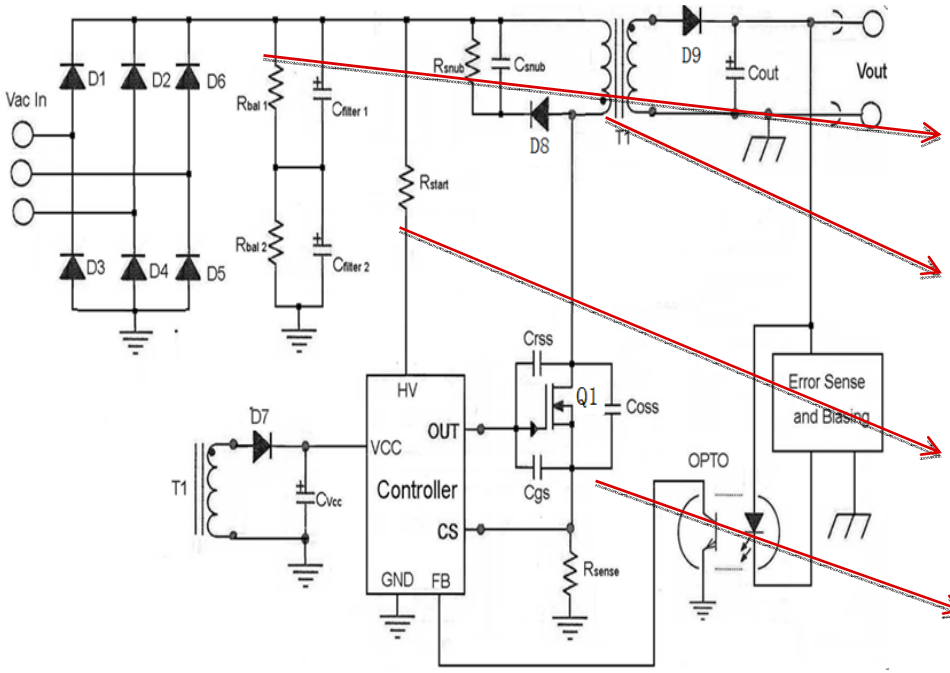
Smart Meter:

Industrial/Solar:

Input Specification:

1) Single Phase:
   85V~450VAC
2) 3 Phases:
   45V~720VAC

Background
- Design Challenge (1)



1) **Bulk-cap**:
Must use 2 or 3 bulky cap and relevant balance circuit.

2) **Transformer design** :
The duty cycle is very small in high line.

3) **Startup circuit :**
Startup current is difficult to balance due to wide range input voltage.

4) **HV switching circuit:**
Difficult to balance high switching loss and low conduction loss.

Background
- Design Challenge (2)

1) Big Space and Circuit Complexity

a) Need 2 or 3 Bulk-caps and relevant balance circuit
b) Complex transformer design

2) Low Efficiency

a) Need use HV MOSFET , big conduction loss and switching loss.
b) High DC link voltage, small duty cycle setting, lower system efficiency.
c) High DC link voltage, high VF secondary diode , big conduction loss.

3) High Cost

a) Device is expensive if adopting single MOSFET structure.
b) Too many components if adopting Cascode FET or ESBC™ structure.

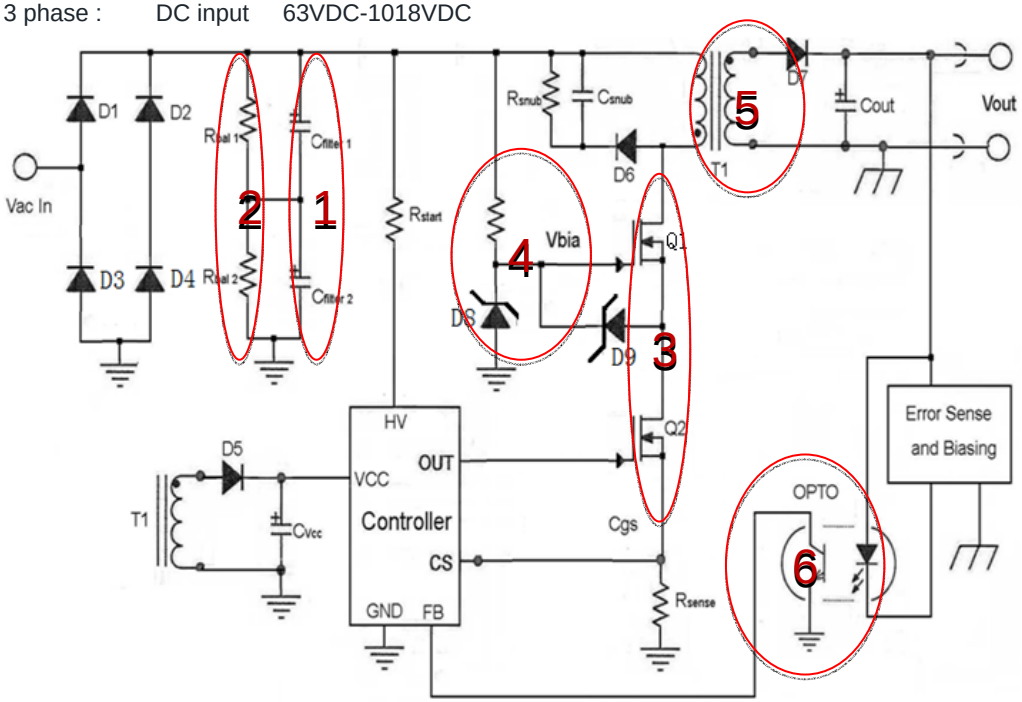
- Background

- Two Traditional Solutions Introduction

- Phase Cut Regulator Introduction

Two Traditional Solutions for HV Application
- Cascode FET Structure

Single phase: DC input 120VDC-635VDC
3 phase : DC input 63VDC-1018VDC



1) 2 Bulk –caps
2) Resistor balance circuit
3) 2 MOSFETs in series
4) Upper MOSFET driver circuit
5) Transformer
6) Feedback circuit

Cascode FET Structure - Advantage and Disadvantage

Advantage:

1) MOSFET could use popular ones.

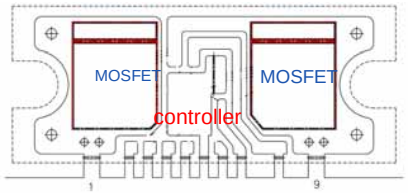
Disadvantage:

1) Need 2 or 3 Bulk-cap and balance circuit.
2) Must use 2 MOSFETs.
3) More components
4) The switching frequency could not be too high, suggest below 50KHz.

Proposal Solution:

1) FSL Series + discrete MOSFETs
2) Three in one solution

FSL Series + discrete MOSFET solution



Integrated MOSFET solution

Two Traditional Solutions for HV Application - ESBC™ structure

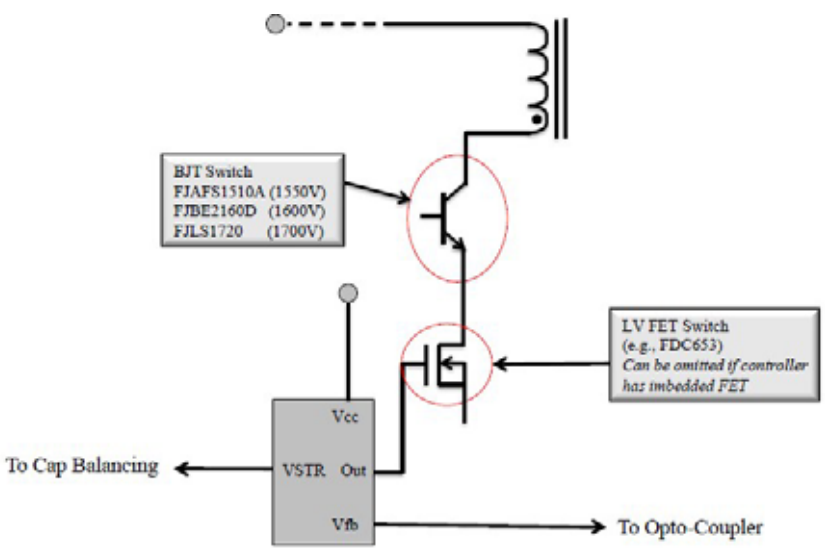
What's the ESBC™ device?

- ESBC™ (Emitter Switched Bipolar/MOSFET Cascode) device is actually a Emitter Switching, which stack a high voltage bipolar transistor with a low voltage MOSFET.

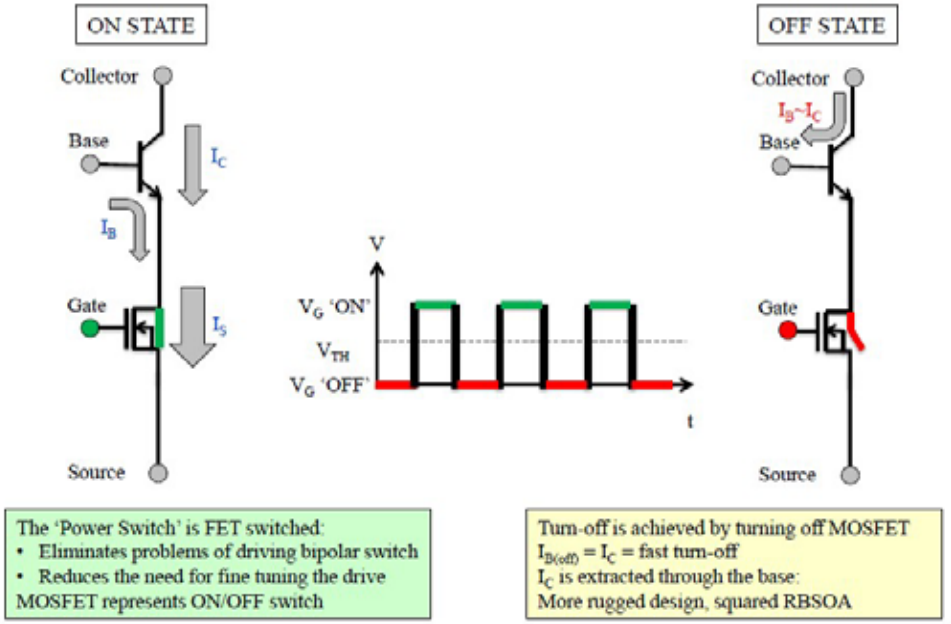
Marriage of Bipolar High-Voltage with Low-Voltage MOSFET

- Negates weaknesses of both devices while taking advantage of their strengths
- Results in a higher breakdown voltage
- Minimum switching loss and conduction loss
- Easy to drive, allows use of standard controllers

ESBC™ Device's Structure



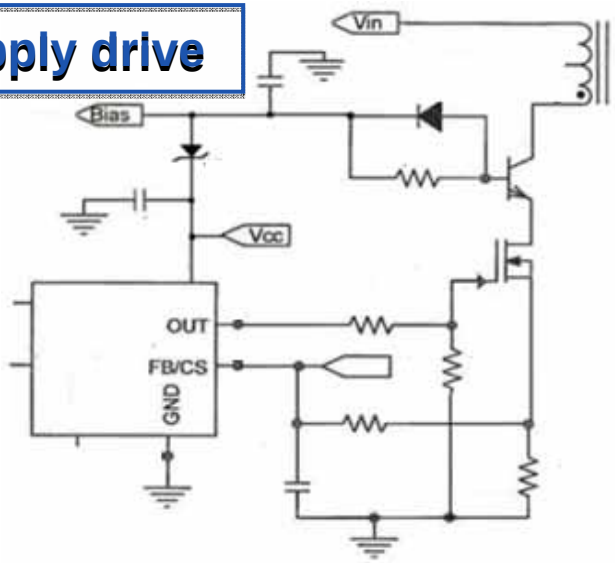
ESBC™ Device's basic structure



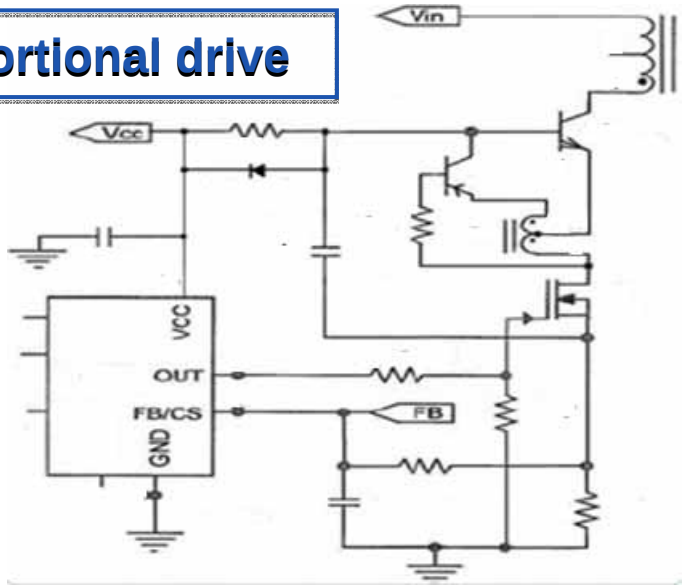
ESBC™ Device's on/off status

2 kinds of Driver Circuit of ESBC™

Bias supply drive



Proportional drive



For ESBC™ application, we must consider if the bipolar can provide a proper current gain Hfe ,this Hfe not only guarantee the saturation conduction of the transistor at turn on, but also decrease the storage time of transistor at turn off. So, Proportional transformer drive is a good choice. It can guarantee the transistor's Hfe not changing at no load or high load. generally, we advice DC bias supply drive use under low power condition (such as <10Watt), for high power, adopting proportional drive is the best solution.

ESBC™ Device's Structure - Advantage and Disadvantage

Advantage:

1) Easy to drive big power

Disadvantage:

1) Also need 2 or 3 Bulk-caps and balance circuit.
2) The driver circuit is a little bit complex.

Proposal solution:

1) FJAFS1510A (1550V,6A) + FDMA86551L(60V,7.5A)

Comparison of Two Traditional Solutions (1) - Efficiency

Solutions	Vin/Vout	Devices	Freq.	Balance Circuits	60Vac	220Vac	380Vac	600Vac
Cascode FET	45Vac-600Vac/ 15V/670mA	FSL137MRIN+ FQP4N90C	67KHz	Yes	63.41%	78.26%	76.92%	71.16%
ESBC™	45Vac-600Vac/ 15V/670mA	FJBE2160D+ FDC653N	67KHz	Yes	67.21%	79.56%	76.15%	65.68%

From above efficiency data ,we could see the different point is at the low line and high line , but In middle area, the efficiency is almost same.

Comparison of Two Traditional Solutions (2) - General Features

1) For Cascode FET solution, there need two MOSFETs and upper MOSFET driver circuit, the switching loss is big.

2) For ESBC™ solution, it just needs one bipolar transistor and a low side MOSFET, it can driver more big power, but the driver circuit is a little complex.

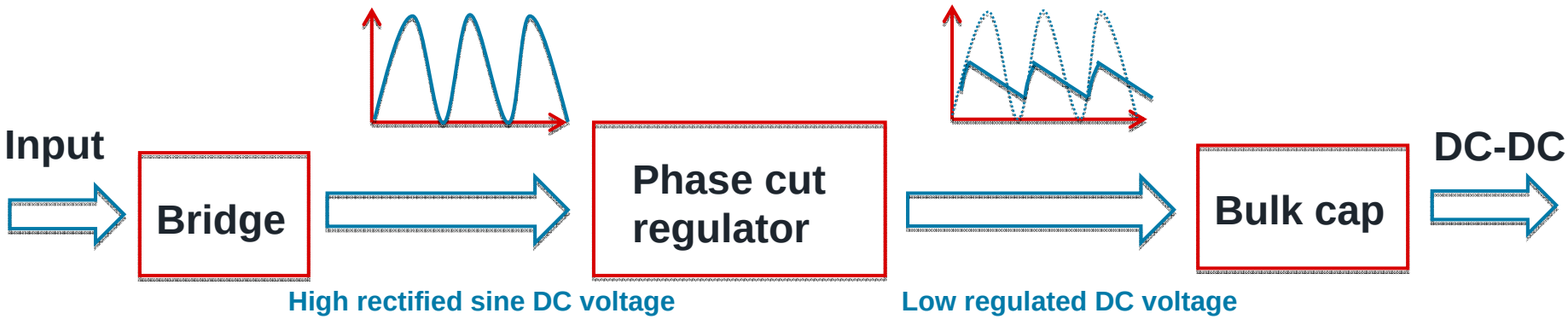
This 2 kinds of solutions all need 2 or 3 bulk-caps and relative balance circuit, this need more big space and more cost. So could we find some simple methods to solve these problems? Could we just use one bulk-cap? Could we adopt more simple driver circuit?

- Background

- Two Traditional Solutions Introduction

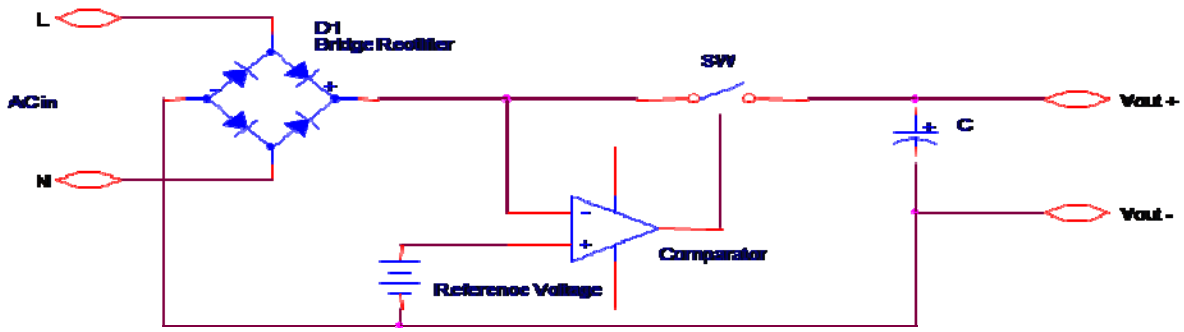
- Phase Cut Regulator Introduction

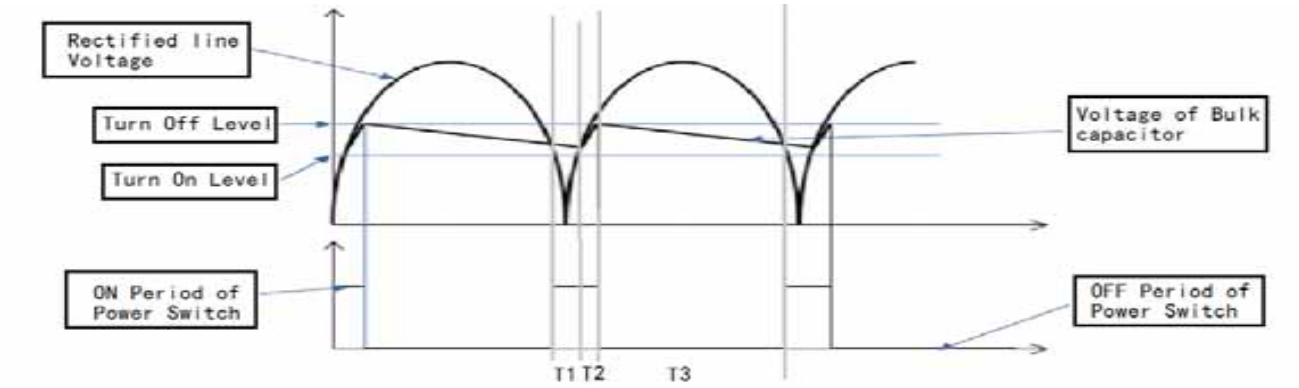
What's Phase Cut Regulator?



The phase cut regulator is circuit which insert between bridge and bulk-cap, which working in switching mode, it can regulate the high sine DC voltage from bridge to a low peak voltage DC voltage for bulk-cap.

Phase Cut Regulator Working Time Diagram





As right pictures shown :

T1: SW on, bulk-cap not charge
(Vline_on < Vref & Vline<Vbulk)

T2: SW on, bulk-cap charge
(Vline_on <Vref & Vline>Vbulk)

T3:SW off, bulk-cap discharge
(Vline_on >Vref)

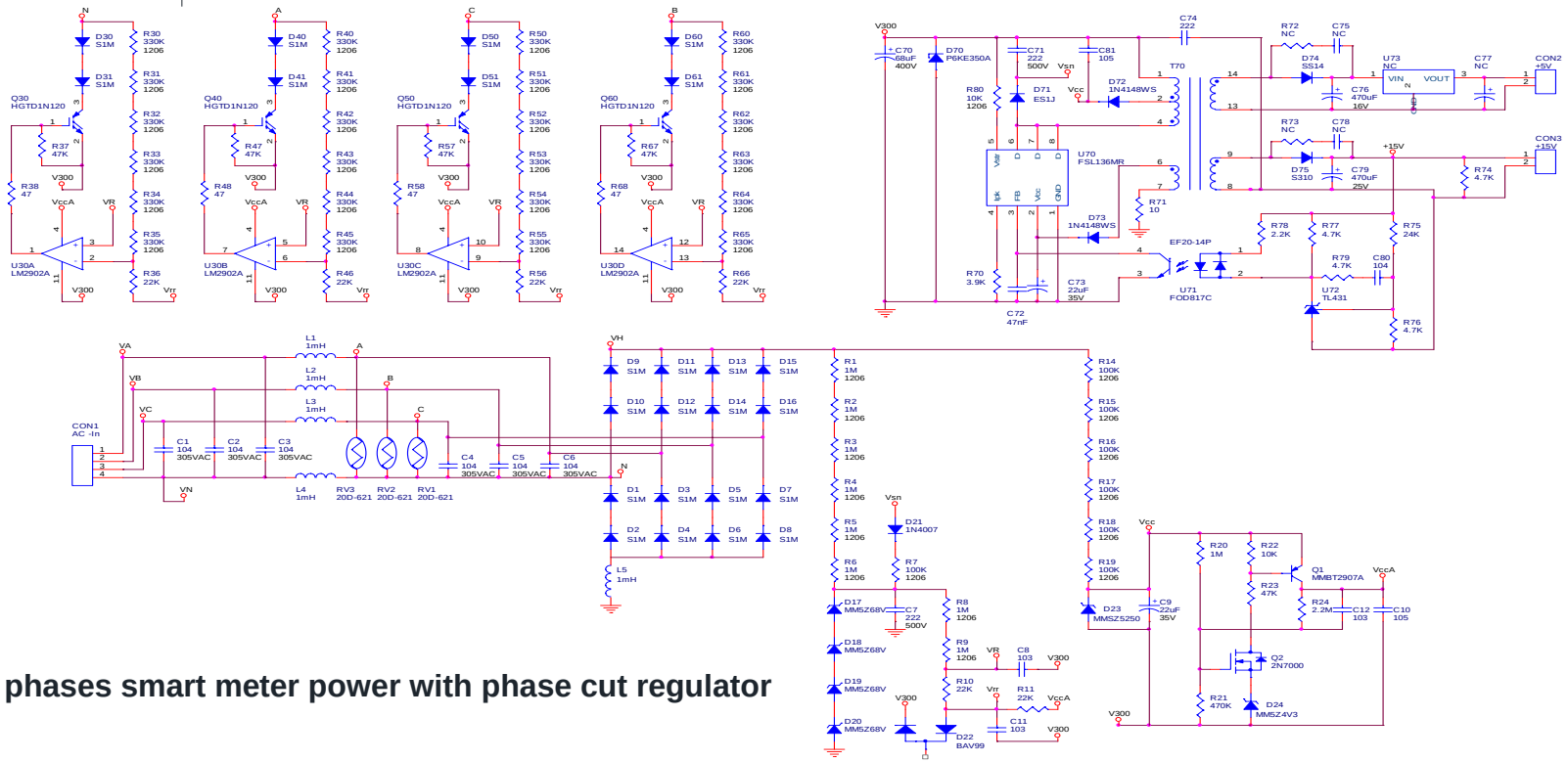
Three Solution's Efficiency Comparison

Solutions	Vin/Vout	Devices	Freq.	Balance Circuits	60Vac	220Vac	380Vac	600Vac
Cascode FET	45Vac-600Vac/15V/670mA	FSL137MRIN+FQP4N90C	67KHz	Yes	63.41%	78.26%	76.92%	71.16%
ESBC™	45Vac-600Vac/15V/670mA	FJBE2160D+FDC653N	67KHz	Yes	67.21%	79.56%	76.15%	65.68%
Pre-regulator	45Vac-600Vac/15V/670mA	FSL136+HGTD1N120	67KHz	No	77.84%	78.54%	75.32%	66.49%

The Benefit of Phase Cut Regulator

- Just need one Bulk-cap ,save cost and space.
- Don’t need Bulk-cap balance circuit , more simple.
- Could use a low breakdown voltage MOSFET , more cheaper.
- As input DC voltage go down, the DC-DC part could set more big duty cycle, the efficiency will increase.

Schematic



Three phases smart meter power with phase cut regulator

THANK YOU