Interface & Energy Buffer for Fuel Cell Applications System

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Outline:

1) **Three interfaces of PE for FC**

2) **Electrical characteristics of FC**

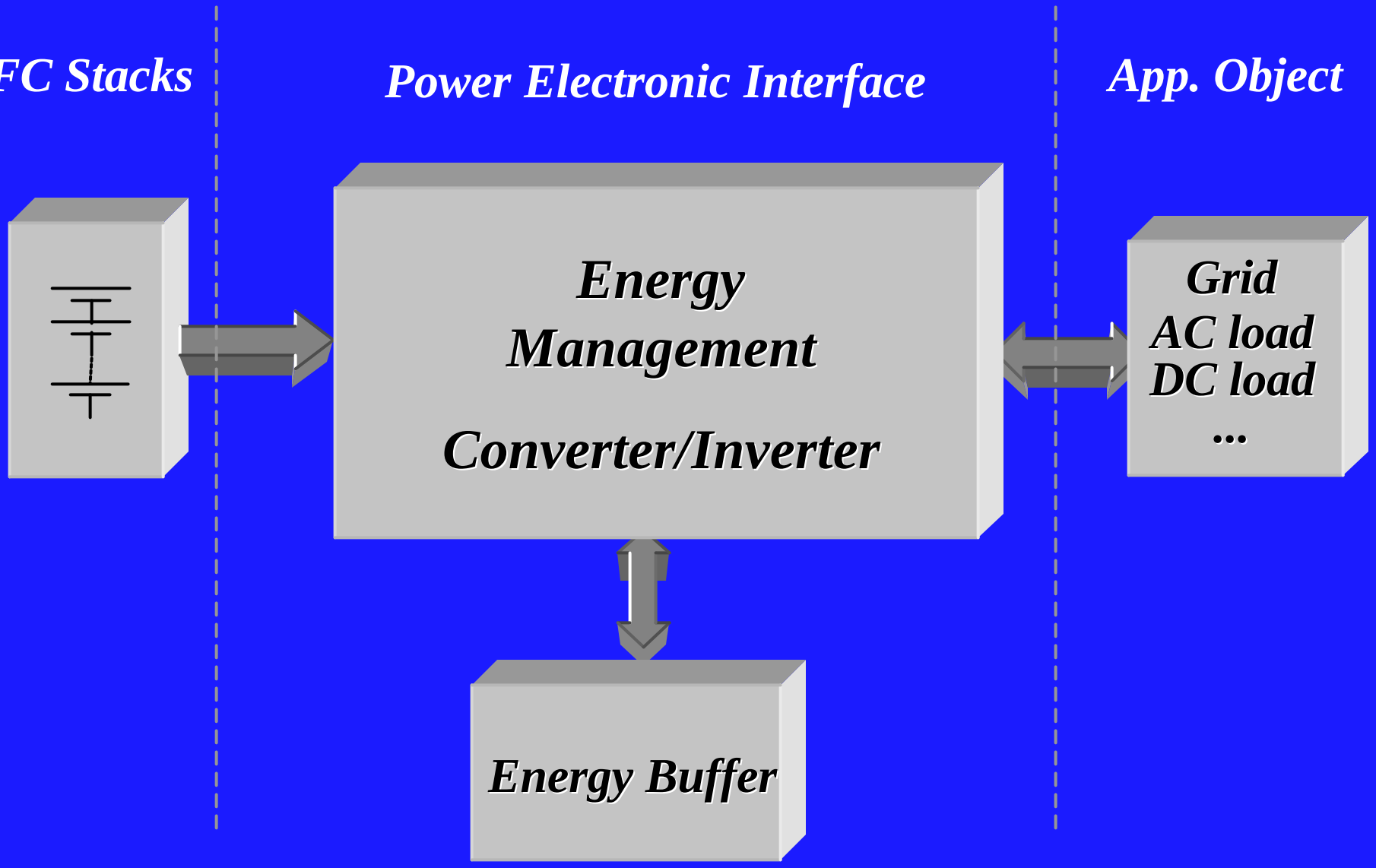
3) **Energy Buffer (*EB*) concept for FC***

   * **Why EB**

   * **Functions & implement**

   * **Example & relationships**

1) A three-interface model of PE for FC



=>

* FC app. greatly depends on PE

* FC app. is an important sub-branch of PE

* Three interfaces

- *FC ~*
- *Load/grid ~*

Ö

- *Energy buffer ~*

!!

2) Electrical characteristics of FC

Main Electrical Characteristics

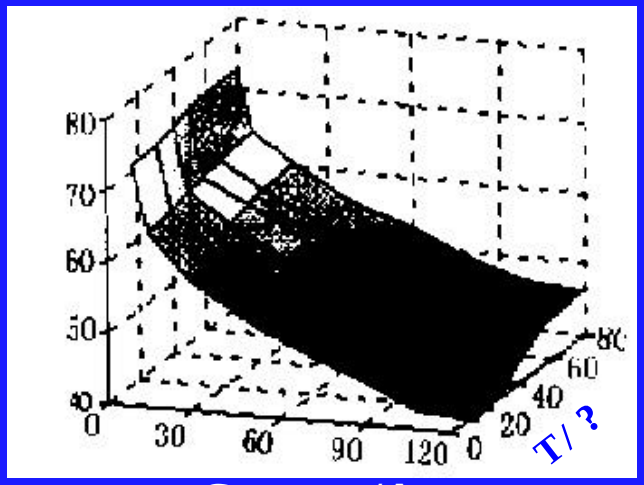
(1) V-I
(2) V-T
(3) P-I (MPP)
(4) Overload ability

Steady state

(5) Ripple tolerance
(6) Response time with load
(7) Warmed up time

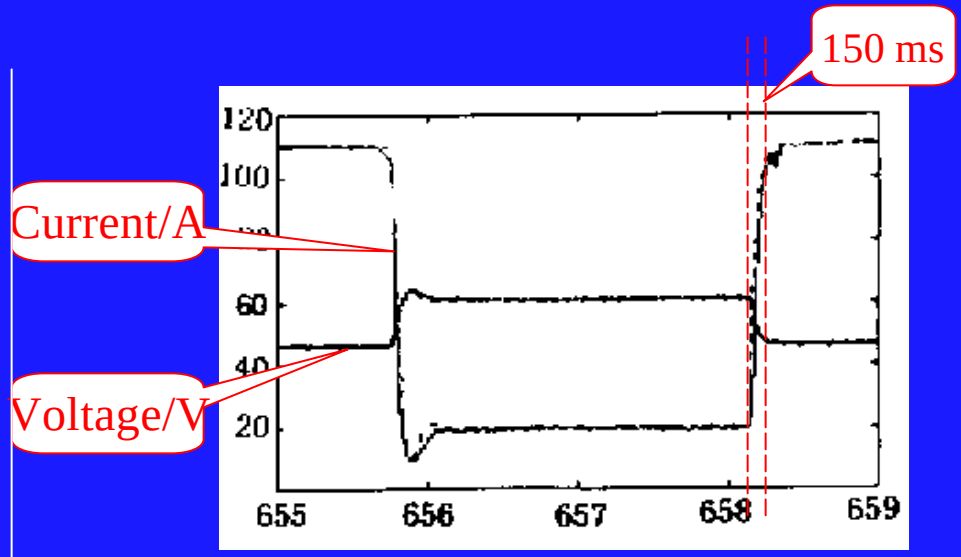
Dynamic ~

Some electrical Characteristics of a 5kW (74 stacks) PEMFC



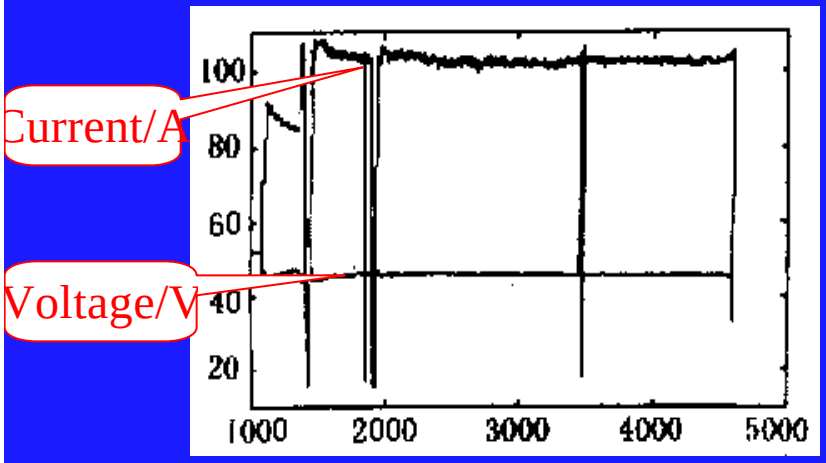
Current/A

V-I Characters at different temperature



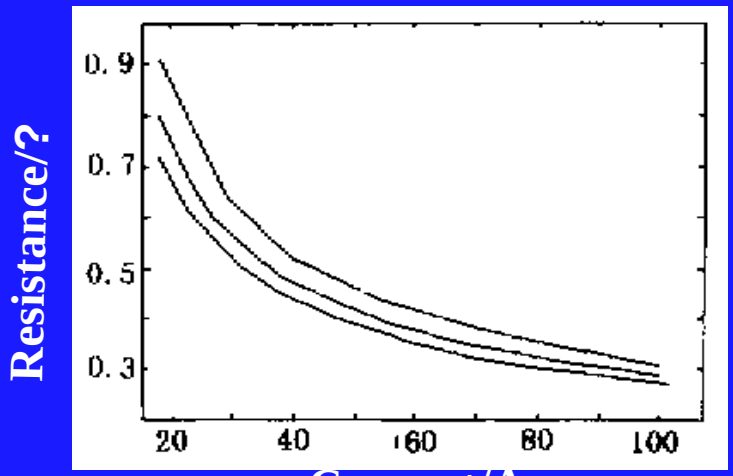
Time/s

Dynamic load Character (78?)



Time/s

Overload Capability (120% load)



Current/A

Equivalent inner resistance (15-48-78?)

3) Energy Buffer (EB) concept for FC*

* Why Energy Buffer ?

Conflict: FC characteristics ?? Energy requirements

FC : *Primary DC source (not ideal)*

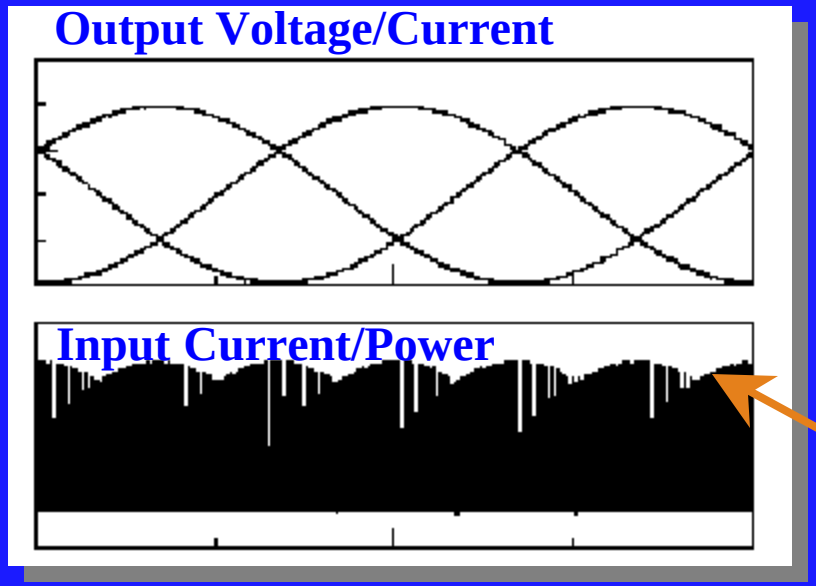
Goal: *Convert to desirable level & forms;*

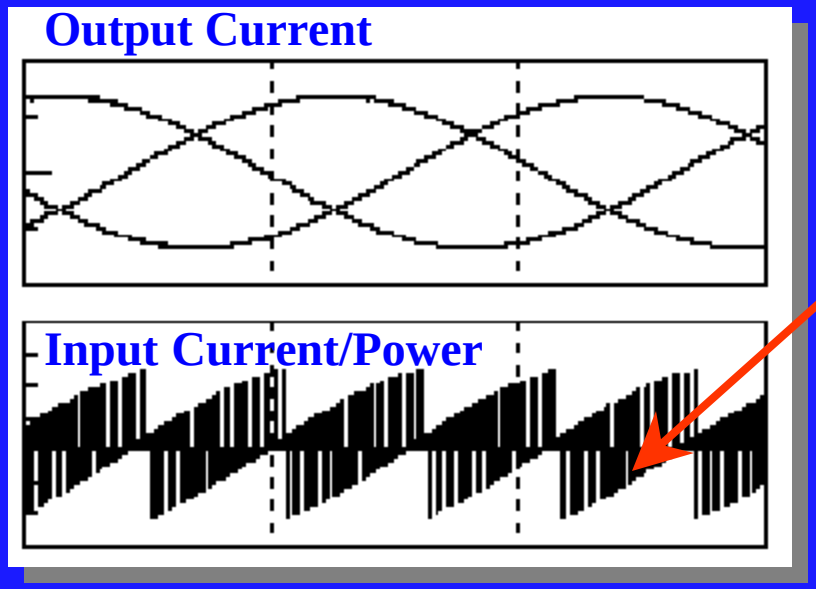
On one hand (Fuel Cell)

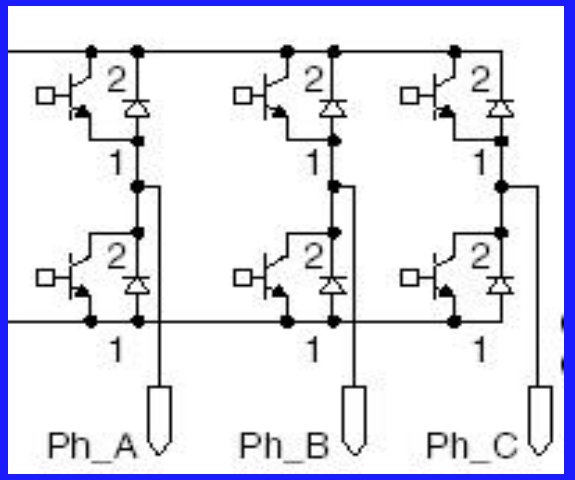
- *** Voltage variable (with Load, Temperature, ...)**
- *** Limited overload capability**
- *** Single power flow direction**
- *** Slow response: 100 ms~s (to Load/PE device)**
- *** Poor ripple tolerance**
- *** Slow warmed up: ~tens of minutes**

However, most applications are subjected to:

Current ripple:	**Output frequency** (60Hz, 120Hz, 360Hz, or variable ~) **Switching frequency** (DC/AC , DC/DC)
Power flow stress:	**Reactive load** (inductive machine)
Response time:	**Load fast change** **Warmed up** (e.g. vehicle)
Overload :	**Induction motor start** (5~10 times of rating)





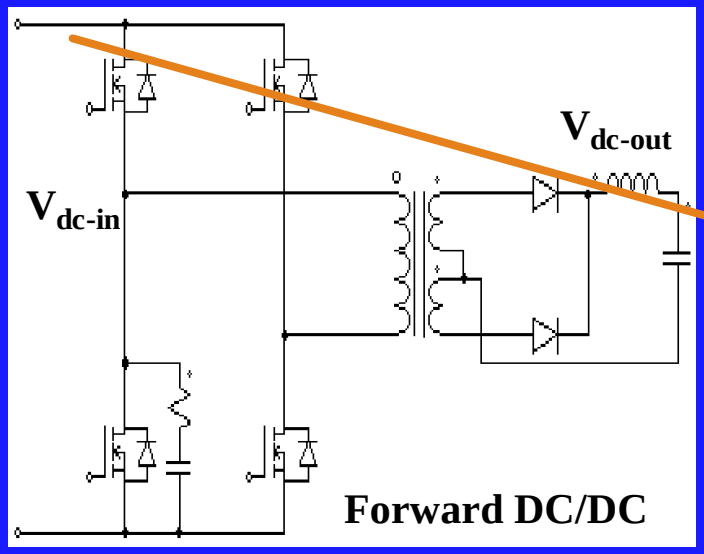


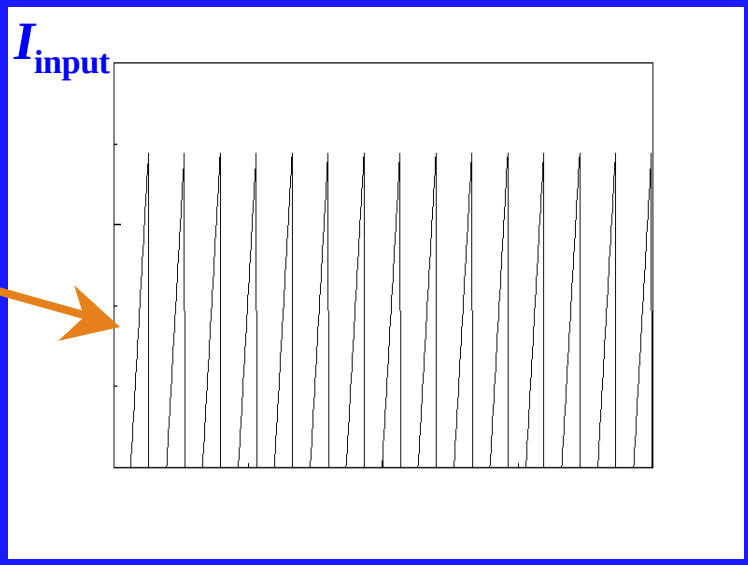
AC Load/Grid

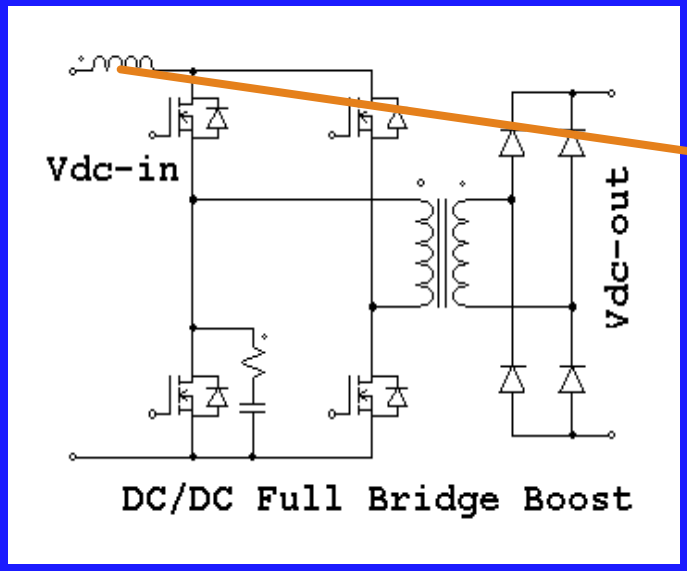
Grid/Resistive load

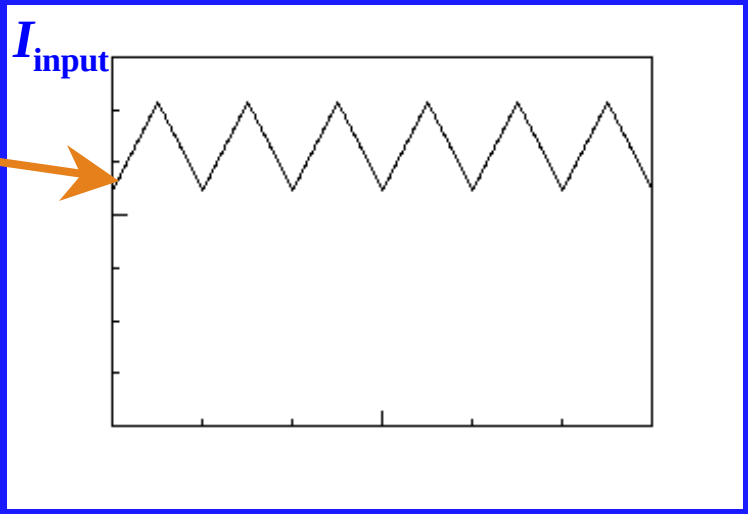
Reactive power/Current flow
(Inductive load)

Input current & power ripples of DC/AC









Input current & power ripples of DC/DC

* *Functions of Energy Buffer*

* **Buffer for Current Ripple**
* **Sink for Reactive/Regenerative Power** (from load)
* **Storage for over-produced power** (from FC)
* **Provide Overload/Peak Current**
* **Provide Warm up power**

* *Implement methods of Energy Buffer*

* Capacitor
* Super-Capacitor
* Flywheel
* Super-inductor
* Battery
* Pumping Generator station
* Rechargeable “Fuel Cell’s device”

Fast response time

Medium term/energy

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Long term, larger Energy

Low efficiency

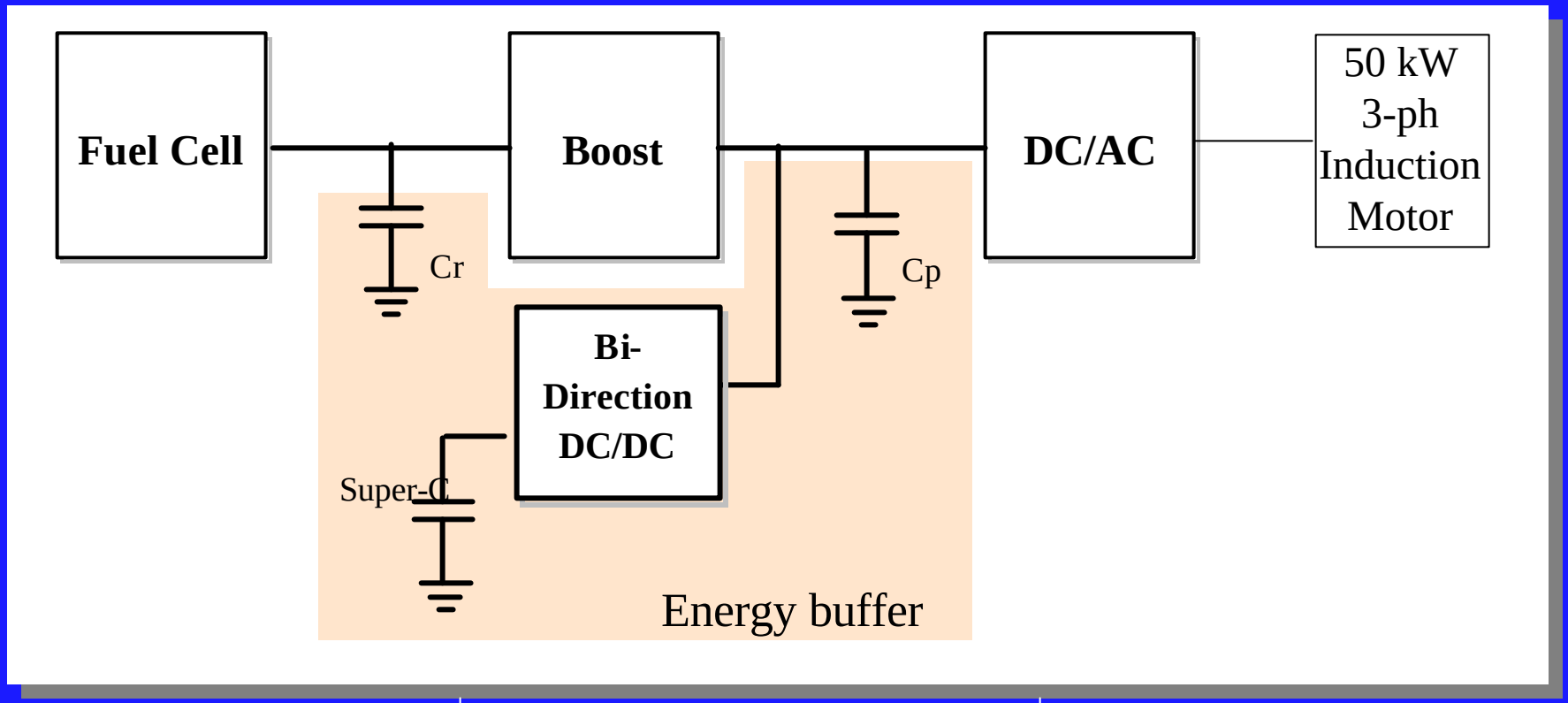
Promising EB trend!

High efficiency/power

Smaller size

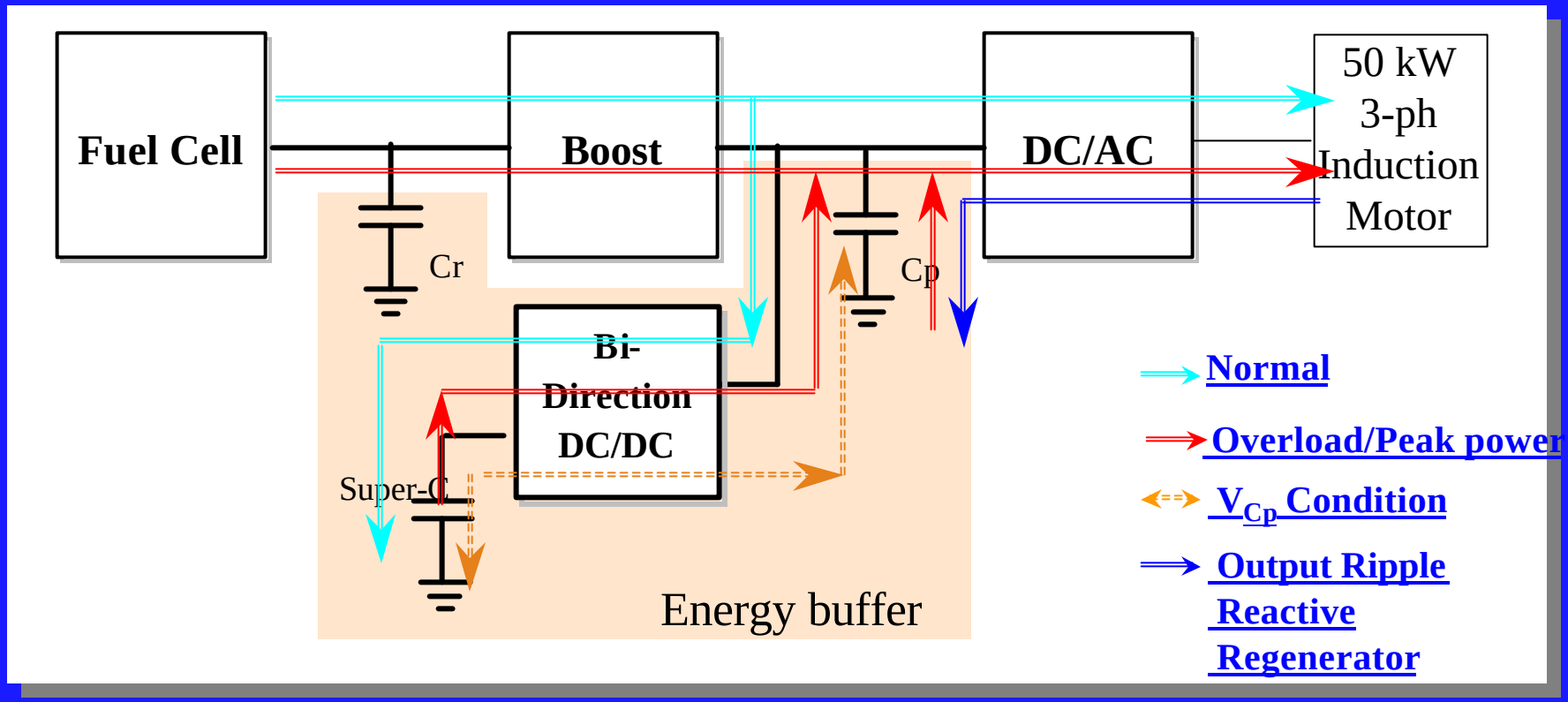
Practical: C+SC or C + Battery

* Example of EB for Vehicle Driver :



Cr	Super C	Cp
• SW frequency ripple	• Long term energy buffer • Warm up	• SW frequency ripple • Output frequency ripple • Peak power (5~ times) • Reactive power flow • Fast load transient buffer

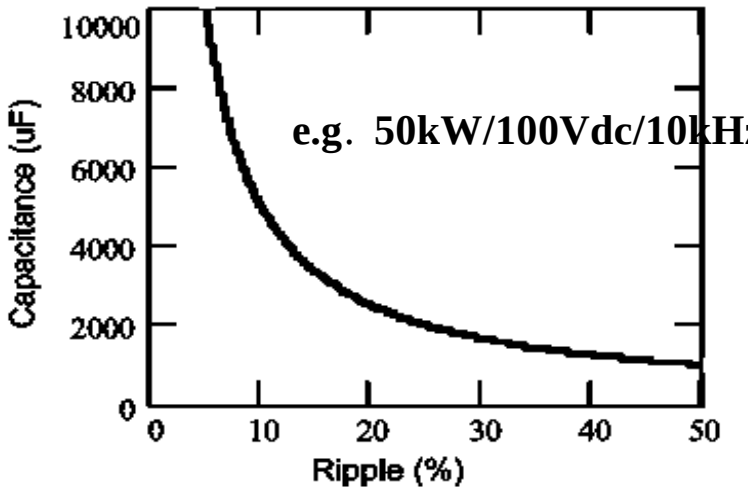
* Power flows in different operation states :



* Some relationships of the Example:

? DC/DC SW Ripple filter

$$C_r = \frac{I_{(peak,max)}}{\Delta V \cdot f_s}$$



? DC/AC Energy Buffer C_p

$$C_p \geq I_{pk}/(f_{out} \cdot \Delta V)$$

$$C_p \geq (1-\sin 60^o) I_{pk}/(6 f_{out} \cdot \Delta V)$$

$$C_p \geq (n-2) P \cdot T_{overload}/(\Delta V \cdot V_{dc2})$$

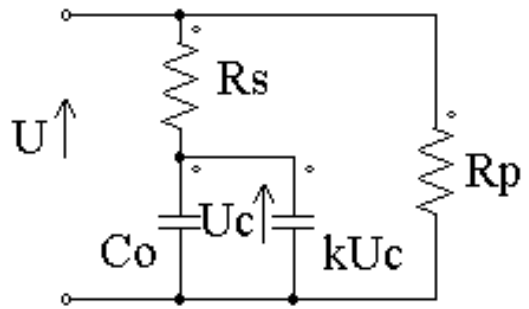
$$C_p \geq P \cdot \sin q \cdot (q/2p)/(f_{out} \cdot \Delta V \cdot V_{dc2})$$

$$C_p \geq P \cdot \Delta T/(\Delta V \cdot V_{dc2})$$

Max(C_p) ⇒

- **SW *f* ripple**
- **Output *f* ripple**
- **Peak power (5~ times)**
- **Reactive power flow**
- **Fast load transient buffer**

? Super-Capacitor-Large Energy Buffer



$C_U = C_0 + kUc$

e.g.	2600F/2.5V/100A
C_0	1800F
k	340F/V
R_s	0.8 m?
R_p	3 k?

Characteristics:

- Larger variable capacitance
- Small leakage current
- Long Energy storage time
- High reusable energy rate

~10^3 F, $i = (C_0 + 2kU_c)\frac{dU_c}{dt}$

nA/mA(large arrays)

>10 days

80% E @ 50%V $\Delta E = \frac{3}{4}E(U_c) + \frac{1}{12}kU_c^3$

•Long response time & limited current Charge/discharge needed !

Energy stored in Super C: ~2000F@50V

? **50s for 50kW load**

? **100Ah/12V Battery**

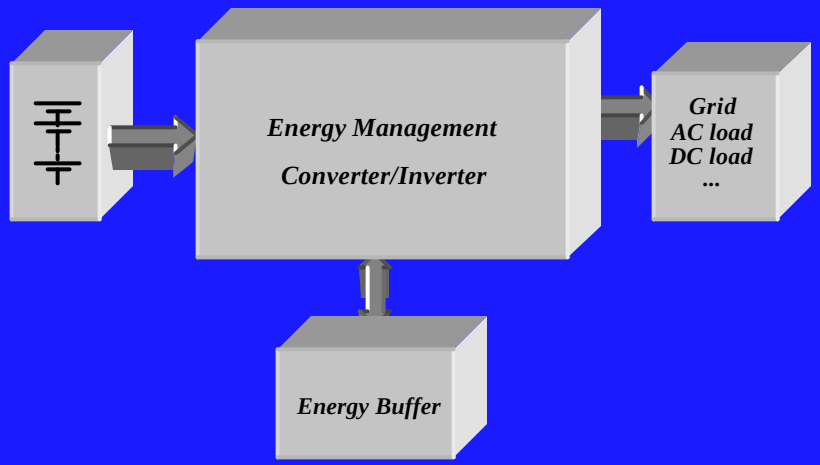
(60% discharge $\frac{1}{2}C(U_c)\cdot(U_{c1}^2-U_{c2}^2)=\int vidt\approx\overline{V}\cdot\overline{I}\cdot T\times 3600)$

"Rechargeable Fuel Cell's device" **is a desirable & Promising Energy Buffer for high power application (~500MW)!**

$$2H_2+O_2\underset{charge}{\overset{Discharge}{\rightleftarrows}}2H_2O+electricity$$

Conclusion

* EB is an important interface of FC's application
* Functions & Implements of EB are discussed
* Relationships of EB based on an example are derived



Thanks!