One-Cycle Control and Its Applications in Distributed Generation

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I. Our Power Systems
   • It is time for renovation
   • Power electronics is a key Component

II. One-Cycle Control
   • A PWM Computer
   • Active power filter derivation
   • Universal OCC Controller

III. Utility Applications
   • Examples
   • A possible configuration
I. Our Power System

Thousands of generating stations, tens of thousands of transmission and distribution substations, 150 control area operators, and over 200,000 miles of transmission lines.

One of the largest structural achievement by humans.
For every BTU electricity generated, twice of that amount is lost, which wastes the natural resources and creates environmental pollution.

Courtesy of Energy Information Administration Annual review

3,333 BTU=1 kwh, 900million tons of coal/year
Issues in our current power system

Centralized generation:  
=> efficiency ~30%  
=> consumes large amount of fossil fuel ~70%  
=> environmental impact

Long transmission line:  
=> transmission losses  
=> system oscillation

Load harmonic currents:  
=> transformer heating  
=> reduced system capacity

Large system:  
=> vulnerable to cascading faults
Power Electronics is a key element for distributed generation

- Inverters --- renewable and alternative energy power generation
- PFC rectifiers--sinusoidal current use
- APF--- power quality control
- STATCON --- VAR compensation and voltage support
II. One Cycle Control

- Cycle by cycle control => fast and precise transient

\[
\frac{1}{T_s} \int_0^t V_2 \, dt = V_1 \\
t = dT_s \\
V_2d = V_1
\]

- OCC solves the first order polynomial equation

- Most power electronics problems can be expressed by a first order polynomial equation.
OCC--A PWM Computer

OCC solves nth order polynomial equations

\[ v_1 = v_2 d + v_3 d^2 + v_4 d^3 + \cdots \]
Three-Phase Converter Control
--e.g. active power filter derivation

Control goal:
\[
\begin{bmatrix}
  v_a \\
v_c
\end{bmatrix} = \begin{bmatrix} R_e \end{bmatrix} \begin{bmatrix} i_a \\
i_c
\end{bmatrix}
\]

Control key equation 0-60°:
\[
\begin{align*}
V_m \cdot \begin{bmatrix} 1 - d_{an} \\ 1 - d_{cn} \end{bmatrix} &= R_s \cdot \begin{bmatrix} 2 \\ 1 \end{bmatrix} \cdot \begin{bmatrix} i_a \\
i_c \end{bmatrix} \\
d_{bn} &= 1
\end{align*}
\]

\[
V_m = \frac{E \cdot R_s}{R_e}
\]

The line cycle is divided into six regions
Three-Phase Converter

UCI Power Electronics Lab

Simple, Reliable, Robust, Modular, Universal.

For symmetric or asymmetric systems.

No multiplier,
No DQ conversion,
No software in the loop.
A Universal 3-phase Controller

OCC controller is universal!

Inverter
Rectifier
APF
STATCON
Etc.

One controller does all!
III. OCC Applications
Active Power Filters

- APF actively cancels the harmonics from the load
- The line current is sinusoidal
- APF only processes the harmonic and reactive power
- Can be used in equipment, buildings, substations, etc
Experimental Waveforms

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Symmetric operation:

Phase A line voltage
Three-phase currents
THD=3.2%
PF~1

Phase A line voltage
Phase A line current
Phase A APF current
Phase A load current
Start-up Transient Test
Load Step Up Transient Test

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Load current-->  
APF current -->  
<--Line current
Grid connected Inverter for Power Generation

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Renewable/Alternative Power Generation

- Sinusoidal current injection
- Robust performance
- Maximum power point tracking

OCC Grid-tied inverter
One-cycle Control Rectifiers for Harmonic Suppression

Traditional rectifiers draw harmonic current

One-cycle control rectifiers draw sinusoidal current
OCC-STATCOM for Reactive Power Compensation

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Static Synchronous Compensator

1. Superior voltage supporting capability
2. Uses small dc capacitors instead of large dc capacitors
3. Needs smaller space than conventional switched capacitors.
One of Possible Hybrid Configuration

OCC Converter functions as:
- inverter
- rectifier
- active power filter
- var generator

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OCC Unified Power Quality Conditioner

- Improve voltage quality.
- Improve current quality.
- Improve power system stability.
- Improve power system security.
- Improve transmission efficiency

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<tr>
<th>Energy Quality Items</th>
<th>AF₁ (Series AF)</th>
<th>AF₂ (shunt AF)</th>
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<td>Source voltage harmonics suppression</td>
<td>Load current harmonics compensation</td>
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<td>Source voltage Regulation</td>
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<td>Voltage balancing</td>
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<td>Voltage flick/sag/dip compensation</td>
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<td></td>
<td>DC Voltage regulation</td>
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<td>Impulse &amp; EMI suppression</td>
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OCC-UPQC

Voltage unbalance and harmonic compensation ==> Reactive and nonlinear Load current compensation

Before                After

Before                After
Reversible OCC Rectifier

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Regenerative power generation
Energy conservation
MPPT at DC side
Cancel harmonics at ac side
Two OCC converters back to back to Form high power quality frequency converter.
Generate reactive as need
Cancels the harmonics in the line.
Combine with Diode/Thyristor type of converters
To achieve high power and low THD.