ECE 529
Utility Applications of Power Electronics
Session 2
Setpoints
$|V|$ (ac,dc),
P, Q, $\Delta f$, etc.

$V_{\text{meas}}$(ac,dc),
P, Q, $\Delta f$, etc.

Outer Control

Open or closed loop controller

$I_{dref}, I_{qref}$ or $V_{ac_{-ref}}, \phi, V_{dc}$

Inner Control

Map commands to switch timing

Desired switching on/off timing

Gate Drives

Pulse shaping
(Often analog circuit)

Gate Pulses

Power Circuit

Switching Devices plus Passives (L, C)

Input
(DC if VSC)

Output
(Often AC)
1. Magnitude
2. Frequency/phase
Transmission Problem Areas

- Bulk power transfer over long distances
- Transmission Limitations/Bottlenecks have one or more of the following:
  » Steady-state stability limits
  » Transient stability limits
  » Power system oscillation limits
  » Inadvertent flows
  » Short circuit current limits
  » Thermal limits

Introduction 1

Deregulated Structure Combined with Renewables

- Results in:
  » Increased variability in network condition
  » Uncontrolled variable generation output
- Needs
  » Better utilization of existing infrastructure
  » Robust, resilient solutions

Introduction 2
Distribution Problem Areas

- Usually fall under power (voltage) quality:
  - Voltage sags due to faults, motor starting
  - Voltage flicker
  - Interruptions
  - Harmonics

Traditional Solutions

- Reactive compensation (distribution)
  - Shunt capacitors/reactors
  - Synchronous condensers
  - Passive harmonic filters
- Reactive compensation (transmission)
  - Shunt compensation (capacitors, synchronous condensers)
  - Series capacitors (SSR issues in some cases)
Traditional Solutions

- Transmission system fixes
  - Automatic Generation Control
  - Excitation control/Power System Stabilizers
  - Phase shifting transformers
  - Faster protection (trip/reclose)
  - Operational limits
  - Recductor lines
  - Increase voltage levels
  - Build more lines
  - Special stability controls

Power Electronic Applications?

- Specialized applications where traditional technologies inadequate
- Apply where power converters matter
  - Fast, dynamic compensation is needed
    - Avoid steady-state AC compensation
  - Conversion ac/dc or between frequencies
    - For transmission
    - Due to nature of generation or energy storage
Power Electronics to Change (Improve) Performance

Classes of devices
- Variable impedance ac compensators
- Switching converter based compensators
  - Effectively controlled voltage source
  - Or controlled current source
- HVDC: ac/dc conversion and power transfer

Concerns:
- Cost
- Losses
- Complexity
- Reliability
- Maintainability

Introduction

Spring 2021
# Early Transmission Applications

- HVDC Transmission
  - Update to Edison's vision
  - Asynchronous connections
  - Long distances overhead
  - Generally 2 terminal lines (evolving)
  - Underwater
  - Back to back
  - Drawbacks: Cost, complexity

---

# Transmission Applications

- HVDC Transmission History
  - Berlin-Charlottenburg early 1940's
  - Moscow (USSR) early 1950's
  - Gotland Island (Sweden) 1954 – first operational
  - Current source converters (Mercury arc valves)
  - Thyristors in 1970's
  - Growth in voltage sourced converter HVDC
## Transmission Applications

### Lecture 1

- **Static VAr Compensators**
  - 1: Reactive compensator--faster response
  - 2: Started with saturated reactors in 1930's developed in Germany, Dr. E. Friedlander
    - Still used in 1960's
  - 3: First thyristor based devices in 1970's
  - 4: Used at transmission and distribution level

### Introduction

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

## Transmission Applications

### Lecture 1

- **Flexible AC Transmission Systems (FACTS)**
  - 1: Shunt compensation
  - 2: Series compensation
  - 3: Phase angle regulator
  - 4: Combined #1, #2, and #3
  - 5: Speed of response
  - 6: Enhanced capabilities
  - Drawbacks: Cost, complexity

### Introduction

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---