Reactive Power Delivery
Incentives
Harvard Electricity Policy Group 12/2/04

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Agenda

• What is Reactive Power?
  – Why do we need it?
  – How is it provided?
  – Who can provide it?
  – How do we balance voltage?

• The UK Reactive supply

• New England & New York Reactive payment arrangements
To the engineer........

Sinusoidal voltage:

\[ V_1 = V_1 \sin (\omega t + \varphi_1) \]

\[ V_2 = V_2 \sin (\omega t + \varphi_2) \]

Constant angular velocity: \( \omega \)

Time-Domain representation
To the engineer......

- Synchronous Generator

\[ \text{Overexcited Generator} \]

\[ \text{Underexcited Generator} \]
To the rest of us.......an analogy helps

You can’t move the wheelbarrow (active power delivery)

unless you lift the arms! (reactive power)
Why do we need it?

- maintain system reliability
  - support local system voltage
  - maintain voltage step changes within specified limits, steady state post fault
- support the transmission of active power
- the requirements vary with location and load
**How is it provided?**

**Generation**
- Lagging
  - Mvar
  - MW
  - 5%
- Leading
  - Mvar
  - MW

**Heavily loaded lines**
- 83%
- Inductive Motors, fridges etc
- 12%
- Capacitive Fluorescent lighting

**Demand**
- Mvar
- MW

**Lightly loaded lines/Cables**
Who can provide it?

<table>
<thead>
<tr>
<th>Controllable Sources/Sinks</th>
<th>Less Controllable Sources/Sinks</th>
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<tbody>
<tr>
<td>• Generators</td>
<td>• Overhead Lines</td>
</tr>
<tr>
<td>• Synchronous compensators</td>
<td>• Underground cables</td>
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<tr>
<td>• Capacitive and inductive compensators</td>
<td>• Transformers</td>
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<td></td>
<td>• Customer demand</td>
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</table>
How we balance voltage
How we balance voltage
How we balance voltage

Post fault Voltage levels
Maintained by automatic change
In generator reactive output

Lost capacitive effects from faulted circuit
Increased inductive effects from more heavily loaded remaining two circuits
UK Reactive Supply

1997 onwards

• Obligatory Reactive Power Service (aka the “Default Service”)
• Enhanced Reactive Power Service
• Both services, especially, enhanced market services, interact with transmission investment and expansion
• Under purview of Regulator
• Funded by daily payment from suppliers
Obligatory Reactive Power Service

- Rule based payments (enforced via Grid Code obligation)
- Default obligation on all large generators (typically >50MW)
- Minimum reactive power range
- Fixed MVArh payment rate (reviewed annually)
  - Transition to utilization only payment (step down from 80% capability to 0% capability over 4 years)
  - Payment is currently approximately $2.40/MVArh
- No need to tender
**Enhanced Reactive Power Services**

- Can be same technical service as the “Obligatory RPS”
- Offered via market tender
- More potential providers (eg. smaller generators)
- Minimum 15MVAr (lead or lag)
- Generator offers price curves
- Contracts 12 months minimum
- Generator chooses prices and other terms to tender
- Can offer additional services
- If tender not accepted, still gets Obligatory RPS (ie. default rate)
Reactive Supply – Enhanced Reactive Power Service

Capability Payments

<table>
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<th>Synchronized capability price</th>
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<tr>
<td>Available capability price</td>
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Utilization (£ per MvArh)

- Synchronized capability price
- Available capability price

£ / Mvarh

Lead Mvar   Lag Mvar

Mvar Output

Q₁, Q₂, Q₃

CU₁, CU₂, CU₃

GridAmerica
Units participating (April tender round)
Features of “Market” Contracts Interacting with System Operation and Investments

• Generator can use Mvarh price to incentivize National Grid (as System Operator) to despatch unit to low Mvar outputs

• Generator creates own financial incentive to maintain Mvar capability; this may reduce transmission investment needed

• Generator can offer capability in excess of regulatory requirement: can reduce transmission investment needed
New England Reactive Compensation- introduced 2001

- Capacity payment made to Qualified Generators
- Payment based on lagging reactive capability demonstrated at real power capability
- $1.05/kVAR-year *capability – reduced if active capacity reserve margin more than 20%
- Lost Opportunity Payments – active power
  - Pull back to provide more reactive
  - Synchronous compensation
  - Active power produced for VAR only requirements
New England
Other Reactive Sources

- Capacitors
  - Capital costs collected by transmission owners through transmission rates
- Synchronous condensers and FACTS devices
  - Capital costs collected by transmission owners through transmission rates
  - Real power consumed treated as losses on the NEPOOL transmission system
  - Treatment will be revisited on an as needed basis.
- Currently considering compensation for merchant HVDC converter reactive output
New York
Reactive Compensation

• Capacity payments made to all generators under contract to supply Installed Capacity
  – Other units and synchronous condensers eligible although receive pro-rata payment based on the number of hours run
• A resource must demonstrate that it has successfully performed reactive power capability testing
• Payments require the ability to produce/absorb reactive power within the resource’s tested reactive capability, and to maintain a specific voltage level under steady-state and contingency conditions
• Payments withheld if unit fails to respond when called upon or following a contingency as determined by NYISO
New York Reactive Compensation

Components

• Capacity Payment
  – Annual payment, 1/12 paid monthly
  – Paid to all qualified resources
  – Equal to $3.919/kVAR-yr for qualified VARs

• Lost Opportunity Payment
  – Paid to units dispatched down to provide reactive supply
  – Equal to the MW reduction times LMP minus the generators energy bid (lost infra-marginal revenue)
### New York

**Other Reactive Sources**

- Capacitors, synchronous condensers and FACTS devices
  - Capital costs collected by transmission owners through transmission rates

- TCCs (FTRs) awarded if installation increases transfer capability
Summary

- RP not commodity – very locational
- Simple RP payments appear to deliver system needs without impeding active markets
  - Benefits of complex arrangements?
- Some limited evidence of Reactive payments interacting with Transmission investment in UK