The role of HVDC & FACTS technologies to enhance the utilisation of existing transmission networks

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HVDC & FACTS

HVDC

- High Voltage Direct Current
- A system used for transmitting or exchanging electrical power by means of direct current

FACTS

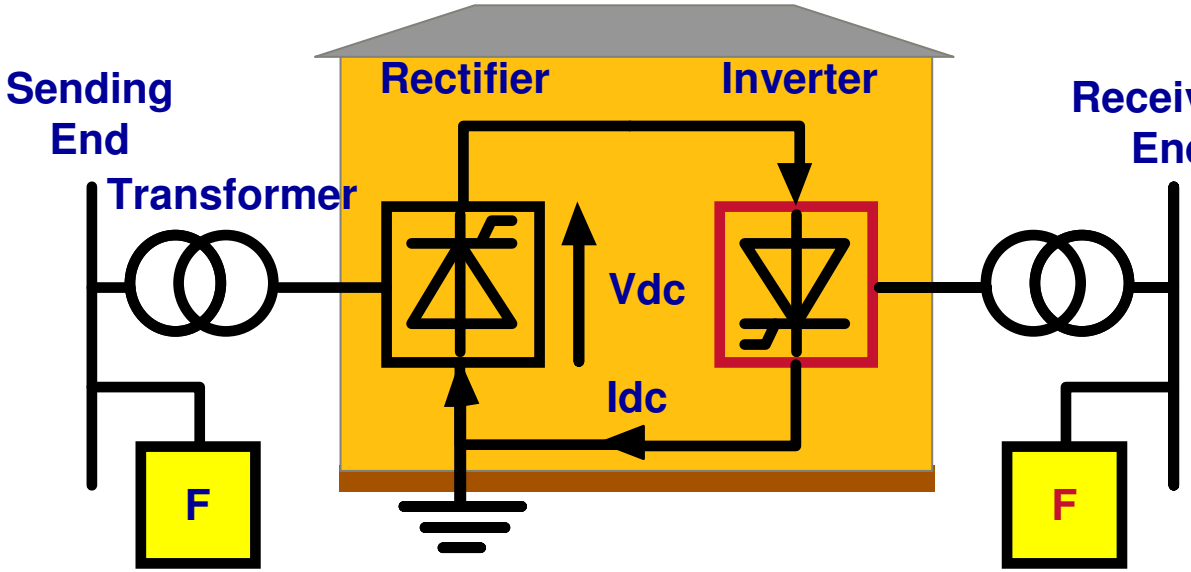
- Flexible Alternating Current Transmission Systems
- Systems used for the dynamic control of voltage, impedance and phase angle of high voltage AC transmission lines

HVDC & FACTS

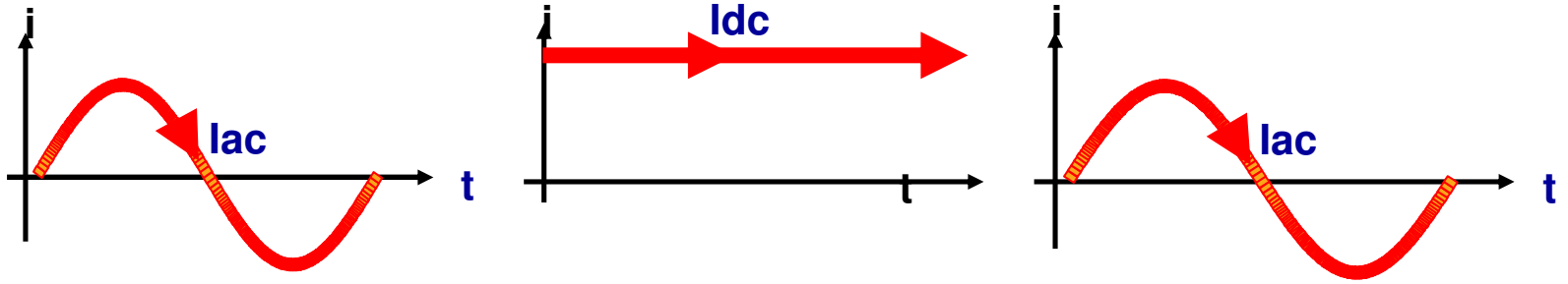
- **HVDC & FACTS are built using Power Electronics devices**
  - **Brings precision of control, dynamic performance, and many other features, into transmission networks**
  - **Two technologies exist:**
    - **Line Commutated Converter**
      - **Classical HVDC**
      - **Thyristor based**
    - **Voltage Source Converter**
      - **VSC HVDC**
      - **Transistor based**

HVDC Configurations

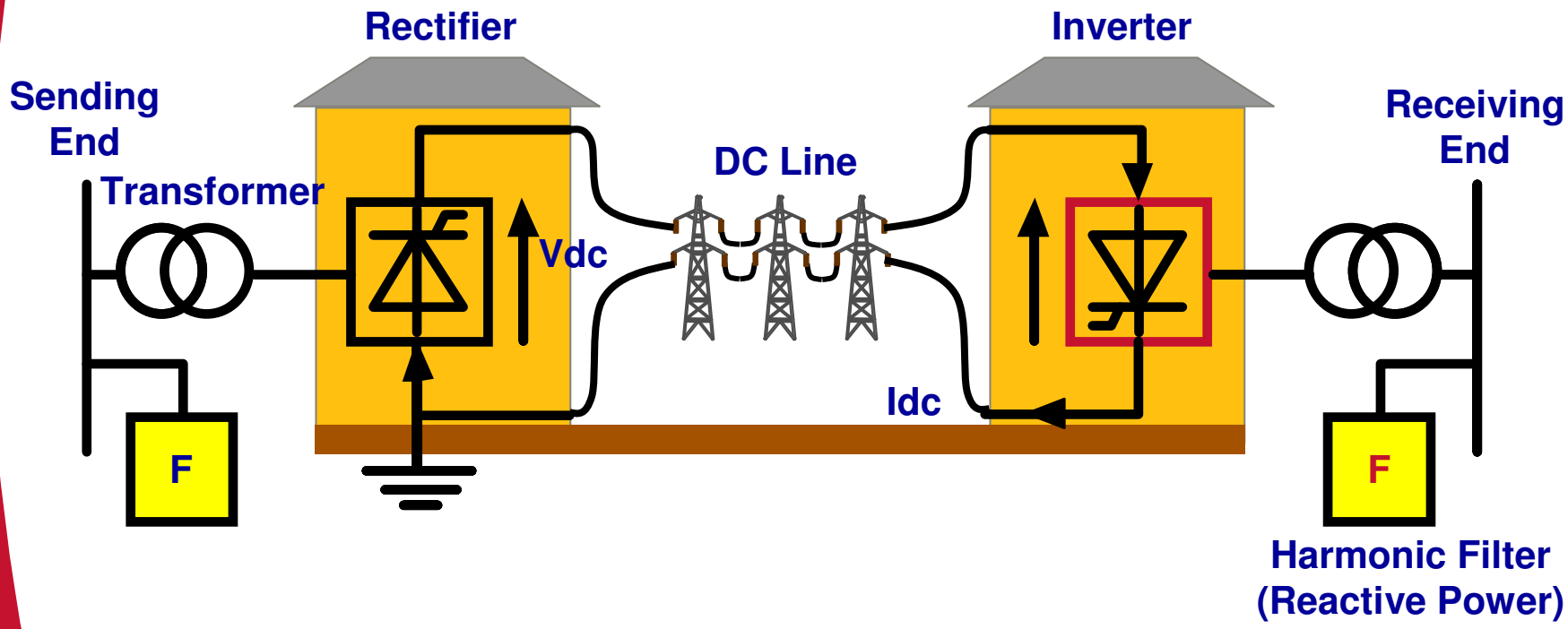
Basic HVDC Transmission Back to Back

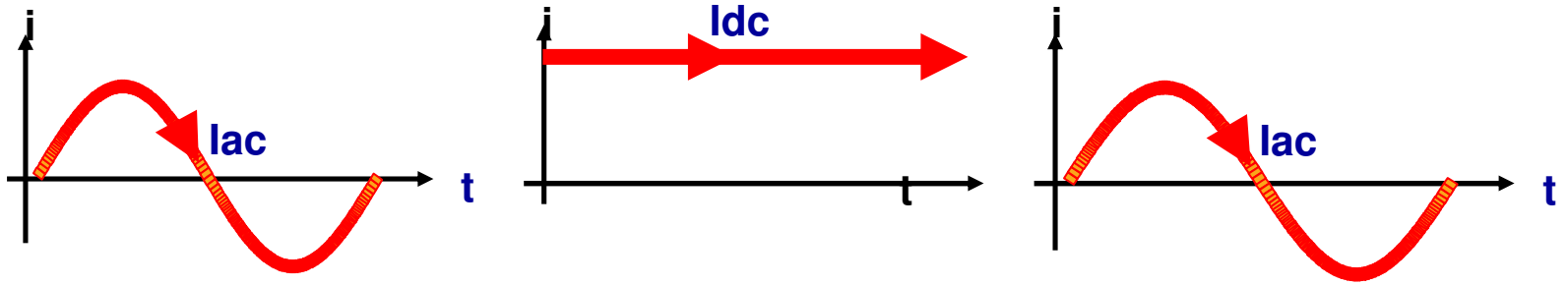


Harmonic Filter (Reactive Power)

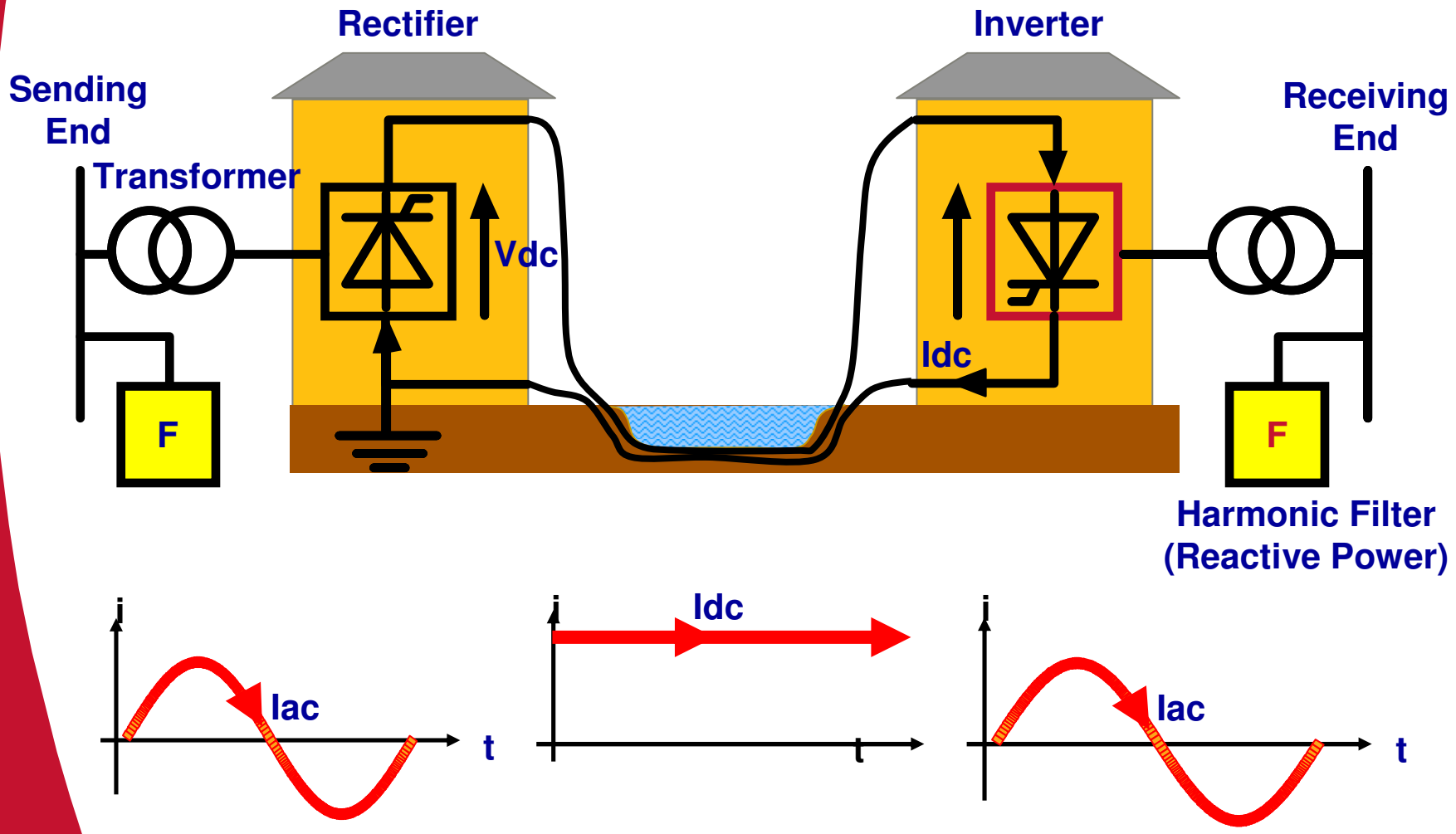


Basic HVDC Transmission
Point to Point – Overhead Line

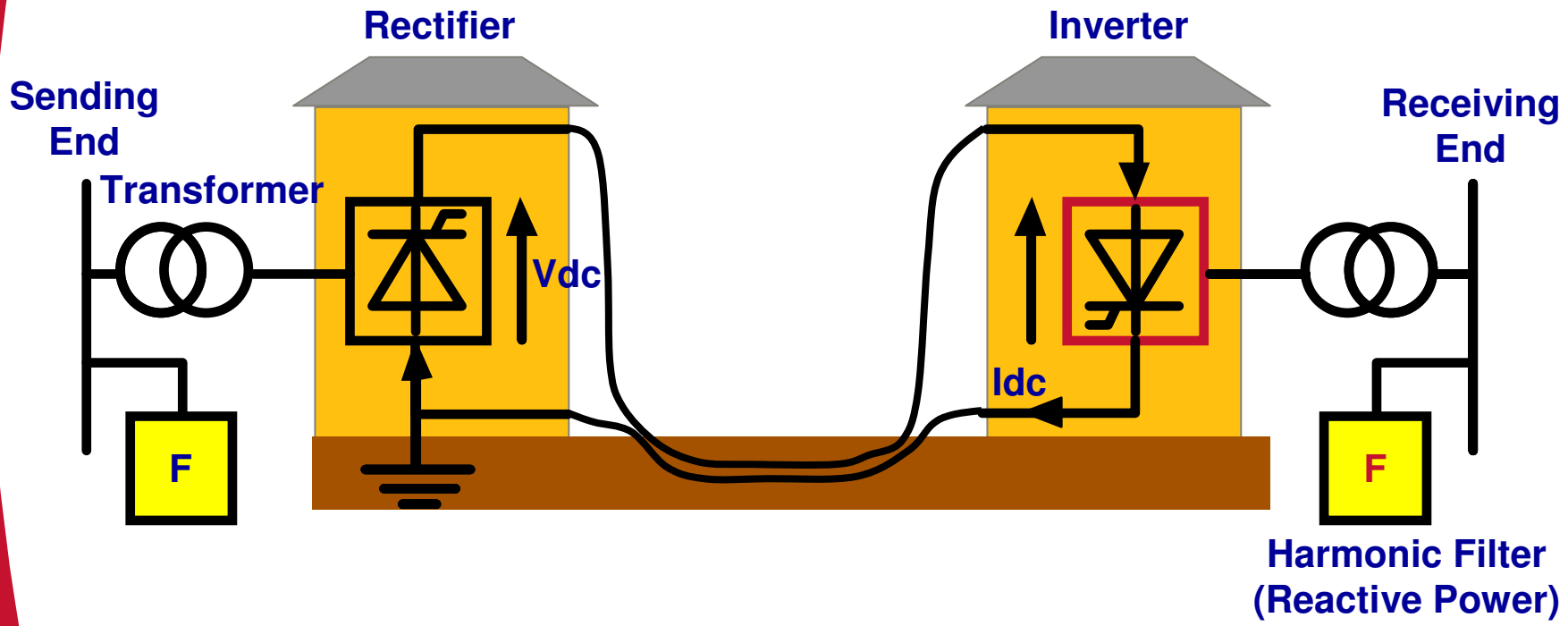


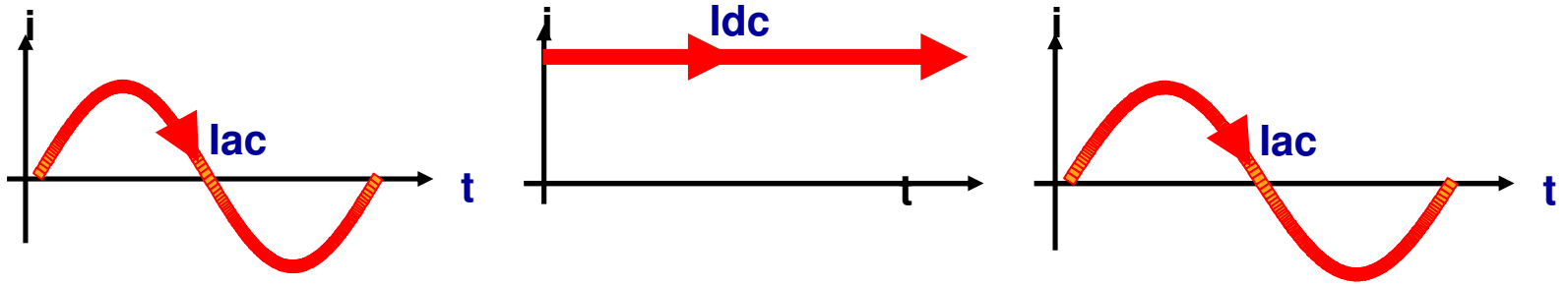


Basic HVDC Transmission
Point to Point – Submarine Cable



Basic HVDC Transmission
Point to Point – Underground Cable

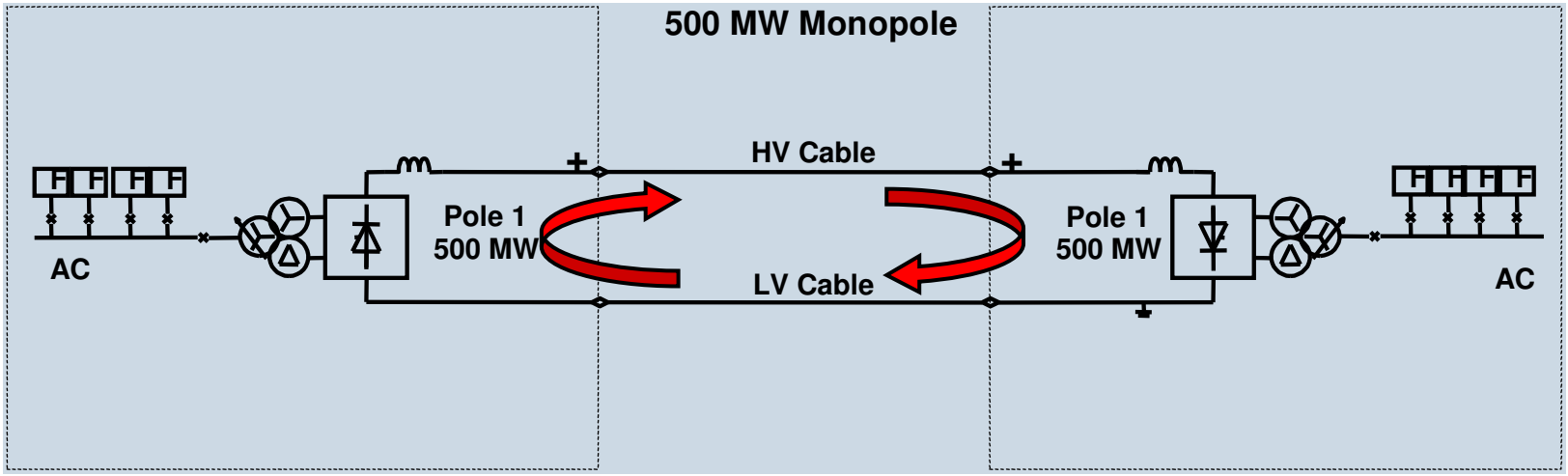




HVDC Converter Valve Hall
Thyristor based system

HVDC Configuration Options
Monopole

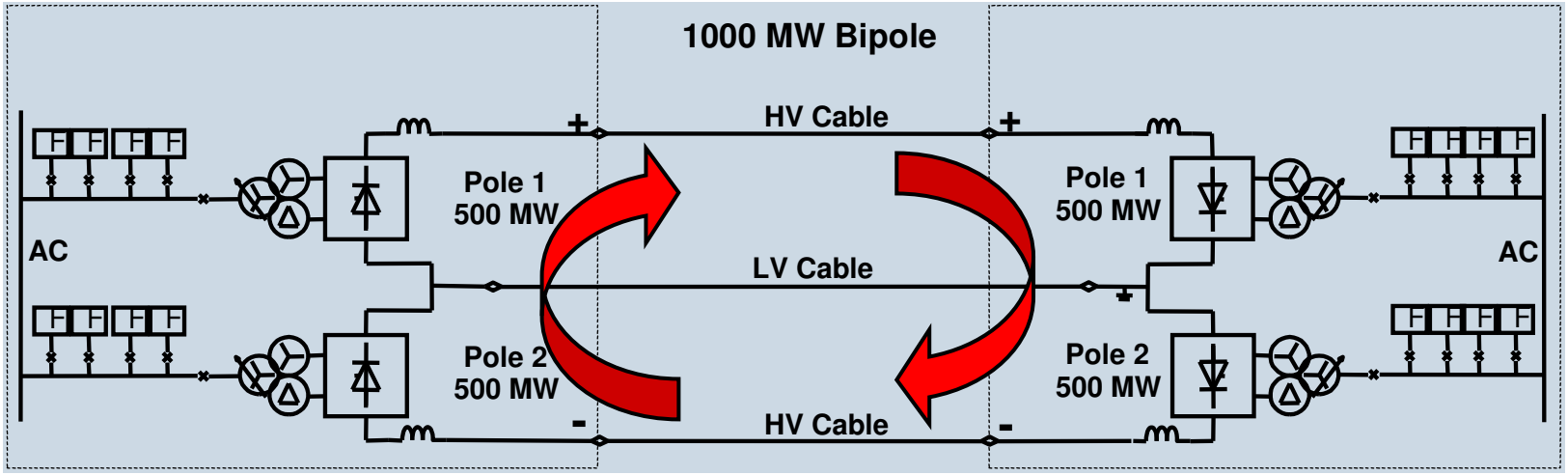
- Monopole example at 500 MW



- 1 x HVDC cable or OHL always needed (unless BtB)
- 1 x HVDC LV connection always needed, could be
  - LV cable or OHL
- Full transmission lost if lose any main item

HVDC Configuration Options
Bipole with bipole control

- Bipole example at 1000MW built from two 500 MW poles



- 2 x HVDC cables or OHL always needed
- 1 x HVDC LV connection always needed, could be
  - LV cable or OHL
- Only 50% transmission lost if lose any main item
- Bipole control of each the two monopoles simultaneously
  - Minimises the DC current in the LV connection

Advantages of HVDC

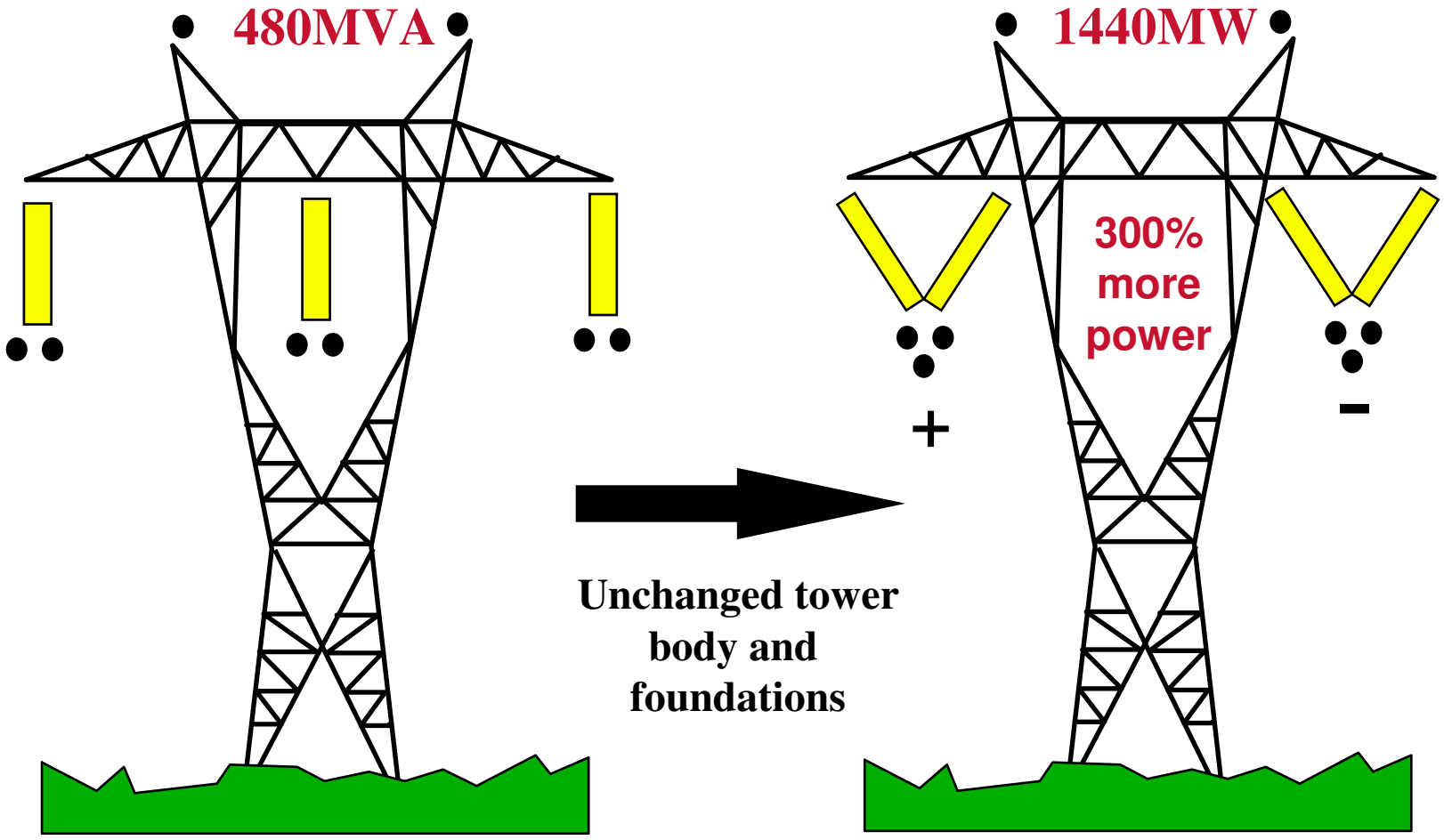
Advantages of all HVDC Links - 1

- The Power Flow on an HVDC link is Fully Controllable - Fast and Accurate!
  - The operator or automatic controller determines how much power flows via the link and in which direction
    - Irrespective of the interconnected AC system conditions
- An HVDC Link is asynchronous
  - The ac voltage and frequency in the two ac networks can be controlled independently of each other
  - No need for common frequency control
- The HVDC link can be used to improve the dynamic conditions in both of the interconnected ac networks (power system damping)
  - Can be controlled independently of AC system variations or to react to AC system conditions

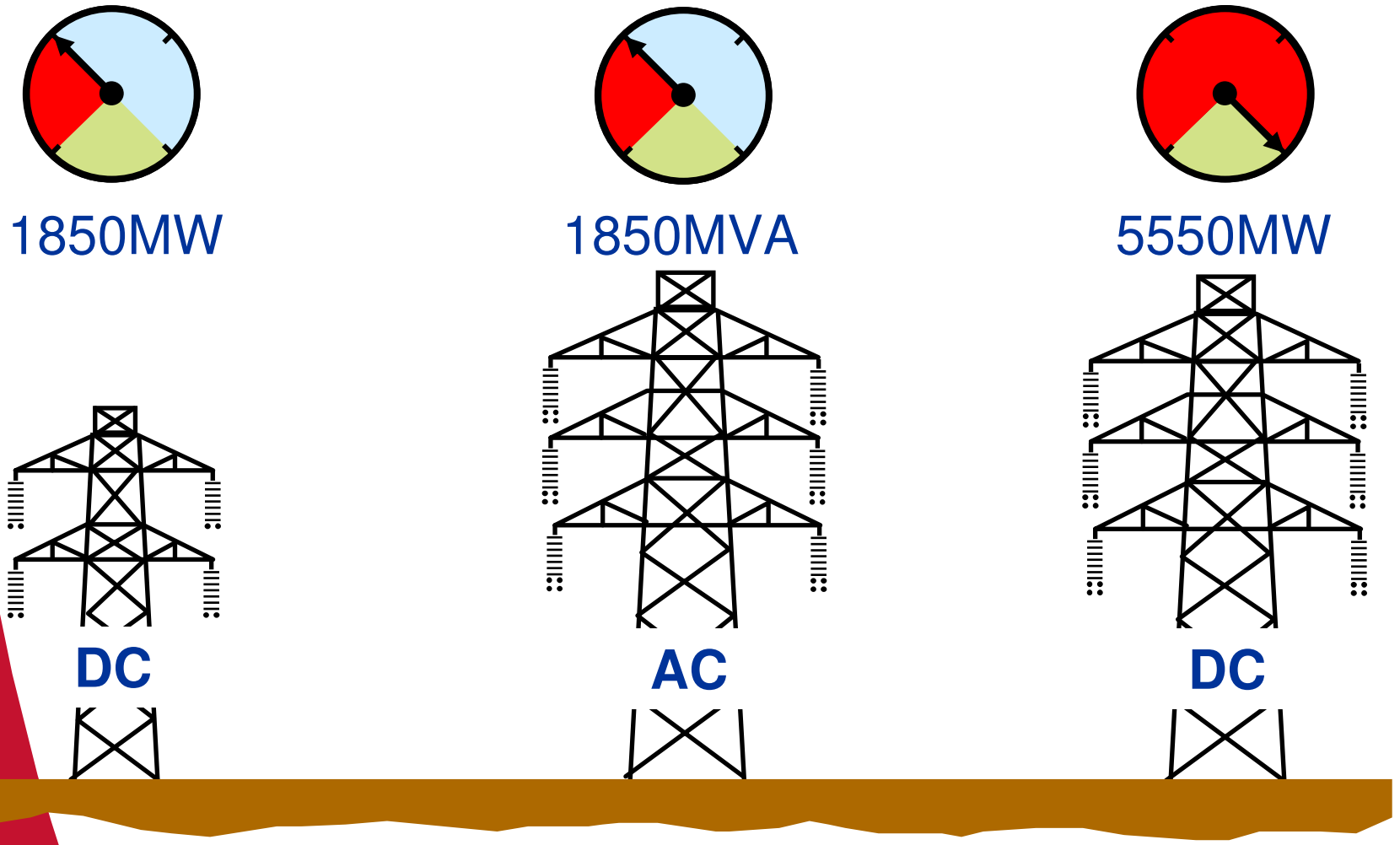
Advantages of all HVDC Links - 2

- HVDC links do not increase the Short Circuit Level of the connected systems
- Faults and oscillations don't transfer across HVDC interconnected systems
  - Firewall against cascading outages
- HVDC can transport energy economically and efficiently over longer distances than ac lines or cables
  - Increased Transmission Capacity in a fixed corridor
  - Up to 3 times more power per tower, therefore narrower rights of way

Using an Existing Wayleave



More Power Per Tower



Up to 3 Times More Power

Why VSC HVDC?
Key Benefits Compared to Classical HVDC - 1

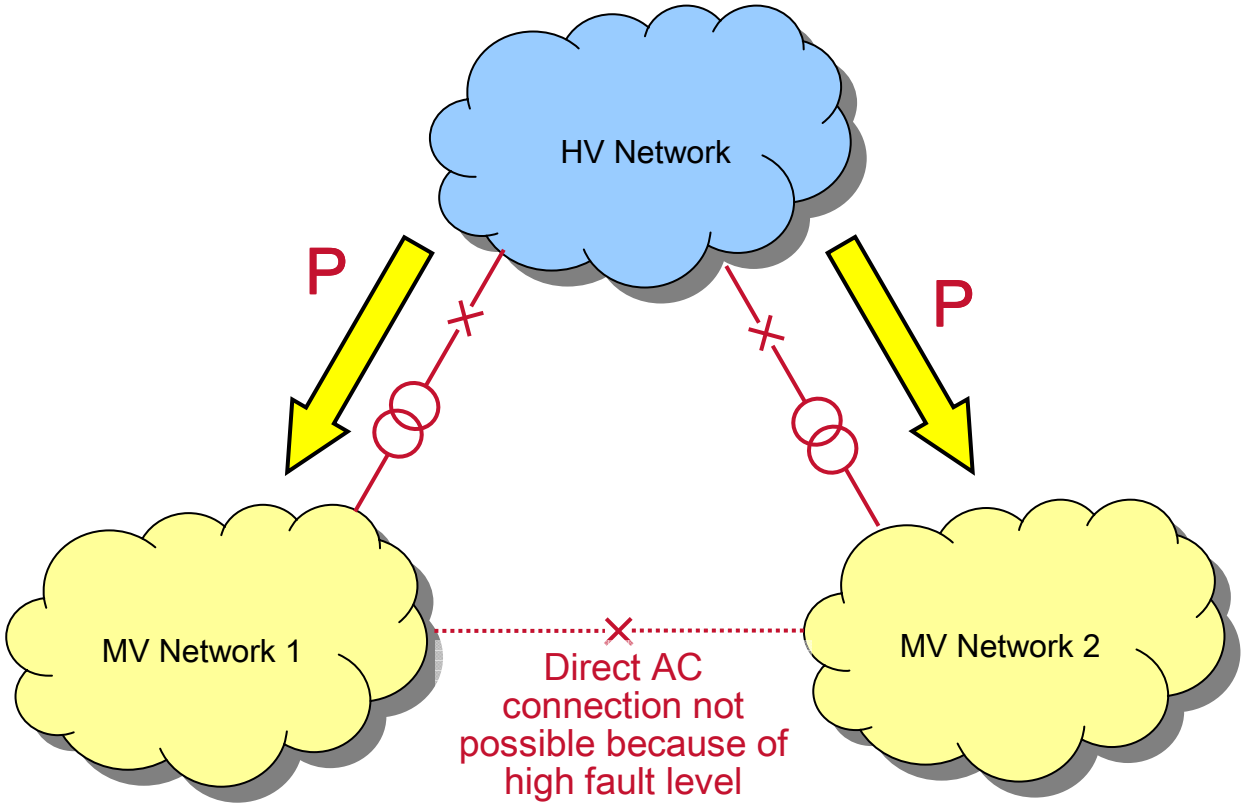
- **Can use ordinary transformers – no star/delta**
- **Both active and reactive power control in one equipment**
  - **Little or no filtering requirements & no reactive power switching**
  - **Significantly reduces application engineering and land area**
- **Operation down to zero short-circuit ratio**
  - **Connect into any network without complex studies and system reinforcement**
- **Multi-terminal configuration are simple to engineer**
  - **Ideal for offshore grids interconnecting wind farms**

Why VSC HVDC?
Key Benefits Compared to Classical HVDC - 2

- **Inherent Black Start capability**
  - Always a requirement for offshore wind and island feeding applications
- **Compact dimensions and lower weight**
  - Ideal for inner cities, reduced visual impact, smaller and lighter offshore platforms
- **Power reversal by adjusting the DC voltage at both converter stations**
  - Enables the use of low cost polymeric cables

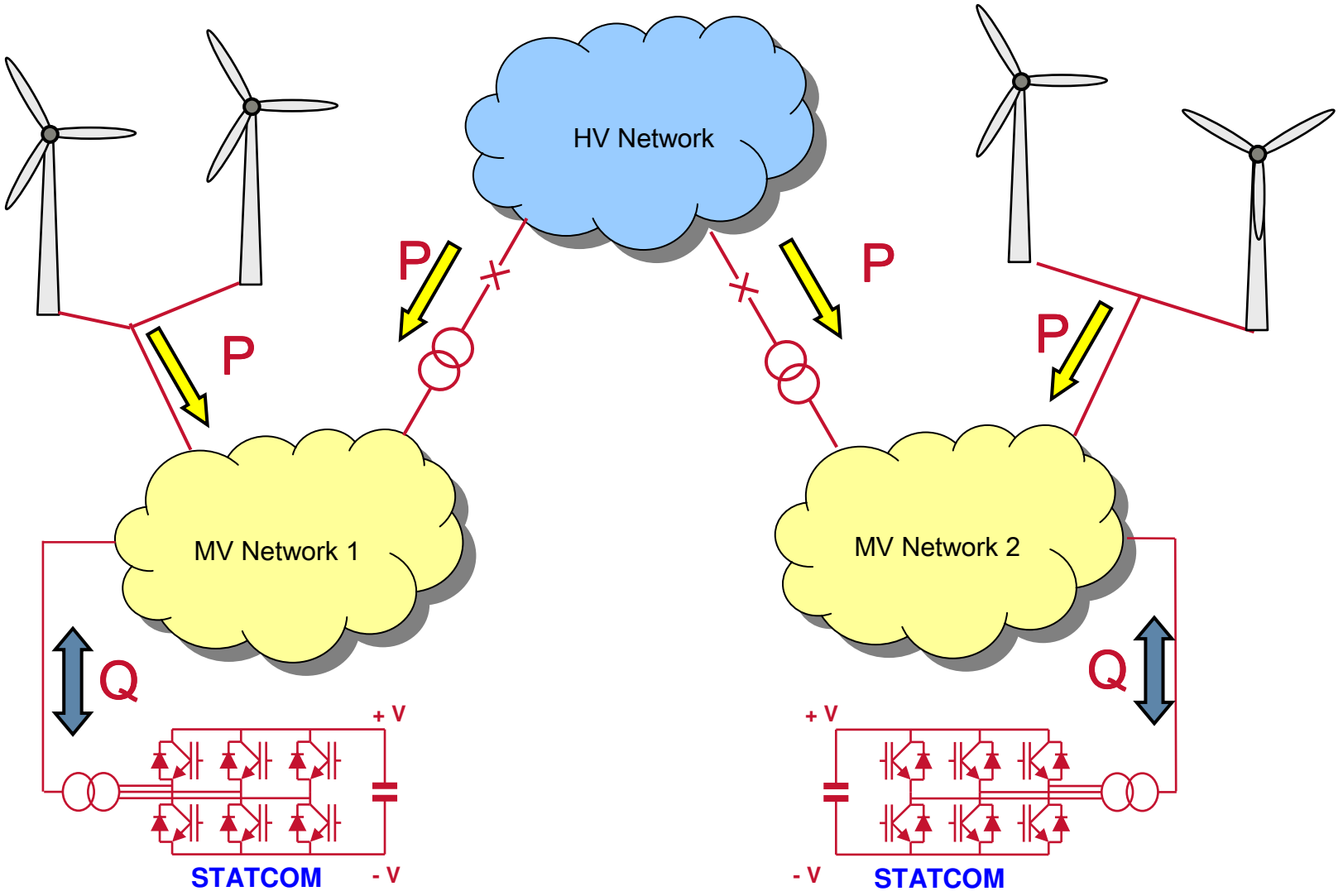
Rapidly growing interest in VSC HVDC + underground cables as an alternative/replacement to overhead AC lines, particularly for inner city feeding

Power Electronics in MV Networks

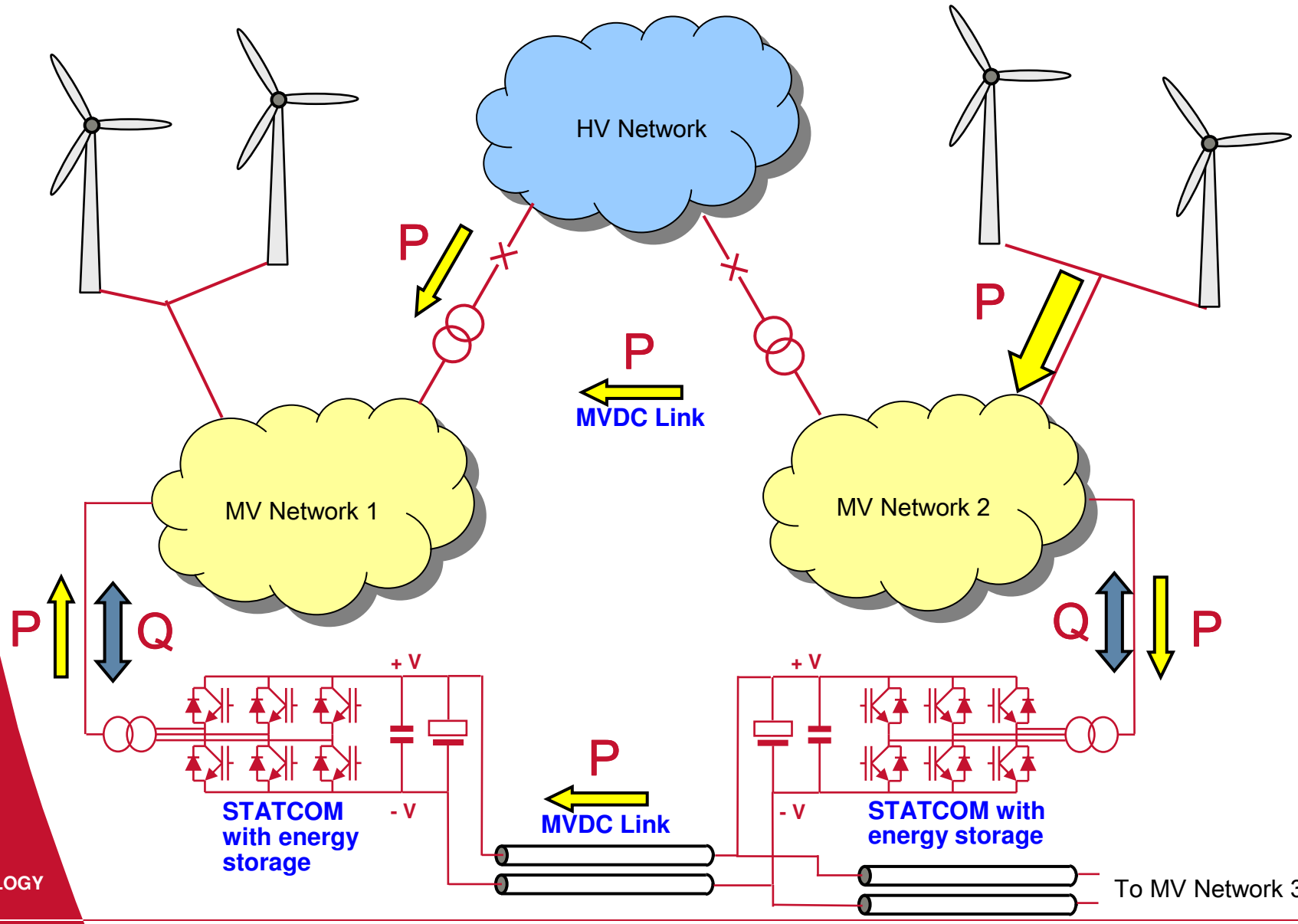


- **The traditional model:**
  - **Network designed for power flow from HV to MV**

Power Electronics in MV Networks



Power Electronics in MV Networks



FACTS Solutions

FACTS Types

Shunt connected

- MSC — Mechanically Switched Capacitor
- MSCDN — Mechanically Switched Capacitive Damping Network
- SVC — Static VAr Compensator
- RSVC — Relocatable Static VAr Compensator
- STATCOM — Static Synchronous Compensator (VSC based)

Series connected

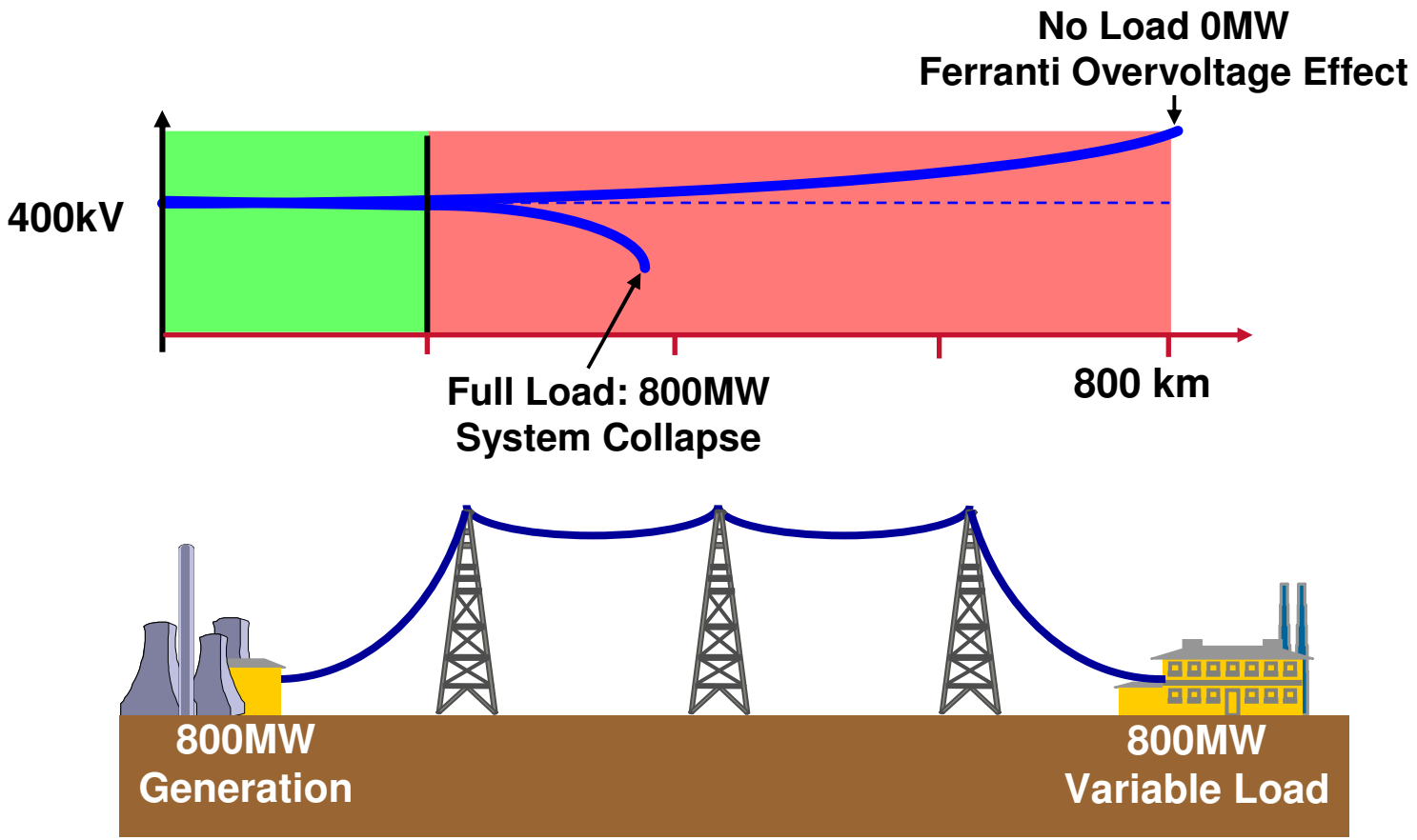
- FSC — Fixed Series Capacitor compensator
- TCSC — Thyristor Controlled Series Capacitor Compensator
- SSSC — Static Series Synchronous Compensator (VSC based)
- UPFC — Unified Power Flow Controller (VSC based)
- IPFC — Interline Power Flow Controller (VSC based)

SVC has been the most popular FACTS device

What are SVCs?

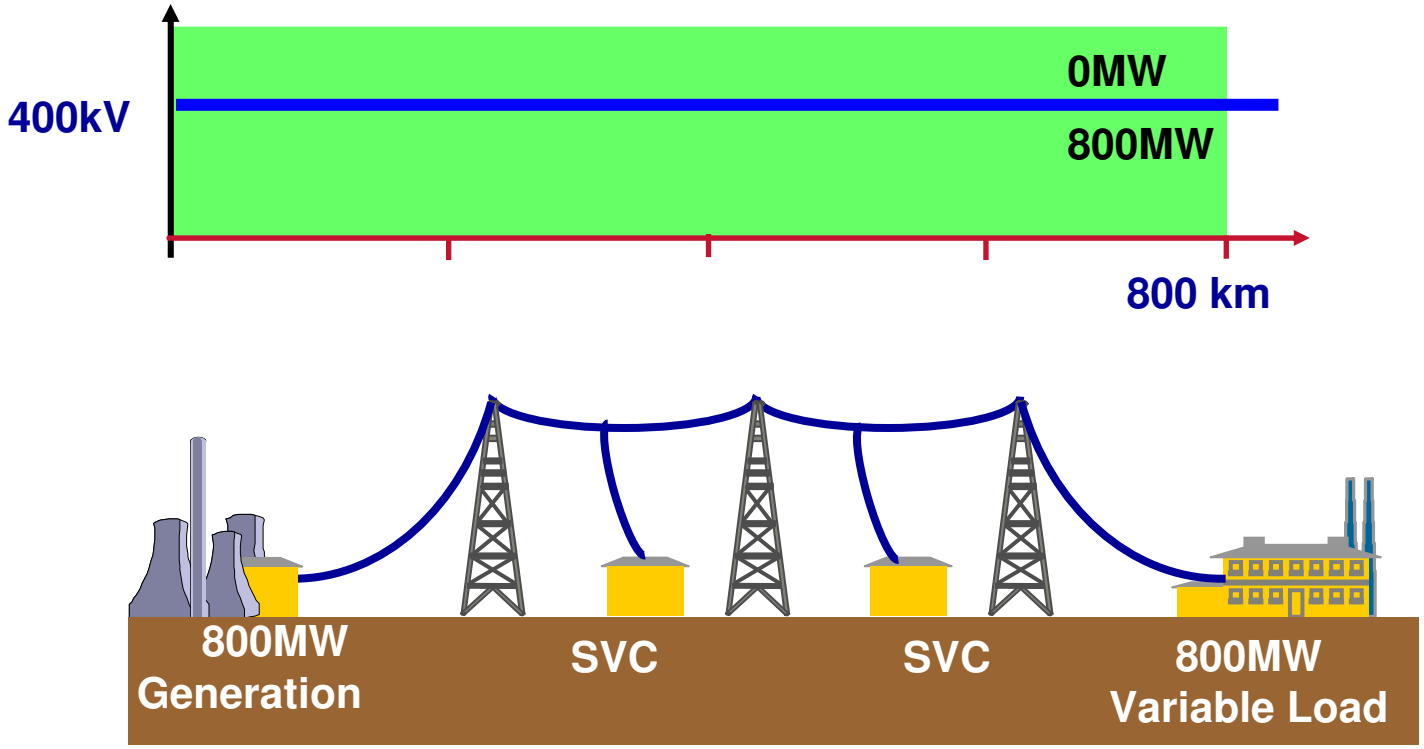
- Shunt compensation devices dealing with reactive power (MVAr)
  - Independent devices connected at appropriate points on the transmission system
    - Location determined by network studies
- Continuously adjustable impedance from capacitance (+ve: generation) through to inductance (-ve: absorption)
  - It can quickly respond to network changes to precisely counterbalance the reactive power variations caused by load changes or a fault

SVCs for compensating effects of load - 1



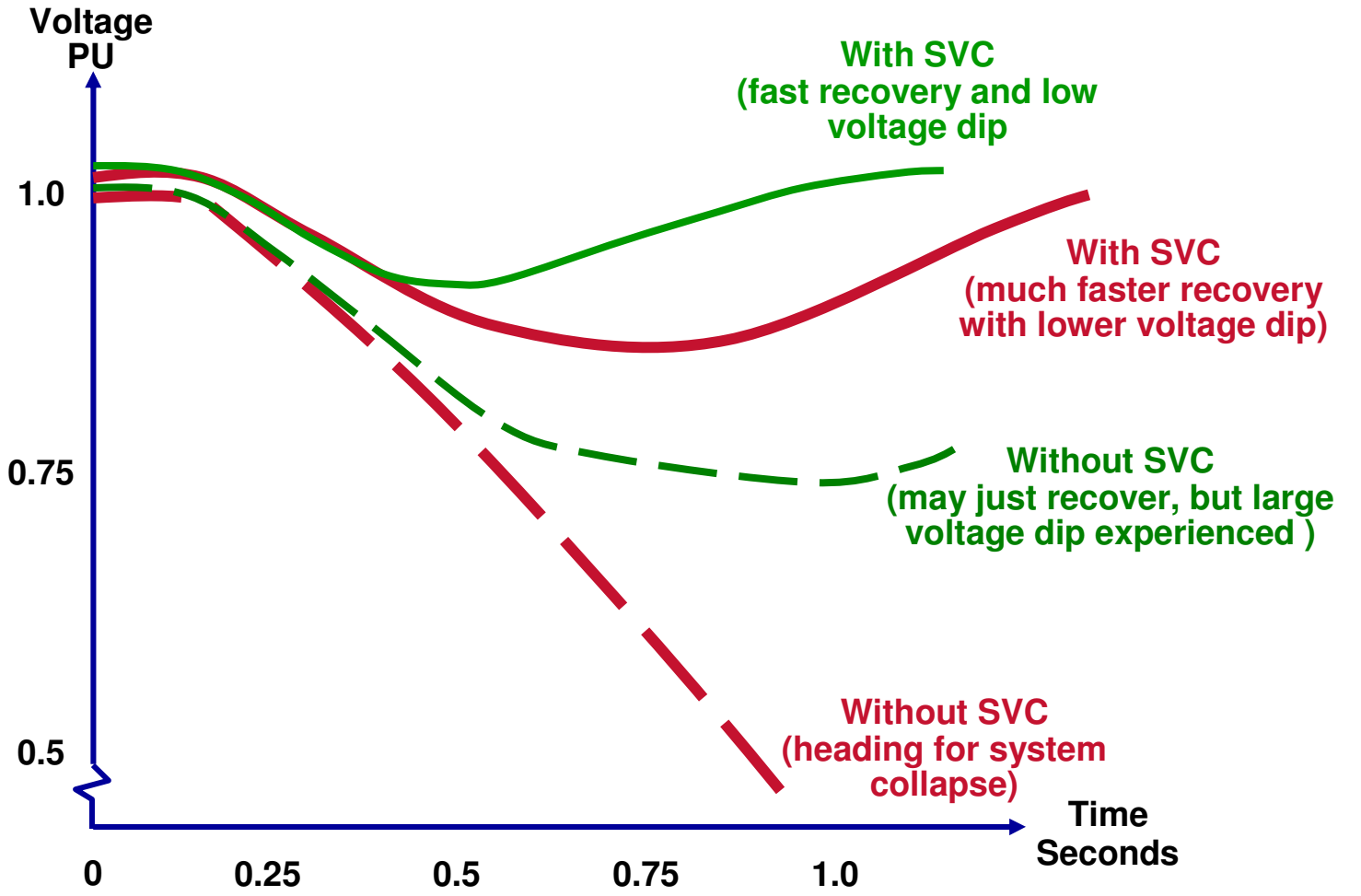
Uncompensated lines are too “short”

SVCs for compensating effects of load - 2

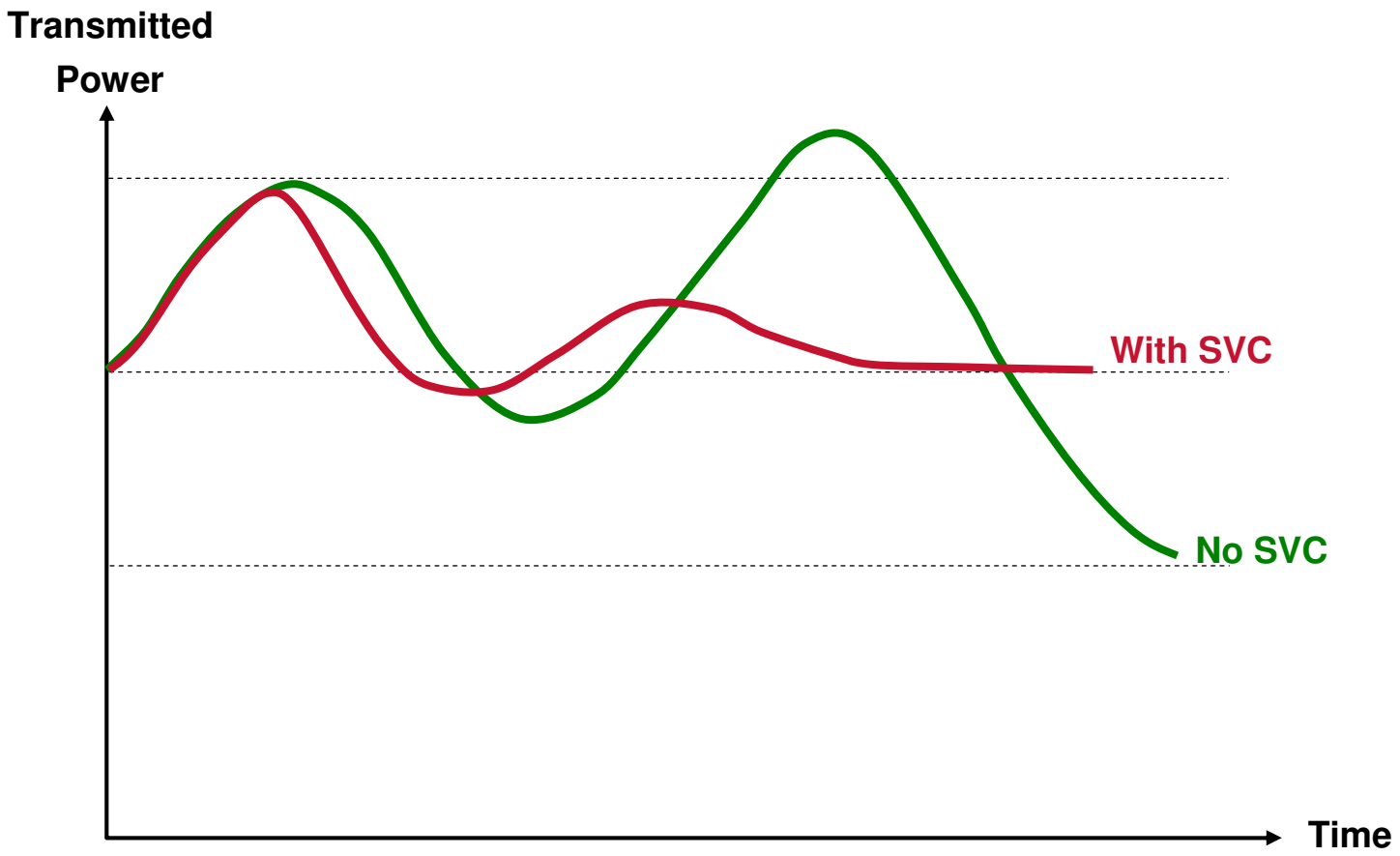


SVCs dynamically regulate the network by providing or absorbing reactive power.
- Transmission line capacity is increased

SVC dynamic stability in action



SVC: Power Oscillation Damping



Summary of Purposes of SVC

- **Steady State**
  - Regulates voltage profile
    - Improves system power flow capacity (at least 30%)
    - Reduce or eliminate requirement for new lines

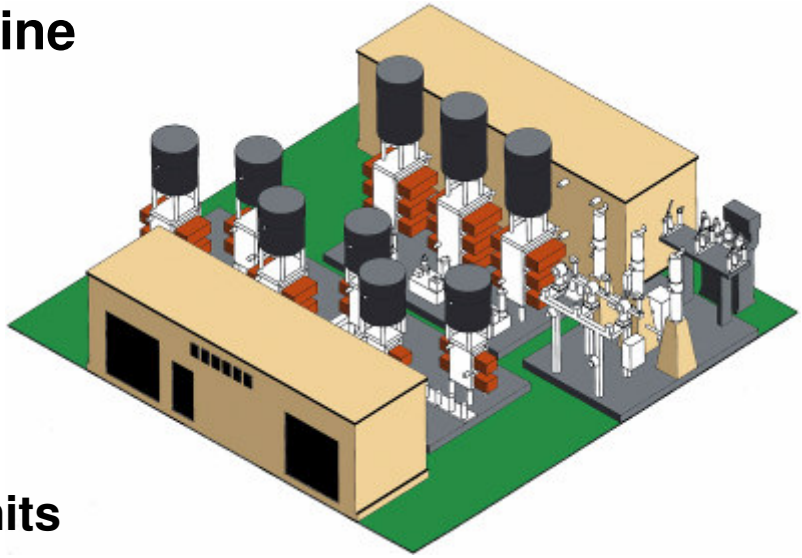
- **Dynamic**
  - Assists in post-fault recovery
  - Power oscillation/swing damping
  - Improves system stability margins
  - Reduction of voltage fluctuations (flicker)
  - Balancing single phase loads onto 3 phase systems
  - Reduces the incidence of black/brown-outs

SVCs enable the maximisation of transmission line assets

-75/+150MVAr SVC
NGT, Lovedean, UK

Relocatable SVCs

- A relocatable SVC adds flexibility
- Enables compensation to be easily moved as transmission line requirements change
  - Cabins for indoor equipment
    - Valves and controls, etc
  - Skids for outdoor equipment
    - Reactors, capacitors, etc
  - Factory assembled & tested units
  - Reduced civil works
  - Simple site work
  - Small footprint



The Flexible Option

Relocatable SVC on its way to Iron Acton

Power on the Move

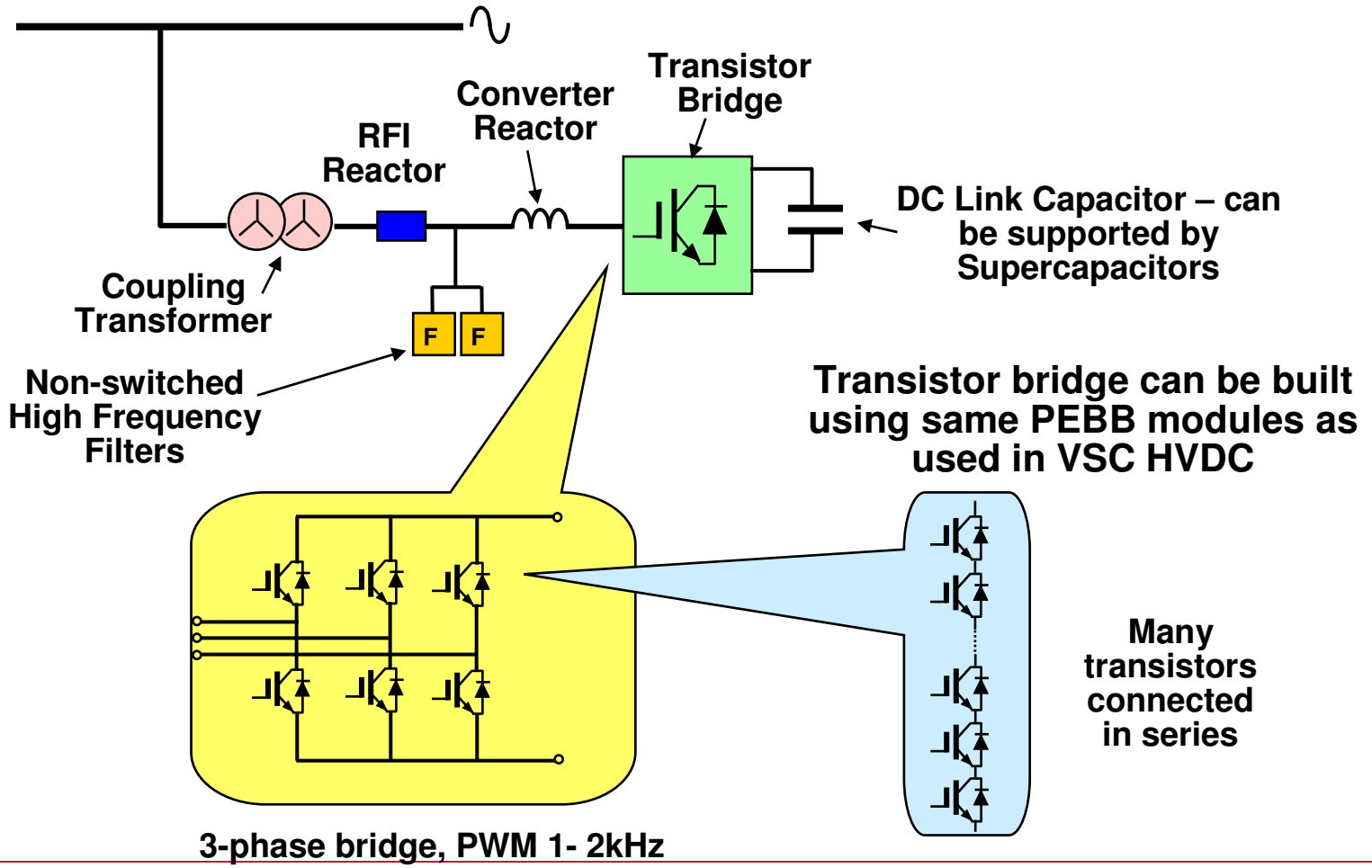
RSVCs at Iron Acton, UK

VSC based FACTS Applications

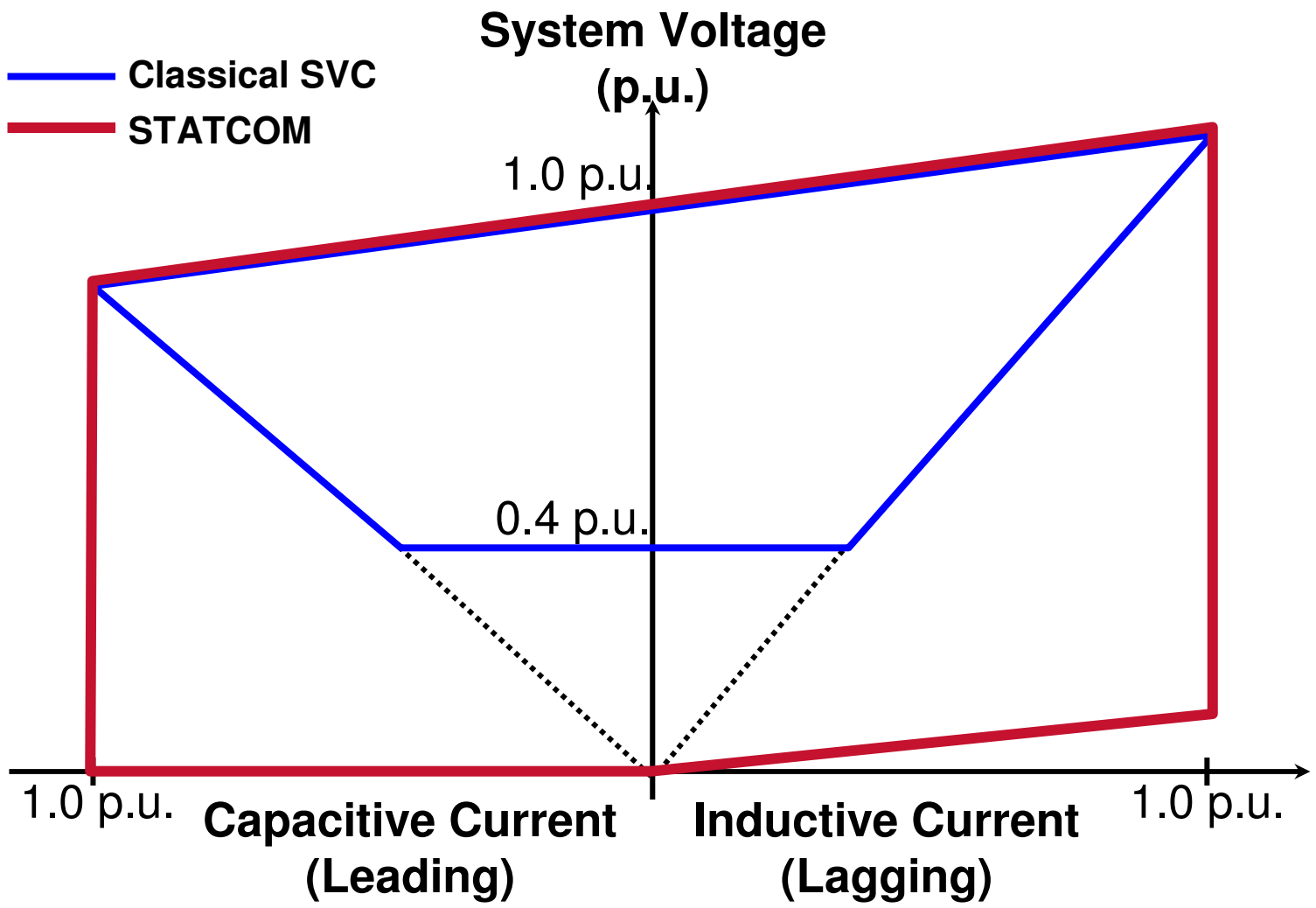
Types of VSC FACTS STATCOM

Static Synchronous Compensator

- Connected in shunt to the network
- Acts like a Synchronous Condenser without inertia and moving parts, but with much faster response to disturbances



STATCOM Characteristics Compared to Classical SVC



Why VSC FACTS

- Grid sees the device as a synchronous machine without inertia
  - Offers sub-cycle response
  - Phases are independently controlled, gives optimum voltage support especially during system disturbances
- Do not require large reactive components (capacitors and shunt reactors) to provide inductive and capacitive reactive power
  - Compact leading to minimum footprint
- Operating range is wider than a classical SVC
  - Higher reactive output at lower system voltages
  - Robust recovery support under severe system disturbances
  - Significantly improved voltage control, particularly under contingencies
- Higher dynamic response characteristics than classical SVC

STATCOMs enable the maximisation of transmission line assets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