# AC Transmission Network Characteristics

- Power flow uncontrolled
- Circuits may be overloaded or underutilized
- Reserve capacity required for contingencies
- Variable reactive power demand with flow
- Requires voltage control and dynamic reactive power reserve
- Often limited to less than thermal by instability or inadequate voltage support
- Transmission capacity a function of distance and intermediate voltage support
- Finite limit to cable length
- Synchronous

# Characteristics of HVDC Transmission

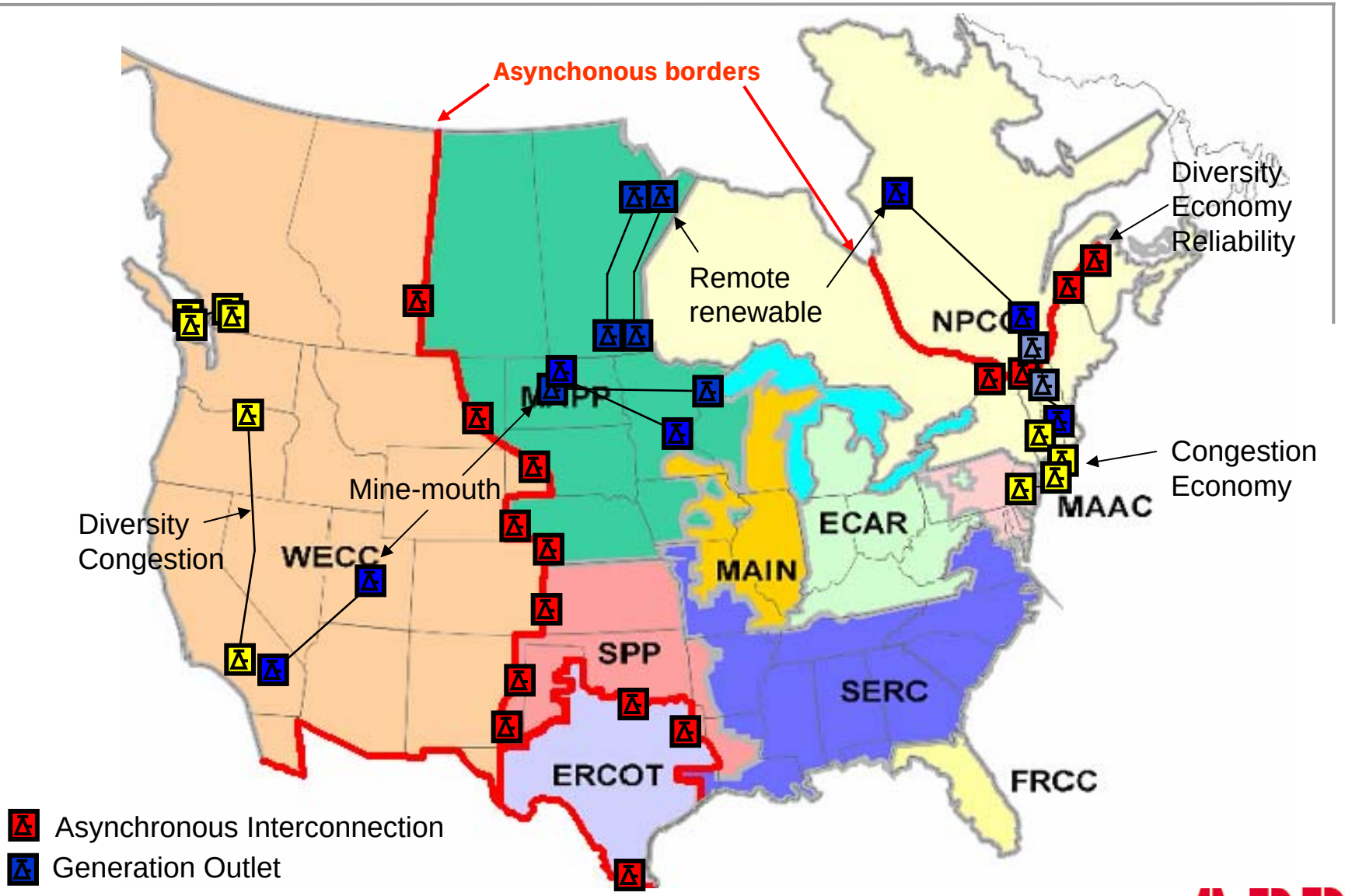
- Controllable - power injected where needed
- Bypass congested circuits – no inadvertent flow
- Facilitates integration of remote diverse resources
- Higher power, fewer lines, no intermediate S/S needed
- Two circuits on less expensive line
- No stability distance limitation
- Reactive power demand limited to terminals
- Narrower ROW, no EMF constraints
- Lower losses
- No limit to underground cable length
- Asynchronous, ‘firewall’ against cascading outages

# Line Loading Capability

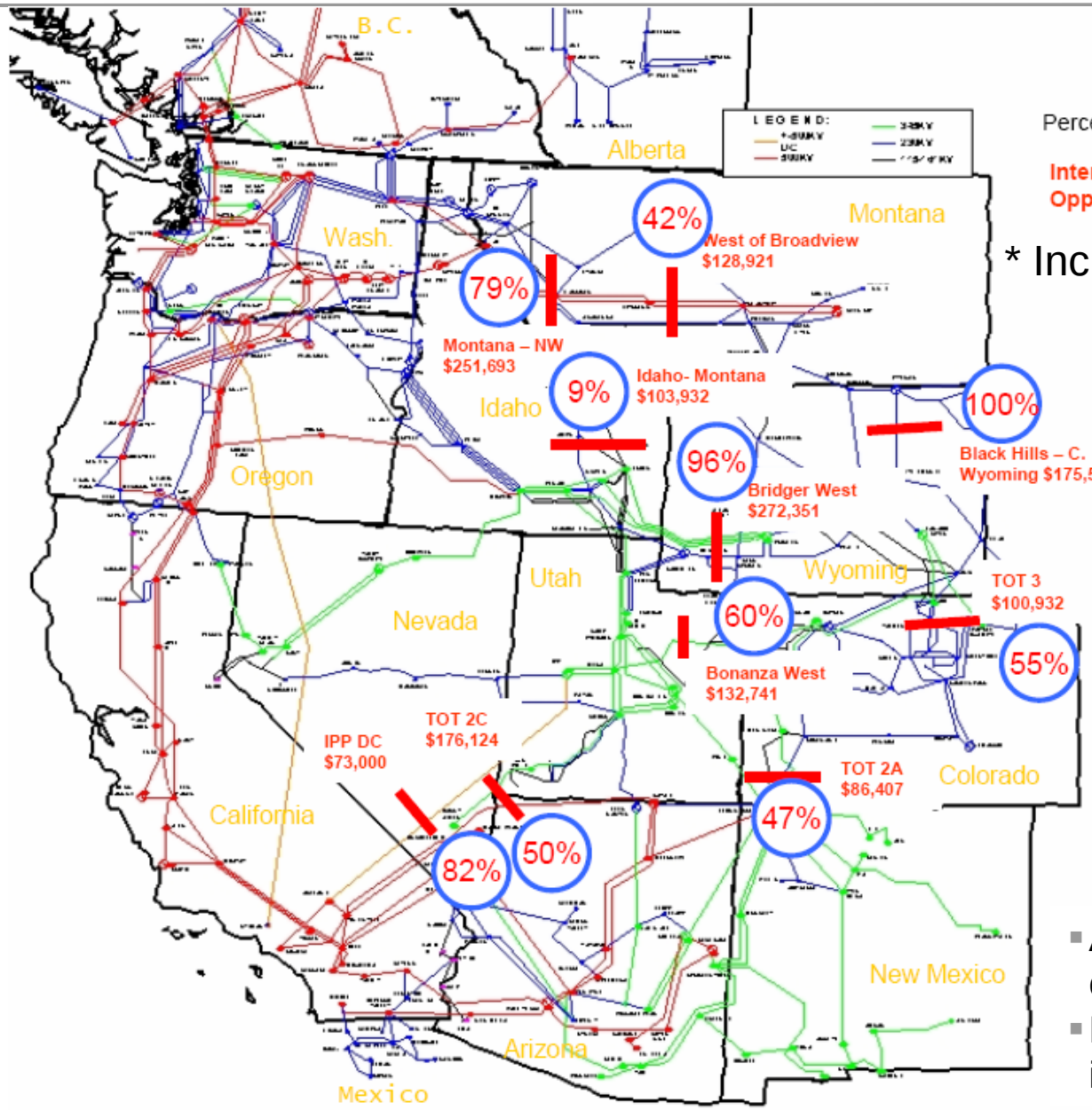
| Line Type | Voltage | Conductor | Thermal Limit of Line | Thermal Limit of Terminal Equipment | SIL | 1.5 x SIL | Req'd no. of lines - EHVAC at 1.5 x SIL | | Charging per 100 mi |
|---|---|---|---|---|---|---|---|---|---|
| | kV | kcmil | GW | GW | GW | GW | 8 GW | 12 GW | MVAr |
| EHVAC - UHVAC | 345 | 2 x 954 | 1.2 | 2.4 | 0.4 | 0.6 | 14 | 21 | 80 |
| | 500 | 2 x 2312 | 2.9 | 3.5 | 0.8 | 1.3 | 7 | 10 | 180 |
| | 765 | 5 x 795 | 6.0 | 4.0 | 2.3 | 3.5 | 3 | 4 | 460 |
| | 1000 | 8 x 795 | 12.5 | 5.2 | 3.9 | 5.9 | 2 | 3 | 800 |
| HVDC | ±500 | 3 x 2515 | 5.3 | 4.0 | n.a. | n.a. | 2 | 3 | n.a |
| | ±600 | 3 x 2515 | 6.3 | 4.8 | n.a. | n.a. | 2 | 3 | n.a |
| | ±800 | 5 x 795 | 7.6 | 6.4 | n.a. | n.a. | 2 | 2 | n.a |

- More lines are needed with lower transmission voltage. Loadability increases and number of ac lines can be reduced by series compensation.
- Fewer lines are needed with higher transmission voltage. More shunt compensation is needed at light load to absorb excess charging.
- Larger contingency impact with fewer lines or circuits
- Conventional HVDC converters are subject to minimum short circuit capacities relative to transmitted power – ac voltage stability issue
- Reactive power compensation issues: AC – distributed, DC - local
- Interconnection issues are similar – the collector and receiving networks must be able to handle the power

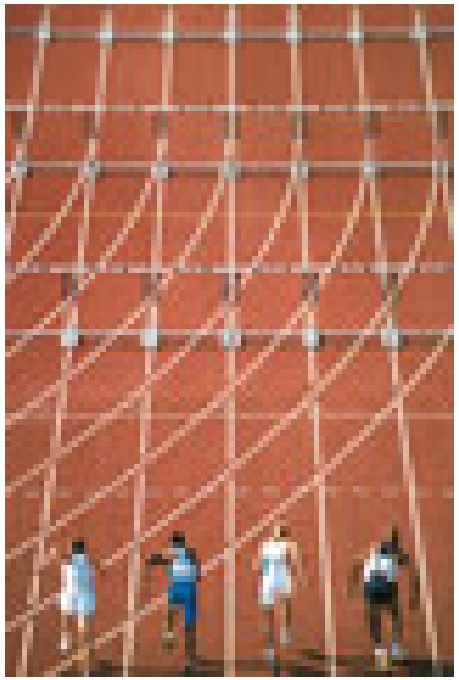
# HVDC in North America



# Path Congestion RMATS 2013 11,700*MW Alt 4 Generation

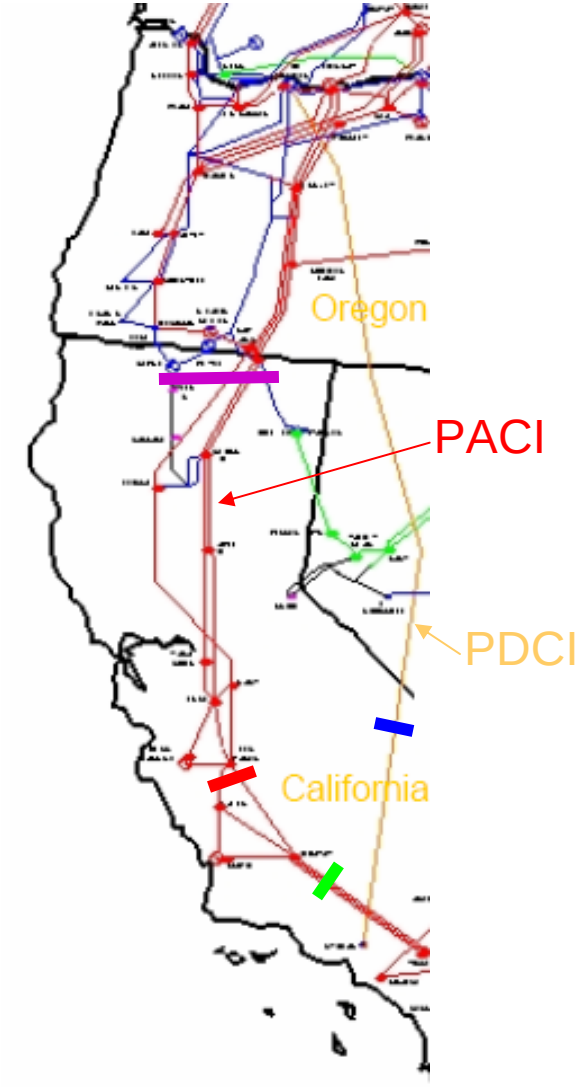



* Includes 7800 MW for Export

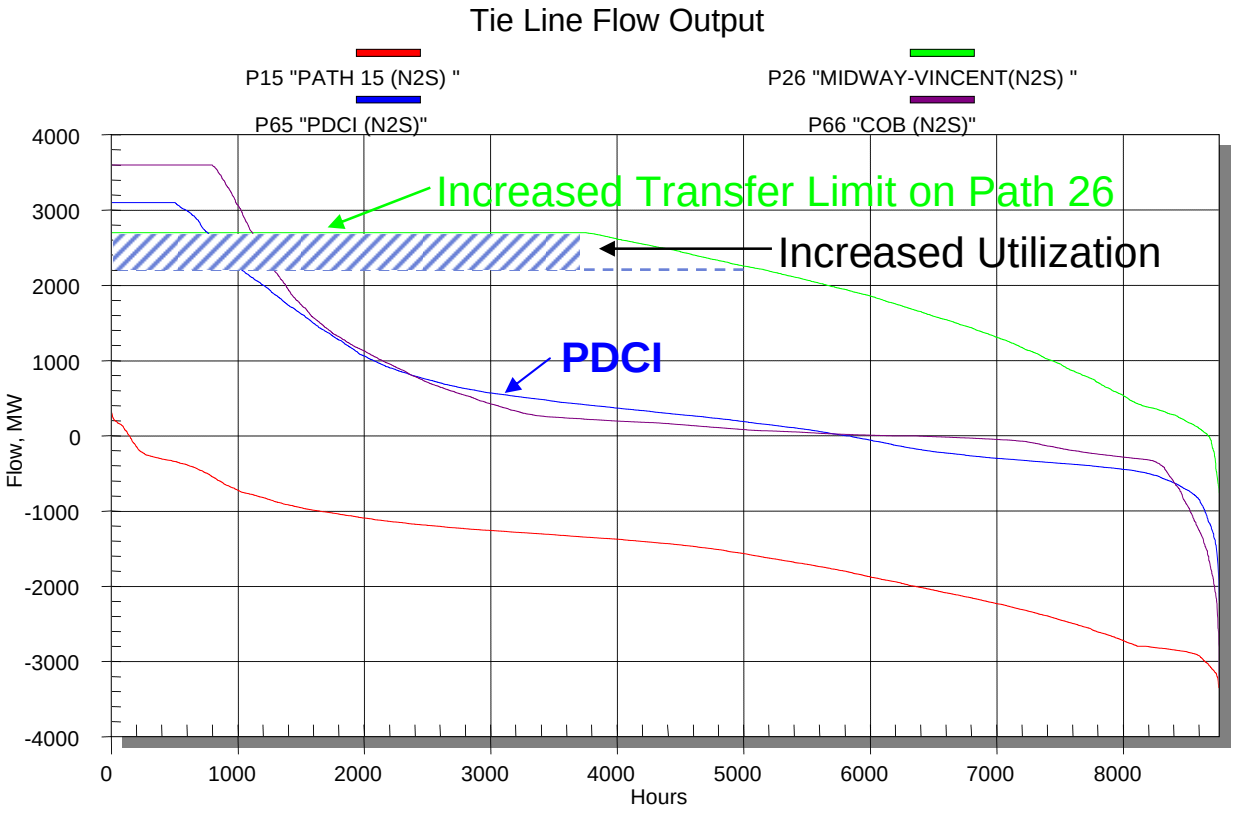


- AC must mitigate congestion one hurdle at a time
- DC is able to leap tall buildings in a single bound

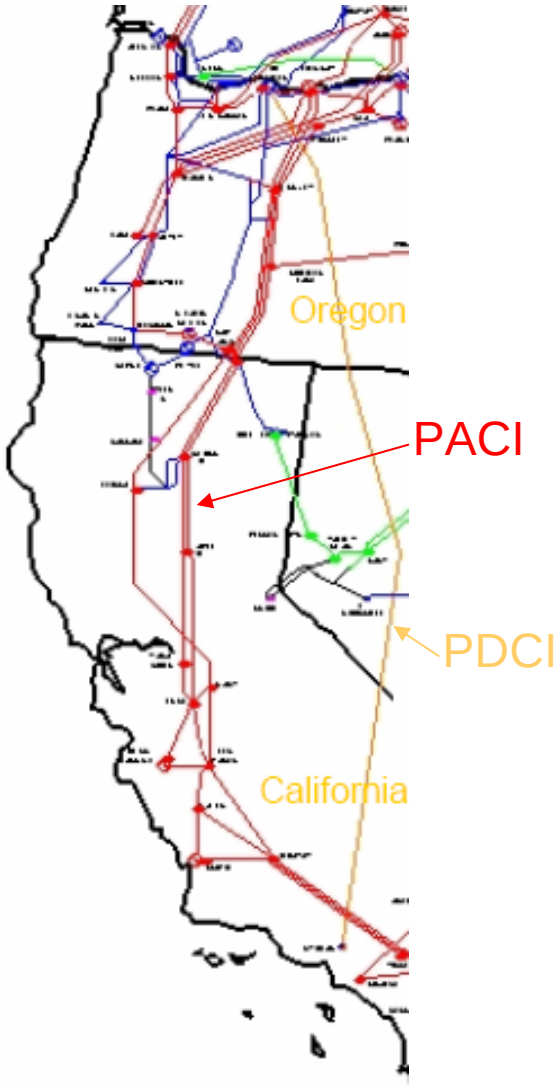
# Value of Pacific Intertie




**Study Result: Annual savings to consumers in southern California due to transfer limits being raised 500 MW by series compensation = $ 72 M**



# Transmission Expansion - Pacific Intertie Model




- Regional resource & load diversity
- Hybrid AC & DC transmission
- Mix of investor-owned and public power
- Shared costs and benefits
- Multiple jurisdictions
- Controllability for optimal power flow
- Serves intermediate load & resources while bypassing congestion
- Would same concept work today for integration of diverse resources?
- Where are the champions?