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Effects of Wind Generation Integration on Power System Transient Stability

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Test System and Wind Turbine Model

This work considers the transient stability of a system with increased wind penetration. Figure 1 shows the SMIB system used. Figure 2 shows the WPP model used.
The following reactive control modes are considered:

- Constant Q mode
- Constant power factor mode
- Voltage support mode

Transient stability is approximated using the critical clearing time (CCLT) for a 3-phase fault at Bus 3.

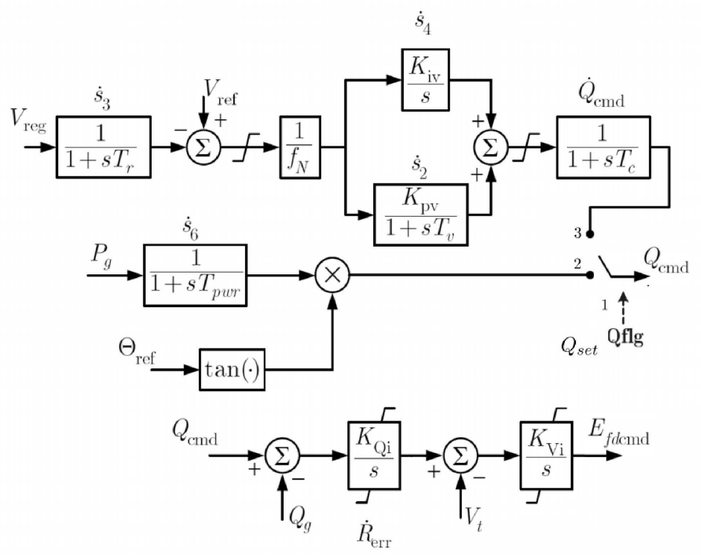
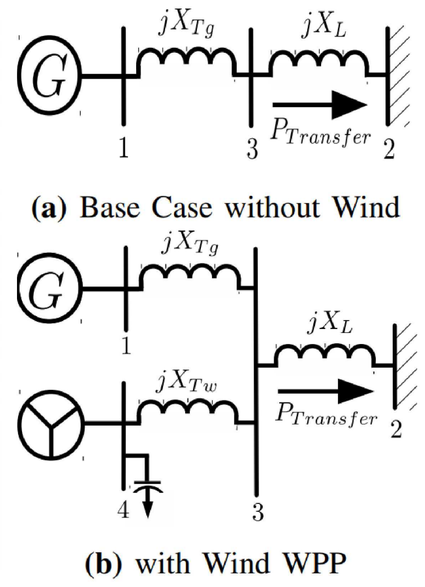


Figure 2: Schematic of the reactive power control of the WPP model used



(a) Base Case without Wind

(b) with Wind WPP

Figure 1: Single machine infinite bus system used for transient stability analysis

Wind Penetration vs Transient Stability

Figure 3 shows the CCLT as the wind penetration is increased from 0 MW to 250 MW. The increase in the power output of the WPP leads to a decrease in CCLT. These results show that there is no noticeable difference in the CCLT between the different reactive power control modes.

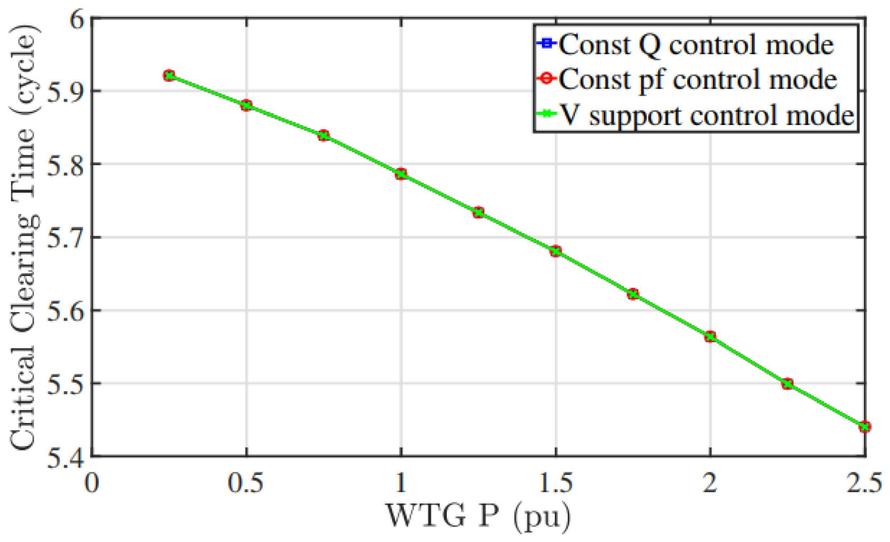
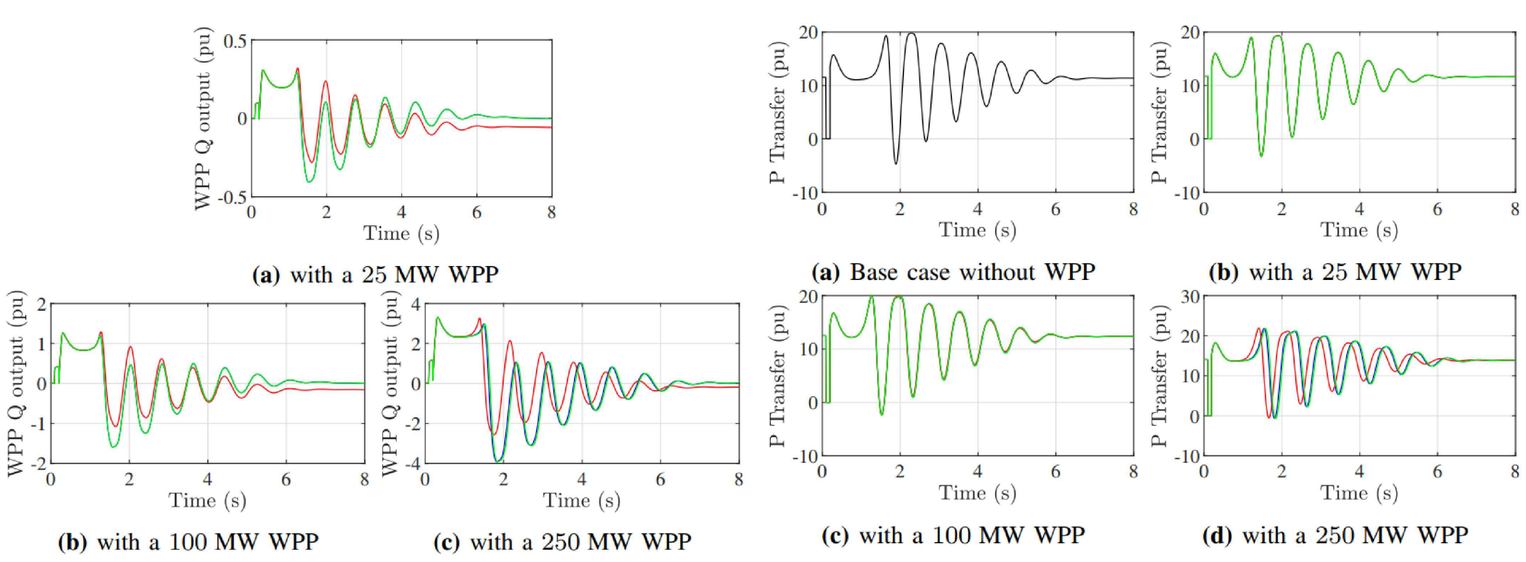


Figure 3: WTG active power output vs CCL



(a) with a 25 MW WPP

(b) with a 100 MW WPP

(c) with a 250 MW WPP

Figure 4: Reactive power output of the WTG at CCLT

(a) Base case without WPP

(b) with a 25 MW WPP

(c) with a 100 MW WPP

(d) with a 250 MW WPP

Figure 5: Active power on the transfer path at CCLT

Figure 4 shows the reactive power output of the WTG. It can be seen that the reactive power output in Voltage support mode increases compared to the other two control modes. However, this difference is not large enough to have a visible effect on the CCLT. Figure 5 shows the active power transfer across the transmission path.

Wind Penetration vs Power Transfer Limits

In these results the synchronous generator is curtailed to achieve a constant CCLT of 6 cycles. This corresponds to a scenario where the system operator is concerned about transient stability and enforces transfer limits on the transmission path. Figure 6 shows the power transfer and synchronous machine output vs increasing wind penetration.

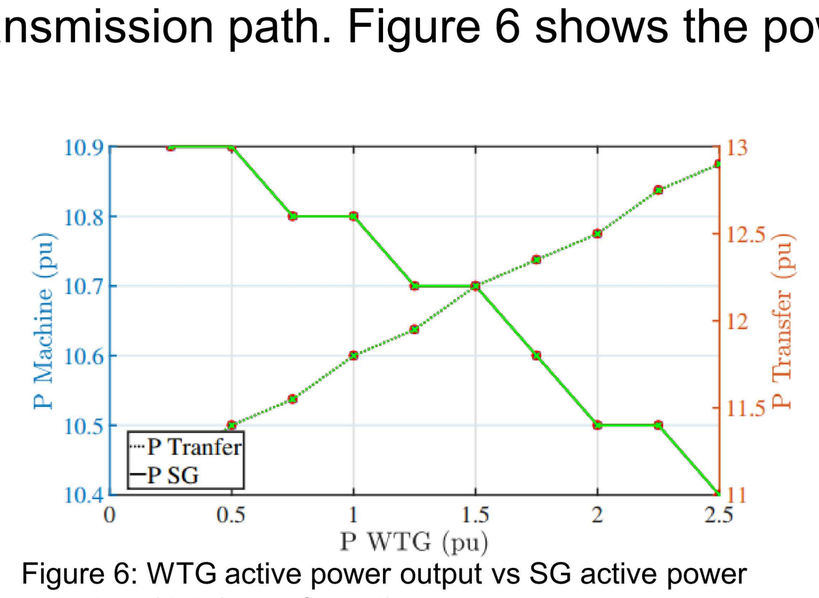
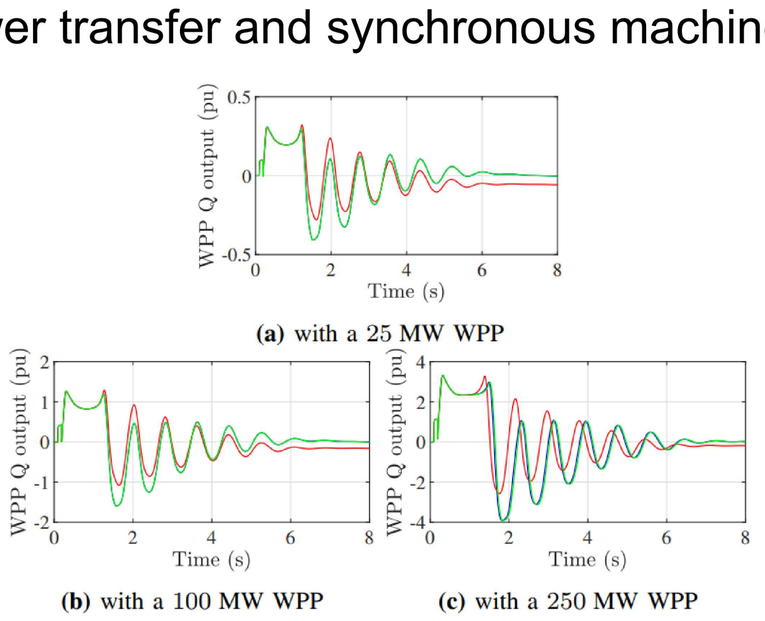


Figure 6: WTG active power output vs SG active power output and total transfer path power

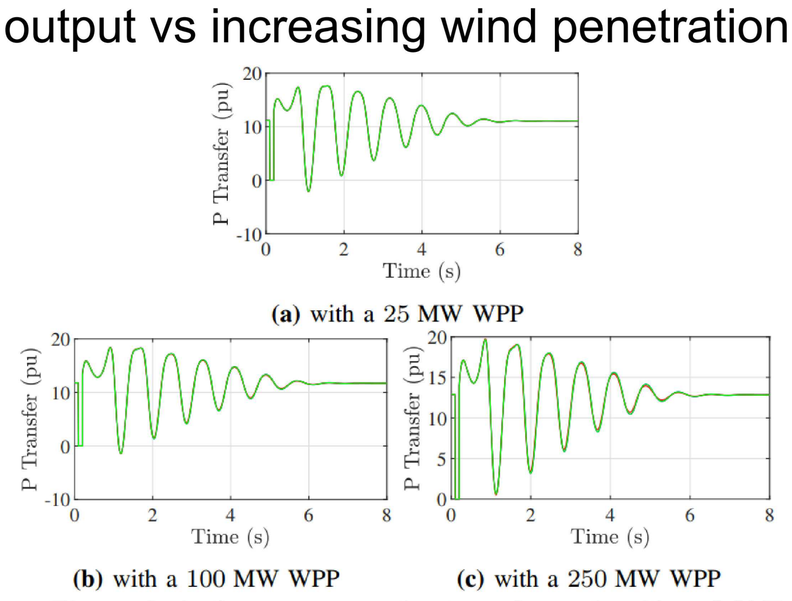


(a) with a 25 MW WPP

(b) with a 100 MW WPP

(c) with a 250 MW WPP

Figure 7: Reactive power output of the WTG at CCLT



(a) with a 25 MW WPP

(b) with a 100 MW WPP

(c) with a 250 MW WPP

Figure 8: Active power on the transfer path with a CCLT of 6 cycles

Similar to the previous results there is no visible difference between the control modes. As wind penetration increases the added output of the WTG is larger than the curtailment of the synchronous machine. This means the transfer across the transmission path can be increased while maintaining constant transient stability margin. Figure 7 shows the reactive power output of the WTG and Figure 8 shows the power transfer on the transmission path

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