

RESEARCH AREA

- Medium scale distributed gen. connected to medium voltage
- Non-firm generation -> curtailment
- Planning and operation stage
- Distributed wind generation reactive power (Q) resource

MATHEMATICAL MODEL



- AC Optimal Power Flow (AC OPF) model (Nonlinear Programming)
- Planning/operation AC OPF model in AIMMS optimization software
- Planning stage: maximise generation at minimum demand
 - Fixed power factor limits (0.96 ind., 0.98 cap.)
- Operation stage: Generation/demand time series
 - AC OPF ran consecutively for each time step
 - Max. energy export: min. loss, max. wind power output
 - Piecewise linear Q capability, P and Q largely decoupled

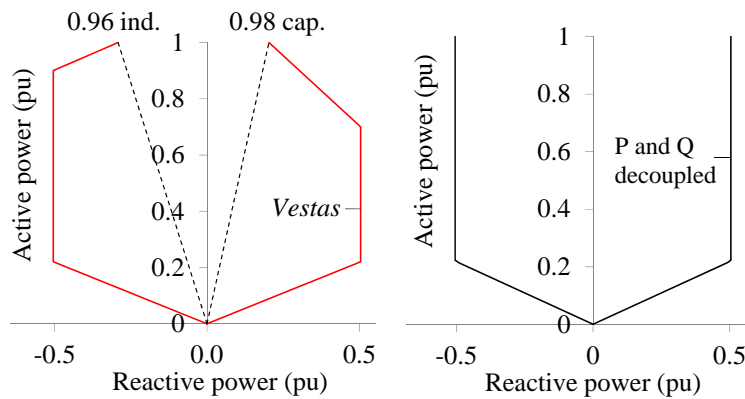


Fig. 1 Asymmetrical (source: Vestas) and symmetrical Q capability diagram

AC OPF PLANNING STAGE

- 6 bus 38kV distribution network (source: ESB Networks, 2010)
- $V_{nom}=38$ kV, $V_{max} = 42.5$ kV, $V_{min} = 36.5$ kV, $V_1 = 41.6$ kV
- Firm (nominal V and I limits): 42.6 MW
- Non-firm (V_{max} and I \uparrow 10%): 70.1 MW (\uparrow 64%)

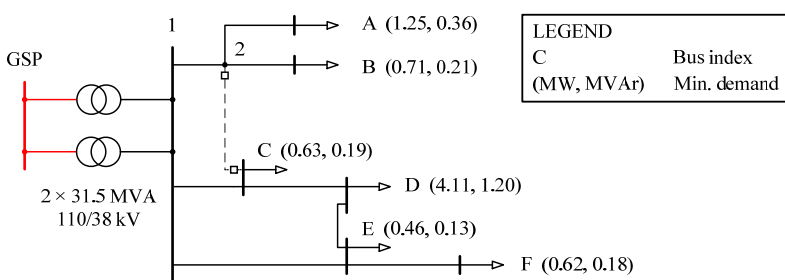


Fig. 2 Representative Irish distribution network at minimum demand

ACKNOWLEDGEMENT

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AC OPF OPERATION STAGE

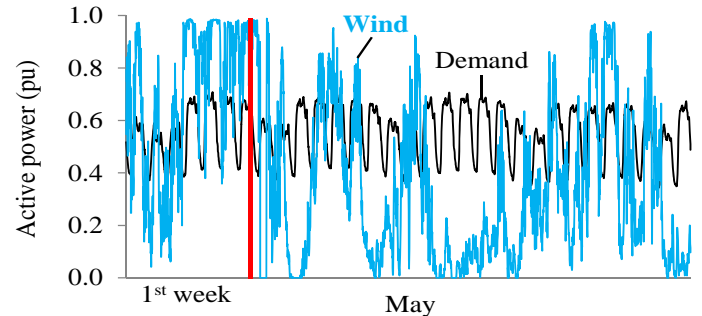


Fig. 3 Quarter hour wind power and demand, relative to peak values, 2010

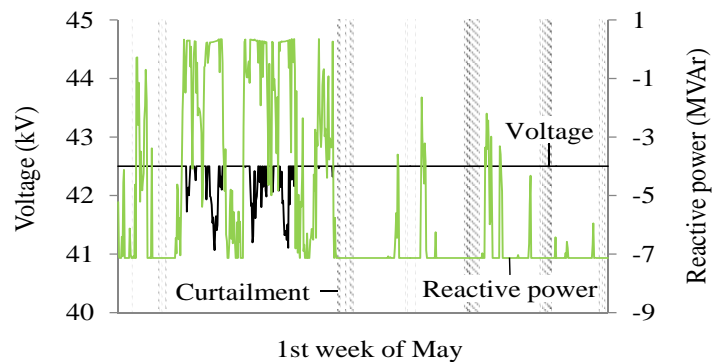


Fig. 4 Wind power curtailment without current constraint: Q-V interrelation diagram in respect of time for wind farm (WF) F connected to bus F

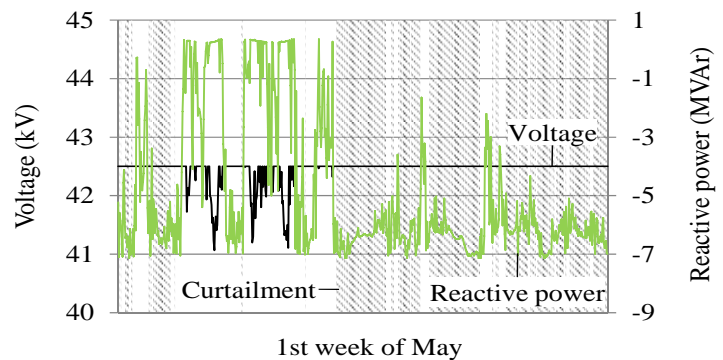


Fig. 5 Wind power curtailment with all constraints: Q-V interrelation diagram for WF F connected to bus F

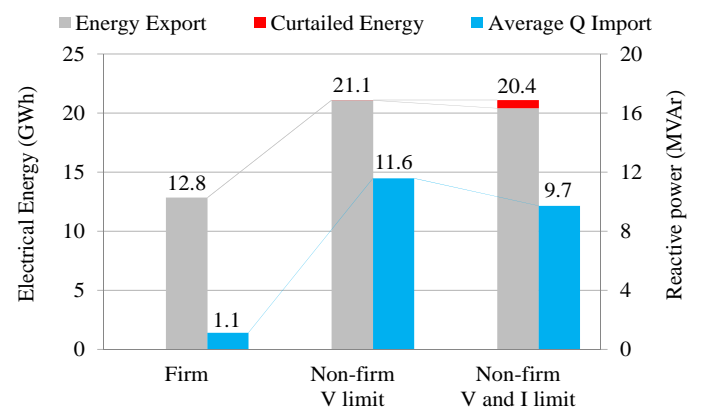


Fig. 6 Firm and non-firm operation stage results summary

CONCLUSIONS

- 59% increase in energy harvesting, 96.7% wind energy utilized
- WFs are required to absorb Q in order to deal with V rise
- SIDE-EFFECT: binding V_{max} and I constraint hinders WFs from using full Q capability