The value proposition of smart distribution system investments

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Introduction

- Distributed generation and demand response (DR) fundamentally rely on new distribution system infrastructures and services, meaning significant new value can be attributed to these investments
- Managing capacity and power quality is complex with DER (wind and demand response) present, potentially demanding new infrastructures including monitoring, remote control, automation, reactive power compensation & voltage management.
- Effective new technologies are available to form these infrastructures, and enable concepts including service level agreements (SLA) and market facilitation…but…
- …the relationship between investment and beneficiary is increasingly complex on the distribution system…
- …and socialised investments must be non-discriminatory & give value for money to distribution system customers

Objectives:

- Develop robust, technically informed methods capturing interdependence between returns for wind and DR, and socialised network investments
- Test & demonstrate in the context of
  - Medium voltage network automation
  - Reactive power compensation & management
- Demonstrate where the value proposition of smart investments may warrant cooperative investment planning or novel regulatory treatment

Methodology

- Analysis & application of ESB Networks field demonstrations results
- Modelling based on
  - historic network performance
  - SEM market data
- Test cases considering
  - ENTSO-E codes
  - Existing infrastructures, planning standards and operational rules
  - Regulatory framework & incentives
- Powerflow & optimisation techniques
- Application of state of the art regulatory & value quantification models

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Test case 1: targeted MV automation

Customer perspective

- Distribution customer value proposition reflected by regulated incentive / penalty:

Parameter	Value applied to deviation from targets				
	2011	2012	2013	2014	2015
CML	261,660	261,660	261,660	261,660	261,660
CI	206,460	206,460	206,460	206,460	206,460

$$\Rightarrow V_d = p_{ci}CI + p_{cml}CML$$

- return determined by population density, environmental conditions, geographical constraints
- Limited regulated allowance, return must exceed threshold ($R_{d,th}$)

$$R_d = {}^{V_d - I}/_{I} \geq R_{d,th}$$

Wind farm / DR perspective…

- DER revenues are based on energy transactions, limited at any given point in time by network capacity & availability

$$E_{der} = \sum_t E(n)_{der,t} + E(d_t, g_t)_{der,t}$$

Total profitable energy transactions — Portion limited by network capacity — Portion limited by local balancing load

- Outages limit network availability to support energy transactions

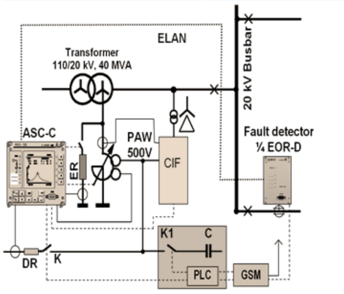
$$O_r = \sum_t (\%l_t . E_{der,t}) + \left((1 - \%l_t) . \%l_t . E(d,t)_{der,t}\right)$$

Probable lost transactions — Entire potential output if loss of supply at DER connection point — Loss of output proportional to % of balancing load lost

- Continuity investments reduce frequency, duration and %l of outages

$$V_r = NPV(O_r - O_{r1}) . \lambda$$

Avoided lost revenues



Example automated MV neutral treatment system from ESBN R&D – results informing this test case

Optimisation based on local conditions can inform novel value based investment mechanism…

- DER

$$ {}^{V_r - x.I}/_{x.I} > R_{der,th} \; ? \qquad (1)$$

- Distribution customers

$$ {}^{V_d - (1-x).I}/_{(1-x)I} \geq R_{d,th} \; ? \qquad (2)$$

Wind / DR customer afforded "SLA" and greater output

Societal gains with improved network performance locally and residual funding available for further investments

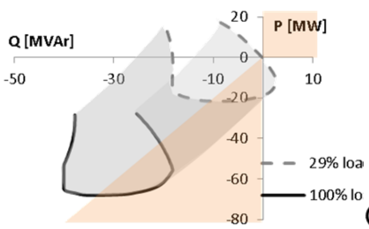
Potential auxiliary benefits if the automation investment affords greater local monitoring & control infrastructure, reducing future wind / DR / network management costs

Test case 2: reactive power compensation & management

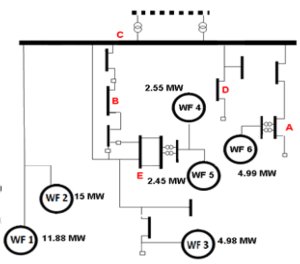
Where ENTSO-E codified power transfer standards require investment in reactive power management, the objective is to minimise the societal costs:

- penalties (*P*)
- capital costs (I_c)
- lifetime network loss costs (*L*)

The capacity, distribution, location & management of installed compensation may increase the capacity of the network for embedded wind generation (G)

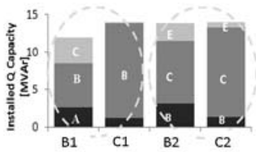


Reactive power transfer capability of test network



Location of potential compensation nodes & wind farms

Optimisation shows a trade-off between additional capacity, cost and loss minimisation



Solution	Capital cost (bcc)	Additional generation capacity (gr)	Loss savings (al)
B1	Low	Low	Low
C1	Med	Med	Med
B2	Med	Med	Low
C2	Med	High	Low

Additional output offers generators a return on cooperative investment

$$R_g = {}^{G_{c2} - x.I_{c,c2} - I_{g,c2}}/_{x.I_{c,c2} + G_{c2}} > {}^{G_{b1} - I_{g,b1}}/_{I_{g,b1}}$$

Adjusted investment burden makes solution C2 societally optimal

$$R_{c2} = {}^{L_{c2} + P_{c2} - (1-x).I_{c,c2}}/_{(1-x)I_{c,c2}} > R_{b1}$$

Optimisation based on output & ancillary service values, cost of additional generation capacity and losses, magnitude of compliance penalties gives mutually beneficial model for allocation

$$x = \left({}^{G_{c2} - I_{g,c2}}/_{L_{c2} + P_{c2} + G_{c2} - I_{g,c2}}\right)$$

Conclusions

This work is demonstrating and quantifying

- **The synergies between the infrastructure requirements for wind and demand response, and more natural social and regulatory investment priorities**
- **Appropriate incentive mechanisms and cooperative investment planning models, reflective of the value returned and the relative value of a given investment, to societal & commercial parties**
- **The circumstances under which greater returns can be seen by both**
- **Technically feasible "SLA" analogous arrangements, deliverable on demand driven by the value a wind / DR customer sees in terms of increased revenues or reduced costs**