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Linking socio-economic aspects to power system disruption models
Supplementary Information

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Modeling power flow in a looped network

Nomenclature

F	Power flow (MW)
l, l'	Transmission line
lf	Loop forming
L, L'	Number of transmission lines
R	Resistance (Ω)
P	Power production/consumption (MW)

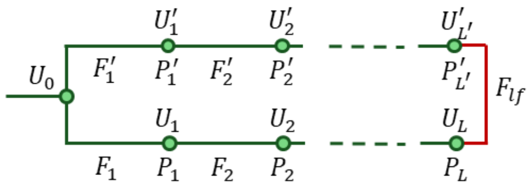

Fig. S1. Power line loop. Red line is a loop-forming line.

The calculation method used to model power flows in a looped transmission grid lines is based on calculation of the power flow in a so-called loop-forming line [1,2]. A loop-forming line represents a line that connects the other two lines to form a loop as illustrated in Fig. S1. The steps of derivation for power flow through such a loop-forming line are as follows.

First, voltage levels for all points are computed for both branches formed when loop-forming line is taken out of the loop:

$$U_1 = U_0 - \Delta U_1 = U_0 - R_1 I_{01} = U_0 - R_1 \frac{F_1}{U} \quad (S1)$$

$$U = \frac{U_0 + U_1}{2} \quad (S2)$$

$$U_1 = U_0 - \frac{2F_1R_1}{U_0 + U_1} \quad (S3)$$

$$U_1 = \sqrt{U_0^2 - 2F_1R_1} \quad (S4)$$

$$U_2 = \sqrt{U_1^2 - 2F_2R_2} = \sqrt{U_0^2 - 2F_1R_1 - 2F_2R_2} \quad (S5)$$

$$U_L = \sqrt{U_0^2 - 2\sum_{l=1}^{L} F_l R_l} \quad (S6)$$

$$U'_{L'} = \sqrt{U_0^2 - 2\sum_{l'=1}^{L'} F'_{l'}R_{l'}} \qquad (S7)$$

Since exclusion of loop-forming line is just imaginary for calculation purposes, power flow through that line has to be included:

$$\begin{cases} F_l \Rightarrow F_l + F_{lf}, & l\epsilon[1, L] \\ F'_{l'} \Rightarrow F'_{l'} - F_{lf}, & l'\epsilon[1, L'] \end{cases} \qquad (S8)$$

$$\begin{cases} U_L = \sqrt{U_0^2 - 2\sum_{l=1}^{L}(F_l + F_{lf})R_l} \\ U_{L'} = \sqrt{U_0^2 - 2\sum_{l'=1}^{L'}(F_{l'} - F_{lf})R_{l'}} \end{cases} \qquad (S9)$$

Then, calculation for one branch is extended though the loop-forming line:

$$U_{L+1} = \sqrt{U_0^2 - 2\sum_{l=1}^{L}(F_l + F_{lf})R_l - 2\mathrm{F}_{lf}R_{lf}} \qquad (S10)$$

U_{L+1} and $U'_{L'}$ describes voltage at the same point, therefore they must be equal:

$$U_{L+1} = U'_{L'} \qquad (S11)$$

$$\sum_{l=1}^{L}(F_l + F_{lf})R_l + F_{lf}R_{lf} = \sum_{l'=1}^{L'}(F'_{l'} - F_{lf})R'_{l'} \qquad (S12)$$

$$\sum_{l=1}^{L} F_lR_l + \sum_{l=1}^{L} F_{lf}R_l + F_{lf}R_{lf} = \sum_{l'}^{L'} F'_{l'}R'_{l'} - \sum_{l'}^{L'} F_{lf}R'_{l'} \qquad (S13)$$

$$F_{lf}\left(\sum_{l=1}^{L} R_l + \sum_{l'=1}^{L'} R'_{l'} + R_{lf}\right) = -\sum_{l=1}^{L} F_lR_l + \sum_{l'=1}^{L'} F'_{l'}R'_{l'} \qquad (S14)$$

$$F_{lf} = -\frac{\sum_{l=1}^{L} F_lR_l - \sum_{l'=1}^{L'} F'_{l'}R'_{l'}}{\sum_{l=1}^{L} R_l + \sum_{l'=1}^{L'} R'_{l'} + R_{lf}} \qquad (S15)$$

References

[1] Niemi R, Mikkola J, Lund PD. Urban energy systems with smart multi-carrier energy networks and renewable energy generation. Renew Energy 2012;48:524–36. doi:10.1016/j.renene.2012.05.017.

[2] Niemi R, Lund PD. Decentralized electricity system sizing and placement in distribution networks. Appl Energy 2010;87:1865–9. doi:10.1016/j.apenergy.2009.11.002.