Distribution Network Reconfiguration for Optimisation of Reliability and Losses

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Background

Motivation

- UK is legally obliged (Climate Change 2008) [1] to an 80% reduction in CO_2 emissions by 2050 compared to 1990 levels.
- The distribution network must accommodate Low Carbon Technologies (LCTs): Distributed Generation (DG), Electric Vehicles (EVs) and Heat Pumps (HPs) in order to meet this target.
- LCTs increase the complexity of network operation and may have a detrimental effect on distribution system reliability.
- Novel ways of operating the network are being investigated—one of which is distribution network reconfiguration to reduce losses, increase reliability and provide extra headroom for LCTs.

Algorithm

The algorithm uses a Graph Theory and Monte Carlo-style approach to find the optimal radial network configuration for losses or CML, then meshes the network one branch at a time until all branches are switched in to demonstrate the gains in loss and CML minimisation.

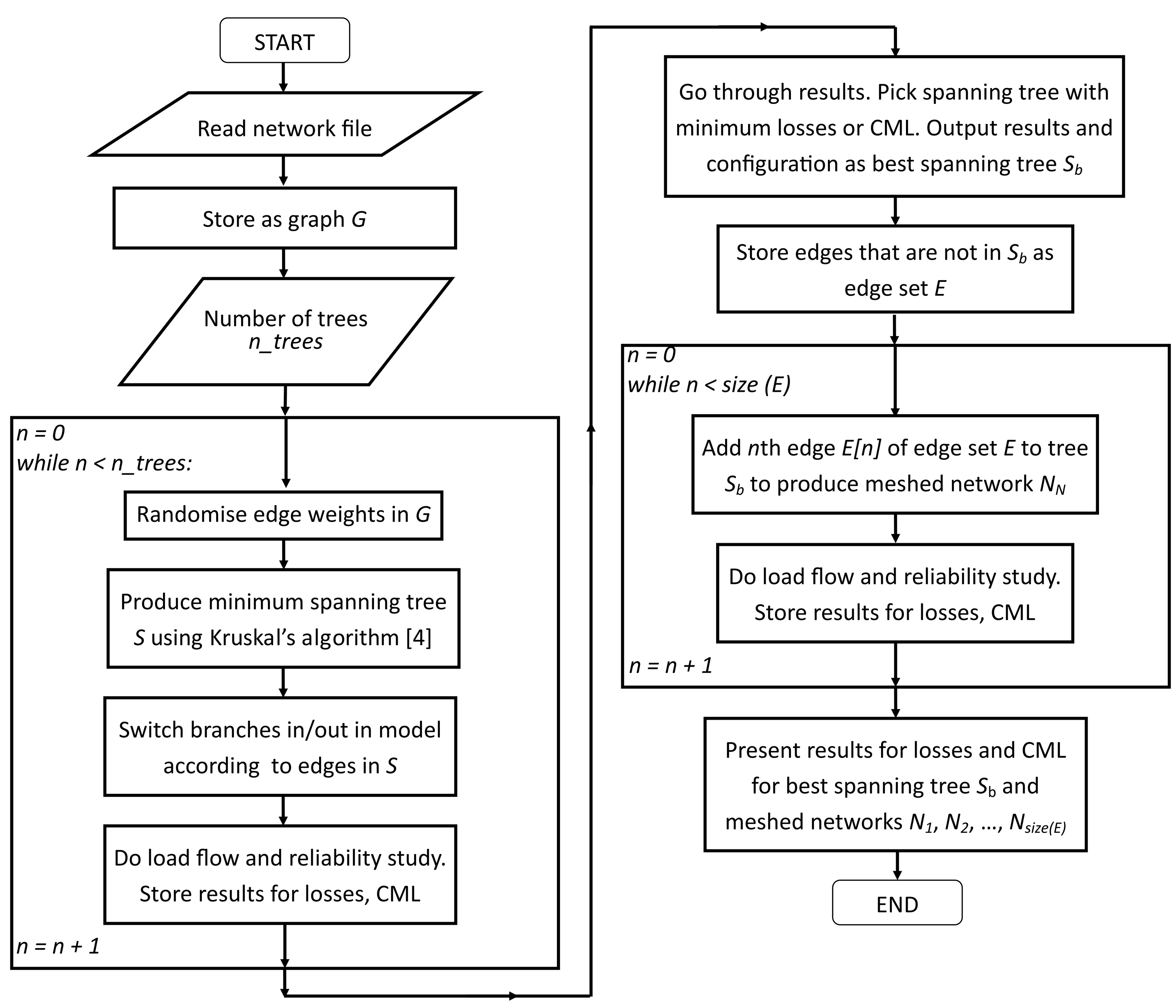

Fig. 1. Algorithm flow-chart

References

[1] UK Parliament, "Climate Change Act 2008" [Online]. Available: www.legislation.gov.uk/ukpga/2008/27/pdfs/ukpga_20080027_en.pdf [Accessed: 28-Apr-2016]

[2] R. Ahuja, T. Magnanti and J. Orlin, "Kruskal's Algorithm" in *Network Flows: Theory, Algorithms and Applications,* 1st ed, Pearson, 1993, pp. 520-523.

Results

Optimal Radial Configuration

The method was tested on the IEEE 33 bus test distribution network with two DG units: a 1.5 MW solar plant and a 0.8 MW wind turbine (Fig. 2). Running the algorithm to optimise losses gives the following result for the optimal radial configuration in Fig. 3 and detailed in Table 1.

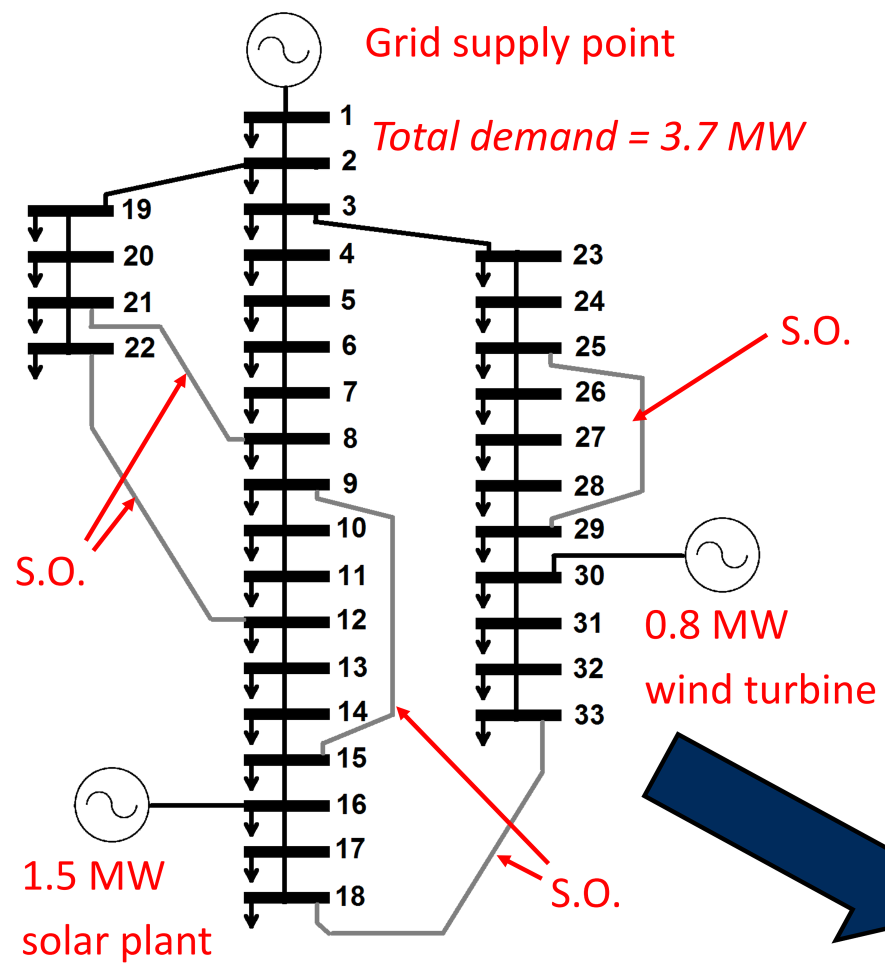

Fig. 2. IEEE 33 bus test distribution network—original configuration

Table 1. Losses and CML for original and optimal radial configurations

Configuration	Total losses (MW)	CML (minutes/customer/year)	Branches switched out
Original	0.089	88879	(8, 21), (9, 15), (12, 22), (18, 33), (25, 29)
Optimal Radial	0.054	74330	(10, 11), (12, 13), (26, 27), (30, 31), (8, 21)

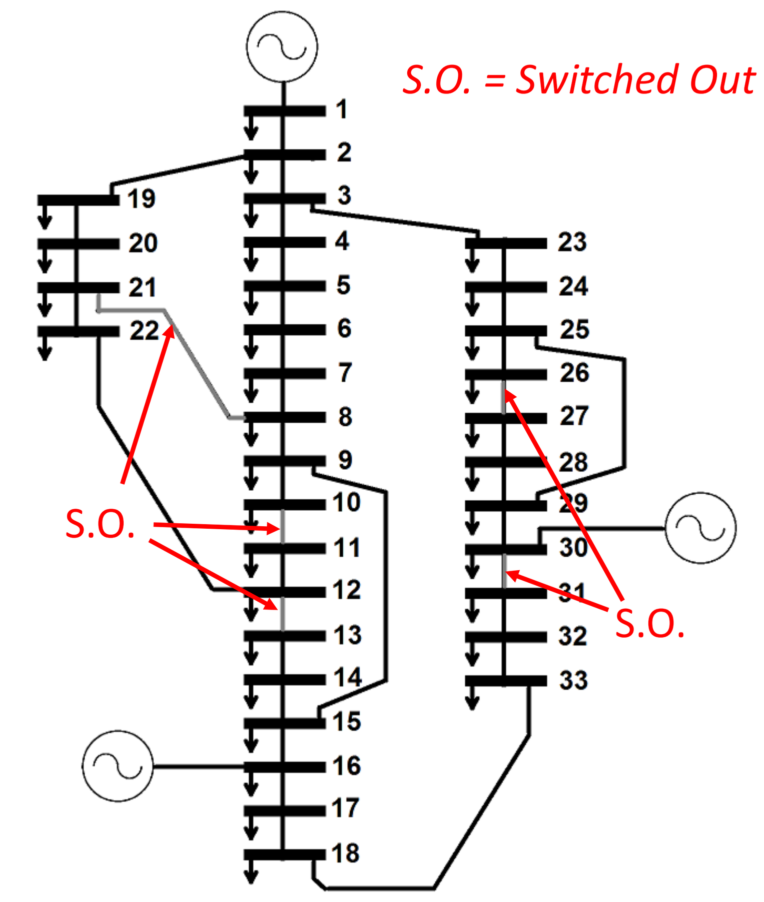

Fig. 3. IEEE 33 bus test distribution network—optimal radial configuration (10,000 trees)

Meshing

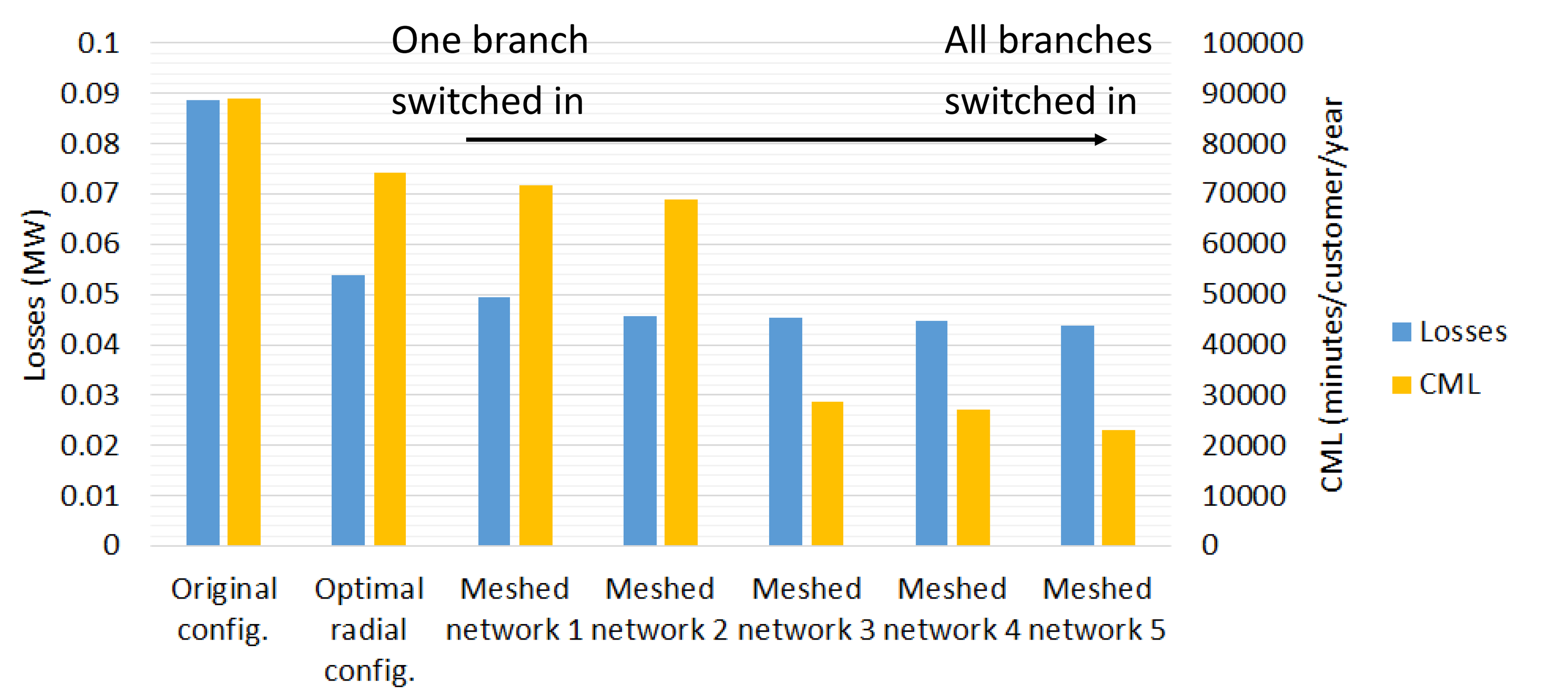

Figure 4. Results for loss/CML minimisation for IEEE 33 bus network (10,000 trees)

It was found that there is most benefit for losses reduction in finding the optimal radial configuration: a 39% reduction is available between the original configuration and the best found radial configuration (with 10,000 trialled). It was found that there is most benefit for CML reduction in meshing the network. Switching in certain branches (such as that between meshed networks 2 and 3 in Fig. 4) brings about dramatic improvements, in this case delivering a 68% reduction versus the original configuration.

Future Work

- Improve algorithm efficiency — investigate biologically inspired methods rather than random sampling
- Investigate other objective functions, e.g. DG/renewables penetration
- Use a Value of Lost Load (VoLL) to quantify gain in CML reduction and compare with increased cost of network protection for meshing
- Include more inputs in the model — demand forecasts, wind/solar forecasts, dynamic ratings/reliability data

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