



# Shadow Pricing of Electric Power Interruptions for Distribution System Operators in Finland

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Continuity of electric power supply is necessary to run critical infrastructure such as transportation, telecommunications, health, and finance as well as keeping industrial production, public services and other daily activities running. As electrification of energy systems continues and more intermittent sources are connected to the power grid, the significance of supply security increases. Understanding the economic impacts of power interruptions from a macro perspective becomes crucial. Shadow pricing technique offers one indirect analytical method. To introduce a different perspective to the phenomenon from a Distribution System Operator (DSO) point of view, we present the method of shadow pricing of power outages which solely relies on publicly available analytical data rather than survey questionnaires. In this way, cost estimation can be done by only using publicly available and objective analytical data such as number of customers, share of cabling in the distribution system, energy supplied to low-voltage customers and the System Average Interruption Duration Index (SAIDI).

Our study makes use of data shared by Finnish DSOs which provide 99% of the energy to low-voltage customers in Finland. The sample consists of 78 distribution system operators from Finland using cost and network information for 2013 to 2015. Numerous previous studies have evaluated the phenomenon of interruption costs from the customer point of view. We evaluate the same problem from the DSO perspective, so that each DSO will be able to have an idea about their interruption losses in a quick and straightforward manner. Nevertheless, the major advantage of obtaining customer-specific results via customer surveys is not applicable here. Using a shadow pricing technique yields average results, which omits sectoral differences in power consumption and customer interruption costs. One should remember that the



cost of one minute of interruption for a residential customer and the same cost for an industry customer will be different. In addition, this cost will vary considerably among sub-sectors of the same sector such as textile, construction, chemical, pharmaceuticals etc. within the industry sector. To reach customer specific outage cost estimations, the network operators should share sector and customer specific energy consumption data.

The shadow price for each DSO stands for the price of one minute of interruption in terms of operational expenses. At this point, the main idea is to increase the desirable output (energy supplied to the customers) by one unit while decreasing the undesirable output (customer minutes-lost) by one unit at the same time. We find that the shadow price of one minute of electricity outage for most Finnish DSOs varies between 0.4 – 0.5 € cents over 2013 – 2015. In 2015, among the DSOs, Muonion Sähkösuuskunta (0.035 € cents), PKS Sähkösiirto Oy (0.066 € cents), Valkeakosken Energia Oy (0.108 € cents), and Vetelin Sähkölaitos Oy (0,135 € cents) had the lowest shadow prices, whilst Forssan Verkkopalvelut Oy, LE-Sähköverkko Oy, Helen Sähköverkko Oy and JE-Siirto Oy had the highest shadow prices of 0.482 € cents/minute each.

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