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# Microgrid Economic Viability Assessment: An introduction to MG-REVALUE[☆]

Amin Khodaei[a,*], Shay Bahramirad[b], Esa Aleksi Paaso[b], Manuel Avendano[b]

[a] University of Denver, United States
[b] ComEd, Chicago, United States

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ABSTRACT

There are many proven advantages to microgrid deployment, however, associated initial investment costs are major obstacles to widespread and rapid deployment of this technology. To ensure that microgrid benefits will surpass the initial investment cost in a given time period, detailed cost-benefit analyses are required. This paper discusses this problem and introduces Microgrid Robust Economic Viability Assessment under Lasting Uncertainty Enclosure (MG-REVALUE) tool as an advanced robust optimization tool for microgrid economic viability studies.

## 1. Introduction

Microgrids show promise of being a major component of the future power grid. Technically speaking, microgrids are localized power grids that can disconnect from the utility grid to operate autonomously to support reliable and resilient power delivery. As an advantage over traditional means of power delivery, microgrids can continue operating while the utility power is interrupted, and can function as a grid resource for faster system response and recovery. Key features include the enabling of multiple integrated Distributed Energy Resources (DERs), coordinated control across the microgrid assets, in addition to the ability to isolate (or island) from the utility grid to meet the resiliency and reliability objectives. The DERs within the microgrid can include traditional fossil fuel based generation, such as natural gas or diesel engines, energy efficient generations, such as Combined Heat and Power (CHP) and fuel cells, and renewable generation, such as wind and solar, as well as Distributed Energy Storage (DES). Produced heat from the CHP generation sources can additionally be used for local process heating or space heating, allowing flexible tradeoffs between the needs for heat and electric power.

Although there are many advantages to microgrid deployment, associated initial investment costs of the microgrids are major obstacles to widespread and rapid deployment of the technology. In order to show net benefits from the microgrid deployment, it is important that the microgrid designs are optimized for their planned purposes. An accurate and holistic assessment of microgrid economic benefits is a challenging task due to significant amounts of uncertain data involved in the assessment. Moreover, some of the assessment results such as reliability improvements are difficult to comprehend for consumers when represented in supply availability terms. Thus, efficient planning models are required for ensuring the economic viability of microgrid deployments and further justifying investments based on cost-worth analyses in uncertain conditions.

Microgrid Robust Economic Viability Assessment under Lasting Uncertainty Enclosure (MG-REVALUE) is a robust optimization tool capable of returning the optimal microgrid sizing and configuration for each unique microgrid deployment scenario. The tool provides a viable means of simulation and optimization for microgrid deployments based on selected user inputs which include: DERs considered by the user, minimum and maximum load capacity, current and future energy consumption forecasts, desired reliability performance levels, budget constraints, and the uncertainty thresholds. The tool gathers this information via a Graphical User Interface (GUI) and converts it into an acceptable format that can be given to a CPLEX® core optimization engine for analysis. For a given objective, the tool produces the optimal generation mix to be utilized in the microgrid, the investment payback period, total and annual investment and operation costs, and potential total and annual revenues as a result of the DER installation, amassing to the overall economic viability for a specific microgrid deployment.

By utilizing the MG-REVALUE tool the user can select multiple candidate DERs for use within the planned microgrid. Through utilization of robust optimization techniques, the tool will determine the investment cost and associated operation costs of the candidate DERs. The cost of power purchase from the utility grid is then compared to the

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* Corresponding author.
E-mail address: amin.khodaei@du.edu (A. Khodaei).

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aggregated investment and operation costs and the cost of loss of power (resiliency cost) of the candidate DERs within the microgrid. The planned microgrid would be justified for installation when the sum of the investment cost, the operation cost, and resiliency improvement value is less than the cost of power purchase from the utility grid. The advantages will be realized and attained by means of the elements and combinations particularly discussed in this article.

## 2. Knowledge behind the development and microgrid design

Microgrids can offer economic, security, resiliency and reliability benefits to electricity customers. While microgrid DERs may require a higher initial investment cost compared to conventional energy resources, certain DERs may provide energy at a less expensive rate compared to the energy purchased from the grid. In particular, at peak hours when the electricity price is relatively high, certain DERs may supply energy for a price that is significantly lower than the electricity price. Thus, a microgrid could harvest significant benefits from generating power using its DERs at peak hours to supply local loads and by selling excess energy and capacity products to the utility grid at the electricity price. The microgrid can also increase security, resiliency and reliability of a local energy supply in case of utility grid disturbances. If there is an outage in the utility grid, upstream of the microgrid, and the system is not able to supply the loads, the load supply would be interrupted. However, the islanding capability of the microgrid can help ensure that local loads are supplied even if the utility grid power supply at the microgrid point of interconnection (POI) is not available.

Under the MG-REVALUE model, economic benefits from selling back the excess power to the grid plus monetized resiliency and reliability improvements represent a portion of microgrid total revenues. One major challenge is that not all the data are known with complete accuracy, and there are several sources of uncertainty to this analysis. The sources of uncertainty in the formulation of MG-REVALUE tool are categorized in two broad categories of forecasting-related and islanding-related uncertainties. Long-term load forecasting is identified as one of the main sources of uncertainty. Generally for microgrid installations, the fixed load can be forecasted with an acceptable accuracy. However, the flexible loads (e.g. loads that can respond to price) in microgrids may significantly complicate the forecasting process, as they may be subject to variations in hourly electricity prices. Renewable generation is identified as another source of forecasting-related uncertainty to the microgrid. A high degree of renewable DERs is often desired in microgrids if the objective is to help reduce greenhouse gas emissions or support certain renewable integration objectives. The renewable energy resources produce a variable and intermittent power output mainly due to changing weather conditions, thus accurate forecasting of power produced by renewable DERs is extremely challenging. Forecasting the electricity price of electricity often implicates a relatively high degree of uncertainty, as several factors are involved in this forecasting process. For example, offers by generation companies, transmission network congestion and configuration, changing market structures, and customer participation in demand response type programs each introduce uncertainty in electricity prices, both in long and short terms. Electricity price is often somewhat dependent on constraints related to the available fuels, such as congestion on natural gas pipelines. For these reasons, the electricity price at the microgrid POI can be a significant source of uncertainty in the microgrid planning as it significantly impacts the unit commitment and economic dispatch of microgrid DERs.

The other category of uncertainty is related to the islanded operations of the microgrid. As previously mentioned, by definition a microgrid can switch to an islanded mode when there is a disturbance upstream of the microgrid POI. Similarly, the microgrid can be resynchronized with the utility grid when the disturbance is cleared. The time and duration of such disturbances, however, can vary significantly and may not be forecasted with an adequate level of certainty. Although microgrids are typically operated in the grid-connected mode and infrequently switched to the islanded mode of operation, there can be significant societal cost savings and customer resiliency and reliability enhancements offered by microgrids during major outages (such as ones caused by major storms and other weather events). Quantifying these benefits can often significantly help justify the microgrid investment decision over installation of just DERs to achieve energy cost savings.

The MG-REVALUE tool is able to simultaneously model both uncertainties associated with forecasting and islanding to obtain the optimal microgrid DER mix under uncertain conditions. Compared to the traditional Cost Benefit Analysis (CBA) tools, a major advantage that the MG-REVAULE tool has is its ability to consider all of the associated uncertainties in the problem formulation and produce more accurate scenario-based predictions and compare these scenarios against the implementation costs to support the investment decision. Compared to deterministic models, MG-REVALUE can consider the design decisions based on the worst cases and is further able to produce results that provide an optimized microgrid design that has taken all of the associated uncertainty in consideration.

## 3. MG-REVALUE

The three major parts of the MG-REVALUE tool are the inputs, the core optimization engine, and the outputs. Inputs include, but are not limited to, DER characteristics and costs, load forecast, local renewable generation profiles and forecasts, electricity prices at POI, available investment budget, existing reliability metrics, reliability target levels, and limit on uncertainty. The initial distribution of candidate DERs is user-selected based on designer's preferences on technology, microgrid objectives, and other considerations such as microgrid location and physical space limitations. For example, one designer may consider solar energy resource as a candidate DER since the microgrid is planned to be installed in a location with high solar radiation, while another prefers wind energy resource as there will be high levels of wind in the planned microgrid location. In that aspect, the selected DERs can comprise a mix of dispatchable and non-dispatchable DGs and DES.

The core engine utilizes these inputs to solve a long-term (20 years) robust optimization with the primary objective of minimizing the microgrid total (aggregated) planning cost (i.e., maximizing its revenue). The solution of this optimization problem, which would appear as the output, includes the economic viability of the investment, optimal DER portfolio, and total and annual costs and revenues. Fig. 1 shows the

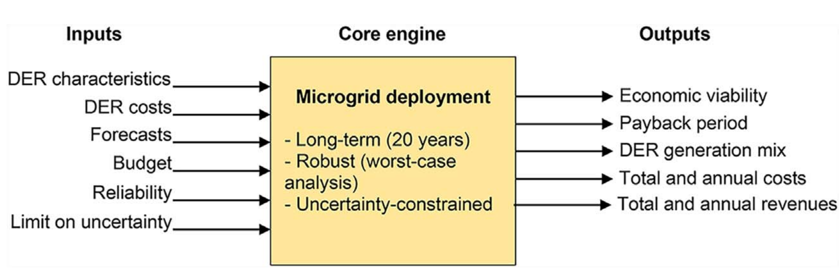


**Fig. 1.** Structure of MG-REVALUE.

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