Uncertainity in Benefit Cost Analysis of Smart Grid Demonstration-Projects in the U.S, China, and Italy

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INTRODUCTION

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Given the substantial investments required, there has been keen interest in conducting benefits analysis, i.e., quantifying, and often monetizing, the performance of smart grid technologies. In this study, we compare two different approaches; (1) Electric Power Research Institute (EPRI)'s benefits analysis method and its adaptation to the European contexts by the European Commission, Joint Research Centre (JRC), and (2) the Analytic Hierarchy Process (AHP) and fuzzy logic decision making method. These are applied to three case demonstration projects executed in three different countries; the U.S., China, and Italy, considering uncertainty in each case. This work is conducted under the U.S. (United States)-China Climate Change Working Group, smart grid, with an additional major contribution by the European Commission. The following is a brief description of the three demonstration projects.

Tianjin Eco-city

The China demonstration covers several smart grid aspects of a Sino-Singapore endeavor in Tianjin. This project is evaluated using Smart Grid Multi Criteria Analysis (SG-MCA) approach. Three Sub-projects from the Eco-city demonstration project are included in this analysis: (1) Sub-project 2: Microgrid with energy storage (MgS), (2) Sub-project 3: Smart substation, (3) Sub-project 4: Distribution automation.

1.Sub-Project 2 (MgS): The 380 V MgS is composed of 30 kW of PV, 6 kW of wind turbines, 15 kW×4 h of lithium-ion batteries, together with lighting loads of 5 kW to 10 kW, plus EV charging for a total 15 kW. Control is by an economic microgrid energy management system that includes distributed power, an energy storage inverter, microgrid intelligent terminals, a microgrid system controller, the server host, and an operator station.

2.Sup-project 3 (Smart Substation): The Cheong 110 kV SS, uses 2x50 MVA electronic transformers, primary equipment on-line monitoring and other intelligent devices.

3. Sub-Project 4 (Distribution Automation): The DA pilot area distribution network uses a ring network power supply, an open-loop operation mode, and the requirement for mutual interconnection capability to meet N-1, important individual line and load reaches the N-2 line break point.

Irvine Smart Grid Demonstration

The U.S. example demonstration is Southern California Edison's Irvine smart grid demonstration project (ISGD). This project is evaluated with EPRI's benefits analysis method. Three Sub-projects from the ISGD project are included in this analysis: (1) Sub-project 1: Zero Net Energy Homes (ZNE), (2) Sub-project 3: Distribution Circuit Constraint Management Using Energy Storage (DBESS), (3) Sub-project 4: Distribution Volt/VAR Control (DVVC).

1. Sub-project 1: (ZNE): ZNE sub-project involves a residential neighborhood with four blocks of homes on the UCI campus used for faculty housing. ISGD has equipped three blocks of homes with an assortment of advanced energy components, including demand response devices, energy efficiency upgrades, residential energy storage units (4 kW/10 kWh), a community energy storage unit (25 kW/50 kWh), and solar PV arrays (ranging 3.2 to 3.9 kW)
2. Sub-project 3 (DBESS): This project domain includes a distribution-level battery energy storage system to help prevent a distribution circuit load from exceeding a set limit, to mitigate overheating of the substation getaway, and reduce peak load on the circuit. DBESS has a rating of 2 MW of real power and 500 kWh of energy.
3. Sub-project 4 (DVVC): DVVC optimizes the customer voltage profiles in pursuit of conservation voltage reduction. Field experiments showed an average 2.6 % energy savings, making this demonstration a major success, and SCE intends to gradually roll the technology out system wide; however, it may not be applicable to all distribution networks depending on pre-existing equipment.

City of Rome

The Italy demonstration involves a pilot project in Rome conducted by ACEA, Italy's third largest distribution network operator. This project is evaluated with JRC's cost benefits method, which is a derivative of the same approach used by ISGD. JRC demonstration was conducted in the Malagrotta area, west of Rome, and involved the installation of new technical solutions on 6 feeders, about 69.5 km of medium voltage (MV) (20 kV) and low voltage (LV) (8.4 kV) lines. There are 4 distributed generation plants directly connected at MV (1 PV array and 3 biomass plants accounting for about 20 MW of installed capacity), and 7 users directly connected to the MV grid accounting for about 3.5 MW of load. The project is made up of 3 main additive components:

1. MV grid automation focuses on enabling the automatic selection of fault line segments, and allows remote distributed generator management based on actual grid conditions
2. At both MV and LV levels, ACEA set up a remote control and monitoring system that allows remote operation of more than 60,000 switches. This sub-project included real-time measurements at secondary substations including technical characteristics of the grid at both voltage levels.
3. Centrally, the development and set up of a new grid management algorithm will allow further benefit capture from sub-projects a and b, allowing: load flow management, optimization of load profiles, and minimization of technical losses.

METHODS

Benefit Analysis with SG-MCA

SG-MCA is a method combining AHP and fuzzy logic to assess the benefits of smart grid projects. In this method, a hierarchy structure is used to evaluate the project's performance. In each hierarchy, all of the indexes (i.e., technical, economic, social, and practical indexes) are assigned with a weight value determined by experts' judgements. Projects are evaluated in four domains, which are technology, economy, sociality, and practicality. Ultimately, a final score is calculated for the project to qualify the performance in both four aspects and as an entity.

Benefit Analysis with EPRI and JRC Approach

Both EPRI and JRC approaches define benefit as a monetized value of the impact of a smart grid project to all stakeholders involved (e.g., consumer, utility, society). All the benefits must be expressed in monetary terms. For smart grid systems, there are four fundamental categories of benefits, as identified by EPRI:

- Economic – reduced costs, or increased production at the same cost, that result from improved utility system efficiency and asset utilization
- Reliability and Power Quality – reduction in interruptions and power quality events
- Environmental – reduced impacts of climate change and effects on human health and ecosystems due to pollution
- Security and Safety – improved energy security (i.e., reduced oil dependence); in creased cyber security; and reductions in injuries, loss of life and property damage.

The benefits analysis in the EPRI method is based on the difference between the benefits and costs associated with a baseline scenario. In the EPRI adapted methodology by JRC, the level of detail of assets, functionalities and benefits are different, in order to take into account the contribution of each single physical asset constituting the project and its impact on the total benefits.

RESULTS

Tianjin Eco-city

The overall performance of the Tianjin Eco-city demonstration project from SG-MCA method is good, with a score of 87 of 100, but the economy is relatively poor with a score of 64. The technology, sociality, and practicality scores are 96, 93, and 80.

ISGD

ISGD demonstration results from EPRI method, shown in Table 1, indicate that ZNE is far from being economically attractive at current project performance and expenditures. The equipment cost, about $146 k/home would need to be about 94% lower to achieve break even, i.e., B/C ratio, greater than 1. The results of this analysis should only be considered illustrative, not financial, for the purpose of evaluating the SGCT. In contrast, DBESS and DVVC appear to be economic.

City of Rome

NPV	ZNE	DBESS	DVVC
Cost	$(4.64M)	$(0.85M)	$(0.59M)
Benefit	$0.30M	$2.14M	$7.58M
Net Benefit	$(4.34)M	$1.30M	$6.99M
B/C Ratio	0.1	2.5	12.9

Table 1. Results for ISGD Sub-Projects

Maloggrata demonstration results from JRC approach indicates that LV remote control and monitoring are the most important in monetary terms. Summing up, the results of the application of JRC's benefits analysis method to the Malagrotta pilot project are extremely promising. The outcome of the analysis points to an internal rate of return for Malagrotta of 1.23%, that however becomes 16.60% when scaling up the solutions tested in the pilot to the whole Rome network.

CONCLUSIONS

Uncertainties in the estimates from all methods and cases are relatively high, based on the range of estimates provided by the studies drawn upon for this report, and the judgment of the authors. Both methodologies present some difficulties in the evaluation of smart grid benefits. SG-MCA, for instance, is not effectively representing public and private costs, but only their effectiveness in achieving the overall goal. EPRI and JRC methodologies are not appropriate in managing intangible impacts, such as practicability, which could be more relevant to policies and strategies at this scale for achieving smart grid benefits.

Italian Affiliate Elects New Officers

At its July Annual Meeting AIEE elected new officers and board members.

Reelected President was **Carlo Andrea Bollino**

To serve with him, Carlo Di Primio Vice President and CEO; and Vittorio D'Ermo, Director of the AIEE Energy Analysis & Forecasting Service.

Board members elected were Luigi Napoli, Rita Pistachio, Marco Porro, Lucia Parisio Visconti, Mario Taraborelli and G.B. Zorzoli.

Bergen Overview (continued)

IAEE Awards Dinner

The IAEE Awards dinner was held in Grieghallen, named after the Bergen composer, Edvard Grieg (1843-1907), and venue of the Bergen Philharmonic Orchestra, one of the oldest orchestras in the world and celebrating its 250-ieth anniversary this year. The Managing Director of NHH, Nina Skage, was an elegant and eloquent master of ceremony of the dinner. She dressed in her national costume, as did several of the other Norwegians attending the dinner. The musical entertainment was performed by the Concertmaster of BFO, Melina Mandozzi on violin, accompanied by Alina Letyagina on piano, and playing music of Norwegian composers, including Grieg. They were followed by Åse Teigland on the special Norwegian music instrument, the Hardanger fiddle, a violin but with five "understrings" in addition to the ordinary ones. She played Norwegian folk music and accompanied two young dancers with music to a Norwegian folk dance called "springar". The musicians and the dancers received well-deserved and long applause from the audience of almost 600 dinner guests.

In addition to IAEE-awards bestowed on the members of the Organizing Committee, Past President Wumi Iledare received the Outstanding Contributions to the IAEE Award from the IAEE President, Gürkan Kumbaroglu, and responded with a short and well-formulated speech of thanks. Immediate Past President Peter Hartley received the Best Energy Journal Article Award and Frank Obermüller the Best Student Paper Competition Award. Finally, the General Conference Chair, Einar Hope, was called on to the stage to receive a gift and a word of thanks from Nina Skage.

Gala dinner attendees were given an introduction to the beautiful cultural heritage of Norway.

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