

DEVELOPING POLICY SCHEMES TOWARDS GRID-SCALE MICROGRIDS; DISCUSSING THE IRANIAN CASE

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ABSTRACT

To achieve an adequate level of integration, microgrids are facing challenges in three fronts; technical, financial, and regulatory. In this study, financial flows of microgrid investment are explored and using an economic viability analysis the financial aspects of microgrid investment as business options are discussed. Finally, while assessing the capacity of financial platforms to help address microgrids development challenges the need to develop new policy schemes and regulatory platforms to help increase microgrids grid-scale penetration is discussed.

INTRODUCTION

Microgrids are known as clusters of distributed energy resources relying on integrated control systems to coordinate distributed generations including intermittent renewables, demand response and storage units [1]. Their development can be beneficial for a variety of players, investors and grid operators. These benefits have been explored in numerous studies and academic papers [2-7].

Microgrids are introduced as future building blocks to enhance the flexibility and resiliency indices of next-generation power networks [8]. They can increase grid reliability [9], inject local active/reactive power generation capability [10], and induct island operation abilities [11]. Microgrids can also help avoid global environmental crises via facilitating higher penetrations of renewable generations [6].

To achieve an adequate level of integration, microgrids are facing challenges in various fronts; Financial and regulatory challenges are among the main barriers impeding microgrids large scale integration into power

grids. Most of these challenges are mainly presenting themselves in the form of unprofitability of investment and unviability of microgrids as business options. Various studies are suggesting a regulatory platform to help microgrids achieve the expected level of grid integration however, prior to engaging any meaningful attempt to structure a regulatory platform in order to evaluate the efficiency of market force, a study shall investigate the capacity of financial structure in helping address the proposed challenges. This paper as a part of a broader attempt for Iranian electrical grid, investigates the capacity of financial structure to assist authorities around the world with a better understanding of the weak points in microgrids developments.

In this regard in the following a platform to financially assess microgrids as business model is presented considering the economical parameters for Iran, then results are evaluated and discussed.

MICROGRID AS BUSINESS INVESTMENT

To assess microgrids as business models the financial flow of microgrid considering the characteristics of Iranian economy is investigated. Figure 1, shows the platform in which the investigations are carried out for this purpose. In this platform in section A, the parameters of revenue and cost flow are investigated and quantified. In section B, five conceptual business models are presented and discussed and in section C, an economic viability analysis using a simple NPV method is performed to financially assess the models.

A: Quantifying the financial terms

As shown in Figure 1, revenue and cost flows in financial assessment of microgrid development is consisted of various terms. In order to be able to formulise economic evaluation of microgrid investment as a business option, these terms are quantified in the following.

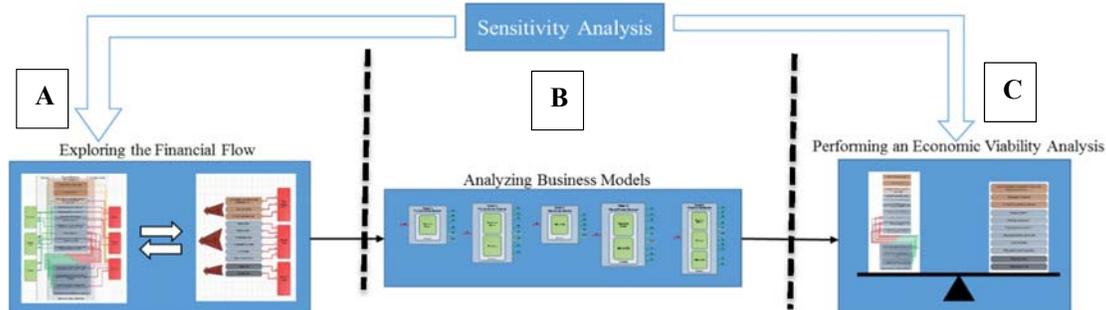


Figure 1: Proposed platform to evaluate microgrids as business options

As in this paper, business models for transforming already established distributed generation into microgrid are not discussed, CT as shown in equation (1) is taken into account for the cost flow.

$$C_T = C_{DER_Inv} + C_{\mu Grid_Inv} + C_{\mu Grid_Op} \quad (1)$$

In this equation, the terms are respectively, cost of DER investment, additional costs to enable microgrid capabilities for a DER and costs of microgrid operation which are discussed and quantified later in this section.

Accordingly, microgrid operation cost as presented in (2), is calculated as projected costs of DERs operation, the cost of energy purchase from the main grid and finally the customers interruption costs. Generation cost for nondispatchable units and energy storage systems are assumed, zero.

$$C_{Mgrid-Op} : \\ \sum_{n=1}^{N_p} \alpha_{Interest-rate} \sum_{D=1}^{365} \sum_{t=1}^{24} \alpha_{Operation-Cost} \times P_{G-D_t_D} \times T \\ + \sum_{n=1}^{N_p} \alpha_{Interest-rate} \sum_{D=1}^{365} \sum_{t=1}^{24} [L_{t_D}^{MG} - (P_{G-D_t_D} + a \times P_{G-ND_t_D})] \times \rho_{price_t_D} \times T \\ + \sum_{n=1}^{N_p} \alpha_{Interest-rate} \times CIC^{microgrid} \quad (2)$$

In (3), three load levels are considered for each day as, peak, shoulder and off peak with equal duration, T. $P_{G-D_t_D}$ is the dispatchable unit output at time t and day D, $a \times P_{G-ND_t_D}$ is the average output considered for non-dispatchable unit during period T and day D. $\alpha_{Interest-rate}$ is the considered interest rate while $CIC^{Microgrid}$ and $L_{t_D}^{MG}$ are respectively the micro-grid customer interruption cost and microgrid load at time t and the day D of the year. Also N_p is the number of the years of planning horizon. CIC is calculated using equation (3).

$$CIC = P_{av} SAIFI c_{ref}^C (0^+) + P_{av} SAIDI \left. \frac{dc_{ref}^C}{dr} \right|_{r=r_a} \quad (3)$$

Generation facility and sitting plant investment costs are calculated as:

$$C_{Der-Inv} : \\ \sum_{n=1}^{N_p} \alpha_{Interest-rate} \times (CC_{Dis} \times P_{G-Dis}^{Max} + CC_{NDis} \times P_{G-NDis}^{Max} + \\ (CP_{Storage} \times P_{Storage}^{Max} + CE_{Storage} \times C_{Storage}^{Max})) \\ P_{G-Dis}^{Max}, P_{G-NDis}^{Max}, P_{Storage}^{Max} \text{ and } C_{Storage}^{Max} : \text{ respectively} \quad (4)$$

rated powers of dispatchable, non-dispatchable and storage units and the rated capacity of the storage system.

Equation (5), calculates the revenue obtained due to the deferred investment, regarding microgrid establishment effect on peak shading.

$$R_5 : \\ DP^{Microgrid} \times (CC_{Dis} \times (P_{G-D_t_D} + a \times P_{G-ND_t_D})) \times \alpha_{Interest-Rate} \quad (5)$$

Equation (7) using the cost for investment of the similar size conventional generation capacity to fulfil the peak load, calculates the financial benefits of the deferred investment. In (8) $L_{Annual-Peak-Network}$ is the annual peak of the network where microgrid is established, and $\alpha_{Annual-Load-Growth}$ is the estimated annual demand growth for the study network.

In (6), revenue regarding the increased reliability for microgrid participants is presented.

$$R_6 : \\ ECOST^{Micro-Grid} = CIC^{ref-Micro-Grid} - CIC^{Microgrid} \quad (6)$$

Reliability increase benefits are calculated as the enhancement in customer interruption costs. In (6), $CIC^{ref-Micro-Grid}$ is the customer interruption cost of the microgrid participants when microgrid is not yet installed, and $CIC^{Microgrid}$ is the interruption cost for microgrid participants when it is installed.

Network utilization quality enhancement benefits, regarding microgrid presence is calculated based on customer interruption cost as the following:

$$R_6 + R_7 + R_{11} : \\ ECOST = CIC^{ref-Grid} - CIC^{Grid+Microgrid} \quad (7)$$

Where $CIC^{ref-Grid}$ is the customer interruption cost for the grid and $CIC^{Grid+Microgrid}$ is the customer interruption cost for the grid when microgrid is installed.

Equation (8) calculates the benefits of microgrid regarding its impact on loss reduction. For this purpose, grid loss costs are compared with and without microgrid presence.

$$R_1 + R_4 : \\ COST(Loss^{Grid}) - COST(Loss^{Grid+Microgrid}) \quad (8)$$

In (11), $COST(LOSS^{Grid})$ is the cost of grid loss when no microgrid is established and $COST(LOSS^{Grid+Microgrid})$ is the cost of grid loss in presence of the microgrid.

Equation (9), shows microgrid income regarding energy sale. The first part calculates the benefit equal to the cost of purchasing energy from the main grid in case the microgrid was unavailable, and the second part calculates the income regarding the sale of the excess energy to the main grid, at the K_{MES} times the price of energy purchase from the grid. Where K_{MES} is supposed to represent the interconnection tariff policy. It is assumed in this paper, that the grid operator is obligated to purchase all the microgrid surplus energy.

$$R_g + R_y: \quad (9)$$

$$\left[\sum_{n=1}^{N_p} \alpha_{Interest-rate} \sum_{D=1}^{365} \sum_{(P_{G-D,t,D} + a \times P_{G-ND,t,D}) \leq P_{t,D}^{MG}} (P_{G-D,t,D} + a \times P_{G-ND,t,D}) \times \rho_{price,t,D} \times T \right] + \left[\sum_{n=1}^{N_p} \alpha_{Interest-rate} \sum_{D=1}^{365} \sum_{(P_{G-D,t,D} + a \times P_{G-ND,t,D}) \geq P_{t,D}^{MG}} \left[(P_{G-D,t,D} + a \times P_{G-ND,t,D}) - P_{t,D}^{MG} \right] \times \rho_{price,t,D} \times K_{MES} \times T \right]$$

B: Conceptual Business Models

In this paper, five different investment models that allow the investors for access to different revenue systems, under three main categories, namely Private investment, State owned and the mixed investment, are discussed. Five business models presented in this paper are carefully set to contain each possible form of microgrid ownership. Microgrids are either, invested and operated by private investors or they are owned and utilized by state owned entities or a mixture of these forms could be considered. To ensure the comprehensiveness of the introduced models, private investment is assumed to contain forms of microgrid participants' investment and a third party private investor, to make possible the assessment of various structures of revenue flow.

C: Economic Viability Analysis

There are various aspects to economic evaluation of an investment project. The NPV analysis method is used in this study, because in addition to being comprehensive, it is also simple. The MARR value can be considered equal to the interest rate, and as the funding resources are presumed unlimited, then any project rejected by this method can decisively be considered a no option. Net present value (NPV) is calculated as:

$$NPV = \sum_{t=0}^n (B_t - C_t) / (1+i)^t = \sum_{t=0}^n (B_t - C_t) / (P/f, i, t) \quad (10)$$

Where, n shows the number of years for planning horizon. B_t and C_t in equation (10) are respectively the income and expense value for the year t and i is the interest rate which is considered equal to the minimum

acceptable rate of return (MARR) value for the sake of analysis simplicity.

DISCUSSING THE RESULTS

In this paper Iranian national power grid data containing hourly electricity prices, reliability indices, investment costs and demand growth data are utilized for the case study. Figure 2, shows the results for NPV analysis of the discussed microgrid business models for the case study. The current contribution tries to explore the potential and capacity of financial framework to address the challenge in the form of evaluating microgrids as business models. As shown in figure 2, the level of economic attractiveness for business models increases, as more entities are involved in microgrid foundation. That is because the financial structure in current microgrid financial flow has deficiencies in appropriate allocation of financial interests as discussed earlier. Rather than that, the results suggest a state investment over private investment, as the current state of financial structure enables state entities to enjoy the advantages of microgrid establishment more than private investors. For the sake of simplicity, analyses are done using per unit values, where numbers are measured as a portion of the cost for generation plant installation. As the results of the analysis suggests where the rate of interest rate for Iranian economy is considered 10% in this study, subsidies of around 0.9 Pu are needed to make microgrid investment economically acceptable. Such data could be of great value, for policy makers if they are seeking to establish a functional supportive scaling policy to help increase microgrid penetration. Without taking contribution share into account, model 5 represents the case when all entities are taking part in revenue foundation. That means a just allocation of revenue sources as all the benefits of microgrid establishment are assigned to its investors. It is equivalent to the results for a revised allocation structure, where all the benefits of microgrid establishment are directed to the right entities. In table 1, the sensitivity analysis for NPV evaluation results are done for several parameters. Sensitivity analysis was done for models 1, 3 and 5 at a 2% interest rate. Selected parameters were chosen due to the possible adoption of different supportive policies regarding microgrids or the fact that they may vary significantly from one grid to the other. The results of analysis confirm that the NPV results are more dependent on adopted policies (ρ_{price} as energy

price and K_{MES} as a supportive interconnection tariff policy) than the inherent technical grid specifications and features (like the cost of service interruption). Economic analysis results high sensitivity to interconnection tariff strategies ($\frac{\Delta NPV}{\Delta K_{MES}}$) as suggested by table 1, confirms

the efficiency of defining tariff policy as a functional governmental supportive strategy to help increase microgrid penetration. The negligible effect of pollution

costs on the NPV results ($\frac{\Delta NPV}{\Delta \rho_{Mit-Pollu-Price}}$) shows the need for supportive policies to invigorate the financial incentives of microgrid establishment in promoting renewable penetration, as a solution to global pollution challenges. The comparison of the NPV results for different business models also reveals the limited capacity of the financial mechanisms to engage the

microgrid development challenges. It also confirms that an attempt solely based on modification of the current structure of microgrids financial flow in order to make microgrid investment an economically competitive option, wouldn't be sufficient, and an exploration of untapped microgrid potentials is also needed.

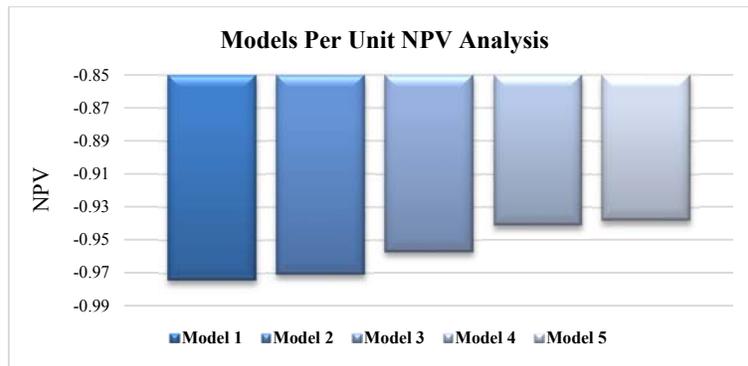


Figure 2: Results of NPV evaluation

Table 1: NPV Sensitivity Analysis

Parameter	Description	$\frac{\Delta NPV}{\Delta f}$		
		Model 1	Model 3	Model 5
ρ_{price}	Energy Price	3.7721	4.3872	5.1097
K_{MES}	Ratio of the price of energy purchase from microgrid to the main grid energy price	1.5228	1.5821	1.8292
CI	Cost of Service Interruption	0.0367	0	0.0441
$\rho_{Mit-Pollu-Price}$	Pollution Price	0	0.0861	0.0990

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