Policy Brief

TECHNO-ECONOMIC ANALYSIS OF WIDESPREAD MICROGRID/MINIGRID (MG) DEPLOYMENT IN PAKISTAN'S ELECTRICAL POWER SECTOR

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INTRODUCTION

In the recent past, the Government of Pakistan has undertaken certain appreciable initiatives in the Electrical Power Sector which is undergoing extensive reform and restructuring process, particularly in the areas of de-carbonization and deregulation. Although Pakistan is blessed with abundant natural energy resources, a significant percentage of the population remains without electricity access since the expansion of the centralized grid is uneconomical due to certain reasons including but not limited to limited financial resources and scattered populations. In this regard, Micro/Mini-Grids (MG) deployment offers an excellent opportunity to address this problem, improve the life quality of the people of Pakistan, and complement the economy thereof.

According to this study's findings, in comparison to fossil-fuel-based MGs, Renewable Energy dominated MGs offer a lucrative investment opportunity/financial viability and also contribute to reducing adverse effects on the environment. Even though MGs present a cost-effective solution for the remote unelectrified areas of Pakistan, they may suffer technical issues if not properly designed. Direct Current MGs and the application of MGs for irrigation purposes present interesting cases with respect to reducing the overall cost of energy. Some of the important factors to be considered to evaluate the feasibility of MGs are the electricity demand pattern, supply reliability requirement, discount rate, project lifetime, etc.

There is an urgent need for a comprehensive policy and regulatory framework since the existing one is insufficient to effectively upscale MGs deployment in Pakistan. While assessing electricity provision options for remote unelectrified areas of Pakistan, the electricity planners must consider and evaluate MGs before proposing huge investments for transmission and distribution infrastructure. One of the important considerations is to align the design of MGs with the affordability of the customers in each specific geographical area, to create a win-win situation for all the stakeholders.

METHODOLOGY

The study is predominately based on simulation and analysis-based research methods. The answers to the research questions have been found through a mathematical model that represents the structure and dynamics of technical and economic processes of MG deployment. Based on qualitative analysis and literature review, three possible scenarios are developed and modeled using the HOMER-Pro hybrid optimization tool. Further, techno-economic analysis is performed keeping in view technical and commercial aspects and also MG impacts on Pakistan's power grid and prospective customers of MGs.

Textual and content analysis of existing policy and regulatory framework precisely ARE Policy 2019, National Electricity Policy 2021, NEPRA Microgrid Regulations 2021 (draft) has been carried out. The relevant case studies, policy instruments, and regulatory documents are prudently analyzed to find coherence in their objectives, identify gaps, and point out missing links while comparing them with international best practices.

Moreover, existing business models currently being implemented for setting up and operating MGs in Pakistan are also considered for analysis. Interviews have been conducted with concerned personnel from Pakhtunkhwa Electricity Development Organization (PEDO) and Punjab Power Development Board (PPDB), the executing agencies for MGs in the provinces of KPK and Punjab respectively, and with the authors of the draft MG regulations from NEPRA. Based on results from the techno-economic analyses of three scenarios and interactions with the public-sector executing agencies and the regulator, certain business models are also proposed in this study.

FINDINGS

1. Comparison for different applicable MG scenarios is tabulated below:

Table: Summarized Comparison of Scenarios

Parameter	Scenario 1	Scenario 2	Scenario 3
LCOE ($/kWh)	0.111	0.0981	0.0929
Net Present Cost ($)	64,120	78,068	118,903
CAPEX ($)	27,836	34,213	16,048
OPEX ($)	1,587	1,918	4,499
Fuel Consumption Savings (Litre/year)	15,216	16,151	0
CO_2 Emissions Savings as compared to Diesel Generator (kg/Year)	39,831	42,276	15,479
IRR (%)	79.5	66.1	20
Payback Period (Year)	1.34	1.57	5.22

Notes: *Scenario 1: Off-grid MGs application for rural villages/areas having solar PV and wind potential.
*Scenario 2: Off-grid MGs application for rural villages/areas having solar PV and micro-hydro potential.
*Scenario 3: Grid-connected MGs application for Housing Societies or Commercial Centers in Urban Areas having utility electricity access.

2. As shown in the above Data Table, MG deployment makes strong financial viability and

presents a lucrative investment opportunity. Upscaling of MGs, therefore, needs to be acknowledged as a business opportunity by the private sector.

3. Fuel-based MG results in CO_2 emissions which is detrimental to the environment. Renewable Energy (RE) based MG saves significant emissions and is thus environment-friendly.
4. RE-dominated MGs present much more financial feasibility as compared to fossil-fuel-based MGs.
5. Due to the increasing trend of electricity prices, the MG deployment has become a cost-effective solution as compared to the conventional integrated grid for particular scenarios/applications.
6. MG option is better than the conventional integrated grid for the above specific scenarios/applications, however, not an optimal solution under all situations. The feasibility will change significantly depending on various factors like no or lesser Renewable Energy (RE) potential, consumer requirement of 0% allowed capacity shortage, change in cost trends of REs vs fossil fuels, etc.
7. Technical issues associated with operations of MGs are stability, safety, protective relaying, harmonics, voltage unbalance, etc. Although MGs present a cost-effective solution for remote unelectrified areas of Pakistan, however, they may face technical issues if not properly designed. Owners of MG must take care of these issues.
8. Existing policy and regulatory framework are insufficient to effectively upscale MGs deployment in Pakistan.
9. DC MGs have become a reality in many countries during recent years. DC MG shows a promising 12 % decrease in the cost of energy as compared to similar AC MG, i.e., from 0.111 $/kWh to 0.098 $/kWh.
10. Application of MGs for irrigation purpose present an interesting case. Hybrid MG having an irrigation application has more economic viability as compared to similar normal rural MG since it shows a promising 18 % decrease in the cost of energy, i.e., from 0.119 $/kWh to 0.0976 $/kWh.
11. Allowed capacity shortage is an important factor to be considered for MG development since the cost of Energy decreases exponentially with the increase in the allowed percentage capacity shortage.
12. Discount rate and project lifetime are important factors to be considered to evaluate the feasibility of MG. The Cost of Energy (CoE) increases linearly with the discount rate and decreases exponentially with the project lifetime.
13. Allowed percentage capacity shortage significantly affects the energy mix decisions. With the consumer requirement of percentage allowed capacity shortage from 0% up to 0.4%, the inclusion of conventional generators in the optimal energy mix is essential, and cannot be achieved exclusively with renewables and storage systems.
14. The demand profile significantly affects the CoE of the MG system; in case the demand profile

is changed from 24 hours to 12 hours (day-only load), it shows a promising 40 % decrease in CoE, from 0.111 $/kWh to 0.0677 $/kWh.

POLICY RECOMMENDATIONS

1. For upscaling of MGs development in Pakistan, a comprehensive policy is surely required addressing long-term uncertainty of market development, financial support schemes, and risks associated with the presence of the centralized grid. Further, a regulatory framework is required to address various regulatory requirements, sustainable operation, and cost-recovery mechanisms.
2. DC MGs should be included in the regulations for Microgrids, to be launched by NEPRA. Similarly, MGs should also be allowed to operate in grid-connected mode; for this purpose, the draft regulatory framework may be customized. Moreover, a mechanism for dealing with the technical issues such as stability, safety, protective relaying, harmonics, voltage unbalance, etc., associated with MGs should be addressed in the final regulations for Microgrids.
3. Coordinated efforts by the stakeholder entities are required to be channelized for utilizing the applicability of MGs in terms of irrigation purposes in remote rural areas.
4. While assessing electricity provision for remote unelectrified areas of Pakistan, it is imperative for the system planner to consider and evaluate the MG deployment before proposing huge investments for transmission and distribution infrastructure.
5. Based on the study findings, the optimal solution of MGs comes out with major share of renewable energy resources, therefore, renewables-based MGs should be promoted in the upcoming policy and regulations. Further, CO_2 emissions should be compensated through a carbon-credit mechanism for fossil fuel-based MGs, to be provided in the upcoming regulatory framework.
6. Given an inverse relationship between CoE and the allowed capacity shortage, the design of MG should be aligned with the affordability of the customers in the specific geographical area, to create a win-win situation for all the stakeholders.