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Regulatory Regime for the Mini-Micro Grid Based Power Generation Systems

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Summary:

Microgrid based systems are getting popularity for access of electricity in remote areas and electricity services in the weak grid areas. The technological applications in microgrids are continuoulsy improving and bringing smart applications that are creating innovative solutions for the end consumers. However, keeping in view the regulatory context, standardization and tariff setting mechanisms, there is a need to meliorate. This paper provides detailed overview of microgrids and its applications and a guide for the regulators and policy makers for setting up a regulatory regime for development of microgrid withint their territories.

Keywords: **Microgrids, regulations, standardization, procedures, tariff setting,**

I. INTRODUCTION

Energy is a key driver for sustainable economic growth. A robust and efficient energy delivery system is very important to ensure an uninterrupted energy supply to the end consumers [1]. To ensure that, it is essential to set forth and maintain standards concerning design, operation, safety, and cost. The growing population coupled with the growing energy demand and climate change issues are important elements for strengthening and enhancing the energy supply system, secure, safe, and sustainable energy for the growing population at an affordable price is a big challenge. Furthermore, ensuring access to affordable, sustainable, reliable, and cheap energy to every citizen is a gigantic task that cannot be accomplished without developing new technological interventions, deployment of non-conventional applications and business models, bringing private sector investment, and introducing transformational changes in the regulatory regime in the country [1, 2].

Renewable energy-based decentralized energy generation in the form of small-scale, locally controlled distributed generation (DG) units coupled in a single entity, a microgrid, are developing in different parts of the world to electrify remote villages and to meet with increasing and multidimensional energy needs of society. Such systems are going to play a vital role in a momentous transformation of the conventional energy supply system to a future energy system. Microgrids often have a single point of common coupling with the grid [3, 4, 5]. A lot of technological advances are happening around the globe, which are enabling the development of microgrid (MG) based energy supply systems. Global experience indicates that MGs are so far tailor-made, designed, and executed as per local conditions and to accommodate the energy needs of the targeted community [1, 4, 5].

The MG concept is not new. In the 19th century, the electricity supply systems were primarily localized and MG based. However in the 20th century, due to rapid urbanization and industrialization, centralized electricity generation with large-scale transmission and distribution grid systems were developed. During the last quarter of the 20th century, the centralized system became under pressure due to amongst others the growing global population coupled with an increasing energy demand and climate issues, liberalization of the electricity market with the introduction of competition, and consumer awareness increased for energy-efficient appliances and emissions. Because of these, the concept of MG regained attention in the 1980s. Countries including the USA, UK, European Union, Sweden, and Singapore started deploying MGs for electricity services in the late 1990s and early 21st century. Particularly, in the US, the MG concept gained increasing interest as a solution to blackouts that happened in 2001 [4, 5, 6]. These countries put in place legislation, regulations, standards, and plans for microgrids. The Institute of Electrical and Electronics Engineers IEEE Std.1547.4-2011, Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems, is treated as a fundamental technical standard to play a key role for MG interconnection standardization with intended islanding purposes, including voltage stability standards as well as grid safety precautions [1, 3, 5, 6].

The Alternative and Renewable Energy Policy, 2019 (ARE Policy, 2019) of Government of Pakistan has included MGs and localized energy systems (LES) in its scope. The ARE Policy, 2019 envisages that MGs based electricity services systems will be one of the key interventions to accomplish the targets set forth therein. As the concept of developing MGs and LES flourished, it is anticipated that there would be significant growth and innovation in the electricity services business [7].

The review of existing regulatory regime in Pakistan indicates that MGs and LES based electricity supply systems are not addressed, which leave behind several questions including who is permitted to own an MG and according to what regulatory regime, what will be the licensing procedure and tariff determination mechanisms for these services providers, what will be the performance standards and grid connection codes and standards to ensure safe MG operation, operational mechanisms and monitoring and evaluation matrix for such electricity services. Also, it is unclear that who is permitted to own the various generation, storage, and distribution assets that might comprise the microgrid. Without a clear regulatory regime, it would be difficult for MGs to grow and flourish in the country.

The challenges for adoption of MGs also include lack of standardization, the procedure for the introduction of MGs within the conventional energy system, regulations for competitive bidding and tariff setting, execution and operation on and off-grid as well as both the energy and monetary transfers between the MG and the central grid if they have interconnected operation and between the different MG participants [6, 7].

This requires that a clear regulatory regime should be set in place to enable the successful development and deployment of MGs in the country and enabling the accomplishment of targets as outlined in the ARE Policy, 2020.

II. Body

2.1 Basics of MGs

Globally, the MGs are now becoming part of the modern electrical grid. The MGs are termed as dynamic MGs, with their grid-interconnectivity advantages, are likely to improve system energy efficiency and reliability, and provide enabling technologies for grid-independence to end-user sites. MG concepts and definitions are in flux as their benefits in terms of integrating renewables, cost savings, and grid reliability and resilience are acknowledged. Early MG definitions have expanded from their islanded generation and load support to include utility support and managing generation and load as a part of a more resilient electric power system (EPS) [1, 4, 5, 7].

As shown in Figure 1 below, a modern MG is a locally controlled entity technically defined through three main requirements; (1) comprising both locally controlled (small-scale) generation units (sources), energy loads (sinks), and possible energy storage units, (2) a potential interconnection with the central electricity grid, either on-grid or islanded, and (3) typically implemented at the low voltage distribution level. The modern microgrid is a smart and flexible energy supply system providing electricity as well as other services to its consumers making use of intelligent communication technology, storage, and renewables [5, 7, 8].

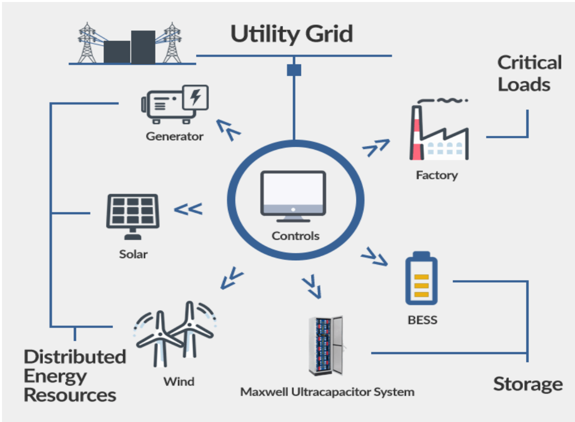

Figure 1: Locally Controlled MGs (*Source: Wind Power Engineering and Development*)[1]

2.2 What Are Microgrids

The normal energy grids that connect homes, businesses, and other buildings to central power sources allowing to use appliances, heating, ventilation, and air-conditioning (HVAC) systems, electronics, etc. typically have a centralized generating station with a very large power generation capacity. While this conventional system has its benefits, unfortunately, it also means that when part of that grid has to be repaired, everyone on the grid is affected [1, 5, 6].

The MGs are the electrical power systems that:

- have distributed energy resources (DERs) and load,
- have the ability to disconnect from and parallel with the area EPS,
- include the local EPS and may include portions of the area EPS, and
- can be intentionally islanded [5, 6, 8].

Figure 2 below provides a typical configuration of MGs.

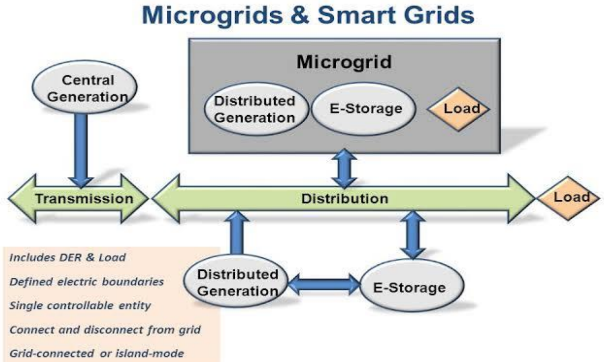

Figure 2: Typical configuration of MGs *(Source: National Energy Technology Laboratory, US)*

The MG systems can be either local EPS islands or are larger EPS islands. The defining characteristics/features of MG are [6, 9, 10]:

1) Geographically delimited or enclosed
2) Can be connected to the main utility grid at one point of common coupling (PCC)
3) Fed from a single substation
4) Can automatically transition to/from and operate islanded
   a) Operates in a synchronized and/or current-source mode when utility-interconnected
   b) b) Is compatible with system protection devices and coordination
5) Includes DER, but generator agnostic and according to needs of the customer with
   a. renewables (inverter interfaced),
   b. fossil fuel-based (rotating equipment generators), and/or
   c. integrated energy storage
6) Includes an Energy Management System (EMS) with:
   a. controls for power exchanges, generation, load, storage, and demand response and
   b. load-management controls to balance supply and demand quickly
7) Includes power and information exchanges that take place on both sides and across the PCC in real-time

[1] https://www.windpowerengineering.com/5-ways-ultracapacitors-operate-in-utility-grids-microgrids/

Figure 3 below provides a schematic overview of the MGs, their typical local control and protection scheme, and central energy management and supervisory control and interconnectivity with the utility grid at the distribution network through PCC.

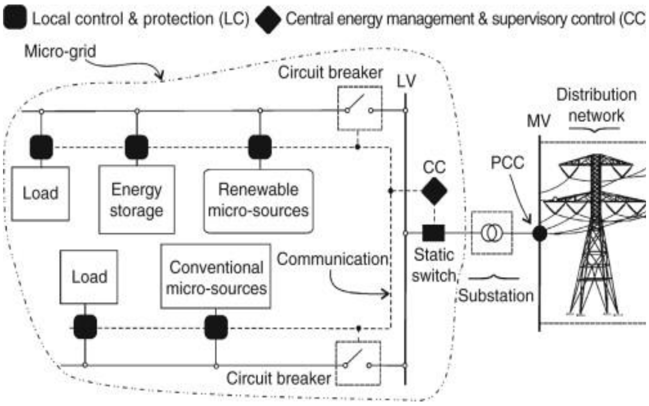

Figure 3: Schematic overview of the MGs (Source: Science Direct)[2]

2.3 Classification of Microgrid Models

Overview of the globally deployed microgrid models indicate that depending upon the utilization and ownership, the micro-grids can be divided into the following five models [3, 4, 5]:

i. Utility model – the distribution utility owns and manages the micro-grid to reduce customer costs and provide high-reliability power to specific customers on the system.
ii. Landlord model – a single landlord installs a micro-grid on-site and provides power and/or heat to tenants under a contractual lease agreement.
iii. Co-op model – multiple individuals or firms cooperatively own and manage a micro-grid to serve their own electric and/or heating needs. Customers voluntarily join the micro-grid and are served under contract.
iv. Customer-generator model – a single individual or firm owns and manages the system, serving the electric and/or heating needs of itself and its neighbors. Neighbors voluntarily join the micro-grid and are served under contract.
v. District heating model – an independent firm owns and manages the micro-grid and sells power and heat to multiple customers. Customers voluntarily join the micro-grid and are served under contract.

Similarly, depending upon the way the microgrids are interconnected, these can be classified into three types:

i. Islanded: refers to the creation of a system that is never interconnected with the area grid
ii. Interconnected at distribution voltages: refers to the creation of a system that is connected with the existing electricity system at distribution voltage level; and
iii. Interconnected at transmission voltages: refers to the creation of a system that is connected with the existing electricity system at transmission voltage level.

2.4 Difference between Conventional Grid and Microgrid

In many ways, MGs are smaller versions of the traditional power grid. They consist of power generation, distribution, and controls such as voltage regulation and switch gears just like current electrical grids do. However, MGs differ in that they provide closer proximity between power generation and power use, resulting in efficiency increases and transmission reductions. Table 1 below provides a comparison between the current grid and advanced MGs [3, 4, 5, 9, 10].

[2] https://www.sciencedirect.com/topics/engineering/micro-grids

Table 1: Comparison between the current grid and advance MGs

	Current Grid	**Micro Grid**
Communications	None or one-way; typically not real-time	Two-way, real-time
Customer Interaction	Limited	Extensive
Metering	Electromechanical	Digital (enabling real-time pricing and net metering)
Operation	Manual equipment checks, maintenance	Remote monitoring, predictive, time-based maintenance
Generation	Centralized	Centralized and distributed
Power flow control	Limited	Comprehensive, automated
Reliability	Prone to failures and cascading outages, essentially reactive	Automated, pro-active, protection, prevents outages before they start
Restoration following disturbances	Manual	Self-healing
System topology	Radial; generally one-way power flow	Network; multiple power flow pathways

Some MGs stand on their own, sometimes called as localized energy systems (LES), apart from any larger grid, often in remote rural areas. These off-grid MGs are a relatively cheap and quick way to secure some access to power for people who now lack it, often more quickly than large, centralized grids can be extended. Table 2 below provides a comparison of present grid technologies, MGs, and LES [5, 6, 9].

Table 2: Comparison between the current grid and advance MGs

	Present Technology	**Micro-Grid**	**Local Energy Systems**
Power	Large-scale Thermal, Hydro, Nuclear Generation	Mainly Controllable Power; Small GE, FC, PV, Wind, etc.	Mainly Distributed Energy; PV, Wind, Micro-hydro, etc.
Storage	Pump Turbine	Storage System (such as Battery) is necessary	
		Equipment primarily cooperates with controllable power	Storage plays the main function, Generators play sub-function
Connection	Wider interconnection with other Grid	Basically interconnected to Grid, and sometimes independent	Basically independent (Co-existence with Grid possible)
Electricity Transfer	Among Grid	No connection with other Micro-Grid	Bi-lateral transfer among Clusters through Power Routers
Power Supply	AC	AC	AC (DC in future)
Scale	Large	Medium	Small
Expandability	Less (Requires long term planning)	Medium (Requires short term planning)	Wide expandability (Independent operation possible)
Application	Large-scale infrastructure	New power supply system (thermoelectric work efficient)	Solutions to deploy the massive amount of renewable energy Utility for un-electrified areas, off-grid communities, and eco-towns (smart cities)

2.5 Components of the Microgrids Systems

Essential components to be employed with MG include state-of-the-art, highly integrated components, innovative controlling devices, advanced intelligent inverters, and compatible balance-of-system elements for all-sector energy applications. Advanced integrated inverters and controllers also incorporate building energy-management functions with improved compatibilities with building energy management. They also communicate with new utility energy portals. MGs employ products equipped for compatibility with the legacy grid of one-way power flow, intermediate evolving grids, and the future grid of two-way power flow. DERs such as solar, wind, advanced demand-response systems, and optimized energy storage are employed in fielded MG systems [2, 3, 6, 9, 10]. The MG systems use similar, but more complex interconnectivity, security, and combinations of renewable energy resources. Figure 4 below provides a schematic overview of generation (DERs), storage, control, load management, and connection to a large grid system for an MG.

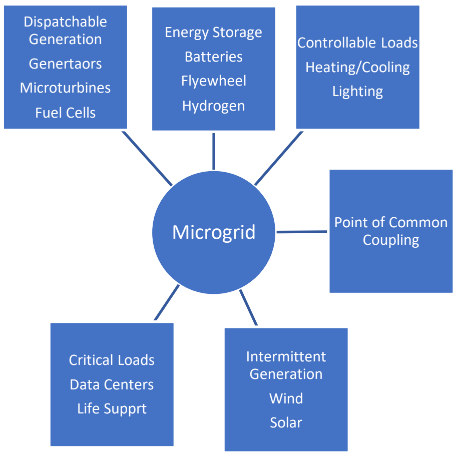

Figure 4: Schematic overview of generation (DERs), storage, control, load management, and connection of MG (Source: Power Engineering)[3]

Table 3 outlines the ranges of probable advanced microgrid early market applications [4, 6].

Table 3. Today's DOE Microgrid Program Applications

Power	Categories
Commercial Greater than 50 kW	three-phase and functionally expandable
Community/Campus 1–10 MW	May be modular or single rating
Utility-Scale >10 MW	possibly using multiple interconnected microgrids

[3] https://www.power-eng.com/2018/04/01/a-dcs-can-enhance-microgrid-controls/#gref

The MG systems present many opportunities and potential applications. It is an area of vigorous and likely exponential growth with a wide variety of applications and interconnections with utility grids. Although current technology is being installed today with early automated functionalities for supplying power to critical loads, the MG systems will be the favored technologies that interconnected utilities will demand as higher DER and renewable energy generation penetration results in the need for a virtual system of MGs and a more complex intelligent electric distribution infrastructure.

2.6 Stakeholders in a typical Community-Owned MG

The MGs are unique in way of their ownership structure, execution, and operations. They can either be owned by individuals, cooperatives, community, public sector entities, or a distribution company. In order to comprehend the operational mechanisms of the MGs, it is essential to distinguish each and every stakeholder involved in the execution and operation of the MGs. Figure 5 below provides an overarching sketch about the stakeholders that are involved in a typical community-owned MG. Each and every stakeholder has an identical role in the all over the MG scheme [3, 5, 9, 10, 11]. It can be seen from this figure that a community-owned grid structure involves:

- Land/property owners who either have rented out the land or have some stakes in the projects because of land or would have sold it to the MG owners.
- Residents who would be served through the MG for their electricity needs. The residents would be required to pay for the services they received from the MG in the shape of billing arrangements between the MG owner/operator and the residents.
- Philanthropic funders who would contribute to the cost of the MG. They

might also be owning the shares of the MG assets.

- Financers who would lend money for the overall scheme.
- Solution providers like equipment suppliers, EPC contractors, operators, etc. whose services would be acquired by the MG Owner(s) to design, construct, execute, commission, and operate the MG.
- Utilities, in case the MG is connected to the distribution network
- Policymakers to provide policy regime and incentives for the MG owners and operators to execute such projects to serve the targeted population. Policymakers can also initiate MG based community electrification projects wherein either the owners can be asked to provide the full cost of the project or some public money can also be made available as support or subsidy.
- Regulator to set in place a regulatory regime for licensing, consumer-end tariff determination, standards, specifications, dispute resolution, etc. as deemed appropriate.
- Municipalities for giving approvals related to land and others.

Figure 5: Overarching sketch of stakeholders involved in a typical community-owned MG

3. Standards and Operational Features of MGs.

3.1 Interconnected and Islanded Operation

An advanced, interconnected MG system must meet all of the operational and interconnection requirements and standards that utility electric grids must meet. The MG systems are required to provide high-quality power to their loads with safety protections, synchronization, harmonic distortion limits, voltage limits, support for devices requiring VARs, surge capabilities, and protection-device coordination. The PCC is typically where the standards and codes in effect today apply. New rules to cover the anti-islanding that have been in place for over a decade are being changed [4, 5, 11, 12]. The IEEE1547 Recommended Practice is commonly applied today, but there is a new recommended practice on the way (IEEE1547a) and the revised IEEE1547.4 has provisions for allowing islanding.

The results of the evolution of the MG concept have been captured in the latest version of IEEE1547. Seamless transfers from grid-interactive to islanded modes will become commonplace. Advanced MGs will be required to meet the new IEEE1547a [11, 12, 13].

3.2 Dispatched, Scheduled, and Autonomous Microgrid Operation

The dispatched, scheduled, or automatic operations of the MGs depended upon several factors [11, 12, 13] including but not limited to:

- power throughput capabilities of the MG's resident controller or inverter-controller,
- speed of detection and speed of response of all equipment,
- communications and the need for dispatch,
- reliability of all equipment,
- number and locations of microgrids on the same feeder,
- energy storage capacity and peak power delivery, and

- codes and standards requirements.

3.3 Commanded Shutdown, Ramp-Up, and Ramp-Down

The MGs connected to a primary energy source needs to have built-in algorithms and communications for shutdown, start-up, and curtailment. Each of these functionalities may also be commanded when the stability or voltage regulation of a section of the distribution line is in danger of drifting out of specification because of a load/distribution mismatch. Adequate communications methods are also necessary for these conditions [11, 12].

3.4 Black Start

The MGs have the capabilities to operate in an Islanded State. In case if the MG is connected to the distribution grid, it still can be operated on the islanded stated especially after the microgrid has been inoperable but loads are still connected and hence serve the connected load during the "black start." In case if the MG is connected to the distribution grid, a situation arises that results in the MG being disconnected from the main utility, the MG is required to transit either seamlessly or as quickly as possible and continue to operate as a connected DG. The black-start functionality helps assure power system operation, power supply reliability, and protection to critical loads. The restoration procedure in an MG is somewhat similar to the approach adopted for medium-sized power systems [12, 13].

4. Lessons learned from Global Experience of deploying Microgrids

The global experiences indicate that the countries intending to introduce and develop microgrids should [2, 3, 5, 13, 14]:

i. set in place legislation/regulations covering key potential areas requiring regulatory interventions including defining microgrids, the procedure for development, tariff setting, services, operations (particularly operating in islanding mode), energy and monetary transfers, billing, and collection, responsibilities for operating and interconnecting to the national grid, responsible agencies for access to national grid and competition.
ii. develop standards, for execution, organization, management, operation, and service delivery to the end consumers
iii. develop standards and codes to enable the microgrids to connect with electricity infrastructure at large and ensure safe grid operation
iv. announce exemptions from certain competition requirements once the open/competitive/bilateral electricity market is established.
v. give clear directions and guidance to the private sector that would indicate its vision and resolve and allow readiness and efficacy in the system and ensure transparency in regulatory regime
vi. emphasize renewable power generation in conjunction with microgrids.

5. Important factors to take into account while promoting Microgrids

The following are the important factors that are required to be taken into account while promoting the microgrids for various applications [2, 3, 5, 13, 14]:

i. Service Territories

The distribution companies have been given monopolistic powers under their licenses to provide services to their customers within pre-defined service territories. The distribution companies have been very sensitive about their service territories and have been objecting to any such intervention that allows other players to provide services to the consumers within their service territories. Though the amendment in the NEPRA Act, 1997 (NEPRA Act Amendment, 2018) requires separating the business of electricity distribution and electricity retail, however, its practical implementation is to be started post-2023. Whereas, the Alternative and Renewable Energy Policy, 2020 requires promoting microgrids with immediate effect. This matter needs due attention.

ii. Utility Tariffs

The tariff structure for the microgrid owners/operators are going to be very crucial for their financial sustainability. The tariff structure needs to be flexible enough so that the entities should be able to sustainability run their businesses. The tariff structure needs to be different than the traditional tariffs for the distribution companies as the overall structure of microgrids include generation, distribution, and retail as a whole.

iii. Interconnection Procedures and Technical Requirements

The interconnection procedures and technical requirements should be designed and specified in a manner that these are fair, and ensure safe and reliable grid services. In case if the microgrid is connected to the distribution or transmission network, the interconnection procedures and technical requirements should be designed and specified well and easy to enforce. In this case, the utilities, while ensuring grid stability, should be bound to fairly support the microgrid owners/operators. The procedures should lay out the timelines and responsibilities of the parties as well as contingencies if either party fails to meet its obligations.

iv. Microgrid customer interactions

The regulatory regime set forth for the microgrids should ensure that the public is protected against unreasonable rates, bad service, and negligence that results in safety or human health risks. Matters related to rate-setting; billing and collection; dispute resolution; insurance holdings; credit; and demand management for reliability should be given due consideration.

v. Environmental and siting laws

The regulatory regime set forth for microgrids should specify that the investors must comply with the environmental and siting laws and they should be required to produce the necessary environmental approvals at the time of award of licenses.

6. Application of MGs in Pakistan

Pakistan has a strongly growing population of more than 208 million people. A large share of the population has no access to electricity due to lack of grid connections and are therefore termed as off-grid areas. According to IEA/IRENA (2017/18), 51 million people (26% of the population) in Pakistan are residing in off-grid areas (based on the number of residential electric connections (NTDCL) and average household size). For several remote off-grid villages, integration into the national electricity grid may not be viable both technically and financially. Moreover, IEA also estimates that a similar number of people are suffering from major supply interruptions from the grid.

Sustainable Development Goal number seven (SDG #7) of the United Nations as adopted by the Government of Pakistan requires access to affordable, reliable, sustainable, and modern energy for all including an increase in the share of renewable energy in the global energy mix by the year 2030.

Various stakeholders including Federal and Provincial Government departments, NGO's, international donors, and private sector companies have undertaken several initiatives to provide electricity services in the off-grid areas using renewable energy technologies (including stand-alone solar PV systems, community-based solar PV systems, community-based micro-hydropower systems, and micro-wind turbine-based systems), and a combination of renewable with diesel genet systems. As prices of equipment, particularly renewable energy solutions are drastically reducing, and their demand for electricity services in the off-grid areas is increasing.

Having a birds-eye view of the services that are stakeholders have been providing in the remote areas, it is noted that the potential technical solutions for rural electrification vary with the electricity demand and potential local resources. For low-income households, solar (battery) home systems are a viable option to provide basic electrification for lighting and mobile phone batterie. The typical DC systems have limited ability to provide electricity for productive use. However, DC systems can be upgraded to AC gradually with increased income generation.

For small villages, an AC mini-grid can provide central electricity and enable productive use applications like pumping, grinding, fridges, and other appliances. In most of the cases, a solar battery system will provide the electricity in conjunction with an optional diesel generator. However, depending on local resource availability, micro hydel, biogas/mass or small wind generators can also be integrated.

As far as the strengthening of weak 11 kV lines is concerned, DERs based MGs can be a commercially viable option to support weak grids. These systems can be executed to supply electricity to small DER plants feed additional electricity into the grid at load centers, thus supporting the voltage level and increasing the bearing capacity of existing lines. In this way, more energy is available through weak lines without requiring a major upgrade of the lines themselves. Local storage at strategic locations in the form of batteries can be an economic option as well.

7. Policy and Legislative Context in Pakistan

The ARE Policy, 2020 has specifically given context for developing mini/microgrids in the country. Sections 1.4.1, 3.1, and 3.2 of the ARE Policy, 2019 provides for MGs and need for establishing its regulatory regime [7].

The NEPRA Act, 1997 defines the term "electric power service", whereas, section 7 of the NEPRA Act, 1997 provides powers to the Authority to set rules, regulations, standards, tariffs, fees, etc. for the electric power services. Section 23E and 23F of the NEPRA Act, 1997 define the licensing requirements, roles, and responsibilities of electric power suppliers. The microgrid owner can be classified as an electric power supplier and can operate under the license issued by NEPRA.

The current licensing rules of NEPRA were designed two decades ago and were written with large utilities in view long before the renewable energy revolution made self and distributed generation ubiquitous. As of today, the distribution and generation licensing rules for a small microgrid and LES are the same as for large public utilities and IPPs. With self-generation without any regulatory oversight always an option, the market for off-grid, microgrids, LES, and B2B solutions faces a disproportionately onerous licensing, fee and tariff regime. Therefore, NEPRA is required to come up with the new regulatory regime for microgrids and LES.

8. Regulatory regime for Promotion of Development of Microgrids in Pakistan:

A. Develop a Regulatory Framework

i. A legal definition of the microgrid should be outlined with a clear operational structure since microgrids have characteristics of both energy generation and consumers.

ii. A regulatory regime should be set in place for microgrids. The regulations should be light-handed and simplified, stating procedures and processes for establishing microgrids at on and off-grid areas. The regulations should separately address planning, monitoring, policy setting, licensing, establishing, compliance, conflict resolution, arbitration, and adjudication issues.

iii. The regulations should account for the varied nature, size, location, and investment of microgrid applications.
iv. The regulations should encourage private sector participants to enter the market for the supply of electricity and ensure fair competition for all suppliers concerning the traditional utility in competing for new customers
v. Special provisions should be made in the regulatory and legislative framework, particularly when a competitive bidding bilateral trading model will be set in place, to safeguard the investments made by the private sector in developing, executing, and operating microgrids.
vi. The regulatory framework needs to address the issue of sharing of locally generated energy, ownership of the generation units, sale/purchase of generated units, and monetary distribution

B. Develop/Specify Technical Limits, Codes, Standards, and Procedures

i. Quality of services by the microgrids should adequately be addressed in codes, standards, and procedures. These should specify minimum interconnection requirements that apply to the microgrids.
ii. The codes and standards should specify that the microgrids shall implement advanced smart metering infrastructure and address the issues of ownership and internal market models for cooperative microgrid neighborhoods.
iii. The procedures should be laid out for how micro-grid owners interact with their customers.
iv. The licensing procedures for billing, collecting, dispute resolution, insurance, credit, etc. should be clearly stated, however, these should be limited in scope to reduce cost and administrative burdens for the micro-grid.
v. The standards and procedures should specify timelines, procedural steps, and the responsibilities of the parties. These procedures should be mandatory, not voluntary.
vi. Provisions should be made to allow microgrids to connect to the national grid infrastructure without any discrimination, provided all codes, technical standards, and prudent industrial practices are followed to ensure safe operation in an environment with bi-directional electricity flows.
vii. Micro-grid owners and operators should be required to provide utilities with information that will affect planning. Utilities should receive information about capacity, system design, and location well before a micro-grid is constructed and interconnected. Utilities should also receive advanced notice of planned micro-grid outages due to maintenance, upgrades, etc.
viii. The regulatory regime should elaborate on metering schemes and compensation mechanisms. Furthermore, safe operation while transitioning to and operating in island mode should be ensured through codes, standards, and procedures.

C. Develop/Specify Tariff Setting Mechanism

i. The tariff setting mechanisms should take into account the execution, management, operation, and maintenance of the microgrids and create a balance between sustainable operations by the microgrid operator and the consumer.
ii. The tariff setting should take into account global best practices and innovative solutions for services, charges, and collection.
iii. The tariffs should not be punitive or discriminatory and preferably should not include stand-by fees based on installed capacity; instead, the concept of demand charges and emergency stand-by rates can be introduced coupling with internal redundancy, demand response measures, and aggressive maintenance schedules.

iv. The tariff mechanism should also take note of the subsidy mechanisms, if any, announced by the federal or provincial governments for microgrids, particularly for off-grid areas.

D. Develop/Specify Mechanism for Competitive Bidding

i. The regulations related to competitive bidding tariff need to be reviewed and amended to enable relevant agencies for undertaking competitive bidding and inviting private sector investment in establishing micro-grids in on and off-grid areas, with or without government subsidies.

III. CONCLUSIONS

Access of electricity to all is one of the SDGs that the world is pursuing. Various smart solutions have been set in place that can lead towards making this very basic amenity available to all. MGs, together with their smart applications and potential to connect with the distribution network can play a vital role in meeting the global targets in this regard. The concept is flourishing in different part of the world. Experience indicate that if the development of MGs is left unregulated, than there can be certain issues relatd to service territory, operations, interconnections, standards, tariff setting, competition and maintaining competition. In order to address such issues, this paper conclude that it is mandatory that a vigorous regulatory framework should be set in place. The paper recommends that while setting the regultory framework, the governments should take into account the overarching developmental framework as presented in this paper.

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