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A Quick Review to Understand Micro Grid System: System Architectures, Modes and Challenges

Mohd Fahmi Abdullah[1], Norzanah Rosmin[2*], Aede Hatib[3], Siti Maherah Hussin[4]
[1,2*,3]Centre of Electrical Energy System (CEES), POWER Department, School of Electrical, Engineering Faculty, Universiti Teknologi Malaysia, Johor, Malaysia, mmfahmi234@gmail.com, norzanah@utm.my, maherah@utm.my
[4]School of Education, Engineering Faculty, Universiti Teknologi Malaysia, Johor, Malaysia, aede@utm.my

ABSTRACT

This paper highlighting the main issues in the new era of distributed generation closed to the distribution network or popularly known as Micro Grid (MG) system, in the electrical power system network. A MG is particularly a section of the large power distribution system that comprises distributed or co-generation, energy storage system and loads. In this paper, review on the system architecture, operational modes and also the control challenges on the demand response in MG system is demonstrated. The gathered information is compressed and then written in brief to be used as a quick guide for the new researchers or newcomers in this field. All important elements in the MG will be explained in brief as well as comparing the worthy outcomes and the potential fields of research in particular in terms of energy flow control that would enhance practical use of MG system and its elements.

Key words: Micro grid, grid connected, stand alone, islanded, demand response, energy storage.

1. INTRODUCTION

The use of renewable energy sources (RESs) is a significant lever for decarbonizing the electric power sector and reducing the effects of climate change to the environment [1]. Nowadays, RES is widely used to provide an alternative to or an enhancement of the conventional grid network system, and typically developed in small-scale capacity. Such RES that also typically supported with storage technologies is known as distributed energy resource (DER) system, which usually in the capacity of 1 kW to 10,000 kW [2]. On the other hands, DER also has defined as small-scale units of local generation connected to the grid at distribution level [3].

DERs are usually numerous, installed closed to the loads or customers in small-scale. Essentially, DERs act as central energy commodities and are often connected to the network on a 'connect-and-forget' basis. Hence, to allow the DERs to penetrate and seemed visible in the energy markets, smart grid (SG) technology is an option as the key to efficient use of DERs. In [4], smart grid (SG) was defined as "an electricity network that can intelligently integrate the actions of all users connected to it – generators, consumers and those that do both – in order to efficiently deliver sustainable, economic and secure electricity supplies." Therefore, SG seems can encourage the active participation and decision-making of consumers as well as to establish the operating environment in which both utilities and energy users influence each other. Users can control utilities in SGs by incorporating DERs such as photovoltaic (PV) modules or point-of-use energy storage and responding to price signals. In addition, utilities can enhance reliability by providing demand response programs, adding distributed generation or energy storage at substations, and automated grid control. Nowadays, the use of RESs in the SG system has increased in recent years, as it provides alternative options to feed the world's energy appetite which allow for consideration of the environmental impact and other social and economic factors. Some studies have mentioned that this technology can provide reliable and comparatively low-cost electricity service [5-7].

In SG system, it may comprise several micro grid (MG) systems. Different to SG, MG is an electrical system that includes numerous DERs, energy storages and customers' loads that can be operated in parallel with the small grid or even with wider utility grid, self-governing power system, to enable the grid to exchange power over a single coupling point, called the Point of Common Coupling (CCP) [8]. With MG, system reliability and efficiency can be increased with reduced transmission length yet provide simpler integration of RES systems. Figure 1 shows an example of MG system that consists of its three main components; various RESs (solar, wind and diesel generators), battery energy storage system (BESS), and loads (AC and DC loads). Here, it can be observed that electricity generations are placed close to the loads, to enhance the MG's development of reliability, efficiency, and quality of power support [9].

Generally, MG can work in 2 different modes; grid-connected and the stand-alone (autonomous) mode. In grid-connected mode, all related feeders will be supplied electrically through the utility grid [11]. In this mode, to achieve maximum operating benefits, MG will regulate the power balance between supply and demand (through a buying or selling process with the main grid) [12]. In fault situations, MG will be immediately isolated and acts as a stand-alone device. Conversely, during stand-alone (autonomous) mode, MG is disconnected from the main grid by opening the feeder's static switch.

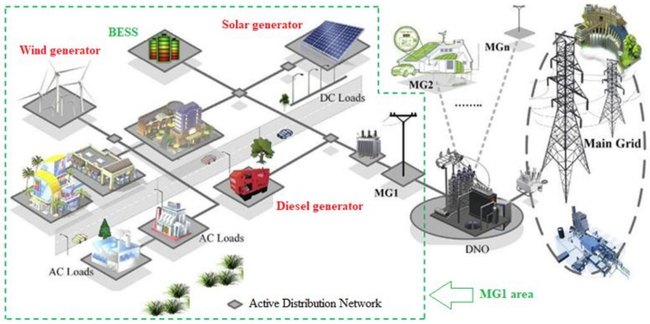


Figure 1: Micro Grid (MG) System Components [10].

Therefore, the micro-source network now supports the remains feeders [11]. In both modes however, the role of energy storages are very significant for energy backup, in particular to enhance the power fluctuations and power quality between the RESs and loads sides, that may effecting the reliability and stability of the MG's operational system. In addition, power from RESs is always variable and fluctuates, instead the issues of nonlinear load changes from the demand sides. In Malaysia, SG or MG is still very new. So far, by the time this paper is written, at the end-user level, the application changes only have been introduced in metering and monitoring system. Smart energy management system (EMS) in SG, or even in MG system, is still far lack. Hence, detailed study on the MG management system, which can optimizing the MG operational strategy that focuses to the RESs, energy storages and demand responses management in Malaysian context is an urgent attention as this strategy is projected may offer more environmental friendly and cheaper electricity price [13]. Situations in both modes also need some attentions for a smarter MG's architecture.

2. SIGNIFICANCE OF REVIEW WORK

RE distributed generator (DG) units are the base of MGs and located at or near the point of use. To convert the energy into grid-compatible ac power, most of the DG technologies require a power electronics interface that assisted with sophisticated control system, that able to convert and control the power flow from one level to another. In Malaysia scenario, PV system has a great potential to be selected as promising DG system. In previous, feed-in-tariff (FiT) was used as incentive for the PV penetration, and since 2019, net-energy-metering (NEM) scheme was introduced to increase the national energy target from RE. Using NEM, energy produced from the solar PV system installed will be consumed first, and any excess to be exported and sold to the distribution licensee (such as TNB /SESB) at the prevailing displaced cost prescribed by the Energy Commission. The introduced NEM not consider energy storage system in the NEM scheme. Hence, study on the smart energy management system (EMS) in residential MG system relating the RES, demand response and energy flow control is very necessary to be executed. To achieve optimum operational MG, with promising minimum electricity costs (from RES and customer sides), so far, no standard guideline has been established or imposed. Hence, other than giving compact information on the MG's architecture and its operational modes, this review work also may provide the information on how to control the energy flow by optimizing the MG operational strategy that focuses to the solar PV as RES, energy storages and demand responses management, to minimize the electricity price.

3. SMART GRID (SM) VERSUS MICRO GRID (MG) SYSTEM

To understand the concept of MG, it is important to understand what the definition of a smart grid (SG) system is. SG has been defined as an electrical network that incorporates a range of technologies, such as distributed generation, energy storage systems (ESS), and communication systems [14], as depicted in Figure 2. SG has close cooperation of measuring equipment to determine consumer power demand, resulting in increased productivity and efficiency overall of the power grid [15]. Essentially, SG is not a new concept, but is a new technology that transforming the grid control and creating a platform for revolution of the traditional electricity grid functions. SG uses the emerging technology to encourage energy and cost-efficiency [16] which can predict, measure and respond automatically to fluctuations in supply and demand, beside offers the potential for greater supply protection through performance. The potential for flexibility is much greater when combined with the roll-out of smart meters, as consumers change their own real-time requirements and accelerate the introduction of renewable energy into the grid [17].

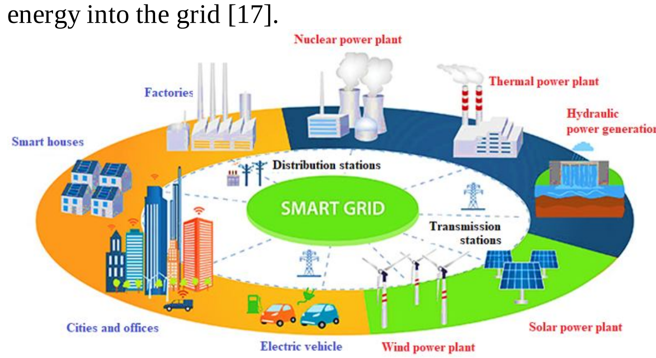


Figure 2: Smart Grid (SG) System [18]

Meanwhile, MGs which are elements in the SG system (as shown in Figure 1) are implemented to address the network shortcomings, to incorporate the power system components into smaller scales. MG is a distributed power grid that consisting of numerous small sources that capable of running parallel and independently to the main grid [19]. Its main objective is to achieve a reliable and efficient supply of electricity and to ensure a higher quality electrical service, while making the service safer and more sustainable, especially in the urban and rural areas. MG helps network operators to control the generation and consumption more flexibly. Therefore, energy management is a critical factor in MG system since it has multiple loads as well as production units. For safety and reliability factors, MG can operate the energy market in both grid-connected and stand-alone (autonomous) [20]. Figure 3 shows a small MG system development for a residential area that uses PV module as an energy source, battery as ESS, inverter as power converter that change the DC signal into AC signal and bidirectional meter as the device that recording the energy supplied or consumed by the consumer [21]. Summary for comparison between SG and MG is given in Table 1. From the table, it can be observed that SG system is more complex than MG system and requires more sophisticated control system due to its size and complexity elements.

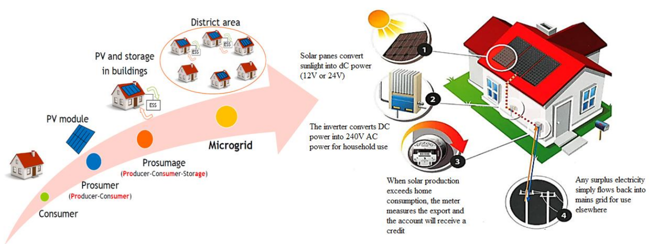


Figure 3: Office area that used energy from PV system Micro grid (MG) System Development [21]

Table 1: Micro Grid (MG) Versus Smart Grid (MG) [17]

Smart Grid (SG)	Micro Grid (MG)
Digitization	Mechanization
Two-way real-time communication	One-way communication
Distributed power generation	Centralized power generation
Dispersed network	Radial network
Large volumes of data involved	Less data involved
Many sensors and monitors	Small number of sensors
Great automatic monitors	Less or no automatic monitoring
Automatic control and recovery	Manual control and recovery
Prone to security and privacy issues	Less security and privacy concerns
Adaptive protection	Human attention to system disruptions
Use of storage systems	Simultaneous production and consumption of energy/electricity
Extensive control system	Limited control
Fast response to emergencies	Slow response to emergencies
Vast user choices	Fewer user choices

4. MICRO GRID (MG) ARCHITECTURE

Micro grid (MG) electrical architecture is basically determined by the application, existing infrastructure, and customer-oriented needs. As mentioned previously, MG structure consists of several types of distributed energy sources (DER) such as solar panels, wind turbines, micro turbines, and thermal power plant, each in the form of distributed generation (DG), including energy reserves from battery (Distributed storage, DS). MG system is typically operating at a low voltage level distribution system and can operate either in grid-connected or stand-alone (autonomous) mode [22].

MG architecture is generally divided into three categories which are AC, DC, and hybrid micro grid system [23]. Among these three MG architectures, AC MG is easier to design and implement by utilizing the existing AC network infrastructure such as distribution, transformers, and its existing protections system [24]. For AC micro grid architecture, it is the most popular structure and commonly used for MG studies and implementations. Example of AC MG can be illustrated in Figure 4 [24], where the distributed generation (DG), energy storage and the mixed AC and DC loads are connected via an AC bus. However, for the DC source, energy storage and load, DC/AC inverter is required when connected to AC bus. Conversely, in DC MG architecture, the MG components are connected via a DC bus, as shown in Figure 5. In this architecture, AC/DC converter is used to convert the AC power from the AC source and AC loads. Compared to AC MG, DC MG provides less power loss since it only requires one-way power conversion to be connected to DC bus. Besides that, DC MG also has better system stability due to lack of reactive power compensation problem, unlike in AC system. Due to this, DC MG has better system efficiency, less expensive and smaller in size compared to AC and hybrid MG architectures [25]. On the other hands, in hybrid AC-DC MG architecture, this architecture attempts to utilize the benefits of both AC and DC concepts to improve its system efficiency. Hybrid MG combines both AC and DC MGs regardless in terms of AC or DC sources, energy storages, loads and distribution grid systems. Energy transfer between AC and DC sections are always tried to be minimized to avoid conversion loss. The interfacing converters are used to provide active power support to both sections and reactive power support to the AC system [25].

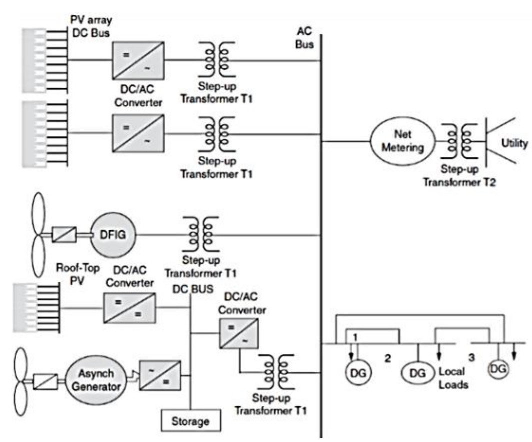


Figure 4: AC Micro Grid Architectures [26]

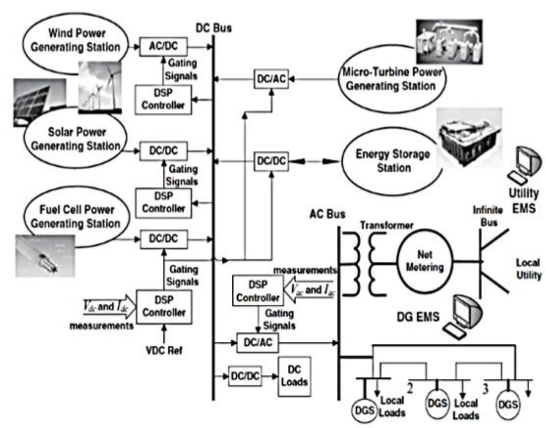
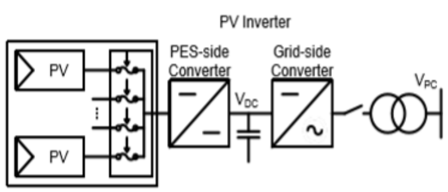


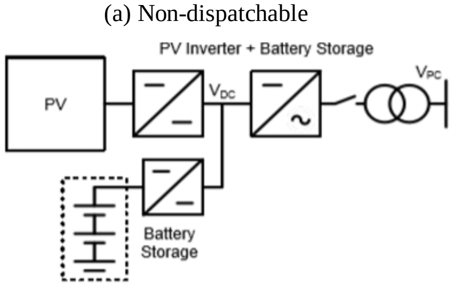
Figure 5: DC Micro Grid Architectures [26]

4.1. Distribution Generation (DG)

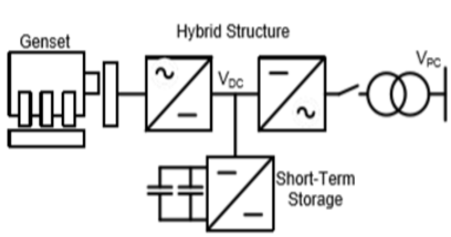
Distributed generation (DG) has gained its attraction by providing positive support benefits. However, an inappropriate planning decision on the DG side may manifest the impacts of DG allocation negatively. Determination of appropriate DG size and placement of DG is important, to maximize overall system efficiency and to ensure stable and reliable operation of power distribution network. Generally, distribution systems are designed as radial and power flows unidirectional from transmission network to distribution areas. The introduction of DG into the network changes the characteristics of the distribution system. Integration of a significantly large amount of DG may causes operational conflicts on the distribution system [27]. This then could alter the active and reactive flows of power and this inversion of flow may causes overvoltage to the network [28]. Beside penetration level, location-specific value of DG also plays a significant role for network reliability and stability [29]. No relief or only partial capacity relief of the network can be achieved by DG sources for inappropriate selection of DG sites [30]. In the context of power flow control in MG system, DG units can be grouped into three-unit types; dispatchable energy (power output can be regulated), non-dispatchable (power output cannot be adjusted) and hybrid unit, as shown in Figure 6 [31].



(a) Non-dispatchable



(b) Dispatchable



(c) Hybrid

Figure 6: Power Flow Control Configuration in MG System [31]

In dispatchable energy unit, output power setting is set externally using supervisory control such as automatic voltage regulator (AVR). Meanwhile, in non-dispatchable energy unit, output power is set based on the maximum power that can be generated using maximum power point tracking (MPPT) concept [32]. The non-dispatchable energy unit however can be converted into dispatchable energy units using additional energy storage systems and power electronic circuit (dc-dc-ac converter) [33]. To provide faster response, electronic converters can be used to limit the short circuit contribution not less than 200% from the rated current and able to prevent damage due to the current's surge [30]. Stability of MG operational system can be setting the loads connected to the network, especially on non-critical loads [31].

4.2 Energy Storage System (ESS)

Energy storage system (ESS) has been considered within the design of the energy grid since long time ago, but it has had limited relevance due to the factors of high cost. Also, ine□ciency of many storage systems have undermined their value and functionality [34]. Additionally, existing perceptions of storage as little more than a bank to assist generators to balance the loads over time fails to capture the true potential of energy storage technologies [35]. Therefore, improvements in smart grid designs and its storage technologies could present unique opportunities to challenge the conventional model. New technologies for ESSs that having the capability to reduce and smooth the peaks power are crucial elements in the future power system network. Great ESSs can be the solution to fix the aging power grid, bridging the gaps between the utilities and customers' demands. They have become a critical tool for increasing consumers' comfort, reducing electricity bills, and earning revenue. The storage device allows the consumer to not only store energy for a longer duration of time but also save the consumer's money by charging the storage devices during off-peak hours when the price is low and uses them during peak hours [36]. This increasing importance of energy storage devices has forced the researchers to put great effort into achieving higher efficient and cost-effective storage device. However, there are many other factors associated with the energy storage devices, for instance in terms of energy storage capacity (MWh), power capacity (MW), device and maintenance costs.

Besides, the charging and discharging process of the storage devices requires adequate control strategies to perform reliable operation of grids even during the peak demand [37]. Consumers may reduce the energy consumption of thermal loads such as air conditioners, water chillers, and water heaters, which results in saving the electricity during peak hours. In Table 2, comparison on the technical characteristics of electrochemical type of energy storage (ES) technology is given [38]. Among all, battery is the most widespread and oldest of all the ES technologies [39][40]. This electrochemical device uses chemical energy to deliver energy in the electrical form by undergoing electrochemical reactions. When designing a battery storage system in an MG system, numbers of requirement must be considered including the technical, economical, and environmental points of view. In an MG application, combining renewable energies (which have an intermittent energy profile) with energy storage systems, may improve the reliability and stability of the energy supply for extended periods [41]. Energy storage such as battery storage technologies is manufactured in a variety of sizes and chemistries depending on their applications. In many literatures, the pros and cons between the different types of batteries are compared for smart grid requirements including the size, efficiency, cycle life, and cost [42].

Table 2: Comparison of technical characteristics of electrochemical type of battery storage technology [43]

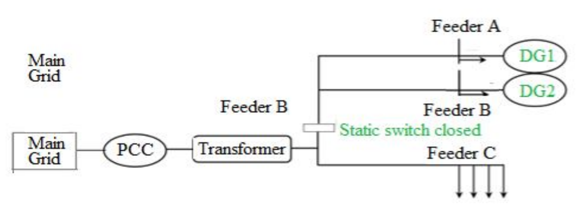
	Specific energy (Wh/kg)	Specific power (W/kg)	Efficiency (%)	Self-discharge (%/day)	Life cycle	Power cost ($/KW)	Energy cost ($/kWh)	Power rating (kW)
Sodium Sulfur (NaS) battery	150-240	150-230	75-90	0	2500	1000 – 3000	300-500	50 - 34000
Sodium Nickel Chloride (NaNiCl2) battery	100-120	150-200	80–95 0	0	>2500	150–300	100–200	50 - 8000
Vanadium Redox Flow Battery (VRFB)	10–25	166	75–85	Low	12 000	600–1500	150–1000	30 - 3000
Zinc Bromine flow battery (ZnBr)	30–50	45	65–75	Low	>2000	700–2500	150–1000	50 - 2000
Lithium ion (Li-Ion) battery	75–200	150–315	85–98	0.1–0.3	1000–10 000	175–4000	500–2500	0 - 100
Lead acid battery	30–50	75–300	70–90	0.1–0.3	500–800	300–600	50–200	0 - 20 000
Nickel Cadmium (NiCd) battery	50–75	150–300	60–70	0.2–0.6	2000–2500	500–1500	800–1500	0 - 40 000
Super Capacitor	5–20	500–5000	95–98	20–40	>50 000	100–300	500–3000	0 - 300

4.3 Demand Response (DR)

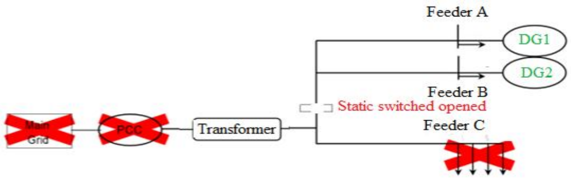
Demand Response (DR) can be defined as the changes or adjustments done by end-use clients or customers to reduce electrical energy consumption by changing their normal behavior when use energy with intention to reduce their electricity bills over time. In other words, DR can also be defined as the inducement compensation designed to encourage lower electricity use at times of high wholesale market prices or when system reliability is risked [44]. DR includes all intended electricity consumption shape modifications by end-use clients or customers that are anticipated to alter the hours of energy used, level of instantaneous need or demands, or overall electrical energy consumption [45]. There are three general actions that performed by consumers [44], where each of these actions involves cost and measures taken by the consumers. For the first consumers response, consumers can reduce their electricity usage by reducing the load usage during critical peak periods (when prices are high), without changing their consumption pattern during other periods. This option however will involve a temporary loss of comfort. This response is achieved, for instance, when thermostat settings of heaters or air-conditioners are temporary changed [46]. Secondly, consumers may respond to high electricity prices by shifting some of their peak demand operations to off-peak periods, as an example, they shift some household activities like dishwashers, pool pumps to off-peak periods. The residential consumers in this case will bear no loss and will incur no cost. However, this will not be the case if an industrial customer decides to reschedule some activities and rescheduling costs to make up for lost services are incurred. Meanwhile, for the third response that can be done by consumers is by using their own on-site generation system [47]. Consumers who generate their own power may experience no or very little change in their electricity usage pattern; however, from utility perspective, electricity use patterns will change significantly, and demand will appear to be smaller.

5. MICRO GRID OPERATIONAL MODE

Micro grid (MG) requires several distributed generation resources, loads and energy storages to enable the grid to exchange power over a single coupling point, called the point of common coupling (PCC) [48]. The idea of bringing electricity generation closer to the loads is to enhance MG's development of reliability, efficiency, and quality of power support [49]. MG can work in two different modes; grid-connected and the stand-alone (autonomous) mode [50] [69]. From the executed study, it has been found that there are seven papers [51-58], that have been worked on these MG's modes, as listed in Table 3. From the table, it can be observed that, mostly research work has been focused either in grid-connected or stand-alone mode. No study has found working on both modes. In Figure 7, the basic diagram for grid-connected and stand-alone mode is shown. In grid-connected mode as shown in Figure 7(a), all feeders will be supplied electrically through the utility grid [59] when the static switch is closed. In this mode, to achieve maximum operating benefits, MG will regulate the power balance between supply and demand (through a buying or selling process with the main grid) [60]. If the power system faults, MG will be immediately isolated from the main grid and acts as a stand-alone device, as shown in Figure 7(b). During this time, the static switch is opened. As a result, the DG systems will be disconnected from the main grid, whereby the micro-source network (DGs) now supports the remains feeders [50].



(a)



(b)

Figure 7: (a) Grid-connected mode [59], (b) Stand -alone mode [50]

Table 3: Summarization of Work on MG's Operational Modes

Author	Title	Microgrid mode		Energy Sources	Important Notes
		Stand-alone	Grid-Connected		
Motevasel M.; Seifi A.R	Energy management of a micro-grid considering wind energy uncertainty.		(shaded)	WT PV MT FC ESS Grid	All units operate within their limits and microgrid has limited trades with upper utility. WT operates at its maximum capacity.
Sfikas E.E.; Katsigiannis Y.A.; Georgilakis P.S.	Simultaneous capacity optimization of distributed generation and storage in medium voltage microgrids.	(shaded)		WT PV Biomass Battery	Microgrid losses are compared in islanded and grid-connected mode. The cost of energy for grid-connected and islanded microgrid are compared.
Alavi S.A.; Ahmadian A.; Aliakbar-Golkar	Optimal probabilistic energy management in a typical micro-grid based-on robust optimization and point estimate method	(shaded)		WT PV MT DiG Battery	Microgrid supplies whole demand from utility grid while DGs and ESSs are neglected. Generated power of WT and PV are probabilistic while the load is deterministic.
Tenfen D.; Finardi E.C.	A mixed integer linear programming model for the energy management problem of microgrids.		(shaded)	WT PV MT FC Battery Grid	-
Rezaei N.; Kalantar M.	Stochastic frequency-security constrained energy and reserve management of an inverter interfaced islanded microgrid considering demand response programs.	(shaded)		WT PV MT FC GE	-
Aghajani G.R.; Shayanfar H.A.; Shayeghi H.	Presenting a multi-objective generation scheduling model for pricing demand response rate in micro-grid energy management.		(shaded)	WT PV MT FC Battery Grid	Operating cost is minimized without and with DR program.
Rabiee A.; Sadeghi M.; Aghaeic J.; Heidari A.	Optimal operation of microgrids through simultaneous scheduling of electrical vehicles and responsive loads considering wind and PV units uncertainties.	(shaded)		WT PV MT FC DiG EV	-

6. RESEARCH ON MG'S ENERGY MANAGEMENT AND CONTROL

Another comprehensive study has been executed on the management and control strategies that have been imposed or proposed in MG system. As mentioned, This time, focus has been prioritized in determining the energy source type, energy management system (EMS) approach, control strategies adopted and the involvement of demand response in the MG system. From the study, it has been found that there are eleven papers [61-71] have strong connections to the searched key points. As the results, summarization on this work is demonstrated in Table 4. From the cited references, it can be observed that, mostly, aim of the executed research has been set on to minimize the operation cost of MG while ensuring stable electricity supply to the demand side.

Based on the summarization that has been given in Table 3 and Table 4, it can be seen that the DG considered in the previous study are mostly considered solar photovoltaic and wind energy as the RES, in both grid-connected and stand-alone (autonomous) mode MG system. From Table 4 itself, in terms of EMS and its control, double-layer approach seems as the most popular ones among the reported works. However, the type of fixed and transferrable loads is varying, depends on the studied system. Hence, there are numbers of alternative approaches that can be studied under second layer approach, for instance proposing the load-shape management e.g. load shifting, valley filling, peak clipping, flexible load shape, and etc. Meanwhile, for the RES side, where the first layer approach is imposed, most of the works considered were considering RES such as solar PV, wind, fuel cell, microturbine and ESS. No standard equations or algorithm have been demonstrated on how this RESs are scheduled or optimized. Hence, there is a need to explore on the optimization operation strategy potential of MG model that relating the optimal RES management system based on the cheapest cost, but yet able to give continuous supply to demands response, as this strategy is projected may offer more environmentally friendly and cheaper electricity price [60][72].

Table 4: Summarization on the Most Relevant Works

No	Authors	Title	Summarization
1.	Xiaoyu Wu, Yin Xu, Xiangyu Wu, Jinghan He, Josep M. Guerrero, Chen-Ching Liu, Kevin P. Schneider, and Dan T. Ton.	A Two-Layer Distributed Control Method for Islanded Networked Microgrid Systems	1. Energy Sources: solar, wind. 2. EMS Method: two layer, four-level distributed control method. 3. Control strategy: perform frequency and voltage regulation and power sharing control of the NMG system.
2.	Jasmine Kaur, Yog Raj Sood, and Rajnish Shrivastava.	A two-layer optimization approach for renewable energy management of green microgrid in deregulated power sector	1. Energy Sources: solar, wind, micro turbine, and fuel cell generation. 2. EMS Method: two-layer optimization. 3. Control strategy: the social benefit maximization of both the main grid and the green microgrid.
3.	Xiaoqing Lu, Jingang Lai, Xinghuo Yu, Yaonan Wang, Josep M. Guerrer.	Distributed Coordination of Islanded Microgrid Clusters Using a Two-layer Intermittent Communication Network	1. Energy Sources: Distributed generator. 2. EMS Method: two-layer optimization. 3. Control strategy: the social benefit maximization of both the main grid and the green microgrid.
4.	Hajir Pourbabak, Tao Chen, Bowen Zhang and Wencong Su.	Control and Energy Management System in Micro grids	1. Energy Sources: wind turbines, solar panels, small scale diesel generators. 2. EMS Method: smart meters and pervasive sensors, and centralized, decentralized and distributed control methods. 3. Control strategy: Optimize power demand and supply based on this collected local information.
5.	TinglongPan, HuiLiu, DinghuiWu, and ZeliangHao.	Dual-Layer Optimal Dispatching Strategy for Microgrid Energy Management Systems considering Demand Response	1. Energy Sources: wind generators, photovoltaic, micro gas turbines, and batteries. 2. EMS Method: add the micro gas turbine power generation as a supplementary power with less emission. 3. Control strategy: prolong the life cycle of battery.
6.	Julio Pascual, Javier Barricarte, Pablo Sanchis, Luis Marroyo.	Energy Management Strategy for A Renewable-based Residential Microgrid With Generation and Demand Forecasting	1. Energy Sources: PV, WT, ESS. 2. EMS Method: Simple Moving Average & Central Moving Average. 3. Control Strategy: Forecasting errors and battery SOC.
7.	Yongli Wang, Yujing Huang, Yudong Wang, Ming Zeng, Fang Li, Yunlu Wang, Yuangyuan Zhang.	Energy Management of Smart Microgrid With Response Loads and Distributed Generation Considering Demand Response	1. Energy Sources: PV, CCHP, ESS. 2. EMS Method: Genetic Algorithm. 3. Control Strategy: Renewable Energy Resources and DR program.
8.	Quanyuan Jiang, Meidong Xue, Guangchao Geng. [63]	Energy Management of Microgrid In Grid-connected And Stand-alone Modes	1. Energy Sources: PV, WT, FC, MT, ESS. 2. EMS Method: Double Layer Coordinated Control. 3. Control Strategy: Forecasting error and reserve power.
9.	Chengquan Ju, Peng Wang, Lalit Goel, Yan Xu.	A Two-layer Energy Management System for Microgrids With Hybrid Energy Storage Considering Degradation Costs	1. Energy Sources: PV, WT, hybrid ESS. 2. EMS Method: Double Layer Coordinated Control. 3. Control Strategy: Degradation cost of ESS.
10.	Siwar Khemakhem, Mouna Rekik, Lotfi Krichen.	Double Layer Home Energy Supervision Strategies Based on Demand Response and Plug-in Electric Vehicle Control for Flattening Power Load Curves in A Smart Grid	1. Energy Sources: PEV. 2. EMS Method: Double Layer Coordinated Control. 3. Control Strategy: DR and PEV power dispatch.
11.	Tinglong Pan, Hui Liu, Dinghui Wu, Zeliang Hao.	Dual-layer Optimal Dispatching Strategy for Microgrid Energy Management Systems Considering Demand Response	1. Energy Sources: WT, PV, MT, ESS. 2. EMS Method: Double Layer Coordinated Control. 3. Control Strategy: Micro source scheduling strategy.

8. CONCLUSION

The quick review on the MG system on its definition, architecture, operational modes, and the EMS control challenges in terms of demand response from the load side has been demonstrated very briefly. For further works, there are so many area can be focused for the sake of enhancing the technical and techno economics assessments of the MG system, for instance in terms of national policy and incentives, rules & regulations, guideline & standards, the safety, capability and reliability of the generation, transmission and distribution smart grid control, internets of things (IoT) in the communication and automation control system, and etc. Demand response is very significant to be regulated and controlled appropriate with the available RES. It is also important to study the behavior or response towards the critical transition period when islanding occurs for stable operation of a microgrid.

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