An Overview on Microgrids Energy Management Systems

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Abstract: At the moment, renewable energy resources are widely deployed to satisfy the demands of higher energy consumption, reduce pollutants and create socio-economic benefits for sustainable development. Micrograms can be integrated into the utility grid with the use of such distributed energy sources. An autonomous system consisting of distributed energy resources that may operate in an island mode during grid failures is included in the micro-grid idea. For the optimal use of these dispersed power resources in a smart, safe, dependable and coordinated way, an energy management system is necessary for microgrids. Therefore, this review paper compares and critically studies decision-making techniques and the related microgrid energy management systems resolution approach. Various approaches of quantification of uncertainties are synthesised to manage the volatility and interference of renewable energy resources and demand. The cost-efficient installation of microgrid energy management systems is also being explored in order to compare communication technology analysis. Finally, we share insights into the future and applications in the real world.

Keywords: Microgrid, renewable energy resources, communication technologies, energy management system, optimisation.

Introduction:

The growing global energy requirement is the leading source of rapid depletion of fossil fuels and increasing emissions of conventional producers of greenhouse gases (GHG) (CGs). In order to resolve these difficulties, for decades, the globe has been taking steps to deploy GW's large-scale renewable energy resources (RERs). One of the most important energy sources for clean energy supplies and for reducing GHG emissions is the energy efficiency of solar, wind, biomass, hydro and tidal energy [1]—Foster RERs as well as the objectives of UN Sustainable Development and the Paris Climate Agreement. Due to rising climate change awareness, the global deployment of RERs, excluding hydropower, reached 921 GW in 2016 with China at the top of the RERs deployment and the US, Germany and the United States, respectively.

The literature typically describes RERs, micro-CGs and energy storage systems (ESSs) as distributed energies (DERs). In the distribution system, DERs are on-site sources of generation. Therefore, for the power transfer to load ends, no transmission equipment is required. The RERs are volatile and intermittent energy sources in DERs, especially solar and wind power. To circumvent these uncertainties, ESSs and micro-CGs are therefore required. Integration of the DERs into the distribution network means that the energy resources are optimally sized, controlled and scheduled [7]. The integration of DERs into the electricity grid along with the capacity to operate in an islanded way during major grid breakdown, is one embodiment of this problem. It, therefore, helps to achieve objectives of the passive network's effective transition into a working, two-way and regulated flow management, reliable and continuous delivery, improved electricity quality and a clean environment.

MG defines as an interconnected DER, controlled load and critical load network of low voltage distribution. It can be operated in grid-connected or isolated mode depending upon the operative features of the main grid. The power electronic interfaces (PEIs) and controls are combined with DERs for power quality monitoring and continuous and dependable power supply to have flexible MG operating. The advantages of MG are various: GHG emission reduction, voltage-profile reactive power support, energy-supply decentralisation, cogeneration thermal load integration, auxiliary services and demand response (DR). It also decreases the transmission and distribution system line losses and outages—the status of the MG market worldwide. Autonomous basic MGs are defined as microgrids that cannot fulfil the load requirement for 24 hours a day. But autonomous complete MGs have provisions for the energy delivery to loading ends all day long [2]. Autonomous basic MGs are already in use worldwide except in the Middle East, while autonomous, fully networked, community-based MGs remain in new phases of deployment and pilot phases.

The MG Energy Management System (EMS) includes supply and demand side management to provide an economic, sustainable, and dependable MG operation while satisfying system restrictions. EMS delivers numerous advantages from energy save generation shipments, reactive power supply for frequency control, loss reduction reliability, energy balancing for lower GHG emissions, and customer privacy involvement.

Microgrid Architecture:

An MG consists of several DER and reactive loads, as depicted in Figure 1. Critical loads A point of common connection connects the MG to the main grid (PCC). Each DER is connected to the PEI in both grid-connected and isolated modes in order to achieve the control, dosing, protection and plug-and-play capabilities. The benefits of power trading to the main grid are derived from an MG during the grid-connected mode. However, MG adjusts operation to isolated mode to maintain system stability in the event of main grid disturbance or collapse. In this mode, the system supplies key loads continuously by efficiently integrated DER, DR and load shedding operations (LS). The complete operation of the MG is managed and coordinated by the MGCC and the local controllers (LCs). Effectively managing the DERs in MG leads to increased system performance and sustainability.

Given the growing awareness of climate change, socio-economic growth and the necessity to decrease emissions of GHGs, GM consists mostly of sustainable energy systems such as renewable and energy-efficient waste systems locally used. The MG EMS that solves decision-making strategies optimisation of these energy systems is realised. These techniques take account of better energy efficiency, improved reliability, lower energy consumption, lower DER operating costs, reduced system losses, and the reduction of sustainable development GHG emissions.

Figure 1: Microgrid Architecture

Microgrid Communication:

Dispersed DER generation and active DR integration require a communication infrastructure to share and improve local operations. For the continuous, rapid, secure and accurate flow of information between sensors, LCs and MGCCs without disturbance and disconnections, an effective data communication system is therefore necessary. However, the investment costs for such systems can be rather high, which relies on the number of repeaters that are needed while covering a certain area to increase the quality of broadcast signals. It is also crucial to reduce installation costs by selecting appropriate data transfer technologies for short and long term applications and maintaining dependable operation.

Several wireless and wireless methods were proposed in the literature to provide effective communication between various MG components. The choice of these communication technologies depends on data rate, coverage area, service quality, trustworthiness, latency and power use. An overview of several communication technologies for MG operations. Wired technology, such as DSL, PLC and optical fibre, has an increased data transfer rate and dependability at the cost of high installation costs among those communication technologies. Instead, the installation price can readily be reduced for wireless technologies (e.g. Zigbee, Z-wave, GSM, wifi) and, therefore, better off for remote places. They nevertheless have a low transmission rate and problems with signal interference. Finally, more sensors, measuring instruments and LCs must be integrated, monitored and constantly controlled with recent advances in the installation of MGs. Therefore, generally, wireless technology is preferable than wired technology because of its reduced deployment costs.

Microgrid Energy Management System :

The International Electrotechnical Commission defines an EMS as "a computing system consisting of a software platform that offers basic support services and a number of applications that provide the functionality needed for the efficient operation of electricity generation and transmission facilities, in accordance with IEC 61970, concerning the EMS application programme interface in power system management. MG EMS usually comprises modules for making decision-making strategies and also have the same qualities. DER/cargo forecasting modules, Human Machine Interfaces (HMI) and, inter alia, monitoring, controlling and data acquisition (SCADA) ensures the effectiveness of EMS Decision-making Strategies through optimum decision-making on each generation, storage and load unit.

An MG EMS performs a number of services, such as monitoring, analysis and forecasting of the generation of DERs, load consumption, energy market prices. These functionalities assist EMS to optimise the MG operation and meeting the technical limitations. There are two types of a control architecture for MG EMS: centralised and decentralised EMS. The central controller accrues all information in centralised EMSs, including DERs generation, cost function, weather data and consumer energy consumption pattern, etc. The centralised EMS then determines MG's ideal energy planning and sends these decisions to all LCs. But MGCC sends and receives all the information in real-time to LCs in a decentralised EMS architecture. Each LC submits an MGCC application or generation for current and future requests. The MGCC determines and returns the optimal schedule to the LC. The latter may differ from the existing operation and continue to negotiate until the global and local targets are met. The MG EMS tactics were broadened from economic dispatch and unit engagement with the inclusion of RERs, ESSs, EVs and DR.

Other tactics include timing DER and load, minimising system losses and failures, controlling RER's intermittence and volatility, and achieving cost-effective, sustainable and secure operation.

EMS based on Fuzzy Logic and Neural Network:

A smooth power profile of a grid-related MG was reported by Arcos Aviles et al. The purpose was to produce a fuzzy logic EMS [3]. The model presented reduces the variations and power peaks in the energy trade with the central grid. It also maintains the SOC level of the battery about 75 percent of its rated lifetime. Better than SOC-based EMS is the approach proposed. Chen et al. implemented the efficient EMS model for a standalone DC MG using the Zigbee-based communications network and the fuzzy logic control [4]. The model suggested ensures that RERs are used efficiently, and the Li-ion battery lives are improved.

Experimentally validated is the efficacy and efficiency of the given strategy. Kyriakarakos et al. suggested a floating logic MG EMS that minimises current net cost and battery SOC, hydrogen, and water storage penalty costs. The electricity demand, the water load and transport load are separated into three groups. Hydrogen is regarded to be a cargo fuel. Battery SOC, water and system frequency are the decisive inputs for the fuzzy logic system [4]. The MG system simulation is conducted for a year of software platforms in Transys, Genopt, Matlab and Trnopt.

Enrico et al. have implemented a fluctuating grid-connected MG logic-based EMS. The genetic algorithm is hierarchical and uses fluid inference systems from Mamdani to reduce the fluidity of EMS rules. The updated MG model is made using practical battery efficiency factors to replace the ideal battery model. The approach is developed to optimise the EMS's flowing rule basis for efficient energy flow and maximise energy trading profit. Compared with a traditional fuzzy-gas method the performance of the proposed methodology seems better. The business dispatch and unit dedication of Fuzzy-based MGs is carried out in that two GAs maximise their planning activities [5].

First GA sets out the programming and fluctuations of MG energy, whereas the second GA sets fluid membership. In addition, the Fuzzy expert system is used for battery power allocation [6]. Chaouachi et al. presented efficient MG EMS, which included the charging and discharge of batteries determined from the fluid expert system to decrease MG's operating and emission costs. The NN artificial ensemble approach predicts RER electricity production and demand for loads. Compared to the conventional multi-target model that does not consider the fluffy battery scheduling mechanism, the efficiency of the proposed technique is better. Wang et al. introduced a Lagrange NN programming strategy in order to decrease MG EMS total cost, including fuel cost, operating and servicing costs and generating emission costs. NN predicts power generation of RERs and demand for the load on a radial basis. Load is classified into four categories, including critical load, controllable load, price-dependent load and thermal load. The approach proposed offers the most efficient solution than PSO. A recurrent NN technique for an effective EMS of an integrated grid has been developed by Urias et al. It seeks to reduce imports of power from the central grid and optimise the use of RER output. Battery DOD is set to 60% to optimise battery life. The demand for loads is separated into two categories: critical and normal loads. A hybrid wavelet works and extends In order to predict demand and power generation for RERs, the Kalman filter-oriented NN technique.

A smart adaptive dynamic EMS for a grid-connected MG was proposed by Venayagameorthy et al. It maximised the use of RERs to ensure a dependable and self-sustaining system and minimised carbon emissions. Battery life also improves. The EMS is modelled and solved with two NNs, employing evolutionary adaptive dynamic programming and enhancements. The suggested EMS method is solved by an active NN, whilst the critical NN controls its optimal performance. In terms of the lifetime of the battery, use of renewable energy and minimum load reduction, the new specified performance index evaluates the performance of dynamic EMS. In comparison to the decision-tab approach based on dynamic EMS, the performance of the suggested approach is better. To achieve optimum battery and wind power use as well as minimum energy reliance on main grid purchasing, Kuznetsova et al. suggested an enhanced learning-based MG EMS. A Q-learning method is utilised to optimise the operation of MG in strengthening learning [8]. The Markov chain model is used to produce predicted wind speed scenarios to account for wind speed uncertainties. The only way to realise low calculating technique costs is to examine two hour-long-term scenarios in the optimisation process.

Real-World Applications and Discussion:

An EMS is particularly significant for efficient energy operations in the services, industry, trade, and residential sectors. It aims at optimising DER planning, reducing energy usage, and reducing emissions of GHGs. EMS's interaction with the SCADA and human to machine Interface (HMI) enables data to be monitored and analysed. It contains electricity generation, weather forecast, demand for load, and price of energy in real-time [9]. EMS uses this data to optimise system performance at the ends of generation, transmission and distribution.

Due to greater DER penetration into the power system, however, the central design confronts significant computational issues, reduced system scalability, and a high level of instability when faults occur. Recently, therefore, academics focused more on the architecture of decentralised control. However, a two-way connection between MG components and their synchronisation demands continual availability, leading to a rise in system costs. Furthermore, these communication systems need to be optimised for upgrading costs. Data before day shipment layer and real-time shipment layer divide the functioning of MG EMS into two levels. In addition, the day ahead of energy shipping is sub-hourly to consider the prognosis errors. The reference values are supplied to LCs via communication links in real-time. The choice of communication technology depends mostly on the cost of deployment and data rates for MGs from rural, residential and remote regions. The better possibilities for such MGs are Zigbee, Z-wave, Bluetooth and wifi. However, the coverage and data rate are most crucial for municipal and utility microgrid systems, and better possibilities are a passive optical network, 3G and 4G. Routers use DERs and load ends to communicate information between LCs and MGCs.

The LCs can be installed with low-cost integrated systems such as Aurdinos and Rasberry PI. It collects data from sensors and smart metres and carries out local control activities to maintain customer confidentiality. With the aid of SCADA, HMI and the information received from LCs, the MGCC operates energy management. The solution approaches are mainly selected in terms of the time complexity and convergence of computational time to optimal solution-based merit. Another way of validating the experimental execution of microgrid energy management systems is linear planning, meta-heuristic methodologies and artificial intellectual control and model predictive control. Furthermore, power firms such as Schneider Electric, ABB, General Electric, Siemens, Alstom, Tesla and others are currently developing and deploying microgrid energy management systems.

Conclusion and Future Trends :

Microgrids usually consist of energy supply, demand response, electric vehicles, local controllers, a central control system-based microgrid energy management unit, and communication devices. This report gave a full and critical analysis of the methods and solution techniques proposed for microgrid energy management. The key goals of the system are to optimise the operation, energy planning and system dependability for sustainable development in island and grid-connected microgrids. The energy system microgrid is, therefore a multi-target issue dealing with technological, economic and environmental issues. This comprehensive analysis addresses solutions, chances and possibilities for achieving energy management goals utilising different, efficient methodologies. These approaches are chosen for the optimal functioning of microgrids based upon their appropriateness, practicality and tractability. The objective categories of the MG EMS depend on their operating method, centralised or decentralised operations, and financial characteristics. They also address environmental problems for conventional generators, battery health, active DR integration, system losses and reliability and customer privacy. They are also concerned. Many investigations of several of these target kinds have been done. But substantial management of customer data, secure and reliable cost management of communication systems, particularly for dispersed operations, is still needed. In addition, the reliability study of microgrid systems for remote and insular applications is not investigated in detail. In order to achieve ideal energy-efficient microgrid functioning, these prospective areas must be addressed in depth.

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