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Rule-Based Multi-Time Scale Energy Management Technique for Standalone Micro Grids

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Abstract**—** In order to handle both techno-economic and environmental factors, this study presents an innovative energy management algorithm for a hybrid solar and fuel cell-based electric vehicle charging station (EVCS). In order to optimize real-time charging prices and improve renewable energy consumption, the current approach, which is intended for a 20- kW EVCS, makes use of a fuzzy inference system within MATLAB SIMULINK to manage power generation, electric vehicle (EV) power demand, and charging periods. Nevertheless, production instability could be a problem for this strategy. By replacing the fuzzy controller with an artificial neural network (ANN) controller, the suggested approach resolves this problem. Findings show that, in comparison to current flat rate tariffs, the ANN-based algorithm not only offers more steady outputs but also lowers energy costs, making it more affordable to charge for both weekdays and weekends. Furthermore, integrating renewable energy sources with hybrid technology greatly reduces greenhouse gas emissions. Due to the charging station owners' comparatively short payback periods, the idea is both environmentally friendly and financially feasible.

Keywords **—** stand-alone micro grid, energy management, rule reasoning, multi-time scale

I. INTRODUCTION

For remote areas with difficult access to the power grid, stand-alone micro grids are widely established in frontier regions and islands. In addition, the diesel generators (DGs) have been the main power in stand-alone micro grid system. Due to high electricity prices and poor reliability, many areas cannot meet the electricity demand of the customers. With the development of renewable technology, a stand-alone micro grid which integrated of wind turbine (WT), photovoltaic (PV), storage battery (SB) device, and DG is an attractive solution that offers advantages of environmentally friendly, full use of local natural resources, and reliable systems. Usually, stand-alone micro grids contain different energy sources, and each energy source has its own characteristic. Proper energy management for multi-source hybrid micro grid has great potential to reduce the cost and improve the power quality. Due to renewable energy resources, such as wind and solar, strongly depend on weather and climate conditions. So PV or WT generation system has intermittent and instability characteristics. Consequently, a backup energy or energy storage system is usually used to play a role of peak shaving and valley filling in a stand-alone micro grid. How to ensure the multi-source hybrid micro grid is in optimized operation, is an important and difficult issue to be research.

Alternative energy sources such as solar and wind energies, has attracted many researchers and communities throughout the world since the ‘‘energy crisis” of the 1970s. In addition, the increasing energy demand, high energy prices, as well as increasing concerns over environmental-, health- and climate changed implications of energy related activities are increasing concerns on alternative energy studies in communities. The high costs of electricity may be due to centralized energy systems which operate mostly on fossil fuels and require large investments for establishing transmission and distribution grids that can penetrate remote regions. Furthermore, the fossil fuel combustion results in the emission of obnoxious gases rising concerns about the climate change and other health hazards. In order to counter these problems there is a strong need for alternative systems of power generation and distribution. Unlike the centralized energy systems, on the other hand, decentralized energy systems are mostly based on renewable energy sources. They operate at lower scales (a few kW h scale) both in the presence and absence of grid, and easily accessible to remote locations because of generation of power in the propinquity of demand site.

Stand-alone systems produce Power Independently of the utility grid; hence, they are said to stand-alone. These are more suitable for remotest locations where the grid cannot penetrate and there is no other source of energy. These systems are not connected to the utility grid as a result they need batteries for storage of electricity produced during off-peak demand periods, leading to extra battery and storage costs.

Due to the technology development and environment protection, some distributed energy resources (DER), such as internal combustion (IC) engines, gas turbines, micro turbines, photovoltaic, fuel cells and wind-power, have emerged within the distribution system. However, application of individual distributed generators can cause as many problems as it may solve. A better way to realize the emerging potential of distributed generation and associated loads is a subsystem called ‘‘Micro Grid’’ (MG), the MG concept assumes a cluster of loads and Micro Sources (MS) operating as a single controllable system that provides both power and heat to its local area. introduce the benefits of MG, such as, enhance local reliability, reduce feeder losses, support local voltages, provide increased efficiency through using waste heat combined heat and power (CHP), voltage sag correction or provide uninterruptible power supply functions. The MG is intended to operate in the following two different operating conditions: normal interconnected mode and emergency mode (islanded mode). Most DERs that can be installed in an MG are not suitable for direct connection to the electrical network due to the characteristics of the energy produced. Therefore, power electronic interfaces (dc/ac or ac/dc/ac) are required. Inverter control is thus the main concern in MG operation. The MG is centrally controlled and managed by a MG central controller (MGCC) installed at the medium voltage/low voltage (MV/LV) substation. The MGCC includes several key functions, such as economic managing functions and control functionalities, and is the head of the hierarchical control systems.

The ever increasing energy consumption, the soaring cost and the exhaustible nature of fossil fuel, and the worsening global environment have created increased interest in green [renewable and/or fuel cell (FC)-based energy sources] power generation systems. Wind and solar power generation are two of the most promising renewable power generation technologies. The growth of wind and photovoltaic (PV) power generation systems has exceeded the most optimistic estimation. FCs also show great potential to be green power sources of the future because of many merits they have (such as high efficiency, zero or low emission of pollutant gases, and flexible modular structure) and the rapid progress in FC technologies. However, each of the aforementioned technologies has its own drawbacks. For instance, wind and solar power are highly dependent on climate while FCs need hydrogen-rich fuel. Nevertheless, because different alternative energy sources can complement each other to some extent, multisource hybrid alternative energy systems (with proper control) have great potential to provide higher quality and more reliable power to customers than a system based on a single resource. Because of this feature, hybrid energy systems have caught worldwide research.

Nowadays, a micro grid system is being considered as one of the solutions to the energy concern around the world and it is gaining more attention recently. It can be viewed as a group of distributed generation sources (DGs) connected to the loads in which the DGs can be fed to loads alone or be fed to a utility grid. In recent years, a Battery Energy Storage System (BESS) can be used in various aspects of the power systems. As the output characteristics of these DGs are quite different from the conventional energy sources, the system should be able to handle unexpected fluctuations and maintain system reliability. When an islanding operation occurs in a micro grid where a DG or a group of DGs continue to supply the micro grid system which is separated from the utility grid, the system needs to have the master generator which can provide voltage and frequency support.

Generally, a synchronous generator can fulfill this demand. When there is no synchronous generator, converters interfaced batteries can act as the master control. Therefore, battery storage devices serve as an important aspect in micro grid operations. BESS is implemented in various aspects of power systems as one key factor for sustainable energy in many countries particularly in Europe, America and Japan. Advantages of BESS include an improvement of system frequency, especially when BESS is used for system frequency control. For small disturbances, BESS is discharging when the system frequency is lower than 50 or 60 Hz. On the other hand, BESS is charging when the system frequency is higher than 50 or 60 Hz. For large disturbances, BESS can enhance the performance of the system frequency control by integrating BESS with an under frequency load shedding scheme, an under or over frequency generation trip. With these different functions, BESS can offer a good solution. Thus, it is concluded that BESS is a rapid and flexible element for power system. Previous optimization procedure was implemented for a large interconnected power system case using a small BESS rated power (i.e., 2 MW) compared to the total volume of the spinning reserve provided by the conventional generations (i.e., 3000 MW). Therefore, the impact of BESS on system frequency behavior was widely negligible. Micro grid system (e.g., a small power system), the BESS rated power cannot be negligible anymore, and thus the grid frequency is now sensitive to BESS output power variations. So, the installation of large/inappropriate size or random size of BESS can cause frequency problems, increase system Losses and add an extra cost to the micro grid system. For these reasons, an optimal sizing of BESS is an essential method for a micro grid.

However, the optimization method can be achieved by many ways such as balanced generation and load demand method, linear programming method, enumerative method, iterative algorithm, genetic algorithm, particle swarm optimization. According to, the advantages of particle swarm optimization (PSO) include simplicity, ease of use, high convergence rate and minimal storage requirement. Especially, it is less dependent on the set of the initial points compared to other methods which implies that convergence algorithm is robust. In, an optimal sizing of BESS by using PSO-based reliability is already proposed for an islanded micro grid. However, two basic problems need to be addressed in a micro grid operation: voltage control and frequency control. When in islanding mode, frequency control becomes the main concern for a micro grid operation. Thus, this paper selected and proposed the optimal sizing of BESS by using PSO method-based frequency control of the micro grid to prevent the micro grid from instability and system collapse after the loss of the utility grid (e.g., blackout or disasters). Modern BESS technologies, which are analyzed and compared the performance and total cost in this study, are the polysulfide– bromine BESS and the vanadium redox BESS (i.e., redox-flow batteries). It is a relatively new commercially available battery and differs from conventional BESS in such a way that the amount of energy it can store is independent on its power rating. Moreover, redox-flow batteries can be designed for both high power and large

energy storage. Due to its new commercialization, recent studies on redox-flow BESS in a micro grid are limited. In this study, the specified costs of two BESS technologies are separated and analyzed in order to compare performances of different technologies for 15 years installation in the typical micro grid.

II. LITRATURE SURVEY

This study involved conducting a review of the literature, which took into account two of the most important and extensively used databases in the field – the IEEE/IEE digital library and the Science Direct electronic databases – as well as other sources.

The proposed methodology is a heuristic approach which uses a stochastic gradient search for the global optimization. In the study, the objective function is the minimization of the hybrid energy system total cost. And the decision variables are PV size, wind turbine rotor swept area and the battery capacity. The optimum result obtained by SA algorithm is compared with our former study's result. Consequently, it is come up with that the SA algorithm gives better result than the Response Surface Methodology (RSM). The case study is realized for a campus area in Turkey describe in [1].

The distributed energy resources (DER) comprise several technologies, such as diesel engines, micro turbines, fuel cells, photovoltaic, small wind turbines, etc. The coordinated operation and control of DER together with controllable loads and storage devices, such as flywheels, energy capacitors and batteries are central to the concept of Micro Grid (MG). MG can operate interconnected to the main distribution grid, or in an islanded mode. This paper reviews the researches and studies on MG technology. Elaborated in [2]

As mention in [3] Micro grids are expected to become part of the next electric power system evolution, not only in rural and remote areas but also in urban communities. Since micro grids are expected to coexist with traditional power grids (such as district heating does with traditional heating systems), their planning process must be addressed to economic feasibility, as a long-term stability guarantee. Planning a micro grid is a complex process due to existing alternatives, goals, constraints and uncertainties. Usually planning goals conflict each other and, as a consequence, different optimization problems appear along the planning process. In this context, technical literature about optimization techniques applied to micro grid planning have been reviewed and the guidelines for innovative planning methodologies focused on economic feasibility can be defined. Finally, some trending techniques and new micro grid planning approaches are pointed out.

An Ac-linked hybrid wind/ photovoltaic (PV)/fuel cell (FC) alternative energy system for stand-alone applications. Wind and PV are the primary power sources of the system, and an FC–electrolyzed combination is used as a backup and a long-term storage system. An overall power management strategy is designed for the proposed system to manage power flows among the different energy sources and the storage unit in the system. A simulation model for the hybrid energy system has been developed using MATLAB/Simulink. The system performance under different scenarios has been verified by carrying out simulation studies using a practical load demand profile and real weather data. Describe in [4]

In the [5] describe Micro grids are Low Voltage distribution networks comprising various distributed generators (DG), storage devices and controllable loads that can operate either interconnected or isolated from the main distribution grid as a controlled entity. This paper describes the operation of a Central Controller for Micro grids. The controller aims to optimize the operation of the Micro grid during interconnected operation, i.e. maximize its value by optimizing production of the local DGs and power exchanges with the main distribution grid. Two market policies are assumed including Demand Side Bidding options for controllable loads. The developed optimization algorithms are applied on a typical LV study case network operating under various market policies and assuming realistic spot market prices and DG bids reflecting realistic operational costs. The effects on the Micro grid and the Distribution network operation are presented and discussed.

The development of energy management tools for next-generation Photovoltaic (PV) installations, including storage units, provides flexibility to distribution system operators. It this paper, the aggregation and implementation of these determinist energy management methods for business customers in a micro grid power system are presented. This paper proposes a determinist energy management system for a micro grid, including advanced PV generators with embedded storage units and a gas micro turbine. The system is organized according to different functions and is implemented in two parts: a central energy management of the micro grid and a local power management at the customer side. The power planning is designed according to the prediction for PV power production and the load forecasting. The central and local management systems Exchange data and order through a communication network. Mention in [6]

A micro grid organization has been studied in order to define the roles and the required control systems for the integration of dispersed PV generators and DER units in the electrical system. The main problem is that the output power from most REBGs fluctuates depending on weather conditions when the power quality of the grid may decrease. Experiences currently show that the maximum penetration ratio of these passive PV generators in European island networks is 30%. One way to increase the penetration ratio is to upgrade actual PV generators in order to transform them into controllable generators. These active generators are new flexibilities for the grid system operator. Describe in [7].

Micro grid is considered as independent power producer company (IPP) in power system. Price of selling/buying power in on-peak or off-peak for MG, DG and upstream power system (DISCO) under pool/bilateral/hybrid electricity market are different. In this study, particle swarm optimization (PSO) algorithm has been implemented for the optimization of the micro grid cost. The costs include capital cost, replacement cost, operation and maintenance costs and production cost for micro grid and DGs. Then, an objective function to maximize total net present worth (NPW) is presented. PSO approach is employed to obtain the minimum cost of micro grid, during interconnected operation by optimizing the production of local DGs and power exchanges with the main distribution grid. The optimization algorithm is applied to a typical LV network operating under different market policies. Specified in [8]

The main challenge in integrating a Battery Energy Storage System (BESS) into a micro grid is to evaluate an optimum size of BESS to prevent the micro grid from instability and system collapse. The installation of BESS at a random size or non-optimum size can increase in cost, system losses and larger BESS capacity. Thus, this paper proposes the new method to evaluate an optimum size of BESS at minimal total BESS cost by using particle swarm optimization (PSO)-based frequency control of the stand-alone microgrid. The research target is to propose an optimum size of BESS by using the PSO method-based frequency control in order to prevent the micro grid from instability and system collapse after the loss of the utility grid (e.g., blackout or disasters) and minimize the total cost of BESS for 15 years installation in the micro grid. Then, the economic performance of BESS with modern different storage technologies is investigated and compared in the typical micro grid. Describe in [9].

As mention in [10] Energy sustainability of hybrid energy systems is essentially a multi objective, multi constraint problem, where the energy system requires the capability to make rapid and robust decisions regarding the dispatch of electrical power produced by generation assets. This process of control for energy system components is known as energy management. In this paper, the application of particle swarm optimization (PSO), which is a biologically inspired direct search method, to find real-time optimal energy management solutions for a stand-alone hybrid wind-micro turbine (MT) energy system, is presented. Results demonstrate that the proposed PSO-based energy management algorithm can solve an extensive solution space while incorporating many objectives such as: minimizing the cost of generated electricity, maximizing MT operational efficiency, and reducing environmental emissions.

III. CONCLUSION

This article has described an energy management system for a stand-alone micro grid, where the penetration of renewable energy is considerable high. Security-stability and economics are the two topics for the micro grid system operation and management. Two key elements make up the proposed strategy: economic scheduling and real-time scheduling. Economic scheduling, coordinating micro sources and energy storage system, focuses on the economic operation at large time scale. While real-time scheduling can pay more attention to reliability of the micro grid system. The real-time control instructions of the EMS are obtained by pre-specified rules, which is very easy to implement in practice.

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