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Microgrid Modelling and its Performance Identification Using Matlab Simulink

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Abstract- In this work, a Microgrid (MG) test model based on the 14-busbar IEEE distribution system is proposed. This model can constitute an important research tool for the analysis of electrical grids in its transition to Smart Grids (SG). The benchmark is used as a base case for power flow analysis and quality variables related with SG and holds distributed resources. The proposed MG consists of DC and AC buses with different types of loads and distributed generation at two voltage levels. A complete model of this MG has been simulated using the MATLAB/Simulink environmental simulation platform. The proposed electrical system will provide a base case for other studies such as: reactive power compensation, stability and inertia analysis, reliability, demand response studies, hierarchical control, fault tolerant control, optimization and energy storage strategies.

Index Terms- Electrical engineering, System diagnostics, Power system operation, Power converter, Smart grid technology, Distributed resources, Microgrid benchmark, Hybrid energy systems, Power flow.

I. INTRODUCTION

The liberation of the energy market and the new conditions in the energy field are leading towards the finding of more efficient ways of energy production and management. The introduction of new ideas capable of evolving in the new conditions might lead to more suitable solutions compared to any possible malfunctions the new market model can create.

Renewable energy systems (RES) propose a new technology that is cleaner and capable of supplying the growing electricity demands of interconnected and isolated communities. In recent years, MGs have become a great attraction for the scientific community as well as a promising solution for future traditional energy systems. MGs are seen as a possible technology for the integration of variable renewable energy systems in the traditional grid.

Currently, with the evolution of new digital technologies, such as micro-processed systems and advances in power electronics, many applications have been implemented in SG, specifically in the development of controllers and electronic energy converters.

In recent decades, researchers have made significant contributions which have had a high impact in these areas, mainly aimed at data acquisition, automation, and control of MGs [1, 2, 3]. MGs not only integrate the distributed generation to the Main Grid in a reliable and clean fashion, but also provide high reliability in its capacity to operate in the face of natural phenomena and active Distribution Grids, which in turn results in less energy losses in transmission and distribution and less construction and investment time [3, 4, 5, 6]. Research developed in [7, 8, 9, 10, 11, 12, 13, 14, 15] show actual implemented MGs. Some of the examples can be seen in CERTS in the US, NEDO in Japan, and a vast majority of MGs in Europe.

The combination of utility restructuring, technology evolutions, recent environmental policies provide the basis for DG to progress as an important energy option in the near future.

Utility restructuring opens energy markets, allowing the customer to choose the energy provider, method of delivery, and attendant services. The market forces favour small, modular power technologies that can be installed quickly in response to market signals.

This restructuring comes at a time when:

- Demand for electricity is escalating domestically and internationally;
- Impressive gains have been made in the cost and performance of small, modular distributed generation technologies
- Regional and global environmental concerns have placed a premium on efficiency and environmental performance; and
- Concerns have grown regarding the reliability and quality of electric power.

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II. DISTRIBUTED GENERATION IN MICROGRID/SMARTGRID

Definition

Generally, the term Distributed or Distributed Generation refers to any electric power production technology that is integrated within distribution systems, close to the point of use. Distributed generators are connected to the medium or low voltage grid. They are not centrally planned and they are typically smaller than 30 MWe (DTI 2001).

The concept of DG contrasts with the traditional centralised power generation concept, where the electricity is generated in large power stations and is transmitted to the end users through transmission and distributions lines (see figure.1).

While central power systems remain critical to the global energy supply, their flexibility to adjust to changing energy needs is limited. Central power is composed of large capital-intensive plants and a transmission and distribution (T&D) grid to disperse electricity.

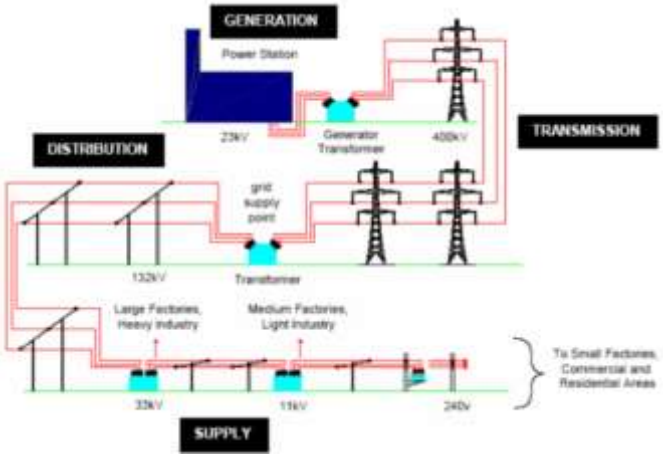

Fig 1: An electric power system

A distributed electricity system is one in which small and micro generators are connected directly to factories, offices, households and to lower voltage distribution networks. Electricity not demanded by the directly connected customers is fed into the active distribution network to meet demand elsewhere.

Electricity storage systems may be utilised to store any excess generation. Large power stations and large-scale renewables, e.g. offshore wind, remain connected to the high voltage transmission network providing national back up and ensure quality of supply. Again, storage may be utilised to accommodate the variable output of some forms of generation. Such a distributed electricity system is represented in figure 1.2 below.

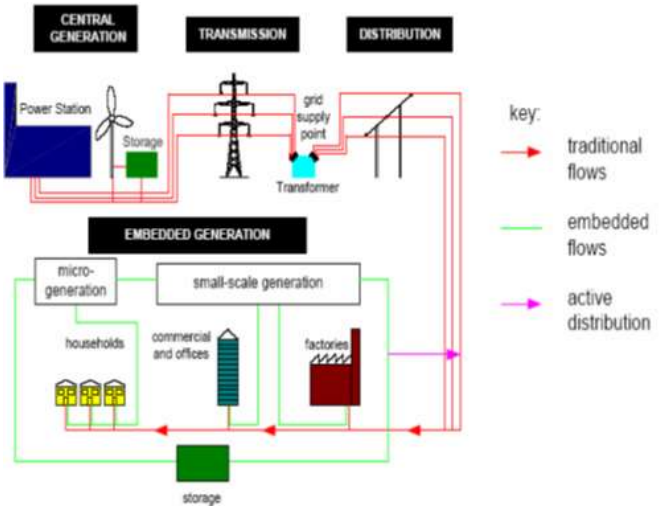

Fig. 2: A Distributed Electricity System

The non-traditional operating model of DG has drawn strong interest because of its potential to cost effectively increase system capacity while meeting the industry restructuring objective of market driven, customer-oriented solutions. These distributed generation systems, capable of operating on a broad range of gas fuels, offer clean, efficient, reliable, and flexible on-site power alternatives. This emerging portfolio of distributed generation options being offered by energy service companies and independent power producers is changing the way customers view energy.

Both options require significant investments of time and money to increase capacity. Distributed generation complements central power by (1) providing in many cases a relatively low capital cost response to incremental increases in power demand, (2) avoiding T&D capacity upgrades by locating power where it is most needed, and (3) having the flexibility to put power back into the grid at user sites. Significant technological advances through decades of intensive research have yielded major improvements in the economic, operational, and environmental performance of small, modular gas-fuelled power generation options. Forecasts predict a total 520GW from newly installed DG around the globe by 2030.

III. MARKET

DG appears especially attractive to policymakers, regulators and the market generally because it provides the option of reducing investments in transmission and distribution systems and also the option of minimizing the T&D energy losses.

One of the powerful forces driving that transition in the market structure has been advances in electricity generation technologies that have reduced the costs of smaller-capacity systems. Technologies such as microturbines are available in

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capacities under 100 kilowatts (roughly the size of an automobile engine). Large-scale power plants (100 megawatts or greater), which are typically used by vertically integrated utilities, no longer have significantly lower costs than smaller plants do. That change has weakened one of the main rationales for maintaining electric power production as a regulated monopoly and the next reasonable step would be to fully exploit the savings in generation and transmission costs from large-scale, centrally located power plants. Policymakers have an interest in the future of distributed generation, not only for the cost savings it can provide to the homes and businesses that produce it but also for the cost savings and additional reliability that it may be able to offer to the entire electricity market. Distributed generation may play a larger role, along with demand-management techniques and further innovations in wholesale and retail markets, in reducing the cost of electricity when traditional supply is tight or market demand is strong. For example, distributed generation may offer retail customers greater flexibility to alter their demand for electricity in response to hourly changes in prices (real-time pricing), thereby promoting the efficient operation and stability of energy markets as they become increasingly competitive. Some observers expect distributed generation to play a role in the commercial development of renewable energy and high-efficiency technologies, adding the associated environmental and safety benefits.

Technology Status

The technical and commercial status of distributed generation globally depends very much on the past history of a country's power industry. Countries, whether developed or developing, with power sectors that are largely state controlled either remain tied to a centrally controlled transmission system that is connected to large-scale fossil fuel, hydro or nuclear power stations, or are developing such systems. Countries where liberalisation has taken place, on the other hand, have the incentive to consider alternatives. It is in these countries that distributed generation has started to gain a foothold because of its lower capital cost, modular construction and short build times. The mix of distributed generation technologies exploited depends on, among other things, energy market and political issues. The USA probably leads the world in developing distributed generation, driven by commercial issues and by poor power quality and the lack of security of supply in a number of states. In other words, the market is demanding solutions that distributed generation technologies can provide. This has resulted in a distributed generation market that is dominated by low-cost, high-reliability fossil-fuel plant (usually gas-based) but that has a growing renewables component.

Distributed or dispersed generation (DG) or embedded generation (EG) is small-scale power generation that is usually connected to or embedded in the distribution system. The term DG also implies the use of any modular technology that is sited throughout a utility's service area (interconnected to the distribution or sub-transmission system) to lower the cost of service. The benefits of DG are numerous and the reasons for implementing DGs are an energy efficiency or rational use of energy, deregulation or competition policy, diversification of energy sources, availability of modular generating plant, ease of finding sites for smaller generators, shorter construction times and lower capital costs of smaller plants and proximity of the generation plant to heavy loads, which reduces transmission costs. Also it is accepted by many countries that the reduction in gaseous emissions offered by DGs is major legal driver for DG implementation.

IV. LITERATURE REVIEW

Review of Past Research

Ram Prakash et al. [1] Over the last few years, Distribution Generations (DGs) are fast finding their importance in solving growing environmental problems and rising energy demands. However, installation of DG in distribution network may have positive or negative impacts on power system depending on system configuration and local issues. Bat Algorithm (BA) with varying loudness and pulse rate is proposed in this paper for the optimal location and sizing of DG in radial distribution system in order to minimize real power losses and maximize voltage stability index (VSI), along with improving voltage profile within the range of the voltage constraint. Two cases based on either real or both real and reactive power generating capability of DG is considered. Both the cases include single as well as multiple DG units for performance analysis of DG on IEEE 69 bus systems. To verify the efficiency of proposed method a comparison is made with Standard Particle Swarm Optimization (PSO). The simulation results reveal that Bat Algorithm (BA) is better than PSO in terms of power losses, VSI and quality of solution.

Sameer Singh, et al. [2] In this paper, a new evolutionary approach has been discussed for reactive power dispatch (loss reduction) with the contribution of particle swarm optimization. Proposed algorithm has been applied to achieve the major objective as the system loss minimization with satisfied equality and inequality constraints. Tap settings of transformer, voltage at generator bus and shunt capacitor banks have been considered as control variables. Successful application of proposed algorithm is done on different IEEE bus systems. In comparison of other previous work, this proposed algorithm provides the better results.

Sunil Joseph P.1, C. Dinesh Balaji et al. [3] Power is generated in generating station, transmitted through transmission line and then distributed to consumers. Power system consists of three types of buses. They are generator bus, load bus and slack bus. Each bus is characterized by four parameters. They are bus voltage, phase angle, active power and reactive power. These buses are classified according to

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known parameters. Unknown parameters are found using load flow studies. In this paper load flow studies are done using Newton-Raphson method. Transmission line is characterized by resistance, inductance and capacitance. This will result in losses. These losses cannot be eliminated but can be reduced. Optimization is a mathematical tool to find the maximum or the minimum of a function subject to some constrains. Using lose function as objective function subjected to generator MW, transformer tapping, reactive power injection and controlled voltage as constrains, optimization technique can be used to minimize transmission losses. Using this we get optimal value for bus parameters such that transmission losses are minimum. In this paper Particle Swarm Optimization (PSO) is employed to solve optimal power flow problems. IEEE 30-bus power systems are used for testing the objective of this paper.

Pardeep Kaur et al. [4] In this research paper, PSO is joint with Newton Raphson method of power flow to optimize optimal location along with size of renewable energy source. A NR method is used to measure the losses and find the voltage at each bus. The PSO is used to locate the best location as well as sizing of renewable energy source. The main aim is to reduce the losses and keep the voltage profile acceptable. IEEE 30 bus standard system is used for the observations. There is the comparison of results of system without renewable energy source and with renewable energy source by some methods of optimization. Wind farm is considered as the renewable energy source.

S.Jaisiva, A.Bharaneetharan et al. [5] In power engineering society, sinking the power loss in transmission lines and/or minimizing the voltage deviation at the load buses by controlling the reactive power is referred to as optimal reactive power dispatch (ORPD). ORPD is necessary for safe operation of power systems with regard to voltage stability. In this paper, the nature inspired Differential Evolutionary based Bat Algorithm (DEBA) is introduced to solve optimal reactive power flow problem in power systems. Generator bus voltages, transformer tap positions and switchable shunt capacitor banks are used as variables to control the reactive power flow. DEBA was tested on standard IEEE 30 bus system and the results are compared with further methods to prove the effectiveness of the new algorithm. The results are quite encouraging and the algorithm is found to be simple and easy to employ.

Deependra Singh, Devender Singh, and K. S. Verma et al. [6] This paper addresses a novel technique for placement of distributed generation (DG) in electric power systems. A GA based approach for sizing and placement of DG keeping in view of system power loss minimization in different loading conditions is explained. Minimal system power loss is obtained under voltage and line loading constraints. Proposed strategy is applied to power distribution systems and its effectiveness is verified through simulation results on 16, 37-bus and 75-bus test systems.

Rakesh Choudhary, Rakesh Singh Lodhi, Dr. Pragya Nema et al. [7] This paper presents real and reactive power loss of IEEE-33 bus radial distribution system using local search optimization for dg placement at optimum location. It describes active power loss, reactive power loss and voltage profile of radial distribution system as well as distributed generation. Here also discuss local search optimization, forward-backward sweep method to determine voltage and current from sending end and receiving end as well as load flow study of IEEE-33 bus. To minimize distribution losses considering cost function for distribution system load flow planning.

To reduce the losses of radial distribution system, it also comprises ring main system and radial distribution system. To minimum real and reactive power losses by placement of distribution generation at particular location, this will be identified by local search optimization. The method named local search method is adopted for finding suitable locations to provide distributed generation & the optimum value of the real power source at that site.

Arun Onlam, Daranpob Yodphet, Rongrit Chatthaworn, Chayada Surawanitkun, Apirat Siritaratiwat et al. [8] This paper proposes a novel adaptive optimization algorithm to solve the network reconfiguration and distributed generation (DG) placement problems with objective functions including power loss minimization and voltage stability index (VSI) improvement. The proposed technique called Adaptive Shuffled Frogs Leaping Algorithm (ASFLA) was performed for solving network reconfiguration and DG installation in IEEE 33- and 69-bus distribution systems with seven different scenarios. The performance of ASFLA was compared to that of other algorithms such as Fireworks Algorithm (FWA), Adaptive Cuckoo Search Algorithm (ACSA) and Shuffled Frogs Leaping Algorithm (SFLA). It was found that the power loss and VSI provided by ASFLA were better than those given by FWA, ACSA and SFLA in both 33- and 69-bus systems. The best solution of power loss reduction and VSI improvement of both 33- and 69-bus systems was achieved when the network reconfiguration with optimal sizing and the location DG were simultaneously implemented. From our analysis, it was indicated that the ASFLA could provide better solutions than other methods since the generating process, local and global searching of this algorithm were significantly improved from a conventional method. Hence, the ASFLA becomes another effective algorithm for solving network reconfiguration and DG placement problems in electrical distribution systems.

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V. CONCLUSION

In this Review, AC/DC hybrid micro-grid using MATLAB/Simulink has implemented. Simulation results at each individual block of the designed systems have given. The simulation results show that the system is stable under various load and supply conditions. A hybrid AC/DC micro-grid concept is introduced in this paper to avoid multiple reverse conversions in an individual AC or DC grid and to facilitate the connection of various renewable AC and DC sources and loads. A typical hybrid grid and the operation issues are investigated. Different operating modes of the hybrid grid and control techniques are investigated. A control algorithm is proposed to eliminate the problem caused by unbalance and nonlinear load in AC link. The simulation results show that the algorithm is effective. A control technique is proposed to maintain voltage stability and smooth power transfer between AC and DC links under various supply and load conditions. The simulation results show that the power flow can be smoothly transferred based on the proposed control index

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