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Hybridized GA and FPSO Based Allocation of Energy Storage System for Risk Mitigation of DISCOs

Binu S[1], J. Jasper Gnana Chandran[2]

PG Scholar [Power Systems], Dept. of EEE, Francis Xavier Engineering College, Tirunelveli, Tamilnadu, India[1],

Professor/Head, Dept. of EEE, Francis Xavier Engineering College, Tirunelveli, Tamilnadu, India[2]

ABSTRACT: Renewable energy came into momentum recently. Increased renewable penetration causes power flow significantly altered in terms of magnitude and direction, which make DISCOS a major challenge. The main renewable energy sources are solar and wind. Both are unreliable. Because at night no solar radiation is available and when wind is not occurring there is no generation of power. When actuating quantities are not there we have to use batteries as the backup storage. A novel battery energy storage system (BESS) based energy acquisition model is proposed for the operation of distribution companies (DISCOs) in regulating price or locational marginal price (LMP) mechanism. Optimal sizing and sitting decisions for BESS is obtained through a cost-benefit analysis method. Based on this new model, a new battery operation strategy is proposed for better utilization of energy storage system (ESS) and mitigation operational risk from price volatility. Allocation of optimal BESS is a non linear optimization technique. Hence traditional optimization technique cannot use. So we first select PSO. But it has drawback that, mathematical model of dynamic relationship of control parameter is difficult. So we select FPSO. But FPSO has lower convergence than Hybridized GA and FPSO. So for optimization we are using Hybridized GA and FPSO

KEYWORDS: Control strategy, distribution system, electricity markets, energy storage system, renewable energy

I. INTRODUCTION

Because of the increasing demand, many countries placed great pressure on energy industry to incorporate renewable energy into their energy mix in the form of wind, solar, etc. Governments are promoting the construction of renewable energy projects with generous subsidies and with regulatory support. The cumulative installed capacity has increased markedly since the last decade. Although these types of power generation is more environmentally sustainable, large-scale integration of renewable energy in power distribution systems may significantly alter network power flow in terms of direction and magnitude, which will impose direct impacts on power quality, protection settings, and etc., making delivering reliable power, on demand, a major challenge. Therefore, with the advent of renewable, distribution companies (DISCOs) are facing emerging challenges. In this project, we assume DISCO to be sole system operator and electricity retailer, and introduce a risk mitigation model for the operation of DISCOs. Normally, DISCOs buy energy through bilateral contracts or pool market to meet electrical demand of end-users. If DISCOs possess renewable energy facilities, they will have more choices to acquire energy. Moreover, DISCOs can also improve their response capability towards electricity market by participating in financial bids for sale of excess energy. Therefore, while DISCOs are struggling with the pressure from integrating more renewable, they can encounter new economic opportunities by participating in different electricity markets. Although there have been note worthy researches underway in formulating more effective operation rules for electricity markets, majority of previous studies placed great emphasis on generation companies (GENCOs). With the further development of electricity markets, increasing research interests have being directed towards DISCOs.

In contract markets, DISCOs buy electricity through negotiated agreements; while in pool markets, DISCOs purchase electricity from forward market and spot market [1]to meet their demand. Normally, energy is purchased at variable prices and sold at fixed or multistep prices. However, due to forecast errors, DISCOs are still responsible for compensating the gap between actual demand and supply.

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a. AIM AND SCOPE

A new battery is operation strategy is using for better utilization of energy storage System and mitigation operation risk from price volatility of DISCOs. In this project, a novel battery energy storage system (BESS) based energy acquisition model is proposed for the operation of distribution companies (DISCOs) in regulating price or locational marginal price (LMP) mechanisms, while considering energy provision options within DISCO controlled areas. Based on this new model, a new battery operation strategy is proposed for better utilization of energy storage system (ESS) and mitigation operational risk from price volatility. Meanwhile, optimal sizing and siting decisions for BESS is obtained through a cost-benefit analysis method, which aims at maximizing the DISCO's profit from energy transactions, system planning and operation cost savings.

II. REVIEW OF EXISTING FINDING

Along with the increasing penetration of renewable energy, distribution system power flow may be significantly altered in terms of direction and magnitude. This will make delivering reliable power, on demand, a major challenge. In this project, a novel battery energy storage system (BESS) based energy acquisition model is proposed for the operation of distribution companies (DISCOs) in regulating price or locational marginal price (LMP) mechanisms, while considering energy provision options within DISCO controlled areas. Based on this new model, a new battery operation strategy is proposed for better utilization of energy storage system (ESS) and mitigation operational risk from price volatility.

Meanwhile, optimal sizing and siting decisions for BESS is obtained through a cost-benefit analysis method, which aims at maximizing the DISCO's profit from energy transactions, system planning and operation cost savings. The proposed energy acquisition model and ESS control strategy are verified on a modified IEEE 15-bus distribution network, and risk mitigation is also quantified in two different markets. The promising results show that the capacity requirement for ESS can be reduced and the operational risk can also be mitigated. [2]

Suitable storage of energy at appropriate time and locations can help to balance generation with consumption, and to maintain system stability. In this paper, a novel battery operation strategy is proposed for better utilization of ESS and power loss reduction in the distribution system. [3]

a. THE NEED FOR ENERGY STORAGE

Critical component of manufacturing, of the service industry, of the renewable energy industry, and of all the portable electronics with which we have become interested is energy storage system. Without modern energy storage, using lithium-ion (Li-ion) batteries, the decade of the smart phone, iPad, and iPod would not have progressed like it did. Besides entertainment, energy storage plays a critical role in high-tech manufacturing where it is essential to have an uninterruptable power source of constant frequency. It is reported that some $80 billion is lost by U.S. industry each year because of mainly short power interruptions. To ameliorate this, high-tech high-cost industry such as chip fabs have large power storage backups, using, for example, lead acid batteries, as well as frequency smoothing. Flywheels and ultra capacitors are also finding application for grid frequency regulation in such critical applications, as utilities commonly vary the frequency to smooth the power output.

b. TYPES OF ENERGY STORAGE

Compressed air and pumped hydro systems store energy using potential energy .In contrast flywheels store energy by kinetic energy. The faster they spin, the more energy they store. There are two dominant kinds of electrochemical energy storage: capacitors and batteries. In a battery, electrical energy is stored as chemical energy whereas in capacitors energy is stored as surface charge. Thus, the attributes of the materials must be quite different. In batteries, the chemical reactions occur throughout the bulk of the solid, and so the material must be designed to allow the ingress of the reacting species throughout the material and to allow its subsequent removal.

Charging and discharging must occur more than thousands of times to provide a commercially viable rechargeable battery. In contrast, for a capacitor, large amounts of surface are required, the storage capacity being directly related to the surface area. As the structural integrity of a capacitor material is not challenged, pure capacitors can be discharged and charged millions of times without any significant degradation of the materials, whereas in batteries, the chemical

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reactions are not always readily reversed because structural changes of the materials occur. Super capacitors are a hybrid between the two, involving both surface charge and some Faradic reactions in the bulk of the material.

Capacitors and Batteries contain two electrodes, the anode and the cathode. The anode is the electropositive electrode, from which the electrons flow on discharge; the cathode is the electronegative electrode to which the electrons flow through the external circuit doing work. To balance this flow of electrons, normally cat-ions flow through the electrolyte in the battery from the anode to the cathode. This electrolyte, which may be a liquid or a solid, only allows for the flow of ions and not electrons. It is typically an aqueous solution, such as sulphuric acid in the Pb-acid battery or potassium hydroxide in water in the case of the common Zn/MnO2 Energy Storage System usually (ESS) based on Batteries, Ultra capacitor Fuel Cell, Fly wheel In these ESS types, Batteries are taken as a better choice because it has high energy density, Compact size and reliability.

c. TYPES OF BATTERIES

LEAD-ACID BATTERIES[2]

Most lead-acid batteries are constructed with the positive electrode (the anode) made from a lead-antimony alloy with lead (IV) oxide pressed into it, although batteries designed for maximum life use a lead-calcium alloy. The negative electrode (the cathode) is made from pure lead and both electrodes are immersed in sulphuric acid. When the battery is discharged water is produced, diluting the acid and reducing its specific gravity. On charging sulphuric acid is produced and the specific gravity of the electrolyte increases. The specific gravity can be measured using a hydrometer and will have a value of about 1.250 for a charged cell and 1.17 for a discharged cell, although these values will vary depending on the maker of battery. The specific gravity also depends on the battery temperature and the above values or for a battery at 15°C.Specific gravity is defined as the ratio of mass of specific volume of electrolyte to the mass of same volume of water. They are the basic measurement used for finding the performance of the electrolyte. If lead-acid batteries are over discharged or left standing in the discharged state for prolonged periods hardened lead sulphate coats the electrodes and will not be removed during recharging. Such build-ups reduce the efficiency and life of batteries. Over charging can cause electrolyte to escape as gases.

TYPES OF LEAD-ACID BATTERY

Starting Batteries – Used to start and run engines they can deliver a very large current so a very short time, discharging by about 2-5%. If deep cycled these batteries quickly degenerate and will fail after 30-150 cycles but should last for a very long time when used correctly.

Deep Cycle Batteries – Used to store electricity in autonomous power systems (e.g. solar, mini-hydro), for emergency back-up and electric vehicles. These batteries are designed to discharge by as much as 80% of their capacity over thousands of charging and discharging cycles. True deep cycle batteries have solid lead plates however many batteries that do not have solid plates are called semi-deep cycle.

Marine Batteries – Usually a hybrid battery that falls between deep cycle and starting batteries although some are true deep cycle batteries. Hybrid batteries should not be discharged by over 50%.

SOLAR CHARGERS

When lead-acid batteries are charged from a variable source, such as PV panels, three charging stages are normally provided by the charge controller:

Bulk Charge – Current is sent to the batteries of the maximum safe rate they will accept until their voltage rises to about 80 to 90% of their fully charged value. The bulk charging voltage is typically about 14.8V but may be as high as 15.5V for a 12V system, this may vary so that the maximum possible current in maintained. Gel batteries often have lower recommended voltages in the region of 13.8 to 14.1V.

Absorption Charge – The voltage remains constant, typically about 14.2V for a 12V system(depending on temperature) and the current tapers off as the battery reaches 100% charge.

Trickle or Float Charge – For a 12V battery bank a voltage of about of about 12.8 to 13.2V is maintained across the batteries to keep them in good condition.

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Some charge controllers have pulse width modulation (PWM) which can be used to provide the last bit of charge and maintain a trickle charge. Rather than letting the current taper off a larger current is pulsed into the battery, the length of the pulses reduces as less charge is required. These are the various charges used.

BATTERY EFFICIENCY

Due to internal resistance and the fact that the charging voltage is greater than the discharge voltage, the energy returned by the battery upon discharge will be less than the energy used for recharging. Typically a lead-acid battery will be 80 to 90% efficient when considering ampere-hours (i.e. charge transferring efficiency). This figure assumes that the charging and discharging voltages are the same since:

$$\text{ampere-hour efficiency} = \frac{\text{discharged Ah} \times 100\%}{\text{charging Ah}}$$

Capacities are quoted in terms of the number of ampere-hours that a full battery can discharge, but this will only be about 80% of the ampere-hours needed to completely recharge the same battery from empty. The charging voltage is the sum of the cell EMF and the internal voltage drop (due to internal resistance) whereas the discharge terminal voltage is their difference. A truer method is to calculate energy efficiency for a battery using watt-hours. The watt-hour efficiency is typically 65% for a lead-acid battery. Ampere-hour efficiencies are still useful for solar power sizing calculations since these often use ampere-hours when sizing the panel array needed to charge the battery bank but be careful.

LITHIUM-ION BATTERIES

A lithium-ion battery (sometimes Li-ion battery or LIB) is a member of a family of rechargeable battery types in which lithium ions move from the negative electrode to the positive electrode during discharge and back when charging. Li-ion batteries use an intercalated lithium compound as one electrode material, compared to the metallic lithium used in a non-rechargeable lithium battery. The electrolyte which allows for ionic movement, and the two electrodes are the consistent components of a lithium-ion cell. Lithium-ion batteries are common in consumer electronics. They are one of the most popular types of rechargeable batteries for portable electronics, with a high energy density, no memory effect, and only a slow loss of charge when not in use. Beyond consumer electronics, LIBs are also growing in popularity for military, electric vehicle and aerospace applications. For example, lithium-ion batteries are becoming a common replacement for the lead acid batteries that have been used historically for golf carts and utility vehicles. Instead of heavy lead plates and acid electrolyte, the trend is to use lightweight lithium-ion battery packs that can provide the same voltage as lead-acid batteries, so no modification to the vehicle's drive system is required. Chemistry, performance, cost and safety characteristics vary across LIB types. Handheld electronics mostly use LIBs based on lithium cobalt oxide (LiCoO2), which offers high energy density, but presents safety risks, especially when damaged. Lithium iron phosphate (LFP), lithium manganese oxide (LMO) and lithium nickel manganese cobalt oxide (NMC) offer lower energy density, but longer lives and inherent safety. Such batteries are widely used for electric tools, medical equipment and other roles. NMC in particular is a leading contender for automotive applications. Lithium nickel cobalt aluminum oxide (NCA) and lithium titanate (LTO) are specialty designs aimed at particular niche roles.

d. BESS OPERATION STRATEGY

Suitable storage of energy at appropriate time and locations can help to balance generation with consumption, and to maintain system stability. In the following study, a novel battery operation strategy is proposed for better utilization of ESS and power loss reduction in the distribution system.

Battery Charging Issues: The energy changing of BESS, the key issue for battery operation strategy, is described.

Operation Objectives: In this paper, the BESS operation strategies are the same in two different markets. Charging/discharging signals are triggered according to demand gap, SOC,and maximum power. The overall target of operation strategy is to track the forecasted demand curve which can be implemented by the following charging signals:

Charging Amount Allocation: In this paper, BESS are optimally allocated at the distribution system; the charging amount for each BESS should be decided during operation process. The remained spaces determine the charging task. When charging/discharging.

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III. PROPOSED METHOD

Optimum allocation of energy storage system based on hybridized GA and FPSO to mitigate risk of DISCO's is the primary objective of this project. The need for energy storage is an important factor to be considered while doing it.

a. FUZZY PARTICLE SWARM OPTIMIZATION

Optimal Allocation of BESS is a mixed integer nonlinear optimization problem which cannot be easily solved by conventional optimization tools .So we conveniently choose Particle Swarm optimization(PSO) The traditional algorithm of PSO mimics the sociological behaviour of fish schooling or bird flocking [3]. Each particle represents a potential solution for the optimization problem. The main idea of PSO is the exchange of information among the velocity, global best, local best and current particle. Performance is sensitive to its control parameters. Control parameters are inertia weight and learning factors. Mathematical model to describe the dynamical relationship of control parameters is very difficult. Control variables are set as constants. In the FPSO, fuzzy control approach [4],[5] is employed to adaptively adjust these control parameters. The main idea is to integrate fuzzy logic into heuristic algorithm

b. GENETIC ALGORITHM

GA is adaptive heuristic search algorithm based on evolutionary ideas of natural selection and genetics. As such they represent an intelligent exploitation of a random search used to solve optimization problems. Although randomized, GA is by no means random; instead they exploit historical information to direct the search into the region of better performance within the search space. The basic techniques of the GA are designed to simulate processes in natural systems necessary for evolution, especially those that follows the principles first laid down by Charles Darwin," survival of the fittest", because in nature, competition among individuals for scanty resources results in the fittest individuals dominating over the weaker ones. The advantages possessed when combining FPSO with GA is significant. It improves the overall performance and the benefits are discussed below. The Genetic Algorithm is robust and it will not break unlike Artificial Intelligence with small noise. Thus hybridization of GA and FPSO is selected for our project

c. ADVANTAGES OF USING GENETIC ALGORITHM

They are better than conventional algorithms in that they are more robust. Unlike older AI systems, they do not break easily even if the inputs are changed slightly or in the presence of reasonable noise.

IV. SIMULATION

Since the allocation of ESS in distribution system is a nonlinear optimization problem and it cannot be easily handled by traditional optimization approaches, a FUZZY PARTICLE SWARM OPTIMIZATION (FPSO) algorithm is to solve this problem. Since SIMULINK has no tool to do the realization of FPSO algorithm we have to do hardcore MATLAB coding.

V. SIMULATION RESULT

Simulation result of the project using FPSO is shown and analysed. The result with hybridized GA and FPSO is expected to have better optimization and robust. This is an Optimization Process with FPSO. It consist of two variables, number of iteration and fitness values. Actually fitness value means cost of the system. According to the graph, up to sixth iteration cost function is constant. From sixth to ninth iteration there is variation (decrease) in cost. From ninth iteration onwards constant value of cost is minimized. Thus cost for proposed system is minimized and profit increased. The simulation result of the project with FPSO & GA is expected to be robust and have faster convergence to the solution.

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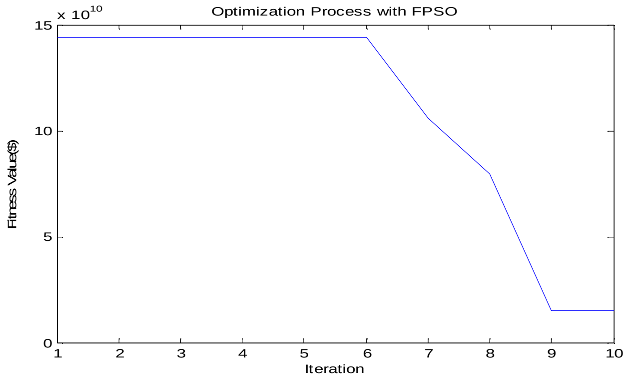

FIGURE 1 FPSO OPTIMIZATION

VI. CONCLUSION

This project is a efficient method and practical model for the operation of DISCOs. The optimal allocation and control strategy of Battery Energy Storage system can help DISCOs mitigate the risk of the energy trading under both LMP market and regulating price market. Especially the distribution system with high penetration of renewable energy, the BESS is applied for reducing the loss caused by the uncertainty of the load and distributed generators. The effectiveness of the proposed project has been tested with comprehensive case studies. From the case study results, the distribution company saves the energy purchasing cost through optimal planning and schedule a more suitable energy purchasing plan. Meanwhile, the BESS optimal allocation method is proved to be effective. Introduction of more stimulus policies and along with development of battery technology, the costs of battery will decrease, which makes the BESS application more feasible.

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