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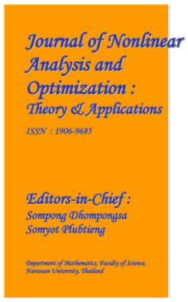

INTELLIGENT ELECTRICAL LOAD SHEDDING IN HEAVILY LOADED INDUSTRIAL ESTABLISHMENT

[1]S Rajesh, [2]R Aruna, [3]A Srinivasulu, [4]A Soddulu

[1234]Assistant Professor, Department of Electrical and Electronics Engineering, Visvesvaraya College of Engineering, Hyderabad.

ABSTRACT

The purpose of a Load Shedding Control System (LSS) is to prevent a dangerous overloading of the generators and/or a general collapse (blackout) of an electric power system due to a generator failure or any contingency which may diminish the capacity of the operational generators below the active power required by the loads. Such a state may create an imbalance in the power supply and thus lead to a frequency decay, voltage collapse and overload on all the power generation units connected to the system. In case the electrical supply is inadequate to meet the demand of the process loads, partial supply to certain areas can be interrupted in order to prevent the failure of the whole electrical system. This process is called load shedding. This is an entirely different concept from a power failure that may occur due to various reasons. Load shedding is an effective method to prevent a total collapse of the electrical supply, which may have a disastrous impact on the continuity of the processes and operations. Unless power imbalances are properly managed, they may cause the entire workflow to collapse until the power to the industrial establishment is restored. The aim of this paper is to discuss the electrical load shedding process of a refinery, which is a heavily loaded industrial establishment, in detail.

INTRODUCTION

Maintaining the power supply to the critical process loads is vital for an industrial cogeneration power plant, both for the continuous production and the overall safety of the plant during emergencies. A sudden interruption of the production may result in significant economic losses and even cause major safety concerns. The majority of industrial establishments that require an uninterrupted energy supply in the form of electric power and steam choose to install cogeneration units [1]. Though power systems are designed to function under normal conditions, they also include a safety margin for emergencies. The main objective of the electric utility is to operate the power system without exceeding the system constraints and operational limits. However, in certain conditions such as a sudden increase in the system demand or an unexpected power failure, system constraints and operational limits may be exceeded beyond the tolerance limits. In such cases, load shedding is considered an emergency measure to avoid cascaded tripping and a blackout [2]. One of the best known methods of load shedding is undervoltage load shedding. In case of an extreme event in a network, undervoltage load shedding can be applied as an economical method to prevent a voltage collapse and to maximize the power system's loadability. In this method, different bus voltages are considered as overloads or voltage collapse indices [3]. A second common type of load shedding is frequency load shedding. An imbalance in the active power supply may lead to frequency changes [3]. If voltage and frequency deviate outside the permissible range, the system becomes unstable. Thus, the system controllers attempt to restore the normal voltage and frequency values within the permissible range. If the disturbance is so large that the controllers cannot restore normal function, load shedding is the last resort to avoid the breakdown of the power system [4]. Load shedding is a commonly applied method in states of emergency/extreme emergency where the system is headed for a collapse. Given the appropriate conditions, the load shedding process should be started as soon as possible [5]. For this purpose, different techniques including circuitbreakers interlocking, LS based on under-frequency relays, and LSS based on PLC or micro-controllers have been developed over the years. These techniques shed a predefined amount of load (power blocks) in order to reach a balanced power state according to the available generation capacity, thereby providing faster and optimum responses during a sudden loss of power. In this paper, we would like to present a load shedding system activated either by under-frequency or a lack of generation capacity depending on operational states.

LITERATURE REVIEW

"Load Shedding Design for Industrial Cogeneration System,"

This paper presents transient stability analysis and enhancement of Industrial Cogeneration Plant (ICP) using Artificial Neural Network (ANN) based adaptive load shedding. By selecting the total in-plant generation, spinning reserve, total plant load and rate of change of frequency as the input neurons of the ANN, the minimum amount of load shedding is determined to maintain in-plant load-generation equilibrium and to ensure continuity of power supply to critical loads of the plant. The comparison of under frequency relay based load shedding and ANN based adaptive load shedding is also preformed to evaluate effectiveness of the ANN based Load Shedding. The system frequency response for deferent generation-load scenarios is also determined. The industrial cogeneration is simulated on ETAP software and transient stability is analyzed by considering various contingencies and load-generation scenarios. ANN has been implemented on MATLAB.

Power supply to critical process loads is extremely important for an industrial cogeneration power plant not only for continuous production but also important for overall plant safety during severe disturbances. A sudden interruption in production may result in significant economic loss and raise safety concern. Most of the industrial customers with requirement of uninterrupted input of energy in the form of electric power and steam have installed cogeneration units. The cogeneration systems are broadly defined as the coincident or simultaneous generation of the combined heat and power (CHP) [1]. By installing cogeneration units industrial customer can achieve better efficiency of energy usage and enhance the reliability of electricity power supply [2]. The cogeneration has to be tied together with the Public Power Company (PPC) to cover the mismatch of load demand and power output by the cogeneration units in the plant and for the consideration of power quality. The several techno-economic studies [3-5] are required periodically throughout the operating life of the plant to ensure that a cogeneration plant will operate safely, reliably, and economically. To prevent total blackout and to stabilize the system under any abnormal condition, appropriate Islanding and Load Shedding (LS) strategies must be developed for industrial cogeneration system. The load shedding technique primarily can be classified as conventional load shedding technique and Adaptive or Intelligent load shedding technique. Conventional load shedding schemes, breaker interlock load shedding [11], under-frequency relay (81) load Shedding [6, 7, 10, 11], programmable logic controller-based load shedding are most common and easy way to isolate the excess amount of load during generation deficit in the islanded power system. The conventional schemes are designed to work on worst system operating conditions. These schemes are not include, real-time system configuration, type and duration of the disturbances, as well as other important information and total loss of the system is an assumed possibility [14]. Conventional methods of system load shedding are too slow and do not effectively calculate the correct amount of load to be shed. Several schemes are reported in the literature [12-17] to overcome the shortcomings of the conventional load shedding schemes, by making it adaptive through complete understanding of power system dynamics. In this paper ANN based load shedding method in comparison to under frequency relay based load shedding is described. In order to illustrate the effectiveness of the proposed ANN based load shedding approach for the islanded ICP system, a large Oil Storage Terminal and refinery distribution system is investigated as a case study. Section 2 introduces system description and configuration of the ICP system. In Section 3, power studies are conducted, the frequency response of the system is analyzed. Section 4 illustrates ANN based load shedding, the 81-relay based and ANN based load shedding methods are compared in section 5 and concluded in section 6.

"Steady State Load Shedding to Mitigate Blackout in Power Systems Using an Improved Harmony Search Algorithm,"

Generation contingencies in a power system lead to under-frequency and low voltages owing to active and reactive power deficiencies. Load shedding is considered as a last alternative to avoid the cascaded tripping and blackout in power systems during generation contingencies. It is essential to optimize the amount of load to be shed in order to prevent excessive load shedding. To minimize load shedding, this paper proposes the implementation of music inspired optimization algorithm known as improved harmony search algorithm (IHSA). The optimal solution of steady state load shedding is carried out by squaring the difference between the connected and supplied power (active and reactive). The proposed algorithm is tested on IEEE 14, 30 and 118 bus test systems. The viability of the proposed method in terms of solution quality and convergence properties is compared with the other conventional methods reported earlier.

Power systems are designed to be operated for normal conditions including a margin for emergencies. Under these conditions the generation and transmission capacities are adequate. The main objective of the power utility is to operate the power system without violating the system constraints and operational limits. But under certain situations such as sudden increase in system demand or unexpected outages, the system constraints and operational limits are violated. Load shedding is considered as a last resort to avoid cascaded tripping and blackout. It is defined as coordinated sets of controls that decrease the electric load in the system to restore the system back to its normal operating condition. By carrying out load shedding, the perturbed system can be forced to settle to a new equilibrium state. Different methods of load shedding either in steady state or in transient state have been proposed. An optimal load shedding program finds a best steady-state stable operating point for a post contingency system with a minimum amount of load shed. The optimal steady state load shedding problem that uses the sum of squares of the difference between the connected active and the reactive load and the supplied active and reactive power has been formulated in [1]. A voltage dependent load model is used to express the active and reactive power demands. Systematic approaches toward minimizing the curtailment of service in a power system after a severe fault have been discussed in [2]. Here, a feasible steady state solution defining the priority schedules for the post fault condition is obtained first and then the minimum load to be shed is obtained by gradient technique. Newton–Raphson technique and Kuhn-Tucker theorem are used to solve the power flow equations and the optimization problem respectively. The active and reactive powers of loads are assumed to be independent of bus voltages. In [3], second order gradient technique (SOGT) has been proposed to minimize the load curtailment during a sudden major supply outage or tripping of tie-line breakers. Here, the generator control effects and the voltage and frequency characteristics of loads are considered during optimization. Optimal load shedding policy with generator control effects and voltage and frequency characteristics of loads has been suggested in [4]. Here, power generation is considered as dependent variable in the dynamic problem formulated. Optimal load shedding using the sum of squares of the difference between the connected active and reactive load and the supplied active and reactive power has been presented in [5], which considers the supplied active and reactive power as dependent variables and modeled as a function of bus voltages only. A sensitivity based approach to solve the load shedding problems and to minimize the loss of loads has been proposed in [6]. In order to limit the size of the load being dropped, different priorities to loads are assigned using a weighted error criterion. The method overlooks equipment and operational limitations. In [7,8], a non-linear optimization problem has been formulated for the optimal load shedding and rescheduling of generators during an emergency state. The non-linear problem has been approximated by an accurate sensitivity model which takes into account the real and reactive nodal injections, voltage magnitudes and angles. Loads' sensitivity to voltage magnitudes is also considered. An upper-bounding sparse, linear programming algorithm is used to solve the problem. To improve the computational efficiency, reduced size problems are considered in the iterative procedure. In [9,10], two different methods for generation rescheduling and load shedding to alleviate line overloads, based on the sensitivity of line overloads to bus power increments have been developed. In [11], a mesh approach has been developed for the formulation of the network equations in the load flow analysis. A hybrid approach using a combination of an impedance matrix method and a nodal-admittance matrix method which exploits the salient characteristics of the impedance and admittance method is developed. A new power flow model for the steady state behavior of large complex power system that allows the study of power flow under normal and abnormal operating conditions has been developed in [12]. In [13], differential evolution algorithm has been implemented for optimal allocation of repair times and failure rates in meshed distribution system. An optimal under-voltage load shedding scheme to provide long term voltage stability using a new hybrid particle swarm based simulated annealing optimization technique has been presented in [14]. The technical and economic aspects of each load are considered by including the sensitivities of voltage stability margin into the cost function. In [15], a new voltage stability margin index considering load characteristics has been introduced in under-voltage centralized load shedding scheme. Quantum inspired evolutionary programming has been implemented in [16] for the optimal location and sizing of distributed generations (DGs) in radial distribution system. In [17], an optimal load shedding scheme has been proposed to monitor the load-generation unbalance in the plants with internal co-generation and to quickly initiate shedding of an optimal amount of load during a contingency. DC optimal load shed recoveries with transmission switching model have been presented in [18]. This model reduces the amount of load shed required during generation and/or transmission line contingencies, by modifying the bulk power system topology. An approach based on parallel-differential evolution has been proposed in [19] for the optimal load shedding against voltage collapse. The non-linearity of the problem is fully considered in this approach and thereby able to escape from local optima and not limited to system modeling. Corrective and preventive control strategies to mitigate power system voltage collapse during severe contingencies have been proposed in [20]. Basically, the optimal load shedding strategies are classified into two types, namely, centralized load shedding and de-centralized or distributed load shedding. Centralized load shedding strategies are solved based on stability margin sensitivities. These methods are based on the assumptions of linearity and constancy of the sensitivities [21], and depend on linear programming techniques to solve the comprehensive optimization problem. In actual practice, these assumptions are not realistic [22], particularly when the non-linear characteristics of the system components, such as, reactive power generation limits, actions of switched shunt devices load-tap changers and so on are considered. A multi-stage method to solve the non-linear optimal load shedding problem stage by stage has been presented in [22]. Here, each stage corresponds to a linearized sub-problem based on sensitivity analysis. Usually these methods do not consider priorities for the loads to be shed, whereas, in distributed load shedding schemes priorities for the loads are being considered. Moreover, in the mathematical formulation of optimal load shedding schemes, reactive power of loads to be shed is not considered [13–22]. Also, the loads are considered to be independent of the system voltage, but in actual practice, the real and reactive power of the loads depends on the system voltage [1]. The contribution of this paper consists of proposing an alternative approach based on improved harmony search algorithm (IHSA) for efficiently and globally optimizing the steady state load shedding problem. The proposed scheme makes use of distributive load shedding with priorities for the significant loads. In this scheme, the active and reactive power demands of the system are expressed using a polynomial function of the bus voltage. In addition, the reactive powers of the loads to be shed are also considered during the problem formulation, which minimizes the amount of load shed required for the contingencies considered.

"New Design of Intelligent Load Shedding Algorithm Based on Critical Line Overload to Reduce Network Cascading Failure Risks,"

In viewing the power grid for large-scale new energy integration and power electrification of power grid equipment, the impact of power system faults is increased, and the ability of anti-disturbance is decreased, which makes the power system fault clearance more difficult. In this paper, a load shedding control strategy based on artificial intelligence is proposed, this action strategy of load shedding, which is selected by deep reinforcement learning, can support autonomous voltage control. First, the power system operation data is used as the basic data to construct the network training dataset, and then a novel reward function for voltage is established. This value function, which conforms to the power grid operation characteristics, will act as the reward value for deep reinforcement learning, and the Deep Deterministic Policy Gradient algorithm (DDPG) algorithm, with the continuous action strategy, will be adopted. Finally, the deep reinforcement learning network is continuously trained, and the load shedding strategy concerning the grid voltage control problem will be obtained in the power system emergency control situation, and this strategy action is input into the Pypower module for simulation verification, thereby realizing the joint drive of data and model. According to the numerical simulation analysis, it shows that this method can effectively determine the accurate action selection of load shedding, and improve the stable operational ability of the power system.

Modern power systems are a typical nonlinear system. In order to maintain the stability of the power system, it is necessary to control the bus voltage within the standard range. The traditional rules and methods of voltage regulation primarily rely on historical experience and off-line research, the effect is not very ideal, sometimes too conservative, and sometimes there are risks, which cannot meet the random changes of the power system. At the same time, with the in-creasing scale of power systems, new energy, electric vehicles and other uncertain factors being added, the safe and stable operation of the power system becomes more challenging [1].

The local active power imbalance, caused by generator unit outage and tie line fault interruption, will lead to grid frequency drop, and further cause the generator unit's low-frequency protection device to operate. Eventually, the generator will be removed. In recent years, major blackouts around the world, that have occurred, are basically following this process. Therefore, taking measures to reduce the imbalance of active power in the early stage of power system failure is the main method used to prevent the frequency collapse of the power grid. When the demand of the system load power exceeds the limit of the system generator output, partial load capacity is actively or passively removed, which is an important measure to maintain the stability of the power system [2].

With the progress and development of science and technology, artificial intelligence technology is more and more widely used in actual industrial production. Reinforcement learning, as a representative artificial intelligence technology, has been successfully applied in AlphaGo. By constantly providing offensive and defensive strategies, it outperforms the competition. In the field of power industry, reinforcement learning has also been applied, especially in power grid control [3].

Reference [4] proposes a method combining game theory and reinforcement learning to improve power system security with a multi-stage game between the attacker and the de-fender. Reference [5] uses the reinforcement learning method to generate a discrete switching control strategy, so as to control the generator tripping in the emergency state of the power system and avoid loss of synchronism. A new false data injection attack strategy is proposed in [6], which is used to attack the normal operation of the power system with automatic voltage control (AVC), and then a Q-learning algorithm is used for online learning and attack to maintain the security of the AVC system. In [7], the convolutional neural network (CNN) is used as a function approximator to estimate the state-action Q function in the learning process of fitting Q iteration, and the strategy which is implemented can effectively reduce the power consumption cost of load cluster. In [8], a reinforcement learning framework is developed to optimize the operation of the power gridand the Artificial Neural network (ANN) is used to replace the state-action value function. The results show that Q-learning with ANN has good approximation ability. Reference [9] presents a consensus transfer Q-learning method for automatic generation control, which accelerates the convergence speed of the algorithm based on the prior knowledge of the source task. In [10], the variable learning rate is adopted to obtained the optimal strat-egy’ and this strategy is applied to the large-scale centralized automatic generation control of new energy and distributed energy in the power grid. Reference [11] develops a suitable convergence criterion for the reinforcement learning method with temporal differences, and this method is applied to the load shedding calculation. In [12], the double Q model and dueling Q model are combined to improve the performance with Q-Learning, and the power system emergency control strategy can be obtained by comparing the Q value to maintain system stability. Reference [13] presents a novel two-timescale voltage regulation scheme for distribution networks, and on a slower time scale, the deep reinforcement learning algorithm is used to minimize the long-term discounted voltage deviation. In [14], an intelligent generation controller based on the deep Q learning algorithm is proposed, and results of the simulation show this controller can control and optimize the active power of the generator in multiple regions. Reference [15] presents an emergency control scheme for generator dynamic braking and low-voltage load shedding based on the combination of an open-source platform and deep reinforcement learning, which results is good robustness. In [16], a Grid Mind paradigm is proposed, which uses the deep reinforcement learning method to achieve autonomous grid operational control, and realize the generation of a voltage control strategy for the power system.

In [17], load frequency is controlled by deep reinforcement learning in a continuous action domain to deal with the uncertainty of renewable energy, and the control strategy of minimum frequency deviation can be derived nonlinearly by this method with fast response speed and strong adaptability. Reference [18] makes use of the simulation data of the open source platform and DDPG method to let the agent learn the power grid voltage control problem from scratch, and realize the autonomous voltage control of the power system.

In summary, the current existing emergency control schemes are usually designed offline based on several typical operating scenarios. And most of the reinforcement learning methods used are the deep reinforcement learning methods of discrete action control. There are not many studies on the continuous action control of the deep reinforcement learning method, especially on the load shedding problem. With the increase of uncertainty and changes in modern power grids, the control and prevention of power grids will face important adaptability and robustness issues. In this paper, based on the DDPG method, a reward function with voltage information is set up to guide the agent for training, and the Pypower module is used for system simulation, so as to realize the emergency control of the power system and ensure the safe and stable operation of the power grid. This research combines both data driven and model driven methods, and allows the artificial intelligence algorithm to have a certain generalization ability.

“Effect of Load Shedding Strategy on Interconnected Power Systems Stability When a Blackout Occurs,”

From the long time ago properly and reliable operation of power systems were being the major portion of designer's and operators concernment. In the interconnected power systems voltage and frequency of system are most significant parameters for analysis the power system operation. In this paper sudden blackouts in a supposition interconnected power system will be simulate and effect of under frequency load shedding to restore the power system in stable condition will be study.

Blackouts of power systems always have been a historical problem in interconnected power systems. However in recent years by improving monitoring and protection techniques, it is not possible to completely prevent of blackouts [1-2]. Sudden and large changes in generation capacity such as the outage of a generator can produce a sever imbalance between generation and load demand. This may lead to a rapid decline in frequency, because the system may not respond fast enough. If voltage and frequency are get out from permissible range that means the system is in unstable condition. In this condition the system controller's are operate and attempt to restore the voltage and frequency in the permissible range. If the disturbance is so large the controller's cant restore the voltage and frequency in the permissible range. In this condition the last solution to avoid the power system breakdown has been load shedding strategy. Blackout of generation units is one of critical disturbances that may occur in the interconnected power systems. In this condition frequency and voltage of power system are rapidly decline and other generation units will be over load. If the other generation units can't suffer this condition, they will be blackout once to once. Blackouts have irreparable economic effects on interconnected power systems. In this paper effect of load shedding strategy on restoring the power system in stable condition and preventing of other blackout in power system will be study. The system may even collapse in sever imbalances. Rapid and selective shedding of loads from the system may be a good option to restore the balance and maintain the system frequency [3]. When a power system is exposed to a disturbance, its dynamic and transient responses are control by two major dynamic loops. These loops are: (A) excitation loop (including AVR), this loop will control the generator reactive power and voltage. The excitation loop is operating via the excitation current regulation. And (B) frequency loop (including LFC), when the system is exposed to a disturbance this loop is control active power and frequency of system. This loop is operating via regulating of Governor.

"Minimization of Load Shedding by Sequential use of Linear Programming and Practicle Swarm Optimization,"

Minimization of load shedding during contingency conditions is solved as an optimization problem. As a new topic, instead of local load shedding, total load shedding of a large power system is considered. Power generation rescheduling is considered to minimize the load shedding, as well. Different importance factors for buses are also considered. The linear programming method (LP) is used to solve this problem in a short period of time without considering some power system constraints. Particle swarm optimization (PSO) is also used to solve the problem by considering all power system constraints, but with a longer solving time. Finally, a new method, the sequential use of LP and PSO, is proposed, which is faster than PSO and considers all constraints. The IEEE 14 bus test system is used to compare the performance of the mentioned methods and a comparison of the proposed algorithm and genetic algorithm is accomplished.

The emergency state may occur in a power system as a consequence of a sudden increase of system load, the unexpected outage of a transmission line, a generator, or failure in any of the system components. This state may result in some problems such as line overloading, underfrequency, voltage collapse, and angle instability [1]. Generation rescheduling and/or load shedding can be used to overcome the mentioned problems effectively. Generation rescheduling means changing the active and reactive power of generators to decrease the severity of contingency. Load shedding is a usual operation in emergency and extreme emergency states in which the system is driven toward collapse. In the emergency state, if the controllers of the power system cannot drive the system to a "normal state," the load shedding has to be applied as soon as possible. Much literature has been published on generation rescheduling and load shedding to alleviate line overloading [2].

It is a common practice for utility companies to perform load shedding by using underfrequency relays to disconnect the predetermined load when the frequency drops below set values [3]. A load shedding method that considers the frequency decay rate is also applied for utilities in reference [4]. The load shedding problem has been solved by many mathematical techniques, such as linear programming (LP), nonlinear programming, and the interior point method [5-7]. These algorithms are fast, but they need some approximation in the power system model. In other words, some constraints cannot be considered in these schemes. In some other research projects, the load shedding problem has been solved by evolutionary algorithms such as the genetic algorithm (GA) and particle swarm optimization (PSO). These evolutionary algorithms are rigorous and can consider all constraints, but they have low convergence speeds [8, 9]. In order to achieve an algorithm that has the advantages of the mentioned algorithms, "rigorous and fast," a new algorithm is proposed by combining the LP and PSO methods. In order to obtain the minimum load interruption, load shedding was applied to the network generally. In this way, energy suppliers may pay the least amount of cost for energy not supplied (ENS). To reveal the superior advantages of the proposed algorithm, each of the 3 algorithms (LP, PSO, and proposed method) were applied to the IEEE 14 bus test system in the event of 2 critical contingencies, and the results were compared. The procedure in reference [8] was also evaluated and applied to this problem, and the results were compared with this paper's proposed methods.

"Optimal Load Shedding Strategy fo Selcuk Univerity Power System with Distributed Generation,"

ditionally under frequency relays and PLCs (programmable logic controller) are used for load shedding. Recently, these methods have been combined with smart power management systems to shed load automatically. These combined systems are the best methods. However, shedding exact amount of load is almost impossible, because it usually ends up with excessive or inadequate load shedding at feeders where it becomes necessary to sustain system stability. Disconnecting a certain amount of loads at a feeder is defined as load shedding. In case of emergency, faster and optimal load relief can be obtained with an intelligent load shedding system. This paper demonstrates an intelligent load shedding strategy in electrical system of Selçuk University Medical Faculty consisting different type and size of loads and being supplied by a distributed generator. Generators which supply with Selçuk University Medical Faculty can't meet energy requirement when there is a disturbance in power system. In case of 1 MW Solar power plant to be building at University Campus supply to Medical Faculty, the difference between power generation and demand will decrease. In this case, load shedding becomes necessary to improve reliability of power supply and sustain system stability. Loads are sorted by importance priority and optimal load shedding method is applied. The fuzzy logic is employed for optimal load shedding solution. Strategy is applied on Medical Faculty loads which have different importance level.

Distributed generation is an electric power plant which is generally connected to the distribution network and located close to customers (Ackermann, Andersson, & Söder, 2001). It is small scale power generation units which include different types of technologies such as wind turbine, photovoltaic arrays, fuel cells, biomass or micro turbines. In the future, distributed generation is expected to make a major contribution to the existing electric power systems (El-Khattam & Salama, 2004). Recently, distributed generation penetration has been increased into distribution networks, which can impact positively or negatively under some conditions at customers and utility equipment. Distributed generation has some advantages such as loss reduction, improved utility system reliability and deferments of new or upgraded T&D infrastructure (Barker & de Mello, 2000). However, distributed generation penetration into the distribution networks will change the structure of distribution system; therefore new problems can occur in power systems. One of the issues is load shedding during islanded mode. The distributed generation system works independent from grid system in islanded mode (Xu & Girgis, 2001). Disconnecting a certain amount of loads at a feeder is defined as load shedding. It is an emergency management type which protects the power system. The power systems should supply continuous, quality and reliable electric energy to end user (Aponte & Nelson, 2006). However, when any failure occurs in power systems, it can't meet energy requirement due to big difference between power generation and demand (Rao et al., 2013). System should shed some loads to compensate for big difference. If this difference is compensated with this technique, system can sustain stability and work more reliable. Traditionally under frequency relays, breaker interlock systems and PLCbased systems (programmable logic controller) are used for load shedding. However these load shedding systems don't consider system operating information. Although these are still best-guess methods, it usually ends up with excessive or inadequate load shedding at feeders.

In case of emergency, faster and optimal load relief can be obtained with an intelligent load shedding system (Shokooh et al., 2005). To sustain the system stability, load shedding techniques are commonly applied. Different researches have been presented to deal with the load shedding problem in distribution network with distributed generation. In (Xu & Girgis, 2001), an optimal load shedding strategy for power systems with multiple DGs is presented and in this paper the load shedding is formulated as an optimization problem subject to system, operation and security constraints. In (Malekpour & Seifi, 2009), a genetic algorithm (GA) based optimal load shedding that can apply for electrical distribution networks with and without dispersed generators (DG). The objective is to minimize the sum of curtailed load and also system losses within the frame-work of system operational and security constraints. In (Hirodontis, Li, & Crossley, 2009), a load shedding method to provide safe operation of islanded distribution network is proposed. The proposed method determines magnitude of disturbance via swing equation. In (Laghari et al., 2012), efficient load shedding strategy based on fuzzy logic for islanding operation of a distribution network and generator tripping in distribution network is presented. This paper demonstrates an intelligent load shedding strategy in electrical system of Selçuk University Medical Faculty. When Medical Faculty is supplied by generators and a distributed generator during blackout, there will be difference between power generation and demand. In this case, load shedding becomes necessary to improve reliability of power supply and sustain system stability. Loads are sorted by importance priority and optimal load shedding method is applied. The fuzzy logic technique is employed for optimal load shedding.\

“IEC 61850-Based Islanding Detection and Load Shedding in Substation Automation Systems,”

Distributed generation (DG) systems are common within industrial plants and allow continuity of supply to critical loads. In cases when DG cannot support the entire system load, islanding detection (ID) and load shedding (LS) schemes are required. Such an automation scheme serves to monitor the connection to the grid and generation-load imbalance, and it controls the load shedding process. The design of such schemes has undergone significant revolution from electromechanical relays and PLC systems to the use of communications-enabled intelligent electronic devices. This paper discusses the design of an IEC 61850-based smart ID and LS scheme using a complete system design approach. Novel control algorithms are presented for the ID and initiation processes as well as the LS process. The study proposes an innovative system, which incorporates the generator governor gain factor in LS decisions, and assists in avoiding unnecessary amounts of LS.

Distributed generation (DG) systems are often installed at industrial plants where the quality and reliability of supply is a major concern. On-site DG offers solutions to many challenging problems, including blackouts and brownouts, and aids in reducing the plant costs. This ensures an uninterrupted supply of power, often large enough for the critical processes in the case of disruptions. Islanding (also known as ‘loss of mains’) is a condition where a part of the network gets disconnected from the grid and continues to operate in a stand-alone mode. The size of on-site generation is often not large enough to run all the normal processes when islanding occurs. In such cases, load shedding (LS) is needed to disconnect the noncritical load, ensuring the continuity and quality of supply to the critical plant loads. IEC 61850 [1] is an international standard developed for substation automation and is likely to impact how electrical power systems are designed and built for many years to come. The model-driven approach of the IEC 61850 standard describes the communication between substation devices and the related system requirements [2]. Simply speaking, IEC 61850 defines how processes in a substation are to be modeled and what/how data are to be communicated between substation equipment [3–5]. Figure 1 shows an industrial substation single-line diagram (SLD). A new nitric acid plant/ammonium nitrate solution plant (NAP4/ANS3) will be built as well as an ammonium nitrate prill plant (ANP3). Higher reliability of NAP4/ANS3 is required and ANP3 may operate at 85% or less availability. A new 12.18 MVA synchronous generator is also being installed. The plant has previously experienced undervoltage (UV) dips below 80% and frequency disturbances of 1–2 Hz. The protection equipment operates under disturbances and trips after 300 ms, resulting in uncontrolled islanding. In the case of grid distortions, a P418 circuit breaker (CB) opens and substation 3 gets islanded. P418 is the incomer CB connecting substation 3 to the utility system. The plant has previously experienced trips from the utility supply. Therefore, it is vital to detect grid separations and have mechanisms in place to shed the noncritical loads, ensuring a healthy supply to the high priority loads. In the case of power disturbances greater than 300 ms, supply should switch to islanded-mode. The plant currently trips under undervoltage conditions (less than 85%) lasting 0.5 s or longer. In this paper, a detailed literature review is presented on the previously reported IEC 61850-based islanding detection and load shedding (IDLS) schemes. The design of the IEC 61850-based IDLS scheme is discussed from a range of aspects including the design of the communication network, Generic Object Oriented Substation Event (GOOSE) messaging, and the development of 2 discrete ‘islanding detection’ and ‘load shedding’ control schemes. The study proposes the incorporation of the generator governor gain factor (K) in LS decisions, the most significant novel attribute of this paper against other published works in this field.

CONCLUSION

The load shedding system is the last resort as a backup measure in cases where an electrical power system faces a disturbance that causes an imbalance between the mechanical power supplied and the power required by the load. A rapid initiation of preventive measures and the optimum response are the key features for a successful system recovery under these conditions. Based on the evaluation of the power generation capacity, loads, and the interconnection constraints of the new and existing refineries, it is possible to estimate the main load shedding scheme for inadequate generation capacity logic used as the main protection against islanding power imbalance conditions. The load shedding scheme and the load priority list are used as design references in the programming process, and all the possible operational modes and load conditions that can occur in the refineries' power networks are taken into consideration. In case of any changes in these parameters, the LSS logic should be updated in order to guarantee the proper operation of an industrial electrical system. In addition, the LSS was also evaluated based on underfrequency conditions. This analysis has pointed to the need for different settings as a function of the power network topology (adaptive logic) due to the different frequency responses depending of the interconnection status between the new and existing refineries and the possible overload conditions. In order to predict these frequency behaviors, a simplified equivalent model of the power systems (the new and existing refineries) has been used, which has helped define the load shedding steps in each specific case studied. These results have demonstrated that is not possible to fully accomplish the decoupling requirements dictated by the Turkish Electricity Market Grid Regulation. Therefore, it is proposed to define a group of settings at the decoupling and under-frequency relays.

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