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Study of PLC based Load Shedding Schemes in a Captive Power Plant

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ABSTRACT: In developing countries a large demand of power will be seen in future. It is essential to maintain power continuity and reliability. Contingencies like fault occurrence and generated power and load demand imbalance causes system frequency instability. Load-shedding is the ultimate solution to restore system frequency and ensure availability of electrical power to critical loads in the plant. To ensure system stability and availability during disturbances, industrial facilities equipped with on-site generation, generally utilize some type of load shedding scheme. Conventional under frequency and PLC-based load shedding schemes have been integrated with computerized power management systems to provide an "automated" load shedding system. The adopted schemes calculates the consumed power continuously and turn off the low priority appliances in case of lack of power.

KEYWORDS: PLC, Load Shedding schemes, Captive power plant.

INTRODUCTION

Electric power generation may not always meet peak demand requirement. In this situation, overall demand must be lowered, either by turning off service to some devices or by cutting back the supply voltage, in order to prevent uncontrolled service disruptions such as power outages (widespread blackouts) or equipment damage. Distribution control centers may impose load shedding on service areas via rolling blackouts or by agreements with specific high use industrial customers to turn off equipments at times of system-wide peak demand.

The major disadvantage of load shedding is that the consumers are totally restricted from using electric power .Even in case of an emergency they won't be able to use electric power. This project mainly aims to address this problem by dividing the loads of the consumer into different priority groups and when it is required to do load shedding then the lowest priority loads of the consumer will only get disconnected from the power supply. Thus providing consumers with the benefit of using electric power for their most needed high priority loads even when load shedding is done.

This paper presents a review of load shedding schemes to restore load generation balance and keep system frequency within permissible limits. Therefore Load shedding helps to maintain the power system stability and reliability.

II.REVIEW OF LITERATURE

In this section, brief overviews on review of literatures regarding load shedding are presented

Sunil Ku. Mahapatro (2014) In his research contributions has provided strategies for load shedding using Fuzzy logic. His idea is to estimate in real time the amount of load to be shed. Fuzzy algorithms are used to generate command vectors to obtain the solution sets.

S. Pahwa *et al.* (2013) in their outstanding work have provided with effective strategies to avoid cascaded network failure in the power grid. In their research they have used tree heuristic algorithms for effective load shedding. Tree heuristic approach overcomes the drawback of an optimization algorithm. Also, it provides an effective solution to avoid the cascading failures.

Emmy Kuriakose and Filmy Francis (2013) in their research contributions have proposed an optimal method for under frequency load shedding using artificial neural networks. In their work a fast and an adaptitive load shedding method is presented using ANN. The test system used by them is an IEEE -39 bus system and the simulations are presented using MATLAB. Also, they have highlighted ANFIS mechanism to predict the amount of load to be shed.

Liu Zhou *et al.* (2012) have proposed a methodology for emergency load shedding based on sensitivity analysis of relay margin. Their work is based upon finding the sensitivity analysis between the relay operation margins and power system state variables. Load dynamics is also considered. Test system is built in real time digital simulator.

Cheraghi Valujerdi and M. Mohammadian (2012)[9] in their research contributions have presented a novel load shedding scheme to improve transmission line performance. The test system used by them is an IEEE – 14 bus and an IEEE -57 bus system. PSO technique is used to check the efficacy of the proposed method.

Mehdi K. Moghaddam and Parisa A Bahri (2012) in their research contributions regarding load shedding have demonstrated a new idea for forecasting electricity loads. In their research non-linear approaches of neural networks and decision trees have been applied. Accordingly, a model has been fitted for load shedding. A modified adaptation of mean absolute percentage error (MMAPE) method is also applied for each model.

M. H. Moradi and M. Abedini (2010) in their research contribution have presented optimal load shedding approach for distribution systems in a way to improve system stability. Their objective is to reduce the amount of load to be shed. Voltage deviation index is used to identify the sensitive buses.

Yuping Lu *et al.* (2006) in their contributions have proposed an intelligent islanding techniques considering load balance. A new concept of cell is proposed as well as heuristic logic is also proposed for an islanding model. Their method is much suited for priority services.

III. DESCRIPTION OF CAPTIVE POWER PLANT

Captive Generating plant means a power plant set up by any person, association or any company to generate electricity primarily for his or her own use and includes a power plant set up by any co-operative society or association of persons for generating electricity primarily for use of members of such co-operative society or association1. A dedicated transmission line can also be build, operated or maintained by the same person for the transmission of electricity produced out of such captive plant. Every such person has a right to open access for the purposes of carrying electricity from his captive generating plant to the destination of his use subject to availability of transmission facility by CTU or STU, as the case may be.

A group captive scheme is where someone develops a power plant for collective usage of many commercial consumers. At present, a power project is considered 'captive' if consuming entity or entities consume at least 51% of the power generated and owns at least 26% of the equity. Various capital structures have evolved to qualify as captive under the rules. For example, a major portion of the capital could be preference shares, with only a small portion being equity capital. Thus, owning 26% of the 'equity capital' actually translates to a very small amount relative to the overall investment in the project. Large group captive capacities that are more efficient and thus less carbon-intensive should be encouraged so that plant capacities are better utilized and surplus power from these captive plants supplied to the grid. Further, taking policy measures to promote rapid development of renewable energy and hybrid low-carbon technologies as back-up and standalone power sources would assist in reducing the carbon footprint of captive power generation.

IV.LOAD SHEDDING SCHEMES

In a stable power system, the total mechanical power input from the prime movers to the generators is equal to the total connected load plus the real power losses in the system. Contingencies during operation such as loss of source or tripping of large loads will disturb this balance. The huge rotating generator rotor is a storehouse of kinetic energy. Hence when there is deficit of mechanical power input, the rotors slow down supplying energy to the system. This causes a proportional reduction in frequency. The governors are set to respond to these changes in frequency and initiate corrective action to bring the frequency back to the set value. However, when the power demand exceeds the operating capacity of the generator, the frequency may not recover. And in case of large deficit, the frequency may drop down to very low values, which are unsafe for turbines, generators, transformers and loads. The amount of drop in the frequency and its rate of drop will depend on the amount of power deficit in the system and inertia of the machine. To avoid such situations, it is necessary to intentionally drop some load, so that the rest of the system can be saved. This process of tripping some loads in order to save the rest of the system is called as load shedding.

BLOCK DIAGRAM

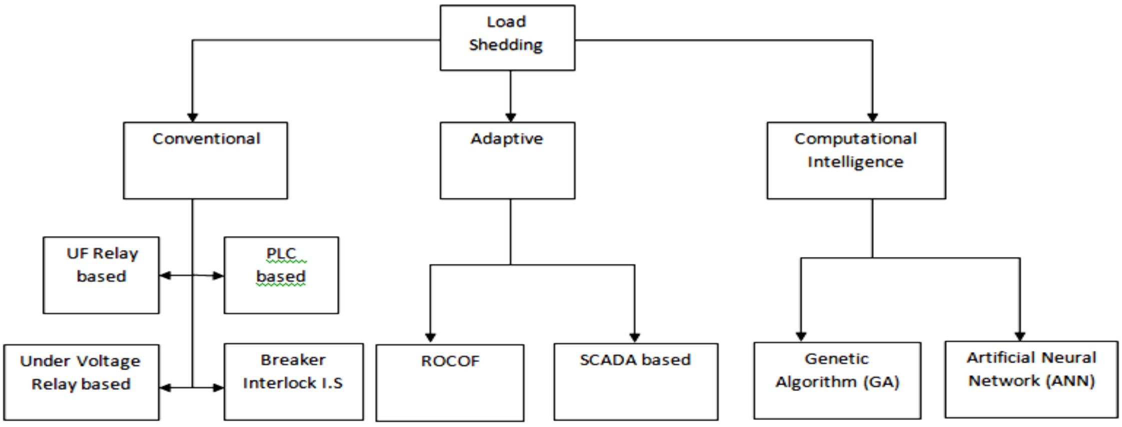

Fig1. Classification of load shedding schemes

The main types of load shedding schemes are as below:

I. The traditional or conventional load shedding: The traditional scheme sheds a predefined amount of the load corresponding to fixed preset values of frequency. These values of the thresholds are decided off-line, on the basis of experience and simulations.

a. Under frequency load shedding relays: Power plants are subjected to failure at low frequencies. If governor actions cannot activate spinning reserve quickly to restore the normal operating frequency, protective frequency relays trip generation units. Under frequency load shedding relays are employed to prevent tripping of the generation units. This scheme involves formation of a contingency list according to worst possible impacts causing severe power imbalance. All the required data such as relays, Circuit breakers, corresponding time delays, operational frequency value, and the priority list of loads are specified by the user.

b. Under voltage relay based load shedding: When a fault takes place, within 1-2 seconds, the system voltage drops much faster than frequency decays. Under voltage protection schemes as per voltage tolerance curves (according to past data) of the critical loads are employed to save in-plant loads and cogeneration units of an industrial system. Time delay setting of under voltage relays should minimum for easy activation. A fault contingency and the residual voltage of the cogeneration units can be calculated by short circuit analysis. Transient stability analysis calculates time delays using the critical clear time (CCT) of the cogeneration system. As the under voltage relays can easily be activated by even small voltage disturbance. This is a drawback of under voltage relay based load shedding.

c. Programmable Logic Controller-Based Load Shedding: Programmable logic controller is programmed at substations to initiate a trip signal to the appropriate feeder breakers. Programming is based on the number of generators, total amount of load, and the under frequency conditions. It involves continuous monitoring of circuit breaker positions, generator status, and overall power flows in the system. Possible contingencies are evaluated, and required load shedding is assembled. However, this table is independent of any changes that may take place in the system. PLC systems are faster and accurate than under frequency relays. However, PLC systems, uses under frequency relays as a backup due to reasons such as:

•The processing time in PLC leads to slow response of load shedding.

•The monitoring is confined to a portion of the network.

•Some sequence of events may occur that are not programmed into the PLC, resulting in load shedding failure.

Despite its added complexity and cost, the PLC load-shedding system is preferred because of its speed of response and its ability to handle changing power system conditions.

d. Breaker Interlock Load Shedding: This is the simplest method of load shedding used when speed of LS is critical. The circuit breakers are linked to a set of load circuit breakers to trip. Any power disturbance automatically sends a fast signals to the load breakers to open. Absence of processing in this scheme gives a fast response without any intentional time delay. Despite fast execution this scheme possesses a number of inherent drawbacks as below:

•Load shedding is based on worst conditions thus changing load priority is difficult.

•Only one stage of load shedding that can completely shut down the entire system.

•Unnecessary load shed than required because breaker interlock list is preselected without knowledge of system transient response.

•Modifications to the system are costly.

II. The adaptive scheme for load shedding: Conventional load-shedding strategies perform well in electrical system distributed on geographical bases, but not in industrial systems. UFLS very often disconnects more or less load than is required. This causes undesired damages and serious costs. No traditional schemes take into account load-level changes, system inertia changes, changes in load composition, governor response characteristics, or changes in system topology. In adaptive UFLS (AUFLS) these parameters are included and magnitude of disturbance is estimated online. This method is based on real time topology and communicates between remote protective relays and centralized UF appliance.

a. Rate of change of Frequency (ROCOF) based Load Shedding: According to equation, the initial ROCOF following a disturbance is directly proportional to the power imbalance and also depends on the electric power system inertia. The active power deficit is dependent on initial mechanical power on turbines, active power consumption just before the disturbance, spinning reserve, turbine-governor reaction and the active power load change due to voltage and frequency deviation. For effective load-shedding, firstly load shedding amount should be minimum, as not more than 20% of spinning reserve can be obtained in first few seconds. Secondly frequency trajectory should be within limits.

b. SCADA Based Load Shedding: To have a high reliability solutions, without any data transfer through communication links the SCADA system are preferred at UFLS. Formal approach based on a finite state transition model is introduced to define the load shedding actions for a medium/large industrial plant. Compared to the frequency based LS schemes, the response time is well within the power system requirements, no special relays or devices need to be installed and load unbalance calculation are much faster. LS scheme based on SCADA is as below.

•Magnitude of disturbance is detected by collecting all generators rate of frequency decline.

•Critical overload is defined and SFR model is designed first.

•If the overload is more than the critical value, total load must be dropped with zero time delay.

SCADA based scheme overcomes the shortcomings of adaptive UFLS procedures and provides a fast and reliable operation.

III. Computational Intelligent load shedding: Even with advanced techniques to improve load shedding efficiency such as adaptive techniques the tripping signal that starts the LS phenomenon is always the frequency or its derivative. These methods does not fit the requirements of industrial plants as Generating capacity varies widely, flexible Distribution network, high Frequency decay rate and small Number of load. This scheme overcomes the drawbacks of previous two schemes.

a. Using Genetic Algorithm: Genetic algorithms (GA) are based on the mechanics of natural selection and genetics. The basis is the Darwinian 'survival of the fittest' concept. Load shedding method in the previous section often causes over shedding as it involves the entire feeder for disconnection neglecting information about type of load connected to it. It is important to supply power to the right load at right time. This section proposes a time priority based load shedding scheme using genetic algorithm in a smart grid field describes the scheme. The objective function is the error between the required load shedding amount at substation and the actual. At the control centre, the load power consumption is obtained in real time and is fed as input to the algorithm, including the time of the day and the required amount of load shedding.

b. Neural-Networks for Under-Frequency Load Shedding System: The artificial neural-networks minimizes the computation time. Each stage of the load shedding system has a time delay of its own. If frequency is recovered before the expiration of the time delay load shedding operation will not be executed. The basic element of a neural-network is the artificial neuron. After a thorough examination the following neural-network model was developed for minimal frequency.

•Each generating unit is represented by two input variables: the actual power and the available power along with spinning reserve.

•One neuron in output layer and a single hidden layer.

•Sigmoid transfer functions as the minimal frequency is a continuous variable.

•Full connectivity between the output and the hidden layers but Partial connectivity between the hidden and the input layers to decrease calculation times and maintain accuracy.

V.PROGRAMMABLE LOGIC CONTROLLER BASED LOAD SHEDDING

With a Programmable Logic Controller (PLC) scheme, load shedding is initiated based on the total load versus the number of generators online and/or detection of under-frequency conditions. Each substation PLC is programmed to initiate a trip signal to the appropriate feeder breakers to shed a preset sequence of loads. This static sequence is continued until the frequency returns to a normal, stable level. A PLC-based load shedding scheme offers many advantages such as the use of a distributed network via the power management system, as well as an automated means of load relief. However, in such applications monitoring of the power system is limited to a portion of the network with the acquisition of scattered data. This drawback is further compounded by the implementation of pre-defined load priority tables at the PLC level that are executed sequentially to curtail blocks of load regardless of the dynamic changes in the system loading, generation, or operating configuration. The system-wide operating condition is often missing from the decision-making process resulting in insufficient or excessive load shedding. In addition, response time (time between the detection of the need for load shedding and action by the circuit breakers) during transient disturbances is often too long requiring even more load to be dropped.

VI. CONCLUSION

Load shedding serves as the ultimate guard that protects the power system from a disturbance induced collapse. Critical load preservation is done with the use of under-frequency relaying and PLC-based schemes. It can be concluded that PLC implementation in load shedding are more efficient with respect to fast response, exact load shedding amount and updated load priority list. However, further improvements are still needed.

For future enhancements we need to introduce an intelligent, optimal, and fast load shedding technology referred to as ILS. ILS combines online data, equipment ratings, user-defined control logics, and a knowledgebase obtained from power system simulation studies, to continually update dynamic load shed tables. This system can perform optimal load shedding in less than 100 milliseconds from the initial occurrence of a disturbance. ILS technology has been successfully installed and operational at several industrial facilities.

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