

MODERN ENERGY SMART LOAD SHEDDING
SYSTEM

INTRODUCTION

Electricity production depending on demand is one well-known picture. When the energy system is normally operating at normal status, the total mechanical power input from primary sources for the generators is equal to the sum of all included loads plus any actual losses in the system.

The voltage frequency of the system will directly depend on the amount of active power that the prime movers can deliver the system.

Main role of the behavior of the system plays the stored energy these primary driving elements accumulated as well. This stored energy varies dramatically between gas, thermal and hydraulic blocks.

Upon gradual increase of load, or sudden, but slight overloading, the governors will feel the change of the speed and increase the supply of power to generators. Overloading is handled by the unused capacity at all generators, included and synchronized to the system. If all generators operate at maximum capacity and all reservations have depleted spinning / hot reserve, governors are powerless to relieve overloading.

Sudden and large changes generating capabilities by loss of generator or bus disconnection affects the dynamic reaction of the primary sources of power and can cause dramatic misbalance between generated power and load. For some interference (which will cause the resulting suspension of production or conditions of transition to island mode) can occur cascading effects and rapid variation in frequency if the system

load shedding had not been set in the time and according to the structure.

For example, short-circuiting of the feeder sub-station can speed up (prime mover) of the turbine. When this happens speed governor will begin closing the fuel or gas inlet valve. Once the error has been removed the turbines meet impact of the load still opened. At that time, fuel or gas valves are closed, which brings tough conditions for further acceleration.

Gas turbines are very sensitive to the critical speed, which influence the blades at low pressure. These critical speeds may be very close to the values for protection Leaving very small margin to the protection level.

Typically, the operation of the protection in low speed gas turbine is set at 96% of nominal. Furthermore, generating system and its stability are at risk after falling frequency.

Very meaningful is the case for thermal power plants, where the output crucially depends on the motor-operated side (additional) loads such as feed pumps, pulverizer coal and fans.

System failure leads to a rapid drop of supply of such additional loads, causing further drop of the output of the turbine. This sequence of events worsens the frequency of the system threatening the stability of the system of the enterprise. To keep the decrease of frequency is necessary and purposeful automatically exclude some of the load equal to or greater than deficit of power to balance and keep system in a stable condition.

Automated load shedding of industrial systems is necessary because sudden disturbances can slide system to a dangerous condition much faster than a operator can react.

These automated systems of load shedding should be designed to support the embedded knowledge in depth of parameters of the acting system, must rely on means for real-time monitoring and communication networks to achieve desired results quickly and optimal exclusion of loads in the mere occurrence of the disturbance.

CONVENTIONAL APPROACH TO LOAD SHEDDINGS

This section provides an overview of techniques for load shedding, which have been used for many years and have their applications qualities and disadvantages.

A. Load shedding by Breaker .

This is the simplest way to accomplish load shedding. For this scheme are ensured interconnected, hardware provided, protection signals from generator and feeder circuit breakers. This usually applies when speed is essential. Although , the reaction time of these schemes is short, they have the following disadvantages:

- Scheme of load shedding, counted on the script of the worst case;
- It can develop only one degree of load shedding ;
- In most cases the load shedding is more than necessary;
- Modification of such systems is difficult.

B. Load shedding by frequency relay

The rules for setting the frequency relays are common to large and small systems. Design methodology is based on exclusion of fixed loads at fixed frequencies of the system. Upon reaching the set rate and after some time, frequency relay exclude one or more loads. This cycle is repeated until the recovery has been achieved in the frequency system ie 10% load shedding on a 0.5% reduction frequency. Since this method is completely independent from the systemic dynamics, total system failure is considered possible.

Additional drawbacks of this approach are described below.

1) Slow Response

In addition to the time, required for grid frequency to reach assignment, there is a purposeful delay, which prevents erroneous exclusion due to peak changes in frequency of the grid. The time may be extended as a result of exceeding frequency due to the transition process during this event.

Upon detection of a drop of frequency and after elapsing of the necessary time, frequency relay starts first phase of load shedding. If the amount of load shedding is not enough, the frequency continues to fall and initiates triggering the next level of discharge. Each stage introduces its delay in this process.

2) Incorrect / excessive discharge

The setting of each relay frequency is usually determined by the most severe conditions - at the most conservative levels of generation and loading. This leads to the most severe conditions for load shedding in situations that are not most severe.

In response to a decrease or change in the first derivative of frequency, frequency relays, switch to a fixed set of breakers, regardless of the current status of their loads.

Some breakers can have a load that is different from preset. Furthermore, the sequence of load shadings can not be optimal or even correct.

3) Knowledge of the analysis is always lost.

To determine the assignment of frequency relays simulation of hundreds of studies of transients are required.

The purpose of these tests is to find the minimum time for removal the event and to determine the minimum load shedding by the method of trial and error. The engineer performing the study learns the behavior of the system and may provide an intuitive reaction in its different operational situations.

The mere result of the study, however, used by load shedding system is a set of assignments of frequency relays. Other useful analysis results together with the acquired engineering knowledge is lost.

C. Load shedding on the basis of programmable controllers.

Through the scheme, based on programmable controllers, load shedding is initiated once a certain proportion between the total load and number of generators, which is monitored continuously and / or upon detection of sub-frequency situation.

Each sub-station controller is set to initiate a protection signal to the associated feeder breaker to exclude pre-selected set of loads. This static sequence continues until the frequency returns to normal.

This system offers many advantages such as, the use of distributed system on the whole utility, and also automated inclusion of loads.

In such applications, however, monitoring of the system is fragmented – the controller monitors the segment, which directly connected to it and the data is scattered.

This shortcoming is removed through use of predefined tables with the priorities of load shedding at the level of controllers to exclude blocks of loads, irrespective of dynamic changes in the system of loads, generators or operational configuration. Information on the total system operating conditions is normally missing in the process of decision-making, resulting in insufficient or excessive load shedding. In addition, reaction time (time between detection of need for load shedding and operation of the breaker) during the transients is often too long, requiring more loads to be excluded.

This is due to a delay in communication between controllers of each segment of the energy system.

APPROACH SMART LOAD SHEDDING "

An effective load shedding requires a thorough understanding of dynamics of the system process constraints, combined with knowledge of system behavior. This requires information that is listed below:

A. Operating conditions before the disturbance:

- Power needs for the enterprise ;
- Sharing power with the national grid;
- Generated power of each local unit;
- Spinning reserve (The unit is switched on and only needs to increase power - easy to hydropower, difficult for thermal power plants- if the boiler is not prepared, the opening of the valves will reduce steam parameters then subsequently - a new drop of power);
- Setup parameters of each unit;
- Setup and load conditions of all major rotating machines;

- System Configuration (number of tie-lines, state of buses, particularly those relating to loads to be shedded, etc.)

B. Operating conditions after disturbance

- New demand for power;
- The remaining generating capacity;
- Spare resources of any remaining block;
- Time to establish spare units;
- New configuration of the system;
- Status, settings and load condition of the other major rotating machinery;
- Status of all excludable load blocks.

C. Nature and duration of disturbance

- Electrical and mechanical failures;
- Complete or partial loss of contact with the national grid;
- Complete or partial loss of local generation;
- Added loads (impact);
- Domestic disturbances;
- Duration of the disturbance and its completion (self- Recovery, isolation of error, triggering of protective devices , etc..)
- Subsequent disruption of the system.

D. System transition process after disturbance:

- Frequency response of the system (damping, first derivative, extreme frequency);
- Reaction of the system voltage;
- Rotor angle stability of each remaining block;
- Operation of protective devices.

System that can embed itself in those described above parameters in its calculations and in the process of decision-making must possess intelligence.

More and more enterprises are supplied with intelligent SCADA systems or DCS, which are able to detect and reorganize on line operational data and conditions of interference.

Furthermore, tools for modeling systems and power incentive software were significantly improved to meet wide variety of system analysis, from simple learning the loads to transient stability.

In recent years, modern system analysis programs were developed as a component of larger systems management to perform analysis in real time.

Moreover, such techniques as Neural Network (NN), Generic Algorithms (GA), Simulated Annealing (SA), Fuzzy Logic (FL), Expert Systems (ES) were embedded in the actual management systems to offer more effective solution of problems by using knowledge and reasoning, study, planning and action for some high nonlinear problems that often can not be solved by conventional methods.

Possessing a combination of such technologies, an intelligent load shedding system can be built to achieve following objectives:

- To transform a complex, highly nonlinear and non-parametric problem of exclusion of loads in a finite space limited number of points to collect information.
- Auto recovery of system configuration, the working conditions and the system reaction to disruptions;
- Possibility of pattern recognition to predict system reaction to disruptions;
- System database learning capacity of scenarios defined by consumer;
- Opportunities for self-training under the new system changes;
- Opportunities for quick solutions to which load to be disconnected, based on the current status of the loads;
- Load shedding of minimum loads in order to keep the system stable.

Fig.1 shows the scheme of intelligent load shedding by few function blocks defined below.

Knowledge-base – utilizes carefully selected inputs and outputs, based on off line studies and models. Dynamic reaction of the system, including variations in the frequency are among the output of knowledge base;

Monitoring and prediction of the behavior of the system -

change in working conditions, feeders flow, generation local capacity, transformers and feeder loads, so also assessment the state of excludable loads;

Models of the grid - include topologic information of connections and electrical properties of the components of the system;

List of initiators for load shedding - based on prior defined system disturbance;

Optimizer of load shedding = tables of calculated optimal load shedding , corresponding to system changes;

Distributed management of programmable controllers quickly perform load shedding based on the detection of initiators interference from the system. This architecture, as described above has the following advantages:

- Use of tables of load shedding in real time, which reflect the true situation of excludable loads;
- Ensuring optimal combination of excludable loads to obtain maximum retention of the loads involved;
- Rapid reaction to initiators of interference (less than 100 ms in most cases);
- Provide environment for ensuring the rapid training of operators with the ability to simulate and evaluate solutions for load shedding.

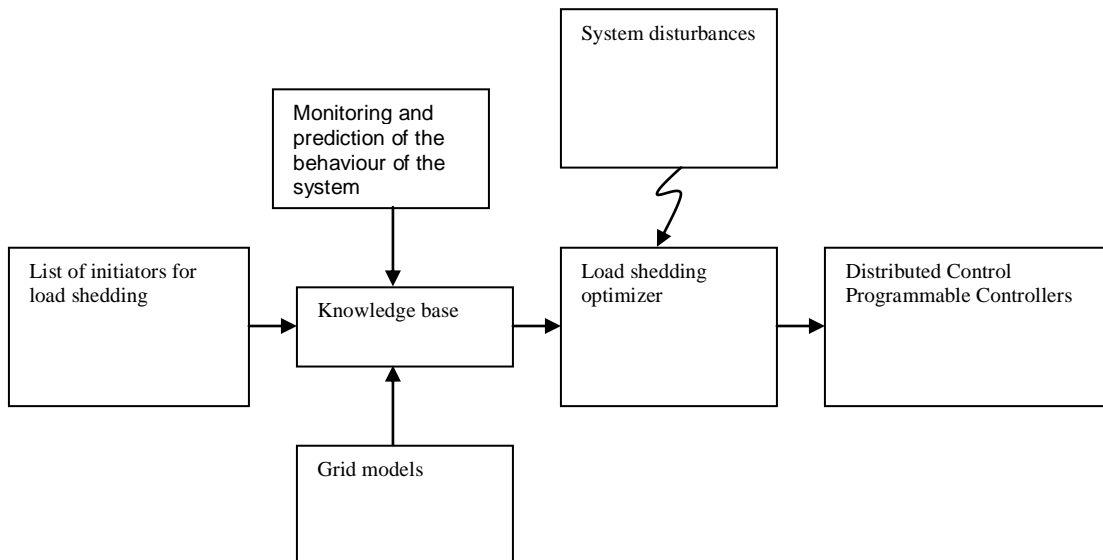


Fig. 1. Functional block diagram of intelligent load shedding.

Concrete realization

The proposed implementation covers all the requirements of the presented characteristics in Fig. 1.

We use:

Programmable controller, which is powerful enough to cover the whole part of the system under load shedding . This is a controller that because of its triple modular redundancy has more than 270 years mean time between failures and is uninterruptible – in case of failure in any of its components-inputs, outputs, power supplies, processors the controller continues to work without any interference and allows replacement of damaged module by simple removal and installation

of the modules.

This approach eliminates all the shortcomings of previous approaches: Load shedding by turning off breaker or Load shedding by frequency relay. Makes the system of orders of magnitude more reliable and uninterrupted, Which is not possible, by using conventional controllers. The proposed Controller is a distributed system of remotely located modules associated with triple redundant communication bus based on fiber optic cables with a high degree of immunity from electromagnetic interference and high speed data exchange of data and commands in both directions. The maximum number of inputs and outputs that can operate this system is 14,000 (fourteen thousand). This controller receives refreshed image of the object from the Server for the Intelligent load shedding in terms of function intelligent handling, as described in the previous Chapter:

- A. Operating conditions before the disturbance,
- B. Operating conditions after the disturbance,
- C. Nature and duration of disturbance,
- D. System transition process after a disturbance.

Highly intelligent and effective software, resident in server and solve tasks:

- transforms a complex, highly nonlinear and non-parametric problem of load shedding in a finite space with a limited number of points collection of information.
- Automatically restores system configuration, operating conditions and system response to disturbance;
- provides a systemic reaction to interference
- Maintains a system database, learning capability of scenarios defined by the user;
- Conduct self-training for new system changes;
- Provides opportunities for quick solutions, by which load to be excluded on the basis of current condition of the loads;

Manufactures instructions for controller load shedding of loads at least to maintain system stable.

This highly efficient and reliable system buys itself by first load shedding, which will be made on the basis of snapshot of the system for 100-150ms.

A simplified scheme of such a system is shown in Figure 2.:

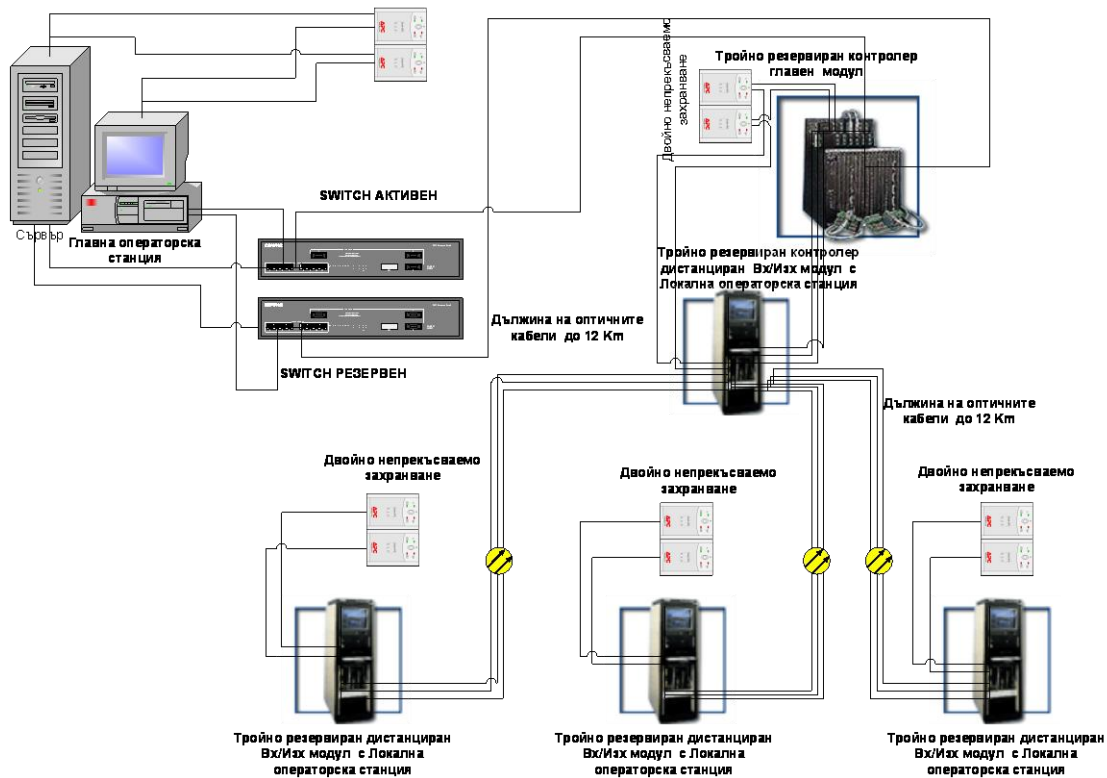


Fig. 2

Necessary data for performing the project

- Single line diagrams;
- Parameters of equipment related to the task;
- Short circuit data (MVAsc, X / R);
- Models (descriptions) of protective equipment / Type / parameters;
- Models (descriptions) of regulators of the turbines, the excitation, together with their parameters;
- Generators test data for connecting and disconnecting of loads- 50 % and 100%;
- AC motors - a dynamic model with characteristics of torque / slip;
- How to derive data from measurements of the feeder;
- Existing studies of the system;

- Historical data on system performance and information disruption;
- Other relevant information describing the system equipment.

The questions are upon provision that, system, after its separation from the national grid remains working with domestic generating capacities (Island mode).

Other features of the management system

Energy Management System developed and implemented by DICS Intertrade in refinery Lindsay Oil, UK

The system is part of the integrated control room of the refinery. The system performs management of the following:

Production of steam for technological processes management; turbo machinery equipment, producing active and reactive power, $\cos \varphi$ and Power factor depending on the requirements of the refinery and provides optimal energy consumption from the national grid, as automatically synchronizes the turbo-generators and include them working to national grid or "island" mode.

For details, visit website www.dicsintertrade.com.