THE LOAD CONTROL OF ONE LOCAL POWER STATION CONNECTED TO THE NATIONAL GRID

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ABSTRACT

The scope of this study is to indicate the functional operations to be carried out by the load control system of the electrical plant to be installed in the electrical control room of an industrial establishment. The power plant sufficient capacity steam driven generators provides electrical demand together with steam requirements. The power plant has also possibilities to parallel with national electrical network in the case of one or more generators to be out of producing electricity.

To provide different type of requirements of the establishment and operate electrical system without any interruption, a redundant programmable logic control system is designed and installed. The functions to be carried out by the load control system are load limit control, load sharing control, load shedding and main transformers voltage control.

1. Introduction

Due to impossibility in short time range to provide huge amount of electrical energy requirement of country by using only state facilities, electrical energy generation and sales regulations have been changed and all related permissions have also given to private sector. It can be easily seen from literature, different type of statistics and investments, the main sources in electrical energy production in decreasing order are natural gas, thermal and hydro.

During plant operation, either island mod or parallel to national grid, many types of protection, measuring and indication instruments have been connected to system in order to get safe and continuous generation with allowable quality limits.

In this study, the electrical requirement of one industrial establishment is provided from its own power plant in normal operation conditions. In case of insufficient production due to different reasons, the generation system is connected to the national grid. The power plant, in addition electrical power generation, has also facilities to provide two different pressure level steam as extraction from its turbines. The extractions from turbines are used to drive the pumps, compressors and to heat raw and process materials.

For safe, continuous and high quality electrical energy generation, transmission and distribution, one redundant programmable logic controller system is adopted to the electrical system and loaded for load limit control, load sharing, load shedding and transformers voltage control.

2. Load Control System- LCS

PLC based system is used to supervise the load control of the electrical system.
The main functions to be carried out by the load control system are:

- Load limit control
- Load sharing control
- Load shedding control
- Main transformers voltage control

Load control system allows necessary intervention/interaction facilities to be used by the operator to initialise the generation system/systems for a specific operating mode and also to disable the PLC system such that all the generation and distribution can be controlled only by the operator with the monitoring facilities not disabled.

2.1 Load Limit Control – LLC

The aim of the LLC is to verify continuously the power demand of the industrial establishment, together with the generated power and the power supplied by the national electric grid giving the

appropriated alarms to the control room operators in order to allow them to bring suitable decisions.

The LLC will alarm for the following causes:
- The total absorbed power from the national grid exceeds a setting value.
- The exported power to the national grid exceeds setting value.
- The output power of each generator exceeds their rated powers.

The setting values relevant the power limits to the absorbed from or exported to the national grid and the output power of each generator, will be imputed by the operator in control room, through suitable Man-Machine-Interface (MMI)

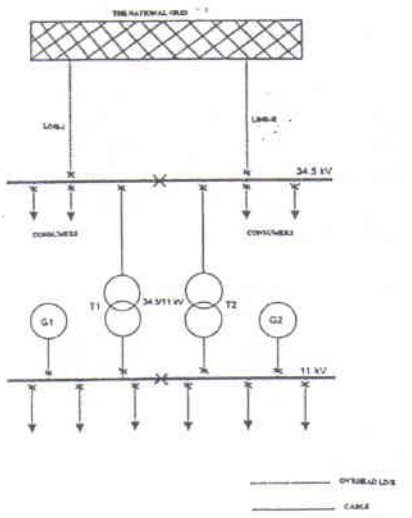


Figure 1-One line diagram of an industrial establishment on which a load control system is connected

The output alarms from LLC will be carried to:
- The display on the event recorder (VDU)
- Through voltage free contacts to activate lighting and acoustic signals on the electrical control panel.
- Recording the causes in the event recorder system.

The operators will acknowledge the alarms through dedicated push buttons installed on control panel and will operate according the happened contingency. The acknowledge will be recorded by the event recorder system.

The one line diagram of the electrical system on which the load limit control system is adopted, is shown in Figure 1

2.2 Load Sharing System – LSS

The aim of the load sharing system is to adjust the load distribution between the turbo-generators according to the relevant operational mode in order to avoid overloading.
The distribution of the loads involves both active and reactive power.

The operational modes of the turbo-generators are grouped in the following four cases.
- A single turbo-generator is running isolated.
- Two or more turbo-generators are running in parallel between themselves but isolated from the national grid.
- A single turbo-generator is running in parallel with the national grid.
- Two or more turbo-generators are running in parallel with the national grid.

2.2.1 A single generator is running isolated

The load sharing system only detects the operating mode and the extension of the electrical network fed by the generator give the order to the turbine governor to operate in speed control monitor continuously the turbo-generator output.

The turbo-generator is controlled in frequency regulation through its own governor system. The voltage of the system is controlled by the generator automatic voltage regulator.
The generator is steady until the power demand is lower than the generating capability. When the power demand exceed the generator capability and the frequency can not be maintained, the load shedding control system is activated.
The flow diagram of this operational mode is shown in Figure 2.

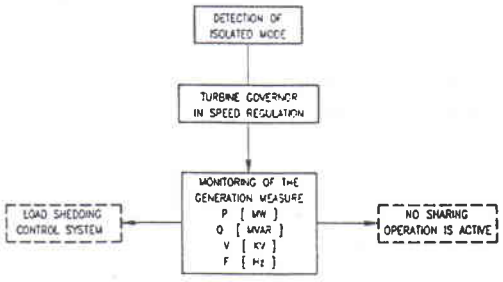


Figure 2-Load sharing algorithm of single generator operation in island mode.

2.2.2 Two or more turbo-generators are running in parallel between themselves but isolated from the national grid.

In this operational mode shown in Figure 3, only one generator is in speed control to lead the frequency and the remaining generators are in back-pressure or load mode according to the industrial establishment needs.

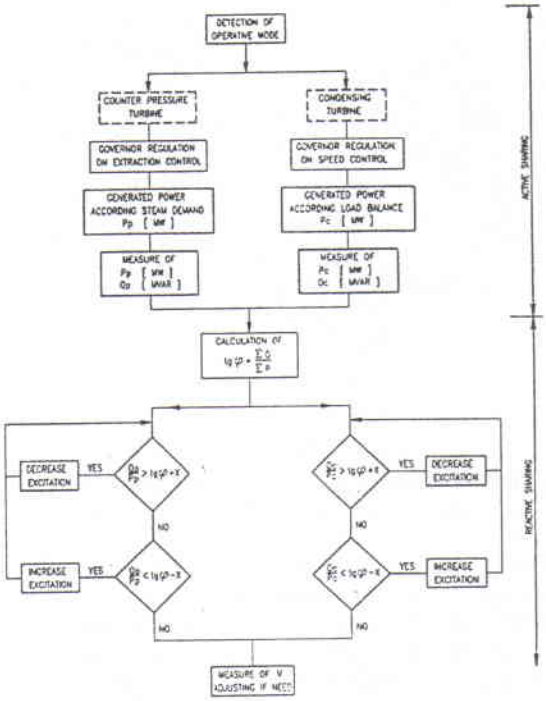


Figure 3-The simplified logic diagram of active and reactive power distribution between generators.

Active load sharing is adjusted by operator according to availability of operating mode. LSS only adjusts the reactive power sharing between the generators in accordance with the respective generated active power (acting the increase/ decrease excitation current through automatic voltage regulator contact).

In case of loss of the speed controlled generator, the LSS gives order to put one of the remaining generator in frequency (speed) regulation and check load balance, if unbalance is occurred, the load shedding control system will be activated according to the requirements as per paragraph 2.3.

2.2.3 A single turbo-generator is running in parallel with the national grid.

The frequency of the electrical system is provided by the national grid. The running generator, according to the industrial establishment's requirements and its nature, are operated either in manual or automatic mode.

If the priority of the establishment is steam, the turbo-generator is operated in back-pressure mode in automatic. The electrical demand of the factory is completely or partially provided by the running generator. If generator capacity is insufficient to meet the requirement of the industrial establishment, the extra power is imported from the national grid. If generation is more than the industrial establishment need, extra power is exported to the national grid.

In case of priority of the industrial establishment is selected electrical power, the running generator is loaded in maximum capacity. If the back-pressure steam relevant to produced electrical power is more than the industrial establishment need, extra steam is sent either to the condenser or to the atmosphere.

The reactive power is shared between the running generator and the national grid according to the relevant active power generation in order to maintain the pre-selected power factor ($\cos\varphi \rightarrow \tan\varphi = Q/P$)

In case of the national grid failure, one of the running generators is automatically passed to speed mode and try to maintain the frequency in pre-selected limits.

2.2.4 Two or more generators are running in parallel with the national grid.

In this operation mode, the frequency of the network is also provided by the national grid. The running generators, according to the industrial establishment requirements and their nature, have facilities to be run on any specific mode on normal operation as stated previous paragraph.

The reactive load is shared between all running generators in accordance with their generated active power to maintain a pre-selected and adjustable power factor ($\cos\varphi \rightarrow \tan\varphi = Q/P$)

In case of one or more generators become out off operation, the remaining generator/generators with load or back-pressure mode keep their position, but the remaining generator/generators with auto load, automatically pass to manual load.

On the other hand when the national grid is off, one of the running generators automatically passes to speed mode and tries to maintain the frequency in pre-selected range. If remaining generator/generators are not met the industrial establishment's electrical power requirement and

are not kept the frequency in predetermined range, the load shedding system as described in next paragraph 2.3, will be activated.

2.3 Load Shedding Control System-LSCS

The aim of the load shedding control system is to prevent dangerous overload of the generators and/or general failure of the electrical network.

The automatic LSCS philosophy is based on the following criteria:

- Under frequency trend control
- Lack of generating power
- Import power limit control

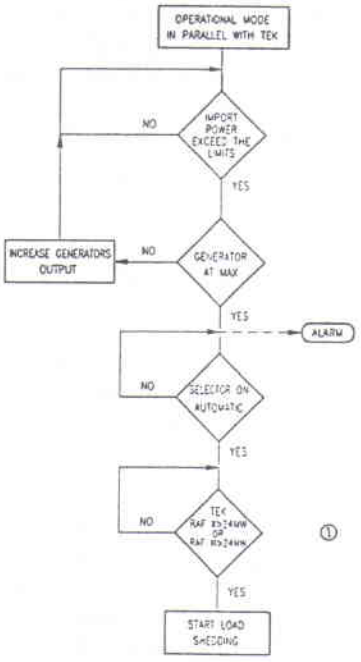


Figure 4- The logic diagram of the load shedding on under frequency control.

The under-frequency control operates as follow

- During the running in parallel between generators and the national grid, if under-frequency is detected, the LSCS will operate to separate the national grid from the network.
- If the under-frequency status is detected during the opera ional modes isolated from the national grid, the LSCS will operate a sequence of load shedding steps, one after another, taking the respective mode of operation into account.

The lack of generating power control is activated during the isolated mode of operation..

The lack of generating power condition actives fast shed of the loads, which amount is based on the comparison between the capability of the generators running (Pg) and the power demand of the loads connected (Pl). The above comparisons are carried out for each possible network configuration.

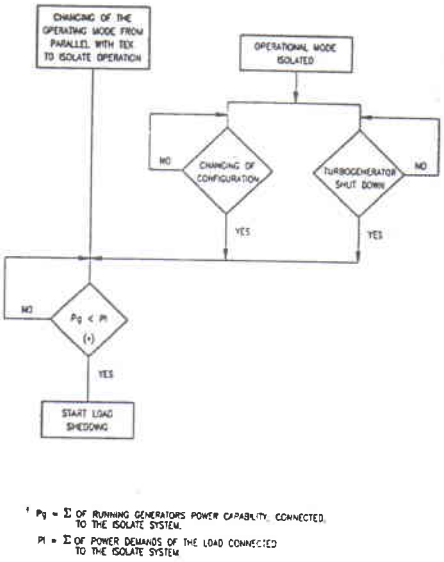


Figure 5-The algorithm of the load shedding on the lack of generating power.

As soon as the power demand of the industrial establishment became higher than the generators capability, the LSCS will provide to trip the circuit breakers of the pre-selected loads or group of loads in order that the condition Pg ≥ Pl should be verified.

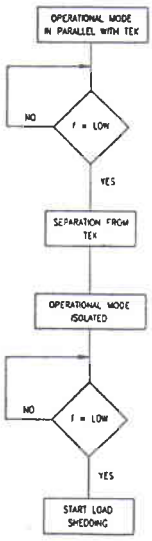


Figure 6-The schematic diagram of the load shedding on input power limit control.

The third operative function of LSCS is to start the shedding of the loads in case that maximum import power limits from the national grid have been reached.

The flow diagrams of the load shedding control system initiated from under-frequency or the lack of generating power, are shown Figures 4, 5 and 6.

2.4 Main Transformers Voltage Control

The main transformers voltage control is a necessary function to operate correctly the reactive load sharing during parallel operations between turbo-generators and the national grid, and to maintain the correct voltage during the modes of operation with the national grid only.

The PLC system controls the transformers ratio in order to:

- maintain the voltage level of the systems under pre-selected limits, corresponding to the on load tap changer step range.
- minimise the variation of reactive power of the generators during voltage fluctuation of the national grid.

The voltage control philosophy is based on the comparison between the voltage value of the national grid supply, corrected by a drop value due to the reactive power, and relevant position of the transformers tap changers. An adjustable factor R with a range of any specified percentage of the rated voltage may be also introduced by the operators to optimise the values according to special contingencies.

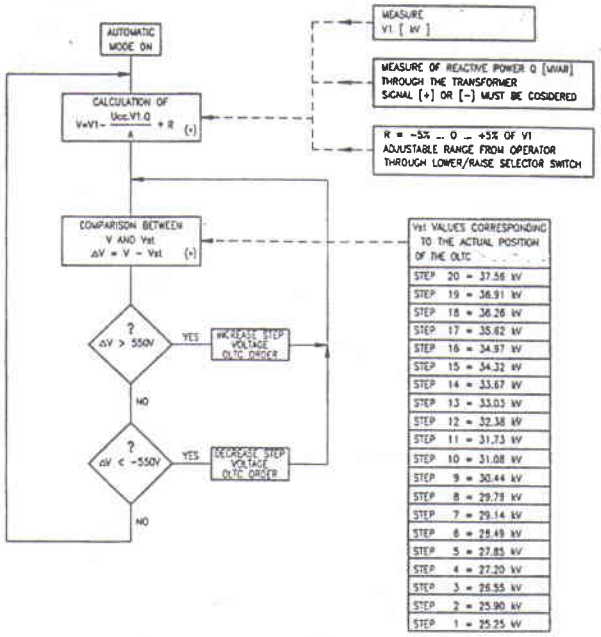
The transformers of the same system have to run with the same ratio, the PLC will verify the concordance of the steps position of the transformers, giving alarm and stopping the regulation, if such concordance is not reached within a certain delay. The simplified logic diagram of the system is shown in Figure 7.

3. Conclusion

Today's modern technology is likely to cause great deal of production losses besides the events which endangers human life during any energy cuts. Because of the above reasons, classic control of the generation, transmission and distribution systems by operators are not preferred any more.
In the beginning of this application, it has been predicted that load control could be realised with the definite number of steps. However, after system designation and detailed studies, it has been noticed that even ordinary and little things can affect energy flows. Therefore, all possibilities and details should be taken into account.

The load control system of which basic functions are presented in this study, has been applied an industrial establishment and taken into service after necessary tests. The most important problem which come up during operation is that the governor of the turbine is mechanic and does not response quick enough. Thus, this starts the load shedding before predetermined and necessary time.

This study will be a good example for the existing generation stations and the ones to be opened in the future.



(*) V1 = MEASURED VOLTAGE OF THE HV SIDE OF THE TRANSFORMERS [kV]
Q = MEASURED REACTIVE POWER FLOWING THROUGH TRANSFORMERS
Ucc=TRANSFORMERS SHORT CIRCUIT VOLTAGE IN P.U. [Ucc=0.1]
A = RATED POWER OF THE TRANSFORMERS [MVA]

Vst=VOLTAGE CORRESPONDING TO EACH OLTC STEPS ON HV SIDE OF THE TRANSFORMER CONSIDERING 11kV THE SECONDARY VOLTAGE

Figure 7-The algorithm of the OLTC transformers automatic voltage control.