Innovative Steam Turbine and Engine Control System for Load Sharing Application in Pulp and Paper Mills

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ABSTRACT

Certain changes that are required to be carried out by existing Pulp and Paper plants in order to integrate themseleves with the changing requirements and the plant needs, are suggested in this paper.

INTRODUCTION

Technological changes have ensured that the upcoming new plants are being designed under consideration that all turbines will share load and if required they will have an integrated cogeneration plant and will export the surplus power to the grid. For this it is essential that each turbine has an electronic governor. What is important is that the number of new plants coming up is comparatively very small to the existing plants. What the existing Paper plants need to do, to ensure that they are able to share the load on all existing turbine/engines is to upgrade the existing governing with electronic governor.

The Need for Electronic Governors

There has been a steady growth in demand for failsafe controls for turbines, which have the increased versatility of load control, process control, load sharing and synchronizing besides the basic speed control. This has created the need for electronic governors. For load sharing application to have the facility of changing the parameters based on the plant need and the steam availability, the electronic governor is best apt for the situation.

Most of the existing Paper plants are having two or more power turbine, which are working in isolation. Each turbine is catering to certain plant load. There are times when one turbine is running at 50% load and the other turbine trips because of overload. This happens in spite of the fact that the installed capacity is say 9 MW and the total plant requirement is 8 MW. In such situations the best possible solution is to ensure that the total plant load is distributed on all the turbines based on the generation capacity and load carrying capacity of each turbine. To understand this, let us talk little about load sharing.

Droop

Droop is decrease in speed or frequency, proportional to load, i.e. as the load increases, the speed or frequency decreases (Fig. 1). This reduction in speed is accomplished with negative feedback. As the system is loaded, the feedback signal increases in magnitude and in opposite polarity to the speed set voltage. The feedback signal is subtracted from the speed set voltage lowering the speed reference in direct ratio to the increases in load. Droop is expressed as the percent that the speed drops below no load speed when the system is fully loaded. With a given droop setting, an engine generator set will always produce the same power output at a particular speed or frequency.

Isochronous

Iso in Greek means single or constant and Chronous means time; Isochronous means repeating at a single

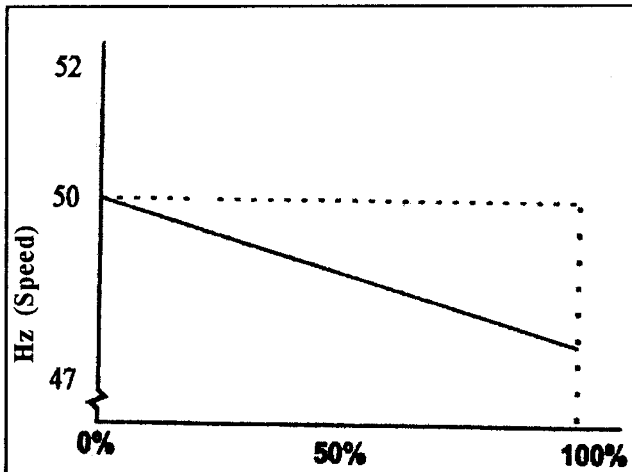

Fig. 1 Droop Mode

rate or having a fixed frequency or period. In other words, an engine-generating set, operating in the Isochronous mode will operate at the same speed/ frequency regardless of the load it is supplying, up to the full load capabilities of the turbine-generator set (Fig. 2). This mode can be used on one turbine-generator set running by itself in an isolated system.

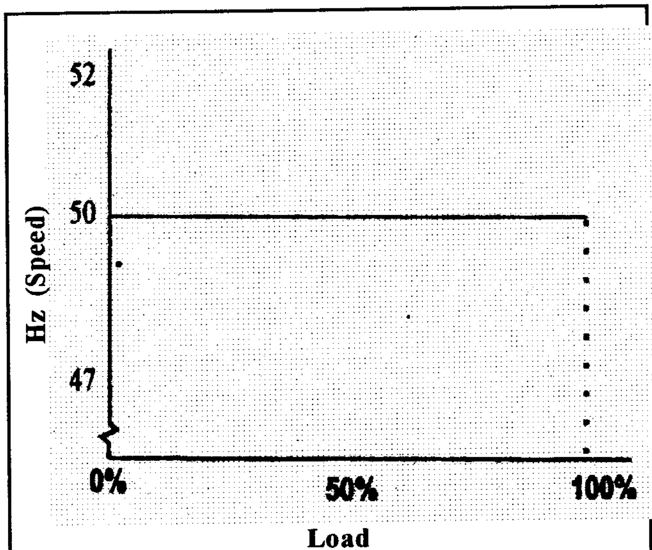

Fig. 2 Isochronous Mode

Concepts of load sharing

There can be two possibilities;

1. You are sharing the load in Isolation from the Utility or the state grid.
2. You are sharing the plant load being tied to the grid. In this mode you can automatically export/import power to/from the grid based on plant requirements.

RESULTS AND DISCUSSION

Load sharing for an isolated system

Droop/Isochronous Load Sharing. Droop and Isochronous combine the first two modes. All turbine-generator sets in the system are operated in the droop mode except for one, which is operated in the isochronous mode. It is known as the swing machine. In this mode, the droop machine will run at the speed/ frequency of the Isochronous unit. The droop percentage and speed setting of each droop unit are adjusted so that it generates a set amount of power. The output power of the swing machine will change to follow variation in the load demand while maintaining constant speed/frequency of the system (Fig. 3).

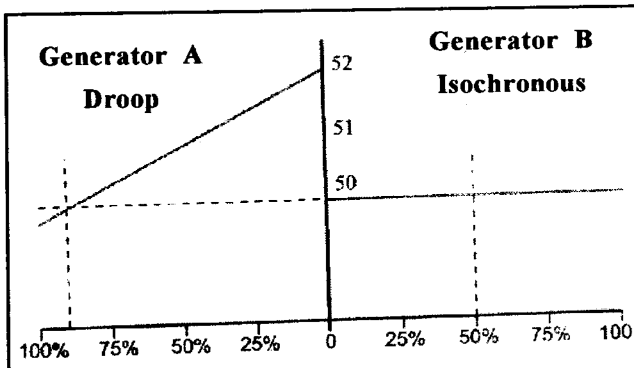

Fig. 3 Droop / Isochronous mode

Maximum load for this type of system is limited to the combined output of the swing machine and the total set power output of the droop machines. A load above this maximum will result in decrease in speed/frequency. The minimum system load cannot be allowed to decrease below the combined output set for the droop machines. If it does, the system frequency will increase and the swing machine can be motorized.

The machine with the highest output capacity should normally be operated as the swing machine so that the system will accept the largest load changes within its capability. This is not a hard and fast rule. Selection of the swing machine will depend on such things as efficiency of different engines and the amount the load that is expected to change. In order to increase the load swing capabilities of a Droop/Isochronous load sharing system, several Isochronous load sharing turbine-generator sets can be connected in parallel to respond as a single swing machine. Other turbine-generators can then be run in droop with these swing machine.

Droop/Droop Load Sharing

In this case all the units are set in droop mode. If the droop set is equal in all the turbines the individual

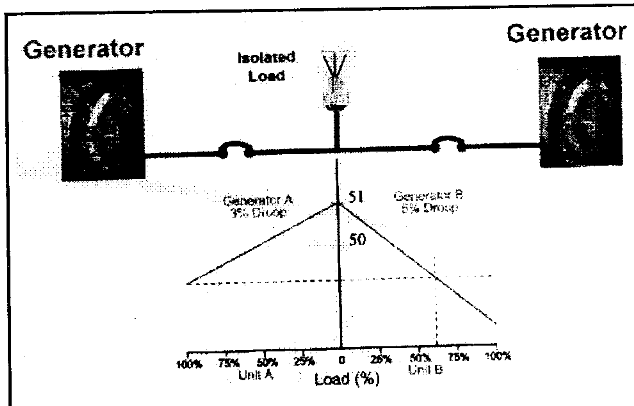

Fig. 4 Unequal Droop/Droop Load Sharing

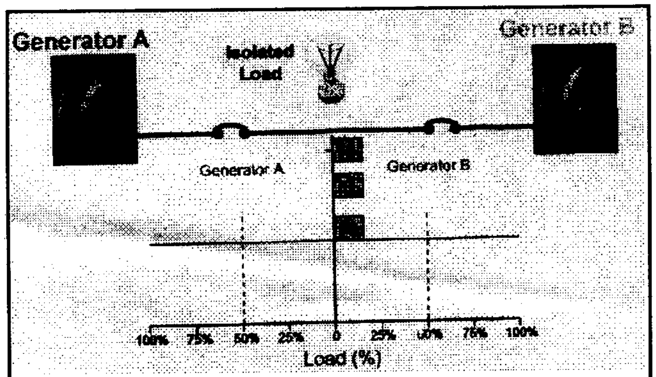

Fig. 5 Isochronous Load Sharing

speed references will very with the same amount to maintain an even percentage of load. Load will stay balanced under all load conditions but the frequency will not stay constant with load variation. In case of unequal droops (Fig. 4) the load sharing will be unequal. For example if the percentage droop for m/c, A is 3% and for m/c, B is 5% for the same frequency the percentage carried by each m/c will be different.

If all engine generator sets in a droop system have the same droop setting, they will each share load proportionally. The amount of load each carries will depend on their speed settings. If the system load changes, the system speed/frequency will also change. A change in the speed setting will then be required to offset the effect of droop and return the system to its original speed/frequency. In order for each engine generator set in the system to maintain its proportion of the shared load, the operator will need to adjust the speed set point equally for each turbine-generator set.

If all turbine/generators in a droop system do not have the same droop setting, they will not share loads proportionally with the same speed settings. If the system load changes, the system speed/frequency will also change but the percentage of load on each turbine-generator set will not be changed proportionately. The operator will need to adjust speed set point differently for each turbine-generator set to make them carry their proportional share of the load.

This could result in running out of speed set point adjustment on an turbine-generator set before it is fully loaded and limiting the system load sharing capability. It is best to have the same percentage of droop set on each turbine-generator set.

Isochronous Load Sharing

For Isochronous load sharing, the controls of all turbine-generator sets in a system are operated in the isochronous mode. Load sharing is accomplished by adding a load sensor to each electronic isochronous governor. The load sensors are interconnected by the load-sharing lines (sometimes called paralleling lines). Any imbalance in load between units will cause a change to the regulating circuit in each governor in the system, causing each unit to produce its proportional share of the load to rebalance the load signals. While each unit continues to run at isochronous speed, load changes force each machine to supply its

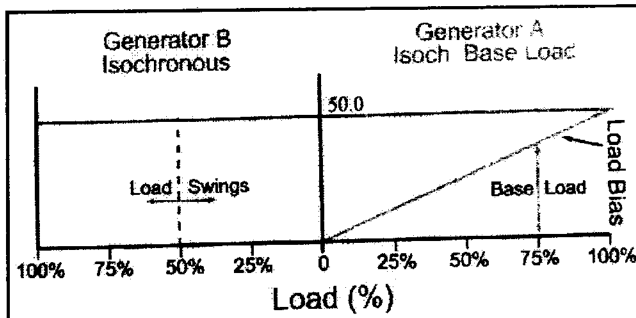

Fig. 6 Isolated Bus with Isochronous base load

proportional share of power to meet the total load demand on the system. If the turbine-generators are of unequal output ratings, the output of each generator set will be proportional to its rated output (Fig. 5).

Isochronous base load

Isochronous base load is a method of setting a base or fixed load on an engine generator operating in the isochronous governing mode. This is accomplished by using an isochronous load-sensing control and connecting an external bias signal across its load-sharing lines (Fig. 6).

The external bias signal impressed on these lines appears to governor as a load imbalance. The Governor will force the generator output to increase or decrease until the output of the load sensor is equal to the bias signal on the load-sharing lines.

At this point, the system is balanced. This method can only be used where other turbine-generator sets are producing enough power to meet the change in load demand. This base loading method is ideal for either soft loading additional units into an isochronous system, for derating or unloading a turbine-generator, or for setting a fixed amount of load on a turbine-generator that is in parallel with other units (Fig. 7).

Implementation of Concept of Load Sharing for Pulp and Paper Mill Application

The concept of isochronous load sharing has been accepted by the various captive power plants in Fertilizer, Sugar and Petrochemical Industries. The

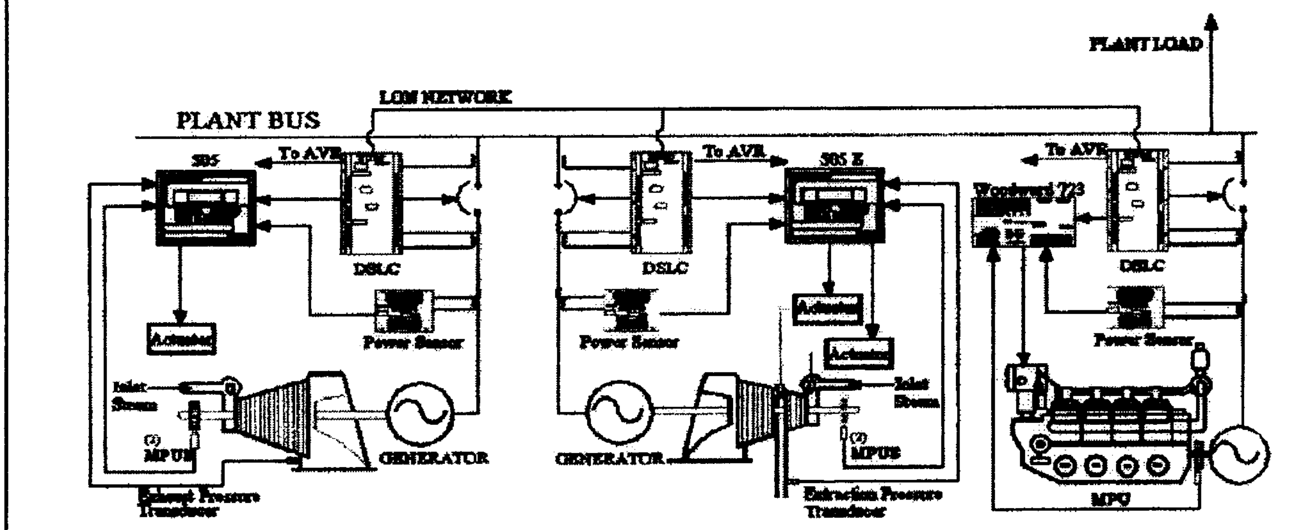

Fig. 7 Scheme for Isochronous load sharing for an Isolated system

pulp and paper Industries is also realizing the potential of Isochronous load sharing as it gives the flexibility of loading the various generators at desired rating and at the same time not sacrificing the frequency of the system. Let us assume that a pulp and paper plant has a combination of three turbines and engines of 2.5 MW each. Each Turbine/engine is loaded to 90% of its installed capacity i.e. 2.25 MW and 250 KW is kept as safety margin for sudden kick loads. This means that total of 750 KW is kept as safety margin. Using concept of load sharing that m/cs can be loaded to their maximum installed capacities as all kick load will be shared by all turbines and engines. For this it is essential that each turbine is fitted with an electronic governor and has its own DSLC (Digital Synchroniser and Load Control). The DSLC performs the function of a synchronizer as well as load controller. Each Turbine has its independent DSLC, which communicates with the speed controller to match the frequency and with the AVR for voltage. Each DSLC communicates to other DSLCs on its own network (LON). The DSLC receives CT and PT inputs to know the generation and the total load requirement. All DSLCs are aware of the individual turbine generating capacity (programmed into the system). The variation in the load is distributed among all the turbines based on generating capacity and the percentage of load required to be shared by each turbine (programmed into each DSLC). This will enusre that no turbine is overloaded within the generating capacities of all the three turbine. Further the load sharing will be Isochronous i.e. the plant frequency will be maintained. This scheme is totally suitable for pulp and paper plants, which are isolated from the grid (Fig. 8).

The limitations of the hydromechanical controls are eliminated in this kind of scheme using digital control system. The Power plant is now able to achieve the following features, which would have been difficult to achieve through a hydromechanical control.

- Manual/Semi Automatic/Automatic start up can now be programmed in the system depending upon the cold hot start-up curves. These curves are configured in the system at the time of detailed engineering.
- Critical speed avoidance is programmed in the system. As soon as the controller senses the critical speed band, the controller crosses the critical band at a faster ramp rate as programmed in the system. The same ramp rate will be followed during controlled shutdown.
- Idle running and acceleration rate adjustments can be programmed.
- Isochronous load sharing between the three STGs/

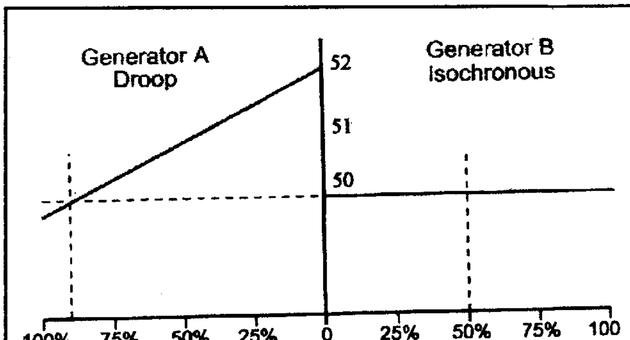

Fig. 8 Droop unit fixed or base load **Grid (Swing Machine)**

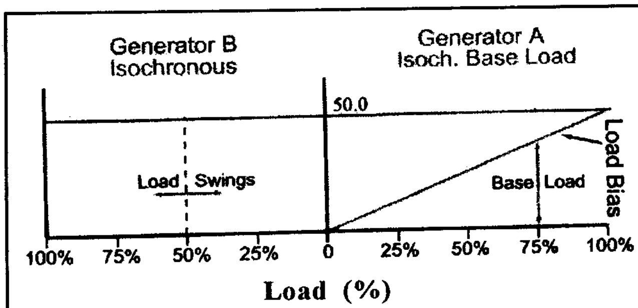

Fig. 9 Grid (Swing Machine) Isochronous base load machine (Fixed or base load)

Engine generator will be achieved through DSLCs in island mode. The system will be provided with the facility of overspeed testing.

- Scan time has been configured between 5 msec to 80 msecs rate groups depending upon the criticality and nature of I/O as per Woodward Standard.
- The digital controller communicates with plant distributive control system (DCS) on Mod Bus.

Systems tied to Utility grids

In case the plant is also tied to utility there are again two of load sharing possibilities.

- Droop base load sharing
- Isochronous base load sharing

Base Load

Droop base load is the same as droop, with the exception that the utility or grid will control the frequency and act as does the swing machine, absorbing any change in load. The speed and droop settings are adjusted so that the turbine-generator set supplies a fixed, or base amount, of power to the utility (Fig. 9).

When the turbine-generator supplying power to the utility is separated from the utility, the speed/ frequency of the now unloaded isolated unit will increase to the speed set point on the control where it was advanced to load the turbine-generator while drooped against the utility.

Isochronous base load

Isochronous base load for a turbine-generator feeding an utility is the same as isochronous base load for an isolated system. Any difference between the speed/ frequency setting of the isochronous base loaded machines, and that of the utility, will show up as a change in the base load. This is why it is so important to have the speed/frequency setting of the oncoming unit as close as possible to that of the utility. As many as 15 turbine-generators can be isochronous base loaded by applying the isolated bias signal across their common system load-sharing lines. The advantage of isochronous base loading over droop base loading is that when separating from an utility, there is no frequency change. Simply removing the bias signal from the load-sharing lines returns the engine-generator to Isochronous speed (Fig. 9).

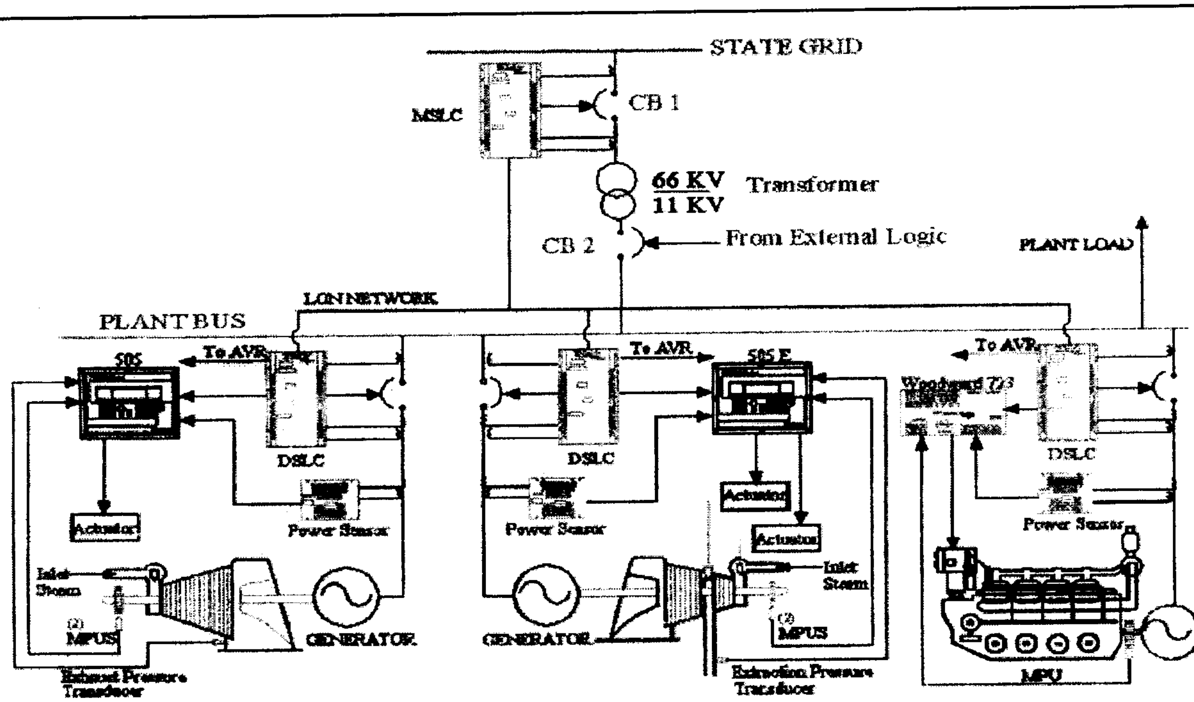

Fig. 10 Scheme for load sharing with the system tied to Grid

Import-Export to the Grid

When an individual pulp and paper plant has surplus MW, then the same can be exported to the grid after meeting the plant requirement. This Import/Export control action will be initiated by MSLC (Master Synchroniser and Load Control) after the TG sets have been synchronized with the grid. Once the plant is synchronized with the grid then MSLC will initiate import/export function. In this mode of import/export control, the MSLC measures the real power flow on the incoming feeder with help of CT and PT inputs. It then determines the power delivery required of each STG set and communicates this requirement to the individual DSLC (Digital Synchroniser and Load Controller). The individual DSLCs will control to its percentage of rated loads, and the MSLC will adjust the load up or down to achieve the proper import/export level set (Fig. 10). Import Control function will be achieved from MSLC when total generation is less than the total plant load. Export control will be achieved when the Captive generation is more then the plant load. In case the plant load increases then the controller will increase the reference to maximum generating capacity of the plant and it will keep exporting, till the maximum set load level is reached. In case the plant load goes beyond the maximum plant load limit level, import will start to meet the plant load.

CONCLUSION

For maximum production it is essential that uninterrupted power is available and the load on all the turbines/engine generator is shared in the same proposition as the generating capacities of individual turbine/engine. This will ensure that all the turbines/engines will share any sudden load coming in the system and no individual turbine/engine will get overloaded. This will have an added advantage to paper mills that they need not keep the safety margins of 10% on individual turbine/engine. This effectively means that on an average adopting the load-sharing concept will make each paper mills utilize 500 to 600 KW of energy, which they normally keep as safety margins for sudden loads.