16

Computer Based Power Management Systems

16.1 INTRODUCTION

Modern power systems that are self-sufficient with their own turbine generators are often equipped with a computer based power management system (PMS). The main purpose of this system is to enable the generators to be operated at high load factors i.e. 85 to 90%. Operating the generators at high load factors has two main advantages:

- The most economic fuel consumption is obtained.
- In some situations less generators need to be installed, especially in old plants where load growth has occurred.

In addition there are other benefits which become available when a PMS is included in the power system:

- Improved range and accuracy of plant measurements and display.
- Improved range and types of alarms, messages and event recording.
- Better control by the control room personnel.
- Greater confidence in the performance of the plant.
- Addition of special technical facilities, e.g. auto-synchronising, condition monitoring, managing the tap-changing of transformers.
- Communication with SCADA systems.
- Data logging, trending and archiving.

The power system is the 'life-blood' of the whole plant and therefore it must have high availability and high reliability. A well-designed PMS will enable the highest performance to be achieved in these respects. A PMS should be considered as an essential requirement in a modern plant.

16.2 TYPICAL CONFIGURATIONS

The PMS central computer and its input and output signal interfaces should all be located in one self-contained unit. If for some reason this cannot be achieved then these functions could be included in

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a SCADA sub-system, but its operation should be kept as independent from other general operations as possible. The reasons for this will be discussed later in more detail.

If the PMS is a part of a SCADA system then faults within the SCADA system could shut down the PMS and thereby put the power system at risk e.g. cascade shut down following the tripping of one generator.

16.3 MAIN FUNCTIONS

A comprehensive PMS would incorporate at least the following functions, those marked with an asterisk* can be regarded as the most necessary:-

a)* High-speed load shedding.
b)* Low-speed load shedding.
c)* Inhibiting the starting of large motors.
d)* VDU display of one-line diagrams.
e)* Alarms, messages and reporting of status at the VDU and printers.
f) Active power sharing for generators.
g) Isochronous control of system frequency.
h) Reactive power sharing for generators.
i) Isochronous control of system main busbar voltage.
j) Condition monitoring of the gas turbines.
k) Scheduling the starting up and shutting down of the main generators.
l) Control of the reacceleration of motor loads.
m) Auto-synchronising of the main generators.
n) Data logging and archiving of data.
o) Trending display.
p) Control of peripheral hardware e.g. VDUs, keyboards, printers.
q) Communication with the SCADA systems.

16.3.1 High-speed Load Shedding

Of all the functions the high-speed load shedding is usually the most important. The objective is to shed a predetermined amount of less essential load simultaneously with the loss of a generator (or utility supply transformer). When a generator, or its driving engine, experiences a fault, a sequence of signals is created within its control panel and main circuit breaker panel to cause the machine to shut down quickly and safely. Within the generator control and protection systems there is usually a ‘lock-out relay’ (86-G, G for generator). All the different trip signals from fault detection devices are wired to the lockout relay, which is the master trip relay for the circuit breaker. It is usually a manually reset relay with an indicating flag or lamp. A similar philosophy of tripping is used in the engine control panel in which all the mechanical failure signals are received at the engine lockout relay (86-T, T for turbine). This lockout relay also trips the generator circuit breaker. Hence any fault

Table 16.1. Relay devices and switchgear mechanism delay times

Device	Circuit breaker delay (millisec)	Motor starter (contactor) delay (millisec)
Lockout relay	5	5
Trip coil	5 to 10	5 to 10
Circuit breaker Clearance time	80 to 120	–
Contractor Clearance time	–	50 to 100
Total delay	90 to 135	60 to 115

detected by either the 86-G or the 86-T relay will trip the circuit breaker quickly and in about the same time duration.

When either the 86-G or the 86-T relay sends its signal to the circuit-breaker trip coil, time is taken before the circuit breaker begins to move and finally reach its fully open state. Table 16.1 shows the accumulation of time for typical high-voltage circuit breakers and motor contractor starters.

The PMS should be designed to monitor the status of all the main circuits in the system, the generator currents and powers, and all the outgoing currents and powers. The monitoring should be a cycle updating process, with a cycle period of at least five cycles of fundamental frequency e.g. 100 to 250 millisec, to allow power transients to decay.

The monitoring process can be approached in two ways:-

16.3.1.1 Precision approach

Every circuit breaker, contactor and switching device in the high-voltage network is monitored for open and close status. In addition each circuit is provided with accurate active power transducers. Hence the PMS will be continually checking the active power balance in the network, and the actual consumption of each load. The PMS will be able to calculate exactly how much, and which, loads to shed when a generator trips due to a fault. The PMS can also add a small margin of power to each load to be shed so that the remaining generators are able to settle at a level similar to that before the faulted generator tripped. This is important when the pre-fault load factor of the generators is high i.e. approximately 90 to 95%, and it will prevent the transient power change in the remaining generators from causing a rise in gas-turbine power turbine temperature (frequently called the ‘operating temperature’).

This approach is the most accurate in terms of selecting which loads to shed and safeguarding the remaining generators.

16.3.1.2 Approximate approach

Every circuit breaker, contractor and switching device in the high-voltage network is monitored for open and close status. Each generator circuit is provided with an accurate active power transducer. Each load will be assigned an active power value from knowledge of the plant operating conditions and the nameplate rating of the load. The power transducers in the generator circuits are necessary because in practice generators seldom share power accurately, as measured and indicated, unless a special load sharing control scheme is used, see sub-sections 2.5.4 and 2.5.5. This is important when the pre-fault load factor of the generator is high, for the reasons given in a).

When a generator trips the precalculated number of loads are also tripped. In this approach there will always be the possibility that one or two loads more than theoretically necessary will be tripped. This is because some of the running loads will have been operating at a power lower than that assigned. This inherent source of error can be minimised if current transducers are fitted to the shedable loads. In this case the assigned power can be modified by the ratio of measured current to the assigned current.

This approach is the most economical in terms of the hardware necessary for load shedding. The PMS can be arranged to detect the fault at the 86-G and 86-T relays, in one of two methods:

a) From the input terminals (operating coil) of the 86 relay, or
b) From the output contacts of the 86 relay.

Method (a) is preferred for a new plant where a high-speed auxiliary relay can be used in parallel with the 86 relay coil.

Method (b) can be used for an established plant where spare contacts are available in the 86 relays, otherwise method (a) can be used.

Upon detection of the signal at an 86 relay the PMS will call from its memory the list of loads to shed, and then send tripping signals to each load simultaneously. In the meantime the generator circuit breaker will have received its tripping signal and its mechanism will have started to separate the main contacts. When the generator circuit breaker has reached its fully open position the load shed circuit breaker and contractor mechanisms will be part way through their travels. It can be seen that the time delay between the generator and the load-shed circuit breakers is approximately equal to the computing time needed by the PMS to create the tripping signals to the loads. This computing time is typically 40 to 60 msec. The whole process takes between 100 and 175 msec. It can be considered that the remaining generators only need to take up the lost power of the faulty generator for approximately the time it takes the PMS to compute the loads to be tripped, i.e. 40 to 60 msec.

If there are N generators operating, each at a load factor F_b per unit, then after one generator is tripped each remaining generator will be operating at a new load factor of F_a, where:

$$F_a = \frac{F_b N}{N-1} \quad \text{p.u.}$$

If the remaining generators are assumed to be able to ride through the disturbance and tolerate an overload of 5% for a long time then the pre-fault critical load factor F_{bc} is:

$$F_{bc} = 1.05\left(\frac{N-1}{N}\right)$$

Table 16.2 shows the critical pre-fault load factor for plants with different numbers of generators.

If the load factor F_b is less than or equal to F_{bc} then load shedding will not be necessary. Most plants that have their own power generation use two, three or four generators. With only two

Table 16.2. Critical load factor versus number of generators

Critical pre-fault load factor (%)	Number of operating generators before the fault
52.5	2
70.0	3
78.8	4
84.0	5
87.5	6

generators it is essential to have a load shedding system. On the other hand a plant with six or more generators operating should not need to have a load shedding system. These are usually plants that have grown in stages over a long period of time.

16.3.2 Load Shedding Priority Table

The consumers in the high-voltage network can be examined for their importance in the operation of the whole plant. Hence each consumer can be placed in a table that identifies its order of importance. This is called the load shedding priority table. Such a table will vary considerably from plant to plant because of the nature of the processes therein. In some exceptional situations it may be necessary to include some of the low-voltage loads.

Table 16.3 shows a typical priority table for an offshore platform that produces oil and gas.

The table as shown applies to a fully loaded platform with all four 4 MW generators running at a load factor of approximately 80%. At first sight it may appear that too many items are included in the table. However, as the platform becomes loaded from its start-up condition the number of items in their ‘on’ state increases from a small number, and each item may be only partially loaded. Once the total load requires two generators to be on-line, then the PMS can be enabled to take load shedding action.

The priorities shown are typical for an offshore platform, but each project should be considered on its own merits and the table prepared from discussions with the process, mechanical and facilities engineers, see sub-section 1.8.

The priority table is stored in the PMS memory and therefore it can be easily modified or rearranged as the plant ages. As plants become established their various processes often need to be modified, especially offshore platforms where the gas-to-oil ratio changes with time.

It may not be necessary to put all the high-voltage consumers in the priority table. The most economical approach is to select enough consumers such that their total nameplate power, when multiplied by a factor (K), is equal to the rated output of one generator when it is operating at its highest ambient temperature in its ‘dirty state’. In Table 16.3 this would apply to the group of items numbered approximately 16 to 23, such that the motor control centres are not included. The factor K will therefore need to take account of:

- Dirty engine conditions.
- Highest ambient temperature.

Table 16.3. Priority table for a power management system on an offshore oil and gas platform

Load shedding priority (1 = low)	Description	Rated load (kW)	Consumed load (kW)	Status (ON or OFF)	Remaining load (kW)	No. of running generators (approx.)
	Generation on-line				16,000	4
	Total load				12,825	4
1	HP compressor A	1,200	1,020	on	11,805	4
2	HP compressor B	1,200	1,020	on	10,785	4
3	IP compressor A	1,000	860	on	9,925	3
4	IP compressor B	1,000	860	on	9,065	3
5	IP compressor C	1,000	0	off	9,065	3
6	LP compressor A	800	700	on	8,365	3
7	LP compressor B	800	700	on	7,665	3
8	LP compressor C	800	0	off	7,665	3
9	Seawater lift pump A	500	420	on	7,245	3
10	Seawater lift pump B	500	420	on	6,825	3
11	Seawater lift pump C	500	0	off	6,825	3
12	Refrigeration Compressor A	350	265	on	6,560	3
13	Refrigeration Compressor B	350	0	off	6,560	3
14	Main oil-line pump A	900	720	on	5,840	2
15	Main oil-line pump B	900	720	on	5,120	2
16	Process MCC LHS A		670	on	4,450	2
17	Process MCC RHS A		630	on	3,820	2
18	Process MCC LHS B		590	on	3,230	1
19	Process MCC RHS B		610	on	2,620	1
20	Utility MCC LHS		750	on	1,870	1
21	Utility MCC RHS		720	on	1,150	1
22	Accommodation MCC		310	on	840	1
23	Emergency MCC LHS		450	on	390	1
24	Emergency MCC RHS		390	on	0	1
25	Spare		0	off		1
26	Spare		0	off		1

- Highest load factor of the generators.
- Operating level of each load shedding consumer.
- A contingency if felt necessary.
- Reappraisal of importance with ageing of the plant.
- Spare and future consumers.
- Base and peak loading of the plant.

16.3.3 Low-speed Load Shedding

Low-speed load shedding takes account of long-term drifting and trending towards an overloaded state. It is applied to each turbine generator individually. The overloading can be detected directly or indirectly as follows:

- Measurement of active power at the generator terminals.
- Measurement of gas-turbine operating temperature.
- Measurement of the power system frequency.

When a plant is heavily loaded with a load factor above 90% it is necessary to ensure that all the generators are equally loaded. The equalisation of load is often left to the droop settings of each governor, or by manual trimming if suitable controls are available. Automatic load sharing can also be included in the PMS, see sub-sections 2.5.4 and 2.5.5. It is also necessary to maintain the gas turbines in a 'clean' state and not let them become widely mismatched in this respect. If mismatches in operating electrical power and engine cleanliness exist at the same time, then it is possible that, for example, say one of the gas-turbine generators will be operating very close to its upper limits. This will be seen as an excessively high operating temperature. Under very steady load conditions this excessive temperature could be tolerated for a long time. If the plant has a number of large motors, comparable in rating to that of one of the generators, then the starting of such a motor will cause a significant power disturbance at the main busbars. It is common practice with offshore platforms to start these motors direct-on-line. It is less common to do this with onshore plants. The disturbance will be shared amongst the generators, and may last for 0.5 to 20 seconds, depending upon the run-up time of the motor. The disturbance will consist of the static power characteristic of the driven machine and the necessary accelerating power for the rotating inertia. Hence the disturbance may be large enough and long enough to cause the operating temperature of the highest loaded generator to exceed its tripping limit. This generator will then shut down.

The PMS will receive this shut-down signal from one of the 86 lock-out relays, and will respond in exactly the same way as with the high-speed load shedding, see sub-section 16.3.1.

The low-speed load shedding will be more active when the ambient temperature is high i.e. near to the site high limit.

16.3.4 Inhibiting the Starting of Large Motors

The volt-drop ΔV at the main busbars can be given by the approximation:

$$|\Delta V| = \frac{X_g(K S_m{}^2 - S_g S_L \sin\phi_L)}{S_g + K S_m{}^2 X_g} \quad \text{per unit} \tag{16.1}$$

Where the prestarting busbar voltage V is unity, and

X_g is the transient reactance X'_d in per unit of the generator
S_g is the KVA rating in per unit of the generator
S_m is the KVA rating in per unit of the motor
S_L is the KVA rating in per unit of the standing load
$\cos\phi_L$ is the power factor of the standing load
ϕ_L is the power factor angle, hence $\sin\phi_L$ can be found.
K is the starting current to running current ratio of the motor

Equation (16.1) can be rearranged to determine the largest motor rating for a given volt-drop limit:

$$S_m{}^2 = \frac{S_g(X_g S_L \sin\phi_L \Delta V)}{K\ X_g(1 - \Delta V)} \tag{16.2}$$

Table 16.4 shows the largest motor rating allowed for different system conditions and designs, where $S_g = 1$ pu.

It can be seen that the most restricting factors are a low standing load or a standing load with a power factor near to unity. In these cases the motor rating is limited to approximately 27% of the total generator kVA capacity. If an allowance is also made for additional volt-drop in the generator and motor cables then the 27% limit would be reduced to between 20 and 22%. Thus a ‘rule-of-thumb’ ratio of 5:1 between the kW or kVA ratings of the generators and the motor to be started is reasonable for quickly assessing a satisfactory system performance, see also Appendix G.

In view of the above findings it would be reasonable to have the PMS inhibit the starting of the large motors when there is insufficient kW capacity of running generators. The PMS would raise an alarm and advise that an extra generator should be brought on-line so that the particular motor can be started. The PMS could incorporate an equation such as (16.2) since all the constants are known from the nameplate data and the variables can be found from the system measurements received at the PMS for other uses.

16.3.5 VDU Display of One-line Diagrams

A PMS can be programmed to display the status of the power system in the form of one-line diagrams. The one-line diagrams can be displayed in colour, where different colours can be used for different functions, such as:-

- Green busbars and feeders are alive.
- Red busbars and feeders are de-energised.

Table 16.4. Relative magnitudes of different parameters that effect the amount of volt-drop experienced during the starting of a large induction motor

Case	S_m	ΔV	K	X_g	S_L	$\sin\phi_L$
a	0.34	0.1	6	0.25	0.5	0.436
b	0.40	0.15	6	0.25	0.5	0.436
c	0.46	0.2	6	0.25	0.5	0.436
d	0.41	0.1	4	0.25	0.5	0.436
e	0.37	0.1	5	0.25	0.5	0.436
f	0.40	0.1	6	0.15	0.5	0.436
g	0.36	0.1	6	0.2	0.5	0.436
h	0.39	0.1	6	0.25	1.0	0.436
i	0.27	0.1	6	0.25	0.0	0.436
j	0.27	0.1	6	0.25	0.5	0.0
k	0.36	0.1	6	0.25	0.5	0.6

- White devices withdrawn from service.
- Yellow devices tripped due to a fault.

Each switchboard in the main distribution network can have its own one-line diagram displayed, and for the more complicated switchboards each busbar section can be displayed. The active and reactive power flows and current flows can be shown for each item where suitable analogue transducers have been fitted. This is particularly beneficial for the main power generation switchboard. All names and tag numbers can be shown for clarity. A diagram similar to Figure 16.1 can be displayed.

16.3.6 Active Power Sharing for Generators

As explained in sub-section 2.5.3 it is possible to compensate for the mismatching of active power delivered by each generator. The PMS can be programmed to calculate the average power of each generator and thereby to determine the power mismatch of each generator. The PMS can then use each mismatch to iteratively readjust the set point of the corresponding governor without changing the common frequency. All the generators must be operating in their droop-governing mode for such adjustments to be applied.

16.3.7 Isochronous Control of System Frequency

As explained in sub-section 2.5.3 it is possible to superimpose an integral controller on to the set point controls of the individual governors. The master integral controller will have a master frequency

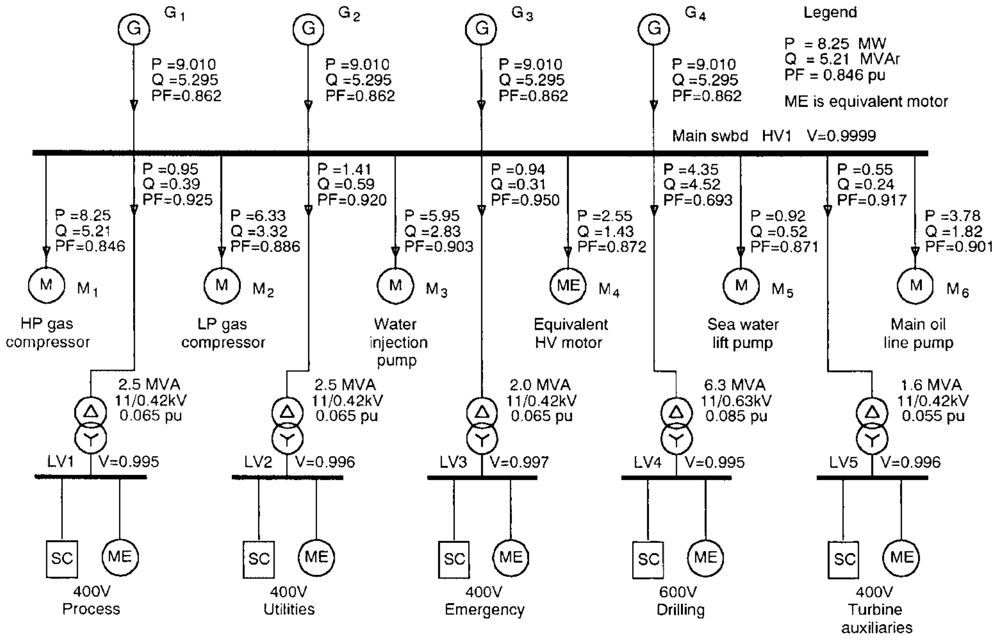

Figure 16.1 One-line diagram of a power system that has its own dedicated generators, showing the load flows between the switchboards.

set point. Such a scheme can be easily incorporated into the PMS because all the measurements and output signals exist if a load-sharing scheme is present. The master integral controller must be slow acting relative to the time response of the governor control action. For a 50 Hz power system, for example, the master set point frequency could be set at 50 Hz or some other frequency to suit the operating conditions.

If it is necessary to switch off the isochronous controller when the plant is heavily loaded, then the PMS should calculate what the individual governor set points should be for a system frequency to suit the overall droop. It should send these signals shortly after the isochronous controller is switched off. This feature will prevent the system frequency rising too high when the plant is lightly loaded. As the frequency rises each motor will run at a higher speed and thus consume a little more power and current. If a motor normally runs close to its nameplate rating, rather than at its originally designed load, then it is possible that the higher current could activate the overcurrent protection of the motor. After some length of time such a motor may trip. Alternatively the PMS could allow the frequency to rise to a predetermined maximum value before the corrective isochronous signals are sent to the governor set points. This would give the benefit of maintaining a good frequency for most operating levels of the plant.

16.3.8 Reactive Power Sharing for Generators

As explained in sub-section 2.5.3 for speed governing it is possible to compensate for the mismatching of reactive power delivered by each generator in a similar manner. If this is achieved together with reducing the mismatch of active power, then each generator will be operating at the same current. This will eliminate the possibility of an overcurrent occurring at one of the generators when a high load factor exists. The method described in sub-section 2.5.3 can be used with frequency being replaced by busbar voltage, and the set points to be adjusted will be those of the automatic voltage regulators (AVRs).

16.3.9 Isochronous Control of Busbar Voltage

Likewise as explained in sub-section 2.5.3 it is possible to superimpose an integral controller on to the set point controls of the individual AVRs. The master set point will be the busbar voltage. The master controller must be slow acting relative to the time response of the AVR control action, so as to avoid the possibility of oscillatory or even unstable operation.

Safeguarding against over-frequency was explained in sub-section 16.3.7. The same concept can be used to safeguard against overvoltage at light loads.

The sharing of active and reactive power and the isochronous control of the system frequency and main busbar voltage can be displayed on the VDU using a diagram similar to that shown in Figure 16.2.

16.3.10 Condition Monitoring of the Gas Turbines

The power output from a gas turbine is greatly influenced by changes in ambient temperature and the state of cleanliness of the combustion equipment and power turbine blades.

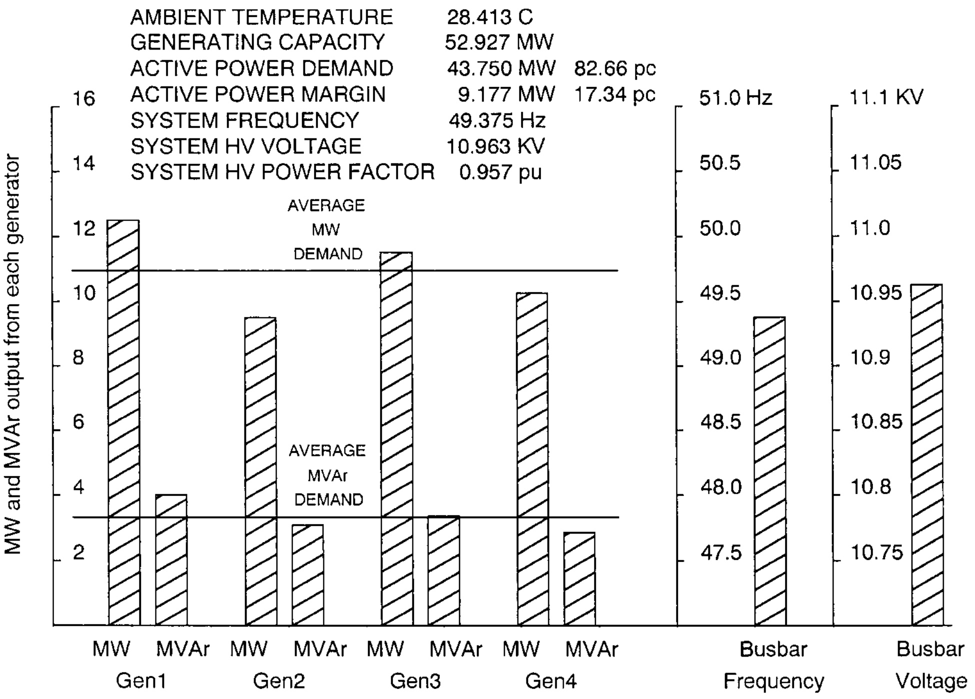

Figure 16.2 Screen page of a power management visual display unit.

The PMS can be programmed to take account of the ambient temperature by storing the 'new' engine power versus ambient temperature characteristic, as referred to the generator terminals i.e. gear-box and generator losses deducted from the shaft power, see Figure 2.10.

The 'dirty' engine reduction in power can be assessed by measuring the electrical power at a particular ambient temperature and the corresponding operating temperature. As the engine becomes more dirty the operating temperature will rise for a given electrical power and ambient temperature. This rise in temperature can be found from site tests on engines that have been running for different periods, since a major maintenance. The longest period would be similar to the figure recommended by the manufacturer. Hence an approximate linear correlation between running time, and hence dirtiness, against excessive operating temperature can be found. This correlation can be applied by the PMS for operating load factors above 70% to ensure that the operating temperature is kept below a predetermined value, which could be 'close to alarm limit'. The correlation can be applied by biasing the power versus ambient temperature characteristic downwards.

The PMS can be programmed to give a message to the control room operator that the engine is in need of being cleaned.

16.3.11 Scheduling the Starting Up and Shutting Down of the Main Generators

The PMS can be used to schedule the starting up and shutting down of the main generators. A simple method can be used as follows. Set the upper load factor of each generator to be say 75% and the lower load factor to be say 60%. As the plant load increases from zero one generator would be used initially until the upper load factor is reached. At this point the PMS should give a message to start up the second generator. The same sequence is used until all the generators are on-line and the plant is at full load.

As the plant load decreases the generators operate at a decreasing load factor. When each generator has become unloaded to the level set by the lower load factor then the PMS should advise the operator to shut down one generator. This sequence can be repeated until only one generator is running.

There needs to be a margin between the upper and lower settings of the generator load factors, otherwise the scheduling will become too frequent and the messages will be subject to short-term fluctuations of load. In addition to the fairly wide margin needed for the above situation it is recommended that the PMS calculates average loading information over say a 30 minute period before a message is given. This will ensure that the fluctuations due to starting and stopping large motors will not create an unacceptable effect.

Figure 16.3 shows the scheduling profile as the load increases from zero to full plant load, and decreases back to zero. The lines shown are based on a 75% upper load factor and a 60% lower load factor.

16.3.12 Control of the Reacceleration of Motor Loads

Some motor control centres are designed to allow the motor starters to reclose upon the restoration of the main busbar voltage following a supply disturbance. This is especially necessary for emergency and essential loads, e.g. cooling water pumps and lube oil pumps for engine-driven generators. If the

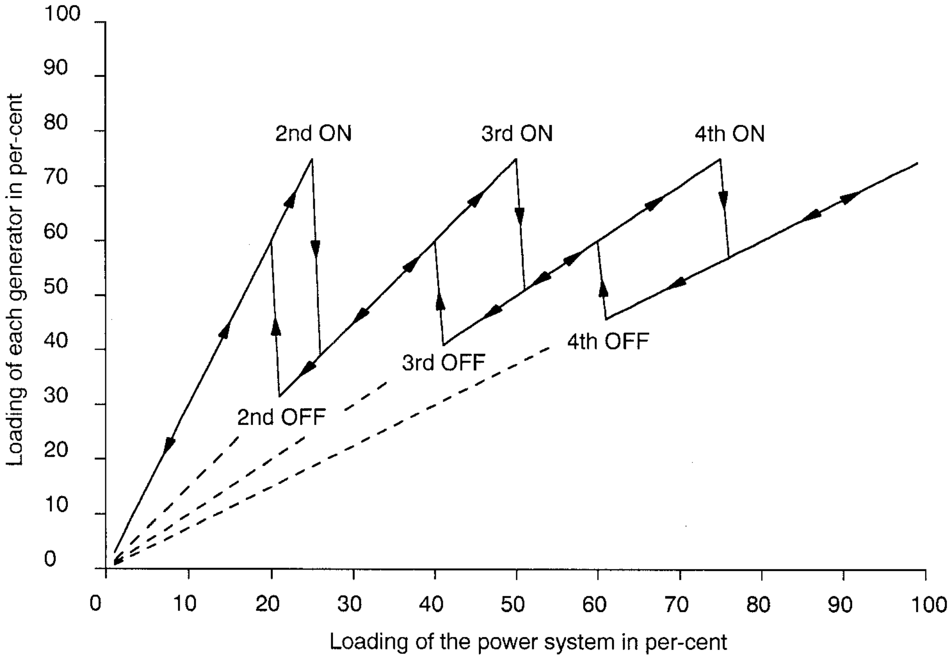

Figure 16.3 Scheduling the starting up and shutting down of generators.

supply is lost for a short time, or even a long time, then these loads should be allowed to restart without the need for operators to manually intervene.

If there is a large number of motors to restart (or also called reaccelerate) then there will be a large surge of main feeder current if they all start at the same time. This will cause a severe volt-drop at the common busbars, which will cause the run-up times to be extended and the possibility of the overcurrent protection relay at the main feeder circuit breaker to trip. Similarly if there is a group of motor control centres all in the same state of restarting their motors, then their common busbar e.g. main generator switchboard, will experience a significant volt-drop which may not be acceptable.

It is therefore necessary to plan the restarting process of all the motor loads by introducing time delays into each motor starter or groups of starters. There are many methods of achieving this, some of which are peculiar to the type of plant and whether it is offshore or onshore.

In general it is better to first restart the smaller motors and those with short run-up times. The larger and long run-up motors should be started towards the end of the planned sequence. This may not be possible in all cases because of plant operational constraints. However, the reason for attempting this is that if the supply is from a generator(s) then the driving emf of the generator increases as the load increases. The initial starting of small motors will gradually increase the emf. Consequently, when the larger motors are started later, the higher emf will benefit the volt-drop, the motors will receive a slightly higher terminal voltage throughout their run-up times.

The restarting process is usually initiated by using a voltage-sensing relay or transducer to detect the return of busbar voltage. The detection also checks that the magnitude of the voltage received is high enough to allow motors to be started e.g. greater than 90%, and a time delay may be included to ensure that the supply settles and is not a transient quantity.

All the functions required for restarting motors can be programmed in a PMS, or in a purpose designed programmable device built into each motor control centre, see also sub-section 7.6.

16.3.13 Auto-synchronising of the Main Generators

If the PMS incorporates active and reactive power sharing facilities, then it is reasonably simple to add an auto-synchronising system for the generators. The generator to be synchronised would be started and run up through its normal sequences, as furnished by its manufacturer, one for the turbine and one for the generator excitation. At the end of these sequences the generator speed and terminal voltage would be close to their busbar running values.

The PMS would then be signalled to start the auto-synchronising process, either by a signal from the turbine-generator control panel or from the operator. The PMS would use a comparator for the frequency and another comparator for the terminal voltage. The terminal voltage of the generator will be checked for nearly equal magnitude and phase angle against the switchboard busbar voltage. Three error signals will be created:-

- Voltage magnitude error.
- Voltage phase angle error.
- Frequency error.

The PMS can use these signals to adjust the AVR set point to reduce the voltage magnitude error, and the governor set point to firstly reduce the frequency error, and secondly to reduce the phase angle error. The PMS would then send a synchronising signal via a Synchronisation Check relay (25) to close the generator circuit breaker, as soon as the following incoming generator conditions are satisfied:-

• Voltage magnitude error	±0.15%
• Voltage phase angle error	-30° to 0°
• Frequency error	+0.05%

Once the circuit breaker has closed the PMS should slightly increase the governor set point to ensure that the generator delivers a small amount of power. This will avoid the possibility that a reverse power situation will develop to a level that could cause the reverse power relay to trip. The PMS will then switch off the auto-synchronising facility.

16.3.14 Data Logging, Archiving, Trending Display, Alarms, Messages and Status Reporting

These facilities are typically incorporated into SCADA systems where all kinds of plant data are collected, time stamped, stored, displayed and printed out.

However, the PMS can be used to handle special electrical power system data in the same way, either as a self-contained PMS or by communicating the data to associated SCADA equipment. The following list gives typical data that would be collected and reported:-

- Change of status of main circuit breakers, motor starters, transformer feeders, busbar bustie circuit breakers, switchboard interconnectors, earthing switches, withdrawn devices.
- Variables such as busbar voltages, system frequency, load flow and current flow in main circuits and interconnectors, generator power factor, ambient conditions.
- Operation of individual protection relays at main circuits and feeders.
- Alarm and trips of engine and generator parameters.
- Trending of engine and generator parameters.
- Trending of active and reactive total power.

Note, the data associated with each consumer e.g. pumps, heaters, compressors and fans would normally be collected and reported by the SCADA system as individual process items.

The data collected will normally be displayed in several forms on the VDU and as printed out information. The operator will be able to choose tabular output of, for example:-

- Chronological alarms and trips received.
- Alarms and trips acknowledged (or not).
- Chronological messages and events.

Note: Once an alarm or trip has been reset it often disappears from the tables, but the time and date of its disappearance can be logged as an event. Colour-coding can be used for unacknowledged and acknowledged data.