Application Guidance Notes: Technical Information from Cummins Generator Technologies

AGN 203 - Japanese National Electrical Distribution System

INTRODUCTION

There are only two standard frequencies used around the world – 50Hz and 60Hz. There are, however; many different voltages at 3-phase and single phase output. The British Standards Institute (BSi) have issued booklet guidance titled: World Electricity Supplies.

ELECTRICITY SUPPLY IN JAPAN

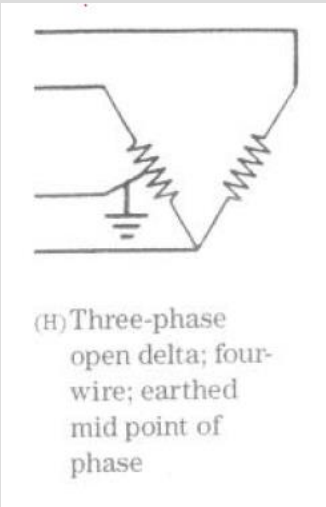
The Japanese national electrical scheme is a unique system. The most commonly requested system is for a 3-phase system that can provide the necessary low power single phase voltages. The following table is a caption of the Japanese national electrical distribution system taken from the BSi World Electricity Supplies booklet:

JAPAN (EAST) (4)	50 ± 0.2 (5)	200/100 (K) 100 (L)	200/100 (H) (K)	6.6 kV 200/100 (H) 200 (G) (J)	± 10
JAPAN (WEST) (4)	60 ± 0.1 (5)	210/105 (K) 200/100 (K) 100 (L)	210/105 (H) (K) 200/100 (K) 100 (L)	22 kV 6.6 kV 210/105 (H) 200/100 (H)	± 10

The 3-phase supply voltages are established at 200V at 50Hz (Japan East) and 200V or 210V at 60Hz (Japan West). The 3-phase voltage (L-L-L) of 200V will have a single phase voltage (L-N) of 115V and the 3-phase voltage of 210V will have a single phase voltage of 121V.

When an alternator is required to supply outputs to match the Japanese national electrical distribution system, the configuration of the stator windings associated with each of the codes – Code H, Code K and Code L – is shown below:

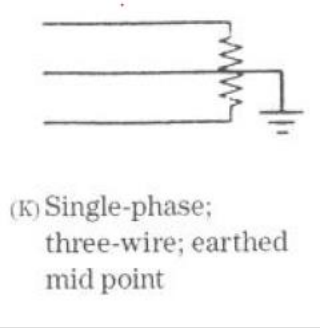
Configuration for Code H:



(H) Three-phase open delta; four-wire; earthed mid point of phase

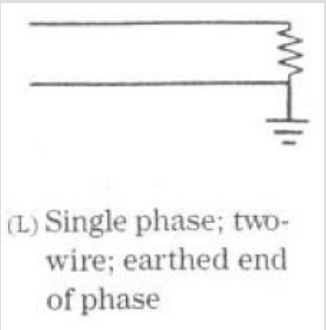
Note: the Code H configuration shows an open-delta, however; an AvK or STAMFORD alternator would always be connected in a full delta configuration.

Configuration for Code K:



(K) Single-phase; three-wire; earthed mid point

Configuration for Code L:

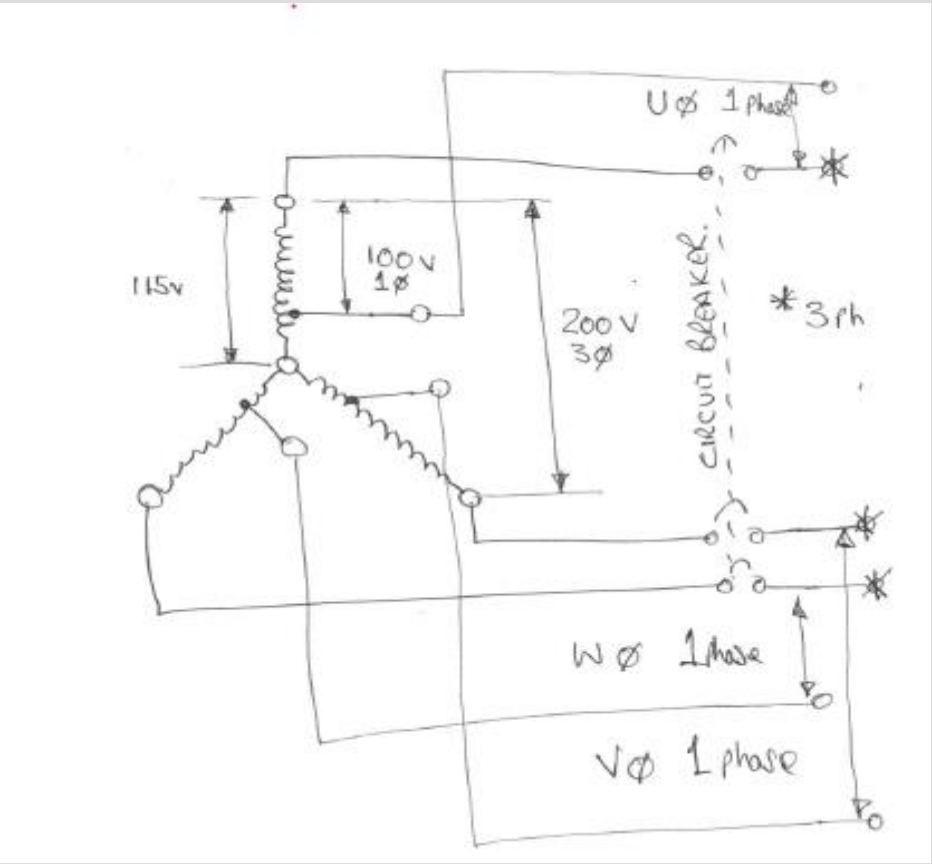


(L) Single phase; two-wire; earthed end of phase

In the past, STAMFORD alternators have been supplied with a specially designed winding for the Japanese market. The specially designed winding was Winding 77, which had a tap brought of each phase just above the star point. The tap was positioned to give the required

single phase voltage of 100V or 105V. Winding 77 was available on the following STAMFORD alternators: BC, UC and HC4, with the low voltage winding tap being rated at < 8kVA.

The current associated with each phase winding, which can be a combination of the 200V load – and this effectively could be 3-phase or single phase at 200V – and the 100V single phase, will combine and so the total phase current all passes through the Circuit Breaker, as shown in the following illustration:



With the upgrade of alternators in the STAMFORD range, it has been decided to obsolete Winding 77. The outputs required for the Japanese national electrical distribution system, can now be supplied from STAMFORD alternators with the standard Winding 311, with a Parallel Star configuration.

ALTERNATOR NOMINATION

Alternators should be selected from the STAMFORD range for the Japanese national electrical distribution system.

Japan East – 200V/100V 50Hz

At 50Hz, a STAMFORD alternator fitted with standard Winding 311 and connected in Parallel Star, has a nominal operating 3-phase voltage of 200V (L-L-L), with a flux level equivalent to

the nominal 400V, 50Hz with a more standard Series Star connection. So all is well. The Winding 311 voltage range at 50Hz with the standard Series Star connection and the optional Parallel Star connection are as follows:

- Series Star connection voltage range at 50Hz: 380V/220V, 400V/231V, 415V/240V
- Parallel Star connection voltage range at 50Hz: 190V/110V, 200V/115V, 208V/120V

However; the single phase (L-N) voltage will be 115V, which is too high as the Japanese electrical equipment is expecting 100V +/- 10%. So, there is a need to establish a compromise, as follows:

- If the single phase (L-N) voltage is supplied at + 8% = 108V, then the 3-phase (L-L-L) voltage will be 187V. 187V is 200V minus 6.5%. So, the system voltage is a compromise, but will not result in any problems with connected equipment.

Japan West – 210V/105V and 200V/100V 60Hz

For the areas of Japan that are supplied by the national 60Hz scheme, Winding 311 is not so good, but there is no better winding solution currently available. The Winding 311 voltage range at 60Hz, is focussed to meet 60Hz voltage requirements around the world, with the standard Series Star connection and the optional Parallel Star connection are as follows:

- Series Star connection voltage range at 60Hz: 416V/240V, 440V/254V, 480V/277V
- Parallel Star connection voltage range at 60Hz: 208V/120V, 220V/127V, 240V/138V

Winding 311 can be used to supply a 3-phase voltage down to a minimum of 190V/110V, 60Hz when connected in a Parallel Star configuration. However; a suitable de-rate for this low flux level operation will be required. To achieve a single phase voltage of 105V +/- 10%, again, there is a need to establish a compromise.

- If the single phase (L-N) voltage is supplied at + 5% = 110V, then the 3-phase (L-L-L) voltage will be 190V. 190V is 210V minus 9.5%. So, the system voltage is a compromise, but will not result in any problems with connected equipment.

Furthermore though, we know, a Winding 311 connected in Parallel Star and operating at a 3-phase voltage of 210V, 60Hz has a flux level of approximately 85% of the design ideal of 100%. For information, the ideal Series Star connection voltage is 498V, 60Hz for 100% flux.

To emphasize; load acceptance at these operating parameters – even with the rating de-rate – will be poor, because the flux level is too low.

To offer the best possible control on the performance of the alternator at these operating parameters, the alternator must be fitted with a 3-phase sensing AVR - MX321 AVR or a digital AVR if this is available. The MX AVR or digital AVR requires a PMG system to be fitted, to provide separate excitation and the benefit of better load acceptance.

For the small P0/P1 alternators, where no 3-phase sensing AVR is available, the EBS will not greatly assist with normal power factor type load applications. Under these circumstances, the alternator must be oversized by at least 10% to provide acceptable performance with the load step situation; where the AVR is only being supplied with 190V and so will have a low excitation ceiling related 'forcing capability'.

The small S0/S1 alternators are not suitable for operating at the outputs required by the Japanese national electrical distribution system.

GENERATING SET DESIGN

To compensate for the low flux level and also the low voltage – low voltage means high current – situation, the 60Hz rating must be reduced. To mitigate the low flux level and keep the current within acceptable limits, the de-rate factor needs to be (210V x 2) / 480V = 0.87. This calculates to a de-rate of 87% of the 480V, 60Hz normal rating.

To support the 200V/100V, 60Hz systems, the alternator will be operating at half normal operating voltage, therefore delivering twice rated current. This will introduce two definite areas of concern that must be explained to the Generating Set manufacturer associated with the electrical output cables connected to the alternator's terminals, which will be of twice the cross sectional area of those normally used.

- Such a mass of cables will create problems in terms of physical space required on each terminal and within the terminal box region.

- The weight of cables being supported by each terminal will be twice the normal loading and so additional support should be provided.

For the above reasons it is unlikely that Generating Sets with an output above 500kVA would be applied to such a low voltage application. If these outputs are considered, then the Generating Set manufacturer's engineering team must undertake careful consideration and issue explicit connection instructions.