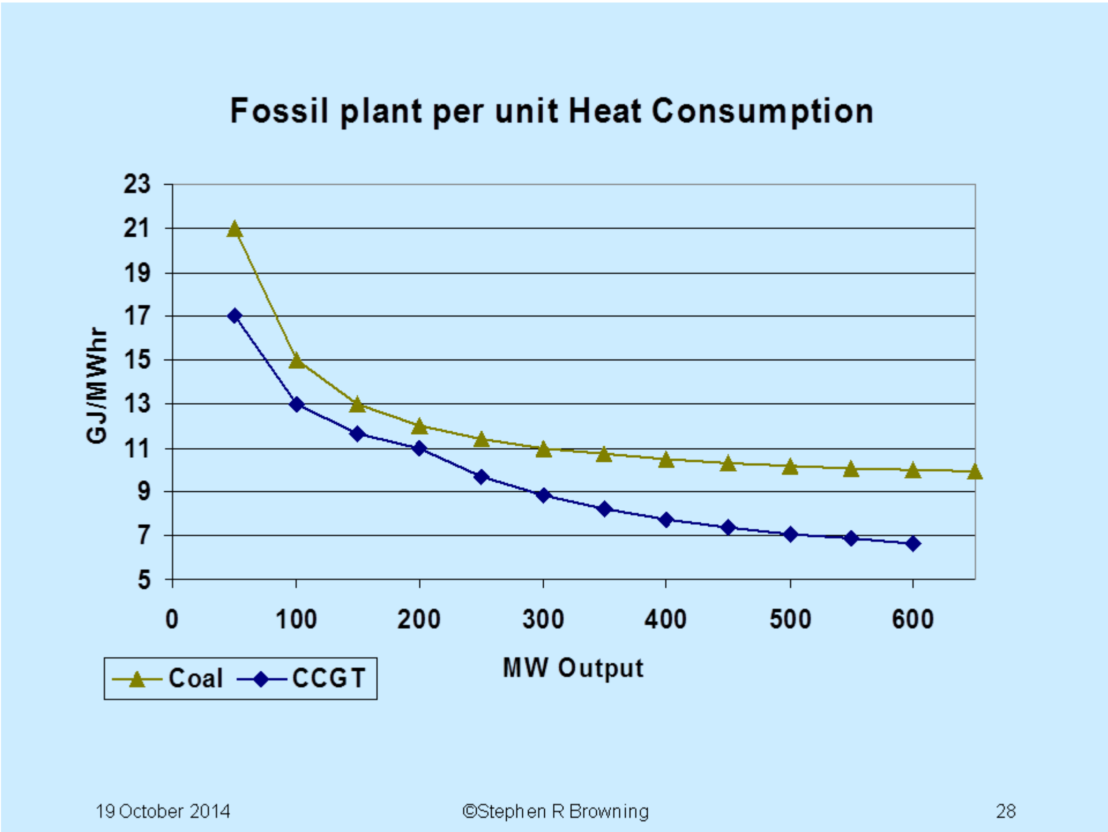
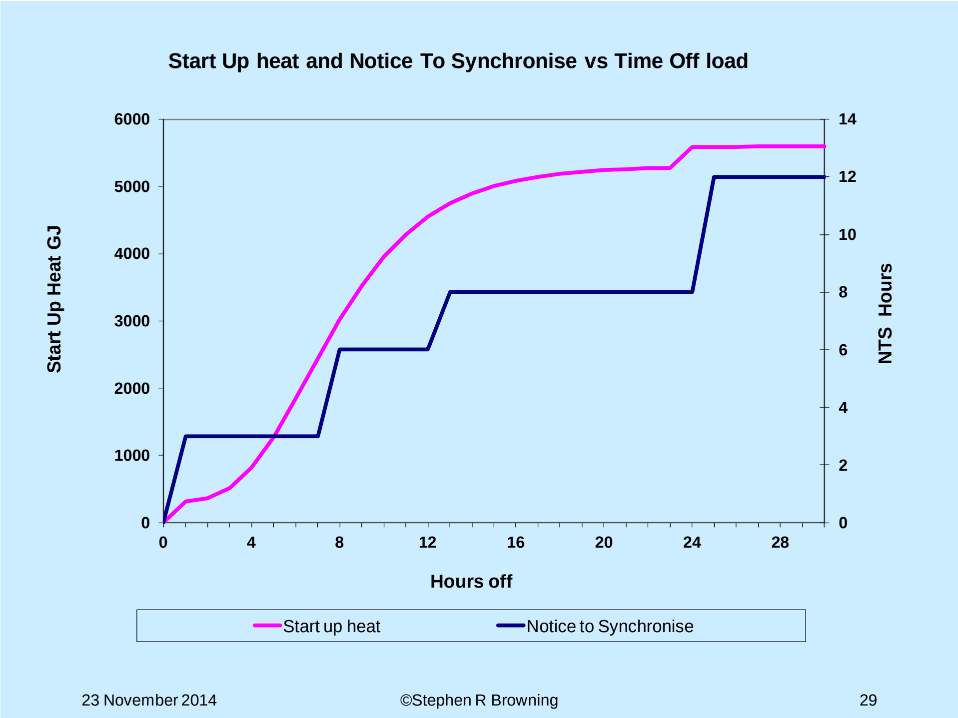
Fossil Plant Heat consumption

Most thermal fossil fired generation is designed to be most efficient at full load. Large coal and oil units are typically 36% efficient at max ouput dropping to 32% at half load. CCGTs can be 55% efficient at maximum, but only 40% when at half load. The fuel burn and thus the emissions, per unit output, follow the same pattern.



In addition, each unit will consume start up heat to bring it on load, which increases with the time the generator has been shut down. Again the fuel burn and emissions lines follow the same characteristic.



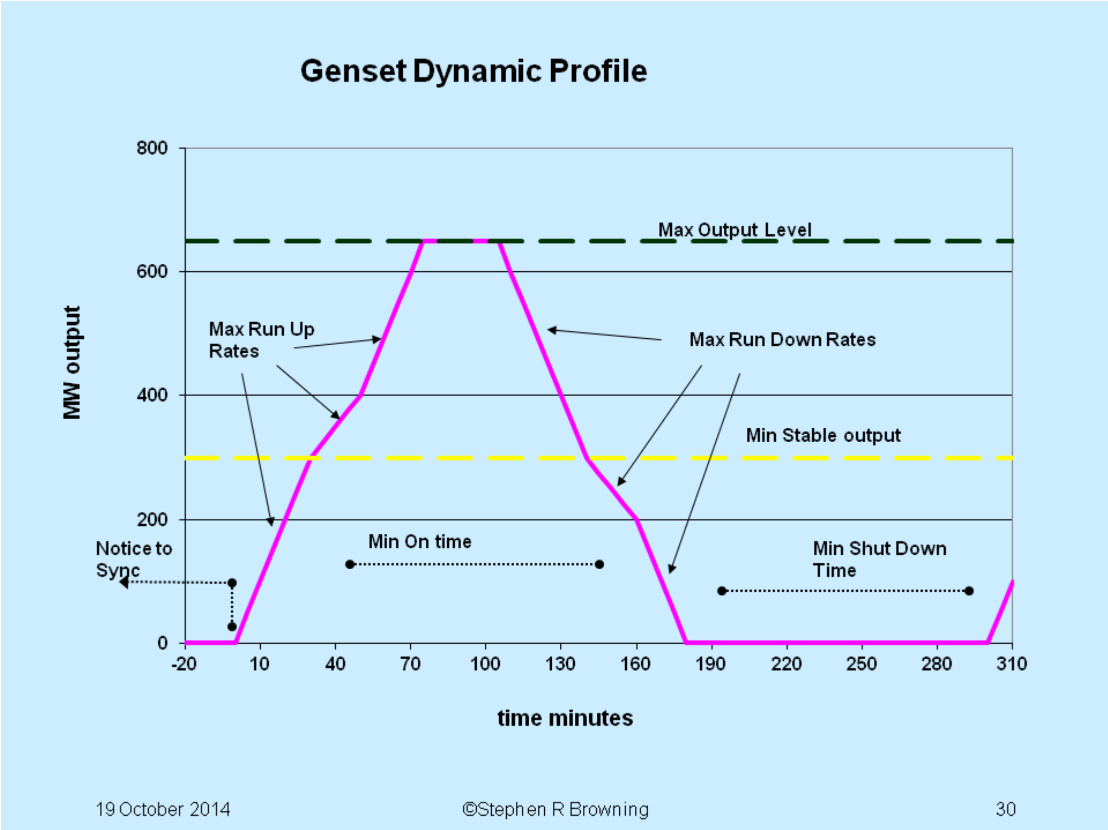
Generating Plant Dynamics

If a Unit is Off then it cannot again synchronise until its minimum shutdown time has elapsed since the time it was last desynchronised and the notice to synchronise time has elapsed from the time it was instructed to come back on. Note that the NTS increases with time off load (see above). Also, each station may have a restriction on how many units can be rolled up to synchronise at the same time. This can be due to a combination of works power supply limitations, staffing requirements while rolling or make up water plant capability. A generator cannot synchronise until the defined interval time has elapsed since the previous unit was synchronised.

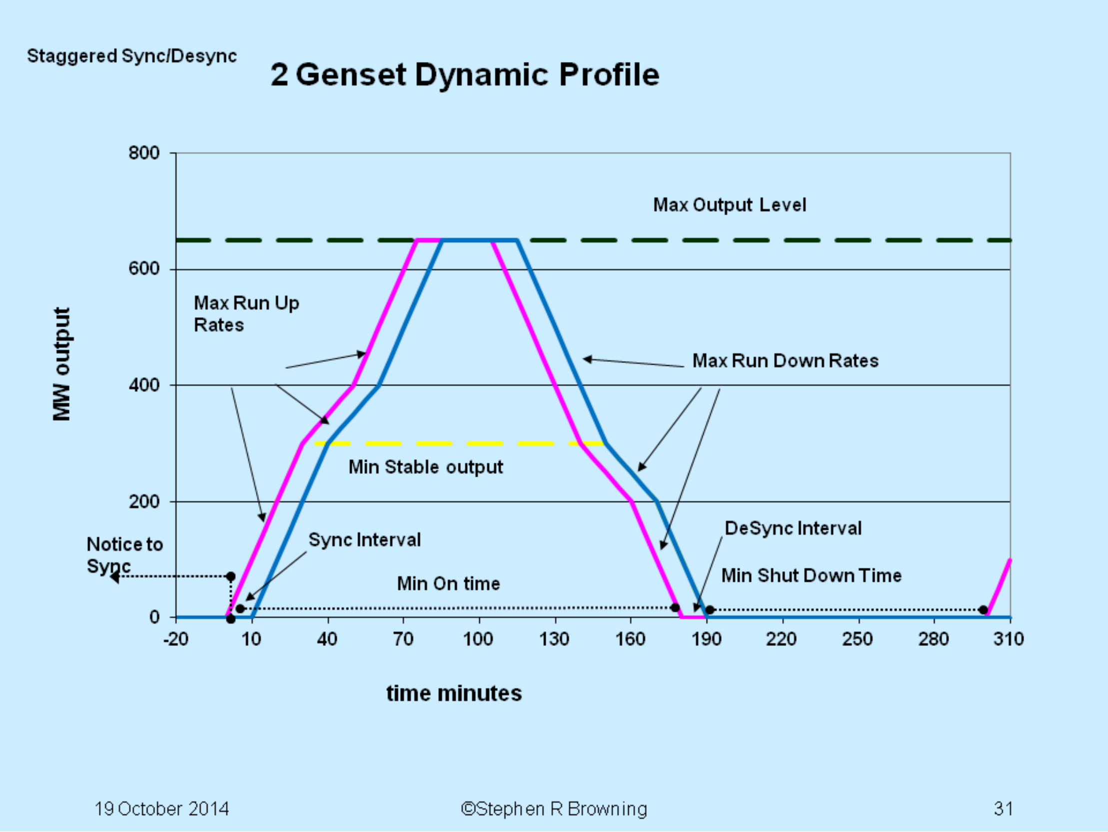
Once synchronised, the unit must increase output at its run up rate until it has reached the lower of its minimum stable generation level, its minimum output profile (inflexibility) or its maximum output profile (availability). It can then operate between this level and availability with ramping speed limited by its run up and run down rates.

When the unit is due to come off it must deload from the lower of minimum stable generation, inflexibility and availability to desynchronise, at its run down rate. The desynchronisation time must be at least its minimum on time from the synchronisation time. A unit cannot be shut down and start back up on each day more than the permitted number of shutdowns. Also, at each station, a unit cannot desynchronise until the defined interval has elapsed from the desynchronisation of the previous unit at the same station.

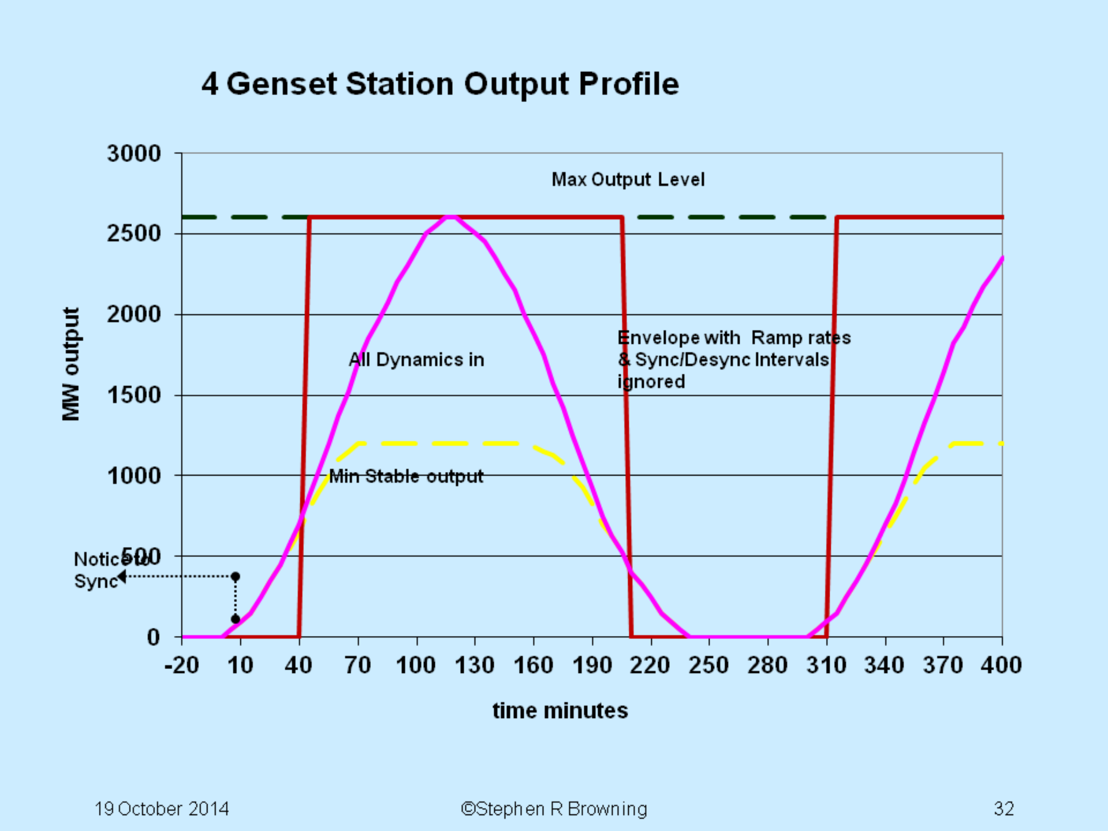
Maximum ramp rates are around 10MW/minute on a large machine. Coal fired units may be able to ramp faster, once hot, by changing the logistics of mill operation.



If there are two or more units at a station, there may be interval restrictions on coming off and on. You can 'stagger' the order (FIFO, LILO).

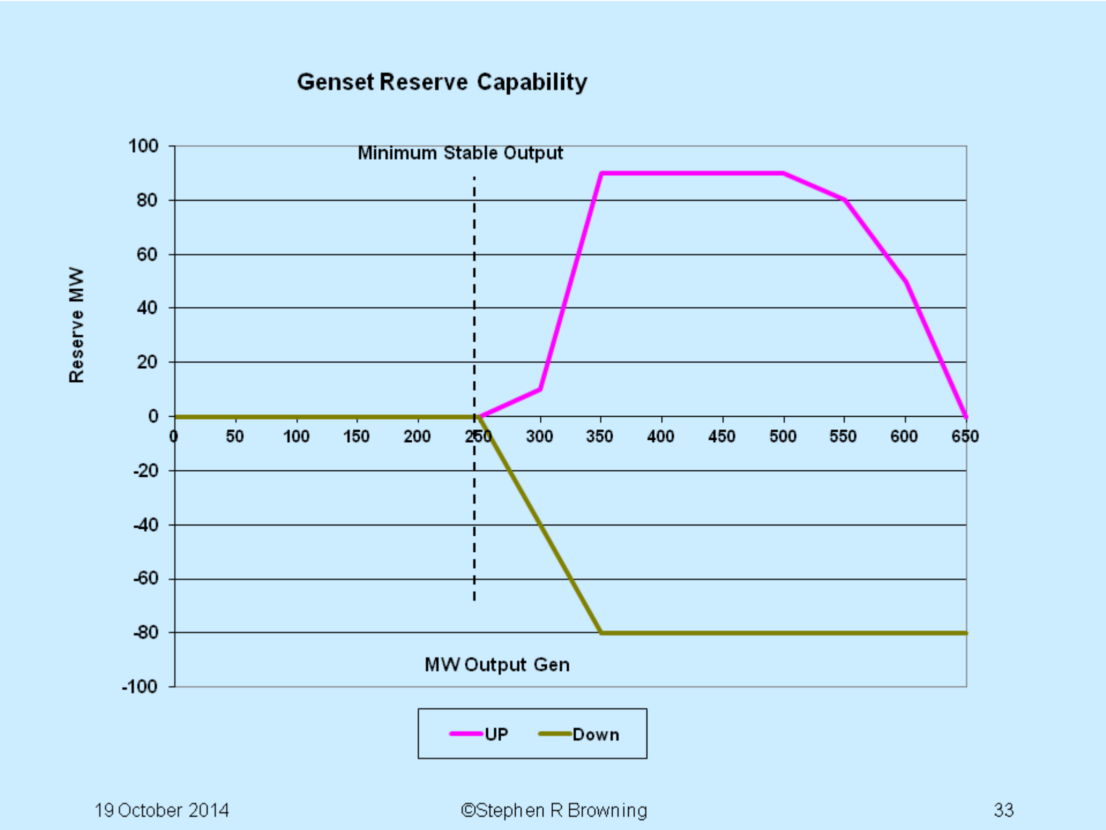


So, for a 4 genset station the envelope could look like this



Response and Reserve

In general fossil units are only able to provide upward and downward regulation while operating between minimum stable generation and availability, with the level of that regulation bounded by those same limits.



Scheduling and Dispatch

The variations in the daily demand curve dictate that a number of generators start up for the plateau and peak periods of the day. Some demand rises are so fast (up to 3000MW/hhr in GB) that a number of units will be ramping simultaneously. At all times, some units are also part-loaded for response, reserve and spare duty, to cover unexpected demand or generation changes. Units have to be ordered far enough in advance that they will synchronise at the correct time. The Transmission flows and voltage/stability condition has to be analysed for each timestep using the predicted generation and demand data. The plant selection (and any variable demand) is adjusted to ensure Transmission security is maintained.

It is vital that the demand curve is accurately predicted and generation is reliably operated to avoid unnecessary part loading, allocation of excess reserve or ordering of generators that aren't actually needed in the event. Prediction, reliability and timing are the key to efficient operation.

Future Power Systems 3 - Main Plant characteristics

The conventional power plant is designed to be controllable for instruction following. Thus, its output is predictable for the purpose of Generation-Demand matching. Even so, allowances have to be made to cover the risk of plant breakdown; response, reserve and spare output is carried to cover the anticipated level of generation shortfall and failure as against the instructed output.

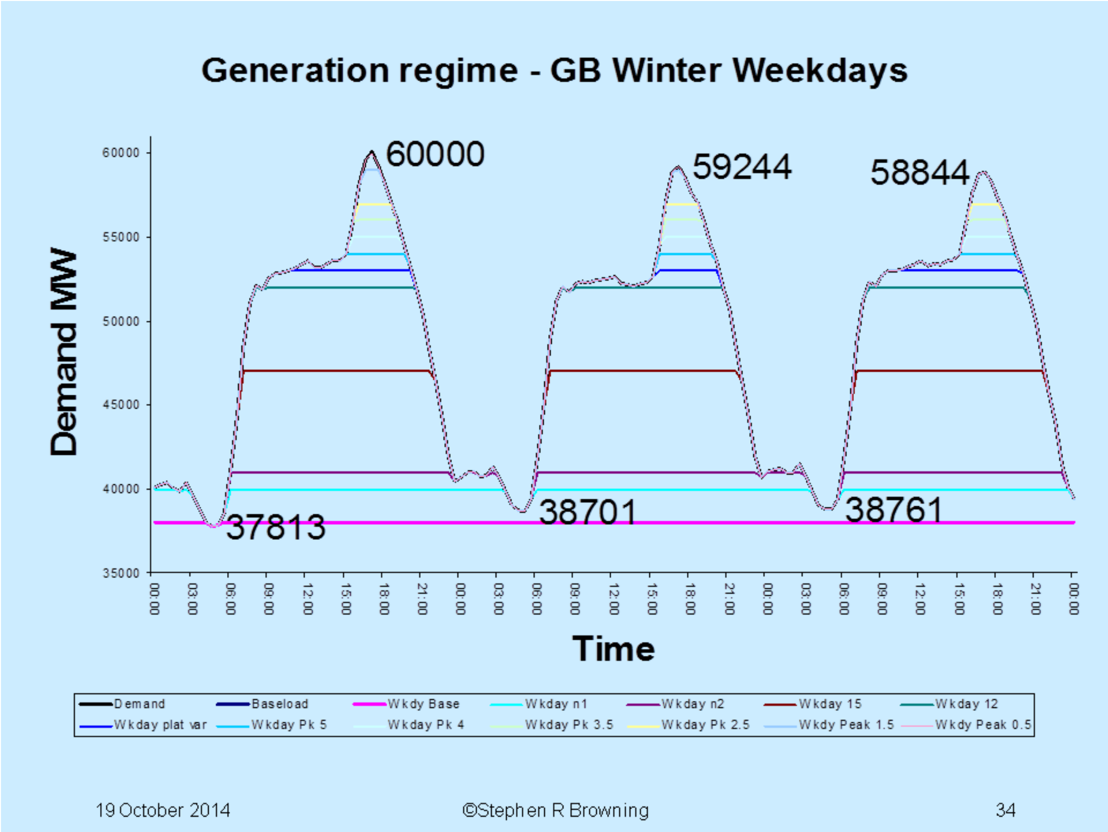
For efficient operation, Generation is 'stacked' into the load curve in on load merit order, each tranche of plant running for shorter periods as merit order cost increases. Start up costs are also taken into account. A unit with high start up cost may not be selected for a short run, if there is other plant with higher on load cost but much lower startup cost which can cover the run period at a cheaper overall cost. Likewise, slow or inflexible units may be rejected for short runs if they incur high 'inefficiency' penalties as a result.

When not in merit, units can either shut down, incurring start up costs and having to stay off for minimum shutdown time, or run through part , incurring extra per unit costs due to operating at lower efficiency. To accommodate their minimum output other, cheaper, plant also has to be deloaded and run inefficiently. Again start up vs running costs and flexibility all have to be taken into account.

At all time Reserve has to be provided, either by part loading generating plant or by response from the retail customer side (supplier market).

Unit Commitment, Scheduling and Dispatch is thus a complex Mixed Integer-Linear time series problem. In addition, any uncertainty about predicted Generation Availability or Demand take will require the Matching process to be continuously re-run and strategies adjusted.

A simplified view of Generating Plant Tranche stacking (without the part loading effects, assuming constant and predictable availability) is shown below


Generation regime - GB Winter Weekdays
Demand MW
Time
60000
59244
58844
37813
38701
38761
60000
55000
50000
45000
40000
35000
00:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Demand
Baseload
Wkdy Base
Wkday n1
Wkday n2
Wkday 15
Wkday 12
Wkday plat var
Wkday Pk 5
Wkday Pk 4
Wkday Pk 3.5
Wkday Pk 2.5
Wkdy Peak 1.5
Wkdy Peak 0.5
19 October 2014
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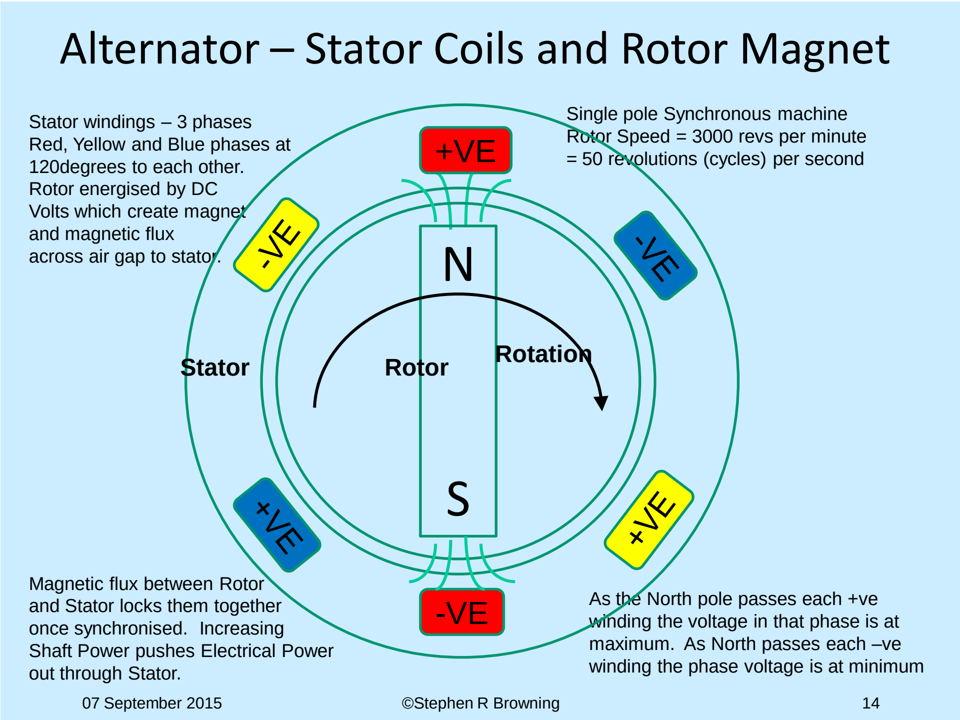
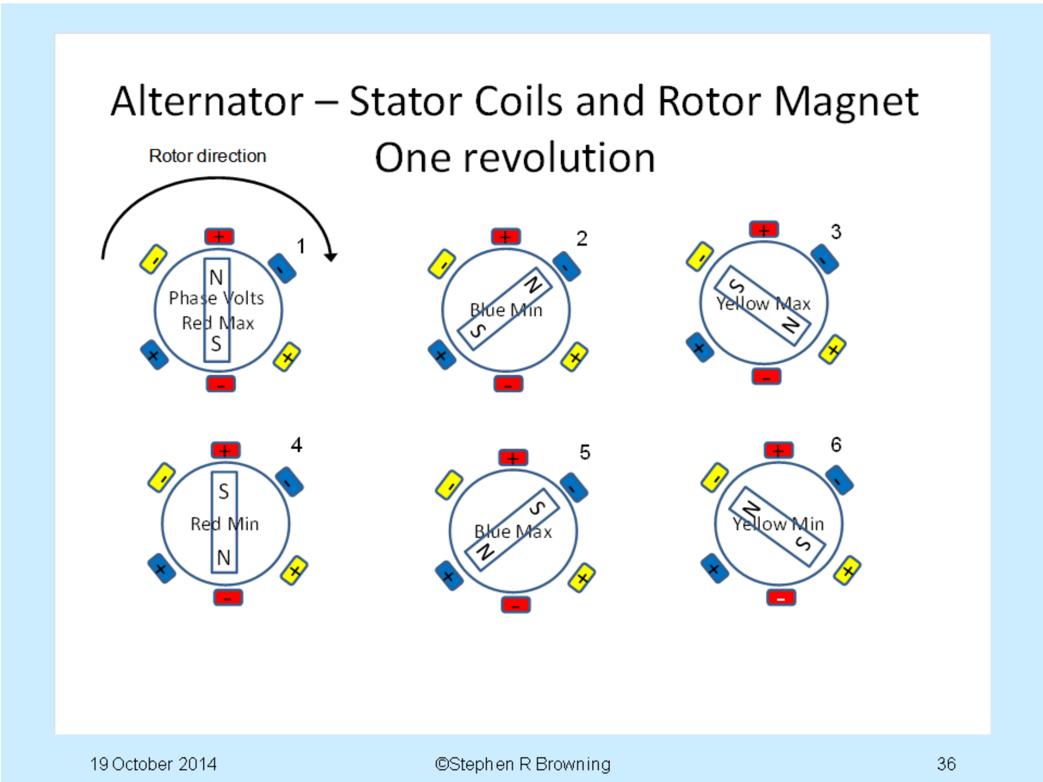
AC Alternator output

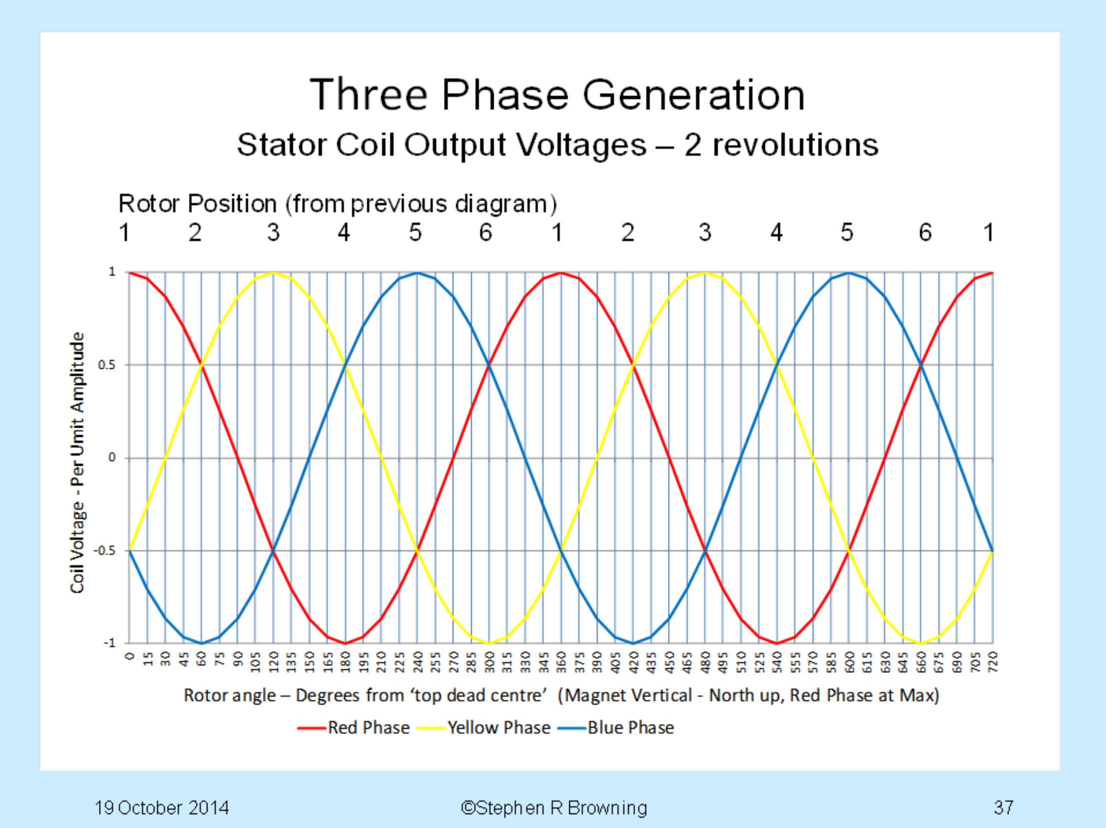
The alternator rotor carries a number of electromagnets (poles) rotating within a stator having one output winding per phase per pole around the circumference. Here is the picture of a single pole 50Hz machine with the phase voltage info.



In one revolution the rotor passes each of the coils as follows.



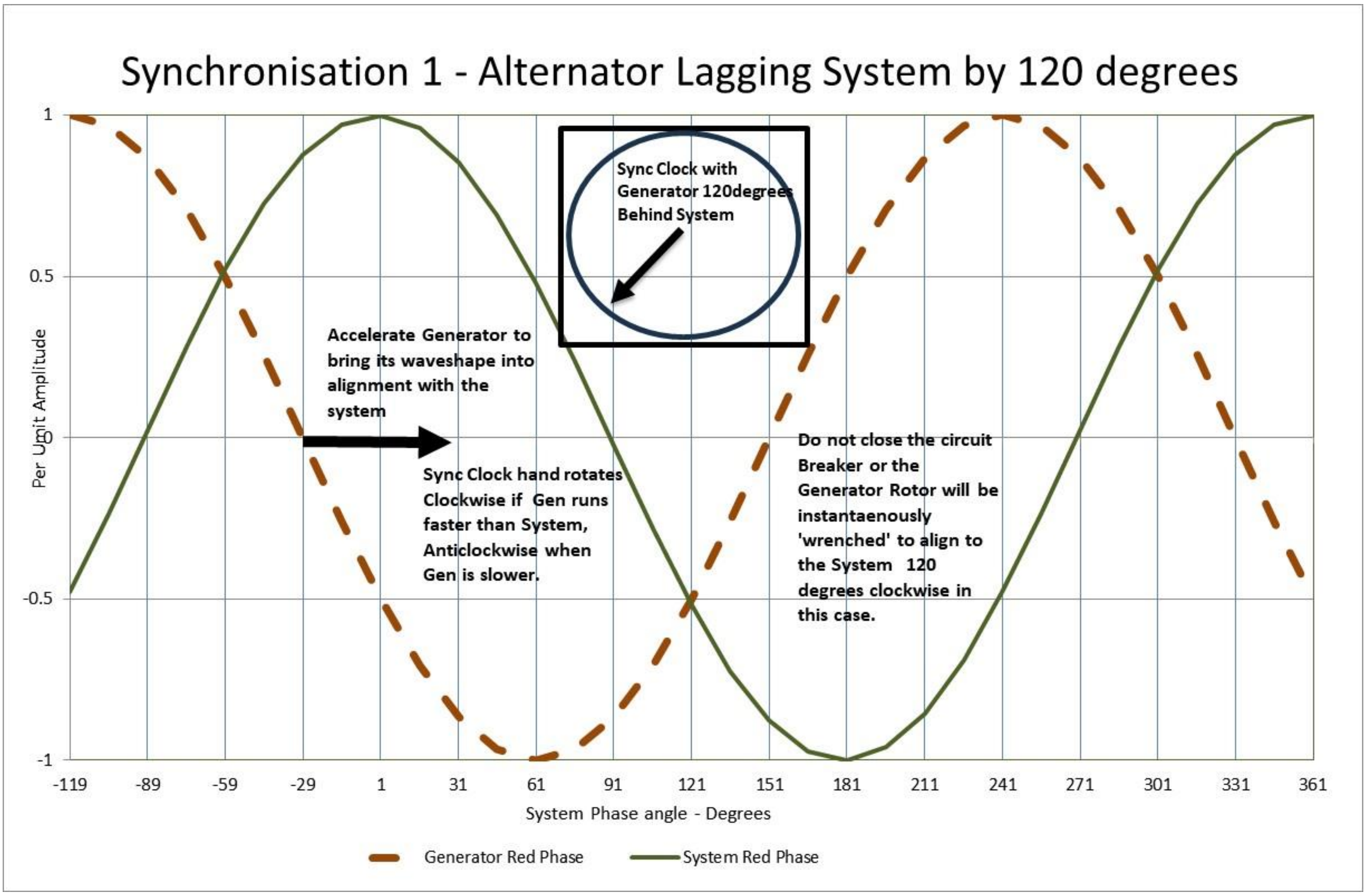
Which produces the following this waveform in each phase (two revolutions shown).

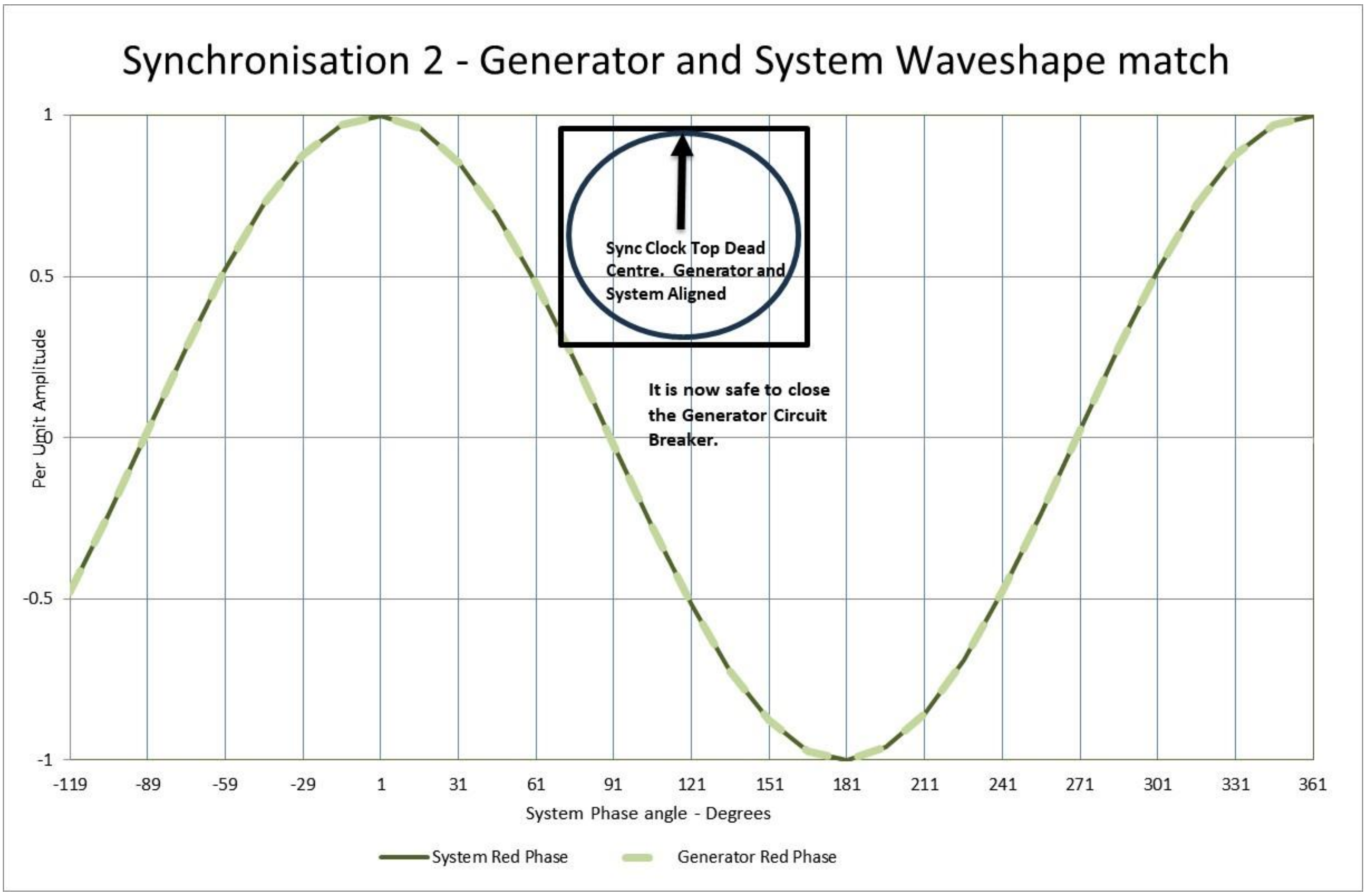


As we noted at the end of Future Power Systems 2, the voltage maxima and minima on each phase occur at the same time everywhere on the system. All the synchronous generators are 'locked together' dynamically.

Synchronisation.

To connect an Alternator to the System the Rotor has to be brought up to speed and the Stator Terminal Waveform aligned with that of the System. We will just look at the Red Phase in the diagrams which follow. In the first you can see the waveform from the Stator when it is lagging the system waveform by 120 degrees. The rotor needs to be accelerated slightly ro run faster than the System so that the two waveshapes align – as you see in the second diagram. Only then is it safe to close the Generator Circuit Breaker. If you were to close the Breaker without the waveshapes aligned and the Sync Clock at Top Dead Centre the rotor would be 'wrenched' round instantaneously to the System Position.





It is now safe to Close the Generator Circuit Breaker