Attachment B: C-FCAS Fast, Slow and Delayed Raise/Lower services:

This is to be read in conjunction with the draft Generator Performance Standards (v0.8) and the Secure System Guidelines Version 4. Both of these documents will require further work for FCAS implementation.

The Generator Performance Standards (GPS) are being developed as standards that are technology agnostic. This ensures that characteristics supplied by existing synchronous generation are also supplied by any type of generating system. As there has been a large interest in Solar PV, this document will provide a few examples on how a proponent may achieve the requirements set out in section 23 of the draft GPS.

It should be noted that the requirements in Section 23 of the draft GPS (v0.8) are focused towards C-FCAS fast raise, however this is an oversight in drafting and the requirements will be for C-FCAS Fast, Slow and Delayed Raise and Lower Services (6 different services total), however the C-FCAS fast is critical for determining the solution implemented as it requires a well-tuned control system to respond rapidly.

C-FCAS raise accreditation is outlined in the Secure System Guidelines (Section 8); the fast C-FCAS is as follows:

$$F_{fast} = \min \begin{cases} \dfrac{2}{t_{ref_{fast}}} \displaystyle\int_{t_m}^{t_m + t_{ref_{fast}}} \Delta P_g \, dt \\ \dfrac{2}{\left(t_{ref_{slow}} - t_{ref_{fast}}\right)} \displaystyle\int_{t_m + t_{ref_{fast}}}^{t_m + t_{ref_{slow}}} \Delta P_g \, dt \end{cases}$$

For the above, the, fast reference time is 2 seconds, with the slow reference as 60 seconds. For equipment where the ramp to maximum capability can always be achieved in less than 2 seconds the timeframe becomes the constraining factor in C-FCAS fast raise capability.

The Secure System Guidelines as an oversight did not include the frequency ramp required for the accreditation of FCAS services: C-FCAS raise and lower is accredited against a frequency ramp of 1 second duration at ±1Hz/s (from 50 Hz), where t_m is the time frequency is outside 50Hz ±01Hz. The use of ±0.1 Hz as the threshold is to provide an adequate transition from regulating services to contingency services. Assessment of ΔP will be based on the pre-contingent output (t= -0.1) if it provides a greater accreditation than from t=0 to include the contribution of equipment also participating in regulating services.

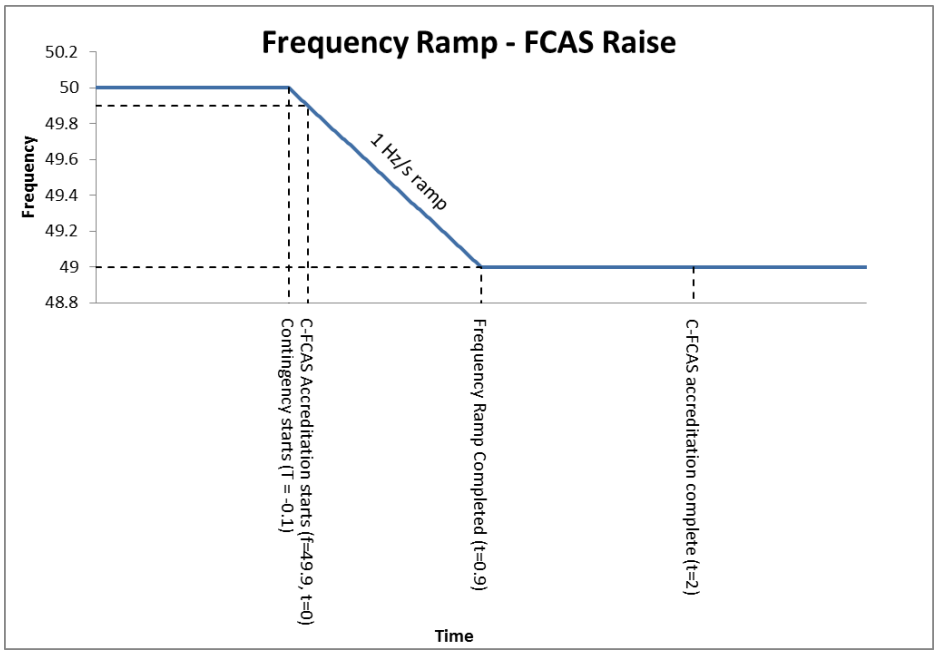


Figure 1: Frequency Ramp - FCAS Raise

It should be noted that the time for the 'longer' assessment of delayed raise in the secure system guidelines needs to be amended prior to implementation to 1800 seconds to accommodate the possibility of a delay in starting standby equipment.

Example 1: Solar PV constrained:

Typically solar PV is an arrangement of panels and inverters, with no supplementary power quality equipment such as batteries or synchronous condensers. This can be made to meet the requirements set out in section 23 by operating in a constrained manner. The following parameters (for a fast response under frequency droop) were tuned to meet the minimum C-FCAS fast raise requirement of 0.4 p.u.

Parameter	Value
Deadband (Hz)	0.05
Droop (1.1%): minimum Frequency (Hz)	49.45
Response Delay (s)	0.1
Maximum Contingency response (p.u.)	0.236
Overload Factor (100% = no overload) (%)	100%

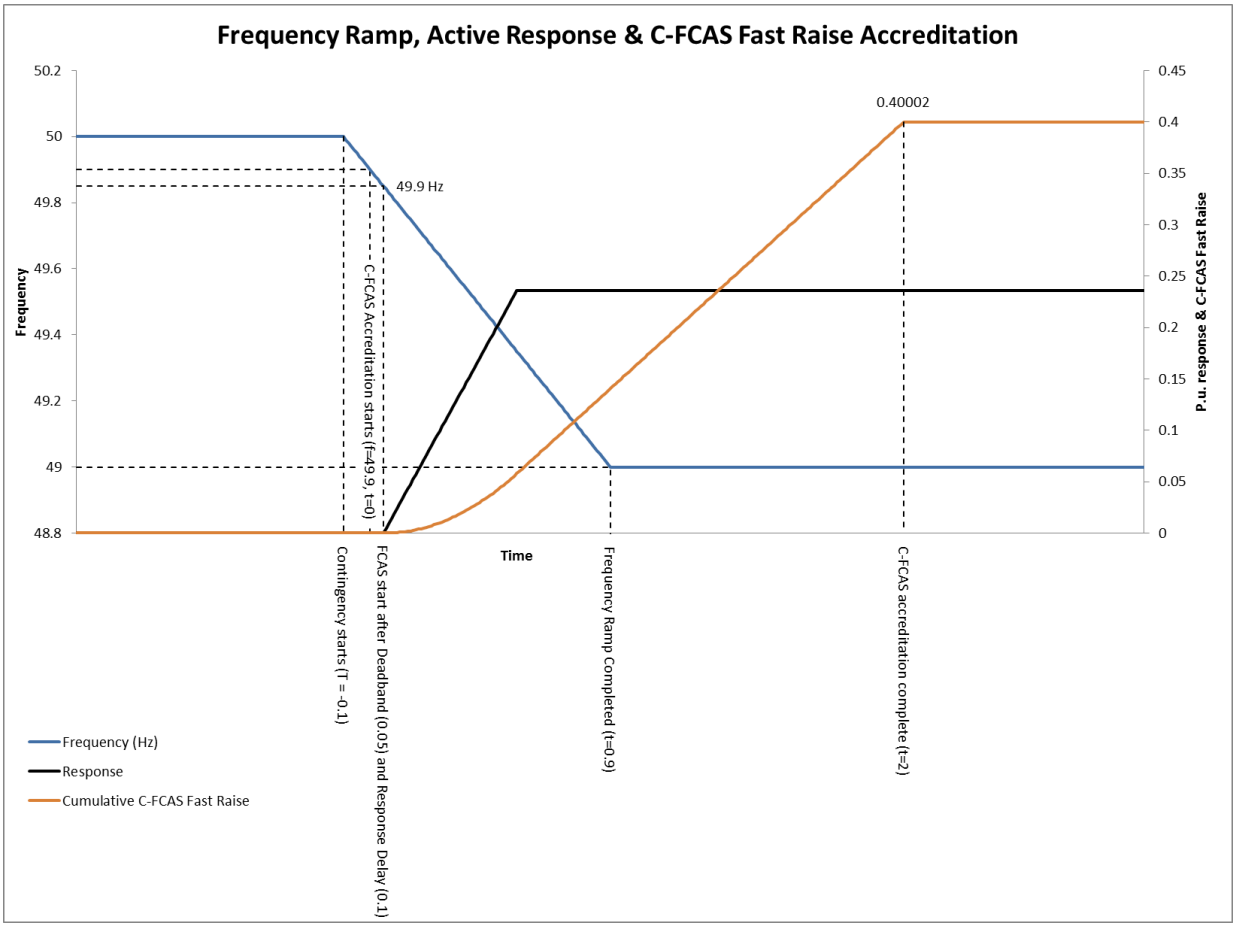


Figure 2: C-FCAS Fast Raise Accredited - Solar PV constrained

The arrangement to operate at ~81% (1/1.236 = 0.80906) of capacity comes from the required contingency response based on the above parameters to achieve the C-FCAS fast accreditation.

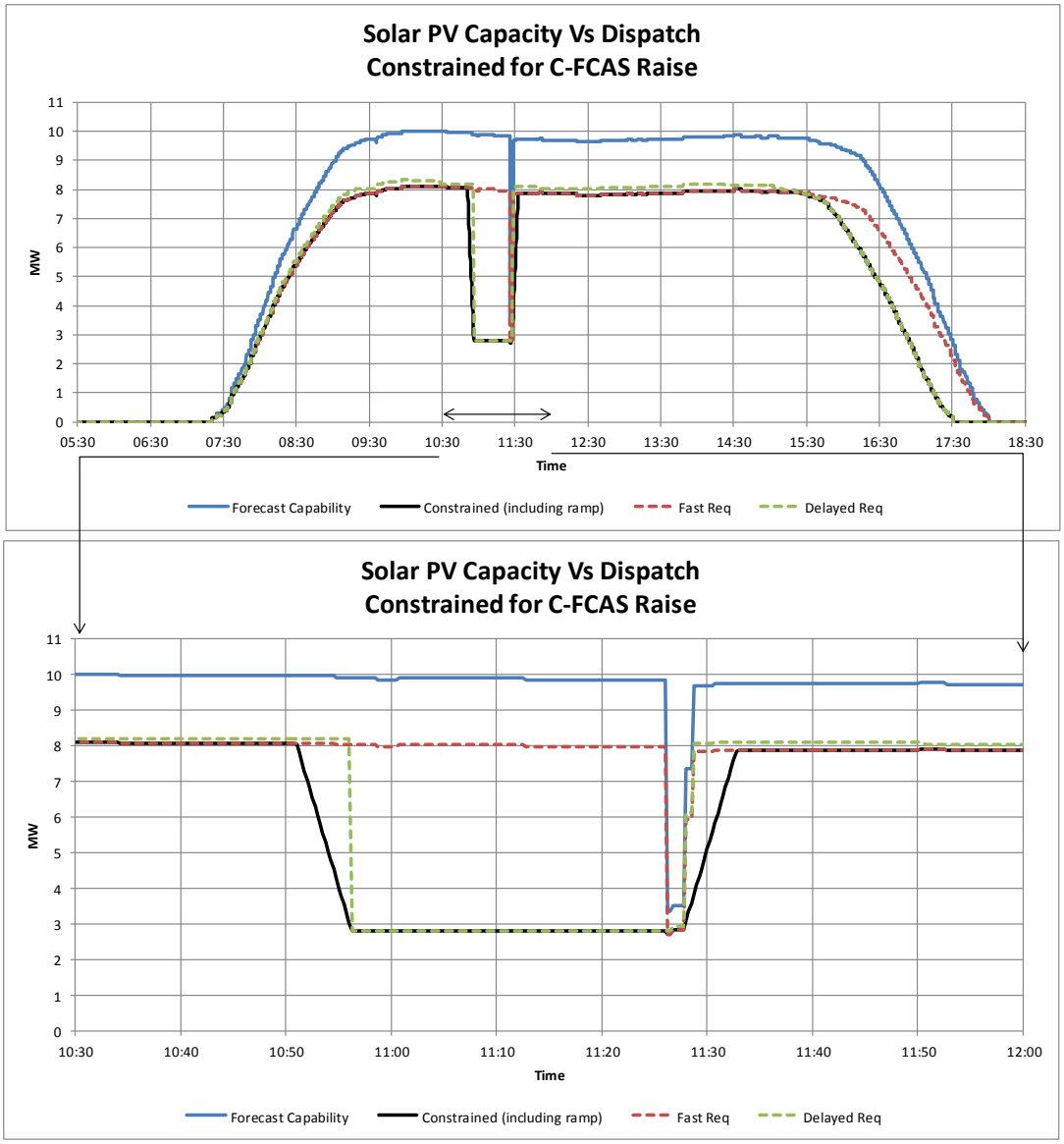


Figure 3: Dispatch over a day vs capacity

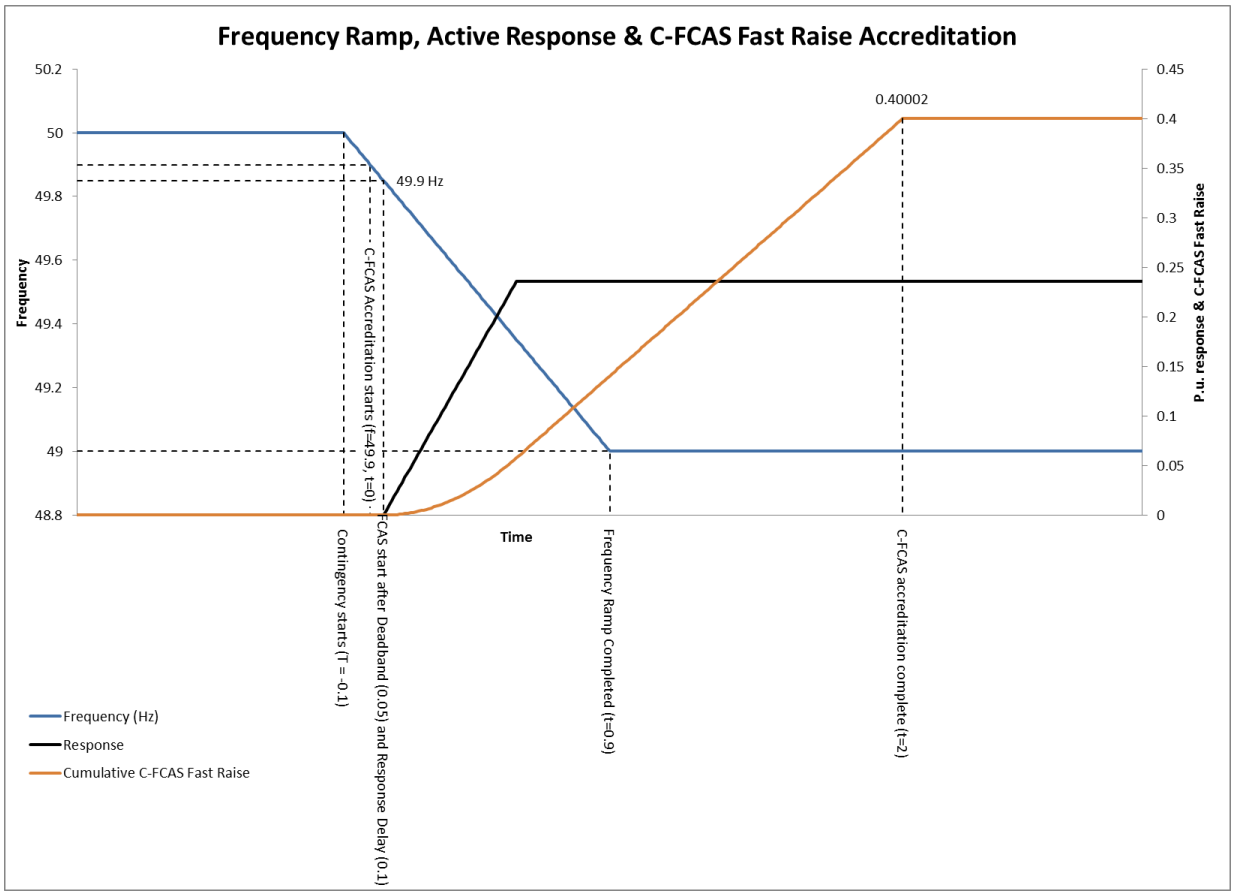
Profile	Percentage	Energy (MW/Hr)
Total	100%	86.40
Fast	80.9%	69.90
Delayed	75.3%	65.04
Combined	73.3%	63.29
Fast - Cloud Dip	3.4%	2.96

The parameters above, result in a C-FCAS fast accredited at 0.4, with slow and delayed accredited at 0.472 p.u. if the additional capacity is maintained for the slow and delayed timeframes. As the requirement for each FCAS service is 0.4 p.u. the constraint for C-FCAS slow would result in the unit operating at a level of $1/1.2 = 83.\overline{3}$ % of output, however the C-FCAS Fast requires a lower dispatch (80.9%) the majority of the time. The delayed service does have a requirement to be provided for 30 minutes ahead, so a forecast drop (as seen in Figure 3) causes the output to be constrained down 30 minutes (+ ramping time at 1 MW/min) ahead of a capacity reduction and 30 minutes earlier in the evening.

Example 2: Fast response Battery with minor overload and no inertia:

The example below is a set of parameters based on utilising the minimum battery size, fastest C-FCAS response and utilising overloading on an inverter to provide sufficient fast raise. The 0.2 p.u. battery size is established to meet the slow and delayed requirement assuming that all ramping is achieved prior to the 2 second ramping time such that the 30 minutes sustained output of an additional 0.2p.u. is equivalent to 0.4p.u. C-FCAS slow and delayed raise.

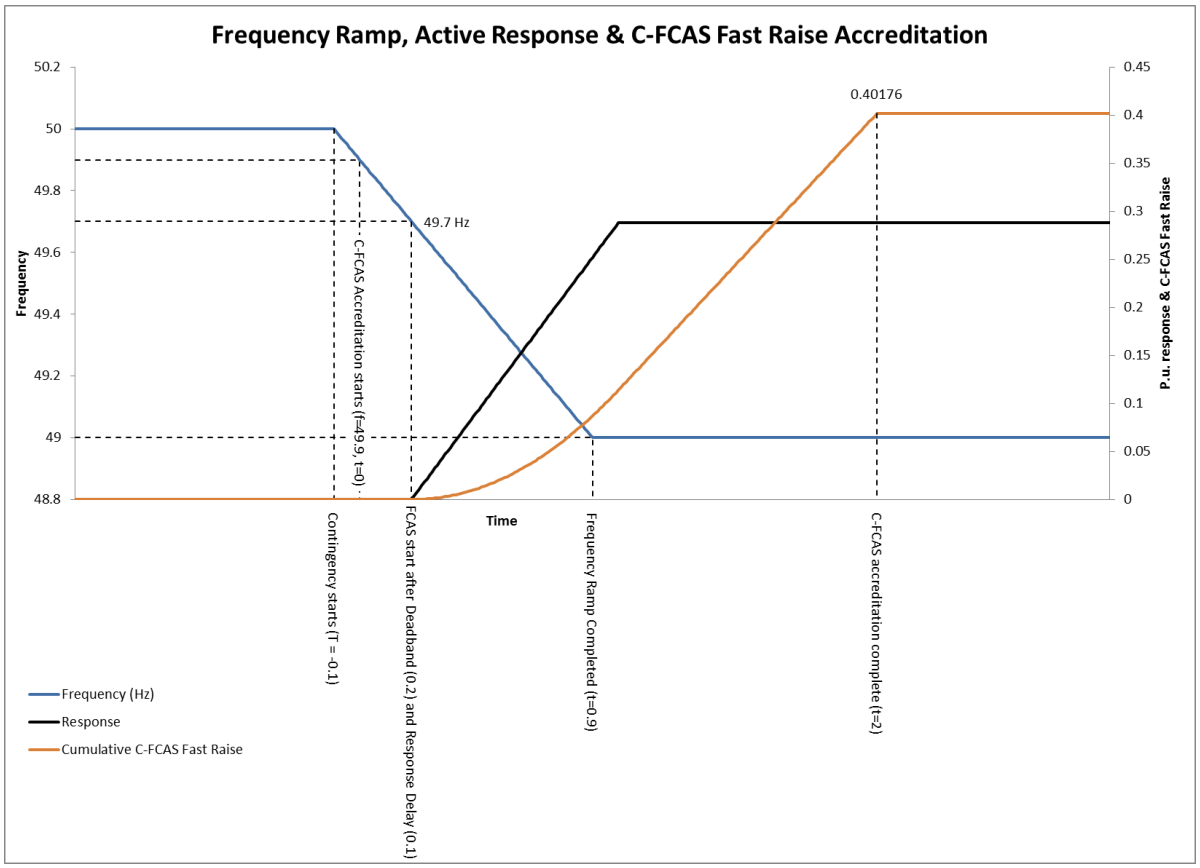
Parameter	Value
Deadband (Hz)	0.05
Droop (1.1%): minimum Frequency (Hz)	49.45
Response Delay (s)	0.1
Maximum Contingency response (p.u.)	0.2
Overload Factor (100% = no overload) (%)	118%



Example 3: Slow response battery with greater overload and no inertia:

The example below is a set of parameters based on utilising the minimum battery size, a slower C-FCAS response and utilising more overloading on an inverter to provide sufficient fast raise. The 0.2 p.u. battery size is established to meet the slow and delayed requirement assuming that all ramping is achieved prior to the 2 second ramping time such that the 30 minutes sustained output of an additional 0.2p.u. is equivalent to 0.4p.u. C-FCAS slow and delayed raise. If a larger battery is provided or a faster contingency response, the amount of overloading required can be reduced.

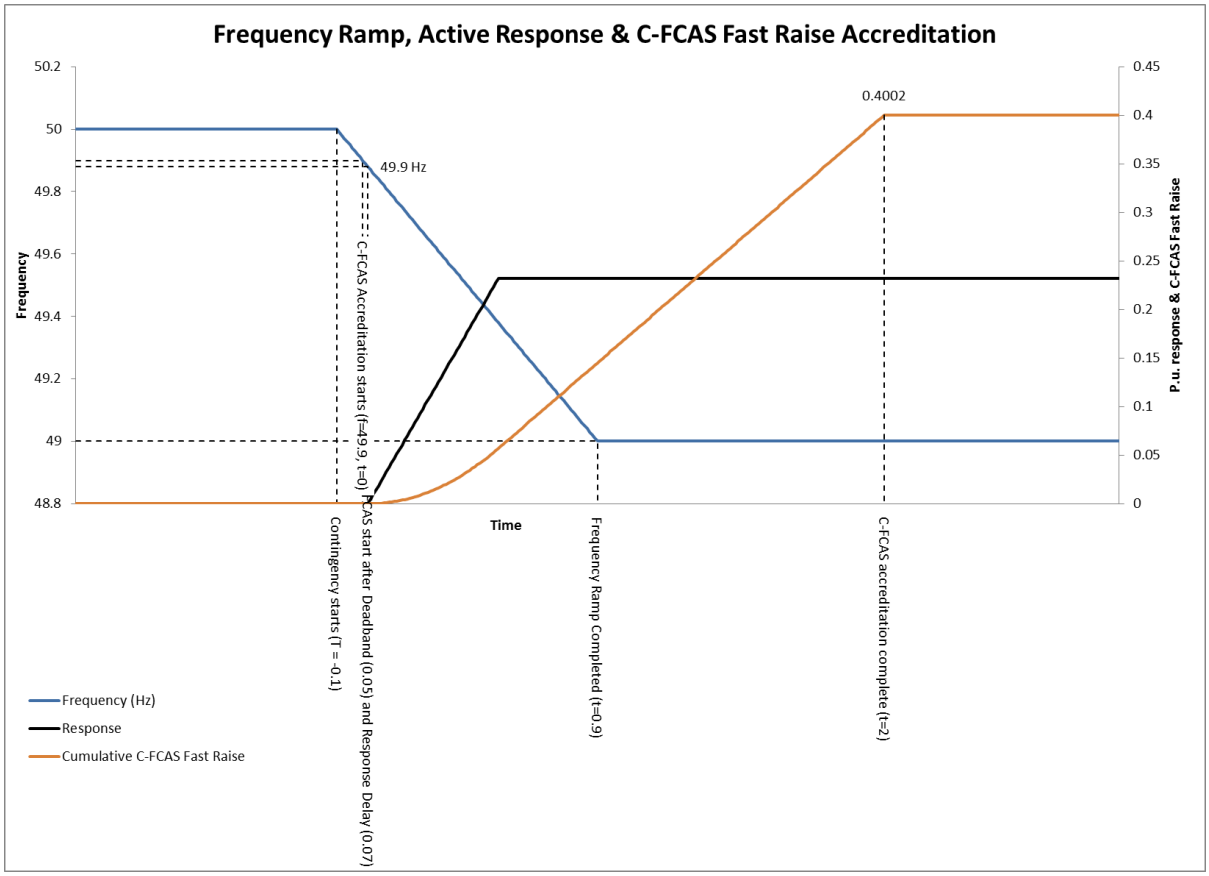
Parameter	Value
Deadband (Hz)	0.2
Droop (2%): minimum Frequency (Hz)	49
Response Delay (s)	0.1
Maximum Contingency response (p.u.)	0.2
Overload Factor (100% = no overload) (%)	144%



Example 4: Fast response larger battery with no overload and no inertia:

The example below is a set of parameters based on utilising a larger battery size, a very fast C-FCAS response to provide sufficient fast raise. This example could provide an excess of slow and delayed raise than the required 0.4 p.u. if the output of 0.232 p.u. can be sustained for 30 minutes.

Parameter	Value
Deadband (Hz)	0.05
Droop (1.1%): minimum Frequency (Hz)	49.45
Response Delay (s)	0.07
Maximum Contingency response (p.u.)	0.232
Overload Factor (100% = no overload) (%)	100%



Term	Definition
Deadband (Hz)	No frequency control operates for frequencies of 50 Hz +/- the deadband
Droop (X%): minimum Frequency (Hz)	The unit is driven to full load when the frequency reaches the minimum frequency according to the droop. Where X≥1.1%
Response Delay (s)	This is the delay after measuring the frequency for the unit/system to achieve the desired output according to droop. This includes any time delays for: • Measurement of frequency (includes filtering of transients) • Signalling times • Activation times • Ramping times
Maximum Contingency response (p.u.)	This is the factor (multiple of) the original output which is seen as the 'full load' response after minimum frequency has been reached for the time delay.
Overload Factor (100% = no overload) (%)	This is a factor (multiple of) the maximum contingency response which only contributes to the Fast Raise capability.