Fault Ride Through Performance Requirements

The System Design Context

System Design, Electricity Network Investment
National Grid

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Introduction

- How Code and System Design analysis combine
- Statutory Voltage Regulation Requirements
- Fault instances upon the transmission system
- How The System is Recovered
- The Voltage Recovery Profile
- Accounting for Generic Uncertainties at Design Stage
- Deviation from Voltage Standards- impact

How Code and System Design Analysis Combine

- **Grid code C.C 6.3.15 a)- fault survival on duration, and active power recovery following fault clearance.**
  - System Design (ref SQSS 2.9.3,2.10.10, 4.5.3, 4.6.9,4.8.3, 5.1.8) shall ensure- against range of generation excitation solutions available in consideration of Grid Code 6.3.8 and CC.A.6 (or in consideration of generation already compliantly connected) - and via transient disturbance analysis of the generators connection to the whole GB system- a year round position of resilience to credible operating positions and system fault scenarios such that no single or multiple generation instabilities, or general system instabilities arise.
  - Provided C.C.6.3.15a) is met on a generic basis, it is expected from past analysis that a natural outcome is that, with appropriate reinforcement of the system, a multi-machine study should be capable of a compliant outcome without individual machine risk.
- **Grid code C.C.6.3.15b)- fault survivability over the period of frequency depression.**
  - System Design (ref SQSS 2.9.2, 2.10.9, 4.8.2, 5.1.7,5.4.4) In addition to the above studies based on performance over the period of fault and immediately following restoration, further studies will be conducted at key datums of the recovery to identify the scale of steady state voltage step change and then subsequent stages of transmission and distrubution equipment control action the overall position in terms of sufficient *voltage performance Margin* against risk of a cascade failure of the network.
  - Based on the specification of the machines, these studies assume at least 90% of the reactive power capability of connected generation is available in each stage of subsequent system recovery. The generic specification of CC6.3.15b) provides confidence that the generator will be available, which can be validated from dynamic studies.

Statutory Voltage Requirements

Grid Code Specifies -

National Electricity Transmission System Nominal Voltage	Normal Operating Range
400kV	400kV ±5%
275kV	275kV ±10%
132kV	132kV ±10%

SQSS Specifies –

“Unacceptable Voltage Conditions” do not arise, and-

“Insufficient Voltage Performance Margins” do not arise.

“Stress Tests” include -

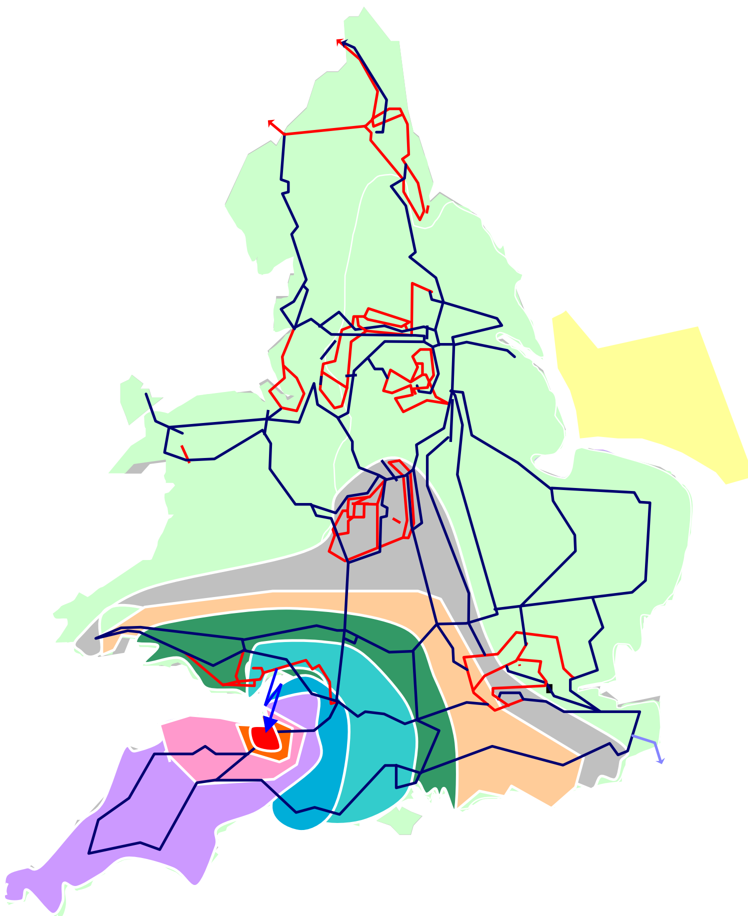
Demand growth sensitivity

Loss of a reactive compensation equipment or a generator

Demand P/Q ratio change, etc

Studies are taken on the basis of realistic availability of transmission system and interfacing generation sources.

Fault Instances Upon The Transmission System



Example - 3 phase fault at Shurton 400 kV substation

- Fault Location 0 % Volts
- 0 - 15 % Volts
- 15 - 30 % Volts
- 30 - 40 % Volts
- 40 - 50 % Volts
- 50 - 60 % Volts
- 60 - 70 % Volts
- 70 - 80 % Volts
- 80 - 90 % Volts

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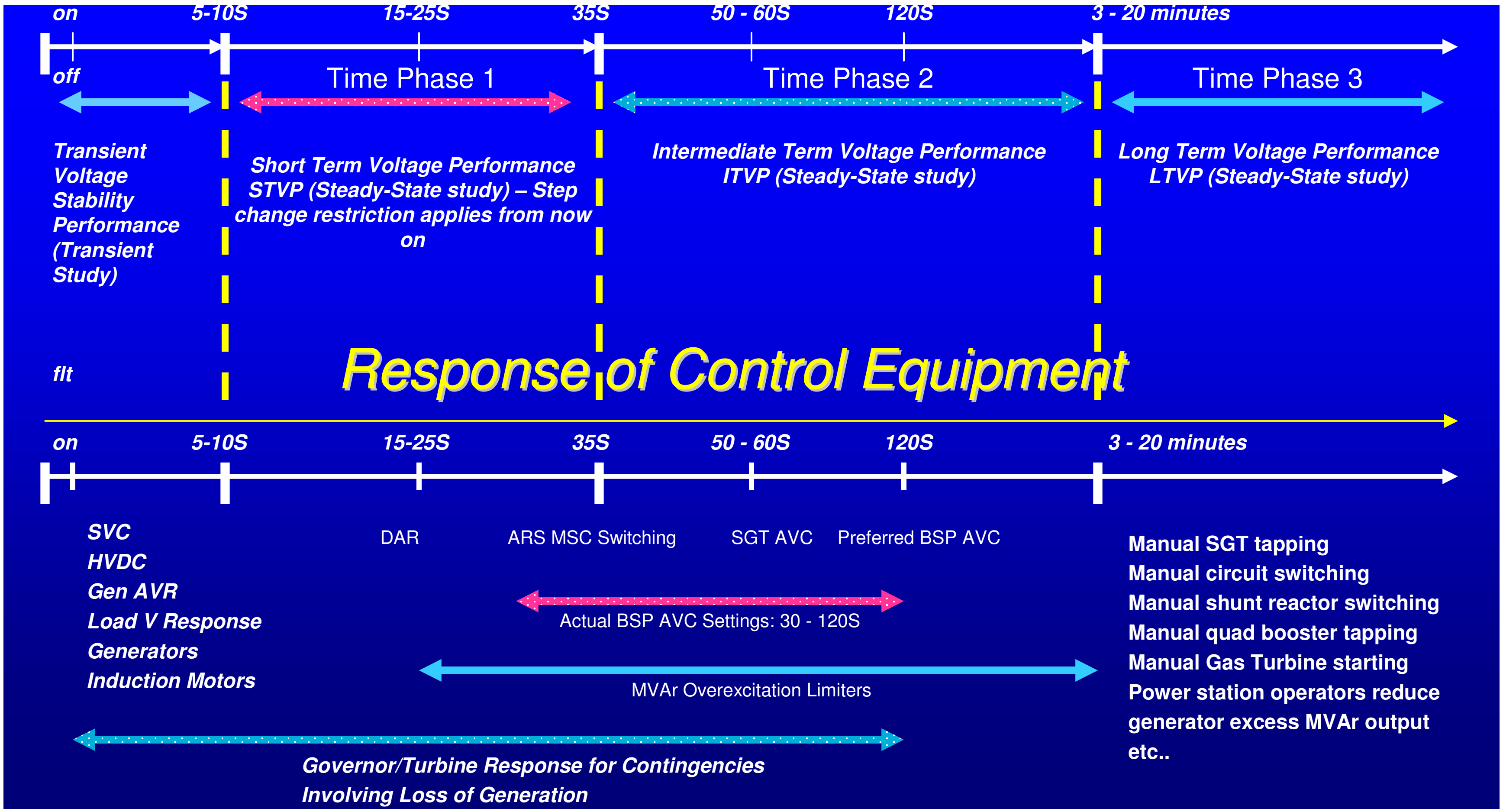
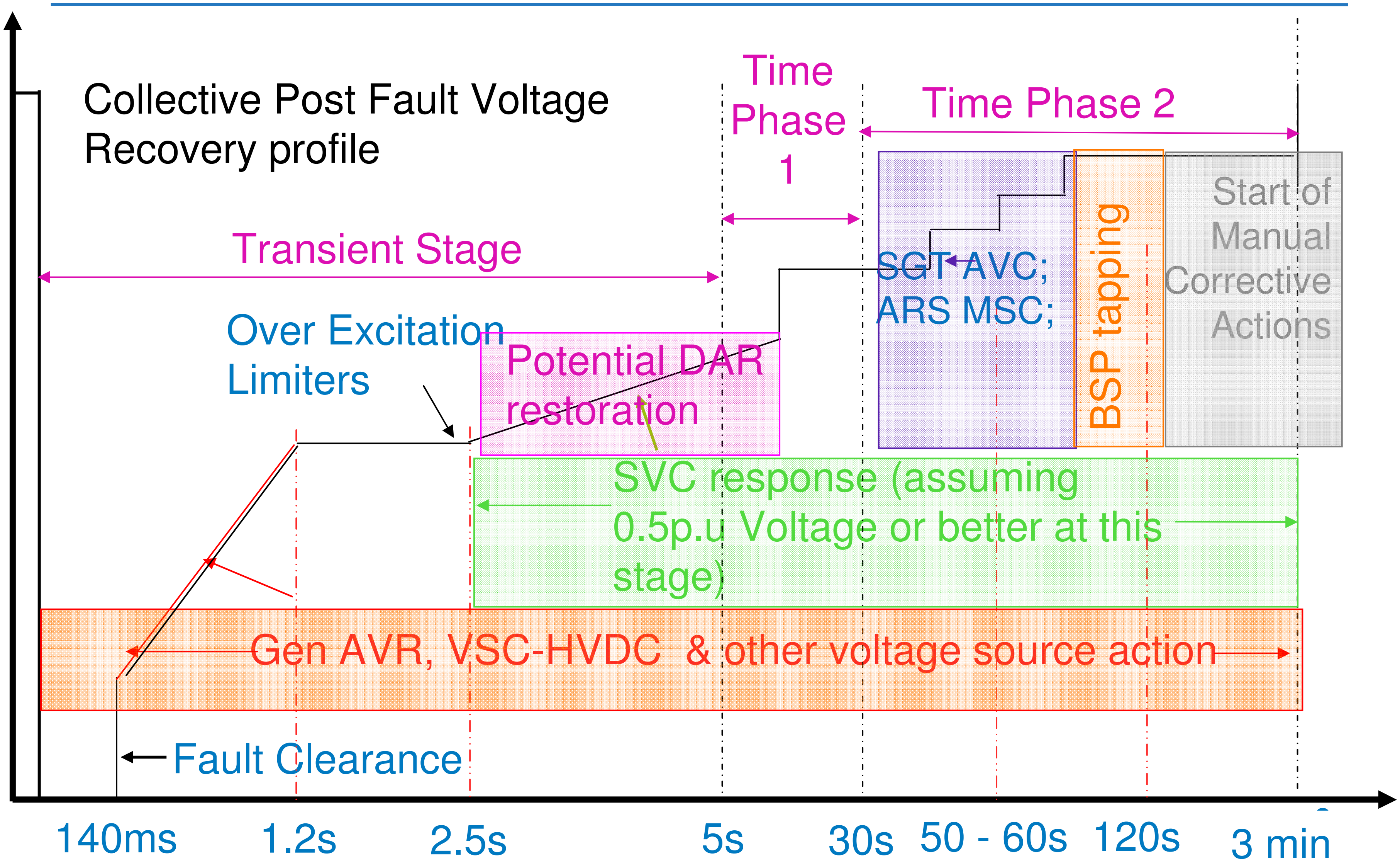
Fault Instances Upon The Transmission System

- The more interconnected the transmission system the greater the extent of impact of Voltage depression from the instantaneous fault.
- The duration of the actual fault will vary in practice due to its location, and associated settings and scope of protections upon the transmission system or interfacing users system.
- The strength of the pre-fault system in practice is not an indicator of the strength of the system post fault clearance. Dependent upon the nature of the fault, significant elements of the transmission system or elements of user systems may be lost as a consequence.
- In the case of the example overleaf, within the area affected with < 0.5p.u. retained voltage some 7 new generation projects are planned (contracted) but have yet to be connected to the transmission system. Still further embedded generation of small or medium scale also seek stable connection to the total system.

How The System Is Recovered



Voltage Recovery Profile- What Determines Its Characteristic



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Voltage Recovery Profile- conclusions

- For the initial period of at least 2.5secs following fault clearance, and thereafter until system voltage is raised above 0.5p.u. *the system is entirely reliant upon the effective voltage sources connected to provide recovery* within the residual un-faulted network.
- Given the interconnected nature of the GB transmission system, the area initially affected by fault will be significant in scale and has the potential to be extended further by system reinforcement that increases network capacity. A great level of variability in assumptions of system state and connected plant can exist within such areas, expected to increase with changes in the energy mix in future years. As such to establish local assumptions on the voltage recovery profile are problematic in nature.
- Later stages of SGT and BSP tapping have the potential to lead to anti-correlated control action, should voltage depressions lower than 0.9 p.u progress into time phase 2. This is avoided by an assumption of combined generator and transmission system action at present- and would otherwise could represent risk of voltage collapse over a large system area.

Voltage Recovery Profile:- Generic Uncertainties At Design Stage

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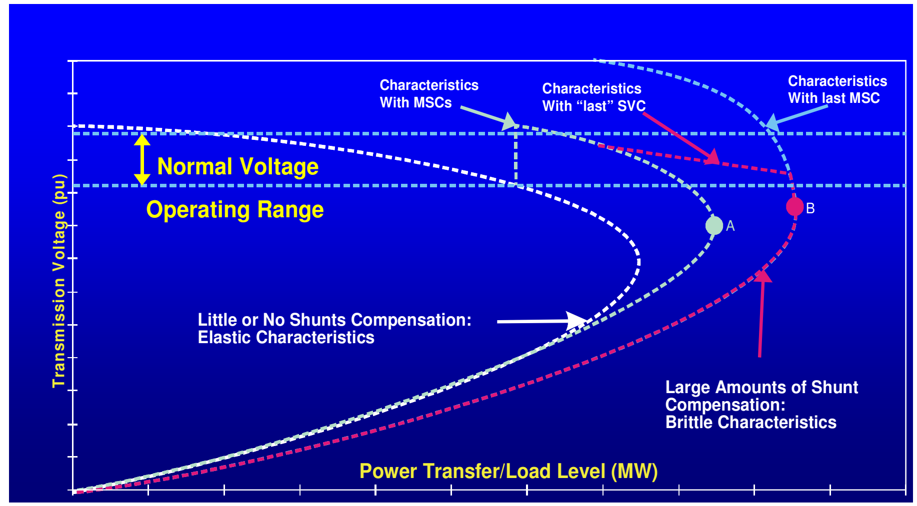
System

- Nature of fault occurring- duration and extent of impact (and system defence assumptions around CB fail consequence).
- Loading of system and associated levels of natural response during the transient time frame
- Performance of new transmission elements by various ONTO and OFTOs
- Transient withstand capabilities of equipment

Demand

- Voltage Dependent Load behaviour
- BSP transformer control strategies
- LV Demand Disconnection strategies



Generation

- Performance of existing commissioned units to area specific profiles- compliance testing requirements?
- Performance of embedded generation
- Specification of culmulative new generation- over specification to compensate individual cases of derogation?

Conclusion- Is this a Worst Case than Grid Code?

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Deviation from Voltage Standards- Impact

SQSS

- Voltage performance is not an area of "connect and manage" acceptable for generation connection; would be "customer choice" in nature
- Customer variation of design is allowable only against chapters 2 and 3 of the SQSS- the performance of the Main Interconnected Transmission System should NOT be reduced to below minimum planning criteria
- No other users should be affected, either now or in future by any customer choice; the choice can be recinded- and require re-design entirely at the users risk.
- Such a choice should not incur additional operation costs- Any additional transmission capital costs would be reflected back directly to the user benefiting from that choice.
- Customer choice should not impact the licence obligations of any Transmission Owner, or the System Operators obligations.

Investment impact

- Were Investments sought to offset any insufficient Generation support investigation would be needed on-
  - faster acting voltage support solutions than currently available- Technology and control design challenges- requiring high level of generator controller information and influence over design.
  - Installation of further additional transmission circuits to increase the extent of the un-faulted system during the recovery period- consent risk and public perception management in programme delivery.
  - Generation recovery beyond code on other users- code and commercial consequence.
- It is not clear (other than for new circuits) the TO would be the appropriate instigator or owner of such work. Further, solutions would not be a static position, but subject to potential review as factors influencing system performance change- re-opening and revising obligation.