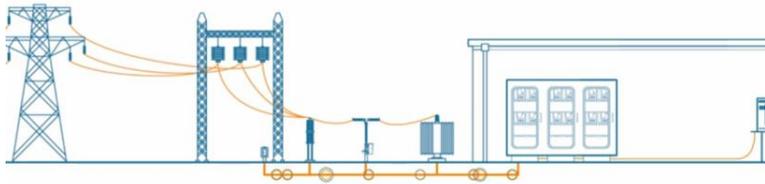**SP ENERGY NETWORKS**

IEC61850 Europe 2017

Amsterdam, 26th – 28th of Sept 2017

PRP & HSR – adopting state-of-the-art redundancy technologies to support high availability in IEC 61850 systems

Priyanka Mohapatra
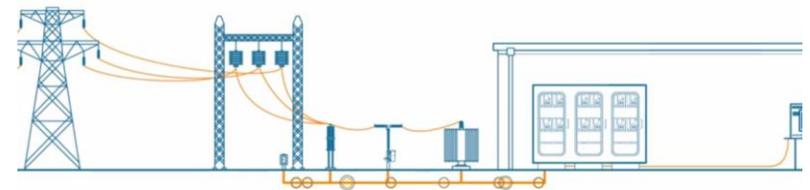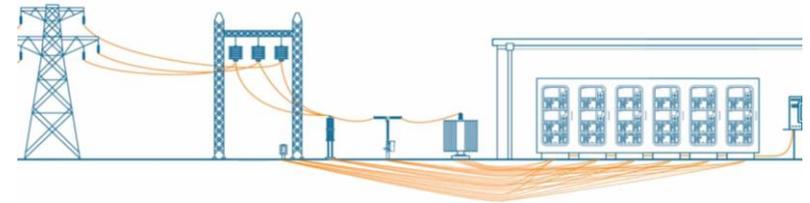pmohapatra@spenergynetworks.co.uk

Topics covered

- Project overview

- Clarifying the similarities and differences between PRP & HSR and determining their optimal implementation into a variety of network topologies

- Quantifying the benefits of implementing PRP & HSR and identifying their introduction into multi-vendor multi-edition systems

- Overcoming the challenges of maintaining a PRP & HSR enabled system in the long term
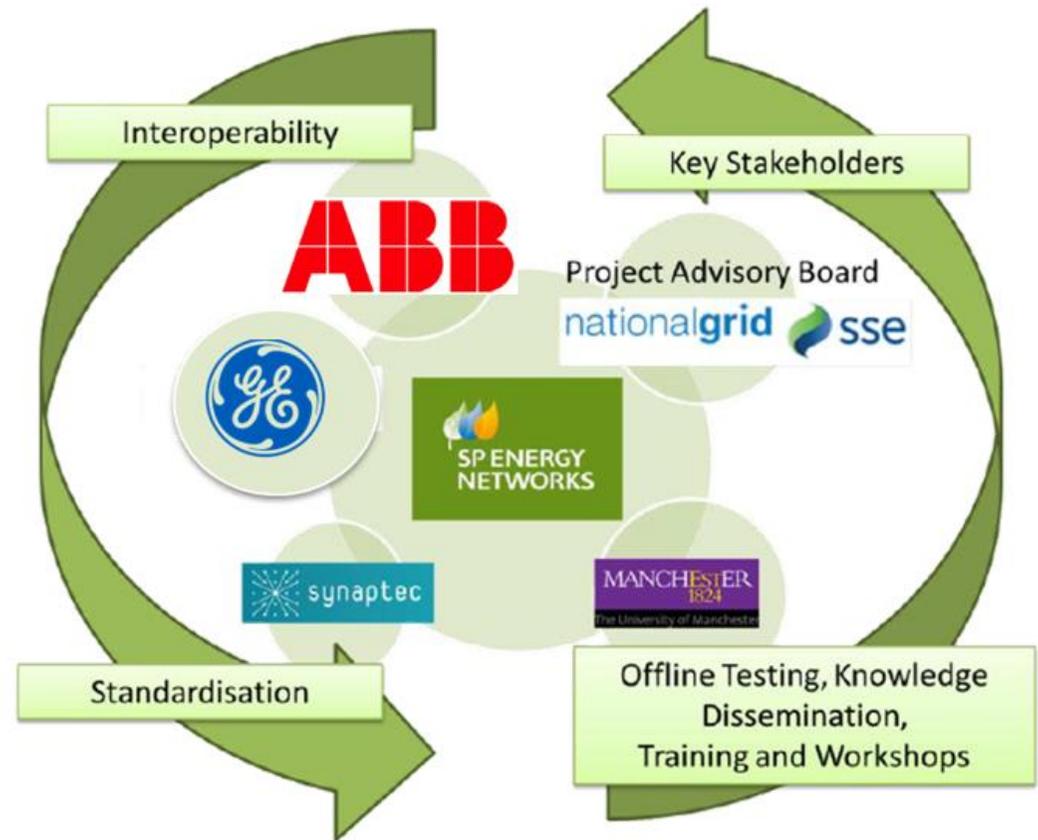
Digital Substation Project **FITNESS**

<u>F</u>uture <u>I</u>ntelligent <u>T</u>ransmission <u>Net</u>work <u>S</u>ubstation (FITNESS) is a flagship innovation collaboration project awarded by the GB regulator Ofgem under the Revenue = Incentives + Innovation + Outputs (RIIO) mechanism to:

- Accelerate the progression to IEC61850 based transmission network substations

- Demonstrate a multi-vendor fully interoperable digital substation

- Develop solutions for Full Digital as well as Retrofit Digital substation deployment

- Investigate the different connectivity options to optimise system availability and reliability

- Reduce copper wiring throughout the substation reducing its overall footprint and environmental impact

- Enhance substation safety through advanced off line and remote system verification

- Enable increased flexibility and greater controllability in substations to meet the need of the Future Grid

A unique collaboration between a major Transmission Operator and two leading Digital Substation technology providers working in partnership and collaboration with Academia, Industry Experts and SMEs to:

- Design and demonstrate full IEC 61850 operation and interoperation

- Educate and inform the industry (including internal) of the technology

- Uncover and overcome issues with the interpretation of the standard

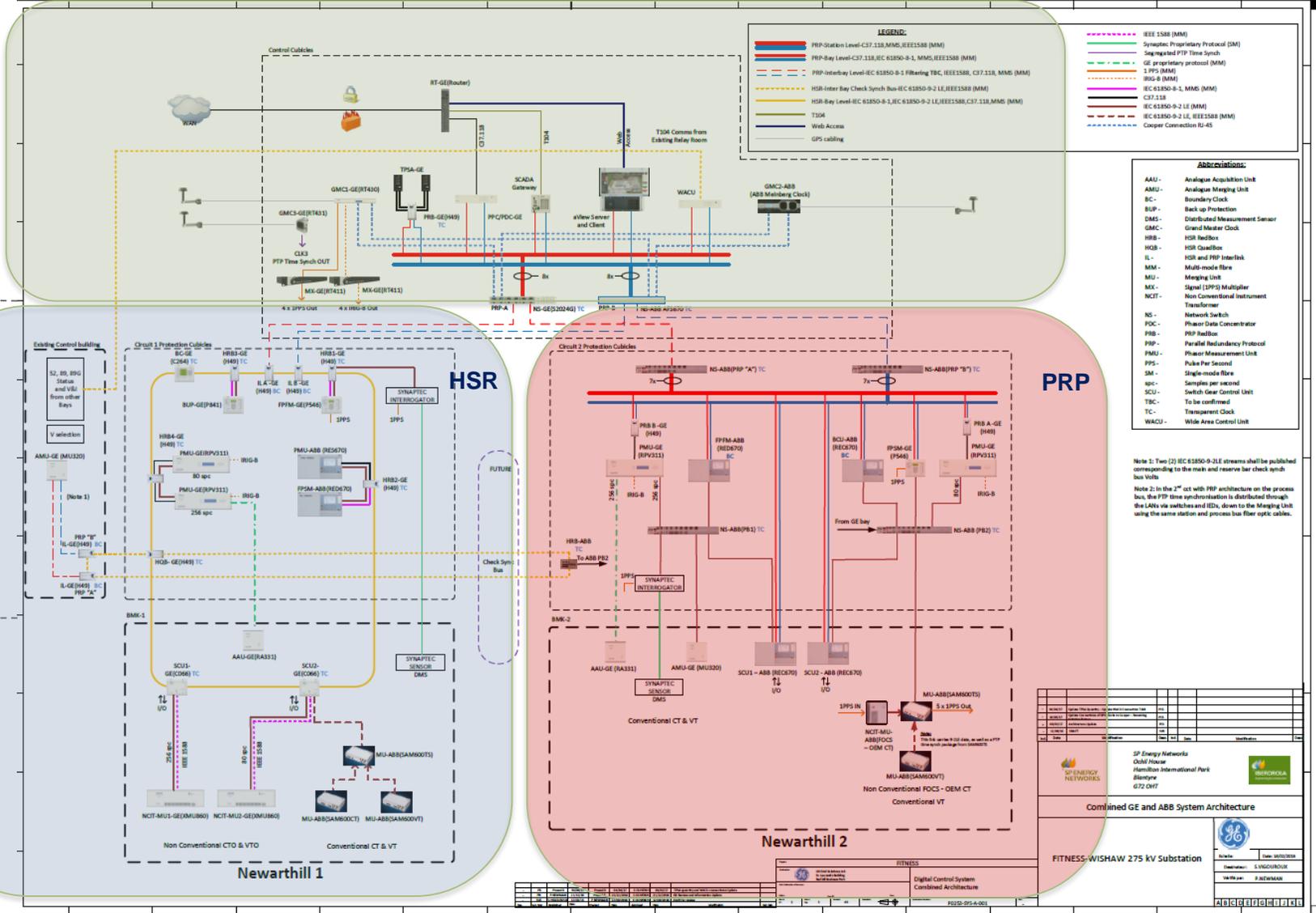- Work with IEC Working Group to develop standard as necessary

# Digital Substation Project **FITNESS –** Architecture & Connectivity

High-Availability Seamless Redundancy (HSR) and Parallel Redundancy Protocol (PRP) are both redundancy protocols that provide

> - N-1 redundancy – Single point of failure tolerance
> - Seamless Redundancy (zero recovery time) with no packet loss
> - High Reliability
> - Low latency transmission of GOOSE and SV without additional delays due to LAN defects
> - Relatively good availability with aim to attain "zero packet loss"
> - Both recommended by IEC62439-3 Standard and mandated by IEC61850 standard

The choice of HSR or PRP, or a combination of both, for a substation application depends on network characteristics, cost parameters and the relative benefits of each protocol.

Clarifying the similarities and differences between PRP & HSR and determining their optimal implementation into a variety of network topologies

- **Topology** : Ring topology

- **Installation Time** : Shorter as compared to PRP due to fewer switches and fibre optic connections

- **Network Management**: Tolerant to single point failure, a second failure will lead to isolation of IEDs and loss of data frames

- **Traffic Regulation/Filtering**: None within the bay

- **Bandwidth Requirements** : Double as compared to PRP
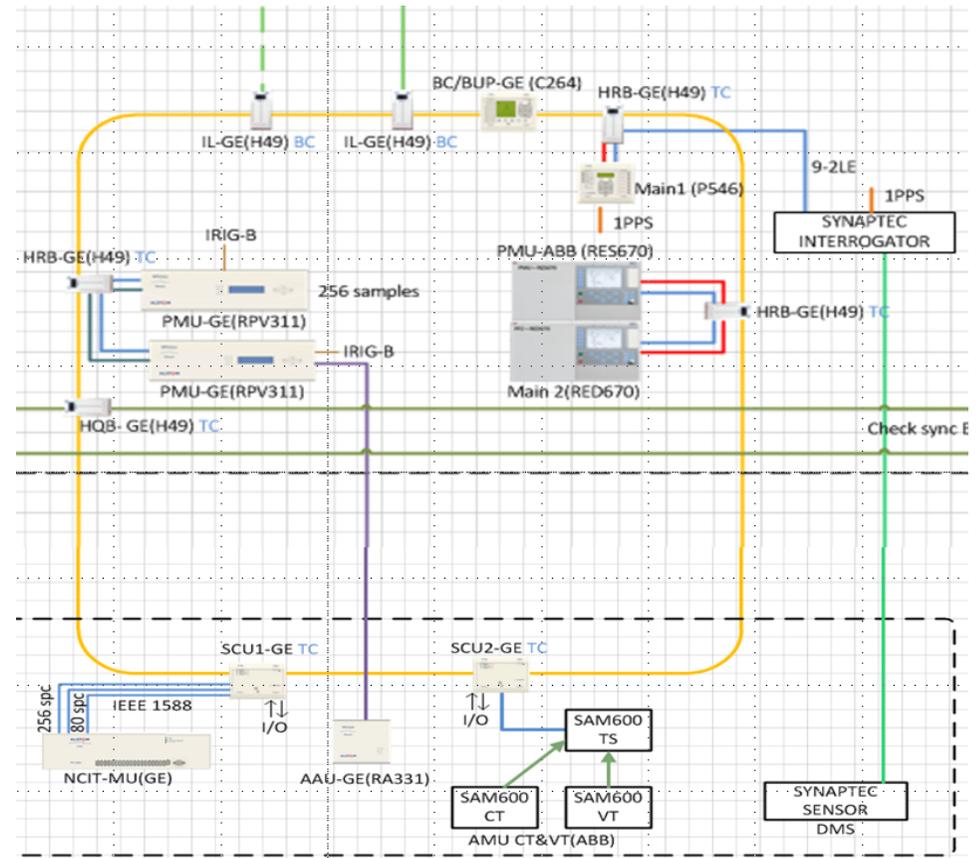
High-Availability Seamless Redundancy (HSR)

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Clarifying the similarities and differences between PRP & HSR and determining their optimal implementation into a variety of network topologies

- Topology : Double Star

- Installation Time : Longer as PRP requires installation of two PRP networks, including the Ethernet switches, which must be completely independent: they cannot be connected or bridged together in any way, and they should have separate power supplies.

- Network Management : "Zero Failover Time", using mirroring frames across both networks

- Traffic Regulation/Filtering : Possible, filtering of multicast messages by the Ethernet switches.

- Bandwidth Requirements: Half as compared to HSR
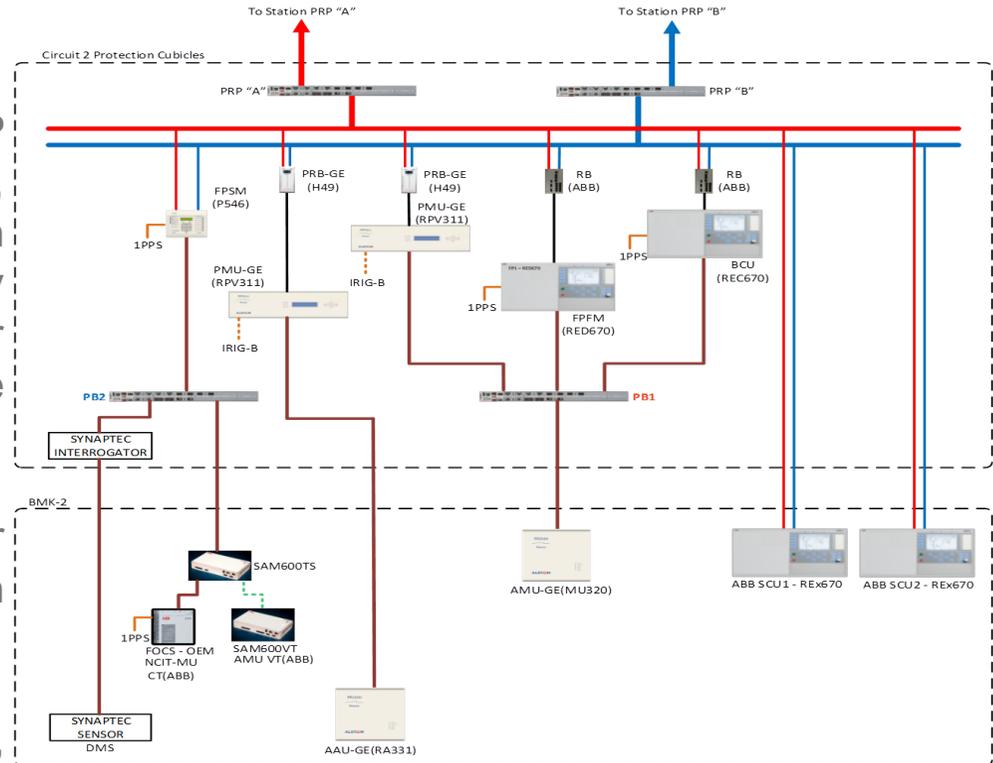
Parallel Redundancy Protocol (PRP)

Learnings from FITNESS Architecture

- PRP allows the connection of single attached nodes (SANs) <u>without the need of a RedBox</u>, although the messages from/to this SAN would only be present on the network to which it is connected. For non-PRP devices to be connected redundantly in the PRP network, the use of a RedBox is required.

- In the case of HSR, a RedBox must be used in order to connect any <u>non-HSR device to the HSR topology</u>.

- For extension in future in the HSR topology the loss of redundancy also comes into play when the ring has to be extended, e.g. temporarily broken to accommodate an extension.

- For extension in PRP networks, the addition of new IED's has minimal impact on other IED's and the redundancy of the network; all other IEDs still send and receive data on two different network paths.

- PRP architectures are more capital intensive and also for complete testing will require deployment of double the number of testing kits to be able to test both networks simultaneously as compared to the HSR ring.

HSR and PRP tests FITNESS
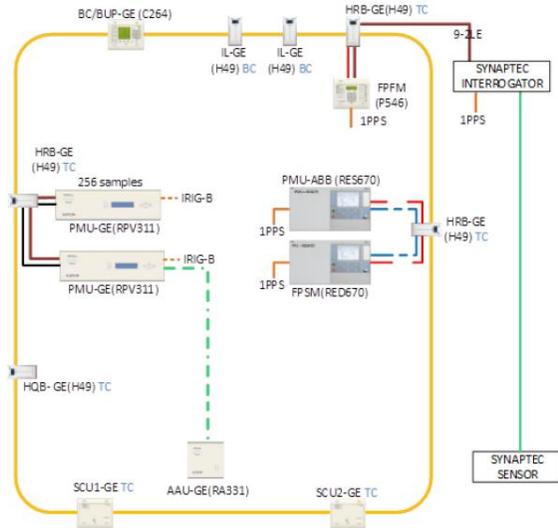
- One HSR ring with a couple of IEDs and other devices connected as Double Attached Nodes (DANHs).
- Testing is done by connecting one laptop into the HSR ring each and verifying the reception of GOOSE and TCP messages following the disconnection of one fibre in the ring. (does not cater for second fibre failure)

- Two 2 x PRP LANs (A & B) with a couple of IEDs and other devices connected as Double Attached Nodes (DANPs).
- The DANPs devices are responsible for implementation of PRP.
- Testing is carried out by connecting two laptops to one LAN each and verify the reception of GOOSE and TCP messages one of the LANs by disconnecting the other LAN.
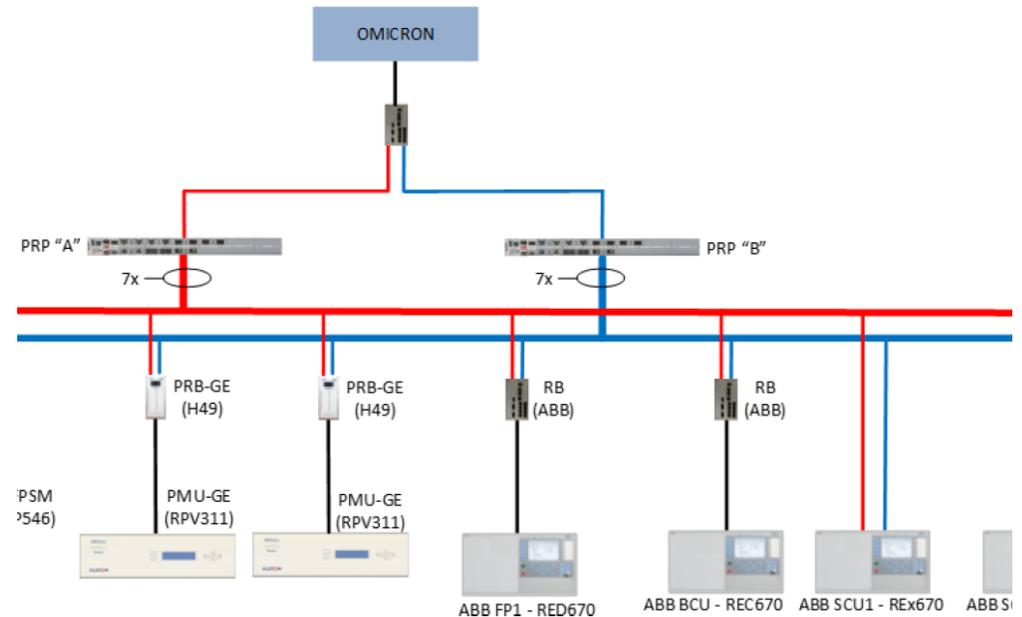
Quantifying the benefits of implementing PRP & HSR and identifying their introduction into multi-vendor multi-edition systems

FITNESS in collaboration with University of Manchester (UoM) performed a series of simulations on PRP, HSR and combined architectures to quantify reliability and availability of different architectures, based on

- ➢ Sensitivity Analysis (Estimated Mean time to failure (MTTF))
- ➢ Life cycle costs Analysis (Estimated capital and operational costs)

Results from Simulations:

Architecture	MTTF (Years)	Failure Rate	Reliability	Availability
HSR	7.390	0.1353	0.9781	0.9998
PRP	11.414	0.0876	0.9993	0.9999
FITNESS (HSR + PRP)	9.36105	0.1068	0.9993	0.9999

Quantifying the benefits of implementing PRP & HSR and identifying their introduction into multi-vendor multi-edition systems

Results from Simulations (Contd.):

Architecture	Investment cost [£]	Renewal Cost [£]	Maintenance Cost [£]	Replacement Cost [£]	Penalty Cost [£]	Life Cycle Cost (40 years) [£]
HSR	26200	65493	20960	14647	34472	161772
PRP	27400	67840	21920	17366	644	135171
FITNESS (HSR+PRP)	34600	86506	27680	20931	409	170127

- There are limitation to the results as they are based on various assumptions and based on large scale applications.

- The penalty costs have a greater effect on the life time costs of both architectures as the cost of losing a transmission circuit and subsequent constraint costs on the network are significantly high in GB networks.

- The selection of the architecture for SPEN will hugely depend on the criticality of the network where it is deployed and ultimately the cost of maintaining combination of architectures across the whole network and/or within the same substation.

Summary

- **HSR Positives**
- Lower CAPITAL costs
- Lower commissioning, operational and maintenance costs
- Potentially a better solution for less complex and smaller applications.
- Can be applied to self contained areas of the S/S design

- **HSR Relative Negatives**
- Challenges with higher degree of contingencies
- Challenges with testing as complete isolation is not possible

- **PRP Positives**
- No special H/W required
- Easy implementation of traffic regulation and filtering
- Easy handling of higher degree of contingencies
- Easy testing as one network can be completely isolate from the other
- Suited for large/complex applications

- **PRP Relative Negatives**
- Higher CAPITAL costs due to requirement of two networks
- Higher cost of designing, configuring, commissioning and maintenance

- FITNESS will monitor both HSR and PRP bays during system performance monitoring phase

- The ultimate decision to select PRP or HSR will depend on the complexity of the system, reliability and availability requirements as compared to the life cycle costs

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Priyanka Mohapatra

pmohapatra@spenergynetworks.co.uk

Thank you