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Transmission & Distribution – SMART GRIDS ASIA 2013

Migration Paths for IEC 61850 Substation Communication Networks Towards Superb Redundancy Based on Hybrid PRP and HSR Topologies

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Background on Network Redundancy

- RSTP (Rapid Spanning Tree) - the most widely deployed redundancy protocol in substation networks
- Eliminates loops introduced by media redundancy
- Loops result in broadcast storm flooding the network
- Automatically determines the best fit tree that spans the entire physical LAN
- Recovery times: in optimized implementations 5ms per hop
- Topology size limited to maximum 40 hops
- Worst case for link failure 200ms
- Root bridge failure - **worst case scenario up to several seconds**
- Recovery time can be deterministic in ring topology, non deterministic in mesh topology

RSTP network automatically recovers from the fault, however there is a certain time when there is no communications

The Need for High Availability Ethernet Network

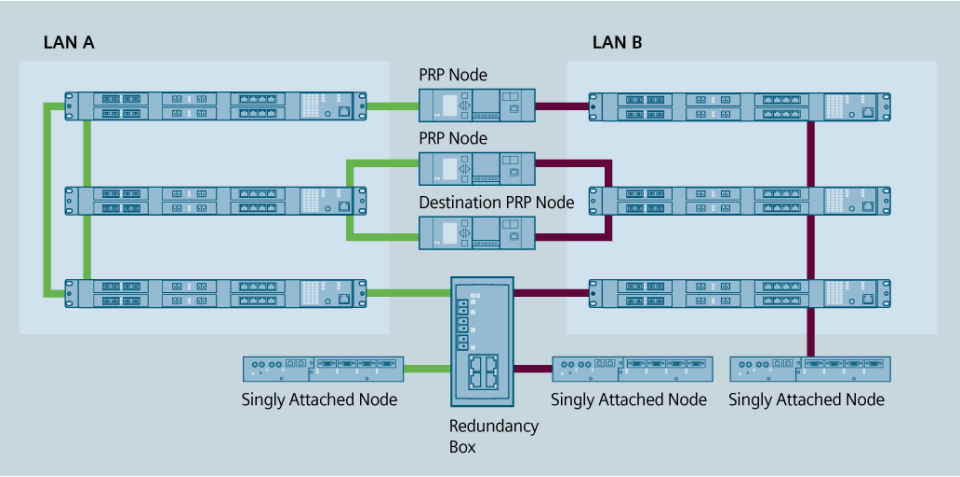
- Zero-time recovery upon network failure
- Deterministic network behaviour
- Ideal for the most critical applications
- Network nodes have two interfaces, port A and port B
- Sending node sends a frame always in both directions
- Receiving node processes the frame that arrives first and discards duplicates
- Each node has the same MAC and IP address on both ports
- Redundancy protocol takes care of duplicate frames
- Transparent to application, devices not aware of underlying redundancy

IEC 62439 Standard

- First documents ratified in May 2008
- Describes several high redundancy protocols with different characteristics: MRP, PRP, CRP, BRP, DRP, RSTP
- Latest official version is Ed. 1.0 IEC 62439 dated 2010
- Amendment for IEC 62439-3 expected in mid 2012
- PRP and HSR had been chosen by IEC 61850 TC57 WG10 for IEC 61850 Edition 2.0 for utility networks
- Referenced in IEC 61850-90-4, IEC 61850-9-2 ed 2.0, IEC 61850-8-1 ed 2.0

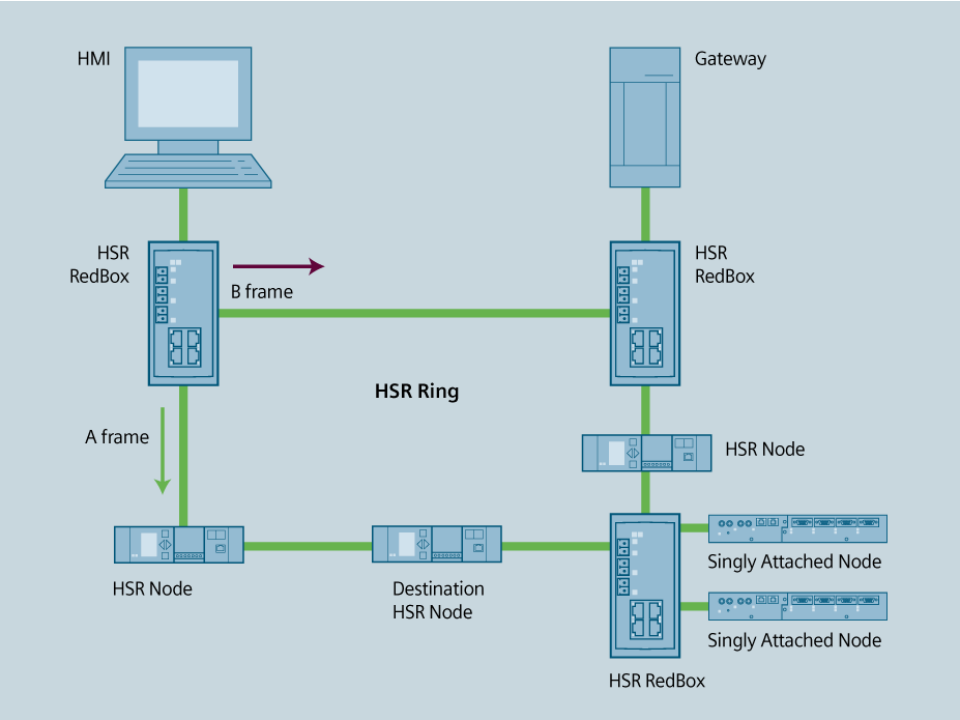
PRP Network Architecture

- Two Parallel Communications Networks
- Simultaneous data transmission
- Non-PRP nodes can be connected either via Redundancy box (RedBox) or directly to any of the two networks
- Ethernet frame augmented while in LAN



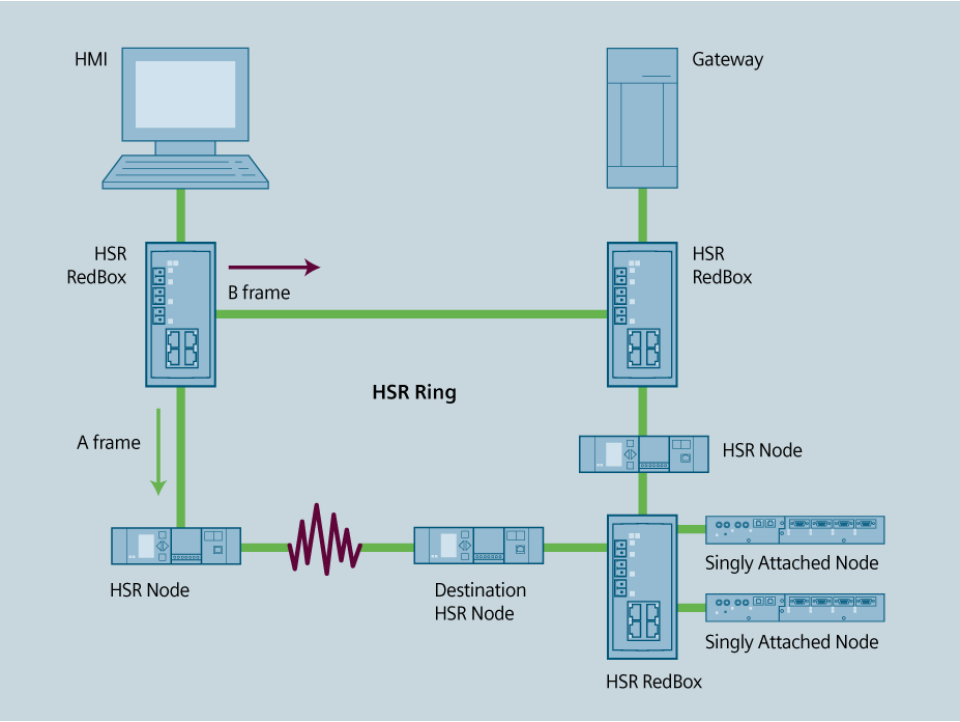
HSR Network Architecture

- Duplicate frames sent in opposite directions
- Ethernet frame augmented while in ring
- Frames are moved through the HSR network with minimal latency
- Duplicate frames are removed from network by the receiving node



How HSR Works After Link Failure

- In case of link failure the frame still makes it through to the receiving node from the opposite direction
- No data loss and no delay in case of network failure



Possible Migration Paths Towards IEC62439 Redundancy

Network Topology Constraints

Criticality of the substation, dictated by:

- Voltage Level

Secondary systems location, influenced by:

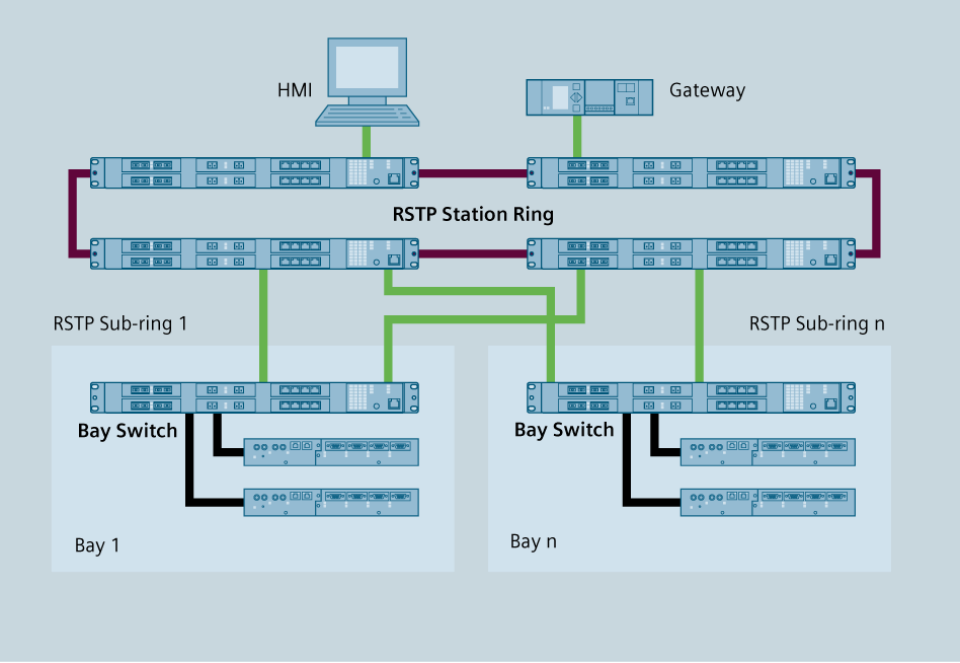
- Geographical extension and topology of the substation
- Existence of building structures and switchyard bay kiosks

Decentralized SAS architecture with bay kiosks in EHV switchyard

Existing Network Topology RSTP

Communications Network in EHV Substation

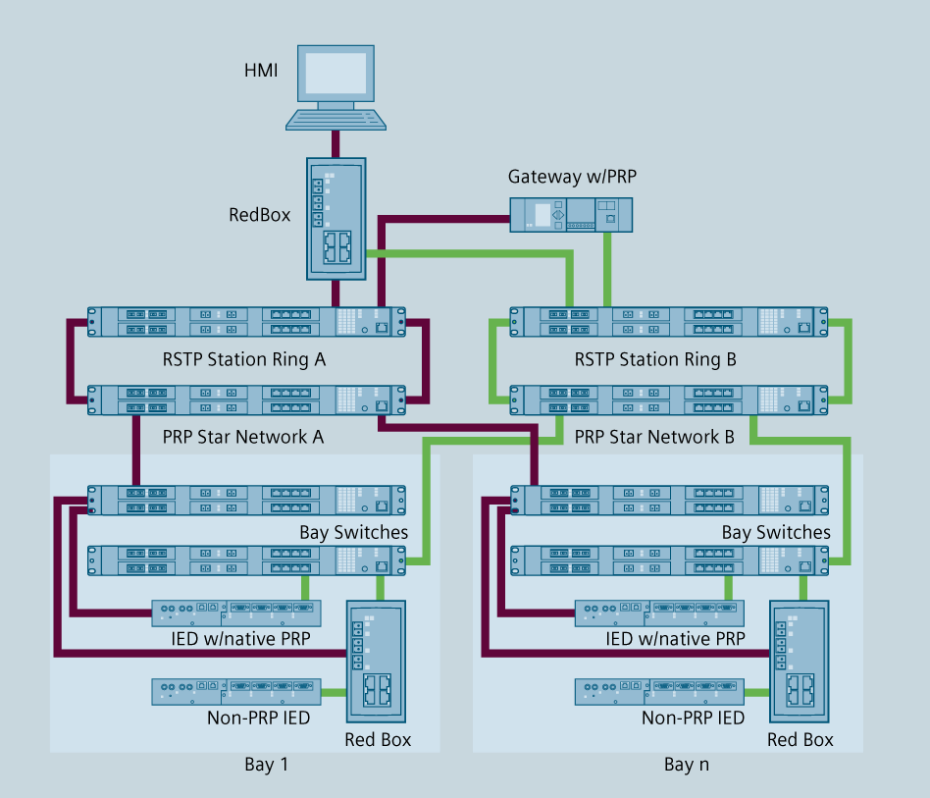
- IEDs connected via single Ethernet interface
- RSTP in the station ring and in bay subrings
- Ethernet bay switches connected via redundant links to the station ring



Bays connected as Redundant Stars

Possible Solution using PRP & RSTP

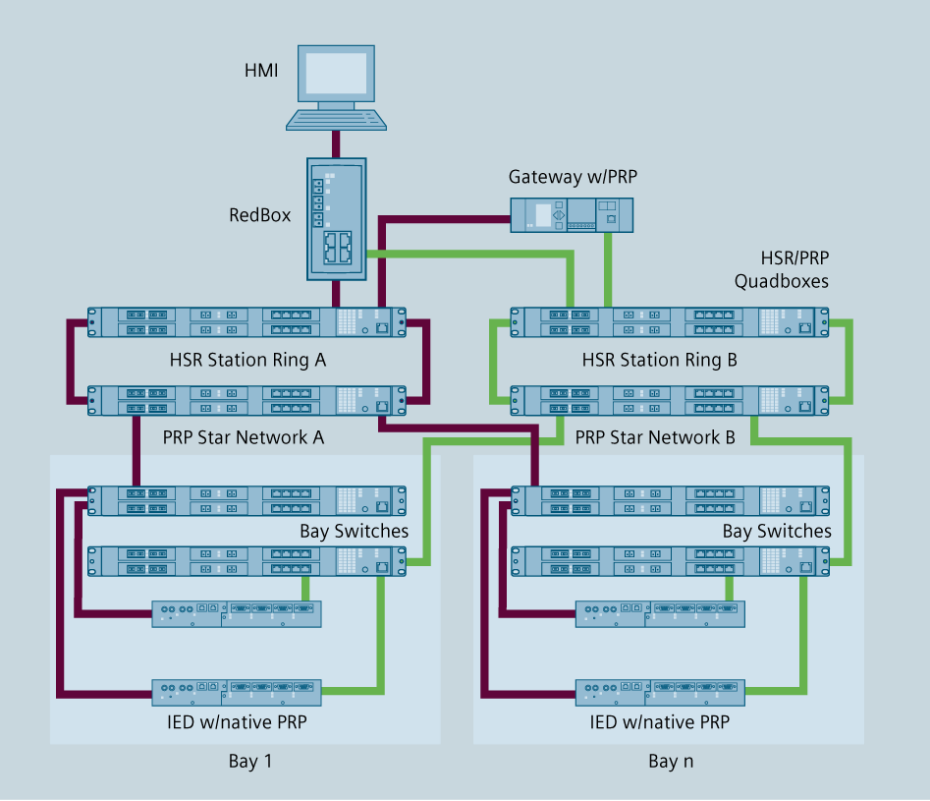
- Station ring split into two separate RSTP rings
- Native PRP in some IEDs, compact RedBoxes used to connect non-PRP IEDs
- Bays connected via two bay switches in a star fashion to station RSTP rings A and B
- Ethernet switches need to be PRP-aware



Bays connected as Redundant Stars

Possible Solution using PRP & HSR

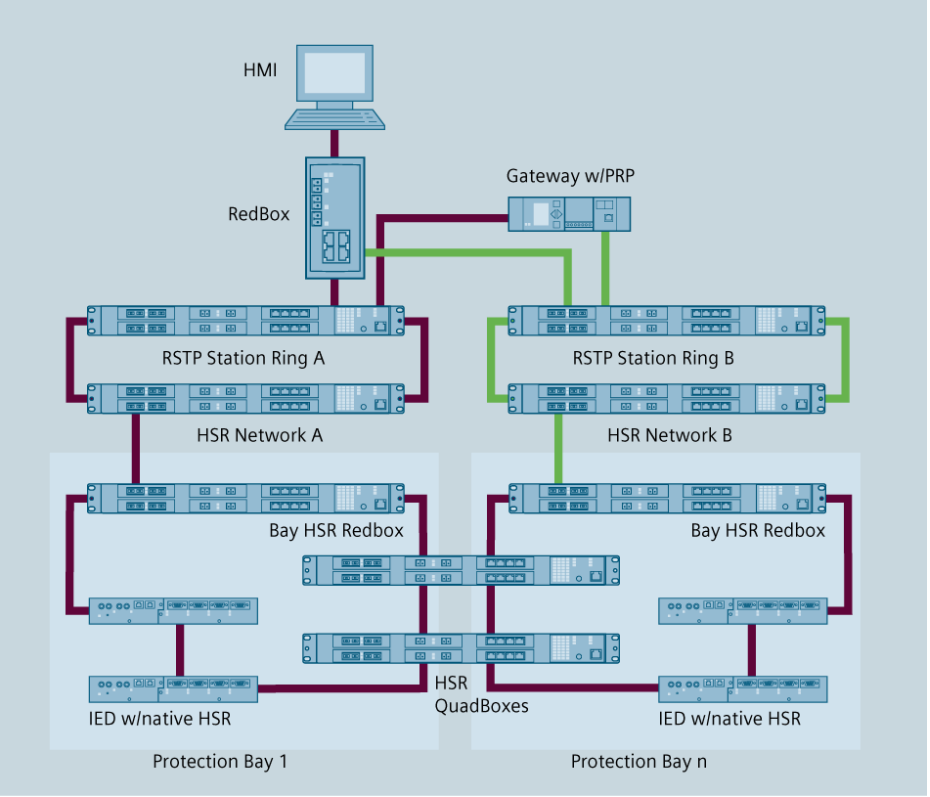
- RSTP in station rings is replaced by HSR rings of switches
- The concept of “PRP as a redundant access to IEDs and HSR as a redundant backbone ring”



Bays as HSR rings

Possible Solution using RSTP&HSR

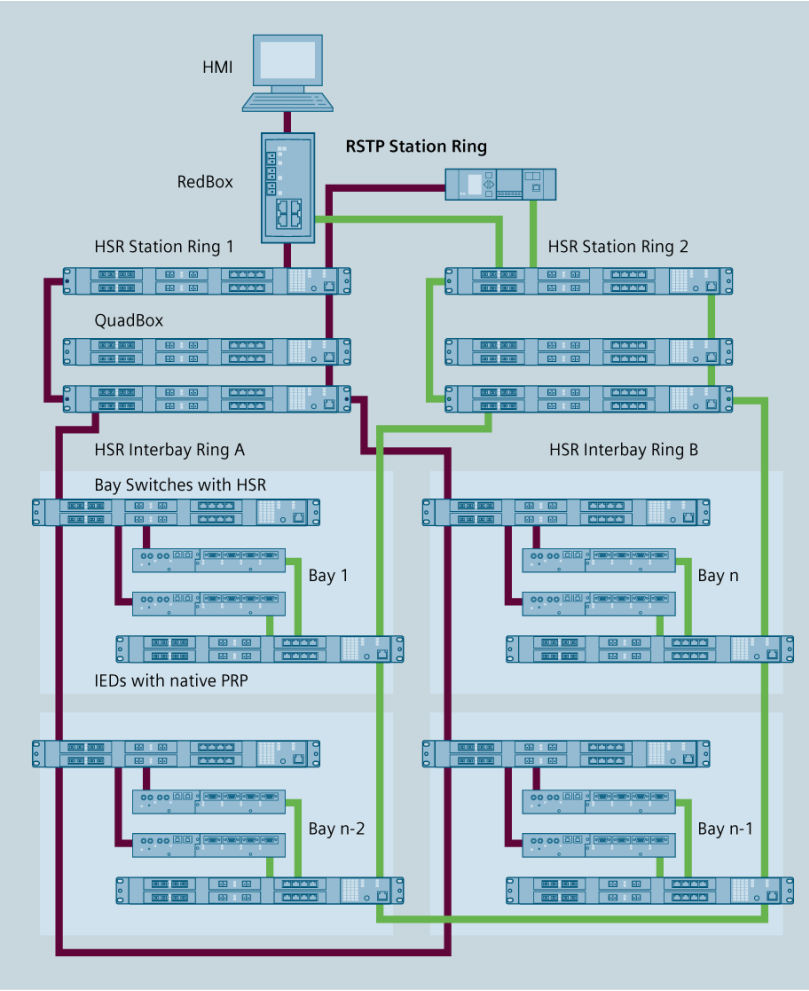
- HSR rings of IEDs in each bay
- Bays interconnected via HSR QuadBoxes
- Bays connected via two HSR RedBoxes to station RSTP rings A and B



Bays as HSR rings

Possible Solution using PRP & HSR

- PRP as redundant access to IEDs in star topology
- HSR as redundant protocol of switches interconnecting bays in a ring fashion
- Two independent HSR inter-bay rings spanning the switchyard
- Two station HSR rings (can also run RSTP for simplification)



Proposed Hybrid PRP / HSR Network

Benefits for AIS EHV Substations

- **Zero-time recovery in case of single point of failure**
  - Zero-millisecond outage upon any link or switch failure
- **Duplication of communications networks**
  - PRP as a redundant access to IEDs, RSTP as redundancy in the rings
  - HSR as future replacement of RSTP. HSR at the switch level, NOT at the IED level
- **Isolation of functions**
  - Communication network is mirroring protection philosophy of independent and redundant Protection A and Protection B systems
- **Scalability, easy maintenance and future upgrades**
  - Taking IEDs or bays out of service or adding new IEDs or bays doesn't affect the whole network
- **Reference design of bay protection & control panels**
  - Minimum design/wiring modifications needed in the future, even if RSTP redundancy between switches in the ring replaced by HSR redundancy

Conclusion

- HSR is a ring architecture that includes IEDs with embedded switch module
- PRP is less cost effective than HSR as more communications links and more standalone switches are required
- PRP introduces less overhead to network nodes in terms of bandwidth and required processing horsepower
- HSR may introduce maintenance issues and limit network flexibility
- HSR seems the right candidate for compact GIS substations, medium voltage switchgear or industrial installations

For EHV substations and large AIS sites with distributed relay kiosks a hybrid PRP/HSR architecture is proposed as the most reliable and flexible solution

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