Developments in Fast Load Shedding

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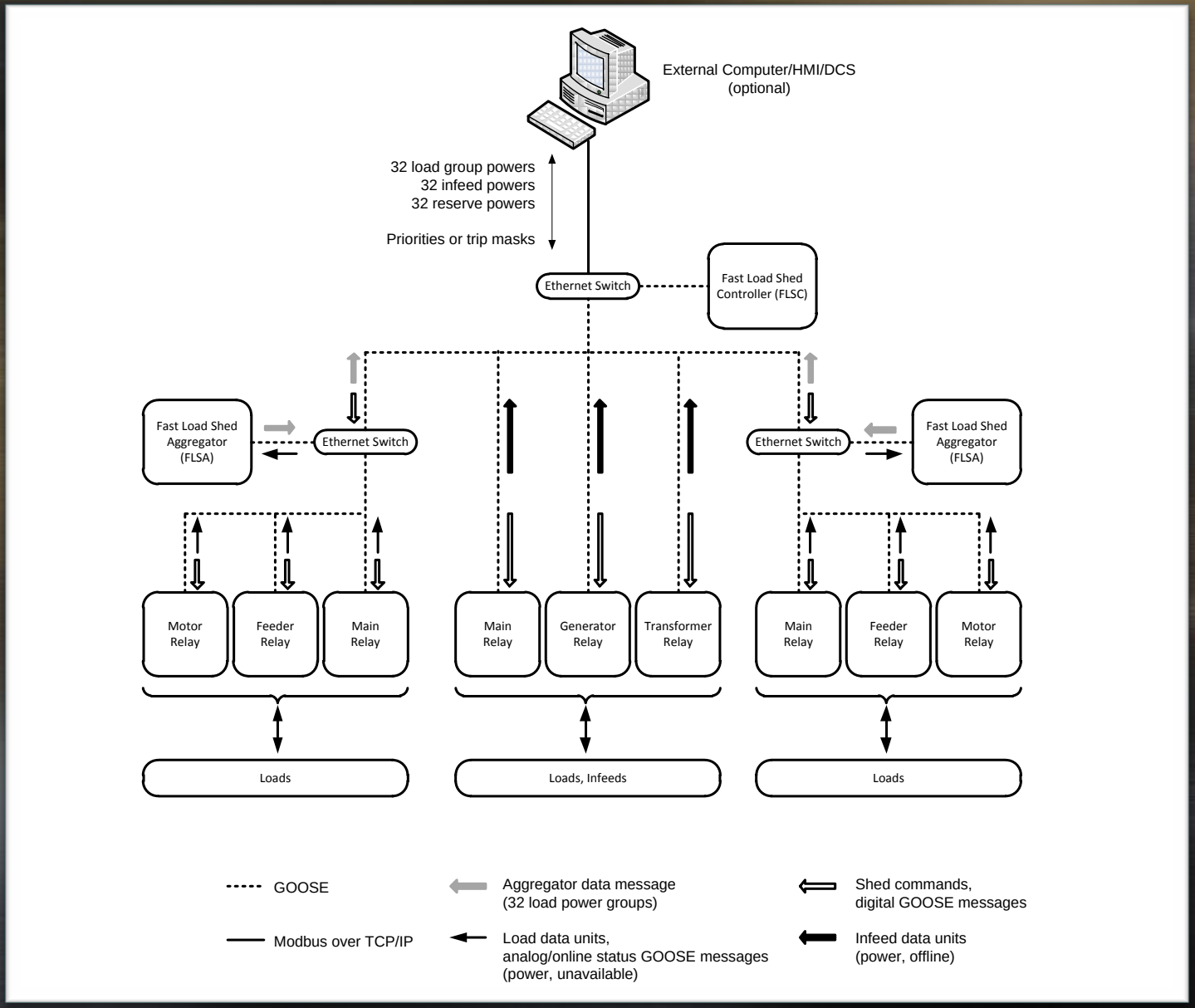
Introduction/Types of Load Shed

- Conventional load shedding schemes (>250ms)
  - Underfrequency and dF/dt
  - Undervoltage
- Traditional contingency based load shedding schemes (160 – 400ms)
  - PLC or PC based (centralized)
- Fast load shedding schemes (<150ms)
  - IED or EMS/SCADA based
  - Source/load power balance calculated

Scalable Architecture

- What is a power-balanced Fast Load Shed (FLS) system?
  - One controller
  - Aggregators
  - IEC 61850-capable Ethernet network
  - IEC 61850-8-1 capable end devices (IEDs)
- Controller supports up to 64 end devices (IEDs)
- Aggregator extends system by 64 Loads
- Controller: 32 sources & 32 loads/load groups
- Each load group has settable priority

FLS Scheme Communications



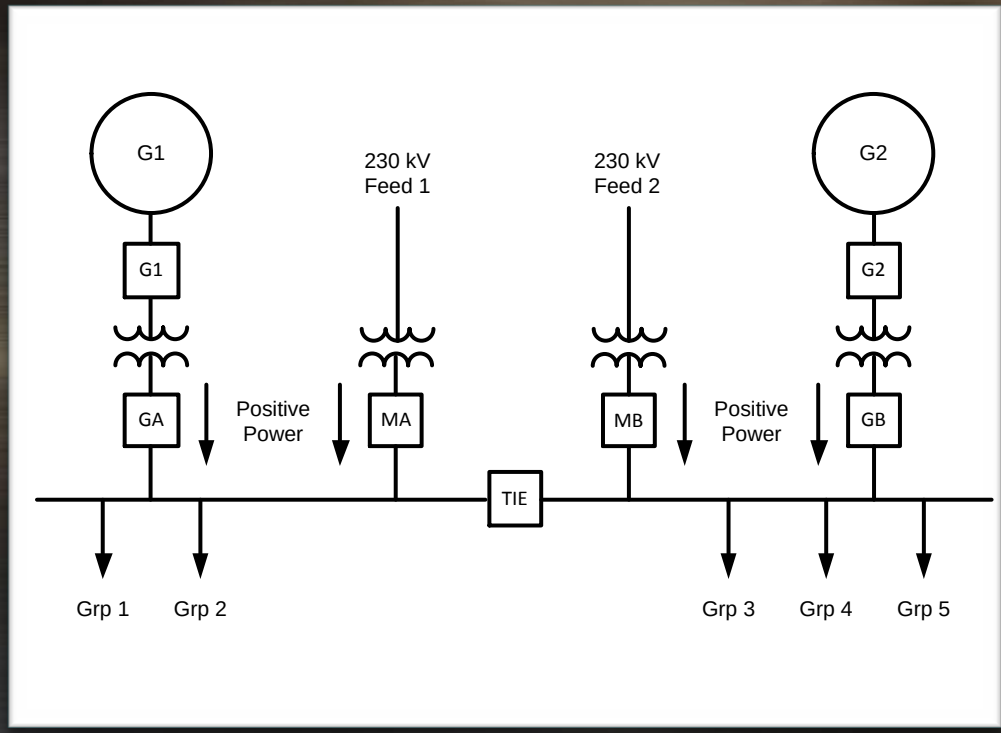
FLS Scheme Architecture

Dynamic Source/Load P Balance

- Goal: re-establish source/load power balance when source power is lost
- Fast Load Shed Controller (FLSC) receives source/load powers once per second
- FLSC calculates power balance
- Checks if generation/source lost exceeds reserve
- Send GOOSE messages to shed Loads per pre-defined priorities above reserve
- FLSC recalculates power balance after contingency time

Simplified Source-Load Example

- Total system load: PGrp1+PGrp2+PGrp3+PGrp4 +PGrp5
- Total source/gen: PG1+PG2+PMA+PMB
- Load group priorities set from HMI



Simplified Source-Load Example

- Load group prioritization (32 load groups; 128 priorities)
- Set by user
- Higher numbers mean lower priority loads
- 9MW source loss above reserve, FLSC will shed groups 3 and 5 (i.e. 10MW)

Asset	Value	Priority/Status (user set)
Group 1	10 MW	1 (highest priority)
Group 2	10 MW	0 (do not shed)
Group 3	5 MW	128 (lowest priority)
Group 4	20 MW	2
Group 5	5 MW	3

Fast Speed

- Fast load shedding including internal processing or execution time

Execution Time	Event
t = 0	End device (Source or Gen Prot) detects trip/breaker operation
3000 µs	GOOSE message with change of online state sent by end device
200 µs	GOOSE message passed through multiple LAN Ethernet switches
3000 µs	FLSC processing and calculations from received GOOSE message
1000 µs	Shed command GOOSE message composed by FLSC
500 µs	FLSC GOOSE message is sent through LAN Ethernet switches (20)
3000 µs	Shed command GOOSE message parsed by end load devices
4000 µs	End load device calculations and processing
2000 µs	Trip contact output closes on end load devices
16.7 ms	Total FLS execution time
67-100 ms	End device load breakers open (3-5 cycle breaker)

Comparison to Legacy Schemes

- Actual Fast Load Shed performance results

Time	Event
0 ms	Breaker MB opened manually
8 ms	Breaker open de-bounded, island detected, priorities 1, 2 and 3 load shed sent by FLSC
10 ms	Shed message received at load devices
13 ms	Trip coils energized
63 ms	Shed breaker open – load shed (assuming 3 cycle breaker) by FLS scheme
64 ms	ROCOF (dF/dt) trigger
106 ms	Underfrequency load shed trigger

Reliability/Redundancy, Network Advantages

- IEC 61850 capable Ethernet network is key
- Reliable Ethernet network enhanced by:
  - Ring architecture using RSTP (5ms/switch)
  - Tagged VLANs and priority (QoS) in GOOSE
- Power analog data transmitted once per second
- Binary values (source status and trip commands) on change of state
- Redundancy by fail-over networks or PRP
- Reliability met by GOOSE retransmission

GOOSE Retransmission

- An aggressive GOOSE retransmission scheme within a FLS controller, aggregator, or end device is used

Sequence Number	Time From The Event	Time Between Messages
0	0 ms	0 ms
1	4 ms	4 ms
2	8 ms	4 ms
3	16 ms	8 ms
4	Heartbeat	Heartbeat
5	Heartbeat	Heartbeat

Device Interoperability/Interchangeability

- End devices (IEDs) send power & receive shed commands via IEC 61850 GOOSE
- IEC 61850 GOOSE is open standard, i.e. any IED compliant to IEC 61850-8-1 can be used
- Use of IEC 61850 increase system longevity – replacing or adding IEDs supported
- Publisher/subscriber architecture makes future IED changes much easier
- Minimal changes to FLSC or FLSA needed for system expansion

Enhancements Over Existing LS Systems

- Speed – much faster than PLC/SCADA/PC
- Future proof – based on IEC 61850 architecture
- Programming based on communications – not logic in PLC
- System changes and expansions much simpler
- Reduction of end devices (hardware & wiring)
- Utilization of existing IEDs and networks
- System can be much larger – up to 2500 IEDs
- Optimal load shedding achieved – no Under/Over

HMI and DCS Involvement

- Load group shed priorities: fixed or dynamic
- HMI, DCS or SCADA to change priorities
  - Process priorities can change – time-of-day; time-of-year or process importance/materials etc.
- Load groups blocked from load shed

Conclusions

- Fast Load Shed is essential for industrials with co-gen for system stability
- Prevents loss of complete system if gen/source is lost
- Fast Load Shed system is proven
- Several advantages over existing systems
- Large and complex systems and expansions more manageable

Thank You

Questions?