Fast Load Shedding Scheme for Enhancing Reliability and Stability of Expanded Liquified Gas Plant

Barry Xu, Jonathan Gao -- GE Grid Solutions

Brandon Bosley, Julio Garcia –- Kiewit Engineering Group

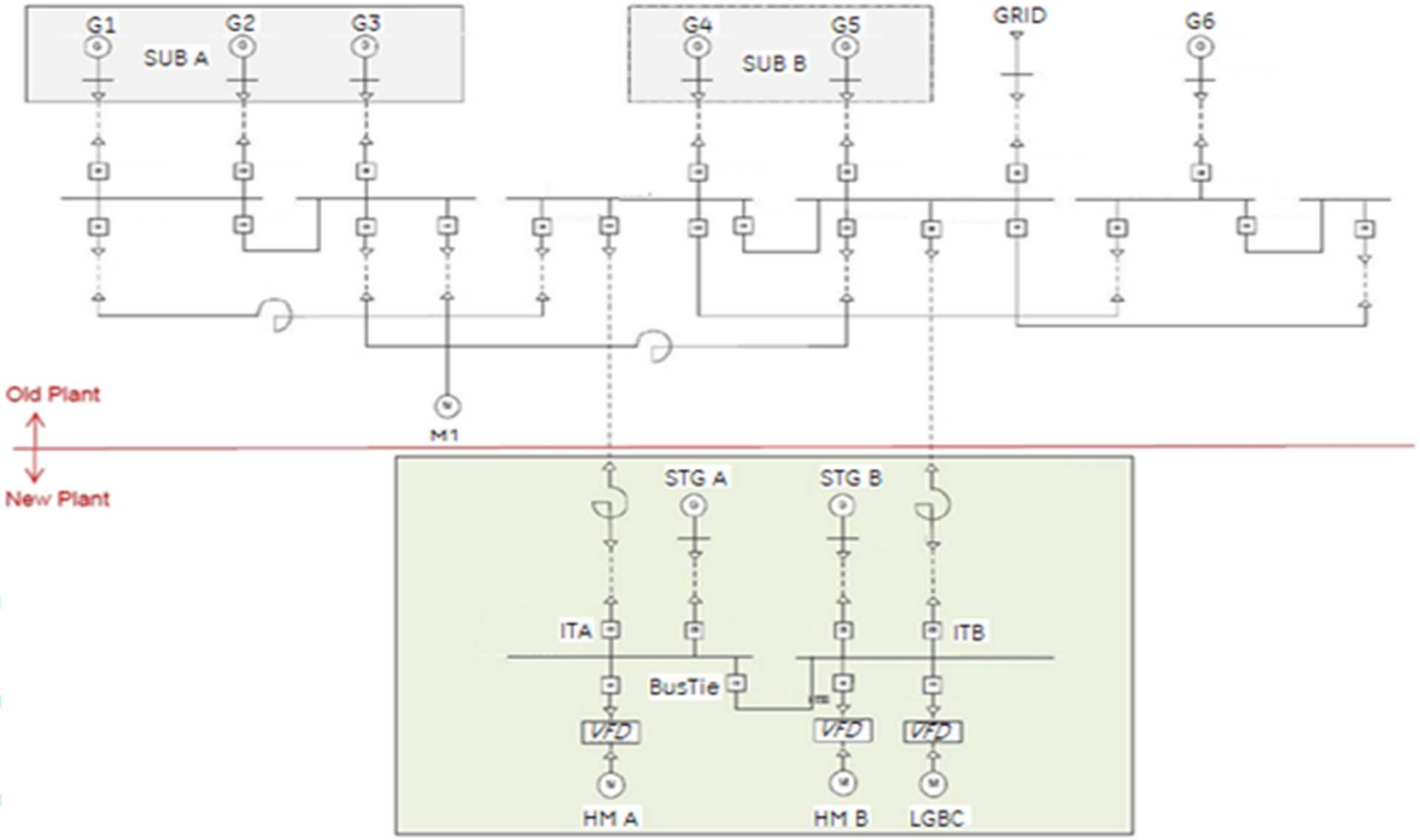
Ty Clark –- BHE Cove Point Liquefaction

2021 Texas A&M Protective Relaying Conference

Introduction

- LNG Plant Fast Load Shedding Project Description
- Fast Load Shedding Project Executions
- Testing and Commissioning
- Conclusions

Simplified One-Line Diagram



Project Description

- The utility line functions as an emergency power source only.
- New plant is connected to old plant through two Interties.
- Two 65MW generators and three expander generators.
- Performing load-generation balance within 100ms to maintain 95% of the nominal frequency to prevent system instability.
- FLS scheme is an effective and required operation to avoid the whole plant blackout.
- FLS Controller will shed the loads based on predefined group priority during loss of generator(s).

Project Executions

- Fast Load Shed Triggers.
- FLS System Redundancy Design.
- VLAN and Ethernet Switch Configurations.
- FLS Performance.
- Power Balance Calculations.
- Participating FLS Sources, Load Groups and Priority Levels.
- Three Compressors Interlocking Function.
- FLS System DCS Interfaces.

Fast Load Shed Triggers

1. A STG generator breaker is tripped or opened while its real power is larger than 4.0 MW.

- Each STG is protected by Relay A with IEC61850 Protocol function and a non-IEC 61850 Relay B.
- Upon a generator trip, Relay A will send a GOOSE message to Controller, triggering the fast load shed scheme. At the same time, Relay B will send trip signals to Controller through hardwired output. These two tripping signals are logically “OR” together in the FLS scheme. Either of these signals would trigger the FLS scheme while Relay A is in service. A tripping signal alone from Relay B while Relay A is out of service will not be considered as a valid FLS trigger.

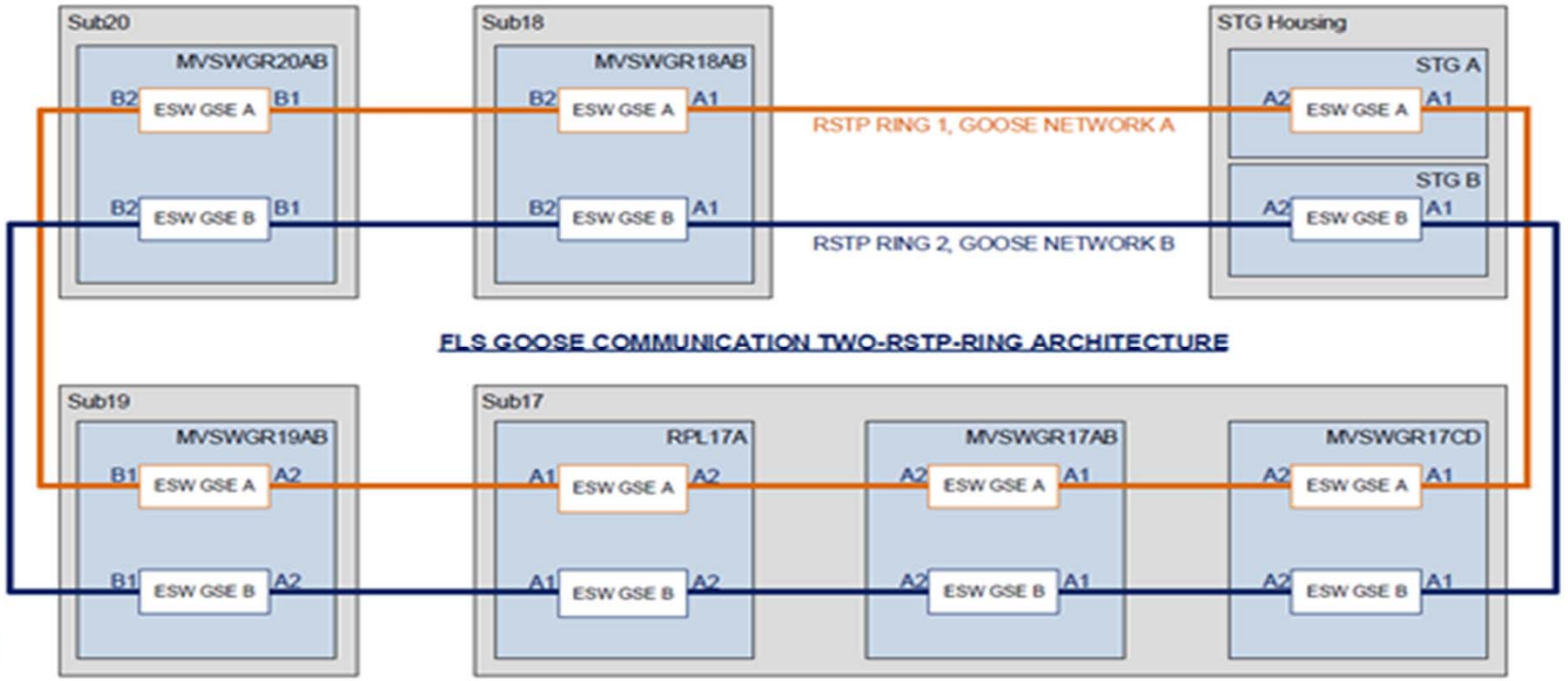
Fast Load Shed Triggers

2. Both Intertie breakers are tripped from a tripping element from any generator protection in the old plant and the combined power of both Interties is more than 4.0 MW.
3. One of the intertie breakers with power more than 2.0 MW is tripped or opened while the 13.8 KV bus tie breaker is open.

FLS System Redundancy Design

➢ Switch Networks Redundancy:

The FLS network architecture was designed to withstand a single point of failure, 14 Gigabit Ethernet Switches (1000Mb) configured as two RSTP rings for the communication networks.



FLS System Redundancy Design

- FLS Controllers Redundancy:

Two FLS Controllers are configured as redundant and run independently.

- Relay Ethernet Ports Redundancy:

All 39 relays have two Ethernet ports running in PRP (Parallel Redundancy Protocol) mode, each port is connected to one of the parallel network RSTP rings. The dual network connections offer protection against any single hardware point of failure, except for relay failure.

VLAN and Ethernet Switch Configurations

- A VLAN is configured on RSTP rings to separate FLS system GOOSE communication traffic from the rest of the devices in the network, which allows GOOSE messages being transmitted only among the FLS devices inside the VLAN. VLAN ID “2” is set for the “Transmission Configurable GOOSE” settings in the all 39 FLS relays, including 2 Controllers.
- To avoid the traffic among the Switches, Fast Load Shedding Commands are configured as GOOSE VLAN Priority “6”, which has higher priority than the other message with VLAN Priority “4”.

FLS Performance

- Speed: The guaranteed total FLS time is 100ms from the moment a FLS contingency trigger activation to the moment the load breakers/contractors tripped.
- Load shed amount: The minimum load shed amount from a contingency trigger will be at least 100% of the related power source loss amount.
- Frequency drop limitation: During a FLS event, the system frequency should never drop below 95% of the normal frequency in order to prevent the system from becoming unstable.

Power Balance Calculations

The FLS controller issues load shed commands in the event of a contingency based on a predefined load shed priority with continuous power balance calculations on measured active power values from the in-feeds and loads in the FLS system.

$$P_{shed} = \begin{cases} 0, & \text{if contingency timer is Off} \\ \sum_{\text{all } i} \begin{cases} +P_I[i] \text{ if } Lost[i] \\ -P_R[i] \text{ if not } Lost[i] \end{cases}, & \text{otherwise} \end{cases}$$

In this equation,

- P_{shed} is the load shed order.
- $P_I[i]$ is the steady-state infeed power of infeed i.
- $P_R[i]$ is the steady-state reserve power of infeed i.
- $Lost[i]$ is the lost status of infeed i.

Participating FLS Sources

The following devices are configured as sources in the FLS system, while the three expanders are not assigned as FLS triggers.

- STG A Generator, base capacity 65MW.
- STG B Generator, base capacity 65MW.
- LNG A Expander, base capacity 1.953MW.
- LNG B Expander, base capacity 0.719MW.
- Liquid Expander, base capacity 0.904MW.
- Two (plant) Intertie breakers, capacity varies.

FLS Load Groups and Priority Levels

Total 18 predefined load groups based on the loads' functions.

Group	Loads	KW	Priority Level
1	LNG Loading Pump A, Pump B, Pump C and Pump D	2588	15
2	Cold Flare Drum Heater A, Heater B and Heater C	5200	0
3	Regeneration Gas Compressor A and Compressor B	1092	14
4	Acid Gas Blower A and Blower B	1972	13
5	Fuel Gas Compressor 901A	2100	12
6	Flash Gas Compressor A	820	11
7	Fuel Gas Compressor 901B	2100	10
8	Flash Gas Compressor B	820	9
9	Fuel Gas Compressor 901C	2100	8
10	Flash Gas Compressor C	820	7
11	Helper Motor A	11050	6
12	Helper Motor B	11050	1
13	Vent Fan Motor A1 and Motor A2	424	0
14	Vent Fan Motor B1 and Motor B2	424	0
15	Lean Gas Booster Compressor	20900	5
16	LNG Product Pump A and Pump B	512	4
17	Amine Circulation Pump A and Pump B	3178	3
18	Lean Amine Pump A and Pump B	354	2

Compressors Interlocking Function

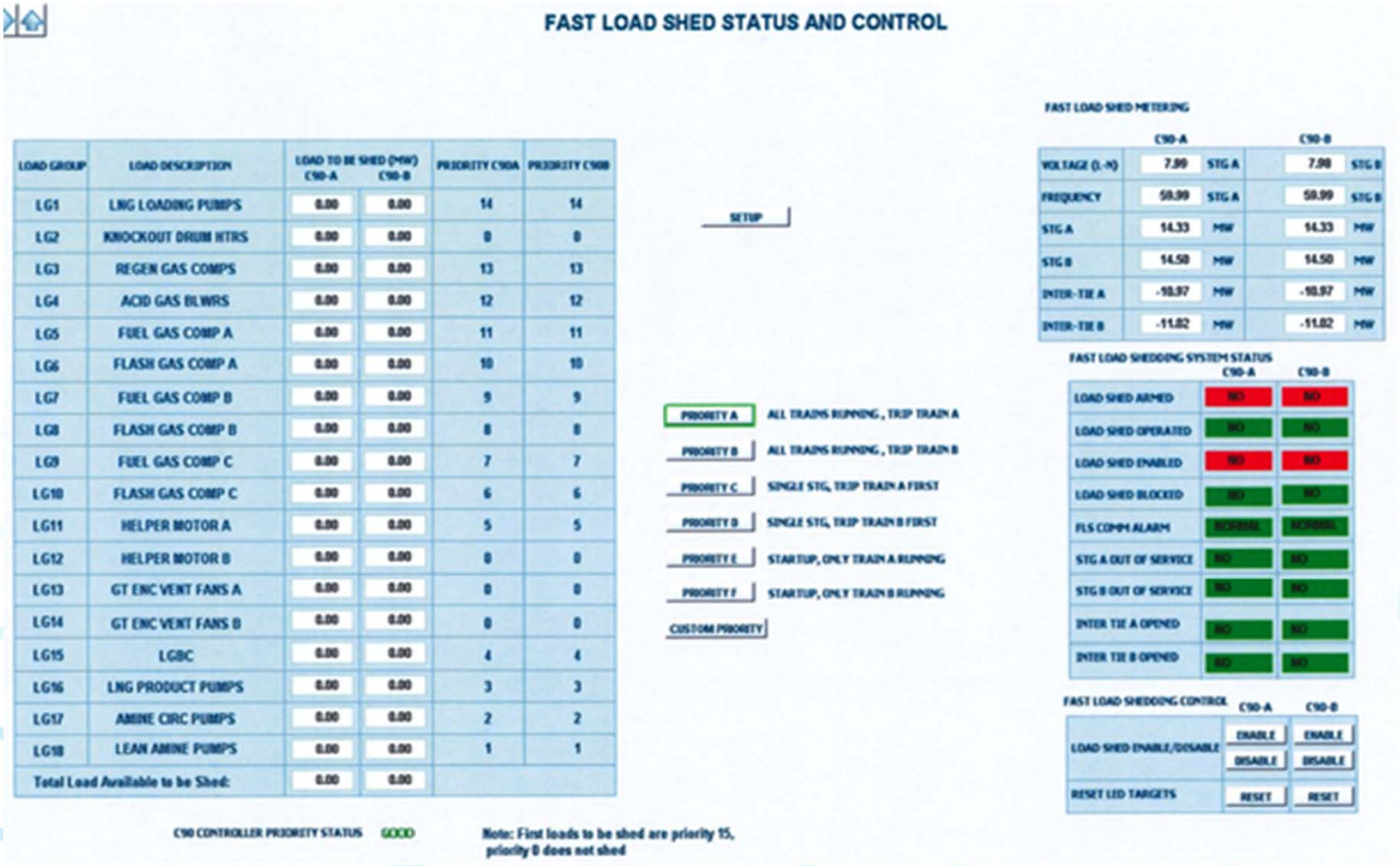
Due to the production process needs, there is a unique requirement for 3 Fuel Gas Compressors 901A, 901B and 901C.

Combination	901A	901B	901C	The unit to be kept running	Unit(s) to be shed
1	0	0	0	N/A	NA
2	0	0	1	Compressor 901C	NA
3	0	1	0	Compressor 901B	NA
4	0	1	1	Compressor 901B	Compressor 901C
5	1	0	0	Compressor 901A	NA
6	1	0	1	Compressor 901A	Compressor 901C
7	1	1	0	Compressor 901A	Compressor 901B
8	1	1	1	Compressor 901A	901B & 901C

Logic in 3 Compressor Motor Relays

- Compressor 901A will never be shed when it is running, “ON” as the unavailability status is sent to Controller, and FLS load shed command is not configured to trip the breaker.
- “901A Offline” is sent to Controllers as the unavailability status of Compressor 901B.
- “901A & 901B Offline” is sent to Controllers as the unavailability status of Compressor 901C.

FLS Status and Control



FLS Priority Level Configuration

FAST LOAD SHED PRIORITY LEVEL CONFIGURATION

STATUS

WARNING MSG

LOAD GROUP	LOAD DESCRIPTION	LOAD (MW)	PRIORITY TO WRITE	SETUP	PRIORITY C90A	PRIORITY C90B
LG1	LNG LOADING PUMPS	0.00	14	SET	14	14
LG2	KNOCKOUT DRUM HTRS	0.00	0	SET	0	0
LG3	REGEN GAS COMPS	0.00	13	SET	13	13
LG4	ACID GAS BLWRS	0.00	12	SET	12	12
LG5	FUEL GAS COMP A	0.00	11	SET	11	11
LG6	FLASH GAS COMP A	0.00	10	SET	10	10
LG7	FUEL GAS COMP B	0.00	9	SET	9	9
LG8	FLASH GAS COMP B	0.00	8	SET	8	8
LG9	FUEL GAS COMP C	0.00	7	SET	7	7
LG10	FLASH GAS COMP C	0.00	6	SET	6	6
LG11	HELPER MOTOR A	0.00	5	SET	5	5
LG12	HELPER MOTOR B	0.00	0	SET	0	0
LG13	GT ENC VENT FANS A	0.00	0	SET	0	0
LG14	GT ENC VENT FANS B	0.00	0	SET	0	0
LG15	LGBC	0.00	4	SET	4	4
LG16	LNG PRODUCT PUMPS	0.00	3	SET	3	3
LG17	AMINE CIRC PUMPS	0.00	2	SET	2	2
LG18	LEAN AMINE PUMPS	0.00	1	SET	1	1

CLEAR TEMPORARY SETUP

WRITE SETTINGS TO C90P CONTROLLERS

Testing and Commissioning

- Verified communications between the relays and the controllers, and communications between the controllers and the DCS HMI Interface.
- Verified 37 infeed/load breakers status and power measurements in the controllers.
- Verified the interlocking function of the 3 fuel gas compressors.
- Simulated the FLS functions under various scenarios, and verified the FLS operations.
- Tested the FLS operating times within the 100ms requirement.
- Performed “One-Shot” FLS live system test to demonstrate the FLS system overall functionality.

FLS Operation Time and Report

The operating times from the FLS initiation signal “STGB 52G/a off” to load breakers open was around 53ms.

Relay Name	C90PA
Firmware Version	1.90
Last Setting Change	Nov 15, 2017 12:11:45
Calculation Mode	Adaptive
Contingency Time Setting	20 s
Events Enabled	Yes

Start Date and Time	Nov 15, 2017 12:12:31.143761
Duration	20 s
Total Infeed	8262.0 kW
Total Reserve	0.0 kW
Total Avail Load	41100.0 kW
Total Infeed Lost	4200.3 kW
Total Load Shed Requested	5300.0 kW
Any FLS Comms Trbl	No

Infeed Designation	Infeed ID	Lost	Power	Reserve
ISTGAG60	IF1	Yes	4200.3 kW	0.0 kW
ISTGBG60	IF2	No	18519.3 kW	0.0 kW
ITA	IF3	No	-7225.7 kW	0.0 kW
ITB	IF4	No	-7231.9 kW	0.0 kW
ISX501	IF5	No	0.0 kW	0.0 kW
ISX502	IF6	No	0.0 kW	0.0 kW
ISX511	IF7	No	0.0 kW	0.0 kW

Load Group Designation	Load Group ID	Priority	Power	Shed Request
LNG Loading Pumps	LG1	0	2200.0 kW	No
Knockout Drum Heater	LG2	0	8700.0 kW	No
Gas Compressors	LG3	0	4100.0 kW	No
Acid Gas Blowers	LG4	12	3300.0 kW	Yes
L5K901A	LG5	11	0.0 kW	Yes
L5K905A	LG6	10	800.0 kW	Yes
L5K901B	LG7	9	1200.0 kW	Yes
L5K905B	LG8	8	900.0 kW	No
L5K901C	LG9	7	1300.0 kW	No
L5K905C	LG10	6	1000.0 kW	No
L5GT501A	LG11	5	100.0 kW	No
L5GT501B	LG12	0	0.0 kW	No
Vent Fan Motor A	LG13	0	4900.0 kW	No
Vent Fan Motor B	LG14	0	5300.0 kW	No
L5K501	LG15	4	300.0 kW	No
L5P551A & B	LG16	3	2900.0 kW	No
L5P202A & B	LG17	0	1800.0 kW	No
L5P231A & B	LG18	0	2300.0 kW	No

FLS Report 1

Live FLS System Operations

- FLS system described in this paper is a necessary requirement for the plant. The system has been running successfully since 2017, and was confirmed to save the facility during several instances by shedding pre-selected loads to maintain power system stability.
- In March 2019, STGA with 40MW tripped offline, the FLS system was activated and shed several large motor loads based on the preset load group priorities. Plant LNG production only dropped by 35% and Operation was able to immediately begin recovery to full production. Without FLS all production would have been lost and the facility would have suffered a cascading power failure and subsequent blackout.

Conclusions

Benefits are achieved from new technologies for this FLS:

- Operating speed of 50-55ms, which would not be possible with an older technology.
- Adaptive approach with continuous monitoring of the power balance and shedding exact amount loads to maintain balance, keeping critical loads not disturbed.
- Continuous monitoring of the health of the system and communications.
- Reduced copper wiring between controller and breakers.
- Ease of commissioning and maintenance.

Thank You

Questions?