Substation FMEA

Failure Modes and Effects Analysis

Process Name:	California Wildfire Substation Mitigation	Prepared by: Jacob Alberti & David Thomas	FMEA Date (Orig) _____ (Rev) _____

	Process Step	Input X (KPIV)	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended	Resp.	SEV	OCC	DET	RPN
Sort Order	What is the process step under investigation?	What is the Input Variable under consideration?	In what way(s) does the X go wrong?	What is the impact on the KPOVs (Customer Requirements) or internal requirements?	How Bad?	What causes the X to go wrong?	How Often?	What are the existing controls and procedures (inspection and test) that prevent the cause or the Failure Mode?	Detect / Prevent		What are the actions for reducing the occurrence of the Cause, or improving detection?	Who's Responsible for the recommended action?				
1	Substation Layout	All substation equipment (see below)	equipment failure	potential fire hazard, catastrophic failure, damage to equipment	10	wildlife, vegetation, weather, improper maitenance	5	defensive space set back zone, NEET first responder, weather modeling, herebicidal treatment	6	300	Public Safety Power Shutoff Plan, increase defensive space , deluge system & sprinkler systems, interactive signage, equipment maitenance, fire barrier walls, optical fire detector, highly sensitive smoke detectors, annual fire assessments and audits, fire safety working groups, awareness, additional agreements with private fire service company		10	4	5	200
2	Arrestor	grounding mechanism, rating	degredation of grounding mechanism, fails to ground, incorrectly sized	potential fire hazard, loss of power to system, equipment damage, ground fault, line disturbance	10	corossion, cracks, manufacture defects, improper engineering design	7	testing, inspections, maintenance	4	280	additional engineering review on quality of material	Subject Matter Expert	10	6	3	180
3	Transformer	rating, load capacity, voltage	overload, internal faults, hot spot, gassing, oil leak, loss of cooling system	oil based fire hazard, loss of power to system, damaged equipment, long repair/replacement lead time, untanking	10	overloaded conditions, aging equipment, manufacturer defects,	5	sudden pressure relays, firewall containment, fire suppression, insulation and resistance testing, oil quality testing, maitenance, hazardous waste management, , firefighters on standby, water reservoir for firefighters	5	250	real-time monitoring (infrared & thermo, high definition cameras, rovers, drones), deluge system, seed oil, reenforce tanks, low explosive bushings, nitrogen gas protection system, annual fire safety drill, additional agreement with private fire service company, 10,000 gallon water tank, more effective oil containment, foam system, fire safety working groups, gas insulated design	Field Operations	10	5	4	200

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Substation FMEA (cont'd)

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	Process Step	Input X (KPIV)	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended	Resp.	SEV	OCC	DET	RPN
Sort Order	What is the process step under investigation?	What is the Input Variable under consideration?	In what way(s) does the X go wrong?	What is the impact on the KPOVs (Customer Requirements) or internal requirements?	How Bad?	What causes the X to go wrong?	How Often?	What are the existing controls and procedures (inspection and test) that prevent the cause or the Failure Mode?	Detect / Prevent		What are the actions for reducing the occurrence of the Cause, or improving detection?	Who's Responsible for the recommended action?				
4	potential transformer	rating, load capacity, voltage	overload, internal faults, hot spot, oil leak,	oil based fire hazard, loss of power to system, damaged equipment, long repair/replacement lead time, untanking	10	overloaded conditions, aging equipment, manufacturer defects,	5	Engineering design, protective relay schemes, oil containment and waste management	5	250	additional redundant protection, fusing, seed oil, more effective oil containment, fire safety working groups	Subject Matter Expert	10	4	5	200
5	Capacitor Voltage Transformer	rating, load capacity, voltage	overload, internal faults, hot spot, oil leak,	oil based fire hazard, loss of power to system, damaged equipment, long repair/replacement lead time, untanking	10	overloaded conditions, aging equipment, manufacturer defects,	5	Engineering design, protective relay schemes, oil containment and waste management	5	250	additional redundant protection, fusing, seed oil, more effective oil containment, fire safety working groups	Subject Matter Expert	10	4	5	200
6	Voltage Transformer	rating, load capacity, voltage	overload, internal faults, hot spot, oil leak,	oil based fire hazard, loss of power to system, damaged equipment, long repair/replacement lead time, untanking	10	overloaded conditions, aging equipment, manufacturer defects,	5	Engineering design, protective relay schemes, oil containment and waste management	5	250	additional redundant protection, fusing, seed oil, more effective oil containment, fire safety working groups	Subject Matter Expert	10	4	5	200
7	Circuit breaker	fault interruption rating and overcurrent rating	fails to clear fault (arc), breaker misoperation, fails to operate, catastrophic breaker failure	potential fire hazard, lose power to system, damages equipment,	10	maximum fault current exceeds design limits, overcurrent loading, hot spots	5	engineering analysis of modifications, testing, maitenance	5	250	real-time monitoring (infrared & thermo, high definition cameras, rovers, drones)	Field Operations	10	5	4	200
8	Grounding Transformer	rating, load capacity, voltage	overload, internal faults, hot spot, oil leak,	oil based fire hazard, loss of power to system, damaged equipment, long repair/replacement lead time, untanking	10	overloaded conditions, aging equipment, manufacturer defects,	5	Engineering design, protective relay schemes	5	250	additional redundant protection, seed oil	Subject Matter Expert	10	5	4	200
9	Bushing	insulator & porcelain/polymer case	cracking, aging, salt contamination, potential discharge	potential fire hazard, flashover, transformer damage,	10	weathering, cracking, aging, manufacturer defect, quality of material	6	inspection for cracks/defects , cleaning insulators, preventative maitenance	3	180	inspection using magnetic particle detection testing, low explosive bushings	Field Operations	10	6	2	120
10	Thyristor Control Reactors (Static Var Compensator, SVC)	connections,	hot spots, loose connections, shorting due to electrical overstress, unsustainable voltage level, corrosion, potting issues, wire insulation	potential fire hazard, arcing, damage to equipment	10	manufacture defects, aging, weathering, salt contamination	3	testing, inspections, maintenance	5	150	x-ray imaging, optical microscopy, infrared & thermo, high definition cameras, rovers, drones	Field Operations	10	3	3	90
11	Inductors (Static Var Compensator, SVC)	connections,	hot spots, loose connections, shorting due to electrical overstress, unsustainable voltage level, corrosion, potting issues, wire insulation	potential fire hazard, arcing, damage to equipment	10	manufacture defects, aging, weathering, salt contamination	3	testing, inspections, maintenance	5	150	x-ray imaging, optical microscopy, infrared & thermo, high definition cameras, rovers, drones	Field Operations	10	3	3	90

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Substation FMEA (cont'd)

Failure Modes and Effects Analysis

Process Name:	California Wildfire Substation Mitigation	Prepared by: Jacob Alberti & David Thomas	FMEA Date (Orig) _____ (Rev) _____

	Process Step	Input X (KPIV)	Potential Failure Mode	Potential Failure Effects	S E V	Potential Causes	O C C	Current Controls	D E T	R P N	Actions Recommended	Resp.	S E V	O C C	D E T	R P N
Sort Order	What is the process step under investigation?	What is the Input Variable under consideration?	In what way(s) does the X go wrong?	What is the impact on the KPOVs (Customer Requirements) or internal requirements?	How Bad?	What causes the X to go wrong?	How Often?	What are the existing controls and procedures (inspection and test) that prevent the cause or the Failure Mode?	Detect / Prevent		What are the actions for reducing the occurrence of the Cause, or improving detection?	Who's Responsible for the recommended action?				
12	Reactor	connections,	hot spots, loose connections, shorting due to electrical overstress, unsustainable voltage level, corrosion, potting issues, wire insulation	potential fire hazard, arcing, damage to equipment	10	manufacture defects, aging, weathering, salt contamination	3	testing, inspections, maintenance	5	150	x-ray imaging, optical microscopy, infrared & thermo, high definition cameras, rovers, drones	Field Operations	10	3	3	90
13	busbar	metal casing, metal supports	rust, support failure, damaged insulators	flashover, arcing, catasrophic failure, equipment damage, potential fire hazard,	3	weathering, age, foundation creeking, damage caused by machinery	7	spotters for vehicles,	5	105	better quality aluminum, fire protective coding	Subject Matter Expert	3	6	5	90
14	Thyristor Switched Capacitor (Static Var Compensator, SVC)	connections, capacitor can	hot spots, loose connections, shorting due to electrical overstress, unsustainable voltage level, corrosion, wire insulation	potential fire hazard, arcing, damage to equipment	10	manufacture defects, aging, weathering, salt contamination, bad capacitor can	5	testing, inspections, maintenance, relay protection schemes	2	100	infrared & thermo, high definition cameras, rovers, drones	Field Operations	10	5	1	50
15	Capacitor Bank	connections, capacitor can	hot spots, loose connections, shorting due to electrical overstress, unsustainable voltage level, corrosion, wire insulation	potential fire hazard, arcing, damage to equipment	10	manufacture defects, aging, weathering, salt contamination	5	testing, inspections, maintenance, relay protection schemes, zero crossing controller	2	100	infrared & thermo, high definition cameras, rovers, drones, zero crossing controller	Field Operations	10	5	1	50
16	Disconnects	motor operater, knife blades, switching orders	misalignmnet of knife blades, wildlife, arc travel distance, opening under load	potential fire hazard, arcing, catastrophic failure	10	switching errors, poor maitenance, mechanical failure, wildlife ignition source	5	calibration, lock out tag out, 3 way communication, bird mitigation	1	50	periodic maitenance and inspections, periodic updates of wildlife plan, review of switching orders, written switching orders only	Field Operations & Environmental Subject Matter Expert	10	5	1	50
17	Circuit Switcher	motor operater, blades, switching orders	misalignmnet of blades, wildlife, arc travel distance, opening under load, locked rotor	potential fire hazard, arcing, catastrophic failure, inoperable due to locked mechanisms	10	switching errors, poor maitenance, mechanical failure, wildlife ignition source	5	calibration, lock out tag out, 3 way communication, bird mitigation	1	50	periodic maitenance and inspections, periodic updates of wildlife plan	Field Operations & Environmental Subject Matter Expert	10	5	1	50
18	Relays	Protection Settings, wiring connections	Incorrect relay settings, cross-wired, loose wiring,	potential fire hazard, fault will not be interrupted or cleared,	10	Settings were not designed correctly, user error while inputing settings,	5	engineering analysis,design review, relay testing, CT polarity check, calibration	1	50	additional review & calibration	Relay Subject Matter Expert	10	4	1	40
19	Current Transformer	blades, polarity,	shortening blades, incorrect readings of current, saturation, CT failure	potential fire hazard, relay misoperation, potential damage to equipment	6	incorrect enegineering design, incorrect selection of equipment (wrong class/accuracy)	3	relay protection scheme, redundacy, equipment inspection, testing	2	36	additional redundant protection	Relay Subject Matter Expert	6	2	2	24

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Transmission Line FMEA

Failure Modes and Effects Analysis

Process Name:	Transmission Line Fire Mitigation	Prepared by: Jacob Alberti & David Thomas	FMEA Date (Orig) _____ (Rev) _____

Process Step	Input X (KPIV)	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended	Resp.	Actions Taken	SEV	OCC	DET	RPN
What is the process step under investigation?	What is the Input Variable under consideration?	In what way(s) does the X go wrong?	What is the impact on the KPOVs (Customer Requirements) or internal requirements?	How Bad?	What causes the X to go wrong?	How Often?	What are the existing controls and procedures (inspection and test) that prevent the cause or the Failure Mode? **Should include an SOP number.**	Detect / Prevent		What are the actions for reducing the occurrence of the Cause, or improving detection?	Who's Responsible for the recommended action?	What are the completed actions taken with the recalculated RPN?				
overhead line	splices, conductor, poles	overheating, phase to ground faults, phase to phase faults, ice/wind loading	pole fire, loss of power to system,	10	vegetation, improper splicing, environmental considerations, wood poles, pole degradation, lightning	7	relay protection schemes, maitenance, steel/concrete poles, vegetation management, lightning protection, engineering design	4	280	infrared & thermo, high definition cameras, rovers, drones, underground lines, additional vegetation management, covered conductors, beam detectors	Field Operations & Vegetation Subject Matter Expert		10	7	2	140
underground line	insulation, cable, splices	open circuit faults, short circuit faults, earth faults	loss of power system, high cost of repair	3	moisture, deteriotation of material, damage during cable pull, improper splicing, wrong cable selection, manufacturer defects	7	insulation testing, engineering design	9	189	isolated duct bank, separation of cables, additional insulation, doble test, thermal cable monitoring	Subject Matter Expert		3	5	7	105

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