Part description	*Failure modes*	*Severity*	*Results / Effects of failure*	*Cause of Failure mode*	*Occ*	*Controls*	*Det*	*RPN*
PV panel	Soiling or shading of panel	9	Reduction in energy output	Improper site selection/Installation	5	Proper site selection / Removal of Vegetation & obstructions	3	135
				Accumulation of dust & soil	5	Regular maintenance	2	90
	Improper Tilt angle	7	Reduction in energy output	Non availability of geographical location data	3	Use weather data (Solar insolation level)	2	42
	Improper orientation	7	Reduction in energy output	Non availability of geographical location data	3	Use weather data (Solar insolation level)	2	42
	Fading in the heat	9	Reduced open circuit voltage	Weak PV modules	2	Selective shading test	2	36
				Charge Controller failure	2	Charge Controller Field test	2	36
	Bypass diode short out	8	Reduced open circuit voltage	Lightning / Surge	2	Lightning / Surge protection	2	32
				Improper material selection	1	Material Selection	5	40
	Bypass diode reverse connection	10	Damaged PV panel	Frequent connection and disconnection of the batteries	2	User Instruction	3	60
				Lack of operating /maintenance manual	2	operating/maintenance manual	4	80
	Corroded or burnt terminals	9	Electric arc Shock/injury Hazard Fire	Material failure	1	Material Selection	5	45
				Loose connections	4	Good installation practice/User training	3	108
				Corrosion	4	Regular maintenance	4	144
	Loose or broken connections	9	Electric arc Shock/ injury Hazard Fire	Excessive torque or pressure	4	Good installation practice / user instruction	4	144
	Broken panel glass front	10	Electric shock/injury hazard Fire	Improper site selection	1	Proper site selection	2	20
				Improper handling	3	Packaging / Handling	2	60
				Hooliganism	1	No Control	n/a	-
	Defect in Panel mountings	8	Mechanical Breakage / Damage of panel Injury Hazards	Material failure	1	Material Selection	5	40
				Improper installation	3	Installation by technician	4	96
				Corrosion	4	Regular maintenance	4	144
Batteries	Swollen or cracked case	9	Injury Hazard	Overcharging	1	Visual Inspection	2	18
	Sulphation	8	Performance deterioration	Idle operation/ undercharging	3	Charge controller field test	3	72
	Dirt/corroded connectors	9	Discharge of battery	Irregular cleaning of the battery	4	Regular maintenance / User instruction	4	144
				Corrosion	4	Regular maintenance/User instruction	4	144
	Not electrically connected	9	Open circuit	Loose / Broken connector	2	Packaging / Handling	5	90
				Material failure	1	Material Selection	3	27
	Reverse connections are made	10	Damage to battery Damage to connection	Inadequate polarization or indexing	1	Manufacturing Inspection	4	40
	Intermittent failure & reduced battery capacity	9	Low energy output	Ageing	4	No control	n/a	-
				End of lifespan	5	No control	n/a	-
	Low battery voltage	9	Low voltage	Faulty controller	3	Charge Controller Field test	2	54
				Ageing	4	No control	n/a	-
				End of lifespan	5	No control	n/a	-
	Completely discharge	10	No output	End of lifespan	5	No control	n/a	-
Charge controller / Inverter	Failure of control IC	9	Improper charging & discharging of the battery Damage to battery	Inferior design	3	Manufacturing Inspection/Design	2	54
				Use of low quality components	1	Material Selection	3	27
	Short circuiting	10	Tripped protective gear	Improper connection	1	operating/maintenance manual	3	30

			Shock/injury Hazard Fire	Fault in electrical wiring	2	Continuity testing	5	100
	Not electrically connected	9	Open circuit	Loose / Broken connector	2	Packaging / Handling	5	90
				Material failure	1	Material Selection	3	27
	Overloading	8	Overheating Damage to the module	Improper selection of PV system	1	Electrical load calculations & study	5	40
				Electrical Fault	3	Using Protective gears	3	72
	Low voltage output	8	Low voltage	Overloading	2	Electrical load calculations & study	5	80
				Busting of fuse	2	Visual inspection	2	32
				Abused Battery	1	Material Selection	3	24
				Failure of PV system	1	PV system field test	3	24
	Overheating	8	Damage to PCB Fire Injury Hazard	Failure of heatsink	1	Material Selection / Manufacturing inspection	3	24
	Corroded or burnt terminals	9	Electric arc Shock/injury Hazard Fire	Material failure	1	Material Selection	5	45
				Loose connections	4	Good installation practice/User training	3	108
				Corrosion	4	Regular maintenance	4	144
Wires	Overloading	8	Overheating Fire	Insufficient conductor ampicity	3	User Instruction	3	72
				Fault in the electrical system	3	Using Protective gears	3	72
	Insulation Failure	10	Short circuit – no power output, tripped protective gear Shock/ injury Hazard Fire	Pinched wire	2	Check for current leakage	3	60
				Mechanical damage	1	Packaging / Handling	5	50
	Conductor failure	8	Open circuit – no output power	Repeated flexing of wire	2	Continuity testing	4	64

The RPN is an optional step that can be used to help prioritize failure modes for action. In general, the failure modes that have the greatest RPN receive priority for corrective action. The RPN should not firmly dictate priority as some failure modes may warrant immediate action although their RPN may not rank among the highest. For using The RPN methodology The range of RPN values is divided into classes: For example

- From 1 to 50: No action necessary
- From 51 to 99: Corrective action is advisable
- For more than 99 : Immediate corrective action

This classification varies from system to system.

4. Conclusions

A FMEA analysis is a good help in finding better solution for a trouble free operation of the Rooftop PV systems. Using this systematic approach gives better understanding of system failures, their effects and remediation methods. Finding and preventing hidden failures is a very important task. Using the right solutions during manufacturing, packaging, installing and to end applications can reduce the risk of serious damage & failure of the system.

The analysis results as checklists and information on critical points at various levels. The FMEA report can be used to improve the system's reliability. Further research could apply this methodology to other PV systems, more components in any topology (e.g., MPPT, etc.), design of fault tolerance, and actual field failure rates. Even though FMEA models use a fixed failure rate, which might not be accurate since failure rates generally vary with time and area of installation, the proposed methodology serves the purpose of a comprehensive, straightforward, and versatile procedure for smooth operation of a Rooftop PV system.

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