Solar Power Charging Station
EMGT 5231.3- Engineering Management Planning

Team 2
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1 Product Planning

1.1 **Mission statement**

For this project our goal is to develop a solar power charging station by applying the product development planning process to the product in every aspect.

Solar power charging stations which the team is planning to build an enhancing innovation. Basically, it's a combination of hardware and software which almost look like these days' normal gas station. However, it holds a high significance in terms of what it has to offer to the customers who owns the electric vehicles.

2 Concept Development

2.1 Customer Needs

By conducting surveys and holding interviews the solar power charging stations team gathered a requirements information from the customers. The below 33 needs statements for the solar power charging stations are grouped and organized into a hierarchy, and the team followed up with the customers to survey the importance of the requirements.

No	**Customer needs Hierarchy and Benefits**	**Importance level**
1	SPCS has reliability	5
2	It provides more sustainable transportation with electric vehicles.	5
3	It reduces greenhouse gas emissions and provides better urban air quality.	5
4	SPCS has no mechanical noise.	4
5	Spcs produce electricity for the grid and provide to an electric charging vehicle.	4
6	SPCS are easy to use	3
7	SPCS conserve foreign energy expenditures	3
8	SPCS has high efficiency.	5
9	SPCS can be installed in many diverse locations.	4

10	An infrastructure of many SPCS allows EV owners to charge their EV more frequently.	3
11	SPCS also provide shade for the charging vehicle.	3
12	SPCS has net metering.	4
13	The roof of SPCS protects the vehicle from rain, ice, and snow.	2
14	SPCS can increase the number of green jobs with needs for installation, maintenance, and operation.	5
15	SPCS could also serve as an educational tool, especially if installed at a school.	4
16	SPCS reduce electricity bills.	4
17	SPCS has low maintenance costs.	5
18	It would encourage more electric vehicles.	4
19	SPCS has programming to approach to charge EV.	5
20	SPCS has algorithm to evaluate performance and develop datasets.	4
21	SPCS has super chargers.	4
22	SPCS has tax credits and incentives.	3
23	SPCS includes a sun-tracking solar array that can charge two vehicles at the same time regardless of weather or time of day.	4
24	SPCS offers connected functionality that offers demands response via software.	3
25	SPCS have committed to 100% renewable networks.	5
26	SPCS expanding access to public charging in rural communities.	4
27	SPCS are free to use outside the major cities and EV-heavy regions.	4
28	SPCS has capacity to derive electricity from burning coal.	5
29	SPCS has clean energy.	4
30	SPCS has integrated installation to transform from DC to AC.	5
31	SPCS has microinverters.	3
32	SPCS save on energy costs	5
33	SPCS has zero carbon footprints.	5

2.2 Product Specifications

2.2.1 List of Metrics

The list of metrics from the customer needs list are in the below table.

Metric No	Need Nos	Metric	Importance level	units
1	2,5	Reliability	5	%
2	2,5	Sustainability	5	%
3	2,3	Non-hazardous.	5	KW
4	2,3	Sound	4	Db
5	3	Automation.	4	Binary
6	3,4	Customer friendly	3	Binary
7	2,3	Sustainability	3	KW
8	2	Efficiency.	5	Min
9	3	Availability	4	F
10	3	Flexibility	3	Binary
11	3	Protection	3	Subjective
12	1	Net metering.	4	KW
13	1,3	Safety	2	Subjective
14	5	Employment	5	%
15	3	Terms and conditions	4	Subjective
16	3,5	Reduce costs	4	US$
17	3	Low maintenance	5	Subjective
18	3	Upgradability.	4	Subjective
19	3	Software development	5	Binary

20	2,4	Performance evaluation	4	%
21	1	Super charger	4	Binary
22	3	Benefits	3	US%
23	4	Solar tracking	4	Binary
24	1	Voice assistant	3	Binary
25	3	Renewable energy	5	%
26	1,3	Diversity	4	Binary
27	5	Versatile	4	Binary
28	3,5	Capacity	5	Subjective
29	3,5	Quality	4	Binary
30	2,4	Transmitting output	5	KW
31	3	Microinverters.	3	Binary
32	3	Low energy cost	5	US$
33	1,3	Zero carbon	5	%

2.2.2 The Needs-Metrics Matrix

The needs-metrics matrix shows the relationship between the solar power charging stations needs and metrics.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Need Metric	SPCS has reliability	It provides more sustainable transportation with electric vehicles.	It reduces greenhouse gas emissions, and provides better urban air quality.	SPCS has no mechanical noise.	Spcs produce electricity for the grid and provide to an electric charging vehicles.	SPCS are easy to use	SPCS conserve foreign energy expenditures	SPCS has high efficiency.	SPCS can be installed in many diverse locations.	An infrastructure of many SPCS allows EV owners to charge their EV more frequen	SPCS also provide shade for the charging vehicle.	SPCS has net metering.	The roof of SPCS protects the vehicle from rain, ice, and snow.	SPCS can increase the number of green jobs with needs for installation, maintenar	SPCS could also serve as an educational tool, especially if installed at a school..	SPCS reduce electricity bills.	SPCS has low maintenance costs.	It would encourage more electric vehicles.	SPCS has programming to approach to charge EV.	SPCS has algorithm to evaluate performance and develop data sets.	SPCS has super chargers.	SPCS has tax credits and incentives.	SPCS includes a sun-tracking solar array that can charge two vehicles at the same	SPCS offers connected functionality that offers demands response via software.	SPCS have committed to 100% renewable networks.	SPCS expanding access to public charging in rural communities.	SPCS are free to use outside the major cities and EV-heavy regions.	SPCS has capacity to device electricity from burning coal.	SPCS has clean energy.	SPCS has integrated installation to transform from DC to AC.	SPCS has microinverters.	SPCS save on energy costs	SPCS has zero carbon footprints.
Reliability	x																																
Sustainability		x																															
Non-hazardous.			x																														x
Silent				x																													
Automation.					x																												
Customer friendly						x																			x								
Sustainability							x																										
Efficiency.								x																									
Availability									x																								
Flexibility										x															x								
Protection											x																						
Net metering.												x																					x
Safety													x																				
Employment														x																			
Terms and conditions															x																		
Reduce costs																x																x	
Low maintenance																	x																
Upgradability.									x									x															
Software development																			x														
Performance evaluation																				x													
Super charger																					x												
Benefits																						x											
Solar tracking																							x										
Voice assistant																								x									
Renewable energy																									x								
Diversity									x																	x							
Versatile																											x						
Capacity																												x					
Quality																													x				
Transmitting output																														x			
Microinverters.																															x		
Low energy cost																																x	
Zero carbon																																	x

2.2.3 Competitive Benchmarking Chart

The following chart is based on perceived satisfaction of needs. The chart compares competitor data from SunPower, Tesla, Sunpro, Momentum, Sunrun.

Rating Scores	
Worst	*
Good	**
Better	***
Best	****
Excellent	*****

SNO	Customer needs hierarchy & Benefits	Importance level	SUNPOWER	TESLA	SUNPRO	MOMENTUM	SU
1 1.	SPCS has reliability	5	*****	***	**	*****	
2	It provides more sustainable transportation with electric vehicles.	5	****	*****	***	***	
3	It reduces greenhouse gas emissions and provides better urban air quality.	5	*****	*****	***	****	
4	SPCS has no mechanical noise.	4	***	**	****	*****	
5	Spcs produce electricity for the grid and provide to an electric charging vehicle.	4	****	*****	***	***	
6	SPCS are easy to use	3	***	****	**	*****	

7	SPCS conserve foreign energy expenditures	3	**	****	***	*	
8	SPCS has high efficiency.	5	***	*****	**	**	
9	SPCS can be installed in many diverse locations.	4	***	****	**	***	
10	An infrastructure of many SPCS allows EV owners to charge their EV more frequently.	3	**	*	***	**	
11	SPCS also provide shade for the charging vehicle.	3	***	***	****	*****	
12	SPCS has net metering.	4	**	*****	****	**	
13	The roof of SPCS protects the vehicle from rain, ice, and snow.	2	****	***	***	**	
14	SPCS can increase the number of green jobs with needs for installation, maintenance, and operation.	5	****	***	*****	*	
15	SPCS could also serve as an educational tool, especially if installed at a school..	4	***	*****	**	**	

16	SPCS reduce electricity bills.	4	**	***	*	*	
17	SPCS has low maintenance costs.	5	***	**	**	***	
18	It would encourage more electric vehicles.	4	**	***	**	***	
19	SPCS has programming to approach to charge EV.	5	***	***	**	*	
20	SPCS has algorithm to evaluate performance and develop datasets.	4	*	**	**	***	
21	SPCS has super chargers.	4	*	**	***	****	
22	SPCS has tax credits and incentives.	3	**	***	**	*****	
23	SPCS includes a sun-tracking solar array that can charge two vehicles at the same time regardless of weather or time of day.	4	*	**	*	****	
24	SPCS offers connected functionality that offers demands response via software.	3	***	*****	****	**	

25	SPCS have committed to 100% renewable networks.	5	**	****	**	**	
26	SPCS expanding access to public charging in rural communities.	4	***	*****	***	**	
27	SPCS are free to use outside the major cities and EV-heavy regions.	4	**	***	*	****	
28	SPCS has capacity to derive electricity from burning coal.	5	*****	**	****	*	
29	SPCS has clean energy.	4	**	*	**	***	
30	SPCS has integrated installation to transform from DC to AC.	5	**	***	****	**	
31	SPCS has microinverters.	3	**	*	***	*****	
32	SPCS save on energy costs	5	****	***	****	**	
33	SPCS has zero carbon footprints.	5	**	**	**	***	

2.2.4 Target Specifications

The target specifications table is provided with marginal and ideal values for the solar power charging stations.

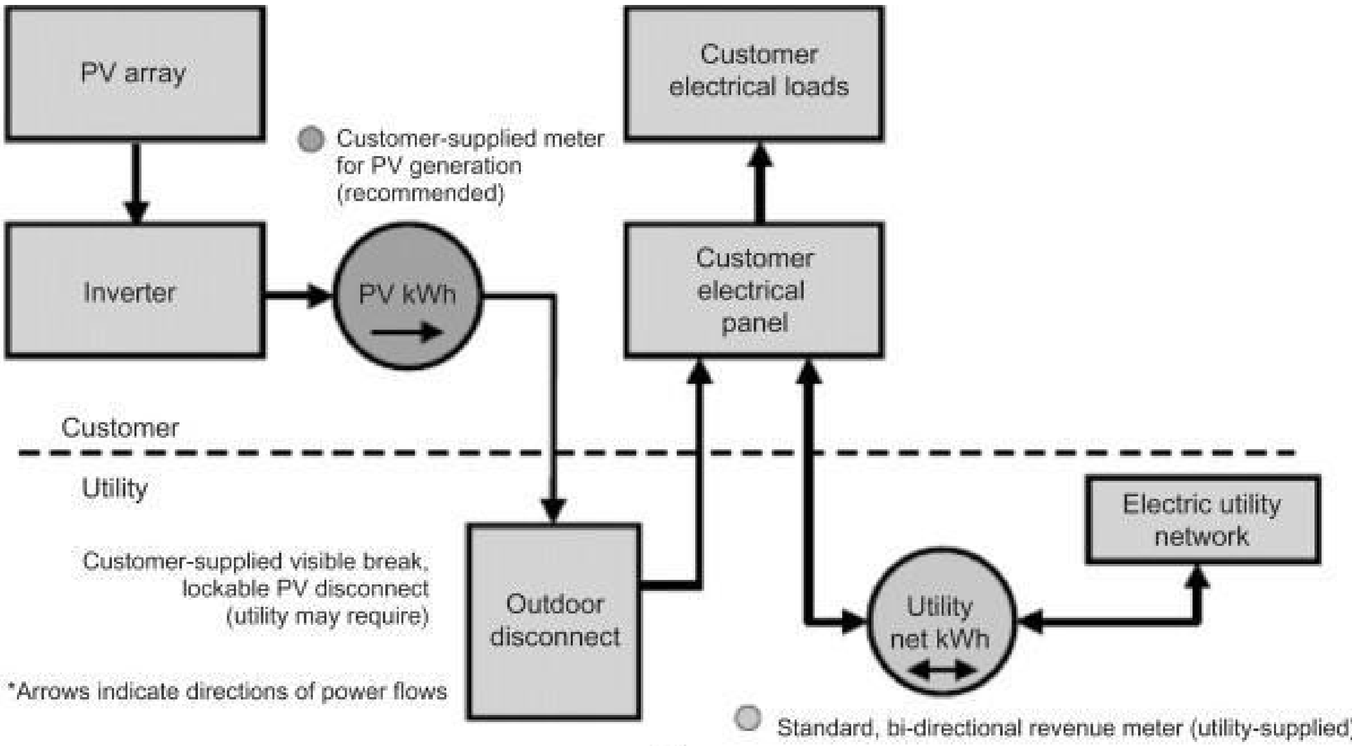
	NEEDS	IMP	units	Marginal Value	Ideal Values
1	Is reliable	5	%	>3	>4.5
2	It provides more sustainability.	5	%	<20%	<30%
3	Is non-hazardous	5	KW	>3	>4.5
4	Is silent	4	Db	pass	pass
5	It is automation	4	Binary	>3	>4.5
6	Is customer friendly	3	Binary	pass	pass
7	It has sustainability	3	KW	pass	pass
8	It has high efficiency.	5	Min	<30%	<35%
9	can be installed in many diverse locations.	4	F	pass	pass
10	Can allows EV owners to charge their EV more frequently.	3	Binary	<75%	100%
11	It also provides shade for the charging vehicle.	3	Subject	pass	pass
12	It has net metering.	4	KW	pass	pass
13	Can be protected from natural disasters.	2	Subject	>3	>4.5

14	Can increase the number of green jobs with needs for installation, maintenance, and operation.	5	%	<20%	<28%
15	Could also serve as an educational tool, especially if installed at a school	4	Subject	pass	pass
16	Can reduce electricity bills.	4	US$	pass	pass
17	It has low maintenance costs.	5	US$	>3	>4.5
18	It would encourage more electric vehicles.	4	Subject	>3	>4.5
19	It has programming to approach to charge EV.	5	Binary	pass	pass
20	Can evaluate performance and develop datasets.	4	%	pass	pass
21	It has super chargers.	4	Binary	pass	pass
22	It has benefits.	3	US$	pass	pass
23	It has solar tracking	4	Binary	pass	pass
24	Offers voice assistant	3	Binary	pass	pass
25	Have renewable energy	5	%	>3	>4.5
26	Move to diversified locations.	4	Binary	pass	pass

27	Is versatile	4	Binary	pass	pass
28	Can derive electricity	5	Subject	pass	pass
29	It has clean energy.	4	Binary	pass	pass
30	It has integrated installation to transform from DC to AC.	5	KW	>3	>4.5
31	It has microinverters.	3	Binary	>3	>4.5
32	It saves on energy costs	5	US$	>3	>4.5
33	It has zero carbon footprints.	5	%	>3	>4.5

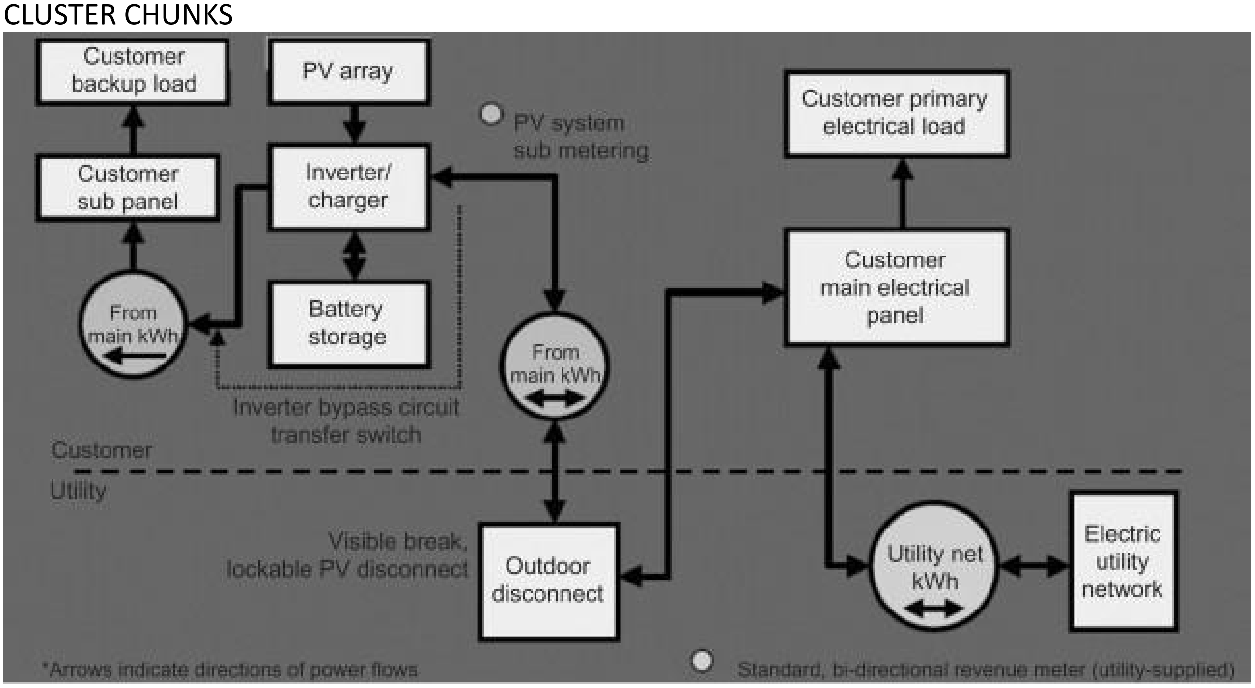
Cluster of the functional element

1. Without Battery Storage

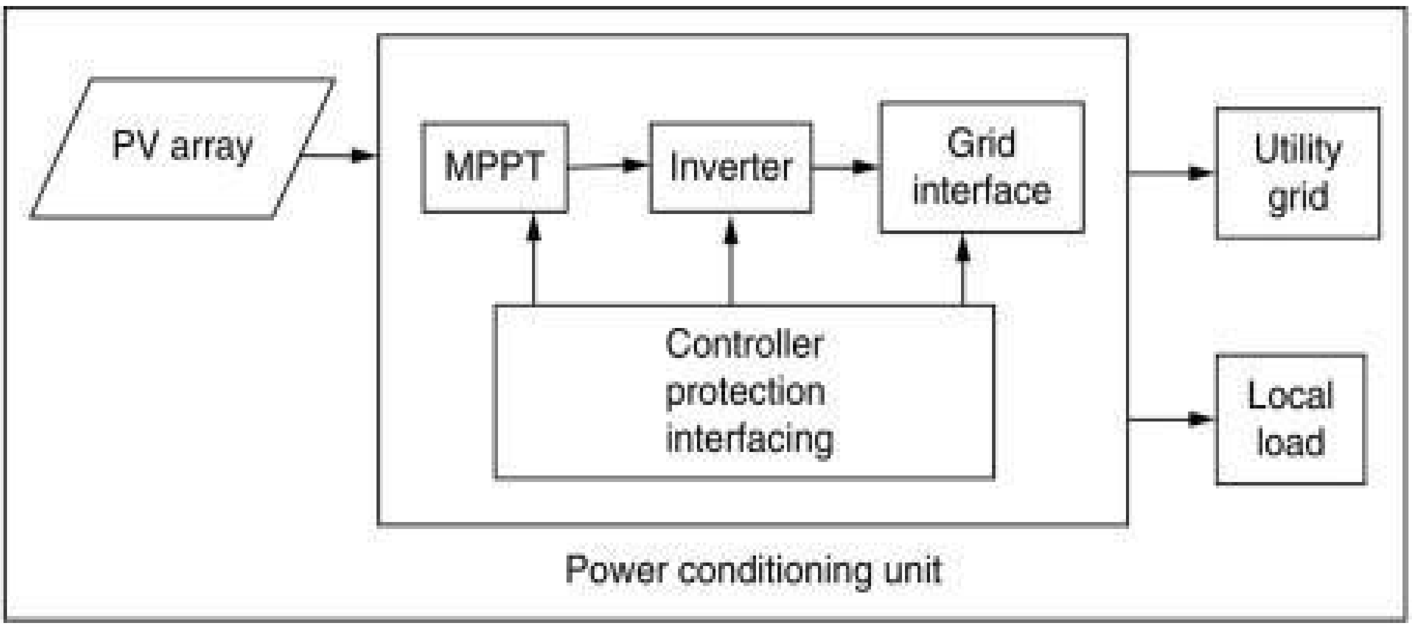


(a)

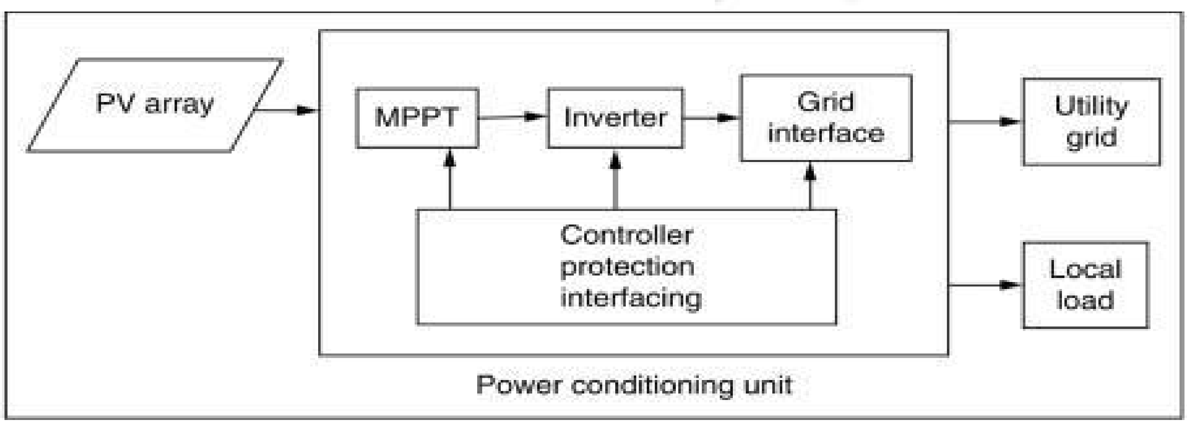
CLUSTER CHUNKS



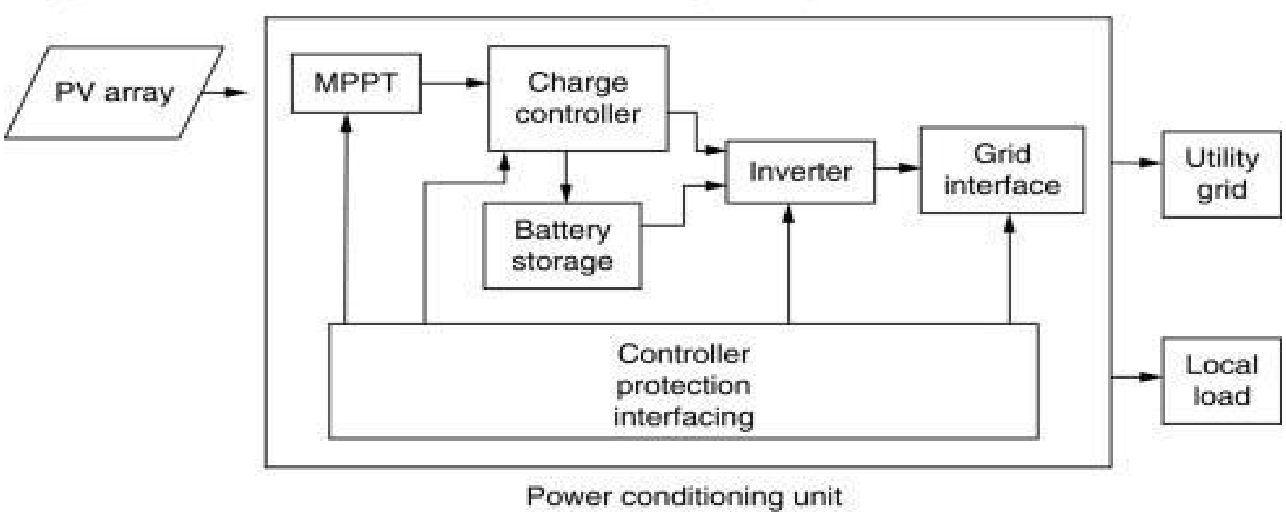
Interaction Graph.



(a) Without battery back-up



(a) Without battery back-up



Cost Estimate

Components	Purchased materials	Machine and labour charges	Assembly labor	Total variable cost	Tooling a other NR
Case	1.19	0.5	0.51	2.69	50
Housing	0.22	0.2		0.24	
Spring and stop	0.32	0.3		1.57	50
Thumb lock	0.49	0.2	0.6	0.29	30
Blade/Tape	2.25	0.6	0.39	1.99	
Hook	0.24	0.15		0.78	25
Rivets	0.25	0.16		0.79	27
Belt Clip	0.61	0.3		1.91	
Total cost direct	5.57	2.41	1.5	10.26	182
Overhead charges	1.28	2.79	2.21		
Total cost					

DFA concepts applied

Components	Purchased materials	Machine and labour charges	Assembly labor	Total variable cost	Tooling and other NRE	Tooling lifetime, K units	Total fixed cost	Final cost
Case	1.09	0.5	0.49	2.69	50	400	0.2	2.71
Housing	0.22	0.2		0.24			0.4	0.28
Spring and stop	0.32	0.3		1.57	50	400	0.24	1.72
Thumb lock	0.49	0.2	0.6	0.29	30	200	0.19	0.48
Blade/Tape	2.25	0.6	0.3	1.99				1.99
Hook	0.24	0.15		0.78	25	200	0.12	0.88
Rivets	0.25	0.16		0.79	27	200	0.12	0.89
Belt Clip	0.61	0.3		1.91				1.91
Total cost direct	5.47	2.41	1.39	10.26	182	1400	1.27	10.86
Overhead charges	1.28	2.79	2.21				0.19	6.47
Total cost								17.33

Case: Nest shape to reduce wasted material
Housing: Molded material is procured in larger quantities to be utilized in other components
Rivets: Purchase a cheaper metallic rivet from another country
Assembly (case): Utilize self latching case to reduce assembly time

Assembly (Blade): Black box method used to have precut and toleranced tape ready.

DFM application

- DFA index before applying DFA concepts
- =(6*5)/450=0.067
- DFA index after applying DFA concepts
- =(6*5)/380=0.0789
- DFA gains=0.011

ROBUST DESIGN

Issues

- Software crashing
- Hardware constructability
- Time it takes to identify setpoints

Solutions

- Run design experiments (low cost)
- Create several prototypes by conditions
- Identify all controlled variable such as materials, tolerances etc.

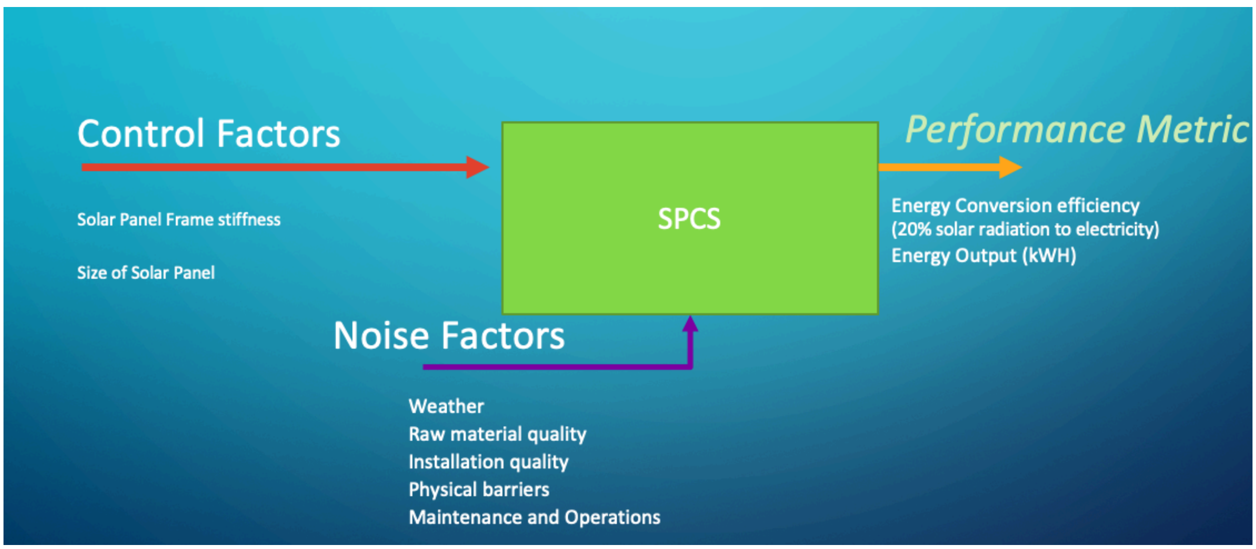
EXPERIMENTAL FACTORS

- Control Factor
  - Solar Panel Frame stiffness
  - Size of Solar Panel
- Noise Factor

- o Weather
- o Raw material quality
- o Installation quality
- o Physical barriers
- o Maintenance and Operations

- Performance Metrics
  - o Energy Conversion efficiency
  - o Energy Output

PARAMETER DIAGRAM



TESTING OBJECTIVE FUNCTION

- Objective Function- Our selected objective function is the Target Value base on performance of Energy conversion and output.
- Experimental Plan- We utilized Full factorial experimental design with N- an N+ noise factor levels with 5 levels of factors to analyze giving us 25 trials/combinations

- Target Value
- N-noise factors
- 2 factors 5 Levels
- N^k=trials

Factors	Param A	ParamB
Run 1	A1	B1
Run 2	A1	B2
Run 3	A1	B3
Run 4	A1	B4
Run 5	A1	B5
Run 6	A2	B1
Run 7	A2	B2
Run 8	A2	B3
Run 9	A2	B4
Run 10	A2	B5
Run 11	A3	B1
Run 12	A3	B2
Run 13	A3	B3
Run 14	A3	B4
Run 15	A3	B5
Run 16	A4	B1
Run 17	A4	B2
Run 18	A4	B3
Run 19	A4	B4
Run 20	A4	B5
Run 21	A5	B1
Run 22	A5	B2
Run 23	A5	B3
Run 24	A5	B4
Run 25	A5	B5

QUANTITATIVE ANALYSIS

Quantitative model	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Sold units		25000	25000	25000	25000
Production ramp up	$100,000.00				
Marketing and support	$42,000.00	$42,000.00	$42,000.00	$42,000.00	$42,000.00
Production cost		$2,500,000.00	$2,500,000.00	$2,500,000.00	$2,500,000.00
Total cost by year		$2,542,000.00	$2,542,000.00	$2,542,000.00	$2,542,000.00
Profit by year		$2,858,000.00	$2,958,000.00	$2,958,000.00	$2,958,000.00
NPV at 5 years	**$10,155,442.78**				

SENSITIVITY ANALYSIS

Factor	Trade off rule	Comments
Product development cost at 10% increase	$9,433.96	For a 10% increase in investing in PD we lose about 1000 dollars over 5 years
Product development time 1 more year	$2,248,673.78	One more year of design will decrease profits by given

Equipment and tooling cost	not applicable	We do not consider tools in this scenerio
Production cost,machines +20%	$1,732,552.81	an increase to production cost will lead to a loss of given per 20%
Retail price, machines (wholesale +20%)	$2,031,088.56	An increase in wholesale price will gain us the given value
Sales volume, machines (+2000)	$831,625.35	If we sold another 2000 units we can gain the given value

CPM Schedule

	YEAR 1				YEAR 2				YEAR 3				YEAR 4				YEAR 5			
Values in $	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Quantitative model																				
Sold Units (wholesale)					6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250
Sold units stations					50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Total revenue					1,260,000	1,260,000	1,260,000	1,260,000	1,260,000	1,260,000	1,260,000	1,260,000	1,260,000	1,260,000	1,260,000	1,260,000	1,260,000	1,260,000	1,260,000	1,260,000
Product development	25,000	25,000	25,000	25,000																
Production ramp up			25,000	25,000																
Marketing and Support			21,000	21,000	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500
Production, units				6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250	6250
Production, Stations				50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Total cost	$25,000	$25,000	$71,000	$746,000	$685,500	$685,500	$685,500	$685,500	$685,500	$685,500	$685,500	$685,500	$685,500	$685,500	$685,500	$685,500	$685,500	$685,500	$685,500	685,500
Period Cash flow	-$2,500	-$2,500	-$71,000	-$746,000																