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A case Study on DSP-210D mono crystalline Solar array With Failure Vs Reliability Analysis by comparative approach

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Abstract— **This paper describes the optimized & un-optimized output for DSP210D mono-crystalline array by using PSO, P&O and GA technique with the help of practical hardware & simulation approach of MATLAB-07, aiming the development of various modern power semiconductor devices for SPV system. Under this aim we cover the Computation of output/solar power for different months of year 2015, failure rate and Reliability analysis of this SPV system for different no of panels also this is compared with different types of solar panels for different no of panels. The initiative step is done by using the data sheet of manufacturer for the comparative study under elementary platform especially for DSP 210D and ZKX-240-24 solar models (Mono Crystalline), BP SX 150 and SPP 280-24 solar models (Poly Crystalline) & other many more PV arrays.**

Keywords— Soalr Photovoltaic (SPV), Photovoltaic (PV); maximum power point tracking (MPPT), DSP210D, ZKX-240-24 solar models (Mono Crystalline), BP SX 150 and SPP 280-24 Array.

I. Introduction

As we know that the different solar panels available in the market are very less efficient and less reliable. Hence various possibilities of failures are often occurring to defect the reliability. Taking this concept under consideration we aim over the selection of SPV array/system under the various criteria of atmospheric conditions &locality by the specification analysis, comparative study, data sheets, simulation results & many more processes. For this purpose exported and the imported energies are metered, calculated & monitored here with respect to failure, reliability, stability & other factors to improve the SPV system so as to develop various modern power semiconductor devices for SPV system.

Different methodologies are adopted for the development of modern power semiconductor devices for SPV system but this is a new concept of this area to achieve the following goals by the developed array:

- To extract maximum power output from PV arrays
- To achieve better reliability & less failure possibilities
- To select the proper SPV array as per requirement

In this paper the DSP-210D mono crystalline solar cell model is introduced and the problem of model parameter determination based on the five parameter model is addressed. So for diagnostic purposes it is followed by simplified formulas& simulation based analysis in five-steps.

Step 1: Solar PV Model
step 2: calculation of Solar power & other important parameters
step 3: Failure rate
step 4: Reliability

II. Solar PV Model

The standard five parameter model of SPV module is shown in Figure.1.

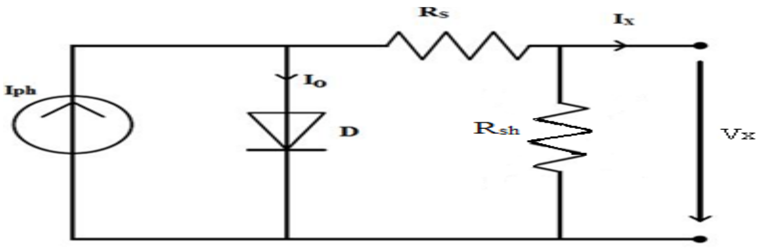

Figure.1: Electrical Equivalent Circuit model of single diode SPV module

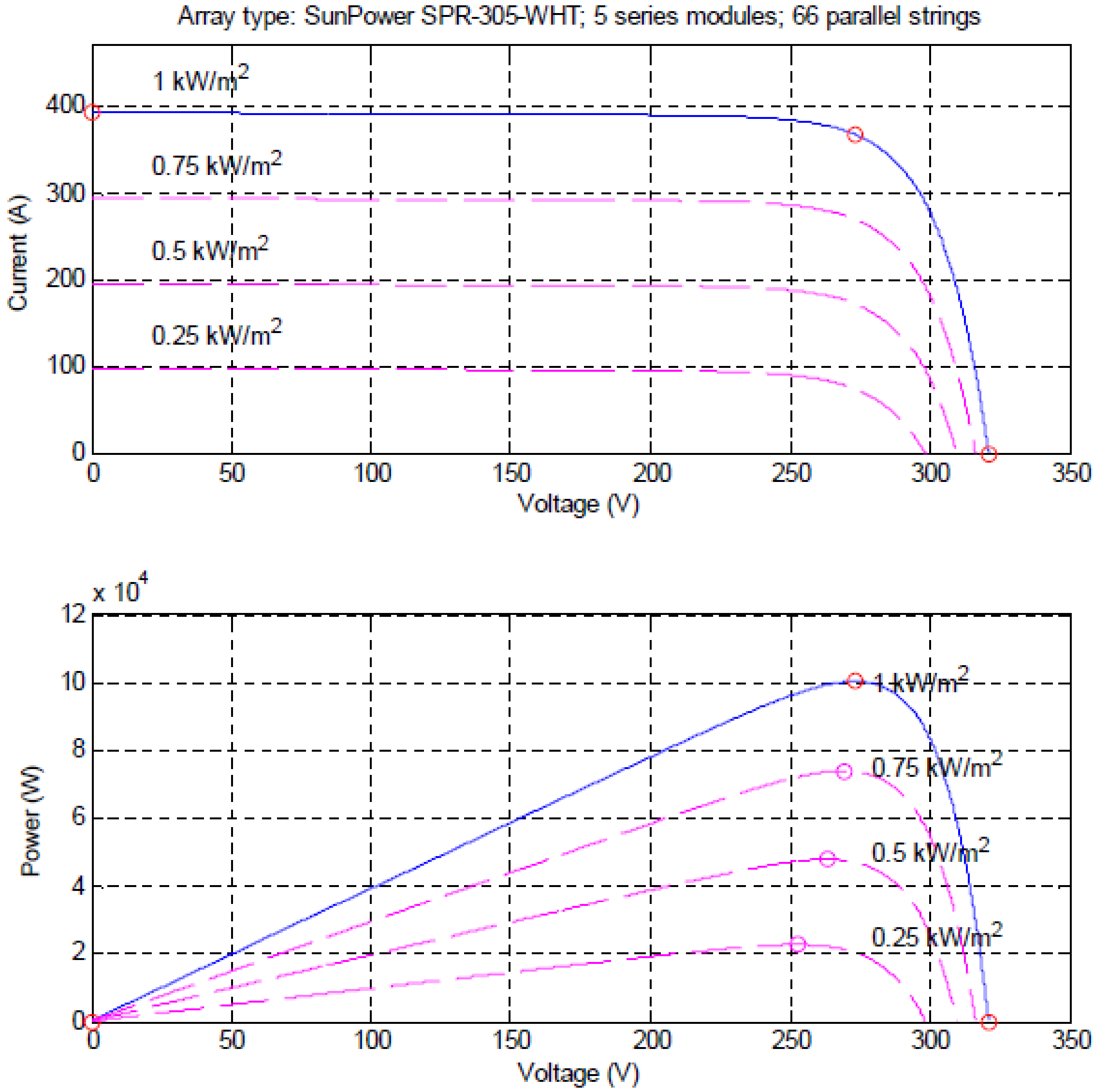

Figure.2: I-V & P-V Charectestics of PV arrayElectrical

III. CALCULATION OF SOLAR POWER& OTHER PARAMETERS

The sample calculation of solar power is done on the roof top for the month daily inspection in the month of January at 11 am in regular basis. For this purpose important ratings and parameters are taken from datasheet of DSP210D along with this the other required parameters are calculated with the help of this datasheet.

:::Table 1: Data Sheet for DSP210D provided by company:::

:ELECTRICAL DATA AT STC:	
Maximum Power (Pmax)	210 Wp
Voltage at Maximum Power (Vmpp)	28.3 V

Current at Maximum Power (Impp)	7.42 A
Open Circuit Voltage (Voc)	37.9 V
Short Circuit Current (Isc)	7.53 A
Panel Efficiency	0.129
Power Tolerance(Positive)	0.03
Power Tolerance(Negative)	-0.03
Standard Test Conditions (STC)	air mass AM 1.5, irradiance 1000W/m2, cell temperature 25°C
:ELECTRICAL DATA AT NOCT:	
Temperature	45±2 °C
Nominal Operating Cell Temperature (NOCT)	800W/m2, AM 1.5, wind speed 1m/s ,ambient temperature 20°C
:THERMAL RATINGS:	
Operating Temperature Range	-45~80 °C
Temperature Coefficient of Pmax	-0.5 %/°C
Temperature Coefficient of Voc	k_v=–(160±10)mV/˚C
Temperature Coefficient of Isc	k_i=(0.065±0.015) %/°C
Variable temperature T_X	28.6˚C
Variable radiation S_X	750 W/m^2
Solar radiation S_C	1000 W/m^2 (At STC)
Temperature T_C	25˚C=25+273K=298K (At STC)
:MAXIMUM RATINGS:	
Maximum System Voltage	1000 V
:MATERIAL DATA:	
Panel Dimension (HxWxD)	1640x992x50 mm
Weight	23 kg
Cell Type	Monocrystalline
Cell Size	156×156 mm
Cell Number	60 Nos
Glass Type	High Transmittance
Glass Thickness	4 mm
Encapsulant Type	EVA
Back Cover Type	TPT
Frame Type	Aluminium Alloy
Junction Box Diodes	3 Nos
Connector Type	MC4
Cable Length	900 mm
:COMPANY DETAILS:	
Company Name	Jinhua Dokio Technology Co., Ltd.
Company Address	NO. 500, Shenli Road, Qiu Bin Industry Zone, Jinhua, Zhejiang
Country	China

::Table 2: Formulas for Calculation of Important Parameters::

α_T=Normalized current Temperature coefficient	β_T=Normalized voltage Temperature coefficient	
$\alpha_T = \frac{k_i}{I_{SC}} = \frac{\text{Temperature coefficient of } I_{SC}\ (A/^\circ C)}{I_{SC}(A)}$	$\beta_T = \frac{k_V}{V_{OC}} = \frac{\text{Temperature coefficient of } V_{OC}\ mV/^\circ C}{V_{OC}\ (V)}$	
Temparture correction factor	$C_{TI} = 1 + \beta_T * \alpha_T * (T_X - T_C)/S_C$(for current)	$C_{TV} = 1 + \beta_T * (T_C - T_X)$ (for Voltage)
Radiation correction factor	$C_{SV} = 1 + \beta_T * \alpha_T * (S_X - S_C)$(for current)	$C_{SI} = 1 + \frac{(S_X - S_C)}{S_C}$(for Voltage)

::Table 3: Calculation of Power::

α_T= 0.0066%/A˚C; β_T=-0.0045/˚C; C_{TV} =1+0.0066*(298-301.6)=0.976; C_{TI} =1+0.0066*-0.0045*(298-301.6)/100 =1.000 C_{SV} =1 + 0.0066 * -0.0045 * (750-1000)=0.992 $C_{SI} = 1 + \frac{(750-1000)}{1000} =$ 0.750		
$V_{CX} = V_{OC} * C_{TV} * C_{SV}$=37.9*0.976*0.992= 36.69 V	$V_X = V_{CX} - I_X * R_s$= 36.69 – 5.647 * 0.5033=33.847 V	$P_X = I_X * V_X$=5.647*33.847= 191.134 Watts
R_S=Series resistance of panel= $0.1*\frac{V_{oc}}{I_{sc}}=0.1*\frac{37.9}{7.53}=$ 0.5033 Ω	I_x= $Isc*C_{TI}*C_{SI}$=7.53*1.0000*0.750=5.647 A	

::Important Annotations::

H = HOURS OF THE DAY
T_X= TEMPARATURE in Kelvin
S_X=Radiation in W/m^2
C_{TI} = Temp correction factor for current
C_{SI}=Radiation correction factor for current
I_X=Panel output current =I_{SC}* C_{TI}* C_{SI} in Amp
C_{VT}=Temp correction factor for voltage
C_{SV}=Radiation correction factor for voltage
V_{CX}=Applying Correction factor, The Panel O/P voltage $V_{CX} = V_{OC} * C_{SV} * C_{TV}$ in Volt
V_X=Actual Panel output voltage $V_X = V_{CX} - I_X R_S$ in volts
P_X= Output Power of one Solar panel in watts ($P_X = I_X * V_X$)

::Table 4: Parameters observed for DSP 210D mono crystalline SPV system for different months of the year 2015::

Monts	H	T_X	S_X	C_{TI}	C_{SI}	I_X	C_{TV}	C_{SV}	V_{CX}	V_X	P_X
Jan	10	298.6	620	1	0.62	4.668	0.996	0.988	37.29	34.94	163.09
	11	301.6	750	1	0.75	5.647	0.976	0.992	36.69	33.85	191.15
	12	303.7	820	1	0.82	6.174	0.962	0.995	36.28	33.17	204.79
	13	304.5	810	1	0.81	6.099	0.957	0.994	36.05	32.98	201.14
	14	304.6	740	1	0.74	5.572	0.956	0.992	35.94	33.13	184.6
	15	304.1	610	1	0.61	4.593	0.959	0.988	35.91	33.59	154.28
	16	303.6	420	1	0.42	3.162	0.963	0.983	35.88	34.29	108.42
	Avg	**302.9**	**681.43**	**1**	**0.68**	**5.13**	**0.967**	**0.99**	**36.29**	**33.71**	**172.50**
Feb	10	299.4	680	1	0.68	5.12	0.991	0.99	37.18	34.6	177.15
	11	302.2	820	1	0.82	6.174	0.972	0.995	36.65	33.54	207.07
	12	303.9	900	1	0.9	6.777	0.961	0.997	36.31	32.89	222.89
	13	304.1	900	1	0.9	6.777	0.959	0.997	36.24	32.83	222.49
	14	304.2	830	1	0.83	6.249	0.959	0.995	36.16	33.01	206.28
	15	303.8	680	1	0.68	5.12	0.961	0.99	36.06	33.48	171.42
	16	303.4	480	1	0.48	3.614	0.964	0.984	35.95	34.13	123.35
	Avg	**303**	**755.71**	**1**	**0.755**	**5.69014**	**0.96671**	**0.992**	**36.3642**	**33.49714**	**190.09285**
Mar	10	301.2	690	1	0.69	5.195	0.979	0.99	36.73	34.11	177.2
	11	302.9	850	1	0.85	6.4	0.967	0.995	36.47	33.25	212.8
	12	303.7	940	1	0.94	7.078	0.962	0.998	36.39	32.83	232.37
	13	304	950	1	0.95	7.153	0.96	0.998	36.31	32.71	233.97
	14	304	870	1	0.87	6.551	0.96	0.996	36.24	32.94	215.79
	15	303.9	720	1	0.72	5.421	0.961	0.992	36.13	33.4	181.06
	16	303.6	520	1	0.52	3.915	0.963	0.986	35.99	34.02	133.19
	Avg	**303.3**	**791.42**	**1**	**0.791**	**5.959**	**0.96457**	**0.993**	**36.3228**	**33.32286**	**198.05428**
Aprl	10	303.1	680	1	0.68	5.12	0.966	0.99	36.24	33.66	172.34

	11	304.2	860	1	0.86	6.475	0.959	0.996	36.2	32.94	213.28
	12	304.8	950	1	0.95	7.153	0.955	0.998	36.12	32.52	232.61
	13	304.9	960	1	0.96	7.228	0.954	0.999	36.12	32.48	234.76
	14	305	880	1	0.88	6.626	0.953	0.996	35.97	32.63	216.21
	15	304.8	740	1	0.74	5.572	0.955	0.992	35.9	33.09	184.38
	16	304.4	540	1	0.54	4.066	0.957	0.986	35.76	33.71	137.06
	Avg	**304.4**	**801.42**	**1**	**0.801**	**6.03428**	**0.957**	**0.993**	**36.0442**	**33.00429**	**198.66285**
	10	303.7	650	1	0.65	4.894	0.962	0.989	36.06	33.59	164.39
	11	304.5	810	1	0.81	6.099	0.957	0.994	36.05	32.98	201.14
	12	305.1	900	1	0.9	6.777	0.953	0.997	36.01	32.59	220.86
May	13	305.2	920	1	0.92	6.927	0.952	0.998	36	32.51	225.19
	14	305.3	850	1	0.85	6.4	0.951	0.995	35.86	32.64	208.89
	15	305.1	720	1	0.72	5.421	0.953	0.992	35.83	33.1	179.43
	16	304.8	530	1	0.53	3.99	0.955	0.986	35.69	33.68	134.38
	Avg	**304.8**	**768.57**	**1**	**0.768**	**5.78685**	**0.95471**	**0.993**	**35.9285**	**33.01286**	**190.61142**
	10	301	480	1	0.48	3.614	0.98	0.984	36.55	34.73	125.51
	11	301.5	570	1	0.57	4.292	0.977	0.987	36.55	34.39	147.6
	12	302	640	1	0.64	4.819	0.973	0.989	36.47	34.04	164.04
June	13	302.1	640	1	0.64	4.819	0.973	0.989	36.47	34.04	164.04
	14	302.1	590	1	0.59	4.442	0.973	0.988	36.43	34.19	151.87
	15	302.1	500	1	0.5	3.765	0.973	0.985	36.32	34.42	129.59
	16	301.7	370	1	0.37	2.786	0.975	0.981	35.25	34.85	97.09
	Avg	**301.7**	**541.42**	**1**	**0.541**	**4.07671**	**0.97485**	**0.986**	**36.2914**	**34.38**	**139.96285**
	10	300	420	1	0.42	3.162	0.987	0.983	36.77	35.18	111.24
	11	300.4	500	1	0.5	3.765	0.984	0.985	36.73	34.83	131.13
	12	300.8	540	1	0.54	4.066	0.981	0.986	36.66	34.61	140.72
July	13	300.9	540	1	0.54	4.066	0.98	0.986	36.62	34.57	140.56
	14	300.9	480	1	0.48	3.614	0.98	0.984	36.55	34.73	125.51
	15	300.9	400	1	0.4	3.012	0.98	0.982	36.47	34.95	105.27
	16	300.6	290	1	0.29	2.183	0.983	0.979	36.47	35.37	77.21
	Avg	**300.6**	**452.85**	**1**	**0.452**	**3.40971**	**0.98214**	**0.983**	**36.61**	**34.89143**	**118.80571**
	10	299.7	490	1	0.49	3.689	0.989	0.985	36.92	35.08	129.34
	11	300.2	610	1	0.61	4.593	0.985	0.988	36.88	34.57	158.78
	12	300.7	670	1	0.67	5.045	0.982	0.99	36.85	34.31	173.09
Aug	13	300.8	660	1	0.66	4.969	0.981	0.989	36.77	34.27	170.29
	14	300.8	610	1	0.61	4.593	0.981	0.988	36.73	34.42	158.09
	15	300.8	510	1	0.51	3.84	0.981	0.985	36.62	34.69	133.21
	16	300.6	370	1	0.37	2.786	0.983	0.981	36.55	35.15	97.93
	Avg	**300.5**	**560**	**1**	**0.56**	**4.21642**	**0.98314**	**0.986**	**36.76**	**34.64143**	**145.81857**
	10	300.4	530	1	0.53	3.991	0.984	0.986	36.77	34.76	138.73
Sep	11	301.1	660	1	0.66	4.969	0.979	0.989	36.69	34.19	169.89
	12	301.9	760	1	0.76	5.722	0.974	0.993	36.65	33.77	193.23
	13	302	770	1	0.77	5.798	0.973	0.993	36.62	33.7	195.39

	14	302	710	1	0.71	5.346	0.973	0.991	36.54	33.85	180.96
	15	301.9	590	1	0.59	4.442	0.974	0.988	36.47	34.23	152.05
	16	301.5	420	1	0.42	3.1626	0.977	0.983	36.4	34.81	110.1
	Avg	**301.5**	**634.28**	**1**	**0.634**	**4.7758**	**0.97628**	**0.989**	**36.5914**	**34.18714**	**162.90714**
Oct	10	301.3	590	1	0.59	4.442	0.978	0.988	36.62	34.38	152.72
	11	302.7	710	1	0.71	5.346	0.969	0.991	36.39	33.69	180.11
	12	303.6	800	1	0.8	6.024	0.963	0.994	36.28	33.25	200.29
	13	303.9	820	1	0.82	6.174	0.961	0.995	36.24	33.13	204.54
	14	303.9	750	1	0.75	5.647	0.961	0.992	36.13	33.29	187.99
	15	303.5	620	1	0.62	4.668	0.963	0.989	36.1	33.75	157.54
	16	303	430	1	0.43	3.237	0.967	0.983	36.03	34.4	111.35
	Avg	**303.1**	**674.28**	**1**	**0.674**	**5.07685**	**0.966**	**0.990**	**36.2557**	**33.69857**	**170.64857**
Nov	10	301.1	610	1	0.61	4.593	0.979	0.988	36.66	34.35	157.77
	11	303.2	730	1	0.73	5.496	0.965	0.992	36.28	33.51	184.17
	12	304.6	790	1	0.79	5.948	0.956	0.994	36.01	33.01	196.34
	13	305.2	790	1	0.79	5.948	0.952	0.994	35.86	32.87	195.51
	14	305.4	720	1	0.72	5.421	0.951	0.992	35.75	33.02	179
	15	305	590	1	0.59	4.442	0.954	0.988	35.72	33.48	148.72
	16	304.4	420	1	0.42	3.162	0.958	0.982	35.65	34.06	107.69
	Avg	**304.1**	**664.28**	**1**	**0.664**	**5.00142**	**0.95928**	**0.99**	**35.99**	**33.47142**	**167.02857**
Dec	10	299.4	590	1	0.59	4.442	0.99	0.988	37.07	34.83	154.71
	11	301.7	720	1	0.72	5.421	0.975	0.992	36.66	33.93	183.93
	12	303.4	780	1	0.78	5.873	0.964	0.993	36.28	33.32	195.69
	13	304.4	770	1	0.77	5.798	0.958	0.993	36.05	33.13	192.08
	14	304.9	700	1	0.7	5.271	0.954	0.991	35.83	33.18	174.89
	15	304.6	570	1	0.57	4.292	0.956	0.987	35.76	33.59	144.17
	16	304.2	400	1	0.4	3.012	0.959	0.982	35.69	34.17	102.92
	Avg	**303.2**	**647.14**	**1**	**0.647**	**4.87271**	**0.96514**	**0.989**	**36.1914**	**33.73571**	**164.05571**

IV. ANALYTICAL COMPARISION

a) Failure rate & Reliability for DSP 210D Mono Crystalline Solar Panel

::Failure rate Vs Reliability Formula::

$$\text{Failure Rate} = \lambda = \frac{\text{Total number of failures}}{\text{Total number of samples} * \text{time interval}} \quad \text{and} \quad \text{Reliability} = R = e^{-\lambda t}$$

Total no of samples taken = 12

i) If no of Failures=8 at n=900, then

$$\text{Failure Rate} = \lambda_8 = \frac{\text{Total number of failures}}{\text{Total number of samples} * \text{time interval}} = \frac{8}{12*1} = 0.6667$$

$$\text{Reliability} = R_8 = e^{-\lambda t} = e^{-0.6667*1} = 0.5134$$

ii) If no of Failures=4 at n=1050, then

$$\text{Failure Rate} = \lambda_{1050} = \frac{\text{Total number of failures}}{\text{Total number of samples} * \text{time interval}} = \frac{4}{12*1} = 0.3333$$

$$\text{Reliability} = R_{1050} = e^{-\lambda t} = e^{-0.3333*1} = 0.7165$$

iii) If no of Failures=3 at n=1200, then

$$\text{Failure Rate} = \lambda_{1200} = \frac{\text{Total number of failures}}{\text{Total number of samples} * \text{time interval}} = \frac{3}{12*1} = 0.25$$

$$\text{Reliability} = R_{1200} = e^{-\lambda t} = e^{-0.25*1} = 0.7788$$

iv) If no of Failures=1 at n=1350 and 1500, then

$$\text{Failure Rate} = \lambda_{1350,\,1500} = \frac{\text{Total number of failures}}{\text{Total number of samples} * \text{time interval}} = \frac{1}{12*1} = 0.08333$$

$$\text{Reliability} = R_{1350,\,1500} = e^{-\lambda t} = e^{-0.08333*1} = 0.9200$$

v) If no of Failures=0 at n=1650, then

$$\text{Failure Rate} = \lambda_{1650} = \frac{\text{Total number of failures}}{\text{Total number of samples} * \text{time interval}} = \frac{0}{12*1} = 0$$

$$\text{Reliability} = R_{1650} = e^{-\lambda t} = e^{-0*1} = 1.0000$$

b) *Failure rate and Reliability analysis*

In this section the comparative study of failure rate, number of failure and reliability is done for the whole year 2015.

::Table 5: Comparison of Failure rate, Number of failures & Reliability::

No of Failures	Failure Rate (λ)	Reliability (R)
0	0	1.0000
1	0.0833	0.9200
2	0.1667	0.8464
3	0.2500	0.7788
4	0.3333	0.7165
5	0.4166	0.6593
6	0.5000	0.6065
7	0.5833	0.5580
8	0.6667	0.5134
9	0.7500	0.4723
10	0.8333	0.4346
11	0.9167	0.3998

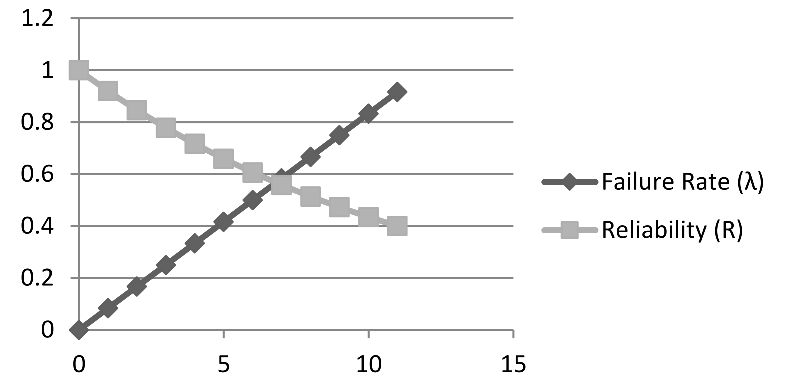

Figure 3: No. of Failures Vs Reliability graph

Reliability analysis of SPV system taken for different no of panels

::Table 6: No. of Panels Vs % Reliability::

S.N.	No. of panels	% Reliability
1	n=900	51.34
2	n=1050	71.65
3	n=1200	77.88
4	n=1350	92
5	n=1500	92
6	n=1650	100

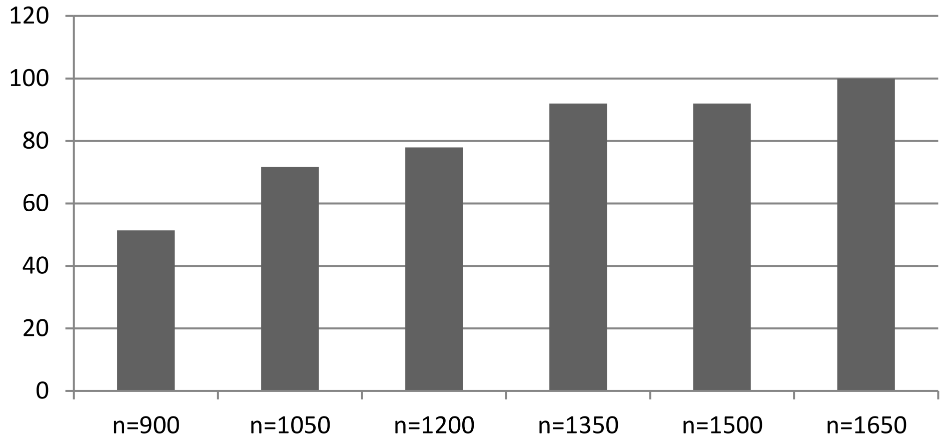

Figure 4: Reliability Comparision of SPV system for different no. of panels

c) Comparative study of Specifications for different PV arrays

Table 7: Manufacturers data sheet of DSP 210D and KS-M 280W solar models (Mono Crystalline)

Electrical Characteristics	**DSP 210D**	**KS-M 280W**	**ZKX-240D-24**
Maximum Power(P_{max})	210W	280W	240W
Voltage at P_{max} (V_{mp})	28.3V	34.9V	48.1V
Current at P_{max} (I_{mp})	7.42A	8.02A	4.93A
Short circuit current(I_{sc})	7.53A	8.82A	5.34A
Open circuit voltage(V_{oc})	37.9V	43.2V	59.4V
Temperature Coefficient of I_{sc}	(0.065±0.015)%/ ˚C	(0.06±0.01)%/ ˚C	0.05%/˚C
Temperature Coefficient of V_{oc}	-(160±10)mV/ ˚C	-(78±10)mV/ ˚C	-0.35%/˚C
Temperature Coefficient of power	-(0.5±0.05) %/ ˚C	-(0.5±0.05) %/ ˚C	-0.45%/˚C
NOCT	45±2˚C	48±2˚C	47±2˚C
Maximum system voltage	1000V	1000V	1000V DC
Size of the panel in mm	1640*992*50	1956*992*50	1580*1060*40

No of Cells in series	60(6*10)	72(6*12)	96(8*12)

Table 8: Manufacturers data sheet of BP SX 150 and SPP 280-24 solar models (Poly Crystalline)

Electrical Characteristics	**BP SX 150S**	**SPP 280-24**	**ZKX-240P-24**
Maximum Power(Pmax)	150W	280W	240W
Voltage at Pmax (Vmp)	34.5V	36.0V	30.5V
Current at Pmax (Imp)	4.35A	7.78A	7.88A
Short circuit current(Isc)	4.75A	8.55A	8.28A
Open circuit voltage(Voc)	43.5V	43.2V	37.6V
Temperature Coefficient of Isc	(0.065±0.015)%/ ˚C	0.05%/ ˚C	0.05%/˚C
Temperature Coefficient of Voc	-(160±20)mV/ ˚C	-0.350%/ ˚C	-0.35%/˚C
Temperature Coefficient of power	-(0.5±0.05) %/ ˚C	-0.47 %/ ˚C	-0.45%/˚C
NOCT	47±2˚C	47±2˚C	47±2˚C
Maximum system voltage	600V	1000V	1000V DC
Size of the Panel in mm	1587*790*20	1962*992*50	1652*1000*50
No of Cells in series	72(6*12)	72(6*12)	60(6*10)

d) Reliability analysis of different types of SPV systems

Table 9: Reliability analysis of different types of SPV systems for different no of panels

Sl. No	**Different Types of Panels**	**Reliability of the Panels**							
		n=600	**n=750**	**n=900**	**n=1050**	**n=1200**	**n=1350**	**n=1500**	**n=1650**

1	DSP 210DMono			0.5134	0.7165	0.7788	0.9200	0.9200	1.0000
2	KS-M 280WMono	0.4346	0.7165	0.7788	0.9200	0.9200	1.0000		
3	SPP-280-24Poly		0.6065	0.7788	0.9200	0.9200	1.0000		
4	BPSX 150SPoly					0.5134	0.7165	0.7165	0.7788
5	ZKX-240D-24Mono		0.4346	0.7165	0.7788	0.7788	0.9200	1.0000	
6	ZKX-240P-24Poly		0.4346	0.6593	0.7165	0.7788	0.9200	0.9200	1.0000

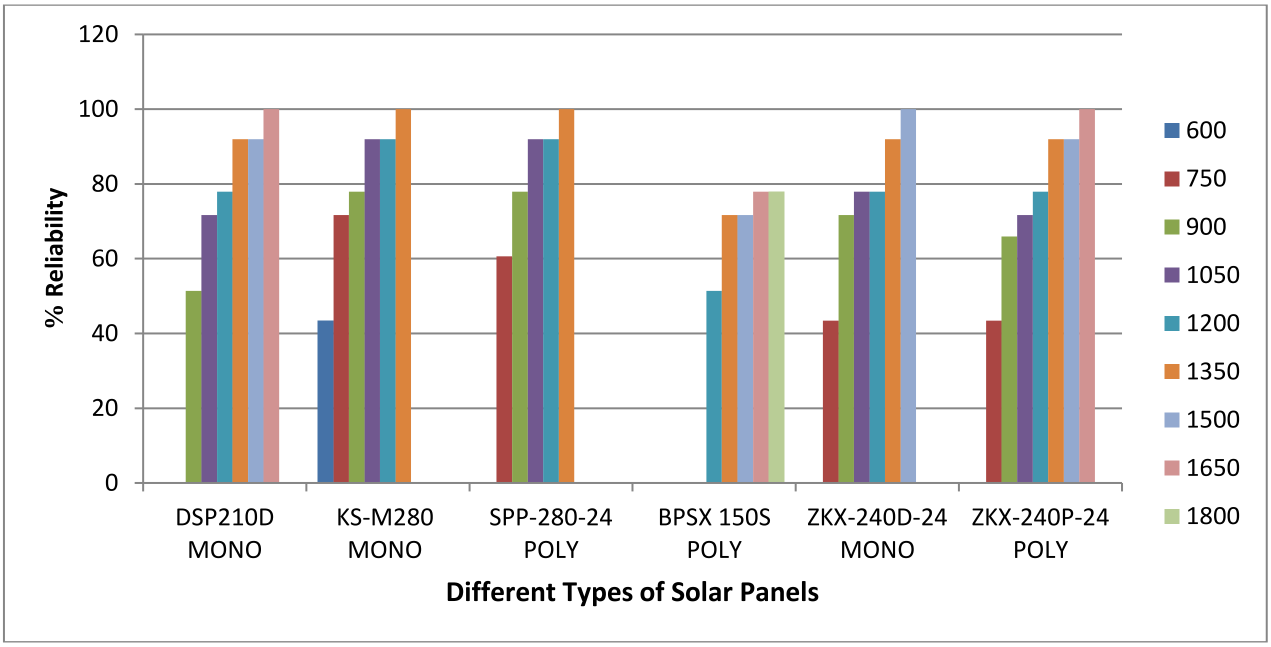

Figure 5: % Reliability vs Different Types of Solar panels for different no of panels

V. Conclusion

This paper successfully implemented the optimized & un-optimized output for DSP210D mono-crystalline SPV system aiming the improvement in the reliability of different types of solar panels for PV system by the new efficient PV array development &the proper selection from available PVs in market. It is also proposed to develop reliability analysis with the help of failure rate calculation for different types of solar panel.

For any given area/site at particular year we can develop or select proper PVs by following these given parameters/stepsto attain the goal of maximum reliability & less failure rate by calculation of output/solar power by the practical hardware as well as MATLAB simulation approach.

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