SuDoKu Reconfiguration Technique to Enhance the Maximum Power under Partial Shading Conditions in PV arrays

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***Abstract*: Mismatch losses ignore the performance of individual photovoltaic (PV) modules and cut back most of the power from the PV array. These losses mainly due to partial shading condition (PSC), are caused by the reduction of spacing between PV modules, passing clouds, and near buildings, etc. Several techniques are present in the literature to cut back the partial shading issues. One of the most effective methods is the reconfiguration techniques, namely reconfigure the location of PV modules in PV array so as to distribute partial shading effects and increase the maximum power output. This paper proposes a Sudoku reconfiguration pattern for 9X9 Total-Cross-Tied (TCT) PV array to enhance maximum power output under partial shading conditions. The main aim of this approach is to arrange the PV modules in TCT array according to the Sudoku pattern without altering the electrical connections. Further, the performance of the proposed pattern is evaluated with different existing PV array configurations by comparing the Global Maximum Power Point (GMPP), Mismatch Losses (ML), Fill Factor (FF) and Efficiency (η). Based on the results of this paper, it is concluded that the proposed improved SuDoKu PV array arrangement enhances the global maximum power under all shading conditions.**

Index Terms*: *PVarray , SuDoKu, GMPP,LMPP,MPPT

I. Introduction

In the ongoing years, the environmentally friendly power sources (RES) become more mainstream and comprehensively supplanted regular fuel sources. Instances of RES are the sun based, the breeze, the biomass and the geothermal fuel sources. Among all, sun based energy is the most fundamental and essential maintainable asset on account of its omnipresence and plenitude in nature. The energy from photovoltaic (PV) exhibits, notwithstanding requiring little Maintenance, is without fuel and contamination free .Also, the PV energy is utilized in a few situations, for example, private structures, streetlamps, joining of intensity frameworks and provincial regions. The productivity of PV modules is influenced by different elements, however one of the main issues is halfway shadings. Incomplete concealing happens if the PV modules are concealed in PV cluster by reason for flying creatures, passing mists and nearby structures, and so forth Under PSCs, the measure of irradiance got by the concealed module is more modest than that got by the un shaded module. Since the shaded PV module limit the output current of an array, the entire PV system is affected by mismatch losses that might cause the damage to the PV Cells or modules.

One of the ways to protect the shaded PV modules from the damage is by connecting bypass diodes across the terminals. Insertion of bypass diodes causes multiple steps in I-V and multiple peaks in P-V characteristics of the PV array. Among the multiple peaks, there is only one global peak (GP) which produces the highest maximum power, which is also known as Global Maximum Power Point (GMPP) and rest of all Local Maximum Power Points (LMPPs).The existence of multiple peaks may mislead the maximum power point tracking (MPPT) technique by tracking the LMPPs instead of GMPP; this would add extra power loss to the PV system. The power loss as a result of partial shading is dictated by the chosen array configuration, shading pattern and physical location of PV modules in the PV array. However, the effect of PV array configuration shows a severe impact on maximum power output. Therefore, choosing the right configuration is necessary under PSCs.

2. LITERATURE SURVEY

The Competence square based PV array reconfiguration technique to reduce the partial shading condition. They considered several types of shading. From the results, it is observed that the proposed method is better compared to DS and TCT' smismatch power loss and percentage power enhancement. CST has proved its excellence in achieving smoother output characteristics, improving fill factor and improving power and energy [1].
The cross diagonal view configuration of a PV system to reduce partial shading condition. They considered several types of shadings. In CDV matrix sum of each rows, each columns and each diagonals are equal. From the results, it is observed that the proposed

method is better with compared to CST method where power loss will be less and efficiency is more comparatively [2].A simple, sensor less and fixed reconfiguration scheme for maximum power enhancement in PV systems.

3.TABLE-1:

The PV array data sheets are given by,

Parameters	Ratings
Rated power (Pmpp)	170W
Open circuit voltage(Voc)	44.2V
Short circuit current(Isc)	5.2A
Current at maximum power(Im)	4.75A
Voltage at maximum power(Vm)	35.8V
Number of cells	72
PV module area	62.2*31.9inc

4. TYPE OF SHADINGS:

In this method we are using several types of shadings they are as shown in fig.1,

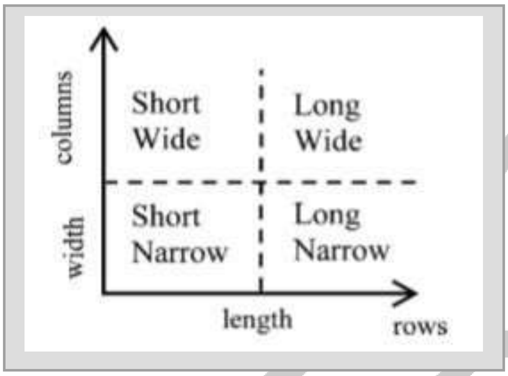


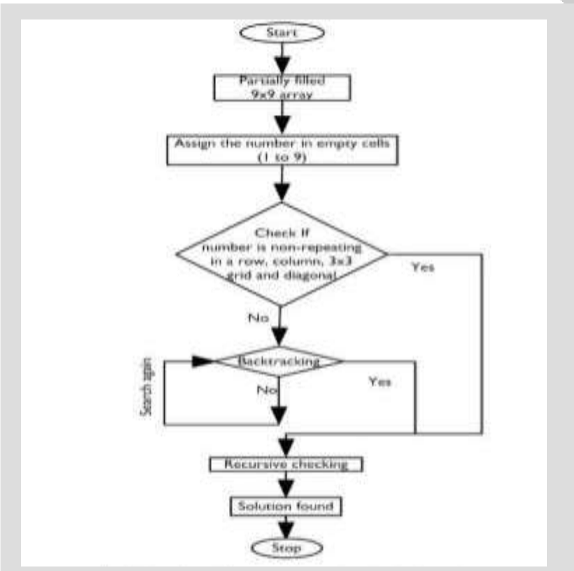
Fig.1-shadings pattern

5. ALGORITHM:

Pseudo code.

Initialize ← Solve SuDoKu (int grid [N] [N]) If there is no unsignedlocation
Loop If (Find unsigned location (grid, row, col));return true Consider digits 1to 9
for (intnum=1;num<=9;num++);return true If looks promising
if (is safe (grid, row, col, num)) Make tentative assignment
If (grid[row][col]=num);return, if success if (solve SuDoKu(grid))return true;
end loop
failure, try again grid[row][col]=Unassigned; return false this triggers backtracking.

The flow chart for proposed algorithm for developing the puzzle is given in fig.2



6. METHODOLOGY:

An implemented Sudoku 9x9 puzzle and pattern arrangement is a logic-based number placement puzzle. It consists of nine 3×3 sub-array matrices. The formation of this logic puzzle is based on the Backtracking method. Backtracking is an algorithm for finding solutions to some computational problems,notably constraints satisfaction problems .The constraintofthisproblemistoplacethedigits1to9 in 9×9 array so that each row, each column, each 3x3sub array and diagonal contains the same number only once. The proposed algorithm works as follows.

- Chose the partially filled 9x9array.
- Try to fill each unsigned cell with the digits from 1to9.
- If the assigned digits satisfied the condition, then try to fill each unsigned cell by performing recursive checking until build the solution.
- Otherwise backtracking algorithm takes place to exchange the assigned cell.

The proposed puzzle is as shown in fig.3,

2	4	6	3	7	1	8	9	5
3	5	7	8	6	9	2	4	1
9	1	8	5	4	2	3	7	6
1	9	5	4	2	6	7	8	3
6	8	3	7	9	5	1	2	4
7	2	4	1	8	3	5	6	9
4	3	2	9	1	7	6	5	8
5	7	9	6	3	8	4	1	2
8	6	1	2	5	4	9	3	7

Fig.3SuDoKuarrangement

21	42	63	34	75	16	87	98	59
31	52	73	84	65	96	27	48	19
91	12	83	54	45	26	37	78	69
11	92	53	44	25	66	77	88	39
61	82	33	74	95	56	17	28	49
71	22	43	14	85	36	57	68	99
41	32	23	94	15	76	67	58	89
51	72	93	64	35	86	47	18	29
81	62	13	24	55	46	97	38	79

Pattern arrangement

7. Total cross tied PV array configuration

As compared with the other connections, the TCT PV array reduces mismatch losses effectively. In TCT, the first PV modules are connected to make rows in parallel, and then all the rows are combined in series to form a string. The general layout of TCT configuration is shown inFig.4.

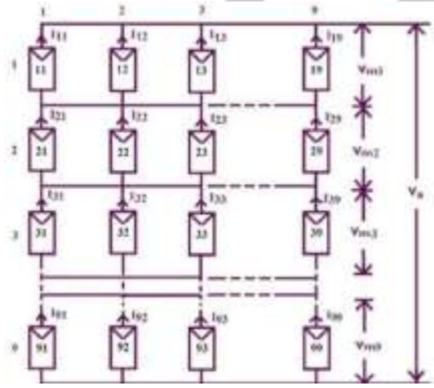


Fig.4 TCT connection for 9x9 array

CASE-1

Here we used Short and wide shading pattern following arrangements as shown in fig.5.

11	12	13	14	15	16	17	18	19
21	22	23	24	25	26	27	28	29
31	32	33	34	35	36	37	38	39
41	42	43	44	45	46	47	48	49
51	52	53	54	55	56	57	58	59
61	62	63	64	65	66	67	68	69
71	72	73	74	75	76	77	78	79
81	82	83	84	85	86	87	88	89
91	92	93	94	95	96	97	98	99

Fig.5.1 TCT arrangement

21	42	63	34	75	16	87	98	59
31	52	73	84	65	96	27	48	19
91	12	83	54	45	26	37	78	69
11	92	53	44	25	66	77	88	39
61	82	33	74	95	56	17	28	49
71	22	43	14	85	36	57	68	99
41	32	23	94	15	76	67	58	89
51	72	93	64	35	86	47	18	29
81	62	13	24	55	46	97	88	79

Fig.5.2 SuDoKu pattern

Results and discussions:

Table.2

	S&W	CST	CDT	Sensor	SDK
Ploss	46.71	33.48	30.76	30.22	28.5
Eff	7.02	8.8	9.0	9.2	9.51
F F	39.5	49.3	51.3	51.2	53.0

We obtained above results as tabulated in table.2 for the short and wide shading pattern shows better performance of SuDoKu among all and bar graph obtained is shown in fig.5.3.

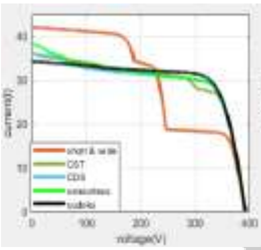


Fig.5.3 VI graph

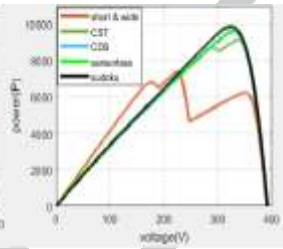


Fig.5.4 PV graph

CASE-2:

Here we used long and wide shading pattern following arrangements as shown in fig.6.1

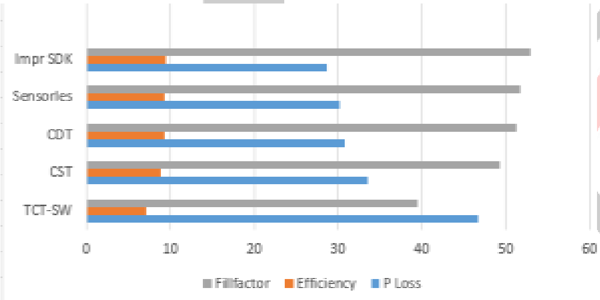


Fig.6.1

11	12	13	14	15	16	17	18	19
21	22	23	24	25	26	27	28	29
31	32	33	34	35	36	37	38	39
41	42	43	44	45	46	47	48	49
51	52	53	54	55	56	57	58	59
61	62	63	64	65	66	67	68	69
71	72	73	74	75	76	77	78	79
81	82	83	84	85	86	87	88	89
91	92	93	94	95	96	97	98	99

Fig.6.1 TCT arrangement

21	42	63	34	75	16	87	98	59
31	52	73	84	65	96	27	48	19
91	12	83	54	45	26	37	78	69
11	92	53	44	25	66	77	88	39
61	82	33	74	95	56	17	28	49
71	22	43	14	85	36	57	68	99
41	32	23	94	15	76	67	58	89
51	72	93	64	35	86	47	18	29
81	62	13	24	55	46	97	88	79

Fig.6.2 SuDoKu pattern

The irradiance from the sun is 900 W/m^2, 600 W/m^2, 500W/m^2, 400 W/m^{2}and 200 W/m^2.

Results and discussions:

Table.3

	L&W	CST	CDT	Sensor	SDK
Ploss	51.54	38.04	38.17	38.62	38.0
Eff	6.45	8.1	8.0	8.1	8.35
F F	35.9	45.3	45.8	45.24	45.95

From the fig.6.3 we obtained above results as tabulated in table.3 for the long and wide shading pattern shows better performance of SuDoKu among all and bar graph obtained is shown in fig.6.4

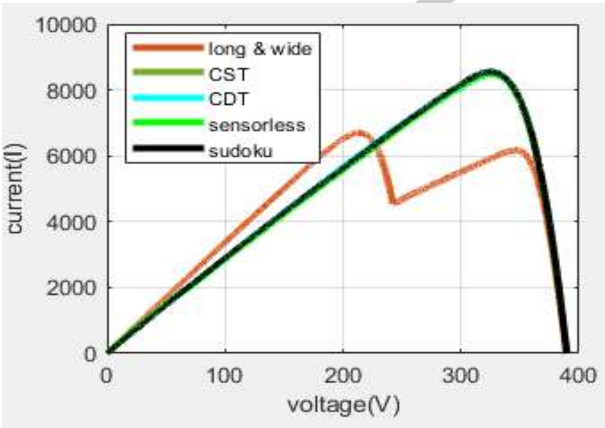


Fig.6.3 PV graph

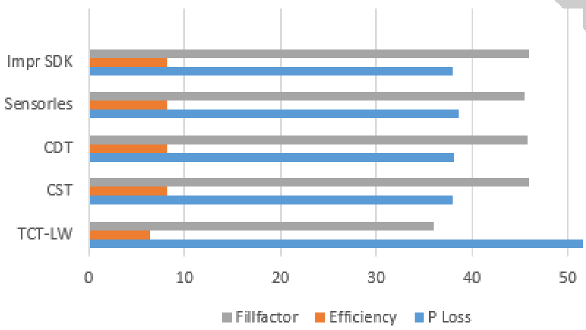


Fig.6.4 bar graph of long and wide shading

CASE-3:

Here we used Short and narrow shading pattern following arrangements as shown in fig.7

11	12	13	14	15	16	17	18	19
21	22	23	24	25	26	27	28	29
31	32	33	34	35	36	37	38	39
41	42	43	44	45	46	47	48	49
51	52	53	54	55	56	57	58	59
61	62	63	64	65	66	67	68	69
71	72	73	74	75	76	77	78	79
81	82	83	84	85	86	87	88	89
91	92	93	94	95	96	97	98	99

Fig.7.1 TCT arrangement

21	42	63	34	75	16	87	98	59
31	52	73	84	65	96	27	48	19
91	12	83	54	45	26	37	78	69
11	92	53	44	25	66	77	88	39
61	82	33	74	95	56	17	28	49
71	22	43	14	85	36	57	68	99
41	32	23	94	15	76	67	58	89
51	72	93	64	35	86	47	18	29
81	62	13	24	55	46	97	88	79

Fig.7.2 SuDoKu pattern

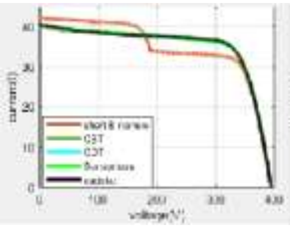
The irradiance from the sun are 900 W/m^2, 600 W/m^{2}and 400 W/m^2.

Results and discussions:

Table.4

	S&N	CST	CDT	Sensor	SDK
Ploss	23.3	17.00	17.15	17.44	17.0
Eff	10.21	11.05	11.0	10.9	11.04
F F	56.85	61.34	61.4	61.20	61.41

From the fig.7.3 and 7.4 we obtained above results as tabulated in table.4 for the short and narrow shading pattern shows better performance of SuDoKu among all and bar graph obtained is shown in fig.7.5



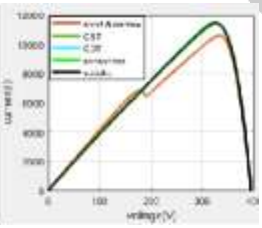


Fig.7.3 VI graph **Fig.7.4 PV graph**

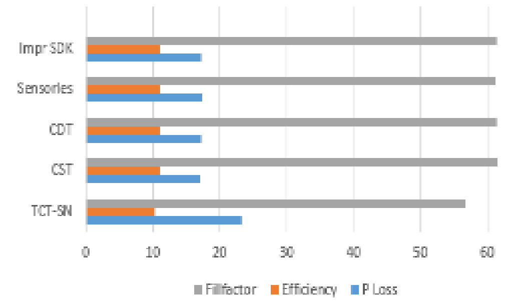


Fig.7.5 bar graph of long and narrow shading

CASE-4:

Here we used long and narrow shading pattern following arrangements as shown in fig.8

11	12	13	14	15	16	17	18	19
21	22	23	24	25	26	27	28	29
31	32	33	34	35	36	37	38	39
41	42	43	44	45	46	47	48	49
51	52	53	54	55	56	57	58	59
61	62	63	64	65	66	67	68	69
71	72	73	74	75	76	77	78	79
81	82	83	84	85	86	87	88	89
91	92	93	94	95	96	97	98	99

Fig.8.1 TCT arrangement

21	42	63	34	75	16	87	98	59
31	52	73	84	65	96	27	48	19
91	12	83	54	45	26	37	78	69
11	92	53	44	25	66	77	88	39
61	82	33	74	95	56	17	28	49
71	22	43	14	85	36	57	68	99
41	32	23	94	15	76	67	58	89
51	72	93	64	35	86	47	18	29
81	62	13	24	55	46	97	88	79

Fig.8.2 SuDoKu pattern

The irradiance from the sun are 900 W/m^{2}700W/m^2, 400 W/m^{2}and 300W/m^2.

Table.5

	L&N	CST	CDT	Sensor	SDK
Ploss	24.61	25.92	20.8	20.9	20.0
Eff	10.02	9.86	10.54	10.53	10.64
F F	55.88	54.91	58.2	58.60	59.27

From the fig.8.3 and 8.4 we obtained above results as tabulated in table.4 for the long and narrow shading pattern shows better performance of SuDoKu among all and bar graph obtained is shown infig.8.5

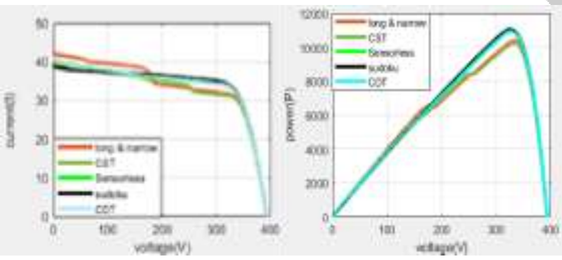


Fig.8.3VIgraph Fig.8.3VIgraph

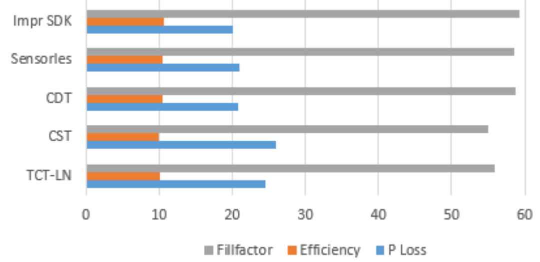


Fig.8.5 bar graph of long and narrow shading

PERFORMANCE PARAMETER UNDER PSC'S:

In this paper four main parameters are considered such as GMPP, mismatch losses (%), fill factor (%) and efficiency (%) to evaluate the performance of proposed arrangement on 9x9 array under different shading condition.

- factor (%)=(Power ofGMPP)/(Voc*Isc)
- ML(%)=(MPPuni-GMPPpsc)/(GMPPpsc)
- Efficiency(%)=(Power atGMPP)/(Pin)

9. CONCLUSION:

This paper proposes on Sudoku arrangement for TCT PV array to increase maximum power output under partial shading condition. Here four important shading conditions are considered. They are short and wide, long and wide, short and narrow and longhand narrow.Ineach condition, the location of GMPP is calculated and validated by using MATLAB/ SIMULINK software. From the results obtained, it is clearly observed that the Sudoku arrangement enhances the global maximum power, reduces the mismatch losses and gives better efficiency and fill factor as compared to CST, CDT, Sensor less and TCT methods. Moreover, the proposed arrangement defeated the multiple peaks under most shading conditions.

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