Determination of Partial Shade Panels in Solar Panels Using Minkowski Theorem

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Abstract. Factors affecting the efficiency of solar power generating systems include factors such as partial shading (contamination, module positioning, weather conditions, cell damage), reflection, cable losses, and extreme temperature. In order to increase productivity: solar tracking systems, maximum power point tracking (MPPT), cooling systems are used. In these methods, in the event of a fault in any panel in the solar panel, all panel belonging to that series are disabled and the efficiency of the system is decreasing. In this study, to solve the problem of shadow that is one of the biggest problems of solar power plants, Minkowski theorem that is a mathematical model, detects the faulty panel or the low current panel and disables the detected panel or panels. In this way, both rapid malfunction detection and system efficiency can be increase.

1. Introduction

Due to the requirements arising in parallel with the developing technological and industrialization and increasing electricity consumption in our country, both manufacturers and users are forced to use new and clean energy sources[1]. In addition, with the technological activities being developed from day to day, efforts to reduce cost, reduce production capacity and increase business volume in the energy sector have been increasing, and efforts to reduce the human impact and security weakness have also accelerated[2-3].

There are works in the literature to generate electricity from solar energy and to increase the efficiency of panels[4-6]. Figure 1 shows the factors affecting the efficiency of solar panels and the amount of loss of these factors. These factors are classified as temperature, dust, contamination, inverter efficiency, battery efficiency, panel structure, cable losses, incompatibility, monitoring and problem areas. The highest amount of these losses is due to the panel structure[5,7].

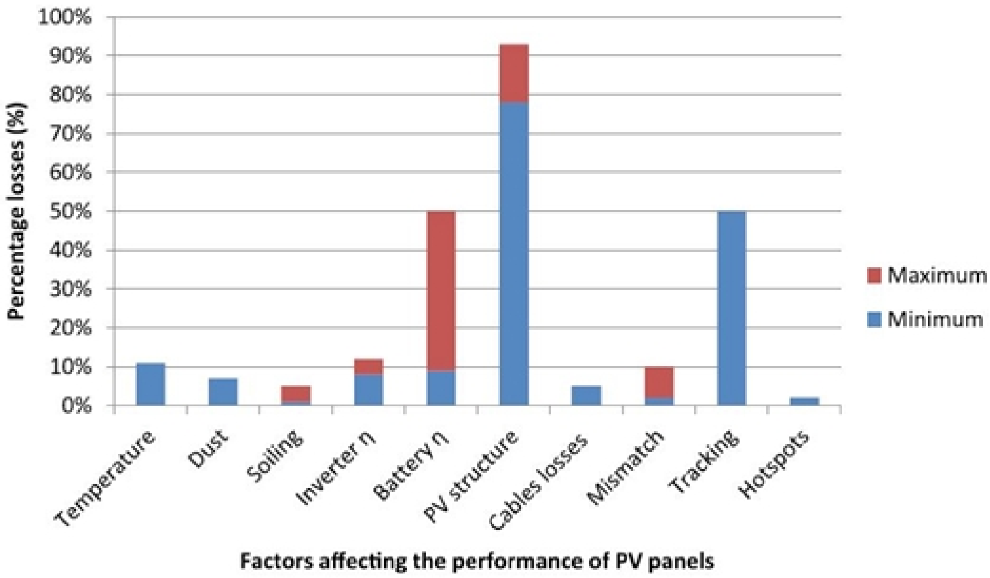

Figure 1. Factors affecting the efficiency of solar panels

Fouad et al. Describe the integration of various factors affecting the performance of photovoltaic panels in their work to improve panel efficiency and how these factors affect system performance. These factors include: environmental, PV system, installation, cost factors and various other factors. Solar radiation, module temperature, dust accumulation, shading and pollution factors are environmental losses[5]. Some of the system factors are solar radiation, module temperature, dust accumulation, shading and I-V characteristics of the solar panel, inverter, battery and panel efficiency, panel material, atomic structure and band gap energy. Cable properties, slope angle, incompatibility effects, fixed / monitoring PV mechanisms and MPPT are very important factors to consider In terms of installation factors[6,7-9].

In literature has investigated effect on output performance of solar panels' surface temperatures for increase efficiency and experimental studies have shown that output voltage, current and output power affect the efficiency at different radiation conditions. It has been observed that the efficiency was changed by 47% by applying cooling test to the heated panels. [10].

Researchers has been extensively studied to radiation parameter together with temperature in order to measure the efficiency of the photovoltaic panels. In addition, parasitic resistance consisting from shunt resistance(Rsh) and series resistance(Rs) located panel structure has shown to have important and great effect on PV panel. Panel performance is measured by measuring the effect of parasitic resistance under irregular radiation conditions[11-13].

Both software and hardware methods are used to increase the efficiency of solar panels. MPPT algorithm which is software method ensures that the energy generated from the panes is at the maximum level. The energy produced varies throughout the day due to changes in sunlight and cell temperature. Maximum power point tracking (MPPT) algorithms are used to monitor changing power. [11,14,15]

The hardware control system used to increase the efficiency has developed a two-axis solar tracker following the sunrise angle. System adjusts panel position using axis motors by LDR used to measure the amount of radiation. In the panel with monitoring system, average monthly earnings have been found to vary between 17% and 31% [12]

Another way to reduce partial ghosting losses that affect the efficiency of solar panels is to use By-Pass diodes to protect the shadowed panels from hot spot effects. [8,16]

As can be seen from similar studies, the biggest problem with panel efficiency is partial shading. Indirectly, partial shading is caused from many reasons. In a result of the shading, the current in the line to which the panel or panes are connected is decreasing and this decrease affects the central efficiency in the negative direction[17-19].

At the same time, the light falling on the panellas diminishes or increases step by step as the sun sets or the sunrise. In this case, the panel is again partially shaded, and the panels that do not fall into the sunlight are adversely affected by the other panels that are heavily exposed to the sunlight[19,20].

In general, when we look at the studies done in the literature, it is seen that there are studies to increase the system efficiency and the effect of the detection or the dissolution of the defective panel in case of panel disturbance is not mentioned. Therefore, the importance of this simulated work is even more pronounced. Thanks to study, partial shading, disturbance panel or panels determine by using minkowski theory which is a mathematical inspection mechanism and then they has removed form system[20].

Thus, system efficiency is maintained and panel life is extended using the shortest path of the current. Simulation of the system is done in the Matlab / Simulink platform. In the simulation, the solar panels are connected to each other to form a 3x3 matrix, and the voltage and the current values transferred to the load are given as the input.

2. Effieciency Increase Method Using Minkowski Theoreme

Minkowski's paths or "Taxicab geometry"were developed by Hermann Minkowski in the nineteenth century. They are also called "distance Manhatan"because this city was the model for his researches. This is a geometry where the usual Euclidean metric is replaced by a new metric in which the distance between two points is the sum of the absolute differences of their coordinates. This metric is also known as rectilinear distance, distance L 1 or L 1 norm[20].

$$d_1 [(x_1, y_1), (x_2, y_2)] = | x_1 - x_2 | + | y_1 - y_2 |$$

To begin the algorithm we perform a coloring of the edges following the traffic light signs, being: green (double line) when the road is open, yellow (single line) for those paths that could open and red (dot line) if it is forbidden to use it. To start, we identify each panel within the matrix by its row and column corresponding { p ij } and we denote by δ(p) the panel state, meaning −1 when not available and 1 if it is fully operative. Let e1 , e2 , . . . , e n the highest points of the topology evacuation analyzed. Let the function d (p) the Minkowski distance operating panels to the nearest evacuation point:

$$d(p) = \min d_1 (p, e_i), \quad i = 1, \dots, n$$

Given an p ij panel we calculate the corresponding connections with those around it, with 0 if the connection is closed and 1 otherwise. Therefore each panel has a code of four binary digits that make up its hexadecimal description, following the order of connections counter clockwise or increasing of angles (right, top, left and bottom or 0, 90, 180 and 270 degrees). This coding transforms a vector of four binary numbers into a single hexadecimal data, in order to optimize the use of computational memory[20].

$$\mathcal{H} = \begin{pmatrix} 1101 & 1110 & 1111 \\ 0101 & 0000 & 1100 \\ 1101 & 0011 & 0000 \end{pmatrix} = \begin{pmatrix} D & E & F \\ 5 & 0 & B \\ D & 3 & 0 \end{pmatrix} \quad (1)$$

If we represent the values of d (p ij) with i ∈ { 1 , 2 , . . . , n } and j ∈ { 1 , 2 , . . . , m } , graphically and through matrices (δfor states, Hfor paths and Dfor distances), we obtain:

$$\delta = \begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 & 1 \end{pmatrix}; \quad \mathcal{H} = \begin{pmatrix} D & E & F & F & F & 7 \\ 5 & 0 & B & F & F & 7 \\ D & 3 & 0 & D & F & 7 \\ C & E & A & E & E & 6 \end{pmatrix} \quad (2)$$

and the solution matrix D = $\begin{pmatrix} 1 & 1 & 1 & 1 & 1 & 1 \\ 2 & -1 & 2 & 2 & 2 & 2 \\ 3 & 4 & -1 & 3 & 3 & 3 \\ 4 & 5 & 5 & 4 & 4 & 4 \end{pmatrix}$ (3)

The connection of the solar panels in the classical system is shown in Figure 2-a. Panels in the connection are connected in series to form arrays. These series are connected to each other in parallel to form a solar power plant. However, if we consider the serial connected panels to be connected to each other as a battery, it gives output according to the one that produces the least power. Thus, power loss which is arise from a single panel is effecting all series. In order to remove this negative situation and to maintain system efficiency, Minkowski theorem was applied together with the connection given in Figure 2-a. Thus, minkowski theorem which is a mathematical method is formed a solution to power optimization problem of solar panels.

Detection of faulty panels in the application of solar fields is carried out by monitoring the voltage and power values of the parallel line connected to the serial line connected via inverter or computer. If the energy production of the array is low, the series is deactivated and the serial panels are measured one by one and the faulty panel or panel is detected. This situtation causes material loss due to extra labor cost, time loss and reduced production.

Thanks to this study which has implemented simulation, Panel or panels continue energy production by deactiving low efficiency panel or panels which has arise from partial shadding, faults, dirt or cracks. Thus, system efficiency is maintained and financial losses are prevented, The current and voltage values of each panel must be measured to implement the proposed solution. The connection of the panels to the general system and the connection scheme which is used in our work are given in Figure 2-b.

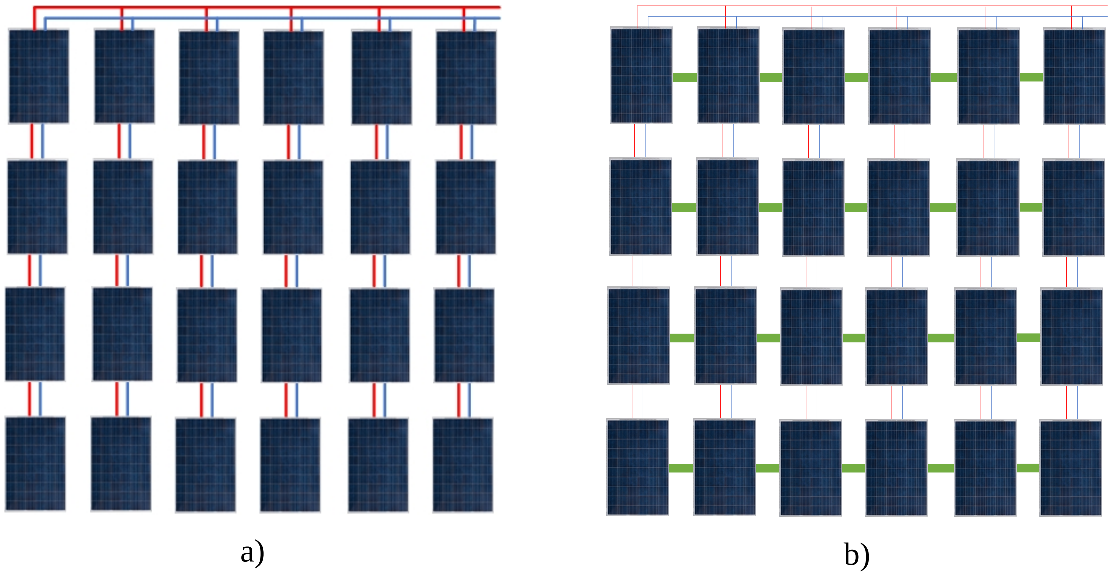

Figure 2. General connection(a) and proposed connection(b)

Minkowski theorem is basically a mathematical method. This theorem is intended to solve the problem of power optimization in solar panels[20]. Panels in a solar power plant are connected serial to each other to form sequences. These series form the solar power plant by connecting parallel each other. However, the panels that are connected in series give out output according to product the least power among panels in array. Thus, power loss which is arise from a single panel is effecting all series. Thanks to proposed method, It has been demonstrated to more efficieny and more stability connection type. In connection type, several ways are emerging for current by removing from array faulty panel or panels. Thus, most efficient path for the current is determined by applying Fuzzy Logic rules together with algorithm created by using minkowsi theorem. Modeling and detection of defective panels were done for the solar panels consisting of 3x3 matrix in Figure 3. Despite the presence of defective panes in the serial line, the current in the serial line completes the circuit.

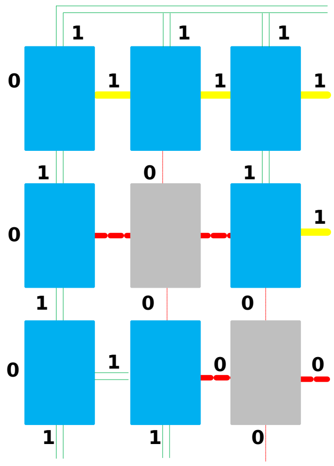

Figure 3. 3x3 modeling and detection of defective panel

Minkowski algorithm has been reconfigured the connection and the system has isolated the defective panels as temporarily. Thus, the remaining panels has continued the optimal production. The relays shown in Figure 4 are used to activate or deactivate panels.

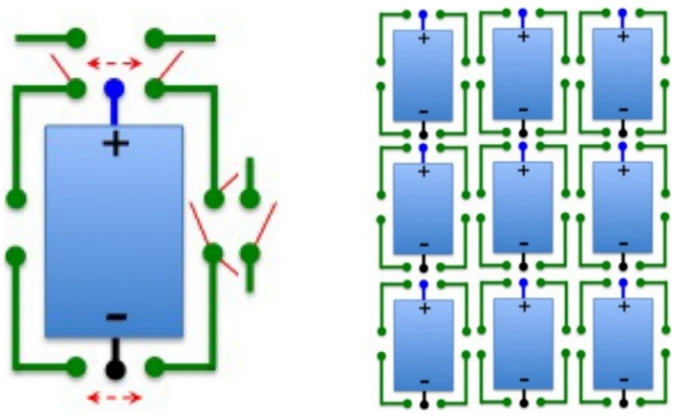

Figure 4. Relay coordination

Figure 5 shows the so-called code of the implemented algorithm. According to this algorithm, variables and panel states are introduced after using voltage and current definitions. Then, algorithm perform to panels serial scanning process. If the panel status is logical 1, the current voltage values continue to work smoothly at the desired values. Otherwise, if the panel status information is logic 0, then the current voltage value of the panel or panels have decreased and it send a deactive command to not reduce efficiency of other panels. Thus, panel or panels created power loss has determined and if problem is temporary, system active to deactive panel or panels when panel efficiency has normal level.

```
global objetive.voltage = mV;
global objetive.intensity = nI;
set initial - solution = null;
set i0=1, j0=1, state1o=1, state2o=1;

function analysis
    {

        set finish-analysis = YES;
        for (i = j0; i <= m; i++)
            for (j = j0; j <= n; j++)
                {
                    if C(i,j) == 0 and delta(i,j) > 0
                        {
                            set finish-analysis = NO;
                            for (state1 = state1o; state1 <= 3; state1++)
                                if i == 1
                                    set state2 = 3;
                                else
                                {
                                    for (state2 = state2o; state2 <= 3; state2++)
                                        if  j<n or (j == n and state1 == 1)
                                            {
                                                set C(i,j)=3*(state1 - 1) + state2;
                                                set i0 = i; set j0 = j; state2o = state2 + 1;
                                                if state2 == 3; set state1o = state1 + 1;
                                                if actual-solution does not have short-circuits
                                                    execute analysis;
                                                else
                                                    set i = m, j = n;
                                            }
                                }

                        }
                        if j ==n, set j0 = 1;

                }
        if finish-analysis == YES;
            if actual-solution.objetive <= objetive and
                actual-solution is better than initial-solution and_
                actual-solution does not have short-circuits
                    set initial-solution = actual-solution;
    }
```

Figure 5. The so-called code of the Minkowski theorem

3. Simulation

This work which is simulated has created on the Matlab / Simulink platform. In the study, both the modeling of existing solar power plants and the modeling using Minkowski Theorem were made and the two systems were compared.

The optimum working point of each panel is determined in real time Minkowski theorem to improve the performance of solar panels, the efficiency of the panel array is increased and therefore the total efficiency is increased. In the simulation study, a real system simulation was performed by changing the amounts of radiation on the panels and the current voltage gains were calculated by connecting loads to the panel outputs in simulations. The model of the Matlab / Simulink belonging to the simulation is given in Figure 6. In the model of the system, Panels with 250W power of American Choice Solar ACS-250-M model were preferred. This panel is the most used panel type in solar power plants and the panel has 37.3 V open circuit voltage and 8.66 A short circuit current.

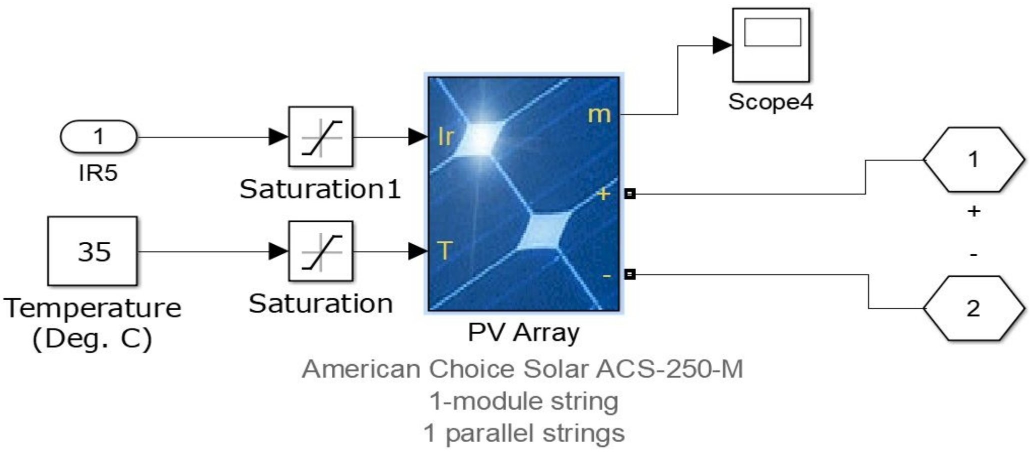

Figure 6. Modeling of solar panel in Simulink

Figure 7 shows the simulation using 3 serial and 3 parallel connections with the method used in the market. The current value of each panel in the simulation is measured. In addition, the lamps next to each panel indicate the level of the amount of radiation applied to the panels. In the simulated case, the red color panel is defective and the green color indicates that the panel generates energy and shows the amount of radiation according to the degree of darkness. The amount of radiation is changed in the simulation to create a partial shadows effect.

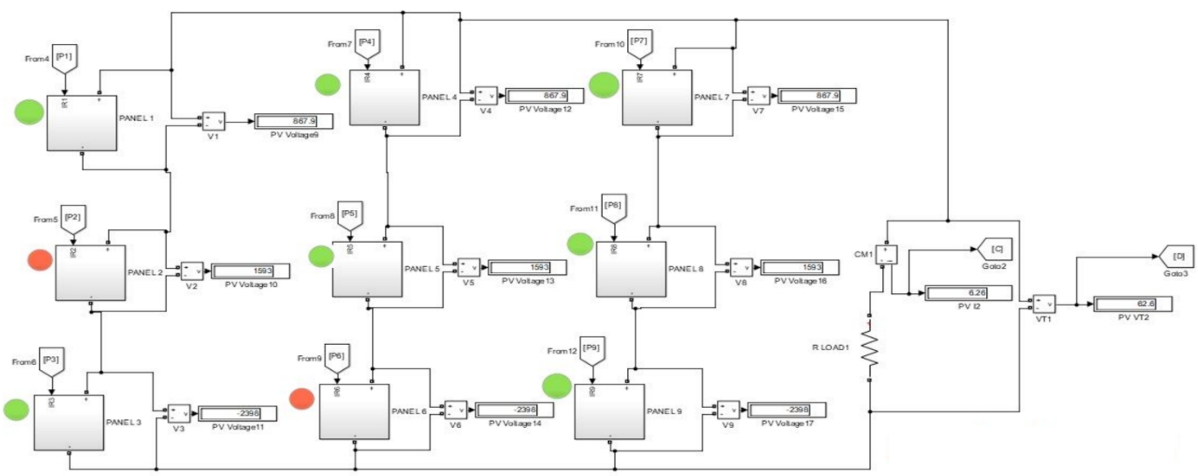

Figure 7. Model of existing solar energy plants

Compared to the conventional systems, the defective panel is detected by the method given in Figure 8 and the current and voltage are compared with the current and voltage values of the other panels. As a result of comparison, it is possible to prevent the system efficiency by disabling algorithm panels or panels.

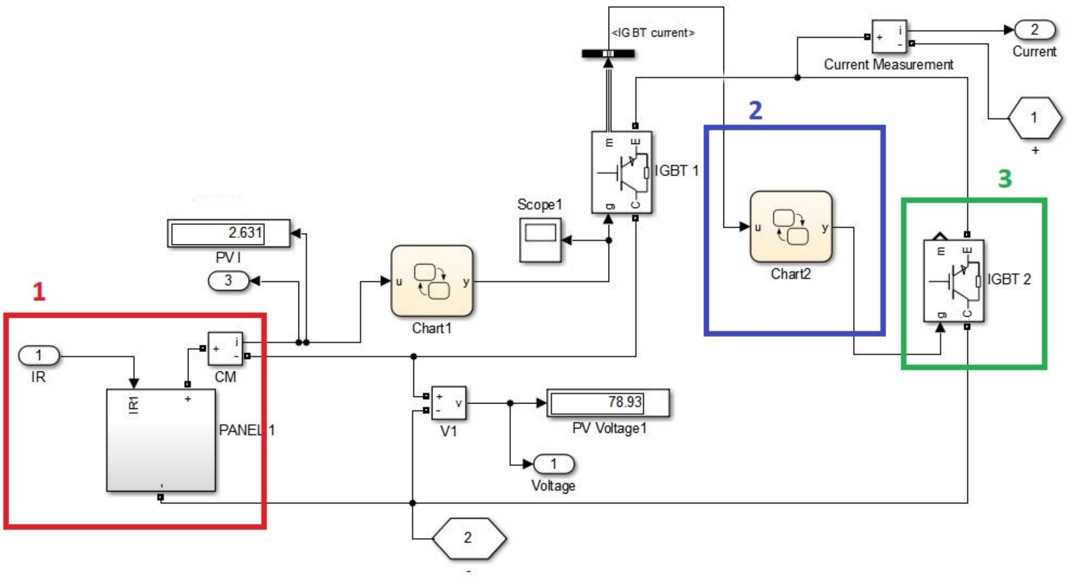

Figure 8. Modeling of the proposed method

The system simulated in Figure 8 is marked in red and the number 1 is identical to the panel structure and subsystem used in the old system. In zone 2 marked blue is a subsystem where comparison algorithms in order to active or deactive panels. The algorithm evaluates the current drawn from the panel with the current of the series and decides whether the panel will be switched off. In the third areas marked green, there are switching elements which will disable the panels on the 1 or 0 information received from the subsystem. Figure 9 shows a subsystem with the algorithm used for modeling the new system. In the system, the currents of each panel and serial line are measured.

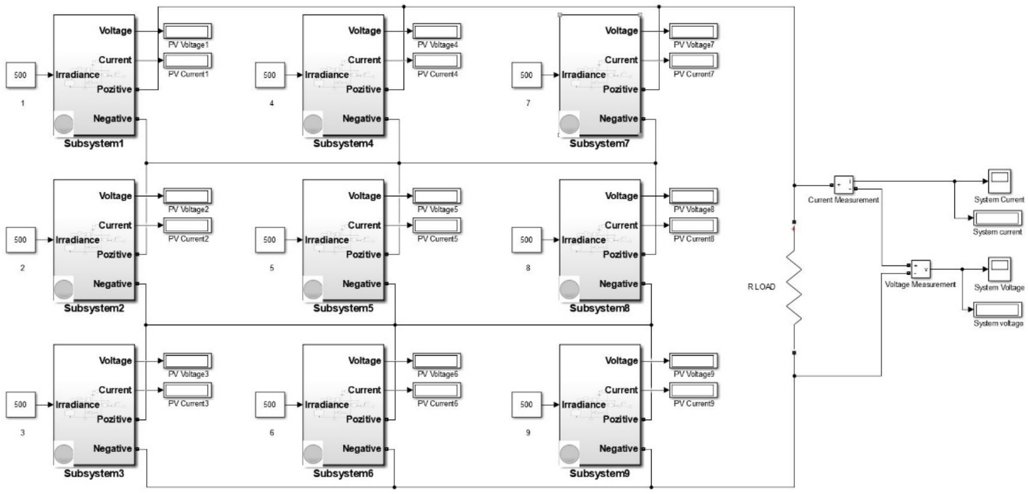

Figure 9. All system formed by the connection of subsystems

Figure 10 shows the flow diagram of the Minkowski theorem for the solar panels consisting of 3x3 matrices used in the simulation. According to this flow chart, the system active or deactive panel or panels

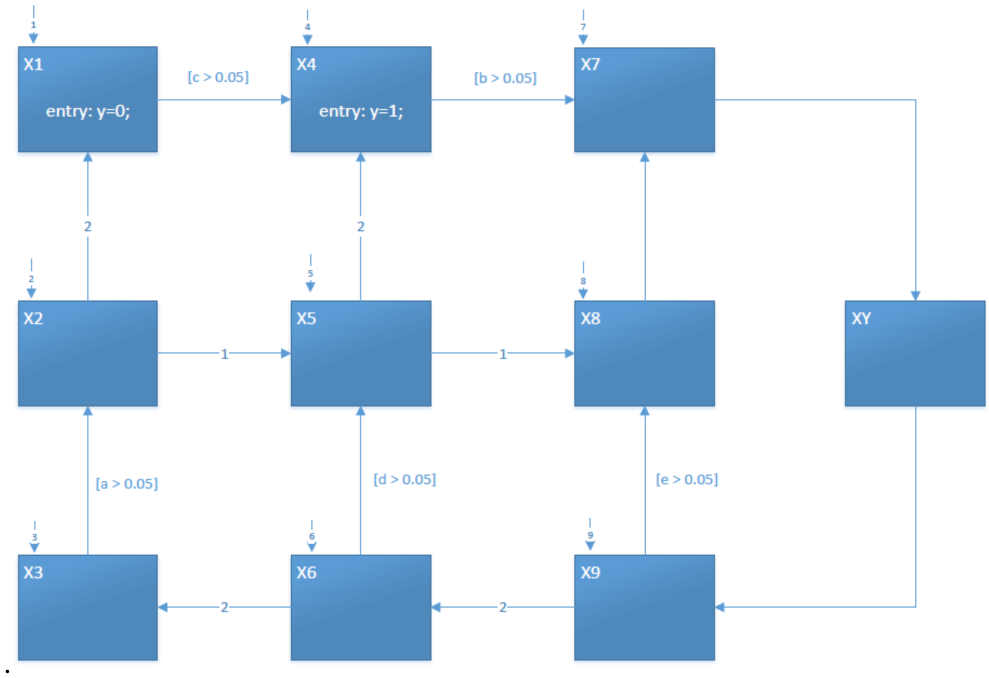

Figure10. Flow Diagram

As shown in Figure 11, the panels are controlled from the management panel. When the panel is not subjected to shadowing, that is, when the blend is at the maximum level, the power is transferred to the load in the same manner in the system proposed and in the classical linked system.

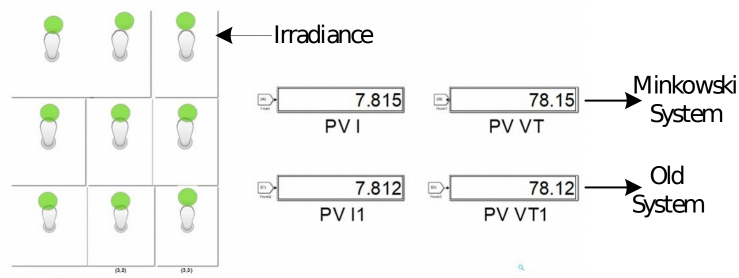

Figure 11. Power to be applied under equal beam of all panels

When the single panel is deactivated, the behavior of both systems is shown in Figure 12 In the system designed using minkowski theorem, the defective panel is deactivated and the series circuit connected to the defective panel continues to generate energy, so the total voltage of the system drops from 78.15 to 70.36 and the current value drops from 7,815A to 7,036A. In the existing old system, the total voltage of the system drops from 78.12V to 53.3V and the current value drops from 7.812A to 5.33A because of defective panel deactive all series. Therefore, when single panel is defective, the efficiency of the system designed using the minkowski theorem decreases by 18.94% and maintains approximately system efficiency. In the existing old system, 51.73% rate is reduced.

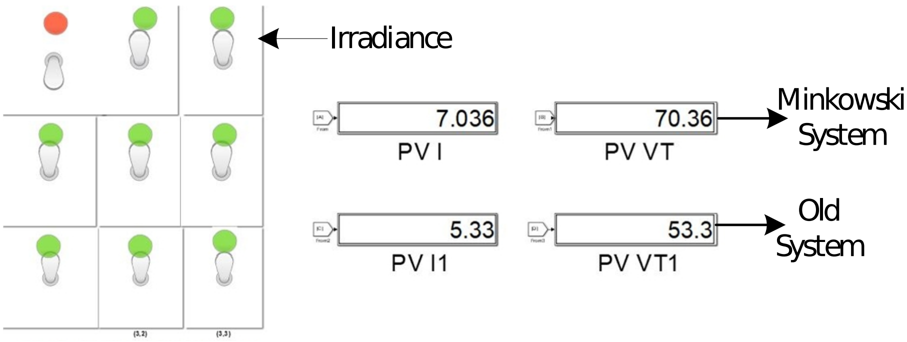

Figure 12. Power transferred to load when shading the first panel

Figure 13 shows the behavior of both systems when two panels are deactivated. In system designed using the minkowski theorem, defective panels are deactivated and the total voltage of the system is reduced from 78,15 to 60,36 and the current value from 7,815A to 6,036A by continuing the energy production in series circuits connected to the faulty panels. In the existing old system, the total voltage of the system drops from 78.12V to 27.02V and the current value drops from 7.812A to 2.702A because of defective panel deactive all series. Therefore, when two panel is defective, the efficiency of the system designed using the minkowski theorem decreases by %22,76 and maintains approximately system efficiency. In the existing old system, 65.41% rate is reduced.

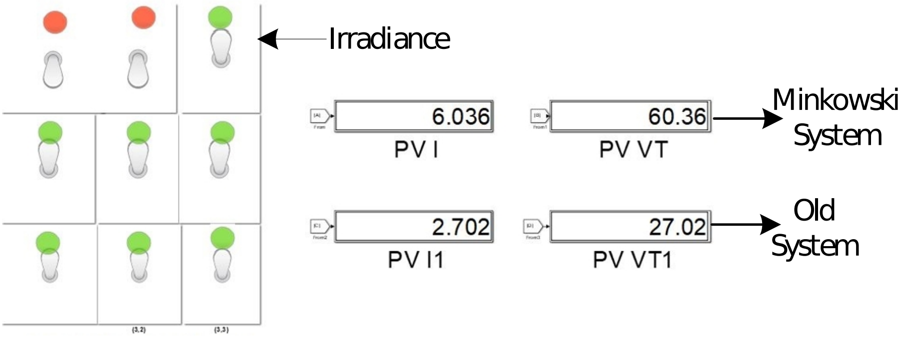

Figure 13. Power transferred to load when shading the two panel

As seen in Figure 14, when the panels 1 and 2 are shaded, a significant loss of power is experienced in the old system but a lesser loss of efficiency is experienced with the system designed. As shown in Figure 14, when a panel in each series arm is defective, power cannot be transferred to the load in the old system. However, in the proposed system, the defective panels are disabled and the energy production of the other panels continues.

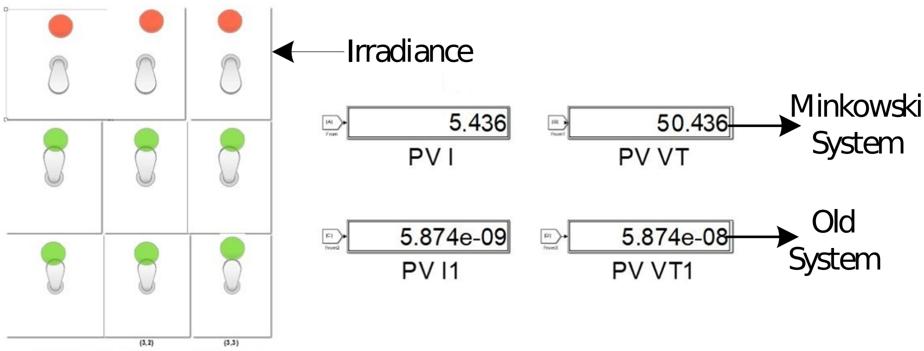

Figure 14. Power transferred to load when shading the three panel

4. Conclusion

As a result of the simulation study, it was observed that the efficiency of the simulation study using Minkowski's theorem was higher than the efficiency of the classical connection systems. In addition, in case of failure in serial circuit with the proposed theorem, the energy production of other panels is ensured without interrupting the series circuit and the system efficiency is maintained.

As can be seen from the simulation study, small structures were added to the classical systems and new hardware structures were formed. It is thought that the simulation works will contribute to the system with great amount.

5. References

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