

# The Effects of Metallization of Busbars on the Performance of PV Cell

Abdul Qayoom, Abdul Qadir, and Qasir Ali

**Abstract**—Photovoltaic (PV) technology is one of the upcoming leading technology to curb environmental issues without affecting sustainable development. However, its efficiency and cost are the significant issues in getting its peak in energy sector. In this paper we have numerically investigated the effects of metallization on the performance of PV cell. By using Griddler2.5 software various designs of H-pattern PV cells have been studied. It is revealed that increase in the number of busbars augments the shading factor from 4.11% to 8.75% and fill factor increases from 69.39% to 81.06%. Moreover, it is found that efficiency of PV cell increases when busbars value reaches to 4, then it decreases, it may be due to the influence of shading. Similarly, as the size of busbar increases so does the shading factor increase from 5.05% to 12.54% and fill factor from 80.29% to 80.49%. While in this case efficiency decreased from 19.91% to 18.17% throughout sizing range of busbar in the study. Hence it found that thin metallic busbars are more beneficial for PV cell performance and optimal number of busbars to be used in a PV cell is 4.

**Index Terms**—Metallization, PV cell, renewable energy, solar energy.

## I. INTRODUCTION

Human being has been exploiting energy from the all-natural resources whether renewable or non-renewable. Whereas, fossil fuels (non-renewable) are being used greatly. The use of these non-renewable energy resources resulted significant negative effects on the earth atmosphere, disturbing natural weather patterns. Most significant effects of these fossil fuels are global warming and climate change, these are cause by increasing concentration of greenhouse gases like CO<sub>2</sub>, CH<sub>4</sub> etc. In Paris agreement of 2015, researchers and scientists reported the increase in global warming by 1.5 Celsius above pre-industrial level [1]. To fulfil the energy needs for sustainable development and prevention of degradation of natural environment, researchers find renewable energy technology as better option

Renewable energy resources (Wind, Solar, Tidal, Bio-Energy, Geothermal and Hydel energy) are the options to exploit energy by different ways. Due to a great amount of solar radiation i-e 120,000MW per day falling continuously, solar energy resource could be one of the promising ways to achieve goals. Solar energy could be converted by direct (PV-technology) and indirect technology (Solar thermal System). However, Photovoltaic (PV) technology has

emerged one of the convenient ways to convert solar energy into electrical energy [2].

In PV technology the current is collected by employing current conducting metals on front and rear side of the cell called metallization.

PV technology uses silicon material doped with tri-valent element and penta-valent element for preparing PV cell (device which converts radiant energy into electrical), due to photo voltages generated in cell current flows which is collect by deploying current conducting metals on front and rear side of the PV cell called metallization [3]. Metal conductors which collect current from semiconductor material are called Fingers and conductors collecting current from fingers to load are called Busbars [4]. Fingers are very integrated with semiconductor device while busbars are pasted on the semiconducting material as shown in fig. 1. Metallization is necessary to collect PV cell generated current, but it also limits conversion efficiency of cell by reducing active area for energy conversion and increasing shading factor [5]. In addition, it has effect on the cost of device.

This paper attempts to numerically investigate the effect of busbar sizing (H-pattern designed) and number of busbars on efficiency and fill factor of silicon PV cell to find optimized sizing of metallization for silicon PV cell which give us better efficiency and fill factor.

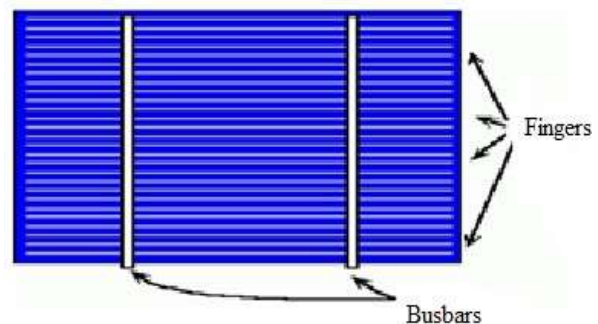


Fig. 1. PV cell fingers and busbars.

## II. OPERATING PRINCIPLE OF PHOTOVOLTAIC CELL

Silicon photovoltaic cell is made of semiconducting device made of semiconductor usually silicon doped with –group-III and group-IV elements of the periodic table. Doping forces free electrons of pentavalent element to flow towards trivalent group element and gets positive charge on it, similarly free holes of another dopant will flow to pentavalent group element and gets negative charge which creates potential barrier, now when sunlight strikes with that semiconducting material photons carrying energy depletes energy gap of semiconducting material and creates path for

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charge carriers to flow, the movement of charges is the electrical energy converted from electromagnetic radiation of sun energy only some of radiations emitted by sun are converted into electrical energy, some of radiations other than causing current are reflected by the outer cover of PV module some are just absorbed by the material and cause increase in the temperature of module [6]. The operation of a photovoltaic cell is shown in Fig. 2.

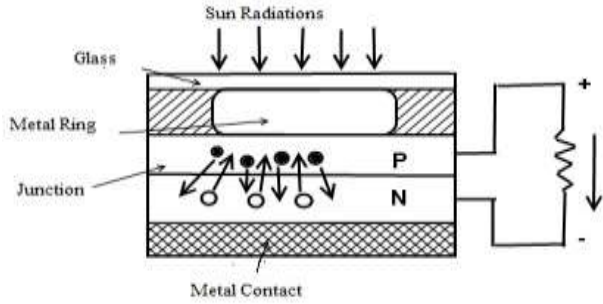


Fig. 2. Operating principle of photovoltaic cell.

### III. BASIC TERMINOLOGY

#### A. Efficiency

Efficiency is an important parameter to analyze and compare the performance of PV cell. It is ratio of power converted by PV cell in in form of electrical energy to power of sun in the form of radiation falling on cell, mathematically:

$$\eta = \frac{V_{oc} I_{sc} FF}{P_{in}} \quad (1)$$

Where  $\eta$  is efficiency,  $V_{oc}$  is open circuit voltage,  $I_{sc}$  is short circuit current,  $FF$  is fill factor and  $P_{in}$  is Power incoming from sun.

#### B. Fill Factor

It is defined as ratio of product of current and voltage of cell operating at maximum power point (MPP) to multiplication of open circuit voltage and short circuit current. Graphically, the  $FF$  is a measure of the "squareness" of the PV cell.

$$FF = \frac{V_{mp} I_{mp}}{V_{oc} I_{sc}} \quad (2)$$

$$FF = \frac{P_m}{V_{oc} I_{sc}} \quad (3)$$

$$FF = \frac{\eta A_c G}{V_{oc} I_{sc}} \quad (4)$$

where,

$P_m$  is Power obtained at MPP,  $V_{mp}$  is Voltage at MPP  $I_{mp}$  is Current at MPP,  $V_{oc}$  is open circuit voltage.  $I_{sc}$  is short circuit current,  $FF$  is fill factor,  $A_c$  is cell area and  $G$  is global solar irradiance.

#### C. Active Area

It is the area of silicon photovoltaic cell available for conversion of sun radiation into electrical energy. Active area

is providing free space for sun radiation to transmit its energy to semiconducting material and it is affected by metallization for current collection.

#### D. Passive Area

Passive area is defined as the area of silicon photovoltaic cell covered by metallization i.e. Fingers and Busbars is called passive area. It does not have any role in energy conversion rather it increases optical (shading and reflective) losses with cell.

#### E. Shading Factor

It is ratio of passive area to active area of silicon photovoltaic cell. It has direct relation with the size of metallization but if cell is well designed shading factor could be reduced. Renowned PV cell producer proposed shading factor as high as 5% but one could optimize metallization to achieve optimal fill factor without affecting conversion efficiency of silicon photovoltaic cell.

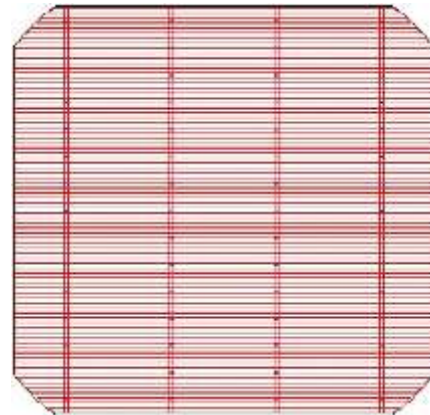


Fig. 3. PV cell with 4-busbar front view.

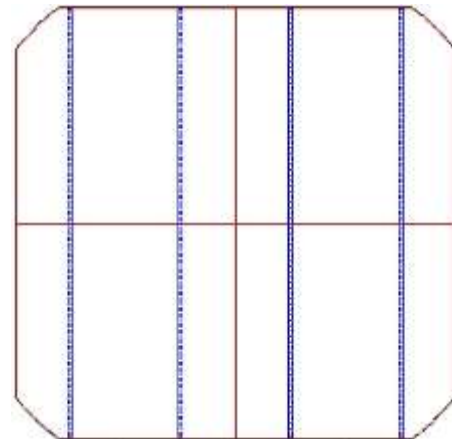


Fig. 4. PV cell with 4-busbar rear view.

### IV. METHOD AND MODEL

AUTOCAD is a 2D and 3D designing software developed for engineers and architects to create any design related to Civil, Mechanical, Electrical and MEP. Design developed can be saved in any format as per requirement of simulation software [7]. In this study various designs of PV cell are designed with different number and size busbars and saved in DXF file format to import in GRIDDLER 2.5 for simulation. Fig.3 and Fig.4 are front and rear view of pseudo-squared PV cell model developed on AUTOCAD. Design is developed using polyline function of AUTOCAD for every section i.e.

Wafer boundary, fingers and busbars while probe points are made by using circle draw function. Wafer dimensions used in this study are 156mmX156mm. Busbars and fingers are created on both front and rear side; front fingers collect front photo generated current and front busbars carry that finger current to load side. The front and rear fingers and busbars perform same job i.e. to collect rear current and supply to load.

Griddler [8] is “a finite-element method (FEM) solar cell simulation tool which models the cell plane as a distributed network of resistors and diodes” [9]. Software is programmed with import function to import AUTOCAD designed PV cell metallization in DXF format for simulation. It creates meshes for creating nodes parallel and perpendicular to lines and then solve current crowding and contact resistance within itself and with semiconductor, this makes GRIDDLER an ideal software for simulation with different metallization grid of a solar cell [10]. Once cell is analyzed by creating mesh file, it is ready to show results of shading factor and generates IV and PV curves along with fill factor of the cell and finally report of the simulation is ready to save [11].

### V. RESULTS AND DISCUSSION

Fig. 5. Shows the influence of increasing number of busbars from 1 to 6 on shading factor of the cell. It is clear in graph shading factor has direct relation with number of busbars. As the number of busbars increases so does the shading factor and it keeps increasing in range of 4 percent to 8.6 percent respective to number of busbar range. As per PV cell producers, shading factor must not exceed by 6% hence optimal value is achieved using 3-busbar designed PV cell. Shading factor increases because busbars are just printed on the surface of semiconducting material.

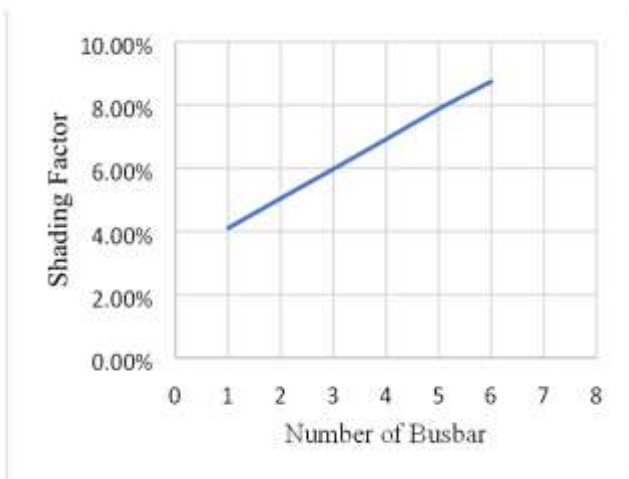


Fig. 5. Influence of number of busbars on shading factor.

In the next simulation run we have investigated the effect of number of bus bar on the efficiency of cell. Fig. 6 depicts the effects of augmenting number of busbars on efficiency. Initially efficiency has a sharp rise and it rises from 17.4% to 19.3% by increasing busbars from 1 to 2, however efficiency curve tries to stabilize until 4-busbars. After which efficiency drops to 19.22% due to large increments in shading factor. It is revealed that optimal maximum efficiency is achieved using 4-busbar designed PV cell.

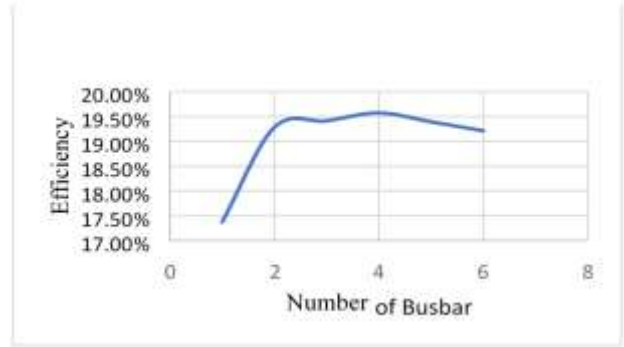


Fig. 6. Influence of number of busbars on efficiency.

Whereas the effect of using a greater number of busbars on fill factor of PV cell is shown in Fig. 7. Fill factor increases rapidly from 69.39% to 77.78% in response to increasing busbar from 1 to 2 busbar. Using 3-busbar designed PV cell, fill factor has shown a significant increment of 1.43% after which fill factor increases a bit and then fill factor become stable.

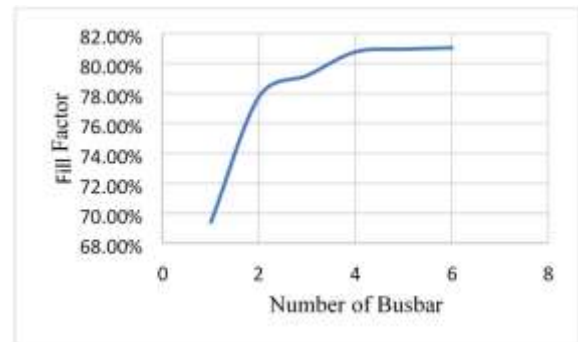


Fig. 7. Influence of number of busbars on fill factor.

Fig. 8. Is to analyze the influence of busbar sizing (width) on the shading factor of PV cell using 3-busbar design. Size shows a positive influence on shading factor. Shading factor increases all the way from 5% to 12.2% in response to increasing busbar size from 0.5 mm to 5 mm busbar each, however shading factor tries to be stable when using 3mm busbar each as shown in figure below.

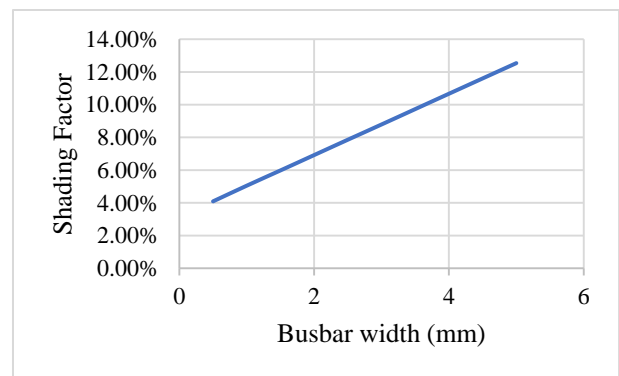


Fig. 8. Influence of busbar width on shading factor.

Fig. 9. Shows the influence of busbar sizing on efficiency using 3-busbar designed PV cell. Efficiency of PV cell decreases linearly by increasing busbar size because size has a great influence of shading which limits sun radiation to be absorbed in PV cell to generate photo current. Size also increases reflective losses which contribute on reduction of

conversion efficiency of cell. It is observed that efficiency goes as low as 18.2% from prescribed sizing range of study.

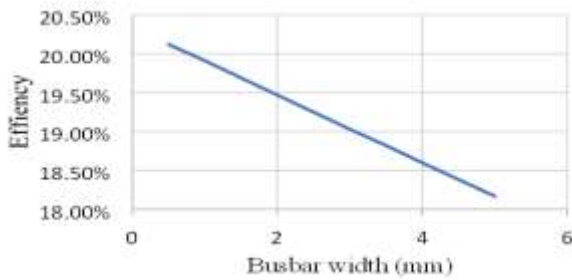


Fig. 9. Influence of busbar width on efficiency.

Fig. 10. Shows the influence of busbar sizing on fill factor of PV cell. Unlike effect of busbar sizing on efficiency, response of increasing busbar size is reversed, and fill factor increases with augmentation of busbar size however it is observed that fill factor improves by only 0.47% with 4.5mm increase of a busbar size for this study.

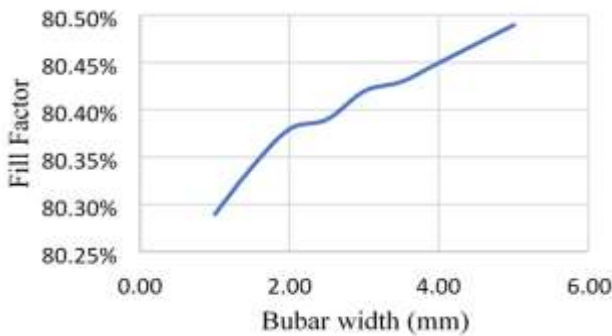


Fig. 10. Influence of busbar width on fill factor.

## VI. CONCLUSION

This study is aimed to highlight the effects of metallization on performance of a silicon PV cell. Numerical study is carried out by designing an H-pattern metallization for PV cell and analysis is done by varying number of busbars and size (width). Shading factor, efficiency and fill factor of device were observed at different number of busbars ranging from [16] and size on the range of [0.5mm-5mm].

Results showed that increase in number of busbar and its size increased shading factor by reducing active area of PV cell for conversion. It is observed that efficiency and fill factor achieved optimal value using 4-busbar and 1mm width each. It is found that fill factor kept rising even after optimal value recorded however efficiency decreased. Increase in fill factor was observed by 0.2% while decrease in efficiency was by 1.7% in prescribed range of busbar sizing. Further studies are needed to design new patterns rather H-pattern and also investigate the influence of fingers on PV cell performance for optimization of metallization on PV cell.

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