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Highlights

- Photovoltaic Power Stations
- Evaluation of Residual Stress
- Kinetic Induktance Charges
- Design and Simulation Patterns

Discovering Thoughts, Inventing Future

VOLUME 14 ISSUE 5 VERSION 1.0

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Photovoltaic Power Stations (PVPS)

By Mohamed A. Darwish, Hassan K. Abdulrahim & Adel O. Sharif
Qatar Environment and Energy Research Institute (QEERI), Qatar

Abstract- Qatar declared that by 2020 solar energy would produce at least 2% of its total generated electric power (EP). The known solar power plants EP at utility scale level are concentrating solar power (using parabolic trough collectors, linear Fresnel collector, and solar tower), photovoltaic (PV), and integrated solar combined cycle using fossil fuel (natural gas) besides solar collectors.

EP generation by PV is reliable, clean, well proven, and matured technology, with 25 years warranties on solar panels. PV is the direct conversion of solar radiation (sunlight) into direct electric current by semiconductors that exhibit PV effect. The PV can be applied to large scale power plants called photovoltaic power station or solar parks. A solar park is connected to the grid, and thus supplies its bulk produced EP to this grid. Transfer solar energy directly to EP is achieved without using moving parts means very low maintenance and operation requirements. Once a solar park is installed (with relatively high cost compared to conventional power plat such as combined cycle), the operating costs with no fuel supply are extremely low compared to conventional power plants.

This paper presents the technology and economics of the PV power station. It outlines the main components of the PV power plants including the solar PV modules, module mounting and tracking systems, inverters (or converters), and step-up transformers. It reviews the materials of the PV cells, the PV cells degradation, and the existing PV power plant. Utility PV power plants around the world were reviewed.

PV panel are extensively used for small-distributed power generation used in homes and in remote areas. One of the advantages of building solar parks in Qatar (and other GCC) is the coincide of its power output with the high air conditioning electric power demand in hot summer days. The GCC is the Gulf Co-operation countries including Saudi Arabia, United Arab Emirates, Qatar, Oman, and Bahrain. Recent reductions in photovoltaic cells cost are the driving force behind the trend of building more solar parks worldwide.

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PHOTOVOLTAICPOWERSTATIONSPVPS

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Mohamed A. Darwish [α], Hassan K. Abdulrahim [σ] & Adel O. Sharif [ρ]

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The System Advisor Model (SAM) software developed by National Renewable Energy Laboratory (NREL) gives the total direct capital cost of the 20 MW PV plant as $88.0 million (M), and total installed cost as $ 97.202 M; or $4.86 M/MW. This is almost half the cost of the CSP using by parabolic trough plants. The LEC, as given by the computer program is $0.16/kWh. The main disadvantage of the PV power station is non-dispatch ability.

I. Introduction

Production of Electric Power (EP)by photovoltaic (PV) is clean well proven technology, that are applied in large scale Power Plants (PPs) called PV Power Station (PVPS), or solar parks. The bulk of the generated EP by the PVSPS is supplied to the electric grid output, Fig. 1, [1].

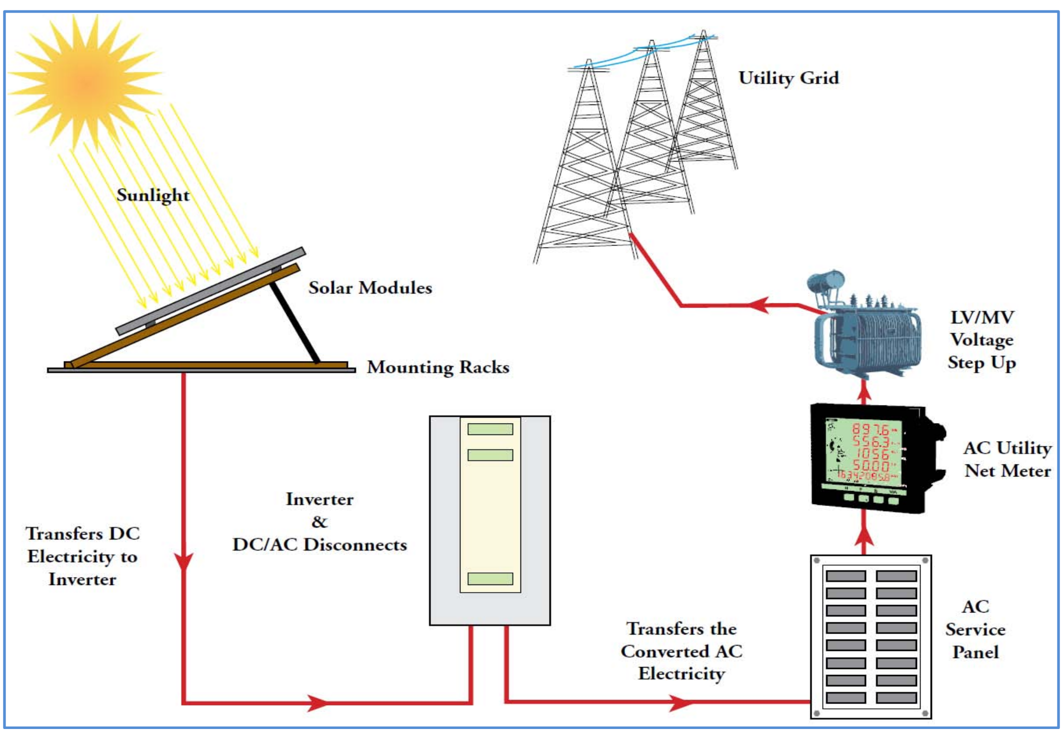

Figure 1 : Overview of Solar PV Power Plant, [1]

Author α σ ρ: *Qatar Environment and Energy Research Institute (QEERI) – Qatar Foundation, Doha, Qatar. e-mail: habdelrehem@qf.org.qa*

Global Journal of Researches in Engineering (J) Volume XIV Issue V Version I Year 2014

The economy of PVPS is improving by time as shown Fig.2a, [2]; and solar cell production is increasing, Fig.2b, [3]. The capacity of the PVPS is on the rise worldwide, Fig. 3a, [3] due to the decrease of PV cells' cost, Fig. 3b, [4]. By the end of 2013, the installed capacity of PVPS reached 136 GW, see Fig. 3a. The PVPS was rated the third in terms of capacity of the renewable energy power plants after hydro and wind in 2011, [3]. This capacity is almost doubled between 2011 to 2013 due to PV cells continuous falling costs and increasing cost of fossil fuel used in conventional power plants. It is estimated that solar module prices used in utility-scale sector (2.5 MW and above) would fall from 1.22 €/W in 2012 to 0.92 €/W in 2022, [5]. Module prices cost, are contineously deccreasing as shown in Fig. 3b. A list of the countries having the highest PVPS capacity is given in Table 1, [4].

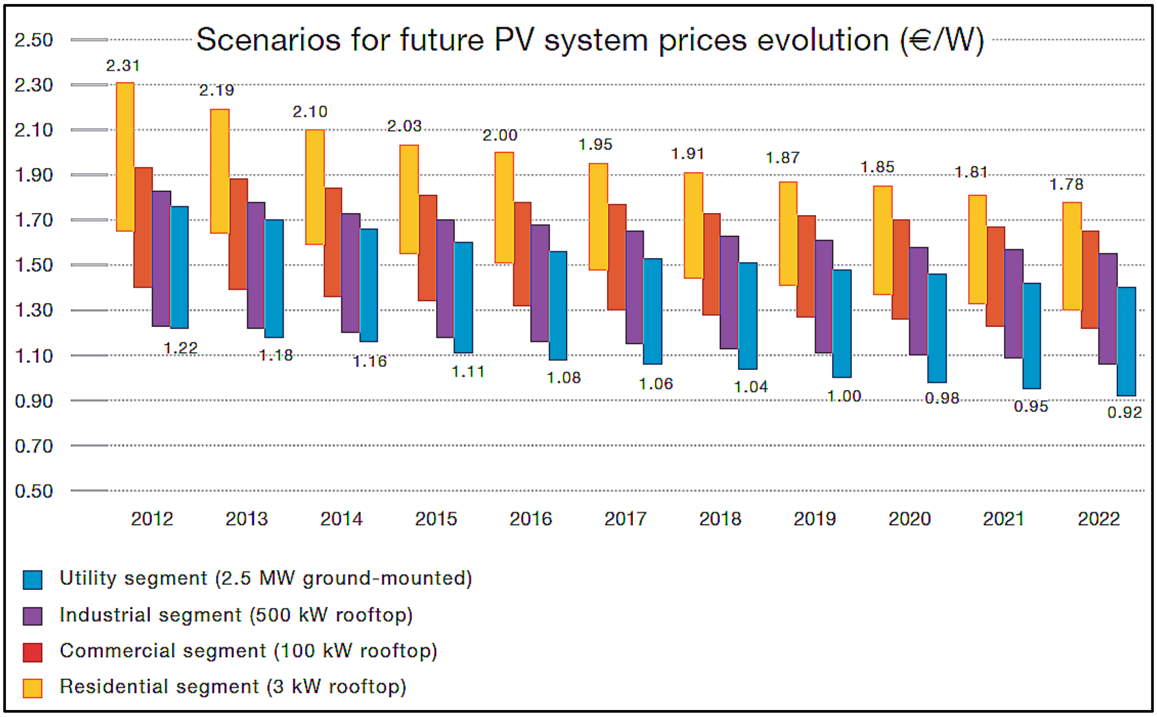

Figure 2a : Future PV Systems Evolution in Euro/W, [2]

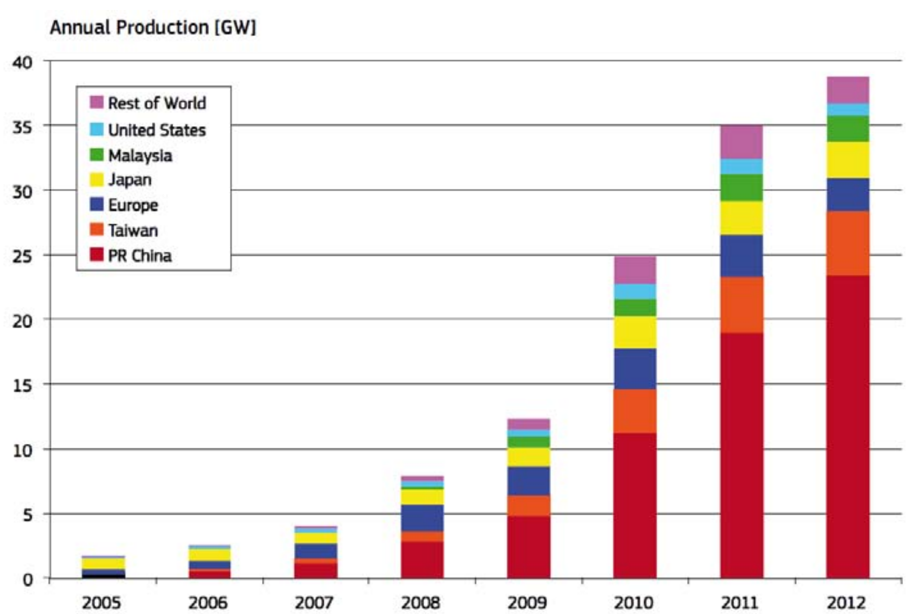

Figure 2b : World PV Cell/Module Production from 2005 to 2012 (data source: Photon International [Pho 2012], PV Activities in Japan [Pva 2013], PV News [Pvn 2013] and own analysis), [3]

Global Journal of Researches in Engineering (J) Volume XIV Issue V Version I Year 2014

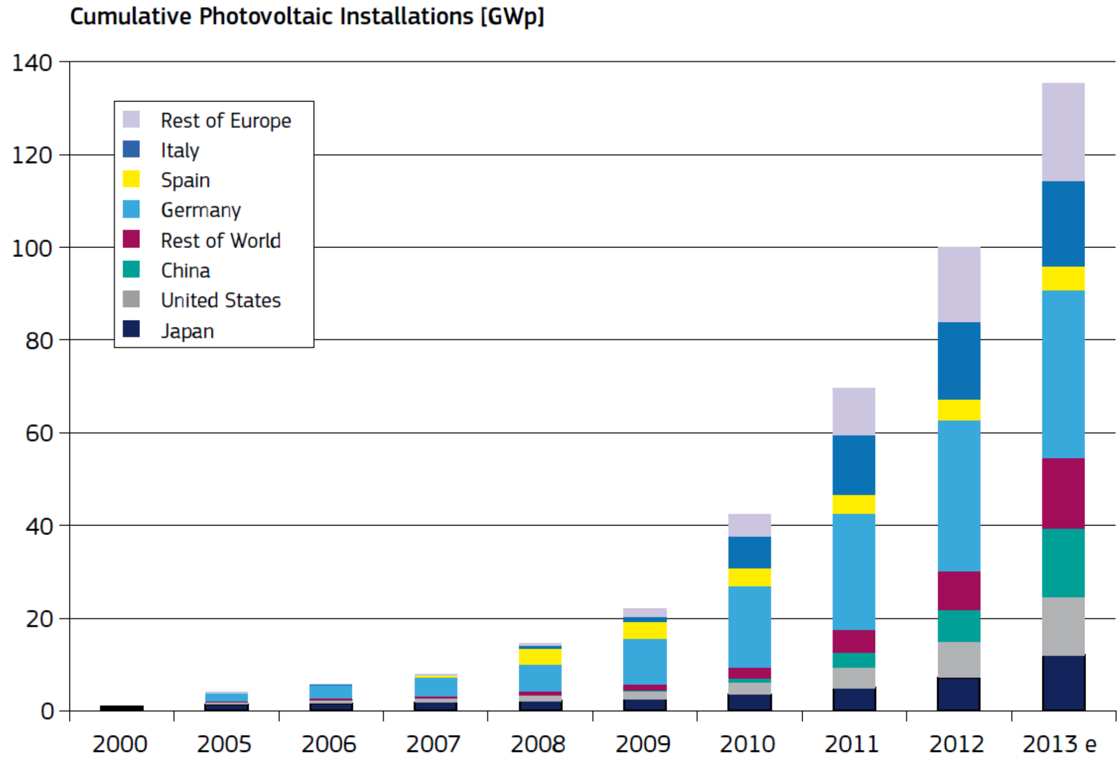

Figure 3a : Cumulative PV Cumulative Photovoltaic Installations [GWp] installations from 2000 to 2013, [3]

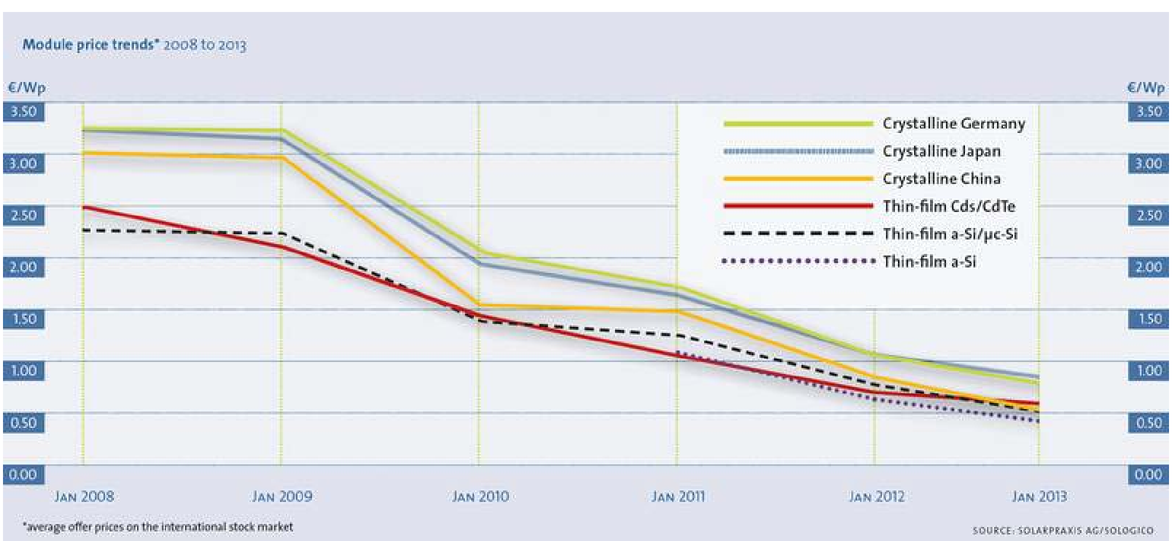

Figure 3b : Module price trends, [4]

Table 1 : Top 15 markets 2012 worldwide, [5]

	Country	2012 Newly Connected Capacity (MW)	2012 Cumulative Installed Capacity (MW)
1	Germany	7,604	32,411
2	China	5,000	8,300
3	Italy	3,438	16,361
4	USA	3,346	7,777
5	Japan	2,000	6,914
6	France	1,079	4,003
7	Australia	1,000	2,412
8	India	980	1,205
9	United Kingdom	952	1,829
10	Greece	912	1,536
11	Bulgaria	767	908
12	Belgium	599	2,650
13	Spain	276	5,166
14	Canada	268	765
15	Ukraine	182	373
	Rest of the World	2,692	9,546
	Total	31,095	102,156

In Qatar, the advantages of using PVPS are clear. The primary solar energy (sunlight) is free and abundant, no moving parts and thus the needed maintenance is low, and low operating cost as no fuel is used. No water is required for operation except that needed for cleaning the panels. The decreasing cost of the PV modules lowers the capital cost and drives for installing more PVPS. The main factors hindering the spread of PVPS are still high capital cost, large needed site area, and the fact that the PVPS are not dispatch-able plants. The site area of a PVPS having 15% efficiency and fixed tilt modules is about 10,000 m^2/MW in tropic regions (23.5 degrees to the North and South of the Equator respectively); and up to 20,000 m^2/MW in Northern Europe. One square kilometer site can be used for 50 MW. This area increased about 10% for a single axis tracker, and 20% for a 2-axis tracker to avoid shadow.

The largest cost of PVPS is still that for the modules, (accounts for about 50% of total cost), followed by costs of installation materials, labor, and the inverters. The inverters replacement cost can be significant. The PV modules warranty is generally about 20–25 years long; while, the inverters warranty is typically 10–15 years long. Improvements are rapidly achieved in many subsectors, [6].

Ratings of PVPS are usually given in terms of the solar arrays DC peak capacity in MWP, or nominal maximum AC output in MW or mega volt-amperes (MVA). Solar parks usually have medium capacity (1-20 MW), although there are large capacity operating PVPS in operation, and large plants capacity (up to one GW) are planned. The Agua Caliente solar project is now the largest operating PVPS with 290 MW in Yuma County, Arizona. Figure 5 shows a 3.5 MW plant operating in Saudi Arabia.

Global Journal of Researches in Engineering (J) Volume XIV Issue V Version I Year 2014

Figure 5 : Saudi Arabia: The ground-mounted photovoltaic plant with a peak output of 3.5 MW is located in Riyadh in the grounds of the KAPSARC (King Abdullah Petroleum Studies and Research Center), the largest oil research center in the world, Photo: Phoenix Solar AG, [4]

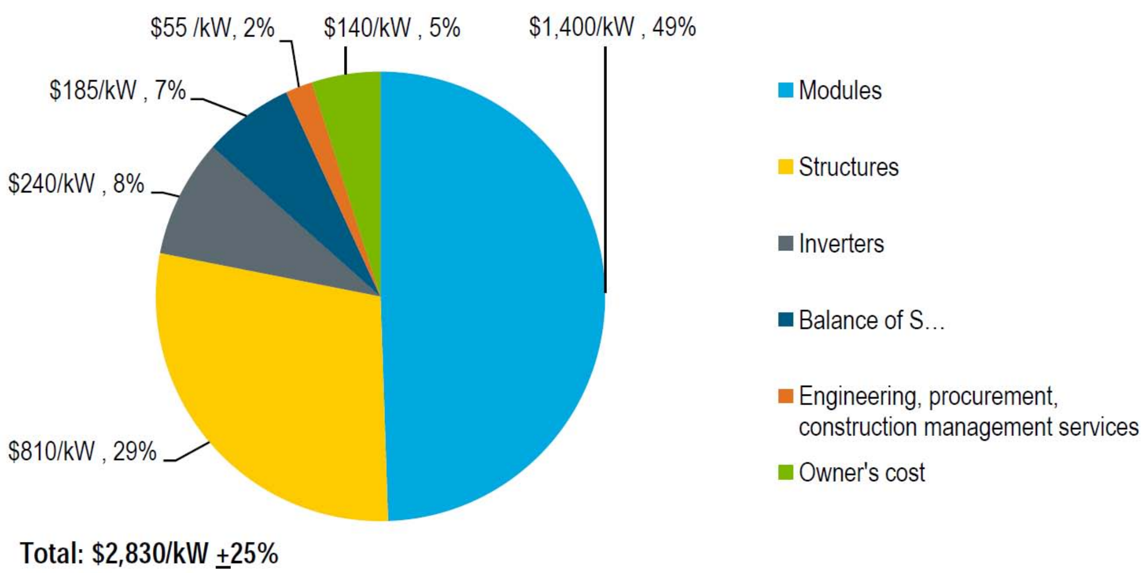

Figure 6a : Utility-scale PV facility by cost component, [7]

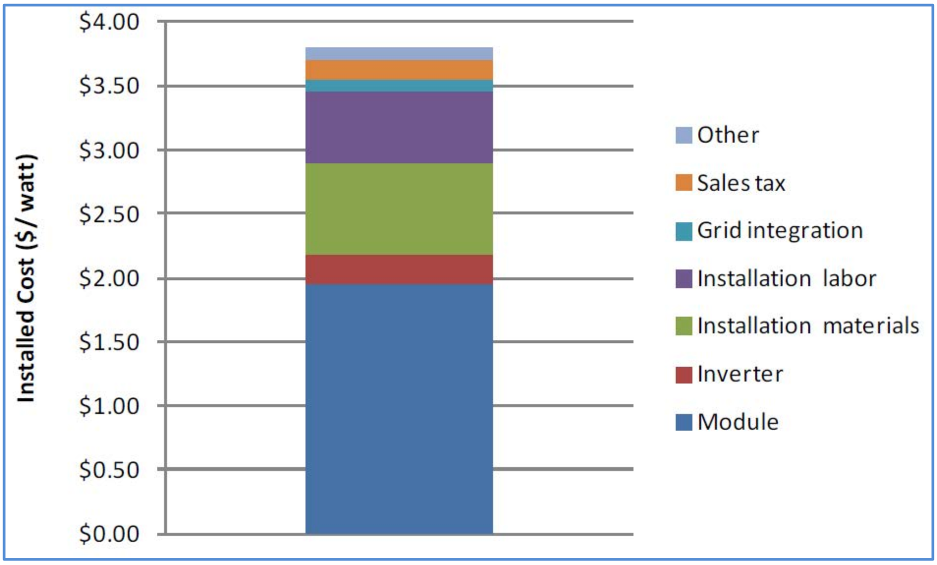

Figure 6b : Utility-scale PV facility by cost component, 2011, [7]

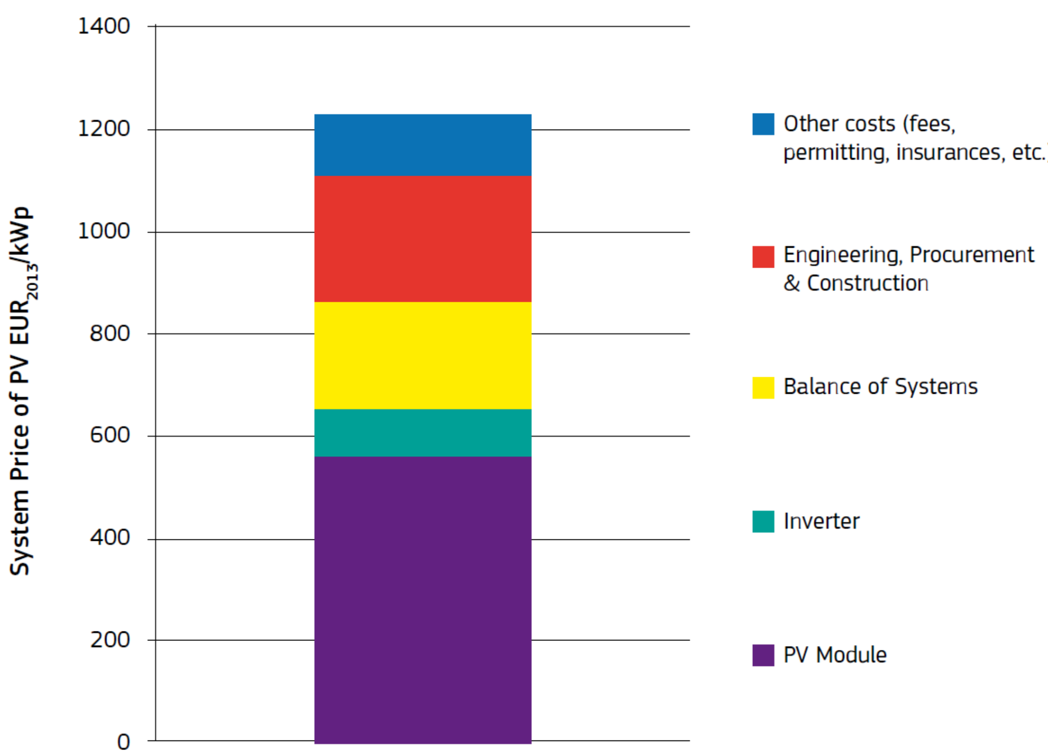

Figure 6c : Utility-scale PV facility by cost component, 2013, [3]

The cost breakdown for a fixed-tilt utility-scale PV system utilizing crystalline-silicon (c-Si) modules is shown in Figs. 6a-6c. Lower efficiency thin-film modules generally cost less but can have higher balance of plant (or non-module) expenses. This includes costs for supporting structures, DC cabling, and inverters.

The PVPS high cost and low load factorin comparison with conventional EP generation plants options are the main obstacles against the widespread of the PVPS. Factors that can improve the competitiveness of PVPS with other EP generating systems are:(a) cost reductions of solar cell modules, (b) growing concerns about energy security and climate change, and (c) continuous increase of the fossil fuels cost. Solar panel cost per watt have been falling steadily from $70/W in 1970 to $4/W in 2011, (this cost does not reflect the total system cost, which will vary widely based on the application.). However, the PVPS cost is still expensive compared to other power generation systems, [8]. The cost of the Gas Turbine Combined Cycle (GTCC) power plants that are commonly used in Qatar is low, in the range of $1.5/W compared with $5/W for the PVPS.

The National Renewable Energy Laboratory (NREL) in US, [9], conducted an analysis showed that the 2010 prices of PV systems in the US (cash purchase, before subsidy and considering reported target installer operating overhead and profit margins) are:

- $5.71/WP DC – 5 kWP DC residential rooftop
- $4.59/WP DC – 217 kWP DC commercial rooftop
- $3.80/WP DC – 187.5 MWP DC fixed-axis utility-scale ground mount
- $4.40/WP DC – 187.5 MWP DC one-axis utility-scale ground mount

The US showed great growth in solar power plants. Solar parks capable of delivering a total capacity of up to 750 MW are being planned or are already under construction in California, Arizona, New Mexico and Nevada.

In the hot summer in the GCC, the highest demands of EP occur in the afternoon when air conditioning machines in homes and public building are working at their highest capacity and solar power produces its maximum yields.

II. Photovoltaic (pv) Power Plant Systemcomponent

The structure of a PV cell, as shown in Fig. 7a, has two semiconductor materials, the n-type that has extra electrons in a conduction band, and the p-type that has extra holes in a valence band. When photons of greater energy than the semiconductor band gap energy, Eg, see Fig. 7b, are absorbed by the cell, the photons excite the electrons of the composite material into a higher state of energy. This allows the electrons separation from their atoms, drive electrons from the valence band to the conduction band. The movement of electrons is allowed in single direction by the nature of solar cell composition. Due to the electrons separation, positive charges are created (called holes) that flow in direction opposite of the released electrons, and this creates holes-electron pairs flowing in opposite directions across the junction, and act as charge carriers for a direct electric current. This process is called photovoltaic (PV) effect. The generated electron/hole pairs by the energy of the incident photons overcoming the energy band gap of the PV material to make a current flow according to the built-in potential slope, typically with a p-n junction of semiconductor, in the material. The freed electrons carried away by metal electrodes, and power is produced by connecting the electrodes to an external load. So, the operation of solar cells is based on the binding energy of electrons of a crystal. Two bands, called conduction and valence, can be totally or partially occupied by electrons, Fig. 7b. Therefore, the PV cells consist of layered of semiconductors in contact with metal electrodes and covered by a protective transparent glazing. The semiconductor material used in cells is predominantly silicon because the band gap energy of silicon results in theoretical efficiency very near to the maximum for solar radiation. The maximum efficiency of a PV cell can be increased further if multiple semiconductor layers, or junctions, are stacked. In this case, the band gap of each layer is optimized for a different range of photon energies, thereby taking advantage of a greater range of the solar spectrum and improving the overall cell efficiency. A solar module consists of assembled and connected solar cells, and an array consists of assembled and connected solar modules. The array converts solar energy into a usable amount of direct current (DC) electricity.

a) Main Components

The main components in the PV power systems include:

i. *Solar PV modules*

As given before, a PV module is combination of PV cells that produce direct electric current (DC) from sunlight with no moving parts.

Typical cells of 3W, 0.5 volts can be connected in series to produce summation of the 0.5 volts and power. When cell are connected in parallel, the output current will be the summation of current produced by the cells, but the voltage would be that of the cell.

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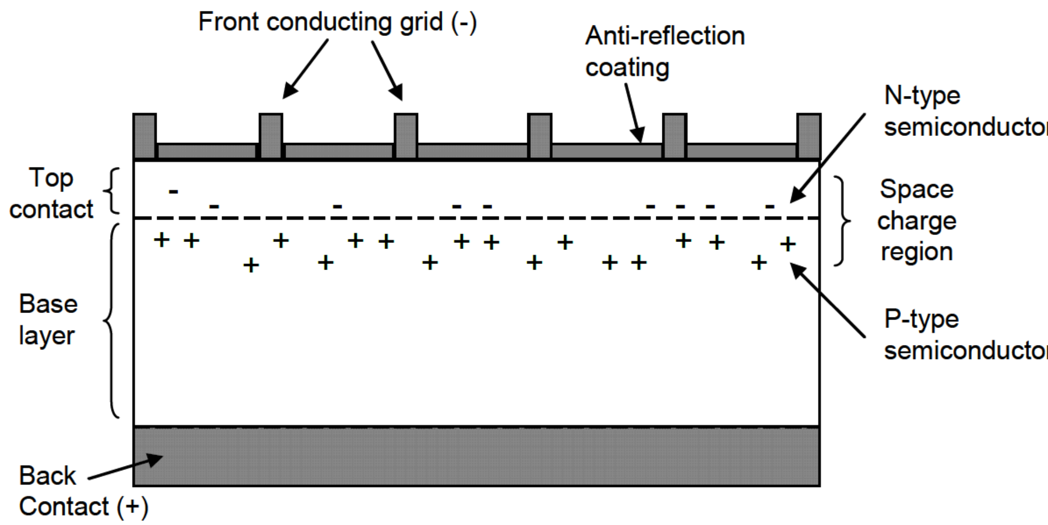

Figure 7a : PV cell structure, [10]

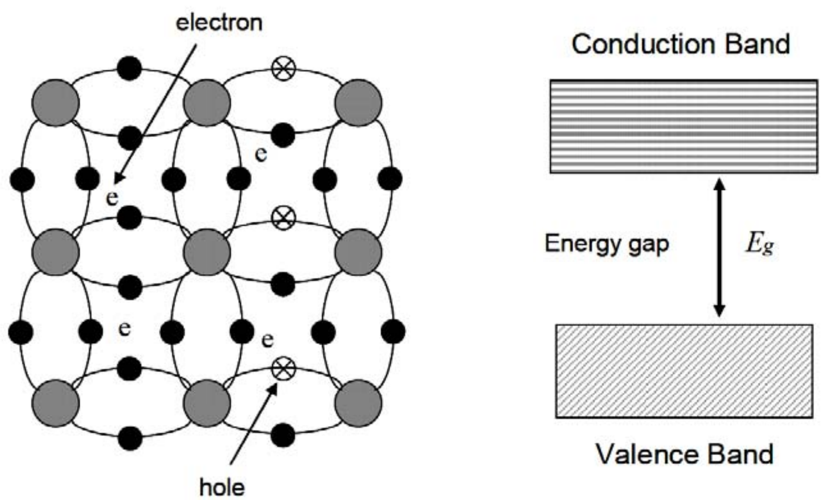

Figure 7b : The cells are electrically connected in series and in parallel to form a module, [10]

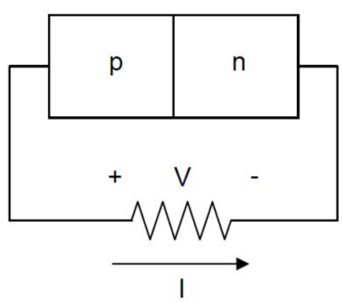

Figure 7c : Operating scheme of photovoltaic cell, [10]

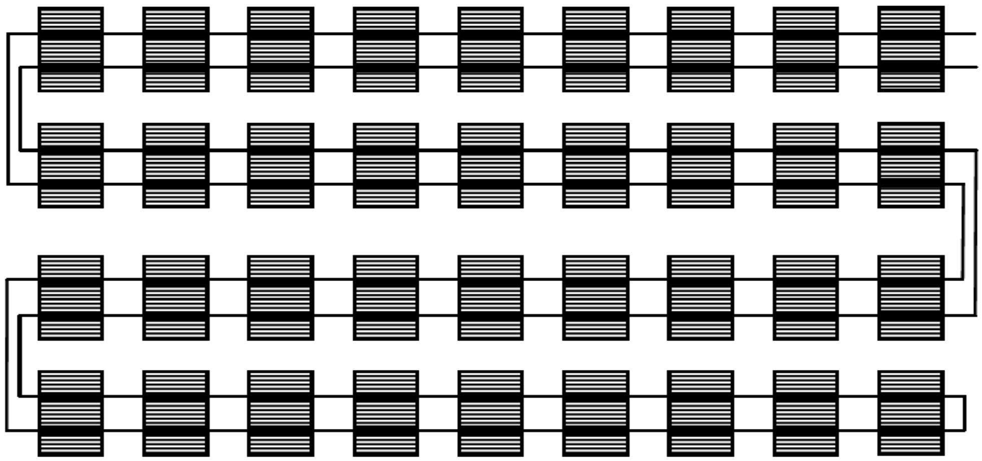

Figure 7d : Sturcture of a PV module consisting of 36 cells connected in series, [10]

When modules are connecting in series, high voltage can be obtained; and when connected in parallel, high current can be obtained.

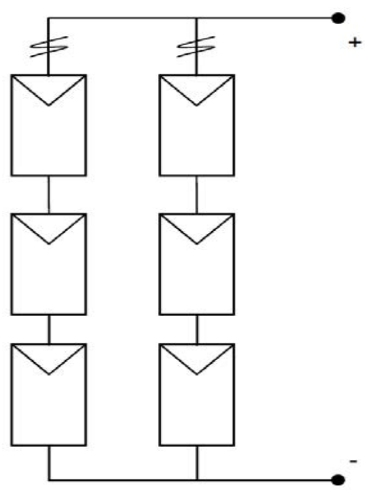

Figure 7e : Modules forming a panel connected in series-parallel with internal by pass diodes and series fuses, [10]

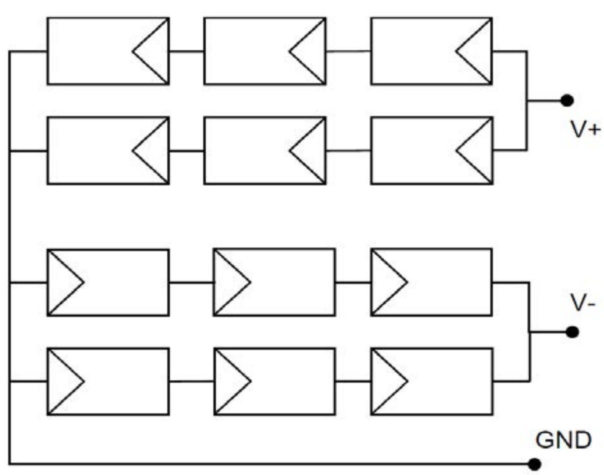

Figure 7f : Modules forming a panel connected in series-parallel with center grounded to provide + and – supplies (fuses and diodes not shown), [10]

Figure 8a shows the current (I)-voltage (V) for a module at specific irradiance. It shows the short circuit current (I_{sc}), open-circuit voltage (V_{oc}) and the maximum power point (Imp; V_{mP}), at which maximum power is attained. These three points are usually given by the PV cell manufacturers as shown for a typical PV module (KC200GT).

The I-V curves of modules are affected by the irradiance and temperatures as shown in Fig. 8a and 8b, [11].

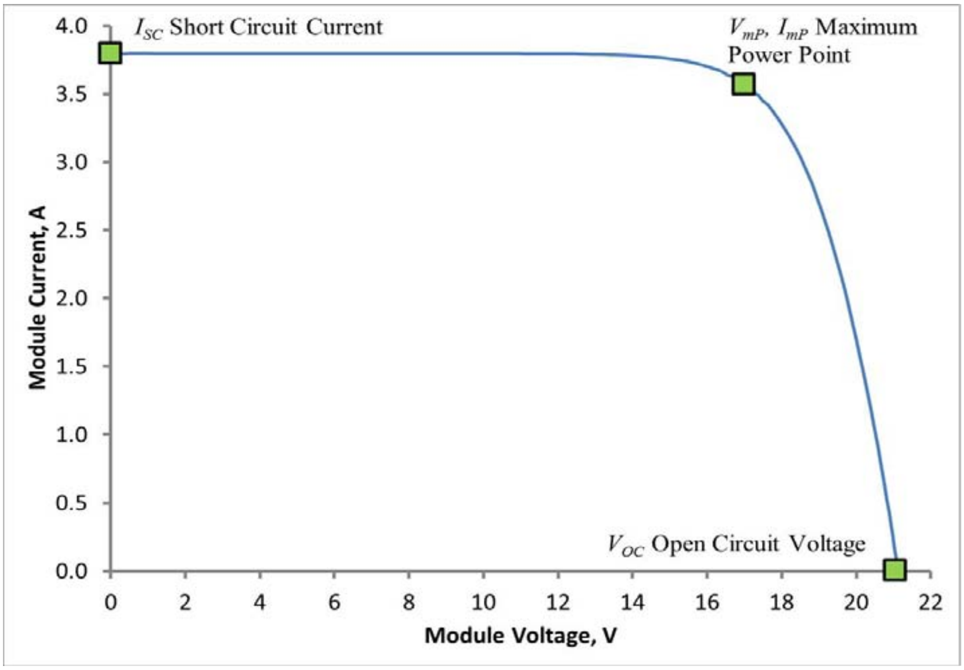

Figure 8a : Photovoltaic module I-V characteristics

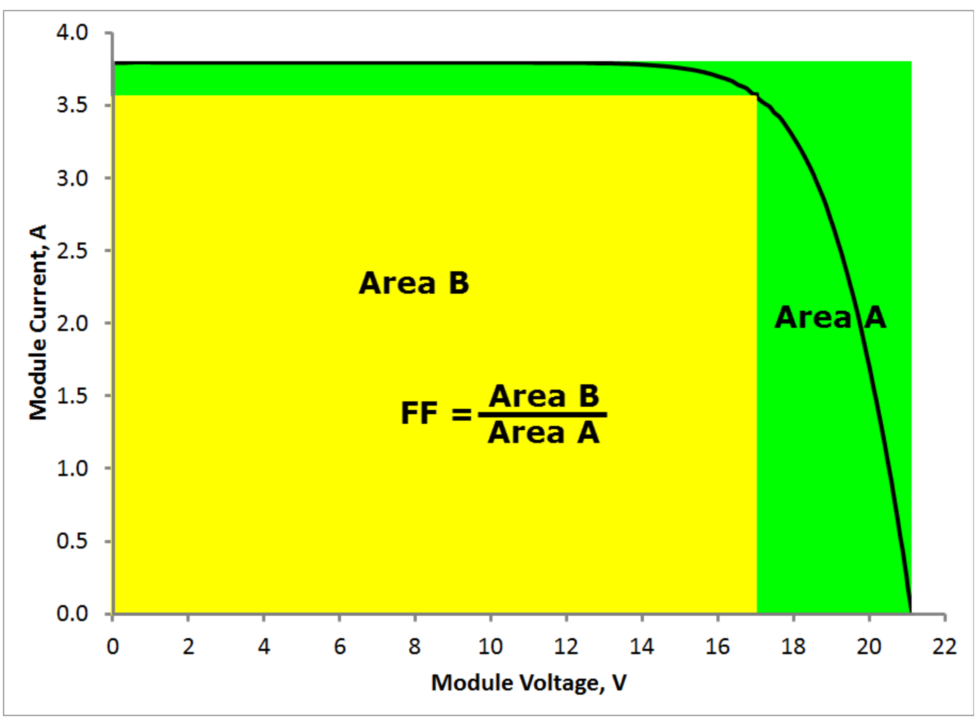

Figure 8b : Photovoltaic module characteristics showing the fill factor, [11]

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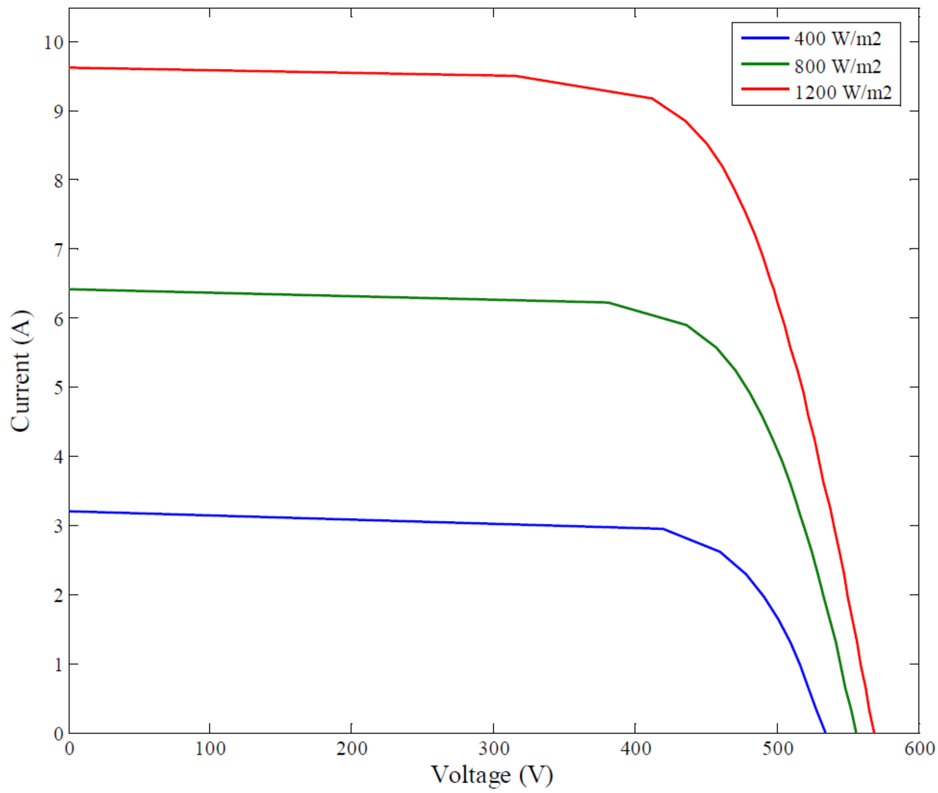


Figure 8c : The effect of irradiance on the I-V characteristics for typical module, [11]

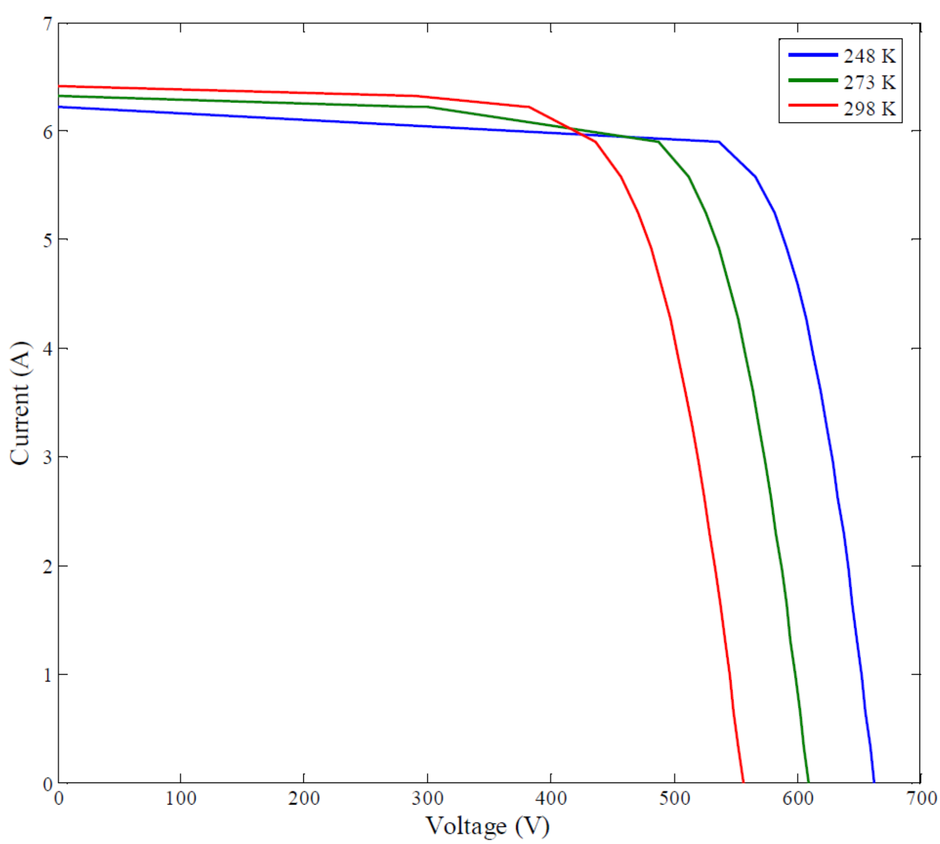


Figure 8d : The effect of temperature on the I-V characteristics for typical module at 800 W/m^2 irradiance, [11]

Table 2 : Datasheet Parameters for KC200GT, [12]

Irradiance	1000 W/m^2	800 W/m^2
Maximum Power Point Current	7.61A	6.13A
Maximum Power Point Voltage	26.3V	23.2 V
Maximum Power Point	200.14 W	142W
Short Circuit Current	8.21 A	6.62 A
Open Circuit Voltage	32.9V	29.9 V

The maximum power point (optimum operating point) shown in Figs 8a and 8b of a PV module is function of cell temperature and in solation level and array voltage, as shown in Fig. 8d for a PV called KC200GT module are given before. A maximum power point tracker (MPPT) is needed to operate the PV array at this optimal point.

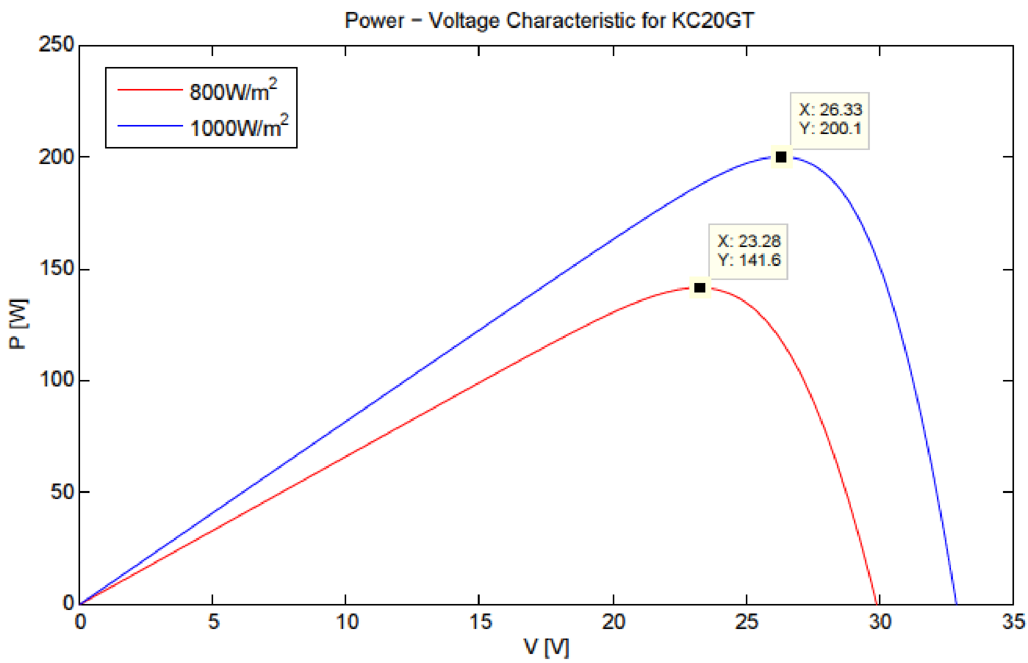


Figure 8e : Power-voltage characteristics of KC200GT, [12]

ii. *Inverters (or converters)*

Inverters convert the generated DC to alternative current (AC) in order to be connected to the utility grid. The modules are connected to the inverters through series strings and parallel strings. The PV systems connected to the grid normally do not have any real influence on the grid voltage. Their voltage operation range are therefore more of a protection function that is used for detecting abnormal utility, rather than regulators

iii. *Step-up transformers*

Further step-up of the inverters voltage output to that required by the AC grid voltage (e.g. 25kV, 33kV, 38kV, 110kV depending on the grid connection point) is conducted by further step-up transformers; see Figure 9, [1].

iv. *Module mounting (or tracking) systems*

The modules should be attached to the ground. They can face the sun at fixed tilt angle, or they can be fixed to frames that track the sun.

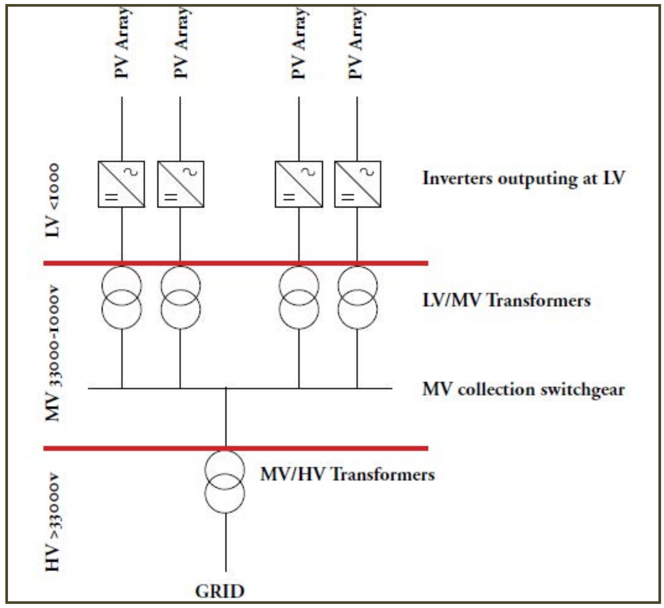


Figure 9 : Typical Transformer Locations and Voltage Levels in a Solar Plant where Export to Grid is at HV, [1]

The substation and metering points are usually located outside the PVPS and typically located on the network operator's property. Connections to the grid network are of major concern when building PVPS in terms of the availability, locality, and capacity. This network should be able to absorb the maximum capacity of the PVSP. The PVPS may be sited at a distance (few kilo-meters) of a suitable grid connection point.

b) Photovoltaic Cell Materials

Most PV cells are manufactured from silicon (Si) that doped with negatively and positively charged semiconductors of phosphorous and boron. When sunlight is received by the PV cell, electrons become free to flow from the negative phosphorus to the positive boron. The produced DC is obtained through a metal grid covering the cell and external circuit. Besides crystalline silicon (c-Si), and amorphous silicon (a-Si) thin-film technologies, only cadmium telluride (CdTe) has had significant success in utility-scale solar development.

Silicon (Si) material can be mono-crystalline, poly-crystalline and amorphous silicon. Ribbon cast polycrystalline cells are also produced by drawing, through ribbons, flat thin films from molten silicon to reduce the silicon waste by sawing from ingots and thus reduces its cost. Other than silicon materials, gallium arsenide (GaAs), cadmium telluride (CdTe), copper indium diselenide (CIS) and copper indium gallium selenide (CIGS) are used in PV cells manufacturing.

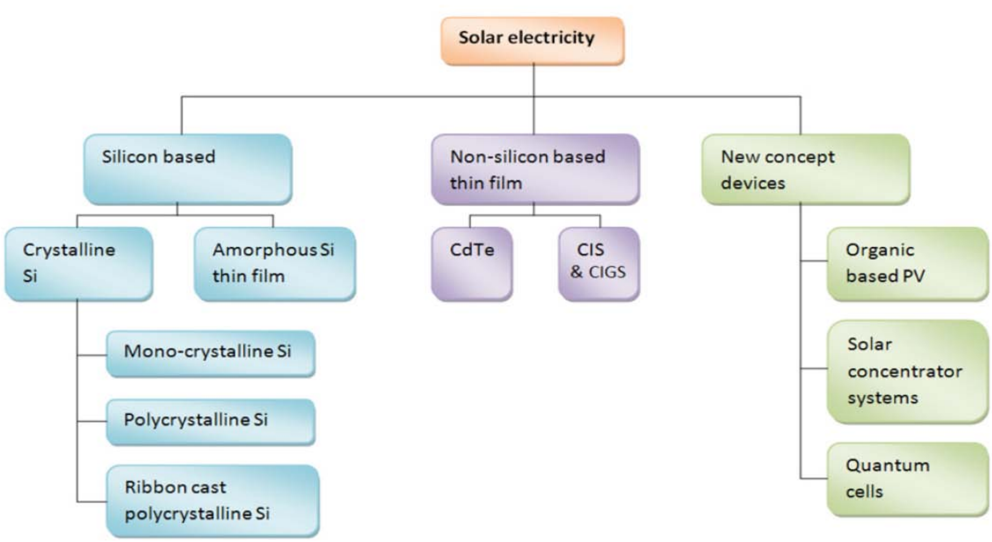


Figure 10a : PV cells material Technology [13]

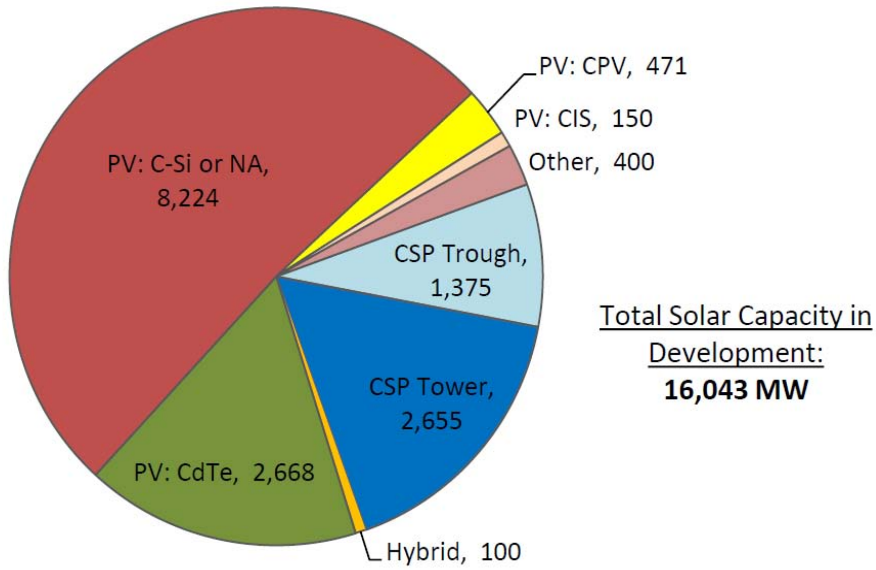


Fig. 10b : Total U.S. utility-scale solar capacity under development (all numbers in MW)

Among the utility scale PV plants in the US, about 24.5% use CdTe, and 74.5% use c-Si, see Fig. 10b.An overview of the different main PV cells materials is given in Fig. 10. The mono-crystalline cells are made of pure silicon, have grey or black color, more efficient (16–24%) than the polycrystalline silicon (14–18%), see Table 3. Solar panel efficiency is the ratio of electric power produced by a PV module to the power of the sunlight striking the module.

The polycrystalline silicon cells are easier to be manufactured (to be sawed from ingots) and thus cheaper but less efficient than the mono-crystalline cells, and have shiny blue color. Amorphous silicon (so called thin-film) cells consist of non-crystallized very thin layers deposited onto a substrate, has brown or red-brown color, reddish brown, and typical efficiency of 4% to 10%, see Table 3.The power per unit area is typically 75–155 Wp/m^2 for mono -crystalline and poly-crystalline modules, and 40–65 Wp/m2 for thin-film modules [13].

The other thin-film cells, other than the amorphous silicon, are Cadmium telluride (CdTe) and Copper indium (gallium) di-selenide (CIGS). The CdTesolar cells are manufactured on as ubstrate glass with transparent conducting oxide (TCO) layer usually made from fluorinated tin oxide (FTO) as the front contact. This is initially coated with an n-type cadmium sulfide (CdS) window layer and secondary with the p-type CdTe absorber layer. The color is reflective dark green toblack and typical cell efficiencies are 9.4–13.8%. The conversion efficiencies of Copper indium selenide (CIS), and Copper indium (gallium) di-selenide (CIGS) cells are shown in Fig. 10b. Values for the highest reported efficiencies of CdTe and CIGS solar cells are shown in Fig. 10b.

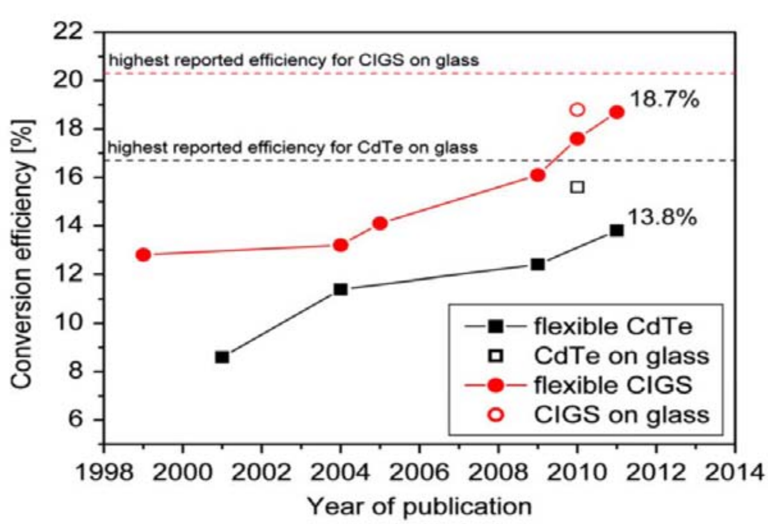


Figure 10c : Conversion efficiencies of flexible CdTe and CIGS solar cells fabricated by low temperature processes Also shown is the in-house reference on glass and the highest reported efficiency for each technology, [13]

Global Journal of Researches in Engineering (J) Volume XIV Issue V Version I Year 2014

The silicon-based crystalline (c-Si) wafers usually give high solar cells efficiency but at high manufacturing cost. The thin film cells are cheaper but less efficient, [1].

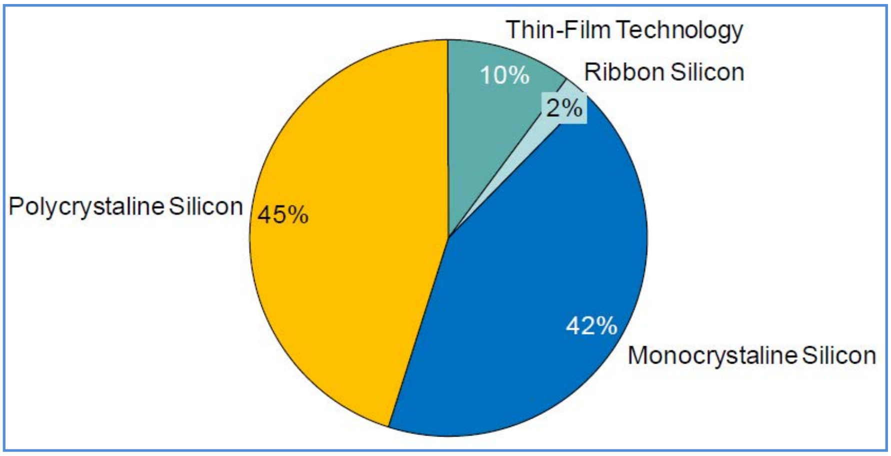


Figure 10d : Market share with regard to technology [in percent], [14]

The characteristics of the cell material affect the cell performance, cost, and methods of manufacture, [3].

In 2010, 78% of the cells used PVPS were wafer-based crystalline silicon modules; and the percentage of amorphous silicon and cadmium telluride thin film modules was 22%. The solar cell materials are classified in Figure 7, [1], and their main characteristics are given in Table 3, [1].

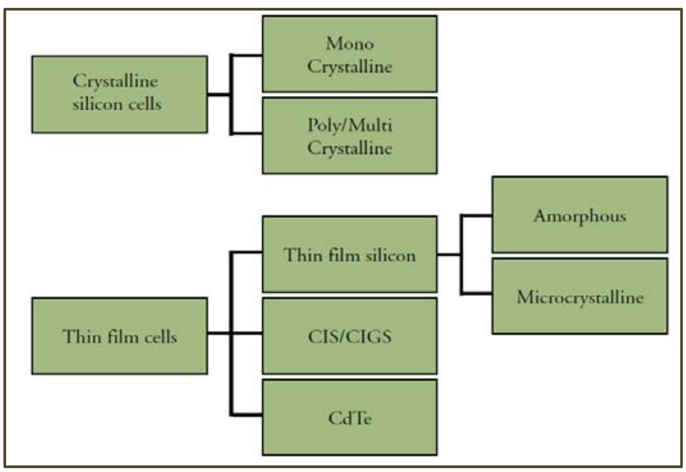


Figure 10b : PV Technology material classes, [1]

Table 3 : Characteristics of various PV technologies, [1]

Technology	Crystalline Silicon	Amorphous Silicon	Cadmium Telluride	Copper Indium Gallium Di-Selenide
Abbreviation	c-Si	a-Si	CdTe	CIGS or CIS
Cost ($/Wp, 2009)	3.1-3.6	2.5-2.8	2.1-2.8	2.7-2.9
Percentage of Global installed capacity	78%	22%		
Thickness of cell	Thick layers (200-300 μm)	Thin layers (<1 μm)	Thin layers (<1 μm)	Thin layers (<1 μm)
Current commercial efficiency	12-19%	5-7%	8-11%	8-11%
Temperature coefficient for power (typical)	-0.5%/°C	-0.21%/°C	-0.25%/°C	-0.36%/°C

Global Journal of Researches in Engineering (J) Volume XIV Issue V Version I Year 2014

Table 3 shows that the cell efficiencies are in the range of 5-7% for amorphous, and 12-19% for the thick layers c-Si. The efficiency can reach up to 44.0% with multiple-junction concentrated photovoltaic, [3].

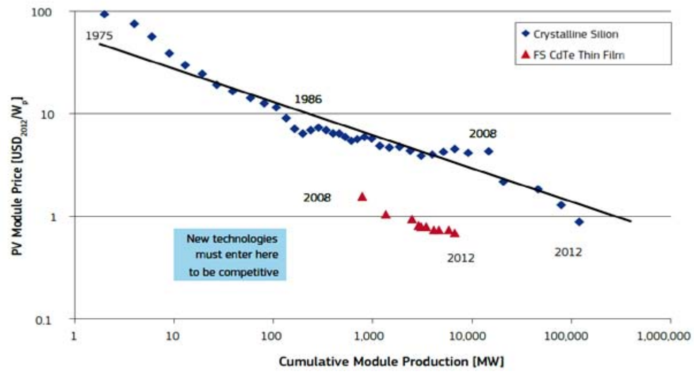


Fig. 10e : Price-experience curve for solar modules (data source: Bloomberg New Energy Finance and PV News), [3]

Global Journal of Researches in Engineering (J) Volume XIV Issue V Version I Year 2014

c) PV Degradation

The performance of PV modules is degraded over time. High degradation occurs in the first year upon initial exposure to light and then it stabilizes. Degradation is mainly affected by used module characteristics. Irreversible light-induced degradation is suffered by c-Si modules due to the presence of boron, oxygen or other chemicals left after cells production. The so called Staebler-Wronski Effect, [15], degrades the amorphous silicon cells, and can cause 10-30% power output reductions in the first six months of exposure to light before stabilization with much less degradation rates. The performance of amorphous silicon cells after stabilization is usually given by the manufacturers. The performance of amorphous silicon is affected by temperature. The modules perform better in hot summer, and drop in cold winter.

Degradation can be caused also by environment effects such as air pollution, dis-coloring or haze of the lamination defects, humidity, and wiring degradation. Degradation can be reduced by regular maintenance and cleaning.

In general, long term of power output degradation rate ranges between 0.3 and 1% per year. Banks often assume a flat rate of degradation rate of 0.5% per annum, [15].In general, good quality PV modules may be expected to have a useful life of 25-30 years.

III. Pv System Performance

a) PV Cell and Module Ratings

The solar modules are compared with each other based on standard test conditions at normal irradiance rate of 1000 W/m^2, cell temperature 25°C and Air Mass (AM)=1.5. The AM is corresponding of receiving surface at 37° tilt angle towards the equator facing the sun.

Solar insolation is the integration of irradiance over a specified time, usually day, year or an hour. Therefore, the insolation has a unit of Watt-hours per square meter. The insolation is usually denoted by *H* is used for insolation for one day; *I* is used for insolation for an hour or year. The symbols *H* and *I* can represent beam, diffuse or global and can be on surfaces of any orientation. Solar radiation consists of beam (direct) radiation received from the sun without having been scattered by the atmosphere, and diffuse radiation received from the sun after its direction has been changed by scattering in the atmosphere. The sum of the beam and the diffuse solar radiation on a surface, global radiation, is often referred to as total solar radiation. The most common measurements of solar radiation are global radiation on a horizontal surface, referred to as global horizontal radiation.

Peak sun hour is the total number of hours of a day that can receive radiation; it is an equivalent form of insolation and most radiation data is represented using either of these units expressed as kWh/m^2/day. The figure below shows the annual insolation map of the United States.

The performance ratio (PR) of the PVPS is defined as percentage ratio of the AC yield to the installed capacity in kWp multiplied by plane array irradiation in kWh/m^2,[1]. It gives the yield to the maximum nominal output. The PR does not take in consideration the size or the solar resource. A PVPS of high PR converts solar energy to electric power efficiently, and can be achieved by well-designed solar PVPS and not operated in high temperature conditions. The PR of varies between 77% in summer to 82% in winter. Amorphous silicon modules in some PVPS show the opposite effect with high PR in hot summer and low PR in cold winter. Electrical losses decrease the PR, [10], see Table2.

Throughout the components of the system there are electrical losses, which de-rate the conversion from nameplate DC power rating to AC power rating (as explained in Table 4), [16]. Table 4 gives the losses due to the several system components.

Table 4 : De-rate the conversion from nameplate DC power rating to AC power, [16]

Derate Factors for Photovoltaic System Components Table 6. PVWatts Default Derate Values		
Component Derate Factors	PVWatts Default	Range
PV module nameplate DC rating	95%	0.80–1.05
Inverter and transformer	92%	0.88–0.98
Mismatch	98%	0.97–0.995
Diodes and connections	100%	0.99–0.997
DC wiring	98%	0.97–0.99
AC wiring	99%	0.98–0.993
Soiling	95%	0.30–0.995
System availability	98%	0.00–0.995
Shading	100%	0.00–1.00
Sun-tracking	100%	0.95–1.00
Age	100%	0.70–1.00
Overall DC-to-AC derate factor	77%	0.09999–0.96001

Table 4 notes that the overall DC-to-AC de-rate factor varies for different PV systems and applications. NREL's PVWatts tool incorporates a standard de-rate factor of 0.77 (or a 23% loss in output from nameplate DC rating to actual AC energy produced).

The load (or capacity) factor of a PVPS power plant (usually expressed in percentage) is the ratio of the actual output over a period of one year and the target yield (output if it had operated at nominal power the entire year), and is defined as:

$$\mathrm{CF} = \frac{Actual\ yield\ E}{Target\ yield} = \frac{Annual\ Energy\ Generated(kWh)}{8760(hours/\ annum)\times Installed\ Capacity(kWp)}$$

Note that the target yield (dominator) is different from the annual sum of global irradiation, h, that hits the module, and it depends on the specific location. The value of h is to be obtained from measurements, or from an irradiance map, and its units is kWh/m^2. The relation between the target a_{out} and h is given by: $\text{Target yield} = h\,A\eta_{norm}$

This gives $\frac{Actual\ yield\ E}{Target\ yield} = \frac{E}{h\,A\eta_{norm}} = \eta_{pre}\eta_{rel}\,\eta_{sys}$

Where, η_{nom} = Nominal efficiency

η_{pre} = Conversion efficiency

η_{rel} = Relative efficiency

η_{sys} = system efficiency

The performance ratio is independent from the irradiation *h* and therefore it is useful to be used to compare systems. The specific final yield, Y_f, (kWh/kWp) is the total annual energygenerated E in kWh divided by the nameplate DC power P0 of the installed modules capacity (kWp), i.e., Y_f =E/Po. Another useful expression is the specific yield to the standard conditions of 1 kW/m^2 irradiance Y_r. The reference yield Y_r is the total in-plane irradiance H divided by the PV's reference irradiance G, i.e., Y_r = H/G (hours). Therefore, Y_r is the number of peak sun-hours or the solar radiation in units of kWh/m^2. The performance ratio PR is the Y_f divided by the Y_r, i.e., PR= Y_f/Y_r (dimensionless).

Qatar annual global horizontal irradiation GHI are given as: 2055 kWh/m^2 (minimum), 2160 kWh/m^2 (maximum), 105 kWh/m^2 (range) and 2134 kWh/m^2 (mean), [17]. The fixed tilt PVPS capacity factor plant in sunny areas is about 16%. This means that a PVPS of 100 MWp plant would generate the equivalent energy of 17.7 MW by combined cycle (CC) having 90% CF.

b) Photovoltaic Power Station

The largest solar PVPS as of March 2014 are given in Table 5.

Table 5 : Large-Scale Photovoltaic Power Plants, Ranking 1-50, [18]

Power	Location	Description	Commissioned
320 MWp	Longyangxia Dam, Qinghai Province ,China,	Longyangxia Hydro-solar PV Station	2013
250 MW	san Luis Obispo, CA, USA	California Valley Solar Ranch	2012-2013
250 MW	Yuma County, AZ, USA	Agua Caliente Solar Project	2012
214 MW	Charanka, India	PV power plant	2012
200 MWp	Gonghe County, Qinghai Province, China	Charanka Park, Patan district, PV power plant	2012
200 MWp	Golmud, China	Golmud PV power plant	2011
166 MWp	Meuro, Germany	SolarparkMeuro	2011-2012
150 MW	Sonoran desert, AZ, USA	Mesquite Solar I	2011-2012
145 MWp	Neuhardenberg, Germany	SolarparkNeuhardenberg	2012
143.2 MW	Kern County, CA, USA	Catelina Solar Project	2013
139 MW	El Centro, Imperial Valley, CA, USA	Campo Verde Solar Project	2013
128 MWp	Templin, Germany	Solarpark Templin	2012
125 MW	Maricopa County, AZ, USA	Arlington Valley Solar Energy II	2013
115 MWp	Toul-Rosières, France	Centralesolaire de Toul-Rosières	2012
105.56 MWp	Perovo, Ukrane	Perovo I-V PV power plant	2012
100 MW	Chengde, Hebei Province, China	Chengde PV Project Phase I and II	2013
100MW	Jiayuguan, Gansu Province, China	Jiayuguan PV power plant	2013
100 MW	Xitieshan China	Xitieshan I,II,III PV power plant	2012
97 MW	Sarnia, Canada	Sarnia PV power plant [2]	2009-2010
92 MW	Boulder City, NV, USA	Copper Mountain II Solar Facility	2012
91 MW	Briest, Germany	SolarparkBriest	2011
84.7 MWp	Finowfurth, Germany	SolarparkFinowTower I,II	2010-2011
84.2 MWp	Montalto di Castro, Italy	Montalto di Castro PV power plant	2009-2010
84 MW	Lopburi, Thailand	Lopburi PV power plant	2011-2012
82.65 MWp	Ohotnikovo, Ukraine	Ohotnikovo PV power plant	2011
82 MWp	Senftenberg, Germany	SolarparkFinsterwalde I,II,III	2009-2010
80.245 MWp	Finsterwalde, Germany	SolarparkFinsterwalde I,II,III	2009-2010
80 MWp	Eggebek, Germany	SolarparkEggebek	2011
75 MWp	Kalkbult, Northern Cape, South Africa	Kalkbult PV facility	2013
71 MWp	Turnow-Preilack, Germany	SolarparkLieberose	2009-2011
70.556 MW	San Bellino, Italy	San Bellino PV power plant	2010
70 MW	Kagoshima pref., Japan	Kagoshima Nanatsujima Mega Solar Power Plant	2013
70 MW	Wittstock, Germany	Solarpark Alt Daber	2011
69.7 MWp	Crimea, Ukraine	Nikolayevka Solar Park	2013
68 MWp	Sault Ste.Marie, Canada	Starwood SSM I,II,III	2010-2011
67.2 MWp	Losse, France	ParcSolaireGabardan	2009-2011

66 MW	Los Angeles, USA	Alpine Generating Station	2013
60.4 MWp	Karadzhalovo, Bulgaria	Karadzhalovo Solar Park	2012
60 MWp	Crucey, France	Centralesolaire de Crucey	2012
60 MWp	Olmedilla de Alarcon, Spain	Parque solar Olmedilla de Alarcon	2008
58 MW	Boulder City, NV, USA	Copper Mountain I Solar Facility	2010
56 MW	Massangis, France	ParcSolaireMassangis	2012
55 MW	Rajastan, India	PV power plant in Rajastan	2013
54.8 MWp	Priozernaya, Ukraine	Priozernaya Solar Park	2013
54 MWp	Straßkirchen, Germany	SolarparkStraßkirchen	2009
52.284 MWp	Walddrenah , Germany	SolarparkWalddrenah	2012
52 MWp	Brandis , Germany	SolarparkWaldpolenz	2007-2008
52 MWp	Tutow, Germany	SolarparkTutow I,II,III	2009-2011
50 MWp	Weidi, China	Weidi Solar Park	2012
50 MW	Alpaugh, CA, USA	SPS Alpaugh solar project	2012

Notes: Power is specified in MWp if DC array power is known. If DC array power is unknown then output power is specified. In some cases, it is unclear if the power is the output or DC array power. Sarnia power plant has AC power of 80 MW. This power was also disclosed in press release. DC array peak power (97 MWp) is unofficial information and is based on personal communication. SolarparkSenftenberg I (18 MWp) was put into service in 2010 and constructed by Phoenix Solar and is a separated project not related to Senftenberg II and III. Last modified: 3/15/2014.

The PVPS can be divided based on its capacity, to mid-capacity station of less than50 MW, and large capacity plants of 50 MW or more. A NREL report issued in 2012 accounted for 56 PVPS of mid-size ranging from 5- 48 MW each, and total capacity 589.5 MW. There are another 57 PVPS in advance development under development of 20-50 totaling 1,329.5 MW.Concerning large capacity PVPS (greater than 50 MW) in US, there are currently 40 plants of 9,425 MW total capacities in the development stages.

V. POWER CONVERSION

Inverters are required to convert the DC power produced by the modules into AC, which can then be connected to the electrical grid. DC rating to actual AC energy produced. Inverters are solid-state electronic devices. Inverters can also perform a variety of functions to maximize the output of the plant. These range from optimizing the voltage across the strings and monitoring string performance to logging data, and providing protection and isolation in case of irregularities in the grid or with the PV modules.

Technological improvements are rapidly occurring in many subsectors. For example, micro-inverters can be paired with each PV module, in contrast to centralized inverters, which are paired with a bank of modules. Therefore, if a single micro-inverter fails, only the module paired to the failed inverter is affected, [6]

There are two primary alternatives for configuring this conversion equipment; centralized inverter and string inverter, see Figure 11.

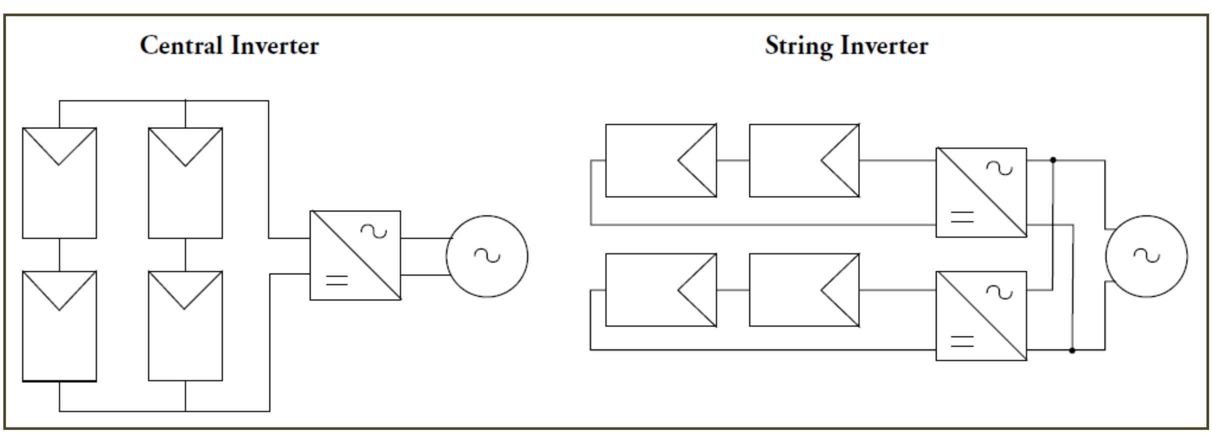


Figure 11 : PV System Configurations, [1]

In central inverters,large numbers of modules are connected in series to form a high voltage string. Strings are then connected in parallel to the inverter, Figure 8. Central inverter configuration is the first choice for many medium and large-scale solar PV plants. Central inverters offer high reliability and simplicity of installation. However, their disadvantages are: increased mismatch losses and absence of maximum power point tracking for each string. This may cause problems for arrays that have multiple tilt and orientation angles, suffer from shading, or use different module types.

Central inverters are usually three-phase and can include grid frequency transformers.

Figure 12 : First Solar 40-MW CdTe PV Array installed by JUWI Group in Waldpolenz, Germany, [19]

The transformer's location in the Waldpolenz Solar Park, shown in Figure 12 is divided into blocks each with a centralized inverter.

String inverters are substantially lower in capacity, of the order of 10kW, and condition the output of a single array string. This is normally a whole, or part of, a row of solar arrays within the overall plant. String inverters can enhance the efficiency of solar parks, where different parts of the array are experiencing different levels of insolation, for example where arranged at different orientations, or closely packed to minimize site area. While numerous string inverters are required for a large plant, individual inverters are smaller and more easily maintained than a central inverter.

VI. Ground Mounting

PV modules must be mounted on a structure to keep them correctly oriented and provides them with structural support and protection. The mounting structures may be either fixed or tracking. The fixed tilt mounting system is simpler, cheaper and has lower maintenance compared to than tracking systems. The tracking systems are more expensive and more complex, but can be cost-effective in locations with a high proportion of direct irradiation.

Most solar parks use ground mounted (sometimes called free-field or stand-alone) arrays. Land area required for solar parks varies depending on the location, and on the solar modules' efficiency, the slope of the site and the type of mounting used. Fixed tilt solar arrays using typical modules of about 15% efficiency on horizontal sites, need about 10,000 m^2/MW.

a) Fixed Tilt

The solar panels in many PV stations are mounted on fixed structures, and thus have fixed inclination calculated to provide the optimum annual output profile, and is generally optimized for each PV power plant according to its location. This helps to maximize the total annual energy yield. These are normally oriented towards the Equator, at a tilt angle slightly less than the latitude of the site. Note that the tilt angle or "inclination angle" is the angle of the PV modules from the horizontal plane. The orientation angle or "azimuth" is the angle of the PV modules relative to south; East is -90° south is 0° and west is 90°.

Fixed tilt mounting systems are simpler, cheaper and have lower maintenance requirements than tracking systems. Frames to carry the PV panels are built first, and then the PV panels are fixed on the frame as shown in Figures 10a-10c, [20].

(a)

(b)

Global Journal of Researches in Engineering (J) Volume XIV Issue V Version I Year 2014

(c)

Figure 13a-13c : Fixed mounting arrangement, [20]

Example of fixed mounted PVPS is the Five Points Solar Station, which has Capacity equal 17.7 MW DC in Fresno County, California. The Five Points project is part of PG&E's 250-MW Utility Owned Generation (UOG) PV Program, a five-year plan for the construction of utility-owned solar PV stations, [15].

b) Seasonally Adjusted Tilt

As the majority of the solar energy is in the direct beam, maximizing collection requires the sun to be visible to the panels as long as possible. The tilt angle can be mechanically adjusted seasonally to optimize output in summer and winter. The angle is usually adjusted twice or four times per year. These require more land area to reduce internal shading at the steeper winter tilt angle. Because the increased output is typically only a few percent, it seldom justifies the increased cost and complexity of this design. Figure 11 shows the arrangement of seasonally adjusted PV panels in photovoltaic power plant near Alamosa, Colorado. In this plant, the 82-acre tract site is one of the largest PV in the US. The Alamosa Photovoltaic Plant, which went on-line in December 2007, and generates about 8.2 megawatts of power.

Figure 14 : Seasonally adjusted fixed-axis photovoltaic panels at the Sun Edison photovoltaic power plant near Alamosa, Colorado

c) PV Panels tracking

Having the direct (beam) radiation, main part of the global radiation, perpendicular on the PV panel surface as much as possible maximizes the energy collected and thus the yield. The main factor affected the energy contributed by the direct beam is the cosine angle between the incoming light and the panel (angle i). The power lost due to deviation of this angle is given in Table 6, and Fig. 15.

Table 6 : Direct power lost (%) due to misalignment (angle i), [19]

i	Lost = 1 - cos(i)	*i*	hours	Lost
0°	0%	15°	1	3.40%
1°	0.02%	30°	2	13.40%
3°	0.14%	45°	3	30%
8°	1%	60°	4	>50%
23.4°	8.30%	75°	5	>75%

Trackers with accuracies of ± 5° can deliver greater than 99.6% of the energy delivered by the direct beam plus 100% of the diffuse light. Thus, high accuracy tracking is not usually used in non-concentrating PV applications.

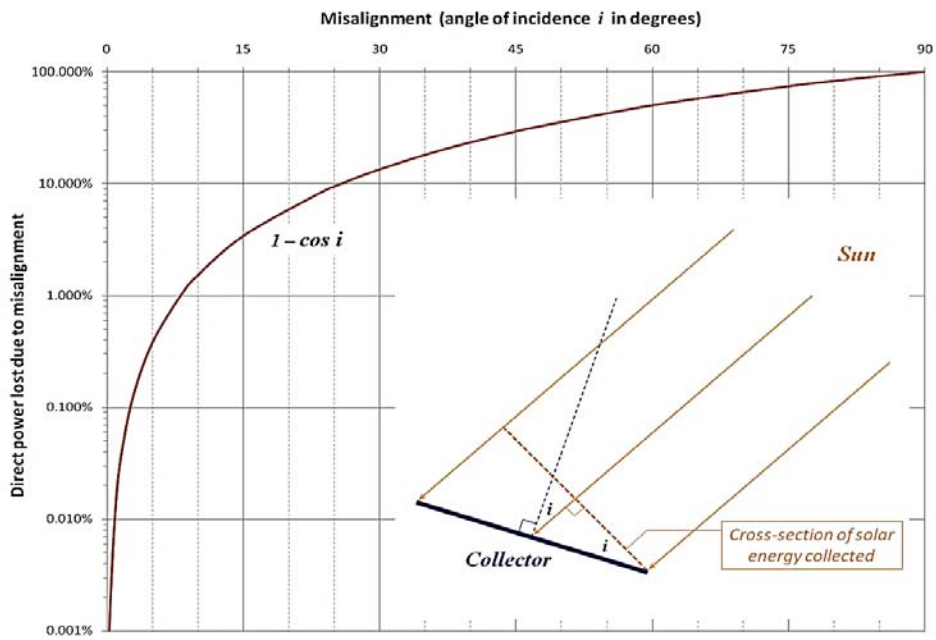


Figure 15 : The effective collection area of a flat-panel solar collector varies with the cosine of the misalignment of the panel with the Sun, [21]

Tracking will always result in a higher energy yield. The amount of the boost however is very much dependent on the location. Generally, locations with a higher proportion of direct sunlight will benefit more from tracking than locations with a high proportion of diffuse light such as Germany, see Table 4.

Table 4 : Boost of PV system by tracking, [20]

	Flat Panel horizontal surface	Fixed mounting, optimum angle	1-axis tracking	1-axis with seasonal adjustment	2-axes tracking
Energy boost in comparison to optimum tilt	-15%	0%	20%	26%	32%
Initial marginal cost per m^2	0%	5%	10%		20%

Tracking increases the performance ratio of a system. It also results in higher yields for the inverter. Dual-axis tracking systems increase the average total annual irradiation in locations with a high proportion of direct irradiation. Tracking systems follow the sun as it moves. Orienting the solar panels to be normal to the sun's rays maximizes the intensity of incoming direct radiation. The two axis tracking system enables tracking the sun in its daily orbit across the sky, and as its elevation changes throughout the year. The arrays have to be spaced out to reduce inter-shading as the sun moves and the array orientations change. So, it needs more land area. The maximum increased output can be of the order of 30% in locations with high levels of direct radiation, but the increase is lower in temperate climates or when diffuse radiation is significant, due to overcast conditions. Schematic increase of power output due to the use of dual axis tracking is shown in Figure 12.

Tracking systems are generally the only moving parts employed in a PV power plant. Single-axis trackers either alter the orientation or tilt angle only, while dual-axis tracking systems alter both orientation and tilt angle. Dual-axis tracking systems are able to track the sun more precisely than single-axis systems. Depending on the site and precise characteristics of the solar irradiation, trackers may increase the annual energy yield by up to 27% for single-axis and 37% for dual-axis trackers. Tracking also produces a smoother power output plateau, as shown in Figure 15. This helps meet peak demand in afternoons, which is common in hot climates due to the use of air conditioning units.

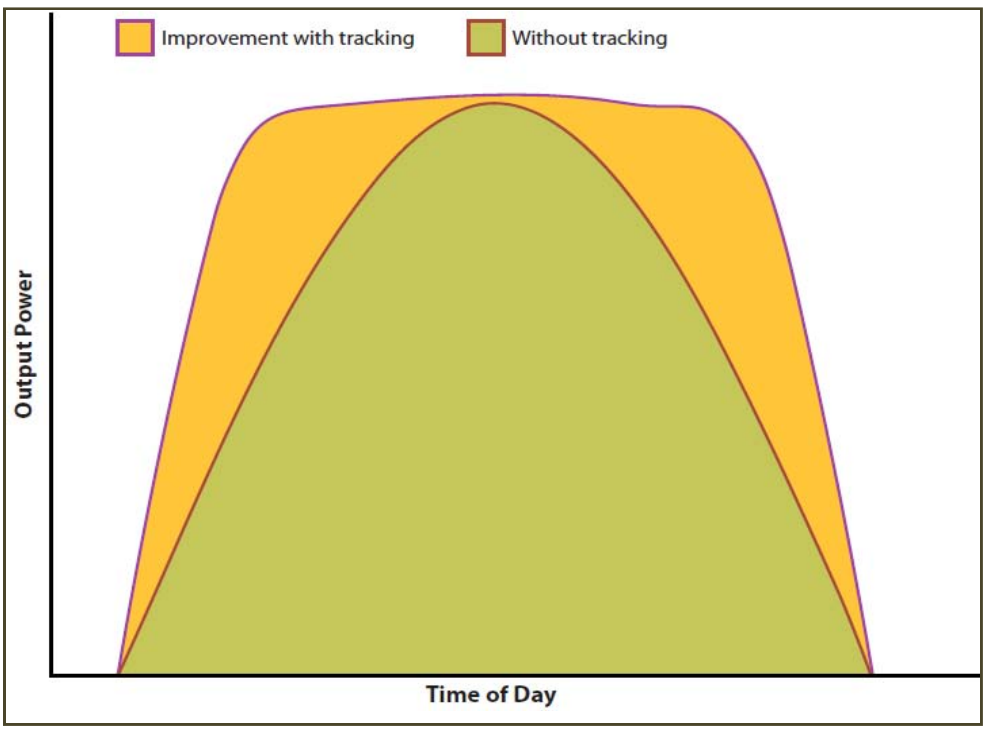


Figure 15 : Benefit of Dual Axis Tracking System, [1]

The tracking system needs additional capital costs for the procurement and installation of the tracking systems (typically $140-700/kWp); and added additional maintenance costs range from $2.8-21/kWp per annum, [1]. It also needs additional land area required to avoid shading compared to a free field fixed tilt system of the same nominal capacity. Almost all tracking system plants use crystalline silicon modules because their higher efficiency. This is reduces additional capital and operating costs required for the tracking system (per kWp installed). Examples of PVPS using dual axis tracking systems are: Bellpuig Solar Park near Lerida, Spain uses pole-mounted 2-axis trackers; and the Erlasee solar park installed by Solon Mover L plant of 12 MWp, shown in Figure 16.

Figure 16 : Azimuth-altitude dual axis tracker - 2 axis solar tracker, Toledo, Spain

Tracking the sun in one dimension can achieves some of the output benefits of tracking, with a less penalty in terms of land area, capital, and operating cost. A single axis tracker with roughly 20 degree tilt at Nellis Air Force Base in Nevada, USA is shown in Figure 14.

Figure 17 : Single axis trackers with roughly 20 degree tilt at Nellis Air Force Base in Nevada, USA. The arrays form part of the Nellis Solar Power Plant. Credit: U.S. Air Force photo by Senior Airman Larry E. Reid Jr,

VII. Economy of PVPS

a) Levelized Cost of Energy (LEC) of Solar PV Systems

The levelized cost of energy (LEC) of solar PV systems reflects the price at which energy must be sold to break even over the assumed economic life of the system. In other words, it is the cost incurred to install and maintain an energy-producing system divided by the energy the system will produce over its lifetime of operation:

LEC = Life time energy cost/ Life time energy generation

This equation yields a net present value in the familiar cents per kilowatt-hour (kWh) of electricity generated. This is an assessment of the economic lifetime energy cost and energy production and can be applied to essentially any energy technology. It is frequently used to evaluate a technology or energy system against electricity purchased from the grid. The LEC equation takes into account system costs, as well as factors including financing, insurance, operations and maintenance (O&M), depreciation and any applicable incentives. Installed costs are a primary driver for solar PV systems as they lack fuel costs and require minimal O&M.

By knowing that the EP produced by PVPS is higher than the EP retail price, it is required to identify if and when the declining LEC of solar PV intersects with the increasing retail electricity prices. The term frequently used to describe this intersection is "grid parity". The installed cost of solar PV systems is the largest component of the LEC.

The installed price of utility-scale systems varies significantly across projects. In the US, among 49 projects completed in 2011, for example, installed prices ranged from$2.4/W to $6.3/W, reflecting the wide variation in project size (from 2 MW to 35 MW), differences in system configurations (e.g., fixed-tilt vs. tracking and thin-film vs. crystalline modules), and the unique characteristics of individual projects, [20]. It is noticed that for very large PVPS plant of 187.5 MWP DC one-axis utility-scale ground mount, the estimated cost was $4.40/WP DC, or $ 5.9/W (by considering 0.75 De-rate Factor from DC to AC). So, for Qatar and 50 MW plant in Qatar if 20% increase is assumed the price would be $7.04, and the plant will cost 352 million (M). In another study for India, 169 Indian Rupee ($3)/W were reported. Again, if this for peak DC, and by considering 0.75 De-rate Factor from DC to AC it would be $4/W, [1].

A study to calculate the LEC by North Carolina State University indicated that for 10 MW plant made the following assumptions: the installed cost is $3.75 -$5/W, economic life of system is 20 years, fixed operation and maintenance is $50-65 kW/year, capacity factor 15-28%, the LEC is $0.24-0.46/kWh, [21]. The cost breakdown was given in Fig. 18.

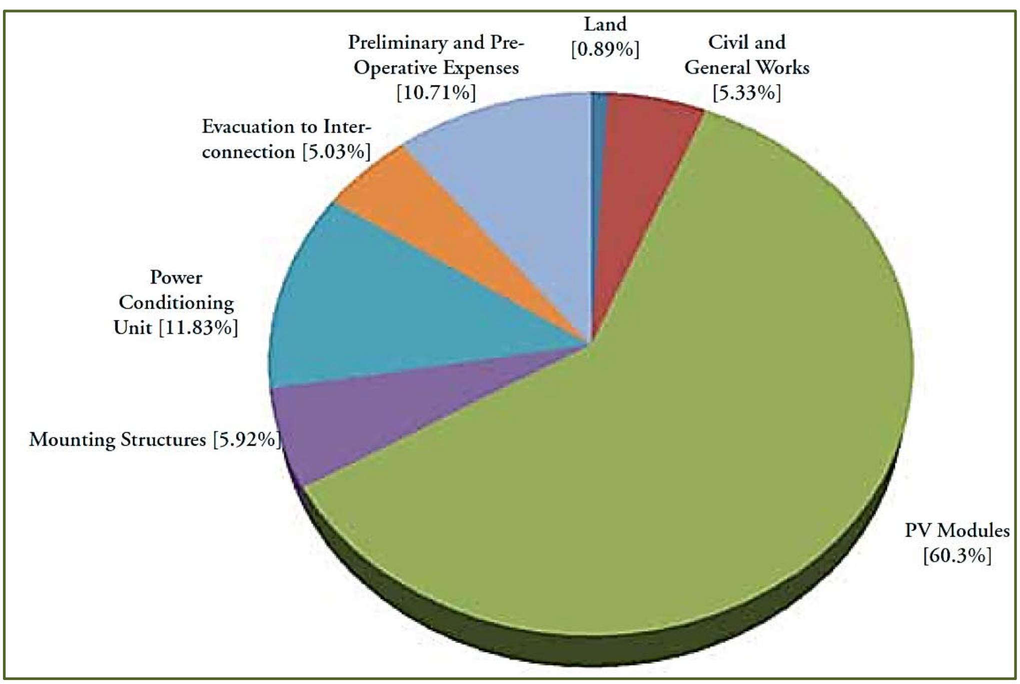


Figure 18 : Cost breakdown of PV power station, [21]

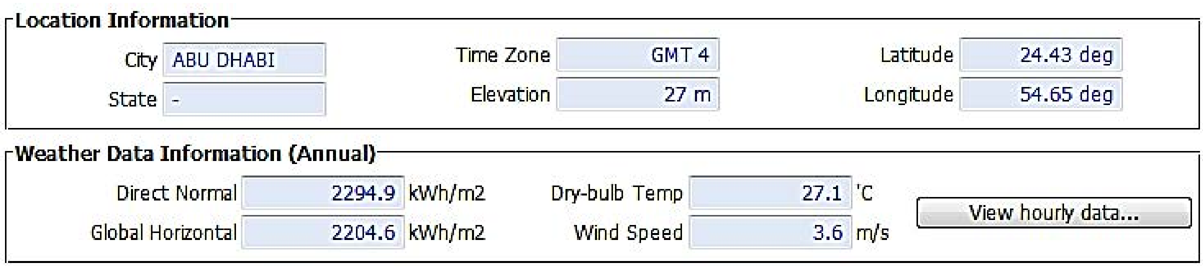
b) Utilities as Contractual Intermediaries

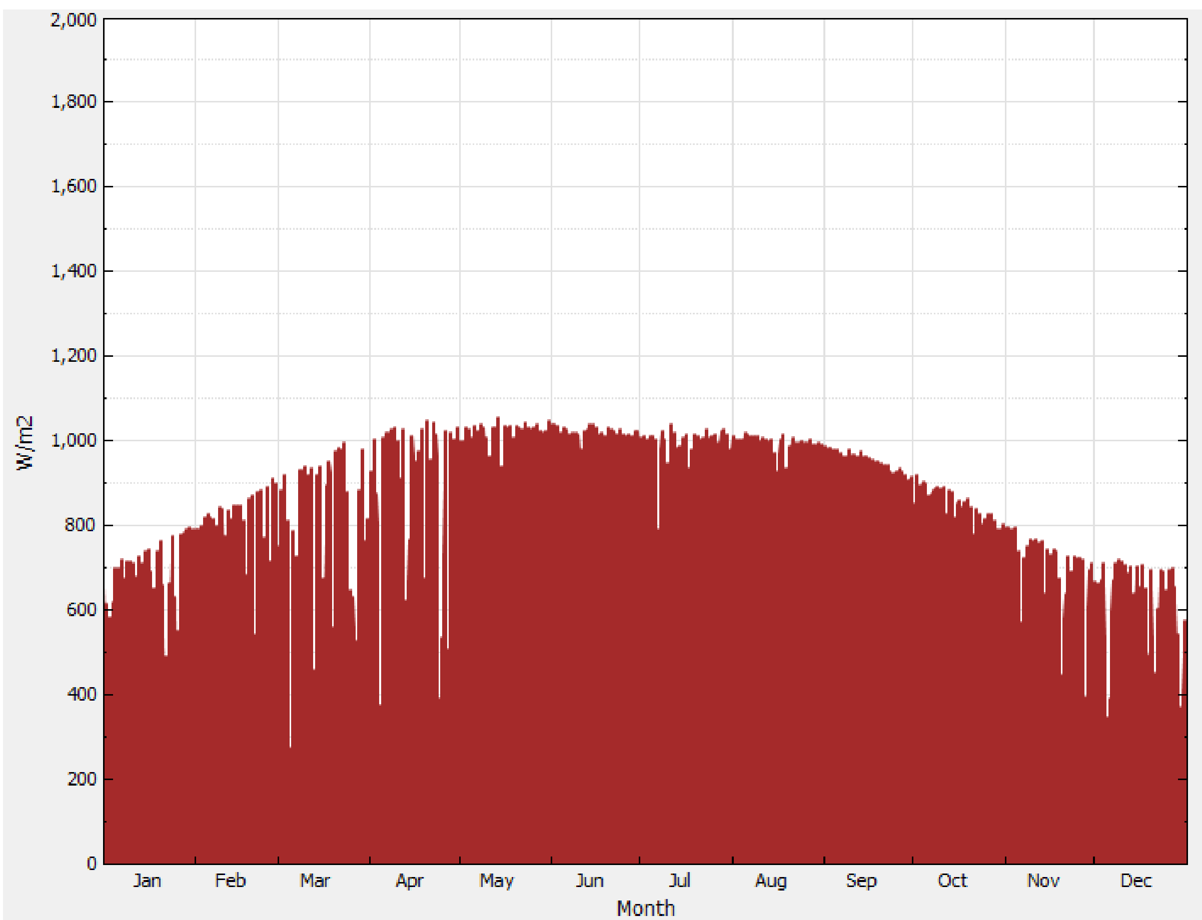
The utility in Qatar is acting as contractual intermediary agent between the power producer and the customers. The owner of the power plant sells power output from the plant (it is solar PV system here) to the utility, which, in turn, sells the power back to the site host/end-user.

This arrangement protect consumers (rates and reliability) and to ensure a highly functioning electric grid. By having a single entity control the system, a utility can balance constantly changing supply and demand to ensure reliability and keep the electricity flow on the grid optimized and safe.

VIII. Suggested PVPS using Flat Type PV System and SAM Computer Program Results

A PV array of 20 MW_{dc} is suggested in this study. The System Advisor Model (SAM) computer program developed by NREL is used here to figure the PVPS characteristics, capital cost, and the EP output cost in $/kWh. Because no boundary conditions data are available for Qatar, the environmental data for Cairo, Egypt is used in running the program. This environmental data is given as follows:

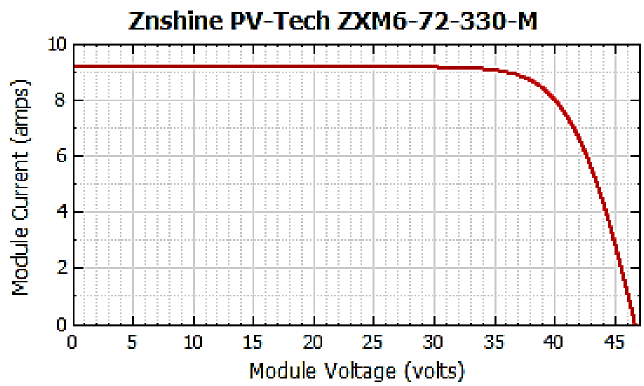




Global Horizontal, W/m^2

Global Journal of Researches in Engineering (J) Volume XIV Issue V Version I Year 2014

PV Module: Znshine PV-Tech ZXM6-72-330-M

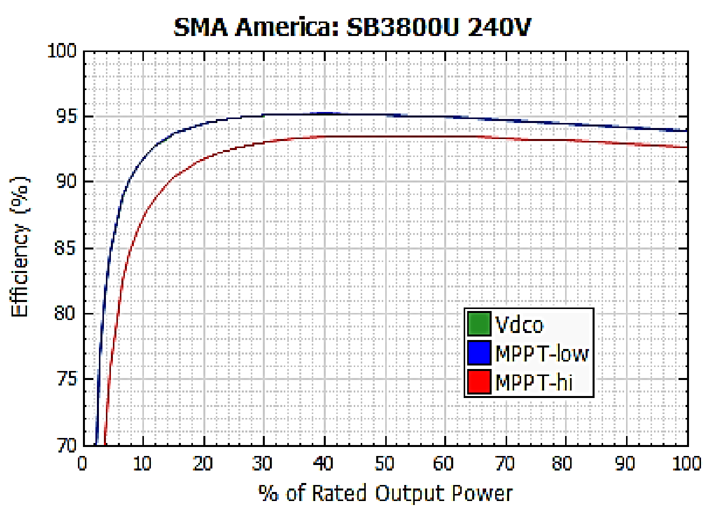


			Temperature Coefficients			
Efficiency	17.00	%				
Maximum Power (Pmp)	329.998	Wdc	-4.530e-001	%/C	-1.495e+000	W/C
Max Power Voltage (Vmp)	38.15	Vdc				
Max Power Current (Imp)	8.65	Adc				
Open Circuit Voltage (Voc)	46.72	Vdc	-3.200e-001	%/C	-1.495e-001	V/C
Short Circuit Current (Isc)	9.19	Adc	5.600e-002	%/C	5.146e-003	A/C

Physical Characteristics

Material	Mono-c-Si	Module Area	1.941 m2	Number of Cells	72

Inverter: SMA America: SB3800U 240V



CEC weighted efficiency	94.5729	%			
European weighted efficiency	94.2751	%			
Maximum AC power	3800	Wac	C0	-9.30559e-006	1/Wac
Maximum DC power	4050.67	Wdc	C1	5.66625e-005	1/Vdc
Power consumption during operation	24.7974	Wdc	C2	0.00268062	1/Vdc
Power consumption at night	0.161	Wac	C3	-0.000103656	1/Vdc
Nominal AC voltage	240	Vac			
Maximum DC voltage	600	Vdc			
Maximum DC current	18	Adc			
Minimum MPPT DC voltage	250	Vdc			
Nominal DC voltage	251.5	Vdc			
Maximum MPPT DC voltage	480	Vdc			

The array consists of 60646 modules of 117,702 m^2 total area, connecting by 7580 strings, or 8 modules per string. The nameplate capacity and Vmp are at module reference conditions. Voc (string) is 373.76 V at 1000 W/m^2 irradiance and 25°C, and Vmp (string) = 305.2 V. The module material is mono Crystalline Silicon (c-Si). The number of used inverters is 5500, V dc max (dc-inverter) 600 V. Data on module's dimensions are given as:

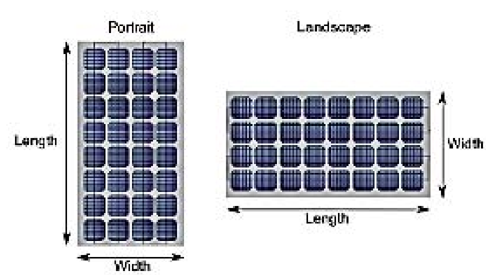
Actual Layout

Modules			Inverters		
Nameplate capacity	20011	kWdc	Total capacity	20900	kWac
Number of modules	60640		Total capacity	22278.7	kWdc
Modules per string	8		Number of inverters	5500	
Strings in parallel	7580		Maximum DC voltage	600	Vdc
Total module area	117702	m2	Minimum MPPT voltage	250	Vdc
String Voc	373.76	V	Maximum MPPT voltage	480	Vdc
String Vmp	305.2	V			

Nameplate capacity and string Vmp are at module reference conditions. String Voc is at 1000 W/m2 incident irradiance and 25 'C cell temperature.

Module

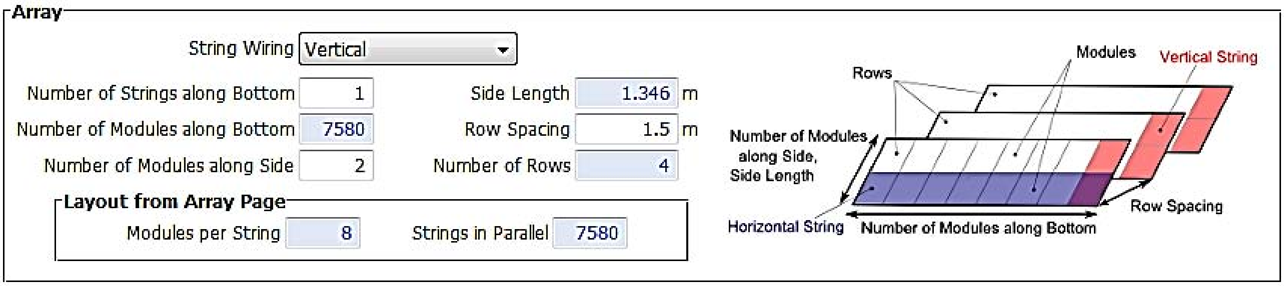
Orientation	Landscape	
Length	2.884	m
Width	0.673	m
Number of Cells along Length	12	
Number of Cells along Width	6	
Number of Bypass Diodes	3	

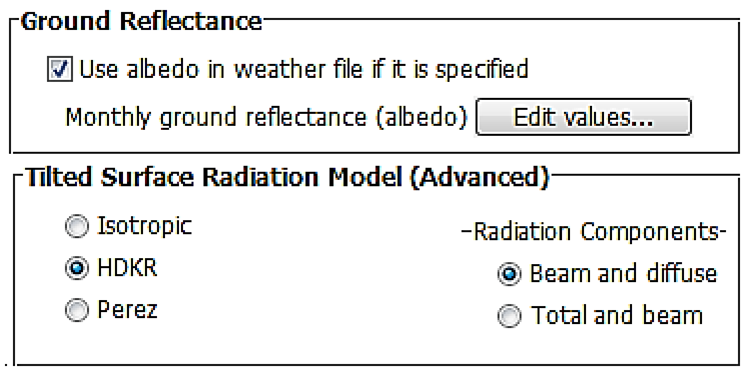


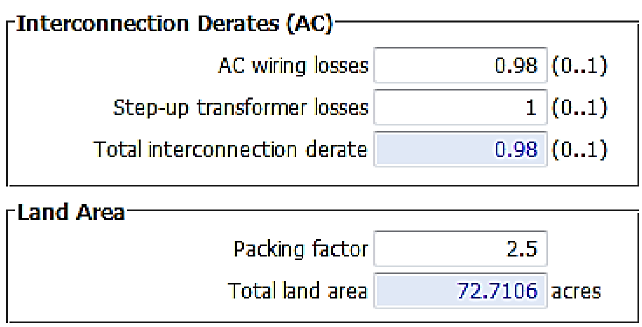
Characteristics from Module Page

Area	1.941 m2	Number of cells	72

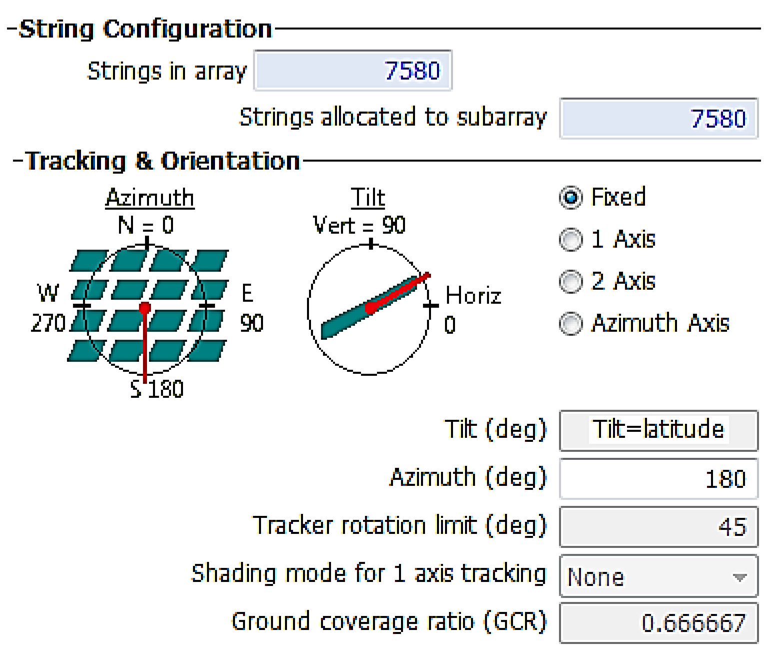
The string wiring is shown as follows:







The tracking and orientation are given as:



Details of capital cost are given by:

Direct capital cost

Direct Capital Costs

Module	60640	units	0.3	kWdc/unit	20011	kWdc	$ 3.302	$/Wdc	$ 66,076,481.82
Inverter	5500	units	3.8	kWac/unit	20900	kWac	$ 0.61	$/Wac	$ 12,749,000.00
Balance of system, equipment	0	$	0.458	$/Wdc	0	$/m2			$ 9,165,060.17
Installation labor	8100	$	0	$/Wdc	0	$/m2			$ 8,100.00
Installer margin and overhead	0	$	0	$/Wdc	0	$/m2			$ 0.00
							Contingency	0 %	$ 0.00
								Total Direct Cost	$ 87,998,641.98

Indirect cost

Indirect Capital Costs

	% of Direct Cost	Cost $/Wdc	Fixed Cost	Total
Permitting, Environmental Studies	0 %	0.00	$ 0.00	$ 0.00
Engineering	0 %	0.00	$ 800.00	$ 800.00
Grid interconnection	0 %	0.00	$ 0.00	$ 0.00

Land Costs

Total Land Area 72.7106 acres

	Cost $/acre	% of Direct Cost	Cost $/Wdc	Fixed Cost	Total
Land	0.00	0 %	0.04	$ 0.00	$ 800,441.94
Land preparation	0.00	0 %	0.20	$ 0.00	$ 4,002,209.68

Sales Tax of 5 % applies to 100 % of Direct Cost $ 4,399,932.10

Total Indirect Cost $ 9,203,383.72

Total installed cost excluding any financing cost

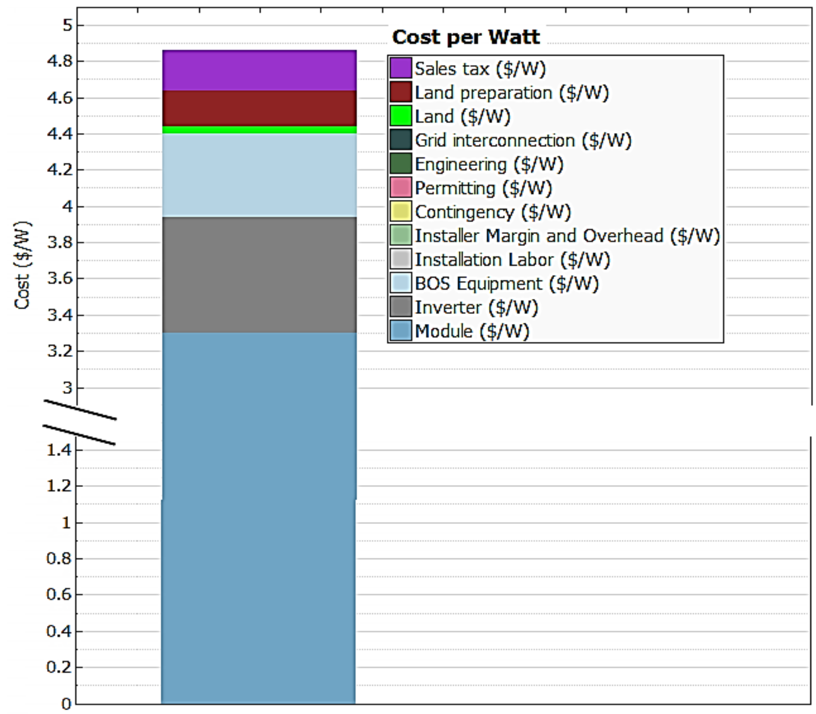
Total Installed Costs

Total Installed Cost	$ 97,202,025.70
Total Installed Cost per Capacity ($/Wdc)	$ 4.86

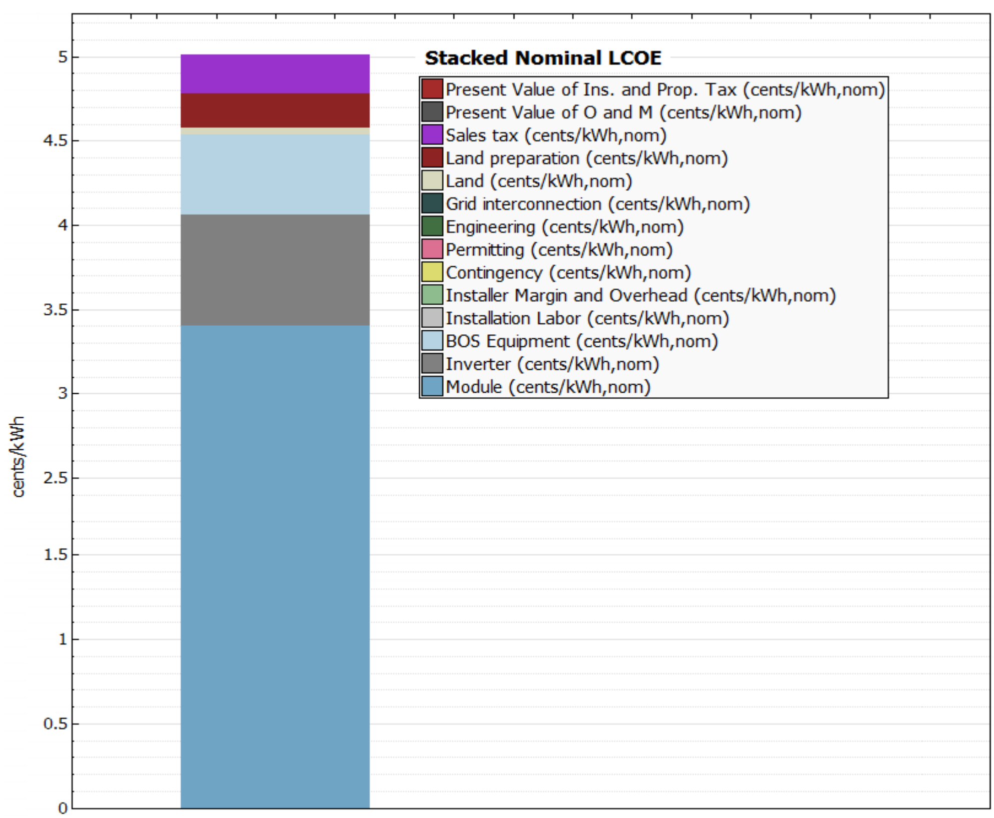
Total Installed Cost excludes any financing costs

Global Journal of Researches in Engineering (J) Volume XIV Issue V Version I Year 2014

The itemized capital cost is given as:



The levelized Electricity Cost (LEC) is given as:



IX. Conclusions

The technology and economics of the PV power station is presented in this paper. The main components of the PV power plants including the solar PV modules, module mounting and tracking systems, inverters (or converters), and step-up transformers was outlined. It reviews the materials of the PV cells, the PV cells degradation, and the existing PV power plant. Utility PV power plants around the world were also reviewed.

The System Advisor Model (SAM) software developed by National Renewable Energy Laboratory (NREL) has been used to predict the total direct capital cost of the 20 MW PV plant as $88.0 million (M), and total installed cost as $ 97.202 M; or $4.86 M/MW. This is almost half the cost of the CSP using parabolic trough plants. The LCOE, as given by the computer program is $0.16/kWh. The main disadvantage of the PV power station is non-dispatch ability.

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Evaluation of Residual Stress Field by X-Ray Diffraction using the Sen²Ψ Method on E308l Stainless Steel Weld Overlays

By Melo, R. H. F.I, Santos, M. A.I & Maciel, T. M.I
Universidade Federal De Campina Grande - UFCG, Brazil

Abstract- The application of metal coatings by welding of steels and alloys resistant to corrosion is an alternative quite reasonable economically facing the manufacturing of solid components in these alloys. However there is a lack of information about the mechanical / metallurgical changes caused by thermal cycles of welding due to the application of these coatings, especially about its influence on the level of residual stresses, that it is essential to understand the phenomenon of stress-assisted corrosion. The aim of this study was to evaluate the level of the superficial residual stresses in coatings of AWS E308L T-1 stainless steel applied by the FCAW process on steel plates of ASTM A36. The measurements of residual stresses were performed by a portable X - ray diffractometer on the surface of the coatings and the main results obtained were that the nature of residual stresses on the surface of the coatings always showed compressive and it was not observed linearity of the magnitude of the residual stresses as a function of the welding heat input.

Keywords: welding, stainless steel, residual stress, x-ray diffraction.

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EVALUATIONOFRESIDUALSTRESSFIELDBYXRAYDIFFRACTIONUSINGTHESENMETHODONE308LSTAINLESSSTEELWELDOVERLAYS

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Melo, R. H. F.I [α], Santos, M. A.I [σ] & Maciel, T. M.I [ρ]

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Keywords: welding, stainless steel, residual stress, x-ray diffraction.

I. Introduction

Global economic pressures and characteristics of national producing basins have increasingly led refineries use heavy oil in their processes. This requires the materials used in plant of exploration and processing of oil and its derivatives excellent corrosion resistance and good mechanical properties [1]. Among these metallic materials stainless steels and nickel super alloy scan be highlighted [2, 3, 4]. However, the manufacture of solid components using these alloys makes them uneconomical equipment. Therefore, a viable alternative to such a problem is the application of metallic coatings by welding of these alloys on structural and piping carbon steel [5].

However, the welding of dissimilar materials leads to rise residual stress level due to difference between coefficients of thermal expansion and contraction [6, 7]. It is well known that the welding residual stresses have very significant influence on the fatigue life, crack growth, acceleration (or retardation) of corrosion processes assisted by tension and other effects [8, 9, 10].

In this context, this study aimed to evaluate the level of residual stresses in surface coatings of stainless steel E308L T1 applied by the FCAW process in plates of ASTM A36 steel.

II. Materials and Methods

a) Base Metal and Consumables

In this paper ASTM A36 steel was used as the base metal and the AWS E308L T1 with a diameter of 1.2 mm as filler metal. Table 1 shows the chemical composition of the materials used according to the manufacturer.

Table 1 : Chemical composition (weight%) of employed consumables

	C	Cr	Ni	Mo	Mn	Si	Cu	P	S	Fe
AWS E-308L	0,03	19,5 - 22,0	9,0 - 11,0	0,75	1,0 - 2,5	0,30 - 0,65	0,75	-	-	Balance
ASTM A 36	0,18-0,23	-	-	-	0,30-0,60	-	-	0,03 máx.	0,05 máx.	Balance

b) Experimental Procedure

The welds were made by FCAW (Flux Core Arc Welding) process. An electronic welding source and a system of data acquisition for control of welding parameters was used. The welding procedure was performed without restriction and without weaving. The specimens consist of three weld beads deposited in the flat position by varying the voltage (U), the wire feed speed (Fr) and travel speed (Ts) generating different values of heat input (H). The values of the welding parameters used in the experiments are shown in Table 2. Un overlap of 1/3 weld beadwidth was used as illustrated in Figure 1. Inclination of the welding torch ($\theta = 15°$ to the vertical), welding direction "pushing" mode current with reverse polarity CC+ and contact tip away from the workpiece of 15 mmhave been kept fixed.

Author α σ ρ: Universidade Federal De Campina Grande - UFCG, Departamento De Engenharia Mecânica, Aprígio Veloso, Cx., Campina Grande, PB. e-mails: raphael.engmec@gmail.com, santos@dem.ufcg.edu.br, theo@dem.ufcg.edu.br

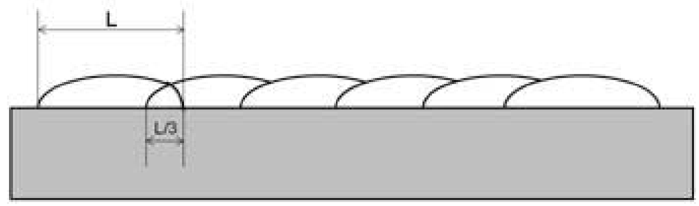

Figure 1 : Illustration of the overlap between the beads

Table 2 : Welding parameters

	U (volts)	Fr (m/min)	Ts (cm/min)	H (kJ/cm)
1	30,0	6,0	20,0	19,65
2	40,0	6,0	20,0	26,19
3	30,0	7,0	20,0	21,20
4	40,0	7,0	20,0	28,19
5	30,0	6,0	26,0	10,97
6	40,0	6,0	26,0	14,51
7	30,0	7,0	26,0	11,82
8	40,0	7,0	26,0	15,99
9	35,0	6,5	23,0	16,94
10	35,0	6,5	23,0	17,52
11	35,0	6,5	23,0	17,44

The stress analysis was performed on the surface of the coatings using a portable X-ray diffractometer (Figure 2).

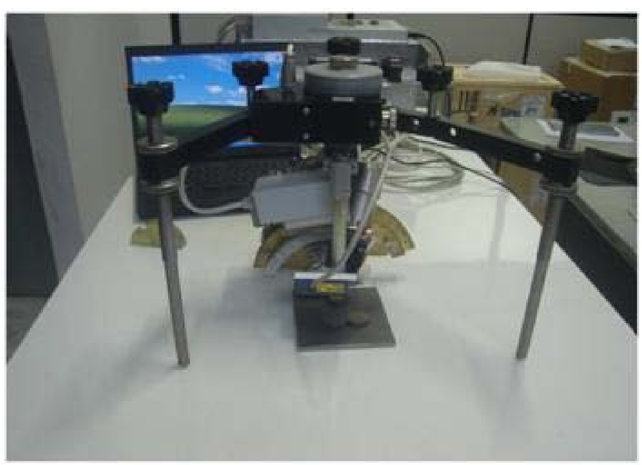

Figure 2 : Portable diffractometer used in the analysis of residual stresses

To examining austenitic steels planes {220} with a wavelength of $\lambda = 2.2896$ Å, and peak angle (2θ) $= 128.84°$ were used. The wavelength is produced by a anodic tube of chromium [11].

The methodology used was the sen$^2\psi$ with measurements for ψ = 0 °, 30 °, 33 °, 35 ° 37 °, 40 °, 42 °, 43 °, 44 ° and 45 °. Analyses were performed in three distinct regions of all coatings. Figure 3 illustrates the arrangement of the points that were analyzed, where I, M and F means the beginning, middle and end of coating.

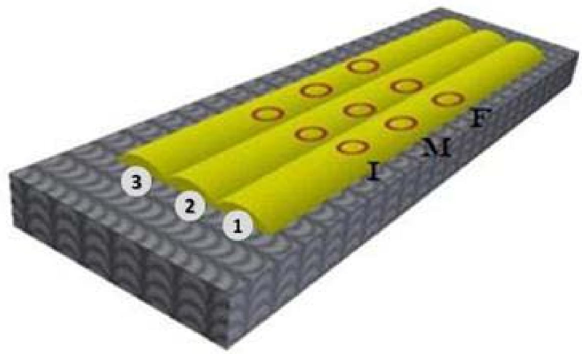

Figure 3 : Analyzed regions on the coatings

III. Results

In Figures 4 to 9 are plotted the longitudinal and transverse fields of residual stresses for coatings FCAW - 1, 2 and 5.These coatings were chosen because were done using extremes and intermediates heat input values: very low (H5 = 10.97 kJ / cm), very high (H2 = 26.19 kJ / cm) and intermediate (H1 = 19.65 kJ / cm).

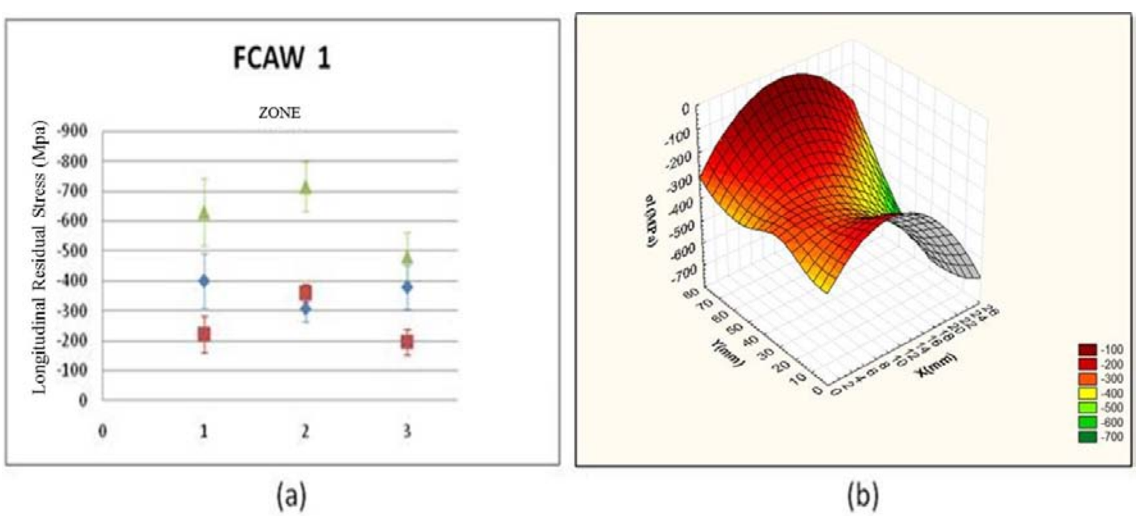

Figure 4 : Mean values of longitudinal residual stresses and their respective uncertainties (a); Field of longitudinal residual stresses into the coating (b)

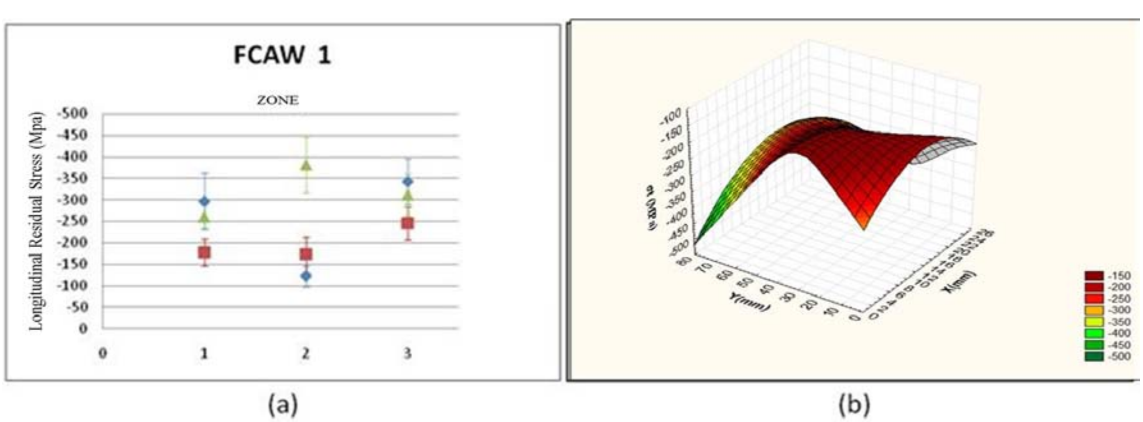

Figure 5 : Mean values of transverse residual stresses and their respective uncertainties (a); Field transverse residual stresses (b) in coating

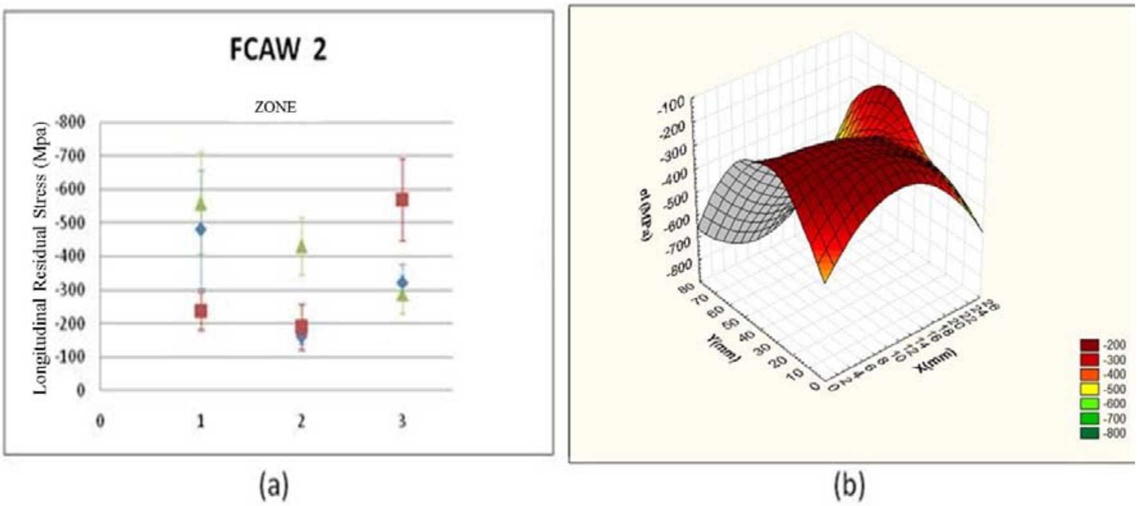

Figure 6 : Mean values of longitudinal residual stresses and their respective uncertainties (a); Field of longitudinal residual stresses into the coating -2(b)

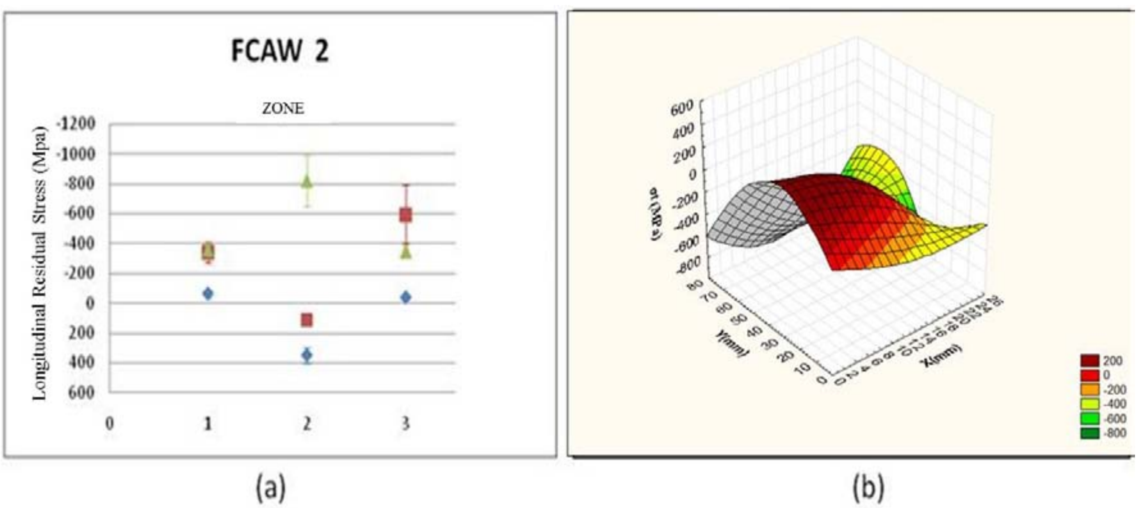

Figure 7 : Mean values of transverse residual stresses and their respective uncertainties (a); Field transverse residual stresses into the coating - 2 (b)

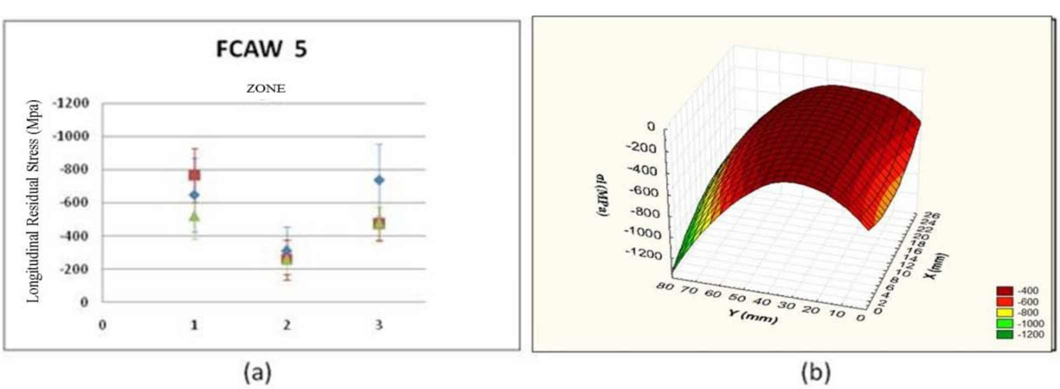

Figure 8 : Mean values of longitudinal residual stresses and their respective uncertainties (a); Field of longitudinal residual stresses into the coating - 5 (b)

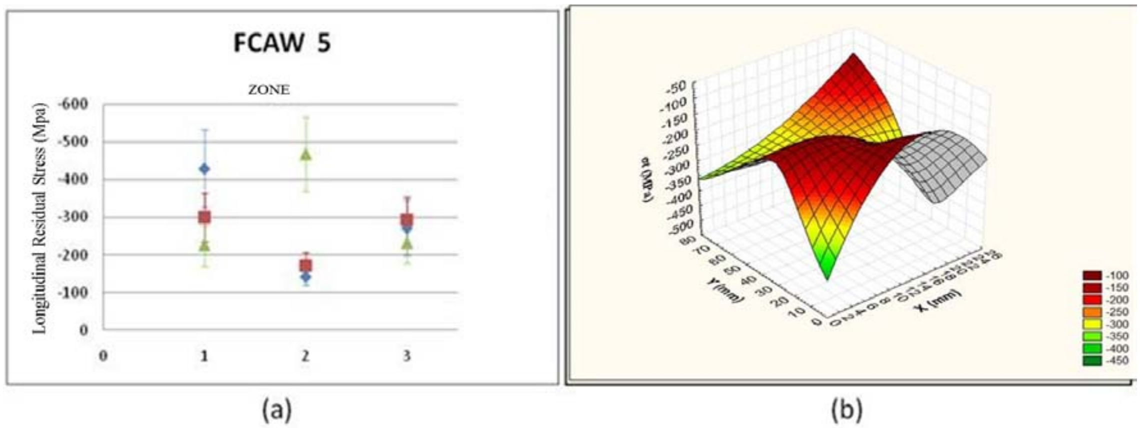

Figure 9 : Mean values of transverse residual stresses and their respective uncertainties (a); Field transverse residual stresses for into the coating - 5 (b)

From these graphs, it is noted that the central region of the coatings is more compressive than the periphery, and that the residual stress field develops compressive values in the top coating with decrease and increase again at the end of coating. Results from the literature [12, 13] indicate that the 18-8 alloys (% Cr-% Ni) show higher variation of the residual stresses along the width of the weld bead. These fluctuations indicate that the residual stresses are not constant in the irradiated areas.

Figure 4 (a) shows that the maximum value of longitudinal residual stress was about 700 MPa in modulus in region 2 at the end of the coating. The minimum value in modulus was 200 MPa, in the beads 1 and 3 through the coating. Figure 5 (a) shows that the transverse residual stresses are smaller in magnitude than the longitudinal. The maximum transverse residual stress was 380 MPa, compared to 700 MPa (longitudinal residual stresses) in the same region.

It can be seen from the Figure 7 (a) the presence of residual tensile stresses at the beginning and middle of the coating bead, subsequently evolving into a state of compressive stress at the end of the coating. Bezerra et al. [14] hypothesized that welding defects such as discontinuities and lack of fusion of the weld metal can contribute to justify the presence of these tensile stresses in these regions.

Figures 8 and 9 show a distribution of the residual stress field similar to previous coatings, although the magnitude of the residual stress values due to the change significantly greater amount of welding energy with which these coatings were applied. Cardoso [15] found that joints subjected to different welding energies have similar distribution of residual stress on the surface, but may have different magnitudes of stresses.

The nature of the distribution of residual stress is closely linked to the nature of electric arc welding characteristic of each process [16].

Table 3 shows the average values of longitudinal and transverse residual stresses and their deviations and coefficients of variation.

Table 3 : Average residual stresses for all conditions of welding by FCAW process

	Longitudinal (MPa)			Transverse (MPa)		
	Average	Desviation	CV	Average	Desviation	CV
1	-410	68	0,1658	-257	44	0,1712
2	-344	88	0,2558	-233	70	0,3004
3	-373	74	0,1984	-260	54	0,2077
4	-591	143	0,2420	-278	54	0,1942
5	-494	144	0,2915	-167	63	0,3772
6	-498	110	0,2209	-286	53	0,1853
7	-393	119	0,3028	-250	57	0,2280
8	-470	111	0,2362	-361	75	0,1847
9	-506	142	0,2806	-195	65	0,3333
10	-456	109	0,2390	-251	110	0,4382
11	-390	107	0,2744	-241	65	0,2697

Table 3 gives an idea of the magnitude of the average longitudinal and transverse residual stresses in the coatings. It is noteworthy that the transverse residual stresses values had lesser magnitude than the longitudinal residual stress, corroborating the results of KOU [7]. All coefficients of variation (CV) are observed near 0.3; as criteria for acceptance in this work it was established that values lower than 0.5 CV are needed to express the average representative form, and CV values close to 0.3 are considered optimal.

The nature of the average residual stresses in the coatings was compression, however, it was observed during the individual analyzes some tensile residual stresses value, indicating the probable presence of welding defects. The compressive nature of the stresses in these coatings can be explained due to a physical characteristic of the filler metal involved. During the process of solidification austenitic stainless steel undergoes two phase transformations, the first liquid metal to δ ferrite, body-centered cubic structure, the second transformation is the δ ferrite to austenite structure which is cubic face centered. In this last phase transformation, there is an expansion of the unit cells, since the parameter of the face-centered cubic structure network is greater than the body-centered cubic [17]. This expansion opposites the nature of the substrate, which is ferritic, which tends to contract during the solidification process, combined with the mismatch between the coefficient of thermal expansion of stainless steel (17 - 19 mm m-1 K-1) and the structural substrate generates compressive residual stresses on the surface of the coating [12, 13, 18].

Figure 10 illustrates the influence of heat input on the level of residual stresses.

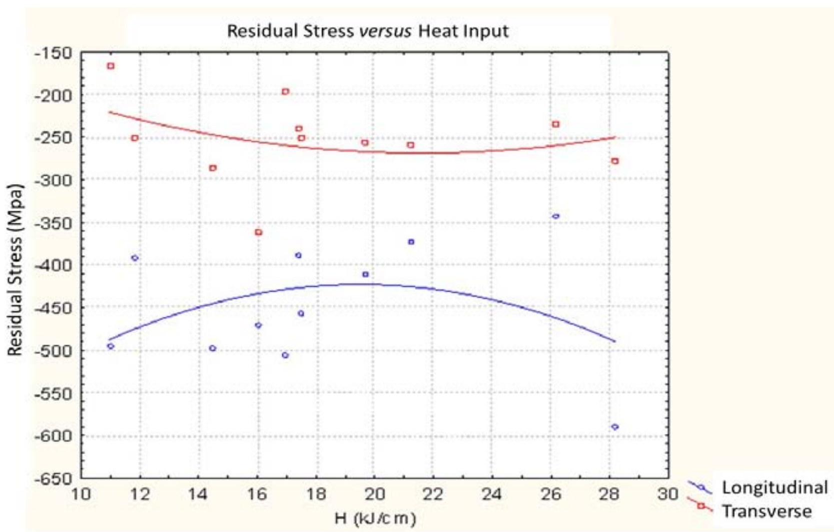

Figure 10 : Influence of heat input on the level of longitudinal and transverse residual stresses, and the interaction between the stress levels in the FCAW process

In this paper, the results do not indicate a linear relationship between the levels of residual stresses and the values of welding energy. This non-linearity can be attributed to competitive phenomena governed by the heat input and its directly influence the magnitude and nature of the residual stresses as:

- The the volumetric fraction of δ ferrite present in the weld metal, whose amount is proportional to the welding energy [19]. From there it can be hypothesize that the presence of δ ferrite can induce compressive residual stresses present in the weld metal;
- The size of the molten pool, where a larger restriction is imposed on the welded assemblies with lower energy, since they do not have major penetrations, which results in a large volume of all that remains solid during welding thereby increasing the restriction and consequently raising the level of residual stress;
- Welded specimens with higher heat input have a large amount of deposited material which results in high levels of residual stress.

Figure 11 shows the volumetric fraction of δ ferrite, evalueted qualitatively by the method of meshes [20]. The CP 5 coating was applied using a heat input H = 10.97 kJ / cm, this welding condition presented 23 mesh nodes on the δ ferrite. The CP 8 was applied using a heat input H = 15.99 kJ / cm with present 45 mesh nodes on the δ ferrite. In general, it can be noticed that increasing heat input occurs an increase in the the volumetric fraction of δ ferrite present in the weld metal. Comparing the information in Table 3 with those in Figure 11it can be noted that this increase results in a slight reduction of the longitudinal residual stresses and there is an increase of transverse residual stresses.

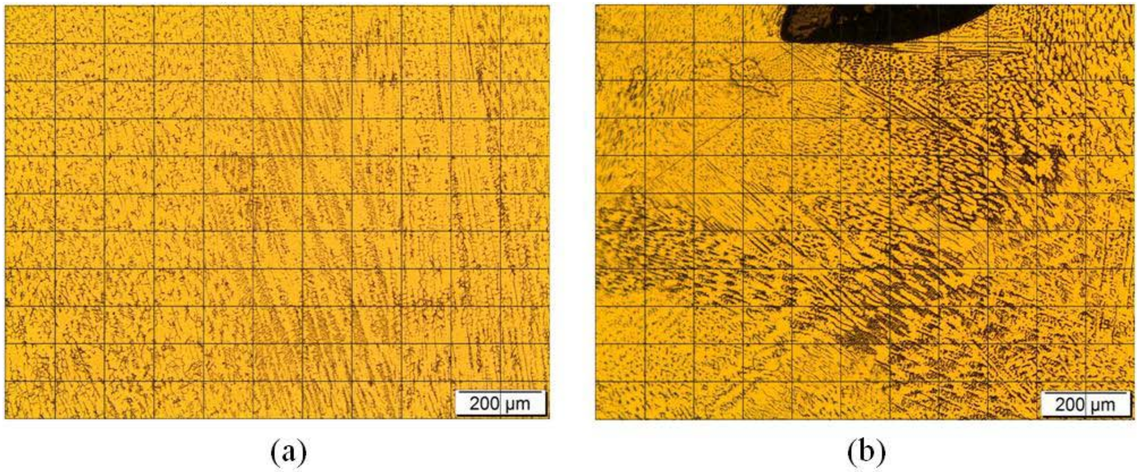

Figure 11 : Volumetric fraction of δ ferrite in the weld metal of the specimens CP 5 (a) and CP 8 (b)

Thus, for the range of low to medium welding heat input the magnitude of the longitudinal welding residual stress decreases with increasing welding energy due to the increased the volumetric fraction of δ ferrite present in the weld metal. However, there is a sharp increase of the transverse residual stresses.

Although it may be inferred that when the longitudinal residual stresses become less compressive the transverse residual stresses tend to become more compressive in order to keep a balance between these stresses.

IV. Conclusions

- The surface residual stresses in the coatings were predominantly compressive. The central region of the coatings always showed less compression than the periphery;
- It was not observed a linear relationship between the magnitude of the residual stresses and the welding heat input due to competitive phenomena such as precipitation of δ ferrite in the weld metal and the volume of material deposited in the application of coatings using high welding heat input;
- In general, the microstructure observed in the weld metal was austenite with δ ferrite, and the volumetric fraction of δ ferrite may play a significant influence on the magnitude of the residual stresses.

V. Acknowledgements

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The Design and Simulation Patterns in Ultrasonic Wedges for Non-Destructive Testing

By Ibe, G. A
University of warwick, Nigeria

Abstract- The design and simulation patterns in ultrasonic wedges for non-destructive testing are critical to the assessment and characterization of a material or structure. Its significance is the mitigation of failures in members. The approach is relevant mostly to non-destructive testing of very expensive and critical mechanical members requiring high level of reliability in operation. In this paper, the design and simulation of ultrasound through both straight and angle wedges are discussed. Also, the characterization of the material using pulse-echo and through-transmission ultrasonic methods is illustrated.

Keywords: design, simulation, ultrasonic wedges, nondestructive testing.

GJRE-J Classification : FOR Code: 299904p

The Design and Simulation Patterns in Ultrasonic Wedges for Non-Destructive Testing

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Abstract- The design and simulation patterns in ultrasonic wedges for non-destructive testing are critical to the assessment and characterization of a material or structure. Its significance is the mitigation of failures in members. The approach is relevant mostly to non-destructive testing of very expensive and critical mechanical members requiring high level of reliability in operation. In this paper, the design and simulation of ultrasound through both straight and angle wedges are discussed. Also, the characterization of the material using pulse-echo and through-transmission ultrasonic methods is illustrated.

Keywords: design, simulation, ultrasonic wedges, non-destructive testing.

I. Introduction

The performance and effectiveness of ultrasonic wedges in non-destructive testing cannot be optimised except appropriate design simulation approach is adopted. Design and simulation of the ultrasound will fix problems of wedge configuration and the interface angle [1]. Ultimately, this approach will enable the simulation of the sound wave into the test sample.

In ultrasonic testing, both longitudinal and shear waves can be transmitted into the specimen. However, refracted shear wave is exploited in angle beam inspection because of its low attenuation [2]. Most importantly, when refracted shear waves are utilized only in the inspection, the refracted longitudinal waves align with the material interface, enabling easy and accurate interpretation of signals [3]. The angle of the incident beam at which the parallel alignment of the longitudinal waves with the specimen surface occurs, is called the first critical angle.

Apart from the benefit of having one wave mode in the sample, the critical angle allows the inspection of sample surfaces such as weldments. For this mode-converted system, the transfer of energy is optimised in steel. Also the defect sensitivity is enhanced in the presence of shear waves [3].

II. Wedge Design

To optimally design an ultrasonic wedge, some basic specifications must be made. The following are the specifications that were used in the study.

a) Longitudinal waves are refracted into the test sample at 90^0.
b) Wedge is Rexolite with longitudinal sound velocity at 2362.2 m/s.
c) The test sample is made of alloy steel (X90CrMoV18) with shear sound velocity at 2478 m/s.

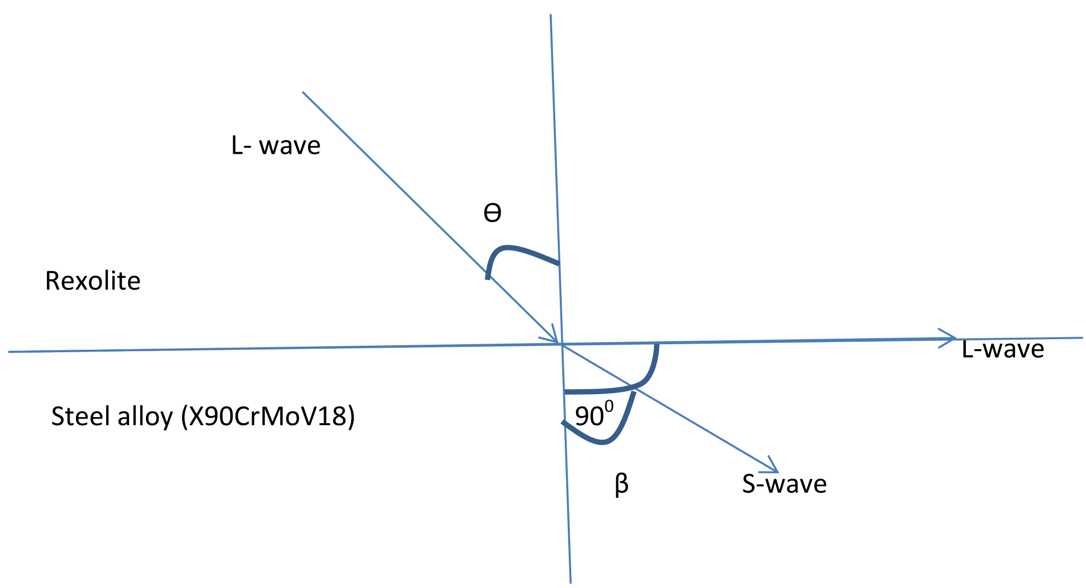

Fig. 1 : Refraction of shear waves into the sample

Author: Advanced Imaging and Measurement, School of Engineering, University of warwick, UK. e-mails: A.G.Ibe@warwick.ac.uk

From Fig.1, applying Snell's law:

$$\frac{\sin\theta}{\sin 90} = \frac{v}{u} \text{------------------------------(1)}$$

Where θ = incident wedge angle;

Longitudinal refracted angle = 90^0 at the interface;

v = longitudinal sound velocity in Rexolite;

u = Rayleigh wave velocity (2900 m/s).

Substituting in equation (1),

$$\frac{\sin\theta}{\sin 90} = \frac{2362.2}{2900}$$

θ = asin (2362.2/2900 sin90)

= 54.54^0

Hence, θ is beyond the first critical angle in steel (i.e. 27.5^0). However, it is below the second critical angle (i.e. 57^0). Therefore, only shear waves would be refracted into the unit under test.

Also, the refracted shear angle β in the specimen can be estimated as follows:

$$\frac{\sin 54.54}{\sin\beta} = \frac{2362.2}{2478}$$

β = asin $\left(\frac{2478}{2362.2}\sin 54.54\right)$

= 58.72^0

III. Material Characterization

The sound velocity of the specimen was measured using pulse-echo and through- transmission ultrasound. With this approach, the sound velocity of the specimen of known thickness can be found. Conversely, the sample thickness can be tested for material of known sound velocity especially in stress corrosion control [4].

As will be shown subsequently, the pulse-echo method gives more accurate results than the through transmission. Another advantage with the pulse-echo technique is that it is more amenable to ultrasonic testing because it requires only one scanning surface of the specimen [5].

For a steel block of thickness 20.3mm, the longitudinal sound velocity, using the two ultrasonic techniques, is compared as follows:

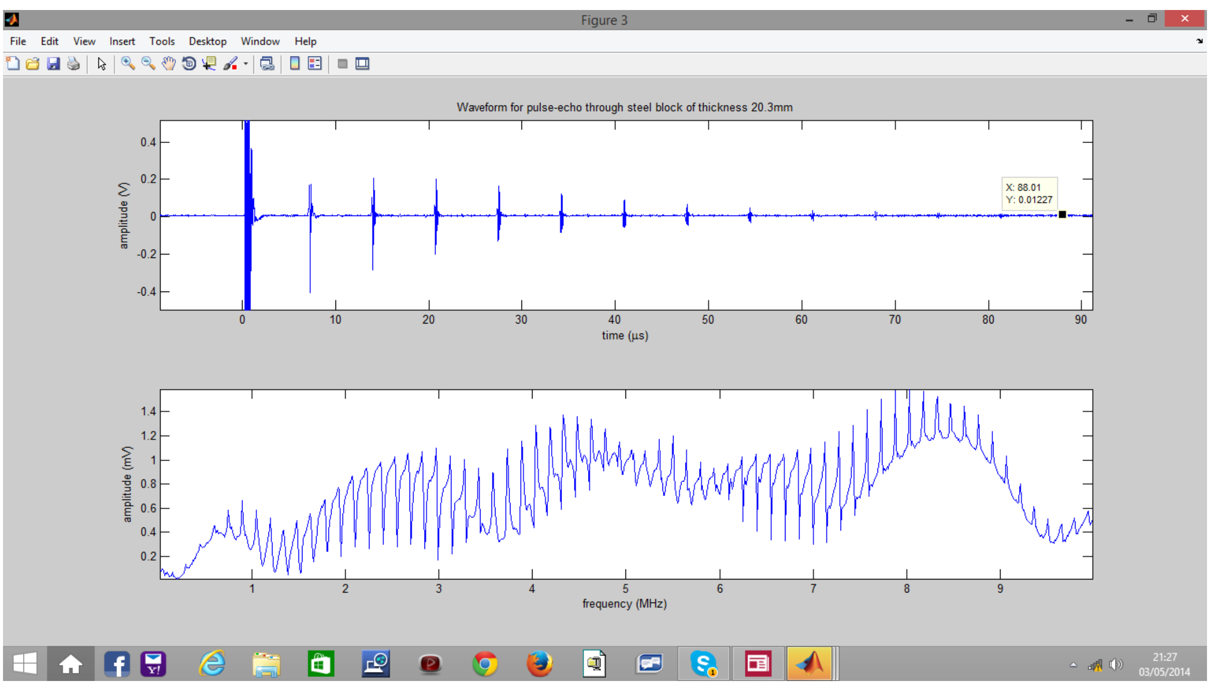

Fig. 2 : Waveform of pulse-echo ultrasound in the steel block

From Fig. 2, the time of flight is the time interval between the pickup and the first echo divided by 2.

Hence, time of flight, $T_f = \frac{7.1-0.2}{2} = 3.45\mu s$

$$\text{Sound velocity in the steel} = \frac{Thickness\ of\ steel\ block}{Time\ of\ flight}$$

$$= \frac{20300\, mm}{3.45 s}$$

=5,884.1m/s

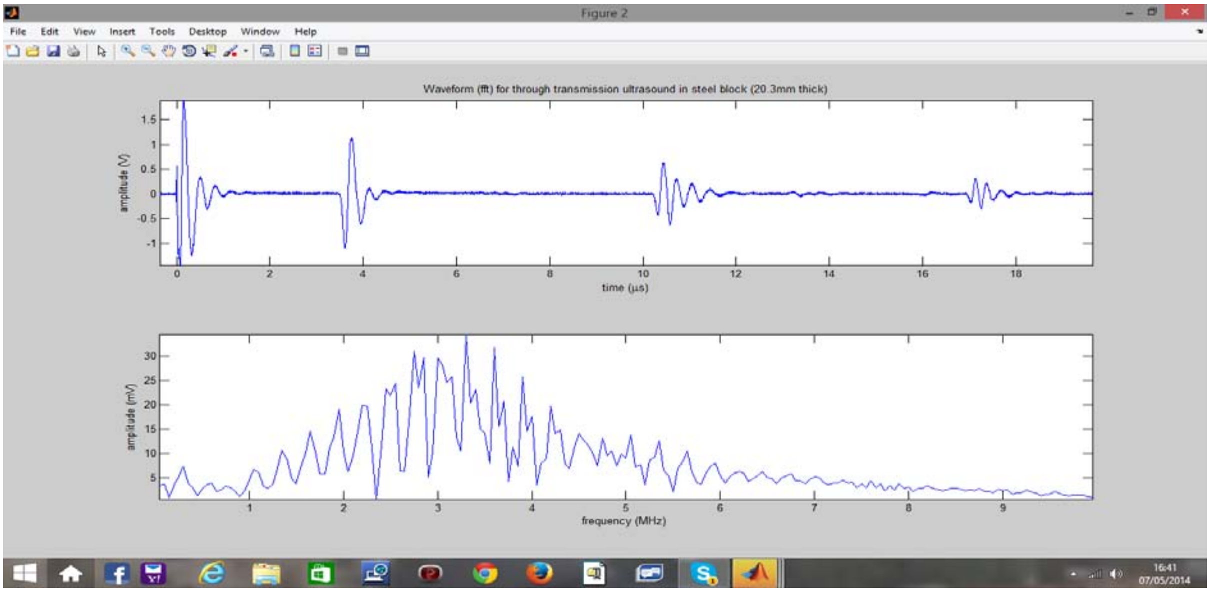

Fig. 3 : Waveform of through transmission ultrasound in the steel block

From Fig. 3, the time of flight is the interval between the pickup and the corresponding point on the first reflection.

$$\text{Sound velocity in the specimen} = \frac{Thickness\ \ of\ steel\ block}{Time\ \ of\ flight}$$

$$\text{From the graph, time of flight, } T_f = 3.48\mu s - 0.014\mu s$$

$$= 3.47\mu s$$

$$\text{Hence, longitudinal sound velocity in the steel} = \frac{0.0203\,m}{3.47e{-}6(s)}$$

$$= 5{,}850 m/s$$

IV. Simulation of Sound Wave in the Steel Sample

A 10mm diameter piston transducer with a centre frequency of 1MHz was used to transmit ultrasound into the specimen through a Rexolite wedge of 0 and 20^0 interface angles. The directivity patterns for both longitudinal and shear waves were plotted in matlab using the directivity function.

a) Zero Degree Interface Angle

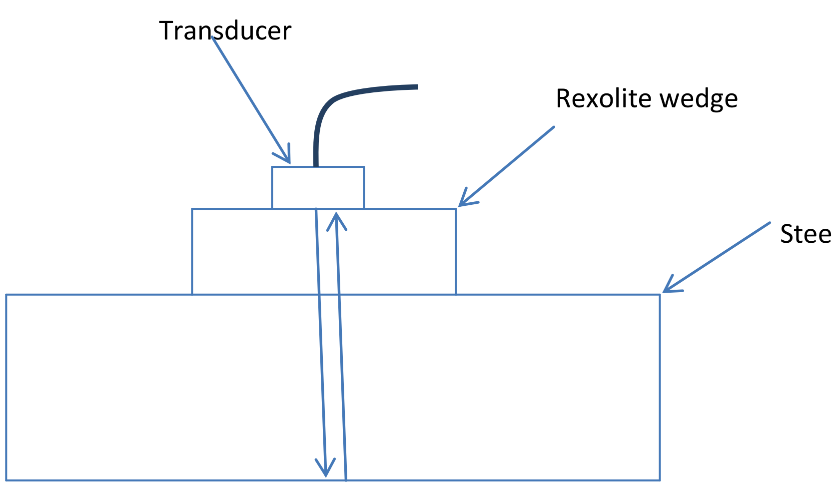

Fig. 4 : Ray propagation from Rexolite into steel at 0^0 Interface angle

The directivity patterns for Fig. 4 are displayed as follows:

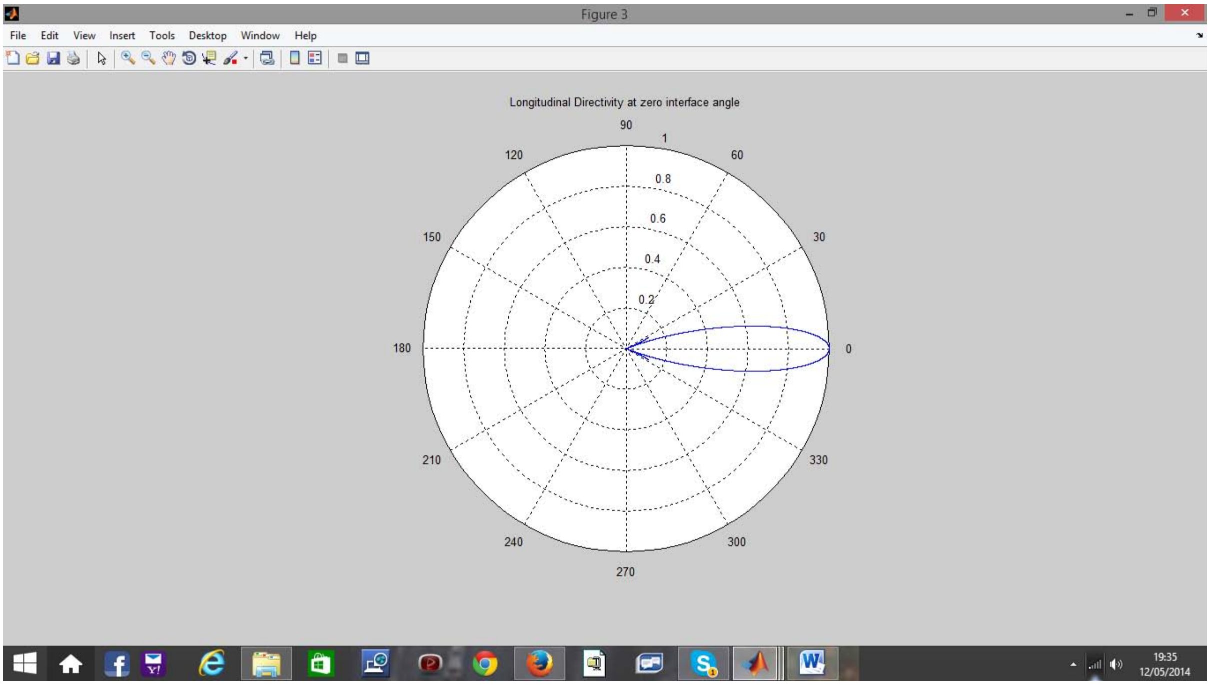

Fig. 5 : Directivity pattern of longitudinal wave in Steel/Rexolite at 0^0 interface angle

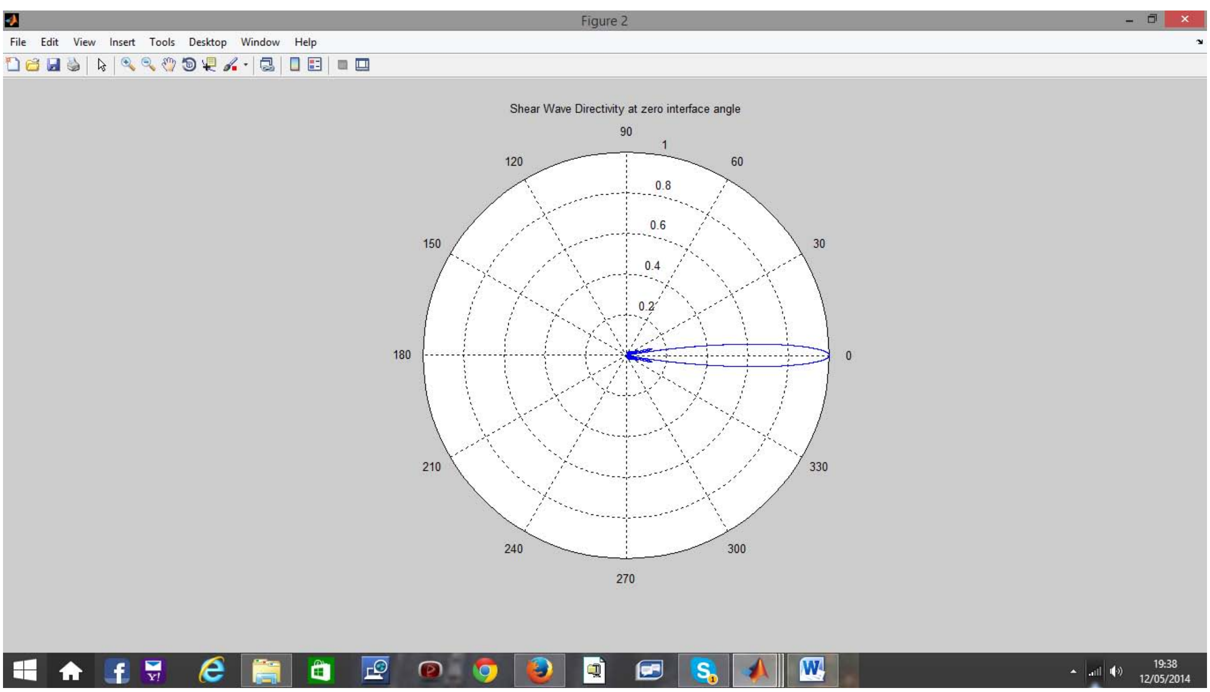

Fig. 6 : Directivity pattern of shear wave in Steel/Rexolite at 0^0 interface angle

b) Twenty Degree Interface Angle

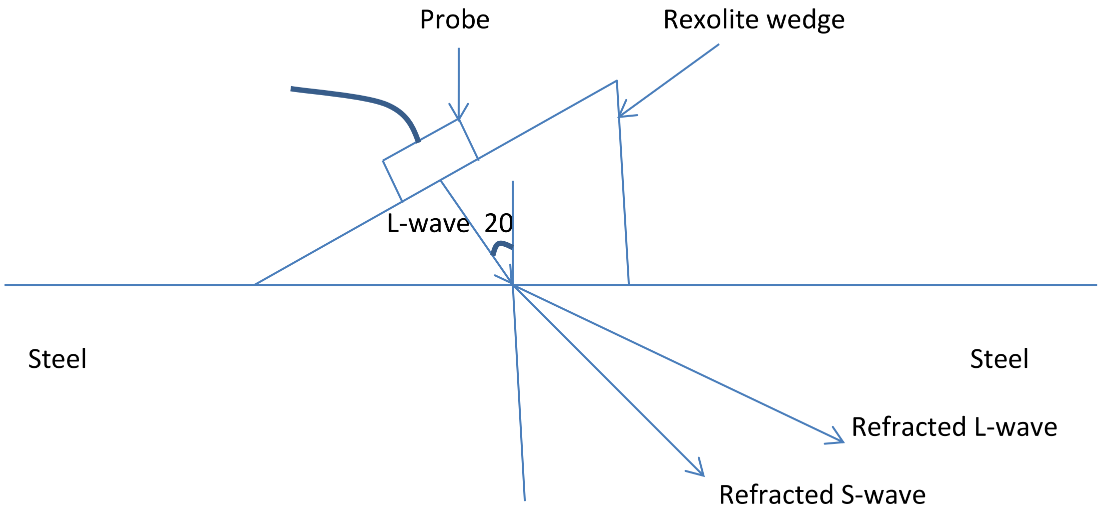

Fig. 7 : Ray propagation through 20^0 Rexolite wedge into Steel

The directivity patterns for Fig. 7 are shown below.

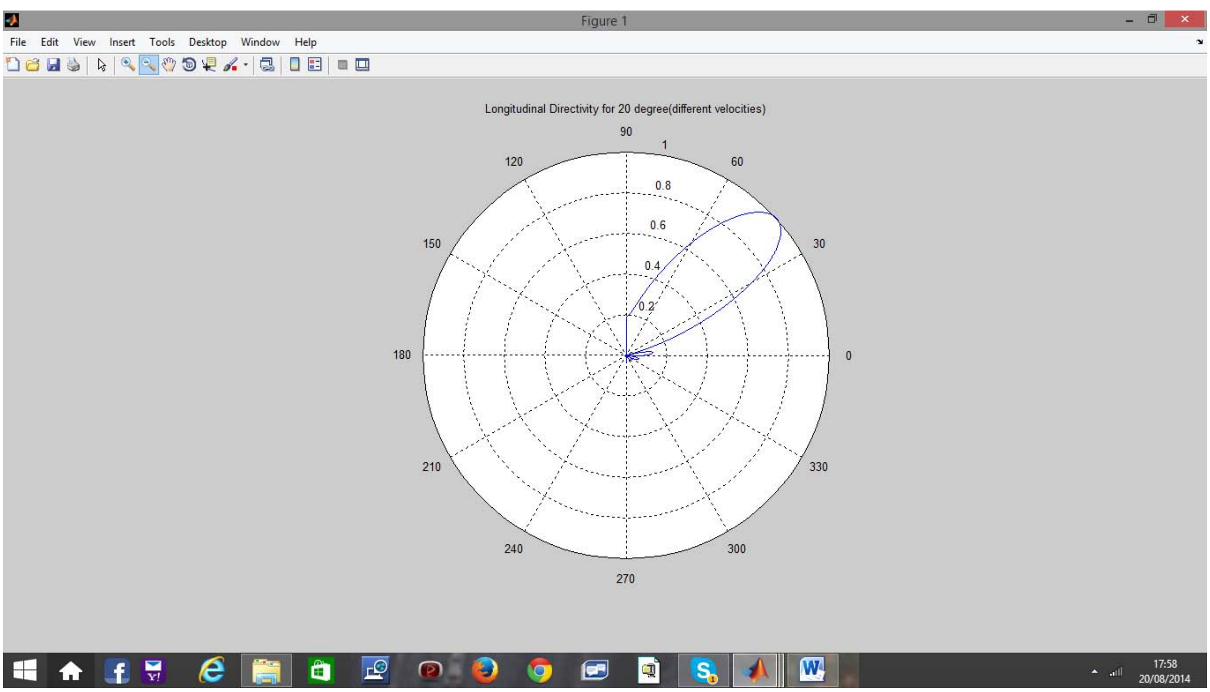

Fig. 8 : Directivity pattern of longitudinal wave in Steel/Rexolite at 20^0 interface angle, 1MHz

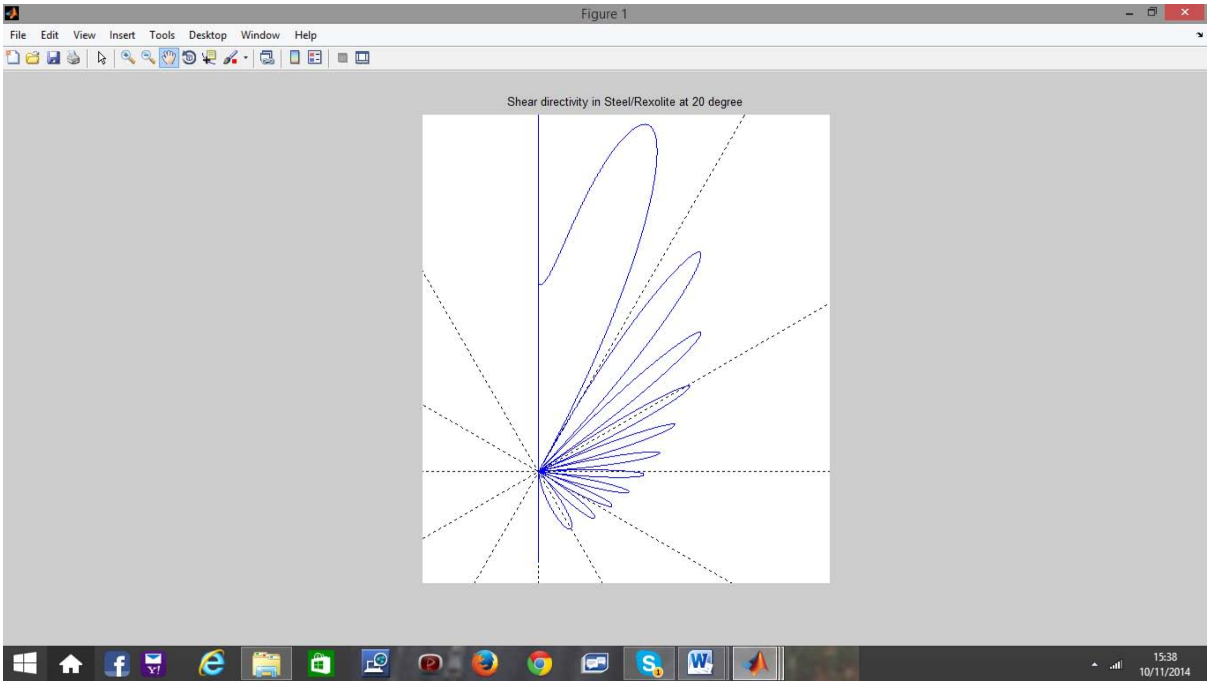

Fig. 9 : Directivity pattern of shear wave in Steel/Rexolite at 20^0 interface angle, 1MHz

c) Reducing The Centre Frequency of the Transducer From 1mhz To 0.5mhz.

The simulation patterns are illustrated below.

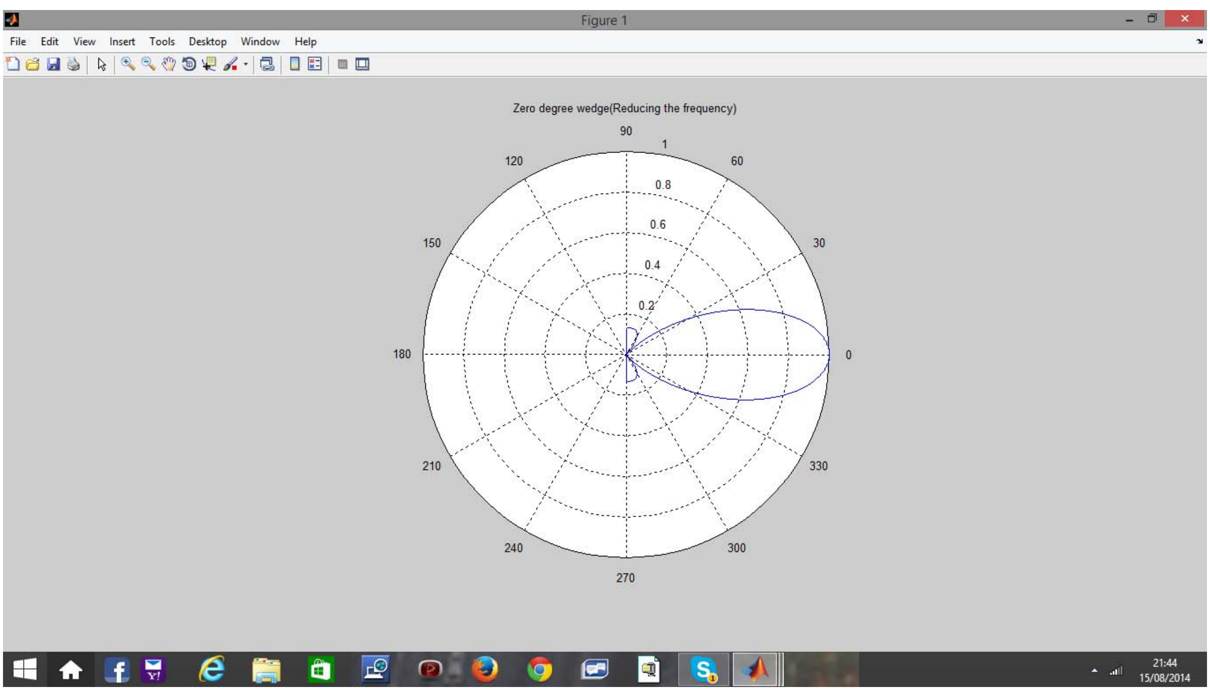

Fig. 10 : Directivity pattern of longitudinal wave in Steel/Rexolite at 0^0 angle and 0.5MHz

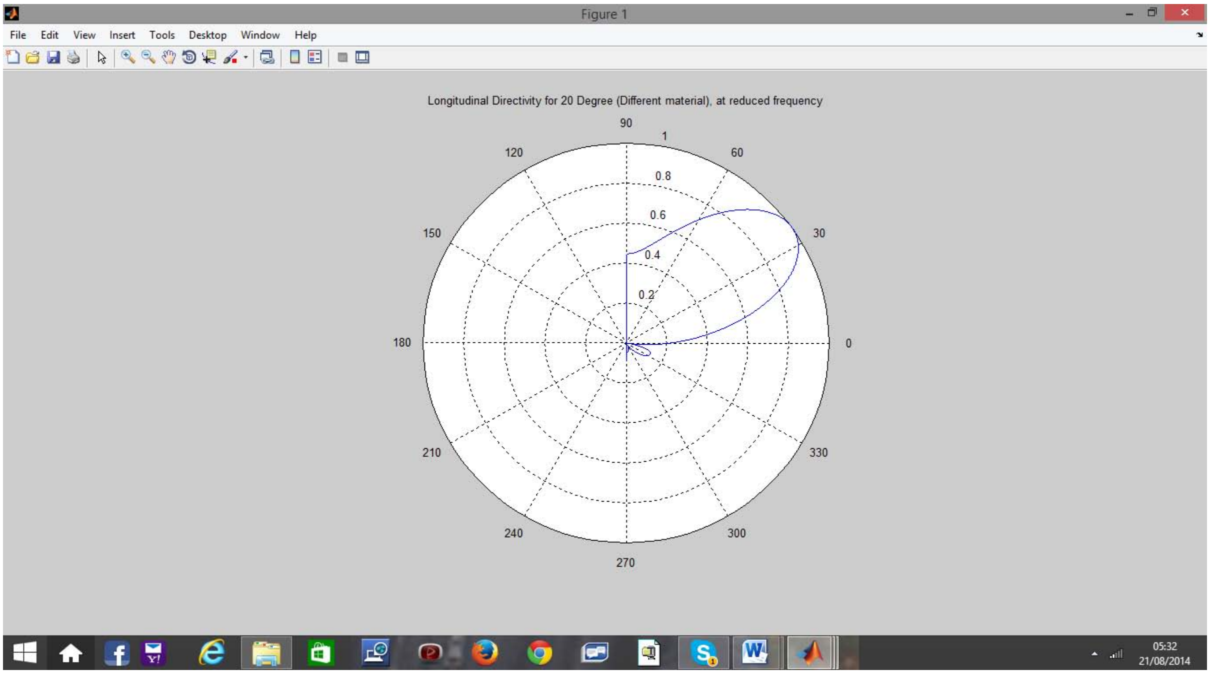

Fig.11 : Directivity pattern of longitudinal wave in Steel/Rexolite at 20^0 angle and 0.5MHz

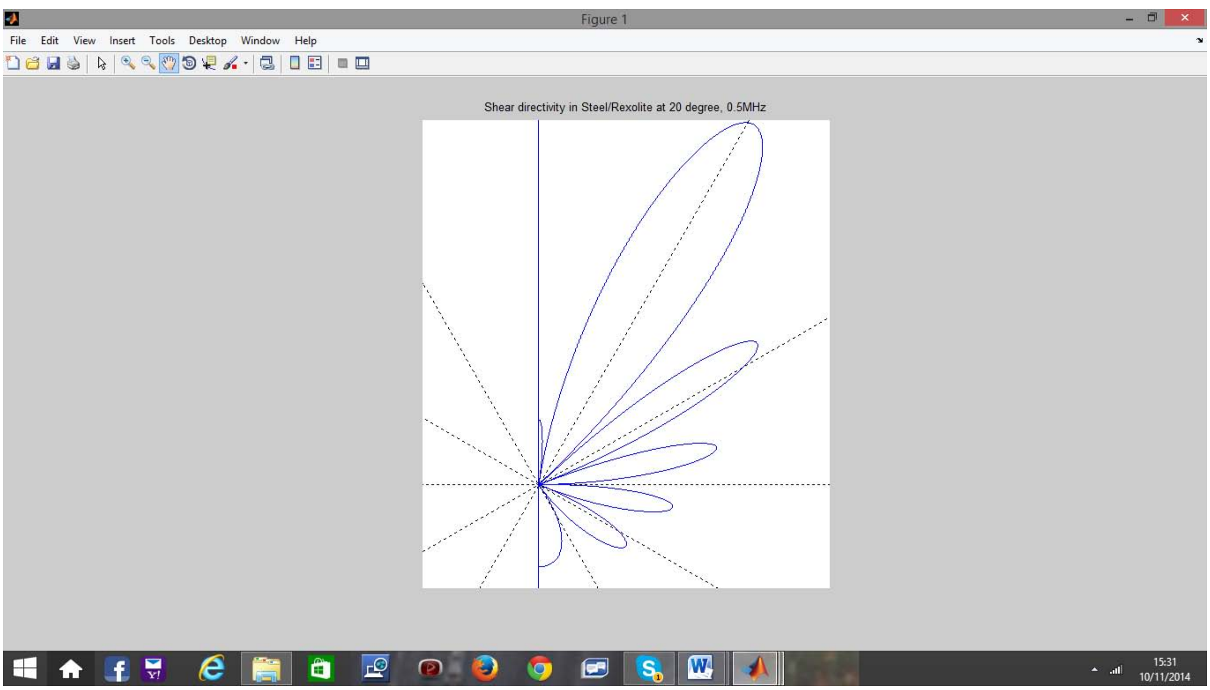

Fig.12 : Directivity pattern of shear wave in Steel/Rexolite at 20^0 angle and 0.5MHz

V. Discussion of Results

For the experiments on material characterization (see section 3), the ideal longitudinal sound velocity of steel is 5890m/s. This literature value could not be attained due to errors of instruments, operator and temperature variations. Also, the pulse-echo method gave more accurate measurement than the through transmission technique as seen from the small deviation when compared to the literature value.

From Fig. 5, the longitudinal directivity is less directional and less focussed than the shear directivity in Fig. 6. Moreover, both patterns are symmetrical, indicating absence of mode conversion. Directional ultrasonic signals are sensitive to small flaws and flaws parallel to the wave direction [6]. Hence, this informs why shear waves are mostly preferred in ultrasonic testing.

In Fig. 8, the longitudinal directivity pattern for the 20 degree wedge is asymmetrical and has a pronounced main lobe while in Fig. 9; the pattern is more distorted with many side lobes.

By reducing the centre frequency of the finite transducer, the following observations are made:

a) The longitudinal directivity patterns for the 0 and 20^0 interface wedges are more omnidirectional compared to the previous patterns in Figs. 5 and 8.

b) In Fig. 12, the shear directivity pattern for the 20 degree wedge is larger with fewer side lobes compared to that in Fig. 9.

Finally, it can be seen that the asymmetrical and distorted form of the patterns for the 20 degree angle wedge is due to mode conversion at the material interface. The directivity patterns for the straight wedge are symmetrical and on axis due the absence of mode conversion. Mode conversion is effected when the incident angle is not perpendicular to the interface in the presence of impedance mismatch [7].

VI. Conclusion

Appropriate wedge design and simulation will greatly facilitate the modeling of ultrasonic wedges. The approach will determine the critical incident angle which is one of the input parameters to numerical modeling.

Also, the analytical simulation done in this study can provide a reasonable picture of the numerical approach.

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Kinetic Induktance Charges and its Role in Classical Electrodynamics

By F. F. Mende
B.I. Verkin Institute, Ukraine

Abstract- The dielectric and magnetic constant of material media are the parameters, which are used during writing Maksvell equations. However, there is still one not less important material parameter, namely a kinetic inductance of charges, which has not less important role, than the parameters indicated. Unfortunately, importance and fundamentality of this parameter in the works on electrodynamics, until now, is not noted, and kinetic inductance is present in all equations of electrodynamics implicitly. This work is dedicated to the examination of the role of the kinetic inductance of charges in the electrodynamics of material media and to the restoration of its rights as the fundamental parameter, on the importance that not less meant than dielectric and magnetic constant.

Keywords: electrodynamics; maxwell equation; kinetic inductance of charges; dielectric constant; magnetic permeability.

GJRE-J Classification : FOR Code: 020302

KINETICINDUKTANCECHARGESANDITSROLEINCLASSICALELECTRODYNAMICS

Strictly as per the compliance and regulations of:

Kinetic Induktance Charges and its Role in Classical Electrodynamics

F. F. Mende

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Keywords: electrodynamics; maxwell equation; kinetic inductance of charges; dielectric constant; magnetic permeability.

I. Introduction

In the existing scientific literature occurs only the irregular references about the kinetic the inductance of charges [1-3]. the most in detail physical essence of this parameter and its place in the description of electrodynamic processes in the conductors is examined in work [4]. In this work is introduced also the concept of surface kinetic and field inductance, which earlier was not introduced:

$$L_K = \frac{1}{\omega |\vec{H}_T(0)|^2} \operatorname{Im} \int_0^\infty \vec{j}^* \vec{E} dz,$$

$$L_H = \frac{1}{|\vec{H}_T(0)|^2} \int_0^\infty |\vec{H}_T|^2 \, dz,$$

Where L_K and L_H - surface kinetic and field inductance, $\vec{E}$ - the tension of electric field, $\vec{j}^*$ - the complexly conjugate value of current density, $\vec{H}_T$ - tension of magnetic field; $\vec{H}_T(0)$ - the value of the tension of magnetic field on the surface; ω - frequency of the applied field. These relationships are valid for the case of the arbitrary connection between the current and the field in the metals and the superconductors, and they reveal the physical essence of surface kinetic and field inductance.

Author: B.I. Verkin Institute for Low Temperature Physics and Engineering Nas, Ukraine, Kharkov, Ukraine.
e-mail: mende_fedor@mail.ru

a) Plasmo-like media

The equation of motion of electron takes the following form:

$$m\frac{d\vec{v}}{dt} = e\vec{E} \quad (1.1)$$

where m - mass electron, e - electron charge, $\vec{E}$ - tension of electric field, $\vec{v}$ - speed of the motion of charge. In the work [2] it is shown that this equation can be used also for describing the electron motion in the hot plasma.

Using an expression for the current density

$$\vec{j} = ne\vec{v}, \quad (1.2)$$

from (1.1) we obtain the current density of the conductivity of the free electrons

$$\vec{j}_L = \frac{ne^2}{m} \int \vec{E} \, dt \quad (1.3)$$

in relationships (2.2) and (2.3) the value n represents the specific density of charges. After introducing the designation

$$L_k = \frac{m}{ne^2} \quad (1.4)$$

we find

$$\vec{j}_L = \frac{1}{L_k} \int \vec{E} \, dt \quad (1.5)$$

In this case the value of L_k presents the specific kinetic inductance of charge carriers [4-7]. Its existence connected with the fact that charge, having a mass, possesses inertia properties.

Pour on relationship (1.5) it will be written down for the case of harmonics:

$$\vec{j}_L = -\frac{1}{\omega L_k} \vec{E}_0 \cos \omega t \quad (1.6)$$

Global Journal of Researches in Engineering (J) Volume XIV Issue V Version I Year 2014

For the mathematical description of electrodynamic processes the trigonometric functions will be here and throughout, instead of the complex quantities, used so that would be well visible the phase relationships between the vectors, which represent electric fields and current densities. from relationship (1.5) and (1.6) is evident that presents inductive current, since. its phase is late with respect to the tension of electric field to the angle.

During the presence of summed current it is necessary to consider bias current

$$\vec{j}_{\varepsilon} = \varepsilon_0 \frac{\partial \vec{E}}{\partial t} = \varepsilon_0 \vec{E}_0 \cos \omega t$$

Is evident that this current bears capacitive nature, since. its phase anticipates the phase of the tension of electrical to the angle $\frac{\pi}{2}$ .Thus, summary current density will compose

$$\vec{j}_{\Sigma} = \varepsilon_0 \frac{\partial \vec{E}}{\partial t} + \frac{1}{L_k} \int \vec{E}\, dt$$

or

$$\vec{j}_{\Sigma} = \left(\omega\varepsilon_0 - \frac{1}{\omega L_k} \right) \vec{E}_0 \cos \omega t \qquad (1.7)$$

Introducing the plasma frequency $\omega_0 = \sqrt{\frac{1}{L_k \varepsilon_0}}$, relationship (1.7) it is possible to rewrite

$$\vec{j}_{\Sigma} = \omega\varepsilon_0 \left(1 - \frac{\omega_0^2}{\omega^2} \right) \vec{E}_0 \cos \omega t \qquad (1.8)$$

If in the conductor are ohmic losses, then total current density determines the relationship

$$\vec{j}_{\Sigma} = \sigma \vec{E} + \varepsilon_0 \frac{\partial \vec{E}}{\partial t} + \frac{1}{L_k} \int \vec{E}\, dt$$

where σ - conductivity of metal.

b) Dielectrics

In the existing literature there are no indications that the kinetic inductance of charge carriers plays some role in the electrodynamic processes in the dielectrics. However, this not thus [7]. This parameter in the electrodynamics of dielectrics plays not less important role, than in the electrodynamics of conductors.

Let us examine the simplest case, when oscillating processes in atoms or molecules of dielectric obey the law of mechanical oscillator.

$$\left(\frac{\beta}{m} - \omega^2 \right) \vec{r}_m = \frac{e}{m} \vec{E}, \qquad (2.1)$$

Where $\vec{r}_m$ - deviation of charges from the position of equilibrium, β -coefficient of elasticity, which characterizes the elastic electrical binding forces of charges in the atoms and the molecules. Introducing the resonance frequency of the bound charges of

$$\omega_0 = \frac{\beta}{m}$$

we obtain from (2.1):

$$\vec{r}_m = -\frac{e\ \vec{E}}{m(\omega^2 - \omega_o^2)}. \qquad (2.2)$$

is evident that in relationship (2.2) as the parameter is present the natural vibration frequency, into which enters the mass of charge. This speaks, that the inertia properties of the being varied charges will influence oscillating processes in the atoms and the molecules.

Since the general current density on Wednesday consists of the bias current and conduction current

$$rot\vec{H} = \vec{j}_{\Sigma} = \varepsilon_0 \frac{\partial \vec{E}}{\partial t} + ne\vec{v}$$

that, finding the speed of charge carriers in the dielectric as the derivative of their displacement through the coordinate

$$\vec{v} = \frac{\partial r_m}{\partial t} = -\frac{e}{m(\omega^2 - \omega_o^2)} \frac{\partial \vec{E}}{\partial t}$$

from relationship (2.2) we find

$$rot\vec{H} = \vec{j}_{\Sigma} = \varepsilon_0 \frac{\partial \vec{E}}{\partial t} - \frac{1}{L_{kd}(\omega^2 - {\omega_0}^2)} \frac{\partial \vec{E}}{\partial t} \qquad (2.3)$$

Global Journal of Researches in Engineering (J) Volume XIV Issue V Version I Year 2014

But the value

$$L_{kd}=\frac{m}{ne^2}$$

presents the kinetic inductance of the charges, entering the constitution of atom or molecules of dielectrics, when to consider charges free. Then relationship (2.3) can be rewritten

$$rot\vec{H}=\vec{j}_{\Sigma}=\varepsilon_0\left(1-\frac{1}{\varepsilon_0 L_{kd}(\omega^2-\omega_0{}^2)}\right)\frac{\partial\vec{E}}{\partial t} \qquad (2.4)$$

But, since the value

$$\frac{1}{\varepsilon_0 L_{kd}}=\omega_{pd}{}^2$$

represents the plasma frequency of charges in atoms and molecules of dielectric, if we consider these charges free, then relationship (2.4) takes the form:

$$rot\vec{H}=\vec{j}_{\Sigma}=\varepsilon_0\left(1-\frac{\omega^2{}_{pd}}{(\omega^2-\omega_0{}^2)}\right)\frac{\partial\vec{E}}{\partial t} \qquad (2.5)$$

Let us examine two limiting cases:

- If $\omega = \omega_0$, then from (2.5) we obtain

$$rot\vec{H}=\vec{j}_{\Sigma}=\varepsilon_0\left(1+\frac{\omega_{pd}{}^2}{\omega_0{}^2}\right)\frac{\partial\vec{E}}{\partial t} \qquad (2.6)$$

In this case the coefficient, confronting the derivative, does not depend on frequency, and it presents the static dielectric constant of dielectric. As we see, it depends on the natural frequency of oscillation of atoms or molecules and on plasma frequency. This result is intelligible. Frequency in this case proves to be such small that the inertia properties of charges it is possible not to consider, and bracketed expression in the right side of relationship (1.7) presents the static dielectric constant of dielectric. Hence immediately we have a prescription for creating the dielectrics with the high dielectric constant. In order to reach this, should be in the assigned volume of space packed a maximum quantity of molecules with maximally soft connections between the charges inside molecule itself.

- The case, when ω ? ω_0 , is exponential. Then

$$rot\vec{H}=\vec{j}_{\Sigma}=\varepsilon_0\left(1-\frac{\omega_{pd}{}^2}{\omega^2}\right)\frac{\partial\vec{E}}{\partial t}$$

and dielectric is converted in the plasma. The obtained relationship coincides with the case of plasma (1.8).

Now it is possible to examine the question of why dielectric prism decomposes polychromatic light into monochromatic components or why rainbow is formed. So that this phenomenon would occur, it is necessary to have the frequency dispersion of the phase speed of electromagnetic waves in the medium in question. If we to relationship (2.5) add the first equation of Maxwell, then we will obtain:

$$rot\vec{E}=-\mu_0\frac{\partial\vec{H}}{\partial t}$$

$$rot\vec{H}=\varepsilon_0\left(1-\frac{\omega^2{}_{pd}}{(\omega^2-\omega_0{}^2)}\right)\frac{\partial\vec{E}}{\partial t} \qquad (2.7)$$

That we will obtain the wave equation

$$\nabla^2\vec{E}=\mu_0\varepsilon_0\left(1-\frac{\omega_{pd}{}^2}{\omega^2-\omega_0{}^2}\right)\frac{\partial^2\vec{E}}{\partial t^2}$$

If one considers that

$$\mu_0\varepsilon_0=\frac{1}{c^2}$$

where C - speed of light, then no longer will remain doubts about the fact that with the propagation of electromagnetic waves in the dielectrics the frequency dispersion of phase speed will be observed. In the formation of this dispersion it will participate immediately three, which do not depend on the frequency, physical quantities: the self-resonant frequency of atoms themselves or molecules, the plasma frequency of charges, if we consider it their free, and the dielectric constant of vacuum.

II. Conclusion

This examination showed that this parameter as the kinetic inductance of charges characterizes electromagnetic processes in the conductors and the dielectrics and has the same fundamental value as the dielectric and magnetic constant of these media. Unfortunately, this important circumstance is not noted not only in the existing scientific literature, but also in the works of Maxwell.

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A Thesis Report on the Application of Preventive Replacement Strategy on Machines in Perspective of Cement Industry in Bangladesh

By M. M. Israfil Shahin Seddiqe, Avizit Basak, Md. Rifaul Islam & Md. Omar Faruk Akanda

Rajshahi University of Engineering & Technology (RUET), Bangladesh

Abstract- The operation of a particular component in deteriorating condition will lead to a high machine downtime. This is due to the failure of component at unexpected time. As a result it will increase cost of maintenance and production lost. One of the solutions to this matter is to use Preventive Maintenance (PM). In industries, Preventive Maintenance (PM) is not a new practice to minimize the sudden breakdown of production machine. PM will be performed at predetermine intervals to provide a balance between failure cost and component utilization (aging). Therefore, the objective of this paper is to introduce the preventive maintenance strategy for determining an optimal replacement time for component that deteriorates over time. In this thesis we consider a particular type of machine (Gear Motor 7.5 KW.) from Holcim Bangladesh ltd. where machines are subject to maintenance. To maximize the benefit from operating the machine two replacement models are used. Among them, one model is used to determine an optimal replacement policy which tells us, when equipment reaches a particular age, whether or not it should be replaced or continue to be operated to minimize the total operating cost. Another model is used to determine the optimal interval between the preventive replacements to minimize the total cost and to operate the machine to the time which is determined by first model. We have determined to find the preventive replacement cost and also the maximum time at which we can use the machine without replacing it. Some time it is more economical to replace the machine rather than maintenance it. So it is most important to find out the age at which the replacement will be most economical to replace rather than maintenance.

Keywords: preventive replacement, mitigate degradation, etc.

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Keywords: preventive replacement, mitigate degradation, etc.

I. Introduction

What is maintenance and why is it performed? Past and current maintenance practices in both the private and government sectors would imply that maintenance is the actions associated with equipment repair after it is broken. The dictionary defines maintenance as follows: "the work of keeping something in proper condition; upkeep." This would imply that maintenance should be actions taken to prevent a device or component from failing or to repair normal equipment degradation experienced with the operation of the device to keep it in proper working order. Unfortunately, data obtained in many studies over the past decade indicates that most private and government facilities do not expend the necessary resources to maintain equipment in proper working order. Rather, they wait for equipment failure to occur and then take whatever actions are necessary to repair or replace the equipment. Nothing lasts forever and all equipment has associated with it some predefined life expectancy or operational life.

The need for maintenance is predicated on actual or impending failure – ideally, maintenance is performed to keep equipment and systems running efficiently for at least design life of the component(s). As such, the practical operation of a component is time-based function. If one were to graph the failure rate a component population versus time, it is likely the graph would take the "bathtub" shape shown in Figure 1.1.1. In the figure the Y axis represents the failure rate and the X axis is time. From its shape, the curve can be divided into three distinct: infant mortality, useful life, and wear-out periods.

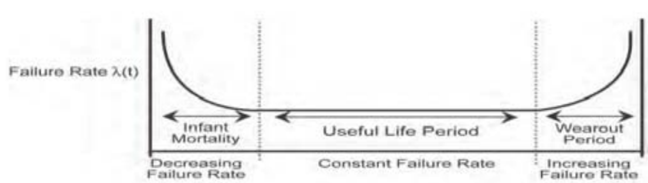

Figure 1.1.1 : Component failure rate over time for component population

Author α σ: B.Sc in Electrical & Electronics Engineering from Rajshahi University of Engineering & Technology (RUET), Rajshahi, Bangladesh. e-mails: mmisrafil@gmail.com,dhrubo_eee88@yahoo.com
Author ρ Ѡ: B.Sc in Industrial & Production Engineering from Rajshahi University of Engineering & Technology (RUET), Rajshahi, Bangladesh. e-mails: rifat.ruet78@gmail.com, dip.ipe08@gmail.com

a) Types of maintenance

The maintenance is mainly two types and they are planned and unplanned maintenances. And these two types of maintenance are divided into some other types of maintenance.

Planned maintenance: It is an organized maintenance work carried out as per recorded procedures having control.

Breakdown maintenance: It is an emergency based policy in which the plant or equipment is operated until it fails and then it is brought back into running condition by repair. The maintenance staff locate any mechanical, electrical or any other fault tor correct it immediately.

Corrective maintenance: It is a maintenance task performed to identify, isolate, and rectify a fault so that the failed equipment, machine, or system can be restored to an operational condition within the tolerances or limits established for in-service operations.

Routine maintenance: It refers to maintenance work that is normally planned for, and performed on a routine basis. Most of the time, routine maintenance can be, and is frequently, carried out without locking out a machine. It involves minor jobs such as cleaning, lubrication, inspection and minor adjustment. It needs very little investment in time and money.

Preventive maintenance: Actions performed on a time- or machine-run-based schedule that detect, preclude, or mitigate degradation of a component or system with the aim of sustaining.

b) Benefits of Maintenance

- Increase functional reliability of production facilities.
- Enables product and service quality to be achieved through correctly adjusted, serviced and operated equipment.
- Maximize the useful life of the equipment.
- Minimize the total production or operating costs directly attributed to equipment service and repair.
- Minimize the frequency of interruptions to production by reducing breakdowns.
- Maximize the production capacity from the given equipment resources.
- Enhance the safety of manpower.

II. Problem Statement

Holcim Bangladesh ltd. is one of the leading cement manufacturing companies in Bangladesh. They have a number of heavy machines these machines are subject to maintenance according to traditional approach. The used traditional maintenance is actually scheduled maintenance and due to this practice a lot of problem occurs. Loss of production, repair and replacement cost, low productivity, long lead time and low reliability of plant machineries result from this type of maintenance.

Due to production loss productivity decreases and which results in the decrease of profitability. Repair/Replacement cost is required to restore the equipment in functioning condition. Since equipments are subject to breakdown then the reliability of the equipments to remain in functioning condition is low. Lower reliability and loss of production lead to take longer lead time of delivery. Moreover bottlenecking and more work in process inventory occur due to this practice.

In Holcim Bangladesh ltd. the total activity is divided into three stages and they are the unloading system, cement production system and packing and delivery system. In these three stages there are many machines required. The machines in these three systems are Hydraulic crane, Belt conveyor, pay loader, motor 1000kw and packer machines. Most of the machines are consisted of different number of Gear motor 7.5kw. All the failures happen in the industry are more often failure of this motor. So here we have chosen to this motor in our calculation.

Maintenance practice is required to overcome above problems which removes loss of production, increase reliability of the equipment, decreases repair/replacement costs and leads the company towards success. Planned maintenance practice is one of those practices which can overcome above problems.

a) Objectives

The objectives of this paper is

- To investigate the economic advantages in implementing appropriate replacement process of equipment with physical impairment,
- To find out an optimal preventive maintenance interval based on the cost.

III. Theoretical Background

a) Optimal replacement policy for equipment whose operating cost increases with use (finite time horizon). (A.K.S JARDINE)

i. *Construction of model*

- I = age of the equipment (in years) since last replaced with n periods of time to go until the end of production plan.
- J = age of the equipment (in years) since last replaced with (n-1) periods of time to go to the end of production plan.
- C(a) = operating cost (in Taka) for one period when the equipment is of age 'a' since last replaced at the start of the operating period.
- C_r = cost of replacement (in Taka).
- C(I,J) = total cost (in Taka) of starting with the equipment of age I at the start of a period & having the equipment of age J at the end of the year.

- $C_n(I)$ = total cost (in Taka) of operating & replacing the equipment over next n years having age I at the start = [C(I,J) + $f_{n-1}(J)$]

$f_n(I)$ = minimum value of $C_n(I)$ = $^{min}{}_{j}$[C(I,J) + $f_{n-1}(J)$]

Where, $f_{n-1}(J)$ = cost of best decision taken over the remaining (n-1) years.

b) Optimal interval between preventive replacements of equipment subject to breakdown.(A.K.S JARDINE)

ii. *Construction of model*

- C_P is the cost of a preventive replacement.
- C_f is the cost of a failure replacement .
- $f(t)$ is the probability density function of the equipment's failure times.
- The replacement policy is to perform preventive replacements at constant intervals of length t_P , irrespective of the age of the equipment, and failure replacements occurs as many times as required in interval (0, t_P).
- The objective is to determine the optimal interval between preventive replacements to minimize the total expected replacement cost per unit time.

The total expected cost per unit time, for preventive replacement at time t_P, denoted by $C(t_P)$ is

$$C(t_P) = \frac{Total\ expected\ cost\ in\ interval\ (0, t_p)}{Length\ of\ interval}$$

Total expected cost = cost of a preventive replacement in interval $(0, t_p)$ + Expected cost of failure replacement

$$= C_P + C_f H(t_p)$$

Where $H(t_p)$ is the expected number of failures in interval $(0, t_p)$.
Length of interval = t_p
Therefore

$$C(t_P) = \frac{C_P + C_f H(t_p)}{t_p}$$

This is a model of the problem relating replacement interval t_p to total cost $C(t_P)$.

c) Determination of $H(t_p)$

There is a process by which the expected number of failures $H(t_p)$ in an interval of length t_p can be obtained. The expected number of failures $H(t_p)$ can be determined by discrete method.

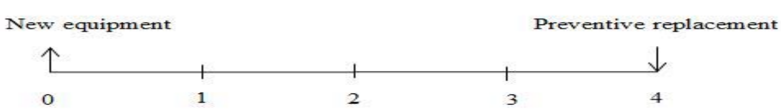

Figure : Illustration of the expected no. of failures in interval (0,4)

In general

$$H(T) = \sum_{t=o}^{T-1} [1 + H(T - i - 1)] \int_{i}^{i+1} f(t)dt \ ; \quad T \geq 1$$

IV. Data Analysis and Calculation

Table: Break down and repair reports

Machine name	No of failure (1year)	Total repair time (min/hours)(in 1 yr)	Total failure cost (1 year)	Data collection time
Gear Motor (7.5KW)	02	45 hrs	20000	(15/01/2011-15/01/2012)
Hydraulic Crane	03	24 hrs	50-100K	(15/01/2011-15/01/2012)
Chain Conveyor	04	32 hrs	100-500K	(15/01/2011-15/01/2012)
Bucket Elevator	02	40 hrs	50-100K	(15/01/2011-15/02/2012)
Water Pump	02	20 hrs	10-20K	(15/01/2011-15/01/2012)

From the above chart
For Gear Motor (7.5KW):

a) Optimal replacement policy for equipment whose operating cost increases with use (finite time horizon)

The objective of this policy is to perform replacements in such a way that the total cost of operating & replacing the motor over next 3 years is minimized having age I=1 years at the start.

Under this policy the relevant data are considered as follows-

Age of motor since last replaced, a in years	0	1	2	3
Operating cost* for one period C(a) in Tk.	4, 37,670	4, 92,720	5, 47,200	6, 02,160

Replacement cost, C_r = 1, 50,000 Tk.

b) Operating cost calculation

Number of motor = 100

Number of operator = 2

Number of shift = 2

Salary of operator per month = 12000 Tk.

Total monthly salary = 12000*2*2 = 48000 Tk.

1st year, operator salary per machine = 48000/100 = 480 Tk.

Operator salary per machine per year = 480*12 =5760 Tk.

Similarly,

2nd year, Operator salary per machine per year =

$$\frac{14000\times4\times12}{100} = 6720 \text{ Tk.}$$

3rd year, Operator salary per machine per year =

$$\frac{15000\times4\times12}{100} = 7200 \text{ Tk.}$$

4th year, Operator salary per machine per year =

$$\frac{17000\times4\times12}{100} = 8160 \text{ Tk.}$$

Power of a Gear motor, P = 7.5 kw.

Per unit rate of electricity = 8 Tk. (for year 1)

Working days = 300 per year

Operating hours per day, t = 24h

Thus total kWh,

W = Pt= 7.5*24= 180 kWh/day = 180*300 = 54000 KWh/year

Since 1 unit = 1 kWh

The cost of operating a motor in a year = 54000*8 = 432000 Tk. per year

This is taken to be the electricity bill for the first year of operation.

Hence, total operating cost:

For First year, operating cost = 432000 +5760 = 437670 Tk.

Similarly,

Taking different values of the per unit rate for 2nd, 3rd& 4th year i.e. 9 Tk., 10Tk. & 11 Tk. respectively, the total cost can be calculated as above-

For second year, operating cost = (54000*9) + 6720 = 492720 Tk.

For third year, operating cost = (54000*10) + 7200 = 547200 Tk.

For fourth year, operating cost = (54000*11) + 8160 = 602160 Tk.

c) Calculation

Cost matrix

J / I	0	1	2	3
0	∞	4,37,670	∞	∞
1	∞	5,87,670	4,92,720	∞
2	∞	5,87,670	∞	5,47,200
3	∞	5,87,670	∞	6,02,160

For 0 year to go,

$f_0(I)$ = 0 for all possible values of I.

For 1 year to go,

$f_1(I) = {}^{min}{}_j[\, C(I,J) + f_0(J)\,] = {}^{min}{}_j[\, C(I,J)\,]$ since $f_0(J) = 0$

Now when I = 0,

$$f_1(0) = {}^{min}{}_j[\, C(0,J)\,] = \min \begin{bmatrix} C(0,0) \\ C(0,1) \\ C(0,2) \\ C(0,3) \end{bmatrix} = \min \begin{bmatrix} \infty \\ 4,37,670 \\ \infty \\ \infty \end{bmatrix} \longleftarrow \text{i.e. continue}$$

$$f_1(1) = {}^{min}{}_j[\, C(1,J)\,] = \min \begin{bmatrix} C(1,0) \\ C(1,1) \\ C(1,2) \\ C(1,3) \end{bmatrix} = \min \begin{bmatrix} \infty \\ 5,87,670 \\ 4,92,720 \\ \infty \end{bmatrix} \longleftarrow \text{i.e. continue}$$

Similarly for I = 2, 3 the values of f_1 (2), f_1 (3) can be determined & can be computed and shown in a table as below-

Table 1 : For 1 year to go

I (year)	0	1	2	3
J (year)	1	2	3	1
Action to take at start of period	C	C	C	R
f_1(I)	4,37,670	4,92,720	5,47,200	5,87,670

C = continue & R = replace

For 2 years to go,

$f_2(I) = {}^{min}{}_j[\, C(I,J) + f_1(J)\,]$

When I =0,

$$f_2(0) = {}^{min}{}_j[\, C(0,J) + f_1(J)\,] = \min \begin{bmatrix} C(0,0) + f_1(0) \\ C(0,1) + f_1(1) \\ C(0,2) + f_1(2) \\ C(0,3) + f_1(3) \end{bmatrix} = \min \begin{bmatrix} \infty \\ 930390 \\ \infty \\ \infty \end{bmatrix} \longleftarrow \text{i.e. continue}$$

In similar process as used for table 1, tables can be made for 2, 3 and 4 years to go-

Table 2 : For 2 years to go

I (year)	0	1	2	3
J (year)	1	2	1	1
Action to take at start of period	C	C	R	R
f_2(I)	9,30,390	10,39,920	10,80,390	10,80,390

C = continue & R = replace

Table 3 : For 3 years to go

I (year)	0	1	2	3
J (year)	1	2	1,3	3
Action to take at start of period	C	C	R & C	R
f_3(I)	13,68,060	15,73,110	16,27,590	16,27,590

C = continue & R = replace

The replacement policy can be summarized as below-

Periods to go (year)	3	2	1
Decision	Continue (Table 3)	Replace (Table 2)	Continue (Table 1)

Global Journal of Researches in Engineering (J) Volume XIV Issue V Version I Year 2014

d) *Optimal interval between preventive replacements of equipment subject to breakdown*

Labor cost per maintenance per personnel in a month = 16750 Tk.

Spare parts (Accessories) cost (Ball bearing / bearing Sleeve) in a year = 3000 Tk. (1500*2)

Spare parts (Accessories) cost (Ball bearing / bearing Sleeve) in a month = 250 Tk. (3000/12)

Production rate = 30 tons (3000kg) per hour = 60 bag (3000/50) per hour

Net income per bag = 100 Tk.

Failure maintenance time in a year = 45 hrs

Failure maintenance time in a month = 3.75 hrs (45/12)

Failure maintenance cost in a year = 20000 Tk.

Failure maintenance cost in a month = 1667 Tk. (20000/12)

i. *C_P Calculation*

Preventive maintenance cost = 17000 Tk. (16750+250)

$C_P = 17000\ Tk.$

ii. *C_f Calculation*

Production loss in a month in unit = 225 bags per month (60*3.75)

Production loss in a month in taka = 22500 Tk. (225*100)

C_f = Preventive maintenance cost + Failure maintenance cost in a month + Production loss in a month in taka

= (17000+22500+1667) Tk.

= 41167 Tk.

μ and **σ** Calculation

Table : Failure analysis

No of failure	Failure occur at (month)
1st	4
2nd	10
3rd	16
4th	21

From the above chart if we calculate then we get,
μ = 5.25 months
σ = .96 month

$$C(t_P) = \frac{C_P + C_f H(t_p)}{t_p}$$

For t_p = 1 month,

$$H(1) = [1 + H(0)] \int_0^1 f(t)dt = \int_0^1 f(t)dt = \varphi(-5.25) - \varphi(-4.43) = 0$$

$$C(1) = \frac{17000 + 41167 \times 0}{1} = 17000 \text{ Tk.}$$

For t_p = 2 months,

$$H(2) = [1+H(1)] \int_0^1 f(t)dt + [1+H(0)] \int_1^2 f(t)dt = [1+0]\times 0 + [\varphi(-3.49) - \varphi(-4.43)]$$

$$= 0 + [3.6 \times 10^{-4} - 0]$$

$$= 3.6 \times 10^{-4}$$

$$C(2) = \frac{17000 + 41167 \times 3.6\times10^{-4}}{2} = 8507 \text{ Tk.}$$

For t_p = 3 months,

$$H(3) = [1+H(2)] \int_0^1 f(t)dt + [1+H(1)] \int_1^2 f(t)dt + [1+H(0)] \int_2^3 f(t)dt$$

$$= 1.00036\times 0 + 1\times .00036 + [\varphi(-2.34) - \varphi(-3.39)]$$

$$= .0036 + (9.55 \times 10^{-3} - 3.6 \times 10^{-4})$$

$$= .00955$$

$$C(3) = \frac{17000 + 41167 \times .00955}{3} = 5798 \text{ Tk.}$$

For t_p = 4 months,

$$H(4) = [1+H(3)]\int_0^1 f(t)dt + [1+H(2)]\int_1^2 f(t)dt + [1+H(1)]\int_2^3 f(t)dt + [1+H(0)]\int_3^4 f(t)dt$$

$$= 0 + 3.6\times10^{-4} + 0.00919 + [\varphi(-1.302)-\varphi(-2.34)]$$

$$= 0.09635$$

$$C(4) = \frac{17000 + 41167\times.09635}{4} = 5241 \text{ Tk.}$$

For t_p = 5 months,

$$H(5) = [1+H(4)]\int_0^1 f(t)dt + [1+H(3)]\int_1^2 f(t)dt + [1+H(2)]\int_2^3 f(t)dt + [1+H(1)]\int_3^4 f(t)dt + [1+H(0)]\int_4^5 f(t)dt$$

$$= [1+.00955]*0.00036 + [1+0.00036]*0.00919 + 0.09635 + [\varphi(-0.26)-\varphi(-1.302)]$$

$$= 0.4158$$

$$C(5) = \frac{17000 + 41167\times0.4158}{5} = 6823 \text{ Tk.}$$

The above results can be shown in a table as below-

t_p(months)	1	2	3	**4**	5
$C(t_p)$ (Taka)	17000	8507	5798	**5241**	6823

V. Limitations

The thesis activity performed here is not out of limitations. The identified limitations are:

- ❖ The research is based on history data and not on real time data.
- ❖ The research is made up with failure data not failure modes.
- ❖ The mathematical formulations did not take into account the time it requires to perform preventive replacements because the model assumed that time to be very short, compared to the mean time between replacements.
- ❖ The calculated value of mean (μ) is not 100% accurate because of lack of the data of failure occurs.
- ❖ For these type of model application, it is necessary to know the characteristics of the machines over a long operating time i.e. performance of machine, number of failure occur during operating etc.
- ❖ The model of replacement decisions are developed by A. K. S. Jardine in separate conditions but this thing is neglected in this thesis.

VI. Conclusion

From the above model machine will be replaced after 2 years since the age of machine is 1. And the total cost of replacement and operation to the three years would be 15, 73,110 Tk.

According to the above method the optimal preventive replacement is to perform at *4 months interval.*

VII. Recommendations

The following recommendations are forwarded for the industry and related Bangladeshi industries that are executing maintenance work in their regular activity

- ❖ Replacement or repair cost, benefit from operating the equipment, labor cost etc. should be collected with high degree of accuracy.
- ❖ Statistical analysis of the data should be done frequently.
- ❖ Proper documentation of each activity should be kept.

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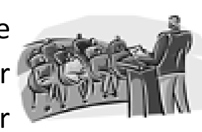

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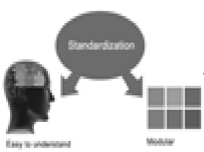

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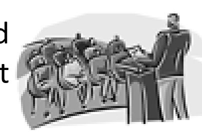

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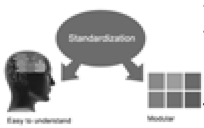

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Metric SI units are supposed to generally be used excluding where they conflict with current practice or are confusing. For illustration, 1.4 l rather than 1.4 × 10-3 m3, or 4 mm somewhat than 4 × 10-3 m. Chemical formula and solutions must identify the form used, e.g. anhydrous or hydrated, and the concentration must be in clearly defined units. Common species names should be followed by underlines at the first mention. For following use the generic name should be constricted to a single letter, if it is clear.

Structure

All manuscripts submitted to Global Journals Inc. (US), ought to include:

Title: The title page must carry an instructive title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) wherever the work was carried out. The full postal address in addition with the e-mail address of related author must be given. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining and indexing.

Abstract, used in Original Papers and Reviews:

Optimizing Abstract for Search Engines

Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Key Words

A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

Tables, Figures and Figure Legends

Tables: Tables should be few in number, cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g. Table 4, a self-explanatory caption and be on a separate sheet. Vertical lines should not be used.

Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.

Preparation of Electronic Figures for Publication

Even though low quality images are sufficient for review purposes, print publication requires high quality images to prevent the final product being blurred or fuzzy. Submit (or e-mail) EPS (line art) or TIFF (halftone/photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Do not use pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings) in relation to the imitation size. Please give the data for figures in black and white or submit a Color Work Agreement Form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution (at final image size) ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs) : >350 dpi; figures containing both halftone and line images: >650 dpi.

Figure Legends: Self-explanatory legends of all figures should be incorporated separately under the heading 'Legends to Figures'. In the full-text online edition of the journal, figure legends may possibly be truncated in abbreviated links to the full screen version. Therefore, the first 100 characters of any legend should notify the reader, about the key aspects of the figure.

6. AFTER ACCEPTANCE

Upon approval of a paper for publication, the manuscript will be forwarded to the dean, who is responsible for the publication of the Global Journals Inc. (US).

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The corresponding author will receive an e-mail alert containing a link to a website or will be attached. A working e-mail address must therefore be provided for the related author.

Acrobat Reader will be required in order to read this file. This software can be downloaded

(Free of charge) from the following website:

www.adobe.com/products/acrobat/readstep2.html. This will facilitate the file to be opened, read on screen, and printed out in order for any corrections to be added. Further instructions will be sent with the proof.

Proofs must be returned to the dean at dean@globaljournals.org within three days of receipt.

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Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated to Computer Science and Information Technology, or doing research study in these areas. If you are novel to this field then you can consult about this field from your supervisor or guide.

TECHNIQUES FOR WRITING A GOOD QUALITY RESEARCH PAPER:

1. Choosing the topic: In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

2. Evaluators are human: First thing to remember that evaluators are also human being. They are not only meant for rejecting a paper. They are here to evaluate your paper. So, present your Best.

3. Think Like Evaluators: If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

4. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

5. Ask your Guides: If you are having any difficulty in your research, then do not hesitate to share your difficulty to your guide (if you have any). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work then ask the supervisor to help you with the alternative. He might also provide you the list of essential readings.

6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

8. Use the Internet for help: An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

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- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

Index

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