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# Integration of Solar Energy Generation with Conventional Power Generation to Reduce the Emission of Carbon Dioxide and Other Harmful GHG

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***Abstract*:** As there is great demand for the reduction of $CO_2$ emission all over the globe. Efforts have been put in the same direction to further reduce the $CO_2$ emission using the solar technology in integration with the Conventional Energy. We have noticed that the proposed scheme may further reduce the emission of $CO_2$ along with that it can also reduce the emission of other harmful green house gases (GHG). Data from a Power situated in Kanpur, India is taken into consideration for analysis on the topic.

***Keywords*:** Green House Gases (GHG), Renewable Energy, Carbon Emission, Solar Energy

## I. INTRODUCTION

Coal is the most dominant fossil gas used in thermal energy power plant (TPP) for electricity era in India. During twelfth five-year plan coal based electricity generation having 56% contribution of India's ability and sixty six percentages (66%) of strength technology. Due to the lowering value of renewable electricity, strain of reducing carbon emission and elevated fossil gas expenses strength era in coal primarily based TPP is discouraged. $CO_2$ is predominant pollutants emitted from TPP and is liable for 60% more advantageous greenhouse effect. Installed capacity of coal primarily based TPP grows slowly up to 270 GW in 2032 and will lessen as much as 253 GW due to integration energy coverage. Renewable strength is a beneficial choice in context of greenhouse effect and energy integration. RETScreen software is used for evaluation of $CO_2$ emission and mitigation with electricity generation in coal based totally thermal power plant in India. Solar radiation and weather facts are used with NASA requirements.

Today coal primarily based electricity generation is 66% of overall power era in India and on slowly increasing in near destiny. In India TPP uses subcritical era and due to the available first-class of coal in India Plant load factor stays 73% up to 2032 and seventy four percentage (4%) thereafter. The cleaner technology extremely good important, Ultra excellent crucial and IPGC are costlier as 5600 – 11000 Rs.Cr. /GW. In 2012 TPP technology contributed to 811 MT $CO_2$e. emission out of 2074 MT strength related $CO_2$e emission. With a determined effort for all energy sectors total electricity related GHG emission is round to be 10848 MT $CO_2$e. in 2047 of which TPP era would make contributions 27.6% or approximately 3002eq MT $CO_2$e. Total electricity related GHG emission might be 11342 MT $CO_2$e of which TPP technology would make contributions 30.8 % or 3495 MT $CO_2$e. if outstanding effort pathway chooses for TPP generation and determined effort for Renewable electricity. On the other hand if first rate attempt pathway for Renewable electricity and determined effort for TPP era, the percentage of GHG emission of TPP generation in total electricity associated emissions could be 20.6% with total GHG emission of 9882 MT $CO_2$eq. [26]. In context of Green residence effect carbon by-products $CO_2$, NOx, SOx, CFCs influences the mankind health and surroundings. $CO_2$ is taken into consideration as a prime surroundings pollutant as $CO_2$ molecule is strong and average residence time of 10 years with three years in troposphere. Emitted $CO_2$ stays in environment around one hundred-two hundred years and $CO_2$ awareness increases with an incredible charge of 0.04% in step with year in the environment. Study indicates that around 450ppm concentration of $CO_2$ inside the ecosystem is chargeable for warming of 3.6˚F or 2˚C [1]. Due to the immoderate $CO_2$ emission, the temperature of earth's floor will boom 1.5 – 4˚C up to 2050. A huge variety of energy generating technology has been advanced through the years to take gain of renewable strength. Solar Photovoltaic era is favoured shape of renewable electricity because of the need of GHG emission mitigation, deregulation and speedy increase inside the photovoltaic strength generation. RETScreen software program device is used for the analysis of electricity efficiency, renewable electricity undertaking in addition to ongoing power overall performance evaluation [2]. Besides being a big $CO_2$ emitter, enterprise has been one of the primary sources of environmental pollution. Large efforts were placed in the closing a long time to minimize the environmental affects. Nevertheless, problems including air pollution because of the emissions of, e.g., $NO_X$, $SO_2$ and particulate matter (PM), still remain. The assessment of latest technologies including CCS need to, consequently, don't forget the ability environmental consequences aside from $CO_2$ emissions reduction. It is very possibly that CCS might come what may have an effect on these air pollutant emissions due to the fact they're typically contained in gasoline streams from which $CO_2$ is captured. There are a number of studies published on post-combustion $CO_2$ capture from electricity plants that have regarded at the changes in the emissions of air pollution along with $NO_X$, $SO_2$, PM and $NH_3$. Distributed strength systems are typically not taken into consideration for CCS because of the tremendously high prices at such scales.[3] However, there are some of differences among diesel generation power plant life and centralized energy flora which can task this declare. Firstly, combined heat and power (CHP) plant life could have warmness integration with $CO_2$ seize procedure that centralized electricity plant cannot. Secondly, the running situations of distributed generation (DG) flowers are one-of-a-kind from those for centralized electricity plants. Thirdly, literature suggests that $CO_2$ seize from disbursed power systems would turn out to be low-priced in the longer term.

In addition, it's far essential to obtain insights into the minimal scale of $CO_2$ emission resources when $CO_2$ seize may be implemented economically. Efforts have been put to take a look at two aspects; (i) To offer an outline of techno-economic overall performance of $CO_2$ seize from dispensed power structures within the short-mid time period (ST/MT) and the long term destiny (LT), which explicitly accounts for variations in time-frame, gasoline type and power plant kind, and (ii) To evaluate the relative cost of $CO_2$ seize from dispensed era in comparison to huge-scale centralized electricity plant life, thinking of the variations in plant scale, operational situations, and the aggregate of $CO_2$ compression and distributed shipping. Global warming lead to high temperature [4]. Among anthropogenic greenhouse gases, carbon dioxide ($CO_2$) is the more important for extended percentage of $CO_2$ in atmosphere since the pre-commercialization is of fossil fuel use as trivial option [5]. $CO_2$ considered as one of the most important fuel which directly contribute to the atmosphere temperature globally of approx 1.5-2.5˚C.

Several research have achieved in many nations to study $CO_2$ emission. Claudia and Leticia used delicate Laspeyres Index method to investigate influencing elements of $CO_2$ emission in Mexican cement industry [6]. $CO_2$ capture and storage (CCS) is considered a vital choice to reduce GHG emissions given the continuing massive-scale use of fossil fuels over the coming many years [7]. CCS comprises the separation of $CO_2$ from business and electricity-associated sources, transport of $CO_2$ to a storage vicinity and long-time period isolation from the ecosystem [8]. CCS may additionally play a sizeable role within the easy and value-powerful transition to a sustainable, low-carbon power future [9-10]. In next section scheme used to reduce the $CO_2$ reduction is discussed in detail.

## II. Methods of Reduction of CO2

There are several procedures discussed in several studies to reduce the emission of $CO_2$. Efforts have been to identify the steps involved during the Reduction of $CO_2$. Based on related work it is identified that reducing $CO_2$ emission using may be done as; (i) using the renewable energy (RE) resources such as energy efficiency, solar energy, wind energy, biomass power, bio-fuels, waste to energy, tidal energy and wave energy etc. for electrical power generation (ii) reducing $CO_2$ emissions using integrated RES with Thermal Power Generation Plants (iii) reducing $CO_2$ emissions by saving of electrical energy (iv) reducing $CO_2$ emissions by replacement of existing old Thermal Power Generation Plants by Ideal New Plants. (v) reducing $CO_2$ emissions by using Heat Exchange Network (HEN) technology in Thermal Power Generation Plants (vi) reducing $CO_2$ emissions by using MPPT Inverter technology for maximum solar energy power generation (vii) reducing $CO_2$ emissions by using Battery Storage Systems (BSS) for solar energy generation. (viii) reducing $CO_2$ emission by making the attractive government policies, incentives and subsidies for promotion and development of RES power generation. These set of procedures have been further explored in the current study.

## III. Proposed Methodology

Fig.1 and Fig.2 are two diagram which are shown to represent the conventional case of power generation and proposed case of power generation with integration of renewable energy (solar potential).

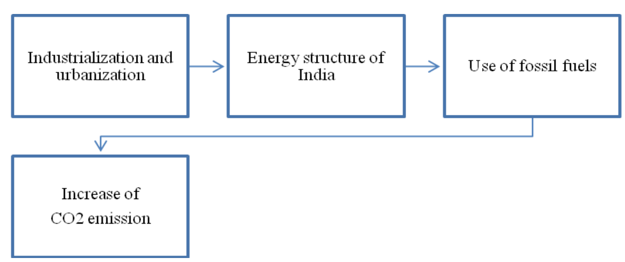


Fig1. Conventional case of power generation

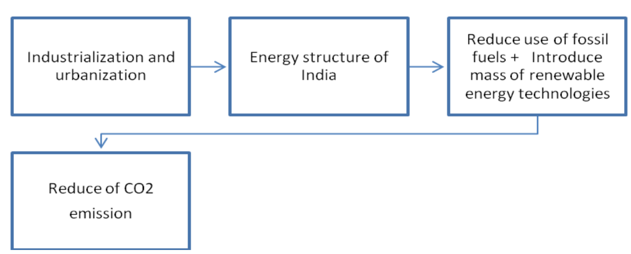


Fig.2 Proposed case of Power generation with integration of renewable energy(solar potential)

## IV. Reducing CO2 by Integration of Solar Energy Generation with Conventional Power Generation

"RETScreen" model is used for the purpose of mitigation analysis of GHG Emission Reduction [11].

$$\Delta_{GHG} = \left(e_{base} - e_{prop}\right)E_{prop}\left(1 - \lambda_{prop}\right)(1 - e_{cr}) \quad \ldots\ldots\ldots\ldots (1)$$

Equation (2) defines the subsequent system used to calculate the base case GHG emission factor (described as the mass of greenhouse gas emitted consistent with unit of electricity produced), ebase:

$$e_{base} = \left(e_{CO2}\,GWP_{CO2} + e_{CH4}\,GWP_{CH4} + e_{N2O}GWP_{N2O}\right)\frac{1}{\eta} * \frac{1}{1-\lambda} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Where $e_{CH4,}$ $e_{N2O}$ and $e_{CO2}$ are the $CH_4$, $N_2O$ and $CO_2$ emission factors respectively for the fuel/source considered. $GWP_{N2O}$, $GWP_{CH4}$ and $GWP_{CO2}$ are the respective global warming Potentials for $N_2O$, $CH_4$ and $CO_2$, $\lambda$ is the fraction of electricity lost in transmission and distribution and $\eta$ is the gas conversion performance. The international warming ability of a gasoline, or "GWP," describes the potency of a GHG in evaluation to $CO_2$. In RETScreen CO2 is assigned a GWP of 1 whereas GWP for $CH_4$ and $N_2O$ may be defined with the aid of the consumer in custom evaluation or through the software program in well known evaluation [12].

## V. Materials and Methods

This section covers the methods used to reduce the $CO_2$ emission.

**5.1 PV modules :** Following five training PV cell phone technologies may also be viewed as correct technologies; CdTe, CIS/CIGS, rising PV, Group III–V, and Silicon-mainly evolved method is principal. Traditionally for most valuable effectively Si and GaAs mono-crystalline solar cellular are suitable [13-15]. In Photovoltaic machine 1-axis and a pair of-axis solar monitoring flat plate packages have 22.3% and 25.2% enhancement inside the annual vigour manufacturing respectively in comparison to the constant flat plate gadget [16-21]. To acquire most solar strength a MPPT mechanism is required, which moves consistent with the temperature, load and the irradiance [17].

***5.2 Charge controller with Inverter:*** Inverter is used to transform the DC force saved in battery into the AC force and controller is used to regulate the cost and discharge cycle of the battery. In general, we use ON-GRID Inverter having 70–96% efficiency [15-21].

***5.3 MPPT (Maximum Power Point Tracker):*** MPPT is used to maintain the running voltage of array to a value that maximizes the output of array. Fig 3 monthly solar radiation respectively at project location with RETScreen analysis. Table 1 represents the proposed project location climate data monthly.

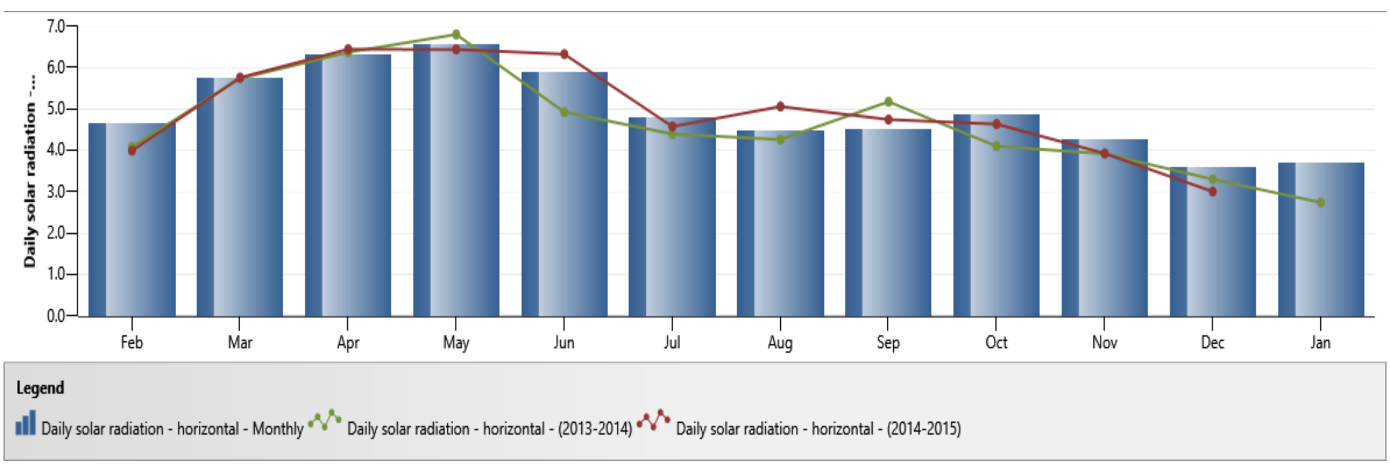


Fig 3. Solar radiation on Monthly basis

In the below mentioned Table 1, project data is reported for considered project location situated at Kanpur, India.

 

Table 1. Weather data for the proposed project location

| Month | Air temperature °C (Ground) | Relative humidity % (Ground) | Atmospheric pressure kPa (NASA) | Daily solar radiation – horizontal kWh/m²/d (NASA) | Earth temperature °C (NASA) | Wind speed m/s (Ground) | Heating degree-days °C-d (Ground) | Cooling degree-days °C-d (Ground) |
|---|---|---|---|---|---|---|---|---|
| Jan | 14.2 | 0.756 | 99.84 | 3.72 | 16.76 | 1.6 | 117.8 | 130.2 |
| Feb | 18 | 0.661 | 99.59 | 4.67 | 21.48 | 2 | 0 | 224 |
| Mar | 23.5 | 0.521 | 99.21 | 5.75 | 29.12 | 2.4 | 0 | 418.5 |
| Apr | 29.5 | 0.411 | 98.79 | 6.32 | 35.56 | 2.4 | 0 | 585 |
| May | 32.4 | 0.467 | 98.39 | 6.57 | 36.49 | 2.6 | 0 | 694.4 |
| Jun | 32.2 | 0.614 | 98.08 | 5.91 | 33.96 | 2.6 | 0 | 666 |
| Jul | 29.9 | 0.801 | 98.15 | 4.8 | 30.3 | 2.5 | 0 | 616.9 |
| Aug | 29.3 | 0.838 | 98.35 | 4.48 | 28.86 | 2.3 | 0 | 598.3 |
| Sep | 28.2 | 0.825 | 98.73 | 4.52 | 27.71 | 1.9 | 0 | 546 |
| Oct | 25.4 | 0.731 | 99.26 | 4.87 | 25.91 | 1.2 | 0 | 477.4 |
| Nov | 20.2 | 0.69 | 99.67 | 4.27 | 22.02 | 1.1 | 0 | 306 |
| Dec | 15.8 | 0.728 | 99.9 | 3.6 | 17.52 | 1.2 | 68.2 | 179.8 |

"RETScreen" software is used for project analysis and GHG emission from from Panki power station. Fig. 4 display the monthly CO2 emission w.r.t. fuel dissipation and electricity production.

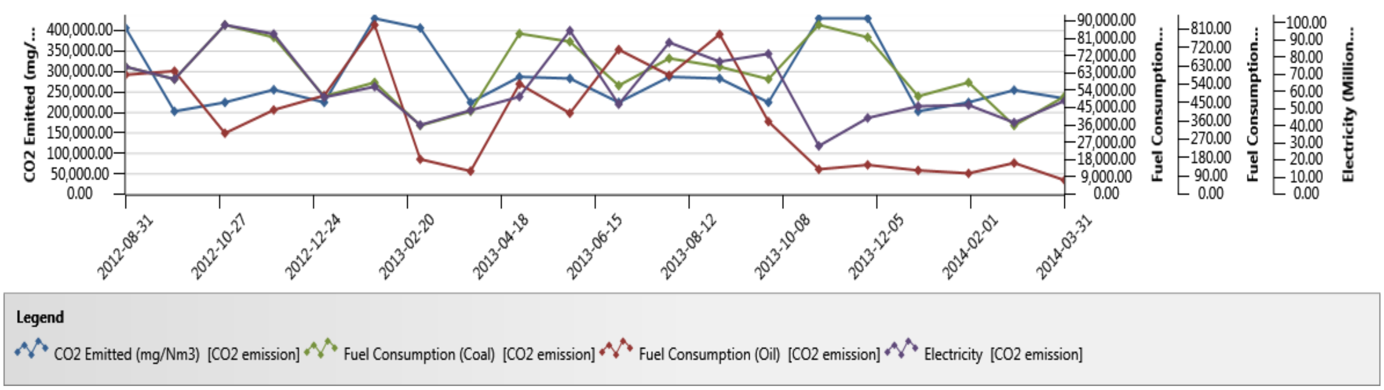


Fig. 4 Monthly CO2 emission w.r.t. fuel dissipation and electricity production

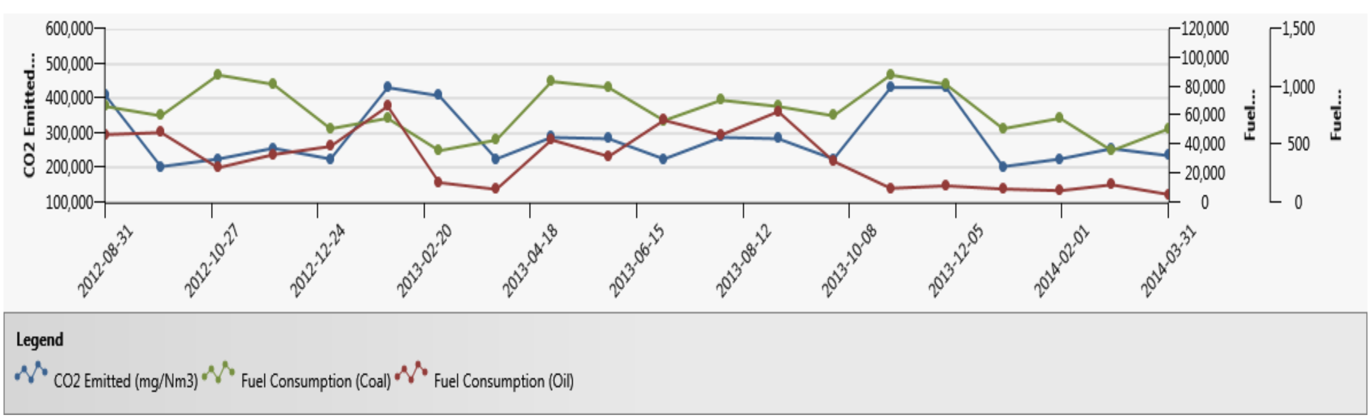


Fig 5. CO2 emission with fuel consumption (Coal and Oil)

Fig.5 show the CO2 emission with fuel consumption (Coal and Oil). GHG emission for panki strength plant is calculated by way of equation (3) [22-23].

GHG emission per unit electricity production

$$=\sum_{i=1}^{n}\left[\frac{GHGemission}{\sum_{i=1}^{n} electricityproduction}\right]\ldots (3)$$

Where i represent each individual electricity unit in database,GHG emissions- calculated for each plant are calculated in $tCO_2e$, Electricity production- calculated for each plant/unit is measured in GWh. [20-24]. **Distributed Generation (DG)** "RETScreen" **Analysis is done based on the equations 4 to 8.** Energy added to the grid can be decided by equation (4) and (5) [20-24].

$$E_g = E_A * \eta_{inv} \ldots\ldots..(4)$$

$$E_d = E_g * \eta_{ab} \ldots\ldots..(5)$$

Where $E_g$, $E_A$, $E_d$, $\eta_{inv}$ and $\eta_{ab}$ are energy available to grid, energy produced by array, energy delivered to the grid, inverter efficiency and PV energy absorption rate respectively.

The average array efficiency ($\eta_p$) depends on average module temperature Tc as in equation (6) [25].

$$\eta_p = \eta_r[1-\beta_p(T_c - T_r] \ldots\ldots\ldots\ldots\ldots.(6)$$

where $\beta_p$ is the temperature coefficient for PV module efficiency and $\eta_r$ is the module efficiency at reference temperature Tr.Tc depends on mean monthly ambient temperature Ta can be determined by equation (7) [21].

$$Tc - Ta = [219 + (832* Kt)]*\left(\frac{T_n-20}{800}\right)\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Where Tn is normal operating cell temperature, Kt is monthly clearness index. For standard technologies following values can be assumed as in table- (2). GHG emission in terms of equivalent $CO_2$ for the panki power plant is calculated by equation (8) with data given in table (3) [21-23].

$$GHG_{Fuel_i} = G_{CO2} + G_{CH4} * 21 + G_{N2O} * 310\left(\frac{.0036}{\eta_{Fuel}(1-J_{T-D})}\right)\ldots\ldots\ldots\ldots(8)$$

$GHG_{Coal} = 1.069$, $GHG_{Diesel} = 0.975$, $GHG_{Solar} = 0$

Table – (3) represents CO2 emission with fuel consumption in present case of Panki Power plant. Table – (4) represents CO2 emission with fuel consumption in proposed case of Panki Power plant.

Table-(2) PV Module characteristics for standard technology

| PV Module Type | ($\eta_{r\%}$) Module Efficiency | Tn (°C) | $\beta_p$(%/°C) |
|---|---|---|---|
| Mono –Si | 13 | 45 | 0.40 |
| Poly- Si | 11 | 45 | 0.40 |
| CIS | 7.5 | 47 | 0.46 |
| CdTe | 7 | 46 | 0.24 |
| a –Si | 5 | 50 | 0.11 |

Table – (3) present case of Panki Power plant

| **Fuel Type** | **Coal** | **Diesel** | **Solar** |
|---|---|---|---|
| Fuel Participation % | 69.77 | 7.6 | 22.63 |
| GCO2 (Kg/GJ) | 94.6 | 74.1 | 0 |
| GCH4(Kg/GJ) | 0.002 | 0.002 | 0 |
| GN2O(Kg/GJ) | 0.003 | 0.002 | 0 |
| ηFuel (%) | 35 | 30 | 19 – 44 |
| J T-D (%) | 8 | 8 | 8 |
| GHG Fuel (tCO2/MWh) | 1.069 | 0.975 | 0 |

$$eq = \frac{69.77}{100} * 1.069 + \frac{7.6}{100} * 0.975 + \frac{22.63}{100} * 0 = .8144\frac{tCO2}{MWh}$$

Table – (4) Proposed case of system integration

| **Fuel Type** | **Coal** | **Diesel** |
|---|---|---|
| FuelParticipation (%) | 92.4 | 7.6 |
| $G_{CO2}$ (Kg/GJ) | 94.6 | 74.1 |
| $G_{CH4}$(Kg/GJ) | 0.002 | 0.002 |
| $G_{N2O}$ (Kg/GJ) | 0.003 | 0.002 |
| $\eta_{Fuel}$ (%) | 35 | 30 |
| $J_{T-D}$ (%) | 8 | 8 |
| $GHG_{Fuel}$ ($tCO_2$/MWh) | 1.069 | 0.975 |

$$Ceq = \frac{92.4}{100} * 1.069 + \frac{7.6}{100} * 0.975 = 1.0618\frac{tCO2}{MWh}$$

$CO_2$emitted for the period of 2012 – 2032 [35]. Time period (Hrs) = 20*12*30*24=172800 Hrs. $CO_2$ emitted for 100 MU in time period with conventional system

= 1.0618*100*172800

= 18347904 tCO2

$CO_2$ emitted for 100 MU in time period with proposed case

= 0.8144*100*172800

= 14072832 tCO2

Reduction in $CO_2$ emission with proposed case(%)

$$=\left(\frac{18347904 - 14072832}{18347904}\right) * 100 = 23.30\%$$

 

## VI. RESULT AND DISCUSSIONS

It may be shown from heritage without a doubt that each country at the moment are putting ahead various techniques to cope with the environmental issues which cause by the increase of carbon dioxide emission. The overall quantity of CO2 emission becomes the severe problem that every country needs to notice. It is clearly shown in section 5 that with the help of proposed scheme the reduction in $CO_2$ is achieved upto 23.30%. This can significantly further reduce and other hybrid approached may be used for more future improvements.

## VII. CONCLUSIONS

As a result, based on our paper some conclusions have been drawn which are as follows;

i. Proposed study based on the Solar Energy Generation with Conventional Power Generation can reduce the $CO_2$ emission rate and that's why it could be considered as one of the challenging area to do research.

ii. As we have achieved the tremendous achievement in the reduction of carbon dioxide emission i.e. upto 23.30%. It is suggested to apply the proposed on the more and more plants and in real time to get the more accurate and justified results.

iii. It could be seen as a supplement in parallel along with the other renewable energy techniques. Proposed scheme may further help in achieving the Low-carbon Economy Development

Finally, it is discovered that there is a need to expand the collaboration in strength integration, photovoltaic era improvement, capability building and financing to accelerate improvements in smooth power projects. Governments have to boom the global collaboration for R&D efforts in renewable and green energy tasks.

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