A Case Study Based on Power Data for Solar and Wind Energy Assessment

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Abstract. The solar and wind energy are the great sources to our world because they are clear and unexhausted. In recent decades so many generation farms had been constructed rapidly all over the world. How to evaluate the investment performance and make a better planning for a long term have becoming an important issue. In this paper we discuss and analysis these questions based on actual data take Germany as a case. We discuss the solar and wind energy utilization situation, the generating electricity ratio, and investigate the rules of solar and wind generation, address an approach to adjust solar generations and wind to take advantage of them. Present a scenario of mid-long term planning in power grid, in order to make use of renewable energy, especially solar and wind sources to satisfy the demand of energy for our society development rapidly.

1. Introduction
The energy play a core role in our society [1], fossil energy reserve is limited, petroleum and gas will be exhausted. So, develop renewable energy become a key work, especially solar and wind energy. Many countries pay further attention to this area. Solar and wind energy can be used to supply large portion energy demand without emission and resource consuming. In the early of research researchers’ focus on how can use these power. Now many studies concentrate on operation assessment of efficient and effective on the power grid in the recent years, and some published researchers focus on renewable energy cost and prediction, the other keep their eyes on the impact of environment and optimization, etc. Next, we will do some literature review as fellow.

Solar and wind energy are the most important renewable energy sources, and many optimization and assessment results have been published [2-7]. Renewable energy many items were discussed in [2], got the ranks of several renewable energy technologies, including photovoltaics, wind, hydro and geothermal, from these indicators price, emissions, land use, efficiency, water consumption and social impacts. The rank revealed that the wind energy is the most sustainable, and hydro, photovoltaics follow it, in turn, geothermal is the last place. Sinha et al. [3], assessed the costs and benefits of US renewable standard, shows that in spite of increasing the costs of investing research renewable energy, reduce water consumption air damage and improve air quality protect the environment. Nie et al. [4] assessed technology-economic of hybrid of PV-wind in Iran, analysis the technology-economic potential of PV-wind indicate it is confirmed in this area. The authors assessed the generation potential of PV in Caribbean region in Columbia [5-6], the energy generation, capacity and use ratio were been evaluated via NASA data, came to the conclusion due to the disadvantage of use fossil fuel, the solar energy is the best alternative solution for Columbia. Zou et al took large-scale PV generation of five cities of China as the research object, analyse current PV generation application in China in off grid and on grid and came out 3kw on grid can cover 90 $m^2$ house, the emulation is helpful to policy
recommendation for PV market in China[7]. Shamoushaki et al. [8], reviewed the results of optimizing size of PV-wind renewable energy system, proposed the popular optimization methods are Graphic construction, probabilistic, iterative, AI, etc., discussed some of the optimization approaches, and indicted hybrid of PV-wind can not only reduce the cost of lifecycle renewable generation, but also improve the reliable of energy. Estimation of wind energy is difficult with the great fluctuate wind, two ways are used to forecast it, one is based on the last data, the other is the wind value of sensors. Krarti, Avola, Yuan and Zou et al. [9-12] assessed different methods of estimation parameters of Weibull, such as Graphics method, an Empirical method of Justus, energy pattern factor method and so on. The evaluations were conducted both daily and monthly to offer analysis, and good to hybrid PV-wind. In integrating PV-wind energy processing the integrated hub must be a focus, an electrical integrated hub use connect renewable energy to grid was studied in [13], the authors used multi-objective optimization to design electrical hub, considered eight criteria at different level of decision, realized evaluate flexibility of power system under several criteria.

In this paper, we focus on how to get the utmost out of these renewable generations, especially solar generations and wind generations. Wind generation land use footprint is about 72 km²/TWh, without any share agriculture land, the photovoltaic land occupation of 28-64 km²/TWh, without any allocation [13]. This literature shows that some researchers proposed wind generation shares land footprint with agriculture, and photovoltaic can be roof-mounted. The way is efficient to deduce land footprint of wind and solar. Features of wind and solar are exist in always, and we can use farthest the energy via improving approach. But now we will discuss wind and solar energy transfer to electric power, how much of it has been utilized by mankind, so that we can give better planning and select better sites to construct generations of wind and solar.

This paper is organized as follows: Section 2, assessment performance of solar and wind energy efficient in actual application. Section 3, states the situation of the solar energy and wind energy utilization in Germany. Section 4, a mid and long-term planning of renewable energy include solar and wind. Some results and conclusions are given in section 5. The last but not the least is some acknowledgements.

2. Assessment of Solar and Wind Energy
In Germany, the solar radiation is not enough in Europe, but in development of renewable aspect it is head of Europe, so we take it as an example to analyse the situation of a performance of application solar energy and wind energy. For the further analysis, the following contents are proceeding.

In Germany, the mean temperature as shown table 1, the data comes from Google, the solar generation relations temperature area, so we give the daily mean temperature from minimum to maximum every month.

| Mon       | Jan. | Feb. | Mar. | Apr. | May. | Jun. |
|-----------|------|------|------|------|------|------|
| Mean of max | 3    | 5    | 9    | 13   | 18   | 21   |
| Mean of min | -2   | -2   | 1    | 4    | 8    | 11   |

| Mon       | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|-----------|------|------|------|------|------|------|
| Mean of max | 23   | 23   | 19   | 14   | 7    | 4    |
| Mean of min | 13   | 13   | 10   | 6    | 2    | -1   |

2.1. Solar Generation
The solar-mounted capacity stability growth slowly monthly in Germany, for example from Jan. to Nov. 2015, the solar mounted capacity increase from 37400 MW to 38500 MW on linear are shown in figure 1 (a). The stability increasing ratio of solar-mounted is about 100MW per month, and then the solar generation during 2015 was shown in figure 2 (a), it indicates the maximum generation is about 6600MW on Jul. and the minimum is about 750MW on Jan. and yearly average generation is about 4000MW. Then, we give the compare figure between the solar capacity and generation in figure 2 (b), which indicates the use ratio of solar generation is very low. How to improve the using ratio is core
question. Figure 1 gives us an efficient of generation and capacity, it is obvious that the highest ratio is about 17.5%, the lowest is lower 2.5%, average performance is about 11%. A solar generation has been affected by solar radiation obviously, here we take 2015 solar generation as an example to illustrate the relationship. In Germany most of the peak of radiation per day presents to 9 to 11 AM, from Jan. to Nov, except the peak, appeared 12 to 14 PM from 15 May to 15 Jul according to our sample data from NASA servers.

Duration of sunshine of a day has a wave peak changed exist in from 15 May to 1 Aug. arrive at 16 hours, the trough of a wave is about 8 hours appeared both months Jan. and Nov. Strength of sunshine of a day has great fluctuation one year, the peak can arrive at about 21000 MW in Aug., and on 15 Jan., it will arrive at valley of wave is about 1500 MW. Equation 1 is the formal of converting solar energy into electricity energy, it denotes three factors affect the performance.

\[ P_{pv} = N_m P_{sm} R_t \]  

Where \( R_t \) is real-time incident irradiation, \( N_m \) is a solar generation station mounted cell modules, and \( P_{sm} \) describes the standard output electricity power of one model cell, and \( P_{pv} \) states a solar station output electricity power in real time.

2.2. Wind Generation

Convert wind energy into electricity power via wind turbine spin, which energy provided by wind, a wind turbine can be right work under 2-30 \( m/s \) of wind speed, and this conversion can be described by math equation as shown equation 2 [14].

\[
P_{wind}(v) = \begin{cases} 
  v - v_{min} & v_{min} \leq v \leq v_s; \\
  v_s - v_{min} & v_s \leq v \leq v_{max}; \\
  0 & v_{min} > v \ or \ v > v_{max}.
\end{cases}
\]  

Where \( v_{min}, v_s, v_{max} \) and \( v \) are wind turbine the minimum wind speed, wind turbine maximum output wind speed, wind turbine maximum input wind speed and real wind speed, respectively. \( P_s \) is the wind turbine output power when wind speed is \( v_s \). \( P_{wind}(v) \) is instantaneous output power.

We present average monthly wind generation of 2015 as shown in figure 2 (c), and wind generation compares with a capacity of wind-mounted in figure 1 (d). It indicates that wind generation has great fluctuation during this year from lowest smaller 6000 MW to the maximum about 16000 MW. The wind generations are valley during Apr. to Oct. smaller 8000 MW, and from Nov. to Mar. the
generation located in a high level, especially in Nov., Dec. and Jan. This figure also shows that there has more wind energy in winter than other seasons in Germany.

![Figure 2.](image)

Figure 2. Solar and wind generation and capacity. (a) and (c) are monthly mean generation of solar and wind respectively one year. (b) and (d) are the comparing chart of solar and wind generation and their capacity respectively.

### 3. Solar and Wind Utilization

In the renewable variable energy solar and wind are the most important source undoubtedly. This section we will propose the contribution of them to power load demand. Firstly, the contribution of solar and wind to electricity load was shown as table 1. Secondly, we show you their profile according to ahead analysis as figure 3. This chart is solar and wind monthly average generation of total mounted capacity, respectively. This table and chart indicate the wind profile percent is higher than solar, the maximum value is over 35 percent far more than the 18 per. of solar, the lowest value wind and solar are about 13% and 2%, respectively, and the monthly average wind generation is over 22% more than 10.4% of solar generation ratio. This figure shows both of wind and solar generation are low efficiency, mounted capacity works on lowing level. At the same time, table 1 present the percent in details over the year too.
Figure 3. Box chart of comparing statistic value between solar generation and wind generation.

Table 2. Contribution of solar and wind to demand

| Month | Total power load(MW) | Contribution Ratio of solar (%) | Contribution Ratio of wind (%) |
|-------|----------------------|---------------------------------|-------------------------------|
| Jan.  | 56452.46             | 1.33                            | 22.4                          |
| Feb.  | 57974.01             | 3.54                            | 13.28                         |
| Mar.  | 56642.52             | 6.83                            | 16.76                         |
| Apr.  | 52099.43             | 11.82                           | 13.22                         |
| May.  | 50473.60             | 11.75                           | 14.19                         |
| Jun.  | 51727.78             | 12.22                           | 10.94                         |
| Jul.  | 53719.97             | 12.3                            | 14.73                         |
| Aug.  | 52344.87             | 11.84                           | 9.92                          |
| Sep.  | 54670.56             | 8.2                             | 14.07                         |
| Oct.  | 55179.25             | 4.74                            | 9.69                          |
| Nov.  | 58793.43             | 2.68                            | 24.97                         |
| Dec.  | 54907.92             | 2.08                            | 28.57                         |

4. Power Energy Planning in Long Term

In power system, all giant generation stations how to run are controlled via dispatch department of a power grid, and this schedule of normalise running in mid and long-term. Do well this work must know all different technology energy generation in the grid, so in this paper, we achieved the characteristics research of two kinds of important renewable energy -solar and wind. Then we give some advice on how to improve utilizing ratio of solar and wind energy summarized as follow.

- Although has abundant mounted capacity in solar and wind energy generation, utilization is in low-level annually, so we should plan to use these renewable energies to response power demand in priority, and research ahead shows some complementary characteristic in solar and wind energy, which can be used to plan in details;
- According to equation 1 improve photovoltaic generation ratio must increase \( R_t \) and \( P_{sm} \). Here we perform to obtain the best \( R_t \), so if need to new design solar radiation generation can think the bigger longitude E area and latitude the closer sunlight incidence area; offshore is prior than onshore in wind energy aspect.

5. Conclusion and Results

In this paper, we obtain some results are summarized as below: firstly, In this case, although has plentiful mounted capacity in solar and wind energy generation, the workpiece ratio located in low level, both of them lower 30% annually, and shows some complementary characteristic; secondly the contribution of solar and wind energy generation to power load demand is low, the solar smaller 10%, the wind is not over 25%, so both of them lower 25% annually.
We should make the utmost of the constructed generations, improve their utilized efficiency try our best. Where is the key pot to improve the ratio, according to this paper results, wind generation instantaneous profile has arrived at over 90%, so if you want to get your goal just let wind turbine is spinning, that’s mean extend the working range of wind speed, about solar energy using ratio the instantaneous maximum arrive at 56.6%, so we should focus on the converting efficiency of photovoltaic cell, that improves the $P_{\text{sm}}$ of equation 1; The last but not the least we should dispatch renewable energy in priority to demand.

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