Calculation of new energy maximum access capacity and design of software platform

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Abstract. In view of more and more new energy access to the power grid, this paper proposes a new energy maximum access capacity calculation method, which considers four factors: voltage fluctuation, voltage deviation, harmonic current and transmission capacity. In addition, it develops a set of computing software platform. The platform is based on Python language. The input format file of the platform is a common excel file, which is simple, convenient, flexible and easy to operate. The platform can calculate the maximum access capacity of new energy under the specific grid structure, and give the reasons for limiting access only after inputting the line parameters, new energy parameters, node parameters, transformer parameters, etc.

1. Introduction

A large number of new energy connecting to the grid will change the distribution network structure and power flow, and cause the traditional radial distribution network become a multi power system [1]. With the rapid development of new energy, especially photovoltaic [2], the application of new energy grid connection becomes more and more extensive, and its negative impact on the whole power system must be considered comprehensively. Due to the seasonal and intermittent nature of wind energy, wind power generation itself has volatility and uncontrollability [3]. As the scale of wind power incorporating into the whole power grid continues to expand, the randomness and uncertainty fluctuations brought by wind power also continue to increase, which directly affects the safety and reliability of the whole power grid. Similar to this, photovoltaic power generation has the characteristics of seasonal and seasonal fluctuations as a power source. From the view of urban distribution network, large-scale access of distributed power such as wind power and photovoltaic power generation is a huge opportunity, which makes the development of power grid tend to be efficient, clean and intelligent, but also a severe challenge.

As the representation of the power grid's ability to resist disturbance events such as faults, the security of power grid directly reflects the strength of power grid and the ability of uninterruptible power supply to users. As an important part of the safe operation of the whole power grid, the distribution network with distributed power supply has made great development. Because of its close relationship with users, its safe operation affects the user's power efficiency and quality. So the distribution network with distributed power supply faces with considerable potential risk factors in its construction process, which cannot be ignored. Power failure will not only make the normal operation of the power grid fluctuate, but also affect the normal power consumption of residents.

The access of new energy to distribution network may cause power quality problems [4-6]. This paper analyzes the impact of new energy access from four factors: voltage fluctuation [7], voltage deviation [8-9], harmonic current [10] and line transmission capacity, and calculates the maximum
access capacity of new energy under specific grid structure. A set of computing software platform is
developed. The platform is based on Python language. The input format file of the platform is a
commom excel file, which is simple, convenient, flexible and easy to operate. The platform can
calculate the maximum access capacity of new energy under the specific grid structure, and give the
reasons for limiting access only after inputting the line parameters, new energy parameters, node
parameters, transformer parameters, etc. Finally, this paper takes an actual power grid as an example
to introduce the function of the software.

2. Main factors affecting new energy access

A large number of distributed new energy generation systems connecting to the distribution
network will have an impact on the traditional power grid, mainly on the following aspects: the impact
on the fluctuation of node voltage, the impact on node voltage deviation, the impact on grid harmonics,
the impact on fault current, system protection, etc.

Among them, it mainly affects the voltage of the point of common coupling (PCC) of the power
grid. Therefore, it is necessary to pay special attention to the voltage deviation and voltage fluctuation
of the public connection points, which are the key factors to limit the capacity of the distribution
network to accept the distributed new energy generation system.

2.1. Voltage fluctuation

According to GB12326-2008 power quality-voltage fluctuation and flicker, the limit value of
voltage fluctuation generated by any fluctuating load user at the PCC of power system is related to the
frequency and level of voltage fluctuation. The voltage fluctuation limit is as Tab.1.

### Table 1. Voltage fluctuation limit

| r/(Sub/h) | LV、MV | d/% | HV |
|-----------|-------|-----|-----|
| r≤1       | 4     | 3   |     |
| 1<r≤10    | 3     | 2.5 |     |
| 10<r≤100  | 2     | 1.5 |     |
| 100<r≤1000| 1.25  | 1   |     |

Where, LV: $U_x\leq1kV$, MV: $1kV<U_x\leq35kV$, HV: $35kV<U_x\leq220kV$

The voltage fluctuation $\Delta U_k$ at the PCC is calculated as follows [11]:

$$\Delta U_k = \frac{\Delta Q_k}{S_k} \times 100\%$$ (1)

Where, $\Delta Q_k$ represents the reactive power fluctuation (MVA) at the PCC, and $S_k$ represents the
small mode short-circuit capacity (MVA) at the PCC.

2.2. Voltage deviation

According to GB12325-2008-T power quality - allowable deviation of supply voltage, voltage
deviation refers to the deviation relative value of actual operating voltage to the nominal voltage of the
system, expressed in percentage. The limits of supply voltage deviation are as follows:

1) The sum of positive and negative deviation absolute values of 35kV and above supply voltage
shall not exceed 10% of the nominal voltage. If the upper and lower deviations of the supply voltage
are the same sign (both positive and negative), choose the larger absolute deviation value as the
measurement basis.

2) The deviation of three-phase power supply voltage of 20kV and below is ± 7% of the nominal
voltage.

3) The voltage deviation of 220V single-phase power supply is + 7% and - 10% of the nominal
voltage.
4) refer to the users with small short-circuit capacity, long power supply distance and special requirements for power supply voltage deviation, voltage deviation shall be determined by agreement of both parties.

2.3. Allowable harmonic current value

GB14549-93 power quality - harmonic of public grid specifies the allowable value of harmonic current corresponding to different voltage levels.

At the PCC, the allowable value $I_{hi}$ of the $h$th harmonic current of the $i$th user is calculated as follows:

$$I_{hi} = I_h \left( \frac{S_i}{S_t} \right)^{a_h}$$

$$I_h = \frac{S_{k1}}{S_{k2}} I_{hp}$$

Where, $S_i$ is the protocol capacity of the $i$th user, MVA; $S_t$ is the capacity of power supply equipment at the public connection point, MVA; $I_{hp}$ is the allowable value of the $h$th harmonic current, A; $a_h$ is the conversion coefficient of the $h$th harmonic, that is, the phase superposition coefficient; $S_{k1}$ is the minimum short-circuit capacity of the common connection point, MVA; $S_{k2}$ is the reference short-circuit capacity, MVA.

2.4. Line transmission capacity

Line transmission capacity is also one of the main factors that affects the maximum access capacity of new energy. Generally, only the upper limit of line transmission capacity is considered. When the capacity of new energy is too large and exceed the transmission capacity limit of the line, it will lead to the failure of new energy to deliver power to the system side. The calculation formula of line transmission capacity is shown in formula (1.4).

$$S = \sqrt{3} U_N I_N$$

Where, $U_N$ is the rated voltage of the line, $I_N$ is the rated current carrying capacity of the line.

3. Software interface introduction

3.1. Input: grid structure information

The software first reads the grid structure information from the new energy access point to the upper power station.

Main information includes new energy information (existing access capacity, access life), line information (line model and length), load information (load location, load size), transformer information (transformer model and parameters), etc.

Through this information, the software can build a power flow calculation model of new energy access distribution network, and calculate the constraints of voltage fluctuation, voltage deviation, harmonic current and line transmission capacity. The imported data file is an excel file, as shown in Fig.1.

![Figure 1. Input interface](image)
3.2. Maximum access capacity and reasons for restrictions

According to the input data of grid structure, voltage deviation, voltage fluctuation, harmonic current and line transmission capacity, the software can calculate the maximum capacity of the distributed power source that can be accessed at this location, and find out the limiting factors that limit its access to a larger capacity.

The output results include: Maximum access capacity (MW), Current access capacity (MW), years of access (year), additional access capacity (MW), reasons for restrictions, as shown in Fig.2.

**Figure 2. Output interface**

4. Study case

Take a photovoltaic access grid in a power grid as an example. At present, the photovoltaic capacity of the grid is 2 MWp. The grid structure is shown in the Fig.3, and the grid parameters are shown in the Tab.2-4.

**Table 2. Transformer parameters**

| Transformer name | Voltage level(kV) | Rated capacity(MVA) | Pk(kW) | Uk(%) | R(p.u.) | X(p.u.) |
|------------------|-------------------|---------------------|--------|-------|---------|---------|
| T1               | 110               | 80                  | 261.5  | 23.91 | 0.00409 | 0.2988  |

**Table 3. Line parameters**

| Line No. | Voltage level(kV) | Line type | length(km) | R(p.u.) | X(p.u.) |
|----------|-------------------|-----------|------------|---------|---------|
| Line3    | 10                | ZR-YJV3*400 | 1.00930    | 0.05734 | 0.09795 |
| Line2    | 10                | ZR-YJV3*400 | 1.84240    | 0.10478 | 0.17881 |
| Line1    | 10                | ZR-YJV3*400 | 0.93531    | 0.05319 | 0.09077 |

**Table 4. Bus load parameters**

| Bus No. | active power(MW) | Reactive power(Mvar) |
|---------|------------------|----------------------|
| Bus2    | 4.080            | 1.360                |
| Bus3    | 1.027            | 0.342                |
| Bus4    | 1.027            | 0.342                |
According to the theory in Section 2, using the new energy maximum access capacity calculation software developed in this paper, the calculation results of the maximum photovoltaic access capacity of the regional grid is as follows:

(1) The maximum photovoltaic access capacity is 6.4 MWp. The calculation results of each factor are shown in Fig.4. At present, the grid has a photovoltaic capacity of 2 MWp, and has been connected for 2 years. The grid can still connect with a photovoltaic capacity of 4.436 MWp.

### Maximum access capacity and reasons for restrictions

| Factor                                      | Value       |
|---------------------------------------------|-------------|
| Maximum access capacity                     | 6.400 MW    |
| Current access capacity                     | 2.000 MW    |
| Years of access                             | 2 years     |
| Additional access capacity                  | 4.436 MW    |
| Voltage fluctuation exceeds                 | 0.012574 is greater than 0.012500 |

**Figure 4.** Maximum access capacity and reasons for restrictions

(2) The limiting factor of photovoltaic access capacity of grid structure in this area is voltage fluctuation value. When photovoltaic power is increased to 7 MWp, the voltage fluctuation is 1.257%, which is greater than the allowable value of 1.25%. As shown in the left bottom figure of Fig. 5.

### Constraints under specific new energy access

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1  proc.calc.findMPV($\theta=20, \phi=\phi$)
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- Harmonic Limit [1]
- Voltage Deviation Limit [2]
- Voltage Fluctuation Limit [3]
- Line Transmission Capacity Limit [4]

**Figure 5.** Maximum access capacity and reasons for restrictions

5. **Conclusion**

This paper introduced the calculation method of new energy maximum access capacity, and built a calculation software platform. The platform only needs to input the grid structure parameters and new energy parameters of the regional power grid, and then it can calculate the maximum new energy access capacity of the regional network and the reasons for restricting new energy access. Taking an actual power grid as an example, the software is used to calculate the maximum access capacity of new energy and the reason for limiting access, which provides some reference for relevant workers.
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