Sample Criteria for Integration of Solar Plant Systems to Electrical Distribution Network

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Abstract

In the last decades distributed generation became very popular in consequence of its low investment costs and easy installations. Nonetheless distributed generation and its requirements is not a literally well-known topic by the electricity regulators, distribution system operators and supply companies in Turkey. The aim of this paper is to be develop a criterion for connection of solar power plant systems to electrical distribution network and defining technical boundaries as a regard to national procedures and standards. This report provides a schematic overview of the connection conclusions. The connection steps were applied as a result of the current legislations and policies in national electricity regulations. Solutions were also presents an overview of solar plant integration and analyze the impacts of them using load-flow and short-circuit analysis methods. As a result of the methodology some unexpected problems or damages in the network could be prevented.

1. Introduction

Distributed generation (DG) can be defined as a power generated at or near the point of use [1]. It is also described as decentralized power stations that supply electricity from a decentralized location, often not far consumptions and users [1]. With growing technology in recent years, DG installations and investments are on the rise all over the world and compared to the rest of European countries Turkey is located in a preferential position [2]. Because of its Mediterranean location and high degree of sun radiation, the possibilities for solar energy are very good in Turkey [2]. Besides, the policy in Turkey encourages renewable energy and making it possible for unlicensed production owners of small solar plants to sell their over plus to the government. For this reason, applications of unlicensed power providers with less than 1 MW of capacity are rising and integrations always are located on the distribution network of the grid. Regarding with this, in July 2015, Turkey Electricity Transmission Corporation (TEİAŞ) published a capacity report including medium-term and long-term situations. According to this report Turkey itself has a growing energy demand that is increasing by about 5 to 6% every year and until the end of 2025 it is estimated Turkey's average domestic production capacity would be 533 MW [3]. This capacity will be 1000 MW in the region of Central Anatolia [3]. Compared with the other 20 distribution companies regions it is very high and important percentage [3]. In summary, it is clear that in the longer term share of solar power plants in electricity supply will increase [4]. As a result of this, distribution companies should determine some guidelines and criteria for the future new and complicated electricity system [4]. This paper has presented an overview of the methodology for distributed generation integration. When the utility begins to review to determine appropriate application path there are four important review paths based on generation size and type, location, analysis and preventions. This study defined the criteria to be followed in integration of distributed generation and process of integration methodology has been established for distributed generation. Using PSS Sincal power systems analysis program, some solutions were analyzed. In these analyses, changing the power and location of the solar power plant, the maximum and minimum change interval of the voltage levels in the system were observed.

2. Distributed Generation and Legislations

Distributed generation is identified as small scale generating technologies that are connected to the electric power grid (e.g. solar, wind, CHP, hydro or newer technologies) [5]. DG systems allow customers to generate the electricity they need [5]. Herewith the customer can effectively reduce their electric load [5]. Although the grid-tied systems allow customers to be powered by their own electric generation systems, rather than by traditional central power plants, most renewable DG systems only produce power when their energy source, such as wind or sunlight, is available [5]. For this reason, there are some standards and renewable energy interconnection process to avoid changeable voltage level, noise and harmonics, frequency, machine reactive capability, islanding and other power quality reliability and safety requirements. To clarify this issue, many European countries have established some regulations and norms for distributed generation integrations. The most important ones are IEEE 1547, ESKOM Guideline and BDEW standards. These guidelines define the essential aspects which have to be taken into consideration for the connection of generating plants to the network operator's medium-voltage network [6].

For distributed generation in Turkey, "regulation relating to the unlicensed production of electricity in the electricity market" is the most important legislation that remarks principles for the determination of the network connection point and limiting values during a network fault. Especially this study has been conducted in accordance with regulations in force and analyzed the voltage profile with and without DG.

3. Criteria of the Integrations Reports

Before the inquiry and the technical examination, and for the elaboration of the connection offer, documents about the generating plant should be submitted to Distribution Company. Application documents such as relevant technical specifications certificates of the generating plant, single-line diagram showing the plant's technical specifications to be established, according to the technical guideline on “Regulation relating to the unlicensed production of electricity in the electricity market” of EPDK (Energy Market Regulatory Authority) and of the distribution company are required [7, 8].

The applications must not be processed until the requisite data is obtained as follows (Table 1). At this point, transient synchronous reactance should be evaluated differently according to the type of plant. For instance, solar power plants use full-scale converter structures and their short circuit contribution is very close to its nominal current.

Therefore, the transient synchronous reactance value is taken as %100 in this paper. On the other hand, the estimated distance of the power will be transported is more important than the distance between connection node and the power plant. Because, the range of the operating voltage levels depend on the length of power line and the load of consumers.

Table 1. Requisite data for simulations or calculations

Power Plant Type	Solar/Hydro/Wind/etc.
Power Plant Size	kW
Reactive Power Value	Cosφ
Connection Node	Net station/Primary substation
Connection Node Distance	km
Power Transmission Distance	km

By using these data, when we analyze or make calculations about the power plant, the following procedure must be reachable (Table 2).

Table 2. Results of simulations or calculations

Voltage Changes	…%<5%
Maximum admissible short-circuit current	…kA<16 kA
Short-Term Flicker	…<1.00
Long-Term Flicker	…<0.80
Total Harmonic Distortion	…<8.00

In all reviews, some additional criteria should be certainly considered. Especially, while we were analyzing the impacts of power plant, there should be only one power plant in the simulation not more. Because, every new power plant may make an additional impact and when evaluated them together in the same simulation, which may misleads us about the results. Also, existing frequency and voltage protection functions must be reported.

As a result of all these analyzes, applications affect the reliability of the system may refuse with technical explanations by referring to existing regulations or may recommended another maximum power value can be integrated.

3.1. A Sample Criteria for Approval Process

When the utility begins to review to determine appropriate application path there are four important review paths based on generation size and type, location, analysis and preventions. This study defined the criteria to be followed in integration of distributed generation and process of integration methodology has been established for distributed generation.

3.1.1. The Power and Type of Plant

Wind energy plants, hydro power plants, biomass, solar plants, etc. are the meaning of the generating plants in this paper. A generating plant consist of a single generator or of several generating units like wind farm or synchronous or asynchronous can generate electricity using with or without inverters like solar cells of photovoltaic plants. For this reason, it is not possible to provide general information in this respect. In other worlds, connection to the medium-voltage network depends on the type and operating regime of the generating plant [6].

In wind and solar plants the source is variable and flicker effect is easily perceptible. On the other hand, hydro power plants or cogeneration units like as biomass, biogas or natural gas-fired power stations produce large short-circuit contribution.

When the amount of generated power increased, the distance of the power to be transported will be prolonged and it might increase the risk of trouble that may damage to the network.

3.1.2. The Location of Power Plant

Reverse-power is remarkable factor for location of the commissioning the power plant for voltage control and protection coordination [7, 8]. If there are multiple power plants in the same area, then they should be assessed according to the power value they generate in total. Besides, depending on frequency and voltage, it must to be confirmed whether there is a critical load to interact with distributed generation.

Here, another important point is stiffness factor that could be determined as the available utility fault current divided by DG rated output current in the affected area. It should be more >30 for cogeneration units higher than 1000 kW_e capacity and >70 for other distribution generations. In case, these values are below the rate of connectivity, Distribution Company may offer another location for the integration [7, 8].

3.1.3. Analyze of Power Plant

In analyses, using geographical information system and power system analysis software support your technical assessments rather than manual calculation methods. Because geographical information system includes all the power network elements (e.i. lines, transformers, and breaker) from substations to load and in order to evaluate the influences of distributed generation simulation software is required which appropriately reflects the special features of distribution company reviews.

For the acceptance of the connection of generating plants at a junction point the following analyses are required, for instance [6].

- Load-flow analysis
- 1-phase, 2-phase and 3-phase short-circuit analysis
- Protection calculations
- Contingency analysis

In this paper, we use PSS®SINCAL (Siemens Network Calculation) for the simulation, evaluation and optimization of supply systems. Additionally, voltage changes between bus-bar of the transformer substation and the junction point should be detected by means of calculations. With these features analysis enables Distribution Company to more accurately model the new power plant technology and gives them better insight into the distribution system. With this improved understanding they can operate the system in an optimized way. Additionally it can be used to estimate the distance to the stability boundaries. It can be used to provide improved starting conditioned or to solve the load-flow [10].

3.2. A Sample Review for Solar Power Plant

In this report, each of them is 1 MW solar power plant installed in Ayrancı-Karaman distribution region has been examined. The obtained results are shown below. The power of solar plant in Dokuzyol village of Karaman has been reported 2 MW. In the following graphic, the point of connection to the distribution system has been given (Fig. 1, 2).

Fig. 1. Location of solar plant in Dokuzyol village of Karaman and its connection point

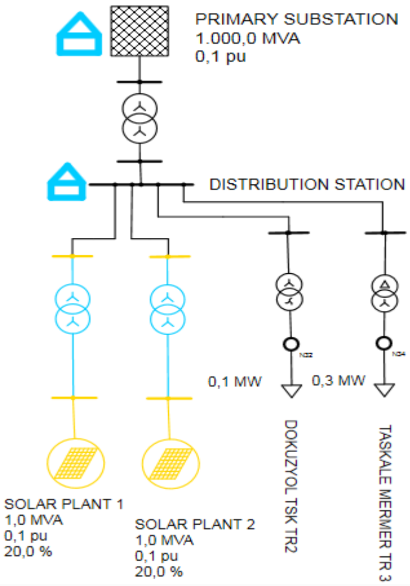

Fig. 2. One-line diagram of solar plant in Karaman

3 phase load-flow and short-circuit analysis in the system was performed (Table 3). Load-flow analysis shows the results in the case where the system is completely unloaded and loaded.

Table 3. Maximum 3 phase short-circuit analysis results

Node Name	Before Integration (kA)	After Integration (kA)
DOKUZYOL TSK TR2	5.33	5.34
TASKALE MERMER TR3	20.32	20.50

Short circuit values given above are based on the medium voltage bus bars contribution of relevant plant.

Power plants which use converter systems as solar power plants and wind power plants, create a 1.1 times short-circuit contribution of the nominal current by themselves. For this reason, normally these types of power plants are not exceeding the value of short circuit resistance of bus-bars.

Load flow results are shown below (Table 4). In this analysis, there are two different conditions, loaded and unloaded.

Table 4. Load-flow analysis results in loaded and unloaded conditions

Node Name	System with load (pu)		System without load (pu)	
	Before Integration	After Integration	Before Integration	After Integration
DOKUZYOL TSK TR2	1.0268	1.0313	1.0565	1.0466
TASKALE MERMER TR3	1.0261	1.0307	1.0565	1.0466

The load flow analysis result shows that, the power plant can make the voltage profile better in a loaded system. For unlicensed plants, permissible power plant range is 1 MW. However, for licensed plants permissible power plant range is between 5 and 10 MW in the same location. At that time, the impacts could be observed clearly.

The majority of solar projects are intended to export power to the grid. Project developers often prefer rural areas due to the lower cost of land. But rural areas have less electrical load than urban network. As a result, these projects may have total effects on the distribution grid as well as local impacts within the network [11]. Especially in the case of minimum load, reverse power is very important issue. Besides, while the power plant is generating, reactive power and power factor continuously varies. For this reason, compensation systems are very important not to pay fines.

4. Conclusions

Today, power systems are changing and classical passive top-down one-way network is transformed to an active bottom-up bi-directional network. The bidirectional distribution system will play an important role in the future power system. For this reason, a rethinking of the control architecture or integration approach is required. This study has defined criteria to be followed in integrations. This paper has presented an overview about distributed generation integrations. Also it has showed that all integrations are different and there could be some differences in impacts of same DG plants in different locations. This study has described the criteria to be followed in integrations. In these analyses, the power and location of the solar plant were changeable. In this manner the maximum and minimum change interval of the voltage levels in the system observed. Consequently, distribution companies may form their own process diagrams for the applications regarding with the existing legislations. After the technical assessments, the company may be accepted or be rejected the applications.

5. References

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