Chapter 10

Emerging Technologies for Renewable Energy Systems

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Additional information is available at the end of the chapter

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Abstract

Considering all aspects involving smart grid deployment, several subjects extrapolate the electrical sector. In the Brazilian scenario, it can be clear that power companies cannot support, by themselves, all steps for establishing renewable energy sources in smart grid systems. The technology demands are greater than what the electric sector can deliver. Such discussions about regulations of renewable energy sources are largely discussed in the society. The search for deploying eolic and solar generation with big energy farms are opposite to the smart grid and smart city renewable energy concept, which require decentralized actions. This chapter will show the concepts of eolic and solar energy sources specifically in the context of Smart Grids.

Keywords: renewable energy, solar and eolic energy, regulations, electrical vehicles

1. Solar and eolic energy in Brazil

With the publication of ANEEL Decree No. 440 in 2010, a working group was created to study the concept of smart grids. Such a group was intended to outline the various aspects, both technological and social, of the subject. The study had numerous findings of smart grid plans, both domestic and international, which point out that the Brazilian electric sector actually could not face, alone, the various technological and financial challenges for the implementation of smart grids [1].

In part, this is because the concept of intelligent networks very soon began to be linked to smart cities, which is composed of elements that go beyond the boundaries of energy generation, transmission, and distribution. Smart cities present a broader context of changing, because, in essence, cities must become more efficient in all its processes and services available to society.

Under this approach, in fact, the changing demands would be much broader than just those in the energy sector. This would require society mobilization to successfully carry out a transition from old models of electrical networks to the new smart grids [2].

Precisely, this broad background of discussions on smart grids and smart cities highlights that the sources of renewable energy are an agenda that deserves much attention. The Brazilian energy matrix is considered clean, but some factors such as cost and implementation time of new hydropower plants have favored the emergence, in recent years, of thermal plants. Today, thermal plants account for almost 29% of the installed capacity of the country's energy generation. Used as alternatives to meet emergency demands, the thermal plants take advantage of its speed of deployment, fine-grained control of generation, and flexibility in the fuel that is used. In addition to its construction being expensive, such plants have a strong social appeal as they do not qualify as a clean source of power generation, requiring fossil fuel to burn for its operation.

It is in this context that an increasing need for alternative energy sources is predominant. The search for alternative energy sources is also a worldwide concern, as can be seen in **Table 1**.

An accelerated global growth can be seen in the deployment of the generation capacity of alternative energy sources from 2010, led by China and the United States. These nations, which notably possesses the greatest industrialization level for the period analyzed, are in the power generation forefront, whether or not alternative sources meet their incremental internal demands.

Such statements only reinforce the commitment of many countries to seek alternative energy sources, which are more efficient, cheaper, and meet the expectations of society for lower environmental impacts.

Country	2007	2008	2009	2010	2011	Δ% 2010/2011	Total %
China	8.2	15.0	19.3	36.4	73.7	102.3	18.8
USA	30.9	39.4	49.4	54.7	64.3	17.5	16.4
Germany	30.9	34.3	41.6	51.3	61.3	19.4	15.6
Spain	16.3	20.8	23.7	26.3	27.0	2.9	6.9
Italy	4.7	6.1	8.6	12.2	23.2	89.7	5.9
India	9.3	11.8	13.2	15.7	20.0	27.8	5.1
Brazil	6.6	7.4	6.7	8.8	12.4	41.2	3.2
France	3.6	5.0	6.3	8.5	11.5	34.5	2.9
UK	4.3	5.2	6.4	7.7	10.8	39.7	2.8
Japan	5.5	5.9	6.7	8.0	9.5	19.3	2.4
Others	40.2	46.5	55.6	63.8	78.7	23.4	20.1

Source: Adapted from reference [3].

Table 1. Installed capacity of renewable energy in the world (GW).

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In Brazil, this concern resulted in the growth of the installed capacity of renewable energies of around 41% between 2010 and 2011, following the trend of other nations [3].

Among the several ways currently available for generating power from renewable sources, we can highlight two ways, which are the most cited by the technical-scientific community: solar energy and wind energy. **Figure 1** shows a representation of the installed generation capacity of solar and wind energy in Brazil.

According to reference [3], the evolution of the installed generation capacity of wind and solar energy in Brazil has been growing at different levels since 2007. While wind farms accounted for 1.7% of the total installed capacity of the country in 2013, solar plants had lower expressibility, up to 0.0% of the total installed capacity. In 2011, about 2200 MW corresponded to generation through wind; however, only 5 MW were declared as the installed capacity of solar power plants.

Brazil has an innate ability to generate solar energy because of its location in a tropical area with a high incidence of useful radiation throughout the year. Notably, one of the major obstacles to implementing this type of generation center is the need for large footprint.

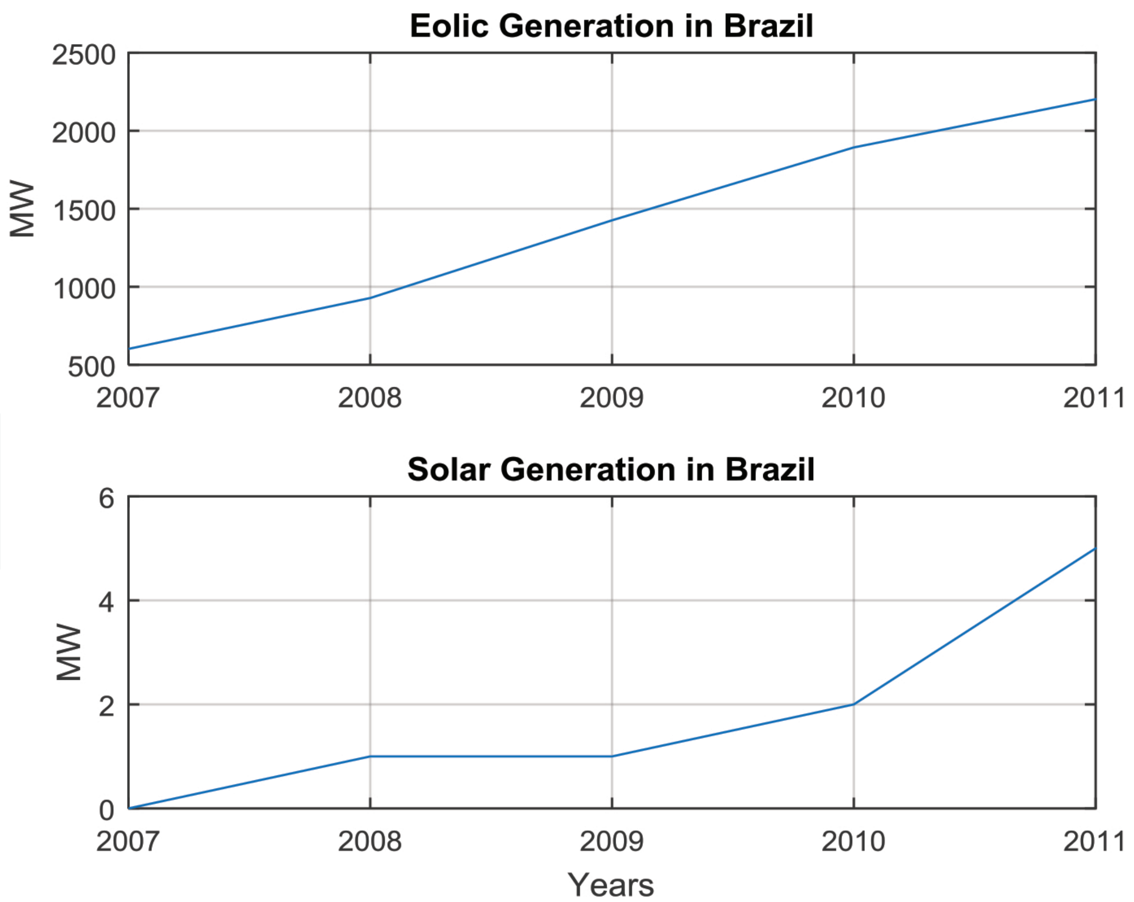

Figure 1. Installed capacity of eolic and solar generation in Brazil. *Source:* Adapted from reference [3].

This is partly because technologies involving solar capture and conversion into electricity through photovoltaic cells are still being constantly researched to find more efficient ways to harness sunlight.

Recently, to increase the installed capacity of solar power generation, the Energy Research Company (EPE) enabled 11,261 MW of 341 projects from solar PV for auction. A large number of qualified projects will surely promote competitiveness in the auction, which is also needed for research and investment seeking more efficient ways of establishing these plants.

The volume of energy is significant and comparable to large hydroelectric projects like the Belo Monte Dam. The state with the largest number of projects is Bahia, which could add 3998 MW to the National Interconnected System (SIN). Piauí state had enabled 61 projects (2077 MW) and São Paulo state 37 (1293 MW) [4].

Regarding wind power generation, Brazil's installed wind power capacity is concentrated in three main regions: the Northeast Coast, being Rio Grande do Norte, Ceará, and Piauí states; Bahia, which also comprises the interior of Pernambuco state; and Rio Grande do Sul, which accounts for more than 90% of the entire installed wind farms in the country. According to reference [5], the average statistics regarding these generation parks are summarized in **Table 2**.

The energy generated on the coverage area of the turbines is a very important characteristic because the catchment area is closely linked with the wind regime of the region. Another factor that should be considered is that the average height of generators is above 80 m in height, which provides monumental landscapes from the wind farms and costly installation.

The need for such high turbines comes from deep investigations concerning the system of winds. If such requirement is not attended the wind potential is not entirely availed.

The wind behavior in Brazil has been studied since the 1970s, showing a prospective scenario for this type of energy generation in the country. The "Atlas of the potential of Brazilian Wind" [6] pointed out that by the end of the 1980s, with measurements up to 10 m tall, trends in wind speeds of 5 and 6 m/s could be considered along coastal and inland areas that have favorable topography and roughness.

In the next decades, following the global trend of deploying wind power on a large scale, new studies have emerged in Brazil, made by several companies in the electricity sector promoting feasibility reports of towers of 30–50 m in height. The government of Ceará state in 2001, for example, published an Atlas of the Wind power generation potential of the state, pointing generation capabilities with average wind speeds of around 7 m/s using towers of 70 m.

Basins	Energy index (W/m^2)	Production index (kWavg/machine)	Wind generators	
			Average power (kW)	Average height (m)
Northeast Coast	345.4	860.9	1934	87.6
Bahia	471.3	812.1	1715	83.5
Rio Grande do Sul	329.3	660.2	2000	82.0

Table 2. Main eolic regions in Brazil.

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Therefore, it is possible to affirm that Brazil has great potential for deploying solar and wind power stations, especially large-scale projects, which are already being conducted. The high importance of these projects is, in part, justified by two reasons.

The first reason lies in the fact that Brazilian system (SIN) is interconnected so that each region can have its power generation potential leveraged in the energy matrix, being it hydro, solar, wind, etc., more efficiently. The energy generated is then transported to the consumer centers. This is one of the practices most used by the Brazilian electric sector currently focusing on the construction of large plants that can make the most of the energy potential of the region in which they operate.

The second reason lies in the fact that consumption centers are far from generating centers, especially in the Southeast region, which is the major consumer of energy in the country. In reference [6], the authors point out that the average distance between generation and consumer centers ranges from 500 to 1000 km, reinforcing that the creation of large power plants is economically justified, since they are installed where there is a better climate, relief, watershed, etc.

This Brazilian model of large power plants has been debated, in various social forums. This subject still needs further discussion, since several sectors have proved incompatible with such model.

2. Solar and eolic energy in the microgrid context

The various factors mentioned in the previous section and that punctuate the Brazilian policy of creating large power plants are opposed to the concept of intelligent networks with the presence of renewable energy.

That is because the context sought by smart cities is precisely that of decentralized energy production, which would be a more appropriate setting for power distribution with distributed generation capacity, where customers could enter the energy mix as well as generators.

ANEEL, through Normative Resolution No. 482 [7], established the general conditions for the micro- and minigeneration access to distributed power distribution systems and electrical power compensation system. This was a response to wishes from the scientific community to the theme of distributed generation, which for a long time was already promoting articles in conferences and journals.

Since 2006, it can be seen in the literature alignment of research involving smart grid topics where distributed generation is also discussed. In this context, small generating units were given the name microgrid. A technological step was necessary to explore more efficiently the system that is now available, such as powerful signal processing tools, data transmission, storage, and knowledge discovery in databases [8].

The distinction in Brazil's microgeneration and minigeneration standardized by ANEEL is used for the power generating unit, as can be found in reference [7]. Microgenerators are the ones with less than 100 MW of installed power and minigenerators are the one that have an installed power between 100 and 1000 MW.

In both cases, renewable energy generation may be used alone or along with high energy efficiency systems, such as hydro, solar, wind, biomass, or cogeneration, connected to the distribution network through consumer units. Unlike what some European countries envision, where in fact consumers may be remunerated by the sale of electricity to companies, in Brazil, consumers make part of the established power compensation system.

In this case, the active energy injected by a consumer unit with micro- or distributed minigeneration is transferred to the local distributor and later compensated with energy consumption. Therefore, a consumer with small generating units, such as photovoltaic panels and wind solar, uses the energy generated to compensate their energy bill. The energy excess is converted into abatement credits for future accounts or current accounts of another consumer unit of the same client. Credits are valid for 36 months [9].

Among the many developments promoted by Normative Resolution 482/2012, it may be noted that it is not established, technically or economically, by ANEEL, the particular characteristics of such generators. It is the consumer's responsibility to evaluate what would be the best conditions of cost/benefit for use in micro- and minigeneration.

The dialogue between customers and distribution companies is also stimulated as companies cannot refuse to perform the connection of the consumer’s generating units, as ANEEL understands that the companies are responsible for ensuring reliable energy utility.

Thus, the indicated benefits, such as postponement of investments, reduced load, low environmental impact, among others, shall only be advantageous for both consumers interested in generating energy, and distributors interested in finding technical and economically viable solutions.

The authors of reference [9] state that complementary to Resolution 482 are Module 3 PRODIST [10] and the Resolution 414/2010 [11]. These documents are made and summarized for customer units connected at low voltage (group B). If the energy injected into the network exceeds the consumption, it will result in payment for the cost of availability: 30 kWh (single), 50 kWh (two-phase), or 100 kWh (three-phase).

For customers connected to a high voltage (group A), the invoice energy portion will be compensated, but the share of the demand will be billed normally. According to ANEEL's data, currently, there are 1466 micro- and mini-generation registered agents associated with Resolution No. 482/2012.

The large-scale use of photovoltaic panels, photothermal, and small wind turbines for homes and businesses certainly would be characterized as a new power generation paradigm, different from the use in the so-called generation farms.

It is precisely these actions involving smart grid initiatives that engage the distributed generation system in the world, where each consumer would be a key element responsible for supplying energy in a mobile way. Although the scientific community focus efforts in managing

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large renewable power plants, which are extremely costly for deployment and management, enterprises that pursue the compatibility of small generating units for supplying loads in distribution networks are of great value [12].

The compensation system proposed by ANEEL for mini- and microgeneration is setup for small applications, following the global trend of distributed generation, by fostering the rise of small distributed generation with great diffusion in homes and businesses. In this new paradigm, where each consumer could own their microgenerator and make better use of renewable energy sources available in their home, some initiatives have gained prominence.

2.1. Heliothermic energy

According to the Society of the Sun [13], which supports low-cost solar heaters projects, it is possible to build heliothermic systems up to half the price of conventional systems. This organization provides free step-by-step execution of the project represented in **Figure 2**.

Simply replacing the electric shower by heliothermic plates, for example, could represent a reduction of 3–9 kW in the loading of homes, which generates savings in the energy bill and also in the protection circuit, which could use conductors and circuit breakers with lower nominal currents.

The materials to be used in the construction of the solar heater needs to be inexpensive, and easily accessible. The system takes advantage of the heat exchange surface of the PVC, painted with black ink, and a capillary water system also made from a PVC tubing. When in contact with the heated surface, water exchange heat, becoming warmer, being stored in a reservoir.

This system exploits the principle that a water tank itself can become a storage element for thermal energy when it has a large amount of heated water. Then, the water is dispensed using special containers. The thermal inertia of the large volume of water and the hot water flux on top of the tank ensures maximum system efficiency. A graphical representation of the system can be seen in **Figure 3**.

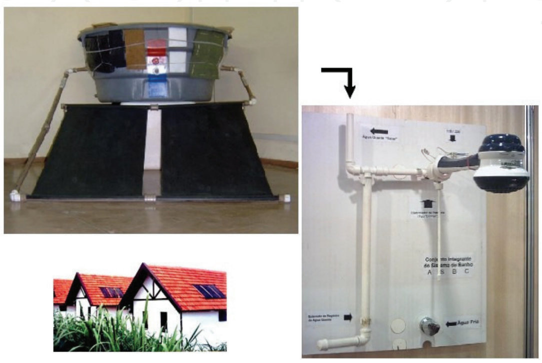

Figure 2. ASBC project. *Source:* Adapted from reference [13].

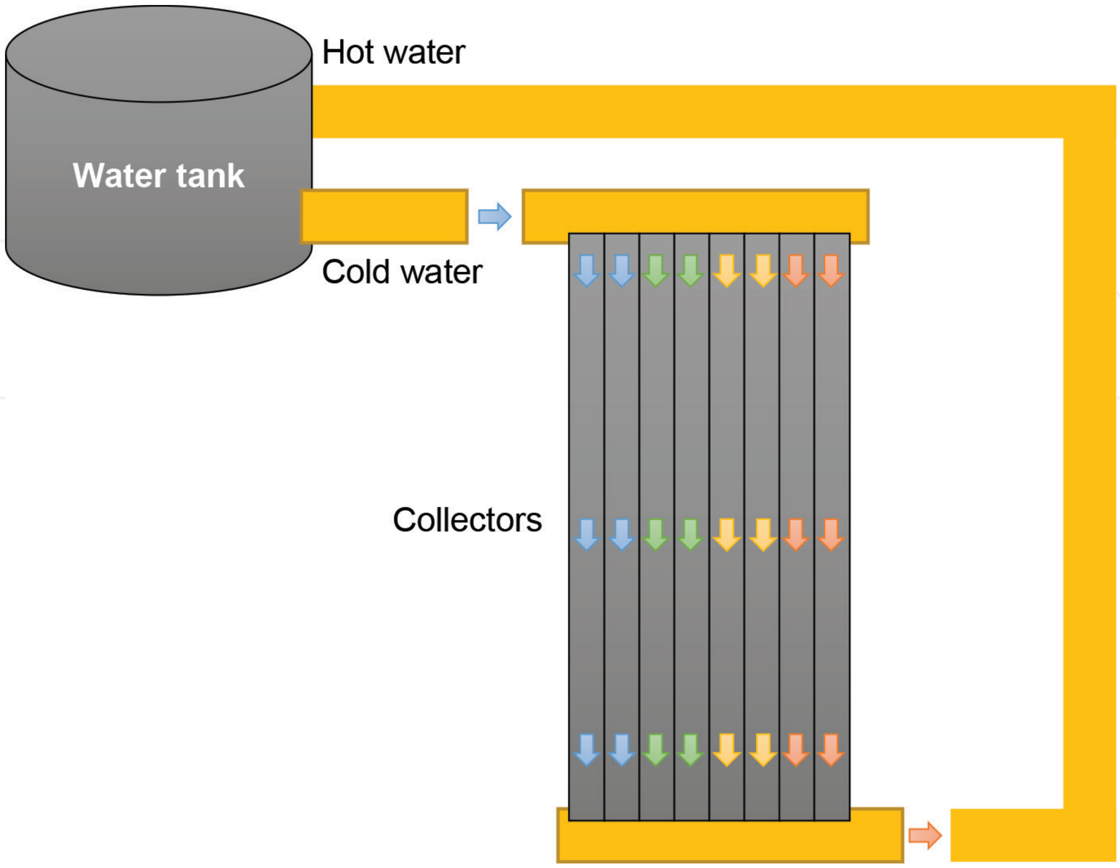

Figure 3. Low-cost solar collector operation.

According to the creators of the project, for a 300 L tank, the area of the collector is about 1.5—2.5 m^2, with a total weight between 15 and 40 kg/m^2 depending on the type. The system slope is ideally set up. However, it still needs a slope adjustment in winter. The roof slope should be close to the local latitude, or up to 10 degrees more. The initiative of the Sunshine Society offers several other projects to avail the Brazilian heliothermic potential at a low cost. The production scale of this projects certainly would provide competitive cost on conventional system, which is still not intensively used due to the high investments and longer return time.

2.2. Photovoltaic energy

Photovoltaic cells still have little market penetration, which is completely contradictory to the potential generating capacity of this system. According to reference [14], considering only the area of the Earth where the deployment of solar power plants would be possible, the energy generated would be around 1011 GWh/year.

As sunlight is composed of a directly incident part and another part that is diffusely incident, the efficient use of this form of energy requires collectors that align with the sun. Otherwise, only a portion of the generation capacity will be available. In Brazil, according to reference [14], the largest global radiation value occurs in Bahia state and the lowest in Santa Catarina state. However, solar radiation values in any region of Brazil are higher than in many countries where the rate of use of this form of energy is higher than in Brazil.

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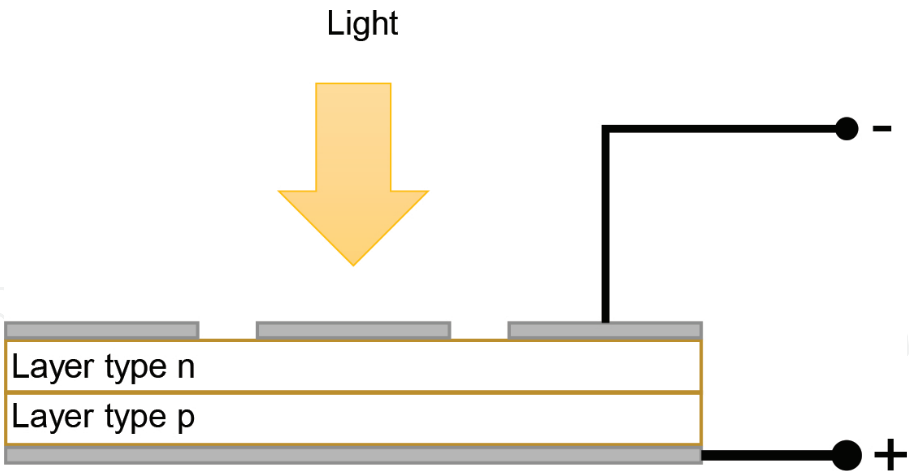

Figure 4. Photovoltaic panel representation.

In **Figure 4**, a schematic representation of a photovoltaic collector plate is shown, where you can check the distribution of type p and n layers and the metal arrangement responsible for the voltage supplied to the circuit.

The semiconductor substrate material, when bombarded by sunlight, generates a voltage which is available in the metallic terminals. To increase generation capacity combinations of these devices are used, since each has an average energy efficiency of less than 15%, that is, 85% of the radiation incident on the light collector is not transformed into energy. The lifecycle of these collectors is also a contributing factor for its high cost to consumers, since it is exposed to the sun, and its low efficiency tends to become even smaller over time when compared to other forms of power generation.

2.3. Wind turbines

Wind turbines take advantage of the kinetic energy of wind captured within the coverage area of the rotor blades to generate electrical power. By reaching the wind turbines, the wind tends to decrease its speed; however, by forming a helical vortex, speed is recovered, since a minimum distance between turbines is required for minimizing loss of performance [6].

A safe working distance is considered to be five times the rotor diameter between alongside turbines and 10 times the diameter between downstream turbines. The rotor speed is inversely proportional to the blade diameter, and speeds of the order of 15–30 rpm are considered slow for practical implementation criteria. This type of practice rule ensures that the blades are visible and avoidable by birds in flight. Another aspect to be considered is that the higher the speed, the higher the rotor noise level.

Initial rates for availing wind lie between 2.5 and 3.0 m/s. Due to the high inertia of the rotor in situations where wind speeds are between 12.0 and 15.0 m/s, it is necessary to activate the power-limiting system of the machine. In situations where the wind regime reaches higher levels, new studies on the feasibility of the deployment become necessary, since it can undergo large efforts from the structure of the machine.

The IDEAL Institute [15], which promotes projects for the development of renewable energy in Latin America, produced a guide with the support of ANEEL and several other entities, to promote the dissemination of information to those who want to install a wind turbine at home. This guide clarifies some findings regarding wind turbine installations in large generation parks, targeting correct orientation for consumers who can benefit from the tax incentive introduced by ANEEL.

According to the guide, small wind systems are closer to the ground than large wind turbines, and analysis of the land around the facility is of great importance for properly utilizing the potential of the winds. As pointed out by reference [6], the wind regime has an increase in speed with greater heights, and at lower heights speeds are mitigated by a multitude of factors. Typically, micro and mini wind generators need to be installed on high towers or top of buildings. **Figure 5** shows some safety distances given by the IDEAL Institute's guide.

According to the Atlas of the Brazilian Eolic Potential [6] along with the IDEAL Institute guide, it can be seen that wind turbine installations for the purpose of micro-/minigeneration has an average wind speed of 6–7 m/s according to the minimum height specification, with good generation capacity. However, as there are a plethora of models available, one should consider the noise that each model produces, it is also required to simulate noise level in the neighborhood. Large wind turbines of wind farms have acceptable noise level of 300 m, so this is a very important factor in choosing the model.

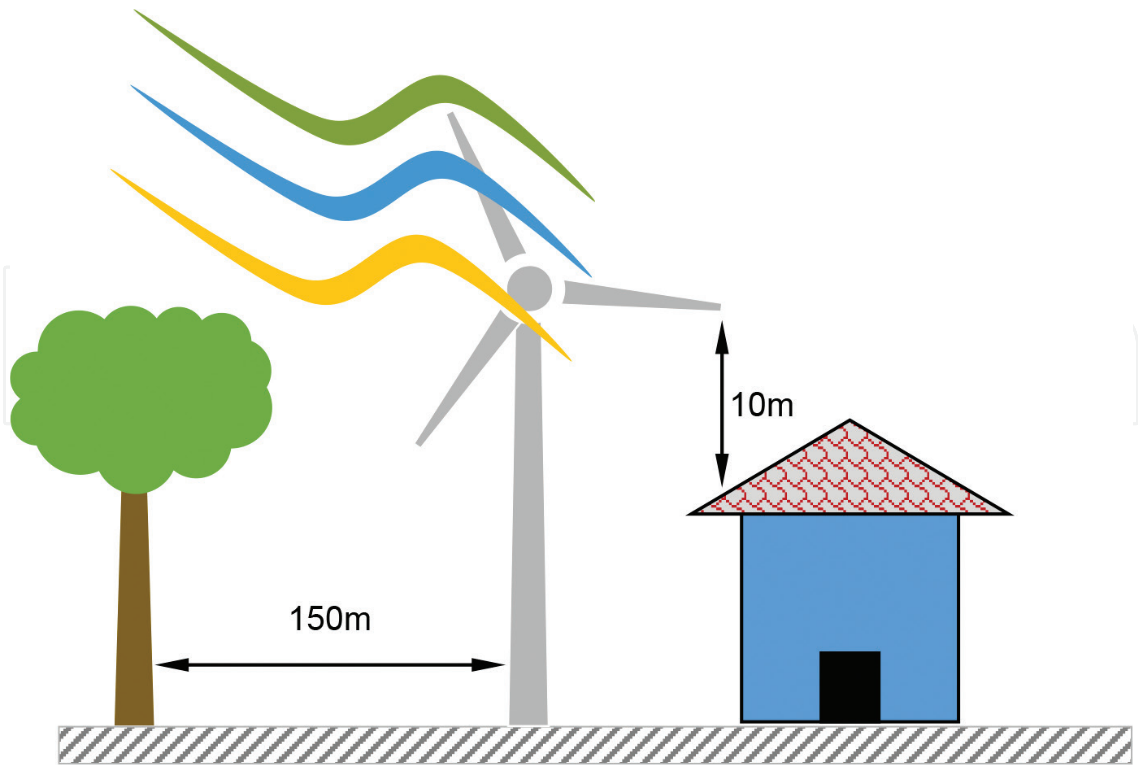

Figure 5. Minimal distances between wind turbines. *Source:* Adapted from reference [15].

As the efficiency of this type of power supply is relatively high, aspects such as power generator size, rotor size, etc., must be thoroughly investigated by consumers so that he can obtain a good cost and benefit relation.

Another important factor concerns the protection of equipment and people. As mentioned above, the speed control system is crucial for safe operation for humans, animals, and properties.

As turbines are installed on high towers, consumers need to keep in mind that a proper grounding system and possibly a new grounding should be considered.

3. Electrical vehicles in the microgrid context

It is estimated that there are approximately 900 million transportation vehicles circling the planet, where 90% of these depend entirely on fossil fuels and internal combustion engines, despite these vehicles being declared obsolete for decades due to their high greenhouse gas emissions and their low efficiency. Effectively no more than 30% of the energy contained in the fuel is transformed into vehicle's workforce. The emission of gasses such as carbon dioxide, nitrous oxide, and chlorofluorocarbons from combustion engines has generated debates in numerous international discussion forums, where actions for minimizing the effects of global warming were in focus.

Therefore, rapid growth has been seen in the electric vehicles industry, whose main purpose is to replace traditional vehicle systems and their high carbon emissions. The deployment of smart grids come at the forefront of a promising scenario to promote change for electric vehicles. The main reason for this prospective scenario is the extrapolation of the concept of smart cities, which brings more efficient, environmentally friendly, and affordable products and services to society [16].

According to reference [17], a major challenge involving the spread of electric vehicles is the strategic distribution of charging points. This topic is certainly what concerns consumers the most when there is the possibility of only charging their vehicle at home. To this end, it is important to gradually establish a broader availability of technologies, so that the user gets used to the idea of abandoning its vehicle using fossil fuel.

Hybrid electric vehicles are those that use a combustion engine together with electric mothers. This was the first technology presented, which started preparing consumers for electric vehicles. Hybrid electric vehicles can effectively be plugged in an outlet to charge their battery banks, in addition to working with combustion engines.

The batteries, in this case, can provide extra mileage range when fuel ends. Vehicles battery-powered only and vehicles with hydrogen fuel cells are the evolution of the hybrid technology, in which combustion engines would no longer be necessary, reducing the greenhouse gas emission.

There are currently several types of batteries in the market, with different features for different application and that may or may not be suitable for use in electric vehicles. In reference [18], the authors list the types of batteries that were used in their study for managing and dimensioning energy supplies for electric vehicles, which can be highlighted as follows:

- Lead-Acid Battery: it is the battery pack used in motor vehicles. It has good reliability when operated with low levels of loading and unloading, also being used in different versions of UPS batteries. To use it in electric vehicles, adjustments are necessary to replace the liquid chemical element with gel to prevent leakage since electric motors require a higher level of discharge.
- Nickel Cadmium Battery: is considered the most efficient batteries to operate at high discharge environments and can provide very high levels of current. Its operation in electric vehicles, however, needs further investigation since the disposal of cadmium can be extremely harmful.
- Lithium Ion Battery: presents high efficiency and low cost as its life is determined by charge/discharge cycles. It works with a very high discharge level, promoting high torque for the electric motors.
- Lithium Ion Battery: this is the most modern lithium batteries in the market. They work with a very high level of discharge; it can also support bigger current regime, which reduces the recharge time.

Supercapacitors are another energy storage source for electric vehicles. Supercapacitors are elements capable of operating with loading and unloading of large amounts of energy, especially suitable for driving large electric motors. Several studies have promoted the use of these elements in electric vehicles for public transportation, which requires larger engines and lower recharge times. Moreover, batteries can be charged at the boarding terminal [18].

The use of supercapacitors and batteries consists of a combination of energy sources technologies capable of supporting both long-haul routes when moving extremely heavy vehicles, a situation still unsupported by current batteries performing alone

In the context of smart grids, considering a heterogeneous environment of electric vehicles having the most diverse types of batteries and supercapacitors, a management of strategic points of recharge is necessary. Mass transit vehicles, for example, using supercapacitors require a high voltage source for rapid charging, while vehicles with battery sources require lower voltages and currents.

You can group the types of loading according to the charging time [19]:

- Slow charging: usually applies a charging current of about 1/10 of the current capacity of the battery. It does not heat and deteriorate the internal elements of the battery. This procedure popularized lithium batteries and nickel.
- Fast charging: uses a recharging current equal to or greater than the battery charging capacity. This type of operation provides plenty of stress to the battery, decreasing its life if it is not designed for this purpose. Lithium ion batteries have shown good response with very high levels of recharging, performing a quick battery recharge to operating levels.

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Recharge time will be a determining factor in the study and expansion of recharge points in smart grids. Power agents recharging points shall also take into account the level of hybridization of the vehicle, driving patterns, the types of batteries available, and also seasonal issues. Electric vehicles will only be successful if they indeed resemble the vehicles consumers use today, i.e., with multimedia stations, air conditioning, heaters, and other electrical optional items. Some items depend on environmental conditions.

On a very hot day, for example, the distributor must be prepared for a larger load at the recharging points due to the intense use of air conditioning by electric vehicles. If the traffic is jammed on a hot day, this can worsen the situation because vehicles are consuming more energy without moving. Such a situation could overload the rapid charging points for vehicles [17].

When considering a conventional power network, which could support the loading of all vehicles during the night, it could result in a contribution of investments in new generating plants far superior to what would be gained with a massive penetration of distributed generation. However, in the context of smart grids, the shipments could be fired in cycles, ensuring maximum efficiency of power during the charging process. Another possibility is differentiated charging, which causes the consumer to adhere to their vehicle loading programs with lower charging times.

Other clusters of discussions are energy storage for electric vehicles during the braking process and recharging using photovoltaic panels. The energy stored while braking could be used via a kinetic retrieval device from the vehicle, such as overtaking or recharging processes of other devices. With the capability of detecting such vehicles connected to intelligent networks, as soon as their batteries were loaded, photovoltaic panels on the roof of vehicles could continue to provide power to the grid, functioning as a distributed solar generator.

In reference [17], a synthesis of several case studies involving the use of electric vehicles in many different types of smart grids is displayed. Bellow, we point out some noteworthy aspects raised in these case studies:

- Overload in transformers: from several simulations using different transformers, it can be seen that a 25 kVA transformer of were overhead when using a quick charging condition of the vehicle in peak hours and operating on the edge outside the peak hours. When slow recharging, the transformer remained within its operating limits. Using load scheduling of vehicles with the smart grid transformer operating limits was also maintained.
- Integration with the network: A study promoted in Belgium showed that the integration of electric vehicles in the distribution network had negative impacts of power losses and also of voltage variations. In conclusion, recharging should be controlled via a centralized operator.
- Impacts on the distribution systems: Studies have indicated that there may be increased temperature of transformers due to increased load, high harmonic levels from the switching power supplies needed to recharge the vehicles, and bushing wear of the transformer.

4. Energy storage in smart grids

Energy storage is a pretty major topic in forums involving various areas of engineering. In the context of smart grid, this topic also deserves special attention, since in a scenario with a strong presence of distributed generation, the idea that every consumer could generate energy for their demands and inject the surplus into the network becomes feasible.

However, a renewable energy system has unique characteristics and how to store any extra energy generated should be analyzed with caution and targeting efficiency.

This debate occurs for solar photovoltaics collectors. With such low efficiency in the generation, the potential of these collectors needs to be leveraged. As during the night, collectors do not generate power, if there is excess produced during the day, it would be interesting to store. In the context of micro- and minigenerators proposed by ANEEL, the client has a second option of injecting the surplus power into the network.

Some designs of microgrid systems propose the use of the entire roof of homes as a source of collecting solar radiation. Part of the energy is intended for heating water and the other to generate electricity. The presence of a wind turbine would result in all three systems functioning, which would result in a much higher production capacity for the consumer demand.

Even with the possibility of a surplus sale, certainly, the consumer should contemplate the possibility that at any contingency of the distribution system, their demands could be met through a stored portion of its energy generated.

The solar thermal energy would be stored taking into account the number of people who would use this energy as well as the minimum time solar radiation is needed to reach the desired temperature for water heating. It is prudent also to consider the situations where the level of sunlight would fall to a minimum, especially in winter, protruding compatible reservoirs and collectors with a strategic reserve of water for at least 3 days without sun.

According to reference [6], wind turbines have higher energy generation during the daytime. Photovoltaic generators only produce energy during the day, so, for both these types of renewable energy, it is important to implement systems for energy storage.

In fact, the nonpredictability of natural resources used to operate the generators shows an interesting issue. A solution is pointed out by using energy storage devices at times of low demand to regularize consumption in times of tip [20].

The combined operation of various renewable sources of energy being used in smart grids are presented in various sources of technical and scientific literature [21].

Energy sources such as solar and wind usually are used with a mandatory energy storage system, just to meet the demand in times where wind or sunlight are not offering the required energy [22]. Such systems have associated environmental impact since they use lead-acid battery banks [23].

Recent literature points out that this factor can be solved with the development of new energy storage technology, such as [24–28]:

- Clean batteries: are batteries that are based on the generation of energy from organic iterations.
- Fuel cells: use hydrogen electron exchange mechanism in isolated compartments.
- Compressed air: in times of low demand, generators utilize the surplus energy to power air compressor coupled to huge reservoirs, which then have the air released controllably driving a turbine system.
- Accumulators: devices such as supercapacitors may be used for accumulation and discharging of large amounts of energy.

5. Renewable energy systems integration in a smart grid

The integration of various renewable energy systems that can be implemented in the context of smart grids foments research involving a combination of tools. The justification for this research empowering is that, in the smart grid environment, a plethora of information about the system is available, providing an avalanche of data that must be properly addressed.

As mentioned before, at first, available information is not observable requiring the establishment of rules that relate the available informational entities. Some combination of tools gives rise to the so-called expert systems.

From a conceptual point of view, expert systems are those particularly distinguishable in their field, bringing together a multitude of techniques to analyze data and that have a high level of interoperability, and are robust and capable of providing efficient results even with data containing uncertainties.

When in operation, a large amount of information of all consumers would be available, such as billing, protection, losses, power quality, among others, since data communication is an essential part of the design of any smart grid.

Resolution 482 from ANEEL dictates only the maximum sizes of generators, leaving it free for consumer and distributors to define technical aspects used to integrate the mini- or microgenerating unit to the system. The equipment market being highly heterogeneous, it is evident that defined procedures and requirements need to be established to result in customer satisfaction and quality service from the distributor.

Considering the alternative sources of power generation various equipment are recommended, namely, frequency inverters, which are needed to ensure correct levels of voltage and frequency for generators operation in the distribution network and energy storage. As already discussed, the most usual storage method used in micro- and minigeneration are made by banks of batteries, formed by associations of lead-acid batteries packed in compartments with monitored temperature and gas emissions.

Notably known for large harmonic content they produce, the inverters can be configured as technological villains, reversing clean energy gains, since these devices were polluting the network with waveforms not purely sinusoidal.

In addition to these, various technological challenges for the integration of distributed generation systems in the context of smart grids are mentioned below:

- Power injection: The entry of the generators must be synchronized on the network to not cause instability problems.
- Protection: Making sure that the generators will not contribute any system failures, such as food shortages.

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