Future Nano-grid technologies and its implementation challenges for Smart Cities

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Abstract. Many technologies have been and are being implemented to make the microgrid model successful in many cities. It is incapable of reaching the scale as predicted because of several obstacles. Smart Nano-grid will cover these lacunae and requirements. The paper illustrates the value of nano-grids in the launch of smart cities by examining the progress of nano and microgrids, alternative energy storage technologies, energy applications, smart gadgets in smart cities. The survey also addressed the implementation challenges associated with a technical and economical point of view. This will provide a wider vision for the researchers to focus on the monitoring and control of nano-grid technologies.

Keywords: Nano grid, Smart grid, Smart Cities, Micro grid, Renewable Energy Sources

1. Introduction

The Smart Grid concept has emerged as the building bridge of the conventional power system to the transformation of the restructured power system. While transforming into the latest technology, many new challenges arose during the implementation of the Smart Grid. Some of the challenges include: protocols, demand-side management, security and the self-control of the overall systems. Some solutions have also been discussed in[1] to address these challenges as follows:

a. Introduction of ultra-low - power wireless sensor networks connected with Smart Buildings to integrate improved safety and security into the overall network.

b. Implementation of the central system to gather all data from the sensors in order to monitor the total network.

c. Introduction of PLC (Power Line Communication) coping with grid convergence security problems that have exploded around the globe in recent days.

d. Implementation of multiple wireless protocols in smart grid systems such as OneNet, ZigBee, etc. for handling real-time operations.

The standard grid has a one-way power flow,[2] which struggles with smart grid energy control while implemented with a bi-directional power flow. This also reflects on some of the problems of turning the traditional infrastructure into a smart grid. This also launched some of the smart devices such as AMI (Advances Metering Infrastructure) that facilitate smarter traditional meters. This provides the customer with an electronic billing system dependent on the use of electricity. This is generating interest among customers about the energy management system. The need to link this AMI to smart appliances is HAN (Home Area Network) or LAN (Local Area Network). HAN can link all appliances, vehicles and storage devices in both domestic and commercial regions [3]. Some modelling strategies are expected to resolve the challenges during the deployment of Smart Appliances on the grid. Behaviour in demand-side control and a variety in optimization approaches reviewed in[4]. The actual communication between customers and the central power provider must
specifically determine the control of the demand side. DR (Demand Response) allows for the realistic application of Smart Grids.

The growing Sustainable Power Network has launched the Distributed Generations (DG) network to link renewable energy sources to traditional transmission lines, which will be another breakthrough for last-mile connectivity [5]. Several energy storage options have been developed, such as flywheels, fuel cells, supercapacitors, hydrogen storage, etc., to be combined with the Distributed Generations (DG) for efficient and safe usage of power [6]. PCC (Point of Specific Coupling) links the current grid to the Microgrid, which works with the aid of renewable energy sources such as sun, wind, biomass, etc. If in the case of Solar, Wind, it depends on time for the efficient generation. To overcome these time-dependent sources, modern energy storages give hand to achieve the overall microgrid system stability [7]. Many security issues arise when MG and SG implementation which includes privacy problems, power theft, consumer safety problems. To avoid those highlighted security issues, the overall protection system has to be developed.

The bi-directional operation of the Microgrid creates curiosity among the researchers to do more research in the areas of power converters, smart gadgets, smart communication systems, smart security systems, SCADA (Supervisory Control and Data Acquisitions) systems, etc. In the paper [8], Researchers introduced a new term called Nano grids. It discussed the overview of Nano grid with its definitions and comparison with Microgrid as follows:

a. Definition: The collection of Nano grids forms the microgrid.

b. Advantage: Nano grids opt for small business investors

c. Application: Microgrids confined to some covered areas but this Nano grid ultimately confined to a single home distribution system.

[9] discussed the hybrid system of Nano grids that includes energy storage, solar PV, wind turbines, etc. The behavior of the Controller that is used in Nano grids technology and different converters under many environmental conditions that ensures the efficient operation also discussed [10]. Though the Microgrid operates only in DC; the Nano grid operates in both AC and DC which is an added advantage. The conversion process of DC to the AC Nano grid achieved with the help of a dual-source converter. When the bidirectional grid operates in DC/AC protection issues also arise. [11] Focuses on the protection against line fault and the ground fault which leads to damage to the overall system and more advanced are discussed in [12].

2. Importance of Implementing Nano-grid to Smart Cities

Many definitions and characteristics were reviewed about the Smart City concept in [13]. The importance of Information and Communication Technology towards the up-gradation of the electrical grid and to transform the citizen from consumer to prosumer will be the ultimate aim of Smart Cities [14], [12]. The load chart presented in [13] based on the average demand, peak demand, off-peak demand that gives the maximum power of the area at particular time duration. [14] Compared the different load profiles of different sectors at different duration. For example, during working days, the load profiles of industries and commercial buildings may differ when compared with holiday load profiles. This paper concluded with the case study of real-time data collected from schools, banks, houses, lighting, restaurants, etc. So that whole scale buying of electricity from the power market can be avoided. The maximum demand for each area varies; accordingly, we can buy electricity. The collection of consumer’s data ensures the equality of living which satisfies one of the main aspects of the Smart City concept.

The objective of a Smart city is to effectively utilize science and technology towards the environment resources to achieve smart infrastructure. This includes waste management, secured systems, health care, transportation, e-governance, etc. [15] In order to make the citizens more responsible and to
create a sustainable environment, Smart Power is necessary to implement in Smart Cities. Some of the importance of implementing Nano grid to Smart Cities listed out here:

(a) The conventional grid fails to meet the power demand of the city which results in black-outs and brown-outs nowadays. So, to supply power continuously smart power generation, transmission and distribution is needed.
(b) To optimize the power consumption of the Smart City, data usage of individual or commercial is collected automatically to the cloud which creates the citizen more responsible towards energy management and can control his/her power consumption by themselves.
(c) It also encourages the modern renewable energy sources that integrate with or without a grid. The standalone grid with modern energy storage becomes a new user-friendly technology.
(d) Predictive control of excessive power usage and wasteful energy helps the consumer to save energy and can be retrieved for future purposes.
(e) By implementing this Nano grid technology to every home, an automatic bill can be calculated for the exact usage of power. So manual labour can be replaced with Smart meters which makes even more efficient and reliable system.
(f) Last-mile connectivity of rural areas motive can be achieved easily with the help of this Nano grid technology combined with Smart Cities.
(g) The financial benefits of prosumer can be developed by either selling or sharing the excess power to the central grid or the individual consumer at a fixed cost.

3. Implementation Challenges of Nano grid

Figure 1 show the Nano grid infrastructure towards Smart Cities consists of generation part which can either be done through renewable energy sources or energy storage systems and Nano grid controllers which connects more than a single Nano grid generation and distribution. This would be different from the conventional buildings today because the power flow of grid in a traditional building is a single way whereas a Nano grid has dual way power flow. The effective regulation of demand and production can be done through power converters.

![Nano grid Infrastructure](image)

**Figure 1:** Nano grid Infrastructure

The overall controller for the Nano grid interacts with all the converters, loads, and grid that can be connected to the individual nano grid. It consists of cutting edge technology that can decide how to
equalize nano-grid generation and load profile of different sectors, also undergo load shedding as required and organize energy transfers between the utility grid and the nano grid. The controller can also serve as a CPU that collects and records dual way power flow data also from the individual to the grid and vice versa. Many modern retailers have already designed the controllers with data recording, data collecting, and automatic switching on and off of the household appliances like televisions, laptops, micro ovens, washing machines, electric stoves, etc. when needed. These Nano grids of homes 1, 2, 3, and so on of particular areas are connected to the microgrid, and this microgrid again connected to the centralized grid. So that data of individuals of the particular area can be collected from the grid is stored in the cloud. The prosumer can view the data at any time and also can retrieve the data which includes electricity billing process, demand forecasting, and prediction of future energy management. From the above description, the challenges can be derived from the working of Nano grid and classified into two categories: Hardware Challenges and Software Challenges

3.1 Hardware Challenges

Some of the hardware challenges associated with the nano grid while implementations to Smart cities are listed here:

(a) Infrastructure Challenges: The transformation of the existing grid to be smart in the particular view of infrastructure is still difficult. Both in the case of grid infrastructure as well as living area infrastructure, many challenges arose in operation, design, and maintenance aspects. Smart buildings that include the automation of smart appliances connected inside the buildings should be in the dual direction. Grid infrastructure should interact with smart buildings for data collection.

(b) Generation Challenges: Prosumers can generate power at a distribution level with the help of alternative sources like solar panels and wind turbines. The challenges here are that the location of alternative source power generation should near to the consumer so that transmission losses can be eliminated. To avoid the time-dependent alternative sources, energy storage devices like a battery, fuel cells, supercapacitors, etc. are the mandatory things to install. To couple the local power generation to the grid, PCC (Point of Common Coupling) is required and it also helps in deciding the nano grid to operate in islanded mode or grid-connected mode.

(c) Converters design Challenges: Nano grid can operate both in DC and AC. Many power converter devices used in the nano grid based on the different types of appliances. Due to the switching components present in the converter leads to losses, to overcome these losses, reactive components should be included. So that fluctuation due to sudden increase in DC/AC can be controlled easily. In some other aspects, renewable energy-based power generation needs MPPT converters for higher efficiency and it also uses a charge controller for controlling the charging/discharging process of energy storage devices. Grid-connected nano grid takes AC from the grid and injecting DC to the grid. Therefore, designing of a bi-directional converter with multi-port topologies with the efficient operation is the major challenge here.

(d) Automation Challenges: Some of the Smart Gadgets like faucet timer for water management in garden areas, bathrooms, washrooms, etc. Vue is a device that can be installed inside the circuit breakers so that the energy monitoring of the entire house can be monitored. Temperature control smart lights connected to LAN have the feature of an automatic turn on/off depends on the situation. Speed control smart fans work according to the climatic conditions. These smart gadgets ensure the collection of power usage data easily but still the challenging task for the manufactures to offer at affordable price.

| Table 1. Smart Gadgets Price list. |
|---|---|
| Price | Features |

4
3.2. Software Challenges

Some of the software challenges associated with the nano grid while implementations to Smart cities are listed here:

(a) Nano grid Controller: This controller can interface communication between the smart appliances, generation, and energy storage device inside the home and also acts as a communication interface to the grid. This dual way communication uses protocols like Modbus, RS485, etc. so that it can control the internal devices based on the information received from the utility grid or vice versa. The bi-directional converter (DC-DC) should connect with the intelligent controller for the efficient and smart working of all the appliances according to the diverse power demand.

(b) Microgrid Controller: All the Nano grid controller of the particular area is connected to the microgrid controller. By connecting LANs, voltage regulation of the DC bus can be done in a bidirectional converter (DC-DC). This controller decides the power-sharing/selling to the central grid based on the collection of data from the nano grid controller, accordingly the converter decides its operation whether to work in voltage regulation mode or current regulation mode.

(c) Power Management: Most challenging task of Nano grid implementation is creating software for power management. Many approaches from different countries researchers were proposed and working still to get efficient software for the communication between the cloud and microgrid controller. The software should work with/without a manual assistant and have the responsibility of managing power. The supply of power depends on the information receiving from the controller. For example, if the battery bank of the nano grid gets fully depleted, it will give the notification to the controller. The controller passes this message to the cloud and acts accordingly. Smart power flow of the nano grid mainly depends on this power management software

(d) Mobile Application: Different software at different levels of the nano grid has proposed till now, these should ultimately connect to the Mobile App which brings the completion of Smart power objective. The prosumer can purchase/sell the power according to the existing/future demand that can be decided only through this Mobile Application platform. The user-friendly software can also be used for bill payments/settlements either to or from the central grid, predicting the demand through forecasting and can also manage the usage of power. If any power theft or security issues occur can also be identified prior with the help of Mobile App notification.
4. Government Policies on Smart Cities

The Government of India has been taking many steps to promote Smart Power for Smart Cities in recent days. Here are some of the focussed news about smart power infrastructure and a sustainable environment.

(a) In budget 2020, the central ministries confirmed the conversion of all electricity meters of our country to smart meters within the next 3 years, so that consumers can easily choose the service providers and make bill payments

(b) Under the National Electricity Mobility Programme, over 1500 e-cars have been under registration and it ensures the 68 public charging stations will locate in main bodies like Hyderabad, Chennai, Jaipur, Ahmedabad, etc.

(c) Tamil Nadu Energy Development Agency (TEDA) undergoing the solar street light project for rural areas and encouraging the installation of Rooftop solar by giving subsidies.

(d) In India 2020 – Energy Policy, some highlighted key points are listed out here:
- Encouraging Entrepreneurship and more job creation in the agricultural sector by implementing new technologies like smart irrigation, climate-dependent agriculture, waste management, etc.
- The priority of Energy policy 2020 is given to energy security with the increasing improvement of renewable energies in global supply contributions.
- A new scheme called FAME (Faster Adoption and Manufacturing of Electric Vehicles) was introduced to promote the EV’s usage.
- IEA expects the energy demand of India will be doubled as present in 2040, so it is necessary to focus on the energy available and energy storage for the future generation
- The Smart Cities Mission aims to include even more 100 cities across the country with reducing energy, enhanced infrastructure, etc.
- It also aims for replacing energy-efficient street lights and pumps for achieving sustainable energy with zero carbon emissions.

5. Conclusion

The paper explored the concept of nano grids and differences between smart grids and nano grids. It also guarantees the importance of Nano grids for the deployment of Smart Cities. This identifies the hardware and software problems associated with the integration of nano grids with smart cities. A lengthy period must take place in order to turn the conventional grid into a smart one with its powerful control systems. Nevertheless, if efficiently introduced, the two-way connectivity of the Nano-Cloud grid provides diverse control and renders all people accountable. It also highlighted that the State and the Central Government are proposing a range of policies and projects to make our country better off with renewable and reliable energy in the future. Future work will focus on overcoming some of the hardware and software problems in the design of smart power converters and controllers.

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