Renewable and Sustainable Energy Reviews 91 (2018) 90–108

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Future effectual role of energy delivery: A comprehensive review of Internet of Things and smart grid

S. Sofana Reka[a,*], Tomislav Dragicevic[b]

[a] School of Electronics Engineering, VIT University, Chennai Campus, Tamil Nadu, India
[b] Department of Energy Technology, Aalborg University, Aalborg East 9220, Denmark

ARTICLE INFO

Keywords:
Internet of Things
Smart grid
Smart buildings
Smart meters

ABSTRACT

In today's ecosystem of energy management, the contribution of Internet of Things (IoT) to smart grids has acquired immense potential due to its multi-faceted advantages in various fields. IoT paves a way to associate and virtually control everything in almost every domain of society. Conversely, the smart grid framework attracted the attention of the universal research community and the idea of merging IoT with smart grid together demonstrates enormous growth potential. This review paper highlights the most significant research works that focus on applying IoT to smart grids. This work also addresses many innovative approaches used in IoT and smart grids along with their respective applications in various fields. The objective of this work is to benefit scientists and new entrants in the field of IoT and smart grids opens up awareness for new interdisciplinary research.

1. Introduction

The number of online capable devices increased to 8.4 billion in 2017, and it is estimated that it will consist of about 30 billion objects by 2020. These devices include physical items, vehicles, home appliances and other objects that are embedded with electronics, software, sensors, actuators, and characterized by its connectivity to internet. Internet of Things (IoT) is a network of such devices through which they can exchange data and command. In the context of smart grid, IoT is at the pinnacle of its expansion stage as it offers a promising future with smart analytics. Energy based analytics data provided from the user to utility could potentially significantly enhance the efficiency and reduce congestions in the smart grid, thus contributing to the improvement power supply reliability in the future 100% renewable energy scenario. Globally, the path of a smart grid offers far reaching parallels in the evolution to smart cities and progress towards IoT. Information and communications technologies has transformed user's lives dramatically in all ventures since the past decade where the utility providers face a diverse challenge in achieving better customer relationships. This rapid transition of IoT with smart grid in the future guarantees benchmark for user utility communication in a more proactive way.

The transformation of the legacy electric power grid into an intelligent, self-healing bidirectional intelligent system had paved the way to the smart grid for the future [1] where a new intelligent grid alters the footprint of its earlier incorporation. Using this advanced technology, utility providers are more involved in conveying efficient power, reducing Co2 emissions, bringing in green energy, reducing costs with maximizing utility profit. The utilization of smart meters in residential, commercial and industrial buildings allows the utility provider in gaining knowledge on a daily basis to their consumption pattern. Information of data from far off substations or identifying failures in scheduled areas enables effective remedial actions quickly without any delay.

Smart meters enable users to interact with the utilities and wirelessly monitor their power consumption on an hourly basis and this assists them in fulfilling the goal of reducing the electricity bills. The adverse need of smart meters at every residential homes and transfer of information brings in the need of IoT for proper understanding of the appliances schedule. Thereby the users are able to analyze and monitor per day energy consumption pattern and schedule the energy usage on day to day basis as well as hour to hour basis even with a mobile application. This smart grid IoT enabled venture brings in a root cause for smart cities mission worldwide. In addition, as in for smart lighting solutions, solving multiple use cases like parking and traffic monitoring by wireless connections are made possible [2].

Smart grid set-up requires continuous devices monitoring, examining and completely controlling the overall grid where these massive amount and their differing types of monitoring devices are deployed at many power plants, transmission junctions, distribution areas

* Corresponding author.
E-mail address: chocos.sofana@gmail.com (S.S. Reka).

https://doi.org/10.1016/j.rser.2018.03.089
Received 14 June 2017; Received in revised form 18 March 2018; Accepted 30 March 2018

and finally at the users side [5]. In this, the utmost concern for smart grid is connecting the devices, controlling them at high speeds and finally monitoring in a continuous fashion. This requires automation control of smart grid for all these devices or in more specific terms as things. At this juncture, IoT technology solves the real world problem of smart grid dynamically serving the purpose in a logical and congruent way. The Internet had been used only for connectivity between people to people but with the changing times the interface has shifted from people to things or devices. According to survey by 2009 [4] the connection between machines to people was moving faster than people to people thereby the collision of Internet of Things keeps proliferating at an accelerated pace. IoT is shortly defined as grouping of physical things which are broadly connected through the internet [2,3]. The devices or things are well developed with embedded processor or systems which can easily interact with different environments among them. These devices or things have the ability to interact with other things, as well as to control, monitor and sense them in the form of two way processes with new communication technologies operating very high speed. In order to rein in a smarter accurate dynamic smart grid, IoT technology is the best solution for connecting billions of devices in the grid. The energy market is the biggest market globally for any country to move economically and so smart grid is one of the biggest applications of IoT. At the present situation, multiple devices using energy surpass the number of machines or devices driven by the internet. All these advanced devices which require more electricity may also need internet for making them smart and efficient. In the future, smart grid cannot be achieved efficiently without the commitment and compatibility of IoT technology.

The prospects of IoT and IoT enabled smart grid are limitless with the possibilities of virtually connecting all the utility providers to the consumers and where communication is more prompt. This complete interface and interconnectivity eases the processes improving the productivity on a larger scale. The interconnectivity through communication such as mobile phones is possible with swift decision- making through social collaboration comprising IoT reducing application TCO (Total cost of ownership). There are many benefits of the cloud at the financial outlook that becomes apparent where the TCO of a particular solution is met from its purchase, considering the outcomes of both the service and operating expenses. Most companies put little effort to solely improve the errors and promptly offers service to an application on a complete cycle. In contrary, when the companies for their requirements, get a workplace software from the cloud, there is a possibility of obtaining these services at a fixed price for the entire contract period without due consideration of any hidden costs [3]. In the past when a transformer failed due to poor supply there was no communication between the user and utility provider. This wide gap is completely reduced for when the transformer is overheated, the utility providers are informed much earlier. The data from the smart meters and sensors receive complete information to the utility helping them to generate a compressive work order and the nearest service to be provided. In present era of IoT and smart grid junction, when the electricity go out, a notification by the sensor on the power line is sent instantly to the utility providers where the transformer action can be monitored. This instant action and communication between the two parties is accomplished more smoothly leading to an efficient wireless system by IoT.

Fig. 1 highlights the use of IoT in power Systems. The figure shows that IoT is mostly used in the distribution and consumption power sector.

Fig. 2 gives an explanation of the power flow. It shows the step by step process of how power is developed and how the usage of IoT is important in smart grids. IoT in smart grids is important for its as immediate informing the power system operation and control center when there is a failure in transformers or accident in any other electrical equipment. IoT also helps us where the power consumption is more and there is a need to save power since everything is monitored on minute by minute basis in the data room. This results in effective power saving and enhanced power quality which is more efficient on a proactive scheduling with more use of IoT in smart grids.

IoT can be broadly classified into: (i) Using Internet technologies, interconnection of all the smart objects (ii) Along with internet services, a group of supporting technologies are required to realize the perception like radio frequency identification (RFIDs), sensor/actuators, machine-to-machine communication devices, etc. and (iii) the ensemble of applications and services leveraging such technologies to open new business and market opportunities [4]. The concept of using three different networks like Home area network (HAN), Wide area network

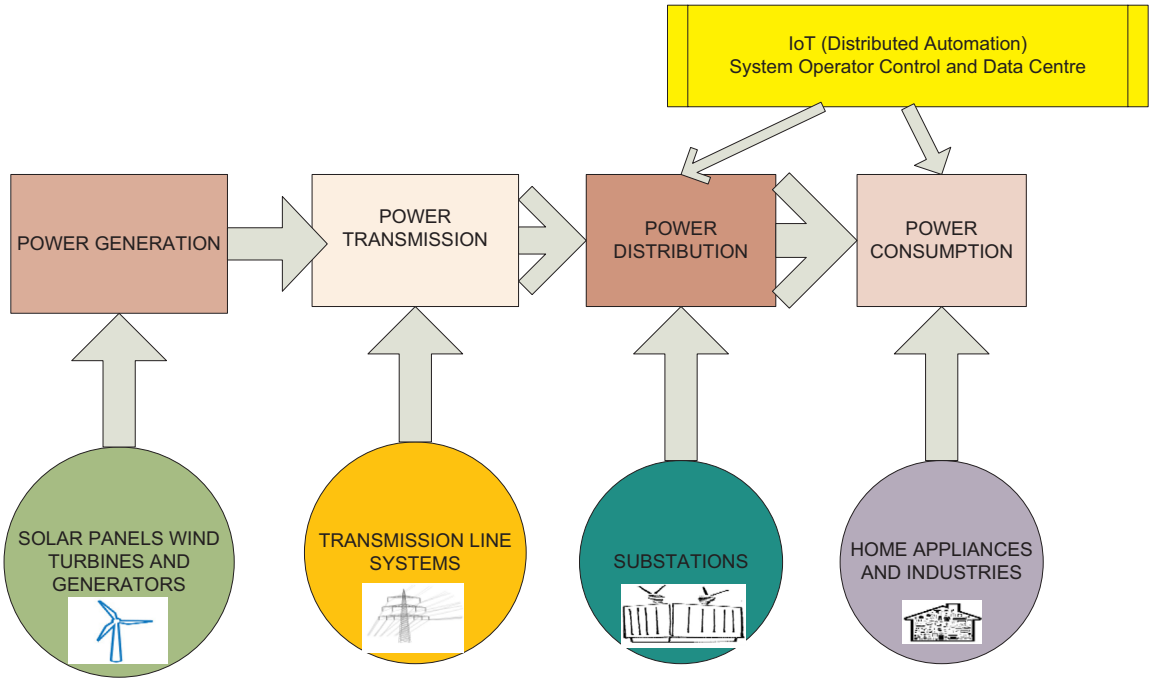

Fig. 1. Usage of IoT in power systems.