Implementing an energy harvesting technology within the concept of Smart city

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Abstract. Smart city is a global goal of big cities, it is an emerging concept, which requires different research activities in many different directions to create an urban infrastructure and, what is even more important, transform minds. The topic of energetics is one of the baseline directions for creating Smart city infrastructure. The concept of energy harvesting becomes in this term quite important and deserves specific attention. This research paper is aiming to highlight an energy harvesting problem in the context of smart city and to make an attempt to propose a potential solution, a technology to be implemented to tackle that problem.

Introduction

The concept of Smart city is connected with the development of cities more suitable for life. The concept includes such components as smart transport, smart mobility, smart environment, smart energy, smart security and so on. There are examples of cities that have already embarked on the development of this concept [1]. A smart city can be defined as an “urban labelling” phenomenon, particularly in terms of what the label ideologically reveals as well as hides. The label smart city is a fuzzy concept and is used in ways that are not always consistent. There is neither a single template of framing smart city nor a one-size-fits-all definition of smart city. This section seeks to dismantle “the diversifying terrain of smart cities” [2].

A smart city seeks to optimize its resources, monitor security aspects, maximizing services for its citizens.

For an intelligent city, innovations are not a goal, but a means. At the same time, for the successful development of the concept of a smart city, integration of various technologies and systems is required [1].

There are interesting projects that correspond to the concept of a smart city. For example, the distribution of energy consumption with the stimulation of the evening peak, which saves energy [3]. At the same time, automated grids that employ ICT to deliver energy and enable information exchange between providers and users, with the aim of reducing costs and increasing reliability and transparency of energy supply systems are used.

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In the field of public lighting, natural resources, and water management renewable resources such as heat, solar, cooling, water, and wind power are used. In the field of waste management applying innovations in order to effectively manage the waste generated by people, businesses, and city services are used. It includes waste collection, disposal, recycling, and recovery. In environment area the technology to protect and better manage environmental resources and related infrastructure, with the ultimate goal of increasing sustainability is applied. It includes pollution control. In the field of transport, mobility and logistics, the optimization of logistics and transport in urban areas is used, taking into account the conditions of traffic and energy consumption. This gives users dynamic and multimodal information for traffic and transport efficiency, which allows to assure sustainable public transportation by means of environmental-friendly fuels and innovative propulsion systems are applied. In the field of office and residential buildings adopting sustainable building technologies to create living and working environments with reduced resources, adapting or retrofitting existing structures to gain energy and water efficiency are used [4].

Literature Review

In connection with the foregoing, the development of new ways of efficient energy use and the search for additional sources of energy is a very urgent task. In addition, the concept of a smart city certainly implies a creative approach to its construction.

In general, many studies are devoted to the problem of the use of renewable energy sources, taking into account the requirements of environmental sustainability and energy security. These studies consider such points as new sources of energy, rational use of energy, reducing energy costs, designing buildings with high energy efficiency, the use of electric vehicles, the use of photovoltaic panels [5], the Smart Grid system, and the promotion of cogeneration. Attention is given to modelling loads, varying loads depending on weather conditions, continuity of power supply, reliability and safety in emergency situations [6].

At present, electric power systems in most countries are modernized and developed on the basis of the concept of deep integration of electrical networks and networks of computer or info communication networks [7]. This concept was called Smart Grid [8]. Smart grid introduced the concept of "information flow". It is designed to integrate information flow and energy flow, providing both data collection and energy transfer. Thus, electricity generation and operation can be optimized in real time, the demand for electricity can be accurately predicted, electricity consumption patterns can be accurately detected, and dynamic pricing mechanisms can be effectively developed. Based on the Big Data analyst, the intelligent network can quickly detect and recover from disruptions, respond quickly to demand for electricity, provide more reliable and economical energy and allow customers to more control the use of energy. Big Data analytics can provide efficient and effective decision support for all manufacturers, operators, customers and regulators in intelligent networks. Big data change the way of energy production and the structure of energy consumption. Currently, an approach called "virtual power plant" (VPP) has appeared. It is a technology associated with an intelligent network that consists in coordinating the management of electricity consumption in a large number of homes and offices, partially shutting down and including consumers in accordance with the needs for energy consumption, in order to synchronize consumption with the growth or decline of many renewable power plants sources. Using intelligent analytics, behavioural algorithms and a physics-based understanding of the network, the system allows enterprises to see and manage the distribution of power and flow across the entire service area in real time [9].

At the same time, world marketed energy consumption is projected to increase by 44% from 2006 to 2030. The EIA (US Energy Information Administration) expects that energy demand from emerging economies — such as the BRIC countries will increase by 73%

during this time frame, far outpacing the 15% increase from developed economies. Large urban populations are a major driver of this trend, and cities often struggle to adequately meet demand due to a lack of supply as well as inefficient transmission and distribution systems to the end customer. Price increases and instability are regular occurrences and are caused by:

- 1) high capital costs to develop new-generation capabilities;
- 2) mandates for more sources of renewable forms of energy — which are often more costly; and
- 3) the tendency for nations to import energy, oil in particular [10].

The consumption of fossil fuels has an adverse effect on the environment, such as, for example, global warming and increased greenhouse gas emissions, resulting in increased health risks and the threat of global climate change [11]. In addition, increasing fossil fuel consumption to meet current energy leads to an energy crisis and increases the interest in promoting alternative options in the form of renewable and clean energy sources.

In this regard, the search for new renewable energy sources, especially for the BRIC countries, is a very important task.

At present, such sources as wind, solar, wave power, geothermal energy, hydrogen from biomass, low value heat sources to utilise new sources of flexibility such as solid, gaseous, and liquid fuel storage, thermal storage and heat pumps and battery electric vehicles. Smart Energy Systems also enable a more sustainable and feasible use of bioenergy than the current types allow [12]. Renewable energy technologies provide an excellent opportunity to mitigate greenhouse gas emissions and reduce global warming. The main forms of renewable energy use are as follows:

- Hydropower - Power generation
- Modern biomass - Heat and power generation, pyrolysis, gasification, digestion
- Geothermal - Urban heating, power generation, hydrothermal, hot dry rock
- Solar - Solar home system, solar dryers, solar cookers
- Direct solar - Photovoltaic, thermal power generation, water heaters
- Wind - Power generation, wind generators, windmills, water pumps
- Wave - Numerous designs
- Tidal - Barrage, tidal stream

As a result, major renewable energy gadgets for domestic and industrial applications such as solar water heaters, solar cookers, dryers, wind energy, biogas technology, biomass gasifiers, improved cookstoves and biodiesel are used [13].

For example, solar energy is used in many areas of electronics, stationary applications, telephone exchanges, emergency telephones at highway, repeater stations, refrigeration for vaccine and medicines in the hospitals, photovoltaic lamps, battery chargers, garden lights, solar heaters in winters, solar cooling units for the buildings, steam generator, etc.

Interesting studies have also been conducted using piezoelectric materials. Piezoelectric materials have high energy conversion ability from mechanical vibration. Representative piezoelectric materials can be categorized into piezoceramics and piezopolymers. Energy harvesting is defined as capturing minute amounts of energy from one or more of the surrounding energy sources, accumulating them and storing them for later use. Micro energy harvesting technology is based on mechanical vibration, mechanical stress and strain, thermal energy from furnace, heaters and friction sources, sun light or room light, human body, chemical or biological sources [14]. The piezoelectric material converts mechanical vibration into electrical energy. Piezoelectricity is a property of such crystalline materials as quartz, Rochelle salt, tourmaline, and barium titanite, which are capable of producing electricity when applying pressure. There are solutions that offer piezoelectric film inserts in shoes that are active when walking, a backpack for collecting energy, generating energy between the trunk and backpack. Ceramic based piezoelectric fiber composite structures (PFCs) and

polymer based piezoelectric strips, PVDF (polyvinylidene fluoride) allow to receive energy from wind speed and water droplets for use in low power electronic devices. The power depends on the material dimensions, drop mass, releasing height of the drops and wind speed.

Methodology

To carry out the research described in this article, a team was assembled consisting of Project Manager, Engineers, Logistics, IT specialists, Designers. The team was tasked to formulate a proposal for improving energy efficiency, applicable to operation in the city of St. Petersburg. The team analysed current trends and proposals in this area, including focusing on the use of renewable energy sources. Attention was drawn to the project, applied in the Olympic Park of London. There was used a special paving slab, which actually produces electricity from footsteps. Such a tile laid out a section of the sidewalk. According to the manufacturer, during the summer Olympics on this site, more than 10 million times passed, and the generated energy was enough for daily lighting of the entire track within 8 hours. This pavement was only used during the Olympics, and in a large city, the use of such technology could become even more effective. As a result, the team focused on the adaptation of this project to the operating conditions in St. Petersburg.

Results

The idea of innovative solution, which is represented in this research stands for the way of how we can implement an existing technology in new shape and bring it into the urban life of big city. The technology, which was picked up for our investigation is piezoelectricity, which appears to be a potentially promising solution for solving the problem of energy in Smart City. The piezoelectric effect is the ability of certain materials to generate an electric charge in response to applied mechanical stress. There are the centres of symmetry for positive and negative charge in a piezoelectric crystal when it's structure is unstressed. Those centres are coincide. The charged ions bound in the crystal lattice. But when the Crystal is stressed or lengthened, the centres of symmetries disperse producing electricity. The key idea is to bring this technology into everyday life of people. The piezoelectric tile can be used as a kind of surface for the city areas. In this case the electricity, produced by the piezoelectric element under the steps will be accumulated in the generators under the surface, which will let it into the city. Analysing the potential stakeholders of this project, we can name quite a few of them. The production enterprises may cut costs by using the new type of source of energy (being stakeholders of this project and investing in it, this energy might be supplied to them and partly or totally replace the traditional). The municipality can reduce costs for lighting up the city (electricity counts about 3% of City costs). The transport companies can reduce costs by using this energy for lighting up the bus stops and for using this energy partly for the electric vehicles (trams and electric buses). The Subway company can use this electricity for lighting up the stations.

The following steps should be taken to implement the project:

- 1) Adaptation of technologies for use in the conditions of St. Petersburg, including taking into account climate and cleaning technologies
- 2) Selection of a street with dense pedestrian activity for the implementation of a pilot project
- 3) Surface preparation, installation of storage devices, connection to the lighting system
- 4) Familiarizing the general public with the project
- 5) Analysis of results

The basic technology behind our idea is represented in the picture below:

Fig. 1. Basics of piezoelectricity technology

Conclusion

The problem of energy harvesting was analysed and discussed in scopes of the comprehensive Smart City concept. An overview of its importance for society was argued. An idea of piezoelectric technology for developing an energy harvesting system was presented. The proposed technology is based on piezoelectric tile to produce energy from human steps and the potential implementation issues were presented and discussed.

The use of renewable energy sources is one of the most urgent ways to solve the energy and environmental problems of large cities. These problems significantly affect the life of the population and require an immediate solution.

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