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A Review-on Energy Harvesting and Energy Management for Sustainable Wireless Sensor Networks

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Abstract: Sustainable wireless sensor networks (WSNs) are being widely used nowadays due to two key driving technologies behind them i.e. energy harvesting and energy management. Energy harvesting from environmental energy sources such as solar, wind, thermal, mechanical and so forth are introduced from the perspective of energy supply to the WSN, while energy management of WSN such as the design of MAC protocol, design of routing protocol, and dynamic power management technology are presented from the perspective of energy conservation within the WSN itself. The suitability of super capacitors to expand the safe operating window of a wind-membrane system was examined in a systematic manner. The super capacitors were able to provide sufficient energy during periods of no wind (intermittency) and enhance the power quality delivered to the membrane by absorbing turbulent wind (fluctuations). Remote devices, such as sensors and communications devices, require continuously available power. In many applications, conventional approaches are too expensive, too large or unreliable.

Keywords: Wind turbine, power conversion, renewable energy, Wireless sensor network.

I. INTRODUCTION

In recent years, wireless sensor networks are widely used in many areas such as disaster management, infrastructure monitoring, security and surveillance, etc [1]. For these applications, the research works are mostly paying attention tothe realization of functions in the designing of wireless sensor networks rather than the sustainability issue of the network. The wireless sensor node always uses power-limited battery as its energy supply. However, there are a number of nodes in the wireless sensor networks and they are always distributed in extensively wide and complex environment, it becomes very difficult to change the battery of wireless sensor nodes on deployment [2]. In order to make wireless sensor networks more practical, researchers began to study the sustainability of the wireless sensor networks, namely, try to extend the life cycle of wireless sensor networks effectively [3]. Energy harvesting and energy management are two key technologies that enable a self-sustainable wireless sensor network.

There are many forms of renewable energy readily available in the environment at which the wireless sensor networks are deployed, such as solar energy, mechanical energy, thermal energy, sound energy, wind power and so on. In this paper, we conduct a review of wide varieties of energy harvesting technologies for wireless sensor networks. We mainly focus on how to transform various forms of energy existing in the environment into electrical energy that can be used to sustain the operations of the wireless sensors. Energy management technology is mainly to solve the problem of energy conservation in wireless sensor networks (WSNs) [4] [5]. Energy management usually includes optimization of medium access and routing protocols, dynamic power management etc. However, if solely relying on reducing energy consumption without energy supplement, it is very difficult to maintain long-term operation of a wireless sensor network. The objective of this paper is to explore on two key enabling technologies of a self-sustainable and self-autonomous wireless sensor network. Firstly, energy harvesting technologies for wireless sensor network, including solar, wind, sound, vibration, thermal, and electromagnetic are introduced. Secondly, energy management technology used in wireless distribution of energy content of wind turbulence is described by the Van der Hoven wind speed spectrum [6]. This shows a clear distinction between long term wind speed fluctuations caused by the passage of weather systems (synoptic variations) or time of day (diurnal) and shorter fluctuations caused by turbulence [6, 7].

There is a ‘spectral gap’ observed in the region between two hours and ten minutes where there is little energy between the synopticdiurnal region and the turbulent region. This gap is attributed to the lack of any physical process that could cause wind speed fluctuations in that range of frequency [6]. The turbulent region occurs over time periods ranging from 5 s up to 10 min with a peak at 1 min. Turbulence causes fluctuations in power that have a negative effect on the quality of power delivered by a wind turbine, therefore these short term fluctuations are considered to be the most significant for the implementation of energy storage in wind energy systems [8]. As already mentioned, several ESS may be used to cover the electricity demand problems of numerous remote islands of Aegean Archipelago in collaboration with the existing APS and RES-based power stations (mainly wind parks and photovoltaic generators).

For application purposes one should, for every ESS, define several operational parameters of every system, like the corresponding service period ‘‘nss’’, the maximum permitted depth of discharge ‘‘DODL’’ for long-term operation, the total (round-trip) energy efficiency ‘‘hss’’, the efficiency of the power output branch ‘‘hp’’, the initial cost ‘‘IC0’’, the annual maintenance and operation coefficient ‘‘m’’ and the power range in which every system can be utilized.

II. LITERATURE SURVEY

Z.G. Wan et. al [1], “Review on Energy Harvesting and Energy Management for Sustainable Wireless Sensor Networks.”In this paper, we provide a comprehensive review on some common energy harvesting technologies of wireless sensor networks, and the introduction of energy management technology. We demonstrate an example of sustainable wireless sensor networks based on solar energy which is for green building. The challenge to harvest environment energy is discussed.

Gavin L. Parka et. al [2] , “Renewable energy powered membrane technology: Super capacitors for buffering resource fluctuations in a wind-powered membrane system for brackish water desalination.” The suitability of super capacitors to expand the safe operating window of a wind-membrane system was examined in a systematic manner. The super capacitors were able to provide sufficient energy throughout periods of no wind (intermittency) and enhance the power feature delivered to the membrane by absorbing turbulent wind (fluctuations). As a result, system shut-down and compromised permeate quality due to reduced TMP were avoided. The use of super capacitors to provide constant power resulted in a 40 % increase in the average flux and 15 % increase in permeate quality under intermittent operation over one hour. The improvements in the average flux and permeate quality under fluctuating conditions due to increased power quality were 85 % and 40 %, respectively. While the SOC of the super capacitor bank was above the minimum threshold value of 27 %, the membrane system operated as under steady-state conditions regardless of the wind speed and power output from the wind turbine.

J.Kaldellis et. al [3],“Techno-economic comparison of energy storage systems for island autonomous electrical networks.” In the present study, an integrated methodology developed is able to estimate the electricity generation cost ascribed to the implementation of various RES-ESS configurations on the basis of minimum energy dependence on local thermal power stations. For this purpose, one should take into account the corresponding schemes’ sizing parameters as well as the electricity features of the network each time examined. In order to designate optimum combinations between the electricity network magnitude and the energy storage technologies, the proposed methodology is applied to four Aegean island-groups resulting from the variation in the rates of peak load demand and electricity consumption.

Raul Moraisa et. al [4] “wind and water flow as energy supply for small stationary data acquisition platforms.” In principle, the energy required to permanently operate the wireless data acquisition nodes and routers in a large sensor network can be obtained by harvesting energy sources present in the environment. Our multi-powered platform was designed for applications in precision agriculture, and focuses on solar and kinetic energy sources (wind and water in pipes). The system that we built proves that the three have sting methods suffice to supply a generic WDAP energy store. Even with low values of solar radiation, the combination of the three energy sources has supplied an energy of about 58 mAh, more than the 39mAh required by network routers. We have observed that the wind turbine is able to generate an important fraction of the harvested energy, in certain cases close to the needs of router nodes. Improving these generators may pay off in the future, particularly in applications where irrigation pipes are absent.

Jonathan W. Kimball et. al [5], “A system design approach for unattended solar energy harvesting supply This paper presented a new design approach for a power source for remote, unattended loads, such as sensors.” The new system, which harvests solar energy and stores it in lithium-type batteries or ultra capacitors, is appropriate for applications that require more energy than can be provided with primary batteries. An important contribution was a sizing program that considers climatic data, energy storage capacity, energy generation capacity, and system efficiency. For a desired level of availability, there is a Pareto curve that relates energy storage to energy generation. The designer may choose a point on the curve that satisfies cost, size, or other requirements .The sizing was based on watt-hours and watts, which can then be translated into solar panel area and energy storage device volume. The system will then be optimally sized, rather than being oversized for worst-case scenarios. An exemplary system topology was also shown. This topology achieves all of the goals of a remote power source: fault-tolerance, energy flow management, MPPT, and modularity. Several prototypes have been constructed.

III.METHOD

A. Compressed air energy storage (CAES).

The CAES cycle is a variation of a standard gas turbine generation cycle. Hence, in a compressed air energy storage system, Fig. 1, off-peak or excess power from RES-based applications is used to pressurize air into an appropriate air storage facility (e.g. underground cavern) via a compressor. During times of peak demand, the required amount of air to cover the consumers' load is released from the cavern and supplied to a gas turbine where expansion takes place. Electricity is then generated from the directly connected electric generator. Before being expanded, the amount of preheated air (in the recuperator) is sufficiently heated in the combustion chamber of the installation, Fig. 1. CAES, like PHS, demands favorable sites and geological formations suitable for underground storage. The storage media most commonly used are rock caverns, depleted gas fields, saline aquifers and salt caverns.

The benefit arising from the operation of a CAES system lies on the fact that the stages of compression and generation are separated from one another. Consequently, what seems to be as much as 60–70% of fuel consumption for the compressor to be driven in a typical gas turbine generation cycle is not the case for a CAES cycle. In conclusion, in a CAES system, the entire power of the gas turbine is available to the consumption, however important fuel consumption is necessary. In fact, during a charging/discharging cycle, approximately one kWh of generated electricity requires about 0.75 kWh of compression energy and 4500 kJ of fuel [16]. This required amount of fuel is the main subject of controversy over the unconditional acceptance of such systems. Due to the distinctive features given by the use of gas in a conventional CAES, the efficiency rate of the system can be expressed in different ways. Excluding the gas role and based only on the efficiency of expansion and compression, an overall electricity efficiency rate that can be directly compared to other storage technologies is around 70%.

It is important to consider that the viability of such systems is well dependent on the storage media. Assuming an already existing cavern is utilized, additional benefits concerning environmental impacts should also be appreciated. In terms of capacity range, if taking into consideration that the rated power of the existing CAES installations are higher than 100 MW, CAES is thought to be the only, up to now, reliable alternative option for PHS.

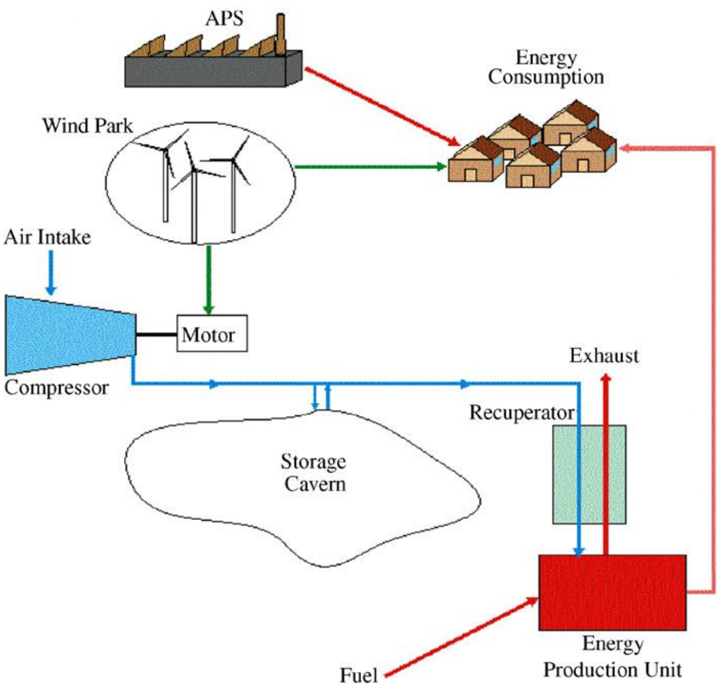

Fig. 1 Compressed air energy storage

B. Pumped hydro storage (PHS)

In a pumped hydro storage system, the energy surplus appearing in times of low demand and increased production (e.g. from existing wind parks or PV stations) is exploited to pump water into an elevated (upper) storage reservoir. Accordingly, during peak demand periods, water is released from the upper reservoir and the hydro turbines of the installation operate to ''feed'' the connected electrical generators. Thus, the system is able to cover the existing power deficit by using the appropriate amount of energy previously stored. Moreover, PHS systems are able of taking upload in a few seconds and are well defined by the high rates of extracted energy. The typical overall efficiency of such systems mostly ranges between 65% and 77% [13], while their maximum depth of discharge is up to 95% without affecting their considerable (up to 50 years) service period. Since the lack of suitable sites is a fact, the main drawback for the creation of a new PHS system is the high capital cost, directly related to the need for the creation of two reservoirs with a respectable elevation difference. Towards this direction, open sea [5] along with underground caverns [4] may also serve as lower reservoirs as well. The environmental impact caused during the construction works and operation on the surroundings is also a matter of concern [6]. Finally, in terms of specific investment cost, a larger project seems more attractive [17], hence installations of rated power less than 1 MW (Island Group-I) will not be analysed here.

IV. CONCLUSION

In this paper proposed a new approach for a power source for remote, unattended loads, such as sensors. The new system, which harvests solar energy and stores it in lithium-type batteries or ultra capacitors, is appropriate for applications that require more energy than can be provided with primary batteries. An important contribution was a sizing program that considers climatic data, energy storage capacity, energy generation capacity, and system efficiency.

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