Survey on Energy Harvesting in Smart Grid Networks

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***Abstract*—The recent development of internet of things devices and communication technology enhancement has been a driving force to the Smart Grid concept in recent power system deployments. The smart grid is capable of delivering power more reliably and efficiently and also respond to system changes and disturbances. Wireless sensor networks have been identified as the most promising technology in smart grid communication architectures. Though it is considered a promising method powering up the sensor node becoming a challenge due to the recharging changing of batteries. The paper explores the comprehensive characteristics of a smart grid followed by different energy harvesting techniques. The existing energy harvesting techniques are been discussed in two categories considering the sources of power. Then Wireless Power Transfer (WPT) and Simultaneous Wireless Information and Power Transfer (SWIPT) techniques which can use for energy harvesting concepts also have been explored. The paper then explored the related work which has been conducted for energy harvesting techniques and finally we explored future research direction considering cybersecurity issue with WPT/SWIPT and also incorporating WPT/SWIPT with the smart grid as an EH technique for sensor nodes.**

***Index Terms*—Smart Grid, Energy Harvesting, Wireless Communication, Wireless Power Transfer (WPT), Simultaneous Wireless Information and Power Transfer (SWIPT)**

I. Introduction

Renewable Energy Resources (RESs) for electricity generation has gained much attention throughout the world considering climate change and greenhouse gas emission due to fossil fuel combustion. Not only the environmental concerns but also the increasing demand for electricity with population growth also has become a key factor to countries to move towards RESs as an alternative source of energy. Though the RES are cable of overcoming the aforementioned issues the intermittent behavior of the generation, the broad level of distribution of the sources, and the lack of proper control mechanism to communicate with distribution are becoming challenges for a traditional grid to integrate the RESs [1]. The traditional grid with centralized control and passive communication between the power system operator and distributed components is not capable to facilitate a system with many distributed resources. Therefore the Smart Grid or Intelligent Grid concept has been introduced. A smart grid is an intelligent electricity network that combines the activities of all users linked to it and utilizes advanced information, control, and communications technology to conserve energy, lower costs, and improve efficiency and transparency. The smart grid communication architectures should provide the foundation for developing automated and intelligent management functions in power systems to ensure the reliable operation of the power system. WSN are small micro-electronic mechanical systems that capture and transmit data from their surroundings. Smart grid assets can be monitored and regulated using WSN. WSN has been identified as the most promising solution for smart grid applications for integration and operation of renewable energy sources or distributed energy sources [2]. This paper is organized as follows: Section II brings the evolution of the traditional grid to a smart grid and discusses the key functionalities of a smart grid. Section III provides a review of different Energy Harvesting (EH) techniques for WSN. Section IV presents a survey on WPT and SWIPT techniques in EH followed by Section V which describes the importance of EH in smart grid networks. In section VI the paper presents a review on related work for EH techniques. At last Section VII presents the conclusions and future research directions.

II. Introduction to Smart Grid

A. Traditional Grid to Smart Grid

The conventional power grid which has been developed over the past 70 years supply electrical power from large centralized generators which is connected to a transmission grid through a generation transformer [3]. This high voltage transmission network starting from transmission grid transmit the electricity to considerable distances and then supply to the consumers using series set of distribution transformers. The electricity system up to the transmission grid has good communication ensure its effective operation, to enable market transactions, to maintain the security of the system and to facilitate the integrated operation of the generators and the transmission circuits. Although the transmission network consists of a good communication link the distribution network which is feeding the load is entirely isolated except the load control and there is very little interaction with the power system.

The term Smart Grid (SG) with the recent revolution in the communication with the support of internet of things (IOT) facilitate the possibility of greater control and monitoring of entire power system. A SG allows energy utilities to monitor and control power generation, transmission and distribution processes in more efficient, flexible, reliable, sustainable, decentralized, secure and economic manners [4]. It is obvious that in order to have greater control and monitoring integrating the intelligent devices or smart measuring devices are the key elements of a SG. This smart measuring device will allow the ICT (Information communication Technologies) to revolutionise the conventional grid with the support of internet of things (IOT) devices.

B. Key Functionalities of a Smart Grid

The conventional grids are generally carry power from a few central generators to a large number of users or consumers. In contrast, the SG uses two-way communication of electricity and information to create an automated and distributed control and monitoring to ensure the efficient, flexible, reliable, sustainable, decentralized, secure operation in the power system. A comparison between the traditional power grid and smart is shown in Table I [1]. A SG which performs to satisfy the said functionalities consist following sub systems.

TABLE I
BRIEF COMPARISON BETWEEN TRADITIONAL GRID AND SMART GRID

Traditional Grid	**Smart Grid**
Electromechanical	Digital
One way communication	Two way communication
Centralized Generation	Distributed Generation
Few sensors	Sensors throughout
Manual Monitoring	Self Monitoring
Limited Control	Pervasive Control

- Smart infrastructure system: Smart energy, information and communication infrastructure system.
- Smart management system: Advanced control and management system of services and functionalities.
- Smart protection system: Gird reliability, fault protection and security enhancement.

III. Energy Harvesting

In WSN tight battery limitations of WSN nodes has become a critical factor due to the recharging or changing the batteries. Therefore harnessing the energy from ambient environment which defined as Energy Harvesting (EH) has been studied previously to overcome the power limitation in WSN nodes. EH is a technique that absorbs un-utilized light, kinetic, thermal, wireless, chemical, wind, acoustic, hybrid, and other renewable resources and transforms them into usable electrical energy capable of delivering power to wire- less sensors for sensing or actuating functions [5]. Although there are many sources available for EH it can be broadly categorized into two main categories considering the nature of the source: Ambient source and external source. The ambient sources means it is readily available in the ambient environment whereas external sources deployed explicitly in the environments for energy harvesting purposes. These two categories can be divided into different sub categories as shown in Fig. 1 [6]. Table III provides a comparison between list of EH techniques and the power density and conversion efficiency of each technique.

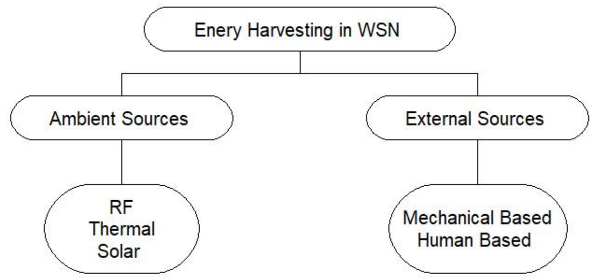

Fig. 1. Taxonomy of EH Techniques

A. Ambient Source

1) Radio Frequency-based energy harvesting: The RF energy can be scavenge which is essentially free energy from cell phone towers, TV broadcast stations, satellite and radar stations, WiFi routers and other communication networks. In simple terms RF EH means converting the received RF signals into electricity. In most of the applications RF based EH shows a significant advantage due its availability at any time or anywhere which will ensure the reliability and stability. The major drawback of RF based EH is amount of power that can be harvested as a result of the inverse square relation with the distance to the radiation source [7]. However due to the network congestion, number of users, terrain etc. the energy levels will vary. Therefore in order to scavenge the full level of energy in these ambient conditions specific hardware set up need be installed in the system including large broadband antennas with high gain, scalability and easy fabrication.

In RF energy harvesting, radio signals with frequency range from 300 GHz to as low as 3 kHz are used as a medium to carry energy in a form of electromagnetic radiation. RF energy transfer and harvesting is also can be considered one of the wireless energy transfer techniques [8]. As discussed in many researches the output power from RF is however very low of the order 1 μW/cm^2, [9]. In order to make RF as a potential EH sources wide band frequency ranges, automatic frequency tuning can be introduced where it will boost the output power.

2) Solar-based energy harvesting: environment as it is from the Sun. Solar energy can be harnessed with the help of a photovoltaic (PV) system that converts sunlight into electricity. Though it is available abundantly the limitation of solar energy harvester is generation power in night time. Therefore researchers have more focused into identify the methods to scavenge energy in maximum efficiency during day time to ensure the viability of solar power. The maximum power point trackers (MPPT) have been discussed widely studied. In MPPTs the supply conditions are tracked continuously and the corresponding load that maximizes the transferred power is determined form the I-V curve of a solar cell [10]. The output power of a solar EH system can vary from μW to MW range depending on the surface area of the solar system and amount of illumination received. The efficiency vary from the illumination level received and it is typically vary for 15% - 25% in outdoor environment and 2% - 10% in indoor environment. Therefore typically solar energy harvesting is suitable for outdoor environment than the indoor environment. The solar system typically use generate, store and utilize mechanism as shown in Fig.2. where the different type storage system are been discussed such as super- capacitors, batteries, or a combination of both [6].

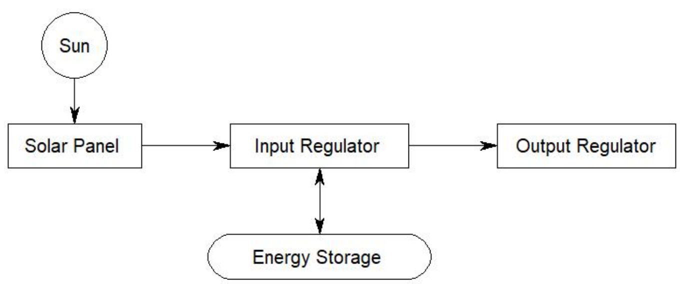

Fig. 2. Generalized Solar Systems

3) Thermal-based Energy Harvesting: Different temperature in ambient environment, systems or objects are creating opportunity harness the energy through heat transferring.Thermoelectric or pyroelectric effects can be used to harvest energy. Peltier effect, Seeback effect and Thomson effect which can be identified as thermoelectric effects has been introduced in researches which can generate power when a heat source is available [11]. When there is not much variation in temperature or the temperature variation is uniform Pyroelectric effect based thermal EH has to be used where spontaneous polarization in certain anisotropic solids due to a time- dependent temperature variation [12].

In order to extract the energy from a thermal source require a thermal gradient and conversion efficiency which depend on the temperature difference between cold hot side. When the difference it greater the power output also will be better. Though it is showing that the temperature difference will offer a better power output there is a limiting factor based on Carnot cycle therefore better design procedures had be followed.Although thermoelectric Energy Harvesters have reliable characteristics the low efficiency (5–6%) of thermal harvesting is a major burden for its widespread adoption. Recently, with the development of new thermoelectric materials and efficient modules, more than 10% efficiency has been achieved [13].

B. External Source

1) Mechanical based energy harvesting: There are numerous way which have been studied to convert Mechanical Energy to Electrical Energy. These techniques will harness the energy from vibrations, pressure and stress strain. They can be categorized into three main groups.

- Piezoelectric Technique - Generate electric potential under mechanical stress using piezoelectric material
- Electrostatic method - A vibration dependent variable capacitor. The vibration will charge the capacitor.
- Electromagnetic Method - A magnet attached to a spring inside a coil. Vibration of the magnet causes an induced voltage in the coil (Faraday's law of electromagnetic induction)

In the vibration EH technique the harvested energy depends on the resonant frequency of vibration which is not same for the different sources. Therefore designing a generalized vibration EH system which may suit any vibrating source becomes challenging. Several studies has been carried out to overcome this with different techniques in the literature [14]–[16]. As mentioned in [6] the harvested energy increases with device volume, i.e., for 100 cm^3 in volume, a device generates 10 mW, and a device with a volume less than 0.01 cm^3 can generate less than 10 mW.

2) Human based energy harvesting: Energy can be harvested in human body in many different ways such as movement of the body part, body heat or blood flow. Accordingly human based energy harvesting (HBEH) can be categorized into activity based harvesters and inherent physiological parameters based harvesters. All the EH techniques which are being discussed previously can be incorporate with HBEH where the miniaturizing the component is a challenge. HBEH gain a considerable attention in the research studies in health care as medical officer need to monitor there patient conditions continuously. Therefore Wireless Body Sensor Network (WBSN) has been introduced where HBEH is an essential element of that. In WBSN sensors will placed inside the human body and to power up them HBEH techniques has been adopted. The amount of power produced in the different human activities are listed in the Table II.

TABLE II
THE AMOUNT OF ENERGY PRODUCED IN DIFFERENT HUMAN ACTIVITIES [10]

Human Activity	Power Produced
Body heat	2.1 - 4.8 W
Exhalation and breathing	less than 1 W
Arm motion	less than 60 W
Finger motion	6.9 – 19 mW
Footfalls	around 67W

IV. Wireless Power and Information Transfer for EH

So far the paper discussed the EH techniques which used ambient sources and external sources. The approach arising from WPT is able to provide a convenient and flexible way for EH that can be performed anywhere, at any time, under any weather condition, and for any desirable amount. WPT's initial efforts were concentrated on long-range and high-power applications. However, both the transmission process's low

TABLE III
COMPARISON OF DIFFERENT EH TECHNIQUES [5], [7]

Energy Harvesting Technique	Power Density	Efficiency	Comments
Photo-voltaic Outdoor	15 mW/cm^2	251.5%	With Direct Sun
Thermoelectric	30 μW /cm^2	0.1%	5 °C gradient
Pyroelectric	8.64 μW /cm^2	3.5%	At the temperature rate of 8.5 C/s
Piezoelectric	8.64 μW /cm^3	-	-
Electrostatic	50 to 100 μW /cm^3	-	-
Electromagnetic	1 to 4 μW /cm^3	-	Human Motion
RF	o.1 μW/cm^2	50%	GSM 900/1800 MHz

efficiency and the health risks associated with such high-power applications stymied further growth. As a result, the majority of recent WPT research has concentrated on near-field energy transmission through inductive coupling [17].

The possibility of integrating WPT with communication networks necessitates the development of technologies that can simultaneously transmit information and power to end-devices. As radio signal can transfer information and power simultaneously and therefore SWIPT techniques has been discussed in wireless communication. SWIPT is an innovative candidate, and an effective solution to ease the contradiction between high transmission rate and long lifetime of battery-powered devices [18].As WSN are playing key role in SG the SWIPT based WSN can be also adopted in SGs. As a result EH schemes based on SWIPT can be suggested to ensure the reliable operation of sensor nodes. The SWIPT system has a concern with security concern because of increasing the undesired risk of information stealth by an eavesdropper [19]. Therefore ensuring the confidentiality while incorporating SWIPT techniques to SG is an important fact.

Though SWIPT technology is promising technology for EH an especially interesting and challenging scenario occurs, as strong signals not only increase power transfer but also interfere with it. Therefore well designed hardware systems are necessary for SWIPT networks. The designs in literature suggest that in order received signal must be split into two sections, one for energy harvesting and the other for information decoding. Time, power, antenna special switching techniques as shown in Fig.3 have been suggested to achieve the signal splitting in SWIPT networks.

V. WHY EH IS IMPORTANT IN SMART GRID NETWORKS

In cooperating a SG with emerging technologies in communication system will ensure the SG more reliable with more choices and also can designed with energy efficient operation schemes. Optimization of energy consumption in SG will be based on grid-integrated near-real-time communications between various grid elements in generation, transmission, distribution and loads.As discussed in Section II (B) SG consists of Smart infrastructure system, Smart management system, Smart protection system where all of these subsystems require reliable and updated information. In a SG its expect immediately act for sudden changes, disturbances, faults and

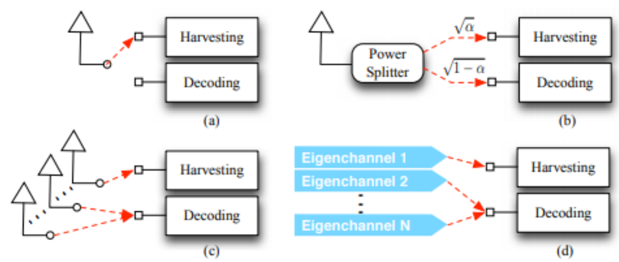

Fig. 3. SWIPT transmission techniques in different domains: a) time, b) power, c) antenna, and d) spacer [17]

outages much be communicate with the system operator and also It is necessary for SG to predict the failures or changes and correct them before they occur or restrict the ability of becoming it as major disturbance. For all these operation reliable and updated data is required.

In overall smart metering communications in SG communication architecture plays key role. Smart meter are equipped with smart sensors which are responsible to sense the real time data in the power system such as voltage, current, frequency, power quality, temperature at different equipment, sags of the transmission lines etc. In the SG installation powering up the smart sensors is a key consideration. EH concept can be used to power up the smart sensor where it ensure the maintenance free monitoring [20].Considering the reliability of the power system proper communicating the measured data from smart sensors is a key challenge in SG environment. In a conventional electric power monitoring wired connection such as power line communicators (PLC) has been adopted. Though the wired techniques are promising the reliability there expensive deployment, high maintenance cost are challenging. Wireless communication has successfully overcome these issues. WSN providing the communication demands for the information and data gathering and control or response actions [7].WSN has also become a low-cost network monitoring, control, measurement, and fault diagnosis solution in the SG network. A sensor node's main components are sensors, memory, processor, power supply, transceiver, and actuator.

These sensors can detect voltage, current, and temperature etc. In a typical network, WSN nodes are operated by batteries, as previously mentioned [21].Although WSN in wireless communication networks is promising technology literature shows that supplying power through wires and recharging or changing batteries has become a challenge. Therefore to avoid such difficulties the EH techniques has been discussed broadly [7]. As discussed in section II scavenging the energy from the energy exits in ambient environment or external sources would be an innovative and advantageous technique for powering network nodes in several scenarios. The same concept can be applied to SG networks where many WSNs are involve in monitoring and controlling the system.

VI. Related work in EH techniques in SG

It has been identified from many studies for a SG environment from above mentioned EH techniques, due to the availability of high current and voltage levels inside the facilities harvesting from electromagnetic and electric field seems promising in SG and also considering the physical size and output power electromagnetic harvesters are found more suitable for smart grid applications. [22].

Cru et al. [7] suggested RF based EH for the development of autonomous nodes within WSNs in smart grid. Beside the advantages of no wires and recharging batteries or replacing this technique has a unique advantage due to the autonomous nodes. As a results these nodes can be used to predict system changes or disturbances using machine learning and AI in advance pattern recognition and actuation methods. The authors of [23] suggested electromagnetic harvester design with a cubical structure that would be placed next to a conductor, avoiding installation issues. Their findings show that when the harvester is placed next to a conductor carrying 170 A of current, it can produce 744 mW of electricity.

Erdem et al. [22] has focused in their study the utilization of electromagnetic filed harvester to assist batteries integrated with WSN in the SG environment. Conductor Winding Harvester (CWH) and Free Standing Harvester (FSH) are been discussed in this study.Two electromagnetic harvester types has been analyzed based on possibility of clamping around the conductor.The first harvester type is clamped around a current carrying conductor which can exploit the energy from the electromagnetic field filed created due the current flow through the conductor according to Faraday's law of induction. It can scavenge the electromagnetic energy with an inductive coil which will be crossing the electromagnetic field's circular area. Since this device is clamped directly with current carrying conductor it is useful to monitor voltage, current and temperature level of the conductor.The second harvester type they have discussed is the type where clamping around the conductor is not feasible or particular locations where the conductor are not existing with in close vicinity of the measured parameters. As a results of located away from the conductor the viability of overlapping the coil cross sectional and electromagnetic field's is lost in this device which causes the lower output power.The performance analysis of this study provides that CWH can improve lifetime of WSN by using low duty cycle values or inter arrival rates. Also they guaranteed the infinite lifetime in case of higher flows.

Roscoe et al. [24] has revealed from their study the magnetic flux level available within the typical substation is sufficient enough to energize the WSNs using FSHs which can be used without clamping around the conductor. It has been identified that the magnetic flux level in a typical 400 kV indoor substation is sufficient enough to energize a MICAz sensor node which is performing data transmission every 4 minutes. The experimental results of this studies observed that useful average power of 300μW can be generated in an environment where the magnetic flux density is 18 μT_{RMS}.

Yildiz et al. [25] a hybrid energy harvesting model for WSN enabled SG applications which can scavenge the energy from either solar or electromagnetic energy sources. This model can select the energy source considering the time and probabilistic weather conditions.. In this study in order to minimize the energy dissipation of the maximum energy consuming node a Mixed Integer Programming (MIP) model which built on top a handshaking based link layer model have been used. The quantitative performance of the suggested model was analyzed on square WSN in an outdoor 500 kV substation where WSN topology is deployed for Line of Sight (LOS) and Non Line of Sight (NLOS) channel cases. The study results showed that this hybrid energy harvesting model can minimize the energy consumption of the maximum energy consuming node up to 91.46% if the full solar energy is available. Although the solar energy cannot be used this hybrid energy harvester minimized the energy consumption by 81.40%.

The authors of [26] have suggested an energy harvester especially for smart sensor powering where it can scavenge the power by capturing magnetic energy from an AC power line. The proposed method convert the magnetic field around the power line into mechanical vibration using miniaturized permanent magnet (PM) synchronous generators. Comparing to the conventional energy harvester this device has a unique feature as it is easily installed on the power line without forming a closed magnetic path around it.

In [27] a E-field energy harvester was suggested where it has a unique feature as it can integrate into a sensor's enclosure. As a results it has ensured he low cost and reduced size. This device can installed in the system without any interruption medium or high voltage assets because of its shape. The study has shown promising results from their prototype as it is cable of providing 17 mW of uninterruptable power at 35 kV with high energy density. It has been identified that the generated power is enough to operate low duty cycle sensor node installed in a MV/HV asset.

The authors in [28] have been suggested a optimization method for magnetic field EH platform for self-powered ac power line monitoring devices in SG applications. The suggested method can be applied to any type of vibration energy harvesters such as electromagnetic, piezoelectric and electrostatic energy harvesters. In this optimization for different PM magnetization vectors, the design method defines the optimum orientation angle of a PM with respect to the direction of vibration.

VII. Future Directions

A. Security and Cyber Attacks

As discussed in Section IV WPT / SWIPT networks enabled with WSN can be considered as an innovative advantageous technique for smart grid communication and also for EH applications in SG. Though it is an innovative candidate as smart grid applications are a broad network comprised of huge networks and protocols, WSN protection and privacy must be carefully considered. Most importantly ensuring customer privacy is a must in SG applications. SM which is employed with the smart meter contains enormous data stored in it which can be used to expose personal data such as a person's habits, actions, hobbies, interests, and even beliefs. Also due to the integration of many distributed resources, smart meters, and covering a large geographical area WSN based SG experiencing a vulnerability. Also the electricity grid are not designed to easily incorporate with the IoT devices this will lead to occur cyber physical security risk [29]. Thus the improvement of existing security measures with a uniform security approach must be pursued in future studies to avoid the instability of SG by altering the information stored in smart meters. As [30] emphasize the public and private security measures for WSN in SG may require costly solutions and therefore cost-security trade-offs must be carefully studied and implemented. Also the electricity grid are not designed to easily incorporate with the IoT devices this will lead to occur cyber physical security risk.

B. Reliability and latency requirements

The parameters like high data rates, latency, reliability and authenticity are vital for quality of service necessities (QoS) of smart grid applications. The main aspects QoS of SG are namely latency and reliability. In a SG the information collected by sensor node must be delivered within the stipulated time bound else the certain information become outdated. And this kind of scenarios may create the severe damages to the grid. Therefore the latency should be taken into the consideration for future SG. Also the reliability which means the high end-end date delivery must be ensured in the communication subsystem of a SG. It has been previously discussed that enabling the SG with SWIPT is challenging as strong signals not only increase power transfer but also interfere with it. This will interrupt the required QoS in the SG environment and it might be better future research direction to pursue further.

C. Harsh smart grid environments

The electricity grid environments are typically interrupted with many external conditions such as rain, solar radiation, wind, humidity, vibrations etc. As a result in SG sensor nodes experience failures and communication link unreliability. The authors of [31] express that smart grid distribution environments have variable link delivery and higher packet error rate due to electromagnetic interference, obstructions, equipment's noise, etc. where it will make the low power link of WSN more unreliable. Though Link quality estimation techniques have been suggested to improve the low power link reliability we have identified that much attention should be given to the link quality estimation when the SG incorporate with WPT/SWIPT techniques. Malfunctioning of sensor nodes also a challenging aspect due to the limited battery capacity and as sensor node can be deployed in the isolated locations that are tough to access and replace battery. EH techniques are been suggested to overcome this scenario as discussed in previous sections of this paper. Though the EH techniques are been discussed WPT/SWIPT enabled EH has to be thoroughly studied according to best of our understanding since it has not been pursued in past studies.

D. Hardware Real Experimentation Impairments

According to the best of our knowledge and through the literature we have identified that comparatively less consideration was given to hardware implementation and real experimentation for the SWIPT enabled EH systems in a SG environment. The systems studies have been conducted in simulation environment mostly for WSN based SG applications considering the channel parameters though the experimental studies have not been pursued in the previous studies. It is very clear there is considerable gap between the real experimentation of EH systems for WSNs in smart grids therefore it would be an interesting aspect to be pursued. Large scale systems with bulky EH systems will not be economically viable or acceptable for ubiquitous contexts, especially with WPT/ SWIPT connectivity to SG networks. Therefore it will be an innovative suggestion to miniaturize EH systems. There in future research activities robust, low power, miniaturized EH systems can be more focused. In fact these miniaturized systems should be able to power the node, sensors, and other associated interfaces. The next effort includes improving the efficiency of each hardware block and developing a common communication protocol that meets the specified criteria.

E. Distributed Decision Making Generic Energy Harvester

Decision-making becomes much complicated when a fault occurs in the WSN enabled SG network where it will not be a trivial problem within a limited time with a thousand sensor nodes. In this regard, attention can be given to distributed decision-making systems and it would be an interesting and valuable research area. This means that the local decision-making system takes caring the faults locally where it will minimize the complex decision-making process and will reduce the response time. Though it will be highly responsive further studies have to be carried out since locally optimal decision is not always globally optimal and therefore we should study how to balance the response time with effectiveness. Also EH techniques can be used as a solution to minimize the effort on decision making for power management. In fact harvesting energy from many sources is one of the most difficult issues, which necessitates the development of improved power management strategies. Therefore a generic harvester which can harness the energy from different power sources may be an interesting topic to pursued further.

VIII. Conclusions

In this paper, the energy harvesting techniques which can apply to smart grid networks have been discussed. The aim of this paper to present a comprehensive outline of the smart grid concept which is suggested as a solution for reliable power system operation. The smart grid is consists of a massive number of smart measuring devices where communication becomes a challenging task to have proper controls and monitoring in the power system. Powering the smart sensors using a wired system has been identified as an ineffective method and therefore the wireless communication techniques have been discussed broadly. Although the wireless communication network has been identified as a promising architecture powering up the sensor nodes with tight battery limitations of WSN nodes has become a critical factor due to the recharging or changing the batteries. Energy Harvesting approaches have been introduced as a solution for this and further some of the interesting future research aspects were discussed considering the EH for WPT/SWIPT enabled SG networks.

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