WIRELESS SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEM FOR PHOTOVOLTAIC INSTALATIONS

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ABSTRACT: Performance of the photovoltaic systems suffers from inappropriate level of supervisory. Limited availability of the information about key system parameters and lack of expert knowledge of the users are the most commonly found problems. In large scale installations, due to high level of complexity, faults become more likely to happen and more difficult to be found. In extreme they may stay uncovered for long periods of time. It decreases financial performance of the PV system putting investment at risk. In presented paper novel, wireless ZigBee technology has been applied to develop robust, accurate, easy to install, low cost and autonomous sensing solution for photovoltaic supervisory systems.
Keywords: Monitoring, PV System, Energy Rating

1 INTRODUCTION

Supervisory monitoring is a convenient way to ensure high performance ratio (PR) of the photovoltaic installations and maintain investment risk. However existing solutions are relatively expensive and troublesome to install (especially in already fitted PV systems). Hardwired sensors must be appropriately isolated from the PV installation to be able to stand at least 1000VDC. Quality of measurements taken by data acquisition system can be affected by additional noise introduced by grid connections. Proposed method eliminates most of the problems convolved with wired sensors. Measuring process (signal conditioning, digitizing) is done by wireless sensing nodes as close as it is possible to the source of the signal. Build-in energy harvesting method make the sensing nodes autonomous from grid or battery powering. Obtained solution is easy and inexpensive to install without compromising on high quality of measurements. Schematic layout of the system architecture was shown in Figure 1.

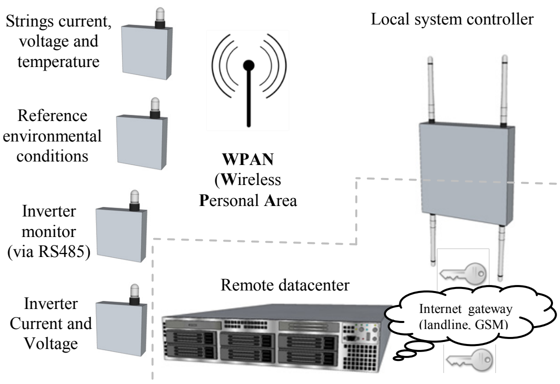

Figure 1: Layout of the wireless photovoltaic system monitoring.

2 LR-WPAN STANDARDS

IEEE802.15.4 is a leading standard for low complexity, low power consumption, low cost, low rate wireless personal area networks (LR-WPAN). From its first release in May 2003 IEEE802.15.4 fulfilled needs of local area networks for sensing applications. IEEE802.15.4 defines physical layer (PHY) and medium access control layer (MAC) of OSI mode[1].

On top of IEEE802.15.4 higher levels of OSI model standards were created with ZigBee as a leading one. ZigBee defines network layer(NTW) and application layer (APL) of OSI model. Application layer is comprised of the application support layer (APS), the ZigBee device objects (ZDO) and the manufacturer–defined application objects. Figure 2 shows detailed outline of ZigBee stack architecture.

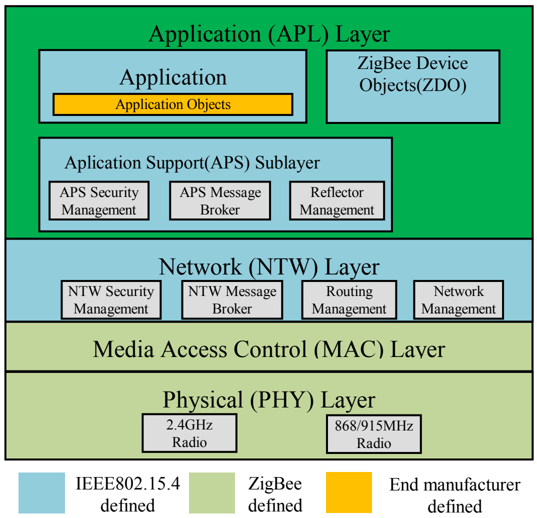

Figure 2: Outline of the ZigBee stack Architecture[2]

IEEE 802.15.4 and ZigBee standards create handy foundation for low rate wireless personal area network developments.

3 NETWORK ARCHITECTURE

According to ZigBee standard, network layer (NTW) supports three topologies: star, tree and mesh. Three types of nodes are possible in the network: end-node, router and coordinator (routing node is optional as its functions can be handled also by coordinator). In star topology network is controlled by single coordinator node which is responsible for initialization and maintenance of the network. Coordinator communicates directly with ends nodes. In tree and mesh topologies network can be extended by routing nodes which work like repeaters. It increases coverage of the network as well as creates alternative data transmission paths in case of failure of one of the nodes. Figure 3 shows topologies available in ZigBee network.

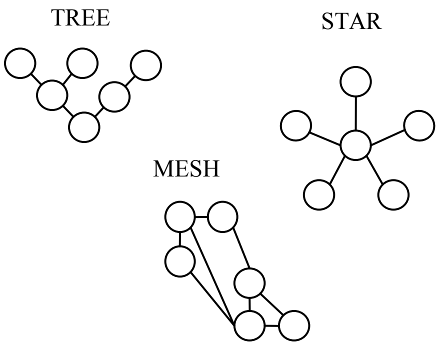

Figure 3: Outline of ZigBee/IEEE802.15.4 topologies.

Use of CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) allows devices to leave and join network with minimal latency. Coordinating node can put end nodes to sleep for specified period of time to preserve its power consumption. After the end-node wakes-up it can transmit data to coordinator and be put to sleep again. In consequence an average power consumption can be limited to few μW (mW in peak, during radio transmission).

4 SENSING NODES ARCHITECTURE

Sensing node was designed as a generic device capable to take measure of signals from variety of connected transducers and transfer collected information to the network coordinator on its demand. Measurements are taken close to the source of the signal what limits influence of an environmental noises. Use of built-in photovoltaic cell and energy harvesting circuit makes node fully autonomous. Application of super capacitors, instead of batteries, as an energy storage removes need of periodic replacements, what decrease maintenance costs.

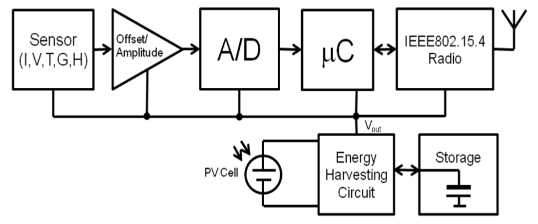

Figure 4: Sensing node block diagram.

To accommodate requirements of the photovoltaic monitoring, three specifications of the sensing node were created accordingly for: string, inverter and environmental conditions. String sensing node is capable to measure direct current and voltage (I_{DC},V_{DC}) as well as module temperature (T_m). Inverter sensing node is capable to measure alternating current and voltage (I_{AC}, V_{AC}). Environmental sensing node is capable to measure signals from irradiance sensor (pyranometer, reference cell) and ambient temperature sensor. Defined functionalities of sensing nodes do not exhaust the wide variety of possibilities and can be easily extended in the future. Compact size and low cost should allow to integrate sensing nodes in other devices (combiner boxes, inverters, distribution boards, etc.) ,what should allow for further reductions of costs of monitoring system.

5 LOCAL SYSTEM CONTROLER.

Local System Controller has been implemented as an embedded computer system. Dedicated application coordinates sensing nodes and collects data from them through IEEE802.15.4 radio. Data are buffered in local database. Buffering data inside local database secure monitoring system against data losses while internet connection to remote data centre cannot be established. Local system controller is powerful enough to process collected data."On-spot" pre-processing of the data can be useful to limit data transfers and workload put on data centre. Local system controller can also be used as WWW server to provide visualization of solar power production. For small domestic installations local system controller can be replaced by ZigBee gateway without loose of main functionalities. Figure 4 shows block diagram of the local system controller.

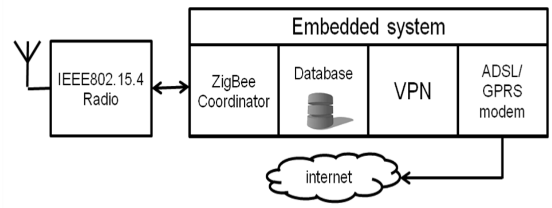

Figure 5.Local system controller block diagram.

Each of local system controllers is configured to be a part of Virtual Private Network (VPN) and as soon as an internet connection can be established data are transferred to the remote data centre for analysis and backup. Local system controller can establish connection to the internet through local area network (LAN) . To provide internet connectivity an optional ADSL or GPRS modem can be integrated within local system controller.

6 CONCLUSIONS

Monitoring of photovoltaic systems has proven its usefulness over the years. New information technologies allow to implement more precise and less expensive solutions, making monitoring available to the wider group of users. IEEE802.15.4 already became leading wireless sensing technology for intelligent houses. Assuming photovoltaic systems as a part of modern, sustainable households integration of PV monitoring with IEEE802.15.4 seems to be natural way to go.

7 REFERENCES

[1] IEEE, *LOCAL AND METROPOLITAN AREA NETWORK STANDARDS*, in *Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (LR-WPANs)*2003, The Institute of Electrical and Electronics Engineers, Inc.: 3 Park Avenue, New York, NY 10016-5997, USA.

[2] ZigBee Alliance, *ZigBee 2004 Specification*, 2004, ZigBee Standards Organisation: San Ramon. CA.