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Performance analysis of low earth orbit satellites for power system communication

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Abstract

In this paper the main performances of communication services based on low earth orbit satellites (LEOs) have been analyzed in order to evaluate their suitability for a typical set of power system monitoring functionalities. As an experimental test bed, an intelligent electronic device (IED) for remote monitoring and protection of power components equipped with a bi-directional communication system based on the LEO satellites of the Globalstar® consortium has been prototyped. Thanks to the adoption of this facility the main parameters characterizing the performance of the satellite TCP/IP services have been evaluated. They comprise in particular the connection time, the degradation of service and data latency for both packet and asynchronous data services. The experimental results obtained show that the application of LEO satellites based communication technologies exhibits a set of intrinsic advantages that could be particularly useful in several fields of power system communication.

Keywords: Power system communication; LEO satellites communications; Intelligent systems

1. Introduction

The increase in the growth of information and communication technology (ICT) could play a strategic role in the attainment of the new targets induced by the liberalized electricity market. In particular, amongst the possible solutions available, the employment of satellite based technologies appears to be particularly suitable since it could make possible the realization of advanced, high value communication services such as:

- sophisticated metering;
- remote control and supervision;
- interactive e-commerce and trading applications.

Without requiring the construction of complex and expensive infrastructure and assuring, at the same time, a set of intrinsic advantages such as wide area coverage, easy access to remote sites, cost independent of distance, low error rates and adaptable to changing network patterns.

Moreover, satellite based technologies are considered a key factor in lowering the degree of vulnerability of complex interactive networks and critical infrastructures as far as the electric power grids and transportation networks are concerned [1–3].

On the other hand, the main factors that in the past have limited the application of satellite based technologies in power system communication have been recurring leasing cost of services and intrinsic time delay.

Nowadays the large number of satellite service providers in conjunction with the continuous lowering of the cost driving factors characterizing the new technologies are driving satellite communications to become competitive with other wireless based services. At the same time the recent launch of low earth orbiting (LEO) satellites, characterized by an orbital period of much shorter than a day, permits large reduction of communication time delay. These technologies have been successfully applied to support a wide range of advanced telecommunication services such as wire-

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less Internet [4] and high-speed terrestrial/satellite networks [5].

Nevertheless, to the best of our knowledge, the application of LEO satellites based telecommunication technology has not so far been explored in the literature on power system communication. With this paper, we intend to fill this gap.

The paper analyses the performance of LEO satellites based communication services in order to establish their suitability for a typical set of monitoring and supervision functionalities required by power system utilities.

In particular, after a comparative analysis of the latest data services offered by the main system providers, the LEO satellites based data services furnished by the Globalstar® consortium have been adopted as reference in our experimental activities.

The performance of these services have been tested by an experimental test bed consisting of a prototype IED that integrates advanced modeling methodologies and LEO satellites based TCP/IP communication services for the remote monitoring and protection of power components.

Thanks to the adoption of this facility the main parameters characterizing the data link performance have been considered. They comprise in particular the connection times, the degradation of services and the data latency. These experimental activities have been developed connecting the IED to the Internet by the Globalstar® satellite gateway and submitting multiple queries to the remote device by a web connected host server. As far as the connections modalities of the host server, several kinds of Internet connections, based on both Local Area Networks and private Internet Service Provides (ISP), have been explored. In the latter case both wired (analog modem connected to a Public Switched Telephone Network (PTSN)) and wireless technologies (based on satellite and GPRS data links) have been considered for the Server/ISP connection. The analysis of the results obtained shows LEO satellites based communication systems, compared with geostationary satellite (GEO) based services, are characterized by a set of intrinsic advantages that could be particularly useful in power system communication such as rapid-connecting packet data, asynchronous dial-up data availability, reliable network services and reduced overall infrastructure support requirements.

The outline of the paper is as follows: an analysis of the existing literature on satellite based technologies applied to power system communication is given in Section 2. In Section 3, a comparative analysis between the main LEOs based communication services is presented. Section 4 describes the main features of the experimental test bed adopted to assess the performance of LEOs based data services and presents a discussion of the experimental results. Conclusions and future work are summarized in Section 5.

2. Related works

The use of satellites by electric utilities has been investigated for a number of years.

In particular in [6] the employment of an Immarsat-C based satellite system is proposed as a communication unit for the remote management of the rural distributions networks. In [7], the integration of geo-stationary (GEO) satellite based technologies and terrestrial communication systems is proposed in order to develop hybrid communication networks supporting dedicated functionalities for power utilities. In [8], the interconnection of distributed networks over satellite links employing asynchronous transfer mode (ATM) cell based transmission is proposed as a sound basis to develop high-speed networks supporting advanced telecommunication services. In these hybrid networks, the satellite component is expected to operate alongside that of terrestrial components providing a complementary rather than a competitive service.

In [1–3], the development of satellite telecommunication systems is considered as a key factor in lowering the vulnerability degree of complex interactive networks such as the electric power grids. In the same papers architectures that integrate machine learning based methodologies and advanced communication services are proposed for the reliable management of critical infrastructures.

In [9] a critical review on the employment of geostationary satellite based systems for communication in EMS/SCADA and Distribution Dispatching Centre Projects is presented.

The studies reported reveal that although the application of satellite based technologies in power system communication could lead to sensible technical benefits, many critical aspects should be overcome in order to assure a wide and useful application of such technologies.

These comprise in particular:

- problematic link feasibility due to the long satellite–user distance (on-board antennas that are very large could be required if low power terminals are considered);
- high propagation delays;
- low minimum elevation angles at high latitudes (i.e. polar regions, cannot be covered);
- leasing cost.

In this regard the employment of LEO satellites based technology could represent a key factor in overcoming most of such limiting factors.

This technology, compared to medium-earth-orbit or geostationary-earth-orbit satellites, offers several intrinsic advantages such as minimum delay, multi-satellite handoff, extremely small antenna, lower power consumption, and lower cost. It appears therefore particularly suitable to support TCP/IP-based services [4] that are emerging as an essential tool in the remote management of large-scale systems.

The profitable extension of these benefits in power system communication requires a preliminary testing of the true functionalities of LEOs based communication systems in order to evaluate their potential integration with the specific power system applications.