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Private WAN Infrastructure for today's Utility Communications

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ABSTRACT

For two reasons, electrical Utilities need today an outstanding Communication Network:

1. **to exchange on-line data to support a secure grid operation and**
2. **to manage the exchange of a wide range of important and decisive market information.**

In both cases the liberalization did increase dramatically the complexity, the number of participants and the amount of information exchanged.

The goal of this paper is to define the different requirements regarding performance, quality, operational and maintenance aspects of such a Communication Network for Utilities. A quick analyze of practical implementations should help to make some final recommendations.

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1 INTRODUCTION

In the past the best way to ensure the supply of electricity was to build a very stable meshed grid that could survive mostly any critical situation. Of course that network was over-dimensioned. The same grid today transports a multiple in electrical power and is unfortunately frequently loaded near his capacity limit. In this situation the Network isn't anymore stable by itself so that sophisticated simulations (State Estimator, Load flow calculations) and corresponding counter measures are continuously necessary to prevent incidents or blackouts. An appropriate comparison could be done with the Plane industry: The good old Jumbo-Jet is probably too big and too heavy but he is extremely stable and reliable. In opposition, modern Jets are optimized to reduce the Operation costs but they are basically unstable and can't fly without Computer assistance, and a multiple internal LAN to acquire information and control the Plane.

Therefore, to optimize the performances of a system, it is necessary to collect in real time very accurate Information's about the actual status of this System.

The Production of electrical energy is moving from a centralized generation in big Hydro or Thermal power plants to multiple decentralized Productions in smaller Gas-Turbines respectively wind- and solar-power plants. In the same time, because of the liberalization, customers may choose their supplier in energy and competition forces the suppliers to offer a wide range of different products and packages not only to the local market, but also to market players in other regions. An animated Energy Exchanges drives heavily the fluctuation of the energy flows.

In this new dynamical market, the prediction of the load flows is extremely complex and the Grid Operators have to better understand and anticipate the needs of their customer.

1.1 Switzerland (Swiss TSO's)

The Swiss high voltage grid, with 36 international Interconnection Points to other European Countries, is embedded in the middle of the European transmission grid. Switzerland count 7 local Transmission System Operators (TSO) and ETRANS is responsible for the entire Swiss grid coordination as well as for the tuning of the Settlement and Planning of international Exchanges. These duties can only be performed through a safe and high Performance Telecommunication Network to exchange national and international Grid- and Market information.

Interconnected Operations started in the early 60th and ETRANS experts (formal EGL) were pioneer and involved from the very beginning, collecting a great experience in realization and operation of several Swiss-internal and European Utility WANs.

1.2 Europe (ETSO)

In Europe, the national TSO's has always exchanged the necessary information to ensure stable Operation of the Interconnected European grid. During the last 40 Years, the bilateral exchange of data was permanently improved by state of the art technology. Only in the last five years, national TSO's started to design and implement common Information Highways connecting each other.

2 DEVELOPMENTS

2.1 Motivations

Each TSO try to obtain enough relevant information about the status of neighboring grid, which could influence the stability of his own Network. So in the past, several Utilities had to install in a Sub-Station connecting different partial grids, their own Data Acquisition Equipment (SCADA-RTU). In Europe and especially in Switzerland were the multiple grids are strongly interconnected, these circumstances lead to an overkill situation. To remedy to this situation and in order to save costs, the Swiss Utilities decided to implement a Partner Information Exchange System, called PIA.

The principle of PIA is the following: process information's are acquired only once by the TSO, which is responsible for a grid element, and are distributed by the PIA system in real time to any other authorized TSO. PIA allows the exchange of on-line data for the actual grid status as well as the exchange of data for the Energy Settlement.

After the liberalization of the electricity market, it became urgently necessary to take measure to limit excessive energy flows, which are critical to the grid Operations. In a very short time period, the European TSO's have planned and implemented a Network, the (EH), in order to better support the new market requirements. This Network, which was primarily designed to exchange the day ahead processes (Congestion forecast, Congestion management, Security Analysis and programmed Exchanges) and the corresponding Settlement Processes, and was designed to be expandable to further Communication purpose, may be considered as the typical future Communication Network for TSO's.

An UCTE (Union for the Coordination of Transmission of Electricity) Network, which was designed to exchange real time data between SCADA/EMS systems of neighbors European TSO's (URTICA) has been merged into the Electronic Highway.

These Examples show that different motivations required by different Business Units to support their activities within different time frame could not lead to a unique solution. The next chapters deal with requirements, solutions and experiences in this context.

2.2 Functional requirements, needs

To face the challenges of the liberalization and also contribute to minimize the costs, the main requirements for a WAN infrastructure for Utilities may be reduced to the following Items:

The Communication Network needs

- to support the transfer of any file handled by the typical Office environment as well as the exchange of all kinds of document based on standardized EDI-messages
- to provide the necessary speed, bandwidth, availability and to have standard facilities to prioritize the traffic allowing the exchange of real time data over the same Network
- to be designed and built without single point of failure and, if necessary, to be expandable without interruption
- to use Open Standard for platform, software and security tools to save development and maintenance costs
- to let a maximum of freedom and flexibility to the connected partners in order to easy interface their own different Standards with the common Network and to decide about their contribution, building part(s) of the Network.

2.3 Options, approaches

Within the above presented requirements for a utility Communication Network, there are still a certain number of options to be examined:

- The **Physical Structure** must show a sufficient redundancy. To exclude a single point of failure, shall the Utilities be connected over a ring?, with cross connections? or a combination of both?
- Modern techniques can multiplex several logical links over one **physical Link** on different (Protocol) Levels: Is it more adequate to build one Multi-Service Network with several logical or virtual Networks? or different Networks using the same physical link (optical fiber, STM-1 or 34 Mbit/s Link, even slower links)?
- As a **Network Protocol**, TCP/IP or X.25 may be used. TCP/IP, the Internet standard protocol, supports many high-level protocols and Services and is available on every IT platform. X.25 is also an open standard that is commonly used. The well-known X.25 technology is more secure then TCP/IP, but also less dynamical and is hard to configure. There may be some interconnectivity problems between different vendors. Probably X.25 will be more and more outfaced by the TCP/IP.
- For the Layers 6 & 7, two protocols have been widely used over the last 10 years for real-time data exchanges between control centers and became de-facto standards: ELCOM-90, introduced by the northern European Countries and ICCP in USA. The Working Group 07 of the Technical Committee 57 of the International Electro technical Commission (IEC TC 57 WG 07) has integrated them into two full IEC-compliant de-jure standards called TASE (Telecontrol Application Service Element) : TASE.1 for ELCOM-90 and **TASE.2** for ICCP. TASE.2 is today the official Standard (IEC 60870-6).
- Organizational aspects must be solved. A **centralized** solution for **Maintenance** and Operations limits the dynamic of the Network. Procedures, Naming Conventions must be revised and amendments are frequently necessary. A distributed Network can grow very naturally but shows often lack of security and performance. A private Network must be protected through Firewalls from the public domain. Strict policies and audits are therefore necessary to prevent holes in the security concept.

2.4 Practical Implementations

The emerging Internet Technology and the Telecom liberalization did encourage the Utilities that were laying their own Optical Fibers to initiate projects to improve their internal Communication Network. Three of them are exposed in this chapter.

2.4.1 PIA in Switzerland

The PIA-Network in Switzerland is successfully in operation since July 1999. A standardized infrastructure provides an easy connection with the different Control- and Settlement Systems of each TSO and ETRANS. Each TSO has implemented an identical infrastructure (PIA Server) that connects them to each other using TCP/IP and TASE.2 Protocol in a strict secure environment. The classical ring structure was enhanced by several cross connections to comply with the principle that every node can reach any other one being routed only through one of them.

The PIA System has been realized as a common project and is managed and operated by a single service company, which also allocate and administrate the common database with the ID of all grid elements shared within the Network. Actually the PIA-Network manages 5000 measurements, 20'000 indications and alarms and about 1000 counter Indexes that are accessible within one second.

2.4.2 SSN (Scheduling and Settlement Network)

Recently, another common project was developed and realized by the Swiss TSO's and ETRANS: the Scheduling- and Settlement Network. This is another router based TCP/IP Network with high transmission capacity, based on a private SDH-ring using exclusively optical Fibers of the Utilities. This WAN is mainly used to exchange voluminous Schedule- and Settlement data files over ftp-servers and to connect remote client Workstations of IT-Systems operated centrally by ETRANS for the other grid partners. Multiple Virtual Private Networks may be operated on this infrastructure to allow Multi-Service for different groups of interest. Also in this case, a single party is responsible for the entire Operation and Maintenance.

2.4.3 The Electronic Highway (EH) for European Utilities

The Electronic Highway connects all European TSO's in order to exchange on a extremely reliable private Network any vital cross border information relevant to the European transmission grid. To reach a high level of availability, this private TCP/IP network is based primarily on infrastructure already owned or hired by the TSO's. Supplementary to real time data (topology and measurement), additional Schedules, Load Flows and planning data as well as operational information are also shared. The implementation was done individually by each TSO according to commonly agreed technical and organizational rules. Therefore there is none overall responsible for Operation and Maintenance except a main- and a subsidiary Operation Supervision Party. For the on-line data exchange the IEC 60850-6 (TASE.2) Protocol is applied. The exchange of measurement data, Schedules and planning data occurs by a central ftp-server within the Network. Another http-server is available for mutual general information exchange.

The main rules and characteristics of this decentralized TCP/IP-Network are:

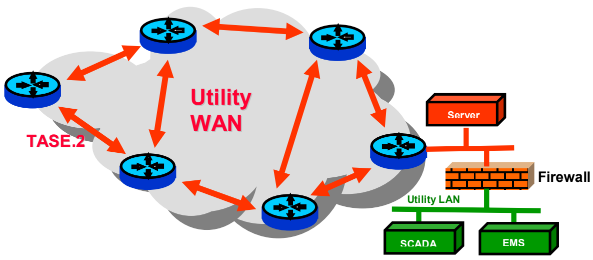
- It is primarily based on private lines (SDH channels) connecting each TSO to at least two other ones
- each TSO keeps a maximum of freedom but has also the responsibility to build a part of the Electronic Highway according to general rules
- based on open standard technology (typically 'Internet'), the Network is easy to implement, includes a rich basic functionality and is suitable for exchanging all kinds of messages / files in any format in using SMTP protocol
- for that reason the EH-Network provides an excellent Price/Performance ratio
- only standard security-measures and tools are used. Additional security will be added later if required
- Exchange of real time data over the EH-infrastructure is based on bilateral agreements. TASE.2 protocol is recommended because it is more flexible and more open to face future needs. Its success is a strong indication that it will remain in use for many years.

2.5 Common Principles

These examples of implementations, which were conceived at different time and for different purposes have altogether some common principles. They are all:

- Router based TCP/IP Networks, based on standard Components
- connected at least over two Paths to the common private Utility WAN
- using Utility-owned transmission lines, Radio Wave- or preferably optical Fiber-Links
- highly reliable by sufficient Meshing, according to the Specifications
- capable to prioritize and secure the Transmission of Information
- centrally supervised through a Network Management
- protected by clear Security Guidelines especially at the interfaces to the local Utility-LAN's
- able to provide a fair billing of the Services offered to the Participants
- using a common Data Engineering Tool for the Identification (Naming) of the bilateral Data Exchange
- utilizable for all kind of future Applications

A typical physical layout of such a WAN for Utilities is given in the next figure:



2.6 Experiences

The presented implementations fully meet the requirements and the associated projects were successful from a technical and investment point of view. The Operation experiences show that the use of private TCP/IP based router-Networks for the mutual exchange of information is absolutely right.

From a technical point of view, it is today possible to cover all the needs with only one unique WAN infrastructure. Providing enough bandwidth and the possibility to prioritize the traffic, the Network is suitable to share continuously on-line process data as well as to exchange voluminous sporadic data files resulting from various dynamic market processes. Whether this makes sense or not, in particular regarding the redundancy aspect, has to be decided case- by-case.

If the technical implementation was never a big challenge, the supervision (monitoring, maintenance, and security audits) of such a network is an absolute necessity and it has to be carefully prepared during the early design phase. Only a professional supervision and support organization allows to really achieve the extremely high availability and reliability, which is theoretically and technically feasible!

Bilateral real time data exchange is rather uncritical but necessitates always a separate cross-reference table to translate the identification of the grid elements. It is therefore mandatory to use a common naming convention on the TASE.2 Network to ensure a unified structure for cross-reference table and this facility should be managed by the supervision organization.

3 Comparison

This section compares the concepts, the technology and the advantages or weak points of the three practical WAN-implementations for Utilities exposed in this paper.

3.1 Technology

The next Table gives an overview of the concepts, technology and organization in use for the three Networks

	PIA	EH	SSN
Concept	each partner had to implement an identical dedicated mini-LAN in a secure area in between the Company LAN and the PIA-Network	dedicated gateways and servers are connected at least with 2 adjacent TSO's	dedicated ftp-servers are connected via a Utility owned SDH-Ring
Transmission Lines	256 kBit/s, 2MBit/s private lines	2MBit/s, 256 kBit/s in a few cases leased lines, privates Lines and ISDN as a backup	2Mbit/s Ring within Utility owned SDH-infrastructure
Protocols	TCP/IP, TASE.2 for real time and file exchange	TCP/IP, ftp, http and TASE.2 for real time on bilateral base	ftp, http SQL net
System Provider	defined and mandatory	free	multiple
Operation	centralized with defined Operation Procedures and SLA	a system monitor organization is in charge	centralized with SLA
Security	Security Policies, Firewalls and periodical Audit	common rules and trust	common rules and trust
Project Organization	one with the Participation of each Partners	one during planning, free for Implementation	one during planning, multiple for the implementation phase

3.2 SWOT

The following Table gives an overview of the strength and weaknesses for the three Networks:

	PIA	EH	SSN
STRENGTH	best of class Security and Availability Same component involved (common HW/SW-Infrastructure) fast response time (optimized for real-time) common Data Engineering tool replace many redundant Data Acquisition Systems	easy, quick implementation short Design phase pragmatic, let enough room for implementation and, as such, is politically correct Multi-Service Platform: is future oriented and can be extended easily an unique WAN covering the whole Pan European grid	the first shot was quick, at low cost and fully met the requirements
WEAKNESS	limited functionality, too many constraints complex up front contract negotiation too many parties involved in planning and operations	no overall responsibility for Maintenance & Operations Data Point ID not unique lack of Security different IT-Policies are an obstacle	consolidation is now necessary ring structure with too many SDH nodes remote responsibility for SDH-links. missing SLA's today

4 TRENDS

The experiences gained from these early projects as well as the new technological developments reinforce our strong believe that the future WAN for Utility will be based on Multi Services TCP/IP Networks. These Networks will support in addition to today's possible real-time applications, file transfer or Office- and Intranet-application, all the Communication needed by Utilities like Telephony, Video-Conferences, surveillance and many more.

These Networks will remain private, based mainly on optical Fibers of the Utilities and reserved to close User Groups.

A vision would be of course to extent the Network to any important sub-station or power-plant. Through the liberalization the number of nodes will increase and parallel the complexity of the system management.

The possibility to define Services Classes (TCP/IP Version 6) improves the performances of the Network but this must be managed extremely cautiously as well.

5 RECOMMENDATIONS

TCP-IP as underlying Network Protocol + TASE.2 (ICCP in Layers 6 and 7) for exchange of real-time data is the de facto Standard for private Utility Network.

File transfer is easiest to implement and handle using ftp protocol and tools.

These Networks will remain flexible, scalable and provide a wide standard functionality while using standard components and techniques. Multi-Service Platforms facilitates the integration of different applications, services and protocols. They allow to prioritize the traffic and, if necessary, may also deliver billing and QoS related information.

5.1 Special Focus

Because several Utilities are concerned by such a Network, it is particularly recommended to define and to agree already in the planning phase about the following points:

- definition of quality, priority and availability as well as of the related Network layout and bandwidth,
- SLA for the connection lines,
- interface and security policies between the WAN and the local Partner LAN (Firewall)
- description of Job and Duties, Operation Procedure, responsibilities and the corresponding tools and SLA for the team providing Operation & Maintenance.
  This includes: monitoring and reporting the traffic, the security and the Quality of Service, planning of extensions, reconfiguration and maintenance of data base for grid elements ID,
- definition of security levels settings and access protection. Security needs strong procedures to achieve the required level of security. Aspects are audits, monitoring abuses and possible intrusions as well as constantly updating the Policies.
- Concept and rules for the management and use of IP addresses within the Network.

5.2 Limitations

Today is too early to implement a few special real time applications on a TCP-IP Network, because grid operators do not yet fully trust the reliability and the guaranteed response time of this technology. At this date none of these projects has ever foreseen to transmit commands to control the grid elements or power plants nor planned to use the WAN to support the power-frequency control or the protection of power lines.

6 Conclusion

Huge improvements in the technology over the last decade facilitate the implementation of powerful multi-services communication Networks for interconnected Utilities. The implementation of multi-purpose WAN is becoming easy and attractive for those who have their own private communication Infrastructure (e.g. optical Fibers).

Most of the technical features are today solved pretty well but the organizational aspects during the planning and in operation are even more challenging and should therefore never be underestimated or neglected.