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COMMUNICATION SOLUTION FOR SMART DISTRIBUTION NETWORK – PUBLIC VERSUS PRIVATE NETWORK

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SUMMARY

Modernization of Power Utility Grid and new network applications causes changing utility communications. A communication infrastructure is an essential part for successful implementation of smart grid. Implementing modern communications infrastructure, a huge amount of data from different applications will be generated for further analysis, control and real-time pricing methods. It is very critical for electric utilities to define the communications requirements and find the best communication infrastructure.

This paper presents the communication infrastructure conceptual model for smart grid as the basis for describing, discussing, and developing the final architecture of the smart grid. The authors provide a survey of communication architectures, including the communication compositions, technologies, requirements etc. Different communications technologies supported by two main communication media, wired and wireless, should be used for data transmission between digital devices and electric utilities, or their centres.

Recognized standards and protocols as well as coming standards are listed in this paper. Typical communications techniques were defined, which can be implemented in the electrical grid, discussed potential advantages and disadvantages, and recommend the best suitable solution.

Special attention is paid on key architectural choices:
- Public networks or utility private networks,
- Licensed or unlicensed spectrum,
- Security Standards.

At the end, typical communication solutions for implementation in the smart grid for EPS (Electric Power of Serbia) are proposed with detailed explanations, having in mind all particularities of data traffic, population field, geography, etc.

KEYWORDS
Smart Grid, Communication Infrastructure, Typical Solutions

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1. INTRODUCTION

Significant growth in interest for Smart Grid in Distribution Network has been seen during last decade, especially where some techniques has progressed, like information and communication technology. Reliable and real time information and communication networks represent substantial role in Smart Grid Implementation.

The Smart Grid is an advanced power grid infrastructure, having better efficiency, reliability and the possibility of integration of renewable energy sources. The main characterization of such grid is two way flows in electrical network power and in communication network. Those broad requirements can be achieved using different technologies like ICT, automation, metering, sensing different signals, energy management techniques, optimizing energy demand etc.

Communication technology represents one of the major factors in transforming traditional grid into smart. In this paper started from Smart Grid Conceptual Model, and then having in mind all changes in technical requirements, presented possible communication solutions with different reason for pro and contra. At the end focused on the implementation solutions, defined typical solutions in Electric Power utility of Serbia.

2. SMART GRID CONCEPTUAL MODEL

The conceptual model of the intelligent network is the basis for describing, analyzing and developing the final architecture of the smart grid. EU model is presented in Fig. 1, which is identical to NIST (National Institute of Standards and Technology) model with the addition of Distributed Energy Resources (DER). The conceptual model identifies not only different smart grid stakeholders, but also provides various electrical and communication interfaces required to understand various interoperability frameworks [1], [2].

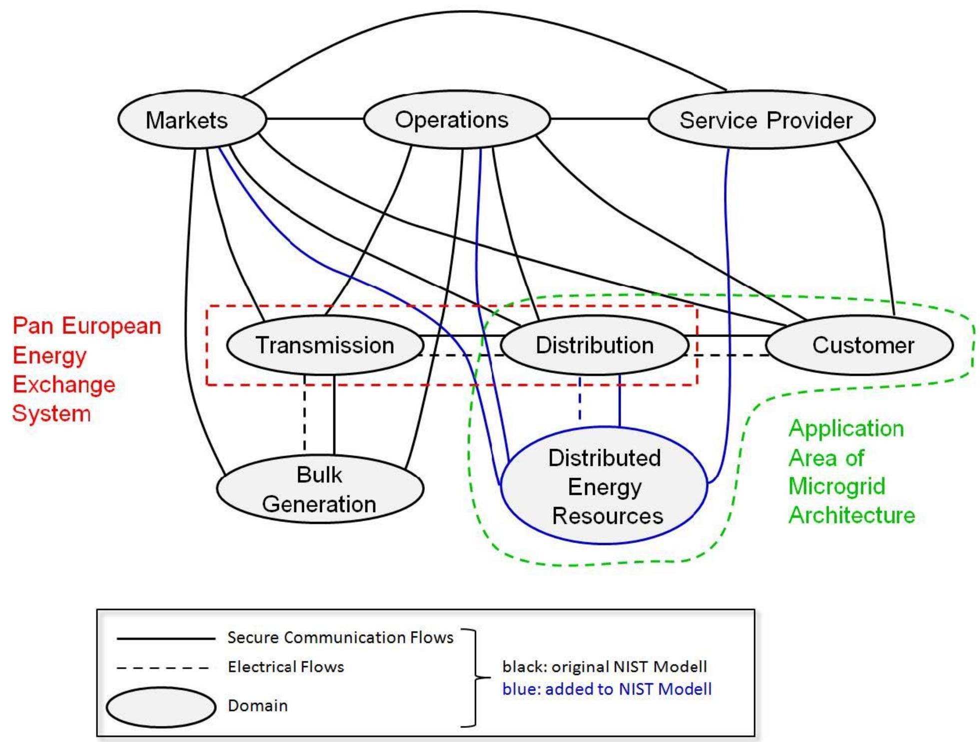

Figure 1. Smart grid conceptual model [2]

Each domain contains two groups, actors and applications. The actors are typically devices, systems or programs that make decisions and exchange information through variety of interfaces in order to perform applications and processes. The applications are various tasks executed by an actor or actors within a certain domain. The domains are able to communicate with each other via communication interfaces. This communication is critical to the overall interoperability of the smart grid, allowing it to collectively generate and distribute electricity efficiently based on the input from all domains [1].

So generally, communication networks in smart grid connect all generations sources, transmissions, distributions and consumptions systems, and transmit to some information and operation software platforms. Such concept of grid brings consequences related to scalability, reliability and cyber security, but also in growing demand for data from multi applications [3]. Considering the distribution networks, driving new networked applications are:

- Smart metering,
- Distribution Automation (DA),
- Distribution substation interconnect,
- Distribution substation security, and
- Field workforce communications.

3. COMMUNICATION INFRASTRUCTURE

3.1. Typical Communication Solutions

The future communication infrastructure implemented in smart grid will use different technologies, wired and wireless networks, hybrid mix of digital transmission techniques [1]. In this paper, communication infrastructure for medium-voltage distribution network control is considered.

Different examples of communication networks are able to fulfill the requirements for data transmission for Smart Grid purpose. In the following table, some of the typical communications technologies for Smart Grid are listed.

Table 1. Comparison of communication technologies for the smart grid [4]

Technology	**Standard/ protocol**	**Max. theoretical data rate [Mbps]**	**Coverage range**	**Network**		
				HAN*	**NAN/ FAN**	**WAN**
Fiber optic	PON	155 – 2,500	Up to 60 km		X	X
	WDM	40,000	Up to 100 km			
	SONET/SDH	10,000	Up to 100 km			
	IP/MPLS	1,000 – 100,000	Up to 100 km			
DSL	ADSL	1 – 8	Up to 5 km		X	
	HDSL	2	Up to 3.6 km			
	VDSL	15 – 100	Up to 1.5 km			
Coaxial cable	DOCSIS	172	Up to 28 km		X	
PLC	HomePlug	14 – 200	Up to 200 m	X		
	Narrowband	0.01 – 0.5	Up to 3 km		X	
Ethernet	802.3x	10 – 10,000	Up to 100 m	X	X	
Bluetooth	802.15.1	0.721	Up to 100 m	X		
ZigBee	ZigBee	0.250	Up to 100 m	X		
	ZigBee Pro	0.250	Up to 1600 m		X	
WiFi	802.11x	2 – 600	Up to 100 m	X	X	
WiMAX	802.16	75	Up to 50 km		X	X
Cellular	2G	0.0144	Up to 50 km		X	X
	2.5G	0.144				
	3G	2				
	3.5G	14				
	4G (LTE)	100				
Satellite	Satellite Internet	1	100 – 6000 km			X

***Legend:**

HAN = Home Area Network
NAN = Neighborhood Area Network
FAN = Field Area Network
WAN = Wide Area Network

It is possible to define three typical telecommunication solutions topologies:
1) Urban telecommunication infrastructure.
2) Suburban telecommunication infrastructure.
3) Rural telecommunication infrastructure.

The main differences between these solutions are in the number of objects to be managed, as well as the locations of individual facilities. The highest density, and therefore the importance of objects (substations, control centers, etc.), is in urban areas, while in rural occurs significantly smaller number of objects. Based on the electricity network structure, it is possible to identify two parts of telecommunication network:

- **Electricity network management -** part of a communication network which is responsible for the data transmission along the power lines and exchange of signals between the automation devices in these lines (reclosers, section breakers, remote fault current indicators), and
- **Facilities management in the electricity network -** part of a communication network which is responsible for data transfer between objects in the electricity network (substations, control centers).

Based on the Table 1 and partition of the telecommunication network, it is possible to suggest typical telecommunication solutions. In the Table 2 some typical communication solutions are listed.

Table 2. Proposed communication solutions [5]

	Communication network topology / **Communication technology**	**U - PL***		**U – O**		**SU – PL**		**SU – O**		**R – PL**		**R - O**	
		ML	**RL**	**ML**	**RL**	**ML**	**RL**	**ML**	**RL**	**ML**	**RL**	**ML**	**RL**
WIRELESS	VHF/UHF digital radio	X				X				X			
	IEEE 802.16 (WiMAX) unlicensed	X		X		X		X		X		X	
	Cellular (2G – 3.5G)		X				X			X	X		
	Cellular (LTE – 5G)		X		X		X		X	X	X		X
WIRED	SONET/SDH			X				X					
	IP MPLS	X		X		X		X					
	DSL/PON	X			X	X			X				X

***Legend:**

U - PL	=	Urban topology along the power lines
U – O	=	Urban topology between objects in the electricity network
SU - PL	=	Suburban topology along the power lines
SU – O	=	Suburban topology between objects in the electricity network
R – PL	=	Rural topology along the power lines
R – O	=	Rural topology between objects in the electricity network
ML	=	Main communication link
RL	=	Redundant communication link

3.2. Comparison of Public and Private Networks

Permanent concerns are discussed whether to implement public or private communication networks. In the table below, the characteriscs of both of them are presented, and then summarized pros and cons.

Table 3. Comparison of public and private communication networks [3]

	Public	**Private**
Availability	Moderate-high availability	Can be designed to be very high availability („five nines“)
Survivability	OK for non-critical data transport, inadequate for mission-critical apps	Highly survivable architectures and technology options
Coverage	Limited coverage in rural/lightly-populated areas	Can be engineered to very high levels, but requres mix of technologies
Latency	100-1000 ms	10-100 ms
Security	Adequate	Highly secure options exist
Life Cycle	Largely outside utility control	Contolled by utility
Cost	Primarily OPEX (Operating expenses)	Primarily CAPEX (Capital expenditures)

Considering data in the table, several conclusions can be derived [3]:

- Utilities that want control should deploy private networks!
- Also, where mission-critical applications sholud be supported, or multiple applications, private networks are the right solution;
- Utilities with diverse service territories will need private/public hybrid, ie private networks sholud be present in urban/suburban area, and public in areas where private networks are not economical;
- Utilities that have long term plan for modernization, sholud use private networks.

3.3. Licensed or Unlicensed Spectrum

Based on the above considerations, the private networks are imposed as a better solution for Smart grid Communication Network. In presented table, private network spectrum options are considered, ie. comparison between licensed vs.unlicensed.

Table 4. Comparison between licensed and unlicensed spectrum [3]

	Licensed	**Unlicensed**
Licensing cost	High	None
Unit Cost	High	Low
Spectrum quantity	Typically 10 kHz to a few MHz	170+MHz, more in some countries
Spectrum availability	No global regime	Near global availability for 2.4 GHz and 5 GHz
RF propagation	Depends on Spectrum	Good
Throughput	Typically less than 1 Mbps	10 Mbps – 100+ Mbps
Interference concerns	Low	Low with cognitive radios
Security	Must be designed into system	Must be designed into system

It is obvious that licensed spectrum has some benefits, but also it has limited availability and only in small narowband chunk and it is very expensive to install. In practice, devices that work in unlicensed spectrum can be more secure, reliable, and much higher performance than licensed spectrum options.

3.4. Security Standards

Generally, cyber security can be described as measures taken to protect electrical automation system and communication networks against unauthorized access or attack. This concept includes large number of standards. Globally recognized regulations are:

- NERC – CIP (current version 3), regulation in USA and Canada,
- NISTIR 7628 – Guidelines for Smart Grid Cyber Security,
- CEN-CELENEC-ETSI Smart Grid Coordination Group,
- Draft EU Directive (2013/0027 COD), market operators,
- ENISA Smart Grid Security Recommendations,
- IEC SG 3.

More details about security standards can be found in [6], [7].

3.5. Optimal Telecommunication Solutions for EPS

Based on the above considerations and techno-economic analysis of the distribution electricity network model in [5], in Table 5 optimal communication solutions for the intelligent electricity distribution networks of EPS are given.

Table 5. Optimal communication solutions for distribution network model of EPS

Communication network topology / Communication technology	U - PL		U – O		SU – PL		SU – O		R – PL		R - O	
	ML	**RL**	**ML**	**RL**	**ML**	**RL**	**ML**	**RL**	**ML**	**RL**	**ML**	**RL**
VHF/UHF digital radio (Private)					X				X			
IEEE 802.16 (WiMAX) unlicensed (Private)	X		X				X				X	
Cellular (2G – 3.5G, Public)						X				X		
Cellular (LTE – 5G, Public)		X		X				X				X
IP MPLS (Private)	X		X	X			X					
DSL/PON (Public)								X				

4. CONCLUSION

An integral part of the infrastructure of electric power system, without which it is impossible to introduce the concept of smart grid is a telecommunications system. In the last decade communication techniques are intensively developed, so they allow the use of different SG demands.

The best suited communication techniques are discussed, and several key measures evaluated. Also, the advantages and disadvantages of public and private communications infrastructure are considered. On the basis of the main communication routes realization analysis for the smart grid of EPS needs, it is suggested to use WiMAX technology in the unlicensed band or optical connections, and for redundant routes some of the public communication services that have sufficient bandwidth.

Regardless of the suggested typical solutions in this paper, for each newly designed power cable 11 kV or 20 kV an optical cable should be planned, as well as for each new transmission line ADSS, OPGW or mini OPPC should be considered. In this way, the costs of fiber optic cable laying are losing their place in the overall price of optical communication networks realization. If a particular MV or LV substations are located in residential, commercial or industrial buildings, or in the immediate vicinity thereof, and it is planned to lay fiber optic cables for these objects for different telecommunications services, it is necessary to provide space for fiber optic cables to those substations. In this way, the costs of fiber optic cables laying to individual substations in the distribution plane are reducing, too.

BIBLIOGRAPHY

[1] E.Hossain, Z.Han, H.V.Por, “Smart Grid Communications and Networking“, Cambridge University Press, 2012.

[2] “Smart Grid Reference Architecture“, CEN-CELENEC-ETSI Smart Grid Coordination Group, November 2012.

[3] ABB Documentation, Utility Communications, SAS and SCADA Technical Seminar, Baden, Switzerland, October 2015.

[4] M. Kuzlu, M. Pipattanasomporn, S. Rahman, “Communication network requirements for major smart grid applications in HAN, NAN and WAN”, Computer Networks 67, April, 2014.
[5] D. Miloradović, J. Mandić-Lukić, M. Mesarović, D. Novaković, B. Milinković, M. Stefanović-Glušac, Ž. Vasiljević, B. Mihić, M. Nikolić, “Smart Grid Study – Strategy and Development of Remote Control and Management of Medium Voltage Distribution System“, Energoprojekt Entel p.l.c. Belgrade, ITEN Engineering, Novi Sad, Serbia, December 2014.
[6] R.Raković, J. Mandić Lukić, N. Čukić, “Information Security in Electric Power Utilities Environment“, 1st SEERC, Portorož, Slovenia, June, 2016.
[7] B.Milinković, J. Mandić Lukić, S.Latinović, “Security principles for ICT infrastructure in a Power Utility Smart Grid“, 1 st SEERC, Portorož, Slovenia, June, 2016.
[8] B.Al-Omar, A.R.Al-Ali, R.Ahmed, T.Landolsi, “Role of Information and Communication Technologies in the Smart Grid“, Jouranl of Emerging Trends in Computing and Information Sciences, Vol.3 No.5, May 2012.
[9] S.Safdar, B.Hamdaoui, E.Cotilla-Sanchez, M.Guizini, “A survey on Communication Infrastructure for Micro-grids“,
[10] “Communication Requirements and Integration Options for Smart Grid Deployment“, Power Systems Engineering Research Center (PSERC), PSERC Publication 12-03, Apr 2012.