Benefits of 6 kV Smart Grid Implementation in Open Cast Coal Mine Suvodol - REK Bitola

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Abstract – **In this paper is presented the benefits of 6 kV radial distribution network upgrading into Smart Grid in the open cast coal mine Suvodol – Rek Bitola. Generally the needs and reasons for implementation of new type of distribution networks called Smart Grids instead of classical distribution networks, are explained. Also, a comparison between the performances of ordinary radial network and Smart Grid is performed. The benefits and advantages of Smart Grid implementation in the open cast coal mine are described in details. Analyze of interruptions duration in the past period when the network in the mine was classical distribution network and the period with Smart Grid implemented, is conducted.**

Keywords – **Distribution network, Smart Grid, Energy efficiency, Dispersed generation.**

I. INTRODUCTION

The main role of the electrical distribution networks is to deliver electricity to the consumers on efficient, safe, reliable and economically way. Recently, with the changes that occurred in the electricity sector and the possibility of open access to the other legal entities on the distribution network, it is possible involvement of independent producers of electricity so-called dispersed production (DP). Widely used definition for dispersed production [1] is production of electricity which is: not centralized planed, not governed by the dispatching center, connected on to distribution network, with power plants less than 50-100 MW. The power plants of dispersed production can use renewable energy sources (solar power plants, wind farms and small hydro plants), or nonrenewable energy sources (natural gas plants, biogas plants, geothermal plants, etc.).

Presence of dispersed power plants connected in different nodes, radically change the working conditions and concept of the distribution network in comparison with classical distribution network without dispersed production. In distribution networks with dispersed production, load-flow is not from one point (supplying high/middle voltage transformer) to the rest elements of the network. Concerning the values and distribution of voltages, power and energy losses it is obvious that differences depend of the working state. Dispersed power plants in different nodes of distribution network, contribute to significant increasing of fault currents. Very important difference is in the concept, types and settings in the relay protection.

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Taking into account all mentioned changes which occurred in distribution networks with dispersed production, it is obvious that the new ways for governing, planning, maintenance, exploitation and analyze of these networks, must be applied.

Nowadays, with wide application of SCADA systems, PLC-s, digital protection, different appliances and protocols for data communications and power computers in distribution networks, a very efficient distribution of electricity is achieved. These modern intelligent distribution electrical networks, popularly called Smart Grids, provide intelligent integration of the functioning of all users which are associated in the network and energy supply on economic and safe way, with greater level of reliability, power quality and reduction of network power/energy losses.

Few years ago, an old 6 kV distribution network in open cast coal mine "Suvodol" was upgraded into Smart Grid. This network enabled more effective and greater production with low level of faults and interruptions.

II. COMPARISON BETWEEN SMART GRID AND CLASSICAL RADIAL DISTRIBUTION NETWORKS

The main purposes of companies which are owners or manage the classical distribution networks are to upgrade and transform these networks into modern, intelligent and efficient type of networks as Smart Grids. Taking into account possibilities for implementation microprocessor based equipment and reliable appliances and protocols for communication in middle voltage distribution networks, two main concepts as control and supervise used in Smart Grids can be connected with classical electrical engineering and electrical equipment. In table I, the main performances of classical distribution networks and Smart Grids are compared.

TABLE I
COMPARISON BETWEEN TWO TYPES OF DISTRIBUTION NETWORKS

Classical networks	Smart Grids
Electromechanically management	Digital management
One way communication	Two ways communication
One point of energy supply	Few points of energy supply
Hierarchical structure	Network structure
Small number of sensors	Big number of sensors
Manually restart	Automatically restart
Limited control	Full control
Few possibilities for load connection	Lot of possibilities for load connection
Supplying interruption in case of faults	Flexible supplying with fault isolation

Upgrading and transformation of classical distribution networks into Smart Grids are complex processes which need time and investments. With implementation of information technology, networking structure of management and communication among loads, dispersed production and middle voltage electrical equipment, classical distribution networks become efficient Smart Grids [2], [3].

III. GENERAL BENEFITS OF SMART GRIDS IMPLEMENTATION

Nowadays, application of Smart Grids for electricity distribution, offers lot of solutions and benefits for the electricity consumers, producers, power distribution companies and society in generally. The main benefits of Smart Grids application are [4]:
- decrease of interruptions in electricity distribution systems;
- decrease of power and energy losses;
- increase of energy efficiency;
- enable application and power/energy management in micro grids;
- greater efficiency in electricity production and consumption;
- higher resistance for negative influences in network;
- ability for faster restarting;
- better control for electricity consumption in network;
- distribution of quality electricity;
- increasing of network performances;
- decreasing of load peak power;
- enable better connection of dispersed production;
- decrease the negative influence on the environment;
- decrease the expenses for network maintenance, etc.

It is obvious that all mentioned benefits of Smart Grids confirm the reasons for their application in commercial and industrial purposes.

IV. SMART GRID IMPLEMENTATION IN OPEN CAST COAL MINE SUVODOL

The system for transportation of excavated earth called “0”-BTO system in open cast coal mine “Suvodol” in REK Bitola was consisted of four driving stations, connected on 6 kV distribution network. At the beginning this network was controlled and managed with electromechanical devices. In that period there were a lot of interruptions with long duration on the process of transportation of excavated earth. The reasons for these interruptions were faults caused by modest information about working data, shortage of communications and exchanging of data among electrical equipment and dispatching center, limited possibilities of relay protection, manually manipulations, etc. As the result of the interruptions a capacities for earth excavation and deferment were limited. Therefore, in 2003 a reconstruction and upgrading of whole distribution system were performed. The managing and control of the working conditions for all four driving stations were performed by the personal computer built in dispatching center. Applying programmable logic controllers (PLC) Simatic generation S7-300 built in dispatching center and driving stations, the whole processes starting from electricity distribution and excavated earth transportation were automated and controlled. Separately, in each driving station was built a control panel OP7 for local control and signalization. The hardware structure for the SCADA system is given on Fig. 1.

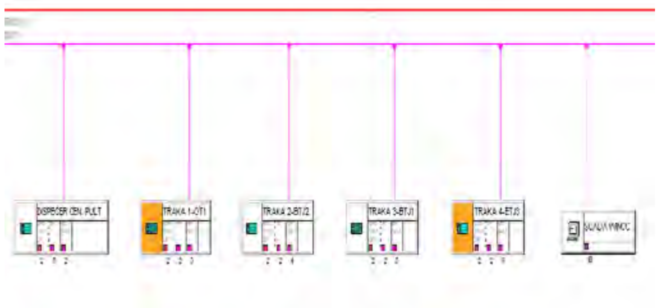

Fig. 1. SCADA hardware structure of the Smart Grid

The software package WinCC V6.2 was used for visualization of all events during the working processes. The base state of the system for earth excavation, transportation and deferment shown on the monitor in dispatching center was as it is shown on Fig. 2.

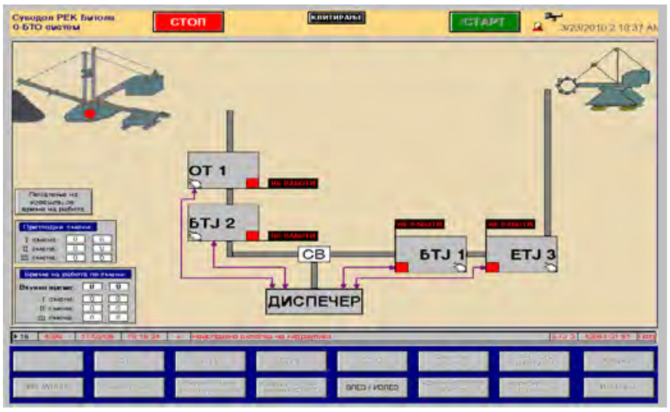

Fig. 2. Visualisation of “0”-BTO system (base state).

All driving stations OT1, BTJ2, BTJ1 and ETJ3 were approximately the same and consisted of 6 kV substations with:
- input and measuring cabinet;
- cabinet for 160 kVA transformer;
- connection cabinet and
- four cabinets for 4 induction motors each of 500 kW.

The low-voltage part of substation consisted of input and measuring cabinets and transformers 380/220 V/V, 220/220 V/V and 220/24 V/V.

V. COMPARISON OF PRODUCTIVITY AND DURATION OF INTERRUPTIONS

The “0”-BTO system for excavated earth transportation and deferment in open cast coal mine “Suvodol” was working from year 2000 to 2009. At the beginning from year 2000 to

2003 the control and managing of the distribution system processes for excavated earth transportation and deferment were on electromechanically way. In 2003 was introduced automation and distribution system was upgraded into Smart Grid. Unfortunately this Smart Grid was working till 2006. Because of unjustifiable decisions of the coal mine managing team at that time, in 2007 the control and managing of the “0”-BTO system was returned to electromechanical way.

In table II is given comparison on excavation capacity of “0”-BTO system between periods when the system was working on electromechanical way (2000-2003 and 2007-2009) and period when the system was working as a Smart Grid (2003-2006, given with bold numbers).

TABLE II
COMPARISON ON EXCAVATION CAPACITY OF “0”-BTO SYSTEM

Year	Planned (m^3)	Realized (m^3)	Coefficient (%)
2000	4.500.000	3.523.377	78
2001	5.800.000	6.422.286	111
2002	5.621.000	6.827.546	121
2003	**5.430.000**	**6.054.377**	**112**
2004	**5.421.400**	**6.427.205**	**119**
2005	**5.584.000**	**7.557.529**	**135**
2006	**5.500.000**	**6.700.203**	**122**
2007	5.883.000	5.997.215	102
2008	3.505.000	3.692.053	105
2009	4.500.040	4.904.664	109
Total	51.744.440	58.106.455	111

From the presented results it is obvious that in the period when the system was working as a Smart Grid, the capacity of excavated earth was the biggest. For these four years the average coefficient of realization was 122%. In the rest two periods when the system was working with electromechanical control and management, the average coefficient of realization was 104%.

During the process of exploitation of “0”-BTO system, a lot of interruptions were occurred. In table III, the durations of interruptions in each year of exploitation from 2000 to 2009 are given.

TABLE III
COMPARISON OF INTERRUPTIONS DURATION ON “0”-BTO SYSTEM

Year	2000	2001	2002	/
Interruptions (h)	2785	2820	2914	/
Year	**2003**	**2004**	**2005**	**2006**
Interruptions (h)	**2447**	**2308**	**2196**	**2218**
Year	2007	2008	2009	/
Interruptions (h)	2624	2819	2568	/

With bold numbers are stressed data for the period from 2003 to 2006, when the system was exploited as Smart Grid.

The average duration of interruptions per year in the period from 2000 to 2002 and 2007 to 2009 is 2775 h. In the second period from 2003 to 2006 the average duration of interruptions per year is 2292 h. The average duration of interruptions in the period when the system was working with control and management on electromechanical way is more than 20 days in comparison with the period when the system was working as a Smart Grid. For the longer period of interruptions for 20 days, the capacity for earth excavation, transportation and deferment was reduced for more than 366.000 m^3 [5].

VI. CONCLUSION

Implementation of information technology and automation for control and management of radial distribution networks with (or without) dispersed generation, enable efficient, reliable and safe distribution of produced and consumed electricity in these networks. In the last few years lot of distribution companies invest in reconstruction and upgrading of classical electromechanical controlled and managed distribution networks in to modern Smart Grids. The advantages of Smart Grids are explained in this paper and confirmed on real case of 6 kV distribution network. The ten years period of exploitation of “0”-BTO system for earth excavation, transport and deferment in the open cast coal mine in REK Bitola was divided in two parts. The first one was the period when the system was working as ordinary distribution system controlled and managed on electromechanical way. The second part was the period when the distribution system was working as Smart Grid. Two periods were compared in capacities of earth excavation, transport and deferment and duration of interruptions. Taking into account relevant data, it was shown that the period when the network and system was working as a Smart Grid, the efficiency was better and durations of interruptions were shorter. It can be concluded that the application of Smart Grids in commercial and industrial purposes has a lot of benefits.

REFERENCES

[1] N. Jenkins, R. Allan, P. Crossley, D. Kirchen and G. Strbac, *Embedded Generation,* the Institute of Electrical Engineers, London, University Press, Cambridge, 2000.

[2] http://www.oe.energy.gov.

[3] M. Glinkowski, J. Hou and G. Rackliffe, “Advances in Wind Energy Technologies in the Context of Smart Grid”, Invited paper, proceedings of the IEEE, Vol. 99, No. 6, June 2011.

[4] http://www.netl.doe.gov/smartgrid.

[5] Data used in the service for plan and analysis of REK Bitola.